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NHS England

Health Technical Memorandum 02-01: Medical gas pipeline systems Part A: Design, installation, validation and verification

Preface

About Health Technical Memoranda

Health Technical Memoranda (HTMs) 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 HTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle.

Language usage in technical guidance

In HTMs and HBNs, modal 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 HTMs/HBNs (readers should note that these meanings may differ from those of industry standards and legal documents):

- "Must" is used when indicating compliance with the law.
- "Should" is used to indicate a recommendation (not mandatory/ obligatory), i.e. among several possibilities or methods, one is recommended as being particularly suitable – without excluding other possibilities or methods.
- "May" is used for permission, i.e. to indicate a course of action permissible within the limits of the HBN or HTM.

Typical usage examples

- "All publicly-funded organisations must ensure that all contracts established to collect and treat waste conform to the Public Contracts Regulations." [obligation]
- "All low voltage (LV) distributions should be configured as TN systems." [recommendation]
- "Alcohol hand gels that do not contain siloxanes may be rinsed out and the packaging recycled or placed into the municipal waste stream." [permission]

"Shall", in the obligatory sense of the word, is never used in current HTMs/HBNs.

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 to the highest and most appropriate technical standards and

guidance. This applies when organisations, providers or commissioners invest in healthcare accommodation (irrespective of status, e.g. Foundation and non-Foundation trusts).

Statutory standards plus technical standards and guidance specific to NHS facilities:

- Health Building Notes
- Health Technical Memoranda

A complete list of NHS estates-related guidance can be found on the NHS England website.

The need to demonstrate a robust process for agreeing any derogation from Technical Guidance is a core component of the business case assurance process (see published derogations guidance).

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

Derogations to standards will potentially jeopardise business case approval and will only be considered in exceptional circumstances. A schedule of derogations will be required for any project requiring external business case approval and may be requested for those that have gone through an internal approvals process.

While it is recognised that derogation is required in some cases, this must be risk-assessed and documented in order that it may be considered within the appraisal and approval process.

Derogations must be properly authorised by the project's senior responsible owner and informed and supported by appropriate technical advice (irrespective of a project's internal or external approval processes).

Sustainability and net zero carbon targets

The UK is leading the way on tackling climate change and improving sustainability, and the NHS is leading the way in England.

In 2019, the UK became the first major economy to commit to net zero emissions by 2050. In 2020, the NHS set out its intent to support this ambition through its 'Delivering a "Net Zero" National Health Service' report. The report sets a clear target for achieving a net zero health service for direct emissions by 2040 and indirect emissions by 2045.

In 2023 NHS England published the 'NHS Net Zero Building Standard'. This applies to all new building projects and major upgrades across the NHS estate. It provides technical guidance to ensure new or refurbished buildings are sustainable, resilient, energy-efficient, and built with reduced "whole-life carbon" (i.e. upfront, operational and embodied carbon).

The NHS estate has a critical role to play in achieving net zero carbon emissions. It is vital that every opportunity is seized across the NHS to do so, and the NHS estate is an area where direct and cost-effective action can be taken with a high degree of confidence.

This guidance is not mandatory (unless specifically stated). However, any departures/ derogations from this HTM – including the measures implemented – should provide a degree of safety not less than that achieved by following the guidance set out in this HTM.

Context and background

Introduction

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

This Health Technical Memorandum (HTM) is divided into two parts. Guidance in this document (Part A) covers all supplies of medical gases. It applies to all MGPS installations in healthcare facilities including anaesthetic gas scavenging disposal systems (AGSS), mobile vehicles and dental medical gases systems. This document covers the design, installation, and validation and verification (testing and commissioning) of the MGPS. Part B covers operational management of the MGPS and cylinders.

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

Existing installations should be assessed for compliance with this guidance document taking account of the priority for patient safety. Any upgrades to the existing system should be assessed and a plan for upgrading the existing system should be prepared where required. It is not necessary to apply the guidance retrospectively unless patient or staff safety would be compromised.

All new installations or modifications to the MGPS should be overseen by the Medical Gas Safety Group (MGSG).

This 2026 edition of HTM 02-01 supersedes all previous versions and HTM 2022.

Basic principles of design

Patient safety is paramount in the design, installation, commissioning and operation of all supplies of medical gases. The basic principles of safety are achieved by ensuring adequacy, identity, continuity and quality of supply.

Adequacy of supply

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

Identity of supply

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

Continuity of supply

This is achieved by installing, as a minimum, duplex components. Additional means of supply provision should also be available, in the event of failure of the primary and secondary plant or supply system. Continuity of supply is assured by continued operation in single fault conditions. Systems should also be connected to the essential electrical supply.

Quality of supply

Medical gases are medicines and as such must comply with the Human Medicines Regulations 2012 (as amended) and the relevant monographs of the British Pharmacopoeia.

Quality of supply is ensured by the use of gaseous or liquid sources that are provided in accordance with an appropriate product specification, usually a recognised monograph of the British Pharmacopoeia. Medical gases are subject to the same regulations as other forms of medicine. Licensed medicines holding a UK marketing authorisation (MA) should be used in preference to unlicensed medicines wherever possible. 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. Medical gases are required to comply with the relevant monographs of the British Pharmacopoeia.

Healthcare Safety Investigation Branch reports

The Healthcare Safety Investigation Branch (HSIB) launched a national investigation into the provision of piped oxygen gas supplies to hospitals during the COVID-19 pandemic. As part of this investigation, two interim bulletins were published, followed by a final report (Healthcare Safety Investigation Branch, 2021a, 2021b, 2021c). The recommendations of the final report are taken account of in this revision of HTM 02-01.

It made the following safety recommendations:

- Safety recommendation R/2021/132: that the key roles, responsibilities and competencies of individuals identified in HTM 02-01 are further reviewed, including identifying how the appointment and training of designated officers may be supported.
- Safety recommendation R/2021/133: that a process is implemented to provide ongoing assurance on the qualifications and experience of individuals identified in HTM 02-01, including how Authorising Engineers (MGPS), or their subcontractors, are appointed by healthcare organisations.
- Safety recommendation R/2021/134: that an updated HTM 02-01 should reinforce multidisciplinary team working and include:
  - updated advice on the type and design of MGPS infrastructure recommended for healthcare organisations
  - enhanced processes to encourage shared working between clinical and non-clinical teams on MGPS issues
  - specifications for the relevant levels of competence and training for healthcare staff on MGPS
  - any updated processes or guidance generated in response to the other safety recommendations specified in this report (R/2021/120, R/2021/132, R/2021/133).

Major changes since the 2006 edition

Introduction

This 2026 revision of HTM 02-01 focuses on risk-based design, clear governance, staff competency, system resilience, sustainability and overall assurance. The core engineering principles remain the same as the previous edition, but the document has moved away from a mainly prescriptive engineering approach and now provides a broader framework for designing and verifying systems that are safe, reliable and fit for the future.

Informed design process

One of the most important changes is the introduction of an informed design process (IDP). The design of medical gas systems should be based on a clear understanding of clinical need, operational risk, technical requirements and future resilience, rather than relying solely on historic norms or prescriptive formulas. It requires research, investigation, risk assessment, development of design options and multidisciplinary decision-making, with clear justification that the chosen design is appropriate for the clinical context.

Medical Gas Safety Group (MGSG)

This edition promotes a collaborative, multidisciplinary approach to the design and operational management of MGPS and cylinder supplies. It introduces the Medical Gas Safety Group (MGSG), aligning with other HTMs which adopt a similar “safety group” structure. It advises that the MGSG should be part of the healthcare organisation’s governance structure and report to the Board. It provides guidance on the remit and membership of the Group, advocating that it should be led and chaired by the Senior Operational Manager or Chief Pharmacist.

Project-specific MGSG

It also advises that, where large or complex projects are being undertaken by a healthcare organisation, a project-specific medical gas safety group (PMGSG) should be established. This is a multidisciplinary team that reports to the main MGSG. Its purpose is to ensure the safety of all future MGPS installations used by patients and staff within a new build or refurbishment project, and to minimise associated risks.

Stronger governance, accountability and competency requirements

The 2026 edition places much more weight on governance and people. It links the design and management of MGPS to the MGSG and states that all new installations or modifications should be overseen by the MGSG. It provides more guidance on the role of the Authorised Person and the Authorising Engineer (MGPS), and places emphasis on competency as a combination of skills, knowledge, experience and behaviours.

Integration of post-2006 legislation and building safety requirements

The 2026 draft introduces a new section on the Building Safety Act 2022, including dutyholder obligations, gateway approvals and the “golden thread” of information. It also sets out how these provisions affect healthcare facilities and their estates and infrastructure.

Explicit incorporation of COVID-19 and HSIB learning

The revised draft incorporates lessons from the COVID-19 pandemic, including findings from the Healthcare Safety Investigation Branch (HSIB) report on piped oxygen supply. It recognises that, while bulk oxygen supply was generally sufficient, the limiting factor was often the ability of the MGPS to deliver the required flow to patients. Increased demand

from modern therapies and the concentration of high-dependency patients exposed constraints in pipeline capacity and system configuration. In response, the guidance places greater emphasis on designing for peak and surge demand, understanding system-wide flow and pressure limitations, and ensuring coordinated, multidisciplinary management of oxygen use across healthcare facilities.

Sustainability and net zero

The revised draft introduces sustainability and net zero as explicit design considerations. It requires that the method of delivering medical gases is as low carbon as reasonably practicable, while maintaining patient safety as the overriding priority. Designers are expected to consider energy consumption and the life-cycle environmental impact of systems, and to align with NHS net zero commitments. The guidance also highlights the environmental impact of certain gases, particularly nitrous oxide, and reflects this in system design choices.

Nitrous oxide infrastructure

Leading anaesthetic organisations have recommended that piped nitrous oxide systems should no longer be considered in modern anaesthetic practice, and that transition to point-of-use cylinders should be completed by the end of 2026/27 where access remains desirable. The revised HTM includes amendments to reflect these changes.

Inclusion of dental systems

In the 2006 edition, dental compressed air and vacuum were treated separately in HTM 2022 Supplement 1 rather than being embedded as dedicated chapters in Part A. The 2026 draft brings dental systems fully into the main body of the document, with separate chapters for dental air systems and dental vacuum systems. It gives dental provision much greater visibility and status within the main MGPS guidance.

New stand-alone content for decommissioning, signage, quality control and mobile vehicles

The revised structure contains several major stand-alone chapters that either did not exist in this form in 2006 or were handled differently. The 2026 contents include separate chapters on decommissioning of piped medical gas systems, signage requirements, engineering validation and verification, medical gas quality control testing and mobile vehicles. (In the 2006 edition, decommissioning did not appear as its own chapter, signage sat in an appendix, pharmaceutical and quality testing sat within the broader validation and verification chapter, and there was no dedicated chapter for mobile vehicles.)

Dedicated chapter on quality control testing criteria for medical gases

Content on the quality control testing of medical gas systems, previously covered in paragraphs 15.109–15.184 of Chapter 15 (validation and verification) of Part A, has been revised and relocated to a dedicated chapter to provide clearer separation and emphasis. Tables 29–31 from that chapter have also been consolidated into a single table, now presented as Table 34 in this edition.

Technical file

The 2026 draft requires a technical file for the MGPS, containing design details, components used, material certificates and pressure test validation, and it states that this file should be updated whenever modifications or extensions are made. The revised draft also links system documentation to auditability and to the wider building safety “golden thread” concept.

Updated approach to quality of supply and pharmacopoeial references

The 2026 draft emphasises that medical gases are medicines and that they must comply with the Human Medicines Regulations 2012. It standardises references throughout to the relevant monographs of the British Pharmacopoeia.

Updated standards framework and technical references

All references have been updated.

Digital delivery and modern construction methods

The 2026 draft includes content on building information modelling (BIM), BS EN ISO 19650 and modern methods of construction (MMC). It explains that BIM should provide the basis for design coordination and installation, and that MMC strategies and digital documentation should be considered.

Pressure management and system configuration

The revised guidance provides greater clarity on pressure management within the MGPS, including the explicit use of pressure-reducing stations (PRS), reflecting a more structured and risk-based approach to system design.

Resilience

The revised guidance emphasises that system resilience should be established through risk assessment, with consideration given to patient groups, anticipated procedures, possible future changes and emergency scenarios such as a pandemic. It also introduces stronger language around system resilience, tertiary supplies, emergency support arrangements and the need to document the decision-making process behind supply configuration. Resilience should be treated as a broader operational and design problem tied to service risk.

Proportionality and wider applicability across healthcare settings

The revised draft broadens applicability while recognising proportionality. It states that the guidance is intended for all healthcare facilities and specifically notes that, in smaller dental practices, a degree of proportionality should be applied to design and management while patient safety remains paramount.

Downloadable test forms

The test forms (referred to as “B-forms” in this edition) used during the testing and commissioning of medical gas systems can now be downloaded as separate Excel files from the same webpage as the HTM PDF. This allows users to enter their own data directly.

Acknowledgements

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New Hospital Programme

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Contents

1 Scope

References to pharmacopoeial standards have been standardised throughout the document. Where appropriate, references now refer to the relevant monographs of the British Pharmacopoeia (British Pharmacopoeia Commission, 2026) to reflect the UK regulatory framework for medicinal products. The British Pharmacopoeia provides the only comprehensive collection of authoritative official standards for UK pharmaceutical substances and medicinal products, including all the monographs and texts of the European Pharmacopoeia.

Guidance in this document

1.1 Health Technical Memorandum (HTM) 02-01 is divided into two parts. It applies to all medical gases used in healthcare premises. This document (Part A) focuses on the issues involved in the design, installation, and validation and verification (testing and commissioning) of an MGPS. Part B covers operational management including roles and responsibilities, training requirements and permits to work (PTWs).

1.2 Parts A and B should be used in conjunction with each other and not used as stand-alone documents.

1.3 The guidance provided in this document should be used for all new installations and refurbishments including the upgrading of existing systems.

1.4 A core principle of this HTM is that the method of delivering medical gases should be as low carbon as possible without compromising patient safety.

1.5 The NHS has a clear responsibility to minimise its environmental impact. A more sustainable NHS also offers an opportunity to deliver better patient care while reducing costs and minimising impacts on future services.

1.6 Healthcare in England is estimated to contribute between 4% and 5% of national emissions, and around 40% of all emissions generated by the public sector. For this reason, the Health and Care Act 2022 introduced new duties for trusts and integrated care boards (ICBs) to consider climate change in their operations, making the NHS the first healthcare system to embed net zero in legislation.

1.7 The energy consumption of medical gas systems should be further minimised by specifying solutions with the lowest life-cycle environmental cost, without compromising patient care and safety.

1.8 When designing an MGPS, the intention should always be to use the most efficient pumps and compressors, remove unused and unnecessary gases and terminal units, minimise the system's environmental impact and reduce/remove the use of piped gases, such as nitrous oxide, which have a long atmospheric lifetime and contribute to climate change.

1.9 Leading anaesthetic organisations in the UK and Ireland have recommended that piped systems should no longer be considered as a

means of supplying nitrous oxide in modern anaesthetic practice. They are calling for the transition away from nitrous oxide MGPS – moving instead to point-of-use cylinders where individual organisations feel that continued access to nitrous oxide remains desirable – to be completed by the end of 2026/27. This HTM includes amendments to reflect these changes in the design parameters for healthcare medical gas systems. Where point-of-use cylinders are used, consideration should be given to continuity of supply.

1.10 It is not necessary to apply the guidance retrospectively unless patient or staff safety would be compromised or environmental sustainability could be optimised. In this case, the guidance given in this document should be followed. It should be supplemented by risk assessment tools/processes and other supporting information (such as the annual Authorising Engineer (MGPS) audit).

1.11 Existing installations should be assessed for current compliance with HTM 02-01 (both parts). A plan for upgrading the existing system should be prepared, taking account of the priority for patient safety. The Authorised Person (MGPS) will need to liaise with medical colleagues, and the plan should be reviewed and approved by the Medical Gas Safety Group (MGSG) (see Part B) prior to any changes being implemented.

1.12 Throughout this document, the term "medical gas pipeline system(s)" is abbreviated to MGPS.

Other guidance

1.13 This HTM should be read in conjunction with HTM 00 – 'Policies and principles of healthcare engineering', which provides the overarching framework for healthcare engineering services. Additional relevant documents include Health Building Notes (HBNs) applicable to the clinical spaces under consideration, and other HTMs such as HTM 03-01 – 'Specialised ventilation for healthcare premises', the HTM 05 series on fire safety (Firecode), and HTM 06-01 – 'Electrical services supply and distribution' and codes of practice published by the British Compressed Gases Association (BCGA). Whenever possible, British, European and international standards specifications should also be used where relevant. This is not an exhaustive list.

Rationale for revision

1.14 This document is a comprehensive revision of the 2006 edition of Part A. The revisions are informed by operational experience, changes in clinical practice, climate and sustainability requirements and lessons learned from incidents, including those arising during the COVID-19 pandemic.

Healthcare Safety Investigation Branch (HSIB) reports

1.15 The HSIB launched a national investigation into the provision of piped oxygen gas supplies to hospitals following two interim reports (https://www.hsib.org.uk/investigations-and-reports/oxygen-issues-during-covid-19-pandemic/) on oxygen supply during the COVID-19 pandemic. The recommendations of the final report are taken account of in this revision of HTM 02-01 (Healthcare Safety Investigation Branch, 2021a, 2021b, 2021c).

1.16 It made the following safety recommendations:

- Safety recommendation R/2021/132: that the key roles, responsibilities and competencies of individuals identified in HTM 02-01 are further reviewed, including identifying how the appointment and training of designated officers may be supported.
- Safety recommendation R/2021/133: that a process is implemented to provide ongoing assurance on the qualifications and experience of individuals identified in HTM 02-01, including how Authorising Engineers (MGPS), or their

subcontractors, are appointed by healthcare organisations.

- Safety recommendation R/2021/134: that an updated HTM 02-01 should reinforce multidisciplinary team working and include:
- updated advice on the type and design of MGPS infrastructure recommended for healthcare organisations
- enhanced processes to encourage shared working between clinical and non-clinical teams on MGPS issues
- specifications for the relevant levels of competence and training for healthcare staff on MGPS
- any updated processes or guidance generated in response to the other safety recommendations specified in this report (R/2021/120, R/2021/132, R/2021/133).

Building Safety Act 2022 (England)

1.17 Those within healthcare organisations who are involved in the design, construction and operation of healthcare facilities should ensure they are fully aware of the changes introduced by the Building Safety Act (BSA), including the approval regime for higher-risk buildings, dutyholder obligations and the golden thread requirements. Paragraphs 1.18–1.26 provide a summary of these key provisions and their relevance to healthcare estates and infrastructure.

1.18 The BSA introduces far-reaching protections for qualifying leaseholders from the costs associated with remediating historical building safety defects, and establishes mechanisms to hold to account those responsible for such defects. It overhauls existing regulations and makes clear how residential and higher risk buildings (HRBs) should be constructed, maintained and made safe. Healthcare facilities are not normally considered to be HRBs under the occupation phase unless they include residential units. However, healthcare facilities that are over 18 metres in height or comprise seven or more storeys are subject to the design and construction phase requirements of the Act.

1.19 The Act created three new bodies to provide oversight of the new regime: the Building Safety Regulator (BSR), the National Regulator for Construction Products (NRCP) and the New Homes Ombudsman.

- The BSR oversees the safety and performance of all buildings, as well as having a special focus on HRBs. It promotes competence and organisational capability within the sector, including among building control professionals and tradespeople.
- The NRCP oversees a more effective construction products regulatory regime and leads and coordinates market surveillance and enforcement in this sector across the UK. The NRCP has already started taking enforcement action.
- The New Homes Ombudsman Service will allow relevant owners of new-build homes to escalate complaints to a New Homes Ombudsman.

1.20 Under the Act, dutyholders such as the principal designer and principal contractor are required to manage building safety risks, with clear lines of responsibility during the design, construction and completion of all buildings. Accountable persons will need to demonstrate that they have effective, proportionate measures in place to manage building safety risks in the HRBs for which they are responsible. Those who do not meet their obligations may face criminal charges.

1.21 The most significant change brought about by the BSA, as it applies to healthcare facilities, is the implementation of a new three-stage gateway approval regime. The system,

introduced via amendments to the Building Act 1984, strengthens regulatory oversight before building work begins, throughout construction, before major changes are made, and before a building is occupied.

1.22 Alongside this approval process, the BSA mandates the creation and maintenance of a "golden thread" of building information. The regulations set out how safety-critical building information must be collected, maintained and managed throughout the building's life cycle to support safety and to keep occupants informed.

1.23 In healthcare settings, responsibility for maintaining the golden thread lies with the responsible person, as defined under the Regulatory Reform (Fire Safety) Order 2005 (FSO). In the context of a workplace, this is typically the employer. For example, the responsible person will typically be the trust board in an NHS hospital trust (or a senior partner in a GP practice). Where control of the premises rests with another party – such as in shared-occupancy arrangements or where a building has been procured under a private finance initiative – Article 3(b)(ii) of the FSO identifies the owner as the responsible person.

1.24 The BSA also places new duties on dutyholders involved in the construction, refurbishment and maintenance of HRBs. These dutyholders align with those defined under the Construction (Design and Management) Regulations 2015 and include:

- clients
- designers
- principal designers
- contractors
- principal contractors.

1.25 The new regulations place duties on the dutyholders to plan, manage and monitor the design work and the building work, ensure they cooperate and communicate with each other, coordinate their work and have systems in place to ensure that building work (including design work) complies with all relevant building regulations.

1.26 There is also a requirement for anyone carrying out any design or building work that they will need to be competent in their roles. Those who appoint dutyholders will need to take reasonable steps to ensure that the people they appoint meet this requirement. Contracts and appointments will need to mention the requirement for dutyholders to comply with the competency requirements.

Informed design process and key principles

1.27 An informed design process (IDP) for new, upgraded and refurbished installations is a method of designing an MGPS based on a clear understanding of clinical needs, operational risks, technical requirements and future resilience rather than relying solely on prescriptive formulas or historic norms. It is intended to encourage collaboration between designers and clinical users, supporting a tailored, risk-based approach to system development. Greater emphasis is placed on patient safety, sustainability, system resilience in emergency situations and the integration of new and emerging technologies. Design decisions should be based on scientific principles (physics, materials science, systems theory), evidence from testing and modelling, professional standards (codes, guidelines, safety regulations) and analysis. This approach supports the delivery of a more robust and efficient MGPS.

1.28 An informed-design approach is underpinned by four key principles:

a. the clarification of the design requirements and constraints

b. research and investigation, including risk assessment

c. the development of design options

d. the involvement and decision-making of a multidisciplinary group, typically the MGSG, at all stages of the design process.

1.29 This HTM should form the starting point for all MGPS designs and provide the underlying framework for decision-making. While certain sections (for example, Table 1 on the selection of terminal units, area valve service units (AVSUs) and local alarms) provide a basis for design discussions, they should not be applied in isolation without further consultation. This should include an assessment of:

- the patient groups
- the procedures that will be undertaken in each space
- the potential for future changes or emergencies such as another pandemic
- the resilience of the system.

Responsibilities and oversight

1.30 The review of the Building Regulations and fire safety by Dame Judith Hackitt in 2018 'Building a safer future' (Hackitt, 2018) highlighted the need for a principles-based approach to design and construction. Central to this is the expectation that all those involved in the delivery of healthcare buildings act with integrity and professional judgement. This approach relies on outcomes-based thinking and requires competent individuals to assess risks and make informed decisions rather than blindly following prescriptive guidance. Competency is the combination of the appropriate skills, knowledge, experience and behaviours (SKEB) – including judgement, integrity and a commitment to doing the right thing, not merely following rules or procedures.

1.31 All those involved in the design, installation and management of an MGPS have a responsibility to ensure the safety, integrity and compliance of the system throughout its life cycle. The level of scrutiny applied during the design and approval should be proportionate to the level of risk posed to patients and users. Higher-risk systems or locations (for example, critical care or operating departments) require enhanced oversight and assurance. These locations place unique responsibilities on clinical and estates staff because these environments rely on the constant, safe and precise use of medical gases. Clinical teams interact directly with oxygen, medical air, anaesthetic gases and vacuum systems on a daily basis, meaning their competence, vigilance and behaviours have a significant impact on patient safety. Enhanced oversight, tighter controls and higher training standards are required for staff working in these areas. This will include the training and competency of designers and contractors together with the Authorised Person (MGPS) and Authorising Engineer (MGPS).

1.32 Maintaining transparency and an auditable trail throughout the system's design, installation and operational phases is essential. This provides evidence of compliance, supports accountability and ensures continued confidence in the safety and performance of the MGPS.

1.33 Collaboration and partnering between clinical teams, design teams, capital delivery project teams, estates teams and the MGSG is essential, with the addition of external expert advice when needed

2 General design principles

Introduction

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

2.2 Medical gases are medicines and, as such, it is recommended that, regardless of operational infrastructure, the Chief Pharmacist should take an active role in the design of medical gas systems.

2.3 Any work on the MGPS should be carried out by specialist medical gas Competent Persons who have been assessed for competence by the Authorised Person (MGPS) and managed in accordance with Parts A and B of this HTM.

2.4 The MGPS will need to provide the appropriate level of resilience for each patient group and departmental requirements. Those requirements will be identified as part of a risk assessment process for existing installations and any new projects.

2.5 It is essential to ensure that there is no possibility of a cross-connection between any part of the MGPS and that all parts of any system to which users can make connections are gas-specific.

2.6 All valve locks should be keyed differently (AVSUs, line valves and line valve assemblies (LVAs)). Lockable non-interchangeable screw-threaded (NIST) connections may be supplied with suited keys for individual gas types.

2.7 A strict maintenance regime is vital and a full test and commissioning procedure should be followed including quality control (QC) testing where appropriate as outlined in this HTM.

2.8 Medical gas systems may be extended to electronic and biomedical engineering (EBME) workshops, sterile services departments (SSDs), endoscope reprocessing units, and other areas where respiratory equipment or surgical tools are serviced. Specific additional uses of air systems are covered in Chapters 7 and 8.

2.9 The MGPS should not be used to supply pathology departments, general workshops or mechanical services.

2.10 While this guidance is intended for all healthcare facilities, for smaller dental practices (for example, those with five chairs or fewer), a degree of proportionality should be applied to both the design and management of the system. Patient safety must remain a priority. See Part B for further guidance on operational management. If further advice is required on the application of this guidance, it should be sought from an Authorising Engineer (MGPS).

2.11 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 an MGPS. They should not be provided with medical gas terminal units.

2.12 For endoscope drying and storage units, the central surgical air pipeline system may be extended. See HTM 01-06 – 'Decontamination of flexible endoscopes. Part D: Validation and verification (including storage/drying cabinets)' for quality of air required.

2.13 The medical gases covered in HTM 02-01 are listed in Table 1 of Chapter 3 in Part B.

2.14 A technical file should be created for the MGPS and contain details of the design, the components used, their material certificates and pressure test validation, demonstrating that the system is safe for its intended use. The technical file should be updated whenever modifications or extensions are made.

2.15 NHS England's (2023) 'NHS net zero building standard' is mandated for projects exceeding £25 million. However, healthcare organisations should aim to meet the standard for all projects. Compliance should be supported by a project-specific net zero carbon report outlining the design interventions and approaches adopted.

Informed design process

2.16 As introduced in Chapter 1, an IDP should be followed for any MGPS installation. As part of that, before any project commences, a risk assessment of all current sources of supply should be completed by the Authorised Person (MGPS) or Authorising Engineer (MGPS). This should consider expected gas usage, historical site data and, if required, information from other similar sites. This should be combined with the professional experience of the design, estates, pharmacy, clinical and installation teams, as well as the Authorising Engineer (MGPS). It is important that auditable, usable evidence is available to support the project design, ensuring patient safety is the priority.

2.17 An evidence-based design should be undertaken for all projects. This should be signed off by the MGSG.

2.18 As the NHS moves towards a digital built environment, building information modelling (BIM) is seen as a key part of the future of the construction industry and the NHS estate in England, one of the largest asset owners in the UK. BIM is a combination of collaborative processes and digital technology, supported by people. BIM uses digital technology to improve the sharing, analysis and quality of data and information within a construction project. Through improving data, information management and collaboration within projects, this supports the industry to deliver greater efficiencies through the design, construction and operational stages of a project. BIM aims to unlock savings across the whole project life cycle, including capital expenditure as well as savings across the operational stages, arguably where the NHS spends the majority of its property budget and therefore arguably the area with the most potential. BS EN ISO 19650 should provide the basis for design coordination and on-site installation. Healthcare organisations should define their BIM requirements within the project specification issued at the tender stage for MGPS projects and wider developments.

Modern methods of construction (MMC)

2.19 Modern methods of construction (MMC) are becoming much more commonplace in construction. MMC encompasses all terms associated with offsite construction (large-scale components) and design for manufacture and assembly (DfMA) and platform construction (P-DfMA). Consideration should be given to modern approaches to design, construction and building operation and adopting digital interventions to realise the client value/benefits requirements.

2.20 NHS England's (2025b) 'NHS modern methods of construction assessment tool user

guide' is intended to help healthcare organisations generate an MMC strategy for healthcare infrastructure projects. The MMC assessment tool is part of a suite of documents that supports effective building approaches that are efficient and offer long term value for money, aligning all the current drivers in line with the construction playbook policies. The decisions made within the development of the project MMC strategy should be cross-referenced to this suite of documents, including:

- Modern methods of construction strategy report. This toolkit should be supported by a strategy report that fully documents the decision-making process, MMC interventions and logistics reviews.
- Digital and smart buildings strategy. The project should be supported by a digital and smart buildings strategy document. This should outline the design approaches to user experience and building management.
- BIM documentation. The project should be supported by the relevant client and design team/contractor BIM documentation, including exchange information requirements, asset information requirements and BIM execution plan (BEP).
- Social value toolkit. The project social value toolkit should be completed.

2.21 Where MMC is used as part of the MGPS, the pipeline system should meet the same standards and requirements as detailed in this HTM.

Quality requirements for medical gases

2.22 Medical gas quality should comply with the relevant monographs of the British Pharmacopoeia. For further guidance on quality control, see Chapter 20.

Sources of supply

General considerations

2.23 In accordance with BS EN ISO 7396-1, all medical gas supplies should comprise three sources of supply identified as primary, secondary and tertiary.

2.24 The supply system should be designed to ensure continuity of supply to the terminal units under normal operating conditions and in the event of a single fault condition. A single fault condition is where a single device is defective or a single external abnormal condition is present. Loss of supply due to planned maintenance of a supply source (or a component within it) is not considered a single fault condition.

2.25 With regard to individual banks of a cylinder manifold, this HTM classifies a manifold as a single source of supply, that is, one single operating unit.

2.26 Regardless of these classification differences, the choice of supply 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.

2.27 For these reasons, the types, capacities and locations of primary, secondary and tertiary sources of supply should be determined based on system design parameters and the need for supply security identified through risk assessment at the planning stage. Security of medical air supplies must be given a high priority. Total electrical failure must not be allowed to jeopardise supplies, and all medical air systems must be supported by an appropriate fully automatic manifold.

2.28 The design process should consider sources of supply, safety, efficiency and sustainability as key factors. In deciding whether a piped system or cylinders are the

most appropriate source of supply, some of the points to consider are:

- patients' reliance on oxygen (for example, the need for continuity of supply and alarm indication on loss of supply)
- storage: both main and satellite cylinder stores
- space required in a clinical area for cylinders
- workforce required for distribution
- staff intervention: managing and connecting cylinders
- cylinder rental, ancillary equipment and maintenance costs
- frequency of deliveries to site
- operational and embodied carbon from both options.

2.29 The final design should be based on a risk assessment and agreed by the MGSG. The decision process should be transparent and clearly documented.

2.30 An MGPS review should be undertaken for all areas where the pipeline is to be extended for new terminal unit provision or alterations. This should include consideration of any changes in clinical practices, as well as the specific medical gas requirements for the procedures to be undertaken and the patient groups served.

Primary supply

2.31 The primary source of supply is the main source of supply and should be permanently connected to the MGPS.

Secondary supply

2.32 The secondary supply should automatically supply the medical gas system in the event that the primary source is unable to do so and should be permanently connected to the system.

2.33 The minimum level of stock for the secondary supply should be based on a risk assessment considering the circumstances when the primary supply system may not be available for use.

2.34 This secondary supply reserve stock level will depend on:

- the proximity of the supplier's distribution depot
- the time that the gas supplier needs to make a delivery under these conditions
- the delivery frequency that can be sustained when the primary supply is unavailable for use.

2.35 On large systems, the secondary supply may be reliant on several separate manifold systems connected into the distribution system. These will be valved to supply specific sections of the system. For example, on a large medical oxygen system there may be multiple automatic changeover manifolds (ACMs) supplied to provide continuity of supply for critical care areas and theatres separate from the general areas. Each individual supply forms part of the secondary supply system and, collectively, constitutes the secondary source of supply.

2.36 The secondary source(s) of supply should automatically come online to ensure continuity of supply to the pipeline. The operation of the reserve source(s) (i.e. changing from one bank to another) of supply depends on the type of component used within the sources of supply:

- if the primary supply is from a cryogenic vessel, then its operation should be automatic
- if the primary supply is dependent on the electrical power supply (for example, a compressor system), then its operation should be automatic

- if the primary supply is from an automatic cylinder manifold, then its operation may be manual.

2.37 Total electrical failure should not jeopardise the pipeline supply. A risk-based plan should be in place for AGSS and vacuum systems as they are fully dependent on the mains electrical supply. An AGSS does not have a tertiary supply; therefore its loss presents a risk of occupational exposure. Vacuum systems may have battery or injector-driven suction as a tertiary source of supply.

Tertiary supplies

2.38 Tertiary supplies provide a third level of resilience for the supply of the pipeline system and patients. They may be local or mobile to cover pipeline system failure and to maintain gas supply to patients during transport within the hospital.

2.39 It is important to consider the requirements for tertiary supplies within wards and departments during the design process for the safety of the patients and for storage and security reasons.

2.40 Tertiary requirements for the site should be risk-assessed to consider:

- the needs of the patient in the event of a pipeline failure
- the day-to-day cylinder requirements:
  - (i) the needs of the patient when unable to be connected to the piped system (for example, trips to the bathroom)
  - (ii) transport needs within the hospital (to and from diagnostics and other areas)
  - (iii) cylinder supplies for emergency treatment (for example, crash trolleys, emergency cylinders on anaesthetic machines, ventilators and resuscitators)
  - (iv) supplies in areas that do not have piped gas.

2.41 Each area should be risk-assessed for their requirements during the design process and reassessed during any upgrades, change of use and change of treatments.

Departmental medical cylinder use

2.42 Mobile cylinders are used within wards and departments for the reasons listed in (i) to (iv) of paragraph 2.40 or for the provision of nitrous oxide. Cylinders should not be used on a day-to-day basis where a pipeline system would be more appropriate (i.e. for areas of high use).

2.43 The location of mobile cylinder storage should be identified early in the design process, with appropriate fire compartmentation provided. Integral valve cylinders should be used as they can reduce the risks of adiabatic combustion and the potential for errors by clinical and portering staff.

2.44 Cylinders greater than 1100 mm in height should not be used within patient areas for safety reasons.

2.45 It is important to use the correct size of trolley for the storage and transport of cylinders. General-purpose and multi-size trolleys (for example, F/G trolleys) should not be used.

2.46 Cylinders should be secured by a suitable strap or other means so that they cannot move within the trolley (see Chapter 17).

2.47 Where trolleys are located next to beds or in general access areas, they should be secured to the wall to prevent the trolley falling or being knocked over.

2.48 The exact numbers of cylinders required will be deduced via a risk assessment for each area. As a guide, the following can be used as a starting point for each risk assessment:

- Wards and departments with piped oxygen will require medical oxygen cylinders on the resuscitation trolley and spare cylinders for internal ward movements.
- If transportation cylinders are also required, these should be identified as a separate set of cylinders and risk-assessed as to their quantity. In wards where high-flow oxygen is to be used, HX- or F4C-size cylinders should be considered. For general use, CD- or AD-size cylinders are more appropriate.

2.49 Cylinders should not be transported on the patient bed with the patient, as this presents both a fire and infection risk. Cylinders should be transported using dedicated cylinder cradles.

2.50 Cylinders should be considered as non-invasive near-patient equipment and should be cleaned in accordance with Appendix 7 of NHS England's (2025a) 'National infection prevention and control manual (NIPCM) for England'. The manufacturer's instructions for use should be considered as some chemicals may damage the cylinder, valves and components.

2.51 Where HX- or F4C-size cylinders are mounted under the bed, clear access to, and visibility of, the contents gauge and flow controller should be maintained. Under-bed mounting of smaller cylinders, such as CD- or AD-size cylinders, is not recommended unless specialist mounts are provided.

2.52 For locations where piped oxygen is not available, individual risk assessments should be undertaken to reflect clinical need. At least one cylinder should be provided for the resuscitation trolley, together with one spare. In operating theatres, this will depend on the theatres and gases used; however, a purpose-built cylinder store should be provided, subject to risk assessment.

2.53 Where spare cylinders are not stored on trolleys or in a satellite store, they should be secured in purpose-built, wall-mounted cylinder cradles. Storage should be provided separately for full and empty cylinders and be sufficient to accommodate all cylinders on the ward, plus one additional cylinder. See also Chapter 17.

2.54 These cylinders do not need to be stored in a locked room within these departments, as access may be required in an emergency; however, the cylinders and access to the area should be appropriately managed. The location of these cylinders should be agreed with the Fire Safety Manager.

2.55 Recesses should be incorporated within the architectural design to safely house cylinders. A ventilation and environmental monitoring risk assessment should be completed and agreed by the Ventilation Safety Group.

Mobile electric vacuum (MEV)/ suction machines

2.56 Electric suction may not be as efficient as pipeline suction in areas of regular use. For areas where it is identified that vacuum will be regularly used, a pipeline system should be installed. MEV units should be provided as an emergency supply or where the pipeline system is likely to be used infrequently (see Table 1).

2.57 Provision of MEV should be determined by risk assessment. Typically, one unit may be provided on the resuscitation trolley together with a minimum of one MEV per 15 outlets in each non-critical ward or department where piped medical vacuum is installed.

2.58 For critical care areas, provision should be determined by risk assessment; however, as a general rule, one unit may be provided for every five patients.

2.59 Theatres should be risk-assessed individually.

2.60 MEV should be included within the medical gas policy and procedures documentation, including details of locations and quantities available for use in emergency situations or during planned works.

2.61 Adequate storage should be provided for the required number of MEVs and their associated accessories.

Injector suction units

2.62 Another source of vacuum is injector suction units. These may not be appropriate for use on resuscitation trolleys, as they can exhaust the gas supply at rates of up to, and in some cases exceeding, 40 L/min. Where used as tertiary supplies, the main pipeline supply should be designed to accommodate the associated gas flow requirements.

3 Provision of terminal units, and the location of AVSUs, local alarm indicator panels and LVAs

3.1 Terminal unit provision, location of AVSUs and local alarm indicator panels are given in Table 1. This table provides typical types and values. It is not intended to be prescriptive but provides a basis for design. An informed design requires the four key stages listed in Chapter 1, along with a collaborative, multidisciplinary approach.

3.2 Those that should be involved in the design process may include (not exhaustive):

- the medical gas design team
- installers
- pharmacy
- the Authorised Person (MGPS)
- the Authorising Engineer (MGPS)
- clinicians and nursing staff.

3.3 Terminal units and AVSUs should be positioned or protected to prevent damage from trolleys, beds and other equipment.

3.4 Provision should be made to prevent the bed or bed attachments, chairs and mobile lockers from damaging bedhead services and equipment while being moved, raised or lowered (for example, by the use of buffering fixed to the wall, bed or floor). These may be separate from, or integrated into, the medical gas trunking system and wall units. In all cases, protection should be incorporated into the architectural design and room data sheets.

3.5 Bedhead services should not impede the insertion and operation of terminal units with equipment attached. Therefore, trunking located within 300 mm below terminal units should not project beyond the face of these units.

3.6 Where piped medical oxygen is installed and regularly used away from the patient bedhead (for example, in bathrooms), terminal units may be provided in these locations. Wall-mounted terminal units should be located not less than 600 mm from any shower or bath and should not be positioned directly above a sink. They should be installed at a height between 1400 mm and 1600 mm above finished floor level (FFL). Where wall capacity is insufficient to accommodate a wall-mounted terminal unit, a single ceiling-mounted flexible pendant may be used. For other areas, such as lounges, the installation heights should be in line with general medical gas terminal unit heights and locations.

Terminal units

3.7 Terminal units should be positioned to minimise the length of flexible connecting assemblies between the terminal unit and apparatus or patient (for example, oxygen

mask hosing or gas connection pipes to ventilators). Refer to HBN 00-03 – 'Clinical and clinical support spaces' for typical examples of room layouts and to HTM 08-03 – 'Bedhead services'.

3.8 A risk assessment should consider patient space, the location of equipment and staff access before deciding on the location of terminal units.

3.9 All terminal units should conform to BS 5682 and BS EN ISO 9170-1.

3.10 Terminal units may be surface- or flush-mounted. They may also be incorporated within medical supply units (MSUs), which include wall panel systems and pendant fittings. Further details are available in BS EN ISO 11197. When they are installed within such assemblies, the concentricity of the terminal unit bezel with the fascia plate aperture should be maintained. Misalignment may cause the bezel to bind on the fascia plate and prevent correct operation of the terminal unit.

3.11 The following are not permitted:

- floor-mounted terminal units
- wet vacuum systems (in which bodily or other fluids are drawn through a fixed pipeline from a terminal unit or other connection to a remote suction jar).

3.12 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. This is particularly advantageous in surgical air systems, as rigid pipework can be used, thereby avoiding pressure losses associated with flexible assemblies used within pendant fittings.

3.13 In critical care areas, the medical gas system circuits should be distributed on both sides of the bed (i.e. terminal units on either side of the bed are provided from "A" and "B" circuits).

3.14 Terminal units intended for directly connected equipment (for example, flowmeters) should include an anti-swivel device. Where intended for hose connection only, anti-swivel devices are not required.

3.15 An anaesthetic gas scavenging (AGS) terminal unit should be provided whenever nitrous oxide and anaesthetic agents are available for anaesthetic procedures.

3.16 Where oxygen/nitrous oxide mixture is provided, low-level extract mechanical ventilation and specialised scavenging systems using high-flow low pressure directly connected to the exhalation valve on the demand valves should be installed (see HTM 03-01 for supporting guidance on ventilation requirements).

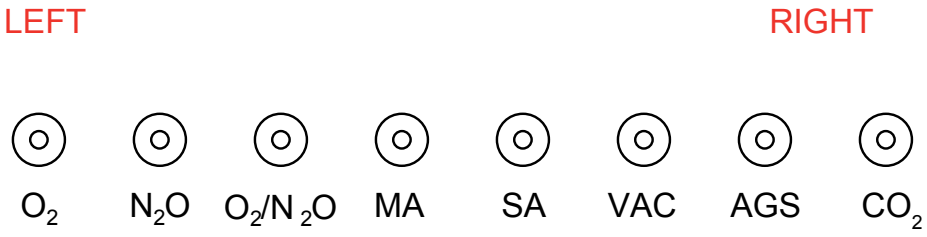
3.17 For dental departments, scavenging should be provided by means of nasal masks and low-level extract ventilation (see paragraphs 12.37–12.50).

3.18 Where respiratory equipment or surgical instruments are serviced, such as in EBME workshops and SSDs, a full range of medical gas terminal units should be installed. An AGSS should be provided as a dedicated system.

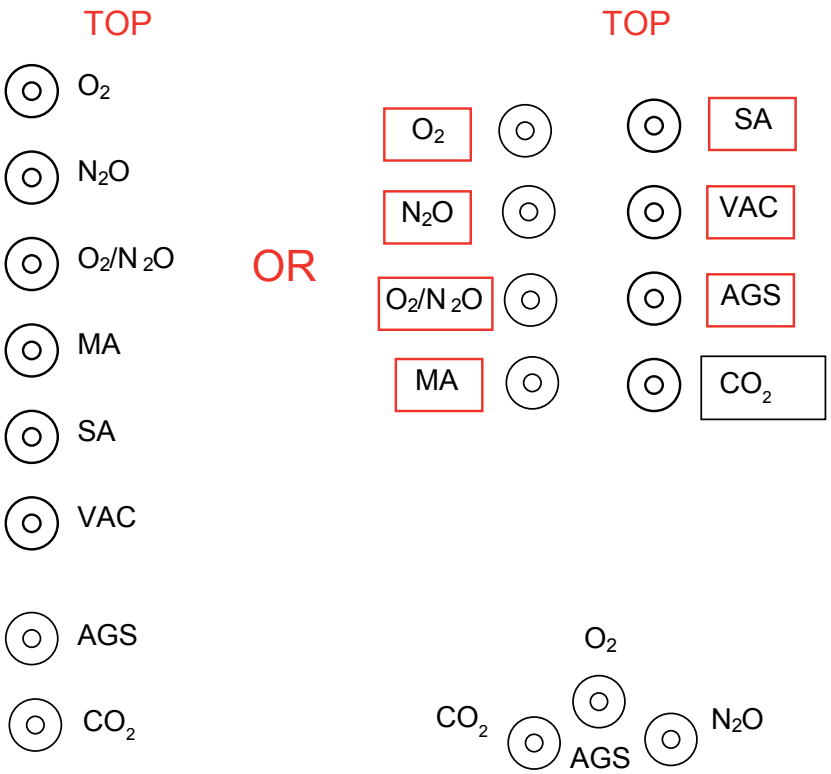
3.19 Where an array of terminal units is provided at a location, they should be arranged as follows (see Figure 1):

- For a horizontal array, when viewed from the front, left to right: oxygen, nitrous oxide, oxygen/nitrous oxide mixture (50% v/v), medical air, surgical air, vacuum, AGS, carbon dioxide. If this arrangement is impracticable, several rows can be used. In this case the order should remain in the same orientation left to right or top to bottom.

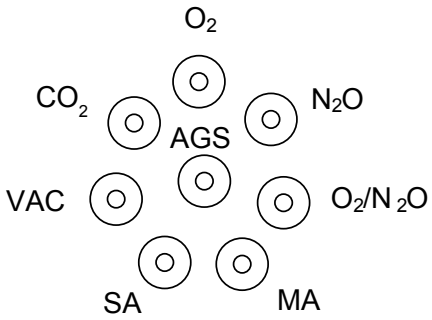
WALL MOUNTED TERMINALS – Horizontal array



WALL MOUNTED TERMINALS – Vertical array



CIRCULAR (eg pendant)– Viewed from below



WALL MOUNTED TERMINALS – Triangular (staggered) array

Figure 1 Terminal unit mounting order

- 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 (see Figure 1).
- 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.
- For a triangular array, the oxygen outlet should be located centrally and above the remaining outlets. Where there are two oxygen outlets, they should be located above vacuum.

3.20 Where carbon dioxide is specified, a NIST connection is required, not a probe connection. For this reason, it should be placed at the outermost point of the array.

3.21 Mounting heights for terminal units should be between 900 mm and 1600 mm above FFL when installed on walls or similar vertical surfaces (see Figure 2). When terminal units are incorporated within a horizontal bedhead service trunking system, which may also include 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.

3.22 The positioning of terminal units should ensure that gauges, flowmeters and suction jars can be easily viewed while administering medical gases to a patient.

3.23 In cases where multi-movement pendants and MSUs are being considered, the proposal should be reviewed by the Authorising Engineer (MGPS) and approval should be sought from the MGSG. Fixed pendants should be the default option to remove the need for flexible connections.

3.24 Hose replacement schemes should be programmed as life-cycle requirements whenever integral hoses are introduced into the MGPS. Hose replacements should be undertaken every five years, unless environmental conditions dictate sooner replacement, or manufacturers' recommendations change. Hose specifications should be determined at the design stage and before installation (see BS EN ISO 5359).

3.25 Multi-movement pendants and MSUs should provide a sufficient range of movement to enable terminal units to comply with the specified height range. Where installed in pendants or similar fittings, terminal units should be of a type suitable for mounting within those fittings.

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

3.27 Terminal units that are wall-mounted should be located as follows (see Figure 2):

- The distance between centres of adjacent horizontal terminal units should be:
- 135 ± 2.5 mm for three or more terminal units
- 150 ± 2.5 mm for two terminal units only.
- The distance between the centre of the terminal unit and a potential obstruction on either side (for example, when installed in a corner – see Figure 2) should be a minimum of 200 mm on either side. A clearance of 200 mm above the outlet and 300 mm below the outlet is also recommended. Where an item of equipment is movable and has various resting positions so that the obstruction can be repositioned to facilitate the appropriate use of the terminal unit and connected devices, this should not be considered as an obstruction (for example, an examination light on an adjustable arm).

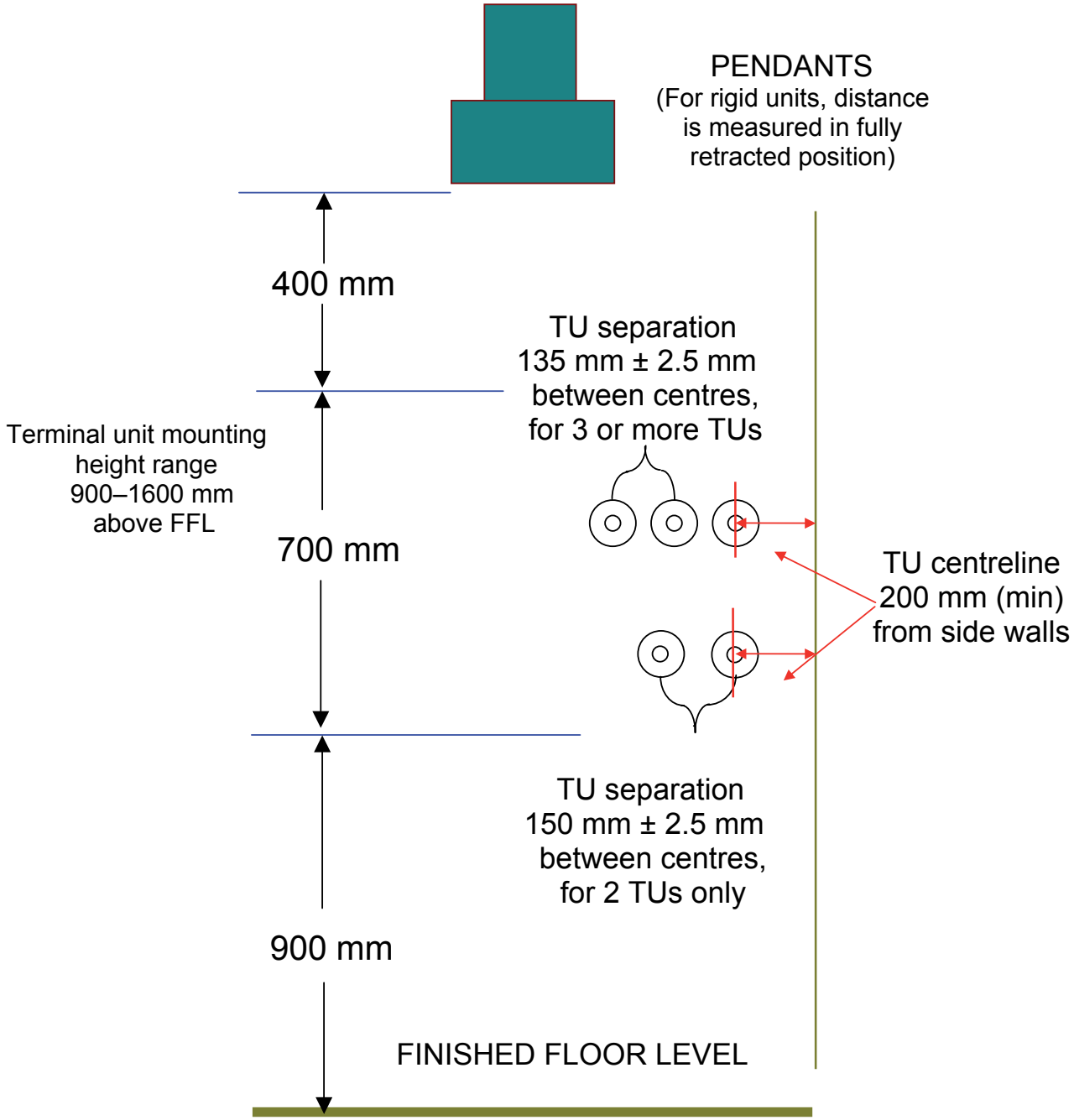


Figure 2 Terminal unit mounting heights

Note:
To promote a more domestic environment, some in-patient accommodation may be provided with terminal units installed in recesses behind covers, decorative panels or cupboards. To accommodate this, an additional 100 mm should be allowed on each side of the outermost terminal units (Figure 2), with clearances of 200 mm from the centre to the top of the recess and 300 mm from the centre to the bottom of the recess. For example, where oxygen and medical vacuum terminal units are installed side-by-side, a centre-to-centre spacing of 150 mm should be provided, together with an additional 100 mm on each outer side, resulting in a minimum recess width of 750 mm wide. The recess height should not be less than 500 mm. Where terminal outlets are arranged in a vertical array, the spacing between outlets should not

be less than 300 mm, resulting in a minimum recess height of 800 mm and a minimum width of 600 mm. The recess depth should be 150 mm. Ventilation is required at both high and low level to ensure there is no build-up of gases in the event of leakage. The surface should be clearly marked with a suitable legend indicating the presence of medical equipment within.

- Care should be taken to ensure that connected medical gas equipment, vacuum jars and hoses do not foul other nearby equipment and services during use. Particular attention should be given to terminal unit positioning with respect to worktops, electrical sockets, cupboards, equipment rails, ventilation flaps and door openings.
- In MSUs such as bedhead trunking (see BS EN ISO 11197), there is no requirement to fit a bezel plate or escutcheon. Where they are provided around the terminal outlet at second fix, a circumferential clearance of not less than 1 mm and not greater than 2 mm should be maintained to ensure that the outlet is reasonably concentric within the aperture provided.
- Where medical equipment rails are incorporated into MSUs, consideration should be given to the maximum mounting height of such rails as set out in HTM 08-03. The height of the vacuum jar in relation to the patient position is critical to prevent back siphonage when the jar is full or spills in the event of a leak. The jar should always be lower than the patient's position. Medical equipment rails (see BS EN ISO 19054) are also used for other items of medical equipment.

3.28 HTM 06-01 and HTM 08-03 advise against the use of plastic trunking systems for the construction of MSUs. Plastic trunking/ containment should not be used to house terminal outlets and pipelines.

3.29 For healthcare facilities defined as temporary (i.e. less than six months), such as those established during a pandemic or other natural disaster, this guidance still applies.

"Do not use" plugs

3.30 "Do not use" plugs should be inserted in all terminal unit second-fix outlets until the terminal unit has been tested and is ready for patient connection. This applies to construction, upgrades and repairs. Plugs should only be removed on completion of all pharmacy checks or Authorised Person (MGPS) testing, including for single terminal unit repairs.

3.31 "Do not use" plugs inserted under a PTW scheme should only be removed with the authorisation of the Authorised Person (MGPS).

3.32 Stickers should not be used in place of "Do not use" plugs due to:

- risks of detachment
- the difficulty of removal and replacement during testing
- the infection risks from residual adhesive.

3.33 "Do not use" plugs should be inspected for contamination and cleanliness prior to insertion and on removal of each use. Where contamination is observed, they should be cleaned in line with the manufacturer's recommendations.

3.34 "Do not use" plugs should be single-piece components inserted into the terminal unit that interlock with the probe-retaining mechanism.

3.35 Removal of the plug should require a deliberate physical action to prevent accidental removal or dislodgement.

3.36 The plug should display the words DO NOT USE in lettering of sufficient size to be clearly legible from the foot of the bed. The

plug should be either red with white lettering or white with red lettering.

3.37 Plugs should be controlled by the Authorised Person (MGPS) and stored in a manner that ensures they can be accounted for and managed, preventing them from being left on site inadvertently. The insertion of plugs should be recorded on the PTW.

Flexible hoses

3.38 All work on hoses requires a PTW.

3.39 The use of flexible medical gas hoses should be avoided in all situations unless there is a requirement for movement between the position of the terminal unit and fixed pipeline system such as MSUs to remove the necessity for hose replacements and contamination risk.

3.40 NIST connections should be used to connect hoses at both ends.

3.41 The pipeline should terminate with a female NIST. NIST blanking nuts should also be provided. The blanking nut ensures the pipe is kept clean and enables pressure-testing of the system prior to the connection of flexible hoses.

3.42 NISTs are used to ensure a gas-specific mechanical connection is available to facilitate the changing of hoses.

3.43 Within an MSU, the terminal unit should include a male NIST connector and nut brazed to the rear of the terminal unit.

3.44 During the design phase, consideration should be given to the replacement of flexible hoses and how disruption to the department or area will be managed given clinical pressures for the space.

3.45 In movable systems, where flexible hoses are used to connect the terminal units to the NISTs, the following requirements should be met:

- All hoses should be BS EN ISO 5359 compliant.
- The hose should be connected to the terminal unit NIST, routed through the MSU to the female ceiling NIST and connected with minimal excess length at the ceiling or within the pendant. Excess length can lead to kinking, twisting and increased pressure drop. The hose length should be sufficient to allow connection and disconnection and pendant movement without risk of kinking.

3.46 Hose replacement should only be undertaken by a Competent Person (MGPS) with specific training in hose manufacture and replacement.

3.47 All hoses should be labelled with the hose assembly manufacturer's details, the date of manufacture and replacement date.

3.48 Hose replacement dates should be displayed on the outside of MSUs or pendants so that they are easily visible to equipment users.

3.49 All hose replacements must comply with the requirements of the relevant monographs of the British Pharmacopoeia for the specific gas.

3.50 Flexible hoses by their design have a porous nature which allows moisture to be absorbed in minute quantities over long periods of time. This can conflict with the dew-point requirements of medical gases. The use of flexible hoses should be restricted where possible, particularly in areas where the terminal units are infrequently used. A rigid pipeline system is the preferred option.

3.51 Purging hoses with medical air prior to installation can aid in the reduction of moisture levels before testing.

3.52 All hoses should be kept in sealed bags during storage and transportation to minimise the ingress of moisture and debris.

NIST connections

3.53 NISTs should be included on all LVAs and AVSUs, and above MSUs for connection to medical gas flexible hoses.

3.54 Where NISTs are installed on LVAs, they should be facing down towards the floor on horizontally installed valves and at 90 degrees to the pipe on vertically installed valves, ensuring full and free access with a minimum clearance of 250 mm from the face of the NIST to any obstruction. Access should provide sufficient room to undertake the insertion and removal of hose connections by hand and require minimal tooling.

3.55 Access spacing is essential for NIST plates in the ceiling for MSU connections and it is recommended that a separate 600 mm x 600 mm hatch is installed in close proximity to the pendant for free and uninterrupted access to the NISTs.

3.56 NISTs should comprise a NIST nut assembly capable of being locked off.

Nitrogen for surgical tools

3.57 BS EN ISO 5359 gives details of connectors for nitrogen for driving tools. The body of the NIST connector should form the wall outlet.

