The COVID-19 Pandemic

and

actions necessary to mitigate its effect on the performance of

Healthcare Cryogenic Liquid Oxygen Systems

Produced by

The NHSI COVID-19 Working Group

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Preface

The effects of the 2020 COVID-19 pandemic are unprecedented in the history of NHS medical gas system engineering and the operational performance of cryogenic liquid oxygen systems.

Cryogenic oxygen systems typically comprise at least one vacuum insulated evaporator (VIE) vessel plus a reserve source of supply that can be derived from gas in cylinders, gas from liquid in cylinders or a second VIE. Supply system arrangements are covered herein.

Much has been made in the media of systems that have *'run out of oxygen'* leaving patients in *'a life-threatening situation.'* However, the performance of the gas suppliers during the pandemic has been exemplary, with all systems benefitting from increased supply resilience, monitoring and operational support on a 24/7 basis. There was **ALWAYS** enough oxygen!

The reasons for medical equipment suffering depleted oxygen supplies must, therefore, be sought beyond the storage system. Closer examination of cryogenic oxygen provision and distribution within hospitals has revealed weaknesses in both plant and system configuration and operational management, neither of which have involved exhaustion of the cryogenic supply.

This **important document** has been produced by NHSI, with input from the UK Registered Authorising Engineer (MGPS) COVID-19 Working Group, and other subject experts, and is intended for **immediate** use by Healthcare Estates and Clinical professionals.

It examines not only all aspects of cryogenic oxygen supply and storage, and associated gas distribution system configuration but also provides guidance on oxygen system auditing and critical operational procedures intended to mitigate the effects of exceptional oxygen demands experienced during pandemic conditions.

The highlighted ***TASKS*** prescribe actions intended to create an awareness of system parameters, audit, design and configuration, while also detailing practical measures designed to enable deficiencies to be identified.

Of **critical importance** is **APPENDIX A** to the document, which provides operational protocols for dealing with excessive demands of cryogenic liquid oxygen. This is intended **for immediate practical use** and should be annexed to the **Medical Gas System Operational Policy**. It should be posted in all Estates Departments for ready consultation.

The pandemic has highlighted the crucial value of liaison with the AE(MGPS). The support of Authorising Engineers and their experience should be sought when auditing oxygen systems and planning remedial measures for a possible second wave.

Remedial actions proposed by the AE (MGPS) will form part of an overall Action Plan. This will contain risk assessed timescales for each identified non-compliance with HTM 02-01 or deficiencies in system condition, configuration or management.

All too often, the same remedial action appears year on year in the AE's Audit Report, despite warnings of potentially serious consequences for patient safety.. These timescales are **not to be ignored or taken lightly**. If, for any reason, achieving a particular objective in the defined time frame is difficult or impossible, the advice and help of the AE (MGPS) should be sought without delay, such that the problem can be resolved.

Further, weaknesses in the MGPS Operational Policy around emergency procedures, outdated contact details, MGPS alarm responses and clarity of functional responsibilities indicate that regular review of the Policy is not taking place. In some cases, responsibilities for review and/or implementation of the Policy have not been clearly defined.

In the interests of the safety of patients, users and the general public it is **essential that a relevant MGPS Operational Policy** is implemented, monitored and regularly updated (at least annually). Status of the Policy should be investigated as part of the AE (MGPS) audit process.

Instrumental in the safe management of medical gases and development of the MGPS Operational Policy is the role **Medical Gas Committee** (MGC). Again, there has been some misunderstanding of the function of this group and an underestimation of its importance, leading to confused messages.

Advice on establishing a MGC can be sought from the AE (MGPS) but its activities should remain an essential part of the work of the HE/T.

Appendix C illustrates the operational requirements of a typical MGC. **.**

Contents

Pandemic resilience of cryogenic liquid oxygen systems

1.0 Introduction

The current COVID-19 pandemic has highlighted deficiencies in plant configuration and operation, and distribution infrastructure design and/or installation. Further, some remedial measures have been taken in haste, reflecting not only a lack of system knowledge but also of the basics of system operation; information freely available in HTM 02-01:2006. This has led to some investment that offers far less than maximum efficacy

2.0 Plant capacity

Much has been made by the press of so-called *'oxygen emergencies'* evidenced by typical headlines such as, *'Hospital runs out of oxygen'* and *'life threatening situations cause by system failures'. Sub*sequent investigations have identified the capacity of the supply and product availability to be, at least, adequate for the increased demand, with other, inherent, problems being responsible for the systems' inability to support the number of patient ventilators proposed.

Prior to the introduction of HTM 02-01, VIE capacity was always 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. Typical effects of this new protocol were to be seen in the installation of smaller VIEs and increased delivery frequency.

Plant capacity is **highly unlikely to be the cause of system failure** but should be reviewed annually (along with plant maintenance protocols) in liaison with the gas supplier, taking account of the environmental impact of increased delivery frequency and site access for larger delivery vehicles. Too often, addition of a further VIE has been assumed (wrongly) to be the solution to gas shortage problems.

TASK

- ***Investigate and confirm the configuration and capacity of the onsite cryogenic vessel(s), age(s) of vessel(s), their 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***

3.0 Telemetry

Telemetric monitoring of the VIE contents and pressure is available from all cryogenic oxygen suppliers.

Although primarily aimed at facilitating effective cryogenic liquid delivery schedules, the value of telemetry in terms of data produced by the systems for client use, should not be underestimated.

It is important to discuss the advantages of the monitoring system with the gas supplier and receive training not only in the operation of the VIE system but also use of internet access codes/ SMS protocols that allow live interrogation of the system, and additional programming features that allow tailoring of flow and usage data to meet site-specific needs.

TASKS

- ***Establish the existence of telemetry and confirm with the gas supplier the internet access codes (including any additional measures when using GSM telemetry, if applicable) for the site plant***
- ***Discuss with the gas supplier the format required for presentation of plant operational data and ensure all software is performing as specified.***
- ***Ensure all those who will be involved in routine maintenance and operation (including emergency operation), are suitably trained.***

4.0 Plant performance parameters

4.1 General

All healthcare cryogenic liquid oxygen plant comprises the basic elements of.

- 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 convert 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 these 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 either by dedicated landline, or SIM card operated service, to the gas supplier, in order to ensure system safety and trigger product deliveries well before vessel depletion occurs.

