Reaching Impact, Saturation, and Epidemic Control (RISE)

Standard Operating Procedure

Medical Gas Pipeline System (MGPS)[1]

[1] ISO 7396-1:2007, Medical gas pipeline systems — Part 1: Pipeline systems for compressed medical gases and vacuum

Contents

Abbreviations

AGS	anesthetic gas scavenging
AGSS	anesthetic gas scavenging system
ATM	standard atmosphere, a unit of pressure defined as 1,01,325 Pa = ~ 1 bar
BiPAP	bilevel positive airway pressure
BTU/LB	British thermal unit (BTU or Btu) per pound, 1 Btu/lb = 2,326.0002917735 J/kg
CCOE	Chief Controller of Explosives
CPAP	continuous positive airway pressure
FAD	free air delivery
HTM	Health Technical Memorandum, UK
h	Hour
ISO	International Organization for Standardization
kL	kilo liter
LMO	liquid medical oxygen
m	Meter
MAWP	maximum allowable working pressure
MGPS	medical gas pipeline system
NFPA	National Fire Protection Association, USA
OD	outside diameter
PESO	Petroleum and Explosives Safety Organization
PSA	pressure swing adsorption
SCF/LB	standard cubic foot / pound
SOP	standard operating procedures
SMPV	static and mobile pressure vessels
1000 litres	1 Kilolitre (KL)

Introduction

Oxygen therapy has always been an essential component of clinical treatment in health care systems. It is used in emergency care, for anesthesia, in surgery, and for managing acute and chronic respiratory conditions. However, the COVID-19 pandemic has led to an unprecedented surge in the demand for oxygen supply, given its crucial role in treating COVID-19 patients. The respiratory complications due to COVID-19 can lead to hypoxemia in patients, a condition when the oxygen level in the blood is abnormally low. In such a condition, a patient requires oxygen therapy and access to medical grade oxygen. Reliable access to medical grade oxygen can mean the difference between life and death for patients.

Sometimes, even if oxygen is available, observations suggest that lack of oxygen access to patients in health care settings can be due to insufficient oxygen systems such as lack of medical gas pipeline, medical grade oxygen generation plant, oxygen concentrators, and low-quality and poorly maintained oxygen delivery equipment such as ventilators, concentrators, CPAP, and BiPAP. Such shortcomings could be due to deficiencies in clinical and technical training and skills among clinical, technical, and administrative health care workers. Thus, creating awareness among the health care professionals and building their capacities to operate and maintain oxygen supply equipment efficiently are of paramount importance. Therefore, an enabling environment is required to streamline efforts to ensure that patients receive oxygen therapy, when needed. These efforts include safeguarding the quality of oxygen supplied by the manufacturer, assuring its appropriate administration to the patient, and drastically improving the screening to identify hypoxemic patients.

Background

Centralized medical gas pipeline system is a vital and integral part of a modern hospital, with emphasis on safety, reliability, and purity of the gases. The central piped medical gas system is one of the newer types of hospital plumbing systems that has been introduced to directly deliver different medical gases to the patients under care. Medical gas piping is needed for oxygen, nitrous oxide, medical air, nitrogen, carbon dioxide, vacuum, and instrumental air and waste anesthetic gas disposal. In Indian hospitals, generally, MGPS network is found only for oxygen, medical air, and vacuum.

Medical Gases Used in Hospitals

Please find below the list of medical gases used in hospitals:

Table 1: Types of medical gases used in hospitals

Medical Gas	Symbol	Function
Oxygen	O_2	Life support and respiratory therapy
Nitrous oxide	N_2O	Anesthetic and analgesic
Medical air	MA4	Respiratory therapy for ventilators and anesthetic machines; carry gas for nebulizer drugs or chemotherapy agents
Surgical air	SA7	Driving surgical tools and other equipment
Carbon dioxide	CO_2	Shielding gas for laparoscopic procedure

Vacuum	VAC	Removal of body fluid from patients
Nitrogen	N_2	Driving surgical tools and other equipment
Gas scavenging system	AGSS	For removal of waste gases

Designing Standards for MGPS

MGPS in any hospital should be designed as per IS 7396 to withstand the pressure at every section of the oxygen piping system. Other standards for MPGP design are NFPA99 and HTM.

Color Code Standards of MGPS Used in Hospitals

There are two color code standards used globally for MGPS. In India, we follow the ISO color code standards, which can be found in the table below.

Table 2: Color code standards for Medical Gas Pipeline System (MGPS) used in hospitals

Gas	U.S. Color Code	ISO Color Code
Carbon Dioxide	Grey	Grey
He-O_2	Brown & Green	Brown & White
Instrument Air	Red (USA Only)	
Medical Air	Yellow	Black & White
Nitrogen	Black	Black
Nitrous Oxide	Blue	Blue
O_2-He	Green & Brown	White & Brown
Oxygen	Green	White
Vacuum (Suction)	White	Yellow
WAGD (Evac)	Purple	Purple

However, the color-coding of oxygen pipelines in India is found to be yellow (ground color) with white bands (color band). Please find guidelines for the same below:

- Ground colors
    - Should be applied throughout the entire length
    - Minimum 2 meters in length
- Color bands
    - Intersection points and change of direction points
    - Midway of each piping way, near valves
    - For a long stretch of piping at 50-meter interval
    - At the starting and terminating points

Purpose of the SOP

The document, titled "Medical Gas Pipeline System (MGPS)", provides step-by-step details on MGPS management. It includes the following: components of MGPS (gas pipeline, valves, pressure gauges, alarm systems, etc.), MGPS distribution design, MGPS testing, merits of MGPS, and safety and precautions with MGPS. This SOP intends to bridge the knowledge and skills gap among health care facility staff by providing in-depth information on the operation and management of MGPS.