AVSUs

3.58 AVSUs should be mounted at a convenient height between 1 m and 1.8 m such that they can be operated comfortably by staff without needing to stoop or overreach (see Figure 3). The order of the location of individual valves in an array should follow that for terminal units, for example: O_2, N_2O and/or O_2/N_2O, MA, SA, VAC, CO_2. If the array exceeds 1 m in height from top to bottom, it may be preferable to arrange them in two

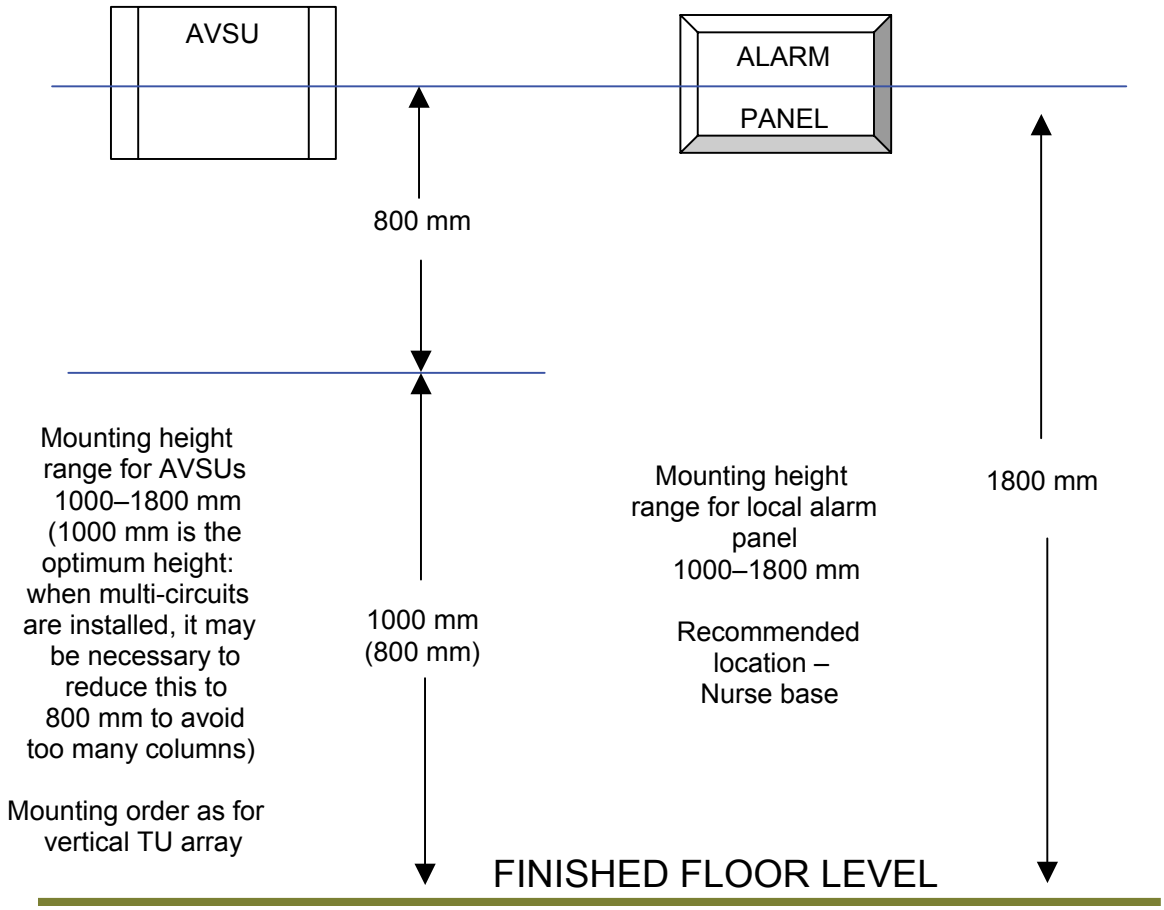


Figure 3 AVSU and local alarm panel mounting heights

columns. Care must be taken to ensure that AVSUs cannot be obscured by opening doors. Details of the design of AVSUs are given in Chapter 15.

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

3.60 Where there are dual circuits, they can be arranged in two separate columns (see BS EN ISO 7396):

> O_2, MA4, VAC in each column or in a single column: O_2, O_2, MA4, MA4, VAC, VAC (see Figure 4).

3.61 If there is sufficient wall space, the two-column arrangement is preferable with local alarms for each column, as this minimises the potential for confusion during isolation.

3.62 Specific signage and a schematic drawing should be located at each AVSU to denote the area and individual terminal units that it isolates.

3.63 Departmental AVSUs should be installed at the hospital street side of the entrance doors to a department to aid isolation of the department in an emergency. It should be noted that in some large departments (for example, an operating department) the clean-service corridor is likely to cross one or more fire compartment walls. Additional AVSUs may therefore be required to align with the fire strategy under the advice of the healthcare organisation's Fire Safety Manager.

3.64 The layout of AVSUs within departments should be developed in consultation with medical and fire safety teams to ensure that their locations support effective gas isolation, fire safety and staff awareness. MGPS mains distribution pipelines that supply AVSUs should not be installed within the area that is isolated by the AVSU unless additional protection is provided for the distribution pipework.

3.65 If a department extends across more than one floor, separate mains from the riser or a ring main will be required, and a set of AVSUs should be provided on each floor.

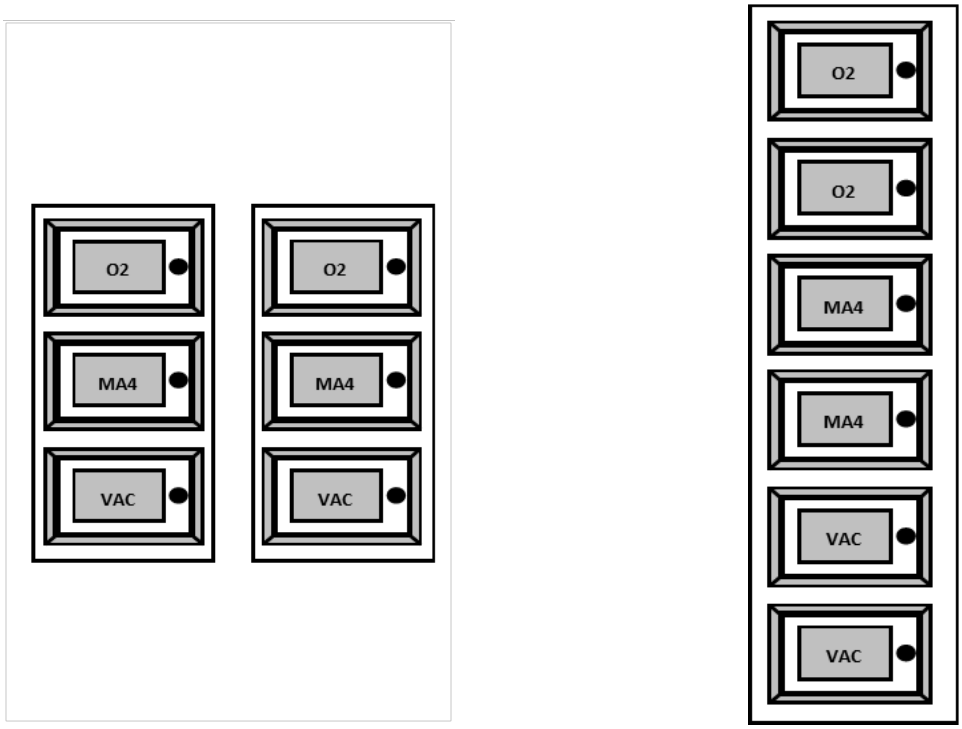


Figure 4 Arrangement for dual circuit AVSUs

3.66 Departmental AVSUs should be external to the departments they serve. Local alarms should be provided for each individual AVSU (not departmental) in all areas.

3.67 Special ventilated isolation facilities (see HBN 04-01 Supplement 1 – 'Special ventilated isolation facilities for patients in acute settings') may have their own set of AVSUs fed from the departmental AVSU to allow the medical gases in each room to be isolated independently from the other rooms in the department. This is to reduce disruption during maintenance or repairs.

3.68 Each different room/department type should be separately isolated via an AVSU in line with Table 1 (ward treatment rooms can be part of the main ward system).

3.69 Where pneumatic brakes are used, a separate surgical air AVSU and flow control system (see Figure 5) should be installed for each pendant.

3.70 The pneumatic brake AVSU may serve various pendants and should be located at the base of the AVSU array or to one side of the main array to ensure that there is no confusion in isolation and be identified as "AIR for brakes" with the appropriate valving downstream of the AVSU. Electrical brake systems are preferable for all moving pendants.

Pressure-reducing station

3.71 Where the pressure needs to be reduced on an air system, a pressure-reducing station (PRS) should be provided (for example, surgical to medical air). Where surgical air is used, an emergency reserve manifold (ERM) for surgical air is essential.

3.72 The PRS should be a duplex system to ensure that the flow of the gas is not interrupted in the event of maintenance or component failure and the failure of a single component does not stop the flow.

3.73 The system should be set up with a lead and lag regulator with a maximum of 50 kPa differential to maintain line pressure.

3.74 Each side should comprise a pressure regulator, an analogue pressure gauge, a safety relief valve, a terminal unit (for testing purposes), a non-return valve and a pressure transducer encapsulated between two line valves (see Figure 6).

3.75 Where the PRS could be subject to damage or external contamination, it should

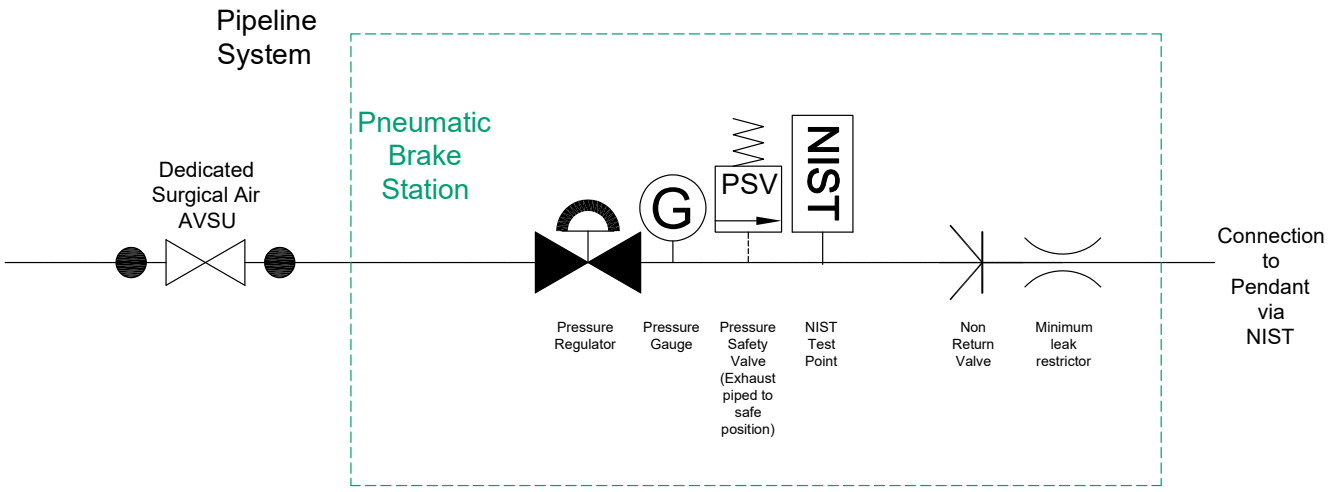


Figure 5 Flow control device for pneumatic brakes

be housed in a cabinet with clear visibility of the gauges and alarm conditions.

3.76 The terminal unit (test point) on the downstream side of the PRS should be gas-specific. In the case of dental air (600 kPa), the terminal should be a surgical air terminal unit clearly identified as a 600 kPa supply.

3.77 To allow safe access to work on the PRS, the pressure-relief valves should be piped away individually to a safe location.

3.78 To monitor the PRS, an alarm should be installed.

3.79 The alarm should be located at the PRS and repeated on the plant alarm system as an individual column.

3.80 The alarm should have a digital readout of the pressure for both regulator outputs and provide high-pressure and a low-pressure conditions (see Figure 6).

Local alarm indicator panels

3.81 The placing of local alarm indicator panels should be such that they are readily visible and audible by staff. If this cannot be achieved, repeater panels should be used. Notices, partitioning and screens should not obscure alarm indicator panels. The mounting height should allow staff to activate the “mute” switch without overreaching in the event of an audible alarm sounding and should not exceed 1.8 m above FFL (see Figure 3).

LVAs

3.82 LVAs should be installed at branches from risers, branches from main runs, and where pipelines pass into or out of a building.

3.83 LVAs should not be installed downstream (patient side) of the AVSU. Where required to achieve double isolation and a physical break, installation upstream of the AVSU may be considered, subject to a risk assessment.

3.84 Details of the design of LVAs are given in Chapter 15.

3.85 Labelling and signage is covered in Chapter 18.

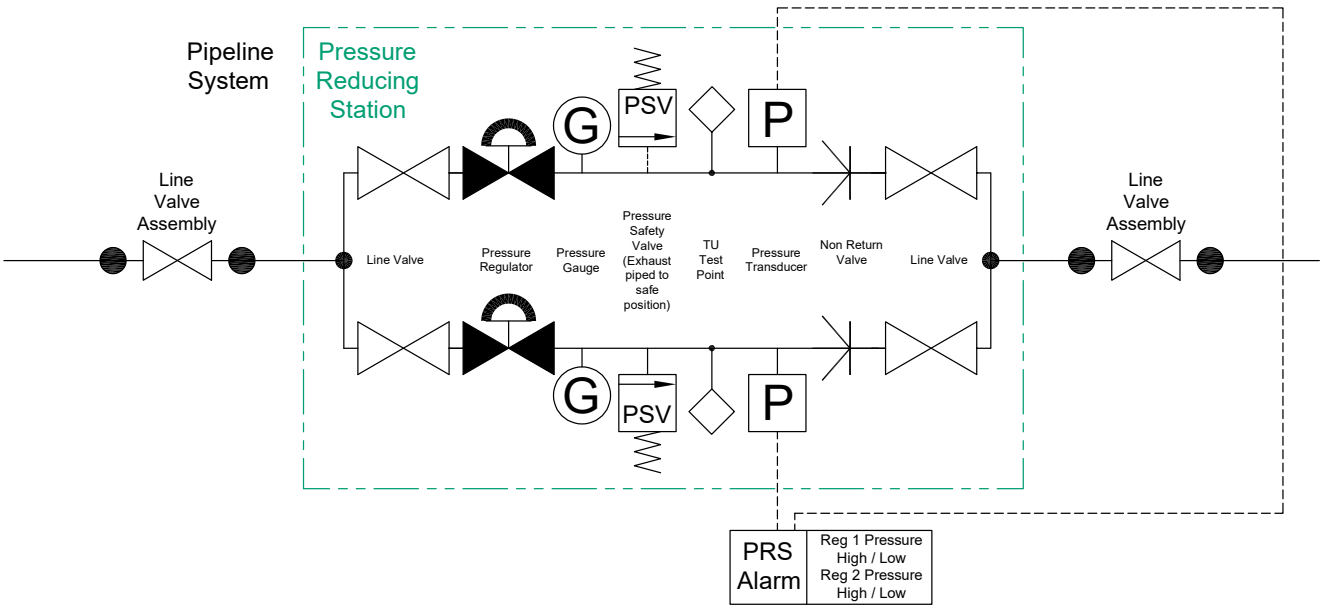


Figure 6 Pressure-reducing station

Table 1 Typical examples for the provision of terminal units, AVSUs and local alarms

Department	O_2	O_2/N_2O	MA4	SA7	VAC	AGSS	AVSU	Alarm	Circuits
Emergency department (UEC, SDEC, ED)							**1 set (departmental)**		
Resuscitation room, per trolley space	4	–	2	–	2	–	2 sets	Local alarm	Dual
Major treatment	4	–	2	–	2	–	2 sets/6 TUs	Local alarm	Dual
Minor treatment	1	–	–	–	1	–	1 set/6 TUs	Local alarm	Single
Treatment room/cubicle	1	–	–	–	1	–	1 set/6 TUs	Local alarm	Single
Triage	1	–	–	–	1	–	1 set/6 TUs	Local alarm	Single
Ambulatory care area	1	–	–	–	1	–	1 set/6 TUs	Local alarm	Single
Plaster room per trolley space	1	–	–	1	1	–	1 set/6 TUs	Local alarm	Single
Operating department*							**1 set (departmental)**		
Anaesthetic room	1	–	1	–	1	1	2 sets per suite	Local alarm	Single
Acute operating theatre	4	–	4	2	4	2			Dual
Day case theatres	2	–	2	2	2	2	2 sets	Local alarm	Dual
Minor ops theatre	2	–	2	2	2	2	2 sets	Local alarm	Dual
Ophthalmic theatres	2	–	2	2	2	2	2 sets	Local alarm	Dual
Post-anaesthesia recovery, per bed space (stage 1)	2	–	2	–	2	–	2 sets (Max 6 beds)	Local alarm	Dual
Post-anaesthesia recovery, per bed space (stage 2)	1	–	-	–	1	–	1 set (Max 6 beds)	Local alarm	Single
Equipment service room per workspace	1	–	1		1	1	1 set	Local alarm	Single

Department	O_2	O_2/N_2O	MA4	SA7	VAC	AGSS	AVSU	Alarm	Circuits
Critical Care units							**1 set (departmental)**		
Intensive care unit (ICU/ITU) per bed space	4	–	2	–	4	–	2 sets (max 6 beds)	Local alarm	Dual
High dependency unit (HDU) per bed space	4	–	2	–	4	–	2 sets (max 6 beds)	Local alarm	Dual
Coronary care unit (CCU) per bed space	4	–	2	–	4	–	2 sets (max 6 beds)	Local alarm	Dual
High dependency ward or decant ward per bed space	4	–	2	–	4	–	2 sets (max 6 beds)	Local alarm	Dual
Maternity department							**1 set (departmental)**		
Operating room (mother)	4	2	2	–	4	1	2 sets per suite	Local alarm	Dual
Operating room (child)	2	–	2	–	2	–			
Post-anaesthesia recovery (per bed space)	2	–	2	–	2	–	1 set (max 6 beds)	Local alarm	Single
LDRP room (normal/abnormal) Mother**	1	1	–	–	2	1	1 set (max 6 rooms)	Local alarm	Single
LDRP room baby (for 2 cot spaces)	2	–	2	–	2	–			
Neonatal unit, per cot space	4	–	2	–	4	–	2 sets (max 6 cots)	Local alarm	Dual
In-patient accommodation: Per bed space (Mother)	1	–	–	–	1	–	1 set	Local alarm	Single
In-patient accommodation: Per bed space (Child)	2	–	2	–	2	–			
Equipment service room per workspace	1	1	1	–	1	–	1 set	Local alarm	Single

Department	O_2	O_2/N_2O	MA4	SA7	VAC	AGSS	AVSU	Alarm	Circuits
In-patient accommodation (general ward/medical or surgical)							**1 set (departmental)**		
Per bed space	1	–	–	–	1	–	1 set (max 30 beds)	Local alarm	Single
Treatment room	1	–	–	–	1	–			Single
In-patient decant ward (general ward/medical or surgical)							**1 set (departmental)**		
Per bed space	2	–	2	–	2	–	1 set (max 30 beds)	Local alarm	Dual
Treatment room	1	–	–	–	1	–			Single
Renal							**1 set (departmental)**		
Per dialysis station	1	–	–	–	1	–	1 set (max 10 stations)	Local alarm	Single
Per bed space	1	–	–	–	1	–	1 set (max 10 beds)	Local alarm	Single
Adult mental health accommodation									
Electro-convulsive therapy (ECT) room	1	–	–	–	1	–	1 set	Local alarm	Single
Post-anaesthesia recovery, per bed space	1	–	–	–	1	–	1 set	Local alarm	Single
Non-acute accommodation (community/hospice)									
Per bed space	1	–	–	–	1	–	1 set (per 12 rooms)	Local alarm	Single
Treatment room (separate from bedroom area)	1	–	–	–	1	–	1 set	Local alarm	Single

Department	O_2	O_2/N_2O	MA4	SA7	VAC	AGSS	AVSU	Alarm	Circuits
Day patient accommodation							**1 set (departmental)**		
Per bed space	1	–	–	–	1	–	1 set (max 30 beds)	Local alarm	Single
Treatment room	1	–	–	–	1	–			Single
Out-patient department							**1 set (departmental)**		
Treatment room/cubicles (per patient space)	1	–	–	–	1	–	1 set (per 12 rooms)	Local alarm	Single
Consulting/examination rooms	–	–	–	–	–	–	–	–	–
Diagnostics departments							**1 set (departmental)**		
Magnetic resonance imaging (MRI) suite	1	–	–	–	1	–	1 set (max 2 rooms)	Local alarm *2	Single
CT examination room	1	–	–	–	1	–	1 set (max 2 rooms)	Local alarm *2	Single
Endoscopy	1	–	–	–	1	–	1 set per room	Local alarm *2	Single
General/specialist diagnostics rooms, X-ray and radiotherapy	1		–	–	1	–	1 set (per 6 rooms)	Local alarm *2	Single
Diagnostics recovery per bed space	1	–	–	–	1	–	1 set (per 12 beds)	Local Alarm	Single
Sterile services department							**1 set**	**Local alarm**	
Wash room	–	–	1	1	–	–			Single
Inspection, assembly and packing (IAP) room	1	–	1	1	–	–			Single
Oral surgery, orthodontic department							**1 set**	**Local alarm (repeater)**	
Consulting/treatment room,	1	–	–	1	1	1	1 set (max 6 rooms)	Local alarm	Single
Laboratory, per workstation	1	–	–	1	–	1	1 set	Local alarm	Single
Recovery	1	–	–	–	1	–	1 set	Local alarm	Single

Department	O_2	O_2/N_2O	MA4	SA7	VAC	AGSS	AVSU	Alarm	Circuits

Notes:

* Dual pipeline circuits should be provided to operating theatres where enhanced resilience is required at the point of surgery. Each theatre pendant may be served from a separate circuit to maintain supply availability in the event of isolation or failure of one circuit. Anaesthetic rooms may be served from a single circuit (one of the theatre circuits) where this is supported by the IDP and local risk assessment. In the event that the circuit serving the anaesthetic room is unavailable, induction may be undertaken in the operating theatre where clinically appropriate. Where the anaesthetic room is identified as critical to service continuity, consideration should be given to providing dual circuits to that room

** For LDRP rooms with birthing pools, an additional O_2/N_2O terminal unit should be located for use of the pool.

- Non-acute hospitals should be addressed in line with the requirements for the sites with restricted hours and therefore this should be reflected in the plant selection. Outlets should be as per this Table.
- To use as guidance in the absence of a direct match, a similar use area for the areas being designed should be used where possible from the list above.
- If the patient is horizontal or in a chair for treatment or observation, (e.g. consulting/examination rooms) the out-patient's treatment room should be used as a basis for the IDP.
- Where dual circuits are stated, the circuits should be evenly split to cover both sides of the bed or each pendant; for example, where there are 4 terminal units on each side of the bed, there should be 2 from each circuit. This ensures the dry and wet side of the beds are maintained. Numbers stated are the total number of terminal units across both circuits. In some circumstances all terminals may be preferable on the wet side of the bed; this requires clinical input into the design.
- Where surgical air is used as the brake system for multimovement architectural systems, it should comply with paragraph 3.69.
- Refer to Chapter 10 for guidance on medical vacuum.

4 Gas flow

4.1 Various layouts of an MGPS are shown throughout this document, and each should be risk-assessed and designed to consider the anticipated design flow area, usage and availability of supplies.

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

- the test flow that is required at each terminal unit for test purposes (this flow is essentially to establish that the terminal unit functions correctly and that there are no obstructions; see Table 2)
- the typical flow required at each terminal (this is the maximum flow likely to be required at any time in clinical use; see Table 2)
- the likely numbers of terminal units in use at any time
- the layout of the ward and how the pipeline system is configured (for example, flow loops, radial circuits)
- the total flow to the ward/department, that is, the sum of the diversified flows in each sub-branch
- the flow in the main branches/risers, that is, the summation of all diversified flows for wards and departments
- the flow required at the plant. In most cases this will be the flow in (f) above except in the case of vacuum that is not used continuously
- the total design flow rate.

4.3 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. Table 2 provides indicative values of the flow that should be achieved at each terminal unit and should be used during the IDP. The flows are expressed in free air. Diversified flows should be used for the purposes of pipe-size calculations.

4.4 The designer should always ensure that due account is taken of the stated use of a particular department and likely potential future changes in use. It should include consultation with the end users and a risk assessment. The Authorised Person (MGPS) should review all designs with the support of the Authorising Engineer (MGPS). The MGSG should review the design and provide approval before any work commences.

4.5 There is a limited range of pipe diameters; design calculations will dictate what size of pipe is required. Where design calculations approach the upper limit of a given pipe size, the next nominal pipe diameter should be chosen. A minimum of 22 mm diameter pipe should be used for distribution and 15 mm diameter pipe should only be used to feed individual terminal units.

4.6 When calculating diversified flows, it is the number of bed spaces, treatment spaces or rooms in which the clinical procedure is being performed that is used; this is not the individual number of terminal units, as, 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.

Service	Location	Nominal pressure (kPa)	Design flow (L/min)	Typical flow required (L/min)	Test flow (L/min)
Oxygen	Operating suites	400	50	20	50
	Critical care units	400	60	15	60
	All other areas	400	10	6	40
Nitrous oxide	All areas (where specified)	400	15	6	40
Oxygen/nitrous oxide mixture	LDRP (labour, delivery, recovery, post-partum) rooms	400	275	20	275
	All other areas	400	20	15	40
Medical air 400 kPa	Operating suites	400	40	40	40
	Critical care areas	400	80	80	80
	Other areas	400	20	10	40
Surgical air/nitrogen	Orthopaedic and neurosurgical operating rooms	700	350	350	350
	All other areas	700	100	50	100
Vacuum	All areas	Minimum 315.5 mmHg	40	40	40
Carbon dioxide	Operating rooms and endoscopy (where specified)	400	20	10	20

Table 2 Gas flows: flows required at terminal units

4.7 The overall pipeline design should be based on a 5% pressure drop from the plant/source of supply to that measured at the terminal unit outlet at the specified test flows.

Pipeline design

4.8 The high flow usage of medical gases during the COVID-19 pandemic highlighted the risk of "starving" medical gas terminal units downstream of a significant load if the pipeline installation is not able to provide adequate flow. Ladder arrangements and ring mains for distribution and flow loops in wards and departments can provide greater resilience in the system.

4.9 Pipeline design can be broken down into three distinct areas:

- supply lines (pipeline from the supply point to the distribution system)
- the distribution system (from the supply line to AVSUs)
- pipelines within wards and departments (the pipeline downstream of the AVSUs).

High-flow terminal unit supplies

4.10 Where an area is designed for continuous positive airway pressure (CPAP), bilevel positive airway pressure (BiPAP) or non-invasive ventilation (NIV), two specific options should be considered. The complete flow loops could be upgraded to accommodate the higher flows (typically by increasing the pipe size by one size), or dedicated pipelines could be installed.

4.11 Dedicated terminal units for high-flow use is likely to cause confusion, particularly in an emergency situation. A dedicated pipeline can cause control and flow issues. Therefore, this option is not recommended

4.12 The preferred solution is to increase the flow-loop pipe size. To accommodate the higher flow rate, the pipework down to each individual terminal unit should be calculated. This is typically increased to 22 mm.

Supply lines

4.13 The pipeline from the supply plant to the distribution system should be sized to achieve the full design flow rate of the system, plus an additional 25%. This will ensure adequate pipeline sizing to remove any future restrictions. This will form part of the IDP.

4.14 A valved bypass arrangement for non-return valves and other inline equipment (such as flow measuring devices) should be installed to permit service/calibration/replacement without the shutdown of a pipeline supply.

4.15 The location of pipelines and the position of connections is dependent on the design and layout of the facility. Some of the primary considerations are:

- support of the pipeline
- the avoidance of external risks to the pipeline
- location for connection into the distribution system
- LVA: isolation at the supply system
- LVA: isolation on leaving and entry of any building
- LVA: isolation prior to the connection to any ring mains or ladder systems where there are two or more points of connection into the pipeline from supply sources
- adequacy of pipeline supply
- pipeline positioning to avoid damage.

4.16 The above considerations will form part of the pipeline design to ensure continuity, adequacy and security of the supplies.

4.17 A minimum pipeline size of 22 mm diameter should be installed for all supply lines. A design calculation should be carried out to determine whether a larger diameter is needed.

Distribution system

4.18 The distribution pipework may be installed in many different configurations. The distribution pipework is the pipework from the point of connection to the supply source within the building to the AVSU at the entrance to a ward or department.

4.19 The distribution network should be designed to maximise effective distribution and minimise risk across all areas by using ladder systems and ring mains where practically possible.

Ladder systems

4.20 Ladder systems are formed by the installation of two or more risers to each floor which are interconnected to the distribution system on each floor. They require LVAs to be installed above and below each branch, as well as on each branch (see Figure 7).

4.21 A minimum pipeline diameter of 22 mm should be installed for all distribution lines. A design calculation should be carried out to determine whether a larger diameter is needed.

4.22 The fire strategy should consider the interconnection between the different risers and supplies.

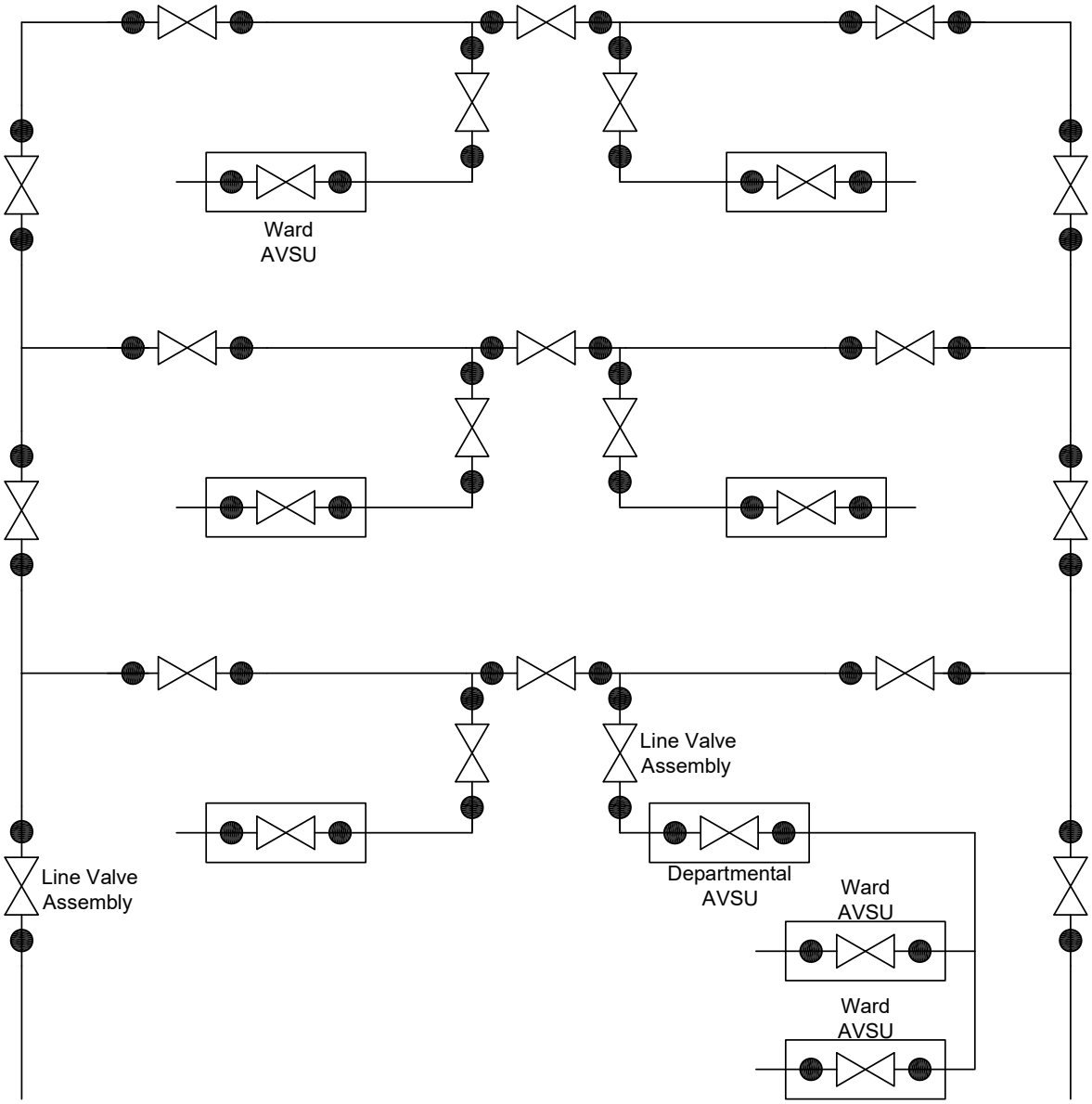


Figure 7 Example of a ladder system for a complete building

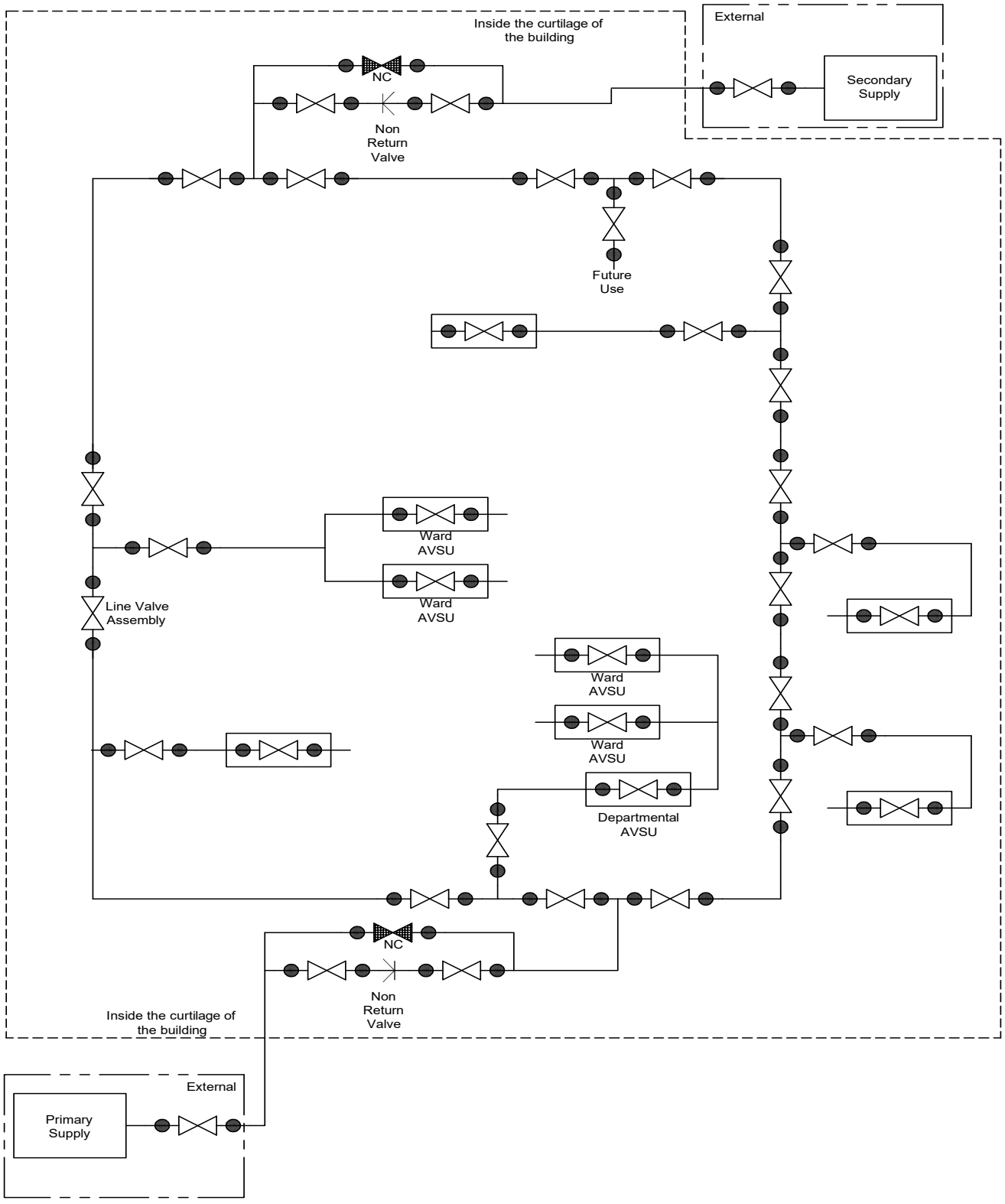


Figure 8 Ring main (showing primary and secondary supplies only)

Ring main systems

4.23 Ring main systems comprise a pipeline distribution system where all of the distribution legs are connected via a pipeline that can be fed from either leg of the ladder (where installed) and from either direction.

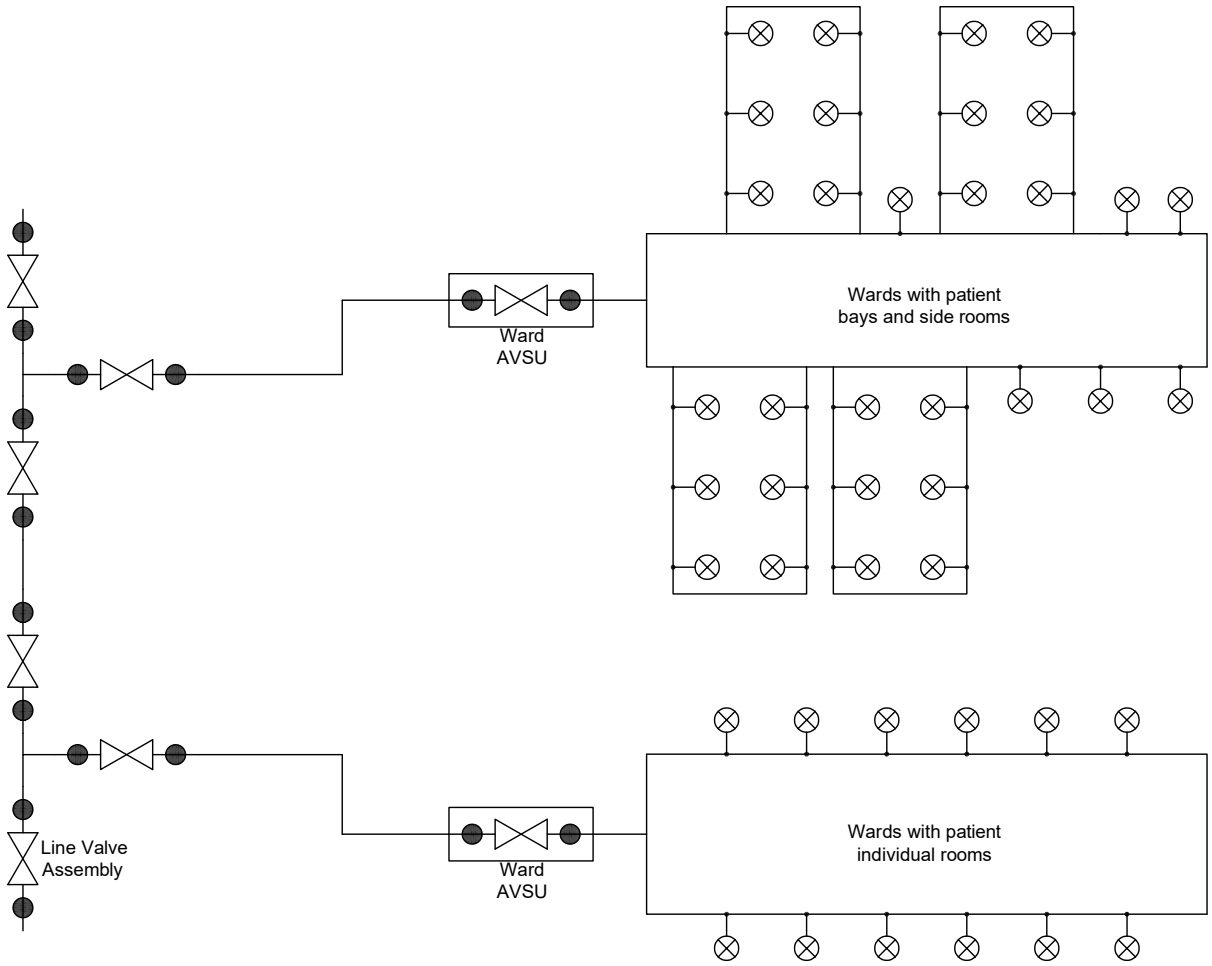


Figure 9 Flow loops with individual rooms and patient bays

4.24 The ring main should include LVAs and NISTs to ensure that each section of pipework incorporates at least one NIST point. A typical arrangement is shown in Figure 8.

4.25 This ensures that isolations of individual segments of the system for additions and maintenance are possible without major disruption to wards and departments.

4.26 A minimum pipeline diameter of 22 mm should be installed for all ring mains. A design calculation should be carried out to determine whether a larger diameter is needed.

Flow loops

4.27 Flow loops are simplified ring mains within the ward or department that are free from LVAs.

4.28 The pipework is distributed through the ward or department, routed along each side, and joined together at the end to form a loop within the area (see Figure 9).

4.29 Flow loops may be used within bed bays over two beds to maintain continuity of medical gas flow. This ensures that, in the event of high medical gas demand at one point, other points can be supplied from either

direction, thereby reducing the risk of pressure drop.

4.30 If used in critical care areas for the provision of high-flow ventilation, the loop should be increased by one pipeline size to enable the high demands within the area.

4.31 Flow loops may be used on:

- medical oxygen
- medical air
- oxygen/nitrous oxide mixture
- vacuum.

4.32 The following gases will not require flow loops:

- surgical air
- nitrous oxide
- carbon dioxide.

4.33 No LVAs or other isolation devices are permitted downstream of the final AVSU between the AVSU and the terminal unit/outlet point (other than as per paragraph 4.36).

4.34 The only exception to this rule would be for MSUs where flexible hoses are utilised internally. In these cases, MSU isolation valves are permitted within the ceiling void within the bed space area to individually isolate the system for urgent repairs or maintenance applications.

4.35 A minimum pipeline diameter of 22 mm should be installed for all flow loops. A design calculation should be carried out to determine whether a larger diameter is needed.

Medical supply units (MSU) containing flexible hoses

4.36 Line valves are only permitted downstream of an AVSU, immediately prior to the NIST connections of an MSU containing flexible hoses, where multiple MSUs are fed from a single AVSU. They should be located in the ceiling void within the bed space.

4.37 NIST connections should not be installed on MSU isolation valves; they are for isolation for hose replacements and remedial work only.

4.38 When isolating an MSU isolation valve, great care should be taken as these valves will not be monitored by the location pressure alarm system. For this reason, it is essential that they are managed in a more stringent manner under the PTW system.

Gas feed via an AVSU (or terminal unit)

4.39 Oxygen supply to the downstream side of an AVSU (with the valve closed) may be achieved using an emergency backfeed kit consisting of a minimum of two cylinders (one on each bank) with individual regulators and associated supply hoses with gas-specific connectors.

4.40 Such an arrangement may be used to support departments during programmed works and where applicable in emergency supply requirements, albeit the unit will usually be of limited capacity by comparison to a fixed automatic manifold system.

4.41 Each backfeed kit should be subject to a risk assessment to determine its suitability to meet the department's flow rate and duration requirements. Consideration should be given to high-flow scenarios, where icing of regulators and hoses may cause supply failure.

4.42 Storage, maintenance, testing, security and deployment arrangements for the emergency backfeed kits should be recorded in the MGPS operating records (see Part B).

Terminal unit flow

4.43 At the design stage, the project team should define the individual room/space requirements. Departments usually comprise

several ward units, treatment rooms and other spaces. To avoid confusion, the nomination of each clinical space should be clearly defined and referenced to a classification in Table 1 for its definition so that the appropriate gas flow requirements can be established at the commencement of the design stage.

Pipeline flow

4.44 Full sites that are not open 24/7 should consider the required demand for medical gas usage across the working hours only.

4.45 Precise prediction of pipeline flow is not possible, but there are guidelines that may be used which have been shown to be adequate in practice. Table 2 provides indicative values of the flow that should be achieved at each terminal unit and should be used during the IDP.

4.46 For vacuum systems, the minimum vacuum should not fall below 315.5 mmHg at the front of each terminal unit at a design flow of 40 L/min (see BS EN ISO 9170-1).

4.47 The design of the pipework system is based on the diversified flows and the permissible pressure loss from the source of supply to, and including, the terminal unit pressure loss. The pipe sizes should be selected to ensure that the pressure loss is below 5% of the nominal pipeline pressure.

4.48 Pressure requirements for surgical air are based on the requirement that the minimum pressure should be 700 kPa at the terminal unit at a flow of 350 L/min or 100 L/min (see Table 2).

Oxygen

In-patient accommodation

4.49 Oxygen is used at a typical flow of 6 L/min with a design flow of 10 L/min as shown in Table 2.

4.50 Usage of NIV, BiPAP and CPAP should be taken into consideration using the high-flow ventilation calculations (see paragraph 4.54).

Operating departments

4.51 The diversified flow (*Q*) for operating departments is based on 50 L/min. Up to 100 L/min may be required for the oxygen flush on some older anaesthetic machines. Each oxygen terminal unit in the operating room and anaesthetic room should be able to pass 100 L/min. It is unlikely that an oxygen flush will be administered simultaneously in several operating rooms. *Q* is based on 50 L/min for the first operating room and 10 L/min for the remainder (see Table 3).

4.52 For anaesthetic rooms, each terminal unit should be capable of passing 100 L/min (it may be necessary to use an oxygen flush), but the actual flow likely to be used is 6 L/min or less. As it is unlikely that a patient will be anaesthetised while another patient in the associated operating room remains under anaesthesia (and because the duration of induction is short), no additional flow allowance is included.

4.53 In recovery, it is possible that all bed spaces may be in use simultaneously; hence, no diversity is used.

Critical care, coronary care and high-dependency departments/units

4.54 For these departments/units, it is assumed that all bed spaces will be occupied and will require the use of oxygen. Each terminal unit should be capable of delivering 100 L/min. *Q* should be calculated at 60 L/min per bed space. This value applies per circuit and is not split between circuits, allowing for the use of high-flow ventilation devices. Where there is no requirement for high-flow ventilation, this is reduced to 10 L/min per bed space (see Table 3).

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Emergency department (ED):		
Resuscitation room, per trolley space	15	$Q = (15 \times n)1.5$
Major treatment/plaster room, per trolley space	10	$Q = (10 \times n)1.5$
All other ED areas	15	$Q = 15n$
Operating:		
Anaesthetic rooms	50	
Operating rooms	50	$Q = 50 + [(nT - 1)10]$
Post-anaesthesia recovery	10	$Q = 10 + [(n - 1)6]$
Maternity:		
LDRP room:		
Mother	10	$Q = 10 + [(n - 1)3]$
Baby	10	$Q = 10 + [(n - 1)1.5]$
Operating suites:		
Anaesthetist	50	$Q = 50 + [(nT - 1)6]$
Paediatrician	10	$Q = 10 + [(n - 1)3]$
Post-anaesthesia recovery	10	$Q = 10 + [(n - 1)2]$
In-patient accommodation:	10	$Q = 10 + [(n - 1)1.5]$
Single/multi-bed wards	10	$Q = 10 + [(n - 1)6]$
Nursery, per cot space	10	$Q = 10 + [(n - 1)1.5]$
Special care baby unit	10	$Q = 10 + [(n - 1)6]$
Radiology:		
All anaesthetic and procedures rooms	100	$Q = 10 + [(n - 1)2]$
Critical care areas:		
High dependency areas (per bed space/circuit) with high flow ventilation	60	$Q = 60n$
High dependency areas (per bed space/circuit) without high flow ventilation	10	$Q = 10n$
Adult acute day care accommodation:		
Treatment rooms	15	$Q = 15 + [(n - 1)6]$
Post-anaesthesia recovery per bed space	15	$Q = 15 + [(n - 1)6]$
In-patient accommodation (ward units):		
Single 4-bed rooms and treatment room	10	$Qw = 15 + [(n - 1)6]$
Ward block/department	10	$Qd = Qw [1 + (nW - 1)6]$
Day patient accommodation		
Single 4-bed rooms and treatment room	10	$Qw = 15 + [(n - 1)3]$
Ward block/department	10	$Qd = Qw [1 + (nW - 1)3]$

Continued on next page

Out-patient:		
Treatment rooms	10	$Q = 10 + [(n - 1)2]$
Non-acute facility (e.g. health centre)	10	$Q= 10 + [(n - 1)2]$
Hospices	10	$Q= 10 + [(n - 1)3]$
Renal	10	$Q = 10 + [(n - 1)2]$
Adult mental illness accommodation:		
Electro-convulsive therapy (ECT) room	10	$Q = 10 + [(n - 1)1.5]$
Post-anaesthesia, per bed space	10	$Q = 10 + [(n - 1)1.5]$
Equipment service rooms, sterile services	100	Residual capacity will be adequate without an additional allowance
Notes: *Q* = diversified flow for the department *Q*w = diversified flow for the ward *Q*d = diversified flow for the department (comprising two or more wards) *n* = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed *nW* = number of wards *nT* = number of theatres		

Table 3 Medical oxygen: typical diversified flow rate calculations

4.55 Oxygen should not be used as the driving gas for gas-powered ventilators if they are capable of being powered by medical air. The minimum flow that has been shown to be adequate to drive current types of ventilators is 60 L/min at 360 kPa. For test purposes the minimum pressure is 370 kPa.

4.56 Where ventilators operate in CPAP mode using oxygen, the potentially high flow rates should be taken into account in the overall system design, including pipeline sizing and supply vessel or manifold selection.

4.57 Ventilators use exceptionally high volumes of oxygen, particularly if adjusted incorrectly. When incorrectly set, they can use in excess of 100 L/min, but their therapeutic benefit will be effective at lower flows. Care should be taken when setting up and using ventilators, with training delivered for staff under governance oversight of the MGSG.

4.58 If significant numbers of beds are required to treat patients using CPAP ventilation, consideration should be given to increasing the size of the flow loop supply pipeline or running a separate pipeline from the source of supply.

4.59 Consideration should be given to air exchange rates in wards/rooms where large numbers of CPAP machines may be in use simultaneously, and where failure of mechanical ventilation could result in elevated ambient oxygen concentrations (see HTM 03-01 for ventilation requirements). Warning systems should be considered to indicate ventilation failure where oxygen concentrations may exceed 23%.

Maternity

4.60 For labour, delivery, recovery and post-partum (LDRP) rooms, diversified flow should be based on 10 L/min for the first terminal unit,

with the remaining terminal units requiring assessment between mother and baby flows. Two cot spaces should be provided in all areas, each with a separate set of terminal units. Only one terminal unit should be the operational in-use outlet.

4.61 Maternity department operating rooms are designed as a suite. It should be assumed that oxygen will be provided either in the anaesthetic room or in the operating room. For calculation purposes, 75% of beds in post-anaesthesia recovery should be assumed to require oxygen (see Table 3).

Paediatric intensive care unit (PICU)

4.62 The flow allowances for a PICU will depend on the age band of the patients to be treated within this department and the equipment that is utilised within this area. Consultation with clinical staff is required to ascertain the flow rates required within this department. Where this unit is being used for young adults, the flow calculations for high dependency areas should be used.

Hyperbaric oxygen chambers

4.63 Hyperbaric therapy should be supplied from a separate branch from the liquid supply with its independent control panel and not form part of any distribution system. Maximum flow demand should be calculated.

4.64 Multiple pressure chambers may be fed from this pipeline. However, in the event of multiple chambers, a risk assessment of the MGPS design should be carried out to ensure that the system is capable of the demand usage.

4.65 Hyperbaric oxygen chambers should be risk-assessed for use and installation by the MGSG. System installation designs should be reviewed by the MGSG with reference to this HTM, BS EN 14931, manufacturers'

	Max. time for one complete treatment	Total consumption for max. treatment time (L)	Consumption for each additional minute (L/min)
O_2 atmosphere and recirculation:			
On open circuit	2 hours	30,000	250
On recirculation	2 hours	7250	40
O_2 only, no recirculation	2 hours	30,000	250
O_2 delivery by built-in breathing mask and overboard pump	2 hours	1200	10
O_2 delivery by built-in breathing hood and overboard pump	2 hours	7250	60

Notes:

The flow for a recirculating unit assumes 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.

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

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.

Table 4 Gas flow: hyperbaric therapy chambers

information and detailed supporting evidence to ensure correct system selection and a clear understanding of system capabilities for the proposed MGPS installation.

4.66 Typical flows for a single patient chamber are shown in Table 4.

Nitrous oxide

Nitrous oxide has been commonly used in anaesthetic and dental practice as both an anaesthetic and analgesic agent for over a century. In several areas and particularly the theatre setting, nitrous oxide has typically been supplied via a manifold of cylinders to enable a continuous, uninterrupted supply. Recent work has demonstrated that nitrous oxide waste commonly occurs due to leakage from the MGPS to the atmosphere before reaching the point of delivery, oversized MGPS installations serving areas of low clinical use and from poor cylinder stock management. Nitrous oxide is an abundant, long-lived greenhouse gas, with an atmospheric lifetime of over 100 years. This means that emissions will accumulate in the atmosphere, resulting in increasing atmospheric concentrations and increasing potential effects on the climate. It has a global warming potential (GWP) around 300 times that of carbon dioxide. As it is a long-lived gas, any reductions in emissions associated with it are meaningful. Nitrous oxide (including oxygen/nitrous oxide mixture) accounts for 94% of NHS emissions from anaesthetic gases and 4.6% of the emissions the NHS controls directly. Many anaesthetists have moved away from routine nitrous oxide use in general anaesthesia, including in previous high-usage areas such as paediatric anaesthesia and general anaesthesia in obstetrics. The Royal College of Anaesthetists (2024) published a consensus statement on behalf of the leading anaesthetic organisations in the UK and Ireland, which recommends that nitrous oxide should no longer be considered an essential drug in modern anaesthetic practice and that continuous supply of nitrous oxide to theatre suites via a pipelined supply is no longer essential. They recommend that healthcare organisations decommission their nitrous oxide manifolds as soon as possible, switching to point-of-use cylinders where individual healthcare organisations feel that access to nitrous oxide remains desirable. They ask that this transition is completed by the end of the 2026/27 financial year in the UK and the Republic of Ireland. By 2023/24, over half of NHS trusts using piped nitrous oxide commenced work on decommissioning nitrous oxide MGPS installations and moving to portable supply. This has led to cost savings of over £2.3 million annually and emissions reductions of around 80 kt CO_2e between 2019/20 and 2024/25. NHS England with UCLPartners has developed a toolkit to support NHS trusts that offers step-by-step guidance to address the practical barriers to reducing waste from piped nitrous oxide. Included in the toolkit are case studies that share best practice from NHS organisations that have already undertaken this

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Operating theatres	15	*Q* = 15
Maternity: operating suites	15	*Q* = 15
Oral surgery/orthodontic: consulting rooms, type 1	15	*Q* = 15
Other departments	15	*Q* = 15
Equipment service rooms	0	Mobile cylinder only

Table 5 Nitrous oxide: design and diversified flows

work. Nitrous oxide toolkit: Reducing waste in NHS trusts - UCLPartners

4.67 In most cases, new nitrous oxide MGPS will not be installed. The guidance in this HTM is therefore intended to support the management and maintenance of existing nitrous oxide installations.

4.68 Provision for secure and compliant cylinder storage should be included in the design.

4.69 Where nitrous oxide is provided for anaesthetic purposes via a pipeline, in all cases, each terminal unit should be capable of passing 15 L/min, but in practice the flow is unlikely to exceed 6 L/min.

4.70 When calculating flows in a department, typically 15 L/min is allowed for the first terminal unit and no additional flow is allocated (see Table 5).

4.71 It is assumed that, for an operating department, nitrous oxide will rarely be in use simultaneously in all operating rooms. As it is unlikely that a patient will be anaesthetised while another patient in the associated operating room remains under anaesthesia (and because the duration of induction is short), no additional flow allowance is included.

Oxygen/nitrous oxide mixture

4.72 Oxygen/nitrous oxide mixture accounts for approximately 75% of NHS nitrous oxide emissions. It can be supplied using either portable cylinders or an MGPS. The "nitrous oxide toolkit" outlines key considerations when choosing the most appropriate supply system, and the choice should be aligned to clinical use and subject to risk assessment. For areas using oxygen/nitrous oxide mixture, mechanical ventilation should be provided to comply with the Control of Substances Hazardous to Health (COSHH) Regulations (see HTM 03-01).

4.73 All terminal units should be capable of passing 275 L/min for a short period (normally of five seconds' duration) to supply inhalation gasps for the patient.

4.74 In a maternity department, diversified flow is based on 275 L/min for the first two bed spaces and 6 L/min for each of the remainder. Peak inhalation gasps are 275 L/min, whereas the respirable minute volume will be catered for with a flow of 6 L/min.

4.75 For larger maternity departments, separate supplies should be provided for each group of up to six rooms. Where more than six rooms are served, the circuits should be divided evenly, with flow loops implemented to ensure balanced distribution.

Department	Design flow for each terminal unit (L/min	Diversified flow Q (L/min)
Maternity: LDRP room(s) ≤6	275	$Q = 275 \times 2 + [(n - 2)6]$
Other areas	275	$Q = 275 + [(n - 1)6]$
Equipment service rooms	275	No additional flow included
Note: n = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed		

Table 6 Oxygen/nitrous oxide mixtures: design and diversified flows

4.76 Design and diversified flows for oxygen/nitrous oxide mixtures are given in Table 6.

4.77 Given the high global warming potential of nitrous oxide, additional consideration should be given to detecting leaks. An annual system pressure test should be undertaken. In a department such as maternity, this can be very challenging given operational constraints. Therefore, individual mechanical components throughout the system should be leak-tested and reported as part of the maintenance regime.

Air

4.78 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 the fire risk and cost. It should not be used where medical air is available unless specifically recommended by the device manufacturer.

4.79 Air should be provided at two different pressures but to the same standard as defined in the relevant monographs of the British Pharmacopoeia:

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

Medical air 400 kPa

4.80 The IDP (see paragraphs 1.27–1.29) will determine the need for medical air for any MGPS design and installation.

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Emergency department:		
Resuscitation room, major/minor treatment per trolley space	40	$Q = 40+ [(n – 1)5]$
Operating:		
Anaesthetic rooms	40	No additional flow included
Operating rooms	40	$Q = 40 + [(nT – 1)10]$
Post-anaesthesia recovery	40	$Q = 40 + [(n – 1)3]$
Maternity:		
LDRP rooms:	40	$Q = 40 + [(n – 1)10]$
Baby	40	$Q = 40 + [(n – 1)5]$
Neonatal unit (SCBU)	40	$Q = 40 + [(n – 2)20]$
Critical care units (including decant wards)	80	$Q = 80 + [(n – 1)40]$
All other departments (All grouped together)	40	$Q = \{40 + [(n – 1)2]\}/2$
Equipment service rooms	40	No additional flow included
Note: *n* = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed *nT* = number of theatres		

Table 7 Medical air 400 kPa: design and diversified flows

General

4.81 The supply system for medical air 400 kPa may be a manifold system and a compressor system including an ERM.

4.82 One of the major uses of medical air is for patients' ventilators and this use would fall into two main categories:

- those used during anaesthesia
- those used during critical care.

4.83 Pneumatically powered ventilators can use up to 80 L/min free air continuously. The exact flow requirements will depend on the design of the ventilator. The medical equipment department should provide the specifics of the ventilators used on site.

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

4.85 Medical air is more commonly being used for CPAP, BiPAP and NIV treatments throughout critical care areas which typically can have flows up to 80 L/min. Usage is also found in ward areas via local air pumps as an integral component of patient ventilation, so no accommodation is required in non-acute areas.

4.86 Medical air 400 kPa is also used for other equipment such as anaesthetic gas mixers, humidifiers and nebulisers. Flow rates should not exceed 10 L/min.

4.87 Medical air should not be used to supply mechanical services or air brakes on MSUs.

Flow requirements

4.88 Flow requirements for medical air are given Table 7.

Surgical air 700 kPa

4.89 Surgical air use is declining due to the introduction of battery- and electrically powered tools. The IDP (see paragraphs 1.27–1.29) will determine the need for surgical air for any MGPS design and installation. Where surgical air is required, the following guidance should be used.

4.90 The pressure requirements of air-powered surgical tools are between 600 and 700 kPa and flows may vary between 200 and 350 L/min.

4.91 Pipeline systems should be designed to provide a flow of 350 L/min at 700 kPa at the outlet from individual terminal units (see Table 8).

4.92 Where surgical air is installed and extended to dental departments, a duplex PRS is required to reduce the pressure to 600 kPa.

Department	Design flow for each terminal unit (L/min)	Diversified flow Q (L/min)
Operating theatres	350	$Q = 350 + [35 \times (nT - 1)]$
Ophthalmic theatres	100	$Q = 100 + [50 \times (nT - 1)]$
Other departments (e.g. equipment workshops, fracture clinic)	350	No additional flow required
Equipment service rooms	350	No additional flow required

Note:

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

Table 8 Surgical air 700 kPa: design and diversified flows

4.93 No diversity will be allowed for dental departments.

4.94 Unlike respiratory equipment, surgical tools are used intermittently, typically for a few seconds and up to a maximum of three minutes. The plant should have the capacity to provide the design flow of the pipeline for a maximum period of five minutes in any 15-minute period.