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

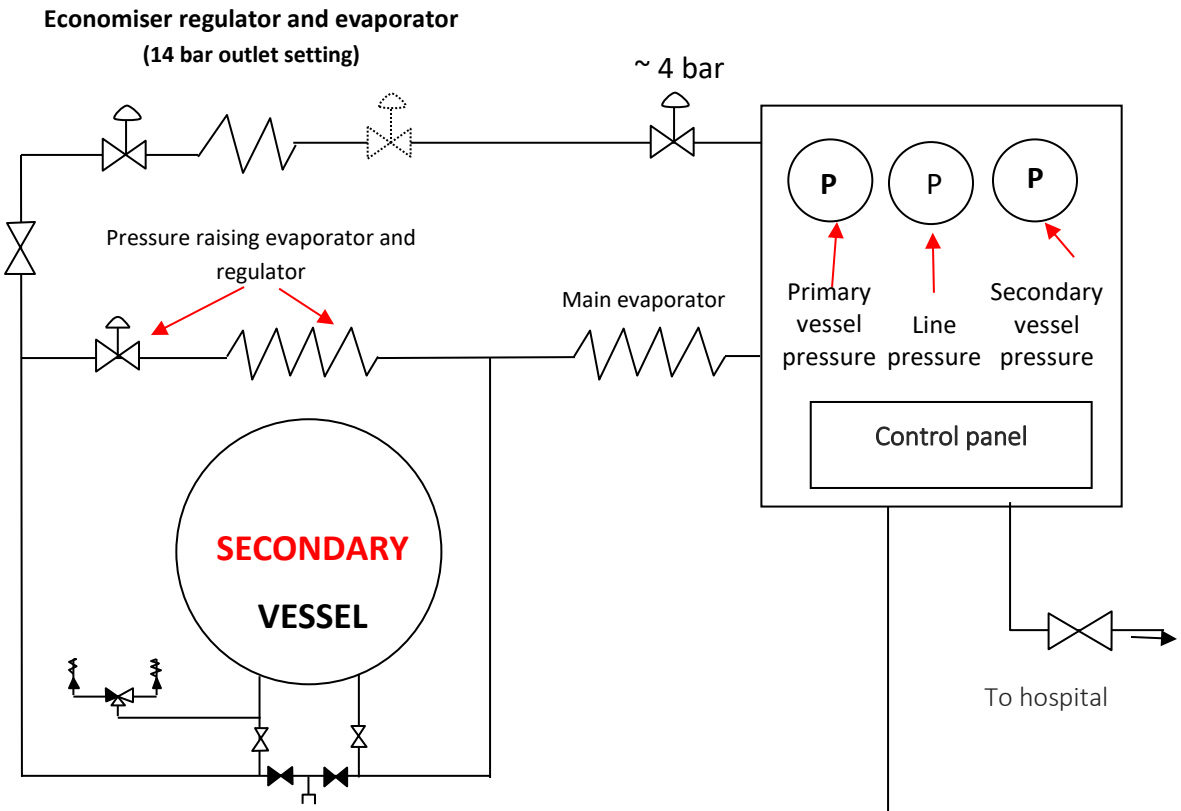
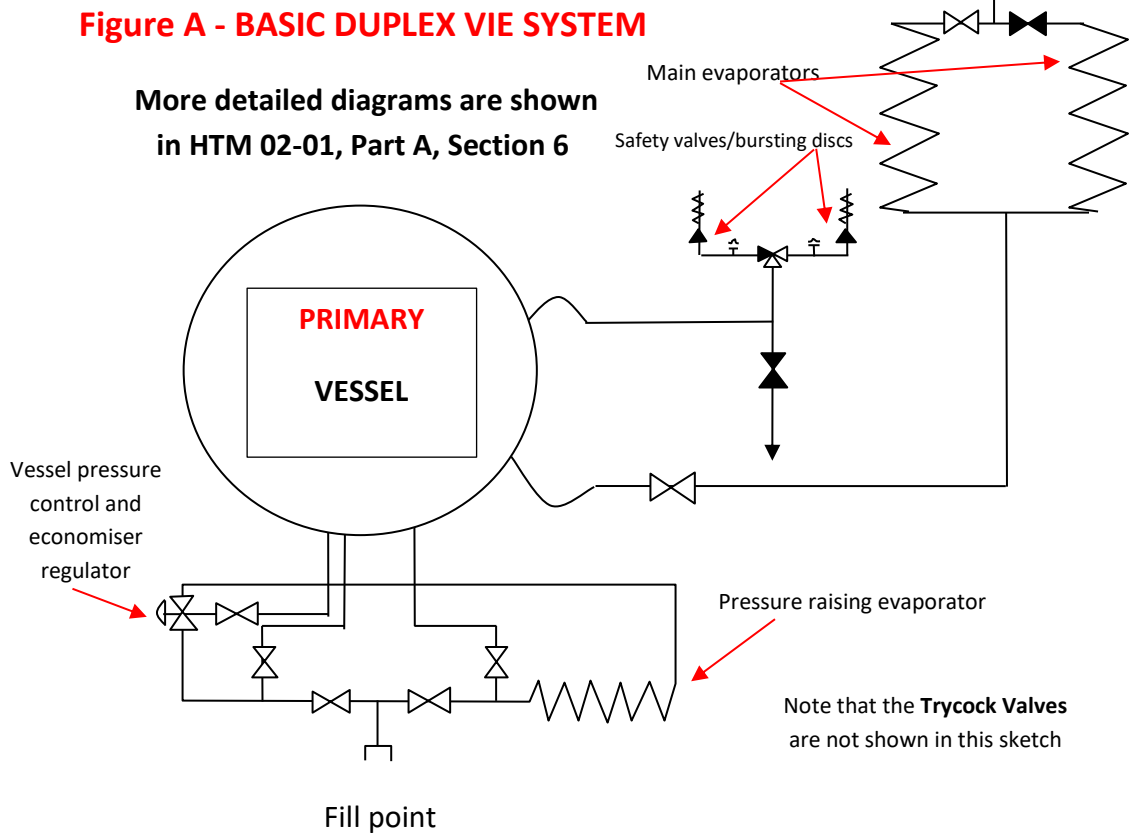


Figure A - BASIC DUPLEX VIE SYSTEM

More detailed diagrams are shown in HTM 02-01, Part A, Section 6



4.2 Control panel performance

Control panels are to be found with 4 bar flow rates varying from 1500 l/min (Now few and far between), 3000 l/min (very common), 5000 l/min (to be found on newer plant) and 6000 l/min (usually achieved by installing 2 x 3000 l/min units in parallel).

Control panel technology is well established and generally very dependable. During the pandemic, adjustments to the control panel regulators were carried out in some instances, to improve system flow, although scope for dramatic increases is extremely limited. All such adjustments must be carried out **after consultation with the gas supplier**, as this equipment is under their ownership.

4.3 Primary evaporator performance

The primary evaporator should evaporate liquid at such a rate as to maintain the flow delivery potential of the control panel. However, maintaining maximum efficiency is **dependent on frequent ice removal**, using water or steam. Unfortunately, not all plant has been fitted with adequately sized evaporators, limiting the flow potential of the control panel. In extremis, both evaporators could be put online, although this is something of a last-ditch measure and must be discussed with the gas supplier, along with overall evaporator performance.

Some systems are fitted with an automatic changeover facility, using electrically powered motorised valves. The changeover time cycle is set by the gas supplier and is typically 8 to 12 hours. Although this lessens the risk of excessive, uncontrolled icing, regular observation of the evaporator performance should be carried out. Manual changeover systems require more diligent attention, particularly under high flow conditions.

4.4 Secondary supply system performance

Evaluation of the primary evaporator parameters must not be done in isolation. Most duplex cryogenics systems have a secondary supply and evaporator system, offering very much lower capacity of vessel and flow rates e.g. a primary evaporator might support 3000 l/min system flow while the secondary supply evaporator maintains only 1500 l/min. The only solution to maintaining the high flow rate of the primary system is to install a secondary system configured 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 and will, therefore, if running alone at primary flow, require refilling at three times the frequency. 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, and frequent inspection of the secondary evaporator under these full load conditions is crucial to maintaining maximum flow.

Some sites employ a secondary vessel as large as the primary, although this is extremely unusual. 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 use of 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 based on supply resilience. It is often difficult to convince clinical colleagues that money would be better spent on improving the distribution system rather than adding capacity. However, should you find yourself in this situation and installation of a second plant is inevitable, you can still play an important role in the plant selection process by following the guidance below.

- Selection of vessels for the new installation should not result in either installation having to be vented regularly or cause the safety valve to lift during normal site conditions.
- The vaporisers and control panel for the new installation should be suitably rated for the total flowrate for the site.
- Selection of vessels for the new installation should also not result in the gas supplier having to replenish them too frequently.
- 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, replenishment may be required at more frequent intervals.

In essence, there is no problem installing much smaller primary and secondary vessels than those currently installed, with an associated pipeline system split to place just enough demand on the new installation to prevent it from venting, while not 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.

A vaporiser evaluation exercise has been undertaken by BOC since the start of the Covid 19 outbreak and is ongoing, with vaporisers being upgraded accordingly, and where necessary.

BOC are working with hospitals to advise on vaporiser capacity and upgrade them if required.

TASKS

- ***Confirm and record full performance parameters for primary and secondary evaporators and the plant control panel(s). Keep a record in the centrally held Medical Gas File (See below).***
- ***Contact your gas supplier to confirm compatibility of evaporators and control panels.***

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

- ***For plant using evaporator(s) with performance below that of the control panel, discuss with the gas supplier options for temporarily/permanently increasing flow, if analysis of expected system flow will exceed current plant performance.***

ESSENTIAL ACTIONS

- ***Read Appendix A to this document for full details of VIE plant and its operation.***
- ***Confirm presence all security measures and accuracy of valve number labels and condition and relevance of the posted P&ID.***

5.0 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 and fitted with telemetry.

What has become clear from analysis of COVID peak flows is that, while it is possible to connect enough medical gas using equipment to force control panels to run above their maximum capacity (causing associated system pressure drops), running out of oxygen is certainly bottom of the list when equipment failure begins to occur. As has been seen above, one risk to supply integrity is the performance of the evaporator(s). There are, however, risks to maintaining system flows other than evaporator and control panel performance.