Components of MGPS

Gas Pipeline

Pipeline Nomenclature

Supply pipeline: It is the main hospital supply pipeline or gas service–specific trunk pipeline from the manifold to the building

Feeder pipeline: This includes risers (horizontal and vertical up to the distribution pipeline)

Distribution pipeline or branch pipeline: This serves one floor or part of it, and there is no vertical movement

Drop pipeline: This includes the distribution to terminal units or outlets

Figure 1: Copper Pipelines

Pipeline Material

The material used is medical grade copper, which is phosphorous deoxidized nonarsenical copper conforming to BS EN 1412:1996 grade CW024A (Cu-DHP)

- Seamless, round, solid drawn, sizes confirming to BS EN 13348
- Suitable for installing vertically or horizontally without sagging or distortion
- The material temper shall be as listed below:
    - For tailpipe: R220
    - For pipe of nominal OD (12–54 mm): R250 (half-hard)

    - For pipe of an OD of 76 mm and above: R290 (hard)
- Cu + Ag 99.90% - 0.015 P 0.040%
- Pipes degreased to ensure hydrocarbons on surface < 20 mg/m^2
- Fittings degreased to ensure hydrocarbons on surface < 100 mg/m^2
- Solder maximum cadmium content: 0.025% by weight

Pipeline Sizing

- Pipe sizing is determined either by the volume of gas to be delivered or by the impact of overall pressure required
- When sizing, for medical vacuum, always provide pipes of one size greater diameter to prevent clogging
- No pipe smaller than 12-mm OD shall be used anywhere in the MGPS installation
- No pipe smaller than 15-mm OD shall be used anywhere in this installation in the surgical suite including operating rooms, preoperative wards, and postoperative wards
- No pipe smaller than 15-mm OD shall be used anywhere in the installation for the medical vacuum service

The pipeline specifications listed in the table below are mandated as per EN 13348.

Table 3: Pipeline specifications

OUTER DIAMETER	WALL THICKNESS
12 mm	1.0 mm
15 mm	0.9 mm
22 mm	0.9 mm
28 mm	0.9 mm
42 mm	1.2 mm
54 mm	1.2 mm
76 mm	1.5 mm
108 mm	1.5 mm

Pipeline Installation

- All tubing, valves, and fittings shall be thoroughly checked for any grease, oil, or other combustible material
- Nitrogen purge: During the brazing of pipe connections, the interior of the pipe shall be purged continuously with nitrogen
- Silver brazing: Fluxless silver brazing alloy to be used, silver-copper-phosphorus brazing alloy CP 104 conforming to BS EN 1044:1999

- Soft solder or 50/50 solder must *never* be used on a medical gas system
- MGPS pipeline shall be adequately supported at sufficient intervals
- Where pipes pass through walls, partitions, or floors, they shall be fitted with sleeves of copper pipes
- Pipelines and electrical services shall either
    - run in separate compartments or
    - be separated by more than 50 mm
- If pipelines are placed underground, they shall be placed in tunnels, ducts, or overhead bridges for pipeline
- All pipelines for medical gases shall be routed in such a way that they are not exposed to a temperature less than 5°C above the dew point of the gas at pipeline pressure

Joining Copper Pipes

- Nitrogen purge is used to ensure that there is no oxidation of the internal pipe bore
- Copper-to-copper joints are soldered using silver (5%)
- Capillary action draws molten solder into the joint
- Some joints are cut out after installation and cut open for inspection
- Solder should penetrate 3x wall thickness or 3 mm, whichever is greater
- This is checked on 1 in 200 fittings

Please see the figure below for civil considerations for MGPS installation. Also, please see the table below for more information on the diameter of MGPS and their maximum interval distance for horizontal and vertical runs.