Terminal units intended for equipment testing

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

Dental air

Flow and pressure requirements at the dental chair

4.96 Dental air is used to drive the tools required for dental operations. These tools run at a pressure of 600 kPa.

4.97 The dental air supply should not be used to drive the chairs; a separate supply should be provided if chairs have pneumatic controls.

4.98 Flow rates for dental air should be between 35 L/min and 70 L/min, but this is not a constant flow and will be intermittent.

Diversity factors and plant sizing

4.99 For surgeries with up to five dental chairs, it can be assumed that all chairs may be in use simultaneously, each requiring a flow of 50 L/min. For surgeries with more than five dental chairs, it can be assumed that 60% of the remainder of the chairs will be using compressed air simultaneously.

4.100 A maximum pressure drop of 50 kPa from the plant to the dental chair floor-box outlet connection can be tolerated under design flow conditions. However, commissioning routines do not include full design flow testing unless specifically requested by the user.

4.101 Compressed air receiver volume can be increased at the discretion of the plant supplier to meet higher short-term flow demands.

4.102 For the purposes of plant sizing, see Table 9.

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Dental treatment chairs (up to 5 chairs)	70	$Q = 100 + [(nc - 1)50]$
Dental treatment chairs (over 5 chairs, fewer than 20)	70	$Q = 200 + [(nc - 1)50] / 2$
Dental hospital (over 20 chairs)	70	$Q = 500 + [(nc - 10)\ 30]$
Dental school training department	50	$nc \times 50$
Dental laboratory	–	Refer to manufacturers of equipment
nc = number of chairs (or dental heads in the event of a teaching hospital)		

Table 9 Dental air

Special cases

Dental schools

4.103 For dental teaching schools, it can be assumed that all chairs in the teaching department will be in use simultaneously at a delivered flow of 50 L/min each. This flow should be added to the diversified flow of any associated system.

Dental laboratories

4.104 When the dental air supply is to be extended into a dental laboratory, additional flow capacity will have to be designed into the system. Equipment manufacturers' data will give the flow and pressure requirements for individual items of equipment. No diversity allowance should be made, unless agreed or specified by the user.

New technology

4.105 Occasions may arise when advances in technology result in equipment requiring pressures or flows considerably more than the current norms. Each such case should be treated individually. The advice of the specialist manufacturer or supplier will be required to fully achieve the potential of the equipment. Under no circumstances should the use of such equipment compromise the integrity of the existing system. If necessary, a separate pressure source should be installed to cope with the demands of the new equipment.

Pipework sizing

4.106 For calculating pipework sizes/pressure drops, the formulae in Table 9 should be used.

Vacuum

4.107 The IDP (see paragraph 1.27–1.29) will determine the need for vacuum for any MGPS design and installation. With advancements in technology, alternative medical vacuum systems may be considered in consultation with the MGSG.

General

4.108 Vacuum should be applied through a suction control device, with fluid collected in suction jars. The control device should incorporate a slam-shut mechanism and a hydrophobic filter to minimise the risk of carry-over into the pipeline system.

In-patient accommodation

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

4.110 Minimum pipeline size for all in-patient ward/department branches is 22 mm in flow loops, reduced to 15 mm droppers for individual terminal units utilising the flow loop design.

4.111 The use of flow loops on the installation will allow for a greater volume to be contained locally, alleviating the necessity for larger mains pipework.

Medical supply units (bedhead trunking systems, walling systems, enclosures generally)

4.112 When designing vacuum, the greatest pipeline pressure losses will occur near to the terminal units. A minimum of 22 mm pipe should be used for vacuum up to the last terminal unit branch within the trunking of multiple terminal units.

4.113 Care should be taken when sizing vacuum pipework within MSUs with two or more bed/treatment spaces.

4.114 In some instances, it may be necessary to provide more than one feed from the main distribution pipeline to the MSU to keep pressure losses within acceptable limits.

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Emergency department (ED):		
Resuscitation room, per trolley space	40	$Q = 40+ [(n – 1)10]$
Major treatment/plaster room, per trolley space	40	$Q = 40 + [(n – 1)10]$
All other ED areas	40	$Q = 40 + [(n – 1)10]$
Operating:		
Anaesthetic rooms	40	No additional flow to be included
Operating rooms	80	$Q = 80$
Post-anaesthesia recovery	40	$Q = 40 + [(n – 1)10]$
Maternity:		
LDRP rooms:		
Mother	40	$Q = 40 + [(n – 1)10]$
Baby	40	No additional flow to be included
Operating suites:		$Q = 40 + [(nS – 1)40]$
Anaesthetist	40	$Q = 40$
Obstetrician/paediatrician	40	$Q = 40$
Post-anaesthesia recovery	40	$Q = 40 + [(n – 1)10]$
In-patient accommodation:	40	$Q = 40 + [(n – 1)20]$
Single/multi-bed wards	40	No additional flow to be included
Nursery, per cot space	40	$Q = 40 + [(n – 1)10]$
Special care baby unit	40	$Q = 40 + [(n – 1)10]$
Radiology/diagnostic departments:		
All anaesthetic and procedures rooms	40	$Q = 40 + [(n – 1)5]$
Critical care areas	40	$Q = 40 + [(n – 1)10]$
Adult acute day care accommodation:		
Treatment rooms	40	$Q = 40$
Post-anaesthesia recovery per bed space	40	$Qd = 40 + [(n – 1)10]$
In-patient accommodation:		
Per ward or department	40	$Q = 40$
Ward block/department	40	$Qd = 40 + [(nW – 1)10]$
Day patient accommodation:		
Per ward or department	40	$Q = 40$
Ward block/department	40	$Qd = 40 + [(nW – 1)10]$

Continued on next page

Out-patient: Treatment rooms	40	$Q = 40$
Non-acute accommodation	40	$Q = 40 + [(n - 5)10]$
Renal	40	$Qd = 40 + [(n - 1)/2]10$
Adult mental illness accommodation:		
ECT room	40	$Q = 40 + [(n - 1)10]$
Post-anaesthesia, per bed space	40	$Q = 40 + [(n - 1)10]$
Equipment service rooms, sterile services	40	$Q = 40$
Note: *n* = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed *nW* = number of wards *Q*d = diversified flow for the department (comprising two or more wards)		

Table 10 Vacuum: design and diversified flows

4.115 BS EN ISO 11197 does not permit flexible connections in fixed MSUs.

Operating departments

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

4.117 Since it is possible for both the surgical team and anaesthetist to use vacuum simultaneously, each operating room will require 80 L/min, and each terminal unit should be capable of passing 40 L/min (see Table 10).

4.118 As it is unlikely that a patient will be anaesthetised while another patient in the associated operating room remains under anaesthesia, the need to clear an airway is extremely unlikely and no additional flow is included.

Dental vacuum

4.119 For a brief overview and flow rate requirements, see Chapter 11.

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Operating theatres:		
Operating rooms flow per room	20	$Q = 20 + [n - 1]5$
Radiology/diagnostic departments:		
All required procedures rooms	20	$Q = 20 + [n - 1]5$
Equipment service rooms, sterile services	20	$Q = 20$
Note: *n* = number of beds, treatment spaces or single rooms in which the clinical procedure is being performed, not the individual numbers of terminal units where, in some cases, more than one is installed		

Table 11 Carbon dioxide: design and diversified flows

Carbon dioxide

4.120 Carbon dioxide is used as an insufflation and dilation gas for expanding cavities within the body to allow access for surgical and visual purposes.

4.121 The flows for carbon dioxide are typically in short bursts and work on a volume requirement rather than a litre per minute requirement. To ensure that sufficient supplies are available, the calculations in Table 11 should be used.

4.122 Pipeline supplies may be provided from VF cylinders located in a manifold room or from a 2 x 2 ACM with a 2 x 1 ERM for the first four terminal units. As a guide, one additional cylinder should be added to each main manifold for every two additional outlets, up to a maximum of ten cylinders per side.

4.123 When the main manifold (ACM) reaches a 2 x 6 configuration, the reserve manifold (ERM) should be increased to a 2 x 2 configuration.

4.124 For areas using carbon dioxide, mechanical ventilation should be provided to comply with COSHH (see HTM 03-01 for ventilation requirements). See also 'CP 26: Bulk liquid carbon dioxide storage at users' premises' (BCGA, 2012) and 'CP 42: Implementation of EIGA carbon dioxide standards' (BCGA, 2025).

Anaesthetic gas scavenging systems

4.125 The performance criteria for disposal systems are specified in BS EN ISO 7396-2 in collaboration with the master BS EN ISO 7396 suite of documents. The disposal system should meet the requirements set out for the high- and low-flow systems only (see Table 12). Passive systems are not used in the UK and are not recognised by this HTM.

Department	Design flow for each terminal unit (L/min)	Diversified flow *Q* (L/min)
Operating:		
Operating rooms with anaesthetic room	130	*Q* = 130 x 2
Operating room without anaesthetic room	130	*Q* = 130
Radiology/diagnostic departments:		
All required procedures rooms	130	*Q* = 130*n*
Equipment service rooms (per room)	130	*Q* = 130
Note: *n* = number of rooms		

Table 12 AGSS design flows and diversified flows

5 Cylinder manifold system

5.1 A cylinder manifold system comprises two banks of individual cylinders with one bank of cylinders on each side of a control system, known as the duty and standby cylinder supply. All manifold systems should be located in a dedicated manifold room(s) (see Chapter 17).

5.2 There are primarily two types of manifolds:

- automatic changeover manifold (ACM)
- manual changeover manifold (MCM).

5.3 All manifolds require a test point (see Chapter 15).

5.4 Primarily the differences are that the ACM will automatically change from one bank to the other and raise the alarm for cylinder change. The MCM requires manual intervention to change banks. Differences to alarm settings and configurations are described in this chapter.

5.5 The use of an ACM as the primary source of supply is required when the main gas supply is provided by cylinders. The primary source will be backed up with an MCM as the secondary source of supply (oxygen/nitrous oxide mixture or carbon dioxide as examples).

5.6 The use of an ACM as the secondary source of supply is required to back up a mechanical or liquid system (medical air or oxygen as examples). An MCM should not be used as a secondary source of supply in these situations.

5.7 Duty and standby cylinder banks together with the control panel become a single source of supply, which can be either a primary or secondary source of supply depending on the system configuration.

5.8 The number of cylinders per bank is determined by the duration they are expected to last. The total design flow and supply time duration is calculated to determine sizing requirements for the installation.

5.9 The primary supply should be determined by the volume of gases required. A detailed IDP of site demand/requirements should be undertaken to understand the sizing and suitability of a manifold supply system.

5.10 As a minimum, the ACM for a primary supply should have two days' supply on each bank for the healthcare facility.

5.11 Where an ACM is used as an ERM for a secondary supply, it should have four hours' supply. Each bank should be capable of delivering gas for two hours per bank. Where an MCM is used as the ERM, each bank should have a minimum of four hours' supply.

5.12 In the case of non-acute hospitals, for the primary supply, the actual time in days may be reduced to the opening hours of the facility. For example, where a non-acute operates from 07:00 to 18:00, calculations should be based on two days of operation at 11 hours per day, whereas acute sites should be calculated on a 24-hour operational basis. This change shows that the volume of required gas would

be less than half. There is no reduction in allowance for a secondary supply.

5.13 Each side of the manifold always has the same number of cylinders on each bank.

5.14 Cylinder contents should be allocated as per the usable contents of the cylinder, not the total cylinder contents (see Table 13). Table 13 assumes a worst-case changeover pressure of 1400 kPa. Advances in manifold technology mean that some systems can now be designed to change over at pressures as low as 1200 kPa, thereby increasing the usable capacity.

5.15 The secure restraint of cylinders is essential for system safety. Restraint points should be positioned between 60% and 75% of the cylinder body height (excluding the valve).

Gas	Cylinder size	Nominal capacity (L)	Usable capacity (L)
Oxygen	W	10,700	10,650
	J	6800	6500
Nitrous oxide	J	18,000	17,900
	G	9000	8900
Oxygen/nitrous oxide mixture	EW	16,275	15,900
	G	5000	4700
Medical air/ surgical air	J	6400	6200
Carbon dioxide	VF	3600	3400

Notes:

Values are based on a 1400 kPa changeover for the manifold.

Information on cylinder contents should be obtained from the gas supplier.

Table 13 Example of typical cylinder contents

Automatic changeover manifold (ACM)

5.16 The ACM supply is provided by two banks of equal numbers of gas cylinders which are connected to the manifold control panel by tailpipes. These are then in turn connected through the control panel to the MGPS.

5.17 A schematic layout for an ACM is shown in Figure 10.

5.18 The changeover from the duty to the standby bank of cylinders should be automatic and controlled by cylinder pressure.

5.19 All manifold control panels should be capable of passing the full pipeline design flow of the individual system it is supplying.

5.20 The temperature of the gas may fall as low as –30°C as the gas passes through the regulator at maximum capacity. The equipment should be designed to manage the potential extreme temperatures. The accommodation for the manifold room will need careful consideration (see Chapter 17).

5.21 Spare cylinders should be provided to replenish the manifold as they are depleted. The sustainability of the number of deliveries relative to on-site cylinder stock should be a determining factor in the IDP. The quantity of cylinders provided should be determined by the IDP considering maximum usage as the worst-case scenario for planning. The specific requirements will depend on the method of primary supply. Where this results in an unrealistic number of cylinders being kept on site, the operational policy should detail procedures for continuity of supply in emergency usage situations.

5.22 Monitoring cylinder change rates will provide data for the IDP, which can be used to determine whether the number in the manifold banks should be increased or reduced.

5.23 To allow safe and sustainable expansion of the manifolds, header racks should be

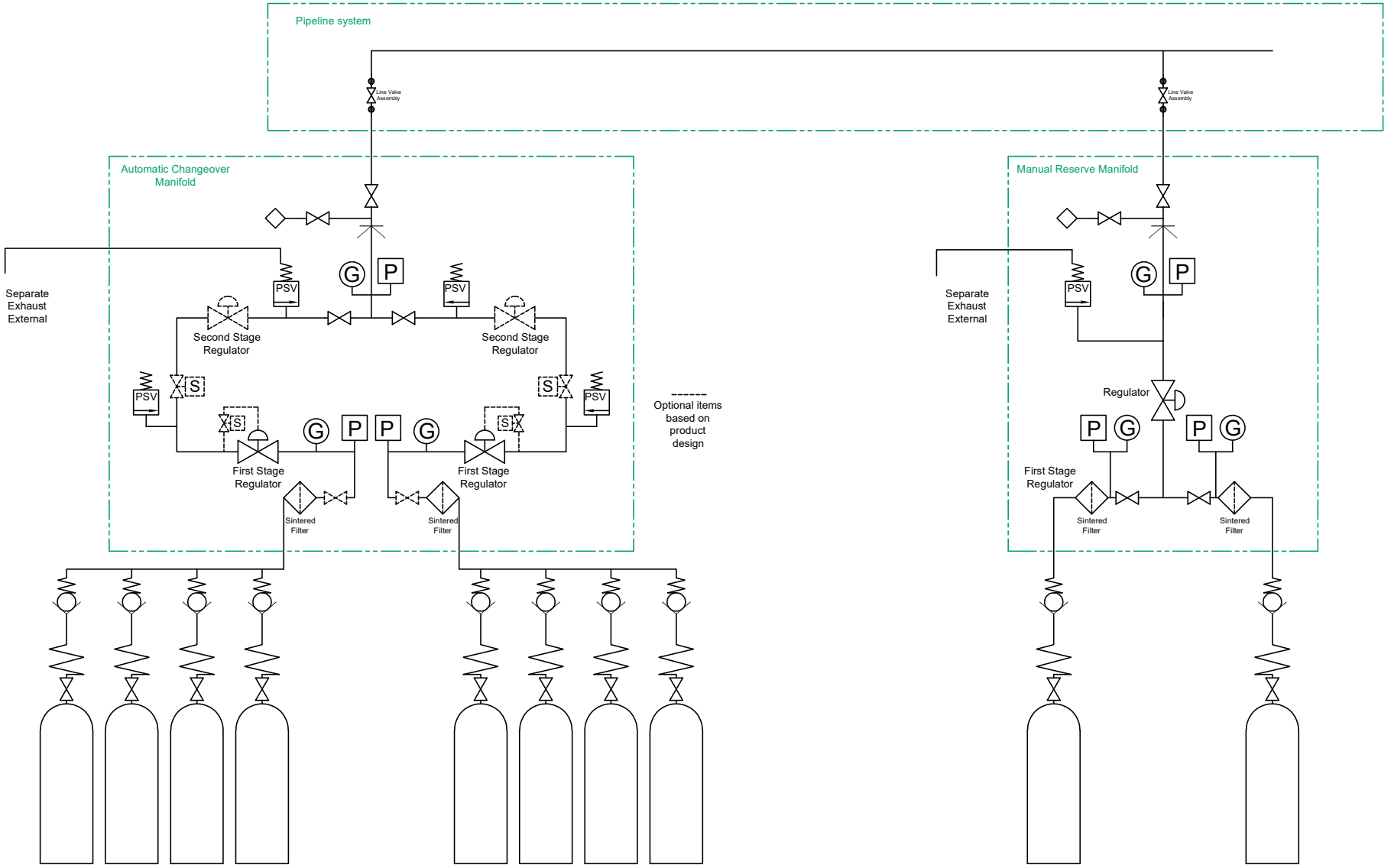


Figure 10 Typical example of an automatic manifold control system

designed to permit in situ reduction or extension without the need for brazing. This facilitates ongoing adjustment of the system, recognising that design flow rates often exceed actual site demand. Reduction in cylinder numbers may therefore reduce on-site storage requirements, costs and carbon footprint.

5.24 Additional cylinders sufficient for one complete bank change should be held in the manifold room. For oxygen/nitrous oxide mixtures, sufficient cylinders for two complete bank changes may be held, as the manifold room is heated whereas cylinder stores are not, thereby reducing the risk of gas separation (see Chapter 17).

5.25 The nominal and usable capacity of the cylinders commonly used on manifolds is described in paragraph 5.14.

5.26 An ACM should transfer from duty to standby at a cylinder pressure that ensures maximum utilisation of the cylinder contents, with no more than 1400 kPa remaining in the cylinder. The lower the pressure remaining in the cylinders, the less gas is wasted. This helps to reduce both carbon impact and cost.

5.27 If the normal operation of the changeover control depends on an electricity supply, the design should be such that failure of the electricity supply does not disrupt the flow of gas to the distribution system.

5.28 Control panels for all manifolds should be located at the same heights (the centre of the display panel should typically be 1.5 m to 1.6 m from FFL), and the header connecting pipes should be manufactured to ensure that the cylinder header racks are fitted at the appropriate heights.

5.29 In the event of power failure, when the power is restored, the original “running bank” should be online – that is, the same bank that was the duty bank prior to interruption of the supply, unless this bank has been depleted.

5.30 The ACM should be restricted to a maximum of ten cylinders on each bank. Where this supply is not adequate, a split system or alternative source of supply should be considered (see Tables 14 and 15).

5.31 Where an ACM is used as a secondary source of supply and more than ten cylinders per bank are required, additional ACMs should be considered, subject to a risk assessment.

5.32 When developing policy documentation, it should be noted that some older manifold designs default to a specific bank following a power failure, regardless of which bank was in operation prior to the interruption. These units may require manual resetting to restore the original condition. Such systems should be subject to risk assessment and managed accordingly, with details recorded in the risk register.

5.33 Manifolds and control panels should be designed and certificated for use with cylinders operating at 23,000 kPa. Where higher-pressure cylinders are introduced (for example, 30,000 kPa), consideration should be given to increasing this rating prior to their use. Manifold headers should incorporate a replaceable check valve to prevent discharge of a complete cylinder bank in the event of tailpipe rupture and to allow cylinder changeover while the bank remains in operation. The check valve should limit flow to a minimum to permit safe connection and is not required to provide full non-return isolation.

5.34 Pressure indication should be provided to indicate pressure in each cylinder bank and in the MGPS, even in the event of loss of power to the manifold or control panel display failure.

Pressure control

5.35 Pressure control should maintain the nominal pipeline pressure within the limits given in Chapter 4. High-pressure regulators should comply with BS EN ISO 10524-2 and be supplied with auto-ignition test results.

Source	Service	Maximum number of cylinders	Cylinder size	Notes
ACM	Oxygen	2 x 10	J/W	Used as a stand-alone manifold or support for cryogenic systems
	Medical air	2 x 10	J	Used as a stand-alone manifold or support for compressor plant
	Surgical air	2 x 6	J	
	Oxygen/nitrous oxide mixture	2 x 10	G/EW	Used as the primary supply
	Nitrous oxide	2 x 2	E/F/G	Used as the primary supply
	Carbon dioxide	2 x 8	VF	Used as the primary supply

Table 14 Suggested ACM sizes for gas sources (these should be sized through the IDP)

Source	Service	Maximum number of cylinders	Cylinder size	Notes
ERM	Oxygen	2 x 4	J/W	Used as a backup to an automatic manifold primary supply
	Medical air	2 x 4	J	Used as a backup to an automatic manifold primary supply
	Surgical air	2 x 4	J	
	Oxygen/nitrous oxide mixture	2 x 2	G/EW	Used as a backup to an automatic manifold primary supply
	Nitrous oxide	2 x 1	E/F/G	Used as a backup to an automatic manifold primary supply
	Carbon dioxide	2 x 1	VF	Used as a backup to an automatic manifold primary supply

Table 15 Suggested ERM sizes for gas sources (these should be sized through the IDP)

5.36 Separate pressure-regulating valves should be provided for each cylinder bank of an ACM and primary sources of supply.

5.37 The control system should be designed so that the cylinders of one bank can be changed without loss of continuity of the gas supply. There should be no maintenance or repairs on a manifold while it is in service; an alternative source of supply should be used.

5.38 Pressure safety valves should be of the self-closing type and be installed downstream of pressure regulators and upstream of isolation valves. They should have a flow capacity at least equal to that of the upstream pressure regulator.

5.39 Caution should be used when changing or installing pressure safety valves. Correct orientation is displayed on all safety devices, and they should be installed in accordance with manufacturers' instructions.

5.40 Pressure safety valves should not be tested on site but should be subject to replacement within a five-year period of their stamped test date.

5.41 The replacement regime should be described in the written scheme of examination (WSE) in accordance with the Pressure Systems Safety Regulations 2000 (PSSR 2000). Only individually tested and individually certificated pressure safety valves should be used.

5.42 There should be a separate discharge pipe for each safety valve that should be at least one size larger than the inlet pipe.

5.43 This discharge pipeline for all gases should be vented to atmosphere, outside the building, in an area where the discharge will not present a fire hazard or cause injury to personnel.

5.44 Warning signs should be posted at the discharge positions; access for inspection should be provided.

5.45 The discharge pipe should terminate at least 3 m from any doorway, window or natural vent capable of being opened, and at least 5 m from mechanical ventilation or air intakes.

5.46 The ends of the discharge pipeline should be turned downwards to prevent the ingress of dirt and moisture and should be positioned and protected to prevent the formation or accumulation of frost.

5.47 For pipelines exceeding 25 mm in diameter, a non-restrictive mesh should be fitted to avoid the ingress of animals. The mesh should not cause any back pressure on the exhausted gases. Where the mesh may cause a restriction, a further increase in pipeline size will be required at the point of discharge to atmosphere.

5.48 The same principles should be applied to safety valve arrangements for installations supplied from liquid cylinders.

5.49 High-pressure cylinders with integral pressure regulation can be used on manifold systems as long as a risk assessment of the location of the exhausted gases considers the release of gas from the pressure safety valve and safety notices are clearly displayed within the area of use.

Manifold monitoring and indicating system

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

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

5.51 All functions should be appropriately identified. Indicators should have a design life of a minimum of five years.

5.52 The system should be capable of automatic reinstatement after restoration of the power supply.

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

5.54 All monitoring systems should be ready for connections to a building management system (BMS) or equivalent remote monitoring system.

Manifold control unit

5.55 The control unit should include a green “mains supply on” indicator on the main panel as well as an indicator on the supply unswitched fuse connection unit (the unswitched fused connection unit should be a maximum of 1.8 m above FFL).

Manifold monitoring

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

- duty bank operating (normal condition)
- duty bank empty and standby bank operating (change cylinders)

- standby bank at 3000 kPa, when the duty bank is empty (change cylinders immediately)
- each secondary supply (emergency reserve) manifold bank below nominal 1400 kPa (for liquid cylinders) and below 50% of the available volume for other gases (reserve low)
- pipeline pressure faults outside the normal range (pressure fault).

Manifold indicator unit

5.57 Indicators should be provided to show the following conditions:

- Each automatic manifold should have:
  - a green running indicator for each bank. This should display when the bank is supplying gas, irrespective of the pressure
  - a yellow empty indicator for each bank when the running bank is empty, and changeover has occurred
  - a yellow low-pressure indicator for each bank to be illuminated after changeover when the pressure in the operational bank falls below 3000 kPa.
- For each secondary supply (emergency reserve) bank, a yellow indicator should illuminate when the pressure in the bank falls below 1400 kPa for liquid cylinders or 50% of the available volume for other gases (this will require the use of separate pressure sensors – one for each bank).
- For the pipeline distribution system, a red “low pressure” and a red “high pressure” indicator to be illuminated when the respective conditions occur.

Alarm signal status unit

5.58 The following indication of manifold conditions should be provided:

a. green normal status indicator – normal operating state

b. yellow duty bank empty indicator, standby running – change cylinders

c. yellow duty bank empty indicator, standby low – change cylinders immediately

d. yellow emergency reserve bank low indicator – reserve low

e. red pipeline pressure fault – pressure fault.

5.59 Conditions (a) to (e) should be transmitted to the central alarm system with an option for BMS monitoring with output provided for outward reporting only. The BMS should not be used to control the manifold.

5.60 Where relays are used, they should be normally open/energised when closed.

5.61 A plant alarm panel should be a separate unit within the manifold room. The cabling should be monitored for open- and short-circuit conditions. In the event of such a cable fault, a red “system fault” lamp should be illuminated on the alarm signal status unit, together with the appropriate alarm condition.

Manifold management

5.62 Connections should be provided that allow monitoring of manifold alarm conditions (a) to (e) and manifold running for each bank.

Emergency reserve manifold (ERM)

5.63 An MCM system should be provided to form a secondary source of supply to an ACM when it is the primary source.

5.64 The design of MCMs should follow that of ACMs with regard to control panels, positioning and racking heights.

5.65 Where provision would result in more than five cylinders on each bank, a second ACM should be considered as the reserve manifold replacing the MCM.

5.66 A non-return valve and isolating valve should be installed immediately upstream of the ERM connection to the pipeline distribution system.

5.67 Spare cylinder capacity required for the emergency reserve supply should be determined by risk assessment. Consideration should be given to cylinder capacity sizing calculations for ACMs.

5.68 The total number of spare cylinders on site for the ACM should be sufficient to allow replenishment of the ERM in the event of an emergency. No additional spare cylinders are required for the ERM.

5.69 For large installations, it may be impractical to rely on a single ERM. Therefore, consideration should be given to multiple ERMs.

5.70 All cylinder valves should be permanently open so that gas is immediately available.

5.71 MCMs should have individual isolation valves for each bank of cylinders; manual operation is controlled by having one of these valves open and the other closed.

5.72 The ERM should go into operation automatically via a non-return valve, and the ERM isolating valve should remain open during normal system status.

5.73 The ERM should be set to come online when the main line pressure falls below 360 kPa.

Location for manifold installations

5.74 The ACM and ERM should be located within the same manifold room so that both systems can be monitored during testing and maintenance procedures.

5.75 ERM accommodation for local supply downstream of an AVSU should be in line with Chapter 17. A local isolation valve or independent AVSU to control the manifold should be provided. This should form part of the fire strategy for the isolation of the manifold in the event of a fire. Clear labelling at the AVSU is required.

Secondary sources of supply for air compressors/ liquid oxygen

5.76 The supply should comprise an ACM as described above.

5.77 An MCM will not be required.

5.78 The manifold system(s) should be installed in an appropriate manifold room separate from the plant.

5.79 The manifold room should be located such that it connects to the main pipeline system independently of the primary source connection pipeline. With regard to configuration and set points, the ERM principles above apply.

Tertiary sources of supply

5.80 Tertiary sources of supply can be provided by a range of methods (for example, mobile cylinders used by clinical staff and backfeed kits used by engineering staff).

5.81 Tertiary-supply locations, quantities and types should be determined by risk assessment and incorporated into the system design.

5.82 During emergencies or planned shutdowns, backfeeding may be carried out by trained engineering staff via a NIST connector or terminal unit.

Backfeed kits

5.83 Backfeed kits should consist of a minimum of two cylinders (one on each bank) with individual regulators and associated supply hoses with gas-specific connectors. Where more than one cylinder is required per bank, multiple cylinders may be provided via a changeover facility that does not interrupt flow.

5.84 These systems should be installed and managed by the estates team under a PTW scheme. They should be subject to a maintenance regime, with details recorded in the MGPS operational records (see Part B).

5.85 Cylinders used for backfeeding should be subject to risk assessment, taking into account:

- staff required for management and operation
- flow rates and volume of supply
- size, location and stability of cylinders
- level of activity within the location of the cylinders.

6 Oxygen systems

Introduction

6.1 This chapter provides guidance on the selection, design and installation of medical oxygen supply systems. The choice of oxygen supply system – whether vacuum-insulated evaporators (VIEs), liquid tank systems or compressed gas cylinder manifolds – should be determined by risk assessment as part of the IDP, considering factors such as:

- anticipated demand volumes
- site constraints
- operational requirements
- patient safety considerations.

6.2 It establishes the principles for ensuring continuous, safe and reliable oxygen supply through appropriately configured primary, secondary and critical emergency supply systems, with criteria for system sizing, siting requirements, safety distances, alarm provisions and operational procedures.

6.3 Compressed gas cylinder manifolds are covered in Chapter 5.

Choosing an oxygen supply system

6.4 The most appropriate method of supplying oxygen will be determined by the potential size and variability of the healthcare facility's medical oxygen demand as identified in the IDP.

6.5 Where available, comprehensive usage and demand figures should be provided to the designer to help determine the most suitable and cost-effective method of supplying medical oxygen and the appropriate size of the installation. These figures (prepared as a part of the risk assessment) should be based on:

- the current average daily gas usage, derived from supply data from the previous 12 months
- the maximum potential daily demand volumes based on peak flow conditions
- the maximum daily recorded usage of the system
- any planned extensions to the hospital or pipeline that may affect the demand
- any expected natural annual growth in the use of medical oxygen
- historical data from the site or similar sites.

6.6 The maximum daily recorded use is taken from the inline flow device, where installed within the system. This should be installed with a bypass configuration for servicing and replacement. It should not be based on theoretical pipeline design flow conditions. Where actual flow monitoring is not present, daily cylinder or liquid consumption figures should be used.

6.7 Control panels should be capable of passing the maximum design flow plus an additional 25%. This may necessitate installing

two control panels in parallel for each source of supply.

6.8 Historical consumption records should be reviewed to assess current usage and trends in medical oxygen demand. Growth predictions should take into account any planned extensions to the healthcare facility or pipeline systems and changes in clinical practices (local and national) that could affect medical oxygen demand.

6.9 Oversized plant can cause operational issues and is not sustainable.

6.10 For new healthcare premises, where no historical information is available, the estimated average continuous demand may be based on similar sites of the proposed size, demographics and type of healthcare facility.

6.11 For smaller healthcare facilities with an annual demand typically below 3000 m³, the most cost-effective method of supplying medical oxygen may be a compressed gas cylinder manifold. However, this should be subject to risk assessment, and all options should be considered.

6.12 As site demand increases, it becomes less practicable to use compressed gas cylinders and more cost-effective to use medical liquid oxygen. Careful consideration for future growth should be factored in. System demand approaching levels typical of liquid supply systems is a key assessment criterion for the MGSG and project team.

6.13 For cylinder manifold sizes, see Chapter 5.

6.14 Liquid tanks may be suited to an annual consumption range of 3000 m³ to 40,000 m³ and can be connected together by a manifold to provide adequate storage capacity and flow rate. This should be subject to risk assessment, and all options should be considered.

6.15 For hospitals with larger oxygen demands, a bulk medical oxygen VIE will generally be used: where average annual usage is between 27,500 m³ and 40,000 m³, bulk VIE or liquid cylinder installations should be considered. System selection should also take into account site-specific factors including delivery access and siting constraints.

6.16 The main benefit of using gas cylinders is that installation costs of manifold systems are significantly lower than those of a liquid oxygen system. However, the unit cost of the medical oxygen in compressed gas cylinders is higher than the cost of medical liquid oxygen (supplied either into liquid tanks or into a VIE). As the demand grows, so the lower unit cost of the liquid oxygen offsets the higher installation costs of the liquid oxygen systems for high volume systems.

6.17 Liquid tank systems should be used where the demand is high enough to make bulk supplies cost-effective and where the demand makes cylinder supplies impracticable.

6.18 Liquid oxygen provides a flexible approach to both the size and the choice of installation design. Its provision is determined by factors such as:

- the size of the hospital
- the availability of space for both the installation and the delivery vehicle
- the proximity of the gas supplier
- the demand for medical oxygen.

6.19 The benefits of using a medical liquid oxygen system over compressed gas cylinders include:

- greater volume of medical oxygen stored on-site
- improved continuity of supply
- reduced manual handling requirements for cylinder handling.

6.20 When determining the cost-effectiveness of specific proposals from suppliers, the total

supply costs should be assessed, including costs for the site preparation and vessel installation, vessel rental and liquid supply over the total period of the contract.

6.21 Cost should not be the determining factor for system selection. Patient safety should always take priority where there is conflict.

Liquid oxygen systems

General

6.22 The IDP should determine the selection of the primary liquid oxygen system. This approach will support the development of the medical oxygen installation, ensuring a safe and practical design and the continuous availability of oxygen for patient use. Selection of a liquid oxygen system should be based on design flow, required gas volume and duration of supply, along with other relevant factors.

6.23 Secondary sources of supply should be subject to risk assessment and may comprise a separate liquid system or an ACM. These systems should be fully independent of the primary source of supply, with dedicated alarm systems, and should be separately located.

6.24 Where the system is too small for a VIE but too large for a manifold supply, liquid tanks (portable cryogenic containers) may be used.

6.25 Where liquid tanks are used as a primary source of supply with an ACM as the secondary supply, two independent systems with separate control panels should be provided.

6.26 The operational impact of the type of supply and supplier chosen should be considered.

Methods of sizing

6.27 BS EN ISO 7396-1 provides methods for sizing medical oxygen vessels and backup manifolds, together with guidance on the appropriate siting of vessels on-site based on risk assessment principles. This ensures the provision of a secure source of supply that reflects the degree of risk associated with the hospital's location and its level of dependency on medical oxygen.

Designation of vessel contents as operational or reserve stock

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

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

6.30 The IDP should determine operational and reserve stock levels.

System configurations

6.31 Primary and secondary supply systems should be installed in separate locations on-site, with independent control systems and independent supply routes into the pipeline system.

6.32 Where a manifold is required as a secondary or tertiary source of supply, it should be sited in an independent manifold room that meets the requirements of Chapter 17.

6.33 The system should be designed such that the primary supply is used in normal operation, with the secondary supply automatically taking over when the primary supply is empty or fails, based on pressure differential. For liquid supplies, boil-off from the secondary supply should be returned to the pipeline system to avoid gas wastage.

6.34 Tertiary supplies should not be sourced from liquid oxygen systems, as boil-off cannot

be prevented over extended periods when the system is not in use.

Primary supply systems

Vacuum insulated evaporators (VIEs)

6.35 VIEs store medical gas in liquid form at cryogenic temperatures and vaporise it to gas at ambient temperature for distribution through the hospital pipeline system.

Plant

6.36 The VIE system consists of:

- a vacuum-insulated cryogenic storage vessel to store the bulk liquid
- two or more ambient-heated vaporisers to convert the cryogenic liquid into a gas
- control equipment to control the pressure and flow of gas to the pipeline
- a test point (see Chapter 15).

6.37 Liquid oxygen is stored at cryogenic temperatures (down to –183°C) and converted to a gas at ambient temperature by passing it through an air-warmed vaporiser.

6.38 The VIE typically comprises a stainless-steel inner pressure vessel supported within a mild steel outer shell. The space between the vessels is filled with high-performance insulation maintained under vacuum to minimise heat transfer to the inner vessel, thereby reducing the rate of liquid oxygen evaporation.

6.39 Vacuum loss increases the boil-off rate and must be addressed to prevent excessive evaporation of the liquid. Vacuum failure is typically indicated by ice formation on the external shell of the VIE.

6.40 A pressure-raising regulator that permits the flow of liquid to the pressure-raising vaporiser automatically controls the pressure in the liquid oxygen system as required, with the vaporised liquid being fed back to the top of the VIE or liquid tank to maintain the pressure in the system.

6.41 Under normal operating conditions for a VIE system, the gas supply to the hospital will be maintained by feeding liquid oxygen to the main vaporiser system where it converts to a gas at ambient temperature. Vaporiser systems may ice up where hospital demand is high or continuous, or where airflow to the vaporisers is restricted. In such cases, consideration should be given to:

- the installation of additional vaporisers
- auto-changeover controls/systems between vaporisers
- automatic de-icing systems
- hot water/electrically heated vaporisers
- increasing the vaporiser size
- repositioning the vaporisers or equipment creating the issues
- regular maintenance including de-icing of the vaporisers.

6.42 Ice build-up may occur on VIE valves and pipework during normal operation. A regular de-icing programme or facility should prevent ice build-up that may occlude valves or impair pipework. Inspections should form part of the daily checks.

6.43 In the event of power failure, control valves on all vaporisers should fail open.

6.44 Where hospital demands are low or very erratic, the natural heat transfer into the vessel causes the liquid oxygen to boil and the vessel pressure to rise. When the vessel pressure rises to a set point, the hospital pipeline is fed from the top gas to prevent the vessel pressure rising above the safety-valve setting. On safety-valve operation, oxygen should be able to vent safely to atmosphere away from the valves and control panel. The operation of a safety valve can cause significant noise pollution. Therefore a noise reduction assembly should form part of the installation.

6.45 In all cases, the pipeline pressure is controlled using a system of duplex pressure regulators and valves. It is essential that all materials used in the construction of the vessels, control equipment and pipeline are compatible with oxygen at the operating temperatures that could be encountered under normal operation with single fault condition. A risk assessment will determine the exact configuration.

6.46 The control panel design should comply with the design requirements specified in BS EN ISO 7396-1 and should be sized to provide the system design flow plus an additional 25%.

6.47 Where trycock valve discharge may result in liquid oxygen impinging on the compound base, suitable protective measures or construction materials should be provided.

Telemetry

6.48 Telemetry should be installed on all VIEs and liquid tanks because it permits both the healthcare facility and the gas supplier to monitor relevant supply conditions continuously, including storage vessel levels and pressures.

6.49 In addition, it can be used to transmit other operational data from the storage vessel, pipeline and associated equipment for monitoring purposes. It may be beneficial to make this information available to the relevant person/s in the healthcare organisation (for example, the pharmacy team).

6.50 Telemetry does not negate the necessity for daily inspections of the plant (see HTM 02-01 Part B).

Flow/usage monitoring

6.51 Flow-monitoring devices should be installed on VIE pipelines to measure medical oxygen usage. Usage data should be recorded and tabulated daily and reported to the MGSG on a quarterly basis.

6.52 This data informs risk assessments and system reviews. Monitoring devices should be inline and via a non-return valve and bypass arrangement (see Figure 11).

Siting

6.53 The Authorising Engineer (MGPS) with the Authorised Person (MGPS) are responsible for agreeing the final location of the liquid oxygen compound/s with the project working group (including the oxygen supply company), taking into consideration any issues identified in the IDP.

6.54 Safety distances are specified in the BCGA's (2013) 'CP 36: Cryogenic liquid storage at users' premises'.

6.55 Guidance on electric vehicle (EV) charging points is provided in the Fire Protection Association/RISCAuthority's 'RC59: Recommendations for fire safety when charging electric vehicles'.

6.56 Each supply system should be located in a secure, fenced compound. The compound should be sized to provide adequate access to all control equipment and allow free access around all items of plant.

6.57 The security fence should be a minimum of 3 m in height and should incorporate anti-climb features. Welded mesh or similar robust, low-profile materials are recommended to discourage unauthorised access while maintaining visibility for inspection and safety purposes. There should be a minimum distance of 1.5 m from the outer fence to any equipment and pipework inside the compound to avoid any contact from outside the compound.

6.58 External lighting and CCTV monitoring should be provided.

6.59 The compound floor should be flat but designed to have adequate falls to prevent water accumulating beneath equipment.

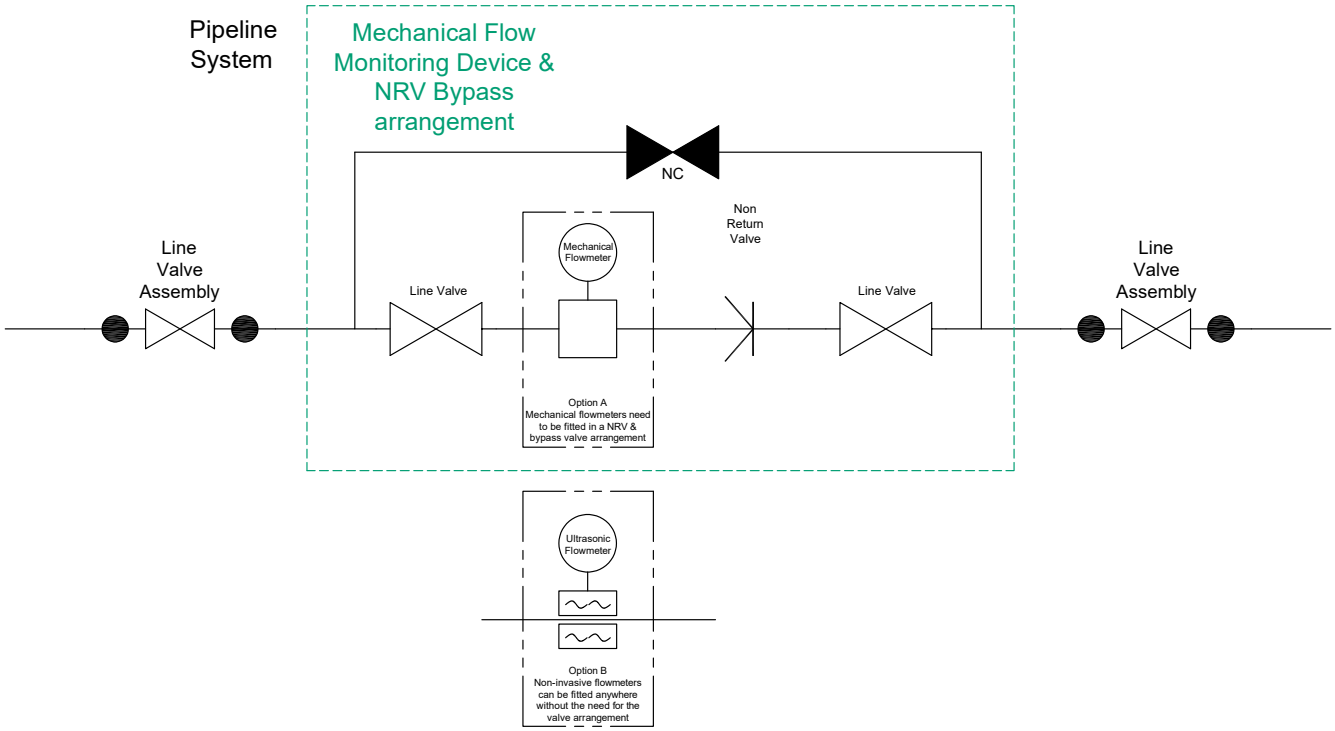


Figure 11 Monitoring device arrangements

6.60 The location of drains and other services in the vicinity of the site/compound should comply with the requirements specified in BCGA's (2013) CP 36.

6.61 Only under extreme conditions should the safety distances specified in BCGA's (2013) CP 36 be reduced. Any relaxation of these safety distances needs to be agreed with the supply company's safety representative and the Authorising Engineer (MGPS) with the Authorised Person (MGPS). Additional safety measures should be put in place. Both parties should ensure that the same level of safety is achieved.

6.62 The layout of the liquid oxygen installation should provide adequate access to all relevant components of the system and permit adequate airflow for the ambient vaporisers. Where there is low level pipework and/or components within the compound, suitable protection is required to prevent accidental damage.

6.63 The plinth and tanker apron should be of suitable concrete construction in line with plant suppliers' specifications. Under no circumstances should asphalt be used in the vicinity of the liquid oxygen filling point or areas where liquid oxygen spillage may occur.

6.64 The location of the liquid oxygen compound should permit the supplier to gain safe access with the appropriately sized tanker. The supplier is responsible for assessing space requirements for vehicular access and undertaking a risk assessment in consultation with the Authorising Engineer (MGPS) and the Authorised Person (MGPS).

6.65 The design of the liquid oxygen installation should take into account the gas supplier's requirements for discharging the liquid oxygen from the cryogenic tanker.

6.66 The area in front of the vessel should be kept clear at all times for delivery access (see BCGA's (2013) CP 36).

6.67 The vent pipes from all safety valves should be piped away from the controls to a safe location within the compound to allow uninterrupted access to the controls and valves during discharge.

6.68 Under no circumstances should any vehicles be permitted to park in front of the compound or within the restricted radius of the compound (see BCGA's (2013) CP 36).

6.69 The compound and surrounding area should be designed to enable them to be maintained in a clean condition and free from vegetation.

6.70 Pipework and installation diagrams of the plant should be displayed clearly on each of the entrances and at the point of the valves to indicate the appropriate valves that are necessary to operate the plant safely.

6.71 Safety signage should be displayed on all sides of the compound and points of access around the compound.

6.72 The medical gases supplier should ensure that the Authorised Person (MGPS) has received site-specific training on the installed system and is familiar with the system and its operating principles.

6.73 This training should be documented and refreshed every two years for all Authorised Persons (MGPS). The refresher training can be undertaken during the servicing of the VIEs but should be documented and recorded.

Liquid tank systems

Plant

6.74 Liquid tank systems can also be used to store the medical gas as a liquid at cryogenic temperatures and to vaporise it to gas for patient use. These systems are used where the demand is too high for compressed gas cylinders to be a practicable option, but where a bulk medical liquid oxygen in a VIE system is not required (see Figures 12 and 13).

6.75 Liquid tanks are constructed in a similar way to the VIE, that is, as double-walled vessels. However, unlike the VIE, the liquid tank has an internal vaporiser coil to convert the liquid into a gas.

6.76 The size of the inner vessel of the liquid tank can vary between 0.15 m^3 and 1.5 m^3. To obtain sufficient storage capacity and to meet the healthcare facility's flow requirements, several liquid tanks can be joined together via a manifold.

6.77 The liquid tank system requires a control panel with duplex components to regulate the pressure and flow of gas to the pipeline.

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

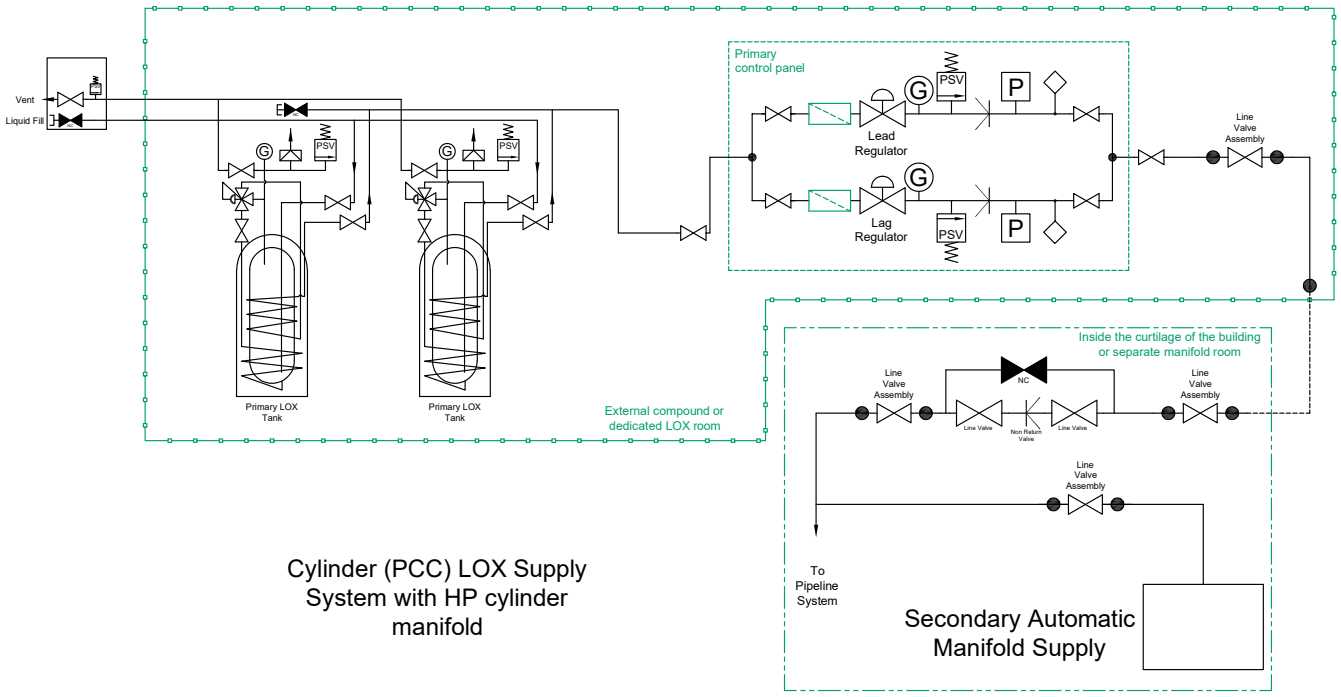
6.79 Liquid tanks are designed and supplied with gas-specific liquid-fill and gas-use connections (including the connection on the remote liquid-fill connection where the liquid tanks are filled in situ).

Siting

6.80 Where a liquid tank system is installed, the area should be adequately ventilated and the vent header (to which all liquid cylinder vents will be connected) should be piped to a safe area via a back-pressure control valve. This valve should be set at a pressure below that of the liquid cylinder relief-valve setting, ensuring that any excess pressure is safely vented.

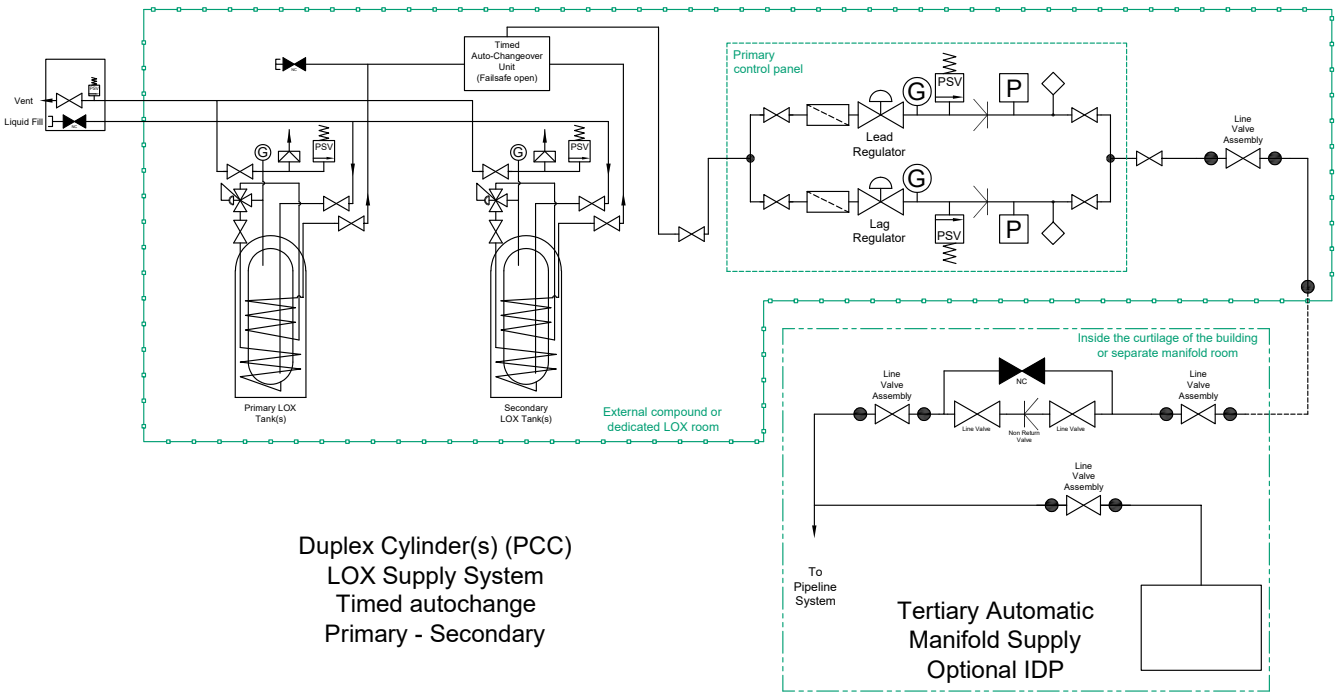
6.81 A pipeline and information diagram of the plant and safety signage should be clearly displayed at plant entrances and within the plant to identify the valves required for safe operation.

6.82 All relevant persons within the healthcare organisation who are directly or indirectly involved with the system should receive the relevant training from the medical gas supplier.



Cylinder (PCC) LOX Supply System with HP cylinder manifold

Figure 12 Liquid oxygen (LOX) system with cylinder manifold



Duplex Cylinder(s) (PCC) LOX Supply System Timed autochange Primary - Secondary

Figure 13 Duplex liquid oxygen (LOX) with timed automatic changeover

Cylinder manifolds

6.83 The simplest supply system to provide medical oxygen to a hospital pipeline system uses compressed gas cylinders, connected together on an ACM. (MCMs are not recommended for primary oxygen supply systems.) As system demand increases, the number of cylinders fitted to the manifold can be increased to meet the hospital's requirements. The secondary supply for this system will usually be an ERM, which comes online automatically (via a non-return valve) in the event of primary manifold failure.

6.84 For a full description of manifold supply systems, see Chapter 5.

Secondary supply systems

6.85 Where the primary supply system is a VIE, the secondary supply system can be another VIE, a liquid tank system or a fully automatic compressed gas cylinder manifold (see Figures 14 and 15).

6.86 Where the primary supply system is a liquid tank system, the secondary supply system should be an ACM that comes into operation automatically (see Figures 12 and 13).

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

6.88 Where the secondary supply is fed from compressed gas cylinders, the size of the changeover manifold header racks and the number of cylinders stored on site should be based on the required design flow and the gas supplier's ability to guarantee a cylinder delivery service in a defined time period to maintain system operation with no outages. Site management processes should form part of the IDP.

6.89 Where a liquid oxygen system is used for the secondary supply, the system should be

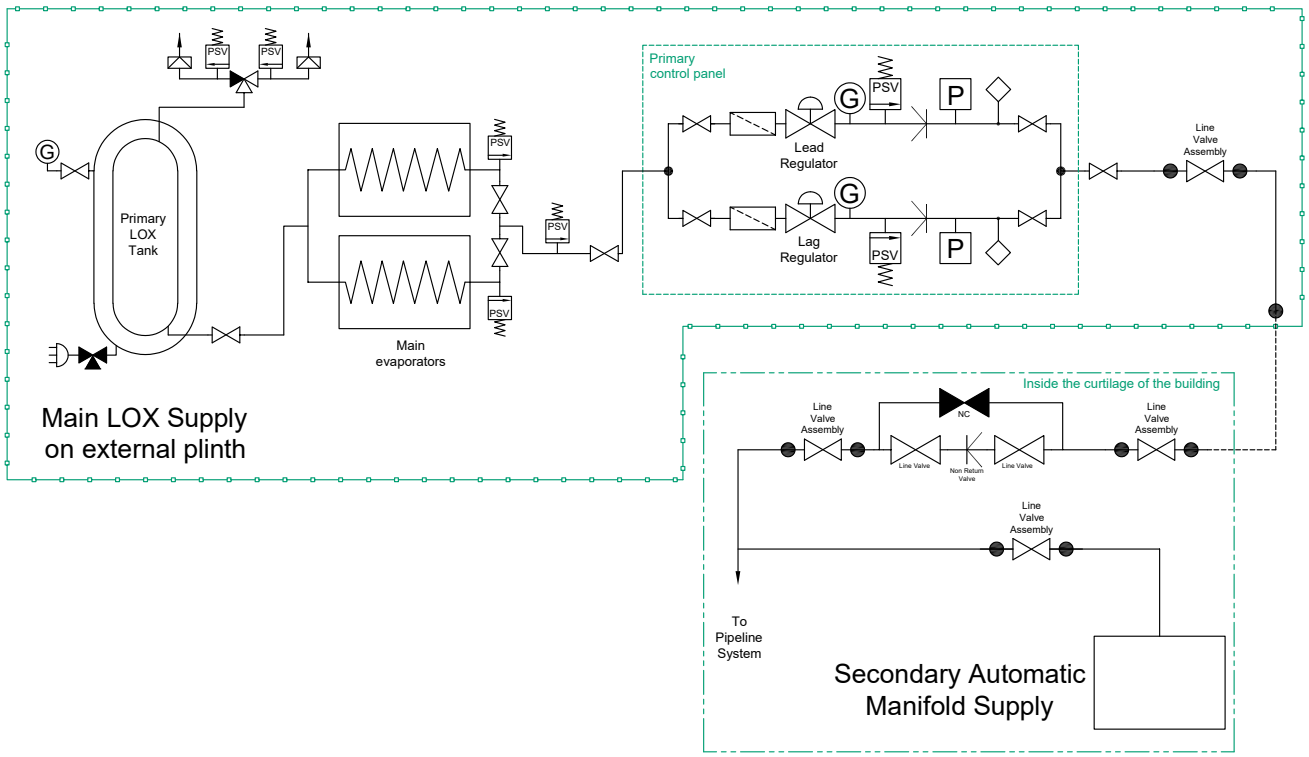


Figure 14 Primary liquid oxygen supply with ACM as secondary supply

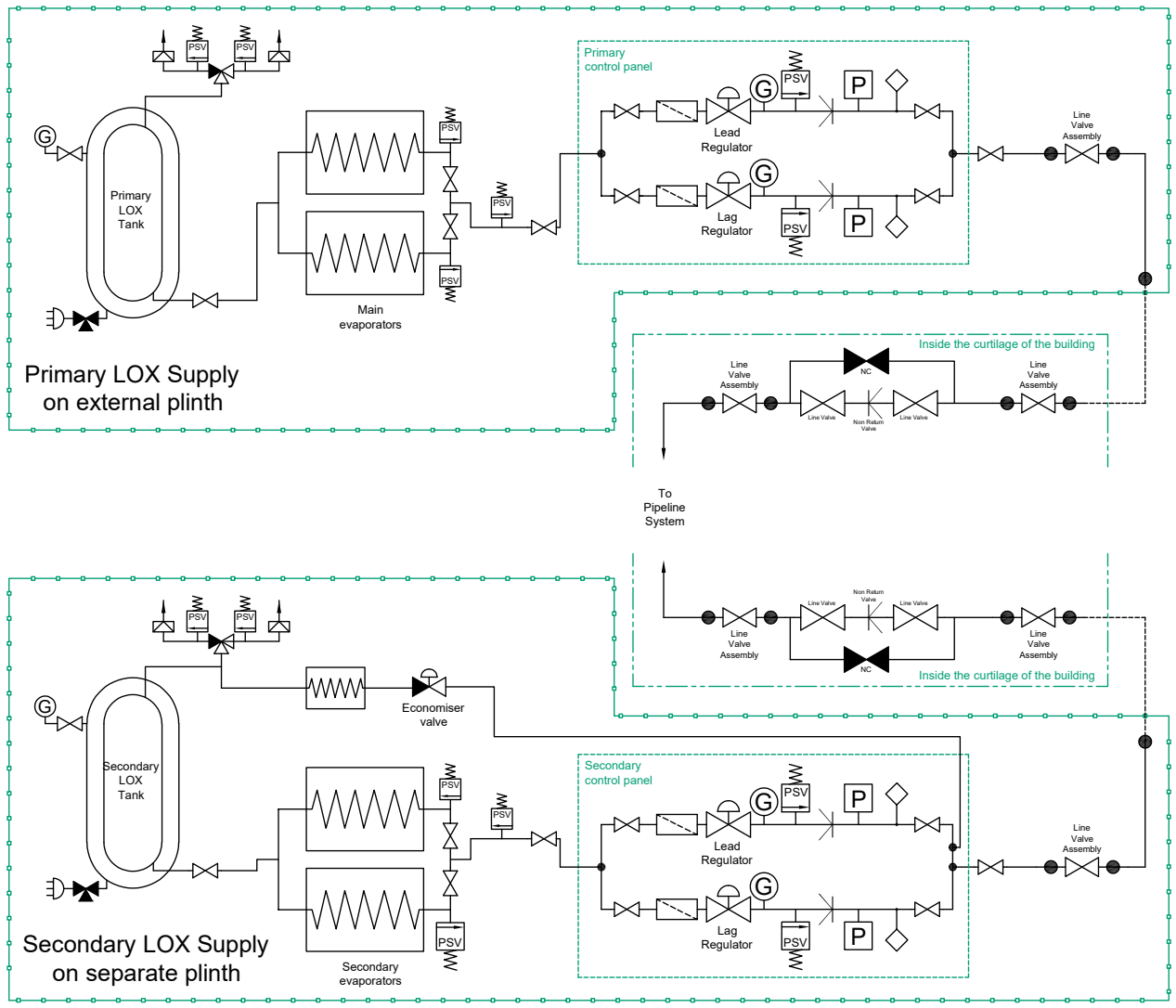


Figure 15 Primary and secondary liquid oxygen supply

designed to return boil-off gas to the pipeline system.

