GUIDEBOOK ON

Medical Oxygen Management System

Health and Family Welfare Department
Government of Meghalaya

OCTOBER 2021
Disclaimer

"This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of Jhpiego and do not necessarily reflect the views of USAID or the United States Government."
The Second wave of coronavirus disease (COVID-19) in India and Meghalaya has been specifically devastating as the demand and consumption for medical oxygen increased exponentially. The crisis brought to the fore the need to promote judicious use of oxygen therapy in patients. It also required to enhance accountability for oxygen conservation through monitoring and audit without compromising quality of care.

In an endeavor to develop a holistic mechanism to handle the need for medical oxygen in future, the Government of Meghalaya, in association with its development partners, has developed a Guidebook on Medical Oxygen Management System to provide technical information on effective and unified management of oxygen management in health facilities. I would like to take this opportunity to express the state’s gratitude to subject matter experts from the Government of Meghalaya, USAID’s NISHTHA project, JHPIEGO and PATH for developing the first edition of the guidebook.

It gives me pleasure to introduce the Guidebook on Medical oxygen Management System and it is my earnest hope that the state and districts can make meaningful use of this guidebook, to ensure rapid rollout and scaling up of the initiative throughout the state, so that the benefits of these investments reach those who need them the most.

I am optimistic that the guidebook will prove to be a source of reference to support the efforts of the state to provide quality and timely medical oxygen services. I congratulate the Department of Health and Family Welfare, Government of Meghalaya, and the partner agencies who have contributed to bringing out this important document.

(James P. K. Sangma)
The Government of Meghalaya has proactively handled the devastating effects of Coronavirus disease (COVID-19) since its very beginning. Wide ranges of approaches were implemented to tackle the transmission chain, strengthen health systems, and building capacity of the communities to alleviate the infection levels.

In a step towards strengthening the health systems, a State Oxygen Cell is being set up within the Department of Health and Family Welfare to provide dedicated and efficient support to patients in emergency scenarios. The cell will comprise of health officials from the department and will primarily be managing the supply, storage, distribution of the Meghalaya oxygen ecosystem.

In this context, the Guidebook on Medical Oxygen Management System has been brought out by the Department of Health and Family Welfare, which will serve as a ready reference to improve the technical skills of all the stakeholders involved for a sustainable oxygen ecosystem. The guidebook is an adaptation of a similar guidebook developed by the UIDAI’s NSITHTA project, its partners, IMPRINT, and PATH, and subject matter experts from the Government of Meghalaya. This guidebook provides the required information on handling oxygen devices for storage, transport, distribution purposes. Additionally, the guidebook also provides tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit.

I would like to express my special thanks to Mr. M. R. Synrem, Commissioner and Secretary, Commerce and Industries Department, who extended his active support to help in managing the oxygen supply during the COVID-19 crisis. I also would like to convey my appreciation to the Team of State e-Mission (SEM) which developed and managed the State Oxygen Dashboard that helped state to take appropriate decisions for oxygen supply to various health facilities based on consumptions. My sincere appreciation to all the health officials of Government of Meghalaya for putting together this guidebook in a very short time. Finally, I would like to acknowledge PATH for their services and contribution in the fight against COVID-19.

(Sampath Kumar, IAS)
Principal Secretary
Health and Family Welfare Department
Government of Meghalaya
FOREWORD

Since the onset of the COVID-19 pandemic, the Meghalaya State Health Department has been working tirelessly in providing medical assistance of all kinds. During the second wave of COVID-19, a sudden surge in cases with less time for preparation has led to overburdening of the healthcare system of the state. As a measure towards a potential upcoming surge, various measures were undertaken to strengthen the health facilities for effective and efficient oxygen management across the state.

I would like to express my sincere appreciation to Shri D.P. W撤销, IAS, Additional Chief Secretary to the Government of Meghalaya, PWD, Education, etc for his support and Management to improve the production and supply of Medical Oxygen across the State especially in the setting up of the PSA Oxygen plants across the state.

I would also like to thank Shri. M.R Syriem, IAS, Commissioner & Secretary to the Government of Meghalaya, Commerce and Industries and the members of the Special Committee to ensure availability of Adequate and uninterrupted Supply of Medical Oxygen for Management of COVID-19 patients for their tireless effort in coordinating the uninterrupted supply of Medical Oxygen during the COVID-19 surge in the past few months. My sincere appreciation to Shri. E. Lyngdoh, Principal Consultant & Head, State e-Governance Mission Team and SoEIT team for developing the Meghalaya Medical Oxygen Dashboard of the State.

I would also like to acknowledge my appreciation to Premix Ciygenics, Meghalaya Oxygen Private Ltd. in collaboration with Sansha Medicals for setting up the Cryogenic tanks in record time, and also the contributions by Pioneer Ceramics, Jaintia Hills Cement Manufacturers Association, Rice Infotech, Power Grid, Rymbai Industries Association, Elkie Drugs, Harris Cylinder for which the State was able to meet the increased demand for Oxygen especially during the peak of the 2nd wave of COVID-19.

The Guidebook on Medical Oxygen Management System lays the foundation for the management of medical oxygen in health facilities in the State. It also reinforces the commitment of the Government of Meghalaya to systematic and coordinated improvements in managing life-saving commodities such as medical oxygen at facility level. Additionally, maintenance and audit are equally important for a sustainable oxygen supply. This Guidebook also provides tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit.

I hope this document will prove beneficial for improving oxygen management across the State of Meghalaya. The Government of Meghalaya and their partners, UNAID’s NISHTHA Project, RJRPHD and PATH, had developed the first edition of this Guidebook and have contributed to its adoption for the State of Meghalaya. I hope that the Guidebook on Medical Oxygen Management Systems will be the guiding force providing the necessary knowledge and skills for the Program Managers, Medical Officers, Nursing Staff, Technicians, and Biomedical Engineers in the state to be effective lenders of the Medical Oxygen Program.

Director of Health Services (MI),
Meghalaya, Shillong
FOREWORD

A robust medical oxygen management system is essential during circumstances like the Covid-19 pandemic. The Government of Meghalaya implemented various strategies to fulfill patient oxygen requirement, especially during the second wave. To deal with a similar situation in future in a holistic way, the state government has come up with dedicated oxygen management system and capacity building measures.

The Guidebook on Medical Oxygen Management System is a collection of reference materials and tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit, developed by the Department of Health and Family Welfare, to serve as a technical tool for handling oxygen devices for storage-transport-distribution purposes. The first edition of this guidebook was developed by the Government of Meghalaya in collaboration with USAID’s NISHTHA project and its partners, JIPILGO and PATH. We would like to take this opportunity to acknowledge their efforts and thank them for assisting in customizing the requirements of the state of Meghalaya. This guidebook will help in improving the technical skills of administrators, district level officers, procurement and planning officers, biomedical engineers, medical and paramedical staff in handling oxygen equipment and devices. It also provides tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit.

I hope the guidebook will prove helpful to all the stakeholders in efficient and effective oxygen management across the state.

Shri. Ranirmurti S. (IAS)
Joint Secretary, DoHFW
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**ABBREVIATION**

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<tr>
<td>ARDS</td>
<td>Acute Respiratory Distress Syndrome</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
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<td>ASTMA</td>
<td>American Society for Testing and Materials</td>
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<td>ASU</td>
<td>Air Separation Units</td>
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<td>BIPAP</td>
<td>Bilevel Positive Airway Pressure</td>
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<tr>
<td>BS</td>
<td>Bureau of Indian Standards</td>
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<tr>
<td>CCC</td>
<td>Covid-19 Care Centre</td>
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<td>CCE</td>
<td>Commission of the European Communities</td>
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<td>CCEO</td>
<td>Chief Controller of Explosive</td>
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<tr>
<td>CFM</td>
<td>Cubic Feet per Minute</td>
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<td>COPD</td>
<td>Chronic Obstructive Pulmonary Disease</td>
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<td>COVID-19</td>
<td>Corona Virus Disease-19</td>
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<td>CPAP</td>
<td>Continuous Positive Airway Pressure Therapy</td>
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<tr>
<td>CuM</td>
<td>Cubic Metre</td>
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<tr>
<td>DCH</td>
<td>Dedicated Covid-19 Hospital</td>
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<td>DCHC</td>
<td>Dedicated Covid Health Centre</td>
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<td>DOT</td>
<td>Department of Transportation</td>
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<tr>
<td>ERP</td>
<td>Emergency Response Plan</td>
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<td>HDU</td>
<td>High Dependency Units</td>
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<td>HFNC</td>
<td>High Flow Nasal Cannula</td>
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<tr>
<td>ICU</td>
<td>Intensive Care Unit</td>
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<tr>
<td>ISI</td>
<td>Indian Standards Institution</td>
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<tr>
<td>KL</td>
<td>Kilolitre</td>
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<tr>
<td>LMO</td>
<td>Liquid Medical Oxygen</td>
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<tr>
<td>LPM</td>
<td>Litre Per Minute</td>
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<tr>
<td>M&amp;E</td>
<td>Monitoring and Evaluation</td>
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<tr>
<td>MCB</td>
<td>Miniature Circuit Breaker</td>
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<td>MGPS</td>
<td>Medical Gas Pipeline System</td>
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<tr>
<td>MOHFW</td>
<td>Ministry of Health and Family Welfare</td>
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### Abbreviation

<table>
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<tr>
<td>MOMC</td>
<td>Medical Oxygen Monitoring Committee</td>
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<td>MT</td>
<td>Metric Ton</td>
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<td>NFPA</td>
<td>National Fire Protection Association</td>
</tr>
<tr>
<td>NICU</td>
<td>Neonatal Intensive Care Unit</td>
</tr>
<tr>
<td>NIV FIO2</td>
<td>Non-Invasive Ventilation Fraction of Inspired Oxygen</td>
</tr>
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<td>O2</td>
<td>Oxygen</td>
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<td>NRBM</td>
<td>Non-Rebreather Mask</td>
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<td>OC</td>
<td>Oxygen Concentrator</td>
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<td>OLED</td>
<td>Organic Light-Emitting Diode</td>
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<td>OT</td>
<td>Operation Theatre</td>
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<td>P&amp;ID</td>
<td>Piping and Instrumentation Diagram</td>
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<td>PCC</td>
<td>Plain Cement Concrete</td>
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<tr>
<td>PESO</td>
<td>Petroleum And Explosives Safety Organization</td>
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<tr>
<td>PICU</td>
<td>Paediatric Intensive Care Unit</td>
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<td>PPE</td>
<td>Personal Protective Equipment</td>
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<td>PRV</td>
<td>Pressure Relief Valve</td>
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<td>PSA</td>
<td>Pressure Swing Adsorption</td>
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<td>SARS-CoV-2</td>
<td>Severe Acute Respiratory Syndrome Coronavirus-2</td>
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<td>SMPV</td>
<td>Static and Mobile Pressure Vessels</td>
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<td>SOPs</td>
<td>Standard Operating Procedure</td>
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<td>SPO₂</td>
<td>Saturation of Peripheral Oxygen</td>
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<tr>
<td>TUV</td>
<td>Technischer Überwachungsverein, English translation: Technical Inspection Association</td>
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<tr>
<td>UNICEF</td>
<td>United Nations Children's Emergency Fund</td>
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<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
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<tr>
<td>UTs</td>
<td>Union Territories</td>
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<tr>
<td>VIE</td>
<td>Vacuum Insulated Evaporator</td>
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<td>WHO</td>
<td>World Health Organization</td>
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# Introduction

Coronavirus Disease 2019 (COVID-19) is an acute respiratory disease caused by a novel coronavirus (SARS-CoV-2). India is currently observing the second wave of the COVID-19 infection. Patients with COVID-19 infection may present mild, moderate, or severe illness; the latter includes severe pneumonia, Acute Respiratory Distress Syndrome (ARDS), sepsis, and septic shock. Although the proportion of moderate to severe cases among all Covid-19 cases have been relatively low, it has put huge strain on the country's health systems.

Pneumonia, ARDS and septic shock have been the major complications in people with COVID-19, who required hospitalization. Many patients with these respiratory complications slip into hypoxemia, a condition when the oxygen level in the blood is abnormally low. Oxygen is a lifesaving resource for the management of hypoxemia, irrespective of its cause. It is included in the WHO’s Essential Medicine List as an essential medicine. Its use in emergency care, for anesthesia, in surgery and for managing acute and chronic respiratory conditions is crucial and well-documented. Oxygen of 93% +/-3% purity is used for the care of medical conditions across a wide range of patients, irrespective of their age or gender. It is produced for medical use in various forms by using many different methods.

Monitoring the levels of oxygen saturation is recommended for all the patients with symptomatic COVID-19 disease along with oxygen therapy for all severe and critical COVID-19 patients with low oxygen saturation. Oxygen can be produced primarily in two forms – the liquid form and the gaseous form, using various methods and devices. Depending on a patient’s need, it can also be administered at different flow rates through various delivery options.

During the second wave of COVID-19 infection, a huge load of patients needed oxygen therapy. The existing production and supply chain system were inadequate to meet patient needs in various pockets across the country and the state. The Government of Meghalaya implemented various strategies to fulfill the patient care needs for medicines and oxygen. As a commitment to its people and considering long term systemic improvement, the Government of Meghalaya is making all efforts to improve the production and supply of medical oxygen, a lifesaving medicine, across the state.

This guidebook presents a comprehensive view at the entire oxygen ecosystem including the production, storage, supply and distribution of medical oxygen and will be helpful to the various stakeholders in this field.
OBJECTIVE OF THE HANDBOOK

The objective of the handbook is to provide guidance for making informed decision on proper usage of oxygen devices according to the requirements and the resources available in the health facilities in Meghalaya.