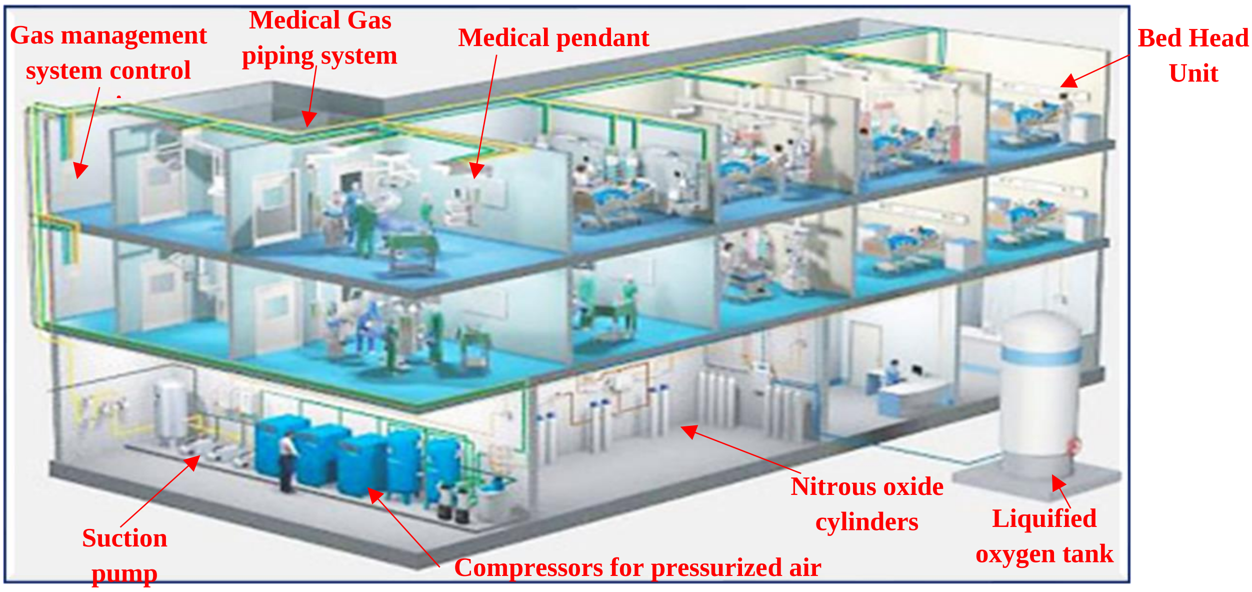


Figure 2: Civil considerations for MGPS installation

Table 4: Diameter of MGPS and their maximum interval distance for horizontal and vertical runs

OUTSIDE DIAMETER	MAXIMUM INTERVALS	MAXIMUM INTERVALS
(mm)	For Vertical Runs (m)	For Horizontal Runs (m)
12	1.2	1.0
15	1.8	1.2
22 - 28	2.4	1.8
35 - 42	3.0	2.4
> 54	3.0	2.7

Pipeline Joint Validation

- Before the wall outlets are installed, blow the pipes free of any particulate
- Other tests and checks that are required are listed below:
  - Pressure testing
  - Locating leaks
  - Cross-connection testing

Valves

Valves are used to control the flow of gas in the pipeline. Please find below some considerations for the valves:

- All valves shall be of the lever ball type
- Flanged O ring seal connections
- Which open and close with a 90-degree rotation
- The handle should be in line with the pipeline when open
- All valves are in an open position in a commissioned MGPS system

The types of valves are listed below:

- Main line valve (source shut off valve)
  - Must be provided at the outlet of the supply source
  - Must always be accessible to authorized persons only
- Branch valves including riser valves
  - Base of risers and every major branch

    - Must be placed in a secure location
- Zone valves

Zone valves are used to isolate large parts of the system, that is, rooms for modification and/or repair. Zone valves are placed on corridor walls and should be labelled to indicate the rooms they control.

    - Provided at each fire zone
    - Accessible to the floor staff and the fire staff
    - Should be marked in the floor evacuation plan
- Line valve assembly
    - Provided at the defined sections
    - At entry exit of each section

Please see the following considerations for line valve assembly:

- Maximum pressure drops at the intended maximum flow of 0.2 psi (g) in pressure service or testing
- Maximum pressure drops at the intended maximum flow of 3.8 mm Hg (0.15 Hg) in vacuum service or testing
- Degreased for use with oxygen
- Use a quarter turn to switch off
- Valves should be provided on items of plant and sources of supply to permit servicing and isolation of the main components and to connect the sources of supply to the pipeline distribution system. Lockable line valves should be provided
- According to the safety parameter, "All valves located outside the plant rooms, wherever possible, should be provided with lockable, ventilated enclosures"

Figure 3: Line Valve

Closure of valves may be necessary when there is:

- A serious gas leak in a ward, resulting from failed/damaged terminal unit or pipeline
- A fire in a hospital ward
- A rise or fall of the gas supply pressure
- Contamination of the gas supply

Area Valve Service Units:

The features of area valve service unit modules are as follows:

- Area valves, when provided with NIST gas specific connectors, gas pressure switch, and pressure gauge (optional)
- Single gas service unit or multiple gas service units
- Installed at a height of 1000–1800 mm
- Assist in emergency gas alarm management
- Alarm and monitoring display unit should be installed at the nursing station

