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# Standard Operating Procedures:

## Operation and Maintenance of Liquid Medical Oxygen (LMO) Storage Tanks

## Contents

## Abbreviations

| | |
|---|---|
| ATM | Standard atmosphere, a unit of pressure defined as 101,325 Pa |
| BiPAP | Bi-level positive airway pressure |
| BTU/LB | British thermal unit (BTU or Btu) per pound, 1 Btu/lb = 2326.0002917735 J/kg |
| CCOE | Chief Controller of Explosives |
| CPAP | Continuous Positive Airway Pressure |
| 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 |
| 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 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 quality-assured medical oxygen. Reliable access to quality-assured medical 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 lack of medical gas pipeline, medical grade oxygen generation plant, oxygen concentrators, low-quality and poorly maintained oxygen delivery equipment's like ventilators, concentrators, CPAP and BiPAP. Such shortcomings could be due to deficiencies in clinical and technical training and skills among clinical, technical, and administrative healthcare workers. Thus, creating awareness among the health care professionals and building their capacities to operate and maintain oxygen supply equipment efficiently is 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 manufacturer, assuring its appropriate administration to the patient, and drastically improving the screening of hypoxemic patients.

## Purpose of the Standard Operating Procedures (SOP)

The document, titled "**Operation and Management of Liquid Medical Oxygen (LMO) Storage Tanks**", provides step-by-step details on LMO management. It includes the following components: pre-installation capacity finalization based on hospital demand, space identification, procurement (different modalities), (Petroleum and Explosives Safety Organization) PESO license approval, civil works, tank installation, and commissioning, granting PESO license post installation, LMO refiling, storage protocol, maintenance aspects, safety guidelines, troubleshooting, etc.

This SOP intends to bridge knowledge and skills gap among health care facility staff by providing in-depth information on the operation, storage, and management of LMO.

## Scope

The specifications and guidelines in the "Management and Storage of Liquid Medical Oxygen (LMO)" intend to support health facility administrators, clinical practitioners, procurement officers, planning staff, biomedical engineers, infrastructure engineers, and policymakers in the states and at the national level to select, procure, use, and maintain LMO equipment. This document may also be of interest to health care workers, academics/researchers, development agencies, non-governmental organizations, regulators, and others involved in oxygen system management.

## Background

Medical oxygen is available in gaseous form in cylinders and in liquid form (kept in cryogenic state, cooled to -297°F (-183°C). Liquid storage is less bulky and less costly than the equivalent capacity of high-pressure gaseous storage. It is a compressed form of oxygen and required to be stored much below -200°C to ensure

that the oxygen remains in the liquid form. Because the temperature difference between the liquid medical oxygen stored (product) and the surrounding environment is substantial—even in winters—keeping the liquid oxygen insulated from the surrounding heat is essential. The product also requires special equipment for handling and storage.

The storage capacity of LMO tank is between1 kilo liter (kL) to 20 kL in hospitals. One litre of LMO is equivalent to 860 litres of gaseous oxygen. Liquid oxygen cannot be stored for more than one to two weeks because it will vaporize (evaporate) and build pressure inside the storage tank. The tank's content must be consumed and refilled often, requiring the scheduling of deliveries. In addition, the system needs PESO license compliance.

Table 1: Properties[1] of Liquid Medical Oxygen

| Property | Value |
|---|---|
| Chemical Formula | $O_2$ |
| Molecular Weight | 31.999 |
| Boiling Point@1 ATM | –183°C |
| Freezing Point@ 1 ATM | –218.8°C |
| Critical Temperature | –118.4°C |
| Critical Pressure | 729.1 PSI (49 BAR APPRAX) |
| Density, Liquid @ BP, 1 ATM | 71.23 LB/SCF |
| Density, Gas @ 68°F(20°C), 1 ATM | 0.0831 LB/SCF |
| Specific Gravity, Gas (AIR=1) @68°F(20°C), 1 ATM | 1.11 |
| Specific Gravity, Liquid (WATER=1) @ 68°F(20°C), 1 ATM | 1.14 |
| Specific Volume @ 68°F(20°C), 1 ATM | 12.08 SCF/LB |
| Latent Heat of Vaporization | 2,935 BTU/LB MOLE |
| Expansion Ratio, Liquid to Gas, BP to 68°F(20°C) | 1 to 860 |

LMO installation and other modes of supply have their respective logistics, installation, and set-up arrangements[2]. Therefore, the extent of benefits and advantages of the LMO system varies depending on the hospital size (bed capacity), location, consumption, local supply, and service support. The design and installation of medical oxygen supply system for healthcare facilities follow specific requirements and guidelines outlined in the following international standards:

- HTM 02-01 Medical Gas Pipeline System – Part A, Design, Installation, Validation, and Verification
- AIGA 049/17 Guideline to Medical oxygen Supply System for Healthcare Facilities
- NFPA 55 – 2016 – Chapter 9, Bulk Oxygen Systems and NFPA 99
- ISO 7396-1/2 specifies requirements for design, installation, function, performance, testing, commissioning, and documentation of pipeline systems used in health care facilities[3]
- For technical specifications of LMO please refer to Annexure I of this document

All medical gas supplies comprise of three sources: "primary" sources such as LMO tank, PSA plant; "secondary" sources like Dura cylinders (micro cylinders, small LMO tank of 400-500 liters capacity and are

mobile), gaseous cylinders (Jumbo-D type and B type) and oxygen concentrators commonly referred to as a third means of supply.

If the LMO and pressure swing adsorption (PSA) plant oxygen delivery is connected with the same medical gas pipeline system, then there should be change over gas regulator for automatic switching between both sources of oxygen. Hence, at any given time, there must be only one primary source of oxygen and other being the secondary/reserve source. It is also possible to have both LMO and PSA supply through the same medical gas pipeline system simultaneously with additional infrastructure of a buffer tank. This buffer tank would have two inlets - one for PSA and other for LMO, and a single outlet connected to the medical gas pipeline system. Usually D-type cylinders are preferred as reserve oxygen supply for LMO.

