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# Performance of healthcare cryogenic liquid oxygen systems

November 2021

# Contents

# 1. Introduction

This document describes optimum supply and distribution systems to mitigate the effects of high oxygen flows during pandemic conditions. It has been produced with input from the UK Registered Authorising Engineer (AE) (MGPS) COVID-19 Working Group and other subject experts. It is intended for immediate use. Examining all aspects of cryogenic oxygen supply and storage, and associated gas distribution system configuration, this document provides guidance on oxygen system auditing and critical operational procedures to mitigate the effects of exceptional oxygen demands experienced during pandemic conditions.

The tasks boxes prescribe actions to bring awareness of system parameters, audit, design and configuration, and detail practical measures to enable identification of deficiencies. **Appendix A** provides operational protocols for dealing with excessive demands for cryogenic liquid oxygen. It should be annexed to the healthcare establishments/trusts' (HE/Ts) medical gas plant and system operational policy and posted in all estates departments where it can be easily consulted.

The pandemic has highlighted the crucial value of liaison with the AE (MGPS). The support and experience of AEs should be sought when auditing oxygen systems and planning remedial measures for high oxygen demand situations. The AE (MGPS) proposed remedial actions should form part of the HE/Ts' overall action plan, along with risk assessed timescales for each identified non-compliance with HTM 02-01 or deficiencies in system condition, configuration or management. If, for any reason, a particular objective cannot be achieved or this is difficult within the defined timeframe, the advice and help of the AE (MGPS) should be sought without delay to help ensure prompt resolution.

In the interests of patient safety, HE/Ts must implement, monitor and regularly update (at least annually) a robust MGPS operational policy. The status of the policy should be investigated as part of the AE (MGPS) audit process.

A HE/T's medical gas committee (MGC) should be instrumental in the safe management of medical gases and the development of the MGPS operational policy. There has been some misunderstanding of the function of this group and an underestimation of its importance with respect to defining medical gas policies and procedures. Advice on

establishing an MGC can be sought from the AE (MGPS) and **Appendix C** outlines the operational requirements of a typical MGC.

# 2. Plant capacity

VIE capacity used to be defined in terms of 'days of supply at typical demand'. HTM 02-01 introduced the idea of risk assessed capacity based not only on average use but also such factors as proximity of the site to a gas supplier's production facility. This led to the installation of smaller VIEs and more frequent oxygen deliveries.

Too often, adding a VIE has been wrongly assumed to be the solution to gas shortage problems. Plant capacity is highly unlikely to cause system failure. However, this should be reviewed annually (along with plant maintenance protocols) with the gas supplier, with consideration of the environmental impact of more frequent deliveries and site access for larger delivery vehicles.

### Tasks

- Investigate and confirm the configuration and capacity of the onsite cryogenic vessel(s), their age(s) geographic location(s); liquid delivery frequency; and any plant access and environmental restrictions.
- Review condition of the VIE evaporators and ensure there are no restrictions to ambient air flow, or access for ice removal.
- Consider installing water/steam feeds to the VIE compound.

# 3. Telemetry

All cryogenic oxygen suppliers offer telemetric monitoring of the VIE contents and pressure, primarily to facilitate effective delivery schedules. However, the value of telemetry in terms of the data systems produce for client use should not be underestimated.

HE/Ts should discuss the advantages of the monitoring system with their gas supplier, and receive training not only in the operation of the VIE system, but also in the use of internet access codes/SMS protocols to interrogate the system and additional programming features to tailor flow and usage data to meet site-specific needs.

### Tasks

- Establish if telemetry is available and confirm the internet access codes (including any additional measures when using GSM telemetry, if applicable) for the site plant with your gas supplier.
- Discuss with your gas supplier the format in which plant operational data needs to be presented and ensure all software is performing as specified.
- Ensure everyone involved in routine maintenance and operation (including emergency operation) are suitably trained.

# 4. Plant performance parameters

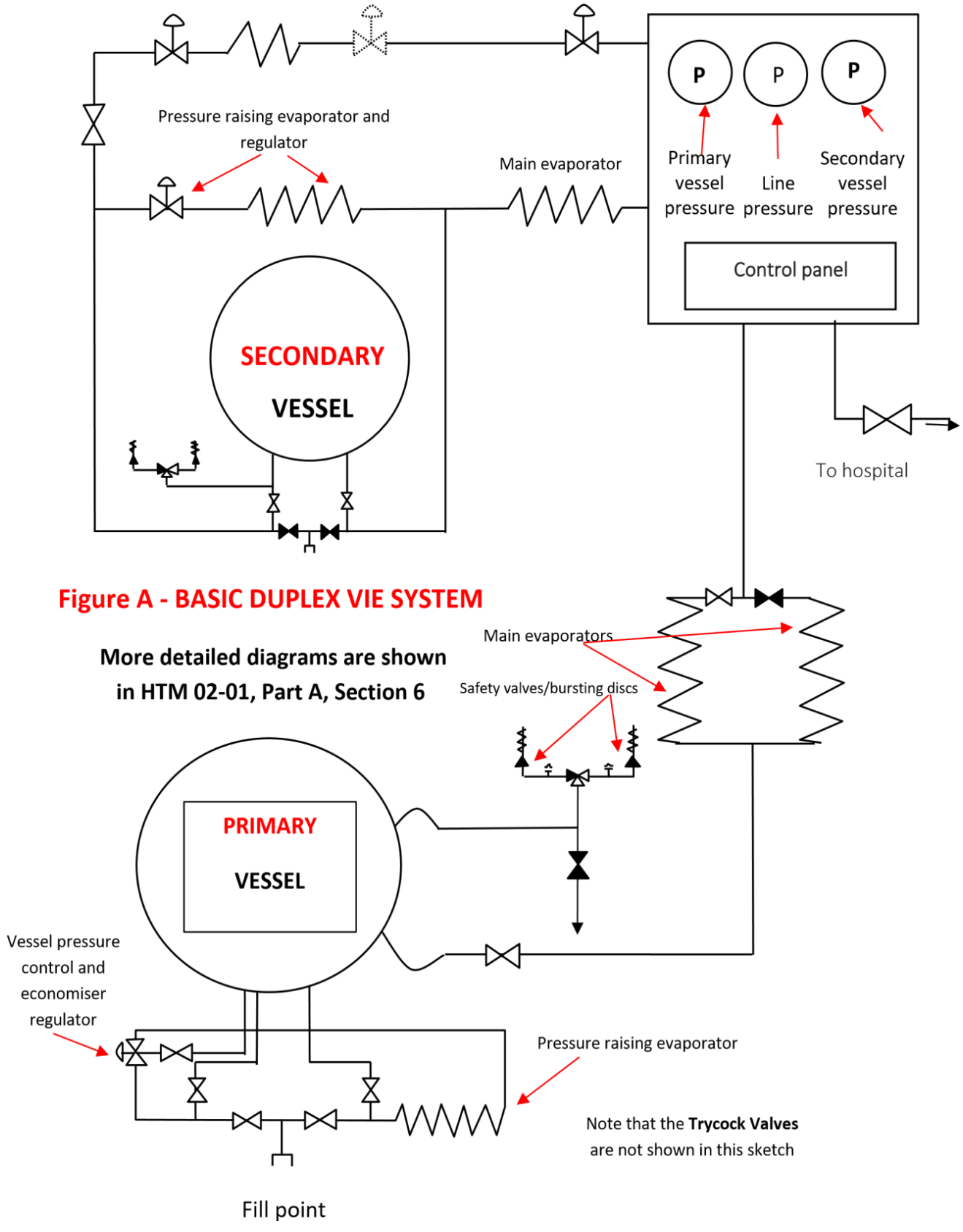
## 4.1 General

All healthcare cryogenic liquid oxygen plant comprises the following basic elements:

- the VIE vessel, used to store the cryogenic liquid oxygen at an extremely low temperature (-196 $^{o}$C)
- two types of evaporator (or vaporiser), used to (a) maintain vessel pressure and (b) convert liquid product into gas by absorption of atmospheric heat
- the control panel, used to lower gaseous product from vessel pressure (~10 bar) to hospital system pressure (~4 bar) while also controlling its flow
- the alarm system, which monitors vessel contents (liquid level) and system pressure, and relays this information to alarm panels around the hospital
- the telemetry system (now fitted to most new installations), which monitors vessel contents and pressure, and feeds this information by a dedicated landline or SIM card operated service to the gas supplier, to ensure system safety and to trigger product deliveries well before the vessel is depleted.

This primary supply VIE will usually be supported by a secondary supply VIE, as shown in Figure 1. Some older, smaller systems may be supported by a cylinder manifold system.

**Figure 1: Basic duplex VIE system - Economiser regulator and evaporator (14 bar outlet setting) ~4 bar**



## 4.2 Control panel performance

Control panels will have one of the following 4 bar flow rates:

- 1,500 L/min (now few and far between)
- 3,000 L/min (very common)
- 5,000 L/min (found on newer plant)
- 6,000 L/min (usually achieved by installing 2 x 3,000 L/min units in parallel).

Control panel technology is both well established and generally very dependable. During the pandemic, some HE/Ts have adjusted their control panel regulator to improve system flow, but the scope for dramatic increases from doing this is extremely limited. All such adjustments must be carried out after consultation with the gas supplier, as they own this equipment.