This document is intended for the administrators, state and district level officers, procurement personnel, planning officers, program managers, biomedical engineers, and medical and paramedical staff handling oxygen devices during its storage, transportation and distribution.

Additionally, the handbook also provides tools for proper functioning, maintenance and safety of the oxygen equipment and for conducting oxygen audit.

The information made available in this guidebook has been sourced from different resources/documents available with WHO, PESO, Ministry of Health and Family Welfare, among others.

We hope that this handbook will be helpful to all the stakeholder involved in oxygen ecosystem in the state of Meghalaya in addressing the gaps identified in the continuous and adequate supply of medical oxygen.

OXYGEN IN MEDICAL TERMS

Oxygen is an odourless gas present in the air; necessary to maintain life. It is given under medical supervision either to reduce volume of other gases in blood or as a vehicle for delivering anesthetics in gaseous form. It can be delivered via nasal tubes, an oxygen mask or an oxygen tent.

1.1 Importance of Oxygen & Caution
- Oxygen is an essential drug, administered when people with breathing issues can’t get enough oxygen naturally.
- Oxygen can’t be inhaled in higher or lower quantities and should be administered in accordance with the body requirement.
- Atmospheric oxygen is moist, whereas industrially manufactured oxygen is dry.
- Medical grade oxygen must be humidified before giving to the patients.

1.2 Medical Conditions of Oxygen
1.2.1. Hypoxia
A condition in which the body has inadequate supply of oxygen at the tissue level.
- Symptoms: Shortness of breath, decreased tolerance to physical activity, waking up out of breath, confusion, wheezing, frequent cough, sweating, and/or discoloration of skin.

1.2.2. Hyperoxia
A condition that occurs due to excess of oxygen in the tissues and organs in the tissues and organs.
- Symptoms: Nausea, muscle twitching, dizziness, disturbances of vision, irritability, and/or disorientation.
- Causes: Occurs when cells, tissues and organs are exposed to an excess supply of oxygen or higher than normal partial pressure of oxygen.

1.3 Oxygen Necessity (during COVID-19)
- 80% of the oxygen produced was for industrial use with the remaining 20% available for medical use,
- Oxygen is mainly administered in gaseous form.
- The huge demand for oxygen during COVID-19 has necessitated replace with either establishment or setting up of large liquid oxygen production facilities.
- There is an acute increase in the demand for medical oxygen across health facilities, which has created a temporary shortage of oxygen.

1.4 Importance of Oxygen
- In COVID-19 patients demand of oxygen varies, starting about 5th day onwards.
- Right amount of oxygen at golden hour is life saving.
- Oxygen is the most important and essential of the drugs for saving the lives of Covid-19 patients.
Oxygen ecosystem involves devices, instruments and equipment used from the production of oxygen to supplying it to the patient as well as for monitoring the oxygen levels. The oxygen ecosystem includes sources of oxygen production, its distribution, regulation, delivery and patient monitoring. The oxygen ecosystem with its components and sub-components is shown in Figure 1 below.

**Oxygen Ecosystem**

![Image of Oxygen Ecosystem diagram]

**Oxygen Sources**

- **Concentrator**
- **Cylinder**
- **PSA/VPSA/PSA Plant**
- **Liquid Medical Oxygen (ASU Plant)**

**Distribution**

- Central or sub-central piping
- Tubing
- Transport (for cylinders)
- Transport (for Liquid Oxygen)

**Regulation and Conditioning**

- ReguAir®
- Flowmeter
- Flowmeter stand (flow calibrators)
- Humidifier (heated and non-heated)
- Blender
- CPAP
- BIPAP
- Ventilators

**Delivery**

- Nasal cannula
- Nasal catheter
- Masks
- Tubing
- Non ReBreather Mask
- Pulse oximeter
- Multiparameter monitor

**Patient Monitoring**

**Power Supply**

- Voltage stabilizers
- Surge suppressors
- Backup power supply

**Maintenance**

- Oxygen analyzers
- Tools and spare parts for maintenance of all devices

**Table 1: Oxygen System and the primary methods**

<table>
<thead>
<tr>
<th>Devices for distribution</th>
<th>Concentrators</th>
<th>Oxygen plant with central piping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulator Tubing</td>
<td>Tubing central or sub-central piping</td>
<td></td>
</tr>
<tr>
<td>Flowmeter (Thorpe tube, Bourdon gauge, Dial click)</td>
<td>Flowmeter stand (flow calibrator)</td>
<td></td>
</tr>
<tr>
<td>Humidifier (heated)</td>
<td>Blender CPAP</td>
<td></td>
</tr>
<tr>
<td>Humidifier (non-heated)</td>
<td>Vertical</td>
<td></td>
</tr>
<tr>
<td>Blender CPAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen delivery devices</td>
<td>Nasal cannula</td>
<td>Oxygen devices</td>
</tr>
<tr>
<td>Nasal catheter</td>
<td>Self-contained fingertip handheld Tabletop</td>
<td></td>
</tr>
<tr>
<td>High-flow nasal cannula (HFNC)</td>
<td>Self-contained fingertip handheld Tabletop</td>
<td></td>
</tr>
<tr>
<td>Pulse oximeter and patient monitoring devices</td>
<td>Oxygen analyzer</td>
<td>Oxygen devices</td>
</tr>
<tr>
<td>Self-contained fingertip handheld Tabletop</td>
<td>Voltage stabilizer</td>
<td>Oxygen devices</td>
</tr>
<tr>
<td>Backup power supply</td>
<td>Surge suppressor</td>
<td>Oxygen devices</td>
</tr>
<tr>
<td>Tools and spare parts</td>
<td>Oxygen analyzer</td>
<td>Oxygen devices</td>
</tr>
<tr>
<td>Voltage stabilizer</td>
<td>Backup power supply</td>
<td>Tools and spare parts</td>
</tr>
<tr>
<td>Surge suppressor</td>
<td>Oxygen analyzer</td>
<td>Tools and spare parts</td>
</tr>
<tr>
<td>Backup power supply</td>
<td>Oxygen analyzer</td>
<td>Tools and spare parts</td>
</tr>
<tr>
<td>Tools and spare parts</td>
<td>Oxygen analyzer</td>
<td>Tools and spare parts</td>
</tr>
</tbody>
</table>

A description of the primary methods, its technical specifications, capacity, maintenance and safety, and its handling are detailed in the subsequent chapters. Inventory management is critical to ensure uninterrupted supply of oxygen to the patient. Considering that the medical oxygen is produced in either gaseous or liquid state, the inventory calculations are in either cubic metres for gaseous oxygen or in litres for liquid oxygen. Because of these different measures, the calculations and conversion are complex. A separate chapter detailing the inventory management for the primary methods of oxygen supply has been included in the guidebook. In addition, the guidebook contains a chapter on monitoring the usage of oxygen, i.e., oxygenaudit.
Chapter 1: Liquid Medical Oxygen

1. Brief Introduction

Liquid oxygen is a cryogenic liquid. It is pale blue in colour and is extremely cold. Cryogenic liquids are liquefied gases that have a normal boiling point below -130°F (-90°C). Liquid oxygen has a boiling point of -297°F (-183°C). It is a compressed form of oxygen, required to be stored much below -200°C, to ensure that the oxygen remains in the liquid form.

Because the temperature difference between the product and the surrounding environment is substantial—even in the winter—keeping the liquid oxygen insulated from the surrounding heat is essential. The product also requires special equipment for handling and storage.

The above figure explains the cryogenic oxygen distillation process. Cryogenic distillation separates oxygen from air by liquefying air at very low temperatures (-300°F). Ambient air is compressed in multiple stages with inter-stage cooling then further cooled with chilled water. Residual water vapor, carbon dioxide, and atmospheric contaminants are removed in molecular sieve adsorbers.

Oxygen is often stored as a liquid, although used primarily as a gas. Liquid storage is less bulky and less costly than the equivalent capacity of high-pressure gaseous storage. A typical storage system consists of a cryogenic storage tank, one or more vaporizers and a pressure control system. The cryogenic tank is constructed, in principle, like a vacuum bottle. There is an inner vessel surrounded by an outer vessel. Between the vessels is an annular space that contains an insulating medium from which all the air has been removed. This space keeps heat away from the liquid oxygen held in the inner vessel. Vaporizers convert the liquid oxygen into a gaseous state. A pressure control manifold then controls the gas pressure that is fed to the process or application.

Vessels used in liquid oxygen service should be designed for the pressure and temperatures involved. Piping design should follow similar design and conform to national standards and codes.
1.1 Liquid Oxygen Containers

Liquid oxygen is stored, shipped, and handled in several types of containers, depending upon the quantity required by the user. The types of containers in use include the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gallons. (In India IS 7396:2017 is followed.)

Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary, depending on the design of the container, external temperatures and the volume of stored product. Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

1.1.1 Dewars

This type of container is non-pressurized. A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from plugging the neck and allows gas produced from vaporized liquid to escape. The most common unit of measure for the capacity of a dewar is the liter. Five- to 200-liter dewars are available. Product may be removed from small dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as dewars. These typical Dewars has no application in Liquid Medical Oxygen use.

1.1.2 Cryogenic liquid cylinders (Dura Cylinder)

A typical cryogenic liquid cylinder is depicted in following figures. This is an insulated, vacuum-jacketed pressure vessel. They are equipped with pressure relief valves and rupture disks to protect the cylinders from pressure buildup. Liquid containers operate at pressures in the range of 100 psig to 350 psig (24 atm) and have capacities between 80 and 450 liters of liquid. Oxygen may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure. (In India typically Dura Cylinders of capacity of 180 L to 250 L are deployed. They come with warranty ranging from 1-3 years.)
1.3 Cryogenic storage tanks

Customer installations generally include a tank, vaporizer, and pressure control manifold (see below figure). Tanks are generally cylindrical in shape and are mounted in fixed locations as stationary vessels or on railcar or truck chassis for easy transportation. All tanks are powder- and vacuum-insulated in the annular space and equipped with various circuits to control product fill, pressure buildup, pressure-relief, product withdrawal, and tank vacuum. Tanks are designed to national and international specifications for the pressures and temperatures involved.

![Typical Oxygen Cryogenic Bulk Tank](image1)

![Typical Vaporizer](image2)

Figure 6: A typical station with a cryogenic storage tank

1.2 Working and construction of LMO tank

The LMO tank working and construction is as per the diagram below -

- **LMO Plant / Dura Cylinder**
- **Outlet - Vaporizer**
- **Vaporizer exchanges heat from the atmospheric air**
- **Water will solidify and have ice accumulations on the pipeline outside, where it is still very cold**
- **At this point, oxygen can be delivered to the oxygen points / vent/valves**
- **To cut this boiling and expanding, pressure regulating valves required to stop down the pressure gradually into the pipelines**
- **Now, oxygen is converted into gaseous form, & when this happens, it is boiling and expanding**

When oxygen passed through vaporizer, it will exchange heat from the atmosphere & liquid oxygen will get converted into gaseous form.

Figure 7: Working and construction of LMO tank & dura cylinder
2. PREREQUISITE FOR LIQUID OXYGEN TANK INSTALLATION

2.1 Following points should be taken into consideration by the Hospital/facility while installing LMO

- Open land space (uncovered).
- Civil Work and PESO approval.
- PESO approval for filling, storage and operation of the Medical Oxygen Installation.
- Crane/Hydra arrangement for unloading Tank and Vaporiser from truck/trailer and Installation on the foundation.
- Fencing and gate around the Installation.
- Fire extinguisher and water connection, Lighting, Safety Signs and Earthing pit.

2.2 PESO Regulations to be followed for the Installation

- Allocated space for Installation Space: W x L: (9 m x 15 m typical).
- At ground level, without overhead power or other utility cable.
- Assigned space to be well connected with internal roads for smooth movement of LMO transport tanker from/to the Installation.

Source –

Liquid medical oxygen installation and other modes of supply have their respective logistics, Installation and set-up arrangements. Therefore, extent of benefits and advantages of Liquid medical oxygen system varies depending on Hospital size (bed capacity), location, consumption, local supply and service support. The design and installation of medical oxygen supply system for healthcare facilities follows specific requirement and guidelines outlined in following international standards globally;

- HTM 02-01 Medical gas pipeline system – Part A, Design, installation, validation and verification.
- AIGA049/17 Guideline to Medical oxygen supply system for Healthcare facilities.
- NFPA55 – 2016 – Chapter 9, Bulk Oxygen Systems.

