7 Public Health - Medical Gas System Design (MGS)

This PH-MGS design guideline written for healthcare facilities, is a consolidated document listing out the design requirements for all new construction and major renovation healthcare projects.

The Medical Gas System security, resilience and storage capability must be designed to ensure that patient safety as well hospital operations are not at risk.

The requirements outlined in these guidelines are not intended to conflict with Federal Regulations, Local Municipality Laws, Executive Orders, or the needs of the end users.

This document is intended for the Architect/Engineer (A/E) and others engaged in the design and renovation of health facilities. Where direction described in applicable codes are in conflict, the A/E shall comply with the more stringent requirement. The A/E is required to make themselves aware of all applicable codes.

The document should be read in conjunction with other parts of the Health Facility Guidelines (Part A to Part F) & the typical room data sheets and typical room layout sheets.

Introduction

- The aim of this section of the guidelines is to promote the correct design of Medical Gas Systems for healthcare facilities.
- The design will discuss storage requirements, type of system proposed as system locations for the following Medical Gas Services:
  - Oxygen
  - Medical Air (MA4)
  - Surgical Air (SA7-SurgicalTool Air 7Bar)
  - Vacuum/Suction Air
  - Nitrous Oxide (N2O)
  - Helium/Oxygen (Heliox)
  - Nitrogen (N2)
  - Carbon Dioxide (CO2)
  - Nitrous Oxide/Oxygen (Gas Mixture – Entonox)
  - Gas Scavenging Systems (AGSS)
- These design guidelines are to be used in new healthcare facilities as well as facilities that will refurbished under the process as mentioned in Part A of these Guidelines.
- The guidelines for pipe sizing and other associated works can be based on ISO 7396.
- NFPA 99 guidelines should be applied for zoning, materials, hazard determination, alarms & equipment's.

Design Criteria

- The Medical Gas Service is designed to provide a safe and effective method of delivering quality medical gas service to the terminals within FPU's in healthcare facilities.
- In addition to Medical Gas Services being supplied to the department, some areas will require gas scavenging disposal systems to control the exposure to nitrous oxide.
- Medical gas services shall only be supplied to clinical areas as per the healthcare briefing requirements shown in Part B of these guidelines.
- Medical gas service should not be provided for non-clinical areas such as workshops (not biomedical workshops) and pathology departments. These areas shall be provided by 11Bar Compressed Air.
- For sensitive patient areas such as patients having infectious diseases, portable suction devices should be used in order to not contaminant the medical gas system.
- The Medical Gas System should be providing a number of sources to serve the facilities. Within these guidelines the sources shall be stated primary, secondary, and

reserve/emergency systems.

- The piping distribution systems according to the RDL level of the facility as well as number of beds can be very simple as a single riser, more resilient with a looped riser and even more with a double riser or a ladder riser. Designer has to make a conscious choice based on project criticality and area served.
- The purity of the medical gases shall be as the European Pharmacopoeia requirements table as shown in table 7.1 below
- Particulate level tests are to be provided with medical gas purity requirements.
- To maintain the sterile services of the medical gas service throughout the healthcare facility, the quality in terms of particulate content, dryness and concentration of impurities should comply with the requirements for maximum concentrations given in Table 7.1 below.
- Bacteria filter are to be included in medical and surgical compressor systems to reduce the risk of delivering spores of infectious material to vulnerable patients.
- The medical gas service connected to the bacteria filter must be a dry service. This is to ensure that any micro-organisms are prevented from bypassing the bacteria filter.
- Micro-organisms can penetrate a bacteria filter if the material is wet. The filter is to be checked every 12 weeks of hospital operation.
- For Medical Gas purity tests these are to be checked by the healthcare operator every 6 months for new builds and refurbished/retrofit facilities.