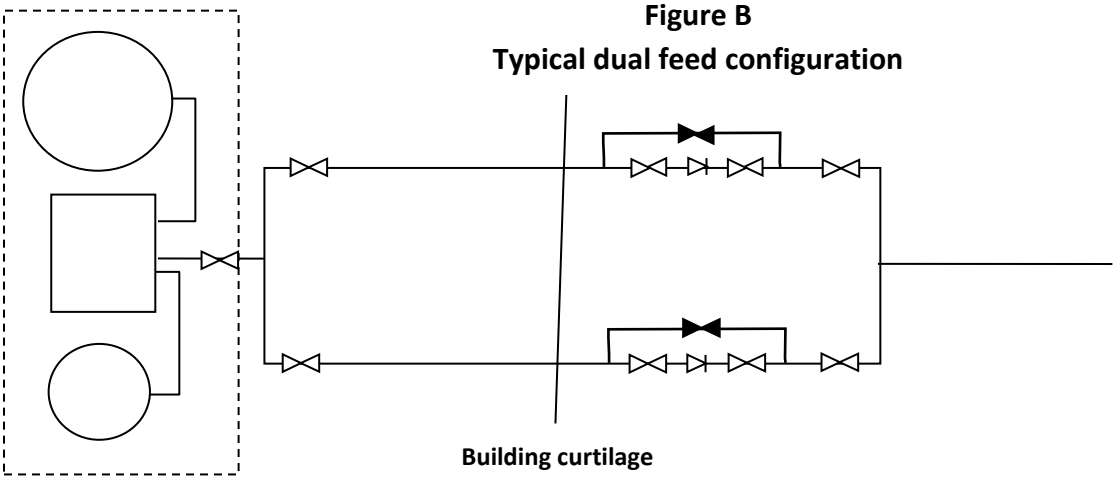
6.0 Connection and security of cryogenic supply sources

Security of the VIE system is paramount to ensuring continuity of a viable sitewide supply. Far too frequently, security measures, as defined by HTM 02-01, to protect the plant inside the VIE compound, are poorly installed and/or maintained. The number of compounds found with unlocked gates is worrying and many compounds are sited in remote, poorly lit areas not covered by hospital CCTV systems.

To militate against failure of the single pipeline from plant to building, HTM 02-01 proposes two similar pipelines be installed, with a minimum separation of 2 m, although the latter should be the subject of a risk assessment. Risk of service loss arising from fracture of one of these pipelines can be reduced using non-return (and bypass) valves at pipeline entry to 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 as far apart as 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, held off by the pressure in the system. Gassing off from the second vessel will be controlled via an economizer circuit, which passes the venting gas into the system pipework.

Figure B
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.***

7.0 Pipework design and assessment of flow capability

7.1 General

Given plant capable of delivering the full design flow, **the final limiting factor of every system will be the ability of the pipework 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 automatically begs the question *'What is wrong with the design?'* So, 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 original installed system is frequently found to be significantly different from what responsibility will be assumed. Obviously, if every extension or amendment were to be properly sized and documented, flow capability of any area could be reasonably assumed.

It is always possible to calculate theoretical pressure drops by using connected equipment operating parameters and pipework design data. However, this method is time consuming and suffers from too many unknowns; the major factors being lack of data on the connected equipment and its usage and distribution patterns.

HTM 02-01 algorithms, even allowing for their integral diversity factors, usually give design flows above measured average flows. It is difficult to generalise, but average flows for oxygen are normally 10 – 20% below the design flow. 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, by use of calibrated orifices as described below. Not only will this give an immediate indication of system performance but will also help identify bottlenecks in the system e.g. use of smaller than specified pipe diameters.

It is important to remember that medical gas system design is based on algorithms that incorporate diversity factors based on realistic 'normal' flows. Further, during the pandemic, areas of the hospital previously designed and used at relatively low flows e.g. acute ward areas, have been reassigned as COVID wards, hence subjecting these areas to much higher flows, for which they were not designed.

What has also become clear is that 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 with some compensation for increased demand but certainly not the levels encountered so far this year. Perhaps the only part of current systems able to cope with such demand will have been dedicated CPAP supplies (75% of terminals with an expected flow of 75 l/min each). However, even here, incorrectly adjusted CPAP machines, not to mention some with predicted 'normal' consumption up to 100l/min each, can impose excessive flows on these circuits.

COVID patient location is critical to system loading; high oxygen use patients being better served in areas previously designated as high dependency and hence, designed to cope with higher flows. Unfortunately, even areas such as Intensive Care Units have often been allocated double patient loading, putting even these high flow areas under stress.

For example, for a 28-bed ward of general in-patient accommodation, HTM 02-01's algorithm will give a **design flow of 50.5 l/min**. With an 85% patient load (24 beds) with all patients on oxygen at 2 l/min each would draw 48 l/min of gas.

With 100 % COVID occupancy, each patient would be drawing around 10 l/min each with when intubated using the most oxygen efficient ventilators (Reaching design flow with only 5 patients), 30 l/min each with several commonly used ventilators (Exceeding design flow by ~20% with only 2 patients),and, potentially, up to 100 l/min each when using high flow CPAP equipment (Exceeding design flow by ~100% with only 1 patient). The resultant excessive pressure drops are inevitable.

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

Care must be taken with any approach to future proofing, as the resulting increased pressure drop will have to be limited, possibly by increasing pipe diameters. While this might be an easy paperwork exercise, its implementation might prove difficult or even impossible if, for example, the increased pipe diameter cannot be accommodated within existing trunking/bedhead units. Installation of a of **local loop** system (See **7.8** below) will lower pressure drops to most remote terminal units.

It is essential that full consultation with clinical colleagues takes place. Inevitably, they will prefer zero diversity or general pipe size increases everywhere, and it is only the technical ability of the AP (MGPS) or the AE (MGPS) to explain the technical and financial implications of any design above and beyond HTM 02-01 recommendations that will result in the most practicable solution. Again, the Authorising Engineer (MGPS) should be involved in all discussions, or their outcomes.

TASKS

- ***With the cooperation 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 effects of any new plant installations such as additional VIEs and / or PSA plant.***

7.2 Flow capability assessment by load testing

Physically loading parts of a medical gas system will give a realistic assessment of the capacity of the tested areas. Obviously, carrying out a physical load test in an area involves working on a live system supporting patients and other services across the hospital: **the exercise should not be undertaken lightly**. Maintaining **patient safety is crucial** and this means the exercise is not just a *'one man and pressure gauge'* effort!

Further, even if the testing conclusively identifies areas which could prove problematic, permanent reinforcement of existing systems, except by use of the portable 'WO' cylinder manifolds described below, is unlikely to be achieved within the time frame of a second wave.

Before carrying out any load test, areas of highest risk, not only those offering lowest flow potential but also from high flows generated during the test procedure, should be ascertained (See ***Tasks*** below).

For each load test proposed, it is assumed that a full, documented, risk assessment will be carried out. It is important to monitor system conditions closely and to **be prepared to halt the procure immediately**, should any adverse effects be observed or reported.

To carry out a load test, it will be necessary to connect the required number of calibrated flow orifices to terminals/AVSUs in the area and monitor the effect on pressures throughout the system. Hence, not only will multiple gauges be required (Minimum 100mm diameter analogue, or digital capable of resolving 10 kPa pressure change) but also adequate personnel to monitor these gauges and report changes as they happen, and 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 flow and pressure drop testers. Although familiarity with their use on various gas systems is likely, use as a 'dial up' variable orifice for loading an oxygen system will probably be a new experience!

A protocol for testing an area e.g. a single ward or department is given below. Note that it is practicably difficult and potentially hazardous to test several wards / departments simultaneously and this should **NOT** be attempted.

A data recording sheet for the process is presented in **Appendix B**.

1. Determine the current oxygen consumption in the ward / department under consideration. This should be completed by the Nursing staff for that ward / department. This information should be recorded in the Table on the LHS of the form.

2. Using a (preferably) digital meter (e.g. Druck), record the pressure at an outlet not in use – preferably nearest the AVSU / ward ' department entrance if possible.

3. Using the MEC flow & pressure drop test kit, add the flowrates available from the test kit and continue to record the pressure on the Druck meter. The figures should be recorded against each flowrate in the RHS Table.

The intention is to determine through physical testing what flowrate we could expect that ward / department to deal with without excessive pressure drop, or at least not setting off the oxygen low pressure alarm on the area alarm panel for that ward / department (which should come on around 3.5 / 3.6 bar).