## Selection of LMO Tank

- The selection of the LMO storage tank is done by the health facility according to the requirement in a hospital based on the number of oxygen beds, days of buffer storage, etc.
- Presently, the available sizes of LMO tanks are 1kL, 3kL, 6kL,10kL,13kL, 20kL, 25kL, 30kL, 50kL, 60kL. Most preferred sizes are 1kL to 20kL.
- Storage quantities vary from a few liters to several thousand liters (In India IS7396:2017 is followed)

***Figure 1: Liquid Medical Oxygen Tank***

| Calculation on the production of LMO | |
|---|---|
| 1m$^3$ of Gas | = 1000 Litres of Gas (1000L) |
| 1 Patient | = 15 LPM (Litres per Minute) |
| 100 Patients | = 15x100 = 1500 LPM |
| For one Hour | = 1500 x 60 = 90000 LPH (Litres per Hour) |
| Convert in m$^3$/h | = 90000/1000 = 90m$^3$/h |

***Table 2: Oxygen requirement/consumption based on bed capacity[2]***

| S. no. | Oxygen requirement for oxygen beds (excluding ICU beds) in dedicated COVID-19 hospital and dedicated COVID-19 health centre facilities | | | | Total requirement of the state for oxygen in m$^3$ for dedicated COVID-19 facilities = 'X'+ 'Y' (e.g., 1440+2160= 3600 m$^3$) |
|---|---|---|---|---|---|
| | A | B | C | D | |
| 1 | Oxygen beds | Oxygen flow rate (LPM) | Oxygen requirement per day in cubic meter (m$^3$) | Total oxygen requirement | |
| 2 | 100 | 10 litres/min | 60 minutes x 24 h/1000 (to convert litres to m$^3$) | 'X'= Columns (A*B*C*) (e.g., 100 x10x 60 x 24/1000= 1440 m$^3$) | |
| S. no. | Oxygen requirement for ICU beds in dedicated COVID-19 hospital | | | | |
| | F | G | H | I | |
| 1 | ICU beds | Oxygen flow rate (LPM) | Oxygen requirement per day in cubic meter (m$^3$) | Total oxygen requirement | |
| 2 | 50 | 30 litres/min | 60 minutes x 24 h/1000 (to convert litres to m$^3$) | 'Y' = Columns (F*G*H*) (e.g., 50 x 30 x 60x 24/1000=2160 m$^3$) | |

Flow rate of 10 LPM/O2 bed and 30 LPM/ICU beds are considered for consumption calculation as per the latest Government of India guidelines D.O. No. – T-20017/03/2021-NCD (FTS-81105554) dated June 21, 2021. These flow rates are subject to change depending on revised guidelines from the government.

Ideally the capacity of a LMO tank should be as per the oxygen requirement of the facility; calculated based on the above formula, and with an additional three days' supply in reserve. At the facility level, the Civil Surgeon or the Medical Superintendent is designated to decide the size of the LMO storage tank.

## Selection of Vaporizer

Selection of Vaporizer (Technical Theory)

There are two important factors to consider:

**i) Consumption pattern (flow rate) of LMO**

For 6kL oxygen tanks – 100 m3/h to 200 m3/h

For 13kL oxygen tanks – 300 m3/h to 400 m3/h

For 20kL oxygen tanks – 500 m3/h to 600 m3/h

**ii) Ambient conditions (temperature and humidity)**

There can be two options for the hospital management to select and operate the vaporizers:

**Option 1:**

Install two vaporizers - Once three-fourth part of one vaporizer surface area (approx. 70-75%) is covered with ice, then switch over to the other vaporizer. The same cycle to be repeated every time.

***Figure 2: Vaporizer***

Example: If there are 20 tubes (finned) in the subject vaporizer, once icing formation occurs on about 14-15 tubes, switch over to the other vaporizer.

**Option 2:**

Install 2 vaporizers - Switch from one vaporizer to the other vaporizer every 8 hours.

Note: The above stated recommendations are based on ambient conditions viz. ambient temperature ranging from +4° C to +46°C and RH not exceeding 70%-75%. In case the ambient temperature is falling close to +0°C or sub-zero, the specific selection of vaporizer should be discussed with a technical expert

## Selection of Pressure Relief Valve (PRV)

Available in 100 m3/h and 500 m3/h
100 – 200 patients : 100 m3/h
Above 200 patients : 500 m3/h

***Figure 3: Two PRV connected to two vaporizers***

## Selection of Pressure Relief Valve (PRV)

The cost for setting up the LMO storage tanks vary depending on the location, hospital size (bed capacity), and installation, e.g., a 10kL tank (complete with all accessories) costs between INR 20-30 Lakhs and 13 kL cost between INR 30-40 Lakhs.

- For LMOs, there are no operational costs because it is only a storage tank.
- The facility has to bear the costs for refilling as per oxygen consumption and preventive maintenance.