Gas & Source	Oil	Water	CO (Carbon Monoxide)	CO_2 (Carbon Dioxide)	NO (Nitric Oxide) & NO_2 (Nitrogen Oxide)	SO_2 (Sulphur Dioxide)	Odor/Taste
Oxygen from Bulk Liquid Storage	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 300 ppm v/v	-	-	None
Oxygen from PSA Plant (Oxygen Generation)	0.1mg/m³	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v	&	None
Nitrous Oxide	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v		N/A
Nitrous Oxide/Oxygen Mixture	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v		N/A
Medical & Surgical Air	0.1mg/m³	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 900 mg/m³ ≤ 500 ppm v/v	≤ 2ppm v/v		None
Synthetic Air	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	-	-	-	-	None
Helium/Oxygen O_2< 30%	-	≤67 vpm ≤0.05 mg/l, atmosphere dew point of -46°C)	≤ 5 mg/m³, ≤ ppm v/v	≤ 300 ppm v/v	≤ 2ppm v/v	-	None

Table 7.1 – Quality of Medical Gases

- For all healthcare facilities and to maintain the operation of the system, the medical gas supply throughout should be designed to achieve continuity of supply to the terminal units in normal condition and in a single fault condition. Loss of supply due to maintenance of a supply source (or a component within it) is not considered a single fault condition.

- The medical gas design provided will need to ensure that both system design parameters and the need for supply security of the service haven been identified. This will need to be carried out via a system/healthcare operator requirements risk assessment.
- As mentioned via the sources of supply section of these guidelines, security of medical air supplies must be given a high priority and electrical failure must not be allowed to jeopardize supplies (as mentioned in the electrical sections of these guidelines, all medical gas system is to be connected to Primary, secondary and tertiary power supplies).
- Gas Scavenging system (AGSS) shall only be provided to areas being serviced with Nitrous Oxide.

Sources of supply

Medical Gas services within the medical system in healthcare facility operate based on a redundancy and resiliency provision of the service to ensure patient safety and maintain the operation of the healthcare facilities.

Liquid Oxygen Cylinder Systems

- Primary Supply – Liquid Cylinder Manifold System (No Change over panel, all cylinders are on at the same time)
- Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply.
- Reserve Supply – Automatic Cylinder Manifold System to Grade A areas.

Oxygen Generation Plant (PSA)

- Primary Supply – Multiplex Compression Unit
- Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
- Recommendation: The secondary supply should be filled from the primary supply. This will provide an indication to the hospital operator when the primary supply fails and ensures that the secondary supply serving the healthcare departments are always filled.
- Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may lead to the use of an Automatic Cylinder Manifold System, a manual Cylinder Manifold system or another Oxygen generated plant located at a different location on site or local bottles to departments to serve Grade A areas.

Medical Air Supply (MA4)

- Duplex Compressor Set-Up:
- Primary Supply – Duplex Compressor System
- Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
- Reserve Supply - Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located locally near Grade A areas.
- Triplex Compressor Set-Up:
- Primary Supply – Two Compressor of a Triplex Compressor System.
- Secondary Supply – Third Compressor of a Triplex Compressor System.
- Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Quadruplex Compressor Set-Up:
- Primary Supply – Two Compressor of a Quadruplex Compressor System.
- Secondary Supply – The Other Two Compressor of a Quadruplex Compressor System.
- Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.

- Recommendation: Each compressor/pump is sized to cope with half the system design flow

Surgical Medical Air (SA7 /Tool Air-7Bar)

- Simplex Unit Set-Up:
- Primary Supply – Simplex Compressor Unit.
- Secondary Supply - Automatic Cylinder Manifold System. Cylinder system shall be Activated when Primary Supply fails or there is a shortage of primary supply. The number of cylinders should be based on a 4-hour operation storage provision.
- Reserve Supply – Departmentally localized valve Cylinders with flow regulators and meters. This will be located in a small plant room near Grade A areas such Operating Theatres.
- Duplex Unit Set-Up:
  - Primary Supply – One Compressor of Duplex System.
  - Secondary Supply – Second Compressor of Duplex System.
- Reserve Supply - Automatic Cylinder Manifold System. Cylinder system shall be Activated when Primary Supply and Secondary fails or there is a shortage of the supply. The number of cylinders should be based on a 4-hour operation storage provision of the specific department.