The downside to the testing is that it only validates that ward / department and does not accurately consider what is happening in adjacent areas. For example, if the adjacent ward / department at the time of testing wasn't drawing off any oxygen then later was drawing off 100 l/min. from the same pipeline branch, then the results within the first ward / department will be affected. If oxygen consumption were to ramp up across the site, careful monitoring would be required by the AP(MGPS) and Clinical/Nursing staff.

7.3 Real time flow measurement

During the recent pandemic conditions, Trusts have become increasingly interested in measuring flowrates within site oxygen systems. Previously, apart from billing and recharge mechanisms, it has not been felt there is a need for this information and 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. It is to be borne in mind that these units need initial and on-going calibration. Ultrasonic units may use inferential, cross wave (or a combination of both) configurations to estimate flow.

An invasive flowmeter will require total supply interruption to facilitate the installation process. Invasive flowmeters should always be provided with a valved by-pass, to enable zeroing and to facilitate removal of the meter for repair or replacement.

Note that the point of flow measurement chosen, usually on mains and distribution pipework, will not consider any oxygen lost during the filling process or any other losses within the VIE system. These are not related to the system flow but will represent the difference between recorded delivery quantity and available oxygen. For the purposes of the described practice, these losses can be discounted.

Once the units have been installed, they really need a zero balance (no flow condition) to calibrate. This can be exceedingly difficult to achieve on an active oxygen main, and although compensating subroutines are capable of iterating accuracy without a zero balance, an ultrasonic unit will have limited accuracy. But does this really matter?

Thought needs to be given to the applicability of flow meters for service continuity/resilience over cost benefit analysis. Non-invasive units are expensive and although especially useful for recharging in multi-site supply networks, careful consideration is needed as to their use and mechanism of control. How can this data influence care at point of use? Will it limit what a clinician uses, or merely (expensively) record the system being overstressed? Further, although more detailed, independent information on real time flow might result, the cost benefit of the procedure should be weighed against data available from the telemetry system.

It is possible to utilise pressure tappings in the main control panel regulators to give an indirect reading of flowrate from the valve, using the characteristic relationship between flow across the valve and the ΔP. This may be relatively cheap, by comparison 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 pressure drop in the system that has to be managed, and this is the limiting factor for flow rate to remain within operating parameters.

A more expedient (simpler and cheaper!) alternative, is improved local pressure reporting, which is usually already fitted in a modern system, where there is a dependency upon its continued function. Devices, either from existing pressure transducers, or in the case of pressure switched alarm systems, from transducers fitted into a NIST on a department AVSU or LVA, or a dedicated transducer port with minimum leak device, feature wireless reporting to a local control area (usually the nursing station or ITU hub). This can utilise 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 the increase in demand from clinical practices.

This presentation is far more likely to impinge on the awareness of a clinician, who is primarily focussed 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 to whatever system/process is used. Flow meters may be an effective, high level strategic tool and, if that is what is wanted , then it is applicable. However, if we are trying to safely maintain 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 date 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.***
- ***Using the as-fitteds and by visual examination, carry out risk assessments to identify areas of the system that could be used to supply higher than 'normal' flow rates and carry out load testing as described above.***
- ***Using the as-fitteds and by visual examination, carry out risk assessments to identify areas of the system 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 of above areas and discuss limitations of potential usage with Clinical Lead colleagues, who will be responsible for connection of high flow medical equipment.***
- ***Ensure that all clinical staff are made aware that they should consult the AP (MGPS) before ANY equipment is connected to the MGPS. This should be stated in the MGPS Operational Policy.***

8.0 Actions to maximise system resilience and flow capability

8.1 Distribution system design and configuration

The advantages of geographical separation of primary and secondary supplies in terms of system resilience are self-evident, as are the benefits of linking supplies to distribution systems via twin, rather than single, feeds.

However, what became apparent during the pandemic was, regardless of the flow capacity of the source, that the flow delivered at the terminal units was, in many installations, severely limited by the ability of radial distribution systems to deliver required flows without excessive pressure drops.

Obviously, expecting a normal acute ward to service a large number of high flow oxygen devices has less chance of success than a high dependency unit. There is nothing inherently 'wrong' with the system, it's simply that the flow algorithms for the two areas (and hence the pipe sizes they attract) are considerably different.

Appraisal of the system to support high oxygen usage will have to reflect these differences. Unfortunately, all too often few areas suitable for such use can be identified. However, given the potentially high influx of patients, it was inevitable that areas unable to cope with the associated high flows would be pressed into service. With the benefit of hindsight, all such areas would have been listed and their flow potential known to both Estates and Clinical services, ensuring that only, say, recovering and palliative care patients would be accommodated therein, with high demand equipment being limited to areas more able to cope.

Such has been the scale of the pandemic that even high flow areas have been stressed, in some cases, over their limits. The benefits of a fully updated 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; all can 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

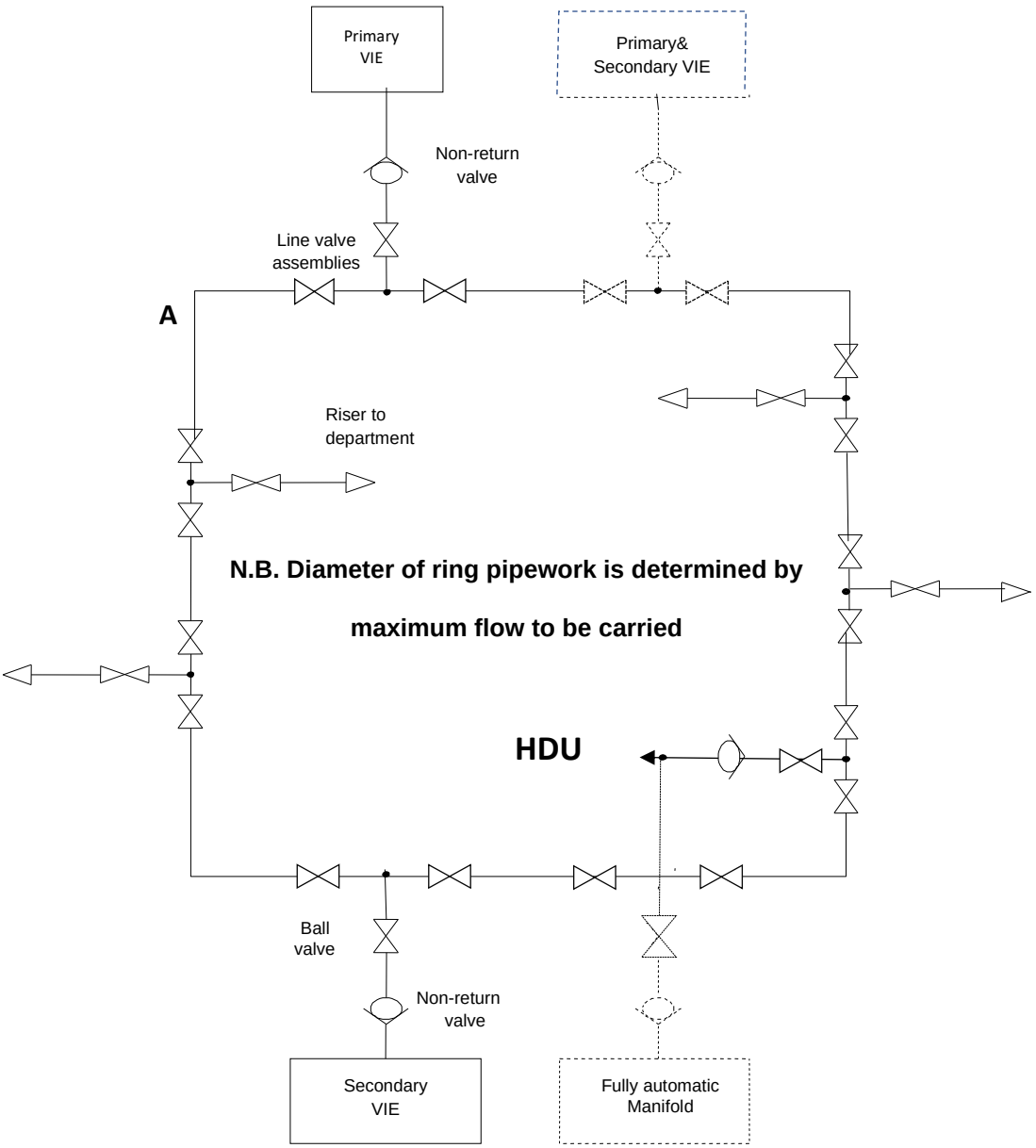
Much is made of the benefits of ring main installation. While this is true of a correctly configured main in terms of sizing, layout and valving, many installations do not reflect these requirements. Further, most sites will probably not have a ring main installed.