6.90 Where the feed from the VIE compound to the hospital extends a long distance, or is exposed to potential mechanical damage, particular importance should be given to siting the secondary supply system remotely from the main VIE compound with an independent separate supply into the hospital pipeline system.

6.91 Where the secondary supply is sited, consideration should be given to the set point of its output regulator. This is to ensure that the pipeline pressure is maintained at a minimum level of 380 kPa, taking account of pipeline sizing and pressure drops through the IDP.

6.92 Where vessels are located separately, a backflow prevention device should be fitted on each connection to the pipeline system. This prevents loss of product from either vessel or from the hospital pipeline in the event of failure or damage to a VIE or its connection to the pipeline system. The backflow protection should be sited in a secure location where it is not liable to mechanical damage and be close to the plant and within the hospital building.

Critical emergency supply systems

6.93 Where specific areas identified in the IDP require additional resilience beyond the three standard sources of supply, a critical emergency supply may be provided. A variety of sources are available for the provision of emergency oxygen which are detailed in Chapter 2. Under most conditions, compressed gas cylinders are the appropriate method of providing a critical emergency supply source.

6.94 The system relies on a manifold system upstream of the AVSU feeding the specific area via a non-return valve installed on the main pipeline.

6.95 The critical emergency supply system should be activated automatically when the primary, secondary and tertiary sources of supply are empty or fail to supply. It should have the provision to automatically prevent the backflow of medical oxygen into the remainder of the pipeline system, should the pipeline fail upstream of the connection.

6.96 The size and design of the critical emergency supply system should allow for cylinders to be changed while maintaining flow rates.

Emergency inlet ports

6.97 Emergency inlet ports should be considered for inclusion in the system during the IDP, taking account of necessity and their practicality for the healthcare facility. In some instances, installation of a fixed manifold system will remove the need for fitting an emergency inlet port. Where the emergency inlet port is required, consideration for the type of system install should be clear and understood by the MGSG with siting a key consideration for supply equipment. At the time of writing, mobile VIEs are not readily available for immediate delivery and connection to these emergency inlet ports. Adequate resilience measures in the design of the system should eradicate the need for these ports.

Alarm systems

6.98 All medical oxygen supply systems (per control panel) should be fully monitored on the medical gas plant alarm system and should be allocated individual channels per supply system. They should be clearly identified on the alarm panel to prevent confusion.

6.99 For liquid systems, the following displays should be presented at the plant and on the plant alarm:

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 at 50%	**Yellow**	Reserve low
Pipeline pressure high or low	**Red**	Pressure fault

6.100 When the "Normal" legend is illuminated green, all systems are available for use.

6.101 When the primary supply operational stock is exhausted and the vessel reaches the

reserve stock level, the first alarm condition will be indicated by a yellow alarm with the legend “Refill liquid” illuminated.

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

6.103 When the secondary supply reaches 50%, the third alarm condition will be indicated by a yellow alarm and the legend “Reserve low” will be illuminated. The condition continues until the supply system has been refilled or cylinders replaced.

6.104 Should the primary supply of medical oxygen to the hospital pipeline fail due to lack of contents or mechanical failure of any of the components, or should a serious leak occur, the pipeline pressure will fall. When the plant output pipeline pressure falls below 380 kPa, the fourth alarm condition will be indicated by a red alarm and the legend “Pressure fault” illuminated. The condition should continue until the pressure has been reinstated.

6.105 If the regulator controlling the pipeline pressure should fail in the open position, the pipeline pressure will rise above 500 kPa. The fourth alarm condition will be indicated by a red alarm and the legend “Pressure fault” illuminated. The condition should continue until the pressure has been reinstated.

6.106 Where the critical emergency supply (see paragraphs 6.93–6.97) is installed on individual zones of the pipeline system, the alarm should be displayed within that zone and repeated at the 24-hour occupied area (see Chapter 14).

6.107 Alarm conditions should be transmitted to the central alarm system and clearly displayed at the plant.

Oxygen concentrator installations (PSA plant)

General

6.108 Oxygen concentrators or pressure swing adsorption (PSA) systems may serve as an alternative to liquid oxygen supply systems in certain circumstances (the terms oxygen concentrator and PSA are interchangeable). PSA systems should only be considered where geographical or environmental constraints prevent the installation or supply of liquid-oxygen or compressed-gas systems, such as in remote or off-shore locations. Agreement from the MGSG should also be sought.

6.109 When installed, a PSA system will deliver product gas via the oxygen pipeline system.

6.110 Oxygen concentrators operate by using pressure to adsorb other atmospheric gases on to materials with specific physico-chemical properties, thereby separating and concentrating the oxygen for storage and use. The adsorbents are known as artificial zeolites, but more commonly referred to as molecular sieves. The sieve units are arranged in pairs: one adsorbing while the other regenerates. The waste product, essentially nitrogen, is discharged to atmosphere during regeneration of the adsorbents. The use of vacuum to remove the nitrogen increases the efficiency of the regeneration/adsorption process. Regeneration requires a proportion of the product gas to be used in the process, and this consumption should be taken into account when sizing the plant.

6.111 The PSA process has achieved a high level of technical sophistication and can produce oxygen concentrations of up to 95%. The remaining content is mainly argon, with some nitrogen. The maximum achievable oxygen concentration is unlikely to exceed 97/98%. In the UK, the emergency reserve manifold is typically configured to activate if the oxygen concentration falls below 94%.

6.112 Care should be taken when designing an emergency reserve manifold to operate with a PSA to ensure that the same oxygen concentration is supplied by the manifold as that from the PSA. Cylinders supplied by a gas supplier will be >99% concentration.

6.113 The major components of a PSA system include compressors, receivers, dryers, molecular sieves, vacuum pumps, filters and regulators. Other components are identical to those used for medical air and vacuum plant. A suitable operating and indicating system should also be provided. Package supply systems should be specified to meet the requirements given in this HTM.

Siting

6.114 The plant should be sited in a room suitable for medical air (see Chapter 17).

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

Plant configuration

6.116 The plant should comprise:

- a duplex compressor: where more than two compressors are installed, the system should be capable of delivering the design flow with one compressor out of service
- duplexed air treatment/molecular sieve devices, that is, duplexed filters and duplexed molecular sieves (one adsorbing while the other regenerates) and one vacuum pump (if required by the manufacturer).

Note:
All duplexed components should be capable of independent operation. The general principles of the resilience of a medical air plant configuration should be followed.

Compressors and vacuum pumps

6.117 Compressors for the PSA systems should comply with medical air requirements (see Chapter 7). The medical air plant should not be used for the PSA plant.

6.118 The vacuum pump, if provided, is used during the adsorption/regeneration process. Vacuum pumps may be of any suitable type, as specified for piped medical vacuum systems (see Chapter 10).

Molecular sieves

6.119 Duplex molecular sieves should be provided in pairs to enable continuous oxygen generation. While one pair is in the adsorption stage, the other undergoes regeneration.

Dryers

6.120 Air dryers of the desiccant type are usually integrated within the molecular sieves and therefore do not regenerate independently. Refrigerant dryers may also be included where the environmental conditions require these.

Oxygen monitoring system

6.121 The plant should include a duplex calibrated paramagnetic oxygen monitoring system comprising:

- two oxygen analysers
- two oxygen concentration indicators
- two oxygen flow monitors and
- an oxygen concentration/flow recorder.

6.122 Connections for calibration cylinders should also be provided. In the event of the concentration falling below 94%, the monitoring system should isolate the PSA system from the pipeline distribution system so that the emergency/reserve supply operates. Additionally, an independent monitoring system should be provided to isolate the plant when the concentration falls below 94%. All

components should be capable of being replaced without interruption of supply.

Operating and indicating system

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

- overall plant control and indication
- individual compressor starting
- individual vacuum pump starting (where fitted)
- control of dryers (where installed as separate component)
- control of molecular sieves
- plant status monitoring and indication
- optional indication of the plant alarm status (this function may be part of the alarm system).

6.124 Each individual compressor/pump should have independent starters and controls.

6.125 Control panels that incorporate pneumatic components should be fitted with vents to allow for the safe release of pressure in the event of a component failure. All functions and indicators should be appropriately identified and should have a design life of at least five years. The operating system should be capable of automatically restarting after reinstatement of the power supply.

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

Plant control unit

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

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

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

6.130 Plant control indication and compressor and vacuum starter units should meet the requirements for medical air and vacuum plant in this HTM.

Molecular sieve control unit

6.131 The molecular sieve control unit should be an independent unit and can be mounted on the molecular sieve columns or may be located with the plant control unit. There should be separate power supplies for the duty and standby sieve assemblies, taken from the same phase.

Plant management

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

- compressor – “on”, “off”, “on-load”, “unloaded”
- molecular sieves – “on” or “off”.

6.133 These connections should be used to provide input to the hospital building management system.

7 Medical compressed air systems

Compressor systems

7.1 Medical compressed air can be obtained from compressor systems and cylinders. Mixing gaseous oxygen and nitrogen from cryogenic liquid supply sources (called synthetic air) is not recommended.

7.2 All plant designs should consider variable speed drive (VSD) compressors.

7.3 For new builds and upgrades or replacements, oil-free compressors should be considered to reduce the risk of contamination of the pipeline system (see paragraph 7.34).

7.4 When an existing system is in place, consideration should be given to using all available usage and maintenance data for its continued operation, or partial/full decommissioning.

7.5 Medical and surgical air should be provided from a single combined system to reduce maintenance and overall energy consumption. The choice ultimately depends on the relative consumption for each supply.

7.6 A single dual-purpose plant designed to supply both surgical and medical air, incorporating VSDs, represents the most sustainable and efficient solution and should be specified. This plant arrangement would have the ability to modulate flow to suit demand and ensure energy efficiency requirements are met.

7.7 Surgical air consumption typically occurs at high flow rates and pressures, up to 350 L/min, but for relatively short durations (minutes). Only a small number of terminal units are likely to be in simultaneous use.

7.8 Air for respiratory purposes is used at much lower flow rates, typically less than 80 L/min in the case of patient ventilation; however, use can be continuous. Medical air demand typically involves multiple terminal units in use simultaneously.

7.9 The use of combined plant (for example, MA4 and SA7) can reduce capital and operating costs. Overall plant capacity requirements are typically lower than for separately specified systems. Plant sizing can be based on the combined usage and demand of both systems under normal conditions, with capacity from medical air design allowances offset by the lower demand for surgical air.

7.10 Where a VSD compressor provides the primary control of operational demand, the capacities outlined in Table 16 should be amended. The VSD compressor should be sized to no more than 80% of the required flow rate.

7.11 An automatic manifold arrangement should be designed as the secondary source of supply in support of the compressor system supply (see Table 17).

	Service	Plant size	Notes
Duplex compressor system	Medical air	Each compressor sized at 100% design flow capacity	Vessel water capacity sized at a minimum of 50% free air delivery (FAD) of the system in 1 minute
Triplex compressor system	Medical air or combined plant	Each compressor sized at 50% design flow capacity	
Quadruplex compressor system	Medical air or combined plant	Each compressor sized at 33% design flow capacity	
Sextuplet compressor system	Medical air or combined plant	Each compressor sized at 20% design flow capacity	
Octuplet compressor system	Medical air or combined plant	Each compressor sized at 15% design flow capacity	
Duplex compressor system	Surgical air	Each compressor sized at 50% design flow	
Simplex oil-free compressor	Dental air	Compressor to supply 125% of design flow	
Multiple oil-free compressors	Dental air	To follow guidance above for triplex, quadruplex, etc.	
Duplex medical air or oil-free compressors	Dental air	Each compressor to supply 125% of design flow	
Note: VSD compressors should be individually sized as per the system configuration.			

Table 16 Compressor capacities

Primary supply	Secondary supply	Tertiary supply
Duplex compressor system (surgical air)	Automatic manifold system To come online automatically in the event of plant failure Number of cylinders based on ability to provide 4 hours' supply at average use	Locally based ready-to-use cylinders
Two compressors of a triplex compressor system.	Third compressor of a triplex system	Automatic manifold system/s. Locally based ready-to-use cylinders
Three compressors of a quadruplex system.	One compressor of a quadruplex system.	Automatic manifold system/s Locally based ready-to-use cylinders

Table 17 Compressor-driven air systems

Quality

7.12 For quality requirements, see Chapter 20.

Siting

7.13 Plant should have all-round access for maintenance purposes, and allowance should be made for changing major components. A minimum 1.2 m from other obstructions and a minimum of 0.9 m between items of plant should be provided (see also paragraphs 17.152–17.155 on compressor noise).

7.14 Where maintenance activities such as the replacement of major components require additional space beyond the minimum clearances, allowances should be increased based on risk assessment to minimise lifting and handling risks. These considerations should also be reviewed during life-cycle upgrades.

7.15 A method statement for the replacement of major components should be provided as part of the plant location design, taking into account lifting equipment requirements and health and safety considerations.

7.16 The location of lighting should be considered to ensure that the plant is correctly illuminated at all locations where works are to be undertaken.

7.17 Manufacturers should be consulted over the range of operating temperatures for which the supply system is designed. In extreme cases, refrigerator cooling may be required between the compressors and the dryer and filter set. Environmental factors should be considered as part of these design criteria.

7.18 Plant siting should provide adequate airflow for the following three purposes:

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

7.19 Air plant should be in a dedicated plantroom where other plant cannot compromise the air-intake quality.

7.20 A schematic drawing of the plant should be provided in the plantroom.

7.21 Medical air plant should not be located in the same room as the medical vacuum or AGSS plant.

Air intake

7.22 The position of an air intake will have a considerable effect on delivered air quality, particularly with respect to levels of carbon monoxide.

7.23 The air intake for a compressor should be located to minimise contamination from internal combustion engine exhausts and the discharge from vacuum systems, AGSS and ventilation systems or other sources of contaminants.

7.24 Air intakes should be ducted where necessary to avoid contamination. A minimum height of 5 m above ground level should ensure a reasonable quality of intake air. Where this cannot be achieved, additional filtration or air treatment may be necessary on the air intake or prior to the filtration system.

7.25 Where there is a risk of the compressor aspirating toxic fumes or smoke in the event of a fire, an automatic shutdown linked to local smoke detectors should be installed, regardless of the air-intake location. 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 online automatically in the event of plant shutdown. A series of non-return valves should be provided within the system for system protection in the event of a fire so that the emergency supply feeds into the system and not the fire in the event of pipeline failure. This use of an automatic isolation system should be agreed and approved by the

MGSG and Fire Safety Manager prior to the final design stages of any project.

7.26 Care should be taken when extending compressor air intakes to ensure that airflow is not restricted due to increased pressure drop.

7.27 Manufacturers' data should be consulted to ensure that intake flow and compressor performance are not adversely affected by excessive lengths of intake ducting.

7.28 Intake material selection is critical. Intakes should be constructed from galvanised rectangular or spiral-wound ductwork in accordance with the Building Engineering Services Association's (BESA) (2016) 'DW/144: Specification for sheet metal ductwork' and should not be constructed from solvent-welded PVC.

7.29 Air-inlet filters should be fitted immediately upstream of the compressor. Additional screens, filters and silencers may be required. The filters should comply with BS ISO 5011 and be either dry medium filters or grade CA paper element filters.

7.30 Consideration should be given to compressor cooling airflow requirements, which may need to be provided mechanically via a duplex system to ensure that a failure does not compromise plant operation.

Compressor types

7.31 There are different types of compressors currently available, the most common types being:

- rotary screw compressors
- reciprocating compressors
- scroll compressors.

7.32 The compressors may be of any type, provided they are suitable for continuous running on load and for high frequency start/stop operation or controlled by VSDs.

7.33 Compressor selection should maximise energy efficiency.

Compressor lubrication

7.34 Oil-free compressors should be considered as replacements for oil-filled compressors as they reduce filtration requirements, minimise the risk of oil contamination and improve system performance.

7.35 Compressors may be oil-lubricated provided that suitable arrangements are made to ensure that the air-quality specification given in Chapter 20 is fulfilled.

7.36 Rotary compressors are sealed and cooled by oil or water. Oil control is therefore essential and is usually provided as an integral part of the compressor. Reciprocating compressors may be of the oil-lubricated, carbon-ring, PTFE-ring or diaphragm-sealed type.

7.37 Water should not be used as a sealant because of microbial contamination risks and potential problems with water treatment.

7.38 There is a danger that PTFE rings and lubricating oils could decompose at high temperatures to form toxic products. This can be countered by fitting a temperature sensor to the cylinder head or output of the compressor, with suitable controls to cut off the power supply to the compressors if excessive temperatures are sensed (manufacturer-specific data will be required here to support temperature range determination).

7.39 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.

7.40 It is not possible to match varying demand precisely with plant capacity. Oil

heaters may be required to avoid emulsification.

7.41 Where oil heaters are to be omitted, manufacturers should be asked to confirm the suitability of the compressor for intermittent operation. But, in general, oil-lubricated compressors are considered satisfactory.

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

7.43 Once a compressor installation plant has been selected, the following should be considered:

- It should include at least two compressors, but additional compressors may be included provided that in all cases the total capacity will provide 100% of system design flow.
- Design should balance capital and operating costs, avoiding low-cost solutions that compromise reliability or increase energy consumption. Operating costs should be calculated based on realistic usage, and the overall sustainability of the plant and system should be evaluated and risk-assessed.
- Compressor plant control systems should include an hours-run counter and be constructed in accordance with the guidelines given below.
- Efficiency of plant expressed as the volume of free air delivered to the pipeline distribution system, after losses in the drying system and filtration system per kilowatt-hour (kWh), should be stated by the supplier of the system.
- The testing procedure should evaluate this efficiency by testing the power consumption over a suitable period of time at 100%, 10% and 0% of the system design flow.
- A minimum efficiency of 5 m^3/kWh at 100% and 10% is required. The power consumption at zero flow should be less than 1% of that at 100% design flow.

After-coolers and separators

7.44 After-coolers and inter-coolers, where required or specified, should form part of the compressor subassembly. After-coolers should be fitted to oil-lubricated medical air compressor systems.

7.45 These will be air-cooled and may need ducting with forced ventilation to ensure an adequate supply of cooling air.

7.46 An inline cyclone water separator should be installed between each compressor and the receivers, fitted with a timed-controlled solenoid drain valve.

Receivers

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

7.48 Air receivers should comply with the relevant British Standards and/or EU Pressure Equipment Directive documentation and be supplied with relevant certification.

7.49 The minimum water capacity of the receivers should be 50% of the compressor output in one minute, stated in terms of free air delivered at normal working pressure.

7.50 Receivers should be fitted with electrically operated automatic drains, as these have been found to be more reliable. A manual drain is also required for the vessel as a bypass to be operated in the event of power loss.

7.51 To facilitate statutory inspections, there should be either two suitably valved air receivers or a bypass arrangement for use in manual operating mode only, in order to avoid interruption to the supply.

Pressure control

7.52 The pressure control should maintain the nominal pipeline pressure within the limits given in Chapter 4.

7.53 Pressure-reducing regulators should be provided with suitable isolating valves.

Safety valves

7.54 All safety valves should conform to BS EN ISO 4126-1. Safety valves with a certified discharge capacity 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 prior to any isolating valves.

7.55 All safety valves should be of the closed-bonnet type and connected to suitably sized pipework to allow discharge to a safe location away from the plant. The discharge location should be out of the compressor plantroom and not on the access route into the plantroom to ensure safe access to the plant in the event of a safety valve release.

Traps, valves and non-return valves

Automatic drainage traps

7.56 Electrically operated automatic drainage traps should be provided on the after-coolers, receivers, separators and coalescing filters.

7.57 Any discharge from these drainage traps must be piped to a suitable oil separator to comply with water regulations and local water operator requirements.

7.58 Separators should be maintained by specialist providers as part of the air compressor contract.

Non-return valves

7.59 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 backfeeding this plant
- upstream of any inlet point that may be used to feed the system in an emergency
- downstream of the emergency cylinder manifold regulators.

Isolating valves

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

7.61 Manually operated ball isolation valves should be located to allow isolation of components such as receivers, dryers, automatic drains, pressure regulators and filters. A valve should also be installed downstream of the compressor plant non-return valve and the connection of the cylinder manifold supply.

Dryer units

7.62 Medical air is produced from ambient intake air; therefore, the cleaner the intake air, the higher the quality of the medical air produced.

7.63 Air treatment is undertaken in a number of stages. In the first stage, compressed air is introduced at a low level and directed against the side wall. This impact removes larger water and oil particles. The air is then drawn from the upper level of the vessel where heavier droplets are unable to remain suspended. This air is then passed through the dryer assembly.

7.64 The dryer system typically consists of a series of filters:

- a water filter/separator (an individual component)
- an oil filter (an individual component)
- two desiccant dryer columns
- a dust filter
- a carbon filter
- a bacteria filter.

Note:
Oil filters and water filter/separators should be individual components to ensure resilience and efficiency.

7.65 From the dryer assembly, the air is passed through a PRS to determine the usage of the air.

7.66 Each individual dryer assembly comprises two dryer columns. While one column is actively drying the compressed air, the other column is being dried using the dry air produced by the active column.

7.67 This full assembly makes up a single dryer assembly, which is duplicated by a second dryer assembly to ensure continuity of supply.

7.68 Each dryer assembly should have its own dew-point sensor and test point, located after the bacteria filter, to enable the individual dryer assembly to be tested before being brought online and to enable continuous monitoring of the product (see Figure 16).

Pressure indicators

7.69 Pressure indicators should comply with BS EN 837-1 or have an equivalent performance if electronic indicators are used.

7.70 Calibration should be in kPa. All gauges should have a minimum scale length of 90 mm and the working range should not exceed 65% of the full-scale range, except on differential pressure gauges. Pressure indicators should be connected by means of gauge cocks.

7.71 Pressure indicators should be located:

- on the plant control unit indicating receiver pressure
- on each receiver
- downstream of each pressure regulator.

7.72 The inclusion of a differential pressure gauge does not remove the requirement for regular inspections. Due to the nature of differential pressure indication, it signals critical failure rather than servicing requirements.

7.73 All control and measuring devices, except for pressure gauges, should be connected directly to the pipework via a minimum-leak device to allow removal for servicing and should not be isolated by valves.

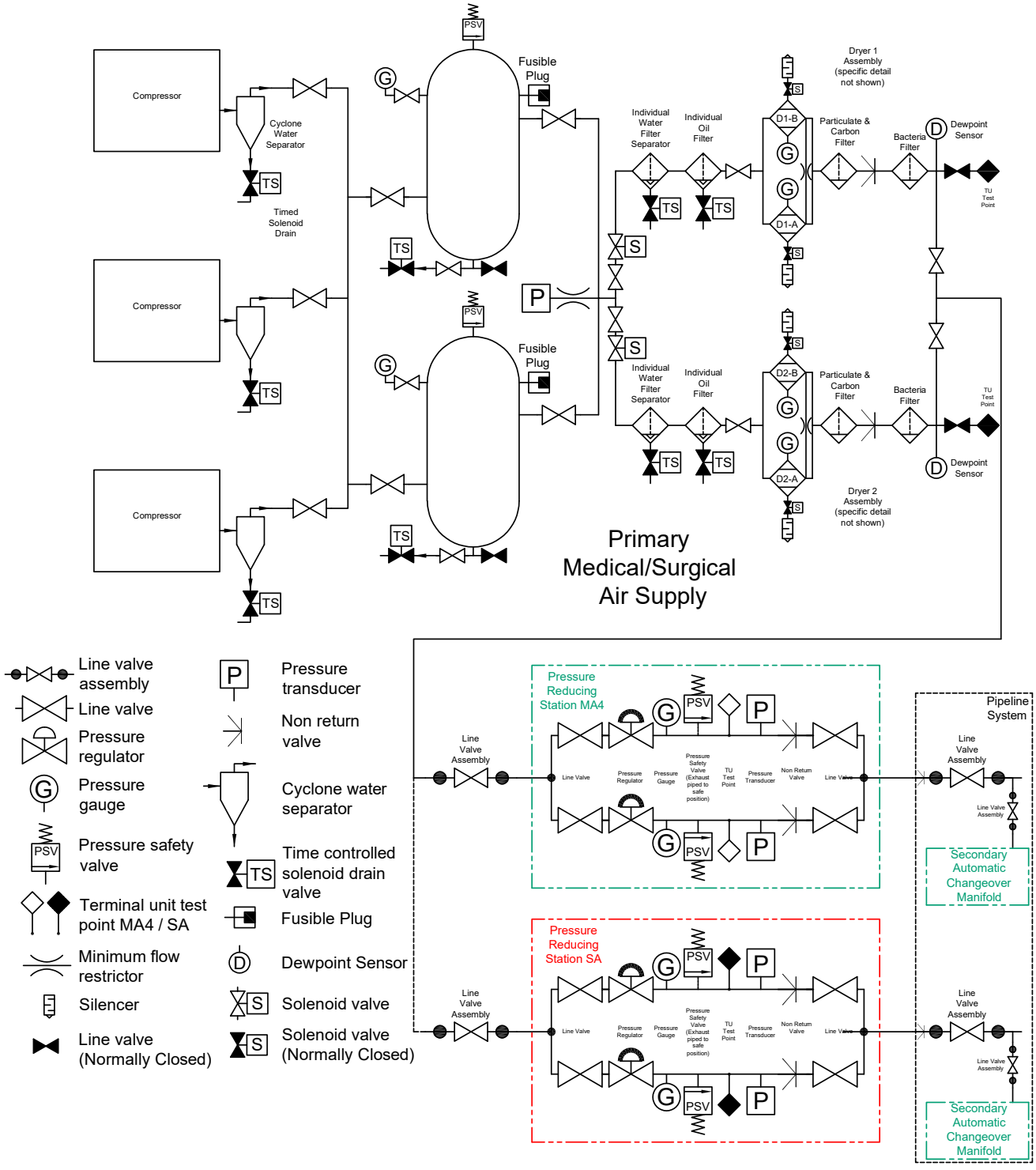


Figure 16 Typical medical/surgical air plant layout

Operating and indicating system

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

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

7.75 Where compressor starters are in a separate compartment, the functions may be provided by separate units or installed within a common panel and located on the plant or on the plantroom wall.

7.76 Control panels containing pneumatic components should have vents to permit release of pressure in the event of component failure.

7.77 All indicators should be appropriately identified and should have a design life of at least five years.

7.78 The operating system should be capable of automatically restarting after reinstatement of the power supply for all conditions.

7.79 All components of the medical air supply system should be considered life-critical electrical equipment. As such, the electrical supply should be provided via an essential electrical source as detailed in HTM 06-01. The control system should ensure that compressors restart in sequence to avoid overloading the power supply.

Plant control unit

7.80 The plant control unit should have a separate power supply for each compressor, controlled by a separate subcircuit and a double-pole isolator.

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

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

7.83 All changes to the selectors should be accessible without codes or entering a programme and clearly identified on the control panel.

Plant control indication

7.84 There should be indicators for each compressor as follows:

- green: mains supply on
- green: compressor called for (which indicates that the compressor motor is electrically energised)
- an indicator of pressure being produced by the compressor.

Compressor supply and control

7.85 The supply and control for each compressor should be individual. Each system should be provided with safety interlocks which stop plant operation until the control system is reset by means of physical interface by a user. Automatic restart of the control system should occur after interruption to the power supply, given no faults have been detected. The individual control system should have:

- a total hours counter (if not included in the plant control unit)
- a green mains supply on indicator (if mounted separately from the plant control unit)
- a means of accurate current measurement
- suitable means of circuit protection

- safety interlocks with any covers.

Dryer control unit

7.86 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 standby dryer assemblies.

7.87 The dryer control unit should contain the following:

- a duty dryer selector switch
- a service function – to enable selection of continuous/normal running
- individually fused, separate cycling systems for each dryer
- a system to control regeneration of the dryers in relation to pipeline demand
- hygrometers and displays with a minimum accuracy of ±3°C in a minimum range from –20°C to –80°C (set to –46°C atmospheric dew point) and a pressure sensor
- an automatic changeover to the standby dryer system in the event of failure of the duty unit by either dryness or pressure, which requires:
  - electrical and pneumatic isolation of the duty subassembly so that it is taken offline
  - electrical and pneumatic energisation of the standby subassembly so that it is brought online
  - activation of the appropriate fault indicator and associated volt-free contacts
  - the subassembly to remain in this mode of operation until the fault has been rectified
- green function indicators for each dryer subassembly to indicate:
  - dryer 1 selected
  - dryer 2 selected
  - selected dryer – normal
  - selected dryer – failed (this fault indicator should remain until manually reset by means of a reset button)
- 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.

7.88 In the event of power supply failure, all drain and vent valves should fail closed and all inlet and outlet valves should fail open.

Plant status monitoring

7.89 The plant should incorporate a monitoring system 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 50 kPa below the standby cut-in pressure
  - receiver pressure 50 kPa above the cut-out pressure
  - dryness above –46°C at atmospheric pressure

- pressure fault (cylinder reserve):
  - pressure in duty bank below 50% (of normal cylinder pressure)
- pressure fault (pipeline):
  - low pipeline pressure
  - high pipeline pressure.

Plant status indicator unit

7.90 In addition to the plant control indication there should be a plant status indicator, panel-mounted, on the plant control unit. It should have a warning notice that complies with BS EN ISO 7010 to indicate the presence of low voltage.

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

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

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

- green – mains supply on
- yellow – dryness fault
- yellow – pressure fault.

Alarm signal status unit

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

a. green – normal
b. yellow – plant fault conditions (b)–(g) in paragraph 7.91
c. yellow – plant emergency low reservoir pressure/high moisture. Condition (b) in paragraph 7.91
d. yellow – reserve low emergency/ reserve banks low <50%
e. red – pipeline pressure fault.

7.94 Conditions (b)–(e) should be transmitted to the central alarm system.

7.95 The plant alarm should be a separate unit within the plantroom. The cabling should be monitored for open and short circuit. In the event of such a cabling fault, a red system fault lamp should be illuminated on the alarm signal status unit together with the appropriate alarm condition.

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

Plant management

7.97 Connections should be provided which allow monitoring of plant alarm conditions (b)–(e) in paragraph 7.93 and pump running for each compressor. These connections should be volt-free contacts normally closed for each. The BMS should only be used to monitor the plant and not be used to control the plant functions, changes or isolations.

Additional use/restrictions of medical air systems

7.98 The use of a medicine (medical air) should not be used for process purposes such as endoscope dryers (see also Chapter 8 on surgical air).

7.99 Medical air systems should not be used to provide air for sterilizer chambers or door-seal use.

7.100 Medical air systems should not be used as a power source for pendant control and braking systems. Electric brake systems should be specified.

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

8 Surgical air systems

8.1 The design of surgical air systems should be based on the IDP approach, with due consideration given to the use of battery-powered and electrically powered surgical tools.

8.2 Surgical air at 700 kPa is used as a power source for surgical tools and equipment. Surgical tools typically require high flows up to 350 L/min at 700 kPa at the point of use. Ophthalmic equipment typically requires 100 L/min at 700 kPa. Where surgical air is used to feed dental tools, this typically requires 50 L/min at a reduced pressure of 600 kPa. Although electrical brakes are the preferred option for pendants, surgical air has been used for this purpose (see paragraph 3.70).

8.3 Where nitrogen is available on site, it may be used as an alternative source of supply. Consideration should be given to the potential for oxygen depletion where nitrogen is used to power tools (see BCGA's (2023) 'CP 52: The management of risks from gases in the workplace'). Additional environmental monitoring should be carried out in areas of high nitrogen use to confirm that oxygen levels remain safe for staff and other persons who may be present in those areas.

8.4 Supply systems for surgical compressed air may be a cylinder manifold system, a dedicated 700 kPa compressor system or a compressor system capable of supplying both the 700 kPa and the 400 kPa supplies. Plant selection should be undertaken using the IDP approach (see Tables 18 and 19).

8.5 A surgical air configuration should be in line with a medical air system (see Chapter 7).

8.6 The pressure control equipment should comprise duplex regulating valves with upstream and downstream isolating valves, pressure gauges, NISTs and pressure relief valves (see Figure 6 in Chapter 3).

Primary supply	Secondary supply	Tertiary supply
Two compressors of a duplex compressor system (each compressor capable of 50% design flow)	Automatic manifold system. To come online in the event of plant failure. Number of cylinders based on ability to provide 4 hours' supply at average use.	Locally based ready-to-use cylinders

Table 18 Minimum requirements for a compressor-driven surgical air system

Primary supply	Secondary supply	Tertiary supply
Combined compressor system	Two automatic manifold systems: • one dedicated to support the medical air system • one dedicated to support the surgical air system. All to come online in the event of plant failure. Number of cylinders on each based on ability to provide 4 hours' supply at average use	Automatic manifold system/s Locally based ready-to-use cylinders should be supplied

Table 19 Combined medical/surgical air plant

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

8.8 The maximum pressure at the terminal unit under static flow conditions should not exceed 900 kPa.

8.9 Where a surgical air system has been specified, there will be a requirement for local cylinder storage at the point of use. Adequate room storage, ventilation and warning signage should be provided for the storeroom. Cylinder store sizes should be in line with the requirements for accommodation as detailed in Chapter 17.

9 Dental air systems

9.1 This chapter provides advice and guidance on the specific requirements for compressed air systems for use in dental hospitals, dental teaching schools, clinics, surgeries and primary care facilities.

9.2 A compliance audit should be carried out on the existing system. A risk assessment should be prepared, taking into account the priority for patient and staff safety covering all statutory requirements.

Use of medical gas systems

9.3 Compressed air is required to power dental instruments and is referred to as dental air (DA6). The performance requirements of dental compressed air differ from those for medical air and surgical air.

Extent of systems and limitation of use

9.4 Dental air and vacuum systems (DAVS) may be extended to the dental laboratory, provided the systems have been specifically designed to cope with this demand.

9.5 The dental air supply should not be used for any other purpose other than clinical and dental laboratory procedures.

9.6 Where medical gas pipelines are installed in a dental surgery or clinic, the guidance given in this HTM should be followed for their installation.

9.7 Separate installations should be provided for pathology applications (see HTM 08-06).

Extension of surgical air systems into dental departments

9.8 While it is acceptable to extend a surgical air system into a dental department, any such decision should take into account the following:

- The extra demand on the existing system should 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 should be carefully assessed.
- Both the Authorised Person (MGPS) and Quality Controller (MGPS) should be aware that extending a surgical air system into a dental unit for dental instrument use will introduce non-gas-specific pipework and terminations that do not form part of the normal surgical air system (for example, crimped or compression fitted connectors).
- Failure of the dental air components should not be allowed to compromise the existing surgical air system.
- If the system is further extended into a dental laboratory, surgical air should not be used to support the operation of such devices as natural gas/air burners.

- A risk assessment should consider the potential for cross-connection of surgical air and other systems.

Dental air quality standard

9.9 Dental air should be the same as medical air in all parameters except for moisture, which should be at –20˚C dew point.

9.10 A medical gas particulate content test is normally conducted for 30 s at 150 L/min flow rate. This will not be practicable on all dental air systems, especially small installations (for example, single chair). In these cases, purging of the system at full flow should be sufficient to remove particulates.

Supply systems

Air compressors

9.11 For systems with five chairs or fewer, it is recommended that a stand-alone or duplex compressor system is used. The compressor should be an oil-free compressor with dryer and filter elements.

9.12 For larger systems where oil-free compressors are not available or where financial constraints limit the selection of a compressor system, the equivalent surgical air system may be used with a line pressure of 600 kPa.

9.13 Any type of compressor suitable for continuous running on load and stop–start duty may be used.

9.14 Oil-contaminated compressor condensate is classed as trade effluent and should only be discharged via an oil/water separator. Oil-free compressors have been used successfully in dental surgeries and obviate the need for oil separators and filters. Care should be taken to ensure that PTFE components do not become excessively hot. A temperature sensor should be fitted, with suitable controls, to cut off the power supply in the event of excessive temperatures.

9.15 Noise levels of plant obviously increase with the capacity. The location of plant should ensure noise levels are maintained in line with health and safety requirements.

9.16 The advice of manufacturers and suppliers should be sought when considering the merits of different plant types for a particular location and the availability of acoustic screening.

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

9.18 The dryer and filter assembly should be designed to ensure that the air produced complies with the relevant British Pharmacopoeia monograph for medical air at 125% of the design flow.

Compressor accommodation

9.19 Accommodation for dental compressors and vacuum pumps should be separate and carefully controlled to prevent overheating of plant and cross-contamination of dental air supplies by a poor air intake location and subsequent damage to drying systems.

9.20 The importance of correct siting for compressor plant cannot be overstressed. The following requirements (which also apply to the siting of dental vacuum plant) should be adhered to as closely as possible.

9.21 Most dental plant is rated for an operational ambient temperature range of 10–35ºC with an optimum range of 10–15ºC. The performance of the compressor and dryer may be seriously impaired if the ambient temperature rises above 35ºC.

9.22 A dental air compressor gives off approximately 70% of its consumed power as heat energy; a compressor system designed to develop 500 L/min at 500 kPa generates approximately 3 kW. This should be taken into account when considering the room ventilation.

9.23 Mechanical ventilation may be required if the ambient temperature exceeds 35°C.

Emergency supplies

9.24 A risk assessment in line with the IDP approach should be undertaken to determine if an emergency supply is required and which would be the most appropriate (see Table 17).

10 Medical vacuum systems

Introduction

10.1 This chapter describes the requirements of the medical vacuum supply system, which provides immediate and continuous suction for clinical needs. The medical vacuum system design should follow the IDP approach. Consultation with all clinical leads for individual areas and the MGSG is essential.

10.2 The medical vacuum pipeline system consists of the vacuum supply system, the distribution pipework, valves and terminal units. The performance of the pipeline system is dependent on the correct specification and installation of its component parts.

10.3 The medical vacuum pipeline system should be designed to maintain a vacuum of at least 315.5 mmHg at each terminal unit during the system design flow tests.

10.4 Medical vacuum plant and equipment should be connected to electrical supplies in line with HTM 06-01 with dual circuits to provide resilience.

10.5 The capacity of the vacuum supply system should be appropriate for the calculated demand. The MGSG should be involved in all new system design, refurbishments or extensions to the medical vacuum system.

10.6 The major components, plant and equipment of a medical vacuum system and their layout are shown in Figure 17. A suitable operating and indicating system with alarms should also be provided.

10.7 The location of each component should provide adequate space for maintenance access. Packaged supply systems are available from manufacturers and should be specified to meet the requirements given in this HTM.

10.8 Vacuum vessels should be installed with a bypass facility. Vessels should be independently isolated while maintaining supply.

10.9 Vacuum systems typically comprise a duplex bacteria filter set with drainage traps, non-return valves, isolating valves, gauges and pressure switches, an operating and indicating system, an exhaust system and a flow test connection.

10.10 For non-acute healthcare facilities with low vacuum demand (for example, hospices and satellite dialysis units), the vacuum plant configuration should be selected to reflect the expected usage profile. A duplex configuration may be considered, with pumps sized to meet the required demand, provided that system resilience and continuity of supply are maintained. Consideration may be given to the use of smaller-capacity pumps to improve operational efficiency and utilisation (for example, by duty sharing between pumps: two pumps each providing approximately 50% of the design flow). Where such configurations are adopted, the system should be designed to maintain continuity of supply under fault and maintenance conditions, and the level of resilience should be justified through risk assessment and agreed with the Authorised

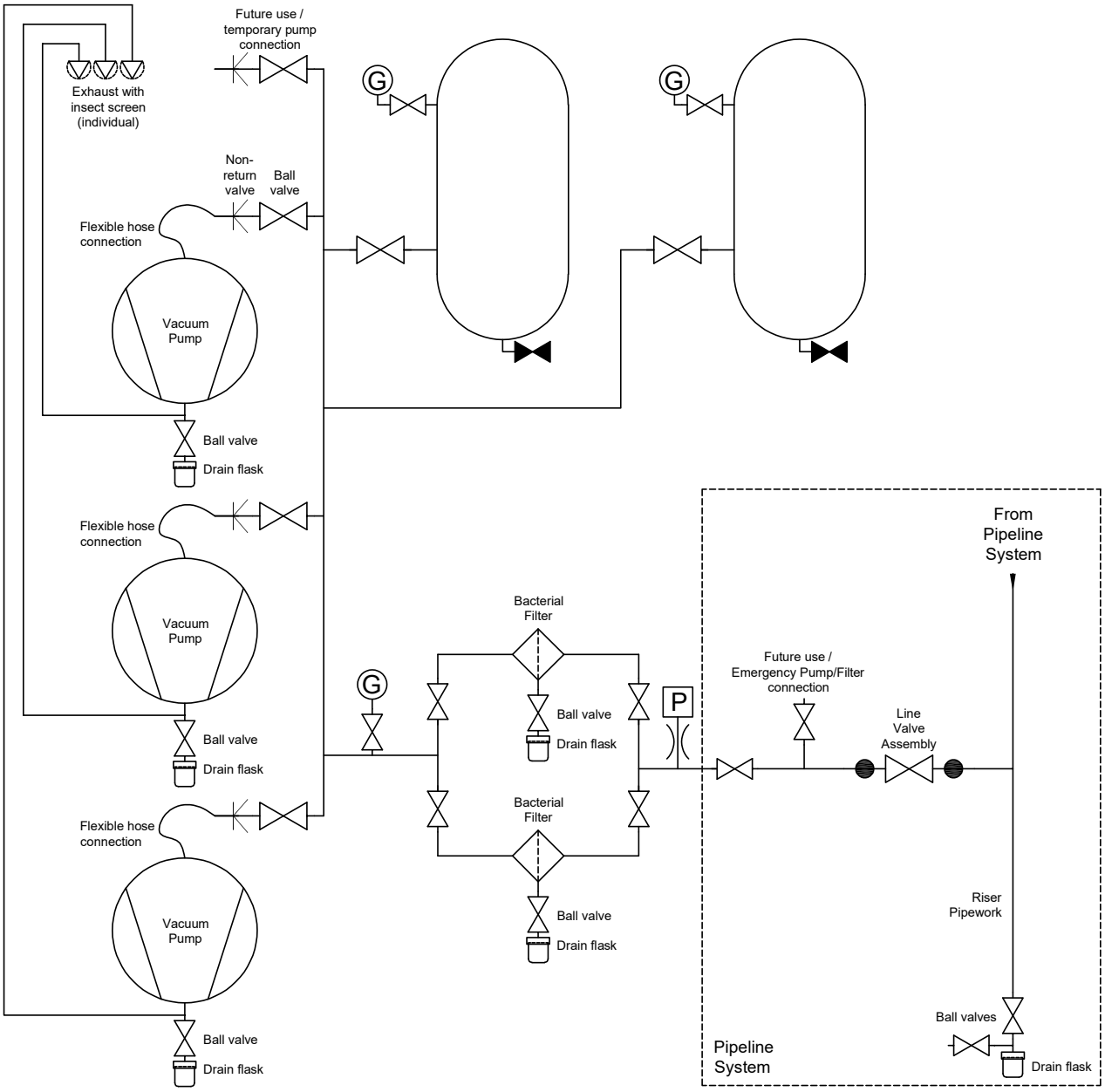


Figure 17 Vacuum plant

Person (MGPS) and Authorising Engineer (MGPS).

10.11 Mobile electric suction units are not appropriate for the main supply due to the power consumption and efficiency of the individual pumps.

10.12 Where mobile electric suction units are proposed, the MGSG should be consulted and the IDP should include the following key points:

- staff training requirements
- equipment maintenance
- resilience of supply (emergency provision and stock backup devices)
- organisational staff resource for allocation and management of devices (ability of an organisation to absorb the use and demand of equipment with resource availability)
- suitable equipment storage facilities
- suitable charging areas and considerations relating to HTM 05 for lithium-ion battery system demand and usage
- areas for equipment testing and decontamination
- critical spares holding for consumables and spare parts
- equipment and associated costing covering the above criteria for the life of the equipment (life-cycle costing)
- pharmacy considerations
- clinical team considerations.

10.13 Where alternative methods of supplying vacuum, such as ejector suction units, are to be used, considerations should be given to the points above and also to the increased demand and impact on the driving gas.

10.14 Medical vacuum systems should not be used for the extraction of bodily fluids during dental procedures. A dedicated dental vacuum system should be used for this purpose (see Chapter 11). Medical vacuum should be used within the dental department only for respiratory applications.

Vacuum pumps

10.15 Water-sealed pumps should not be used as they represent a biohazard.

10.16 All pump types, sizes and quantities as per Tables 20 and 21 should be evaluated to identify opportunities for improving the sustainability of the plant.

10.17 The configuration of vacuum plant should be based on BS EN ISO 7396-1. The supply system for vacuum consists of three or more pumps, which can be switched between the different sources of supply to provide adequate capacity. These should be arranged so that during maintenance on any pump and during a subsequent single fault condition of any component of the system (for example, the control system), the remaining pumps and components should be capable of supplying the system design flow to ensure continuity of supply. This could be achieved by the example arrangements shown in Tables 20 and 21.

	Service	Plant size
Triplex pump set	Medical vacuum	Each pump sized at 100% design flow capacity
Quadruplex pump set	Medical vacuum	Each pump sized at 50% design flow capacity
Sextuplet pump set	Medical vacuum	Each pump sized at 25% design flow capacity
Octuplet pump set	Medical vacuum	Each pump sized at 17% design flow capacity

Notes:

Water capacity of reservoir sized at a minimum of the total design flow rate for the system.

Larger storage capacity may provide additional efficiencies.

Table 20 Example pump plant size and flow capacities

Primary supply	Secondary supply	Tertiary supply
Two pumps of a triplex system	Third pump of a triplex system	Portable suction equipment with battery backup
Two pumps of a quadruplex system	Other two pumps of a quadruplex system	Portable suction equipment with battery backup

Table 21 Example central medical vacuum systems

Alternatively, consideration for reducing pump sizes can be accommodated by connecting a temporary pump into the system during maintenance to maintain the 100% design flow during maintenance and single-fault condition.

10.18 All pumps should be designed for high frequency stop/start or continuous operation.

10.19 For the efficient running of the vacuum pump during low use, a vessel should be provided and be sized to minimise the stop/start cycles of the plant. The number of cycles per hour should not exceed the manufacturer's recommendations, typically six.

10.20 Provision should be made for draining the reservoir under vacuum conditions. Bypass 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.

10.21 The vacuum reservoir should have ample space for installation and accessible maintenance for the life of the installation.

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

10.23 Duplex subassemblies should be provided, each subassembly consisting of a minimum of one bacteria filter and a drainage trap with a clear collection flask. Manual isolating valves should allow either subassembly to be used independently, with each one rated to handle the full plant capacity. To enable the reduction in the size of filters, each subassembly may consist of multiple filters in parallel.

10.24 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.

10.25 Bacteria filters should be compliant with BS 3928.

Efficiency

10.26 The vacuum pump arrangement should be capable of producing a higher vacuum than that which is required in the pipeline, so that resistance of the bacteria filter and back pressure in the exhaust system can be overcome.

10.27 The capacity of the vacuum pump should be specified in terms of the free air aspirated (FAA) in L/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 plant exhaust

10.28 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.

10.29 Noise from the exhaust should be subject to a risk assessment. A silencer should be installed where there is potential for noise issues.

10.30 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 exhaust pipe should be turned downwards to prevent the ingress of rainwater and should incorporate a mesh guard to prevent the entry of insects, vermin, birds and similar.
- 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 a transparent collection jar at its lowest point.
- The exhaust outlet discharge should be located to avoid unnecessary back pressure or the risk of obstruction from a solid surface.

Pressure control and regulation of the vacuum system

10.31 The vacuum pump’s start setting should be adjusted to allow for the pressure drop across the pipeline distribution system and the bacteria filters. The vacuum pump start/cut-in level should be set around 550 mmHg, subject to plant design.

10.32 The pump’s off setting should be selected at an appropriate point on the pump’s performance curve to minimise stop/start cycling. It should correspond to a vacuum level that is both achievable by the pump and compatible with a demand-led control arrangement. This cut-out setting may be expected at about 650 mmHg.

10.33 A minimum vacuum of 412 mmHg is required to the back of each terminal unit with a flow of 40 L/min while the system is operating at system design flow.

10.34 A pressure drop of 112 mmHg is allowed across the terminal unit at a flow of 40 L/min. The minimum pressure at the front of the most distal terminal unit should be 315.5 mmHg at a flow of 40 L/min.

Valves

10.35 Non-return valves should be fitted at the inlet of each pump to prevent backflow between the flexible connection and the pipeline (see Figure 18).

10.36 Common discharge pipes should not be used to avoid backflow or a venturi effect.

10.37 Manually operated valves should be arranged in the positions shown in Figure 18 to allow the isolation of components such as pumps, reservoirs, bypass pipework, drainage taps and bacteria filters.

Vacuum indicators

General description

10.38 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.

10.39 Individual pumps should have separate compartmented means of electrical isolation without interrupting the supply to other pumps.

10.40 Pneumatic components should have ventilation. All functions should be appropriately identified. Indicators should have a design life of at least five years.

10.41 The operating system and plant following loss of power supply should automatically restart back to normal operation after reinstatement of the power supply.

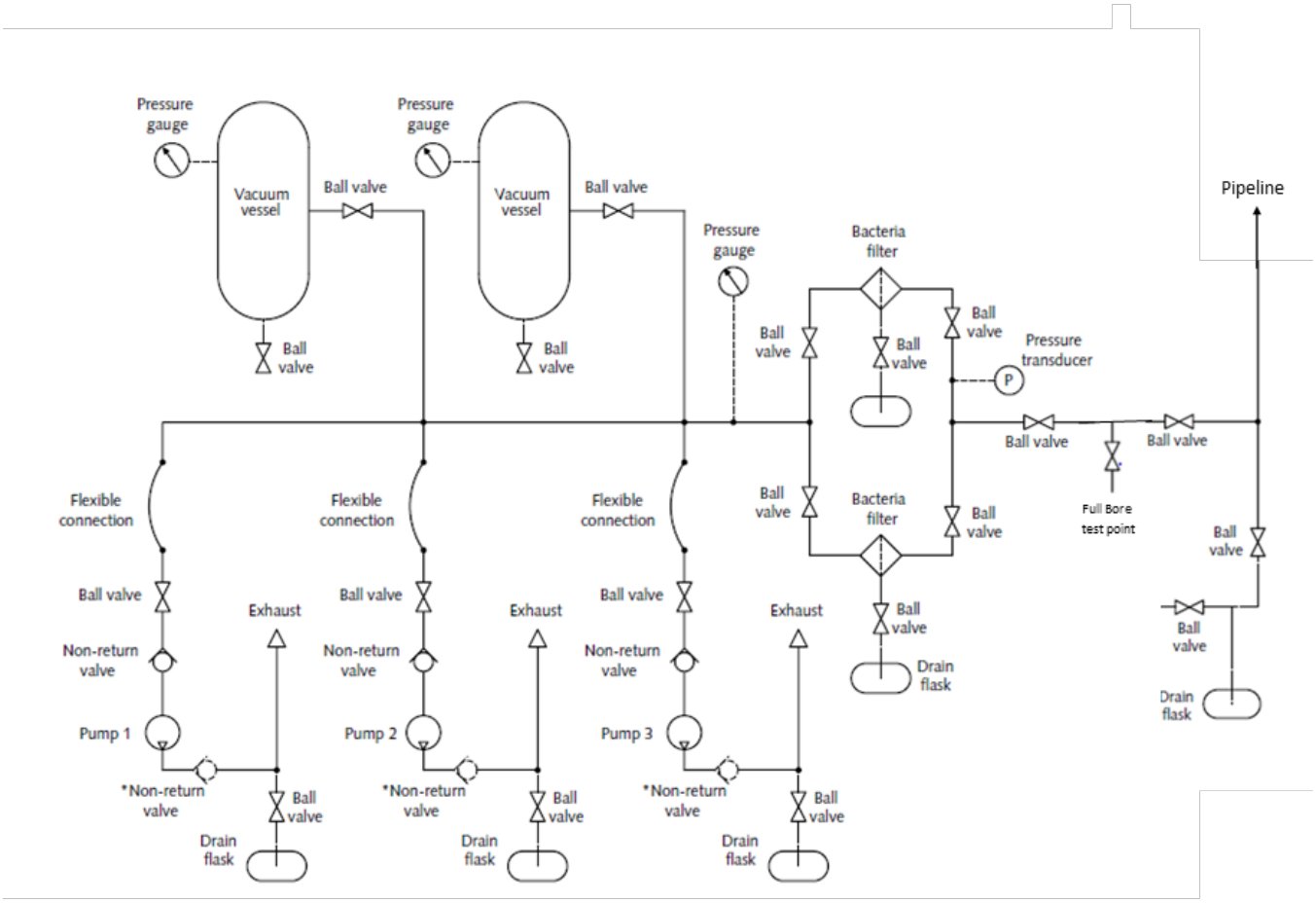


Figure 18 Arrangement of manually controlled valves

10.42 The vacuum supply system should be connected to the essential electrical supply. The control system should ensure that pumps restart in sequence to avoid overloading the power supply.

10.43 Vacuum indicators should comply with BS EN 837-1 or have an equivalent performance if electronic indicators are used. Calibration should be set over a range of 0–760 mmHg.

10.44 All gauges should be a minimum scale length of 90 mm.

10.45 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 vessel.

Plant control unit

10.46 The control unit should have a separate power supply for each pump controlled by a separate subcircuit. It should be installed in accordance with HTM 06-01 and BS 7671, and the design should be such that no single component failure in the control unit will result in loss of plant output.

10.47 The unit should allow either manual selection of duty/standby for each of the pumps or have an automatic sequence selection with an independent manual override. The control unit should ensure that two or more pumps do not start simultaneously when power is applied.

10.48 A warning notice which complies with BS EN ISO 7010 should be affixed to indicate the presence of low voltage.

Plant control indication

10.49 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 and is drawing vacuum
- an indicator of the vacuum produced in the pipeline.

Pump starter units

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

- an isolator interlocked with the covers
- either HRC fuses to BS EN IEC 60269-1 or suitable circuit breakers to BS EN IEC 60947-2 and/or BS EN 60898-1
- a starter
- an industrial grade ammeter to BS EN 60051-1 or an electronic digital instrument of comparable, or higher standard
- a total hours counter, if not included in the plant control unit
- a green “mains supply on” indicator, if mounted separately from the plant control unit.

Plant status monitoring

10.51 A monitoring system should 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 (failed to produce vacuum)
  - activation of other safety devices supplied by the manufacturers
- plant emergency – vessel vacuum has fallen, for example, by –63 kPa (475 mmHg) below the cut-in setting for the pump
- pressure fault (pipeline) – pipeline vacuum less than –48 kPa (360 mmHg).

Plant status indicator unit

10.52 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 HTM 06-01 and BS 7671.

10.53 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

10.54 The following indication of plant conditions should be provided to the central alarm system

- green – normal (indicator normal)
- yellow – plant fault conditions (b)–(d)
- yellow – plant emergency condition (e)
- red – pipeline vacuum fault (low vacuum fault).

10.55 The panel can be incorporated into the plant status indicator unit and a separate unit should be provided within the plantroom. 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

10.56 Connections should be provided to allow system condition monitoring via the BMS or equivalent. These connections should permit monitoring only, not control. At a minimum, they should include plant alarm conditions and individual pump running status for each vacuum pump.

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

Infectious diseases units

10.58 Central medical vacuum systems should not be connected to an infectious diseases unit (IDU).

10.59 Portable suction units or a dedicated local IDU vacuum plant should be provided. These units should be installed locally to the IDU and not in the central vacuum system plantroom. The IDU vacuum pipeline should only be routed through the IDU. The exhaust location has specific infection risks which need to be considered during design.

10.60 Access to and any works on the plant should be restricted and controlled by the infection prevention and control (IPC) team.

10.61 An annual risk assessment and system inspection by the IPC team should be carried out for existing systems where vacuum is used.

Laser/surgical diathermy smoke extraction

10.62 Piped medical vacuum should not be used for extraction of fumes. A purpose-designed local exhaust ventilation (LEV) is required.

11 Dental vacuum systems

Introduction

11.1 The advice and guidance in this chapter provides specific requirements for vacuum systems in dental hospitals, dental teaching schools, clinics and surgeries and primary care facilities. Water, electrical and fire requirements should be managed for these environments from the specific associated HTM.

11.2 The information in this guidance should be followed for all new installations and refurbishment projects. Existing installations should be assessed for compliance with this document for dental work in the NHS for NHS patients and should be observed as good practice by private dentist practices.

11.3 Owners, occupiers, general managers, dentists and chief executives should ensure that the premises for which they have responsibility and any activities carried out therein comply with statutory requirements.

11.4 This guidance should be followed for dental systems and plant accommodation

System types

11.5 Dental vacuum systems are classified as:

- dry systems in which, with an air separator, dental detritus, sputa and cooling water from high-speed drills and instruments have been removed from the airflow and passed to a drain before the air enters the vacuum pump, and in which the separator and vacuum pump are two different devices (see Figure 19)
- semi-dry systems in which a similar separation takes place but the vacuum pump and separator are combined into one device (see Figure 20)
- wet systems in which larger solids have been removed from the air/water/debris mixture by a filter before air and liquid enter the vacuum pump, where they are in turn separated (see Figure 21).

11.6 The merits of each system are not described here, as installations should be assessed on an individual basis to find the most effective solution.