Combined Medical Air & Surgical Air Plant

- Duplex Compressor Set-Up:
  - Primary Supply – Duplex Compressor System.
  - Secondary Supply – 2 No. Automatic Cylinder Manifold System (1 No. for Medical Air and 1 No. for Surgical Air). Cylinder system shall be Activated when Primary Supply fails or there is a shortage of primary supply. The cylinders may be filled by the primary source or already filled cylinders provided by a local supplier. The number of cylinders should be based on a 4-hour operation storage provision.
  - Reserve Supply - Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located locally near Grade A areas.
- Triplex Compressor Set-Up:
  - Primary Supply – Two Compressor of a Triplex Compressor System.
  - Secondary Supply – Third Compressor of a Triplex Compressor System.
  - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Quadruplex Compressor Set-Up:
  - Primary Supply – Two Compressor of a Quadruplex Compressor System.
  - Secondary Supply – The Other two Compressor of a Quadruplex Compressor System.
  - Reserve Supply – Automatic Cylinder Manifold System to support the entire healthcare facility.
- Recommendation: Each compressor/pump is sized to cope with half the system design flow.

Liquid Gas Mixture (Oxygen & Nitrous Oxide)

- Primary Supply – Liquid Oxygen and Liquid Nitrogen Vessels with Mixer Unit.
- Secondary Supply – Secondary Liquid Oxygen and Liquid Nitrogen Vessels with Mixer Unit.
- Recommendation: The for Primary and secondary unit, depending on the specialty and size of the facility a cylinder system may be sufficient, but this will need to be confirmed by a risk assessment.
- Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may an Automatic Cylinder Manifold System, a manual Cylinder Manifold system or another Oxygen generated plant located at a different location on site or local bottles to departments to serve Grade A areas.

Medical Vacuum System

- Triplex Pump Set-Up:
  - Primary Supply – Two Pump of a Triplex Pump System.
  - Secondary Supply – Third Pump of a Triplex Pump System.
  - Reserve Supply – Portable Suction Equipment.
- Quadruplex Compressor Set-Up:
  - Primary Supply – Two Pump of a Quadruplex Pump System.
  - Secondary Supply – The Other two Pump of a Quadruplex Pump System.
  - Reserve Supply – Portable Suction Equipment.
- Recommendation: Each pump is sized to cope with half the system design flow.
- Important Note: In the event of power failure, cylinder- or medical-gas-system-powered vacuum generators can be used, but the use of venturi-type vacuum generators is recommended only for emergency use, as these units are generally driven from the medical oxygen system and use large amounts of gas. This can lead to oxygen enrichment and present a potential fire hazard and may result in the emission of pathological material.

Gas Cylinder Manifold System

- Primary Supply – Automatic Cylinder Manifold System and the number of cylinders based on the system design. Number of hours of operation as well as the availability of the cylinder supplier needs to be considered through a risk assessment to determine the number of operating hours, which will provide the exact number of cylinders.
- Secondary Supply – Manual Emergency Reserve manifold. System to come in line via a non - return valve. Number of cylinders based on 4 hours of system operation.
- Reserve Supply – Automatic Cylinder or Manual Emergency Reserve manifold supplying the system via a non-interchangeable screw threads connecter.

OR

- Local gas cylinder bottles or cylinders within departments with flow regulators.
- Important Note: For Carbon Dioxide Gas or Carbon Dioxide Mixture Gas, depending on the number of beds as well as the type of facility, gas bottles shall be provided local to the departments as per Part B requirements. But for larger facilities they shall follow the cylinder manifold arrangement as mentioned above (Primary, Secondary and Reserve Supply).

Vacuum Insulated Evaporator System (VIE)

- Simplex Unit Set-Up:
  - Primary Supply – A Simplex VIE Vessel System.
  - Secondary Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply.
  - Reserve Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. This type of manifold system may only be located near Grade A areas.

OR

  - Automatic Cylinder or Manual Emergency Reserve manifold supplying the system via a non-interchangeable screw threads connecter.
  - Please Note: Medical vacuum is provided by means of a central vacuum plant. The vacuum system should always be used in conjunction with vacuum control units that include vacuum jars. In the event of inadvertent contamination of the pipeline systems resulting from vacuum jars overflowing, immediate action is required to clean the system before any fluids etc. dry out.
- Duplex Unit Set-Up:
  - Primary Supply – One Vessel of a Duplex VIE Vessel on plinth.