For estimating the supply, installation, testing, and commissioning of additional capacity of LMO tank, following cost elements should be considered, along with fixed costs such as LMO tank installation charges including copper pipe and bridge i.e.; INR 7-10 Lakh and PESO approval charges i.e., INR 50 thousand per year.

| S. No. | Description of Works - For estimation of budget |
|---|---|
| 1 | LMO tank<br>a) Gross capacity in litres: 12676 (approx. 12 kL)<br>b) Net capacity in litres: 12042 (approx.12kL)<br>c) Maximum Allowable Working Pressure (MAWP) kg/cm$^2$: 17.60<br>d) Design temperature: (-) 196 to +40 degree Celsius<br>e) Outer vessel<br>Material: Carbon Steel<br>Operating pressure: Vacuum |
| 2 | LMO Vaporizers (8-hour duty cycle)<br>a) Capacity: 100 to 500 sM$^3$/h for LOX (to be decided by the hospital authorities) |

| | |
|---|---|
| | b) MAWP Kg/cm$^2$: 38.00 |
| 3 | Skid: Interconnecting piping between tank and vaporizer and up to battery limit as per system P&ID ENQ-11441<br>Scope:<br>1. Supply Storage Tank<br>2. Supply air ambient vaporizer (AAV) along with pressure reducing skid<br>3. Interconnecting piping between the storage tank and AAV vaporizer for use for pipeline<br>4. Transportation<br>5. Foundation bolt for tank & vaporizer for installation |
| 4 | For an additional vaporizer (8-hour duty cycle)<br>a) Capacity: 100 to 500 sM$^3$/h for LOX (to be decided by hospital authority<br>b) MAWP Kg/cm$^2$: 38.00 |
| | GST 18% for (1), (2), (3) & (4) |
| 5 | For construction of platform and foundation for mounting LMO tank |

Note: These costs were calculated in July 2021 and are subjected to change as per the market dynamics, location, and government guidelines.

## Safety, Storage, and Handling

The Government of India, Ministry of Home Affairs, National Disaster Management Authority (NDMA) has issued guidelines on safe storage, transportation, and handling of LMO for medical use vide DO.595/2020/Mitigation dated April 23, 2021, that needs to be followed to minimize the inherent risk involved4.

**Safety while storage and handling LMO:**

- Store and use liquid containers with adequate ventilation. Do not store containers in a confined area or in an area unprotected from extremes of weather.
- Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure. Under normal conditions, these containers will periodically vent product. Do not plug, remove, or tamper with any pressure relief device.
- Oxygen must be separated from flammables and combustibles by at least 5 m or 2.5 m fire wall. Post 'No Smoking' and 'No Open Flames' signages.
- Cryogenic containers must be stored, handled and transported in the upright position. When moving, never tip, slide or roll containers on their side. Use a suitable hand truck or trolley for moving smaller containers. Avoid mechanical and thermal shock while moving cryogenic oxygen cylinders.
- Use only transfer lines and equipment designed for use with cryogenic liquids.
- Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle liquid oxygen and its associated equipment. Their eyes are most susceptible to the extreme cold liquid and vapors of liquid oxygen.

**Best practices:**

- A diffuser to be attached to the transfer hose to reduce turbulence and release of gas while filling up from tanker.
- Use phase separator or funnel for the inlet of the receiving hose pipe.
- Never dispose off liquid cryogens down the drain or sink. Allow cryogenic liquids to evaporate in a 'Fume Hood' in open space.

**Safety precautions:**

- Provide information and advice in health, safety, and environmental protection including on the safe use of compressed gases.
- Develop and administer health, safety, and environmental programs.
- Provide health and safety training.
- Provide hazardous waste disposal services.
- Respond to reported incidents and spills of hazardous materials
- Support regulatory compliance.
- A copy of material safety data sheet to be printed and kept at site. This could be use form the supplier.
- Wear proper personal protective equipment when performing lab operations/tasks involving compressed gases: long sleeved lab coat, long pants, covered toe shoes, safety glasses, and gloves

## Regulatory Requirements

The following regulatory requirements are important as per Government of India guidelines vide DO.5-95/2020/Mitigation dated April 23, 2021:

- Civil work & PESO approval (online application)
- PESO approval for filling & operation of the LMO installation
- Fencing & gate around the installation
- Fire extinguisher, water connection, lighting, safety signages, earthing pit for lightning arrestor
- Allocated space for installation should be 9 m (W) X 15 m (L)
- Site should be selected at ground level, outdoor, without overhead power, or other utility cable
- Should have assigned space for smooth movement of LMO tanker(s) from/to the installation
- Display of liquid oxygen level and outlet gas pressure should be provided
- Automatic change-over should be provided between the LMO tank and the existing oxygen manifold in the health facility premises
- All statutory requirements of the Chief Controller of Explosives (CCOE) of India and Static and Mobile Pressure Vessels (SMPV) rules need to be followed
    - Approval letter from CCOE along with approved drawing from CCOE
    - Approval letter from CCOE for use of cryogenic vessel(s) at site
    - Certificate from the authorized inspection agency
    - Heat chart for pressure parts
    - Dimensions check report
    - Dished End report
    - Mechanical properties test report for production test coupon
    - Visual inspection report
    - Radiography examination report
    - Liquid penetrant examination report
    - Cleaning inspection report
    - Hydro-pressure test report
    - All regulations and guidelines put forward by the state/union territory competent authority

## PESO Online Application Requirement (Stage 1: Prior Approval)

Currently, all the PESO certifications are done online5. Online forms are available at the website: www.peso.gov.in. The health facility needs to submit an online application by uploading the following documents:

- Land ownership document/agreement copy clearly showing hospital premises
- Cover letter
- Site layout plan
- Four copies of layout design for the proposed storage tank
- GST certificate
- Specimen signature
- Form AS-1
- Online payment receipt
- Topo plan/key plan
- HAZOP study
- Username and password generated in the facility name on PESO website