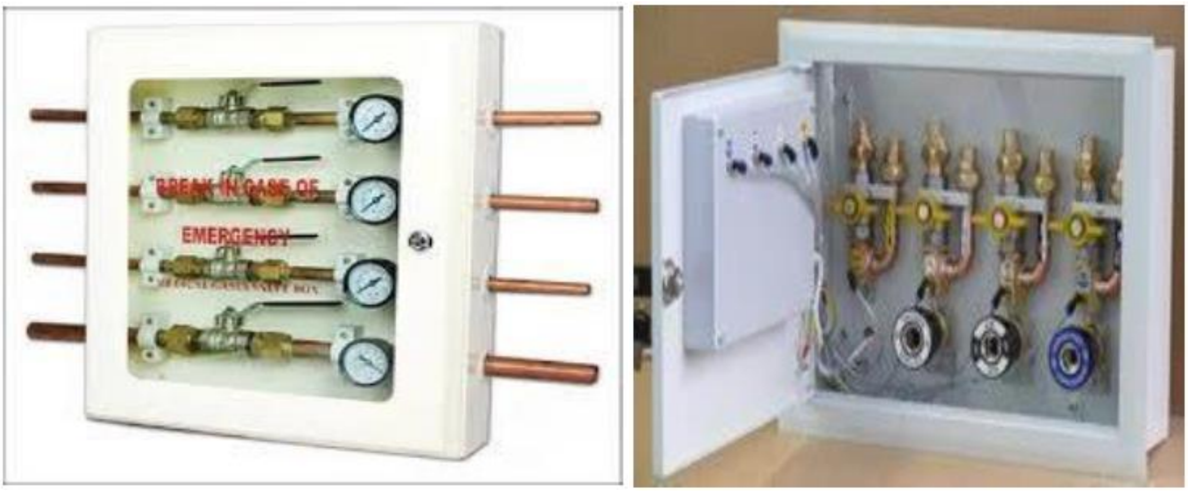


Figure 4: An Area Valve Service Unit

Pressure Gauges

Multiple pressure gauges are used in MGPS. Pressure gauges are instruments designed to measure the pressure of gas in the pipeline. Measuring the pressure in the pipeline is a critical quality step to ensure consistency of a product and safety check to be aware of leaks or building pressure in a system.

Medical Gas Outlets

Types of gas outlets are listed below:

- DISS (Diameter Indexed Safety System) used for medical gases such as nitrogen
- Latch Indexed (Chemetron)
- Geometric Indexed (Puritan-Bennett Series B) is used for oxygen, medical air, and vacuum
- Pin index

All outlets are gas-specific and serviceable.

Figure 5: Types of Medical Gas Outlet

Alarm Systems

There are two types of alarms used in MGPS: area alarm and central alarm.

Area Alarm

The primary purpose of the alarm is as follows:

- It is a clinical emergency alarm and should be located near the seating station of nurses
- It is there to prompt clinicians to act when pressure is too high or too low

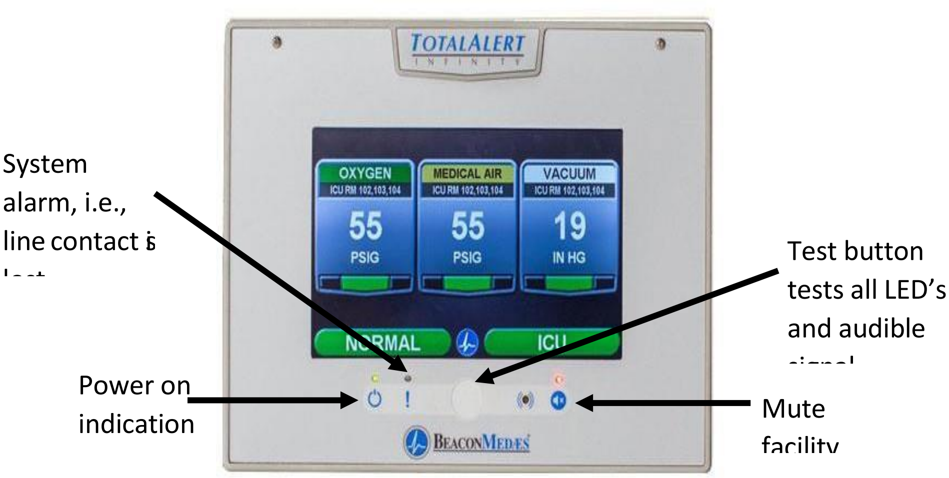


Figure 6: Area alarm

Central Alarm

The primary purpose of the central alarm system is as follows:

- It provides operating and emergency operating alarm indications
- It is there to prompt technical staff to act when one or more sources of supply are no longer available
- Some of the conditions that initiate an operating alarm include the following:
    - A bank of cylinders is exhausted
    - A vacuum pump fails
    - A compressor fails to start
    - A compressor overheats
    - There is a malfunction with a supply source
    - The main supply pressure is outside acceptable limits
    - Quality of gas is outside tolerance limits. This happens when:
        - Presence of oxygen is very less in a synthetic air mixer
        - Carbon monoxide level is above 5 ppm
        - Dew point of air is too high

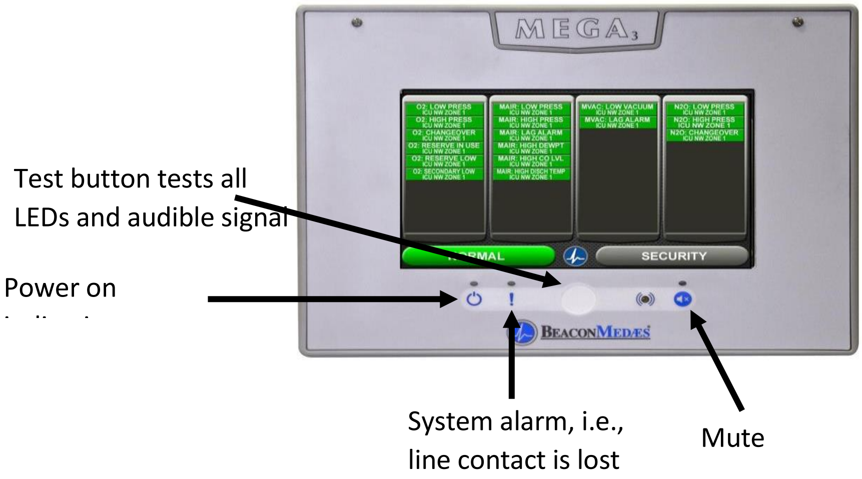


Figure 7: Central alarm

Pendants

Rigid Pendants

Octagonal section full bodied rigid ceiling pendant

- Manufactured using powder-coated steel, with a stainless-steel fascia on the underside
- Capable of housing up to eight Gem 10 medical gas terminal units plus AGS System
- Maximum of four twin electrical and four single electrical sockets

Figure 8: Rigid pendant

Purpose

- Convenient for doctors to access critical supply, for example, gases or electric socket at one point
- Avoids unnecessary cable or electric gazette in the operating room
- Less contamination, for example, bacteria

Medical Pendants

The medical pendant is an indispensable gas supply medical device in the modern operating room of the hospital. It is mainly used for the terminal transfer of oxygen, suction, compressed air, nitrogen, and other medical gases in the operating room.