  - Secondary Supply – Second Vessel of a duplex VIE System on the same plinth as Primary Supply.
  - Reserve Supply – Automatic Cylinder Manifold System. Activated when Primary Supply fails or there is a shortage of primary supply. Reserve to be used to serve the entire healthcare facility.

- Separate VIE Vessel Set-Up:
  - Primary Supply – One Vessel of a Duplex VIE Vessel on plinth.
  - Secondary Supply – Second Vessel of a duplex VIE System on a separate plinth as Primary Supply. Location of supply is carried out through a s risk assessment as it determines that there is a risk of the primary supply in that location being a failure and therefore the secondary supply needs to be located in a different location. Secondary supply to be installed with a non-return or double check valve to prevent gas loss in the event of one vessel leak or failure.
  - Reserve Supply – This type of supply will depend on the risk assessment carried out by the design consultant. The conclusion may an Automatic Cylinder Manifold System, a manual Cylinder Manifold system etc. The risk assessment may also a certain that a reserve supply is not required as there is a dual supply or ring main approach has been provided by the secondary supply system.

Important Note: For all compressor systems with a design flow greater than 500 L/min, two receivers, each able to be isolated individually.

Gas Scavenging System (AGSS)

For operating theatres and other critical clinical spaces (Grade A), the number of AGSS plant depends on the number of Air Handling Units to those areas. For example, for each operating theatre having its own dedicated Air Handling Unit then a Simplex AGSS plant is to be provided for each operating theatre. The reserve provision shall be a Simplex AGSS unit that can serve up to 6 No. Areas. If there are 12 areas then 2 No. simplex units shall be spare if all 12 areas are being served by 12 No, Simplex AGSS Units.

- Simplex Unit Set-Up:
  - Primary Exhaust – Simplex Pump Unit.
  - Reserve Exhaust – Simplex Pump Unit in Manual Change Over.
  - Important Note: For operating theatres and other critical clinical spaces (Grade A), where more than two areas are being served by a single Air Handling Unit, then a Duplex AGSS plant is to be provided with an automatic change over to the spare pump.
- Duplex Unit Set-Up:
  - Primary Exhaust – Duplex Pump System (one Pump).
  - Reserve Exhaust – Second Pump from Duplex AGSS Unit.

Basic Sizing of Medical Gas Cylinder Sources

- The sizing of the cylinders and major systems such as VIE system, will need to be carried out via risk assessment based on the following parameters:
  - Healthcare operating Hours
  - Distance from Supplier
  - Traffic Data
  - Supplier operating Hours
  - Supplier Response time in Peak working hours of the day
  - Supplier Response time in slow night operating hours.
  - Cylinder Delivery and Restocking History (if Known)
- The objective of the risk assessment is to ensure that the risk to patient safety eliminated or reduced to as low as possible as well as ensure that hospital operation is undisturbed.
- Cylinder manifold and storage capacities should be determined in line with NFPA 99, Chapter

5 (Gas and Vacuum Systems) requirements.

Number of Medical Gas Outlets and Locations

- As per the part B of these guidelines, the number of medical gas outlets as well as the type of medical gas service to FPU's shall be provided via the use of Room Layout Sheets (RLS) and Room Data Sheets (RDS).
- International guidelines can also be used for briefing based on project team's decision, which then have to be implemented in project specific RDS and RLS.

AVSU and LVA

- Area Valve Service Units (AVSU's) and Medical Gas Zone Valves (LVA) are the main isolation valve terminal units used to isolate the medical gas services serving the clinical departments.
- The AVSU's & LVA must be located by a nurse station that is continuously occupied during the healthcare facility operating hours.
- The panel is to be a combined panel with valves as well as alarm panel. This is not a separate alarm panel in one location and service isolation valve in another.
- The installation height requirements of the panel for healthcare facilities, shall be around 1000-1500mm. This height is based on the comfortable average heights for nurses.
- The installation height of the panel ensures that the healthcare operational staff can operate the panel if needed (alarm mute, valve isolation in emergencies).
- The panel needs to be provided with access requirements to operate the valves if need be.
- Access to the panel must be provided via a dedicated key or a break glass hammer. These shall only be provided for hospital operational staff (Nurses, Doctors and Maintenance staff).
- The minimum height for AVSU installation shall be 1m for dual circuits.
- Dual circuits shall only be arranged (in two columns) if the height from the top to bottom of the unit exceeds 1m.
- To avoid using an excessive number of Panels, this can be increased to 1.2m.
- The panels located on a wall will need to ensure that there is a minimum clearance of 100mm behind the unit for Medical Gas pipework (175mm for back to back pipes serving the AVSU's).
- The panels are to be labelled with permanent naming templates and not adhesive labels.
- A key is to be provided at the fire command center for Civil Defense Access.