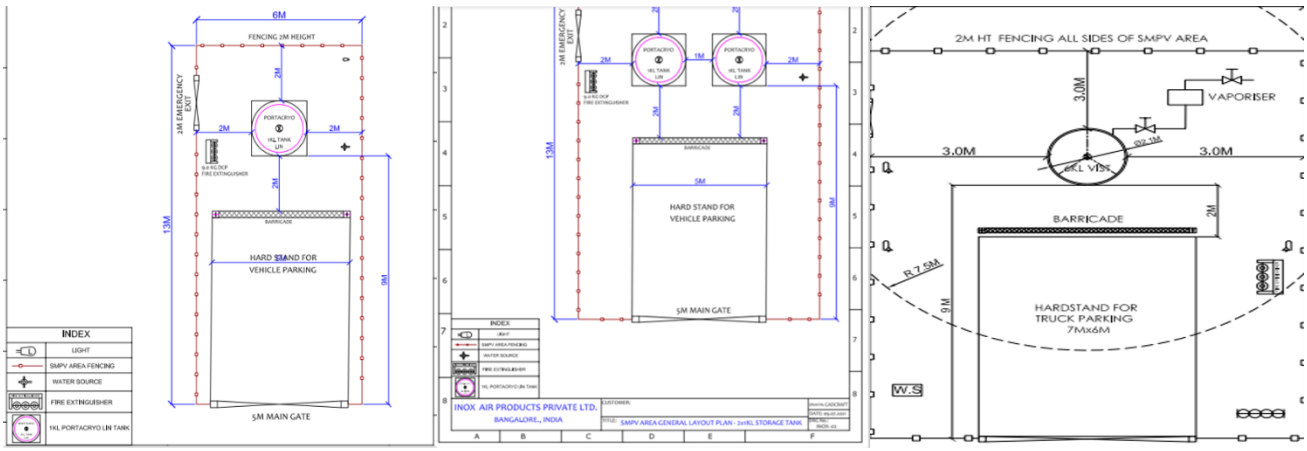


*Figure 4: Space requirement for installation of storage tank (Portacryo Tank/VIST) as per PESO norms*

Typically, the layout should ensure the following conditions for the Government of India's PESO's Chief Controller of Explosives (CCOE) approval:

- 3 meters of clear space between the tank & fencing.
- 1.5 meters of clear space between two tanks.
- 5 meters in the case of tanks with water capacity not exceeding 10kL, 7.5 meters in the case of tanks with water capacity exceeding 10kL, clear between the vessel and flammable structure, naked flame, pipeline containing flammable fluids, electrical installations or places of public assembly or drain.
- Lorry stopper in front of the tank
- 2 fire extinguishers of 10 kg each.
- Water source near the tank.
- Main gate and emergency exit.

- 2 meters high industrial fencing
- Tank is to be erected under the supervision of experienced/skilled person as per the approved drawing

| Test certificates under SMPV rules |
| --- |
| The following test certificates are required under SMPV rules:<br>1. Safety certificate under Rule 33 for the new installation<br>2. Safety valve certificate under Rule-18 certificate<br>3. Pneumatic Test certificate under -Rule-19 certificate-Once in five years.<br>4. Arrange a license for storage from CCOE.<br>5. Once the installation is given license, the delivery of product will be done by supplier |

## Essential Certification/Approval for LMO Storage Tank Operations: PESO License

As a part of the pre-installation stage of LMO storage tanks, the PESO license has to be obtained by the hospital/facility. This has to be done through an online application by the facility and no other third party is encouraged to fill/submit this approval form online except the hospital/facility. Therefore, the licensing application must be submitted by the hospital/facility itself by generating its username and ID. The following documents are to be uploaded by the hospital/health facility:

- Covering letter
- Online application
- Form AS-1
- Four copies of as built site Layout, Foundation, P & I Drawings and Fabrication drawings of pressure vessel
- Test & Inspection certificate issued by recognized 3rd party inspection agency (Original + 2 Copies)
- Safety certificate under rule 33 (original + 2 copies) issued by PESO personnel
- Three copies of certificate of periodic test of vessel and safety valve under rule 18 & 19 certificate
- Online payment reference no. generated by depositing grant licence fees (usually Rs 5000/- for first 5kL and additional Rs 2500/- per additional kL for one year)
- Specimen signature of persons authorized to make correspondence in the subject matter
- Copy for Initial site approval letter with approved drawings declaration submitted GST certificate

## Procedures for Installation

The following procedure is followed for installation of storage tanks at the customer site:

1. Request from the customer via sales department for putting up a storage installation in their premises.
2. CSE/Sales personnel ensure that the space requirements as per SMPV rules.

| Activities under the SMPV Rules 1983 |
|---|
| 1. Gas exerting pressure exceeding 1 kg/cm$^2$ gauge in a closed vessel at maximum working temperature is covered under this rule.<br>2. License for storage of compressed gases installations.<br>3. Space requirement for Portacryo Tank-1 kL capacity - For 1 no-6 m x13 m. For 2 nos 1 kL-9 m x13 m.<br>4. Space requirement for 4 kL up to 20 kL- for one tank-9 m x15 m, for 2 nos-12 m x 15 m. |

Note: LMO tanks should only be installed, commissioned, and maintained by technicians who are suitably trained with piped medical gas systems, and who are fully conversant with the contract specifications and safety procedures.

## General

Keep all components dry and clean during installation. LMO tanks can be safely handled and stored under normal working and environmental conditions[6].

Adverse environmental conditions and harsh abrasives or chemicals may cause damage to the unit.

## Storage Tank Lifting Procedure

- Place the tank in horizontal position, keeping the tank on wooden supports on ground.
- Make the tank vertical with the help of two cranes as per requirement.
- Keep the tank in a vertical position on the foundations.
- Care should be taken to see that the tank is not jerked while removal from truck and keeping on ground, positioning from horizontal to vertical, lifting and keeping on to the foundation
- If necessary, use these shims (plate packing) to keep in a vertical position and to maintain the level.
- After the tank is positioned, fully tighten the nuts of foundation free bolts.