Ring mains are better installed as part of the original infrastructure, as retrograde installation can present considerable difficulties.

Figure C - 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 by passes and NIST connections are not shown.



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

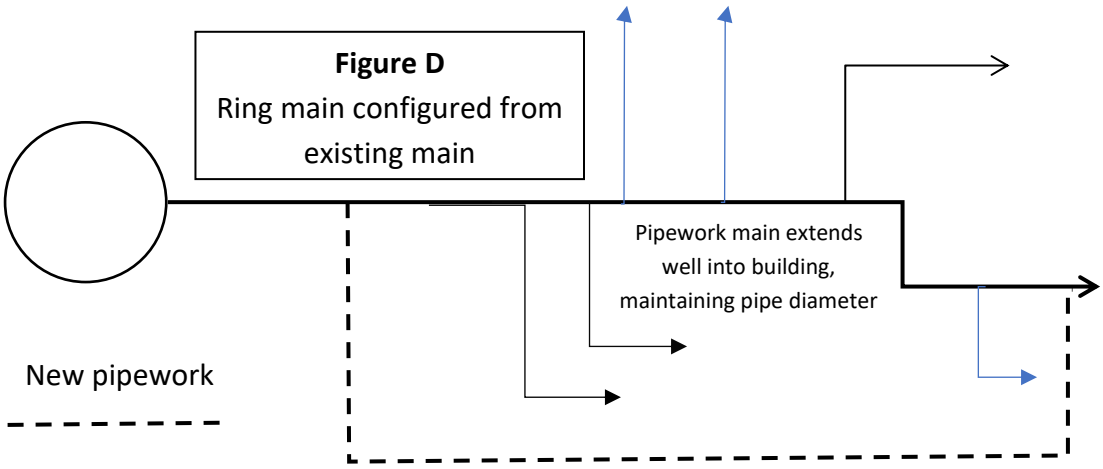


Figure D
Ring main configured from existing main

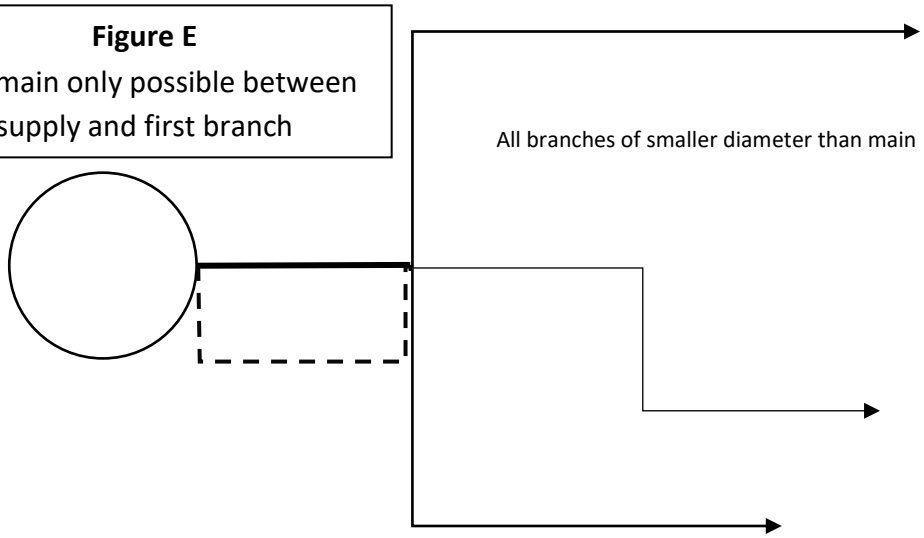


Figure E
Ring main only possible between supply and first branch

Establishing a ring main structure with the first configuration will be simpler, as a connection of a return pipe of the same diameter to the distal end of the main might be possible. However, a major shutdown to achieve the connection is highly likely, unless the original pipework has a suitably valved take off point.

The second arrangement allows ring formation at supply main pipe diameter only between plant and building curtilage, essentially a variation in a vessel-to-hospital dual feed arrangement. Not exactly a ring main!!! 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 completely new pipework. While costly, this approach has the advantage that installation of the ring with all its associated valving and take off points can be completed and tested without system shutdown. Departments can then be connected successively to the ring take offs without having to shut down the whole ring.

Many hospital sites have one or more tower blocks. In these circumstances it is advisable to take two risers (e.g. East and West sides of each tower) from separate parts of the ring and link the tops of these risers, forming a tower ring structure.

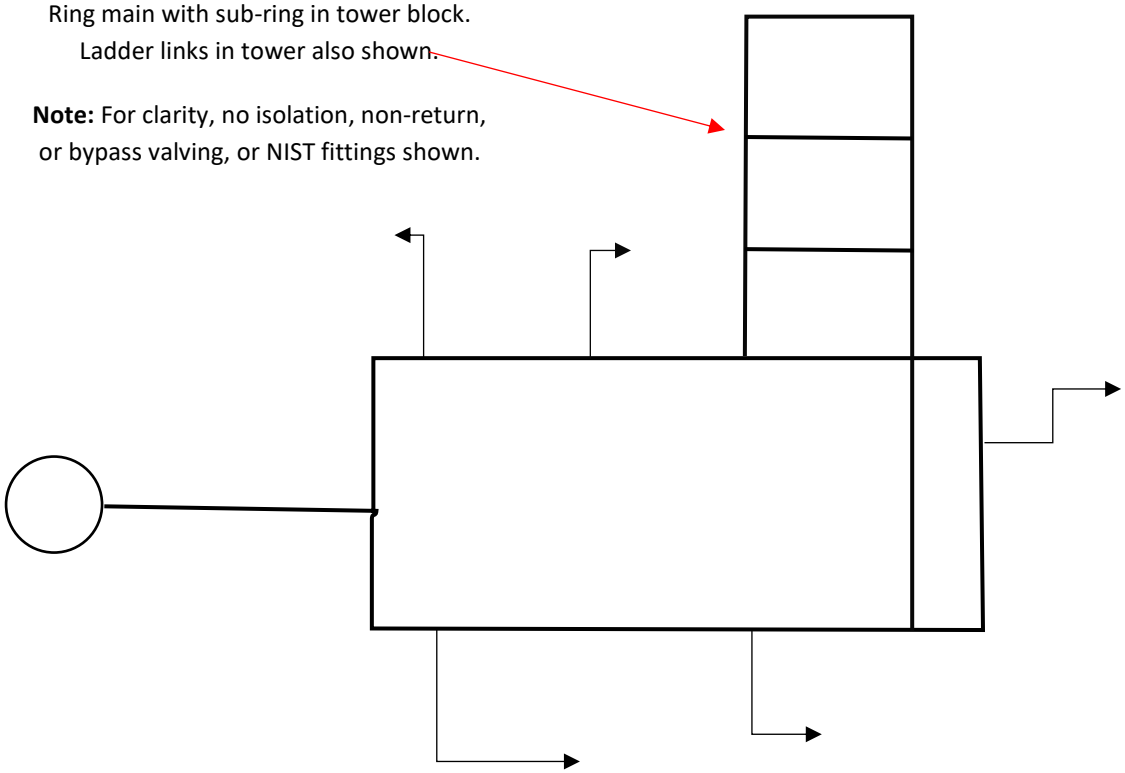
Further advantages can be obtained by cross linking the risers (via valved connections) at one or more intermediate floors (ladder configuration). (**Figure F** below)

All options should be discussed with both AE (MGPS) and Clinical Lead.

Figure F

Ring main with sub-ring in tower block.
Ladder links in tower also shown.

Note: For clarity, no isolation, non-return, or bypass valving, or NIST fittings shown.



8.3 Ring main supply sources

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, it is essential to ensure that the gas supplier installs an economiser circuit on the secondary VIE to prevent gas wastage. The size of the secondary and its evaporator(s) requires careful consideration, as reduction in capability of any component will limit performance when supplying the ring.