<table>
<thead>
<tr>
<th>General Characteristics</th>
<th>Liquid Oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Bulk liquid oxygen generated offshore and stored in a large tank and supplied throughout a health facility via a central pipeline system. Tank requires refilling by liquid oxygen supplier.</td>
</tr>
<tr>
<td><strong>Clinical application and/or use case</strong></td>
<td>Can be used for all oxygen needs, including high-pressure supply and in facilities where power supply is intermittent or unreliable.</td>
</tr>
<tr>
<td><strong>Appropriate level of health system</strong></td>
<td>Secondary and tertiary,</td>
</tr>
<tr>
<td><strong>Distribution mechanism</strong></td>
<td>Central pipeline distribution system,</td>
</tr>
<tr>
<td><strong>Electricity requirement</strong></td>
<td>No.</td>
</tr>
<tr>
<td><strong>Initial costs</strong></td>
<td>Can be high; tank, pipeline installation and civil.</td>
</tr>
<tr>
<td><strong>Ongoing operating costs</strong></td>
<td>Moderate (can be high if tank is leased); refill costs, maintenance.</td>
</tr>
<tr>
<td><strong>Maintenance requirement</strong></td>
<td>Periodical maintenance of system and piping required by highly trained technicians and engineers, can be provided as part of contract.</td>
</tr>
<tr>
<td><strong>User care</strong></td>
<td>Minimise at terminal unit only.</td>
</tr>
<tr>
<td><strong>Merits</strong></td>
<td>99% purity of oxygen obtained. High oxygen output for small space requirement.</td>
</tr>
<tr>
<td><strong>Drawbacks</strong></td>
<td>Requires transport supply chain, Exhaustible supply, High maintenance for piping, High total cost, Needs adequate infrastructure, Requires backup cylinder supply, Risk of gas leakage from piping system.</td>
</tr>
</tbody>
</table>

Table 2: General characteristics of liquid oxygen tank
2.3 Pros and cons of LMO

a) Pros

Liquid oxygen can be stored in a portable tank and connected to a Central pipeline. Liquid oxygen is highly concentrated, so more oxygen can be stored in a smaller tank and ensure continuous supply at high pressure. Most cost-effective system for larger facilities.

b) Cons

Liquid oxygen cannot be stored for more than a week or two because it will vaporize (evaporate) and build-up pressure inside storage tank. The tank’s content must be consumed and refilled often, requiring the scheduling of deliveries. In addition, the system need PESO license compliance.

3. MAINTENANCE

All routine preventive maintenance and break-down maintenance of the liquid oxygen storage system should be done by the vendor or authorised 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.

3.1 Routine inspection, checks and maintenance

Cleaning

- The use of abrasive or solvent based cleaning solutions is not recommended.
- 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 and must be observed to ensure continued safe operation of the system.

<table>
<thead>
<tr>
<th></th>
<th>Actions</th>
<th>Commissioning</th>
<th>Monthly</th>
<th>Quarterly</th>
<th>Annually</th>
<th>5 Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection, checks and tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability of location</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate room for ventilation</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate access for maintenance</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Visually inspect the unit for damage</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Planned preventive maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete commissioning procedure</td>
<td>✔</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Table 3: Inspection and maintenance Schedule of LMO

3.2 Fault diagnosis/troubleshooting

There are several faults that can be diagnosed. These are relatively simple to resolve, without replacing expensive regA setlpl assemblies. Most faults can be avoided by undertaking a regular planned preventive maintenance routine, carried out by a competent person.
**Possible Cause** | **Remarks/rectification action**
--- | ---
Excessive withdrawal | Increase capacity of pressure building
Liquid level too low | Refill tank
Leaks on outer piping | Seal
Safety valves do not close | Replace
Strainer at inlet of pressure building regulator plugged | Clean
Improper adjustment of regulator, or regulator defective | Correct adjustment or replace regulator-see Maintenance section

**Erroneous or irregular contents/gauge readings**

**Main safety valve leaking**

**Inner vessel bursting disk has burst**

**Shut-off valves leaking**

**Loss of vacuum**

**Wrong or incorrect vacuum gauge reading**

---

**Table 4: Fault diagnosis/troubleshooting of LMO**

---

**CHAPTER 2**

**OXYGEN CYLINDER**

![Cylinders type](image1)

![Dura Cylinder](image2)

Figure 8: Oxygen cylinder Types

**1. BRIEF INTRODUCTION**

Oxygen gas can be compressed and stored in cylinders (Figure 8). These cylinders are filled at a gas manufacturing plant, either via a cryogenic distillation/ASUs in liquid oxygen form or a process known as pressure swing adsorption (PSA) in gaseous oxygen form or by an LMO-based re-filler and transported to health facilities to be connected to manifold systems (groups of cylinders linked in parallel) that are piped to areas of the health facility, or cylinders can be used directly within patient areas. The use of cylinders typically involves transport to and from the bulk supply depot for regular refilling, which could have logistical challenges and ongoing cost implications, often leading to unreliable supply in many settings. Though it is not so common, cylinders in gaseous form can also be filled by a PSA oxygen plant that is co-located with a health facility and that has a high-pressure compressor for cylinder filling purposes.

Cylinders do not require electricity, but they do require several accessories and fittings to deliver oxygen, such as pressure gauges, reguAralrs, flowmeters, and, in some cases, humidifiers. Cylinders also require periodic maintenance, commonly provided by gas suppliers at the point of refilling. In this chapter, we will see the colour codes of medical gas cylinders, user care and preventative maintenance and troubleshooting recommendations for oxygen cylinders.
1.1 Cylinder naming and sizing

Oxygen cylinders are of different sizes. Cylinder sizes for medical gases are named alphabetically, unlike industrial cylinders which are named numerically. In India and Meghalaya, most commonly used cylinders are D type (Jumbo) and B type (Portable) cylinders which contain gaseous oxygen. Dura cylinders with liquid oxygen are also used in the region.

Cylinders are fitted with customized valves (either pin index or bullnose type) that are opened with valve keys, and with valve guards for safety. The Pin Index Safety System (PISS) is designed to ensure the correct gas is connected to the regulator or other equipment. The arrangement of the pins is unique for each gas, and the positions of the holes on the cylinder valve must correspond with the pins to prevent the use of the wrong gas. Some cylinders have built-in, integral pressure regulators, which do not require a separate pressure regulator to be fitted to the cylinder valve before use.

<table>
<thead>
<tr>
<th>Type of Cylinder</th>
<th>Capacity in liters</th>
<th>Capacity in CuM (m³)</th>
<th>Equivalent to Jumbo cylinders in CuM (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type B (Gaseous O2)</td>
<td>1500</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Type D Jumbo (Gaseous O2)</td>
<td>7000</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Dura Cylinder 180 L (Liquid)</td>
<td>180</td>
<td>158</td>
<td>-23</td>
</tr>
<tr>
<td>Dura Cylinder 200 L (Liquid)</td>
<td>200</td>
<td>175</td>
<td>25</td>
</tr>
<tr>
<td>Dura Cylinder 225 L (Liquid)</td>
<td>250</td>
<td>219</td>
<td>31</td>
</tr>
<tr>
<td>Oxygen Tank 3KL</td>
<td>3000</td>
<td>2633</td>
<td>376</td>
</tr>
<tr>
<td>Oxygen Tank 6KL</td>
<td>6000</td>
<td>5267</td>
<td>752</td>
</tr>
<tr>
<td>Oxygen Tank 10KL</td>
<td>10000</td>
<td>8778</td>
<td>1254</td>
</tr>
<tr>
<td>Oxygen Tank 20KL</td>
<td>20000</td>
<td>17556</td>
<td>2508</td>
</tr>
</tbody>
</table>

Table 5: Measurement of various sources in terms of jumbo cylinder

1.2 Colour coding for gases

The International standard for the colour coding of gas cylinders is ISO 32: 1977 Gas cylinders for medical use — Marking for identification of content. According to the ISO standard, oxygen should be labeled as white. The below figure shows differences in gas cylinder colour coding between ISO and US standards.

![Figure 9: Differences in colour coding of different gases between ISO colour coding standard and United States convention](image)

1.3 Cylinder labelling

Medical gas cylinders are required to be labelled, as the primary means of identifying the contents of the cylinder. The colour of the cylinder is only a guide. Labels for gas cylinders can be reduced in size and shape to the dimensions specified in ISO 7225 – Gas cylinders – Precautionary labels. The below figure is an example of a typical label.

![Figure 10: Oxygen cylinder labelling](image)
1.5 Oxygen cylinder description (Type B and D)

Cylinder – Gaseous Oxygen Storing Capacity

Type B Small Cylinder
- 1500 liters

Type D Jumbo Cylinder
- 7000 liters

Figure 12: Oxygen cylinder size

1.5.1. B-Type Small Medical Oxygen Cylinder (1.5 CU.M.)
- B-type high pressure seamless cylinder for medical oxygen gas, cylinder is ISI marked conforming to IS:7285 part 2, certified by the Bureau of Indian Standards (BIS) and approved by the chief controller of explosive (CCOE) Government of India.
- Cylinder made from manganese steel.
- 10.2 ltr. Water capacity (40 cu.ft.).
- Valve made of brass and chrome plated.
- Working pressure 150 kg, $F_{cm^2}$ at 15 deg., C.
- Hydraulic test pressure 250 kg, $F_{cm^2}$.
- Colour code of the cylinder should be as per IS: 3933-1966 with updating till date.
- Filled with medical oxygen gas of medical grade.
- Matching key cum spanner to release oxygen for each cylinder separately.
- Minimum two years guarantee for cylinder.

1.5.2. D-Type Jumbo Medical Oxygen Cylinder (7 CU.F.M.)
- Cylinder made from manganese steel.
- 46.7 Ltr. water capacity (220 CU.FT.).
- Valve made of brass and chrome plated.
- Working pressure 150 Kg, $F_{cm^2}$ at 15 deg., C.
- Hydraulic test pressure 250 Kg, $F_{cm^2}$.
- Filled with medical oxygen gas of medical grade.
- Matching key cum spanner to release oxygen for each cylinder separately.
- Minimum two years guarantee for cylinder.

(Source: Specification of medical oxygen cylinder- Rajasthan Medical Services Corporation Limited, Jaipur)
1.5.3. Working of Manifold
- Jumbo manifold system has two banks and one reserve bank.
- Each bank connected to a common header with a separate manifold pressure regulator & and banks alternately supply the pipeline.
- Manifold system operates on differential pressure mechanism.
- The secondary bank comes into operation automatically when content of the primary bank is exhausted.
- Manifold control panel assists in switching automatically between left bank and right bank.
- Automatic control panel need no power or electricity requirement for operation.
- In case of power failure, control panel has fail-safe mechanism, if required.
- Both right and left bank opens in case of power failure and will ensure unobstructed flow to hospital on self-displacement method.

1.5.4. Oxygen Cylinder – Pros and Cons

Pros
- Installation does not need permission from any authority like Petroleum and Explosives Safety Organization (PESO).
- Space accommodating as construction is long and linear.
- Easy setup, can also be used bedside without medical gas pipe system.

Cons
- Recommended as primary source for small size hospital up to 30 beds.
- Not recommended (especially in current pandemic) as primary source to ICU’s.
- Erratic supply chain.
- Chances of carrying infection.

1.6 Dura Oxygen Cylinder

1.6.1. Introduction
- Dura cylinders are small portable LMO tanks that stores liquid oxygen.
- They have capacity to store approx 200 to 240 liters of liquid oxygen in each cylinder.
- Some have inbuilt vaporizer and safety valves to maintain the pressure of oxygen.
- Dura cylinders are sent to plants for refilling as they are small in size and portability.
- An external vaporizer is required if more than one dura cylinder is used. PRV is also required if a dura cylinder bank is used.
- Dura cylinders should be purchased with a proper trolley as they are very heavy.
- There should be either a vehicle to pick and drop to refill the dura cylinders or dura cylinders should have an in-built chain pulling system / alternative system to lift the dura cylinder. The third option includes sub-system installed on the hospital premise.

1.6.2. Technical Specification for Dura Oxygen Cylinder
- Dura liquid oxygen cylinder (capacity - 200 Litter) with following set up,
  - Should include its dura trolley and facility to carry by train notch.
  - Should include its complete connection kit to panel of our facility.
  - Service: Oxygen.
  - Gross capacity: 208 Ltr.
  - Net capacity: 198 Ltr.
  - Relief valve setting: 17 to 24 bar.
  - Dimension: diameter: 20 inch.
  - Height: 65 inch.
  - Empty weight: 136 kg.

Cryogenic Medical Oxygen gas system
- Vaporizer 100 Nm³/hr-1 No.
- Inlet manifold – 5 inlets
- Outlet manifold with appropriate connector 1”-01 Nos.
- Outlet gas line regulator with low pressure high flow- 100 Nm³ -1 No.
- 3/8” hose pipe - 1 No. length 2 meter long.
- Dura cylinder should certify with BIS/department of transportation (DOT)/TUV or similar, ISO 9001-2005, PESO fire explosive and approved by the chief controller of explosive (CCOE) Government of India. (should attach all certificates, double mate for accidental safety).

1.6.3. Dura Cylinders – Installation Guidelines
- Dura is primary source of supply for smaller hospitals and could be secondary source of supply for larger hospitals.
- Recommended as primary source for hospital up to 100 beds with ICU of maximum 10 beds.
- Dura cylinders require limited space. System of 4 dura can be installed in 1m x 4m space.
- The number of dura to be installed is strictly decided on the basis of number of oxygen beds / ventilators to be installed in a particular facility.
- This is a small capacity vessel and does not needs permission from petroleum and explosives safety organization (PESO).
- A jumbo cylinder manifold serves as a back-up for dura cylinder set up.
- If pressure of primary source drops below the set pressure, then secondary system automatically caters to deficiency.
- Good access to the facility is required as dura cylinders are fixed on trolleys and have to be sent to the refilling facility.
- Dura comes on trolley, good access up to hospital facility is required as it needs to be sent out to refilling facility.
1.5.4. Working & construction of liquid oxygen facilities dura cylinder

- Dura cylinder delivers liquid oxygen through vaporizer to distribution lines of hospital.
- When oxygen passed through vaporizer, it exchanges heat from the atmosphere & liquid oxygen is converted into gaseous form.
- In the above process, water solidifies and has ice accumulations on the outside pipeline, where it is still very cold.
- Oxygen is then converted into gaseous form, boils and expands.
- Pressure regulatory valves are required to step down pressure gradually into the pipeline to eliminate boiling and expansion.
- Oxygen is then delivered to the oxygen points / ventilators.

2. SAFETY AND HANDLING

This topic is detailed in chapter 9 Medical oxygen safety and handling guidelines.