## 4.3 Primary evaporator performance

The primary evaporator should evaporate liquid at a rate that maintains the flow delivery potential of the control panel. However, for maximum efficiency ice must be frequently removed using water or steam. Unfortunately, not all plants have been fitted with adequately sized evaporators, limiting the flow potential of the control panel. In extremis, both primary evaporators can be put online, although this should not be a first-line response and must be discussed with the gas supplier, along with overall evaporator performance.

Some systems are fitted with an automatic changeover facility that uses electrically powered motorised valves. The changeover time cycle is set by the gas supplier and is typically 8 to 12 hours. Although this reduces the risk of excessive uncontrolled icing, evaporator performance needs to be regularly monitored. Manual changeover systems require more attention, particularly under high flow conditions.

## 4.4 Secondary supply system performance

Primary evaporator parameters must not be evaluated in isolation. Most duplex cryogenics systems have a secondary supply and evaporator system, but this offers much lower vessel capacity and flow rates. For example, a primary evaporator might support 3,000 L/min system flow while the secondary supply evaporator maintains only

1,500 L/min. The only solution to maintaining the high flow rate of the primary system is to configure the secondary system with the same evaporator(s) and control panel(s).

However, it must be remembered that, in 'standard' configuration, the secondary supply vessel will offer around 30% of the capacity of the primary. Therefore, if running alone at primary flow, it will need to be refilled three times as often. Further, the secondary vessel will, in 'standard' configuration, be supported only by a single, low capacity evaporator. When supplying the site, rapid icing may be a problem. Frequent inspection of the secondary evaporator under these full load conditions is crucial to maintaining maximum flow.

Rarely, sites employ a secondary vessel as large as the primary one. Such an arrangement is not without its problems, primarily that of gassing off from the temporarily redundant secondary vessel until the primary vessel fails (although this wastage can be overcome by using an economiser circuit).

Further, with both plants on the same plinth, the potential for a single point failure arising from catastrophic mechanical damage still exists. Indeed, with most currently installed equipment, the control panel within the compound is used to control feeds from both vessels and is also a single point failure risk.

All too often, you might find yourself under pressure to install a second complete VIE system. It is often difficult to convince clinical colleagues that for supply resilience money would be better spent on improving the distribution system rather than adding capacity. However, if a second plant is to be installed, you should play an important role in the plant selection process by following the guidance below:

- the vessels selected for the new installation should not require the installation to be vented regularly, cause the safety valve to lift during normal site conditions or need to be replenished too frequently by the supplier
- the vaporisers and control panel for the new installation should be suitably rated for the total flow rate for the site
- if the new installation must supply the whole site in the event of an operational issue with the existing VIE installation, the gas supplier should accept that during this period more frequent replenishment may be required.

In essence, there is no problem with installing primary and secondary vessels that are much smaller than the current ones, with an associated pipeline system split to put just enough demand on the new installation. This will prevent the new installation from venting without causing the existing installation to vent. If there is a problem with the existing installation, the new, smaller, installation (with suitably rated evaporator(s) and control panel(s)) could supply the whole site until the problem is rectified.

BOC has been running a vaporiser evaluation exercise throughout the COVID-19 pandemic, with vaporisers being upgraded where necessary. BOC is also advising NHS trusts about vaporiser capacity and any required upgrades.

## Tasks

- Confirm and record full performance parameters for your primary and secondary evaporators and the plant control panel(s). Keep a record in the centrally held medical gas file (see below).

**Data sheet 1: A typical liquid oxygen plant datasheet**

| Primary vessel size | Primary evaporator flow capacity (L/min) | Secondary vessel size | Secondary evaporator flow capacity (L/min) | Control panel regulator flow capacity (L/min) | Number of regulators |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

- Contact your gas supplier to confirm compatibility of evaporators and control panels.
- For plant using evaporator(s) with performance below that of the control panel and if system flow is predicted to exceed current plant performance, discuss with your gas supplier options for temporarily/permanently increasing flow.

## Essential actions

- Read **Appendix A** to this document for full details of VIE plant and its operation.

- Confirm presence of all security measures and accuracy of vale number labels and condition and relevance of the posted P&ID.

# 5. Supply system configuration

So far, emphasis has been on a ‘standard’ cryogenic system – viz. a duplex VIE arrangement with dedicated evaporators – feeding the system via a single (or paralleled) control panel fitted with telemetry.

What has become clear from analysis of COVID-19 peak flows is that enough medical gas can be connected using equipment that forces control panels to run above their maximum capacity (causing associated system pressure drops). However, running out of oxygen will be at the bottom of the list of concerns when equipment begins to fail. As has been seen above, one risk to supply integrity is the performance of the evaporator(s).

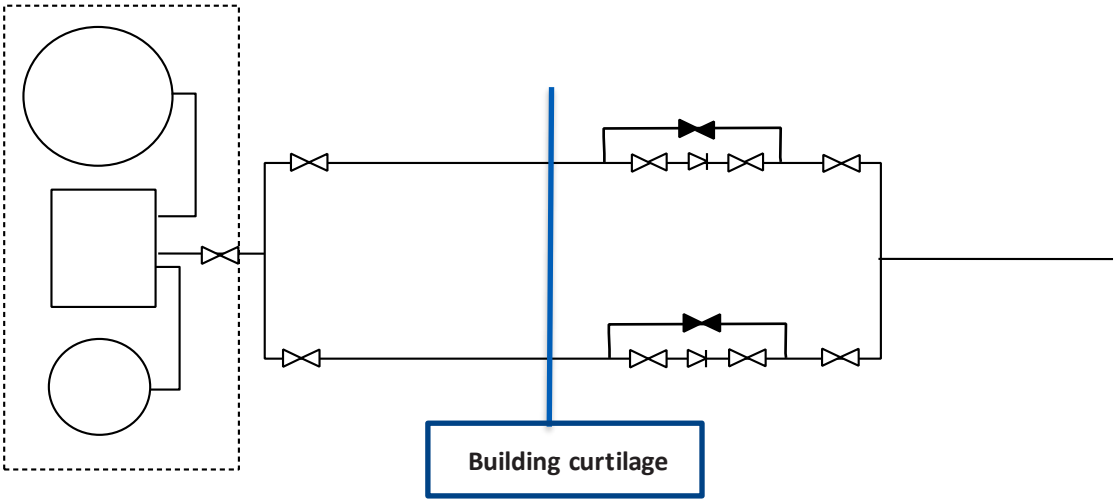
# 6. Connection and security of cryogenic supply sources

Security of the VIE system is paramount in ensuring continuity of a viable site-wide supply. Security measures, as defined by HTM 02-01, to protect the plant inside the VIE compound can be poorly installed and/or maintained. Compounds are often sited in remote, poorly lit areas not covered by hospital CCTV systems; their gates must be kept locked.

To mitigate against failure of the single pipeline from plant to building, HTM 02-01 proposes two similar pipelines are installed, with a minimum separation of 2 m although this should be the subject of a risk assessment. Risk of service loss from one of these pipelines fracturing can be reduced using non-return (and bypass) valves where the pipeline enters the building. Both pipelines will be capable of carrying the full design flow of the system and both will be kept live under normal circumstances.

Risk of supply failure can be reduced by geographical separation of primary and secondary vessels, in some cases by siting them at opposite ends of the site. Both vessels will have a dedicated control panel and evaporator system and can be fed into the main network via single or, preferably, twin pipelines. One vessel will be the primary supply, the other the secondary and held off by the pressure in the system. Gassing off from the second vessel will be controlled via an economiser circuit, which passes the venting gas into the system pipework.

**Figure 2: Typical dual feed configuration**




## Tasks

- Using HTM 02-01, Part A, Section 6 as reference, examine VIE compound location and protection for security risks. Assess compound fencing resilience, compound separation distances, access locking provision and provision of flood/task lighting/CCTV.
- Examine configuration, condition and protection of pipework feeds from plant to hospital.
- Record any identified deficiencies and produce a remedial action plan.

# 7. Pipework design and assessment of flow capability

## 7.1 General

Given a plant is capable of delivering the full design flow, the final limiting factor for every system will be the pipework's ability to carry the volume of gas required to ensure operation of connected medical equipment.

Pipe sizing is probably the most contentious issue, as any deficiency in flow capability begs the question, 'What is wrong with the design?', and consequently, is HTM 02-01 at fault for not producing a design capable of dealing with pandemic requirements, or are other factors at work? In many situations, the answer will be, 'Nothing is wrong with the design'. However, the system is likely to have undergone many changes since it was originally installed, and only where every extension or amendment was properly sized and documented, can flow capability of any area be reasonably assumed.

It is always possible to calculate theoretical pressure drops from the connected equipment operating parameters and pipework design data. However, this method is time consuming and has too many unknowns – data on the connected equipment and its usage and distribution patterns is often lacking.

Measured average oxygen flows are usually below (10-20%) those designed using HTM 02-01 algorithms. Hence, the only viable method of assessing the effect of connected equipment is to load the specified areas of the system with the potential maximum demand, using calibrated orifices as described below. This will give an immediate indication of system performance and help identify bottlenecks in the system, e.g. where pipe diameters are narrower than specified.