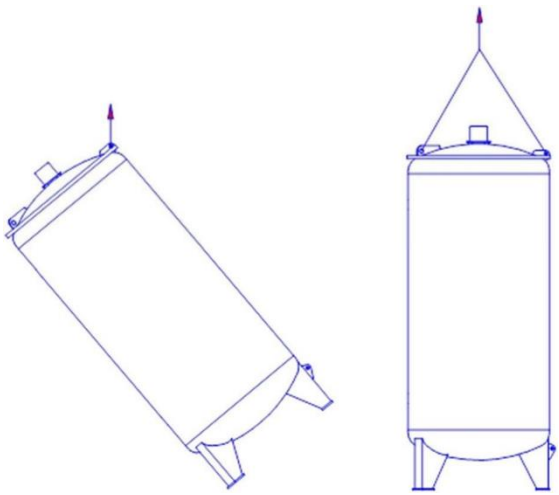

***Figure 5: Lifting the tank from the horizontal position***

# Procedures for Operating

## General Operating Instruction

1. In case of a prolonged standstill or withdrawal of quantities that are too small, for the prescribe filling temperature and the permissible service pressure, the filling level should be lowered.
2. Pressurization through normal evaporation will be slowed down if the gas space increases.

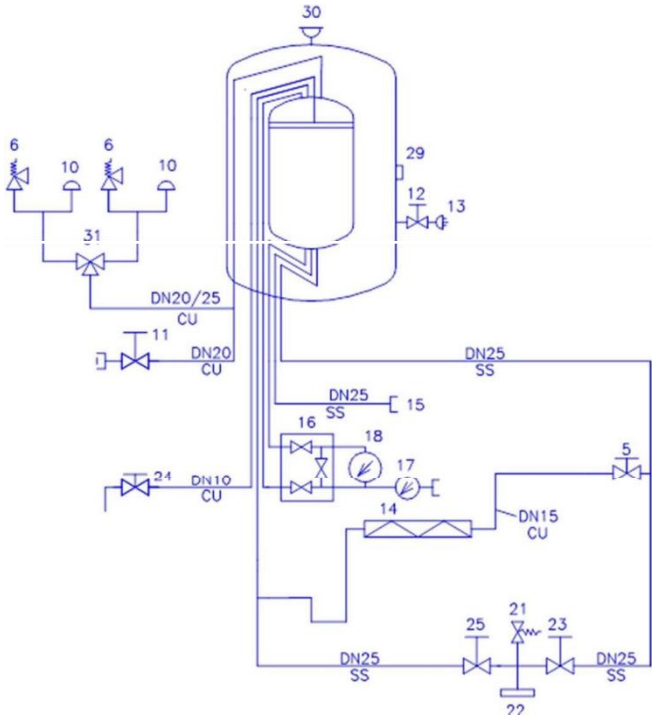


*Figure 6: Liquid Medical Oxygen Plant I*

| Key | Description |
|---|---|
| 1 | Shut-off valve pressure building |
| 2 | Shut-off valve pressure building |
| 3 | Shut-off valve pressure building |
| 5 | Shut-off valve pressure building |
| 6 | Main safety valve |
| 7 | Pressure building regulator |
| 8 | Shut-off valve - pressure reducing |
| 9 | Pressure reducing regulator - economiser |
| 10 | Inner tank bursting head |
| 11 | Vent valve |
| 12 | Vacuum probe valve |
| 13 | Vacuum probe |
| 14 | Pressure building coil |
| 15 | Liquid withdrawal valve |
| 16 | Three valve manifolds |
| 17 | Pressure gauge |
| 18 | Liquid level gauge |
| 21 | Sectional safety valve |
| 22 | Fill connection |
| 23 | Fill valve liquid phase |
| 23a | Liquid phase service valve |
| 24 | Fill try cock |
| 24 | Overflow valve |
| 25 | Fill valve - gas phase |
| 25a | Gas phase service valve |
| 26 | Additional liquid withdrawal line |
| 28 | Additional liquid withdrawal line |
| 29 | Evacuation connection |
| 30 | Vacuum bursting disk - outer tank |
| 31 | Changeover valve |
| 32 | Section safety valve |
| 35 | Purge valve |
| 36 | Speed shut off valve |
| 37 | Shut off valve process safety |
| 38 | Pressure reduction control - process protection |

(a) Filling Valve

(b) Pressure Build-up Valve

(c) Diverter Valve

(d) Safety Valve

## Pressure regulation

- Please refer to Figure 6 to identify the valve numbers with their locations in the system
- Pressure regulation is by means of the liquid phase fill valve (23) and the gas phase fill valve (25)
- Pressure drops when filling is complete through the gas phase fill valve (25), and rises when filling takes place through the liquid phase fill valve (23)
- When the tank is filled to three-quarters full, open and watch the overflow valve, 24
    1. When liquid spurts out at the overflow valve, the tank is full
    2. Close the fill valve on the tanker
    3. Close the liquid phase valve (23) and the overflow valve, (24)

4. After a few minutes the residual liquid in the fill pipe will have vaporized
5. Close valve (25) (fill valve - gas phase)
6. Relieve the pressure in the fill pipe
7. Fill the tank only up to 90%-92%

Note: Re-fill the tank if the level falls to a quarter full (20-25%).

## Withdrawal from Cold Converters

- Please refer to Figure 7 for identifying the valve numbers with their locations in the system.
- After opening the liquid withdrawal valve no. (15), liquid gas will flow into the distribution line or through the clip-on vaporizer.
- The pressure building system works automatically if valve no. (1) and (5) are open, and they maintain the necessary working pressure.
- Readjust 'pressure regulators' (refer to Annexure II).
  For maximum liquid withdrawal quantities for each type of tank, please refer to the technical datasheet for the product.