3. MAINTENANCE AND TROUBLESHOOTING

3.1 Maintenance

3.1.1 User care and preventive maintenance

The below table provides daily and weekly guidance for user care and routine maintenance of oxygen cylinders and associated accessories. However, preventive maintenance of the cylinders should be carried out periodically (every 5–10 years) by the gas supplier, and a color-coded cylinder test ring may be fitted around the cylinder neck indicating the next due date for testing.

3.1.2 Duties of Supervisors

- Ensure relevant staff is trained on handling compressed gases and its usage.
- Ensure that compressed gases are used only for intended purpose and in accordance with defined procedures and rules.
- Ensure that Emergency Response Plan (ERP) or other relevant literature is made readily available to staff.
- Provide staff and visitors with appropriate personal protective equipment (PPE).
- Provide appropriate supervision of staff.
- Ensure staff, and visitors adhere to applicable occupational health and safety regulations on compressed gases usage.
- Investigate reported incidents to determine the cause and develop appropriate preventive measures to minimize recurrence.
- Maintain appropriate records pertaining to the handling and use of compressed gases including an up-to-date inventory, training records, and reported incidents.

3.1.3 Duties of Staff are to

- Adhere to defined procedures and rules, and applicable occupational health and safety regulations for the use of compressed gases.
- Wear and maintain PPE provided.
- Notify their supervisor of identified hazards related to the use of compressed gases.
- Notify their supervisor of any incident related to the use of compressed gases.

<table>
<thead>
<tr>
<th>Schedule/ Period</th>
<th>Activities</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Cleaning</td>
<td>Ensure delivery tubes and masks are decontaminated. If humidifier bottle is used, disinfect and refill with clean water.</td>
</tr>
<tr>
<td></td>
<td>Visual checks</td>
<td>Check cylinder is correct type and correctly labelled. Check at parts are fitted tightly and correctly</td>
</tr>
<tr>
<td>Weekly</td>
<td>Function</td>
<td>Before use, ensure cylinder has sufficient pressure. Ensure flow is sufficient for intended use. Close cylinder valve after each use</td>
</tr>
<tr>
<td></td>
<td>Cleaning</td>
<td>Clean cylinder, valve and flowmeter with damp cloth.</td>
</tr>
<tr>
<td></td>
<td>Visual checks</td>
<td>Check for leakage: hissing sound or reduction in pressure,</td>
</tr>
<tr>
<td></td>
<td>Function</td>
<td>Remove valve dust with brief, fast oxygen flow checks. Check flow can be varied using flow control.</td>
</tr>
</tbody>
</table>

Table 6: User care and preventive maintenance cylinders (and associated accessories) recommendations for oxygen

3.2 Troubleshooting for oxygen cylinders

Below table provides some troubleshooting tips for common issues with oxygen cylinders and associated accessories. Refer to user and service manuals for more guidance.

<table>
<thead>
<tr>
<th>Problem or fault</th>
<th>Possible cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>No oxygen is flowing</td>
<td>Empty cylinder</td>
<td>Replace cylinder.</td>
</tr>
<tr>
<td></td>
<td>Flowmeter knob or cylinder flow valve is closed</td>
<td>Open the valves, and then check the meter registers flow.</td>
</tr>
<tr>
<td></td>
<td>Faulty reg/Air</td>
<td>Close all the valves and replace the reg/Air.</td>
</tr>
<tr>
<td>Leakage from cylinder or flowmeter</td>
<td>Cylinder is not connected to pressure reg/Air properly</td>
<td>Tighten all fittings.</td>
</tr>
<tr>
<td></td>
<td>Faulty or missing washer between reg/Air and cylinder.</td>
<td>Replace the washer.</td>
</tr>
<tr>
<td></td>
<td>Flowmeter seal damaged or loose,</td>
<td>Replace sealing of the washer and realign the flowmeter.</td>
</tr>
<tr>
<td></td>
<td>Cylinder faulty,</td>
<td>Label faulty cylinder and take appropriate action.</td>
</tr>
<tr>
<td>Leakage cannot be located</td>
<td>Leakage too small to be heard</td>
<td>Apply detergent solution (NOT oily soap) to the joints. There will be bubbles at the leakage point. Clean replace the washer and tighten the joint.</td>
</tr>
<tr>
<td>Flowmeter ball not moving, yet oxygen is flowing</td>
<td>Faulty flowmeter,</td>
<td>Close all the valves, disconnect flowmeter, and clean the flowmeter. Reconnect and test. If problem persists, replace the flowmeter.</td>
</tr>
<tr>
<td>Pressure gauge does not show pressure, yet oxygen is flowing</td>
<td>Faulty pressure gauge</td>
<td>Replace pressure gauge.</td>
</tr>
</tbody>
</table>

Table 7: Troubleshooting for oxygen cylinders (and associated accessories)
Chapter 3

Pressure Swing Adsorption (PSA) Plant

Oxygen is an essential medicine required at all levels of the health care system; and only high quality, medical-grade oxygen should be given to patients. Pressure swing adsorption (PSA) oxygen generating plants are a source of medical-grade oxygen. This chapter provides details on the guidelines and technical specifications as the minimum requirements for installation of a PSA Oxygen Plant.

1. Brief Introduction

1.1 Pressure swing adsorption (PSA) is the process by which ambient air passes through an internal filtration system (e.g. a molecular sieve of zeolite granules or membranes), which has a large enough total surface area to separate nitrogen from the air, concentrating the remaining oxygen to a known purity. It typically consists of an air compressor, dryer, filters, dual separation chambers, a reservoir, and controls.

![Figure 13: Pressure swing adsorption plant](image)

Main installation parts (pre-assembled)

1. Air Compressor
2. Air Filtration
3. Air Drying
4. Air Buffer tank
5. Trace Oil Particle Filter
6. Air Buffer for Pneumatic Valves
7(A). Adsorbing Tower A
7(B). Adsorbing Tower B
8. Flue Gas Vent Silencer
9. Oxygen Surge/Buffer Tank
10. Oxygen Storage Tank

PSA oxygen generator plant is a unit designed to concentrate oxygen from ambient air at scale, with output capacity varying according to calculated oxygen demand, typically ranging from 2 Nm³/hr to 200 Nm³/hr. For distribution of oxygen produced from PSA plants, oxygen can either be piped directly from the oxygen tank to wards, or further compressed to fill cylinders via a supplemental booster compressor and a cylinder filling ramp/manifold.

1.2 Operations of PSA plant

- Atmospheric air is compressed while passing through the compressor attached with inlet.
- The compressed air moves to initial filter, where the impurities and water particles are removed.
- As a next step, air moves through a refrigerated air dryer, at a temperature between 2 to 7°C. This phase removes water vapors.
- The air then moves to sieve containers / adsorbent tower through and inlet valve and various filters where the foreign materials and carbon particles are removed from the air.
- The adsorbent towers with zeolites molecular sieve, selectively adsorb the nitrogen and deliver the oxygen enriched air to the oxygen receiver, where the oxygen is stored under pressure.
- This oxygen rich air passed through after filter and bacteria filter. It is then provided to patients after through MGPS system or used for refilling cylinders which can be connected to manifold and MGPS.

1.3 Parameters

- Oxygen Purity: 93±3%
- Oxygen Pressure: minimum 4.2 barg at all times of operations
- Air pressure: 4.5 - 5 barg
- Air Inlet Temperature: 45°C max
- Ambient Temperature: 45°C max
- Air quality: ISO 8573 - 2010 class 1-4-1
- Working Pressure: 5 barg
- Voltage: 220-240 VAC, 3 Phase.

Detailed specifications are in the Annexure 1.

2. Prerequisite: Pre Installation Requirements and Installation Process

Proper housing and compatible electricity with back up support is required before setting up a PSA plant. Civil work and electricity requirements should be completed depending on the plant size as suggested by the vendor. The generic requirement for the power supply and room is mentioned in Annexure 1 as suggested by Gol, but these requirements may vary based on the model of the PSA, so it is very important to consult the vendor before starting the site preparedness.

2.1 Installation process

- Oxygen generator should be installed in a closed, adequately ventilated, clean, dry room protected from very high or very low temperature with restricted access of the room to personnel qualified in maintenance and operation.
- The generator must not be directly exposed to sources of heat. The temperature of the room must not exceed 43°C/109°F.
- Distance between the sub-units and positions of different sub-units of the system should be maintained, especially of dryer and other components using electricity. Electromagnetic compatibility directive should be followed.
2.2 Electrical Connections
- Separate MCB (Miniature Circuit Breaker) connections for both the air dryer and oxygen generator needed.
- Copper type, electrical power cable, 220-240VAC, 3 Phase, grounded power supply.
- Compatible back-up power supply (e.g. generator) should be connected in case of grid failure.
- Earthing at two places - compressor and module.
- A separate UPS for the generator module only, to keep it running at all times.

2.3 Availability of central pipeline system
Medical Gases Pipeline Systems (MGPS) within the hospital building is a pre-requisite for distribution of oxygen through Generators. Connections from the oxygen generation plant to the MGPS with appropriate pressure gauge and monitor should be established. Backup to oxygen generator should always be setup. It is essential and compulsory. This can be in form of oxygen manifold which has a group of cylinders installed in one set. Minimum two back up manifolds should be laid.

2.4 PSA Generator Plant – Properties
2.4.1 Operational Friendly
PSA plants are easy to operate with the features listed below:
- Concerns like oxygen cylinder filling capacity, oxygen wastage, noise due to loading and unloading of oxygen cylinders & extra staff to manage oxygen cylinders no longer required.
- Cost Effective as compared to cylinders / LMO.
- Helps save 65-70% each year on present hospital oxygen consumption.
- Purity of oxygen: oxygen purity is monitored and should meet United States European Pharmacopeia (93% +/-3%) standards.
- Safety: PSA is a low-pressure action. All the safety issues related to high pressure action do not exist.
- Stability: Oxygen plant requires stable power source and a proper power back up.
- Suitability: Oxygen generators come in different sizes and can be added up as modules also. PSA plants are flexible to support to any size of a hospital.
- Ownership – Third party dependence for supply of oxygen is eliminated.
- PSA is a programmable logic controller driven machine. Hence, it does not require live monitoring.

2.5 PSA Generator Plant – Pros & Cons
a) Pros
- PSA could be primary source for small as well as larger hospitals depending on the need.
- Installation does not need permission from any authorities like PESO.
- Relatively compact, needs enclosed space for installation.
- Efficient, oxygen is produced as per requirement.
- Reduces dependence on manpower.
- Safe to operate and maintain.
- Maintenance is preventive.
- Eliminates third party dependence.

b) Cons
- Good access upto hospital facility is required during installation and maintenance purposes.
- Assured power supply is a mandatory requirement. PSA plant needs Diesel Generator Backup in case of power failures.

3. MAINTENANCE AND TROUBLESHOOTING
As per NABH, each hospital should have minimum three independent sources of Oxygen. A PSA generator should have atleast two different oxygen cylinder banks connected to the primary pipeline. The generator should be offered a minimum 95% uptime by the vendor. A generator operates best when it is optimally used within its design parameters. hence, it is imperative that plant use is planned for adequate scope of spike and organic growth expected. If oxygen requirement is beyond the prescribed design parameters, the load should shift to secondary source like cylinders.

3.1 User care and preventive maintenance
- The PSA plants should be operated by trained technical manpower. Each hospital should identify such 2-3 people who are well trained in the operation of the PSA plant and depute them for operating such plants. The generator should be maintained by the vendor who installs it. Alternatively, the OEM should officially designate Companies who can / should service these generators.
- Only professionals trained on the preventive maintenance or persons fully conversant with the process should perform preventive maintenance or performance adjustments on the oxygen generator. Ideally, the vendor who installs a generator should have the provision of spares and trained technical resources to service and maintain the generator.
- There should be adequate ventilation in the room where the PSA plant is placed. Proper ventilation is important since the compressor generating hot air exhaust would raise temperature leading to malfunction of the PSA plant. Heavy duty exhaust fans could be one solution or hot air exhaust duct to maintain the room temperature. Ideally, there should be at least two compressors with each PSA Plant.
- The room where the PSA Plant is installed should be closer to the MGPS for ease of maintenance.
• The minimum outlet pressure of PSA plant should be verified at 4.2 bar to maintain adequate pressure and flow of oxygen to service ventilators.
• The PSA plant operator should be well-versed with routine maintenance aspects and minor fault resolution (electrical and technical). The toolkit and spare parts needed for such purpose should be available at the site. This will ensure maximum uptime of the equipment.
• To ensure uninterrupted, seamless operation, inspections listed below should be performed regularly. A detailed checklist is added for the maintenance.

a) Monthly inspections
• During the monthly routine inspection, check that:
  • The drying and regeneration cycles function normally.
  • The silencers are not clogged.

b) Semi Annual Inspections
• During the semi-annual routine inspection, check that:
  • That the drying and regeneration cycles function normally.
  • The silencers are not clogged.
  • Replace filter elements.

C) Annual Inspections
• During the annual routine inspection, check that:
  • The drying and regeneration cycles function normally.
  • The silencers are not clogged.
  • Replace filter elements.
  • The state of all valve seals.
  • During the entire preventive maintenance operation, the compressor and the generator must be shut down. It is recommended for all personnel who are in the presence of the desiccant to wear dust masks.

d) Changing the Desiccant
• Bypass the oxygen supply into the secondary line.
• Disconnect the power supply to the generator.
• Make sure the inlet air supply to the generator is closed.
• Depressurize the pressure in both towers.
• Loosen the dummy present in the tower bottom desiccant port.
• Remove the old desiccant and replace new desiccant one.

e) Replacing the filter element
• Before replacing the element the staff should to check whether the replacement is required.