It is important to remember that the medical gas system design uses algorithms that incorporate diversity factors based on realistic 'normal' flows. Further, during the pandemic, areas of the hospital previously designed for use at relatively low flows, e.g. acute ward areas, have been reassigned as COVID wards and are therefore subject to

much higher flows than they were designed for. Some additions to medical gas systems, e.g. an additional ward, have led to loadings beyond the capacity of the existing pipework, again causing excessive pressure drops.

Designing systems to better cope with future pandemic events is charting unknown territory. HTM 02-01 offers a design that compensates to some extent for increased demand, but certainly not the levels encountered during the COVID-19 pandemic. Perhaps the only part of current systems able to cope with such demand are the dedicated CPAP supplies (75% of terminals, each with an expected flow of 75 L/min). However, even here, incorrectly adjusted CPAP machines as well as those with predicted 'normal' consumption of up to 100 L/min each can impose excessive flows on these circuits.

COVID-19 patient location is critical to system loading; high oxygen use patients are better served in pre-existing high-dependency areas that are designed to cope with higher flows, rather than those newly designated as such. Unfortunately, even intensive care units (ITU) are being put under stress by being allocated double patient loading. For example, HTM 02-01's algorithm gives a design flow of 50.5 L/min for a 28-bed ward of general inpatient accommodation. With 85% occupancy (24 beds) and all patients on oxygen at 2 L/min, each ward would draw 48 L/min of gas. If the ward instead was designated for treating COVID patients, each would draw around 10 L/min of oxygen when intubated using the most oxygen efficient ventilators (the area reaching design flow with only five patients); 30 L/min with several commonly used ventilators (exceeding design flow by ~20% with only two patients); and, potentially, up to 100 L/min with high flow CPAP equipment (exceeding design flow by ~100% with only one patient). Excessive pressure drops would be inevitable.

If respiratory use is planned for such wards, zero diversity will raise flow capability to 280 L/min.

The approach to future proofing needs care because the resulting increased pressure drop has to be limited, possibly by increasing pipe diameters. This may prove difficult or even impossible if, for example, the increased pipe diameter cannot be accommodated within existing trunking/bedhead units. Installation of a local loop system (see Section 8.7) will lower pressure drops to most remote terminal units.

Full consultation with clinical colleagues is essential. Inevitably, they will prefer zero diversity or general pipe size increases everywhere. The authorised person (AP)

(MGPS) or AE (MGPS) will need to explain the technical and financial implications of any design above and beyond HTM 02-01 recommendations that gives the most practicable solution, and should be involved in all discussions or their outcomes.

### Tasks

- With the co-operation of the gas supplier, ascertain average system flows before and during the pandemic.
- Examine all temporary and/or permanent measures taken to mitigate poor plant performance and assess their viability for future pandemics.
- Assess the ongoing revenue demands of any new plant installations such as additional VIEs and/or oxygen concentrator (PSA) plant.

## 7.2 Flow capability assessment by load testing

Physically loading areas of a medical gas system will give a realistic assessment of their capacity. As this exercise involves working on a live system supporting patients and other services across the hospital, it should not be undertaken lightly and is not simply a 'one man and pressure gauge' effort. Maintaining patient safety is crucial.

Even if the testing conclusively identifies areas which could prove problematic, permanent reinforcement of existing systems, except by using the portable 'WO' cylinder manifolds (see Section 9), is unlikely to be achieved quickly within the time frame of a second wave.

Before carrying out a load test, areas of highest risk – those offering lowest flow potential and those at highest risk from high flows generated during the test – should be ascertained (see the tasks box below) by carrying out a full, documented risk assessment. It is important to monitor system conditions closely and to be prepared to halt the procedure immediately if any adverse effects are observed or reported.

To carry out a load test, the required number of calibrated flow orifices need to be connected to terminals/area valve service units (AVSUs) in the area, and the effect on pressures throughout the system monitored. Hence, multiple gauges will be required (minimum 100-mm diameter analogue, or digital capable of resolving 10 kPa pressure

change) as well as adequate personnel to monitor these gauges and report changes as the required load is added **gradually** in the area under test.

Not all APs (MGPS) will have access to a set of calibrated orifices, but most will possess one or more MEC Medical Ltd. flow and pressure drop testers. Most will be familiar with using them on various gas systems, but possibly not as a 'dial up' variable orifice for loading an oxygen system.

A protocol for testing an area, e.g. a single ward or department, is given below. Note that practically it is difficult and potentially hazardous to test several wards/departments simultaneously and must **not** be attempted as it is practically difficult and potentially hazardous. A data recording sheet for the process is given in **Appendix B**.

- Ask the nursing staff for the ward/department being tested what the current oxygen consumption is, and record this information on the left-hand side of the data recording sheet.
- Using a (preferably) digital meter (e.g. Druck), record the pressure at an outlet not in use – preferably the one nearest the AVSU/ward 'department entrance if possible.
- Add the flow rates available using the MEC flow and pressure drop test kit and continue to record the pressure on the Druck meter. The figures should be recorded against each flow rate on the right-hand side of the data recording sheet.

The aim is to determine through physical testing what flow rate a ward/department can deal with without excessive pressure drop, or at least without setting off the oxygen low pressure alarm for that ward/department (usually triggered at around 3.5/3.6 bar).

The downside to testing is that it only validates the area tested and does not accurately consider what is happening in adjacent areas. For example, if the adjacent ward/department at the time of testing was not drawing off any oxygen, but subsequently draws off 100 L/min from the same pipeline branch, the results for the tested ward/department will no longer be accurate. If oxygen consumption increases across the site, careful monitoring of local pressure conditions and equipment operation by the AP (MGPS) and clinical staff will be required.

## 7.3 Real-time flow measurement

During the pandemic, trusts have increasingly wanted to measure the flow rates within site oxygen systems. Other than for billing and recharge purposes, this information was previously rarely sought. Bulk average day rates have been obtained from the tank telemetry over expired time, rather than real-time actual measured flow. Metering is now being considered as a control measure for oxygen system management/resilience.

Both invasive and non-invasive (ultrasonic) units have been proposed, but it should be borne in mind that they need initial and ongoing calibration. Ultrasonic units may use inferential or cross-wave (or a combination of these) configurations to estimate flow. Invasive flowmeters require total interruption of supply to facilitate installation. They should always be provided with a valve bypass, to enable zeroing and to facilitate removal for repair or replacement.

Note that at the point chosen for flow measurement, usually on the mains and distribution pipework, oxygen lost during the filling process or any other losses within the VIE system will not be measured. While these losses have no effect on system flow, they do represent the difference between recorded delivery quantity and available oxygen. These losses can be discounted for all practical purposes.

Once the units have been installed, a zero balance (no flow condition) is needed to calibrate them accurately, something that is exceedingly difficult to achieve for an active oxygen main. Again, this limited accuracy can be ignored for all practical purposes.

The cost–benefit of flow meters for service continuity/resilience needs to be analysed. Non-invasive units are expensive and, although especially useful for recharging in multi-site supply networks, their use and mechanism of control needs to be carefully considered. How will this data influence care at point of use? Will it limit oxygen use by clinicians or merely (expensively) record the system as being overstressed? In addition, the cost–benefit of getting more detailed, independent information on real-time flow than that from the telemetry system should be weighed.

Pressure tapings can be used in the main control panel regulators to give an indirect reading of flow rate from the valve, using the characteristic relationship between flow across the valve and the '$\Delta P$'. This may be relatively cheap compared to other non-invasive units and more accurate, while still giving a remote value of a flow rate from a supply system into the delivery network.

**Ultimately, it is any pressure drop in the system that has to be managed,** as this will be the limiting factor for flow rate to remain within operating parameters.

A more expedient (simpler and cheaper) alternative is improved local pressure reporting. Modern systems are usually fitted to do this and depend on it for their continued function. Devices, either from existing pressure transducers, or in the case of pressure switched alarm systems, from transducers fitted into a non-interchangeable screw-thread (NIST) on a department AVSU or line valve assembly (LVA), or a dedicated transducer port with minimum leak device, feature wireless reporting to a local control area (usually the nursing station or ICU hub). This can use a multi-media reporting format (R,Y,A,G background colour to see system condition at a glance, numerical figures for actual local system pressure, and an audible alarm for final hazard condition) and provides an immediate response to changes in local conditions and increase in demand from clinical practices. This presentation is far more likely to attract the attention of a clinician, who is primarily focused on caring for a potentially very sick person.

Any control mechanism is built around its ability to control and influence, so an educational and cultural element exists in whatever system/process is used. Flow meters may be an effective, high level strategic tool and, if that is what is needed, a flow meter is useful. If the concern is safely maintaining the four tenets of safety of a MGPS (identity, adequacy, continuity and quality of supply), then a more operationally-based system centred on local pressure monitoring and relevant clinical practice is a far more compelling and efficient control process.

## Tasks

- Ensure all as-fitted drawings/schematics/mimics are up to data and subject to a controlled access storage/recording system.
- Using the as-fitteds and by visual examination, carry out risk assessments to identify areas of the system:
  - vulnerable to pipework fracture and prepare a remedial action plan.
  - that could be used to supply higher than ‘normal’ flow rates, and carry out load testing as described above
  - that would **not** normally be used to supply high flow rates, e.g. a typical acute ward, and carry out load testing as described above. Ascertain maximum loading for use as recovery/palliative care areas.

- Document all maximum flow capacities for the above areas and discuss limitations for potential use with clinical lead colleagues, who are responsible for connecting high flow medical equipment.
- Ensure that all clinical staff know that they should consult the AP (MGPS) before **any** equipment is connected to the MGPS. This should be stated in the MGPS operational policy.