A secondary of volume equal to the primary, with same sized evaporator(s) and control panel(s) is the only solution to supporting the ring in exactly the same way as the primary but, given that VIE plant is inherently highly reliable, with minimum down times, flow capability of the secondary can equal that of the primary but storage capacity can be reduced to 50%, or even less.

A further alternative configuration would be two geographically separated dual vessel supplies. This arrangement is, of course, a more expensive option but does have 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. The latter option has proved popular, as it keeps both plants operational, overcoming any problems of gas wastage if economisers are not fitted. However, to a certain extent it defeats the objective of a ring supply and would be better suited to supporting radial systems in which high demand areas of the hospital are supplied from one system and lower usage areas from the other. Pipework modification to achieve this separation of activities would almost certainly be necessary.

Whatever supply arrangement for ring support is chosen it is important to understand that feeding a ring with two 3000 l/min plant will not offer a ring capable of delivering 6000 l/min, as when the primary plant outlet pressure begins to drop with excess usage, the secondary plant will cut in to maintain the ring flow at 3000 l/min. The only way to obtain 6000 l/min from the two VIE systems would be to supply the ring as two separate sections using up to 3000 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 potential for supply resilience improvements 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 extension to tower blocks etc and possibly using separated sources.***

8.4 Ring main sizing

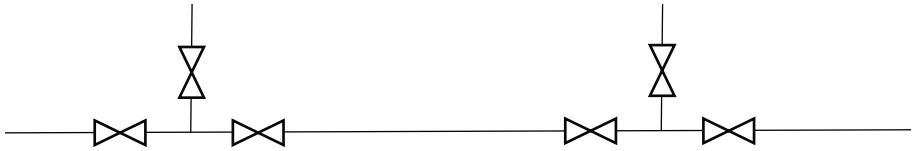
A **significant benefit** of a ring main is the facility to **isolate any desired area, while maintaining supplies to the remainder of the site**. This implies that any section of the ring main must be capable of (and hence sized for) carrying the **full system design flow** and **correctly valved**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

8.5 Ring main valving

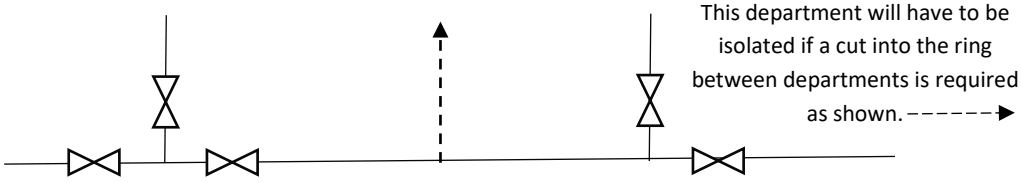
None of the figures above show details of valving in a typical ring. HTM 02-01 details the valving necessary for an oxygen ring main in **Part A, Section 13**. It is important to note that each supply and take off point has a triple valve arrangement, although some savings can be made by using only one valve between take off points but only if adding further connections between the two take offs (without isolating one or more areas) is not envisaged. (**Figure G** below)

Figure G

Typical ring valved take off points to two departments



Economy of valving but only if no future connection between departments envisaged, as this would require shut down of one department.



HTM 02-01 prescribes dual supply circuits for high dependency areas, dedicated pipelines for supporting high numbers of CPAP machines and ring mains for basic infrastructure. It is essential that as-fitteds are used in association with visual examinations to confirm which of these measures are in place and how additional measures might be implemented.

8.6 Use of NIST fittings and non-return valves

None of the above sketches shows 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 should be used in all situations where their configuration is advantageous 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, rather than the cost.

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

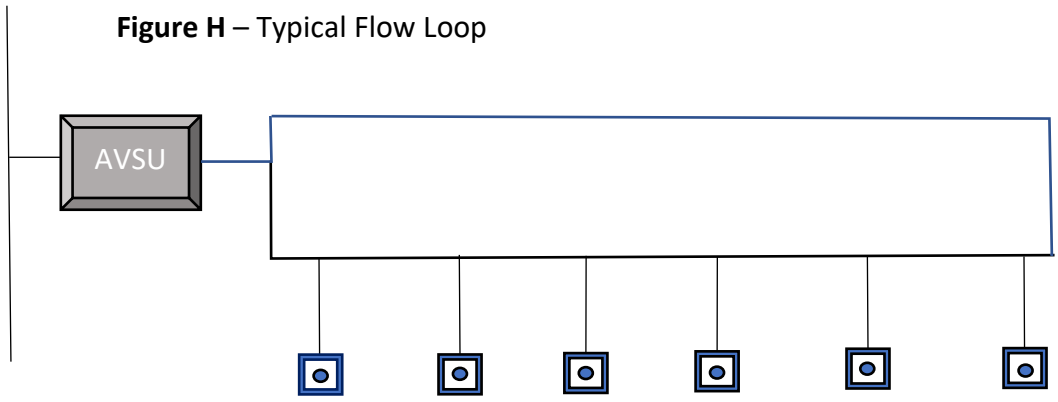
For all critical situations where blockage of the non-return valve might interrupt service, a bypass arrangement should be installed. Non-return valves of one pipe size larger than the installed pipework it protects will reduce frictional pressure losses.

8. Flow loops

This configuration is not documented in HTM 02-01 but is good engineering practice. It does incur a nominal extra installation cost as it involves fitting a piped return from the top of the final terminal unit drop, to as close as possible to its controlling AVSU outlet. This 'mini-ring' improves local flow, leading to reduced pressure drops at distal terminal units and is to be commended. Care should be taken to ensure modified pipework designs do not lead to formation of dead ends as this will lead to stagnation of the gas (although some Brownian mixing will take place). For this reason, the distal connection of the loop pipework should be at the final terminal unit, as shown below in **Figure H**.

Such an arrangement allows for connection of highest flow demand equipment to be connected furthest from the riser.

Figure H – 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 will have 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 load testing of both the CPAP and HDU feeds should still be carried out if patient load is to increase.

8.9 Dual circuits for high dependency areas

This configuration of independent feeds to left and right sides of beds was originally intended to facilitate work on one system while the other maintained a service, hence obviating the need to shut down beds. Over time, clinical practice has dictated that ITU/HDU beds are better served by using one side of the bed as 'wet', for use of such items as infusion pumps and the other as 'dry' e.g. for use by monitoring equipment.

However, influx of COVID-19 patients has seen single ITU bed spaces used for two beds, with equipment for one bed fed from left side terminals and the other from the right. Again, load testing should be carried out to ensure pressure drops are not excessive.

Tasks

- ***Discuss with the AE (MGPS) all the above measures for potential improvements to flow and/or system resilience.***
- ***Prepare for the discussion by consulting the as-fitted drawings and making notes for discussion.***

9.0 Alternative supplies

9.1 General

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

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

9.2 Liquid cylinder manifolds

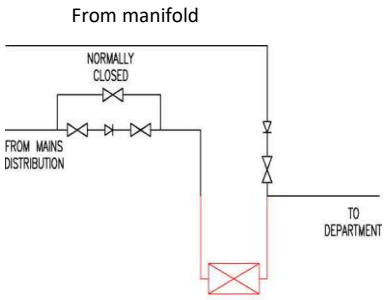
Liquid cylinder manifolds have, been proposed as back up sources for VIEs. However, the pandemic has revealed an inherent deficiency in the typical 24 J size units e.g. BOC's LC200 vessels, operating without the benefit of external evaporators. The flow range for these units is typically 150 – 300 l/min (from supplied data). However, most are deployed in private healthcare establishments where demand is relatively high for short periods, and with extended periods of little, if any, use. This regime allows for the vessels to regain pressure by influx of atmospheric heat and, therein, the ability to cope with relatively short periods of high flow. ,

Unfortunately, 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 will be similarly limited to palliative and recovery care and, even then, for extremely low patient numbers if used continuously.