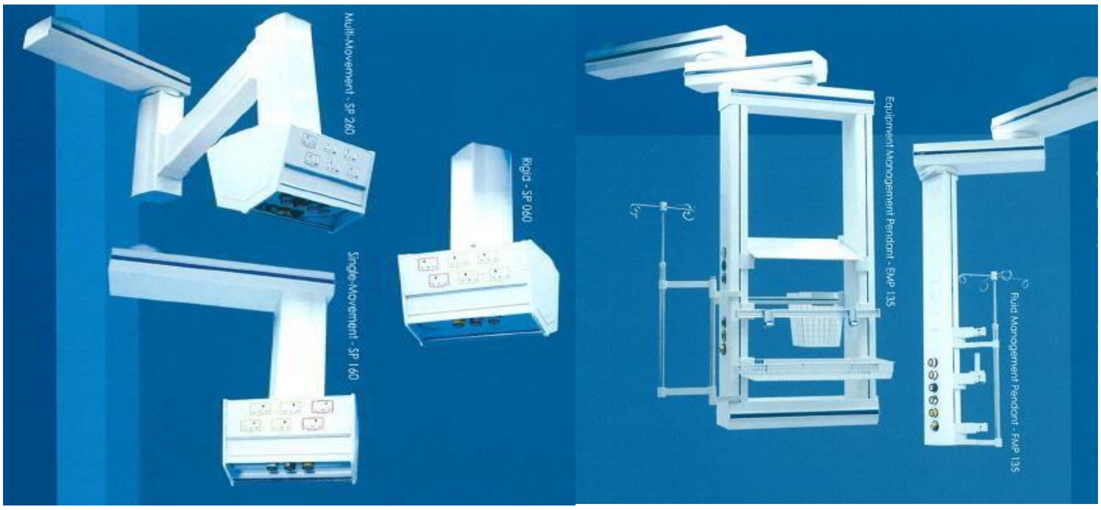


Figure 9: Multimovement surgeon pendants (left) and anesthesia double pendants (right)

MGPS Distribution Design

- Analyze each specific area of the health care facility to determine
    - Which piped medical gas systems are required?
    - How many of each different type of medical gas outlet/inlet terminal are required?
    - Where should the outlet/inlet terminals be located for maximum efficiency and convenience?
    - Which type and style of outlet/inlet terminal best meet the needs of the medical staff?
- Anticipate any building expansion (vertically or horizontally)
- Determine the needs to accommodate the future expansion

Please see the table below for oxygen flow rates that must be assumed for designing oxygen pipe size.

Table 5: Oxygen flow rates for designing oxygen pipe size

Area of Hospital	Flow Rate
Wards, Labor room, Newborn Care Stations	10 LPM
Operating Rooms	100 LPM
Ventilator Points	100 LPM
Bio Medical Equipment Service Stations	100 LPM

Designing of MGPS should also consider the following:

- Number of stations: Outlet/inlets are often called “stations” for each specific gas type. It is estimated by the medical planner or the architect based on the requirement of the facility.

- Flow rates: The flow rate and diversity factors vary for individual stations depending on requirement (the total number of terminal units and the type of provided care). Pressure range is usually kept in between 4 bar and 4.2 bar.
- Medical gas outlet/inlet terminals**:** Various types of terminals are provided from different manufacturers. The terminals are available in various gas sequence centerline spacing and concealed mounting.

MGPS Accessories

Bed Head Panels

- Provided for dispensing gases in wards and patient care areas
- Houses nurse call system, flow meters, infusion pumps, and reading light

Figure 10: Bed head panel

Trunking System

- Running panels along the walls.
- Like bed head panels

Ward/Theater Vacuum Terminal Unit

- Ward vacuum unit is equipped with a regulator
- The vacuum bottle is available in various sizes, ranging from 250 mL to 2 L
- Based on the usage, bottle size may vary, for example, operating rooms need larger bottle size
- Suction catheter is connected to the ward vacuum unit

Oxygen Flowmeters

For setting up of desired flow for oxygen gas delivery to patients.

MGPS Testing

The figure below depicts the type of tests required for MGPS.