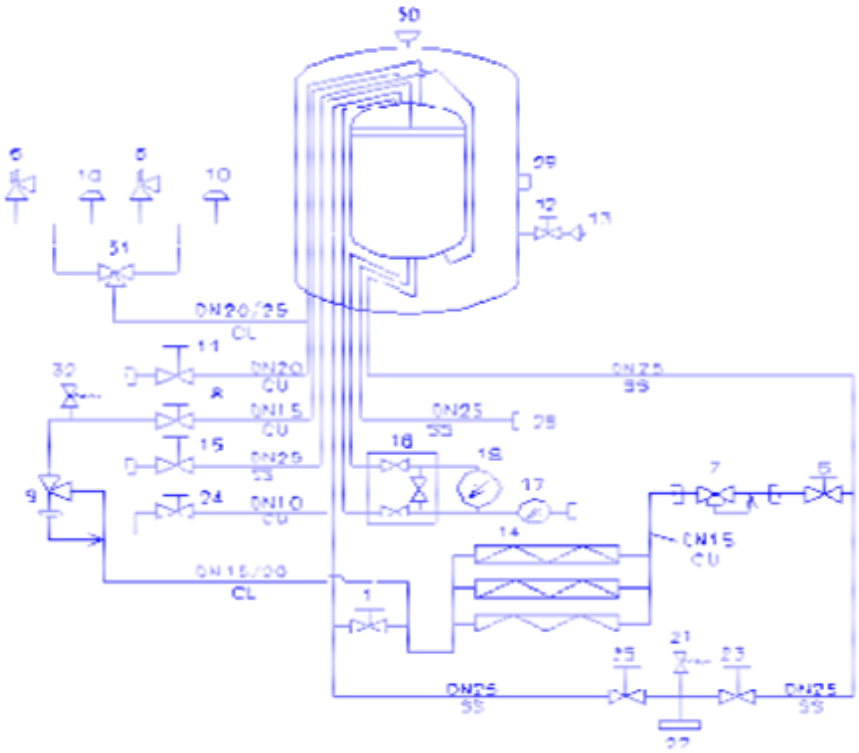


***Figure 7: Liquid Medical Oxygen plant II***

# Procedures for Commissioning of LMO storage Tank

## Introduction

- Commissioning is carried out in full after initial installation, after a major component change, and as part of a planned preventative maintenance programme.

- The objective of commissioning is to ensure that all components are serviceable.
- Personnel carrying out the following commissioning procedure must be qualified and fully conversant with the information contained in this manual.

## Initial Filling with Oxygen

Before initial charging of the tank, precooling of the inner vessel is to be carried out to bring the inner vessel, which is at atmospheric temperature, close to the temperature of the liquid i.e., -297°F (-183°C).

**Procedure**

1. Please refer to Figure 7 for identifying the valve numbers with their locations in the system.
2. Close all valves except the valves on the contents gauge
3. Connect the filling pipe to the fill connection
4. Open valves 23 (fill valve liquid phase) and 24 (fill try cock)
5. Open the valve of the tanker

**When filling is in progress**

1. Watch the manometer. Tank pressure must always be lower than filling pressure
2. When the tank is filled to three-quarters full, open and watch the overflow valve, 24 (fill try cock)
3. When liquid spurts out at the overflow valve, the tank is full
4. Close the tank fill valve
5. Close valves 24 (fill try cock) and 11 (Vent valve)
6. After a few minutes the residual liquid in the fill pipe will vaporized
7. Close valve 23 (fill valve liquid phase)
8. Relieve the pressure in the fill pipe

## Pre-Use Test

Testing of the installation prior to commissioning the following tests shall be carried out as per the procedures:

1. Cleaning of pipeline
2. Pressure testing for onsite fabricated pipe work

Note: Due regard must be paid to the safety of personnel. Testing should not create a hazard; particular attention should be given to foreign matter located in discharge outlets.

## LMO Refilling

LMO refilling is ensured from the vendor's (supplier's) end. The following precautions need to be taken for the LMO refilling:

- Refilling must be done with 3-4 days buffer stock or a 25% min level before replenishment
- There is less than 1%-2% loss during refilling, but tank must be of right quality
- Use adequate eye protection
- Must ensure auto cut off post filling

**Preparation before decanting**

- On reaching the delivery point and before starting the decanting operation, the driver must do the following:
- Once the vehicle is parked, chock the wheels of the vehicle.
- Put on the individual protection equipment, making sure that they conform to the safety equipment rules.
- Verify that the delivery point complies with operational standards.

**Figure 9: LMO Refilling**

- Verify that nothing abnormal has occurred since the last delivery: there is no leakage, the pressure and level gauges are in working order, there is no functional anomaly at the customer delivery point.
- Verify that the relief valves and bursting disks of the overpressure safety device are in good condition.
- If the delivery will be made using a pump driven by an electrical motor, confirm that the socket and the earthing of the delivery point are in good condition.
- Verify that the discharge pressure of the pumping unit of the vehicle is suitable for the maximum service pressure of the storage to be filled. Even though there is a safety system for preventing overpressure at the end of filling, the driver should take measures to prevent such an incident. See EIGA 59/98 'Prevention of Excess Pressure in Cryogenic Tanks during Filling'.
- Lastly, note the pressure and the level in the storage before the delivery in order to determine the operating rate of the pump to be used and to estimate the quantity to be transferred.

## Maintenance

To ensure the maintenance and adequate training of the health facility staff a set of guidelines vide DO.5-95/2020/Mitigation dated April 23, 2021 have been prescribed for the vendor and suppliers:

- The vendor/supplier should organize satisfactory on-site training to the health facility staff designated by the authority for a period of two weeks.
- Refresher training shall be provided by the vendor/supplier at the time of scheduled preventive maintenance visits by the service engineer.
- Maintenance, repair, and safety of the whole installation and LMO related to liquid oxygen vessels will be the responsibility of the supplier and monitored by the hospital management committee.
- The facility will be responsible for routine check, maintenance & demonstration of functioning of LMO and preventive measures to be highlighted in case of emergency to technical staff of the hospital at their own cost.

- The oxygen tank and associated equipment, control panel, pipeline, etc. should be placed under Comprehensive Annual Maintenance Contract (CAMC) for five years. Online helpline support/complaint system shall be provided by the vendor/supplier.

## Introduction

- Regular routine minor maintenance operations are recommended to prove the system integrity.
- Maintenance operations are carried out in accordance with the planned preventative maintenance contract purchased by the customer.