Medical Gas Plant Rooms

- Table 7.2 below provides a safety distance compliance for location of Bulk Liquid Oxygen Tank from buildings, vehicles etc. (based on the volume of gas liquid stored).

Safety Distances from Exposure to Vessel/Point Where Oxygen Leakage or Spillage Can May Occur	Up to 20 tons (Distance in m)	Over 20 tons (Distance in m)
Areas where open flames / smoking are permitted	5	8
Places of Public Assembly	10	15
Offices, Canteens, and areas of Occupancy	5	8
Pits, Ducts, surface water drains (un-trapped)	5	8
Openings to underground systems	5	8
Building Footprint	5	8
Public Roads	5	8
Railways	10	15
Vehicle Parking Areas (other than authorized)	5	8
Large Wooden Structures	15	15
Small Stocks of combustible materials, site huts etc.	5	8

Safety Distances from Exposure to Vessel/Point Where Oxygen Leakage or Spillage Can May Occur	Up to 20 tons (Distance in m)	Over 20 tons (Distance in m)
Process Equipment (not part of installation)	5	8
Continuous Sections of Flammable Gas Pipelines	3	3
Flanges in Flammable Gas Pipelines (Over 50mm)	15	15
Fuel Gas Vent Pipes	5	8
Compressor / Ventilator Air Intakes	5	8
Fuel Gas Cylinders (up to 70m^3)	5	5
LPG Storage Vessels (up to 4 tons)	7.5	7.5
LPG Storage Vessels (up to 60 tons)	15	15
Bulk Flammable Liquid Storage Vessels (up to 7.8m^3)	7.5	7.5
Bulk Flammable Liquid Storage Vessels (up to 117m^3)	15	15
MV or HV Electrical Sub-Station	5	8

Table 7.2 – Safety Distance Compliance for Medical Gas Plants

- The Medical Gas Cylinder plant room must be located on the ground floor of any healthcare facility.
- The Medical Gas Compressor and Vacuum may be located in the basement of a facility as long as that area is ventilated but is highly recommended for the plant room to be located on the ground floor for maintenance.
- In hot climates, the Medical gas plant rooms (including the cylinder rooms) need to be air-conditioned to provide an air temperature of less than 40℃.
- Medical Gas Cylinder Store Rooms should be well ventilated and that cylinders of this gases (especially Mixture gases) are kept above 10°C for 24 hours before use, and arrangements should be in place to ensure that cylinders collected from a cold store are not used immediately for patient treatment.
- Medical Gas Cylinders should not be subjected to extremes temperature. Cylinders should be kept away from sources of heat (this includes hot water service pipes, steam pipes, hot air emitters and direct sun exposure).
- No other chemicals, flammable material, or rubbish to be stored within the medical gas plant room.

Medical Gas Plant Rooms – For Hyperbaric Chambers

- Special Gas cylinder room should be provided for the hyperbaric chambers
- Gas cylinder room should be large enough able to store enough (H) cylinders and manifolds for the reserve breathing gases required for chamber operations. Cylinders quantity should be decided by the vendor. Liquid O2 tank with vaporizer is also permitted as source of oxygen. If central gas / compressed air is available, it can be utilized provided it complies with NFPA 99 Chapter 14 requirements.
- Have explosion proof electrical fittings.
- Have an automatic gas manifold monitored by alarm. Maintain an alarm that monitors the high and low gas pressure.
- Provide a door to the room with door vents for O2 to pass in case of leakage from cylinders
- Provide access for a truck to refill the O2 in case the facility uses liquid O2 for the treatment.