Table 6: MGPS testing

Tests	Procedures
Blowdown	Lines are blown clear using oil-free dry nitrogen
Initial pressure test	System is subjected to 1.5 times working pressure to check leaks
Standing pressure test	System is subjected to 29% higher pressure for 24hr
Piping purge	Purging of each outlet until there is no discoloration of the white cloth held over it
Cross-connection test	One gas system at a time using oxygen analyzer
Final tie-in test	Active vacuum pipeline joints are tested using as ultrasonic leak detector

Advantages of Using MGPS

For Patients

- No distressing sign of oxygen cylinder at bed side
- Elimination of noise produced by their movement
- Protection of sterile areas from contamination caused by the use and movement of cylinders
- Uninterrupted and clean gas supply at the desired locations

For Hospital Staff

- Instant availability of gas
- Clean, safe, and reliable delivery of gases
- Continuous flow of gases when and where required
- Minimal accident hazards due to mishandling of cylinders
- Less labor-intensive

For Hospital Administrator

- Easy purchase of gases in bulk quantities at favorable terms
- Economy on purchase and refilling of cylinders
- Fewer breakages
- Minimum damages to buildings due to the handling of cylinders
- Rationalization in ordering, storing, and transporting

Despite all the advantages, yet many hospitals in India do not have MGPS.

Safety Measures and Precautions with MGPS

Safety Measures

- Safety valves provided to be set at 1.5 times the working pressure
- Locknut provision on regulators for preventing inadvertent high-pressure settings
- Two-stage regulators for avoiding fluctuation in flow
- Line pressure alarms for continuous monitoring pipeline pressure
- Gas-specific color-coding in each pipeline
- Gas-specific color-coding on cylinders
- Specific color-coding on each outlet
- Noninterchangeable adaptor for each outlet

Precautions with MGPS

The following precautions should be taken when using MGPS:

- Formulating SOPs and maintaining logbooks
- Preventive maintenance of equipment
- Leak test of pipelines should be ensured on a quarterly basis
- 24-hour manning by trained personnel
- Periodic training of manifold personnel
- Daily checking of the contingency plan
- Mock drills of pipeline failure, fire, and explosion should be regularly conducted
- Managing pressure of different sources to manage the cumulative flow
- Ensuring if all sources are contributing in a cumulative manner or if any source is failing to supply oxygen due to pressure difference

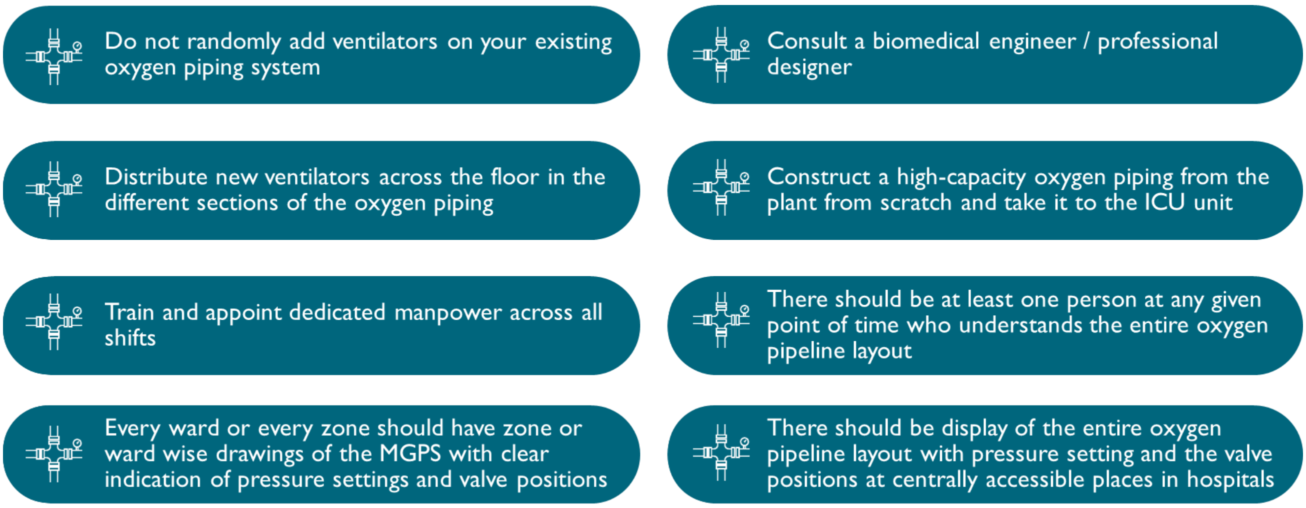


Figure 11: Safety measures and precautions with MGPS

Do’s and Don’ts of MGPS

Do’s

- Do report any gas leaks as soon as detected
    - Report if any noise of leaking gas is detected to maintenance department for urgent action
    - Set off medical gas escape alarm
- Do enhance ventilation if a leak is detected
    - Open windows and doors to lower the gas concentration in the air
- Do regular checks to the piping
    - Check for damage especially serious abrasion, corrosion, leakages, or mechanical damage of pipelines

Don’ts

- Do not stay nearby the gas leakages
    - Do not stay in the vicinity of gas leakage because of the possibility of gas saturation in the air, asphyxiation, explosion, and fire
- Do not cover piping linemakers and signage
    - Do not paint over piping networks to cover labeling, identification, flow direction arrows, valve, box labels, and so on
- Do not use oily-soap solutions to check for leaks
    - Do not use water solutions with soap that contains oil and/or animal fat. The animal fat may burn easily in an oxygen-enriched atmosphere.

Appendix

Types of Medical Gas Systems Used in Hospitals

Medical Air

Medical air refers to a clean supply of compressed air used in hospitals and health care facilities to distribute medical gas. It is free of contamination and particles, has no oil or odors, and is dry to prevent water buildup in the facility's pipeline. When a patient is in the operating room, whether it's an emergency or not, a surgeon relies on a medical air compressor to keep the patient comfortable and breathing. It is blended with medical oxygen during patient delivery process.