# 8. Actions to maximise system resilience and flow capability

## 8.1 Distribution system design and configuration

The advantages of geographically separating primary and secondary supplies in terms of system resilience are self-evident. This also links supplies to distribution systems via twin, rather than single, feeds.

However, regardless of the flow capacity of the source, the flow delivered at the terminal units in many installations is severely limited by the ability of radial distribution systems to deliver required flows without excessive pressure drops. But there is nothing inherently 'wrong' with these systems. A normal acute ward should not be expected to service a large number of high flow oxygen devices, unlike a high-dependency unit (HDU), and thus the two areas have very different flow algorithms (and hence different pipe sizes).

System appraisal to support high oxygen use will have to reflect these differences. Unfortunately, all too often, few areas suitable for such use can be identified and it is inevitable that during the pandemic areas pressed into service to manage the high influx of patients have not been able to cope with the associated high flows. Efforts should be made to identify flow potential of all areas. This information should be used to inform decisions on placement of high demand critical care equipment and lower demand recovering and palliative care patients.

Such has been the scale of the pandemic that even high flow areas have been stressed, in some cases beyond their limits. The benefits of a fully up-to-date set of as-fitted drawings in determining plans for increasing system resilience cannot be overestimated. Flow bottlenecks, lack of valving, potential isolation difficulties and feasibility of additional supply connections can all be identified from the drawings.

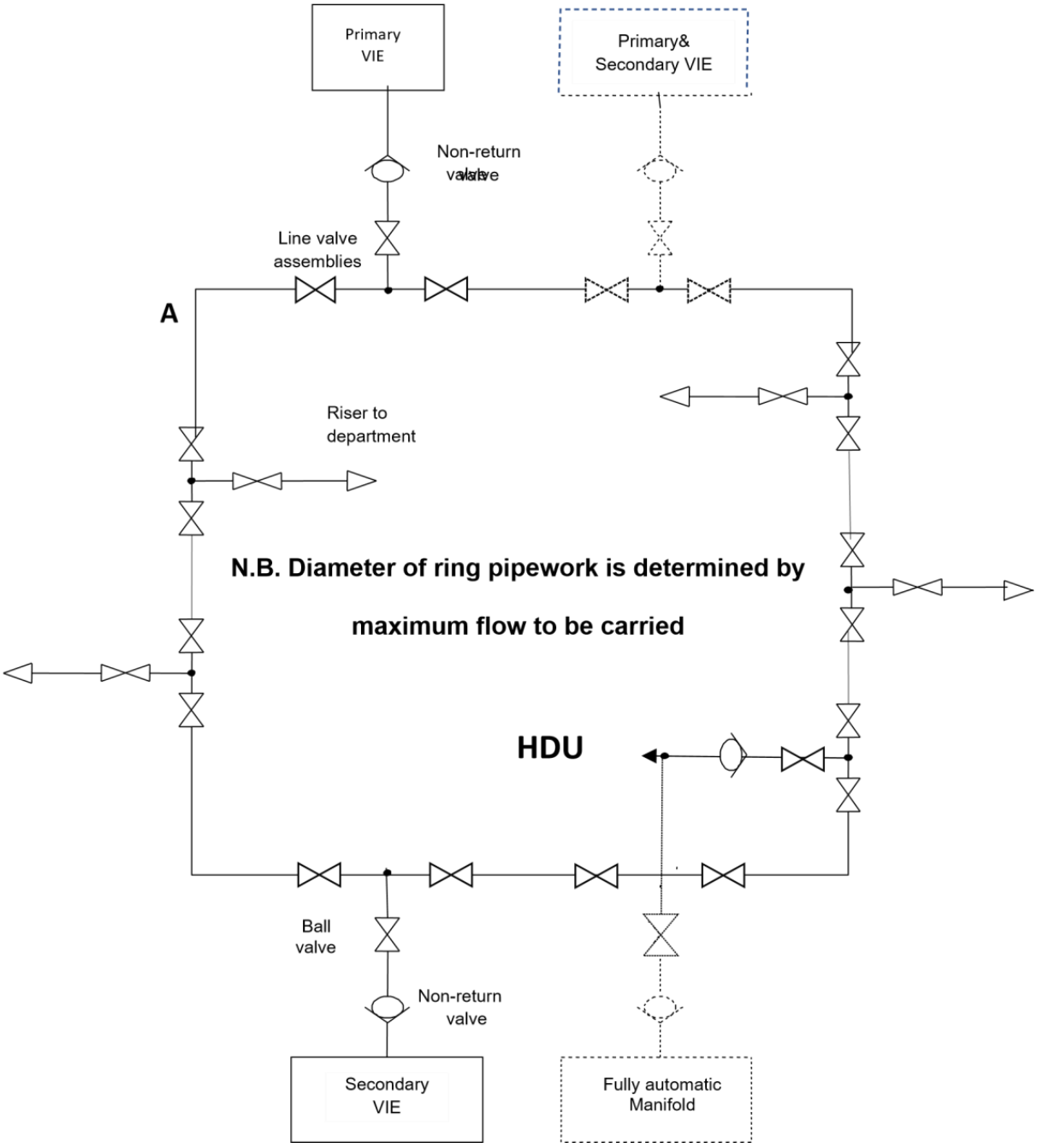
### Tasks

- Ensure possession of a full, up-to-date set of as-fitted drawings and any other relevant schematics and data. Keep these in a central medical gas file under controlled access.
- Using the as-fitteds and in consultation with the AE (MGPS), attempt to identify flow bottlenecks, lack of valving, potential isolation difficulties and feasibility of additional supply connections.
- Prepare an action plan for all proposed system amendments/improvements.

## 8.2 Ring mains

Much is made of the benefits of ring main installation. However, where a ring main has been installed, this is often incorrectly configured in terms of sizing, layout and valving. Ring mains are best installed as part of the original infrastructure; retrograde installation can be very difficult.

**Figure 3: A typical ring showing connection of geographically separated VIEs (and an alternative duplex system).** Connection of a cylinder manifold supporting a high-dependency area is also shown. For clarity, non-return valve bypasses and NIST connections are not shown.



Most installations of radial configuration will comprise a principal main feed (typically of 42 mm or 54 mm diameter) from plant to the hospital curtilage. From this point the pipe diameter may be maintained for some considerable distance around the hospital, with distributors (of smaller diameters) to various departments taken off as the site is traversed (Figure 4 below). An alternative arrangement is division of the main at the curtilage into two or more radial circuits, of smaller pipe diameters (Figure 5 below).

**Figure 4: Ring main configured from existing main**

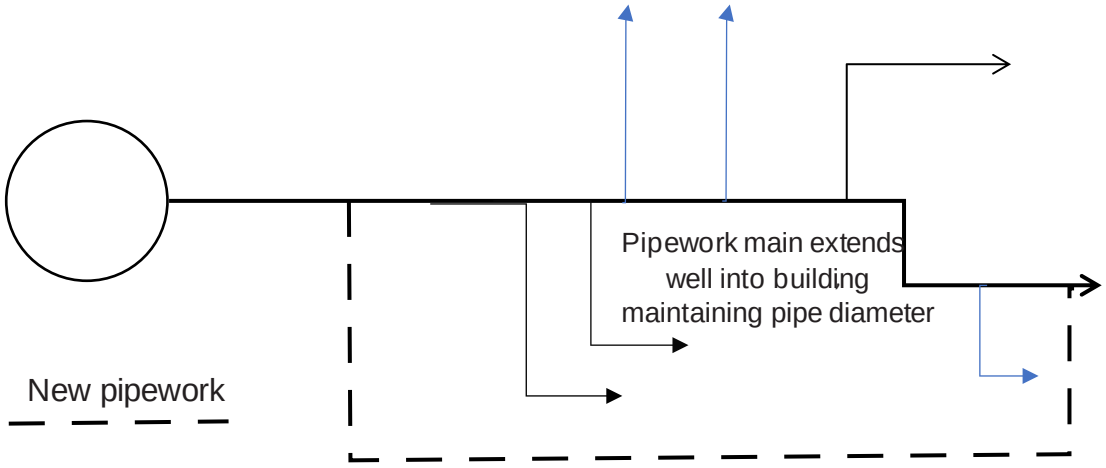
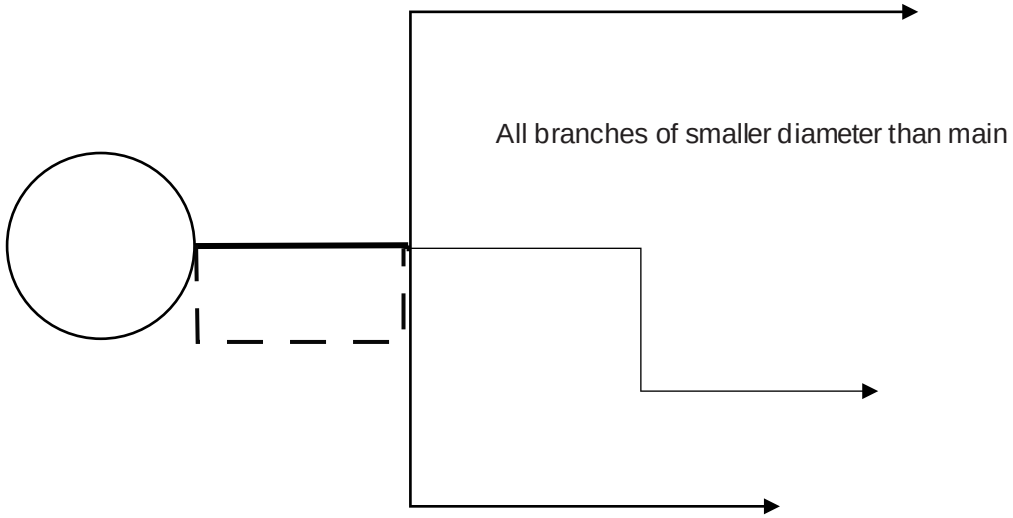



**Figure 5: Ring main configuration only possible between supply and first branch**



Establishing a ring main structure with the configuration shown in Figure 4 is simpler, as it may be possible to connect a return pipe of the same diameter as the ward distributor to the distal end of the main. However, unless the original pipework has a suitably valved take-off point, a major shutdown will probably be necessary to make the connection.