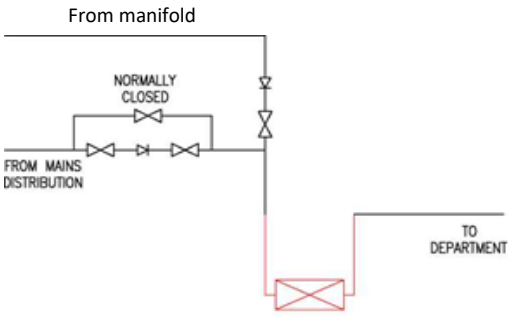
9.3 Compressed gas cylinder manifolds

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 into the system will require careful consideration, as provision of the protective non-return valve is important, as is its by-pass. The connection point can be upstream or downstream of the area AVSU but downstream of the AVSU brings all components into a convenient control zone and avoids any potential for disturbance of the main supply, should any component fail. A dedicated AVSU for the manifold will clarify control for Estates staff but would require additional pipework and wall space and could confuse medical staff in an emergency. An alternative would be a ceiling connection via a line valve assembly.

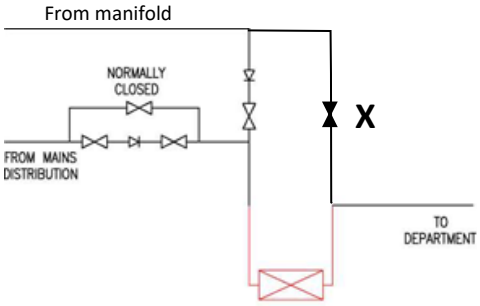
Some connection configurations are shown below.



(S) HTM 02-01 Part A 6.99 compliant

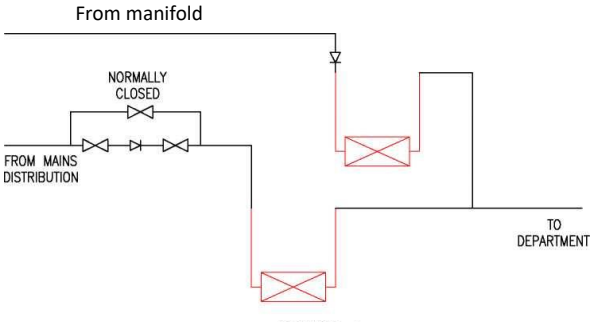


To ensure AVSU is final point of isolation e.g. for fire/major gas leak



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

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



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

Alarm indicators for the manifold will require careful consideration: locally adds a further level of confusion for medical staff and remotely will require additional, dedicated display panels, although use of a spare display channel can be used to signal fault conditions from multiple manifolds as shown below.

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

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

For situations where the remedial measures described above are impossible to implement, use of portable emergency supplies remains an option.

Until recently, such supplies comprised one or more cylinders connected via (a) 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 GCE.

This comprises a detachable trolley and frame unit. On the frame is mounted the manifold (with integral alarm and four off outlet terminals/hoses)., The unit can be wheeled from a store to its required position, at which point the frame is lowered to provide stability and the trolley is removed.. The cylinders are then loaded into the frame and connected to the manifold via hoses. Change-over of cylinders is enabled by a frontal access for individual cylinder changes overs. When a cylinder change-over is required it is identified on the manifold on the manifold panel.

The unit can be used to supply individual or multiple items of medical equipment directly, or via connection to a ward terminal/ASVU NIST, respectively. The unit can also be used as a temporary supply during area isolation for cut-ins etc

The unit is ideal to reduce 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 produce oxygen by passing air, under pressure, through a special mineral, known as a Zeolite. Nitrogen is removed from the air in the process, leaving (mostly) oxygen for patient therapy. The nitrogen is discharged to the surrounding air.

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

- Oxygen concentration at, typically 93-94% (+/- 3%) is **NOT** the same as from VIE plant or compressed gas cylinders (99.5 %), although two stage psa plant exists. The second stage removes most of the argon from the final product, leaving a typical oxygen concentration of 99%. Two stage plant are more expensive than a single stage plant, although the cost of the latter will usually be in the region of £100-200k.

- If they are running continuously at full specified flow, the oxygen concentration of 93% will not be maintained. Ultimately, the oxygen concentration will decrease to around 90 % and possibly even lower. The time taken for this to occur will depend on use of the plant. Running an 850 l/min plant at 600 l/min should help reduce the risk of falling concentration.

- As a source of supply for a pipeline system they should comply with the requirements **of EN ISO 7396-1 Medical gas pipeline systems**; Pipeline systems for compressed medical gases and vacuum. This standard requires the medical gas pipeline system to have three sources of supply to ensure that the gas supply is maintained under single fault condition. To be installed in compliance with the standard requirements, more than one plant will need to be installed to ensure that supplies can be guaranteed.

- They occupy a lot of space e.g. an 850 l/min plant will fill a 40 ft x 12 ft shipping container.

- They generate a lot of heat and nitrogen. Cooling and nitrogen/waste heat removal are essential. Ducted air intakes are advisable.

- PSA plant requires significant volumes of air to be compressed to produce the oxygen. It requires five times the volume of air to produce one volume of oxygen, with additional volumes of air for regenerating the Zeolite beds.

- To power the compressors, a significant electrical supply is required, which potentially can produce electrical supply issues elsewhere in the facility not least of which will be the additional load on the hospital's essential electricity supply (generator).

- They require an automatic cylinder manifold as backup. Depending on the design flow of the PSA, system support using this manifold will be minimal e.g. if a 500 l/min PSA plant fails, a 2 x 10J manifold will give **only two hours service per bank**.

- If the automatic manifold comes online, there will be a **rapid rise in oxygen concentration from 93% to cylinder concentration of 99.5%.**

  Medical and Nursing staff **should be made aware** of this, and warning notices should be 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 time to fill a single J size runs into several hours.

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 will be difficult and might cause fluctuations in delivered oxygen concentration and maybe system pressure.

- Mixing to two Ph Eur-monographed gas sources produces a gas that has no pharmaceutical monograph. Its acceptability to QC Pharmacists and Anaesthetists is **unlikely**.

- If the primary and secondary plant 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 gas volumes delivered. Many of these will be ongoing, should the plant be mothballed for any length of rime.

For the above reasons, use of PSA plant should only be a means of supplying a defined part of a system, segregated from the main VIE supply, to reduce load on the latter.

Important: Responsibility for oxygen product

- Where oxygen is manufactured on-site within a Healthcare facility, the healthcare facility Pharmacist has the responsibility of 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 Co-operation Scheme Guide PE010-4 Guideline to good practices for the preparation of medicinal products in healthcare establishments).

  This means that the Hospital 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) at low pressure.
  While they can be used to support patients via nasal cannulae, they **are NOT suitable for ventilator support domestically, or in a healthcare facility, or for connection into VIE systems**.

- They should be connected to the essential electricity supply.

10.0 Developments in cylinder technology

J size oxygen cylinders hold 6,800 litres of gas at 137 bar pressure. BOC has now released a W size oxygen cylinder ('WO'), which contains 11,300 litres of gas at a storage pressure of 230 bar and is almost the same size as a J cylinder. This means that a WO manifold has almost twice the storage capacity of a similarly sized J manifold. Such manifolds are a viable source of oxygen in previously discounted locations. The portable unit described above is designed to carry two 'WO' cylinders and will be marketed by Gas Control Equipment Ltd

11.0 Gas pressure alarm developments

Traditional local alarms display green for 'normal' conditions and red for pressure faults. There is no indication of the slowly worsening condition between green and red. However, alarms are now being trialled that signal changes in pressure not only as a digital readout of the line pressure but also as a colour change from green, to yellow, to orange, to red, to offer clinical and nursing staff an easily recognised indication of the effects of adding an increasing number of items of medical equipment to the system.

12.0 MGPS Operational Policy

Finally, how should the Operational Policy reflect the organisation's approach to the pandemic?

Most importantly, the Policy should already contain protocols for dealing with gas failures and falling pressure. Undoubtedly, the hospital will also have a Major Incident Plan covering major civilian-related incidents e.g. train crashes and radiation leaks, maybe even a flu outbreak! However, in many Policies, it is unlikely that a global pandemic will be mentioned specifically.

During the pandemic it was obvious that, whatever was written in the Policy, Estates and Clinical Managers found themselves (in some cases, for the first time!) in close liaison, with the performance of the oxygen system top of the discussion list.

It is to be hoped that the words and actions embodied within this document will ensure you are better placed to answer the overriding question. Why can't you give me more oxygen?