Oxygen

Oxygen is a medical gas required in every health care setting and is used for resuscitation and inhalation therapy. It can be used for medical conditions such as chronic obstructive pulmonary disease, cyanosis, shock, severe hemorrhage, carbon monoxide poisoning, trauma, cardiovascular and respiratory arrest, resuscitation, and life support.

Carbon Dioxide

Carbon dioxide is used for insufflating medical gas for less invasive surgeries such as laparoscopy, arthroscopy, endoscopy, and cryotherapy, as well as for respiratory stimulation during and after anesthesia. Carbon dioxide may be piped in large hospitals, but more likely it comes from a tank.

Nitrogen (Liquid)

Nitrogen is a medical gas used for cryosurgery removal of some cancers and skin lesions, and for the storage of tissues, cells, and blood in cryogenic temperatures to avoid oxidation of the samples. It can also be used as part of the medical gas mixture for lung function tests. Nitrogen as gas is used to power tools in places where they do not have instrument air. Most of the time it comes from a manifold of cylinders and is piped at pressure with an alarm system at the source and on the use site.

Nitrous Oxide

Nitrous oxide is a medical gas commonly known as "laughing gas". This medical gas is used in numerous surgical procedures as both an anesthetic and an analgesic. There are certain times when this medical gas is contraindicated, and patients undergoing those types of procedures are provided with a medical gas warning wristband that alerts your facility's staff not to administer it.

Table 7: Various medical gas systems in hospitals

Medical oxygen system	Primary supply	1) Liquid oxygen VIE tank/LMO tank (including portable LMO tanks) 2) PSA plant 3) Cylinder manifold
	Secondary supply	Automatic changeover manifold, e.g., 2 x 16
	Primary supply	Automatic changeover manifold, e.g., 2 x 2

Nitrous oxide System	Secondary supply	Reserve, e.g., four cylinders
Medical air and surgical air system	Primary supply	1) Combined air plant, e.g., FAD: 5,320 L/minute @ 7 bar (g). FAD is the actual quantity of compressed air converted back to the inlet conditions of the compressor. It means standardized measure of the capacity of the compressor. 2) Pressure-reducing station 7 Bar (g) – & or 4 Bar (g)
	Secondary supply	Automatic changeover manifold, e.g., 2 x 10 or duplex or triplex air pump plants
Medical vacuum system	Primary supply	Medical vacuum plant: Federal Aviation Administration (FAA) USA Standard: 2,560 L/minute @ 450 mmHg
AGS system	Two sets of pumps	1) Duplex pumps: serving level 1 operating rooms 2) Duplex pumps: serving level 2 operating rooms

Liquid Oxygen System

Liquid oxygen tank is required for hospitals. The primary supply can be tapped from the existing LMO tank/portable cryogenic (LMO) container-PCC/PSA, and the secondary supply can be tapped from type D cylinder manifold system.

Figure 12: LMO tank

PSA Plant

PSA plant separates nitrogen from air (to obtain oxygen purity of 93±3%) under pressure according to nitrogen molecular characteristics and affinity for an adsorbent material. It operates at a near-ambient temperature and significantly differs from the cryogenic distillation commonly used to separate gases. Selective adsorbent materials (e.g., zeolites, which are also known as molecular sieves, activated carbon, etc.) are used as trapping material, preferentially adsorbing the target gas species (nitrogen) at high pressure. The process then swings to low pressure to desorb the adsorbed gas.