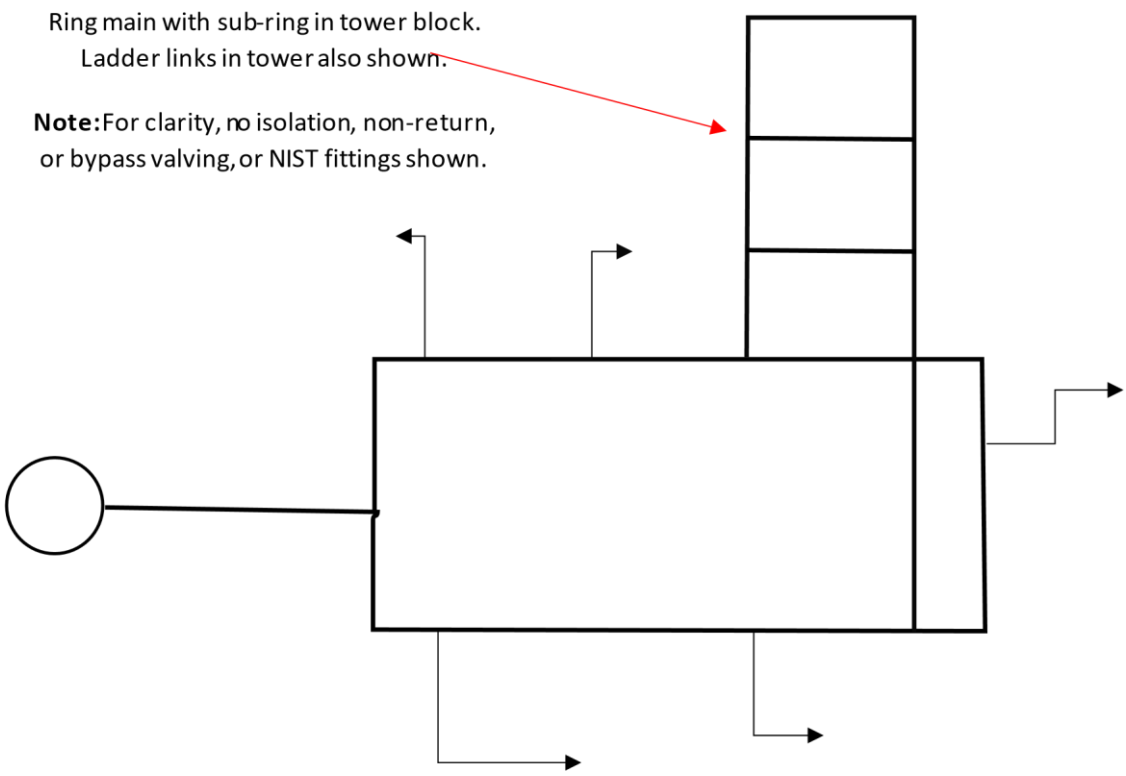
The arrangement shown in Figure 5 only allows ring formation at supply main pipe diameter between plant and building curtilage, essentially a variation of the vessel-to-hospital dual feed arrangement. However, smaller rings could be established with each of the radial circuits, subject to accessible connection points.

In most situations, retrograde installation of a full-site ring system will be a major undertaking involving new pipework. While costly, this has the advantage of being able to install and test the ring with all its associated valving and take-off points without system shutdown. Departments can then be connected successively to the ring take offs without having to shut down the whole ring.

Where hospital sites have one or more tower blocks, it is advisable to link the tops of two risers (e.g. east and west sides of each tower) from separate parts of the ring, forming a tower ring structure. Cross-linking the risers (via valved connections) at one or more intermediate floors (ladder configuration) (Figure 6 below) gives further advantages – and facilitates isolation of sub-sections of the installation.

All options should be discussed with both the AE (MGPS) and clinical lead.

**Figure 6: Ring and Ladder Configuration**




## 8.3 Ring main supply sources

The typical connection of oxygen supply sources into the ring is illustrated in Section 6 of HTM 02-01. The advantages of geographically separated sources (two VIEs, one acting as a primary supply, the other as a discrete secondary) must be considered and risk assessed. However, the gas supplier must install an economiser circuit on the secondary VIE to prevent gas wastage. The size of the secondary and its evaporator(s) needs to be carefully considered, as reducing the capability of any component will limit performance when supplying the ring.

The secondary has to be of the same volume as the primary, with same sized evaporator(s) and control panel(s), if the ring is to be supported in exactly the same way as the primary. However, given that VIE plant is inherently highly reliable, with minimum down times, the flow capability of the secondary can equal that of the primary even with half the storage capacity, or less.

Another possible configuration is two geographically separated dual vessel supplies. This arrangement is, of course, more expensive but it has the advantages of full flow ring support from either plant, maximum supply source resilience and freedom to split the

ring and feed each half from its own source. This option is popular as it keeps both plants operational and if economisers are not fitted, overcomes any problems with gas wastage. However, to a certain extent it defeats the objective of a ring supply and is best suited to supporting radial systems in which a hospital's high demand areas are supplied from one system and lower usage areas from the other. Pipework would almost certainly need to be modified to separate activities.

Whatever supply arrangement is chosen for ring support, it is important to understand that a ring fed by two 3,000 L/min plants will not deliver 6,000 L/min. When the primary plant outlet pressure begins to drop with excess usage, the secondary plant will cut in to maintain the ring flow at 3,000 L/min. The only way to obtain 6,000 L/min from the two VIE systems is to supply two separate sections of the ring with up to 3,000 L/min each, in the same way that two radial supplies are deployed, as described above.

### Tasks

- Discuss with the AE (MGPS) and clinical lead the potential for improving supply resilience by installing a ring main and implications for temporary shutdowns of departments to allow connection to the completed ring. Timescales will be particularly important.
- If a ring main exists, discuss options for improving resilience by extending it to tower blocks, etc, and possibly using separated sources.

## 8.4 Ring main sizing

A significant benefit of a ring main is the facility to isolate any desired area, while maintaining supplies to the rest of the site. This implies that any section of the ring main must be capable of (and hence sized for) carrying the full system design flow and correctly valved at each distributor take-off point. Hence, medical gas ring mains differ from electrical ring mains: in the latter, the demand from any particular socket is met by supplies from both sides of the ring; hence, a cable narrower than that in a radial circuit of equivalent total current is used. Ring mains maintain full flow capability from either side of a branch.

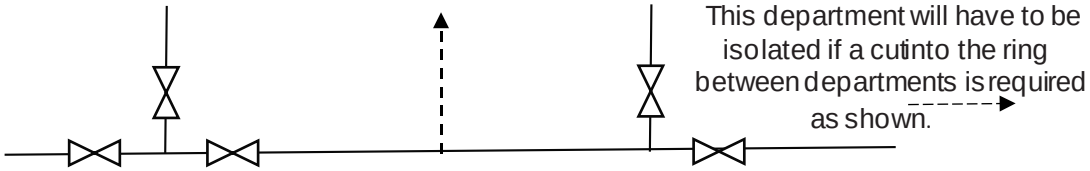
## 8.5 Ring main valving

Figures 4 to 6 do not show details of valving in a typical ring. HTM 02-01 Part A, Section 13 details the valving necessary for an oxygen ring main. Note that each supply and take-off point has a triple valve arrangement. However, some savings can be made by using only one valve between take-off points, but only if no further connections between the two take-offs (without isolating one or more areas) are envisaged, as adding these would require one of the departments to be shut down (Figure 7).

**Figure 7: Typical ring valved take-off points to two departments; (B) Economy of valving, but only if no future connection between the departments is envisaged**

**A**

**B**




HTM 02-01 prescribes dual supply circuits for high-dependency areas, dedicated pipelines to support high numbers of CPAP machines and ring mains for basic infrastructure. As-fitteds must be used, and systems visually examined to confirm which of these measures are in place and how additional measures can be implemented.

## 8.6 Use of NIST fittings and non-return valves

Figures 4 to 7 do not show the distribution of NIST fittings. However, their value in facilitating commissioning tests, pressure measurement and emergency back feeding should not be underestimated. Line valve assemblies come preassembled with integral NIST fittings and they should be used in all situations where their configuration is

beneficial, e.g. main branch, riser, or supply feeds. Some economy of NIST deployment is easy to envisage with ring mains but specifying line valve or line valve assembly should depend on the practical advantages of the latter, not the cost.