3.2 Troubleshooting and corrective maintenance
The following problems may exist while using the oxygen plant. This section details the potential issues and possible resolutions.

3.2.1 General troubleshooting
Before reviewing the troubleshooting chart, the following steps may be useful to isolate any malfunctions:
• Turn the generator on. If unit does not turn on, refer to troubleshooting chart.
• Make sure all filters are clean.
• Make sure the unit is cycling properly. If the unit is not cycling properly, refer to troubleshooting chart.
• If generator is not meeting specifications, make sure that the unit is leak free by testing all tubing connections and fittings with leak testing solution. Repair all leaks by tightening connections and fittings.
• Review troubleshooting chart to isolate and repair any other malfunctions.

3.2.2 Other issues

<table>
<thead>
<tr>
<th>Issue</th>
<th>Troubleshooting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Displays not showing up</td>
<td>Check the power supply connection and tension</td>
</tr>
<tr>
<td>Tower Status LED not changing</td>
<td>Change the controller</td>
</tr>
<tr>
<td>LEDS Status Change but Tower not Switching</td>
<td>Check the coil connection at DIN® terminal connector in the controler. Check the solenoid valve</td>
</tr>
<tr>
<td>No Purging</td>
<td>• Check the solenoid valve</td>
</tr>
<tr>
<td></td>
<td>• Check the exhaust valve</td>
</tr>
<tr>
<td></td>
<td>• Clean the silencer (muffler) continuous purging at tower 1A</td>
</tr>
<tr>
<td></td>
<td>– Shuttle not closing</td>
</tr>
<tr>
<td></td>
<td>• Check pilot air for exhaust valve</td>
</tr>
<tr>
<td></td>
<td>• Check exhaust valve piston if it is stuck</td>
</tr>
<tr>
<td>High Purge Loss</td>
<td>• Check outlet shuttle closing</td>
</tr>
<tr>
<td></td>
<td>• Check for silencer choke</td>
</tr>
<tr>
<td>High Pressure Drop across Generator</td>
<td>• Pre-filter may be clogged. Check and replace filter elements.</td>
</tr>
<tr>
<td></td>
<td>• Check whether the generator is being overfilled</td>
</tr>
<tr>
<td>Oxygen Analysery (Purity) Issue</td>
<td>• Follow the flow diagram given by the manufacturer</td>
</tr>
<tr>
<td>Low Operating Pressure</td>
<td>Lower than normal operating pressure may indicate any of the following:</td>
</tr>
<tr>
<td></td>
<td>• A restriction in the suction air intake filter, which limits the amount of air pass through it to the generator. Clean the air filters free from foreign materials.</td>
</tr>
<tr>
<td></td>
<td>• An improperly operating circuit board or solenoid valve. Confirm that the circuit board and solenoid valves function properly.</td>
</tr>
<tr>
<td></td>
<td>• A leak in the unit, which allows system pressure to escape. Perform leak test in the unit.</td>
</tr>
<tr>
<td></td>
<td>• A compressor with reduced output. Ensure that the oxygen concentration level at the desired Her flow is within Tridon’s specifications. If it is below specifications, replace or repair the compressor.</td>
</tr>
</tbody>
</table>
1. INTRODUCTION:

1.1 Medical gas pipeline system (MGPS)

Medical gases are used for patient’s healthcare in multiple ways. In the early 1960s, healthcare providers recognized the hazards of using heavy high-pressure cylinders of medical gases. Now medical gases and vacuum systems are provided by medical gas pipeline system. Medical gas pipeline system is installed to provide a safe, convenient, and cost-effective system for the provision of medical gases to the clinical and nursing staff at the point-of-use. It reduces the problems associated with the use of gas cylinders such as safety, portability, storage, and noise. Patient safety is paramount in the design, installation, commissioning, and operation of medical gas pipeline systems. The basic principles of safety are achieved by ensuring quality of supply, identity of supply, continuity of supply and quality of supply. Pipeline systems supply oxygen at a high pressure to equipment such as anesthetic machines and ventilators. A key advantage of pipeline systems is that they obviate the need for handling and transporting heavy cylinders between hospital wards. The high cost of installing centralized oxygen sources with copper pipelines and the high level of specialized maintenance required currently may make these systems of oxygen delivery unsuitable for many hospitals.

Medical gases are specific gases that are separated from the air individually for various applications. The MGPS provides vital medical gases for patient ventilation and various clinical applications. Commonly used medical gases in hospitals are,

- a) Oxygen (O₂)
- b) Nitrous oxide (N₂O)
- c) Medical air 400 KPa or 4 bar (MA4)
- d) Medical air 700 KPa or 7 bar (MA7)
- e) Carbon dioxide (CO₂)
- f) Nitrogen (N₂)
- g) Medical vacuum

a. Oxygen (O₂)

Oxygen is the most important gas on the earth; it forms about 21 percent of the natural air. In application, it is used as a medical gas to sustain life. It is used in anesthesia machines and ventilators in addition to other methods for manual ventilation. Three sources are used for oxygen supply: cylinders, liquid oxygen tank and oxygen generation plants (Pressure Swing Adsorption). Oxygen is coded in white color.

b. Nitrous oxide (N₂O)

Nitrous oxide is a medical gas administrated via anesthesia machine. It is mixed with oxygen and various anesthetic agents. Therefore, operating rooms are sole location of supply for nitrous oxide. Usually, a manifold supply system is the source of nitrous oxide gas. Cylinders as well as the pipelines coded with blue color.
c. Medical air 4 bar
In general, MedicalAir 4 is used for respiratory applications. The source of supply can be a medical gas manifold system or a medical compressor system. The color code is black color.

d. Medical air 7 bar
Medical air 7 is known as surgical air because it is primarily used for surgical equipment such as tourniquet and bone saw. The supply source is similar to medical air 4.

e. Carbon dioxide (CO₂)
Carbon dioxide is a medical gas used for insufflation purpose in open heart surgery and laparoscopy procedures. Usually, portable cylinders are the source of CO₂, which are coded with grey color.

f. Nitrogen N₂
Nitrogen for surgical power tools is likely to be used only on the sites where it is available, for the production of synthetic air.

g. Medical vacuum
Medical vacuum is provided by means of a vacuum central plant. The vacuum system should always be used in conjunction with vacuum control units that include vacuum jars. In fact, it is not a gas, it is a negative pressure used for suctioning and for anesthetic gas scavenging system. Typically, vacuum is delivered at pressure of 400 mmHg (53 KPa) below atmospheric pressure. Vacuum pipes are coded with yellow color.

2. SOURCES OF SUPPLY
All medical gas supplies are comprised of three sources: “primary”, “secondary” and “reserve”, with the last one commonly referred to as a third means of supply. The supply system should be designed to achieve continuity of supply to the terminal units in normal condition and in a single fault condition. A single fault condition is where a single means for protection against a safety hazard in equipment is defective or a single external abnormal condition is present. Loss of supply due to maintenance of a supply source (or a component within it) is not considered a single fault condition.

Regardless of these classification differences, the choice of central source will be defined by the ability of the source to not only to provide a continuous supply of gas over a range of possible flow rates but also to offer security of supply by virtue of adequate capacity.

For these reasons, types, capacities, and locations of sources of supply are based on both system design parameters and the need for supply security, identified by a risk assessment during the planning stage. Security of medical air supplies must be given a high priority. Total electrical failure must not be allowed to jeopardize supplies, and all medical air systems must be supported by an appropriate fully automatic manifold. Table 9 below elaborates more on the primary, secondary and reserve sources of supply alongside the sources for each.

<table>
<thead>
<tr>
<th>Type of system</th>
<th>Primary supply</th>
<th>Secondary supply</th>
<th>Reserve supply (third source of supply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressed gas cylinder manifold systems</td>
<td>Fully automatic manifold. Number of cylinders based on system design</td>
<td>Manual emergency reserve manifold. To come online automatically via a nonreturn valve. Number of cylinders based on ability to provide 4 hours’ supply at average use</td>
<td>Automatic/manual manifold supplying via non-interchangeable screw thread (NIST) connectors OR Locally based integral valved cylinders with regulator/flowmeters attached</td>
</tr>
<tr>
<td>Liquid cylinder systems</td>
<td>Liquid cylinder manifold system. NB: This is NOT a changeover manifold. All cylinders are on-line simultaneously.</td>
<td>Automatic manifold system. To come on-line in the event of plant failure.</td>
<td>Automatic manifold system. May be sited to support high dependency areas or whole site OR Locally based integral valved cylinders with regulator/flowmeters attached.</td>
</tr>
<tr>
<td>PSA plant</td>
<td>Multiplex compressors and columns (adsorbers). Subject to design.</td>
<td>Automatic manifold system. To come on-line in the event of plant failure. May be filled with third party cylinders or filled from compressor of main plant. Number of cylinders based on ability to provide 4 hours’ supply at average use. Locally filled cylinders or gas suppliers’ cylinders can be used</td>
<td>Type and capacity of supply to be determined by risk assessment.</td>
</tr>
</tbody>
</table>

Table 9: Various options for gas supply

3. PIPELINE DISTRIBUTION SYSTEM DESIGN
The following general information is required to design a medical gas pipeline system:

- Schedule of provision of terminal units.
- Design flow rates and pressure requirements at each terminal unit.
- Diversified flows for each section of the pipeline system.
- Total flow.

4. COMPONENTS OF A MEDICAL GAS PIPELINE SYSTEM
- Each medical gas must be supplied from a separate system. It is essential that all parts of each system are gas specific to ensure that there is no possibility of cross-connection between systems. Indeed, a common configuration is designed to each system including the following components.
4.1 Sources
Sources are supplies that produce the flow of medical gases through piping networks. There are four main sources for medical gases:

a. Bulky systems: They consist of special insulated vessels, vaporizers, and regulators. These systems can be constructed with cryogenic vessels or a high-pressure manifold, depending on the usage. Typically, oxygen, nitrous oxide, and carbon dioxide are supplied to large hospitals in cryogenic tanks.

b. Manifold systems: It consists of high-pressure cylinders on 2 banks; one is a back-up to the other. In addition, the main control panel is installed for primary and secondary regulators, pressure regulators, and warning lamps.

c. Medical air treatment systems: Medical air treatment systems are usually 2 or more compressors equipped with a receiver, derivers, regulators, filters, dew point monitors, and carbon monoxide alarms. The air produced should be free of dust and moisture.

d. Vacuum pumps: Vacuum pumps are mechanized devices that create a negative pressure in the piping system. The pumps should alternate automatically. A reservoir tank is used for storage to permit cycling on and off instead of continuous operation. Each pump should be capable of maintaining 75% per cent of calculated demand during peak time.

4.2 Pipeline Network
Medical gases and vacuum are distributed via the pipeline distribution system to provide gas or vacuum at the endpoint or terminal units. The terminal units may be either wall-mounted or pendant-mounted. The pipes should be made of high-quality copper, seamless type, and non-arsenic. Moreover, it should be protected against physical damage, corrosion and color coded as per gas content.

4.3 Valves
There are 2 types of valves, zone valves and service valves. Zone valves are used to isolate large parts of the system, i.e., rooms for modification and/or repair. In addition, zone valves are placed on corridor walls and should be labeled to indicate the room that they control. On the other hand, service valves are used to isolate certain parts of the system for modification and/or repair. Accordingly, they are accessible by the clinical staff.

Copper seamless pipes with fluxless silver brazing are should be as per ASTM standard and Lloyd’s certification. They are intercepted by the area valve service units (AVSUs) and area alarm panels (AAPs). In the following figures, AVSUs are placed in each clinical sector, to cutoff the gas delivery to the area beyond it during maintenance or to handle emergency. AAPs display the line pressures and have audiovisual alerts.

4.4 Warning and alarm systems
The function of warning and alarm systems is to give information for the responsible staff about the whole plant in case of failure detection or change requirement. This includes the sources, the pipes, the valves, etc. Therefore, there are 2 main alarm systems; master alarms and area alarms. Master alarm monitors the main gas lines and sources conditions. Area alarms are found on alarm panels and their function is to monitor the conditions of specific critical care area.

4.5 Outlets and inlets
Outlets are points at which connections can be made to the medical gas piping system to supply gases under pressure, while inlets are to supply vacuum. These are the final delivery points are color coded, incorporating either the diameter index safety system or are of the quick connect type, available in two varieties, the Diamond and Chemetron in below figures. The Chemetron is a more sturdy variant and is resistant to leakage.

4.6 Secondary equipment
Hoses, gas flow meters, gauges, and vacuum regulator. While these are not part of the
pipeline system, they can contribute substantially to gas and vacuum consumption. These items should be checked as a part of routine inspection procedures.

5. PIPELINE DISTRIBUTION SYSTEM DESIGN

- Number of stations: The first step is to locate and count outlets/inlets, often called "stations" for each specific gas type. There is no code that mandates the exact number of stations in various areas of healthcare facilities. Therefore, this is usually done by the medical planner or the architect based on requirements of the facility.

- Flow rates: Each station must provide a minimum flow rate to ensure proper functioning of connected equipment. The flow rates and diversity factors vary for individual stations depending on the total number of terminal units and the type of provided care. A diversity or simultaneous use factor is used to allow for the fact that not all of the stations will be used at once. It is used to reduce the system flow rate in conjunction with the total connected load for sizing mains and branch piping to all parts of the distribution system. This factor varies for different areas of the facility. For example, diversity factor for operating rooms and emergency rooms is 100 per cent, meanwhile for inpatient rooms is 10 per cent. In general, minimum flow rates can be estimated for any pipe section as: Oxygen - 200 L/min; Medical air - 200 L/min; Vacuum - 85 L/min; Nitrous oxide - 28 L/min; Carbon dioxide - 28 L/min; Nitrogen - 425 L/min.