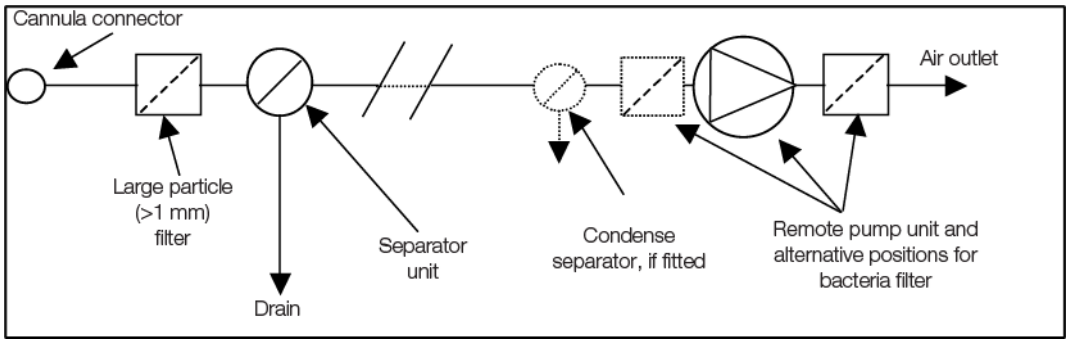


Figure 19 Dry system

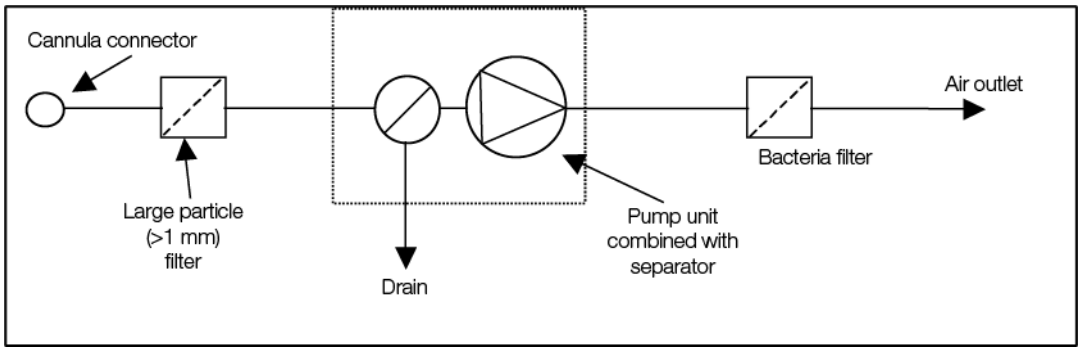


Figure 20 Semi-dry system

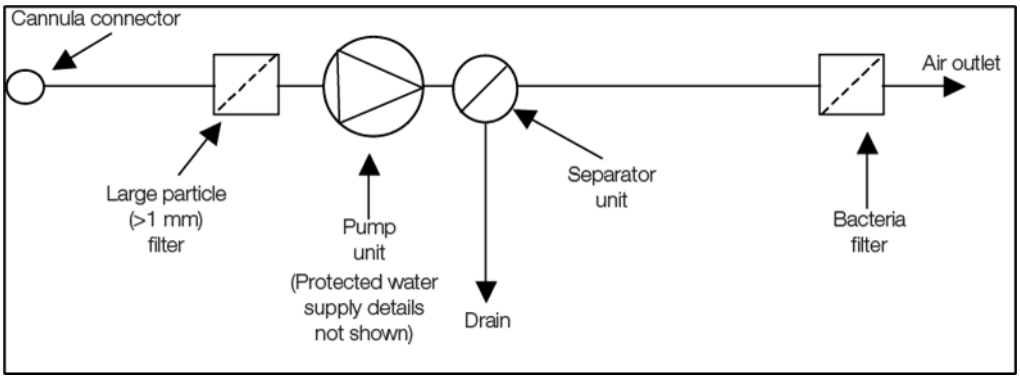


Figure 21 Wet system

11.7 A further classification, according to the air volume flow rate provided, is given in BS EN ISO 10637:

a. High volume systems: vacuum system with an air intake of more than 250 L/min at each cannula connector of the largest bore operating hose when operated at full power and in accordance with the manufacturer's instructions.

b. Medium volume systems: vacuum system with an air intake between 90 and 250 L/min at the cannula connector.

11.8 Medium volume systems are not generally specified or used in the UK and are not covered in this HTM.

11.9 Low volume systems, that is those less than 90 L/min, are not used in dentistry. Medical vacuum is typically 40 L/min.

11.10 In dry systems, the vacuum line is relatively dry and clean compared with a wet system, which helps minimise bacterial contamination of the vacuum line. However, some dry systems are installed with the separator unit relatively close to the pump(s), leaving a considerable amount of the pipework to carry detritus. This should be taken into account when carrying out maintenance on such systems.

11.11 An amalgam separator should be included in all systems, either as an integral part of the vacuum plant or as a discrete recovery unit.

11.12 Special attention should be given to protecting dental unit water supplies from cross-contamination, including contamination arising from dental vacuum plant.

11.13 The operational policy should detail hygiene procedures covering all work on vacuum systems to ensure staff and patient safety when, for example, breaking into an

existing system. The advice of the local IPC team should be sought.

11.14 In all systems, drainage of water from the pumps/separators will pass into the normal foul drainage system. Efficient separation of detritus and amalgam will, therefore, help prevent pollution of sewerage systems. Pipeline falls are not generally required but may be incorporated, depending on the system type and building structure.

Plant types and noise

11.15 Electrically driven, side-channel pumps are frequently used in dental vacuum systems and may be combined with a separator unit. An amalgam separator may also form an integral part of the unit or be fitted as a discrete self-powered unit elsewhere in the system.

11.16 Liquid ring pump systems typically incorporate water-saving measures (for example, recirculation systems) and may be fed from a reservoir or from the water mains via an air gap.

11.17 For plant situated in a typical plant room, the noise levels below are considered as maxima:

Free field noise at 1 m	Power
75 dBA	<5 kW
82 dBA	5.1–15 kW
89 dBA	15 kW+

11.18 Smaller plant will produce much lower noise levels; for example, a single chair unit combining pump, separator and amalgam separator may produce a typical noise level of 64 dB(A).

11.19 Acoustic screening, giving (typically) 10 dB(A) reduction in noise level, may be added if desired.

11.20 Vacuum plant should be fitted with a vacuum gauge capable of displaying maximum system vacuum.

Filtration

11.21 In dry vacuum systems, it may be feasible and is certainly desirable to fit a bacteria filter between (condensate) separator and pump inlets. In wet systems this is not practicable. If upstream filtration is not possible, a bacteria filter should be fitted in the pump exhaust line. All filters and their housings should be capable of withstanding the maximum system negative pressure when installed upstream of the pump unit.

11.22 The exhaust pipe from the vacuum system should be sited outside, preferably at roof level and away from air intakes, opening windows, etc. It should be clearly labelled “Dental vacuum discharge point – do not obstruct”.

11.23 The exhaust pipe should be turned downwards to prevent the ingress of rainwater and have a mesh guard to protect against the entry of insects, vermin, birds and similar.

11.24 The exhaust pipe should be provided with a drain valve at its lowest point.

11.25 A silencer should be fitted to the exhaust if required.

11.26 The exhaust from a duplex (or triplex) and multiple smaller demand-led pump system may be piped together via non-return valves to one external exhaust.

11.27 Vacuum pumps and associated pipework should be sized to account for the back pressure of the exhaust system and the resistance of any bacteria filter fitted.

11.28 In the very few cases where it would be impracticable to extend an exhaust line to the outside of a building, a bacteria filter should be fitted in the exhaust line. A route to the exterior of the building is the primary requirement before selection of alternative options. The

process should be risk-assessed and agreed by the MGSG in a hospital setting and the executive manager/practice owner (or person of similar authority) in a dental practice. Where a bacteria filter is used, it should be integrated with an activated charcoal filter to remove unpleasant odours arising from the system. The filter should provide particle removal to 0.01 µm with a DOP (aerosol) efficiency of not less than 99.9999%. The bacteria filter unit 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.

11.29 These filters should be changed in accordance with manufacturers' instructions. A procedure applicable to the changing and disposal of filters is described in operational management of this document series. Vacuum filters are classified as clinical waste and they should be treated accordingly. Filters containing waste amalgam should be disposed of via a specialist waste contractor.

Plant accommodation

11.30 The details given for dental compressed air apply to the siting of vacuum plant.

11.31 Maintaining a minimum temperature of 10ºC is particularly important in the case of wet vacuum systems. If exposed to freezing temperatures, considerable damage could occur.

11.32 Dry vacuum systems can suffer from excessive condensation where pipework is exposed to low temperatures and, if necessary, should be fitted with a condensation separator, mounted as close as practicable to the pump units. This separator should be fitted with an automatic drain. A second separator with automatic drain will be needed at the bottom of a main riser in situations where the pumps are mounted at high level in a system.

Pipework system design

11.33 Vacuum system design can be complicated by various factors, for example:

a. Flow resistance of a condensate separator on a dry vacuum system. Condensate separators should offer no more than 0.2 kPa resistance under design flow conditions.

b. The siting of the pump unit. Dental suites use pumps mounted next to the chair as an extension of the floor-box system. In other suites, a similar duty pump could be sited on a different floor of the surgery and use extended pipework.

c. The pipework arrangement. A series (see Figure 22) connection is often used for dry vacuum systems, as only air is aspirated through the pumps. Wet or semi-dry vacuum systems additionally aspirate liquid through the pipework system which, if installed in a series arrangement, could cause a loss in performance at some of the chairs. A star arrangement, in which all chairs drain back via individual pipework to the pump/separator unit, is therefore quite common in these systems (Figure 23).

d. The type of pump/separation method employed.

11.34 Vacuum generation and separation functions are often driven by the same power source. The number of chairs such a unit is able to support will be determined not only by the vacuum capability of the unit but also by the maximum flow rate of liquid the separator is able to process. Additionally, the specifications of a discrete amalgam separator should be taken into account when defining the number of chairs to be attached to a system.

11.35 For the points above, it is very important that full consultation between the designer, installer and user takes place to

Figure 22 Series connection of chairs to pump unit

Figure 23 Star connection for improved liquid flow

choose the most appropriate system. The MGSG should be involved for all designs and considerations for sign off, with the correct risk assessment criteria followed for the particular system in scope.

11.36 The diversity factors here are presented for guidance only. Each installation should be considered on an individual basis, as it is not unknown for users to request a 60% diversity factor on a low number of chairs.

Performance requirements

11.37 The system is designed to aspirate air, saliva, blood, amalgam, dust from tooth tissue and other materials using a high flow rate together with a specially designed cannula.

11.38 The detritus is aspirated through the suction hose at a typical air speed of 15–20 m/s. A filter for larger particles, that is >1 mm, fitted upstream of the air separator/ pump unit may be specified by plant

manufacturers. The air separator separates the residual particles and water.

11.39 For high volume systems (dry or wet), the system performance should be based on a flow rate of 300 L/min at each dental chair cannula connector.

11.40 For surgeries with up to ten dental chairs, it can be assumed that all chairs may be in use simultaneously, each requiring a flow rate of 300 L/min and, therefore, no diversity should be allowed.

11.41 For systems with more than ten dental chairs, it may be assumed that 60% of the remainder of the chairs will be in use simultaneously.

11.42 The total system demand therefore will be:

$$Q_{vac} = (10 \times 300) + [(n - 10)(0.6 \times 300)];$$

i.e. $3000 + (n - 10)180$ L/min

where n = number of chairs.

For example, for a 20-chair system, total flow will be 4800 L/min.

11.43 The system should be designed to allow a maximum pressure loss of 6 kPa for large systems (>7000 L/min) and 3 kPa for smaller systems between the plant and the cannula connector (including any loss across a condensate separator in a dry system). The pumps should be capable of generating a maximum negative pressure of 25 kPa (76 kPa absolute) but systems are normally set to provide a maximum operating negative pressure of 18 kPa (82 kPa absolute).

Special circumstances

Dental schools

11.44 For dental teaching schools it can be assumed that all chairs in the teaching department may be in use simultaneously at a delivered flow of 300 L/min each. This flow should be added to the diversified flow of any associated dental system.

Dental laboratories

11.45 An apparatus such as a dust extraction unit uses very high flow rates (typically >1000 L/min) and connection of such equipment to the dental vacuum system could impose unacceptable loads. Equipment manufacturers' data will give the flow and pressure requirements for individual items of equipment. No diversity allowance should be made, unless agreed or specified by the user.

Primary care dental practice

11.46 For a practice with typically fewer than five chairs, self-contained suction systems remain acceptable.

Safety – anaesthetic gas scavenging

11.47 Dental vacuum systems operate at very high flow rates and as a result, there will inevitably be some scavenging of gases (via the cannula) exhaled by patients during surgery. Under no circumstances should the dental vacuum system be considered an AGSS. Scavenging systems are not generally applied to patients undergoing relative analgesia. An accurate risk assessment of residual levels of anaesthetic agents should be completed and reviewed regularly.

Vacuum system pipework sizing

11.48 The formula for flow and pressure drop given below can be used to calculate pipework pressure drops:

$$\Delta p = P_1 - 100\sqrt{\left[\left(\frac{P_1}{100}\right)^2 - \frac{0.1152 Q_2 L}{d^5}\right]}.$$

where:

Δp = pressure drop (kPa)

P_1 = inlet pressure (kPa absolute)

Q = flow (L/min measured at 15ºC and 1013 mbar)

L = pipe length (m)

d = internal diameter of pipe (mm).

11.49 Equivalent lengths for typical vacuum fittings are shown below:

	40 mm	50 mm	70 mm	100 mm	125 mm
Tee (thru')	0.95	1.23	1.65	2.20	2.56
Tee (branch)	2.76	3.38	4.57	6.12	7.68
90º elbow	1.25	1.71	2.44	3.08	3.84

11.50 Exhausts are chosen to match pump outlet port size. However, if the length of the exhaust is greater than 20 m, the next larger pipe diameter should be used.

Vacuum pipework materials and jointing techniques

11.51 The vacuum and exhaust lines should comprise materials resistant to attack from substances carried and be so constructed as to withstand a negative pressure of 25 kPa. Pipework made from acrylonitrile butadiene acrylate (ABS) or acrylonitrile styrene acrylate (ASA) materials is generally unsuitable as it is susceptible to chemical attack. Copper pipework used in wet systems may be attacked by dental amalgam.

11.52 Polyethylene, polypropylene and heat-welded uPVC have all been found suitable.

11.53 Where non-metallic pipework passes through fire compartment walls/barriers, they should be suitably sleeved.

11.54 Solvent, ultrasonic and heat welding are all suitable as jointing techniques but any method which ensures system integrity under vacuum may be used.

Plant monitoring and alarm systems

11.55 A pressure fault alarm, where fitted, should be activated when the system vacuum is 20% less than its value under commissioning conditions.

11.56 When an amalgam separator is fitted, indication should be provided. If the amalgam separator is remotely sited, relayed to the dental suite. Indication should show:

- unit failure
- separation capacity achieved.

Dental vacuum systems and amalgam separation

11.57 Dental amalgam is about 50% mercury by weight. Its other components include silver, zinc, copper and tin. Mercury is on the UK red list of dangerous substances that represent the greatest threat to the aquatic environment. Dental amalgam has been phased out as of January 2025, especially for vulnerable groups. The 'National plan to phase down use of dental amalgam in England' (Department of Health and Social Care, 2019) should be referenced for information on amalgam use. It is supported under European Union (2017) Regulation 2017/852 on mercury (Article 10(3)).

Waste amalgam

11.58 Amalgam separators should conform to BS EN ISO 11143. Waste arises:

a. when new amalgam becomes surplus during treatment and cannot be reused

b. when old amalgam fillings, or teeth with fillings, are removed from patients' mouths during treatment, or during drilling, carving and burnishing

c. when dental equipment is cleaned

d. as residues in packaging, including used capsules, and

e. as residues removed during cleaning or maintenance of separators, sieves and traps.

Amalgam in wastewater

11.59 Particles of waste amalgam become mixed with water during treatment, rinsing and cleaning. If particles are not separated out of wastewater, they will be carried into drains and sewers, eventually ending up in sludge at sewage treatment works and in effluent from those works. Most will lodge in pipes and drains along the way and may be released much later.

11.60 The mercury in dental amalgam is in a bound form and is not biologically available (not readily absorbed). The Department of Health and Social Care advises that the use of dental amalgam does not risk systemic toxicity (general rather than localised toxic effect) and only a few cases of hypersensitivity (excessive reaction) occur in individuals. However, once waste amalgam enters the wider environment, it may present different and more significant risks.

Legal issues

11.61 Both wastewater and waste are covered by laws intended to protect human health and the environment. For reference the following legal documents should be used for generation of organisational policy and procedures in England:

- The Water Industry Act 1991 (governing water supply, sewerage services, and the management of effluent). The Environment Agency exercises powers under law using this Act.
- The Environmental Protection Act 1990 (governing waste management, duty of care for controlled waste, and contaminated land). The Environment Agency exercises powers under law using this Act.
- The Environmental Permitting (England and Wales) Regulations 2016 (providing the current permitting framework used by the Environment Agency to regulate waste operations, water discharges and other environmentally controlled activities).

11.62 The UK, along with other countries, is committed to reducing the amount of mercury in the environment.

Established good practice

- Amalgams should be used effectively; this will reduce waste and cost.
- Amalgam separators should be installed as soon as possible; they should be fitted either to existing equipment or when replacing equipment. Other traps and sieves may still be useful as supplements.
- Amalgam separators should protect all known routes including spittoons, sinks or basins by which amalgam may enter the drainage system. When working with amalgam, unprotected routes to the drainage system should not be used, including for the cleaning of instruments and utensils. Waste amalgam should not be discharged directly into the drainage system or flushed down the toilet. During refurbishment or cleaning, care should be taken to ensure that sediments in

pipework are not flushed into drainage system.

- Amalgam separate should be separate from other waste. This will help with the recycling of its silver and mercury content; but if the recycling is not feasible, it will make disposal safer. Only authorised waste management firms should be used – special attention should be paid to the duty of care. Specialised firms offer sealed container systems and separate collection. Amalgam residues should be disposed either in clinical waste containers or as normal refuse, or through other general arrangements for packaging waste.
- Regulatory advice from local sewerage operators or other bodies should be followed.
- An inventory of equipment currently should be undertaken, and operational procedures and any additional measures required for compliance with the code should be identified.

11.63 Design and performance criteria for amalgam separators are given in BS EN ISO 11143.

12 Anaesthetic gas scavenging disposal systems

12.1 An AGSS should comply with BS EN ISO 7396-2 except where this HTM specifies alternative performance criteria to ensure compatibility with the receiving systems and anaesthetic equipment used in healthcare facilities.

12.2 Historically, many systems have been used from passive to semi-passive and hybrid systems. These systems are not recognised and not covered in this HTM: all systems referred to in this document are fully active systems.

12.3 Standards have been designed for patient connection safety and to address occupational exposure risks.

Terminology

12.4 For the purposes of this HTM, AGSS are specified as either high-flow or low-flow systems using the criteria set out in Table 22.

12.5 AGSS are high-flow low-pressure systems powered by an electric pump or fan. They are used to remove waste anaesthetic gases from the patient's breathing circuit via the system's fixed pipework.

12.6 Low pressure is essential to reduce noise levels at the point of termination and should be monitored at regular intervals.

12.7 The balance valve should be located within the plantroom either on the source plant or adjacent to it. It should be monitored and any debris cleaned on a weekly basis to ensure the system does not become unbalanced.

12.8 A detachable filter should be installed to ensure that the balance valve does not become occluded and can be readily cleaned or replaced.

12.9 Pipework is terminated within the patient area with a fully adjustable, gas-specific terminal unit that complies with BS EN ISO 9170-2.

12.10 A disposal hose then connects the terminal unit to the receiving system.

12.11 A transfer hose connects the receiving system to the patient's exhalation valve, which collects waste gases either from the patient or the ventilator.

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

12.13 The flow rates of the AGSS directly affect the induced flow on the patient breathing system and therefore should be set up and maintained correctly at the specified service intervals.

12.14 Dental anaesthetic gas scavenging systems (DAGSS) are a different concept and are covered in paragraphs 12.37–12.50.

Note:
AGSS should not be incorporated into vacuum systems.
AGSS are not designed for the extraction of self-administered analgesic gases such as

oxygen/nitrous oxide mixture. This is due to the tidal volumes of the patient exceeding the capabilities of the AGSS. Alternative systems are available to extract these gases with a tidal volume in excess of 500 L/min. However, they must be combined with low-level extraction.

General

12.15 Anaesthetic gases are considered to be substances hazardous to health for the purposes of COSHH 2002, except where they are administered to a patient in the course of medical treatment.

12.16 Additional guidance is given in the Health & Safety Executive's (2020) 'EH40/2005 Workplace exposure limits'. COSHH regulations are covered in Chapter 4 in Part B.

12.17 HTM 03-01 provides guidance on low-level extraction from certain environments of a healthcare facility.

12.18 For new installations, an assessment should be made of the transfer and receiving equipment currently in use and intended for use with the new installation.

12.19 Pipeline design should be based on the high-flow criteria in Table 22 irrespective of whether the intended connected equipment is high-flow or low-flow. This allows future adaptability.

12.20 High-flow systems can be adapted to be compatible with low-flow equipment. It should be clearly identified at the terminal unit as low-flow AGSS.

12.21 A typical system schematic is illustrated in Figure 24 and shows the terminology used.

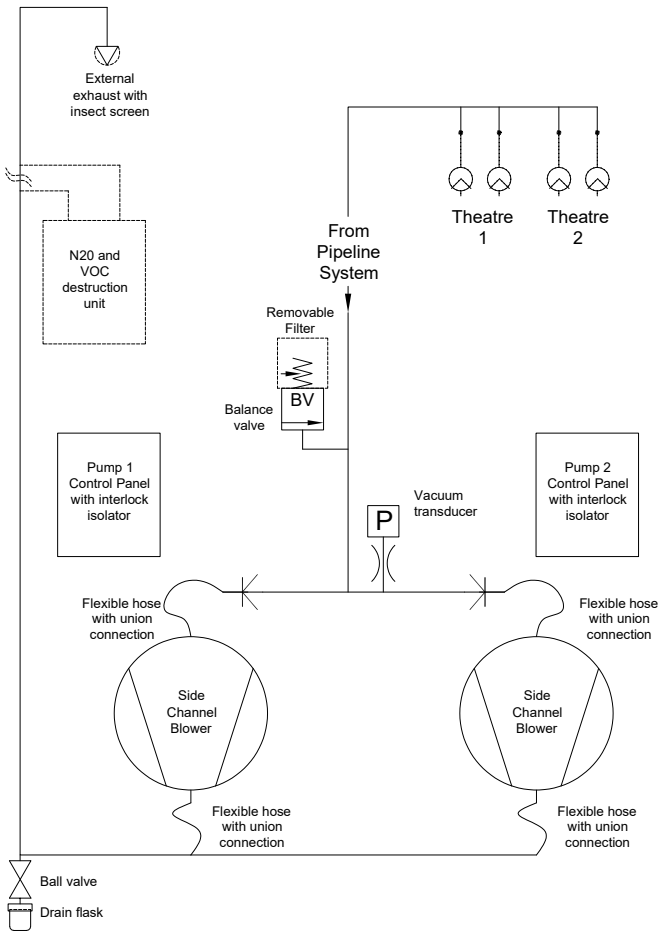


Figure 24 AGS disposal system

12.22 The internal components and pipework of AGSS are in contact with a patient's expired breath. Although considerable dilution occurs within the receiving system (which forms part of the anaesthetic equipment), there remains a potential for microbiological contamination. Materials should be resistant to microbiological contamination and capable of withstanding cleaning, disinfection or sterilization, as appropriate.

12.23 Fixed pipework should be made of copper. To avoid confusion, degreased pipework of the same specification as that used for the MGPS should be used (see Chapter 15).

Pump selection

12.24 VSD AGSS pumps should be considered for all systems to allow for a sustainable response to varying system demands. The isolation of pumps when not in use should be based on a risk assessment and designed to ensure control via an independent system, ventilation setback or other suitable means. For example, PIR control of the plant should be considered.

12.25 The AGSS should be designed to serve a maximum of six terminal units (maximum two theatres).

12.26 Each system should be a duplex set which can be both mechanically and electrically isolated to enable pump replacement while the system is still in use. A full recommissioning procedure should be undertaken following a pump replacement.

12.27 All systems should be designed to allow conversion from a high- to a low-flow system without the need for component or pipework changes. If additional balance valves are required, a connection point should be installed, clearly identified as the low-flow system balance valve connection point, and securely blanked off. A spare balance valve should be supplied with the system.

Plant system power

12.28 For duplex AGSS, each pump should have its own independent control panel. Each pump and control panel should be fed from its own electrical supply.

Flow and diversity

12.29 For convenience, more than one AGS terminal unit may be installed in an operating room or anaesthetic room. Only one terminal unit in each room will be in use at any given time.

12.30 The AGS terminal unit in the anaesthetic room and operating room are likely to be in operation simultaneously; therefore, the plant should be sized for two AGS terminal units for each operating suite.

12.31 Performance criteria for AGSS should be in terms of the extract flows at a specified resistance. The AGSS should meet the requirements set out in Table 22, based on the number of terminal units it is designed to support.

Discharge outlet

12.32 The discharge outlet should be in line with the guidance in paragraphs 12.48–12.49.

12.33 For guidance on signage, see Chapter 18.

Plant control indication

12.34 Indicators should show the following conditions:

- green "mains on"
- green "airflow" normal
- yellow "duty pump failed" (plant fault)
- red "system failed" (plant emergency).

12.35 Indicator panels should be installed in operating rooms.

	Disposal system standard			
	Pressure drop		Flow rate	
	High flow	Low flow	High flow	Low flow
	1 kPa	1 kPa	130 L/min (maximum)	80 L/min (maximum)
	4 kPa	2 kPa	80 L/min (minimum)	50 L/min (minimum)
Maximum static pressure	20 kPa (–ve)	15 kPa (–ve)		
Note: These values differ from BS EN ISO 7396-2 Type 1H/1L values to maintain compatibility with receiving systems and anaesthetic equipment in use.				

Table 22 Performance criteria for AGSS

12.36 The “airflow normal” indication should be initiated by either a pressure switch or airflow detection device at the pump.

Dental anaesthetic gas scavenging system (DAGS)

12.37 DAGS should be used in dental surgeries that use sedation. This section does not apply to general anaesthesia for dentistry performed in operating theatres.

12.38 DAGS is a specialised independent system that is a single-chair installation.

12.39 Dental scavenging should be connected from the pump unit to the nasal mask disposal tubes using a disposal hose.

12.40 This system works by extracting exhaled gases from around the nasal mask.

12.41 DAGS should be installed in each dental treatment room. They should be simplex systems and have the following performance requirements.

Dental AGSS plant

12.42 The unit should comply with BS EN ISO 80601-2-13.

12.43 The fan unit should produce a flow rate of no less than 80 L/min and should be controlled by a flow switch.

12.44 The unit should have a flow switch and a flow indicator to show that the system is running at a specific flow rate.

12.45 There should be an on/off switch on the front of the unit with a green LED indicator to show the unit is powered.

12.46 The connection for the disposal hose should comprise a female 30 mm conical connector.

Exhaust

12.47 The exhaust should be routed externally using a pipe of at least 32 mm diameter, made of material compliant with fire regulations. This pipe should be sleeved with a copper pipe one size larger.

12.48 A risk assessment should be undertaken when determining the discharge location of the disposal system. It should be sited at roof level, at least 5 m away from mechanical inlets and 3 m from passive inlets.

12.49 The discharge should not be located over opening windows or doors. Where the roof is enclosed by a parapet exceeding 100 mm in height and contains air inlets, exhaust outlets should be located outside the enclosed area to prevent recirculation of discharged air.

12.50 Warning signs should be placed at the exhaust point (see Chapter 5).

13 Other medical gases

Introduction

13.1 It is possible to apply the design principles of medical gas systems to other gases supplied from cylinders, while still maintaining the essential elements of gas specificity and all relevant safety considerations.

13.2 Pipeline systems should incorporate gas-specific connections in compliance with British Standards. This requirement inherently limits the number of services that can be accommodated within the pipeline infrastructure.

13.3 Should there be a requirement to introduce additional medical gases in the future, a gas-specific connector should be designed and approved in accordance with BS EN ISO 7396-1. This connector should be incorporated into the relevant specifications before any associated pipeline installation is undertaken.

Liquid nitrogen (local supplies)

13.4 Liquid nitrogen should be managed and controlled in accordance with the requirements applicable to medical gases.

13.5 It is supplied in mobile dewars, from which it is decanted and distributed across the site to the points of use.

13.6 Liquid nitrogen is primarily used for cryotherapy (cryosurgery), a treatment that uses extreme cold to freeze and destroy abnormal tissue, particularly skin lesions. It is also used for the cryopreservation of biological samples.

13.7 A risk assessment should be conducted for the storage of liquid nitrogen, including consideration of asphyxiation hazards.

13.8 The decanting and transportation of liquid nitrogen within the healthcare facility should also be subject to risk assessment, along with the designated points of use. See BCGA's (2024) 'CP 30: The safe use of liquid nitrogen dewars'.

Nitric oxide

13.9 Inhaled nitric oxide (iNO) is primarily used as a selective pulmonary vasodilator (a medication that dilates blood vessels in the lungs) to treat neonates with persistent pulmonary hypertension of the newborn (PPHN) and other respiratory conditions. It improves oxygenation and reduces the need for more invasive interventions such as extracorporeal membrane oxygenation (ECMO).

13.10 The installation of nitric oxide pipeline systems is not recommended. This gas should be supplied exclusively in cylinder form.

13.11 Risk assessments should be undertaken for the delivery, transportation and use of this gas. Suppliers must provide product data sheets, which must be adhered to in order to ensure safe storage and handling.

Heliox

13.12 In hospitals, heliox (a mixture of helium and oxygen) is used as a breathing gas to help patients experiencing respiratory difficulties, particularly those with airway obstructions or conditions that increase airflow resistance, by reducing the effort required for breathing.

13.13 Heliox is generally supplied via cylinder; however, gas-specific terminal units and NIST connectors are available.

13.14 With regard to the standard order of terminal units, heliox should be positioned before the AGS terminal unit and after carbon dioxide.

13.15 Heliox should be installed in compliance with medical oxygen systems with a flow rate of 10 L/min per outlet with no diversity.

Carbon dioxide

13.16 Medical carbon dioxide (CO_2) is used as an insufflation gas in minimally invasive procedures such as laparoscopy and endoscopy to enlarge and stabilise body cavities for better visibility. It is also used as a respiratory stimulant when mixed with oxygen, in cryotherapy, and to prevent hypocapnia during episodes of hyperventilation.

Safety precautions

13.17 Carbon dioxide is classified as an asphyxiant gas; strict controls need to be applied wherever it is stored or used.

13.18 The UK workplace exposure limits for carbon dioxide are as follows:

- a long-term exposure limit (eight-hour time-weighted average (TWA)) of 5000 ppm
- a short-term exposure limit (15-minute reference period) of 15,000 ppm.

Accommodation

13.19 Medical gas manifolds should comply with Chapter 5. Manifold rooms should be adequately ventilated to prevent any build-up of gases and should be ventilated directly to the outside of the building.

13.20 Where local cylinders are used, a risk assessment should be undertaken for their storage. The number of cylinders to be stored should be agreed in advance, with appropriate ventilation, environmental monitoring and alarm systems in place.

13.21 The risk assessment should include the equipment to which the carbon dioxide cylinders are connected, as the cylinders will remain in place when not in use. Their location and storage should also be assessed for safety and environmental risks.

13.22 All carbon dioxide cylinders stored in satellite locations should be clearly signed at the entrance to the cylinder storeroom and be securely restrained (see Chapter 17).

14 Warning and alarm systems

Introduction

14.1 Medical gas alarms should be a stand-alone alarm system but may be mirrored to other devices for monitoring purposes only.

14.2 There are three types of medical gas alarm: area alarms, plant alarms and PRS alarms.

14.3 The provision of a warning and alarm system is essential to monitor the safe and efficient operation of an MGPS for patient safety.

General requirements for all alarms

Visual signals

14.4 Flashing visual signals should have alternate “on” and “off” periods, each of equal duration between 0.25 and 0.5 s.

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

14.6 Light sources should have a design life of at least five years of continuous operation.

Audible signals

14.7 Medical gas alarms should provide an alternating two-tone audible signal modulated at 4 Hz (±15%), with fundamental frequencies within:

- 440–512 Hz (lower tone)
- 880–1024 Hz (higher tone).

Note:
These ranges preserve the nominal 2:1 harmonic relationship defined in this HTM while accommodating established crystal-derived frequencies used in legacy installations. This implementation maintains compatibility with existing UK healthcare alarm systems and aligns with the temporal pattern principles of BS EN 60601-1-8, which standardises alarm timing and priority structure rather than mandating exact frequencies. Accordingly, the audible design supports HTM intent and BS EN 60601-1-8 temporal requirements while preserving recognised clinical alarm behaviour.

Automatic resetting

14.8 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.

Mute functions

Temporary muting

14.9 Means should be provided on each panel for the user to mute the audible signal. The signal should resound 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. In

the event of a further fault, this should override the mute facility. Operation of the mute function on the central plant alarm panel should result in the corresponding visual indicator changing from flashing to steady illumination on both the central plant alarm panel and any associated repeater panels. Operation of the mute function on the area alarm or repeater panels should not result in a change from flashing to steady illumination of the corresponding visual indicator.

14.10 Operation of the temporary mute on an individual alarm panel should silence the audible signal for a period of 15 min +/– 5 min. During this time, the corresponding visual indicator should change from flashing to steady illumination on that panel only, without affecting the status of visual indicators on other alarm panels.

Continuous muting

14.11 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 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.

14.12 The continuous mute should inhibit the 15-minute reinstatement of the audible alarm.

14.13 Operation of the mute should not inhibit the visual or audible indication of any subsequent alarm conditions.

Electrical wiring

14.14 All electrical wiring should be in accordance with BS 7671 and HTM 06-01.

System integrity

14.15 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.

14.16 Where multi-core cabling is used, the alarm cables should be dedicated to the medical gas alarm systems only.

14.17 The system should be designed to reject spurious radio frequency interference (RFI) and electrical noise, which commonly occur in healthcare environments. Typical sources include diathermy equipment and transient currents generated during plant start-up.

Relay conditions

14.18 All relays should be energised in their closed condition (closed = no fault; open = fault) and must drop open on loss of power. This configuration ensures a fail-safe design, providing a single, reliable interface for fault signalling on gas condition fault, system fault, or loss of power, and supports integration with a BMS without adding complexity or multiple outputs.

Mains power supply

14.19 The mains electricity supply should be taken from a dedicated circuit that forms part of the essential power supply. A non-switched fused spur should be provided adjacent to the alarm panel to allow for electrical isolation. This spur should be clearly labelled to indicate both the equipment it isolates and the source of the supply. This circuit should be a dedicated circuit for medical gas alarms.

Safety extra low voltage/functional extra low voltage power supply

14.20 The panel's power supply may be designed either as a separated extra low voltage (SELV) system or as a functional extra low voltage (FELV) system, as defined in BS 7671.

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

14.22 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

14.23 Each panel should be provided with a means to test all visual and audible signals. The power supply should be capable of sustaining all indicators and audible signals. For liquid crystal display (LCD) screens that incorporate a rotating display, this test should show all alarm conditions for all gases.

Battery backup

14.24 Battery backup should be provided for a minimum duration sufficient to maintain operation during transfer to standby generator power − often at least 30 s.

14.25 Under loss of mains power, the alarms are required to provide full gas monitoring, system fault indication and audible signalling for a minimum duration of four hours.

14.26 Trickle charge rates should be stated on the data sheet. These are protective values specific to the individual battery chemistry. To protect battery cells, a minimum charging time should be defined for each individual battery, but must not exceed 72 hours.

Construction

14.27 The fascia panel should be removable using a tool to allow access to the rear of the fascia and internal components for maintenance purposes.

14.28 Access to the interior of the panel should be tamper-proof and require the use of a tool to prevent unauthorised access.

14.29 Panels should have electrical sections with protection at least equal to IP4X as defined by BS EN 60529 to provide protection against both environmental ingress and accidental contact.

14.30 Panels and their housings should be of adequate strength for their intended purpose and be manufactured from corrosion-resistant materials.

Warning and alarm system faults

General

14.31 A flashing red visual indicator and an audible signal should operate on all panels when any of the following conditions occur:

a. line fault from the initiating device
b. communication fault or other wiring fault
c. mains power failure
d. battery fault.

Legend

14.32 The legend on this indicator should be “alarm system fault”.

Line fault

14.33 The system should monitor the integrity of the lines between the initiating devices and the panel or transmitter units.

14.34 The “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

14.35 The system should indicate a system fault in the event of loss of data transmission between panels and transmitters.

Mains power failure

14.36 Failure of mains power should be shown by a flashing red indicator and an audible signal, which should be powered from an internal battery independent of the digital display.

14.37 The audible signal may be muted and will be automatically reinstated as required under normal power supply, but the visual indicator should continue to flash until either the fault has been rectified or the battery has discharged.

Indicators

14.38 Panels should be provided with indicators for all medical gas services in local use.

14.39 Visual indicators should be arranged vertically in order of priority, with indicators showing normal operating conditions positioned at the top of the display. The sequence of gas services on the panel should match the order of the corresponding terminal units.

14.40 The “power on”, “system fault” and “audible warning” features should operate independently from the gas condition display(s). This ensures that, in the event of a failure of the gas warning display or digital interface, these three critical functions remain fully operational.

14.41 Area alarms monitor the pressure of the pipeline system and are dedicated to zones controlled by the AVSUs.

14.42 Area alarms monitor the pressure between the AVSU and terminal unit that provides the point of connection to the patient. Therefore there cannot be any other form of isolation (apart from MSU valves) between the AVSU and terminal unit to ensure monitoring up to the terminal unit is maintained.

14.43 The alarms should display the pressure and vacuum readings on the alarm fascia; this should be extended to all areas.

14.44 Transducers should not be capable of being isolated by a separate shut-off valve, and they should be connected to the pipeline using a minimum-leak connection device.

14.45 Alarm sensor devices should be located directly above the alarm or within the AVSU where the alarm is located within the AVSU module. In all cases, the location should be clearly identified adjacent to the alarm panel via a permanent (traffolyte type preferred) label.

14.46 Alarm transducer testing should be undertaken annually.

14.47 All area alarm panels should be permanently labelled (traffolyte type preferred) labels adjacent to the alarm according to their function. The labelling should include:

- AVSU identification
- transducer location.

14.48 Information showing the battery date should be on a replaceable label and be updated when the alarm battery is replaced. All other information should be on a permanent label.

Panel displays and legend

14.49 Area panels should display the conditions listed in Table 23. The alarm system should include automatic monitoring capable of detecting loss of display operation, loss of communications or controller malfunction. Detection of such faults should generate a visible fault indication and an audible alarm.

Location of alarms

14.50 Area alarms should be located at the main location within the ward or department (for example, at the nurse station for wards and departments; in the control room for

Alarm function	Legend	Display	Colour	Auditory signal
Pressure gases	High pressure	Digital readout of pressure	Red	Yes
Pressure gases	Low pressure		Red	Yes
Vacuum	Vacuum fault		Red	Yes

Table 23 Area panel legend and display

imaging suites; and within the operating theatre, positioned separately from the surgeon's panel).

14.51 In large departments, local alarms may require repeater alarms in other areas to ensure adequate visibility and clear audibility.

Remote monitoring

14.52 All area alarms should be capable of being monitored by the BMS, with output provided for outward reporting only.

14.53 The methodology for this testing is provided in Chapter 19.

Plant alarm systems

14.54 All MGPS warning and alarm indicating panels should comply with the requirements of this HTM, including all operating room panels.

14.55 The plant alarm system monitors and remotely displays the current status of the plant.

14.56 Plant alarm systems are required for all medical gas supply systems.

14.57 A separate, simplified system is required for an AGSS, with a warning/ indication panel installed in the room where general anaesthesia is administered. This may be integrated with the BMS for monitoring purposes.

14.58 Plant alarm systems comprise relays and pressure switches or transducers to initiate the alarms. A central system providing information on all plant should be provided in the 24-hour occupied area. Repeater panels should be provided at additional locations where such information is required to ensure that the necessary action can be taken.

14.59 Pressure sensors or transducers should be connected to the pipeline via minimum-leak devices.

Panel location

Central indicator panel

14.60 Warning and alarm conditions for all medical gas supply systems should be displayed on a central panel located in a position where there is continuous 24-hour occupation, such as the main reception area. PRS alarms should also be located at the same position.

14.61 This location should be risk-assessed due to different local protocols and requirements.

Repeater indicator panel location

14.62 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.

14.63 Plant alarms should be located within manifold rooms and plantrooms to ensure plant testing can be monitored via the alarm system as well as the plant display.

14.64 Plant alarms should be located in a 24-hour occupied area and not within wards and departments. Where no such location is available (for example, in a hospice or small community hospital), installation within wards or departments may be permitted.

14.65 Medical gas plant alarms should be connected to the BMS for monitoring purposes only. The BMS should not be used in place of the plant alarm system. Local alarms may be connected to the BMS for the same reason.

System components

14.66 Warning and alarm systems include the following functional elements:

a. interfaces and transmitters that convert the signal from the plant or manifold volt-free alarm contacts into a form which can be transmitted via multiplexed cable which includes line contact monitoring (for example, using pulse-width modulation). The transmitter may be a separate unit or may be incorporated:

   (i) into the plant or into a manifold control panel

   (ii) into an indicator panel

b. both cases should include line-fault monitoring devices

c. indicator panels which display the transmitted signals

d. interconnecting multiplex wiring which connects all interfaces and transmitters to all indicator panels.

General requirements

Labelling

14.67 All LCD plant alarms should display the gas and plant ID. LCD local alarms should display the gas and area served.

Central indicator panel requirements

Displays

14.68 The central panel should display all signals for all MGPS which are generated by the warning and alarm system, as described in paragraphs 14.69–14.72.

Normal

14.69 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

14.70 Warning conditions appropriate to each MGPS should be displayed as a flashing yellow visual signal that should be accompanied by a mutable audible signal (see Table 24).

Emergency alarms

14.71 Emergency alarms are generated by changes of pressures outside of set parameters and are indicated by flashing red visual signals accompanied by mutable audible signals.

Alarm system fault

14.72 The “alarm system fault” condition should be displayed as a flashing red visual signal accompanied by a mutable audible signal.

Panel legend and display

14.73 The panel legend and display should be as shown in Table 24. For dental systems, see Table 25.

Supply system	Alarm conditions	Legend	Colour	Audible system
Automatic manifolds	1. Duty bank empty: standby bank running	Change cylinders	Yellow	Yes
	2. Standby bank below 10% capacity	Change cylinders immediately	Yellow	Yes
	3. Reserve manifold below 68 bar (from ERM)	Reserve low	Yellow	Yes
	4. Pipeline pressure too high or too low	Pressure fault	Red	Yes
Emergency reserve manifolds (ERM)	Reserve pressure below 68 bar (<14 bar for N_2O)	Reserve low	Yellow	Yes
Medical air compressor and surgical air compressor	1. Fault on compressors or dryer that does not compromise the Air quality or outlet pressure	Plant fault	Yellow	Yes
	2. Multiple faults on compressors or dryers that affect the quality quantity of air supply	Plant emergency	Yellow	Yes
	3. Reserve manifold below 68 bar (from ERM)	Reserve low	Yellow	Yes
	4. Pipeline pressure too high or too low	Pressure fault	Red	Yes
Medical vacuum plant	1. Plant fault	Plant fault	Yellow	Yes
	2. Plant emergency	Plant emergency	Yellow	Yes
	3. Pipeline vacuum level low (315.5 mmHg)	Pressure fault	Red	Yes
Liquid oxygen systems **(Duplex tank systems)** **(Timed changeover systems)**	1. Primary tank below 25% (or risk assessed level)	Refill liquid	Yellow	Yes
	2. Primary tank empty	Refill liquid immediately	Yellow	Yes
	3. Secondary tank below 50%	Reserve low	Yellow	Yes
	4. Pipeline pressure too high or too low	Pressure fault	Red	Yes
Cryogenic cylinder systems with cylinder manifold reserve	1. Primary tank(s) below 25% (or risk assessed level)	Refill liquid	Yellow	Yes
	2. Primary tank(s) empty	Refill liquid immediately	Yellow	Yes
	3. Reserve manifold below 50% (note: independent to liquid system)	Reserve low	Yellow	Yes
	4. Pipeline pressure too high or too low	Pressure fault	Red	Yes

Table 24 Signals and displays for central alarm panels and repeater panels

	Normal condition	Plant fault	Pressure fault
At the plant	Plant and system operating within specified parameters – signalled as a signalled as a GREEN light	(i) Compressor unit: failed to start, overheated, motor-tripped or any other plant alarm as determined by the plant manufacturer – signalled as a YELLOW light (ii) dryer unit: dryer failure, dew point above –20°C at atmospheric pressure – signalled as a YELLOW light	Line pressure ±20% of nominal – signalled as a RED light
In the dental department or other specified location	GREEN	YELLOW	RED
Notes: Yellow and red alarms should be accompanied by an audible warning (with 15-minute, user-operated MUTE facility). Regardless of whether an alarm system is fitted, the departmental operational policy should detail staff actions in the event of service failure.			

Table 25 Schedule of alarm system indications for dental systems

Repeater indicator panel requirements

Displays

14.74 The repeater indicator panel should always display “normal”, “emergency alarm” and “alarm system fault” conditions as given above. The repeater panel should display all warning conditions that are displayed on the central indicator panel. The extent of the display of gases should be varied to suit local requirements.

Integrated systems

14.75 The introduction of computer-based systems for functions such as patient information, nurse call and general alarm management presents an opportunity to integrate selected medical gas pipeline warning and alarm conditions into these systems. While this provides an additional layer of monitoring, it should not be considered a replacement for the primary medical gas alarm system, which should remain fully compliant with relevant standards and operate independently.

Pressure-reducing station (PRS) alarms

14.76 PRS alarms monitor the pressure of the pipeline system downstream of each pressure-reducing regulator.

14.77 PRS alarms monitor both high and low system pressures.

14.78 Transducers should not be capable of being isolated by a separate shut-off valve, and they should be connected to the pipeline using a minimum-leak connection device.

14.79 Alarm transducer testing should be undertaken annually.

14.80 All PRS alarm panels should be labelled using a permanent label (traffolyte label preferred) adjacent to the alarm according to their function. Information showing the battery date should be on a replaceable label and be updated when the alarm battery is replaced.

Alarm function	Legend	Colour	Auditory signal
Duty regulator	Normal	Green	No
	High pressure	Red	Yes
	Low pressure	Red	Yes
Standby regulator	Normal	Green	No
	High pressure	Red	Yes
	Low pressure	Red	Yes

Table 26 PRS alarm conditions

Panel displays and legend

14.81 PRS panels should display the conditions listed in Table 26.

Location of alarms

14.82 PRS alarms should be located at the PRS location and repeated adjacent to the plant alarms.

Remote monitoring

14.83 All PRS alarms should be repeated to the plant alarms and be capable of being monitored by the BMS, with output provided for outward reporting only.

14.84 The plant alarm display should display the conditions listed below:

Display	Colour
Normal	Green
High pressure	Red
Low pressure	Red
Power fault	Red
Station fault	Red

14.85 High- and low-pressure alarms activate when either of the regulators have a pressure fault.

14.86 The power fault monitors the power to the PRS alarm panel.

14.87 The station fault activates when there is a pressure fault on both sets of regulators.

14.88 The methodology for this testing is provided in Chapter 19.

15 Pipeline installations

General

15.1 This chapter provides practical guidance on the installation of medical gas and dental pipeline systems following the completion of system design, as detailed in Chapters 3 and 4. It includes considerations for pipework routing, jointing, support, isolation valve arrangements, pressure regulation and testing provisions.

15.2 While not intended to cover detailed design calculations such as flow rates or pressure drop (see Chapters 3 and 4), this chapter addresses key physical and safety requirements essential during installation. It also includes specific requirements for dental air pipeline systems, emergency connections, and infrastructure considerations associated with medical gas services.

Introduction

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

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

15.4 Guidance on deriving and calculating the above parameters is given in Chapters 3 and 4.

15.5 The definition of a “department”, which may comprise several wards and treatment rooms, should be agreed at the project design stage to avoid confusion.

15.6 The allowance for expansion and change of use should be subject to a risk assessment; generally, a 25% minimum allowance should be calculated into the supply system capacity.

Safety

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

- identity
- adequacy
- continuity
- quality of supply.

15.8 Identity is assured by using gas-specific connections throughout the pipeline system, including terminal units and connectors, and by the adherence to strict testing and commissioning procedures of the system during installation, modification and repair.

15.9 Adequacy of supply depends on:

- an accurate assessment of demand
- the selection of plant appropriate to the clinical/medical demands on the system and
- the correct sizing and layout of the pipeline system.

15.10 Continuity of supply is achieved by:

- the specification of a system that has multiple supply sources and components
- the provision of a third means of supply for all systems
- the provision of alarm systems and
- connection to the emergency power supply system.

15.11 Pipe sizing is critical to ensuring continuity and adequacy of the system. A minimum pipe diameter of 22 mm should be used for the carcass pipeline.

15.12 Quality of supply is achieved by the use of gases purchased in accordance with the relevant monographs of the British Pharmacopoeia, 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 testing and commissioning procedures.

15.13 The vacuum discharge and pipeline distribution system for vacuum should be constructed of material and pipework in line with BS EN ISO 7396 and other associated British Standards for medical pipeline systems. Fire precautions relating to the construction and routing of medical vacuum systems should be in accordance with the HTM 05 Firecode series.

Modifications

15.14 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 supplies to patients are not compromised.

15.15 The section to be modified should be physically isolated from the section in use. Closing isolating valves is insufficient for this purpose. Where AVSUs or LVAs have been installed, blanking spades should be used to form a physical break. This isolation procedure is not required when work is carried out on the second fix of an individual terminal unit.

15.16 Modification of existing systems may be detrimental to overall system performance. In older systems, insufficient capacity may prevent safe operation at the flow rates typically encountered today. A risk assessment and flow calculations are required prior to any work being undertaken.

15.17 Any work involving alteration, extension or maintenance work on an existing system should be subject to the PTW procedure (see Part B, Chapter 8).

Removal of pipework

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

15.19 Refer to the decommissioning of medical gases in Chapter 16.

Validation and verification

15.20 The objective of validation and verification is to ensure that all the necessary safety and performance requirements of the MGPS will be met. Validation and verification procedures should be carried out for new installations, additions to existing installations and modifications to existing installations. The scope of work will dictate the specific programme required. This is described in Chapters 19 and 20.

General fire precautions

15.21 The HTM 05 Firecode series should be followed at all times for fire safety and fire precautions.

15.22 The siting and general structural principles for the design of liquid oxygen storage accommodation are given in Chapter 6, and the requirements for plantrooms and gas manifold rooms in Chapter 5.

15.23 Guidance on cylinder storage and handling is given in HTM 02-01 Part B.

Confined spaces for all works

15.24 Risk assessments must be undertaken in line with the Confined Spaces Regulations 1997, and safety precautions must be implemented.

Electricity supply to medical gas installations

15.25 All electrical work must be undertaken under the control of the Authorised Person relevant to their discipline (see HTM 06-02 – 'Electrical safety guidance for low voltage systems' and HTM 06-03 – 'Electrical safety guidance for low voltage systems').

15.26 All design works should be signed off by the Authorised Person (LV/HV).

Resilience of supply

15.27 MGPS, associated equipment and alarms are a critical service within a healthcare facility. Continuity of service must be maintained in the event of a mains power failure.

15.28 Medical gas equipment should be supplied from a dedicated, final circuit which is considered "essential" within the electrical distribution strategy. Alternative means of supply should be considered in the event that internal subdistribution is compromised.

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

15.30 Site resilience strategies and planning should be clearly understood by all relevant staff and management. All emergency preparedness plans should be fully capable of supporting operations during total loss of electricity or other adverse conditions.

Electrical installation

15.31 Care should be taken when installing electrical and medical gas pipeline systems to avoid contact between pipework and electrical services (i.e. cables, conduit or trunking). When physical separation is impractical or contact with extraneous metalwork occurs (for example, where the pipeline is carried in metal partitions or where terminal units are mounted on metal bedhead units), the pipeline should be effectively bonded to the metalwork in accordance with HTM 06-01 and BS 7671.

15.32 The final connection to any equipment (for example, alarm panels or control panels) should be made using an unswitched fused connection unit; a double-pole switch should be available to permit work on the equipment.

15.33 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), ELV and communications and data systems are maintained together but separate from pipeline systems. Access to unprotected live parts within the pendant should only be possible by means of a tool.

Earthing

15.34 Medical gas pipelines should be bonded together and bonded to the local electrical distribution board in accordance with HTM 06-01 and BS 7671. Pipelines should not be used for earthing electrical equipment.

15.35 All flexible pipeline connections, wherever used, should be visually bonded across the fixed points to ensure earth continuity.

15.36 Where a medical gas outlet or pipeline system is present within a Group 2 location, as defined by Section 710 in BS 7671, care should be taken to ensure the resistance of the bonding connection is in accordance with the required value.

Pipeline routing, location and protection

15.37 MGPS installations should be kept away from areas where they may be subject to any of the following:

- mechanical damage
- chemical damage
- excessive heat
- splashing, dripping or permanent contact with oil, grease or bituminous compounds, electrical sparks, etc.

15.38 Pipelines supplying AVSUs should be fed from pipework located external to the fire compartment being protected.

15.39 Service ducts or voids containing pipelines that include valves or other mechanical connections should have adequate ventilation to prevent gas build-up in the event of any leakage. Where pipelines are brazed along their entire length and fully pressure-tested, no ventilation is required.

15.40 Exposed pipelines should not be installed in lift shafts, kitchens, laundries, boiler houses, generator rooms, incinerator rooms, storage rooms designed to house combustible materials, or in any other fire-risk areas (see HTM 05-03 Part K – 'Guidance on fire risk assessments in complex healthcare premises').

15.41 Where pipelines in hazardous areas are unavoidable, they should be enclosed in non-combustible, non-corrosive materials that have no electrolytic reaction with copper to prevent the possibility of the liberation of gases into the room in the event of pipeline failure.

15.42 Medical gas pipelines should be routed away from natural gas pipelines where there is a risk of flammable gas accumulation in the event of a leak.

15.43 Where pipelines are installed in enclosed ducts with other services such as steam mains and water supply systems, they should be inspected annually, as corrosion may occur due to chloride deposits following leakage.

15.44 Pipelines should not be run in enclosed ducts with other services where they cannot be inspected.

15.45 External pipe runs should be avoided wherever practicable. Where unavoidable, they should be protected as follows:

a. On external vertical surfaces up to the maximum height of potential damage (for example, from vehicles): by means of galvanised profile-section steel of sufficient thickness to provide adequate protection. The protection should cover the entire width taken up by the pipeline(s) plus a minimum of 50 mm each side, and stand off the surface such that the pipes can be inspected visually (50 mm). (The armour should be readily detachable to permit more detailed inspection.)

b. When crossing horizontal surfaces and roofs: similar protection should be provided to prevent damage from foot

traffic, using galvanised profile-section steel as described in (a).

15.46 The complete boxing-in of the pipework should follow the requirements for ducts.

15.47 Pipework should be protected from lightning strikes by ensuring that it is run within a 60-degree cone beneath the lightning conductor (for example, when running along parapet walls or when penetrating parapet walls). When the pipework is run across roof surfaces, a copper lightning conductor should be run along the top surface of the pipework cover, which provides physical protection and should be bonded to it.

15.48 Internal pipelines should be suitably protected where there is a possibility of physical damage (for example, from the passage of trolleys and tugs).

15.49 Where pipelines are installed in plantrooms or other areas (excluding dedicated risers), they should be positioned at a height that minimises the risk of damage.

15.50 A clearance of at least 25 mm should be maintained between each service, and the separation distance between the medical gas pipeline and heating pipes, hot water services and steam pipelines should be at least 150 mm.

15.51 Where pipelines cross other services and a clearance of 25 mm cannot be maintained, they should be electrically bonded and wrap-insulated in accordance with HTM 06-01 and BS 7671.

15.52 All medical gas pipelines should be bonded to the main earth terminal at building entry and exit.

15.53 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.

15.54 Underground pipelines should be run in appropriately drained ducts measuring no less than 450 mm x 450 mm and fitted with removable covers.

15.55 Where it is not possible to provide removable covers, two pipes should be run in separate trenches, with the appropriate LVAs configured at each end to allow for individual or dual feeding. Each pipeline should be capable of being isolated individually.

15.56 Each pipe should be capable of carrying 100% of the designed flow rate.

15.57 The separation distance between the two trenches should be at least 2 m. The two pipes should each be sized for the design flow. One or more different gas pipelines can be run in each trench. The pipeline route should be identified on the surface and clearly shown on site layout drawings.

15.58 Pipelines should not be concealed within walls or encapsulated within floors. Where this is unavoidable, the pipeline routes should be clearly shown on the as-fitted drawings.

15.59 Joints should be kept to the practicable minimum.

15.60 Pipelines in stud or plasterboard walls or partitions are acceptable, provided they are protected against corrosion and potential damage (for example, from drilling). Where enclosure within plastered walls is unavoidable, pipelines should be wrapped in protective grease-free tape.

15.61 Pipes passing through walls or partitions should be sleeved using copper pipe that is one size larger than the pipe being installed. The sleeving should be of sufficient length to be clearly visible on both sides of the wall or partition and extend a minimum of 50 mm beyond the fire-stopping.

15.62 Fire protection should be applied:

- between the wall and the sleeve and

- between the sleeve and the pipeline.

15.63 The sleeving should be inspected and signed off on test form B4 (see Chapter 19). Split sleeves should not be used. No joints should occur within the sleeves.

15.64 Where pipes pass through floors, the sleeving should penetrate the floor and follow the same requirements as wall penetrations. It should remain clear of the fire-stopped material and be individually fire-stopped.

15.65 Sleeving should be secured where there is a risk of movement prior to fire-stopping.

15.66 Pipelines need further protection in certain circumstances:

- In diagnostic imaging rooms such as MRI suites, waveguides may be needed to maintain the integrity of radio frequency shielding and prevent interference (the advice of the equipment manufacturer should be sought).
- Pipework may corrode where it comes into contact with timber treated with fire-resistant or flame-retardant compounds (for example, that used in roof trusses and floor joists). To prevent this, impermeable non-metallic materials should be used at all potential points of contact. Suitable materials include PVC spacers or adhesive PVC tape. Where spacers are used, they should be securely fixed and resistant to displacement resulting from shrinkage or movement of the pipework or timber.

Pipeline materials

Quality

15.67 Manufacturers should comply with BS EN ISO 7396-1 for the production of pipes and all associated materials, including fittings, terminal units and related components. Suppliers should be registered in accordance with BS EN ISO 9001 and/or BS EN ISO 13485. Alternative materials to rigid copper, such as corrugated metal tubing (CMT), may be considered where full compliance with BS EN ISO 7396-1 can be demonstrated and the product is CE-marked and validated to the satisfaction of the Authorising Engineer (MGPS) and the MGSG.

Pipes

15.68 Rigid copper pipework should be Grade CW024A (Cu-DHP) phosphorus-deoxidised, non-arsenical copper to BS EN 1412 and supplied in metric outside diameters:

- R250 (half hard) 15, 22, 28, 35, 42 and 54 mm is suitable for bending
- R290 (hard) 35, 42 and 54 mm and above is not suitable for bending
- R220 (annealed coils).

Pipe jointing fittings

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

Note:
For straight couplings, expanded joints may be used where the pipeline integrity is not compromised.

Other fittings

15.70 Other fittings for connection to copper pipes (for example, valve and control panel fittings) of copper, brass, gunmetal, bronze or stainless steel may be suitable.

Cleaning

Pipes

15.71 All pipes should be cleaned and degreased for oxygen service and be free of particulate matter and toxic residues in accordance with BS EN 13348. They should be individually capped at both ends and

delivered to site identified as medical gas pipes.

Pipe jointing fittings

15.72 All pipe jointing fittings and subassemblies of fittings for connection to pipes should be cleaned and degreased for oxygen service and be free of particulate matter and toxic residues. They should be individually sealed in plastic bags and delivered to site identified as medical gas fittings.

15.73 Although it is not essential for quality purposes to degrease vacuum pipeline 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 installations to avoid confusion.

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

Pipeline jointing

15.74 Except for mechanical joints, only copper-to-copper joints should be permitted on site, using brazing filler rods that do not require flux.

Note:
Brazing is performed at a higher temperature than silver soldering with capillary fittings; the exterior of the pipe will therefore have considerably darker oxide deposits.

15.75 Copper joints to brass or gunmetal fittings will require the use of flux, with subsequent cleaning to remove the flux residues and oxide deposits.

15.76 Heating of joints for brazing should be carried out using liquefied petroleum gas (LPG)/oxygen torches. Additional heating may be required for some fittings (for example, by means of a second torch).

15.77 Acetylene should not be used.

15.78 The techniques recommended cover all copper-to-copper and copper-to-alloy joints (brass, gunmetal and bronze) within an MGPS and are explained in more detail below.

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

Pipe preparation

15.80 Pipe ends should be cut square with the pipe axis using sharp wheel-cutters and be burr-free. Joints should be free of any cuttings or burrs so that cleaning prior to assembly is not necessary. When cleaning or removing burrs, strict controls are required to ensure that the removed particles do not contaminate the pipeline.