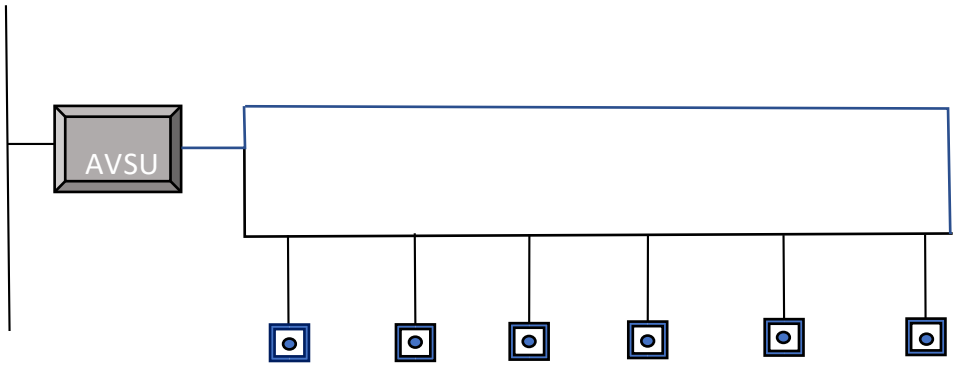
Non-return valves should be employed to prevent loss of gas into a fractured pipe or back feeding into a main (e.g. riser or branch) from an emergency supply connection, such as a locally sited manifold supporting critical care areas.

A bypass arrangement should be installed for all critical situations where blockage of the non-return valve could interrupt service. A non-return valve of one pipe size larger than the installed pipework it protects will reduce frictional pressure losses.

## 8.7 Flow loops

Flow loops are not documented in HTM 02-01 but they are good engineering practice. They do incur a nominal extra installation cost as they involve fitting a piped return from the top of the final terminal unit drop to as close as possible to their controlling AVSU outlet. This 'mini-ring' improves local flow and is recommended because it reduces pressure drops at distal terminal units. Care should be taken to ensure modified pipework designs do not form dead ends as they will stagnate the gas (although some Brownian mixing will still happen). For this reason, the loop pipework should be distally connected at the final terminal unit, as shown below in Figure 8. Such an arrangement allows the highest flow demand equipment to be connected furthest from the riser.

**Figure 8: Typical flow loop**



## 8.8 CPAP and dedicated high flow circuits

If a dedicated CPAP feed is installed it will probably be configured as a single circuit taken, via a dedicated AVSU, from the same riser that feeds other terminals in the ward. Occasionally, a CPAP feed has to be taken back to a main distributor, or even a dedicated tapping in the VIE compound.

CPAP feeds will operate in high-dependency areas, where design flows are relatively high, although both the CPAP and HDU feeds should still be load tested if patient load is expected to increase.

## 8.9 Dual circuits for high-dependency areas

Independent feeds to left and right sides of beds (known as a dual circuit system) were originally intended to facilitate work on one system while the other maintained a service, avoiding the need to shut down beds. Over time, clinical practice has dictated that ITU/HDU beds are better served if one side of the bed is 'wet' for items such as infusion pumps, and the other as 'dry', e.g. for monitoring equipment. However, faced with an influx of COVID-19 patients, trusts have needed to put two beds in single ITU bed spaces, with equipment for the bed on the left fed from left-side terminals, and from the right-side terminals for the bed on the right. Again, load testing should be carried out to ensure pressure drops are not excessive.

### Tasks

- Discuss all the above measures to potential improve flow and/or system resilience with the AE (MGPS).
- Prepare for this discussion by consulting the as-fitted drawings and making noting what needs to be discussed.

# 9. Alternative supplies

## 9.1 General

HTM 02-01 describes alternative supplies for cryogenic oxygen systems in the form of a second VIE, and permanently connected cylinder manifolds (liquid or compressed gas) or stand-alone cylinders. Given predicted high flow demand, manifold and stand-alone cylinders are usually only deployed to local areas.

Some old VIE systems have a supporting auto-changeover cylinder manifold. These work at the lower end of VIE flows and are not discussed further here, other than to advise the viability of replacing the cylinder manifold with a cryogenic supply is discussed with the AE (MGPS) and gas supplier.

## 9.2 Liquid cylinder manifolds

Liquid cylinder manifolds have been proposed as back up sources for VIEs. However, the pandemic has revealed an inherent deficiency in the typical 24-J units (e.g. BOC's LC200 vessels); they operate without the benefit of external evaporators and their flow range is typically 150–300 L/min (from supplied data). However, most are deployed in private healthcare establishments where demand is relatively high only for short periods, and they are little used, if at all, for extended periods. This regime allows the vessels to regain pressure with influx of atmospheric heat and because of this they can cope with relatively short periods of high flow. Unfortunately, if these units are used on a 24/7 basis, the maximum expected flow falls dramatically: as low as 45 L/min in some cases.

Hence, LC200 type vessels are **not** suitable to support a failed VIE system. Pandemic use should be limited to palliative and recovery care and, even then, for extremely low patient numbers if used continuously.

## 9.3 Compressed gas cylinder manifolds

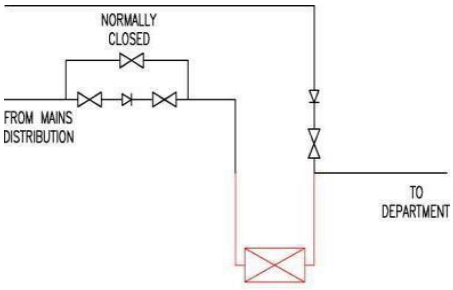
HTM 02-01 proposes the permanent installation of local compressed gas manifold systems to support high-dependency areas in the event of system failure. For best results, such manifolds must be able to operate without initial manual intervention and change banks automatically. Connection to the system requires careful consideration, as

provision of the protective non-return valve is important, as is its bypass. The connection point can be upstream or downstream of the area AVSU, but if downstream all components will be brought into a convenient control zone and, should any component fail, it will not be necessary to disturb the main supply. A dedicated AVSU for the manifold will clarify control for estates staff but requires additional pipework and wall space and can confuse medical staff in an emergency. An alternative is a ceiling connection via a line valve assembly. Some connection configurations are shown in Figure 9.

**Figure 9: Connection configurations**

Option A.

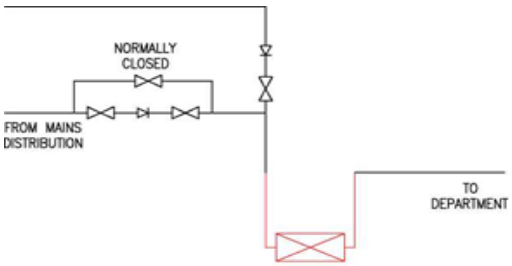
From compliant manifold




**(S) HTM 02-01 Part A 6.99**

Option B.

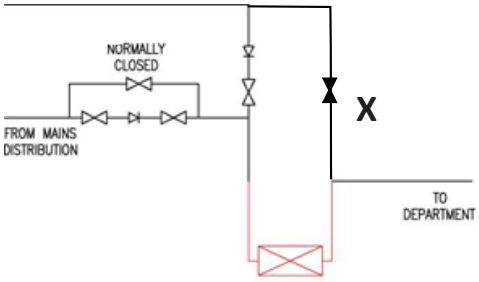
From compliant manifold




**To ensure AVSU is final point of isolation, e.g. for fire/major gas leak**

Option C.

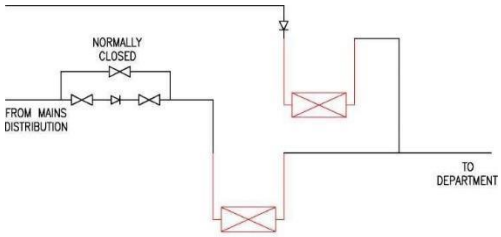
From compliant manifold




**A separate point of connection downstream to provide an alternative back feed facility.**

Option D.

From compliant manifold




**Final points of isolation (AVSUs) for both sources. Both AVSUs would require closure in an emergency.**

**NB:** Valve X is normally closed but can be opened during maintenance.

Alarm indicators for the manifold require careful consideration; locally this adds a further level of potential confusion for medical staff and, remotely, requires extra dedicated display panels. However, a spare display channel can be used to signal fault conditions from multiple manifolds as shown in Figure 10.

Arrangements for cylinder management and maintenance of the manifold and alarm are crucial to faultless system operation.

**Figure 10 – use of six channel alarm display to monitor critical care areas:**

| Oxygen | Nitrous oxide | Medical air | Surgical air | Vacuum | Emergency oxygen manifolds |
|---|---|---|---|---|---|
| Normal | Normal | Normal | Normal | Normal | Normal |
| Refill liquid | Change cylinders | Plant fault | Plant fault | Plant fault | ITU |
| Refill liquid immediately | Change cylinders immediately | Plant emergency | Plant emergency | Plant emergency | HDU |
| Reserve low | Reserve low | Reserve low | Reserve low | | NICU |
| Pressure fault | Pressure fault | Pressure fault | Pressure fault | Pressure fault | Theatre 1 |

## 9.4 Portable emergency supplies

Where it is not possible to implement the remedial measures described above, portable emergency supplies are an option. Until recently, such supplies comprised one or more cylinders connected via regulator(s) to either an item of medical equipment, or via a terminal unit or AVSU NIST fitting.