- Medical gases outlet/inlet terminals: Various types of medical gases outlet/inlet terminals are provided from different manufactures. The terminals are available in various gas sequence center-line spacing, and concealed mounting. It is more practical to select terminals specifications with the adapters found on hospital’s anesthesia machines, flow meters, vacuum regulators, etc.

6. PIPELINE TESTING

Every new installation needs to be tested and verified as per the laid guidelines before putting the system into use. It is important to have a contingency plan to avoid crisis situations.

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

6.1 Indigenous arrangement:

All critical areas should have bulk oxygen cylinders, fitted with a double-stage regulator, tubing, and an adaptor. In case of manifold failure, the AVSU of the area is closed. The pipeline beyond it can now be fed with oxygen from this cylinder, by connecting the adaptor to any oxygen outlet point within the territory. Crisis due to vacuum pipeline failure can be titled over with portable electrical suction units.

7. COLOR CODING FOR GAS PIPELINE

Lack of uniformity of colour coding of pipelines in industrial installations has often been responsible for destruction of property and injury to personnel due to faulty manipulations of values, particularly when outside agencies, like fire-fighting squads, are called in. Colour coding become more crucial in the hospital setup where the life of the patients is on stake. Uniformity of color marking promotes greater safety, lessens the chances of error and reduces hazards involved in the handling of material inside the pipelines. The Indian standard covers the colour scheme for the identification of the contents of pipelines carrying fluids and gases in domestic and public buildings and such industrial establishments where a colour codes do not exist.

![Figure 20: Pipeline identification colours](https://www.joaocp.org/text.asp%3F2018%2F4%2F1%2F99%2F27571)
For the purpose of this standard, piping systems shall include pipes of any kind and in addition fittings, valves, and pipe coverings. Supports, brackets or other accessories are specifically excluded from application of this standard. Identification of the particular contents of the pipelines is achieved by imposing suitable color bands on the ground colour. All pipelines should be color coded with colored bands put at intervals of every 3 meters.

- Ground Colour - The ground colour identifies the basic nature of the fluid and gasses carried and also distinguishes one fluid/gas from another for example oxygen from nitrogen, for the oxygen pipeline ground colour is canary yellow.
- Colour Bands - For the oxygen white colour band is used. Bands will be superimposed on ground colour at the following locations,
  - At battery unit points,
  - Intersection points and change of direction points in piping ways.
  - Other points such as midway of each piping way, near valves, junction points of service appliances, walls on either side of pipe culverts,
  - At the start terminating points

8. SAFETY AND HANDLING
Safety and handling of the MGPS system is covered under safety and handling chapter.

8.1. Duties of Manifold Operator
- First time in the morning, ensure that all the cylinders in the manifold room are OK.
- Open the number of cylinders to ensure the correct pressure in the pipelines.
- Using cylinders from one side of the manifold cylinders bank (right sight or left side)
- The cylinders of the other side should be sent for refilling as soon as all the cylinders of that bank are empty.
- Check all cylinders for leakage using soap water mixture.
- Maintain a stock of required tools with him in the Manifold room.
- After checking the manifold room, take a round of the hospital to see all the outlets by him, and to find out its proper functioning from staff posted there.
- Repair or arrange to repair any defects in the outlets or in the pipeline including Main Manifold room.

- Place order for refilling of the cylinders in consultation with the Authorized officer.
- Take care of the Nitrous cylinders in the operation theatres if there is no central supply of this gas. Ensure supply of oxygen in other areas without central pipeline.
- Help OT Technician in the maintenance of the Boyle’s machine.
- Changing the ward’s cylinder is also his duty.
- All the major problems are to be brought to the administrators immediately.

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CHAPTER 5

OXYGEN CONCENTRATORS

1. BRIEF INTRODUCTION
An oxygen concentrator is a self-contained, electrically powered medical device designed to concentrate oxygen from ambient air. Utilizing PSA technology, an oxygen concentrator draws in air from the environment, extracts the nitrogen, and can produce a continuous source of 95.5% concentrated oxygen.

Oxygen concentrators provide a safe source of oxygen-enriched air. Oxygen concentrators (sometimes referred to as oxygen generators) are devices that draw room air through a series of filters that remove dust, bacteria and other particulates. In the first step of the concentration process, the machine forces air into one of the two cylinders containing a molecular "sieve" material or semi-permeable membranes, where nitrogen is absorbed, leaving concentrated oxygen (90% or higher) and a small percentage of other gases found in room air. At the same time, in the other cylinder, nitrogen is desorbed and drawn out into the atmosphere. In the second step, the function of the cylinders is reversed in a timed cycle, providing a continuous flow of oxygen to the patient. A typical oxygen concentrator may deliver oxygen flows of 0.5–5 LPM (low-flow oxygen concentrators), while some models may generate up to 10 LPM (high-flow oxygen concentrators).

The clinical purpose of oxygen concentrator is to delivery of low-flow, continuous, clean and concentrated oxygen (> 82%) from room air (21%). With appropriate accessories, two or more hypoxaemic patients can be treated with one concentrator. The concentrators can be used across all the levels of care including primary, secondary and tertiary levels.

Figure 22: Oxygen Concentrator

Capacity determined by flowmeter in liters per minute (LPM)
1.1 Functional characteristics

- Contains oxygen monitor to verify concentration.
- Delivers oxygen through a nasal prongs or nasal catheter.
- Flow from one concentrator can be divided for at least two paediatric patients with (built-in or add-on) flowmeters that allow continuous flow rate control.
- Requires continuous AC power source to operate, such as solar power, battery or mains electricity & backup (e.g. generator, UPS or battery).

(Maximum flow is chosen based on the expected patient load at any given time. Oxygen needs vary per patient and application. In general, up to 2 L/min per patient under 5 years of age is needed.)

1.2 Advantages and disadvantages

Evidence arising from both prospective and retrospective trials and randomised controlled trials (with a minimum 12-month follow-up) suggests that oxygen concentrator use where appropriate improves survival rates for respiratory conditions, improves mental attentiveness, increases stamina and improves mood. The majority of studies have been performed in patients with COPD and that the duration of oxygen supply per se affects survival. In hypoxaemic chronic obstructive lung disease, continuous oxygen therapy is associated with a lower mortality than is nocturnal oxygen therapy.

1.2.1 Advantages

Oxygen concentrators do not need to be refilled. The concentrators run on electrical power and thus supply an unlimited amount of oxygen. Portable concentrators can be used in an “on-the-go” mode with a battery pack, resulting in up to 12 h of continuous use for some models. From a long-term view, concentrators are more cost-effective than compressed gas cylinders, and they are known to last for up to 1500 h of continuous use.

1.2.2 Disadvantages

The significant disadvantage of oxygen concentrators is the need for electrical power to function. It is necessary to prepare for unscheduled power outages by setting up a backup power generator at home. Patients using stationary oxygen concentrators need to consider changing filters weekly, regular servicing and the warm-up period of the machine, as well as noise and vibration from the older models of device.

2. PREREQUISITE: PRE INSTALLATION REQUIREMENTS

- Verify plug electrical requirements with socket to be used.
- Clinical and staff training on device use.
- System for procuring spare parts.

2.1 Electrical connections

- Electrical source requirements to be locally compatible (voltage and plug type need to be specified).
- Capacity for safe operation on at least ± 10% of local rated voltage.
- Mains power cable to have length ≥ 2.5 m.
- Electrical protection by resettable circuit breakers or replaceable fuses, fitted in both neutral and live lines.
- Power backup in the form of UPS and inverters is suggested.

3. MAINTENANCE AND TROUBLESHOOTING

3.1 User care and preventive maintenance

3.1.1 User care

- Device exterior to be wiped effectively with a mild solution of detergent or cleaning agent (weekly), without connection to mains power.
- Gross particle filter to be cleaned effectively when removed and washed with soap and water (weekly).
- Do not clean with alcohol. (User care needed more often in very dusty environments.)

3.2 Corrective maintenance and troubleshooting of oxygen concentrator

<table>
<thead>
<tr>
<th>Schedule Period</th>
<th>Activities</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Cleaning</td>
<td>Remove any dust / dirt with damp cloth and dry off. Fill humidifier bottle up to marker with clean distilled water,</td>
</tr>
<tr>
<td></td>
<td>Visual checks</td>
<td>Check all screws, connectors, tubes and parts tightly fitted,</td>
</tr>
<tr>
<td></td>
<td>Function</td>
<td>Check oxygen flow before clinically required.</td>
</tr>
</tbody>
</table>

| Weekly          | Cleaning   | Clean cylinder, valve and flowmeter with damp cloth, |
|                 | Visual checks | Check for leakage: hissing sound or reduction in pressure, |
|                 | Function    | Remove valve dust with brief, fast oxygen flow checks. Check flow can be varied using flow control. |

Table 11: Preventive maintenance oxygen concentrators
**Problem or fault** | **Possible cause** | **Solution**
---|---|---
Unit not operating, power failure alarm sounds | No power from mains socket | Check mains switch is on and cable inserted. Replace fuse with correct voltage / current if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for repair if required.
Concentrator circuit breaker has been set off | | Press reset button if present
Electrical cable fault | | Try cable on another piece of equipment. Contact electrician for repair if required.
Unit not operating, no power failure alarm | Alarm battery dead | Replace battery and test as above
Flow not visible | | Place tube under water and look for bubbles. If bubbles emerge steadily, gas is indeed flowing
Tubes not connected tightly | | Check tubing and connectors are fitted tightly
Water or matter blocking the oxygen tubing | | Remove tubing, flush through and dry out before replacing
Blocked flow meter or humidifier bottle | | Replace meter / bottle or refer to biomedical technician
Temperature tight or low oxygen alarm is on | Unit overheated or obstructed | Remove any obstruction caused by drapes, bedspread, wall, etc. Clean filters, Turn unit off, using standby oxygen system. Restart unit after 30 minutes. Call biomedical technician if problem not solved.
Electrical shocks | Wiring fault | Refer to electrician

Table 12: Troubleshooting and corrective maintenance of oxygen concentrator

**CHAPTER 6**

**PULSE OXIMETER AND ACCESSORIES**

**1. BRIEF INTRODUCTION**

**1.1 Purpose**

Pulse oximeter is a portable, tabletop device intended for use in simultaneously measuring, displaying and recording functional oxygen saturation of arterial hemoglobin (SpO2) and pulse rate of adult and pediatric and neonatal patient. Oximetry refers to the determination of the percentage of oxygen saturation of the circulating arterial blood.

In clinical practice, percentage of oxygen saturation in the blood is of great importance. This saturation being a bio-constant (usually 95 to 100 percent in normal human being), is an indication of the performance of the most important cardio-respiratory functions.

**1.2 The main application areas of oximetry are**

1. The diagnosis of cardiac and vascular anomalies.
2. The treatment of post-operative anoxia (absence of oxygen).
3. Treatment of anoxia resulting from pulmonary affections.
4. A major concern during anaesthesia is the prevention of tissue hypoxia (decrease in oxygen level to tissues), necessitating immediate and direct information about the level of tissue oxygenation.
5. Oximetry is now considered a standard of care in anaesthesiology and has significantly reduced anaesthesia-related cardiac deaths.
6. Spot checking and/or continuous monitoring of patient during both motion and no-motion conditions.

<table>
<thead>
<tr>
<th>General Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-contained fingertip</strong></td>
</tr>
<tr>
<td><strong>Illustration</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
</tbody>
</table>
### General Characteristics

<table>
<thead>
<tr>
<th>Self-contained fingertip</th>
<th>Portable handheld</th>
<th>Tablettop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement of pulse rate and SpO2 to detect hypoxaemia, supporting the diagnosis of respiratory disorders. Almost always designed for adults. Some paediatric models can be used on children (check weight range for device), but are not appropriate for use in neonates. Suitable for spot checks only.</td>
<td>Measurement and/or ongoing monitoring of pulse rate and SpO2 to detect hypoxaemia, supporting the diagnosis of respiratory disorders. Most, but not all, will display a plethysmography waveform. Suitable for spot checks, or for continuous monitoring if used for continuous monitoring, alarm feature must be available and activated, and device must be regulatory approved for continuous monitoring.</td>
<td>Monitoring of pulse rate, SpO2 and plethysmography waveform to detect hypoxaemia, supporting the diagnosis of respiratory disorders. Suitable for longer term continuous monitoring.</td>
</tr>
</tbody>
</table>

### Appropriate level of health system (and areas of use)

| Primary, secondary and tertiary level, but application dependent, i.e., where spot checking on adults (or children, if a paediatric model for an appropriate weight range is used) is the desired function. | Primary, secondary, tertiary, e.g., health centres, general medical and outpatient areas, operating room, ICU, neonatal intensive care unit (NICU), recovery. | Secondary and tertiary, e.g., general medical and outpatient areas, operating room, ICU, NICU, recovery. |

### Parameters monitored

| SpO2, Pulse rate. | SpO2, Pulse rate (some may have additional features as RN). | SpO2, Pulse rate (some may have additional features). |

### Accessories required

| Replacement batteries, may have USB cable for charging. | Probes; size specific to the patient – adult, child, infant and neonate (measles probes typically need replacing at least once per year), Replacement batteries, Charging power cable. | Probes; size specific to the patient – adult, child, infant and neonate (measles probes typically need replacing at least once per year), Charging power cable. |

### Merits

| Low upfront cost, Portable, Self-contained unit, no external probes/leads. | Multiple use-case options. Portable, More alarms and internal memory than fingertip devices. Typically, have 12 hours operational capacity on rechargeable built-in battery and take ≤ 4 hours to charge. Typically have a port (or Wi-Fi) for downloading and/or printing data. | Multiple use-case options. May be wall mounted, Large internal memory to store patient ID’s and records, Ideal for hinged probe (or Wi-Fi) for downloading and/or printing data. Most accurate, in general. |

### Table 13: Types pulse oximeter

1.3 Controls on display
- Power/standby button
- SpO2 alarm setting button
- Heart rate alarm setting button
- Set button (alarm, volume)
- Alarm silence button

1.4 The pulse oximeter probe

The oximeter probe consists of two parts, the light emitting diodes (LEDs) and a light detector (called a photo-detector). Beams of light are shone through the tissues from one side of the probe to the other. The blood and tissues absorb some of the light emitted by the probe. The light absorbed by the blood varies with the oxygen saturation of hemoglobin. The photo-detector detects the light transmitted as the blood pulses through the tissues and the microprocessor calculates a value for the oxygen saturation (SpO2). In order for the pulse oximeter to function, the probe must be placed where a pulse can be detected. The LEDs must face the light detector in order to detect the light as it passes through the tissues. The probe emits a red light when the machine is switched on; check that you can see this light to make sure the probe is working properly. Probes are designed for use on the finger, toe or ear lobe. They are of different types as shown in the diagram. Hinged probes are the most popular but are easily damaged. Rubber probes are the most robust. The wrap around design may constrict the blood flow through the finger if put on too tightly.