## Tools and Equipment

- No special tools are required, however, all common hand tools used must be clean, completely free of oil and grease and checked for serviceability before commencing maintenance procedures.
- All necessary spare parts must be obtained before commencing work.

**Mandatory Spares**

- Cryogenic Globe Valve DN 25 (1")/ 15 (1/2") and Cryogenic Regulator
- Gaskets all sizes
- Standby Vaporizer
- PRV Safety Valve
- Tank Safety Valve
- 500/100 m3 Regulator
- Flange Inlet, Outlet, and Vaporizer

***Figure 10: Mandatory Spares***

## Maintenance of Storage Tank

- All routine preventive maintenance and break-down maintenance of the LMO storage system should be done by the vendor or authorized trained personnel only.
- Experienced trained personnel should be readily available.
- Log of all works undertaken in the system should be meticulously maintained by the vendor.

**Cleaning**

- The use of abrasive or solvent based cleaning solutions is not recommended.
- For cleaning external surfaces - use a damp cloth only. Mild soap solution may be used but detergent/surfactant solutions are not recommended.
- Phenol or halogen-based disinfectants or agents that release chlorine or oxygen should not be used.

**Minimum requirements**

- Minimum requirements for routine inspections, checks and maintenance are given in Table 4 and must be observed to ensure continued safe operation of the system.

*Table 4: Inspection and maintenance schedule of LMO tank*

| Actions | Commissioning | Monthly | Quarterly | Annually | 5-yearly |
|---|---|---|---|---|---|
| Inspection, checks, and tests | | | | | |
| Ambient temperature | √ | √ | √ | | |
| Suitability of locations | √ | | | | |
| Adequate room for ventilation | √ | | | | |
| Adequate access for maintenance | √ | √ | | | |
| Visually inspect the unit for damage | √ | √ | | | |
| Planned preventive maintenance | | | | | |
| Complete commissioning process | √ | | | √ | |

## Prevention of Fires in Oxygen System

- Newly assembled equipment for oxygen service should be thoroughly checked for leakages using air or nitrogen either by a timed gas pressure drop test, a leak detection test with an approved leak spray, or other suitable methods.
- The main oxygen supply valve shall be closed to avoid possible oxygen leakage while the equipment is not being used.
- Filters, where fitted, shall not be removed to obtain higher flows. Filters should be inspected at frequent intervals and all debris removed.

## Troubleshooting and Rectification Actions[2]

**(a)** **(b)** **(c)**

***Figure 8: (a) Leakage from pressure and level gauges; (b) Leakage from pressure equalization/controller valve; (c) Leakage from gasket of flanges***

| Problem | Possible Cause | Remarks/Rectification Action |
|---|---|---|
| Failure to reach or maintain operating pressure | Excessive withdrawal of oxygen | Increase the capacity of pressure building coil |
| | Liquid oxygen level is too low | Refill the liquid oxygen tank |
| | Leaks on outer piping | Seal the piping with oxygen compatible sealant or replace piping<br>Sealant/thread PTFE tape/replace gasket |
| | Safety valves do not close/seat back | Replace the safety valves<br>De-icing, or replace the safety valve |
| | Strainer at the inlet of pressure regulator clogged | Clean the strainer to remove the clogging |
| | Improper adjustment of pressure regulator, or regulator defective<br><br>Cryogenic Safety valve passing<br><br>Improper pipe design | Correct adjustment or replace regulator<br><br>1.De-icing,<br>2.Spray water on top of the valve (not on the vent).<br>3.Change direction of diverting valve<br><br>Check the piping design/diagram<br>Liquid should supply form bottom line |
| Erroneous or irregular contents & Pressure gauge readings | Equalizer valve is not closed | Check “equalizer” valve & close properly |
| | Wrong adjustment | Calibrate and re-adjust |
| | Gauge damaged or leaking<br><br>LMO tank pressure gauge error without icing on pipe/tube<br><br>Gaseous pressure gauge showing under/over pressure | 1.Replace the gauge<br>2.Repair leak from fitting<br>3.Recalibrate or replace the gauge<br>4.No leak on tubes/fittings<br><br>1.Calibrate/ change gauge<br>2.Check for damage,<br>3.Check the pressure regulator valve setting<br><br>1.Calibrate/ change gauge<br>2.Check for damage<br>3.Check the pressure regulator valve setting |
| Main safety valve leaking | Dirt or ice under disc cone | Repair/Replace |
| Inner vessel bursting disc has burst | Bursting disk with too low pressure<br><br>Corrosion or material fatigue | Replace<br><br>Replace |
| Shut-off valves leaking | Valve seat loose<br><br>Damaged seat or cone | Tighten<br><br>Replace Seat |
| LIQUID vessel bursting disk has burst/ Rupture disc | Under capacity Bursting disc fitted | Replace with right pressure rating of cryogenic bursting disc |

| | | |
|---|---|---|
| | Corrosion or material fatigue | Replace with right pressure rating Cryogenic Bursting Disc |
| | Tank pressure goes beyond MAWP | 1.Maintain MAWP pressure by venting the gas when PRV doesn't pop-up/work at MAWP.<br>2.Replace with right pressure rating Cryogenic Burs Disc.<br>3.Change position of diverter valve direction |
| Shut-off valves are leaking/passing | Valve seat loose/ not tighten due to ice | De-icing and tight the valve by rotating the wheel clockwise |
| | Valve sheet broken/crack | Replace the sheet (but the tank must be empty and depressurized) |
| | Gland leaking | Slightly tighten gland nut |
| | Leaking from body stem | Change PTFE gasket (but tank must be empty and depressurized) |
| Loss of vacuum | Leak on vacuum bursting disc | Relace |
| | Leaking measuring socket | Seal |
| Wrong or incorrect vacuum gauge reading | Gauge not properly calibrated | Calibrate |
| | Batteries have no charge | Replace |
| | Defective vacuum gauge tube | Replace |