15.81 Expanded joints should be made using the appropriate tools and dies. Cut pipes that have deformations or burrs that could restrict the gas flow or become loose and contaminate the pipeline should be replaced.

15.82 Only oil-free and grease-free tools and dies should be used.

15.83 When brazing copper-to-copper joints:

- brazed joints should be made using a silver–copper–phosphorus brazing alloy CP104 to BS EN ISO 17672. No flux should be used
- ensure the adequate protection of adjacent pipe runs and other services.

Note:
Brazing copper to brass, gunmetal or 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 the complete assembly is cleaned and degreased for oxygen service. Brass, gunmetal or bronze fittings 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

15.84 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.

15.85 OFN should be supplied to the inside of the pre-assembled, unbrazed pipework through a pressure regulator and flow controller or flow-regulating device. It should completely fill the pipeline and have a steady flow through the pipeline to be effective in omitting oxidisation.

Application

15.86 OFN as an internal inert gas shield should be used for all medical gas pipelines.

15.87 By agreement between the Authorised Person (MGPS), Authorising Engineer (MGPS) and pipeline contractor, the requirement for purge gas may be waived for certain joints, such as connections to existing pipeline systems where joints have not been made in accordance with this technique. Purging should be carried out to clear any debris formed.

15.88 The pipeline to be brazed should first be purged to remove air. During the brazing operation, a continuous flow should be maintained to prevent the ingress of air.

15.89 Pipe ends may be capped if desired to direct the flow of nitrogen into sections of the pipe or pipes to be brazed.

15.90 Particular attention should be given to the gas shielding of T-joint fittings. Care should also be taken to ensure that other pipelines in close proximity to the one being brazed do not oxidise due to heat transfer.

15.91 It is essential that there is a leak-free connection between the pipework to be brazed and the nitrogen supply.

Safety

15.92 If working for prolonged periods in very confined spaces, precautions should 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. The Confined Space Regulations must be followed to minimise the risks. Where appropriate, the confined space PTW system should be used.

Note:
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

15.93 The contractor and site engineer should keep a record of nitrogen cylinders held on site. Nitrogen cylinders should be accounted for and removed from the site at the end of the contract. They should be kept separate from medical gas cylinders at all times.

Note:
Pipelines should not be dry-fitted and left unbrazed for more than 72 hours. This is to prevent contamination and copper tarnishing due to moisture ingress.

Inspection of joints

15.94 Joint inspections should be carried out frequently as a rolling procedure on a pre-determined and risk-assessed basis as work progresses for each team performing the installation in accordance with the following procedure:

- The site engineer should identify the fittings to be cut out for examination in order to establish the quality of the finished joint. The exact number to be cut out will vary with the size of the installation: as a guide, a ratio of one fitting per 200 should be cut out; a minimum of two fittings per pipeline should be cut out and examined (these checks should be performed before pressure-testing sections of the pipeline).
- Fittings that have been cut out should be cut open (quartered longitudinally), filed flat and examined. If unacceptable joints are found, adjacent fittings should be cut out until the extent of any faulty work has been established; a further 3 m of pipework in each direction should be removed and all adjacent fittings inspected. This may require extensive removal of sections of the installation and in some cases the removal of the total system.
- On small works up to ten fittings, it is possible for the Authorised Person (MGPS) who is competent in brazing to observe the joints being undertaken and to have a bench joint made for inspection to avoid the cutting out of the installed pipeline.
- Where single joints are undertaken, the Authorised Person (MGPS) should be present to witness the joint and ensure that the correct brazing techniques are undertaken.

Internal cleanliness

15.95 The tube and fitting should be internally clean and free from oxides and particulate matter. Some minor discoloration or heat burnishing may be apparent and is acceptable.

Penetration

15.96 Penetration of brazing alloy:

- Due to tolerances of the capillary space on 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 should be three times the wall thickness of the tube or 3 mm, whichever is the greater.
- The pipe should be cut square and fully inserted up to the shoulder of the fitting.

Note:
These tests should be carried out on a sectional basis and for each team of installers on site.

Jointing methods (mechanical)

15.97 In addition to mechanical connections to plant and valve assemblies, mechanical connections may also be used in situations where brazing may present an unavoidable serious fire risk. These should be agreed by the Authorised Person (MGPS) as part of the design.

15.98 Mechanical connections should have comparable structural integrity to brazed fittings in normal operation and in the event of fire. Any lubricant required for swaging should be oxygen-compatible. The fittings should not contain elastomeric materials.

Note:
Open ends of the remaining pipework should be capped off. The installation should be made good as soon as possible.

15.99 PTFE tape is not an acceptable sealing material on oxygen systems or on supply plants.

Note:
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.

15.100 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

15.101 Sections of pipeline should be capped as soon as they are completed so as to prevent the ingress of debris. Temporary degreased push-on caps are appropriate for short-term use during an installation; brazed caps are required for permanent capping.

Pipe supports

15.102 The pipeline should be adequately supported at sufficient intervals in accordance with Table 27 to prevent sagging or distortion. Supports for surface-mounted pipework should provide clearance to permit painting of the surface.

15.103 Where it is essential for pipes to cross electric cables or conduit, they should be supported at close intervals on either side of the crossing to prevent them from touching the cables or conduit.

15.104 Supports should be of suitable material or suitably treated to minimise corrosion and prevent electrolytic reaction between pipes and supports.

15.105 LVAs and other pipeline-removable components should be supported either side at a close proximity to remove any strain from the pipeline during operation or servicing. This becomes more critical as the pipeline size increases due to the extra strain required to activate the valve and disconnect the mechanical fittings.

15.106 The bracketry should be substantial enough to ensure that no stress is applied to the pipeline in the event of the valve being activated or the component being removed. In the case of 35 mm pipelines and above, a metal frame should be installed to support the component on both sides.

15.107 Where pipelines are included within MSUs, the number of pipeline supports should comply with Table 27 and also take into consideration the support offered by the terminal unit fixed into the MSU and the last pipeline support immediately before the pipeline enters the MSU.

15.108 Pipelines do not need to have a fall on the length of the pipeline.

15.109 Connections from individual or groups of vacuum terminal units to branch pipelines should be made at the top of the pipeline to prevent the risk of flooding adjacent vertical drops, should liquid carry-over occur.

15.110 Each vacuum main riser should be provided with a double (15 mm) valve arrangement at the base, with an intervening full bore pipe section, terminated with a transparent collection jar to permit drainage when the system is under vacuum; one of the valves should be lockable in the open position. These require inspection on a quarterly basis.

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: Consideration should be given to additional supports near elbows where the potential effects of inadvertently applied torque can result in severe pipeline distortion or fracture.

Table 27 Intervals between copper pipe supports (horizontal and vertical)

Identification of pipelines

15.111 Pipelines should be identified in accordance with BS 1710, and colour banding for the pipelines should be used. Colour band identification (see Figure 25) should be applied adjacent (within 300 mm) to valves and junctions, and on both sides where the pipe passes through walls or similar structures.

15.112 A label identifying the gas, with lettering at least 6 mm in height, should be applied at intervals not exceeding 3 m. Self-adhesive plastic labels from an approved manufacturer may be used for this purpose. A band width of 150 mm is usually adequate. All colour-coded tapes applied by pipe manufacturers should be removed before the systems are identified, in accordance with this paragraph.

15.113 Care should be taken to maintain pipeline identification when periodic repainting is undertaken. The direction of flow should be indicated.

15.114 Where a ring main is installed and flow may occur in either direction, two flow-direction arrows should be applied – one either side of the identification tape, facing outwards – to indicate bidirectional flow.

Medical supply units (including bedhead trunking/walling systems/enclosures)

15.115 Separate chambers should be provided for electrical services (nurse call/radio and other cabled services which should have appropriate compartmentation within the chamber for various voltages), and medical gas/vacuum pipelines. The access requirements for maintenance or adaptation of each service should satisfy the requirements set out in BS ISO 11197. If modifications are made, the modifier or maintainer of the MSU should assume the responsibility of manufacturer and should fulfil all of the responsibilities set out in BS ISO 11197 as if they were the original manufacturer.

15.116 Any flexible connecting assemblies used within the fitting should comply with BS EN ISO 5359. Flexible connections should not be used within fixed non-adjustable or rotating MSUs as set out in BS EN ISO 11197.

15.117 The default option should always be to use a rigid pipe installation. In all cases where flexible hoses are to be used, consideration to the possibilities of rigid systems should be risk-assessed and where possible utilised. This is particularly important in emergency departments and critical care areas. In such cases, the systems may be replaced with floor-to-ceiling columns housing all required services, thereby eliminating the need for multi-movement and other flexible-hose MSUs.

15.118 The medical gas chamber should be provided with ventilation to prevent the accumulation of any gas in the event of rupture of the medical gas pipeline services.

15.119 Requirements for venting of MSUs are set out in BS EN ISO 11197.

15.120 Where medical gases and other bedhead services are installed in concealed recesses (or behind decorative panels, paintings, etc.), adequate ventilation and sufficient access for equipment connection and disconnection should be provided. Covers should be clearly labelled to indicate that medical gas equipment is installed within or behind.

15.121 Where pipelines exit or enter an MSU, the sequence of pipelines may differ from that applied to the infrastructure pipelines at high level, as a consequence of the specific manufacturer's product design.

15.122 Pipelines contained within an MSU should be labelled as set out in paragraphs 15.111–15.114.

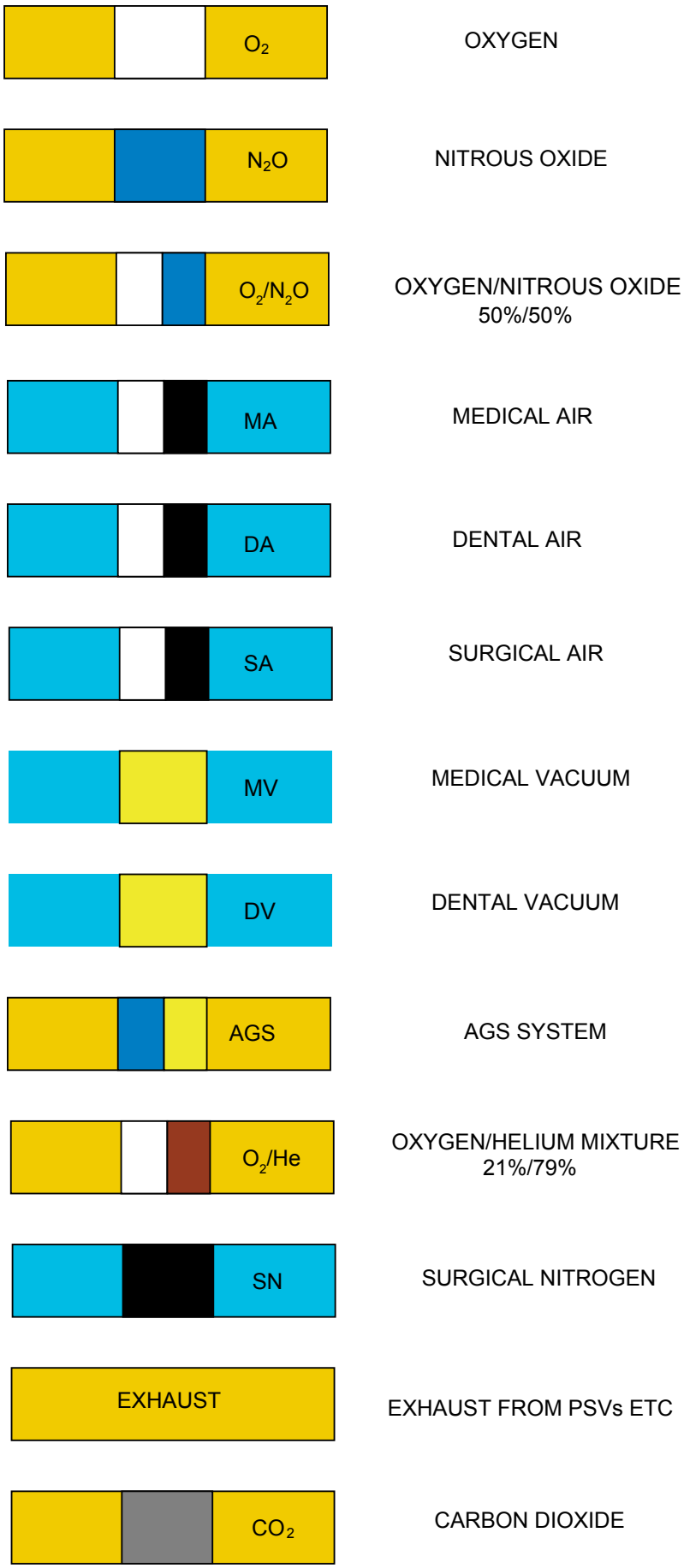


Figure 25 Pipeline identification colours

15.123 There are two possible installation procedures:

- The connection between the pipeline and a pre-piped trunking/MSU should be considered as a second fix, with the trunking/MSU certificated as having passed a first-fix test. As a minimum to ensure the cleanliness and integrity of the MGPS is retained, brazed copper end caps or temporary mechanical connections should be a requirement for all pipe terminations After brazing to the site distribution pipeline, the joints should be subject to a second-fix test and leak-tested by the site's medical gas contractor as a complete system.
- The pipework should be installed into the trunking/MSU on site.

Non-interchangeable screw-threaded (NIST) connectors

15.124 NISTs are threaded connection devices designed to prevent cross-connection. For all pressure gases, they incorporate a check valve.

15.125 When the NIST probes are inserted into the female NIST and the threads engaged, the design of the check valve should not impede the full flow of the gases.

15.126 All NIST bodies should be supplied with NIST nuts.

15.127 NISTs should be installed at locations where gas testing, emergency backfeeding or connection of flexible hoses is required (for example, LVAs and AVSUs).

15.128 NISTs form part of the main pipeline installation, not part of an MSU, and should be installed as a pipeline component serving the MSU on a NIST plate. These should be installed within 500 mm of the MSU and should be accessible via an access panel with minimum dimensions of 600 mm x 600 mm.

15.129 NISTs form part of the first-fix pipeline system.

15.130 Where NISTs are fitted, they should be freely accessible for the connection and disconnection of test probes, and for the use of tools required to connect or disconnect hose assemblies.

15.131 Where NISTs are installed on horizontal pipelines and are not contained within an AVSU or pressure-reducing system, they should be oriented to avoid the ingress of contamination.

15.132 In all cases, accessibility should be maintained.

LVs and LVAs

15.133 All valves should be of the lever-ball type, having flanged O-ring seal connections which open and close with a 90-degree rotation. The handle should be in line with the pipeline when open. All valves should be lockable.

15.134 All valves should have independent keys for each lock, which should be kept in the medical gas key safe and listed on the key register. The valve should be permanently labelled, clearly indicating the gas type, valve number and key register number.

LVs

15.135 LVs should be used for isolations where NISTs are not required or will not be used for connection (for example, MSU isolation valves).

15.136 LVs should meet the requirements of the LVA excluding the NIST components.

LVAs

15.137 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.

15.138 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.

15.139 The valve flange and bolt assembly should be of sufficient length to permit loosening to allow removal and replacement of the spades without loss of structural integrity of the connection. Union-type connections with O-rings are permissible, but the securing nut should also have sufficient thread length to permit venting while maintaining the structural integrity of the connection

15.140 In the event of leakage of the through or blanking spade, gas should be capable of venting to atmosphere and should not be able to enter either the valve port or the pipeline section blanked.

15.141 The appropriate NIST connector bodies with self-sealing check valves and lockable blanking nuts should be provided upstream and downstream of the flanges.

15.142 NIST nut locks should be capable of being secured using a suited gas-specific lock appropriate to each gas type.

15.143 Gas identity and flow direction arrows should be provided for each valve and brackets.

15.144 LVAs should be provided as follows:

- at the connection of the pipeline to any source of supply
- at the emergency inlet port (that is, it forms the emergency inlet point)
- at the pipeline entry to a building
- at the pipeline exit from a building
- at the connection of branches to the main pipeline run
- at the connection to risers
- at branches from risers to serve a number of similar departments
- upstream, downstream and in the branch connection to a ring main
- in locations to allow maintenance of AVSUs with minimum disruption to multiple wards or departments.

15.145 Where departments on a floor are functionally very different (for example, wards and diagnostic areas), separate branches from the risers should be provided.

15.146 LVAs should not be installed where a gas leakage is likely to result in a hazardous atmosphere developing.

AVSUs

15.147 AVSUs are provided for user access in an emergency (or for maintenance purposes). They should be in accordance with the requirements 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.

15.148 The location of AVSUs should be subject to a risk assessment to minimise the risk of accidental damage to the glass panels; this may be undertaken by adding further protection or recessing these within the walls further.

15.149 In an emergency, the user should 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 should be safe and secure and should clearly act as a deterrent to tampering without introducing undue risk of injury to the user.

Float glass should not be used. The method of emergency access should be obvious and clearly labelled, and its use should be evident.

15.150 NIST connectors should not be accessible via break-glass emergency entry. NISTs within an AVSU do not need to be locked.

15.151 Each AVSU should be designed for a single gas pipeline and should be gas-specific. The AVSU may incorporate provision for pressure gauges, pressure switches or transducers, using separate bosses with minimum bleed points.

15.152 The bottom of the enclosure should have adequate ventilation to prevent the accumulation of gas in the event of a leak.

15.153 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.

15.154 Gas identity and flow direction arrows should be provided internally within the enclosure for each valve. The flow direction should be a permanent identification once fitted and should not be capable of being reversed without tools or a PTW.

15.155 Provision and location of AVSUs is covered in Chapter 3.

15.156 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). They should be kept clear of signage and other occlusions. Protection should be provided in line with bedhead services.

Specific labelling requirements

15.157 All AVSUs should be individually labelled as a minimum to identify:

- the AVSU's individual identification number
- the number of rooms and/or the number of terminal units
- the gas it is supplying
- flow direction
- key cabinet number for the key.

15.158 All AVSUs should be accompanied by a spatial plan drawing detailing the AVSU location and the terminal unit locations fed from the AVSU.

15.159 In critical care areas, where dual circuits or subdivisions of circuits occur, terminal units should be correspondingly identified with the specific AVSUs using circuit numbers (for example, 1 & 2 or A & B). These identifications should be permanently fixed adjacent to the terminal units.

15.160 For MSUs, they may be engraved into the covers at the time of manufacture. This will require much planning and, therefore, special care should be taken during validation and verification for circuit identification.

15.161 AVSUs that control pneumatically powered pendant brakes should clearly identify the pendant they control.

15.162 Electrical brake systems are preferable for all moving pendants.

15.163 Each individual pendant should be clearly labelled to indicate which AVSU controls the brakes.

Pressure control equipment

15.164 Medical gases may be distributed at a higher pressure than the eventual nominal pipeline distribution pressure at terminal units.

15.165 Where this is the case, the maximum working pressure should not exceed 1100 kPa and a PRS should be installed.

15.166 The PRS should only be installed in an area that has good ventilation and be in a position where it is readily accessible for inspection, maintenance and servicing. These should not be installed within ceiling spaces or areas that may pose a risk to patients or staff.

15.167 Simplex systems should not be used.

15.168 The PRS should include duplex pressure-regulating valves, each with upstream and downstream isolating valves, safety relief valves, test points, pressure transducers and non-return valves.

15.169 See Figure 6 in Chapter 3 for a recommended layout.

15.170 The safety relief valve discharges should be run to the exterior of the building. Where this is not possible, air exhausts may be exhausted to a safe location away from the reducing set to enable safe working on the PRS.

15.171 Where air is being used to power the breaks for MSUs, a simplified version is permitted but should comply to the configuration in the following section.

Air brake pressure reducing system (ABPRS)

15.172 The ABPRS should consist of the following components:

- pressure-reducing regulator
- pressure-relief valve
- NIST test point
- non-return valve
- flow restrictor
- line valve.

15.173 These are simplex units and are installed to control multiple systems

15.174 See Figure 5 in Chapter 3 for a recommended layout.

Pressure sensors

15.175 Pressure sensors to provide the alarm function should be fitted to pipeline distribution systems. In all cases they should be installed in adequately ventilated locations with appropriate access for maintenance.

15.176 Transducer-type sensors are preferable to mechanical switches.

15.177 They should be located downstream of the AVSU isolation and prior to any terminal units.

15.178 No valves (apart from MSU isolation valves) should be installed downstream of an AVSU or after the pressure switches.

15.179 They may be incorporated within the enclosure of the AVSUs on the downstream side of the system.

15.180 Where not incorporated into an AVSU, the pressure sensor should be above the local alarm, ensuring that it is accessible for maintenance. The pressure switch location should be clearly identified at the local alarm.

15.181 All pressure sensors should be connected to the pipeline by means of a minimum leak connector.

MGPS test points

15.182 Each supply plant (that is, liquid oxygen supply control panel, manifold (ACM and MCM), compressor plant, PSA and blending plant) should be provided with a test point. A lockable line valve should be installed prior to the test point where it is directly connected to the pipeline. Where a test point is installed in one leg of a PRS set, for example, the test point may be isolated using the valves of that leg.

15.183 Where two sources of supply are connected to the main pipeline (for example, ACMs and duplex dryers), the tests points should be located to enable each source to be tested independently prior to being brought

online. For example, a test point should be located downstream of each dryer unit, after the final filtration but prior to the PRS; and for manifolds (both ACM and ERM), the test point should be located prior to the final pipeline connection valve.

15.184 It is not necessary to have a test point for each bank of a manifold as they form a single source of supply.

Temporary inlet port

15.185 A temporary inlet port is a connection point for a temporary supply to support the MGPS during emergency repairs or modifications. Where provided, it should be located downstream of the main source of supply line valve isolation point to permit connection of a temporary supply and should be sized for full flow.

15.186 The temporary inlet port should comprise an LVA, an additional non-return valve on the temporary inlet side, and a connection that can be blanked.

15.187 The location of this port should be compatible with the installation of a temporary or mobile supply and the area constructed in accordance with the supply plant's requirements.

Dental air pipework system design

15.188 The installation of a duplex compressor set, as commonly used in many medical air installations, is not standard practice in dental air systems. Many dental air systems are small-scale and localised (for example, supplying a single chair using a dedicated compressor matched to the performance requirements of the dental air instruments).

15.189 For surgeries with up to five chairs, a single compressor may be used to all outlets via a localised pipework system. In such cases, the pipework serves as a means of interconnection rather than a pipeline system and may comprise synthetic flexible tubing (for example, nylon).

15.190 Where synthetic materials are used, they should not promote microbiological growth and should not compromise fire safety.

15.191 The material should be compatible for pressure testing at 1000 kPa and should not have properties that can be absorbed into the air under deterioration or age.

15.192 The age-hardening properties of the material should be suitable for the function, and a replacement schedule should be clearly identified for these pipelines where copper pipe is not used.

15.193 On systems with more than five chairs, copper pipeline installations should be undertaken in line with medical air requirements.

15.194 A ten-chair unit is often supported by two compressor systems, each feeding five chairs via a dedicated pipework system, rather than a larger single plant. This configuration has the added advantage of a degree of service protection, should one plant fail when interconnecting valving arrangements are incorporated. (Emergency supply manifolds are not often used to support dental air systems.)

15.195 The design of larger systems may also involve split installations; for example, in a dental hospital with an integral dental school, a large number of teaching chairs will be in use simultaneously. It is possible that the total flow requirement of the teaching school and hospital would be supplied from a separate compressor plant.

15.196 Where the flow rate exceeds 500 L/min, a VSD compressor system should be utilised to ensure sustainability of the systems.

15.197 A combination of central and local provision, depending on the type of equipment in use, may be the preferred option.

15.198 Planning and design of DAVS, therefore, needs to be undertaken using the IDP in collaboration with the user, Authorising Engineer (MGPS), Authorised Person (MGPS) and the MGSG to achieve the most effective design.

15.199 The parameters below will serve as guidelines when designing dental air systems.

Flow and pressure requirements at the dental chair

15.200 Dental air is used to drive the tooling required for the dental operations. These tools typically run at 600 kPa.

15.201 The dental air supply should not be used to drive the chairs; a separate supply should be provided if chairs have pneumatic controls.

15.202 Flow rates for dental air should be between 35 and 70 L/min, but this is not a constant flow and will be intermittent.

Diversity factors and plant sizing

15.203 To ensure that a minimum of 550 kPa is available at each operating point, the dental air system should be designed to offer a minimum plant outlet pressure of 600 kPa at design flow.

15.204 For surgeries with up to ten dental chairs, it can be assumed that all chairs may be in use simultaneously, each requiring a flow of 50 L/min. For surgeries with more than ten dental chairs, it can be assumed that 60% of the remainder of the chairs will be using compressed air simultaneously.

15.205 A maximum pressure drop of 50 kPa from the plant to the dental chair's floor-box outlet connection may be tolerated under design flow conditions. A full design flow test should be carried out on all system installations.

15.206 Compressed air receiver volume may be increased at the discretion of the plant supplier to meet higher short-term flow demands.

15.207 For the purposes of plant sizing, the total system demand (Q) will be as follows:

Fewer than 10 chairs:

$$Q = (n + 1)50.$$

More than 10 chairs, fewer than 70:

$$Q = (550) + [(n - 10)30]$$

where n = number of dental chairs.

For large dental installations (over 70 outlets), a further (diversified) flow will be required:

$$Q = (3500) + [(n - 70)30)].$$

Special cases

Dental schools

15.208 For dental teaching schools, it can be assumed that all chairs in the teaching department will be in use simultaneously at a delivered flow of 50 L/min each. This flow should be risk-assessed and added to the diversified flow of any associated system if deemed required. Therefore, the flow for a full dental school would be:

$$Q = n \times 50.$$

Dental laboratories

15.209 When the dental air supply is to be extended into a dental laboratory, additional flow capacity will have to be designed into the system. Equipment manufacturers' data will give the flow and pressure requirements for individual items of equipment. No diversity allowance should be made, unless agreed or specified by the user.

15.210 Typical flows from the laboratory equipment are as high as 100 L/min.

New technology

15.211 Advances in technology may result in equipment requiring pressures or flows considerably greater than current norms. Each case should assessed individually, with advice sought from the specialist manufacturer or supplier to achieve optimal performance.

15.212 The use of such equipment should not compromise the integrity of the existing system. If necessary, a separate pressure source should be installed to cope with the demands of the new equipment.

Pipework sizing

15.213 Pipework should be designed to produce a minimum of 550 kPa at each dental chair floor connection outlet, with plant operating at a nominal delivery pressure of 600 kPa at total system design flow, taking into account any allowance for diversity.

15.214 For the purpose of calculating pipework sizes and pressure drops for small systems having fewer than five chairs, the data in Table 28 can be used for nylon pipelines. When calculating the total pipeline length, fittings such as valves, tees and elbows should be treated as an additional equivalent length of straight pipe, as shown in Table 28.

Dental system test points

15.215 To facilitate pharmaceutical testing of the dental air system, test points should be provided at the plant and in each of the dental unit's floor connection boxes.

15.216 The test point should be a medical air gas-specific Schrader-type connection with independent isolation from the system. Medical air terminal units should not be used. The test point should be clearly identified as dental air test point use only.

Pipework materials and jointing techniques

15.217 All pipework should be of materials appropriate to the demands of the system. Synthetics such as nylon may be used for smaller installations of up to five chairs while copper pipelines should be used in larger installations.

15.218 Copper systems should be installed to the same standards as an MGPS.

15.219 Any appropriate method of jointing compatible with the system test pressure (for example, compression fittings) may be used with synthetic materials.

Pressure safety valves

15.220 Pressure safety valves should be provided on pressurised vessels and pipework in accordance with the system's requirements.

15.221 All pressure safety valves should conform to BS EN ISO 4126-1 or equivalent.

15.222 A receiver pressure safety valve will typically have a nominal lifting pressure 10% above receiver working pressure.

	Equivalent pipe length added for fittings (m)			
Pipeline diameter	Ball valve	Tee (Thru')	Tee (branch)	90º elbow
6 mm	0.10	0.12	0.46	0.17
8 mm	0.10	0.15	0.52	0.20
10 mm	0.20	0.18	0.70	0.25
12 mm	0,30	0.21	0.80	0.33

Table 28 Pipework sizing: equivalent pipe length allowance for fittings (m) to account for pressure drop

15.223 It should never be set to lift at a pressure higher than the maximum allowable pressure of the vessel that it protects.

15.224 Furthermore, the normal working pressure in the vessel should be below the pressure-safety-valve set pressure by a suitable margin to protect against nuisance opening and to permit the pressure safety valve to reseat.

15.225 Pressure safety valves protecting distribution pipework should have a lifting pressure 10% above nominal line pressure.

15.226 A certificate of conformity should be supplied with each pressure safety valve.

15.227 All pressure safety valves should be replaced as identified in the WSE (usually every five years).

15.228 The dental system must be included within the PSSR 2000 system.

MRI systems

15.229 Quench pipes from magnetic resonance imaging (MRI) cryostatic units should be sized appropriately to accommodate the large volumes of helium gas released during a magnet quench.

15.230 They should be routed to safe areas and protected from obstruction. Failure to install adequately sized pipework will result in the venting of asphyxiant helium or nitrogen at low temperatures into the working environment, with potentially fatal results.

15.231 They should be a minimum of 5 m from any re-entry positions or natural air intakes. Where there are mechanical air intakes, a minimum of 10 m is required, ensuring the discharge is away from the intake. A physical barrier may be installed to ensure that there is no feedback into a mechanical air intake.

15.232 A risk assessment for the point of discharge should be undertaken to ensure gases are safely vented clear of the building and any re-entry points, in consultation with the supplier, Authorising Engineer (MGPS), Authorised Person (MGPS), Fire Safety Adviser and environmental officer.

15.233 Plant-specific specifications are required, as exhaust flows vary between individual items of plant. The discharge should be sized for 125% of the total maximum discharge flow rate and volume.

15.234 Pressure testing of both PVC and copper pipework should be carried out at 150 kPa for two hours, with zero pressure loss, using a calibrated digital gauge accurate to two decimal places.

15.235 See also HBN 06-01 – ‘Facilities for diagnostic and interventional imaging’.

16 Decommissioning of piped medical gas systems

16.1 Medical gas pipelines should only be decommissioned by a Competent Person (MGPS) under a PTW.

16.2 Decommissioning falls into one of five categories:

- the decommissioning of a system to allow works to be undertaken within the area where it needs to be brought back into service
- the partial decommissioning of the medical gas system where only some terminal units within an area are to be removed
- full ward or department from the AVSU
- the total decommissioning of a specific system
- decommissioning for demolition.

16.3 In all instances, where there has been an alteration to the system, the following documentation should be undertaken:

- All works should be undertaken under a PTW with a full risk assessment and method statement.
- The Authorised Person (MGPS) should inspect the pipeline runs with the Competent Person (MGPS) to confirm the method statement and confirm the safe method of works.
- The as-fitted and schematic drawings should be updated.
- The signage at the AVSU and within the wards and department plantrooms should be updated in line with the works completed.
- The medical gas key register should be updated.
- The medical gas policy should be updated.
- The medical gas service contracts and PPM schedules should be updated.

Temporary decommissioning

16.4 Where an area is to be redecorated or renovated and the medical gas system is not subject to alteration, the system should be isolated to ensure that the main hospital system remains unaffected.

16.5 To establish a safe area and protect the main system, the following steps should be undertaken as a minimum (a risk assessment and method statement (RAMS) should be completed):

- Isolate the AVSUs for all gases within the affected area and install spades.
- Isolate the local alarm.

- Label the AVSUs and alarm with the words “system temporarily decommissioned under PTW number **”.
- Insert “Do not use” plugs in all terminal units and record the total number of plugs on the PTW.
- Safely drain medical gases from the system to atmosphere.
- Remove all the medical gas pipeline equipment including medical gas flowmeters, vacuum controllers, suction jars and all tubing.
- Refill the system with medical air up to a pressure of 200 kPa to keep the system clean.
- Add further protection to all the medical gas components where required to prevent damage or ingress of foreign objects, liquids and other materials.
- To ensure the pipelines are not put at risk, all personnel working in the area should undergo a full induction; associated risks should be reflected in the contractor’s RAMS.
- The Authorised Person (MGPS) should oversee and witness all parts of the decommissioning process on site.

On completion of the works

- Remove all protection put in place for the medical gases.
- Physically inspect the system to ensure that it is free from damage.
- To reinstate the system, follow a full validation and verification procedure (see Chapter 19).

Partial decommissioning of sections of the system

16.6 Where only one or a small number of terminal units downstream of an AVSU are to be isolated, the following procedure should be used as the minimum requirements.

- Identify the terminal units to be removed and document on the high hazard PTW.
- Ensure the area is clear and that the medical gas system to be worked on is not in use.
- Insert “Do not use” plugs in all terminal units.
- Isolate the AVSU and deploy a spade within the AVSU downstream of the main system.
- Isolate the local alarm.
- Drain the medical gas system to atmospheric pressure and ensure that there are no residual gases within the system. This may require purging with medical air or OFN.
- For each terminal unit identified for removal, remove the second-fix and, where practicable, the first-fix components.
- Where possible, remove the pipeline back to the branch where the terminal unit is connected.
- Cut out the tee at the pipeline connection and replace with a straight section of pipework and straight couplings. A minimum of 300 mm of pipeline should be removed. If the tee is close to other joints, the cut may be extended to include these joints to minimise the number of joints within the system. This should be risk-assessed at the point of work and agreed between the Competent Person (MGPS) and duty Authorised Person (MGPS).
- Where an individual terminal unit is being replaced, there is no need to purge the pipeline during brazing, but where there are two or more terminal units to be removed, the system should be purged using OFN.

- Braze the system backup and undertake the full validation and verification for the system (see Chapter 15).
- Ensure a full QC test has been completed prior to returning the system to use.
- Complete all PTW documentation. Where terminal units have been removed, either fit blanks if they were installed in trunking systems or carry out wall repairs, as appropriate.
- Where pipework is inaccessible for removal, it should be cut back, leaving tails of 150 mm. Identification tape marked “decommissioned pipework” should then be fixed to the remaining tails.

Full ward or department decommissioning

16.7 The AVSU to be isolated and the terminal units to be removed should be clearly identified and recorded in the high hazard PTW:

- Ensure the area is clear and that the medical gas system to be worked on is not in use.
- Insert “Do not use” plugs in all terminal units.
- Isolate the local alarm and remove the gas service that is to be removed.
- Isolate the AVSU and deploy a spade in the AVSU downstream of the main system.
- Reinstate the local alarm.
- Drain the medical gas system to atmospheric pressure and ensure that there are no residual gases within the system. This may require purging with medical air or OFN.
- For each terminal unit identified for removal, remove the second-fix and, where practicable, the first-fix components.
- Where possible, remove the pipeline back to the branch where the terminal unit is connected.
- Where possible, remove all the carcass pipework back to the AVSU.
- Where pipework is inaccessible for removal, it should be cut back, leaving tails of 150 mm. Identification tape marked “decommissioned pipework” should then be fixed to the remaining tails.
  Where pipework remains accessible, decommissioned labels should also be affixed along its length, where appropriate.
- Trace the system backwards towards the plant, isolate and deploy spades on any valves that only feed this section, and remove interconnecting pipework.
- Once the final point of connection has been identified and isolated, all other valves downstream can now be removed.
- Fit a brazed cap to the pipeline directly downstream of the last isolated valve to protect the system in the event of a valve failure.
- Leak-test the isolated valve.
- Leave the AVSU spade in place and remove the valve handle.
- Insert NOT IN USE signage on the AVSU.
- Complete all PTW documentation. Where terminal units have been removed, either fit blanks if they were installed in trunking systems or carry out wall repairs, as appropriate.

Full system decommissioning

16.8 When a complete MGPS is to be removed in the case of nitrous oxide and surgical air, the following procedure should be followed:

- Isolate the medical gas plant alarms, remove the channel from all the alarms and remove the legend from the alarm.
- Insert “Do not use” plugs in all the terminal units.
- Isolate the local alarm and remove the gas service that is to be removed and remove the alarm legend.
- Bring the local alarm back into service.
- Isolate the supply system from the pipeline distribution system (ensure both primary and secondary systems are isolated).
- Go to the furthest location away from the plant where the gas is located.
- Drain the medical gas system to atmospheric pressure and ensure that there are no residual gases within the system. This may require purging with medical air or OFN.
- For each terminal unit identified for removal, remove the second-fix component.
- Where possible, remove the first-fix terminal unit. If this is located within a pendant, disconnect the flexible hose from the pendant. If the hose cannot be removed, the NIST connector should be securely capped. In trunking systems, where replacement trunking lids are unavailable, the open orifice should be blanked off. All associated pipework should be fully stripped out of the trunking system.
- Where possible, remove the pipeline back to the branch where the terminal unit is connected.
- Where possible, remove all the carcass pipework back to the AVSU.
- Insert NOT IN USE signage on the AVSU.
- Where pipework is inaccessible for removal, it should be cut back, leaving tails of 150 mm. Identification tape marked “decommissioned pipework” should then be fixed to the remaining tails. If the unremovable pipework is accessible, decommissioned labels should be fixed at intervals in line with the pipeline identification requirements as set out in Chapter 15.
- Trace the system backwards towards the plant and continue to strip out the accessible pipelines.
- Once all pipelines have been stripped back and labelled and all remaining pipelines have been identified and internally decommissioned as required, the plant may then be decommissioned.
- Where the supply plant is via a cylinder manifold system, the cylinders should be isolated and removed from the manifold, returned to the central cylinder store and then returned to the supplier as soon as possible. (All spare cylinders, both empty and full, should also be returned).
- Electrically isolate the manifolds and remove all electrical connections back to the distribution board.
- Strip out the manifold, racking and all associated products including signage and exhaust pipelines.
- Ensure that any pipework passing through walls is repaired and fire-stopped correctly, with records maintained for the full run of the pipeline.
- Where pipework passing through a wall has not been removed, it should be capped and brazed to maintain the fire integrity of the structure.

- Where the supply plant is from a compressor set or other supply system, this should be removed completely; dispose of all oils and other liquids correctly.
- If the plant or sections of the plant cannot be removed, disconnect all electrical supplies, remove any liquids or lubricants and strip out all connecting pipework.
- Strip down the plant and remove all removable components from the site.
- Where pressure vessels are present, remove inspection hatches and open all orifices. All connected components such as drains, gauges, pressure-relief valves and fused plugs should be removed, rendering the vessel unusable. The vessel should then be permanently marked to indicate that it has been decommissioned.
- Update the PSSR 2000 register and provide decommissioning evidence for any equipment retained on site.
- Complete all PTW documentation. Where terminal units have been removed, either fit blanks if they were installed in trunking systems or carry out wall repairs, as appropriate.

Decommissioning for demolition

16.9 Where a full healthcare facility is to be demolished, it is imperative that medical gases are decommissioned safely to ensure that there is no risk to the demolition team.

16.10 It is not essential for the pipelines to be removed prior to demolition but the following steps should be undertaken.

16.11 A full site inspection should be undertaken to ensure that there are no medical gas cylinders left on site. Medical vacuum plant should be opened and ensured that there is no risk of infection from the system.

16.12 All valves should be inspected to ensure that they are all in the fully open position to ensure there are no pockets of pressurised gases.

16.13 No demolition works are to commence until the VIE has been either fully decommissioned or removed from site.

16.14 The demolition company should be aware of any oils, lubricants or other liquids left on site so as they can be disposed of correctly.

16.15 Where the healthcare facility contains specific plant and components that may be reused in other healthcare facilities, these should be carefully removed to preserve their condition for recycling and reuse, enabling other sites to benefit from the recovered parts.

16.16 These works should still be undertaken under a PTW so that there is a fully documented procedure in place.

Note:
The removal of vacuum systems may present additional microbiological hazards and should be undertaken in accordance with routine hygiene practices (for example, covering open wounds and promptly cleansing and dressing any cuts or scratches sustained during the work). Immunisation against relevant diseases may be required; therefore, all operatives must ensure that their immunisation status is up to date. If contamination is found within the pipeline during removal, the affected pipework must be disposed of in accordance with appropriate waste management procedures.

17 Accommodation

Introduction

17.1 A risk assessment in line with the Confined Space Regulations should be undertaken for all medical gas cylinders and plant areas. Where practically possible, prior to any design sign-off, the design should ensure that these areas are not confined spaces. For guidance on how to carry out a risk assessment, see the Health and Safety Executive's (2014) 'Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice L101'.

17.2 Medical equipment or cylinder connecting equipment should not be stored within any cylinder stores.

17.3 There are two types of cylinder store:

- Main cylinders stores: where the main stock of cylinders are stored and collections and deliveries are undertaken. These are external.
- Satellite stores: a local storage area for ready-to-use cylinders in wards and departments. These are usually internal.

17.4 Where cylinders over 1.2 m in height are stored or used, a concrete floor should be provided. The wall and ceiling structure should be of a non-combustible material and be suitable for the securing of large cylinders without risk of the restraints coming adrift.

17.5 There are no specific heating requirements for satellite stores as the ambient conditions of the ward/department are generally sufficient to maintain appropriate cylinder storage temperatures. However, special attention should be given to stores containing mixed gases to ensure temperatures do not fall below 10°C.

17.6 Refer to BCGA's (2022) 'CP 44: The storage of gas cylinders' for specific requirements on construction and access.

Fire prevention

17.7 A risk assessment should be completed in accordance with HTM 05-03 Part K. Fire detection and alarm systems should be designed in accordance with HTM 05-03 Part B – 'Fire detection and alarm systems including the reduction of false alarm and unwanted fire signals'.

Ward and department accommodation

17.8 All wards and departments should have specific locations for the storage of full and empty cylinders. These locations should be identified as cylinder parking areas and satellite stores.

17.9 A dedicated storage location should be incorporated into the design of all new wards and departments and should be introduced wherever possible during refurbishments and renovations. These areas should be free from flammable materials.

17.10 Space for full and empty cylinders should be provided to allow efficient cylinder exchanges. Empty cylinders should be

replaced with full cylinders at the earliest opportunity.

17.11 The type, size and quantity of each cylinder should be agreed with the MGSG with input from the relevant department, clinical teams and fire safety advisers for each area. This should be supported by a documented risk assessment.

17.12 Local cylinders are intended for use in providing patient gas supplies where wall outlets are not available, such as in emergencies, in bathrooms, and for patient transfer within the hospital. Where cylinders are used regularly, a risk assessment should be undertaken to determine whether a pipeline system would be more appropriate and safer.

17.13 Appropriate cylinder restraints should be provided and fitted with the required signage in accordance with this HTM.

17.14 Small cylinders should be placed in cradles positioned no less than 300 mm above FFL to facilitate effective cleaning. IPC requirements should be followed.

17.15 HX, F4C and other similar-sized cylinders should be placed on suitable cylinder trolleys or restrained using cylinder supports, positioned at a height of 520–570 mm from FFL.

17.16 Cylinders exceeding 1000 mm in height should not be used in patient areas.

17.17 Accessibility should be risk-assessed to balance the need for security with the need to ensure that cylinders are readily available for use in an emergency.

17.18 Cylinders should not be stored against any heating devices such as radiators.

17.19 Lighting levels should be a minimum of 200 Lux to ensure safe storage, inspection and handling of the cylinders.

17.20 Signage should be provided to:

- identify the store location
- designate areas for empty and full cylinder storage
- display safety warnings
- provide emergency contact numbers.

17.21 Instructions on the usage of the cylinders should be posted at these locations for reference.

17.22 Safety signage should be displayed on the entrance door to the area housing the cylinders.

Theatres and critical care areas

17.23 It is essential that in the design of these areas, cylinder management is accounted for and the facilities provided for the medical gas cylinder storage is compliant and safe.

17.24 The cylinder storage area should be risk-assessed. In this environment, specific attention should be given to special gases and asphyxiant gases (for example, nitric oxide).

17.25 The type and quantity of each cylinder should be agreed with the MGSG with input from the relevant department, clinical teams and fire safety advisers for each area.

17.26 Cylinders in theatres and critical care areas provide patient gas supplies where wall outlets are not available, including for specialist equipment, connections to anaesthetic machines and ventilators, and for patient transfer within the healthcare facility.

17.27 The range of cylinder gases to be stored can be extensive and varied; therefore, clear segregation is required, both by gas type and by status (full or empty).

17.28 Appropriate cylinder restraints should be provided and fitted with the required signage in accordance with this HTM.

17.29 No flammable products should be allowed in these stores.

17.30 Small cylinders should be placed in cradles positioned no less than 300 mm above FFL to facilitate effective cleaning. IPC requirements should be followed.

17.31 C, D, CD, and E size cylinders may be stored horizontally in dedicated cylinder storage racks designed specifically for this purpose, with vertical and horizontal separation between individual cylinder.

17.32 Larger cylinders should be restrained with wall racking. HX, F4C and other similar-sized cylinders should be placed on suitable cylinder trolleys or restrained using cylinder supports, positioned at a height of 520–570 mm from FFL.

17.33 Cylinders exceeding 1000 mm in height should not be used in patient areas.

17.34 The requirement for environmental monitoring should be risk-assessed. Where installed, the alarms should be visual and audible to warn staff prior to entry of any oxygen increase or depletion.

17.35 There are no specific heating requirements for satellite stores as the ambient conditions of the department are generally sufficient to maintain a temperature above 10°C.

17.36 Excessive build-up of cylinders should not be allowed, and only cylinders within the designed racking systems should be stored within these areas.

17.37 Cylinders should not be stored against any heating devices such as radiators.

17.38 Lighting levels should be a minimum of 200 Lux to ensure safe storage, inspection and handling of the cylinders.

17.39 Signage is required to:

- identify the store location
- designate areas for empty and full cylinder storage
- display safety warnings
- provide emergency contact numbers.

17.40 Instructions on the usage of the cylinders should be posted at these locations for reference.

Main cylinder stores

17.41 It is essential that in the design of these areas, cylinder management is accounted for and the facilities provided for the medical gas cylinder storage is safe and secure.

17.42 The location of the cylinder store should be marked clearly on the site plan for ease of identification in the event of an emergency.

17.43 All medical gas cylinders stores should be located in areas where site security is highest to minimise the risk of cylinder theft.

17.44 Both CCTV and alarm systems are required for cylinder stores to provide external security. Internal CCTV is optional but recommended.

17.45 Cylinder stores should be located at ground level, with level access, and should be accessible to delivery vehicles for the safe loading and unloading of cylinders.

17.46 Rooms should be provided with double doors that open outwards, and a clear area should be maintained outside the rooms to ensure unobstructed access. Parking in front of these areas should not be permitted.

17.47 The type and quantity of each cylinder should be agreed with the MGSG with input from pharmacy and clinical teams.

17.48 Provision should be made within the design for a percentage allowance to accommodate an increase in cylinder numbers during pandemic conditions and anticipated natural growth. Sufficient racking should be included to store these additional cylinders.

17.49 Cylinders in the main store should be used for the replenishment of satellite stores, cylinder parking areas and manifold rooms.

17.50 All cylinders should be stored securely in accordance with a site-specific risk assessment (see guidance in BCGA's (2022) CP 44). Where practicable, cylinders should be secured individually to prevent movement or dislodgement. Where cylinder storage bays are used, the depth of storage should be limited so as not to inhibit the safe manoeuvring of cylinders, and the total bay width should not exceed 75% of the nominal cylinder height (see Figure 26).

17.51 Where possible, large cylinders intended for manifold rooms should be stored separately from smaller cylinders used in patient areas in order to reduce health and safety risks. The location of these stores on site should also minimise lifting and handling requirements.

17.52 Therefore, the main cylinder store for manifold gas cylinders should be located close to the manifold room, with step-free access between the two locations.

17.53 A separate main cylinder store may be required for cylinders used internally within the building to facilitate ease of access for cylinder transport into the building.

17.54 In both cases, access for delivery and collection vehicles should remain unobstructed, with flat and level access provided.

17.55 Access suitable for standard delivery vehicles is suitable for gas cylinder deliveries. A flat, level surface, or a gradual slope not exceeding five degrees, is essential to minimise manual handling risks. Steps are not permitted.

17.56 Where level access is not possible, a raised unloading area aligned with the delivery vehicle's tailgate should be provided. However, this is not the preferred method and should only be used where absolutely necessary.

17.57 The range of cylinder gases to be stored can be extensive and varied; therefore, clear segregation is required, both by gas type and by status (full or empty).

17.58 Only medical gas cylinders should be stored within a cylinder store; no industrial or other gases, equipment or other products should be stored within these areas.

17.59 A no-parking red hatched zone should be provided at the store access, with adequate warning signage to prohibit smoking and the use of naked flames in the vicinity. A minimum safety radius of 5 m around the store is recommended.

17.60 Compliant storage areas should display the following appropriate signage:

- safety signage (Hazchem notices) in accordance with the requirements of the Health & Safety (Safety Signs & Signals) Regulations 1996, the Health and Safety at Work etc. Act 1974 and BS EN ISO 7010; this should be posted within and outside any area where cylinders are stored
- a store identification notice; suitable wording may include: "Medical gas storage area – smoking, welding and naked lights prohibited"
- a store contents notice, clearly indicating the contents of the store
- a medical gas cylinder identification chart and other relevant safety warning charts, posted inside the storage area
- an "emergency actions" notice, giving details of emergency action procedures and location of keys and contact numbers, on the front of the cylinder store.

17.61 Appropriate cylinder restraints and racking should be provided.

17.62 Where asphyxiant gases are stored, environmental monitoring should be installed

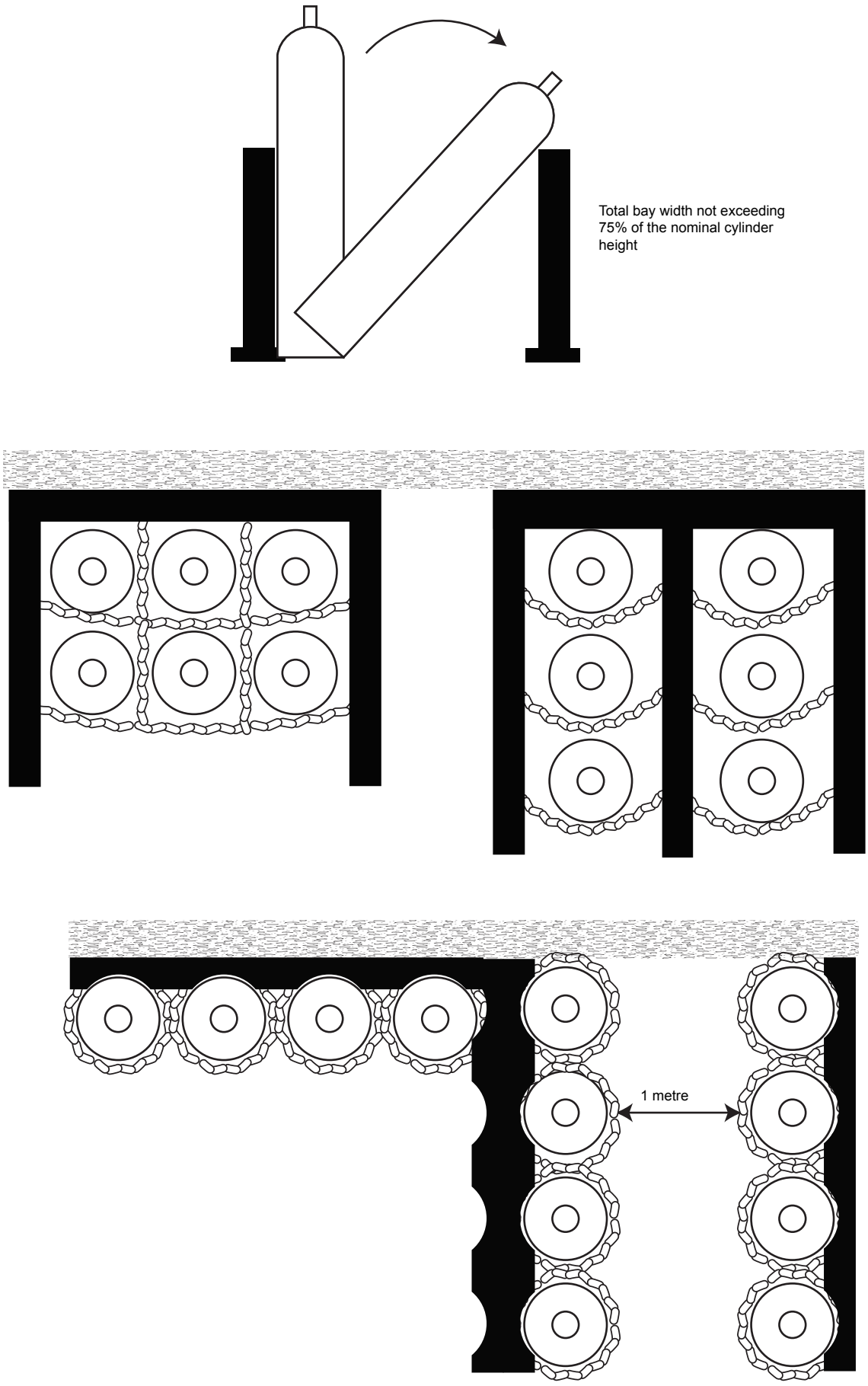


Figure 26 Example cylinder storage arrangements

with alarms to warn staff prior to entry of any oxygen increase or depletion to minimise the risk to staff.

17.63 Where specialised gases are utilised (such as nitric oxide), further risk assessments should be carried out to ensure that the storage is safe and compliant.

17.64 Cylinder inspections should be undertaken routinely to ensure that they have been correctly isolated, are not leaking, are in date and are in good condition. These inspections should be documented

17.65 There are no specific heating requirements for cylinder stores as any gases that should be kept warm prior to use will be moved to the satellite internal stores a minimum of 48 hours prior to use.

17.66 Excessive build-up of cylinders should not be allowed, and only cylinders within the designed racking systems should be stored within these areas.

17.67 Cylinders should not be stored against any heating devices such as radiators.

17.68 Cylinder stores should have an entrance that opens directly to the outside rather than an entrance from inside the building such as through corridors or other rooms.

17.69 The external area of the cylinder stores should be level and smooth without any steps or obstructions.

17.70 The internal floor of the cylinder store should be of a flat, clean, concrete construction. Floor painting is acceptable although it may wear quickly due to regular cylinder movement.

17.71 Ventilation is required to ensure that any small leakage of gas is adequately dispersed and will prevent a hazardous atmosphere being created (see BCGA's (2022) CP 44).

17.72 Ventilation louvres should be provided at both high and low level for all cylinder stores to allow circulation of air. Separated openings equivalent to at least 1.5% of the total area of the walls and floor should be provided as free air ventilation at both high and low level. For example, given a manifold room 8.0 x 6.0 x 2.6 m with a total area of the walls and floor of 124.8 m², the total free open area for ventilation required is 2 m². This would be therefore 2 m² of free air ventilation at high and low level.

17.73 Where ventilation louvres are used, the free area of the vent should be calculated, not the total area of the vent.

17.74 The siting of the vents should take into consideration the environmental risks associated with the natural surroundings and the potential of vehicles and other contamination risks.

17.75 All ventilation louvres should be designed to prevent the ingress of vermin and birds.

17.76 Signage should be provided in compliance with Chapter 18.

Manifold rooms

17.77 Cylinder gas and liquid supply systems should not be in the same room as medical air compressors, PSA systems or vacuum plant.

17.78 Medical air and medical vacuum/AGSS plant should not be located in manifold rooms.

17.79 Manifold rooms should not be used as cylinder stores.

17.80 Spare racking for cylinders should be provided for one full bank plus one cylinder only. This is to ensure that no cylinders are free-standing at any time.

Location of manifold rooms

17.81 At the design stage, a number of specific factors need to be taken into consideration

with regard to the location of manifold rooms. A risk assessment should be undertaken with specific input from the MGSG, pharmacy and estates departments.

17.82 The location of manifold rooms, including emergency and reserve manifold rooms for medical gas liquid systems, should be subject to a risk assessment and should take into account proximity to the medical gas cylinder storage area and the distribution system connection point. Where practicable, manifold rooms should be located at ground level, with level access, and be accessible to delivery vehicles for the safe loading and unloading of cylinders, with due consideration given to manual handling requirements.

17.83 Rooms should be provided with double doors that open outwards, and a clear area should be maintained outside the rooms to ensure unobstructed access. Parking in front of these areas is not permitted.

17.84 The proximity of the manifold room to the main building should be risk-assessed to ensure that the extension of pipelines into the building does not introduce unnecessary risks.

17.85 Manifold rooms should not be integral to the main building.

Access to the manifold room

17.86 Access to the manifold room has to accommodate the moving of large cylinders in and out of the room. A flat, level surface, or a gradual slope not exceeding five degrees, is essential to minimise manual handling risks. Steps are not permitted.

17.87 Two doors should be provided in a large manifold room. One should be large enough to facilitate cylinder handling and should be on an outside wall and the other should facilitate emergency escape.

17.88 Exits should be free of all obstructions. Doors should open outwards. All doors should 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).

17.89 Manifold rooms should have an entrance that opens directly to the outside rather than an entrance from inside the building such as through corridors or other rooms.

17.90 The external area of the manifold room should be level and smooth without any steps or obstructions.

17.91 A separate cylinder store may be required to house manifold cylinders away from mobile cylinders apart from the ready-for-use cylinders for the manifold.

Design and construction of manifold rooms

17.92 Manifold room size should be based on risk assessment.

17.93 Manifold rooms should have solid walls and a robust roof to prevent environmental contamination. Walls should be suitable for securely mounting cylinder manifolds and racking.

17.94 Internal walls, ceilings and any internal doors within the manifold room should be constructed from suitable non-combustible materials providing a minimum of two hours' fire resistance where practicable. Internal doors should be FD120-rated.

17.95 The internal floor should be of a flat, smooth, concrete construction. Floor painting is acceptable, although it may wear quickly due to regular cylinder movement.

17.96 Manifold rooms house the primary and secondary cylinder supplies for the MGPS. Manifold systems within these rooms comprise the ACM, any reserve manifolds and one spare bank of cylinders to replenish the main manifold. (For oxygen/nitrous oxide 50/50% manifolds, sufficient spare capacity for two banks of cylinders should be provided.)

17.97 Although the ERM for liquid oxygen systems has traditionally been located within the VIE compound, it should be sited separately to the VIE. Where this is not possible, it should be in a separate enclosed area within the plinth space and be compliant with the manifold room's construction and design.

17.98 For new installations, oxygen ERMs should be located in compliant manifold rooms either on or off the plinth with separate control panels and connections into the main pipeline supply.

17.99 Manifold rooms should have spare cylinder racking installed adjacent to each manifold to house one full bank of the manifold plus one cylinder for each manifold. This is to ensure that no cylinders at any time are free-standing.

17.100 Cylinders should have restraints to secure them to the manifold header rack and cylinder racking substantial enough to restrain the cylinders.

17.101 Spare cylinder racking should be installed at the same height as the manifold header racks.

17.102 Further replacement cylinders should be supplied from a medical gas cylinder store.

17.103 Adequate space should also be allowed for cylinder handling. There should be a minimum of 900 mm between the cylinders and other obstructions to allow free access.

17.104 All manifold rooms that store medical gas cylinders should be located in areas where site security is highest to minimise the risk of cylinder theft.

17.105 Both CCTV and alarm systems are required for cylinder stores to provide external security. Internal CCTV is optional but recommended.

17.106 Smoke detector systems must be provided.

17.107 Adequate ventilation should be provided in internally sited manifold rooms.

Layout of manifold rooms

17.108 All manifolds, including ERMs, may be located within the same room. Manifold rooms should be located on an external wall(s) to facilitate high- and low-level ventilation.

17.109 A typical automatic manifold with two duty and two standby cylinders is 1.8 m long and 0.6 m deep. One extra cylinder on each bank adds approximately 0.5 m to the overall length, so that a 2 x 6 manifold is approximately 4 m long. This should be confirmed with the manufacturer on completion of the specification and before appointment of the installer.

17.110 Double-bank cylinders should not be provided due to the inability to access the header rack for testing and the lack of ability to disconnect the rear cylinders without removing another.

17.111 Where these configurations have been installed, a risk assessment should be undertaken and a methodology for cylinder changing and maintenance should be developed.

17.112 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.

17.113 Racks should be designed along the lines of those on the manifolds, but the stored cylinders may be closer together. Racks should conform to ISO 32.

17.114 Manifold rooms should not contain gas cylinders other than those appropriate to their manifolds.

17.115 Where a mixture of gas manifolds is used within one room, the risks from all gases should be risk-assessed and precautions put in place (medical oxygen poses an oxygen

enrichment risk; carbon dioxide poses an asphyxiation risk).