A portable automatic manifold system will be available soon for general purchase from Gas Control Equipment Ltd (GCE). This comprises a detachable trolley and frame unit. The manifold is mounted on the frame (with an integral alarm and four off-outlet terminals/hoses). The unit can be wheeled from a store to its required position, the frame lowered to provide stability and the trolley removed. The cylinders are then loaded into the frame and connected to the manifold via hoses. The change-over of cylinders is enabled by a frontal access for individual cylinders. A cylinder that needs to be changed over will be identified on the manifold panel.

The GCE unit can be used to supply individual or multiple items of medical equipment directly, or via connection to a ward terminal/ASVU NIST, respectively, and also as a temporary supply during area isolation for cut-ins, etc. It is the ideal solution for reducing the risk of low pressure in local ward areas and for setting up temporary areas of oxygen supply.

## 9.5 Oxygen concentrator (PSA) plant supplies

Oxygen concentrator (PSA) plant passes air under pressure through zeolite to remove the nitrogen, leaving (mostly) pure oxygen for patient therapy. The nitrogen is discharged to the surrounding air.

If a PSA plant installation is planned, the important considerations are:

- Oxygen concentration provides oxygen at a slightly lower concentration than that from VIE plant or compressed cylinders; typically, 93–94% (± 3%) cf99.5 %. However, two-stage PSA plant exists, with the second stage removing most of the argon from the final product to leave a typical oxygen concentration of 99%. Two-stage plant is more expensive (£100,000 to £200,000) than single-stage plant.
- If PSA plant runs continuously at full specified flow, 93% oxygen concentration will not be maintained; when it starts to fall will depend on how much the plant is used. Ultimately, it will decrease to around 90%, possibly lower. Running an 850 L/min plant at 600 L/min should help reduce the risk of falling concentration.
- This source of supply for a pipeline system should comply with the requirements **of EN ISO 7396-1 Medical gas pipeline systems**; **Pipeline systems for compressed medical gases and vacuum**: the medical gas pipeline system must have three sources of supply to ensure that the gas supply is maintained under single fault condition. To meet the standard requirements, more than one plant will need to be installed.
- PSA plant occupies a lot of space, e.g. an 850 L/min plant is the size of a 40 ft x 12 ft shipping container and generates considerable heat and nitrogen. Cooling and waste nitrogen removal are essential. Ducted air intakes are advisable.
- PSA plant needs to compress significant volumes of air: five volumes of air to produce one volume of oxygen, with additional volumes of air for regenerating the zeolite beds.
- A significant electrical supply is required to power the compressors, potentially introducing electrical supply issues elsewhere in the facility, not least of which will be the extra load on the hospital's essential electricity supply (generator).
- PSA plant requires an automatic cylinder manifold as back up. Depending on the design flow of the PSA, system support using this manifold will be minimal. For example, if a 500 L/min PSA plant fails, a 2 x 10 J manifold gives **only two**

**hours of service per bank**. If the automatic manifold comes online, **rapid rise in oxygen concentration will rise rapidly from 93% to cylinder concentration of 99.5%**. Medical and nursing staff **should be made aware** of this, and warning notices posted at nurse bases.

- PSA plant is **difficult** to source for immediate use.
- Some plant can be fitted with an optional cylinder filling plant, but it takes several hours to fill a single J size unit.

**Important:** Connection of a PSA plant directly into the existing oxygen distribution system is **not advised** for the following reasons:

- Balancing the plant against system pressure is difficult and can cause the delivered oxygen concentration and possibly also system pressure to fluctuate.
- Mixing to two Ph Eur-monographed gas sources produces a gas that has no pharmaceutical monograph. QC pharmacists and Anaesthetists are **unlikely** to accept it.
- If the primary and secondary plants lose pressure, the PSA plant will be left supporting the whole system. Given that the PSA is usually of lower capacity, whole system pressure failure will be **inevitable**.
- Revenue costs will be relatively high when measured against the gas volumes delivered. Many of these will be ongoing, even if the plant be mothballed for any length of rime.

Thus, PSA plant should only be used to supply a defined part of a system, segregated from the main VIE supply to reduce load on it.

**Important: Responsibility for oxygen product**

- Where oxygen is manufactured within a healthcare facility, the facility's Chief Pharmacist is responsible for ensuring that the product meets the appropriate and specific quality and safety criteria for medicinal products prepared in pharmacies (as defined in the Pharmaceutical Inspection Convention and Pharmaceutical Inspection Cooperation Scheme Guide PE010-4 Guideline to good practices for the preparation of medicinal products in healthcare establishments).
- This means that the hospital's Chief Pharmacist is responsible for the quality control and certification of the gas manufactured, the traceability of the product

used, the appropriate indications and contra-indications for its use, and any pharmacovigilance requirements.

**Important: Use of domestic PSA plant**

- These small, electrically powered units supply oxygen at low flows (typically up to 10 L/min) and low pressure. While they can be used to support patients via nasal cannulas, they **are <u>not</u> suitable for ventilator support domestically or in a healthcare facility, or for connection to VIE systems.**
- They should be connected to the essential electricity supply.

# 10. Developments in cylinder technology and in gas pressure alarms

## 10.1 Cylinder technology

J size oxygen cylinders hold 6,800 L of gas at 137 bar pressure. BOC has released a W size oxygen cylinder ('WO') which is almost the same size as a J cylinder but can hold 11,300 L of gas at 230 bar. This means that a WO manifold has almost twice the storage capacity of a similarly sized J manifold and may provide a viable source of oxygen in previously discounted locations. The portable unit to be marketed by GCE and described by Section 9.4 is designed to carry two ‘WO’ cylinders.

## 10.2 Gas pressure alarms

Traditional local alarms display green for 'normal' conditions and red for pressure faults, but nothing in between for a slowly worsening condition. Alarms are now being trialled that signal changes in pressure not only with a digital readout of the line pressure but with a colour change from green, to yellow, to orange, to red, so clinical staff can easily see the effects of adding more and more medical equipment to the system.

# 11. MGPS operational policy

The MGPS operational policy should contain protocols for dealing with gas failures and falling pressure and the trust will also have a major incident plan covering major civilian-related incidents. During the pandemic, estates and clinical managers have found themselves (in some cases for the first time) needing to closely liaise about the performance of the oxygen system. We hope this document helps estate managers answer the overriding question: Why can't you give us more oxygen?

## Tasks

- A fully updated MGPS operational policy, which you may be responsible for implementing and monitoring, should be in place and accessible to all stakeholders.
- The medical gas committee must meet to start a policy review process, bearing in mind the technical advice you will be sharing with the group in light of proposed pandemic measures. Consider inviting the AE (MGPS) to the first meeting as they can comment on the results of their last system audit and the hospital's pandemic response.
- Ensure policy covers emergency procedures such as gas failure and fire, and both technical and clinical responses to these situations.
- Consider producing and distributing action cards for use by nursing/medical staff. Topics could include emergency isolation of a gas supply, responses to medical gas alarms, and use of medical air terminal units.

# Appendix A: Liquid oxygen VIE installation: operational management considerations during periods of high demand

The following information is a general guide for authorised persons (AP) (MGPS) on the operational management arrangements for their liquid medical oxygen system during periods of increased demand. The advice is based on information from cryogenic oxygen storage systems suppliers and generally applies to both Air Products and BOC VIE installations. Note that valve number references vary between Air Products and BOC installations. Reference should be made to (S)HTM 02-01 Part B, Appendix F for the valve numbering schedule. The valve number schedule from Table A1 - (S)HTM 02-01 Part B, Appendix F is reproduced below for ease of reference. The piping and instrumentation diagram (P&ID) specific to the installation in question should also be displayed at the installation – typically attached to the fence of the VIE compound adjacent to the main gate.

| Valve control function | Valve no – BOC | Valve no – Air Products | Operating condition<br>NC/NO normally closed/normally open |
|---|---|---|---|
| Trycock* | V4 | V4 | NC |
| Economiser (gas take-off from vessel) | V5 | V22 | NC |
| PSV/bursting disk changeover | V6 | V21 | NO |
| Liquid feed to main evaporator | V7 | V14 | NO |

| Valve control function | Valve no – BOC | Valve no – Air Products | Operating condition<br>NC/NO normally closed/normally open |
|---|---|---|---|
| Gas return from pressure-raising evaporator | V9 | V12 | NO |
| Liquid feed to pressure-raising evaporator | V11 | V3 | NO |
| Top fill* | V12 | V2 | NC |
| Bottom fill* | V13 | V1 | NC |

*For liquid oxygen supplier use only.

The VIE installation is monitored by the central alarm system. Information on liquid level and tank pressure is relayed back to the supplier via the telemetry system. For a system comprising a primary and smaller secondary VIE, the following alarm conditions are typically be displayed on the central alarm panel.