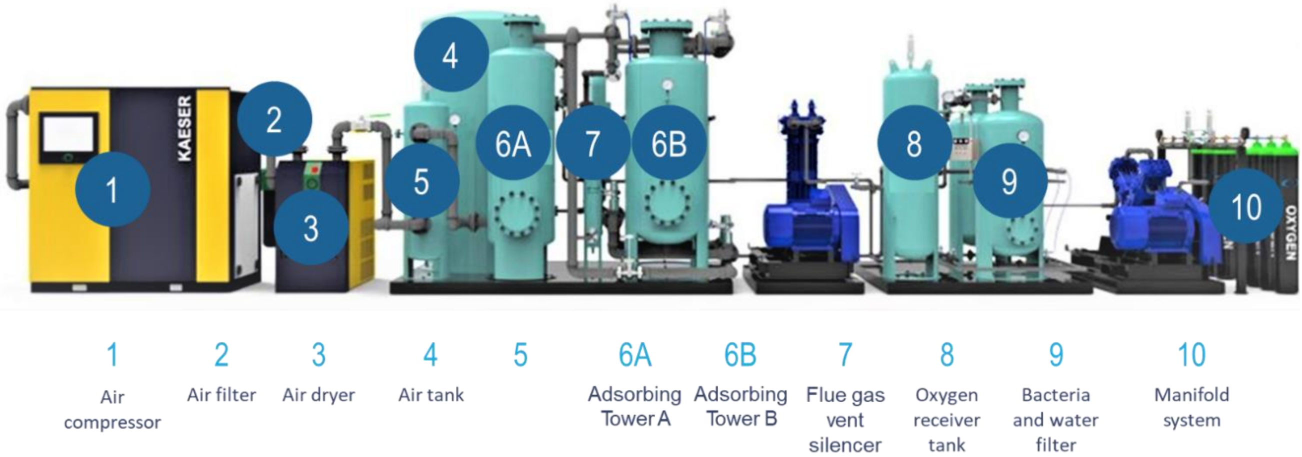


Figure 13: PSA plant

Manifold System

- Primary manifold for oxygen system: 2 x 20 (please note that the size could vary based on oxygen demand)
- Primary manifold for nitrous oxide system: 2 x 2
- Primary manifold for carbon dioxide and nitrogen: 2 x 2
- Back-up/emergency manifold for oxygen: 2 x 4
- NFPA: compliant
    - New forging manifold design has fewer leakages
    - National pipe thread (tapered) connection to O-ring sealed connections also has fewer leakages
    - The manifold has an improved flow rate and is tested as per the ISO-10524 standard
    - It is available in both Standard Electronics and Terminal Adapter Equipment (TAE) Electronics
    - Power supply and control board mounted inside National Electric Manufacturer Association (NEMA 4), a USA-based standard for electric enclosers – outdoor environments
    - NFPA requires isolation valves
    - Isolation valves are used to shut off one or both sides of the manifold for servicing
    - ¼ turn ball valves
    - Free-floating valves connection between bank regulator forging and line regulator forging and are O-ring sealed

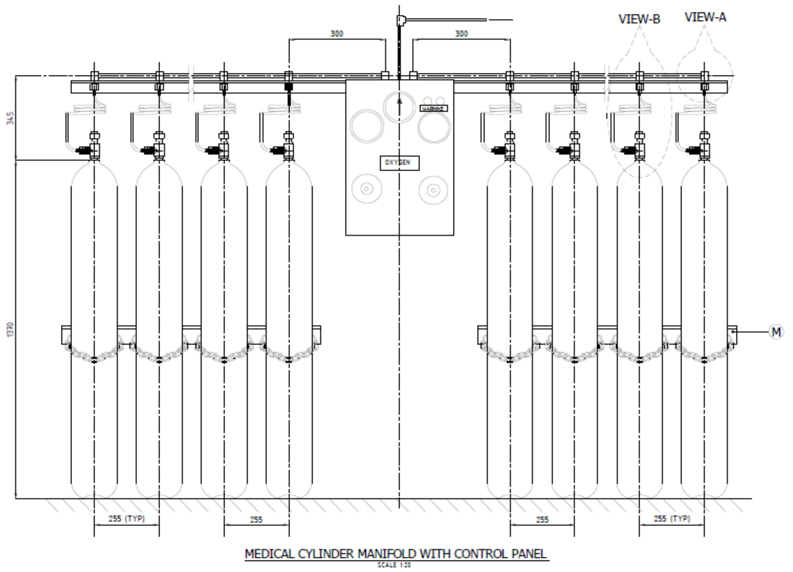
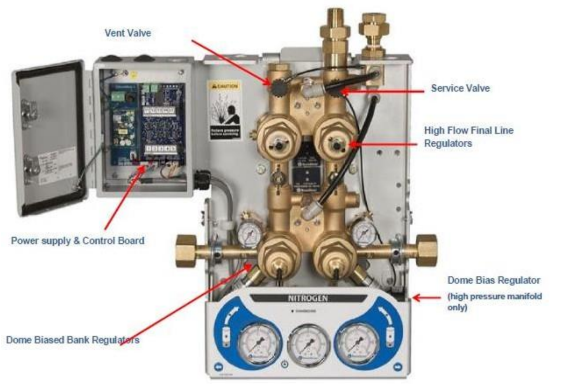


Figure 14: Cylinder manifold schematic diagram



MANIFOLD ROOM

Figure 15: Cylinder manifold room

Medical Air Plant

Medical Air System

- Should comply with NFPA
- FAD: Any LPM as per hospital demand - l/min @ 7/4 Bar (g)
- Normal air for ventilator will be 4–4.2 bar and surgical air will be 7 bar for medical tool operation
- Scroll medical air compressors
- Plant is factory-tested prior to shipment

- System consists of three compressors, duplex desiccant dryers, and 2 x 1,500/2,000/3,000 (as per demand) liters of vessel

Why Is Dry Air Needed?

- Low dew point inhibits bacterial survival and growth
- At low temperatures, liquid water could form
- At less than 0°C, ice can form, blocking the pipeline
- Anesthesia machines and ventilators are damaged by liquid water
- High humidity promotes oxidation of the inside of piped distribution system (copper oxide)

Figure 16: Medical air system

Table 8: Properties of medical air

Contaminant	Limit
Oil	≤0.1 mg/m^3
Water	≤67 ppm
Carbon monoxide (CO)	≤5 ppm
Carbon dioxide (CO_2)	≤500 ppm
Odor/taste	None

Medical Vacuum Plant

AGS System

General requirements:

- Duplex pump assemblies
- An AGS terminal unit comes with an adjustable orifice to ease setup and commissioning
- Remote switches operate from 24V for added safety
- Duplex pump assemblies incorporate separate starter enclosures to enable pump replacement while the system is still operational
- High specification pumps with good vacuum to flow relationships enable smaller pipe sizes to be used
- To drain out excess anesthesia gases from the operating room
- Collects and removes waste gases from the patient breathing circuit and the patient ventilation circuit

Figure 17: AGS System

- Operating rooms will be provided with an active AGS disposal system
- Dedicated, high-flow, active extraction, and disposal system that can provide an open scavenger interface
- Discharge should be at a safe place away from any air intake source

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