17.116 Liquid nitrogen should not be stored in the same room as medical gas manifolds.

17.117 All ventilation louvres should be designed to prevent the ingress of vermin and birds.

17.118 Signage should be provided in compliance with Chapter 18.

Lighting

17.119 Manifold rooms should be provided with lighting to achieve an illumination level of 200 Lux at the point of work (for example, the control panel and cylinder manifold header rack) using bulkhead lighting fittings to BS EN 60529. An IP should be specified, although BS EN 60529 defines acceptable ranges rather a fixed value.

Plant accommodation

17.120 Plant should have all-round access for maintenance purposes with a minimum 1200 mm from other obstructions and a minimum of 900 mm between items of plant. Adequate space and access should be provided to allow for the replacement of major components, minimising manual handling risks.

17.121 A job plan and initial project method statement should be provided for any project, alongside the project risk assessment, taking into account the specific requirement for specialist lifting equipment for tasks beyond standard manual handling capabilities.

17.122 Plant siting should provide adequate airflow for pump cooling. Manufacturers should be consulted on the range of operating temperatures for which the supply system is designed. In extreme cases, refrigerator cooling may be required. Plant area temperature and humidity should be risk-assessed for ranges over the course of a year.

17.123 Plantrooms should be provided with suitable lighting appropriate to the type of equipment installed and the nature of the work undertaken in the room. Guidance on workplace lighting is provided in the Health and Safety Executive's (1997) 'HSG38: Lighting at work'.

Plantrooms

17.124 PSA and VIE plants should not be located in plantrooms but should be located externally on specifically designed plinths (see Chapter 6).

17.125 Medical air, vacuum and AGSS should be housed in weatherproof enclosures, preferably as part of the main building in purpose-built plantrooms.

17.126 The location of plantrooms should take account of the following factors:

- air intake requirements
- exhaust requirements
- access to the plant for servicing
- access for major component replacements
- clear segregation for negative and positive systems
- routes of the medical gas pipeline.

17.127 AGSS should be located in plantrooms or near the point-of-use pipeline route, ensuring that exhaust can be safely discharged to an external location.

17.128 AGSS should not be located in staff or patient areas and should be accessible for maintenance without the use of steps.

Design and construction of plantrooms

17.129 Plantrooms should be constructed from materials that provide a minimum of a two hours' fire resistance. The design and

construction should also consider noise attenuation and the reduction of vibration transfer.

17.130 Sufficient space should be provided within the plantroom to accommodate the plant layout, with a minimum of 900 mm clear space around equipment. Free and unobstructed access should be maintained to allow for maintenance and the replacement of major components.

17.131 The plantroom should be a dedicated room for the medical gas plant or be clearly segregated from other plant within this location. This is to restrict access to the plant to trained personnel only.

17.132 Flammable materials should not be stored within this area.

17.133 Internal doors should be avoided where practicable. Smoke detectors should be provided. Automatic fire suppression should be considered.

Heating and ventilation

17.134 Ventilation louvres should be provided at both high and low level. The free area of the vent should be calculated, not the total area of the vent.

17.135 Vent siting should take into account environmental conditions, including the presence of vehicles and other potential sources of contamination.

17.136 Where possible, air intakes for compressor inlets should be located externally. However, they should not be used as a substitute for providing adequate ventilation for cooling purposes.

17.137 Cooling and ventilation requirements should be determined in consultation with the compressor manufacturer or plant supplier, as volumetric calculations are specific to each installation.

17.138 All ventilation louvres should be designed to prevent the ingress of vermin and birds.

17.139 PSA and medical air compressors draw in ambient air for the production of medical breathing air. Under maximum flow conditions, they generate considerable heat. Therefore, adequate natural ventilation should be provided; where this is not practicable (for example, as in deep-plan plantrooms), mechanical ventilation should be provided.

17.140 The ambient temperature of manifold rooms and plantrooms should be maintained within the range of 10–40°C. Ventilation rates should ensure that the plantroom temperature does not exceed ambient temperature by more than 10°C.

17.141 To achieve temperature equilibration, additional heating may be required; natural ventilation should not be reduced. Where such heating is provided, it should be by indirect means (for example, steam, hot water or warm air).

17.142 Naked flames and exposed electrical elements should not be used, and excessive surface temperatures should be avoided.

17.143 Signage should be provided in compliance with Chapter 18.

Lighting

17.144 Plantrooms should be provided with a lighting level of 200 Lux at the point of work. The lighting should allow for all tasks to be undertaken safely without the use of extra task lighting. This is specifically essential between compressors where natural shadows may occur.

Pump noise

Noise control

17.145 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 dBA for each additional pump or compressor operation over and above the specified limits.

17.146 Consideration should be given to providing acoustic enclosures to reduce the free-field noise levels in noise-sensitive areas adjacent to plantrooms.

17.147 Acoustic enclosures and plantroom design should not inhibit normal cooling functions or maintenance activities.

17.148 Free-field noise levels should be provided to support the acoustic design of plantrooms.

17.149 The discharge from some vacuum pumps may require silencing.

17.150 Exhausts from electronic drains and purge valves may also require silencing as the pitch and volume of the noise may cause a nuisance.

17.151 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. Equipotential bonding should be provided on all flexible connections.

Compressor noise

17.152 Noise values for compressors should be assessed as part of the main project design. Where necessary, advice should be sought from a competent acoustician to ensure compliance with environmental and operational noise criteria.

17.153 Compressors and pumps should be mounted on appropriately selected anti-vibration mountings, where necessary, to minimise the transfer of noise and vibration to the building structure.

17.154 The noise level produced by compressors generally increases with compressor capacity. The maximum noise level for unsilenced compressed air plant at 1 m will vary depending on several factors, including the type and power of the equipment.

17.155 Acoustic treatment of the plantroom, such as acoustic lining, may be preferable to the use of individual acoustic cabinets. Where acoustic cabinets are removable, the associated noise attenuation may be lost. This potential loss of noise control should be considered as part of the design process.

Labelling/signage

17.156 Labelling for medical gas systems, equipment and accommodation should be in accordance with Chapter 18.

18 Signage requirements

Location	Wording/detail	Notes
Terminal units	Circuit A, Gas Circuit B, Gas	Dual-circuit terminal units should be identified by a circular label surrounding the terminal unit. This label should be colour-coded in accordance with the terminal unit, with gas identification at the top and circuit identification below. The label should have a minimum orifice size of 52 mm and an external diameter of 75 mm
AVSU	In an emergency break glass (or pull-out cover) and shut off valve Flow direction On/off position for handle Gas identity	Instructions for use on the glass or cover Inside the AVSU
AVSU	Gas identity Area controlled Key peg number Valve number Number of terminal units served	At the side of each AVSU door on a permanent indelible sign (traffolyte type preferred) Area controlled to be defined by the clinical nomenclature
AVSU	Area space plan drawing	Local to the AVSU set to show the rooms with medical gases graphically
Alarms	Area monitored Gas names Gas pressure Normal/Fault/Condition indicators	Alarms with multi columns monitoring separate areas should be clearly marked above all columns giving the name of the clinical area monitored
Alarms	Action required to alarm condition	Responses may be posted nearby/on the alarm digitally and/or in an extract from the MGPS operational policy kept locally
LVs & LVAs	Gas identity Flow direction	On pipeline within 1 m each direction
LVs & LVAs	Gas identity Valve number Key peg number	Strapped to valve on a permanent indelible sign (traffolyte type preferred)

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Location	Wording/detail	Notes
Ward cylinder signage	Medical gas cylinder parking area Compressed gases Danger no smoking Support combustion or asphyxiant Wash, rinse dry hands Do not use alcohol gels, hand creams or oil-based products while using medical cylinders Staff should be trained in the safe use and handling of medical gas cylinders Tel no: Pharmacy or porters	Gas hazard warnings and symbols Basic safety instructions for staff with symbols Notice for staff to be trained Phone number should be the internal site used by clinical staff to request cylinder replacements
Ready to use store	Medical gas cylinder ready to use store No unauthorised entry, keep door clear Secure cylinders Danger no smoking Danger compressed gas Support combustion or asphyxiant Wash, rinse dry hands Do not use alcohol gels, hand creams or oil-based products while using medical cylinders Staff should be trained in the safe use and handling of medical gas cylinders Tel no: Pharmacy or porters Emergency tel no: Estates	Both outside on entry and inside Make sure cylinders are secure at all times Gas hazard warnings and symbols Basic safety instructions for staff with symbols Notice for staff to be trained Tel no: Should be the internal site used by clinical staff to request cylinders replacement. Emergency tel no: Estates or facilities to report issues with the racking or incidents
Main Cylinder Store	Medical gases cylinder store Danger no smoking Danger compressed gas Warning oxidising/asphyxiant gas No unauthorised entry No parking/Keep doors clear, keep locked Approved personal protective equipment should be worn Gas identification Tel no: Pharmacy and porters Emergency tel no: Gas suppliers & Estates	External on all entry doors

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Location	Wording/detail	Notes
Main cylinder store	Medical gases cylinder store Danger no smoking Danger compressed gas Warning oxidising/asphyxiant gas Approved personal protective equipment should be worn Secure cylinders Full cylinders Empty cylinders Gas identification Cylinder chart Tel no: Pharmacy and porters Emergency tel no: Gas suppliers & Estates Emergency exit keep clear	Internal
Liquid oxygen compound	Medical gas liquid oxygen compound Danger no smoking Danger compressed gas Danger oxygen oxidising agent No unauthorised entry, keep locked No parking, keep clear Approved personal protective equipment should be worn Valve open/closed P&ID IFU Instructions for de-icing Emergency tel no: Gas supplier and Estates Tel no: Pharmacy and porters	Posted on all accessible sides of the compound. Pipeline and instrumentation diagram (P&ID) with instructions for use (IFU) to be hospital-specific inside near valve arrangements
Manifold room	Medical gases manifold room Danger no smoking Danger compressed gas Warning oxidising/asphyxiant gas (as required) Gas identification No unauthorised entry, Keep locked No parking, keep clear Approved personal protective equipment should be worn Tel no: Pharmacy and porters Emergency Tel no: Gas suppliers and Estates	External

Continued on next page

Location	Wording/detail	Notes
Manifold room	Medical gases manifold room Danger no smoking Danger compressed gas Warning oxidising/asphyxiant gas (as required) Gases identification Approved personal protective equipment should be worn Primary manifold or ERM Valve open/closed on ERM Secure cylinders Tel no: Pharmacy and porters Emergency tel no: Gas suppliers and Estates	Internal
Air plantroom	Medical/surgical compressed air plantroom No parking, keep clear No unauthorised entry, Keep locked PTW should be used Noise hazard (+ ear defender symbol) Medical air intake. Do not obstruct Emergency tel no: Estates	External
Air plantroom	Medical/surgical compressed air plantroom PTW should be used Noise hazard (+ ear defender symbol) Plant is connected to essential electricity supply Electric shock hazard Danger 415 volts Danger 240 volts Danger rotating machines Warning: These machines stop and start automatically without warning Emergency tel no: Estates	Internal
Vacuum plantroom	Medical vacuum plantroom No parking, keep clear No unauthorised entry, Keep locked PTW should be used Noise hazard (+ ear defender symbol) Emergency tel no: Estates	External

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Location	Wording/detail	Notes
	Medical vacuum plantroom PTW should be used Noise hazard (+ ear defender symbol) Plant is connected to essential electricity supply Electric shock hazard Danger 415 volts Danger 240 volts Danger rotating machines Warning: These machines stop and start automatically without warning Biological symbol Emergency tel no: Estates	Internal
AGSS plantroom	Medical AGSS plantroom No parking, keep clear No unauthorised entry, Keep locked PTW should be used Noise hazard (+ ear defender symbol) Noxious and toxic gas symbol Emergency tel no: Estates	External
	Medical AGSS plantroom PTW should be used Noise hazard (+ ear defender symbol) Plant is connected to essential electricity supply Electric shock hazard Danger 415 volts Danger 240 volts Danger rotating machines Warning: These machines stop and start automatically without warning Noxious and toxic gas symbol Emergency tel no: Estates	Internal
Pipework	Gas identification Gas direction Ring main	
Work in progress	Maintenance in progress Medical gas test area Hot work in progress Danger high pressure test in progress Danger nitrogen purging in progress Danger elevated oxygen levels purging in progress Confined space	These signs should be posted during installation/ modification/maintenance and testing of an MGPS. Multiple signs may be required.

19 Engineering validation and verification

19.1 This chapter covers the validation and verification of the installation, repair and modification of an MGPS. It describes the required tests, the methodologies for carrying them out and the equipment needed.

19.2 Validation and verification are required to ensure a safe and compliant system, and should start at the design stage, continuing through to final handover to clinical staff for patient use.

19.3 All steps should be followed and documented to ensure system safety and compliance.

19.4 Responsibility for overseeing these processes rests with the Authorising Engineer (MGPS), Authorised Person (MGPS) and Quality Controller (MGPS), who should be independent of each other and be independent of the installation and contractor organisations. They should be formally appointed by the healthcare organisation in the contract documentation before the project commences.

19.5 Engineering validation and verification should be undertaken only by contractors registered to BS EN ISO 9001, with a scope of registration that includes testing and commissioning of piped medical gas systems. QC testing should be carried out by a Quality Controller (MGPS) appointed to the Quality Controller (MGPS) register. (The UK register is maintained by the UK Medical Gas Group under the auspices of the NHS Pharmaceutical Quality Assurance Committee (see HTM 02-01 Part B).)

19.6 Engineers undertaking the tests should hold, as a minimum, the qualification of Competent Person (MGPS). The tests should be witnessed by those identified in Table 29.

19.7 The contractor should provide all calibrated test equipment required for engineering tests.

19.8 The Quality Controller (MGPS) should provide calibrated test equipment for the quality tests.

19.9 Calibration certificates should be provided for all test equipment.

19.10 Tests are listed in Table 29.

19.11 The objective of testing and commissioning is to ensure that all the necessary safety and performance requirements of the MGPS are met, tested in full, witnessed and documented.

19.12 Testing and commissioning procedures are required for installation works including, but not limited to, new installations, additions to existing installations and modifications to existing installations.

19.13 The Authorising Engineer (MGPS), Authorised Person (MGPS) and Quality Controller (MGPS) should be given free access to the system throughout the works for

inspections and tests. This should be clearly identified in the contractual documentation prior to project commencement.

19.14 A method statement should be produced for the order of testing and be agreed with the Authorised Person (MGPS) prior to these tests being carried out. The method statement should be attached to the B-forms (see Table 29) as part of the commissioning package.

19.15 The scope of work will dictate the specific test programme required. The required tests should be recorded on form B0, and only the relevant B-forms should be completed and submitted to support testing and commissioning.

19.16 The PTW system should always be followed whenever any work is carried out on an existing system. The Authorising Engineer (MGPS), Quality Controller (MGPS) and Authorised Person (MGPS) should act on behalf of the healthcare organisation and should not be members of the installation contractor's staff.

19.17 For new installations, a PTW should be raised for system commissioning to provide an auditable trail.

19.18 For modifications or extensions, it is advisable, where practicable, to test both the existing and new systems separately prior to connection.

19.19 Existing systems should, if possible, be tested to determine their performance and to identify any potential limitations that may arise as a result of modifications.

19.20 Where there is any doubt regarding cleanliness, particulate tests should be carried out on the existing system prior to connection. This is in the interest of both the contractor and management. The healthcare organisation should ensure that such tests are carried out prior to the design phase of any modifications or extensions.

19.21 It is the responsibility of the healthcare organisation's management team to ensure that any required remedial work is carried out on an existing system before extensions are added.

19.22 A PTW should be issued if additional works are to be carried out during commissioning, regardless of whether one was issued for the original commissioning.

19.23 For modifications and extensions, all work should be carried out under an inert gas shield. A physical separation should be maintained between the pipeline being modified or extended and the live system, typically by the use of "spades" in AVSUs and LVAs or by creating a physical break.

19.24 "Do not use" plugs should be installed in all terminal units affected by the works prior to any isolation works.

19.25 For small extensions comprising fewer than ten brazed joints per gas service, all tests may be carried out using the working gas, with the carcass pressure test replaced by a system leakage test of the complete extension.

19.26 An extension comprising more than ten joints 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 should be tested at pipeline distribution pressure.

19.27 For the purpose of ascertaining the number of joints, a straight coupling should be considered as two joints and a tee as three joints.

19.28 The programme of tests should be divided into four phases:

a. pre-commission tests and checks

b. tests and checks on the pipeline carcass

c. tests and commissioning of the complete pipeline system (with second-fix terminal units installed) for safety,

performance and particulate contamination using test gas

d. the identity, quality and purity tests by the Quality Controller (MGPS) on the medical gases prior to handover to clinical staff.

19.29 Following the engineering tests, systems that are not to be handed over to the clinical team within 12 weeks should be filled with medical air and maintained at 50% of the standard system pressure awaiting the QC testing.

19.30 They should be filled with medical air from cylinders or a fully QC-tested and certificated compressor plant. Pipelines that have over 40% oxygen concentration should only be filled from cylinders to avoid any oil within the system.

19.31 "Do not use" plugs should remain in the terminal units until such time as all QC testing has been completed and the system is ready for handover to clinical staff.

19.32 Filling and commissioning of liquid supply systems too long in advance of handover should be avoided. (Under "no flow" conditions, liquid will evaporate and oxygen will blow off to atmosphere.)

19.33 Test equipment needed for these tests is listed in Table 29 together with the test requirements.

19.34 The particulate contamination test for all pipeline systems may be checked using medical air or OFN to establish that the pipeline has been constructed correctly and is not contaminated. This should be undertaken in two stages:

- The test is first carried out by the Competent Person (MGPS) on completion of the system pressure test to ensure that the pipeline is not contaminated and further works are not required on the system prior to the commencement of the testing. This also ensures that all the medical gas calibrated test equipment is protected from contamination due to particulate matter in the pipelines.
- The test is then repeated by the Quality Controller (MGPS) during QC testing.

19.35 Successful completion of all commissioning tests and B-forms normally marks the end of installation of the medical gas system; however, this may not coincide with handover to the clinical team. Therefore, all "Do not use" plugs should remain fitted to terminal units until clinical handover. If this is to be for a period greater than two weeks but less than 12 weeks, a purging regime should be implemented and agreement with the Quality Controller (MGPS) should be sought to determine whether further QC tests will be required to be performed prior to handover.

19.36 During this period, the system should be left charged with working gas under pressure.

19.37 Responsibility for the system – from completion of QC testing to final handover – should be clearly defined in the contract, including the point at which day-to-day management transfers to the Authorised Person (MGPS).

Tests	Form	Persons required				
		MCR	CP	AP	QC	AE
Record documentation:						
Record of tests	B0	Yes	Yes	Yes	Yes	Yes
Pre-commissioning requirements:						
Design signed off by the MGSG	B1	-	-	Yes	Yes	Yes
Carcass tests:						
Brazing inspection	B2	-	Yes	Yes	-	-
Snagging and interim inspections	B3	Yes	Yes	Yes	-	-
Labelling and marking, sleeving and supports	B4	Yes	Yes	Yes	-	-
Carcass pressure test	B5	Yes	Yes	Yes	-	-
Verification of drawings	B6	Yes	Yes	Yes	-	Yes
HTM compliance	B7	Yes	Yes	Yes	-	Yes
Supply system tests:						
Plant room compliance	B8a	-	Yes	Yes	-	-
Manifold room compliance	B8b	-	Yes	Yes	-	-
Cylinder stores compliance	B8c	-	Yes	Yes	-	-
Air plant	B9	-	Yes	Yes	-	-
Pressure-reducing stations	B10	-	Yes	Yes	-	-
Vacuum plant	B11	-	Yes	Yes	-	-
AGSS plant	B12	-	Yes	Yes	-	-
Manifold systems	B13	-	Yes	Yes	-	-
Liquid systems	B14	-	Yes	Yes	-	-
PSSR 2000 documentation	B15	-	Yes	Yes	-	Yes
Pipeline tests:						
Second-fix items installed	B16	-	Yes	Yes	-	-
“Do not use” plugs installed	B17	-	Yes	Yes	-	-
Pipeline pressure test	B18	-	Yes	Yes	-	-
Vacuum leakage test	B19	-	Yes	Yes	-	-
Engineer’s particulate test	B20	-	Yes	Yes	-	-
Cross-connection test	B21	-	Yes	Yes	-	-
LVA zoning, closure, identity and gas specificity test	B22	-	Yes	Yes	-	-
AVSU zoning, closure, identity, gas specificity test	B23	-	Yes	Yes	-	-

Tests	Form	Persons required				
		MCR	CP	AP	QC	AE
Terminal unit tests	B24	-	Yes	Yes	-	-
Purging and filling of the system	B25	-	Yes	Yes	-	-
Design flow performance tests	B26	-	Yes	Yes	-	-
Plant alarm tests	B27	-	Yes	Yes	-	-
Local alarm tests	B28	-	Yes	Yes	-	-
QC tests:						
Particulate test	B29	-	-	Yes	Yes	-
Identity and quality	B30	-	-	Yes	Yes	-
Completion documentation:						
Key register	B31	-	Yes	Yes	-	-
“Do not use” plugs removed	B32	-	Yes	Yes	Yes	-
Completion certificate	B33	Yes	Yes	Yes	Yes	Yes
Key personnel:						
Mechanical contractor’s representative = MCR						
Competent Person (MGPS) = CP						
Authorised Person (MGPS) = AP						
Quality Controller (MGPS) = QC						
Authorising Engineer (MGPS) = AE						

Table 29 Personnel and tests

Documentation

19.38 B-forms may electronic or paper-based.

19.39 Where an electronic format is to be used, a traceability system incorporating date stamps and electronic signatures should be in place.

19.40 Where a paper format is to be used, completed forms should be scanned in full and included in both paper and electronic formats as part of the handover procedure.

Summary of tests

19.41 All testing should be recorded on the relevant B-form or an equivalent format provided by the installation company. The list below provides a summary of the required tests; detailed procedures are outlined later in this chapter.

19.42 All components should be tested – batch or sample testing should not be permitted.

19.43 Engineering tests should be undertaken by the Competent Person (MGPS) and witnessed by the relevant personnel (see Table 29).

19.44 All QC tests should be undertaken by the Quality Controller (MGPS) and witnessed by the relevant personnel (see Table 29).

B-form overview

Sample B-forms are provided in Appendix A for reference only. Editable Excel versions are available from the HTM web page and may be completed electronically with site-specific information.

19.45 Form B0 is the record of tests undertaken on the installation. It should clearly indicate which tests have been completed and identify any tests not carried out, along with the reason (for example, not applicable to the installation).

19.46 Form B1 records design sign-off and any derogations from this HTM. It confirms that the system has been validated against the approved specification.

19.47 Form B2 records the number of joints cut out and longitudinally sectioned for inspection. It should include the date of removal, approximate location of each joint within the system, gas type, size of pipework, type of fitting or penetration, and assessment of cleanliness. The form also records the dates of interim site inspections and includes copies of any snagging sheets issued during the installation phase.

19.48 Form B3 is the record for interim inspections and snagging during the installation phase of the work.

19.49 Form B4 comprises visual checks of pipeline labelling, colour-coding, sleeving and supports. Where fire-stopping is present, the sleeving must be visible on both sides of the penetration. These inspections should be completed following the installation of the pipeline carcass but before the concealment of any pipework within walls or ceilings.

19.50 Form B5 records the pressure test on the pipeline carcass. The test is carried out at 2.5 times the system's normal working pressure to verify the integrity of the installation and confirm that no leakage is present.

19.51 Form B6 documents the verification of the as-fitted drawings. This verification may be undertaken during the site inspections for the B3 and B4 works. Its purpose is to ensure that the drawings accurately represent the installed pipeline system. A copy of the approved as-fitted drawings should be issued to the Quality Controller (MGPS) at this stage to enable preparation of the appropriate test protocol for the system.

19.52 Form B7 is used to record any known non-compliances with the specification, drawings and this HTM. It serves to confirm that a compliant system has been installed and that any variations have been approved to ensure a safe and functional system is being presented for testing.

19.53 Forms B8a, B8b and B8c are used to record the inspections of plantrooms, manifold rooms and cylinder stores, respectively.

19.54 Form B9 records the supply system engineering tests for medical, surgical and dental air plant. These tests confirm that the systems operate and function correctly and that all necessary components (such as oil–water separators) are in place.

Note:
At this stage, the air quality QC test of the system may need to be carried out so that the system can be used for purging, testing or filling. These tests will be repeated during the final verification testing by the Quality Controller (MGPS).

19.55 Form B10 is used to record tests carried out on a PRS. It should be used for all PRS installations within the system, irrespective of location.

19.56 Form B11 records the supply system test for medical vacuum and dental vacuum systems. These tests confirm the correct operation and functionality of the vacuum plant. Once the plant has been commissioned, it may be used for subsequent vacuum testing.

19.57 Form B12 covers the testing and commissioning of the AGSS. This should follow the procedures set out in paragraphs 19.163–19.175.

19.58 Form B13 covers the manifold testing of all cylinder-supplied gases and secondary and tertiary supplies. This test confirms the functionality and operation of the manifolds and associated equipment. Medical gas cylinders should be available on site for this test; therefore, manifold rooms and cylinder stores should be fully completed prior to testing.

19.59 Form B14 records the witnessing of the supplier's testing of the liquid oxygen or nitrogen systems. This test may be deferred to a later stage of the project due to the complexities associated with filling the systems at this point. However, results should still be recorded on form B14. It is not uncommon for this test to be undertaken after form B28 but it should be completed prior to form B29, which marks the commencement of QC testing.

19.60 Form B15 records compliance with the PSSR requirements for the system. It ensures that a WSE is in place and that all relevant components are certified and have been inspected. The five-year validity period begins from the date of testing indicated on the certificate, not from the date the equipment is brought into use. This should be checked to ensure the maximum permitted service life remains for all applicable components.

19.61 Form B16 records the commencement of pipeline testing. It confirms that all second-fix terminal units and other components such as pressure transducers have been installed, and documents the quantities installed for each medical gas, by area.

19.62 Form B17 is to confirm that "Do not use" plugs have been inserted into all second-fix terminal units. This measure is essential to prevent the connection of medical equipment to an untested pipeline system, thereby avoiding potential contamination and associated patient safety risks.

19.63 Form B18 is the pipeline pressure test. This test should be carried out on all medical gas systems. It should be performed at the normal system working pressure for positive pressure systems and at 200 kPa for all negative pressure systems.

19.64 Form B19 is the medical vacuum negative pressure test. This test is undertaken to verify that all components within the vacuum pipeline system maintain integrity under negative pressure conditions and that no leakage occurs.

19.65 Form B20 is the engineer's particulate test. This test should be undertaken by Competent Persons (MGPS) to confirm that no particulate matter is present within the pipeline. It should identify inadequately purged pipelines or any debris that may have entered the system. This test is essential and should be completed prior to the connection of any calibrated test equipment to prevent potential damage to the equipment.

19.66 Form B21 is the cross-connection test. This test confirms that each terminal unit is supplied only by the correct pipeline and is connected through the appropriate valves.

19.67 Form B22 covers the full testing of LVs and LVAs. It includes the following:

- valve closure test: to ensure the valve achieves a full seal and does not permit gas to pass when in the closed condition
- zoning test: to confirm that each valve or assembly isolates only those terminal units it is intended to control
- NIST test: to verify that all NIST connectors are correctly installed, gas-specific and lockable
- identification and signage inspection: to ensure that all valves and assemblies are correctly identified and labelled.

19.68 Form B23 records the complete testing of AVSUs. It includes the following:

- valve closure test: to confirm that the valve achieves a full seal in the closed condition
- zoning test: to confirm that the valve isolates only those terminal units or zones it is intended to control
- NIST test: to verify that all NIST connectors are correctly installed and gas-specific, and the NIST nuts are in place
- identification and signage inspection: to ensure that the valve is correctly identified and labelled
- schematic drawing verification: to confirm that the schematic drawing is correct, corresponds to the installed system and is available on-site
- overall condition and functionality: to confirm the general condition and operation of the AVSU.

19.69 Form B24 covers the testing of individual terminal units. This verifies that:

- the terminal unit is gas-specific
- the terminal unit resists rotational movement and securely retains the appropriate probe
- the terminal unit is correctly labelled including clear circuit identification
- full functional tests have been carried out.

19.70 Form B25 records the purging and filling of the pipeline. This may be witnessed by the Quality Controller (MGPS) as well as the Authorised Person (MGPS) and Competent Person (MGPS), as it involves the introduction of medicinal gases into the pipeline.

19.71 Form B26 is the design flow performance test. This is required for all installations where additions and modifications have been made to the system.

- The flow test should be conducted from the first point of isolation through to all terminal units and NIST terminations within the modified section.
- In the case of a new-build hospital or stand-alone wing with independent plant, the test should also include the plant performance
- For smaller additions, such as modifications to a single ward, the test should begin from the last system isolation valve upstream of the modified area and be conducted at the specified design flow.

19.72 Form B27 is the plant alarm test. This test ensures that all functions of the alarm operate correctly and that faults are correctly identified on the alarm and mirrored on any remote monitoring systems. This should also check the backup battery and the identification of alarms.

19.73 Form B28 covers the local alarm test. This test confirms that all functions of the alarm operate correctly and that pressure faults are correctly identified on the alarm. This should also check the backup battery and the identification of alarms.

19.74 Form B29 is the Quality Controller (MGPS) particulate testing record. This test is carried out using the working gas to assess particulate levels. It does not remove the requirement for the engineering particulate test, which ensures the pipeline is clean and suitable for subsequent Quality Controller (MGPS) testing.

19.75 Form B30 is the Quality Controller's (MGPS) record of testing. This form documents the full set of quality control tests carried out on all medical gases (except vacuum and AGSS) to confirm compliance with the relevant monographs of the British Pharmacopoeia for each individual gas.

Testing should be carried out at all terminal units, supply points and plant. The format of this form will be determined by the Quality Controller (MGPS). Results from form B29 should be used to support this form and recorded accordingly.

19.76 Form B31 is used to record the verification of all medical gas keys. This includes keys for all valves, AVSUs and NISTs.

19.77 Form B32 is the record for the removal of the "Do not use" plugs from the terminal units and this should be undertaken when all testing and commissioning has been completed and the system is ready for handover to the clinical team.

19.78 Form B33 is the completion of the works certificate.

General requirements for testing

19.79 The tests described in this HTM 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 should be taken, however, to ensure that the basic principles are followed and all relevant B-forms are completed.

19.80 No system should be modified during the process of testing. It is important that any modifications are documented and that any additional testing required, as a consequence of those modifications, is performed.

19.81 The results of all tests should be recorded on B-forms and form part of the healthcare organisation's permanent records.

19.82 All signatories should be provided with copies of the test forms. The procedure for filing and retaining these forms should be included in the local MGPS operational policy.

19.83 All errors found during testing should be rectified, and the relevant systems should be retested as appropriate. New B-forms should then be produced as a record of the new tests. All failed B-form test records should be retained as part of the B-form documentation pack.

19.84 The contractor (MGPS) should provide all B-forms, labour, materials, instruments and test equipment that are needed to carry out the tests described in this chapter.

19.85 For engineering tests, this should include all test gas cylinders along with the required calibrated medical gas testing equipment. This includes NIST connectors, terminal unit probes, pressure-measuring equipment, gas specificity and flow pressure testing device(s), metered leak apparatus and AGSS test equipment.

19.86 The Quality Controller (MGPS) is responsible for supplying all calibrated test equipment and connections.

Carcass testing

Joint inspections

19.87 Periodic inspections should be carried out during the installation, with joints identified for removal and inspection. These inspections should follow a rolling programme based on a pre-agreed timescale and should be undertaken as work progresses. Each installation team should be subject to this process, which should be carried out in accordance with the procedures outlined below:

- The Authorised Person (MGPS) should identify a number of fittings to be cut out for examination in order to establish the quality of the finished joint. The exact number to be cut out will vary with the size of the installation: as a guide, a ratio of one fitting per 200 should be removed; a minimum of ten for all systems should be cut out for examination (it is preferable to perform

these checks before pressure-testing sections of pipeline).

- Joints should be cut longitudinally along their full length and filed flat to allow inspection of the brazing alloy penetration within the joint. Where unacceptable joints are identified, adjacent fittings should be removed until the full extent of any defective workmanship has been established. Once acceptable joints are found, a minimum of two further joints in all directions should be removed and inspected. This process may necessitate extensive removal of sections of the installation.

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 should be three times the wall thickness of the tube or 3 mm, whichever is the greater.
- The pipe should be fully inserted up to the shoulder of the fitting.

19.88 Internal cleanliness should also be inspected, and all these tests should be documented on form B2 including the gas, location type of joint and pipe size

19.89 Snagging of the installation should be undertaken and recorded on form B3.

Labelling and marking, sleeving and supports

19.90 A full system inspection should be undertaken prior to the concealing of any compartments or enclosures containing the pipeline to ensure that labelling and marking has been completed in line with paragraph 19.49.

19.91 Periodic inspections should be made during the installation and documented.

19.92 Special attention should be paid to flow direction arrows, especially on ring mains, dual circuits and flow loops where double arrows are required. Where dual circuits are installed, each circuit's identification should be clearly identified on the pipeline corresponding to the AVSUs and terminal units' identification.

19.93 Supports should be checked for compliance and security, including the operation of the valves, to ensure that they are adequate to retain the valve during operation without undue stress on the pipeline.

19.94 Valves should be capable of operation by applying force to the valve handle only. Operation should not cause stress or flexing of the pipeline in any direction.

19.95 All sleeving should be visible for a minimum of 50 mm on either side of partitions and walls, clear of the fire-stopping. This space between the sleeve and the pipeline should be separately fire-stopped.

19.96 All fire-stopping should be undertaken by a third-party accredited contractor (see HTM 05-02 – 'Guidance in support of functional provisions (Fire safety in the design of healthcare premises)').

19.97 During all visual tests (label marking, sleeving and supports), a visual inspection should be undertaken for cross-connection of pipework.

19.98 These inspections should be recorded on form B4.

Carcass pressure testing

19.99 The aim of this test is to establish that there is no leakage from the piped medical gas system, using electronic pressure-measuring equipment with a minimum resolution of 0.01 kPa in 10,000 kPa and 0.05 kPa in 20,000 kPa.

19.100 This test should be carried out with AVSUs, LVAs and other service valves open; any safety valves and pressure-sensing devices installed may be removed and the connections blanked off.

19.101 During a test period of a minimum of two hours, (once the system has been filled and settled) the maximum pressure loss should be less than 0.2 kPa for 400 kPa systems and vacuum, and 0.5 kPa for 700 kPa systems.

19.102 No allowance should be made for pressure variation due to temperature during the two-hour test period. If there is any doubt about the accuracy of the pressure-measuring equipment, the test period should be extended to 24 hours.

19.103 Table 30 details the test pressures required for carcass pipeline testing.

19.104 The carcass pressure test should incorporate a physical break between the system under test and any adjoining systems. The practice of combining multiple systems for a single test should not be permitted as it may lead to complications at later stages and introduces a risk of cross-contamination between pipeline systems.

Medical gas	Nominal pressure (kPa except where shown)	Carcass test pressure (kPa)
O_2	400	1000
N_2O	400	1000
O_2/N_2O	400	1000
MA4	400	1000
SA7	700	1800
DA6	600	1500
Vacuum	650 mmHG	500
Dental vacuum	450 mmHG	200
COm	400	1000
AGSS	200 mmHG	500

Table 30 Required pressures for carcass testing

19.105 Only carcass components (first fix) should be included within the system; terminal units, pressure switches, pressure safety valves and other ancillary equipment should be excluded.

19.106 A PRS within the pipeline should be treated as a second-fix component.

19.107 Digital gauges should be used for this test (if analogue gauges are to be used, a minimum of 100 mm gauge should be used for a 24-hour period). The test gauges should be connected via a NIST connection into the system and have calibrated gauges fitted. These remain in place during the pressure test.

19.108 The test gauge should have a connection for a pressure hose to be connected to allow for the system to be filled.

19.109 When the system is being filled via cylinders, the cylinders should be removed from the area once the system has been filled and settled, and prior to the commencement of the testing.

19.110 The tests should be performed with nitrogen, since – in the event of a leak or cross-connection – remedial action can be taken immediately.

19.111 Where medical air from compressors is to be used, it is important not to introduce a compressor until all QC tests have taken place on the compressed air system and passed.

19.112 Portable non-medical air compressors should not be used. Not only should a Quality Controller (MGPS) check all compressors before use, but also QC checks during use are important. An inline dew-point meter should be fitted to the plant or pipeline system.

19.113 When employing compressors for this type of test, the system demand should not exceed the maximum flow capacity of the dryers, otherwise wet air will result. The total flow required by the system under test should

not be more than 75% of the flow capacity of the dryers.

19.114 Such a compressor system may also be used for the single-point performance tests and for initial purging and particulate testing of these systems.

19.115 The system should be filled to the required pressure and left until stabilised.

19.116 The system should then be left on test for two to 24 hours depending on the agreed testing methodology. This will vary depending on system volume and atmospheric changes.

19.117 Once the test has been completed and passed, the pressure should be reduced to a maximum of 25% of the test pressure.

19.118 These tests should be recorded on form B5.

Gas pressure variation with temperature

19.119 The following calculations should only be used on a 24-hour test where there are large changes of temperature between the start time and finish time of the pressure testing.

19.120 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.

19.121 Pressure changes due to temperature differences may be calculated using the gas laws, namely Charles's law and Boyle's law.

19.122 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

19.123 The change in gas pressure with temperature is as follows:

$$P_1/T_2 = P_2/T_1$$

where:

P_1 = the initial absolute pressure of a fixed volume of gas

P_2 = the final absolute pressure of a fixed volume of gas

T_1 = the initial absolute temperature

T_2 = the final absolute temperature.

Therefore:

$$P_2 = (P_1 \times T_2)/T_1. \qquad (1)$$

19.124 Care should be taken to express pressure and temperature in absolute values.

19.125 Pressure is normally expressed in "gauge" pressure: Absolute pressure = gauge pressure + atmospheric pressure.

19.126 Temperature is normally expressed in °C.

Examples

19.127 The carcass of a medical air pipeline is tested for leakage at a working pressure of 14 bar pressure. The temperature is 13°C at the beginning of the test and 17°C at the end of the test:

$P_1 = 14 + 1.0 = 15$ bar

$T_1 = 273 + 13 = 286$ K

$T_2 = 273 + 17 = 290$ K.

19.128 Therefore, using Equation (1):

$P_2 = (15 \times 290)/286$

= 15.21 bar (absolute pressure)

= 14.21 bar (gauge pressure).

19.129 That is, gauge pressure should read 14.21 bar at the end of the test, assuming that no leakage has occurred.

Verification of drawings

19.130 As-fitted drawings should be verified against the actual fitted pipeline to ensure that they are a true representation of the installation and that they can be used to trace the pipelines at a future date.

19.131 They should include the pipe diameters and valve numbering.

19.132 These checks can be undertaken as part of the inspections for labelling and marking, sleeving and supports. Any changes should be noted on the drawings for rectification. It is essential to get the drawings verified prior to the closure of any walls or compartments where access would not be possible at a later date.

19.133 On completion of the verification of the drawings, a full set of drawings should be forwarded to the Quality Controller (MGPS) to enable them to produce their test regime and plan the works. This will also allow the Quality Controller (MGPS) to familiarise themselves with the system prior to the commencement of their testing and identify end of runs and specific areas where they may require extra testing.

19.134 This inspection should be recorded on form B6.

Compliance with HTM 02-01

19.135 The MGPS should be inspected to confirm compliance with the approved design, the requirements of this HTM, the works undertaken under forms B1 to B6 and the verified as-fitted drawings recorded on form B6. The outcome of the inspection should be recorded on form B7.

19.136 The purpose of this inspection is to confirm that the pipeline has been correctly sized and installed in accordance with the approved design and verified as-fitted drawings.

Plant, manifold and cylinder store compliance

19.137 All plantrooms housing medical gas plant should be inspected for compliance with this HTM. Access to the plant and adequate free space around it should be inspected and checked. This visual check should be documented on form B8a and should include the location, security, signage, cleanliness, lighting and ventilation of the area. See Chapter 17 for further guidance.

19.138 All manifold rooms should be inspected for compliance with this HTM and the inspection should be recorded on form B8b. See Chapter 17 for further guidance.

19.139 All cylinder stores, including the main store and any satellite stores, should be inspected for compliance with this HTM. Stores should be checked to confirm that they are appropriately sized to accommodate the prescribed quantity of cylinders and that adequate cylinder racking is provided. Where inspection cannot be completed due to the stage of construction, this should be undertaken on completion of the works. The results of the inspection should be recorded on form B8c.

Supply system tests

Air plant

19.140 Air plant includes medical, surgical and dental air plants.

19.141 These plants should have the full systems inspected and checked for function and controls.

19.142 The filtration systems should be inspected as well as the sequencing of the pumps and dryer systems.

19.143 It should be demonstrated that the automatic change from primary to secondary source of supply is seamless and without manual interaction.

19.144 Each plant should be tested through full cycles, demonstrating the functions of the plant are correct and in line with the manufacturer's specifications.

19.145 A full maintenance test, check and examination should be undertaken as part of the validation and verification.

19.146 A visual inspection of the plant is required to ensure that all specifications have been met. Where oil-cooled or lubricated compressors are used, an oil–water separator system must be in place. This must be inspected for compliance and operation.

19.147 These tests and inspections should be recorded on form B9.

Pressure-reducing stations

19.148 PRS installations should be tested to verify inlet and outlet pressures, automatic changeover on depressurisation of the duty regulator, valve positions, the correct discharge of safety valves to a safe location, full functional operation and alarm performance.

19.149 PRS signage and system identification should also be inspected.

19.150 The results of these tests and inspections should be recorded on form B10.

Vacuum plant

19.151 Vacuum plant should be inspected and checked for function and controls.

19.152 Each plant should be tested through full cycles, demonstrating the functions of the plant are correct and in line with the manufacturer's specifications.

19.153 A full maintenance test, check and examination should be undertaken as part of the validation and verification.

19.154 These tests and inspections should be recorded on form B11.

AGSS plant

19.155 AGSS plant should be inspected and checked for function and controls.

19.156 Each plant should be tested through full cycles, demonstrating the functions of the plant are correct and in line with the manufacturer's specifications.

19.157 A full maintenance recommissioning should be undertaken as part of the validation and verification.

19.158 Where the AGSS is controlled by PIR or ventilation systems, the overrun, isolation and reinstatement should be proven.

19.159 A visual inspection of the plant is required to ensure that all specifications have been met.

19.160 These tests and inspections should be recorded on form B12.

19.161 BS EN ISO 9170 specifies the tests to be carried out on AGSS. The tests specified are designed to ensure adequate performance and that the safety provisions of receiving systems will be met.

19.162 Responsibility for the tests should be clearly defined at the contract stage for new installations, in the same manner as for the MGPS. In general, the contractor should carry out the tests, which should be witnessed by the Authorised Person (MGPS).

Performance tests

19.163 All equipment should be tested to ensure that it performs satisfactorily during continuous operation under full load for one hour.

19.164 All electrically powered equipment should be tested to confirm:

- the correct rotation
- the current drawn by the powered device at full load.

19.165 The disposal system should be tested to ensure that it meets the requirements set out in Chapter 12, with the number of terminal units for which it has been designed in use.

19.166 The test device and a number of metered leaks are then inserted into the system to replicate the design flow. The measurements above are repeated. If the test results are satisfactory, the test device is rotated with metered leaks until all terminal units are tested.

19.167 The test device is designed to replicate either type of receiving system for which the disposal system has been designed.

19.168 For the purposes of diversity, it may be assumed that in any operating department only one receiving system for each operating room is in use at any time. (In a typical theatre suite with two terminal units in the operating room and one in the anaesthetic room, the total number of metered leaks used for testing is two; that is, one being placed in an operating room terminal unit and the other in the anaesthetic room terminal unit.)

19.169 The operation of user-controlled switches, power-on indicators and alarm systems should also be checked.

19.170 Where the AGSS is controlled by a third means (for example, PIR controls or ventilation set-back), this should be checked including the run-on timer

19.171 AGS terminal units should be checked for correct mechanical operation and that the check valve operates satisfactorily.

Annual recommissioning of an AGSS

19.172 Annual recommissioning of an AGSS should be undertaken for patient and staff safety.

19.173 Full systems should be shut down, recommissioned and cleaned.

19.174 Recommissioning involves:

a. pump filters and silencers: strip, clean or replace

b. terminal unit: strip and clean, reset

c. system pressure and flow set up.

19.175 The following steps should be completed at intervals no greater than 12 months:

a. Pump strip and clean:

(i) Ensure the plant is electrically isolated (on both pumps if a duplex system).

(ii) Remove the balance valves and strip and clean them fully.

(iii) Refit the balance valves in the fully open position to allow maximum airflow through the valves.

(iv) Strip the pump and remove the internal filters and silencers, clean or replace as appropriate.

(v) Reassemble the pump.

(vi) Check all electrical connections internally in the control panel.

(vii) Check security of the panels, pumps and pipework.

(viii) Check the anti-vibration mounts on the pumps, replace when required (signs of cracking).

(ix) Ensure all mechanical fittings are tight.

(x) Clean the pump exterior and surrounding area.

b. Terminal units:

(i) Strip all second-fix terminal units and remove the adjustable bobbins.

(ii) Strip and clean the bobbins and second-fix components.

(iii) Reassemble the bobbins in the fully open position (allows maximum airflow).

(iv) Reassemble the terminal units.

c. System pressure and flow set up:

(i) Restore power to the pumps.

(ii) Ensure that the pump runs quiet, without any unusual noises or vibration.

(iii) Check all pump functions and check the alarms are functioning correctly.

(iv) Where the pump is powered by the ventilation system or PIR, activate the ventilation or PIR and then deactivate the system to enable control of pump check (overrun should be set at a minimum of 30 minutes).

(v) Using the test point at the pump, gradually close the balance valve until the pressure reaches approximately 10 kPa.

(vi) In turn, check the single flow rates of the terminal units and record; adjust the flow of the terminal units to the lowest flow rate for the system set up (for example, 50 L/min or 80 L/min).

(vii) If the required flow rates cannot be achieved at the terminal units, the balance valve should be adjusted to increase the line pressure until the set flows are reached.

The aim is to set the system to the lowest pressure with the terminal units fully open. This accounts for any occlusions within the terminal units or balance valves, which will reduce flow and increase pressure.

(viii) Check the system with all of the terminal units in use: one per theatre and where applicable one in the anaesthetic room. Only one terminal unit will be in operation in each theatre, with the anaesthetic room running simultaneously. If an AGSS is installed within a radiology department, no diversity is permitted during the full system flow test.

Manifolds

19.176 Manifolds including the ERM should be inspected and checked for function and controls.

19.177 Each manifold should be tested through full cycles, demonstrating the functions of the manifold are correct and in line with the manufacturer's specifications.

19.178 A full maintenance test, check and examination should be undertaken as part of validation and verification.

19.179 It should be demonstrated that the automatic changeover from primary to secondary source of supply is seamless and without manual interaction.

19.180 A visual inspection of the plant is required to ensure that all specifications have been met.

19.181 Specific attention should be given to the header racks and spare cylinder with regard to security and quantity. There should be enough spare racks for one full bank plus a spare cylinder.

19.182 These tests and inspections should be recorded on form B13.

Liquid systems

19.183 The gas supplier should demonstrate all functions of the liquid systems.

19.184 The supplier should demonstrate the full system maintenance cycle including plant sequencing, liquid and vapour draw capability, and full performance flow rates.

19.185 All documentation should be inspected for PSSR 2000 requirements and all relevant safety documentation and certification should be available.

19.186 Compounds should be inspected for compliance, lighting, signage, security and access.

19.187 The location should be assessed, and the filling methodology demonstrated. Road markings and parking restrictions should be inspected.

19.188 These tests and inspections should be recorded on form B14.

PSSR 2000

19.189 The associated PRS and vessels should be inspected for compliance with PSSR 2000 and information recorded. The WSE requirements need to be agreed with the inspection company at this stage to ensure that the equipment is covered prior to going in to service.

19.190 All PSSR 2000 information must be collated and the pressure safety systems inspector should undertake the WSE for all plant.

19.191 All certification should be collated and provided to the Authorised Person (PSSR) and formally handed over to ensure that the records are complete and up to date and the WSE is in place before the plant is taken online.

19.192 These tests and inspections should be recorded on form B15.

Pipeline tests

Second-fix installation and “Do not use” plugs

19.193 On completion of carcass testing, the next stage is to install the second-fix components into the system.

19.194 These components should be recorded on form B16.

19.195 First-fix blanks should be removed and the second-fix components installed, including terminal units.

19.196 Installing a second-fix terminal unit enables the connection of medical equipment.

19.197 Inadvertent connection of medical equipment to an untested medical gas pipeline may result in a significant adverse event. To prevent this, all second-fix terminal units should be fitted with “Do not use” plugs. These should remain in place until the Quality Controller (MGPS) has signed off the system for patient use. The plugs should only be permanently removed by the Authorised Person (MGPS). This is recorded on forms B17 and B32.

19.198 The plugs may need to be temporarily removed during testing. During such operations, the terminal units should be continuously attended by the commissioning team.

19.199 Where works are undertaken adjacent to or within a live healthcare facility, clinical staff should be made aware of the presence and purpose of “Do not use” plugs.

Pipeline pressure test

19.200 Prior to the commencement of the pipeline pressure test, a full system inspection is required to ensure that all valves are open and all second-fix components are installed.

19.201 The aim of this test is to establish that there is no leakage from the piped medical

gas systems with the second-fix components fitted.

19.202 This should be demonstrated using electronic pressure-measuring equipment with a minimum resolution of 0.01 kPa in 10,000 kPa and 0.05 kPa in 20,000 kPa.

19.203 During a test period of a minimum of two hours, (once the system has been filled and settled) the maximum pressure loss should be less than 0.2 kPa for 400 kPa systems and vacuum, and 0.5 kPa for 700 kPa systems.

19.204 No allowance is made for variation of pressure with temperature over two-hour tests. If, however, the accuracy of the available pressure-measuring equipment is in doubt and recourse is made to a 24-hour test, the pipeline pressure test can be undertaken with the same source as the carcass testing.

19.205 For all extensions and modifications, a physical break should be maintained from the pipeline system.

19.206 Testing should be undertaken at the pressures given in Table 31.

19.207 No cross-connection of the systems is permitted.

Medical Gas	Nominal pressure (kPa except where shown)	System test pressure (kPa)
O_2	400	450
N_2O	400	450
O_2/N_2O	400	450
MA4	400	450
SA7	700	800
DA6	600	700
Vacuum	650 mmHG	200
Dental vacuum	450 mmHG	200
CO_2	400	450
AGS	NR	NR

Table 31 Pipeline pressure test

19.208 Where MSUs are included within the contract but via a separate supplier, it may be necessary to undertake this test without the systems connected and then repeat the test once the systems are installed. In such cases, the ceiling NISTs should be capped off.

19.209 Pressure testing for pipeline systems should be undertaken in accordance with the carcass testing procedure.

19.210 Once the test has been completed and passed, the pressure should be reduced to a maximum of 50% of the test pressure.

19.211 These tests and inspections should be recorded on form B18.

Vacuum leakage test

19.212 Vacuum systems should be drained to atmospheric conditions prior to being connected to the vacuum plant.

19.213 Prior to testing, vacuum plant should be operated to allow any moisture in the system to evaporate.

19.214 All vacuum pressure sensors should be installed for this test.

19.215 With the system at pipeline distribution pressure (plant cut-out pressure) and with the source isolated, the pipeline should be allowed to settle prior to commencing any testing.

19.216 There is no additional allowance for temperature correction in this test.

19.217 The plant can be set to hand operation to draw the vacuum down on the system.

19.218 Once the system has been drawn down to the required levels, the isolating valve on the output of the plant should be isolated and locked off to ensure that it cannot be used to maintain the pressure (see Table 32).

Medical gas	Nominal pressure (mmHg)	Vacuum test pressure (mmHg)
Vacuum	–650	–650
Dental vacuum	–450	–450
AGSS	Not required	Not required

Table 32 Vacuum leakage test

19.219 During a test period of a minimum of two hours, (once the system has settled) there should be no loss of vacuum.

19.220 On completion of this test, the vacuum plant may be reinstated and the system left under vacuum.

19.221 These tests and inspections should be recorded on form B19.

Engineer's particulate testing

19.222 MGPS should be free from particulate contamination, as they are constructed using chemically cleaned, capped components, and joints are made in a controlled process using a shield gas. However, on-site contamination may occur due to the ingress of building materials, dust and inadequate purging techniques. The presence of such particles can adversely affect the quality of the delivered gases. Therefore, tests to indicate their absence are important.

19.223 The test for particulate matter should be carried out at every terminal unit on a new system. It should be carried out by the Competent Person (MGPS). When tested with a membrane filter at a flow not less than 150 L/min for 30 s, the filter should be free from visible particles when viewed in a good light.

- When testing surgical air terminal units, a flow of 350 L/min for 30 s should be used.
- When testing nitrous oxide and carbon dioxide terminal units, a maximum flow of 75 L/min for 30 s should be used.
- When testing oxygen/nitrous oxide terminal units, a maximum flow of 275 L/min for 30 s should be used.

19.224 Where particulate matter is found and purging will not clear the system, a decision either to accept the level of contamination present, or to agree a cleansing procedure, or to condemn the system should be made by the Authorised Person (MGPS) on the advice of the Quality Controller (MGPS) and the Authorising Engineer (MGPS).

19.225 These tests and inspections should be recorded on form B20.

Cross-connection test

19.226 The cross-connection test should be carried out in two stages:

a. from the plant to the departmental AVSUs

b. from the departmental AVSUs to the terminal units.

19.227 These tests and inspections should be recorded on form B21.

19.228 The plant to departmental AVSU cross-connection test is carried out by first closing all departmental AVSUs. Each gas supply system is then opened in sequence, and gas flow is tested at the upstream NISTs of all the departmental AVSUs and at each individual LVA. After each test, the system should be depressurised before proceeding to the next gas. This process is repeated for all MGPS.

19.229 The test for departmental AVSUs to terminal units begins by opening all valves downstream of the departmental AVSU. Then:

a. Open the vacuum AVSU and allow the system to stabilise. Then isolate the vacuum AVSU.

b. Slowly open the medical oxygen supply and confirm that the pressure builds up steadily; allow it to stabilise.

c. Check the vacuum system to ensure it remains under negative pressure and that no leakage has occurred into the vacuum line.

d. Once confirmed, slowly reopen the vacuum valve to reinstate the vacuum supply from the plant.

e. Repeat this procedure for the vacuum system and each of the other medical gas supplies in turn.

19.230 Where only two gases are present, both the oxygen and vacuum supplies should remain live, and each terminal unit should be tested using an open probe to confirm the correct pressure and suction at the terminal unit.

19.231 Where a third gas, such as medical air, is present, it should be proven that flow is available from all outlets; then the medical air supply should be isolated. At this stage:

- oxygen terminal units should indicate positive pressure
- medical air terminal units should indicate no pressure
- vacuum terminal units should provide suction.

19.232 For systems supplying multiple gases, each pressure gas should be tested in turn.

19.233 This test should be carried out in full for each AVSU and should be repeated if any subsequent modifications are made to the pipeline system.

LVA closure test

19.234 For pressurised systems, the section upstream of the closed valve under test should be maintained at pipeline distribution pressure and the downstream line pressure should be reduced to about 100 kPa. The downstream pressure should be recorded, and there should be no change in pressure over a period of 15 minutes.

19.235 For vacuum systems, the section upstream of the closed valve under test should be maintained at pipeline distribution pressure and the downstream line pressure should be reduced to about –100 kPa. The downstream pressure should be recorded, and there should be no change in pressure over a period of 15 minutes.

19.236 This should be repeated for all LVAs independently.

19.237 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.

LVA zoning

19.238 This test should be carried out to ensure that each LVA controls only its intended AVSUs, in accordance with the design and LVA labelling.

19.239 The test is performed by turning on an individual LVA and venting all other systems in the area to atmospheric pressure. A check should then be made to establish that only those AVSUs controlled by the LVA are at pressure.

19.240 All other AVSUs, including those for other gas services, should be at atmospheric pressure. All LVAs should be checked individually for zone control and verified via the signage and as-fitted drawings.

19.241 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.

LVA NISTs

19.242 All NISTs should be tested for gas specificity, tightness, accessibility and

markings, and to ensure that they are lockable.

19.243 For gas specificity, each NIST should be checked with all calibrated test NISTs to ensure that only one NIST can be fully screwed in and release gas, and that no other NIST can connect or release gas.

19.244 The NIST should be accessible and locked off. MGPS locks should be keyed differently (KD). Suited keys should not be used on MGPS to ensure that locks remain individually controlled and secure.

19.245 It should 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.

19.246 Every NIST should be checked that it has a check valve included for all pressure gases and that full flow pressure can be passed through the NIST; this is undertaken with a pressure gauge and connection hose.

19.247 NISTs can also be found on PRS, connections for MSUs and ceiling pendants. These should be addressed during LVA testing.

LVA identity

19.248 All LVA labels should be installed prior to testing so that they can be identified for areas served.

19.249 All LVA tests and inspections should be recorded on form B22.

AVSU closure

19.250 For pressurised systems, the system upstream of the closed valve under test should be maintained at pipeline distribution pressure and the downstream line pressure should be reduced to about 100 kPa.

19.251 The downstream pressure should be recorded, and there should be no change in pressure over a period of 15 minutes.

19.252 For vacuum systems, the systems on the supply plant side of the closed valve should be maintained at pipeline distribution pressure and the terminal unit side should be at about –15 kPa.

19.253 The upstream (terminal unit side) pressure should be recorded, and there should be no change in vacuum over a period of 15 minutes.

19.254 This should be repeated for all AVSUs independently.

19.255 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.

AVSU zoning test

19.256 This test should be performed to ensure that each AVSU controls only its intended terminal units, in accordance with the design and AVSU labelling.

19.257 Correct identification is particularly important where dual or separate circuits are installed, as it may not be apparent from the spatial relationship of AVSUs and terminal units which AVSU controls which terminal units.

19.258 The test should be carried out by turning on an individual AVSU and venting all other systems in the area to atmospheric pressure. A check should then be made to establish that only those terminal units controlled by the AVSU are at pressure.

19.259 All other terminal units, including those for other gas services, should be at atmospheric pressure. The other AVSUs should then be tested successively.

19.260 Every AVSU should be checked for zone control and verified via the signage and as-fitted drawings.

19.261 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.

AVSU NIST test

19.262 All NISTs should be tested for gas specificity, tightness, accessibility and markings, and to ensure that they are lockable.

19.263 For gas specificity, each NIST should be checked with all calibrated test NISTs to ensure that only one NIST can be fully screwed in and release gas, and that no other NIST can connect or release gas.

19.264 It should 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 a reduction in pipeline pressure.

19.265 Every NIST should be checked that it has a check valve included for all pressure gases and that full flow pressure can be passed through the NIST. This is undertaken with a pressure gauge and connection hose.

AVSU identity

19.266 All AVSUs should be labelled with a unique valve number prior to testing so that they can be identified for the areas served.

19.267 All AVSU tests and inspections should be recorded on form B23.

Terminal unit tests

19.268 Each terminal unit should be checked to ensure that it is for the correct service and that complies with BS EN ISO 9170-1.

19.269 The following tests should be carried out as individual tests using appropriate test devices with the correct probes inserted for the pipeline(s) under test.

19.270 The pressure should achieve the values given in Table 2 at the specified flows.

19.271 All terminal units should be tested for the following:

- Gas specificity: Only accepts the desired probe and not any other probe. This is undertaken by using calibrated solid test probes. A full set of probes should be available for use; each of the probes in turn should be attempted to fit into the terminal unit; only the correct gas probe should enter the collar and lock in the terminal unit.
- Probe retention: Probe locks in and passes the pull test. This is achieved by using the correct solid test probe. Insert fully into the terminal unit and ensure that the probe is captured and does not freely fall out of the terminal unit. A small reverse force should be applied to the probe to ensure that it cannot be pulled out of the terminal unit.
- Security of fixings: Checking the terminal unit is fastened correctly. This is undertaken as part of probe retention. A gentle force is applied to the probe in all directions to ensure that the terminal unit is securely fixed.
- Terminal unit concentricity within the fascia: This test ensures the terminal unit is not occluded. This is both a physical and visual check. Visually inspect the terminal unit collar to ensure it is concentric within the fascia plate. Depress and release the terminal unit collar to verify that it moves freely without obstruction or catching on the fascia. There should be a maximum of 2 mm gap between the collar and the fascia.