- Oxygen Normal
- Refill Liquid Liquid level down to 25%
- Refill liquid Immediately Standby system in use
- Reserve Low Liquid level in standby low system (Down to 50%)
- Pressure Fault Pipeline pressure risen to 4.9 bar, or fallen to 3.75 bar

**Typical system operating parameters:**

- **Tank pressure.** For a dual VIE installation, the pressure within the tanks can range from 10.5/12 bar to around 16 bar. The safety valve will lift typically at around 17 bar and the bursting disc will rupture at around 21 bar. The actual pressures for your installation may vary slightly and should be detailed on the P&ID particular to your installation.
- **Evaporators/vaporisers.** There will be two, one online (duty) and the other valved off (standby). Estates often changes them over on a weekly basis to allow the evaporator/vaporiser which has been on duty to thaw out. Change

over may be more frequent during periods of high demand and/or low ambient temperatures, and thawing assisted by using water spray or steam. The evaporator/vaporiser essentially dictates the flow rate the installation can achieve as its function is to warm the liquid oxygen to gas for distribution via the pipeline distribution system supplying the hospital.

- **Pipeline pressure.** The VIE control panel typically regulates this at around 4.1/4.2 bar. The pressure safety valve within the control panel will typically lift at 5.3 bar.

**VIE installation valving.** For most hospital sites that have a relatively constant demand for oxygen, the liquid feed to main evaporator (BOC – V7/Air Products – V14) will be open and the economiser (gas take-off from vessel) (BOC – V5/Air Products – V22) closed. Some smaller hospitals with relatively low demand reverse this arrangement, i.e. BOC – V7/Air Products – V14 closed and BOC – V5/Air Products – V22 open. VIE installations configured in this way may have to be changed by the AP (MGPS) should the oxygen demand increase, and the system closely monitored thereafter.

**Increased demand on the system:** This will largely be evident from ice build-up on the evaporator/vaporiser that is online (duty). Ice must not be allowed to build up as it severely restricts the efficiency of the evaporator/vaporiser. Build up should be prevented by either:

- Swapping over to the standby evaporator/vaporiser to allow the duty evaporator/vaporiser to thaw out – this may need to be done daily or even more frequently in some circumstances. The isolating valves are located downstream of each evaporator/vaporiser; or
- De-icing the evaporator by directing water from a hose onto the ice –warm water can be sprayed although cold water is also effective. Steam can also be used if available close to the VIE compound. Care should be taken not to direct water or steam near or onto the pressure safety valves. **On no account attempt to remove the ice by striking it with a mallet or similar.**

As stated, the flow rate from the VIE installation depends on the size of the evaporator/vaporiser and the amount of liquid it can boil off to gas. Evaporator/vaporiser performance will increase as the ambient temperature increases.

Where the demand on the system is greater than the evaporator/vaporiser boil off rate, consider putting both evaporators/vaporisers online. This should be resisted if possible but if done, **both evaporators/vaporisers must be regularly checked for ice build-up and build-up promptly removed using one of the above methods. In extreme cases, this could well be a 24/7 activity and the resource input should not be underestimated. The section of pipeline running from the evaporators/vaporisers to the VIE control panel should also be checked for ice build-up and any ice promptly removed.**

Frequent formation of large amounts of icing should be risk assessed for local fogging, etc and the potential need for evaporator upsizing noted.

**If downstream pressure drops are encountered due to the demand, increasing the pipeline pressure from the regulators within the VIE control panel should be considered. The lead regulator will typically be set at around 4.1/4.2 bar. While there is scope to increase this, the revised setting should be sufficiently below the setting for the fourth stage alarm 'Pressure Fault', which is typically 4.9 bar. This should ensure that the pressure safety valve does not lift (5.3 bar); often it will not re-seat fully once it has lifted. Note also that increasing the pipeline pressure does not increase flow rate through the pipeline system; it only off-sets, to some degree, downstream pressure drops should these occur.**

That hospital demand is starting to exceed what the system can deliver will likely to be evident from:

- activation of the fourth stage (Pressure Fault) alarm: indicates that the pipeline pressure has fallen typically to around 3.75 bar
- subsequent activation of area alarm panels in the hospital: indicates that the pipeline pressure has fallen typically to around 3.5/3.6 bar.

At this point, the AP (MGPS) should advise hospital management that the system is working above capacity and that serious consideration must be given to restricting further use of the oxygen pipeline system. While some medical equipment can operate effectively below 3.5/3.6 bar, any decision to continue oxygen administration must be made by the relevant clinical authority. Alternatively, additional oxygen supply methods should be considered, such as localised cylinder supply or, preferably, the portable automatic manifold detailed in Section 9.4.

**General:** Other considerations should include:

- Activation of the first stage alarm (Refill Liquid) does not indicate that the supply will imminently run out; there will still be a reasonable quantity of liquid in the primary and secondary VIE. It would be prudent, however, to contact the liquid oxygen supplier to confirm that a delivery has been scheduled and when it is likely to arrive on site.
- Keep a record of consumption/liquid level to determine the interval between fills.
- Ensure that clear and free access to the VIE compound is maintained at all times, with no parked vehicles obstructing access for road tanker deliveries.
- Ensure the relevant parties know the emergency contact number for the liquid oxygen supplier.
- Record any unusual occurrences or failures and feed this back to the AE (MGPS) for 'lessons learnt' and wider review.

**Summary:** This appendix is for practising AP (MGPS) who are already familiar with liquid oxygen VIE installations. It does not provide a recap on other emergency actions such as:

- spillage of liquid oxygen
- significant gas release from pressure safety valves lifting/bursting discs rupturing
- issues during filling
- fire.

When this guidance has been issued to the co-ordinating AP (CAP), the CAP should ensure that it is cascaded to all other AP (MGPS) in their organisation. The guidance must be generic in nature considering the range of liquid oxygen installations in use. Further advice should be sought from the AE (MGPS) and/or liquid oxygen supplier as required.

# Appendix B: Flow capability assessment – data recording sheet

| | |
|---|---|
| Hospital | |
| Ward/department | |
| Date of test | |
| Authorised person (MGPS) | |
| Record pressure (bar) using Druck meter at outlet not in use (select outlet nearest AVSU/ward entrance if possible). | |

| Terminal units in use (room/bed space)<br>To be completed by nursing staff responsible for the ward/ department concerned. | Flow rate (L/min) observed |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| Totals | |

| Flow rate applied at outlet not in use using MEC test kit (L/min)* | Record pressure using Druck meter at outlet not in use (bar) |
|---|---|
| 10 | |
| 15 | |
| 20 | |
| 40 | |
| 80 | |
| 100 | |
| 275 | |

*Select outlet

The flow rate should be applied as per the above increments and stopped when the pressure recorded on the Druck reaches a minimum of 3.7 bar.

The outlet selected should be furthest away from AVSU/ward entrance if possible.

| Recommended maximum flow rate based on the above analysis (L/min) | |
|---|---|

# Appendix C: Guidelines for establishing a medical gas committee (MGC)

The importance of an efficient MGC has been stressed in the document. In particular, it is instrumental in implementing and monitoring an effective MGPS operational policy.

The following guidance is taken from samples of actual MGC documentation. Note that some MGCs rotate the chair position among all core group members.

**Purpose**

To assure the medicines management committee that medical gases are effectively monitored and managed in the healthcare establishment/trust (HE/T).

**Functions**

- Develop, review and update the medical gases operational policy and related policies and procedures, including the Terms of Reference, at agreed frequencies, or immediately on receipt of pertinent technical or clinical advice, including safety alerts, hazard warnings, etc.
- Promote and monitor the implementation of medical gas policies and procedures, and ensure they are adhered to throughout the HE/T.
- Assess training needs, implement training prescribed by HTM 02-01:2006 and monitor any non-attendance.
- Co-ordinate education and training support to improve the quality of medical gas system management (including the MGPS permit to work system), incident reporting and safe working practices associated with the MGPS and patient connected medical equipment.
- Ensure that relevant competencies are in place and validated.
- Act as a forum for monitoring medical gases risk management activities.
- Promote staff participation in the prevention of accidents, incidents and near misses by identifying, developing and promoting best practices for medical gas

safety. Implementation will require co-ordination of and support for process and system changes, to reduce the likelihood of occurrence and/or reoccurrence of serious (Medical Device) Incident Reports.

- Disseminate information and provide feedback to appropriate groups, committees, staff and other stakeholders on medical gas-related issues.
- Act as an early warning mechanism for emerging risks.
- Receive the MGPS authorising engineer's (AE's) annual audit report and ensure remedial actions are carried out to the AE's defined timescales.
- Provide regular feedback to clinical staff, patient care areas and hospital committees on MGPS and medical equipment risks, and planned actions to minimise these risks.

**Quorum**

A minimum of four committee members must be in attendance. Core members of the committee are expected to send appropriate representation to the meeting if they are unable to attend. Other professionals will be co-opted onto the committee on occasions when specific topics are to be discussed.

In addition to the chair (chief pharmacist) and deputy chair, the permanent membership will comprise nominated operational/clinical representatives from:

- community health
- estates department
- dental services
- clinical skills
- hotel/portering services
- health and safety
- anaesthesiology
- any department nominated during formation of inaugural constitution.

**Frequency of meetings**

The committee will meet (quarterly) but may convene additional meetings as appropriate.

**Reporting**

The committee will report to, for example, the trust board via the medicines management committee. Core committee members are responsible for providing feedback from meetings to their respective teams. The committee chair is accountable to, for example, the chief executive.

**Circulation of agendas and minutes**

Meeting agendas will be distributed to all proposed meeting attendees. Minutes will be distributed to all MGC members.

**Review**

The Terms of Reference and membership of the MGC will be reviewed annually.

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