Ear probes are lightweight and are useful in children or if the patient is very vasoconstricted. Small probes have been designed for children but an adult hinged probe may be used on the thumb or big toe of a child. For finger or toe probes, the manufacturer marks the correct orientation of the nail bed on the probe.

![Types of probes](image)

The oximeter probe is the most delicate part of a pulse oximeter and is easily damaged. Handle the probe carefully and never leave it in a place where it could be dropped on the floor. The probe connects to the oximeter using a connector with a series of very fine pins that can be easily damaged, see diagram. Always align the connector correctly before attempting to insert it into the monitor. Never pull the probe from the machine by pulling on the cable, always grasp the connector firmly between finger and thumb.
# 2. USER SET UP INSTRUCTIONS

After supply of the equipment ensure that it is open from the box and installed properly by authorized company personnel.

## 2.1 Operating instructions
- Turn the pulse oximeter on: it will go through internal calibration and checks.
- Select the appropriate probe with particular attention to correct sizing and where it will go (usually finger, toe or ear). If used on a finger or toe, make sure the area is clean. Remove any nail varnish.
- Connect the probe to the pulse oximeter.
- Position the probe carefully; make sure it fits easily without being too loose or too tight.
- If possible, avoid the arm being used for blood pressure monitoring as cuff inflation will interrupt the pulse oximeter signal.
- Allow several seconds for the pulse oximeter to detect the pulse and calculate the oxygen saturation.
- Look for the displayed pulse indicator that shows that the machine has detected a pulse. Without a pulse signal, any readings are meaningless.
- Once the unit has detected a good pulse, the oxygen saturation and pulse rate will be displayed.
- Like all machines, oximeters may occasionally give a false reading - if in doubt, rely on your clinical judgement, rather than the machine.
- The function of the oximeter probe can be checked by placing it on your own finger.
- Adjust the volume of the audible pulse beep to a comfortable level for your theatre – never use on silent.
- Always make sure the alarms are on.

## 3. MAINTENANCE AND TROUBLESHOOTING OF PULSE OXIMETER

### 3.1 Maintenance and preventive Care
- Regularly clean the pulse oximeter so as to prevent accumulation of dust and other hospital fluids on the body of the pulse oximeter.
- Ensure protection from bright lights.
- Keep a patient away from devices inducing electromagnetic fields like MRI, CAUTERY machine etc.
- Check cable and equipment for any external damages.
- Fold the SpO2 cable properly and do not pull the sensor.
- Clean reusable sensors with spirit after each patient use.

### 3.2 Troubleshooting of Pulse oximeter

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oximeter will not power up</td>
<td>Battery is completely discharged</td>
<td>Change the batteries for 6 hours by connecting to the AC mains.</td>
</tr>
<tr>
<td></td>
<td>Battery is not getting charged</td>
<td>Check the AC mains socket for proper voltage.</td>
</tr>
<tr>
<td></td>
<td>Sensor or patient cable is disconnected from the oximeter</td>
<td>Check sensor patient cable connections</td>
</tr>
<tr>
<td>No pulse shown on the bargraph</td>
<td>Sensor is incorrectly positioned on the patient</td>
<td>Reposition the sensor</td>
</tr>
<tr>
<td></td>
<td>Poor patient perfusion</td>
<td>Reposition the sensor</td>
</tr>
<tr>
<td></td>
<td>Defective sensor or patient cable</td>
<td>Try a new sensor or patient cable or contact our dealer.</td>
</tr>
<tr>
<td>Segments of SpO2 or pulse rate missing</td>
<td>Excessive motion at sensor site may be prohibiting the oximeter from acquiring a consistent pulse signal</td>
<td>Eliminate or reduce cause of motion artefact OR reposition sensor to new sensor site where motion is not present.</td>
</tr>
<tr>
<td></td>
<td>Displayed pulse rate does not correlate with pulse rate on ECG monitor</td>
<td>Patient may have arrhythmia resulting in some heart beats that do not yield a perfusion signal at sensor site</td>
</tr>
<tr>
<td></td>
<td>ECG monitor may not be functioning properly.</td>
<td>Examine the patient: condition may persist even though both the monitors are functioning properly if patient’s arrhythmia persists.</td>
</tr>
<tr>
<td>Erratic pulse display and/or yellow perfusion LED during concurrent use of electrosurgical equipment (ESU)</td>
<td>ESU may be interfering with oximeter performance</td>
<td>Examine the patient: Replace ECG monitor OR refer to operator’s manual of ECG monitor</td>
</tr>
<tr>
<td>Perfusion is blinding yellow with each pulse</td>
<td>Perfusion signal at sensor site is marginal</td>
<td>Examine the patient: Reposition sensor OR select alternate sensor site</td>
</tr>
</tbody>
</table>
### Common problems and remedies of pulse oximeter

<table>
<thead>
<tr>
<th>Problem Description</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low patient pulse strength sensor site poorly perfused sensor not correctly positioned. Excessive cold condition.</td>
<td>Reposition sensor on patient</td>
</tr>
<tr>
<td>Sensor attached too tightly or tape is restricting perfusion at sensor site</td>
<td>Reposition sensor, select alternate site or remove restrictive material from sensor site</td>
</tr>
<tr>
<td>Circulation reduced due to excess pressure between sensor and hard surface</td>
<td>Allow sensor and finger to rest comfortably on surface</td>
</tr>
<tr>
<td>Excessive ambient light</td>
<td>Reduce ambient light</td>
</tr>
<tr>
<td>Excessive patient motion</td>
<td>Reduce patient motion OR select alternate sensor site</td>
</tr>
<tr>
<td>Sensor applied to polished fingernail</td>
<td>Remove fingernail polish</td>
</tr>
<tr>
<td>Interference from arterial catheter, blood pressure cuff, electro-surgical procedure, infusion line.</td>
<td>Reduce or eliminate interference</td>
</tr>
<tr>
<td>Inadequate perfusion signal at sensor site</td>
<td>Examine the patient; Reposition sensor OR select alternate sensor site</td>
</tr>
<tr>
<td>Excessive motion at sensor site may be preventing the oximeter from acquiring a constant pulse signal.</td>
<td>Eliminate or reduce cause of motion artefact OR reposition sensor to new sensor site where motion is not present</td>
</tr>
<tr>
<td>Sensor alarm sound continuously</td>
<td>Check sensor connection to oximeter; Check proper connection to patient; Sensor fault needs replacement.</td>
</tr>
<tr>
<td>Alarm sounds continuously</td>
<td>Reset the alarm limits OR Reset the oximeter to factory default settings</td>
</tr>
<tr>
<td>Error &quot;Oximeter Module Faulty sensor/Try replacing sensor&quot;</td>
<td>Contact your dealer for repairs</td>
</tr>
</tbody>
</table>

### 3.3 Do’s and Don'ts

**a. Do’s**
- Inspect sensor site every 2 to 4 hours for any erythema (reddish ness of patient skin) or discoloration.
- Change sensor site every 4-6 hours.

**b. Don’ts**
- Do not apply sensor too tightly.
- Do not apply probe to edematous (edema - accumulation of fluid beneath skin) and or bruised sites.
- Do not autoclave, pressure sterilize or gas sterilize.
- Do not soak or immerse the pulse oximeter in liquid.
- When cleaning the display area do not use abrasive cleaning compounds or other materials that could damage the screen.
- Do not use petrol based solutions, acetone solutions or other harsh solvents to clean the pulse oximeter.

### 3.4 Fast moving spares and accessories

- Electrical fuses.
- Sensor probe.

### 3.5 Bare minimum tools required

- Screw driver for fuse replacement.
1. BRIEF INTRODUCTION

1.1 Devices for oxygen regulation and conditioning

The oxygen therapy products covered in this section include flowmeters, flow-splitting devices and humidifiers. These devices play different roles in the regulation and conditioning of oxygen gas for the delivery of oxygen therapy to patients.

1.1.1 Flow meter

In oxygen therapy systems, flowmeters are needed to measure and control the rate of oxygen flow to patient, either from a concentrator, a high-pressure cylinder, or a terminal unit of a piped system.

Concentrators have built-in flowmeters so there is no need to purchase them separately. When using oxygen sources with varying pressures (e.g. oxygen cylinders or terminal units), it is important that flowmeters are placed on the low-pressure side, downstream of a pressure-reducing valve.

Three types of gas flowmeters are described in this overview: Thorpe tube, Bourdon gauge and dial/click. All three types come in various flow ranges. The choice of appropriate flowmeter will depend on clinical needs and device capabilities. Below mentioned table provides a comparison of these three device types.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Merits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorpe tube</td>
<td>A variable orifice flowmeter consisting of an upright clear tube contains a float, which rises and falls in relation to gas flow. There are two types: uncompensated and compensated for back pressure. Requires a separate pressure-reducing valve.</td>
<td>Affected by gravity; works in a vertical position only. Needs additional pressure regulator and gauge. Fragile. Uncompensated: can display an erroneously high flow rate.</td>
<td>Can only choose flow rates in fixed increments. Expensive. Accurate only at rated pressure.</td>
</tr>
<tr>
<td>Bourdon gauge</td>
<td>In a fixed orifice flowmeter gas enters a chamber and as the pressure is increased, a coiled copper tube straightens out and the needle valve turns to read a higher unit. This device integrates with a pressure-reducing valve.</td>
<td>Not back pressure compensated. As flow increases, the indicated flow reading becomes inaccurate.</td>
<td></td>
</tr>
<tr>
<td>Dial/click</td>
<td>Flow-meter calibrated to deliver flow in specific increments, labeled with a dial. This device integrates a pressure-reducing valve.</td>
<td>Ideal for ambulance transportation. Recommended for use with smaller portable cylinders common for emergency and ambulance transportation.</td>
<td></td>
</tr>
</tbody>
</table>

Table 15: Description and comparison of flowmeters

Thorpe tube flowmeter has following variants -

a) Pressure regulator and outlet connector (e.g., DISS) (male). Connector (DISS or other convention) can be connected to flowmeter.

b) A barbed “Christmas tree” connector for oxygen tubing.

c) A humidifier bottle.

d) An example of a dual flowmeter from a single wall source for use with two patients.
1.1.2 Flow-splitting devices

A flow-splitting device can provide an effective and efficient means of economically administering medical oxygen to multiple patients from a single source, when the supply permits. Flow-splitting devices may be used with concentrators, cylinders and centralized systems for both paediatric and adult patients. The two main devices for splitting oxygen flow discussed here are the flowmeter stand and the dual flowmeter.

a. Flowmeter stand: A flowmeter stand, also referred to as flowmeter station or assembly, is a device that distributes medical oxygen, in a controlled manner, from a single source to multiple (up to five) outlets through independent flowmeters, to meet individual patient needs. It is most commonly used with concentrators or in settings where there are few oxygen sources.

The flowmeter stand is equipped with independent pressure-compensated Thorough tube flowmeters to measure and regulate the flow at each outlet. Each flowmeter is adjusted separately to ensure precise control with a visual indication for flow safety. The ability of the flowmeter stand to deliver indicated flow rates is limited by the flow and pressure provided by the oxygen source. For example, when used with an oxygen concentrator, the combined flow rates of individual outlets cannot exceed the output flow rate of the concentrator. Because of this combined flow limitation, the flowmeter stand is recommended for paediatric or neonatal use where lower flow rates are required.

b. Dual flowmeter: This is a twin configuration of a Thorough tube flowmeter to allow independent gas supply to two patients from a single gas source. This device is most suitable for connection to a terminal unit oxygen source.

c. Plastic flow splitter: These are devices that distribute medical oxygen from a single source to multiple outlets. For example, Y connectors divide flow into two outlets. These devices, however, are not recommended to be used alone because the flow may not be divided equally and there is no indicator of actual flow from each outlet.

Table 16: Description and comparison of flow splitting devices
1. 1.3 Humidifiers

a. Oxygen humidifiers: These are medical devices that can be integrated into oxygen delivery systems to humidify supplemental oxygen. Humidification is generally not necessary when oxygen is delivered at relatively low flow rates through nasal prongs or nasal catheters. When oxygen is delivered at higher-than-standard flow rates, or when methods of oxygen delivery bypass the nose, such as when nasopharyngeal catheters are used, humidification is needed—especially when cold oxygen is delivered from a cylinder.