- Anti-swivel pin: Correct installation and function. This should be verified during the probe retention test by attempting to gently rotate the probe. On vertical-facing terminal units, the probe should rotate freely; on forward-facing terminal units, it should not rotate.
- Probe seal leakage: Ensure that the seal on the probe nose is sufficient to prevent leaks. This should be verified during the probe retention test by gently moving the probe in all directions and confirming that no leaks are detected.
- Static pressure: Testing the system pressure without any flows induced. This should be achieved using a test gun fitted with a gas-specific probe, inserted into the terminal unit without the trigger being depressed. A reading is taken from the gauge.
- Flow pressure and flow rate: Testing the pressure at the terminal unit under prescribed flow rates. This should be achieved using a test gun fitted with a gas-specific probe, inserted into the terminal unit. The required flow rate should be selected by fitting the appropriate flow jet and depressing the trigger to allow flow through the jet. A reading is taken from the gauge.
- Labelling and identification: ID to meet BS EN ISO 9170-1. This is a visual check only.

19.272 All terminal unit tests and inspections should be recorded on form B24.

Design flow performance tests on the pipeline system

19.273 A full system performance test is only applicable when there has been a completely new pipeline system installed.

19.274 Where large extensions are added to an existing system, a sectional performance test may be undertaken to prove pipe sizing is adequate in relation to pressure drop in this area only. Special care should be taken to ensure that the existing system and patient safety is not compromised.

19.275 It is not necessary to insert metered leaks into the actual number of terminal units used to calculate the diversified design flow, provided the numbers used are evenly distributed and orifice sizes are selected to achieve this flow.

19.276 The metered leaks should be stamped or be similarly identified to show the flow (air equivalent) at, for example, 10, 20, 100 and 275 L/min for 400 kPa systems, and 350 L/min for 700 kPa systems.

19.277 The performance of individual pipeline systems is tested by introducing calibrated metered leaks using orifice sizes that provide flow rates representative of the range of medical devices for which the pipeline is designed (see Table 2). These should represent the total diversified system design flow, less the flow generated by the test device.

19.278 Thereafter, a representative number of terminal units (see paragraphs 19.279–19.280) should be tested for pressure and flow: the diversified flows should be derived from the data in Tables 3, 5, 6, 7, 8 and 10.

19.279 In a 28-bed ward, a representative sample of terminal units located furthest from the AVSU and nearest to the entrance, including the treatment room, should be tested.

19.280 In an operating department, a representative sample of terminal units in each operating suite and 20% of terminal units in recovery should be tested. For oxygen, one terminal unit should be tested at 100 L/min to represent oxygen flush.

19.281 These tests should be recorded on form B26.

Plant alarm tests

19.282 The operation of warning and alarm systems should be tested in all normal operating, fault and emergency modes. Particular attention should be paid to the following:

- All alarms should operate within the specified tolerance limits at all operating parameters and fault conditions.
- All alarms should be capable of being seen and heard within the locations they are installed.
- The system should return to its normal operating status on completion of each test.
- Where digital displays are used, they should be inspected to ensure the correct information is displayed.
- All indicator panels and switches should be correctly labelled.
- All functions on all indicator panels should operate correctly.
- The backup battery facility should be checked for operation.
- The battery replacement date should be clearly identified on the exterior of the alarm unit.
- All indicator panels should be labelled to indicate the plant and PRS they serve, in accordance with the contract specifications.
- It should be confirmed that the neon light indicator on the unswitched fused connection unit is lit.

19.283 The following tests should also be carried out:

- 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.
- Check power failure operates red “system fault” indicator and the audible alarm.
- Check that a line contact monitoring 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 that each item of plant and associated PRS is correctly identified on all alarm panels and plant-specific labels.
- Check that each alarm panel emits the correct (two-tone) audible alarm. (Some manufacturers supply panels set for a single tone – in use, staff may confuse this sound with that emitted by some models of patient monitoring equipment.)
- Run each plant through the full sequence of alarms and check they are displayed correctly.
- Where the PRS alarms are shown on the plant alarm system, these should be tested in accordance with the procedures described above.

19.284 These tests should be recorded on form B27.

Local alarms

19.285 Local alarms should be tested for the correct responses to pressure changes on all gases.

19.286 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:

- All alarms should operate within the specified tolerance limits at all operating parameters and fault conditions.
- All alarms should be capable of being seen and heard within the locations they are installed.
- The system should return to its normal operating status on completion of each test.
- Where digital displays are used, they should be inspected to ensure the correct information is displayed.
- All indicator panels and switches should be correctly labelled.
- All functions on all indicator panels should operate correctly.
- The backup battery facility should be checked for operation.
- The replacement date of the battery should be clearly identified on the alarm.
- All indicator panels should be labelled to show the areas they serve, or as detailed in the contract specifications.
- It should be confirmed that the neon light indicator on the unswitched fused connection unit is lit.

19.287 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 remains in place.
- For area indicator panels, check that the operation of the mute switch cancels the audible only, for all systems and conditions.
- Check power failure operates red “system fault”.
- Check that a contact line fault operates the “system fault” indicator, the main alarm displays and the audible alarm.
- Check audible reinstatement for each alarm panel.
- Check that the audible signal can be continuously muted via operation of the internal push-button for gas service alarm conditions only.
- Check for correct identification of each gas service on alarm panels and “departmental” or plant-specifying labels.
- Check that each alarm panel emits the correct (two-tone) audible alarm. (Some manufacturers supply panels set for a single tone – in use, staff may confuse this sound with that emitted by some models of patient monitoring equipment.)

19.288 These tests should be recorded on form B28.

Requirements before an MGPS is taken into use

19.289 Before a system is used, the appropriate persons should certify in writing that all required tests and procedures have been completed and that all systems comply with the applicable requirements. This should include certification that all drawings and manuals required by the contract have been supplied and as-fitted drawings are correct.

19.290 All certificates should be dated and signed by the appropriate witnesses.

19.291 For modifications or extensions to existing systems, the performance tests for flow and pressure drop should be carried out on the completed system if practicable. If the performance is in accordance with the specification prepared, the system may be taken into use, provided that all the other tests have been satisfactorily completed.

Removal of "Do not use" plugs

19.292 Once all tests, including QC testing, have been satisfactorily completed and all relevant B-forms and PTWs have been completed, the "Do not use" plugs should be removed by the Authorised Person (MGPS) prior to the system being taken into clinical use. This should be recorded on form B32.

Dental air and vacuum system validation and verification

General principles

19.293 Pipeline systems from source to the connection of the chair or cart should be installed and tested in accordance with Chapter 14.

19.294 Installation and commissioning of DAVS chairs and carts differs from that of medical gas systems in that fewer tests are performed, some to different parameters. Connection of dental equipment (functional tests) should form an essential part of the validation and verification process.

19.295 Each system should be examined in the light of these recommendations. In some cases, it may be impractical to carry out the test in full. For example, leaks in a single-chair dental air installation may be readily identified using leak detector fluid; therefore, conducting a two-hour leak test in such circumstances would be unnecessary.

Test gas for dental air systems engineering tests

19.296 The dental compressor may be used as the source of test gas once it has been QC tested. Alternatively, a medical air cylinder can be used.

Commissioning tests

19.297 For DAVS, the guidance given in Chapter 9 should be followed as far as practicable. All copper pipeline installations should be installed in compliance with the requirements listed in Chapter 15.

19.298 A particulate test should be carried out on all pipeline installations.

19.299 For labelling, marking and signage, Chapter 15 should be followed.

19.300 For providing sleeving and the protection of pipework, see Chapter 15. Nylon pipework should be supported at intervals not exceeding 800 mm to prevent sagging of the pipeline. The principles of support on either side of valves and similar components should be maintained irrespective of the materials used.

Dental air system tests

Pipework pressure test

19.301 Measurements should be taken from the floor box to the chair connection point and back to the plant connection.

19.302 With the pipework pressurised to working pressure and the source of compression isolated, the system should show no pressure loss over a two-hour period.

Dental vacuum system tests

Leak test

19.303 All practicable means should be taken to ensure that the system is leak-tight. In its simplest form this test may be limited to a

water-leak test; that is, the system should be examined for leaks during the flow of clean water.

Cannula flow test

19.304 With the vacuum pump(s) operational and all dental chairs connected to the system, each cannula connector should be tested in turn with the flowmeter. It should be possible to generate the specified flow rate (a minimum of 350 L/min) at the flowmeter. This test should be performed using the largest-diameter delivery hose. Where possible, a full diversity flow test should be undertaken.

Vacuum-limiting device test

19.305 With all other cannula connections closed and all pumps operating, a vacuum gauge should be attached to a selected cannula connection and the vacuum observed. The gauge should not read more than 18 kPa negative pressure (82 kPa absolute).

Tests following repairs/modifications

19.306 All attempts should be made to ensure that system integrity and performance is maintained following repair, modification or replacement of system elements. Full testing is required for all system modifications.

19.307 Confirmation of system performance should be given to the clinical team in the form of a service report.

19.308 It is necessary under PSSR 2000 to notify the Competent Person (PSSR) if repairs and modifications are made to the pressure system. In addition, the WSE may need updating.

Pharmaceutical testing

19.309 Air quality testing of the dental air to ascertain whether it complies with the required standard should be performed during system commissioning.

19.310 For dental surgeries with up to five chairs, air quality testing should be completed annually as a minimum. Quarterly air quality testing is recommended but this should be a risk-based decision, taking into consideration what type of dental work is performed and the risk to the patient. The test requirements and frequency should be based on system performance and agreed between the users, the Authorised Person (MGPS) and the Quality Controller (MGPS), with reference made in the operational policy.

19.311 Records of pharmaceutical test results should be kept for at least five years.

20 Medical gas quality control (QC) testing

Introduction

20.1 Medical gases are medicines and, as such, must comply with the Human Medicines Regulations 2012 (as amended) and the relevant monographs of the British Pharmacopoeia to ensure patient safety.

20.2 This chapter describes quality control (QC) testing protocols, with associated acceptance criteria, required to provide assurance of medical gas identity and quality.

20.3 QC testing is carried out on new medical gas installations or following repairs and modifications to existing pipeline systems. Periodic routine QC testing is also carried out on the MGPS and plant.

20.4 Medical gas QC is the final independent part of the verification process of medical gas identity and quality. QC testing is the responsibility of the Quality Controller (MGPS). This responsibility should not be delegated to other individuals, unless the Quality Controller (MGPS) is directly supervising trainees. QC testing should not be carried out by those acting as Authorised Persons (MGPS) or Competent Persons (MGPS) on the project or those responsible for signing as the Designated Clinical Officer. Testing should be carried out by a Quality Controller (MGPS) registered within the UK. Appointment, registration and competency requirements are described in Part B.

Quality control testing/ verification process

20.5 The Quality Controller (MGPS) should verify the identity and quality of medical gases following:

- the installation of a new MGPS
- the planned extension, upgrade, modification or repair to existing installations where there is an interruption in supply
- unplanned interruption in supply (emergency).

20.6 The Quality Controller (MGPS) should also carry out:

- regular planned QC testing and verification (for example, the quarterly testing of compressor plant)
- ad hoc testing of the MGPS and source supplies and additional testing in response to adverse or spurious results recorded during QC testing or operational concerns raised by the Authorised Person (MGPS).

New installations

20.7 For new installations and extensions, the Quality Controller (MGPS) should be involved from project concept. They should have access to pipeline construction drawings and

should prepare a QC test protocol (programme and methodology) for the required works in advance of commencement of testing. Information should be supplied by the project team to support the development of the test protocol.

20.8 The appointed Quality Controller (MGPS) should be invited to planning meetings and granted access to any site where works are in progress to maintain familiarity with the installation.

20.9 In new installations, QC testing should be carried out to demonstrate compliance with pharmacopoeial monograph acceptance criteria at the supply source (for example, an oxygen VIE, medical air compressor plant and manifolds prior to bringing online). This will avoid contamination being introduced into the pipeline system from the supply source.

20.10 "Do not use" plugs should be in place. These should be removed to undertake the testing but immediately replaced to ensure that medical gas equipment cannot be connected to the system.

20.11 It is recommended that QC testing should not be undertaken on any site until post-construction cleaning has been completed. Where patient use of the MGPS is not planned immediately following completion and approval of QC results, a programme of purging and retesting agreed with the Authorised Person (MGPS) should be implemented.

20.12 All test results should be documented to demonstrate completion of QC testing and compliance with acceptance criteria (see paragraphs 20.85–20.88). The Quality Controller (MGPS) should supply a record of the results within an agreed reasonable timescale, including all completed B-forms, PTWs and the Quality Controller's (MGPS) certificate of registration, for inclusion within the project file. Any non-conformances to pharmacopoeial monograph acceptance criteria should be documented, along with remedial actions, as agreed with the Authorised Person (MGPS). A copy should be sent to the project team, Authorised Person (MGPS) and Chief Pharmacist and should be presented to the MGSG.

20.13 No medical equipment should be brought into any department for connection to the pipeline system (for example, flowmeters and anaesthetic trolleys) until validation and verification testing has been satisfactorily completed.

Modification of existing systems and emergency repairs

20.14 Prior to any QC testing, the Authorised Person (MGPS) should provide the Quality Controller (MGPS) with the relevant information needed to establish the QC testing protocol (programme and methodology). This includes (but is not limited to) a description of the engineering work to be carried out, details of the medical gases involved, the location and reference of the point of isolation and location of work and relevant as-fitted drawings. Site familiarisation should be provided as required.

20.15 All work involving modifications to an existing pipeline system and QC testing is controlled under a high hazard PTW. This also includes the connection of a new installation to an existing system.

20.16 When testing modified or repaired systems, "Do not use" plugs should be in place. These should be removed to undertake the testing but immediately replaced to ensure that medical gas equipment cannot be connected to the system.

20.17 During all QC tests, the Authorised Person (MGPS) should be available to assist the Quality Controller (MGPS).

20.18 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.

Any amendments to the planned programme should be risk-assessed and agreed with the Authorised Person (MGPS) and recorded on the test report.

20.19 The system should only be taken back into use by the Designated Clinical Officer once the medical gases have been tested and verified as being fit for patient use and the PTW completed.

20.20 No unplanned modifications should be undertaken to any system once the testing has commenced. If modifications 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 recommencing the QC test protocol and be included with the QC test records.

20.21 All test results should be documented to demonstrate completion of QC testing and compliance with acceptance criteria (see paragraphs 20.85–20.88). The Quality Controller (MGPS) should supply a record of the results within an agreed reasonable timescale, including all completed B-forms, PTWs and the Quality Controller's (MGPS) certificate of registration, for inclusion within the project file. Any non-conformances to pharmacopoeial monograph acceptance criteria should be documented, along with remedial actions, as agreed with the Authorised Person (MGPS). A copy should be sent to the project team, Authorised Person (MGPS) and Chief Pharmacist and should be presented to the MGSG

Regular planned QC testing

20.22 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, or dental air compressor plants, synthetic air plants and oxygen generators should be carried out in accordance with Table 33.

Reference testing	Frequency
(a) Medical/surgical air compressor plants	Quarterly
(b) Dental air compressor plants (hospitals, health centres, mobile units, etc.)	Quarterly (recommended) Annually (minimum) See paragraph 20.24
(c) Synthetic air plants	Quarterly
(d) Endoscopy plant	Quarterly
(e) Oxygen generator plant	Quarterly

Table 33 Routine QC testing scenarios and frequencies

20.23 When carrying out QC testing on medical, surgical or dental air plant, oxygen generators and other supply sources, test protocols should be in place and agreed with the MGSG.

Dental

20.24 For dental surgeries with up to five chairs, air quality testing should be completed annually as a minimum. Quarterly air quality testing is recommended but this should be a risk-based decision, taking into consideration what type of dental work is performed and the risk to the patient. The test requirements and frequency should be based on system performance and agreed between the users, the Authorised Person (MGPS) and the Quality Controller (MGPS), with reference made in the operational policy.

20.25 Dental surgeries should comply with the medical air testing requirements for quality, with the exception of the dew point: this is accepted at –20ºC so long as this can be maintained.

20.26 All test results should be documented to demonstrate completion of QC testing and compliance with acceptance criteria (see paragraphs 20.85–20.88). Any non-conformances to pharmacopoeial monograph acceptance criteria should be documented, along with remedial actions. A copy should be

sent to the persons responsible for this service.

Ad hoc testing of the MGPS/source supplies

20.27 Ad hoc testing of the wider MGPS may be required as part of an investigation following the recording of anomalous results during regular compressor plant quarterly/ annual testing or following pipeline installations or modifications, or in response to concerns raised by the Authorised Person (MGPS) (for example, reports of discoloured flowmeters).

20.28 When developing test regimes in response to situations described in paragraph 20.27, consideration should be given to sampling at:

- terminal units (end-of-line and random locations)
- the source (for example, the oxygen VIE or medical air compressor plant and manifolds).

The test regime should be developed by the Authorised Person (MGPS) and the Quality Controller (MGPS) and agreed by the MGSG.

20.29 Ad hoc testing should be undertaken in low-usage or dormant areas to ensure continued medical gas quality. It may also be required where medical gases are supplied through pendant hoses, especially in areas of low usage.

20.30 Consideration should be given to the routine testing of end-of-line terminal units within the site test protocol. This should be determined by risk assessment and documented in a site-specific testing strategy, which should be periodically reviewed by the MGSG.

20.31 QC testing should also be carried out in empty wards or departments that are to be reopened or repurposed for patient use (for example, to accommodate winter bed pressures). Although no modifications to the MGPS may have occurred, the identity and quality of the medical gases should be verified.

20.32 Records of these tests should comply with requirements listed in paragraphs 20.85–20.88. Reports should be submitted to the Authorised Person (MGPS) and presented to the MGSG.

Pharmaceutical quality of medical gases and MGPS

General principles

20.33 The objective of these tests is to ensure compliance with pharmacopoeial monographs and HTM 02-01 guidance for medical gas quality.

20.34 The relevant monographs of the British Pharmacopoeia should be regarded as the baseline minimum standard for assessing the quality of medical gases.

20.35 This HTM supplements the pharmacopoeial 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. Table 34 combines pharmacopoeial and HTM tests and lists relevant acceptance criteria.

20.36 The Quality Controller (MGPS) should prepare a QC test regime with the Authorised Person (MGPS).

20.37 Reports should be prepared in accordance with paragraph 20.85. Any non-conformance to acceptance criteria and investigations undertaken should be recorded.

20.38 The Quality Controller (MGPS) should ensure that all equipment used for medical gas testing is maintained and serviced according to the manufacturer's recommendations and local protocols. Records should be retained.

20.39 Electronic equipment should be used for QC testing due to repeatability, resolution and accuracy. Where used, it should be calibrated on-site prior to testing, using certificated calibration gases.

20.40 If a drift in concentration of the medical gases is identified during testing, the analyser calibration should be checked and recalibrated. The Quality Controller (MGPS) should consider repeating a sample of tests carried out at the point of drift identification. Calibration should also be carried out once all tests are completed. Records should be kept of all calibrations.

20.41 It is acknowledged that at the time of publication of this HTM, pharmacopoeial tests for oil, carbon monoxide, carbon dioxide, sulfur dioxide, oxides of nitrogen (NO and NO_2) and water vapour can be carried out using detector tubes. Although detector tubes provide a quantitative response, Quality Controllers (MGPS) should be aware of the following limitations:

- They are single-use only.
- They may be adversely affected by ambient operating conditions (for example, high humidity or low temperature).
- Cross-sensitivities may occur.

20.42 Polytest tubes respond to a range of compounds (for example, volatile hydrocarbons) and may be used as an optional general test for pipeline contamination on a representative sample of terminal units.

20.43 The Quality Controller (MGPS) should ensure that appropriate health and safety precautions are taken when carrying out QC testing, in particular when testing nitrous oxide or carbon dioxide MGPS.

Medical gas identification, purity and quality

20.44 The identity of the gas should be confirmed as compliant with pharmacopoeial specifications. The following testing strategies should be used:

- For new MGPS installations, all terminal units should be tested.
- Where a modification or extension to an existing pipeline system has involved the use of shield gas, all terminal units should be tested.
- Where a modification or extension to an existing system has taken place and a shield gas has not been used, the sample size and location should be risk-assessed but should include new terminal units and terminal units at the end of lines/branches.

20.45 QC testing should commence at terminal units located at the furthest point(s) from the AVSU.

20.46 The identity of the gas should be confirmed during QC testing of source supplies. When testing medical gas quality at compressor plants, transient increases in oxygen (O_2) concentration may occur during dryer changeover. The values should be recorded and, provided they remain within specification, will not constitute a failure.

20.47 The composition of the specific medical gas should be positively identified in accordance with pharmacopoeial monographs, and not inferred.

20.48 For oxygen and oxygen/nitrous oxide systems, as well as medical, surgical and dental systems, an oxygen analyser should be used to verify that oxygen concentration complies with the acceptance criteria in Table 34. A paramagnetic analyser is the specified instrument for the identity of oxygen.

20.49 For nitrous oxide systems, an instrument based on thermal conductivity, or an infrared meter, should be used to check nitrous oxide concentration.

20.50 Where oxygen and nitrous oxide terminal units are installed within the same terminal unit bank, oxygen systems should be tested to confirm the absence of nitrous oxide, providing assurance that no pipeline cross-connection has occurred.

20.51 When testing pipelines that supply helium/oxygen mixture, an initial test should be carried out with nitrogen connected after completing the particulate test. An oxygen analyser should be used and all terminal units tested. After a zero reading is achieved, product cylinders should be connected and the system purged. A second test should be performed with an oxygen analyser; the oxygen content should meet the criteria in Table 34.

20.52 The criteria for testing carbon dioxide are given in Table 34. The carbon dioxide system terminates with a NIST terminal unit. A portable analyser using infrared technology provides an accurate identification of carbon dioxide.

20.53 Carbon dioxide gas flow should not exceed design flow during testing as this can cause the system components to freeze.

20.54 Multi-gas analysers that measure carbon dioxide in parts per million (ppm) are not suitable, as piped 100% carbon dioxide can overload the sensors, thereby affecting their reading and sensitivity. Other suitable (portable) analysers can be used. Equipment suitability should be confirmed by contacting manufacturers.

20.55 The British Pharmacopoeia recommends that carbon dioxide should be tested for hydrogen sulphide at concentrations not exceeding 1 ppm (v/v). Suitable gas detection tubes are available for this purpose.

Particulate matter

20.56 The MGPS should be free from particulate contamination.

20.57 All terminal units should be tested for particulate content using a 47 mm diameter (0.45 µm) filter.

20.58 Particulate testing should commence at terminal units located at the furthest point(s) from the AVSU.

20.59 New systems should be tested to show that the particulate filter is completely clear of visible particles when viewed in a good light.

20.60 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. The system should be purged to remove particles as far as practicable.

20.61 Where it is evident that extended purging may not completely clear the system of particulates, a decision should be made by the Authorised Person (MGPS) and the Quality Controller (MGPS) either to:

- accept the level of contamination present
- agree a procedure for removing particles
- in very exceptional circumstances, condemn the system.

20.62 When testing medical gases with a membrane filter, the following flow rates and times should be used:

Gas	Flow rate (L/min)	Duration (s)
Oxygen	150	30
Nitrous oxide	50	60
Oxygen/nitrous oxide mixture	275	30
Medical air	150	30
Surgical air	350	30
Dental air	50	60
Carbon dioxide	50	60
Heliox	50	60

20.63 When tests or purging are carried out on the MGPS serving an operational healthcare facility, test flows should not adversely affect the continuity or adequacy of supply to operational areas. Where a flow rate of 150 L/min or more cannot be achieved without compromising the system, a lower flow rate may be used at the discretion of the Quality Controller (MGPS), provided that the test duration is increased to maintain the total volume of gas tested. This should be documented on the QC report.

Oil

20.64 This test should be carried out at the plant test point for all newly installed compressed air plant and for existing compressed air plant at the frequency specified in Table 33. This test is not required following modifications to a tested (and compliant) medical or surgical air system.

20.65 Work involving the stripping-down of compressor plant and the subsequent replacement of oil-sealing components will require a follow-up oil test by the Quality Controller (MGPS).

20.66 The concentration of oil present should not exceed 0.1 mg/m³.

20.67 Oil may be present as liquid, aerosol or vapour, and an appropriate test device should be used to ascertain the levels present (for example, an oil detection tube or oil impactor).

20.68 For new installations, an oil test should be carried out at a plant test point before any pipeline system is supplied by that plant so as to prevent inadvertent contamination of the distribution system.

20.69 A representative sample of terminal units on both new and modified compressed air and oxygen concentrator systems supplied by compressor plant should be tested by the Quality Controller (MGPS).

Water vapour

20.70 Terminal units should be tested to confirm the absence of water vapour using an appropriate electronic test device. The concentration of water vapour present should not exceed 67 vpm, equivalent to an atmospheric pressure dew point of approximately –46°C or 0.05 mg/L.

20.71 When testing terminal units supplied via flexible hoses, it is often found that on initial testing the water-vapour levels exceed the limits due to inherent absorption of water vapour in the absence of flow. All hoses should be purged before testing. The Quality Controller (MGPS) should establish that any elevated water-vapour levels at the terminal units result from adsorption and not water contamination of the pipeline. (For example, the results should be compared with the readings achieved at nearby terminal units supplied by rigid pipework.)

20.72 This test at the terminal unit is intended to identify contamination of the pipeline system by water vapour. The test at the compressor plant is to confirm dryer performance.

20.73 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.

20.74 Failure to achieve the minimum dew-point standard should not be accepted. In the event of test failure, remedial action should be discussed with the Authorised Person (MGPS).

Carbon monoxide

20.75 Terminal units should be tested for the absence of carbon monoxide. The concentration of carbon monoxide should not exceed 5 ppm (v/v).

Carbon dioxide

20.76 Terminal units should be tested for the absence of carbon dioxide. The concentration

of carbon dioxide should not exceed 500 ppm (v/v) in medical, surgical and dental air or 300 ppm (v/v) in oxygen, nitrous oxide or oxygen/nitrous oxide pipeline systems. Increasing or fluctuating carbon dioxide readings in air or PSA-generated oxygen can be an early indication of dryer failure or poor compressor maintenance.

Sulfur dioxide

20.77 Terminal units should be tested for the absence of sulfur dioxide. The concentration should not exceed 1 ppm (v/v).

Oxides of nitrogen (NO and NO_2)

20.78 Terminal units should be tested for oxides of nitrogen. The concentration should not exceed 2 ppm (v/v).

Pipeline odour

20.79 An odour test is performed because it incorporates, qualitatively, many impurity checks, as several contaminants are detectable by odour. This should be carried out as part of QC testing using the working gases. Nitrous oxide, oxygen/nitrous oxide mixture and carbon dioxide should not be included within the odour test.

20.80 A check for any strong acrid odours should be carefully performed during purging and particulate testing. For flexible hoses, where strong odours or fluctuations in contaminant readings are witnessed during testing (apart from high moisture), they should be left for a short period of time and retested to determine whether odours or contaminant readings persist.

Vacuum systems

20.81 Vacuum systems should be checked for identity.

AGSS

20.82 AGSS should be checked for identity on pendants.

Requirements before an MGPS is taken into use

20.83 Before a system is brought into use, the appropriate persons should certify in writing, by signing the PTW, that all required tests and procedures have been completed and that the system complies with the relevant requirements.

Removal of “Do not use” plugs

20.84 When all tests have been completed satisfactorily by the Quality Controller (MGPS), the “Do not use” plugs inserted into the terminal units should be left in situ until their removal is approved by the Authorised Person (MGPS).

Reporting medical gas testing results

20.85 All test results should be recorded on medical gas report documents. The reports should include:

- the location (for example, hospital and department of the QC test)
- date and time of the QC test
- a set of RAMS which should include the test protocol, a description of the works carried out, points of isolation, points of works and tests undertaken
- the name of the Quality Controller(s) (MGPS) in attendance
- the name of the Authorised Person (MGPS) in attendance
- name of the Competent Person (MGPS)/ contractor

- batch numbers and expiry dates of consumables as appropriate (for example, calibration gases)
- tests and acceptance criteria for each medical gas
- serial numbers of test equipment and calibration certificates
- test results
- Quality Controller (MGPS) registration certificate.

20.86 Results should be recorded individually as numerical values for each terminal unit and test point where possible (electronic equipment) and as a “pass” or “fail” for particle and odour tests or for tests using detector tubes.

20.87 Any damage to terminal units should be recorded.

20.88 Action taken in response to non-compliant results should be recorded.

20.89 The relevant B-forms and part 5 of the PTW should be signed and dated.

Table 34 QC testing criteria for medical gases

Medical gas and source	Medical gas identification and concentration	Particles	Carbon monoxide	Carbon dioxide	Sulfur dioxide	Oxides of nitrogen	Water vapour	Oil	Odour	Polytest
Oxygen (bulk liquid or cylinders)	Oxygen ≥99.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	–	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	No odour	No discoloration
Oxygen (PSA plant)	Oxygen ≥94%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	≤2 ppm (v/v)	≤2 ppm (v/v)	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	≤0.1 mg/m3	No odour	No discoloration
Oxygen (concentrator)	Oxygen ≥94%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	–	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	No odour	No discoloration
Nitrous oxide	Nitrous oxide ≥98.0% (–0.2% oxygen analyser)	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	≤2 ppm (v/v)	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	Safety – not performed	No discoloration
Oxygen/nitrous oxide 50:50	Oxygen 50% ± 2% Nitrous oxide 50% ± 2%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	≤2 ppm (v/v)	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	Safety – not performed	No discoloration
Medical air	Oxygen 20.9% ± 0.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤900 mg/m3 ≤500 ppm (v/v)	≤1 ppm (v/v)	≤2 ppm (v/v)	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	≤0.1 mg/m3	No odour	No discoloration
Surgical air	Oxygen 20.9% ± 0.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤900 mg/m3 ≤500 ppm (v/v)	≤1 ppm (v/v)	≤2 ppm (v/v)	≤67 vpm ≤0.05mg/L Dryer than –46°C dew point	≤0.1 mg/m3	No odour	No discoloration
Dental air	Oxygen 20.9% ± 0.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤900 mg/m3 ≤500 ppm (v/v)	≤1 ppm (v/v)	≤2 ppm (v/v)	≤1020 vpm ≤0.78 mg/L Dryer than –20°C dew point	≤0.1 mg/m3	No odour	No discoloration
Synthetic air	95–105% of the nominal value of 21–22.5% oxygen	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	–	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	No odour	No discoloration
Helium/oxygen mixture	Heliox 21% Oxygen 20.9% ± 0.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	≤300 ppm (v/v)	–	–	≤67 vpm ≤0.05 mg/L Dryer than –46°C dew point	–	Safety – not performed	No discoloration
Carbon dioxide	Carbon dioxide ≥99.5%	Free from visible particles	≤5 mg/m3 ≤5 ppm (v/v)	–	≤2 ppm (v/v)	≤2 ppm (v/v)	≤67 vpm 0.05 mg/L Dryer than –46°C dew point	–	Safety – not performed	No discoloration

Key: v/v = volume per volume; vpm = volume parts per million

21 Mobile vehicles

Piped medical gases in ambulances and mobile vehicles

21.1 This chapter covers:

- piped medical gases in ambulances
- mobile x-ray units
- mobile theatres.

Ambulances

General principles

21.2 Piped medical gas installations in ambulances are supplied either from a single cylinder or via a pipeline.

21.3 Where a pipeline is used, it should comprise flexible hoses, terminal units, changeover valves and cylinder connections.

21.4 Where piped MGPS installations are required within a patient compartment in a vehicle, the guidance contained in this HTM should be followed

21.5 Existing installations should be assessed for compliance with this HTM. Operators of vehicles should carry out a risk assessment to establish the extent of any remedial action required. A plan for upgrading the existing system should be prepared, taking account of the priority for patient safety.

21.6 The vehicle design should ensure adequate ventilation to prevent the accumulation of medical gases within the ambulance.

Provision of gases

21.7 The provision of oxygen and oxygen/nitrous oxide mixtures should form part of the IDP.

21.8 The oxygen supply should comprise a source with a capacity of at least 2000 L of gas. This can be achieved either by two size HX/F4C medical oxygen cylinders.

21.9 All cylinders used within the ambulance should be of integral valve design.

Provision of terminal units

21.10 Terminal units should be fixed rigidly to the superstructure or internal cladding of the vehicle at the head of each bed position so that the ancillary gas flow gauge is visible and the flow rates can be adjusted easily.

21.11 Terminal units should comply with BS EN ISO 9170-1.

Cylinder supply and pressure regulation

21.12 Supply cylinders should be securely fitted to withstand acceleration, deceleration and hard braking. The system should be designed to retain the cylinders safely in the event of a vehicle roll-over.

21.13 The contents gauge should be visible to the crew during administration of gas to the patient.

21.14 Each terminal unit should be capable of providing continuous oxygen delivery at a flow rate of 40 L/min with a nominal supply pressure at the terminal unit of 420 kPa.

21.15 Oxygen/nitrous oxide mixture is used as a self-administered analgesic through a demand regulator and will require a flow rate of 275 L/min.

21.16 The provision of a line pressure gauge is not necessary on a small installation (usually less than 5 m). If provided as a client option, a line pressure gauge may be installed in the pipeline system where it would be most visible to the crew. The pipeline system's design pressure should be in excess of the pressure regulator relief-valve setting (540 kPa).

21.17 To optimise the use of gas, a changeover device should be provided for two or more cylinders. This device should incorporate a line pressure gauge with clearly visible indication of which cylinder is in use. Connections to the device should be gas-specific and on a quick-release medical gas specific probe. The changeover device should be attached securely to a bulkhead within the vehicle adjacent to the cylinders.

Changeover unit

21.18 Continuity of supply is the primary function of changeover units, and seamless changeover from one cylinder to another is essential. Automatic systems should fail safe. The changeover valve may be manual or automatic, digital or analogue. The cylinder online should run until the pressure reaches 350 to 420 kPa, at which point the second cylinder should automatically take over to maintain a minimum of 350 kPa and return to static line pressure. Manual changeover valves need the intervention of the ambulance crew. An audible and visual indication should be activated on changeover or when a manual system requires changing.

Pressure alarm

21.19 Line pressure should be monitored by an audible and visual alarm.

Pipeline installation

21.20 Rigid pipework should not be used in ambulances as vibration could cause damage.

21.21 The interconnecting pipework between the cylinder regulator outlet and terminal units should be carried out using low-pressure flexible connecting assemblies in accordance with BS EN ISO 9170-1, including all the appropriate connectors and hose material.

21.22 All hoses should be crimped in accordance with BS EN ISO 9170-1.

21.23 All pipework should be surface-mounted or readily accessible for inspection and replacement, and adequately and securely clipped to the vehicle walls. Fixing methods should prevent hose chafing and be non-corrosive. Where any pipework passes through a compartment, non-split grommets should be fitted. Holes should be sized to accommodate the passage of end fittings (for example, NIST connecting nuts).

21.24 Where tee fittings are used to connect hose branches to terminal units, they should be fitted with hose-tail connections in accordance with BS EN ISO 9170-1.

21.25 All ferrules used in the attachment of hose to hose-tails should meet the requirements of BS EN ISO 9170-1.

21.26 Hoses should be connected to cylinders by a probe in accordance with BS EN ISO 9170-1.

21.27 The hose from the changeover valve to the terminal units should be supplied as a single tested product to avoid on-site crimping and to ensure ease of replacement.

21.28 All hose connections to changeover valves (pipeline and bottle connecting hoses)

should be gas-specific to prevent cross-connection.

21.29 Holes within the bulkhead should be sized to allow free passage of the hose assembly without undue stress.

21.30 Replacement of the hose assembly (or repairs) and cylinder connection hoses may be carried out on site by authorised and trained personnel.

21.31 Only task-specific tools and equipment should be used, and the appropriate quality assurance documentation should be completed. Specific training will be required to ensure competency.

Commissioning installations

21.32 On completion of a repair, refurbishment or new installation, the system should be purged and particulate-tested with compressed air of medical quality from a cylinder in line with paragraphs 19.222 to 19.233 (the engineer's particulate test) prior to any other tests. Tests should be undertaken at this stage to ensure that no contamination is present which may damage test equipment during subsequent tests.

21.33 The system should be pressurised and leak-tested at 1.5 times the working pressure (typically 600 kPa). The system should be charged with compressed air of medical quality from a cylinder supply over a 30-minute test period; no pressure drop should be found.

21.34 This test should be undertaken using a digital pressure gauge with a resolution of two decimal places. Results of these tests should be documented.

21.35 The changeover valve should be leak-tested and function-tested through a minimum of five repeat-and-return cycles. This should be achieved by isolating the online cylinder supply and inducing a system bleed of no more than 5 L/min to activate changeover to the secondary cylinder. The process should then be repeated to demonstrate that the changeover valve maintains continuity of supply.

21.36 Terminal units should be inspected for the following:

- They should be inspected to ensure clear, undamaged identification.
- The anti-swivel pin for the medical oxygen terminal unit should be positioned at the top (12 o'clock position) when viewed from the front face of the terminal unit. The oxygen/nitrous oxide mixture does not require an anti-swivel pin as connection is made solely via a flexible hose.
- Terminal units should be free from damage and contamination.
- Gas specificity and probe retention should be verified by inserting a test probe and applying a gentle tug to confirm secure engagement.
- Terminal units should be checked for leaks from unit seals both with and without the test probe inserted.
- The pressure at medical oxygen terminal units should be not less than 400 kPa under static conditions and 390 kPa at a flow rate of 15 L/min. For oxygen/nitrous oxide mixtures, the pressure should be not less than 400 kPa under static conditions and 380 kPa at a flow rate of 275 L/min. This should be tested using a flow device consisting of a medical gas probe, pressure gauge and metered leak; adjustable units are available, but dedicated units for each gas are preferable.

21.37 Each system should be certified by the testing person prior to being returned to the user in accordance with quality assurance procedures. Such certification should include details of all tests carried out.

21.38 On completion of all works, the following tests should be undertaken to ensure the safety of the system:

- purged and particulate tests with a working gas
- gas quality tests for individual gases.

The above tests should be undertaken by a Competent Person (Ambulance). This should be witnessed by another Competent Person (Ambulance).

Routine testing, maintenance and general safety

- Daily: the pipeline system where visible should be inspected daily for obvious signs of damage; this should be undertaken by the users.
- Three monthly: the pipeline installation should be inspected every three months for evidence of damage, abrasion, leakage at joints, signs of deterioration and soiling. Damaged products or pipeline installations should be isolated and repaired. In the event of soiling, pipework should be cleaned. Care is needed to avoid contamination of the pipeline system. Terminal units and changeover systems should be inspected for leakage and for the condition of any elastomeric components (for example, seals and valve seats). This work should be undertaken by the Competent Person (Ambulance).
- Annually: the full system should be tested in line with the commissioning installations procedure. This work should be undertaken by the Competent Person (Ambulance).

Hose inspection and replacement

- The hose should be examined along its full length for signs of wear, damage, kinking, leakage and bubbling.
- Annual pressure and particulate testing, together with gas quality testing and quarterly and weekly inspections, should ensure that hoses remain in good condition for continued use.
- Annual testing and inspection of hoses allows them to remain in service for up to a maximum of eight years. Failure of any test should require replacement of the complete pipeline assembly.
- The main components of the system may be recycled and refurbished to avoid unnecessary waste and reused in the construction of new hose assemblies.
- Terminal units and changeover valves should be replaced at intervals not exceeding eight years.

General safety

21.39 Cylinder handling is described in Part B.

Vacuum systems

21.40 Vacuum systems powered by the vehicle's DC supply should include:

- an indication of the vacuum level
- a means of adjustment
- on/off indication.

21.41 As with permanent fixed installations in healthcare premises, the vacuum system should be used in conjunction with a suction jar assembly incorporating a shut-off float switch and a bacterial filter. The system should be supplied from the auxiliary circuit.

Mobile X-ray units

21.42 In most cases, mobile X-ray units should use cylinders and portable battery-powered vacuum systems.

21.43 If a pipeline system is required, the guidance in this HTM should be followed.

21.44 Guidance on securing cylinders is given in Chapter 17.

Mobile theatre units

21.45 These units should be installed to comply with this HTM, with the following extra requirements.

21.46 Each time a unit is relocated, a full test and commissioning procedure should be carried out and certified prior to use in line with Chapters 19 and 20.

21.47 Consideration should be given to vibration during transportation and its impact on the MGPS when designing mobile theatres.

21.48 Cylinders should be removed prior to transport and new cylinders supplied and fitted once the unit reaches its new location.

21.49 All cylinder connections should be sealed when no cylinders are fitted.

21.50 Care should be taken to avoid damage to the compressors and pumps while in transit. Therefore, transit bolts should be installed during transportation.

21.51 Care should be taken to ensure that lubricating fluids are not spilled during transportation of the medical gas plant.

Appendix 1 – Sample B-forms

Sample B-forms are provided in this Appendix for reference only. Editable Excel versions are available from the HTM web page and may be completed electronically with site-specific information

B0 record of tests undertaken			Signed off by					
		Completed	MCR	CP	AP	QC	AE	Comments
B1	Design sign-off by the MGSG	Yes/No	N/A	N/A				
B2	Brazing inspections	Yes/No				N/A	N/A	
B3	Snagging and record of interim inspections	Yes/No				N/A		
B4	Labelling and marking, sleeving and supports	Yes/No				N/A	N/A	
B5	Carcass pressure test	Yes/No				N/A	N/A	
B6	Verification of drawings	Yes/No				N/A		
B7	HTM compliance	Yes/No				N/A		
B8a	Plantroom compliance	Yes/No				N/A	N/A	
B8b	Manifold room compliance	Yes/No				N/A	N/A	
B8c	Cylinder store compliance	Yes/No				N/A	N/A	
B9	Air plant	Yes/No	N/A			N/A	N/A	
B10	Pressure-reducing stations (PRS)	Yes/No	N/A			N/A	N/A	
B11	Vacuum Plant	Yes/No	N/A			N/A	N/A	
B12	AGSS Plant	Yes/No	N/A			N/A	N/A	
B13	Manifold systems	Yes/No	N/A			N/A	N/A	
B14	Liquid systems	Yes/No	N/A			N/A	N/A	
B15	PSSR 2000 documentation	Yes/No	N/A			N/A		
B16	Second-fix items installed	Yes/No	N/A			N/A	N/A	
B17	“Do not use” plugs installed	Yes/No	N/A			N/A	N/A	
B18	Pipeline pressure test	Yes/No	N/A			N/A	N/A	
B19	Vacuum leak test	Yes/No	N/A			N/A	N/A	
B20	Engineer’s particulate test	Yes/No	N/A			N/A	N/A	
B21	Cross-connection test	Yes/No	N/A			N/A	N/A	
B22	LVAs (zoning, closure, identity and gas specificity)	Yes/No	N/A			N/A	N/A	
B23	AVSUs (zoning, closure, identity and gas specificity, signage)	Yes/No	N/A			N/A	N/A	
B24	Terminal unit tests	Yes/No	N/A			N/A	N/A	
B25	Purging and filling	Yes/No	N/A				N/A	
B26	Design flow performance tests	Yes/No	N/A			N/A	N/A	
B27	Plant alarm tests	Yes/No	N/A			N/A	N/A	
B28	Local alarm tests	Yes/No	N/A			N/A	N/A	
B29	QC particulate tests	Yes/No	N/A	N/A			N/A	
B30	QC identity and quality tests	Yes/No	N/A	N/A			N/A	
B31	Key register	Yes/No	N/A			N/A	N/A	
B32	“Do not use” plugs removed	Yes/No	N/A			N/A	N/A	
B33	Completion certificate	Yes/No						
			Signed			Print		Date
	Competent Person MGPS							
	Mechanical Contractor							
	Quality Controller (MGPS)							
	Authorising Engineer (MGPS)							

B1 Design sign-off by the MGSG					
The piped medical gas design has been checked for compliance with the relevant parts of HTM 02-01 and the following specifications and drawings.					
			Date	Specification reference	
	Specification reference/s				
Register of design drawings					
		Reference	Description	Reason	
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
The following derogations have been agreed and accepted:					
Register of derogations from HTM 02-01					
		Reference	Description	Reason	
	1				
	2				
	3				
	4				
	5				
All of the above has been agreed by the Medical Gas Safety Group.					
			Signed	Print	Date
	Chair of the MGSG				
	Authorising Engineer (MGPS)				
	Authorised Person (MGPS)				
	Quality Controller (MGPS)				

B2 Brazing inspections

No.	Date	Location	Gas	Pipeline size	Type of fitting	Penetration Pass/Fail	Cleanliness Pass/Fail	Initial AP (MGPS)	Initial CP (MGPS)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									

All joint inspections completed	Yes/No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B3 Snagging and record of interim inspections

							Initial	
Date	Area inspected	Drawing reference	Issue	Rectified	Date	MCR	AP (MGPS)	CP (MGPS)
All joint inspections completed			Yes/No				Sheet 1 of	

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B4 Labelling and marking, sleeving and supports

No.	Date	Gases	Gas identification	Flow arrows	Dual circuit identification	Sleeving	Supports	Location inspected
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

All inspections completed	Yes/No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B5 Carcass pressure test			
Description of the extent of the pipeline to be tested:			
Gas pipeline to be tested		Gas used to test	
Test pressure to be applied			
Duration of the test			
Test gauge identification			
Test gauge certificate number			
Actual test pressure on commencement		Test start time	
Actual test pressure on completion		Test stop time	
All tests completed	Yes/No		Sheet 1 of
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B6 Verification of drawings					
No.	Date	Drawing reference	Description	Initial	
				AP (MGPS)	CP (MGPS)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
All drawings completed			Yes/No		**Sheet 1 of**
			Signed	Print	Date
Authorised Person (MGPS)					
Competent Person (MGPS)					
Mechanical Contractor					
Authorising Engineer (MGPS)					

B7 HTM compliance																
The following installation has been inspected in line with forms B1 and B6:																
Drawing number	**Gases**												**Installation compliant**			
	O_2	N_2O	O_2/ N_2O	MA4	SA7	VAC	CO_2	AGS	DA	DVAV	DAGS	Other	MCR	CP (MGPS)	AP (MGPS)	AE (MGPS)
All areas completed				Yes/No											Sheet 1 of	
				Signed				Print					Date			
Mechanical Contractor																
Competent Person (MGPS)																
Authorised Person (MGPS)																
Authorising Engineer (MGPS)																

B8a Plantroom compliance		
Gas:		
Description of plant:		
	Pass/Fail	Comments
Access to plantroom		
External signage		
External lighting		
External security		
Internal signage		
Internal lighting		
Heating		
Ventilation		
Cleanliness		
Segregation of plant		
Plant space for access		
All inspections completed	Yes/No	Sheet 1 of
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B8b Manifold room compliance		
Gas		
Description of manifold/s		

	Pass/Fail	Comments
Access to manifold room		
External signage		
External lighting		
External security		
Internal signage		
Internal lighting		
Heating		
Ventilation		
All cylinders secure		
Spare cylinder racking		

All inspections completed	Yes/No	Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B8c Cylinder store compliance					
Cylinder store type		Main	External/Internal	Satellite	
	Pass/Fail	Comments			
Access to cylinder store					
External signage					
External lighting					
External security					
Internal signage					
Internal lighting					
Heating					
Ventilation					
Cleanliness					
All cylinders secure					
Spare cylinder racking					
Gas	Cylinder size	Quantity	Full	Empty	Comments
All inspections completed		Yes/No			Sheet 1 of
		Signed		Print	Date
Authorised Person (MGPS)					
Competent Person (MGPS)					
Mechanical Contractor					

B9 Air plant						
Type of plant	Medical*	Surgical*	Combined*	Dental*		
Compressors	Compressor 1	Compressor 2	Compressor 3	Compressor 4	Compressor 5	Compressor 6
Type						
Size						
Identification						
				Tested	Yes/No	Pass/Fail
Notes						
Vessels	Vessel 1	Vessel 2	Vessel 3	Vessel 4		
Type						
Size						
Identification						
Tested	Yes/No	Pass/Fail				
Oil–water separator installed and connected to drains			Yes/No			
Notes						
Dryers	Dryer 1 RHS	Dryer 1 LHS	Dryer 2 RHS	Dryer 2 LHS		
Type						
Size						
Identification						
			Tested	Yes/No	Pass/Fail	
Notes						
Individual tests to be recorded on the CP documentation and supplied with this B form.						
All tests completed			Yes/No			
		Signed		Print		Date
Authorised Person (MGPS)						
Competent Person (MGPS)						
Mechanical Contractor						

B10 Pressure-reducing stations (PRS)				
Air supply from plant:				
Supply to departments:				
Regulator 1	Duty*	Standby*		
Input pressure	kPa		Output pressure	kPa
Regulator 2	Duty*	Standby*		
Input pressure	kPa		Output pressure	kPa

All valves in the open position	Pass	Fail
Pressure safety valves piped to a safe location	Pass	Fail
Exhaust warning signage installed for pressure gas	Pass	Fail
Pressure gauges clear and visible	Pass	Fail
Test points accessible and compliant	Pass	Fail
Alarm tested for high and low pressure	Pass	Fail
System identification clear and correct	Pass	Fail

Individual tests to be recorded on the CP documentation and supplied with this B-form.		
All tests completed	Yes/No	Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B11 Vacuum plant						
Type of plant	Medical*	Dental*				
Pumps	Pump 1	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6
Type						
Size						
Identification						
Tested	Yes/No	Pass/Fail				
Notes						

Vessels	Vessel 1	Vessel 2	Vessel 3	Vessel 4	
Type					
Size					
Identification					
Tested	Yes/No	Pass/Fail			
Notes					

Bio filters	RHS		LHS	
Type				
Size				
Identification				
Tested	Yes/No		Pass/Fail	
Notes				

Individual tests to be recorded on the CP documentation and supplied with this B-form.		
All tests completed	Yes/No	Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B12 AGSS plant						
Locations supplied						
Type of plant	Medical*	Dental*				
Pumps/Blower	Pump/Blower 1		Pump/Blower 2			
Type						
Size						
Identification						
Balance valve						
Balance valve filter						
Tested	Yes/No		Pass/Fail			
Notes						
		Individual flow rate in L/min		System flow rate all terminal units in operation		
Terminal unit	Static line pressure	130 */80 *	80*/ 50*	130 */80 *	80*/50*	
1						
2						
3						
4						
5						
6						
Notes						
Individual tests to be recorded on the CP documentation and supplied with this B-form.						
All tests completed			Yes/No		Sheet 1 of	
		Signed		Print		Date
Authorised Person (MGPS)						
Competent Person (MGPS)						
Mechanical Contractor						

B13 Manifold systems					
Manual change manifold					
Primary*	Secondary*	Tertiary*			
Gas					
Number of cylinders					
Locations supplied					
Tested in accordance with manufacturers' requirements			Pass	Fail	
Tested in accordance with HTM 02-01			Pass	Fail	
Spare cylinder racking for 1 bank = 1 cylinder installed			Pass	Fail	
Notes					
Automatic changeover manifold					
Primary*	Secondary*	Tertiary*			
Gas					
Number of cylinders					
Locations supplied					
Tested in accordance with manufacturers' requirements			Pass	Fail	
Tested in accordance with HTM 02-01			Pass	Fail	
Spare cylinder racking for 1 bank = 1 cylinder installed			Pass	Fail	
Notes					
Individual tests to be recorded on the CP documentation and supplied with this B-form.					
All tests completed			Yes/No	Sheet 1 of	
	Signed		Print		Date
Authorised Person (MGPS)					
Competent Person (MGPS)					

B14 Liquid systems					
Description of system					
Primary*	Secondary*	Tertiary*			
Gas					
Locations supplied					
Tested in accordance with manufacturers' requirements			Pass	Fail	
Tested in accordance with HTM 02-01			Pass	Fail	
Compound secure, lighting installed and clean			Pass	Fail	
Signage and instructions posted internally and externally			Yes	No	
Road markings and parking restrictions clear and present			Yes	No	
Training received on the installation			Yes	No	
Notes					
Individual tests to be recorded on the CP documentation and supplied with this B-form.					
All tests completed			Yes/No	Sheet 1 of	
		Signed	Print		Date
Authorised Person (MGPS)					
Competent Person (MGPS) (system supplier)					

B15 PSSR 2000 documentation

Item	Description	Unique ID	Pressure rating	Certificate supplied		Register completed		WSE completed	
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No
				Yes	No	Yes	No	Yes	No

All works completed	Yes/No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B16 Second-fix items installed

The following second-fix components have been installed following the carcass tests, and the system is ready for pipeline commissioning.

Component	Location	Gas	Quantity

Individual tests to be recorded on the CP documentation and supplied with this B form.

	All tests completed	Yes	No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B17 "Do not use" plugs installed				
Location	Gas	Number of terminal units	Plugs installed	AP (MGPS) initial
			Page 1 of	
	Signed	Print		Date
Authorised Person (MGPS)				
Competent Person (MGPS)				

B18 Pipeline pressure test

	Gas	From	To
Pipeline to be tested:			

Start pressure (kPa)			Final pressure (kPa)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

	Gas	From	To
Pipeline to be tested:			

Start pressure (kPa)			Final pressure (kPa)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

	Gas	From	To
Pipeline to be tested:			

Start pressure (kPa)			Final pressure (kPa)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

			Page 1 of
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B19 Vacuum leakage test

	Gas	From	To
Pipeline to be tested:			

Start pressure (mmHg)			Final pressure (mmHg)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

	Gas	From	To
Pipeline to be tested:			

Start pressure (mmHg)			Final pressure (mmHg)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

	Gas	From	To
Pipeline to be tested:			

Start pressure (mmHg)			Final pressure (mmHg)		
Type of gauge			Time on test		
Gauge number			Pressure differential		
Gauge certificate				Pass	Fail

Page 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B20 Engineer's particulate test

Pipeline tested

Gas	From	To	Number of terminal units	Time of purge	Result
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail

All tests completed	Yes/No	Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B21 Cross-connection test						
Gas						
Location of test						
Pipeline from						
Pipeline to						
Cross-connections found	Yes	No		Pass	Fail	
Gas						
Location of test						
Pipeline from						
Pipeline to						
Cross-connections found	Yes	No		Pass	Fail	
Gas						
Location of test						
Pipeline from						
Pipeline to						
Cross-connections found	Yes	No		Pass	Fail	
All tests completed	Yes/No				Sheet 1 of	
	Signed		Print		Date	
Authorised Person (MGPS)						
Competent Person (MGPS)						

B22 LVAs (zoning, closure, identity and gas specificity)										
Valve number	Gas	Location	Closure	Zoning	NISTs	Signage	NISTs locked	Key number	Valve locked	Key number
			Pass/ fail	Pass/ fail	Pass/ fail	Pass/fail				
All tests completed					Yes/No		Sheet 1 of			

	Signed	Print	Date
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B23 AVSUs (zoning, closure, identity and gas specificity, signage)							
Valve number	Gas	Location	Closure Pass/fail	Zoning Pass/fail	NISTs Pass/fail	Signage Pass/fail	Key Number
Schematic drawing of area controlled located at AVSU			Yes/No		Pass	Fail	
Overall functionality of the AVSU			Yes/No		Pass	Fail	
All tests completed			Yes / No		Sheet 1 of		

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Mechanical Contractor			

B24 Terminal unit tests			
Location			
Gas			
Number of terminal units			
Mechanical function tests	Pass	Fail	
Flow and pressure tests	Pass	Fail	
Individual tests to be recorded on the CP documentation and supplied with this B-form.			
Location			
Gas			
Number of terminal units			
Mechanical function tests	Pass	Fail	
Flow and pressure tests	Pass	Fail	
Individual tests to be recorded on the CP documentation and supplied with this B form.			
Location			
Gas			
Number of terminal units			
Mechanical function tests	Pass	Fail	
Flow and pressure tests	Pass	Fail	
Individual tests to be recorded on the CP documentation and supplied with this B form.			
All tests completed	Yes / No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B25 Purging and filling test			
Gas	Pipeline from	Pipeline to	Pipeline filled and purged with working gas
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			
Quality Controller (MGPS)			

B26 Design flow performance tests			
Gas			
Description of the system			
Design flowrate of the system	L/min		
System static pressure			
Location of bleed	Flowrate of bleed	Accumulative total	
System pressure under full flow			
Pressure loss under full flow			
System design pressure loss			
	Pass	Fail	
All tests completed	Yes/No		Sheet 1 of
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B27 Plant alarm tests		
Number of plant alarms		
Locations		

	Alarm 1		Alarm 2		Alarm 3		Alarm 4	
Battery backup tested	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Battery date identified	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Labelling completed	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Audible signal tested	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
Automatic reset	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
All gases show correct alarms	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail
All commissioning completed	Pass	Fail	Pass	Fail	Pass	Fail	Pass	Fail

Individual tests to be recorded on the CP documentation and supplied with this B-form.

All tests completed	Yes/No		Sheet 1 of

	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B28 Local alarm tests					
Alarm 1					
Location of alarm					
Location of transducers					
Master alarm				Repeater alarm	
Battery backup tested	Pass	Fail		Pass	Fail
Battery date identified	Pass	Fail		Pass	Fail
Labelling completed	Pass	Fail		Pass	Fail
Audible signal tested	Pass	Fail		Pass	Fail
Automatic reset	Pass	Fail		Pass	Fail
All gases show correct alarms	Pass	Fail		Pass	Fail
All commissioning completed	Pass	Fail		Pass	Fail
Alarm 2					
Location of alarm					
Location of transducers					
Master alarm				Repeater alarm	
Battery backup tested	Pass	Fail		Pass	Fail
Battery date identified	Pass	Fail		Pass	Fail
Labelling completed	Pass	Fail		Pass	Fail
Audible signal tested	Pass	Fail		Pass	Fail
Automatic reset	Pass	Fail		Pass	Fail
All gases show correct alarms	Pass	Fail		Pass	Fail
All commissioning completed	Pass	Fail		Pass	Fail
All tests completed	Yes / No				
	Signed		Print		Date
Authorised Person (MGPS)					
Competent Person (MGPS)					

B29 QC particulate test					
Pipeline tested					
Gas	AVSU number	Tested: NIST or terminal unit	Number of terminal units/NISTs	Time of purge	Result
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
					Pass/Fail
All tests completed	Yes No		Sheet 1 of		

	Signed	Print	Date
Authorised Person (MGPS)			
Quality Controller (MGPS)			

B30 QC identity and quality tests						
QC test sheet supplied via the QC should be used as B30						

B31 Key register			
Confirmation of the supply of correctly identified keys located in the master and Authorised Person's (MGPS) key cabinets inline with the existing*/ new* key registration system has been completed. An electronic copy of the updated key register has been supplied to the Authorised Person (MGPS)			
A completed key register should be recorded on the CP documentation and supplied with this B-form.			
All tests completed	Yes/No		Sheet 1 of
	Signed	Print	Date
Authorised Person (MGPS)			
Competent Person (MGPS)			

B32 "Do not use" plugs removed				
All testing and commissioning has been successfully completed, and the system is ready for handover to the clinical team.				
Location	Gas	Number of terminal units	Plugs removed	AP initial
			Page 1 of	
	Signed	Print		Date
Authorised Person (MGPS)				
Competent Person (MGPS)				

B33 Completion certificate			
Testing and commissioning			
All tests and inspections as identified on form B0 (record of tests) have been completed and passed. No further remedial or corrective action is required to be undertaken. All engineering and QC tests have passed and the permit to work form is completed.			
Permit to work number			
The system is ready for clinical use.			
	Signed	Print	Date
Competent Person (MGPS)			
Authorised Person (MGPS)			
Mechanical Contractor			
Quality Controller (MGPS)			
Authorising Engineer (MGPS)			
These medical gas works have been completed and accepted for clinical use.			
Print	Signed	Date	
Position			

References

Note:
The publication dates provided in the references list below correspond to when this edition of HTM 02-01 was drafted. The dates give context on the currency of referenced sources at the time of writing.
Standards and other specification documents are continually being updated, and readers should ensure they consult the latest editions of such documents, including any amendments issued after publication, to ensure they remain up to date with and can react to changing requirements.

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