## Annexure

## Annexure I - Technical Specification of LMO Tank[4]

Source - DO.5-95/2020/Mitigation dated 23rd April 2021

- The double walled Vacuum Insulated Evaporator (VIE) shall be constructed of stainless-steel inner vessel contained within a carbon steel outer vessel.
- The annular space between the vessels shall be filled with non-inflammable perlite insulation material to insulate under vacuum.
- The VIE should be self-pressurizing type, by partial evaporation of liquid oxygen through a pressure building coil by a non-ferrous imported pressure regulator.
- The vessel shall be supplied as a functional whole with all materials of construction & the cleaning regime suitable for medical grade liquid oxygen.
- Material used (including lubricants) should conform to EIGA IGC 73/17/E (revised version of Doc 73/08).
- The LMO tank should have liquid outlet & gas outlet along with all the necessary valves and accessories.
- There is constant display of the level of LMO and pressure, etc. inside the vessel.
- The output from the tank is connected through a copper pipe of suitable diameter to the medical gas pipeline system network at the MGPS Manifold.

| Physical characteristics | |
|---|---|
| Quantity | 10 kL x 1 No. |
| Installation | Outdoor |
| Type | Double walled, vertical |
| Capacity | Minimum 20,000 liters water capacity |
| Design code | ASME Sec.VIII Div.I latest Edition / EN - 13458-2 Annexure-C/ AD2000 MARKBLATTER 2004 Edition |
| Max. working pressure | 17 Bar G |
| Design temperature | -196 to +50 degrees Centigrade |
| Hydraulic test pressure | 26 Bar G |
| Type of insulation | Vacuum, perlite filled |
| Safety valve set pressure valve<br><br>Bursting disc set pressure | 17 Bar G (Dual safety valve with three-way diverter valve)<br><br>23 Bar G |
| Standard fittings | Pressure rising coils capacity and size, dual safety valve with imported three-way diverter valve, bursting disc., pressure gauges, liquid overflow line, Liquid level gauge and adequate numbers of extended spindle glove valves etc. |
| Pressure regulator | It should be made of suitable material (Non-ferrous) with bonnet & trim parts. Inlet pressure max. 20 Kg/sq cm., outlet pressure range within 0.5 to 10 kg per sq cm (adjustable). |
| Maximum evaporation rate | <1% of net value |
| Material of construction | Inner shell and wetted parts of SS 304 Outer shell of CS ASTMA 516 Gr. 70 / CGA 341 2002 EN13455 S275/S355 |
| Joint efficiency | 100% |
| Radiography | 100% for inner, for outer spot |

| | |
|---|---|
| External piping | From LMO Tank to Vaporizer SS304. From Vaporizer to inlet of Pressure Reducing Station SS304. From the Outlet of Pressure Reducing Station to the Main Header Copper. |
| Cryogenic valves | Non-ferrous |
| Cryogenic safety valves | Non-ferrous |
| Pressure building regulator | Non-ferrous with standard specifications |
| Leak detection test | Helium Leak detection |
| Inspection | By 3rd party (eg; SGS/LLOYDS/TUV) |
| Cleaning nitrogen | with degreasing for Service and Pressurize |
| Withdrawal rate | 1000 cum per hr. at 12 bar G |

Should have safety features in line with Global Safety as part of installation The minimum safety (Alarm) features for LMO installation are as follows:

- Alarm VIE (Vacuum Insulated Evaporator)
- For low content level (audio-visual)
- Low pressure alarm (audio-visual) and backup in the manifold room
- Alarm VIE low pressure alarm (audio-visual) low pressure in pipeline system. Deviation or fall in pipeline pressure by more than plus minus 10% from nominal distribution pressure (the nominal distribution pressure should be within the range of 400 kPa to 500 kPa)
- Alarm for changeover from primary to secondary supplies
- Alarm for secondary or reserve supply below minimum pressure
- Dual parallel regulator system for uninterrupted supply in case the regulator has to be changed for repair
- One regulator is set at 4.2 bar and the other at 3.8 bar as per international practice
- Three-way gauge valve for isolation of line pressure with manual manoeuvre
- Remote monitoring telemetry-continuous monitoring of VIE stock based on daily consumption (automatic modification of tank replenishment)

Pressure Reducing Station

- The healthcare facility supply pipeline reducing station which reduces supply pressure must consist of a dual parallel regulator system
- Both regulators must be online, and all isolation valves and regulators must be kept in the open position
- The nominal distribution pressure should be maintained within the range of 400 kPa to 500 kPa
- Pressure relief valve – medical oxygen pipeline system should be provided with a pressure relief device downstream of the line pressure regulator connected by means of a 3-way valve
- Material used should conform to (including lubricants) EIGA IGC 73/17/E
- The control equipment should be protected from weather

## Annexure II - Pressure Regulators[6]

1. Set the service pressure 0.1 bar above the desired opening pressure.

   For a higher service pressure:

   Open valves no. 11 or 24 and release pressure.

   For a lower service pressure:

   After loosening the locknut on the regulator, turn the pressure screw into the casing (approximately 1 bar per turn).

2. Check the reading on the pressure gauge.

**Adjustment**

1. Close valve no. 23a.
2. Loosen the locknut on the regulator, screw out the pressure adjustment screw a few turns.
3. Release the pressure in the line between the regulator and valve no. 23a by carefully loosening the threaded joint.
4. If gas is still being discharged, check out pressure screw on the regulator until gas flow is interrupted.
5. Turn in the pressure screw slowly until the regulator starts to open.

**Check**

1. Release the pressure in the tank by opening valve no. 24.
2. If the pressure falls below the set pressure the regulator will open completely or will start to open when the requested pressure is reached.
3. Close valve no. 24.
4. Refit the locknut.
5. Fit the threaded joint between regulator and valve and reopen valve no. 23a.

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