Tasks

- ***A fully updated MGPS Operational Policy, for which you might hold responsibility for implementation 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 pandemic meeting as he/she will be able to comment on the results of his /her last system audit and the hospital's pandemic response.***
- ***Ensure Policy includes 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 should include emergency isolation of a gas supply, responses to medical gas alarms and use of medical air terminal units.***

Appendix A - Liquid Oxygen VIE Installations

Operational Management Considerations During Periods of High Demand

The following information is intended to form a general guide for Authorised Persons (MGPS) with the operational management arrangements for their liquid medical oxygen system during periods of increased demand. The advice is based generally on information provided by the suppliers of cryogenic oxygen storage systems and applies generally to both Air Products and BOC VIE installations. It should be noted 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. There should also be a Piping & Instrumentation Diagram (P&ID), which is specific for the installation in question, displayed at the installation – typically attached to the fence of the VIE compound adjacent to the main gate. The Valve Number schedule as displayed in Table A1 - (S)HTM 02-01 Part B, Appendix F is detailed below for ease of reference.

Valve Control Function	Valve No. - BOC	Valve No. – Air Products	Operating Condition 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
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 will be monitored by the central alarm system. Information on liquid level and tank pressure are relayed back to the supplier via the Telemetry system. For a system comprising of a primary and smaller secondary VIE, the following alarm conditions will 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 system down to 50%
Pressure Fault	Pipeline pressure risen to 4.9 bar or fallen to 3.75 bar

Typical System Operating Parameters:

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 around 17 bar and the bursting disc will rupture around 21 bar. The actual pressures for your installation may vary slightly and should be detailed on the P&ID particular to your installation. There will be two evaporators / vaporisers, one of which will be on-line (duty) and the other will be valved off (standby). The evaporators / vaporisers are often changed over by Estates on a weekly basis to allow the evaporator / vaporiser which has been on duty to thaw out. This activity may be more frequent during periods of high demand and / or during low ambient temperatures and can be assisted by use of water spray or steam. It is the evaporator / vaporiser which essentially dictates the flowrate achievable from the installation as its' function is to warm the liquid oxygen to gas for distribution via the pipeline distribution system supplying the Hospital. The pipeline pressure as regulated within the VIE control panel is typically regulated at around 4.1 / 4.2 bar. The pressure safety valve within the control panel will typically lift at 5.3 bar. During normal use for most Hospital sites where there is a relatively constant demand for oxygen, the liquid feed to main evaporator (BOC–V7 / Air Products–V14) will be open with the Economiser (gas take-off from vessel) (BOC–V5 / Air Products–V22) closed. There will be some installations with relatively low demand where this arrangement is reversed i.e. (BOC – V7 / Air Products – V14) will be closed and (BOC – V5 / Air Products – V22) open. VIE installations on smaller Hospital sites which have been configured this way may have to be changed by the Authorised Person (MGPS) should the oxygen demand increase and the system closely monitored thereafter.

Increased Demand on the System: This will largely be evident by ice build-up on the evaporator / vaporiser which is on-line (duty). It is essential that ice does not get the chance to build up as this will severely restrict the efficiency of the evaporator / vaporiser. This should be addressed by either:

- Swapping the evaporator / vaporiser over to the standby to allow what was the duty evaporator / vaporiser to thaw out – this may even be required daily or more frequently in some circumstances. The isolating valves are located downstream of each evaporator / vaporiser.
- De-icing the evaporator manually. This can be achieved by directing water from a hose onto the ice – this can be warm water although cold water is also effective in removing ice. Steam can also be used if a supply is available within the proximity of the VIE compound. In all cases, care should be taken not to direct water near to or on the pressure safety valves**. On no account, must the ice be struck with a mallet or similar, to remove it.**

As stated, the flowrate from the VIE installation is dependent on the size of the evaporator / vaporiser and the amount of liquid which this can boil off to gas. The performance of the evaporator / vaporiser will increase as the ambient temperature increases.

In instances where the demand on the system is greater than what the evaporator / vaporiser can boil off, consideration can be given to putting both evaporators / vaporisers online. This should be resisted if possible.

If this is done, it is essential that both evaporators / vaporisers are regularly checked for ice build-up and ice build-up removed promptly using one of the methods advised previously. In extreme cases, this could well be a 24/7 activity and the resource input should not be underestimated. The section of pipeline which runs 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 identified as a potential need for evaporator upsizing.

If downstream pressure drops are encountered due to the demand, consideration can be given to increasing the pipeline pressure from the regulators within the VIE control panel. The lead regulator would typically be set at around 4.1 / 4.2 bar. While there is scope for increasing this pressure, the revised setting should be sufficiently below the setting for the fourth stage alarm 'Pressure Fault' which is typically 4.9 bar. This should also ensure that the pressure safety valve does not lift (5.3 bar) as, often, it will not re-seat fully once it has lifted. It should also be noted that increasing the pipeline pressure will not result in increased flowrate through the pipeline system. It will only be effective for off-setting, to some degree, downstream pressure drops should these occur on the system.

If the demand from the Hospital starts to exceed what the system can deliver, this will likely be evident by:

- Activation of the fourth stage (Pressure Fault) alarm which would indicate that the pipeline pressure has fallen typically to around 3.75 bar.
- Subsequent activation of area alarm panels within the Hospital which would indicate that the pipeline pressure has fallen to typically around 3.5 / 3.6 bar.

At this point, the Authorised Person (MGPS) would have to 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 there may be medical equipment which can operate effectively below 3.5 / 3.6 bar, any decision to continue oxygen administration must be made by the relevant clinical authority. . Alternatively, consideration shall be given to additional oxygen supply methods such as localised cylinder supply or, preferably, the portable automatic manifold detailed previously.

General: Other considerations should include:

- Activation of the first stage alarm (Refill Liquid) should not result in mass panic. There will still be a reasonable quantity of liquid within the primary and secondary VIE and the supply will not be about to run out. 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 records of consumption / liquid level so that a record can be developed which will be useful in determining time periods between fills.
- Ensuring 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 Emergency Contact Number for the liquid oxygen supplier is known to the relevant parties.
- Record any unusual occurrences or failures and feed this back to the Authorising Engineer (MGPS) for 'lessons learnt' and wider review.

Summary: This guidance is intended for practising Authorised Persons (MGPS) who are already familiar with liquid oxygen VIE installations. It is not intended to recap other emergency actions such as:

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

It is expected that the Authorised Person (MGPS) is already familiar with dealing with such issues. When this guidance has been issued to the Co-ordinating Authorised Person (CAP), the CAP should ensure that it is cascaded to all other Authorised Persons (MGPS) within their organisation. The guidance must be generic in nature considering the range of liquid oxygen installations which are present. Should further advice be required, then this should be sought from the Authorising Engineer (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) **To be completed by Nursing staff responsible for the ward / department concerned.**	**Flowrate (l/min) observed**
Totals	

Flowrate 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	

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

*Select outlet furthest away from AVSU / Ward Entrance if possible.

Recommended maximum flowrate based on the above analysis (l/min)	

Appendix B Guidelines for establishing a Medical Gas Committee (MGC).

Introduction

The importance of an efficient MGC has been stressed elsewhere in this document. In particular, the MGC will be 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, to include all Core Group members.

Purpose of MGC

To provide assurance to the Medicines Management Committee that medical gases are effectively monitored and managed within the Healthcare establishment / Trust (HE/T).

Functions

The functions of the Medical Gases Committee are to:

1. Develop, review and update the Medical Gases Operational Policy and related policies and procedures, including these Terms of Reference, at agreed frequencies, or immediately on receipt of pertinent technical or clinical advice, including issue of Safety Alerts, Hazard Warnings etc.
2. Promote and monitor that Medical Gas Policies and Procedures are implemented and adhered to throughout the HE/T.
3. Assess training needs, implement training prescribed by HTM 02-01:2006. and monitor any non-attendance.
4. 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
5. Ensure that relevant competencies are in place and **validated**.
6. Act as a forum for monitoring medical gases risk management activities.
7. 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 and support for process and system changes, to reduce the likelihood of occurrence and/or reoccurrence of serious (Medical Device) Incident Reports.
8. Disseminate information and provide feedback to appropriate groups, committees, staff and other stakeholders on medical gas related issues.
9. Act as an early warning mechanism to alert for emerging risks.
10. Receive the MGPS Authorising Engineer's annual Audit Report and ensure remedial actions are carried out to the AE's defined timescales.
11. 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 4 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.

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 Chair of the Committee is accountable to, for example, the Chief Executive.

Circulation of 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.

Core Membership of the Medical Gases Committee

Chief Pharmacist (Chair)
In addition to the chair and deputy chair, permanent membership will comprise of 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.