There are various types of humidifiers, and their designs differ in how they apply the main principles related to humidification:

b. Temperature: As the temperature of gas increases, its ability to hold water vapor increases.

c. Surface area: There is more opportunity for evaporation to occur due to greater surface area of contact between water and gas.

d. Time of contact: There is more opportunity for evaporation to occur when a gas remains in contact with water for a long duration.

<table>
<thead>
<tr>
<th>Bubble humidifier – Non heated (reusable)</th>
<th>Bubble humidifier – Non heated (single use)</th>
<th>Bubble humidifier – heated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Illustration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A reusable bottle that reduces the dryness of oxygen by bubbling the gas through distilled water (or water that has been boiled and cooled) at room temperature.</td>
<td>A single-use bottle that reduces the dryness of oxygen by bubbling the gas through distilled water at room temperature.</td>
<td>A device consisting of a humidification chamber whereby the bubbling water warms the water in the chamber to add moisture to the airstream as it passes over the surface.</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduces drying of the nasal passages during oxygen therapy. Used when oxygen is delivered at higher-than-standard flow rates, or when methods of oxygen delivery bypass the nose, such as when nasopharyngeal catheters are used.</td>
<td>Heated humidification is needed for CPAP and for HFNC oxygen therapy.</td>
<td></td>
</tr>
<tr>
<td><strong>Clinical application and/or use case</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary, secondary and tertiary level.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Appropriate level of health system (and relevant medical units)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 17: Description and comparison of humidifiers

2. OXYGEN DELIVERY DEVICES

This section describes the devices that connect an oxygen source to a patient, for the delivery of oxygen therapy. These delivery methods can be used regardless of what source of oxygen is used (cylinder, concentrator or piped system).

Devices for oxygen delivery differ in cost, efficiency of oxygen use, and ability to provide the requisite fraction of inspired oxygen (FiO2) (i.e. the percentage or concentration of oxygen that a patient inhales). The choice of appropriate delivery device will thus depend on clinical needs and device capabilities.

<table>
<thead>
<tr>
<th>Nasal Cannula (prongs)</th>
<th>Nasal Catheter</th>
<th>Other noninvasive options (face mask, head box, incubator, tent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illustration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic tube that end in two short, tapered prongs that are placed in the nares.</td>
<td>Thin, flexible tube that is passed into the nose and ends with its tip in the nasal cavity.</td>
<td>Various non-invasive methods of oxygen delivery are available, including head boxes, face masks (simple, partial rebreathing and non rebreathing), incubators and tents.</td>
</tr>
<tr>
<td><strong>General characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-flow oxygen therapy for the treatment of hypoxaemia.</td>
<td>Low-flow oxygen therapy for the treatment of hypoxaemia.</td>
<td>Applications where FiO2 needs to be tightly controlled. Typically, higher flows are required to achieve adequate concentration of oxygen and prevent carbon dioxide accumulation.</td>
</tr>
<tr>
<td><strong>Clinical application and/or use case</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. OXYGEN ANALYSERS

Oxygen analysers, also referred to as oxygen monitors, are devices that measure and display the concentration of oxygen in patient breathing circuits, medical gas supply lines, compressed gas cylinders, and oxygen concentrators. They are also used to check and adjust devices used to administer oxygen to patients.

Some oxygen analysers are designed to continuously measure oxygen concentration inhaled by a patient in a respiratory therapy setting (e.g., in an anaesthesia or ventilator breathing circuit, infant oxygen hood, or oxygen therapy system tubing). Oxygen analysers can also be built into ventilators or anaesthesia units, where the oxygen sensor is automatically enabled when the system is in use. In a continuous patient monitoring application, an alarm is required to alert clinical personnel when the oxygen concentration reaches a dangerous level or goes beyond a predetermined range.

Other analysers are intended to perform routine oxygen spot checks either at the oxygen source (e.g., an oxygen concentrator), in the environment (e.g., oxygen hood) or during equipment maintenance. In this case, alarms may not be necessary. In this chapter, the focus is on such portable handheld analysers that a biomedical engineering technician or health worker could use to test the concentration of oxygen from a concentrator or the low-pressure side of a compressed gas cylinder or terminal unit source.

### 3.1 Oxygen analyser features

- **Oxygen analyzer for testing concentration:** Electrochemical
- **Oxygen analyzer for testing concentration:** Ultrasonic
- **Multiparameter analysers:** (Concentration, flow and pressure)

### General characteristics

<table>
<thead>
<tr>
<th>Description</th>
<th>Oxygen analyzer for testing concentration using electrochemical sensing technology.</th>
<th>A device that measures and displays the oxygen concentration using ultrasonic oxygen sensing technology.</th>
<th>A device designed to test all types of gas flow equipment especially those requiring high accuracy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical application and/or use case</td>
<td>Can be used for continuous monitoring and for spot checking at an oxygen source or in an environment. All clinical departments that use oxygen should have an analyser and use it regularly.</td>
<td>Spot checking and servicing of PSA-generated oxygen, from concentrators, and clinical departments that use analysers.</td>
<td>Equipment spot checking and servicing.</td>
</tr>
<tr>
<td>Appropriate level of health system</td>
<td>Primary, secondary, tertiary.</td>
<td>Primary, secondary, tertiary.</td>
<td>Secondary, tertiary.</td>
</tr>
</tbody>
</table>

![Multiparameter analysers](image)

### Other technologies

- **Venturi mask**
  - Delivers 24-80% oxygen
  - Different colours deliver different rates
  - Flow rate: Appropriate flow rate is denoted by the colour of the mask and percentage of oxygen delivered is annotated on the mask.

Types:
- **BLUE** = 2-4L/min = 24% Oxygen
- **WHITE** = 4-6L/min = 28% Oxygen
- **YELLOW** = 6-10L/min = 35% Oxygen
- **RED** = 10-12L/min = 40% Oxygen
- **GREEN** = 12-15L/min = 60% Oxygen

**Figure 26: Venturi mask**

Venturi masks are often used in COPD, where it is important not to over-oxigenate the patient.

### Table 18: Description and comparison of oxygen delivery options
4. VENTILATORS

Mechanical ventilator is an apparatus which can replace normal mechanism of breathing either by providing intermittent or continuous flow of oxygen or air under pressure, which is connected to the patient by a tube inserted through mouth, the nose or an opening in the trachea.

Mode

Mode is the set up or level that characterises and modifies the manner in which oxygen is delivered to the patient.

- Types of non-invasive mode
  - BIPAP Mode
  - C PAP Mode

- Types of invasive mode
  - Controlled
  - Supportive
  - Combination

Ventilator equipment maintenance includes cleaning, sterilization, adjustment, servicing, and repair.

Minor maintenance procedures can be done at the hospital by a biomedical engineer, as per instructions by the manufacturer. For major repairs, it is suggested to have a maintenance and repair check through the biomedical engineer allocated by the manufacturer.

This is the way to achieve ideal working conditions and to enhance reliability and durability of the equipment. It is obvious that regular servicing is better than expensive repairs and is less costly in the long run. Both systems working together would be more efficient, but this is difficult to achieve because of the restrictions in personnel.

**CPAP & BiPAP**

CPAP and BiPAP machines are both forms of positive airway pressure therapy, which uses compressed air to open and support the airway during sleep. A portable machine generates pressurized air and directs it to the user's airway via a hose and mask system. Both systems use the same masks, hoses, and other accessories.
4.1 CPAP
Continuous airway pressure machines direct pressurized air — usually set between 4 and 20 cm H2O — into a user’s airway while they sleep. This pressure keeps air passages open and ensures the user can breathe properly, allowing them to avoid the pauses in breathing (or apneas) that are the primary symptom of sleep apnea.

CPAP machines continuously pump air at one pressure setting rather than varying in pressure between the inhale and exhale, which can cause some people to feel as though they cannot exhale properly or that they are choking. Most users adjust to CPAP relatively quickly, while others find BiPAP easier to tolerate.

Unlike BiPAP machines, CPAP machines are available in a range of sizes. The most common type is intended to be used at home and is slightly smaller than a shoebox, while travel versions may be small enough to fit in the palm of your hand. Travel models sometimes have backup batteries for use while camping, and FAA-approved models are available for use on planes.

4.2 BiPAP
Bi-level positive airway pressure machines have two air pressure settings: one for the inhalation phase (IPAP), and one for exhalation (EPAP). The EPAP is usually significantly lower than the IPAP, allowing users to breathe more naturally and not experience resistance from the machine during exhale. Most machines have a range of approximately 4 to 25 cm H2O, 5 cm H2O higher on the upper end than CPAP machines.

BiPAP machines have up to three settings for the switch between IPAP and EPAP:
1. Spontaneous switching automatically senses the user’s breathing pattern and switches between the two pressure levels when they naturally inhale and exhale. The majority of BiPAP users rely on this setting, and it is standard for BiPAP devices.
2. Timed switching allows users to program how long each IPAP and EPAP phase should last. This ensures users take the correct number of breaths per minute and can function much like a ventilator.
3. Spontaneous/timed switching is primarily spontaneous, following the user’s natural breathing patterns. On this setting, timed switching turns on when the machine senses that the user has dropped below a set number of breaths per minute.

1.1 OXYGEN CALCULATION
1.1.1 Oxygen Calculator Purpose
• Evaluating the capacity of oxygen available in the hospital.
• Determine total litres per minute requirement in normal circumstances.
• Estimate oxygen supply balance.
• Used as an estimation tool during oxygen weaning protocol implementation.
• Helps understand complex conversion from Metric Ton to Kilo Litres, Kilo Litres of liquid oxygen to gaseous state of oxygen.
• Will assist auditors to fill audit forms compiled by Government of Meghalaya and other governance.
• Factors amount of oxygen required through in LMO Tanks.
• Factors amount of residual oxygen in dura & jumbo cylinders.
• Manages the safety factor and determines the period for which the oxygen supply would last. Keeps safety factor and arrives at when oxygen supply should last.

1.1.2 Oxygen Calculator - Points to Remember
If oxygen supply utilization time in the hospital practically differs from the time determined using the calculator calculator, it could be due to the following reasons:
• There could be leakages
• Oxygen weaning protocol is not properly practiced
• Pressure settings in the hospitals are wrong

a. Oxygen Supply Process and Delivery Conversion
• Oxygen is supplied by manufacturers to hospitals in cryogenic form and is measured in metric tons.
• Oxygen is moved to LMO tank, it is measured in litres or kilo litres.
• Oxygen is delivered to patients in gaseous form in litres per minute via oxygen points.

b. Oxygen Supply Process and Conversion Calculation
Conversions
• 1 CuM (m³) = 1,000 liters (Gaseous O₂)
• 1 Metric Ton (MT) = 770 CuM (m³) = 7,70,000 liters (Gaseous O₂)
• 1 Metric Ton (MT) = 876 litres of Liquid Oxygen
• 1KL Liquid O2 = 877.8 CuM
• 1 Litre Liquid O2 = 861 litres of gaseous O₂
1. Gaseous oxygen litres to cubic meters (m3) to metric ton (MT)

<table>
<thead>
<tr>
<th>Qty in liter of gas</th>
<th>Qty in CuM</th>
<th>Qty in kg</th>
<th>Qty in MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1</td>
<td>1.429</td>
<td>0.001429</td>
</tr>
</tbody>
</table>

2. Gaseous Oxygen LPM (liter per min) to MT/day

<table>
<thead>
<tr>
<th>Qty in liter of gas per day (LPM x 60 mins x 24 hours)</th>
<th>Qty in kg per day (Litres of gas x 0.001429)</th>
<th>Qty in MT per day (Qty in kg / 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LPM</td>
<td>1,440</td>
<td>2.05776</td>
</tr>
<tr>
<td>100 LPM</td>
<td>14,400</td>
<td>205.776</td>
</tr>
<tr>
<td>500 LPM</td>
<td>72,000</td>
<td>1,028.880</td>
</tr>
<tr>
<td>1000 LPM</td>
<td>144,000</td>
<td>2,057.760</td>
</tr>
</tbody>
</table>

3. Converting kilo liter (KL) (Liquid oxygen) to metric ton (MT)

<table>
<thead>
<tr>
<th>Qty in litres of liquid oxygen</th>
<th>Qty in KL</th>
<th>Qty in kg</th>
<th>Qty in MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1</td>
<td>1141.7</td>
<td>1.1417</td>
</tr>
</tbody>
</table>


1.2 Oxygen Requirement/Consumption based on bed strength

<table>
<thead>
<tr>
<th>Column No</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oxygen beds</td>
<td>Oxygen flowrate (LPM)</td>
<td>Oxygen requirement per day in Cubic meter</td>
<td>Total oxygen requirement</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>10 litres/min</td>
<td>60 minutes x 24 hrs /1000 (to convert litres to m³)</td>
<td>X=Column(A) x (LPM/1000) x 24</td>
</tr>
</tbody>
</table>

 Oxygen requirement for ICU beds in DCH facilities

<table>
<thead>
<tr>
<th>Column No</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ICU beds</td>
<td>Oxygen flowrate (LPM)</td>
<td>Oxygen requirement per day in Cubic meter</td>
<td>Total oxygen requirement</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>30 litres/min</td>
<td>60 minutes x 24 hrs /1000 (to convert litres to m³)</td>
<td>X=Column(F) x (LPM/1000) x 24</td>
</tr>
</tbody>
</table>

Table 20: Oxygen requirement/consumption based on bed strength

Note: Flow rate of 10 LPM/O2 best and 30 LPM/O2 ICU bed are considered for consumption calculation as per latest GoI guideline D.O.No. T:20017/53/2021-NCD (PT): 81/0354 dated 21st June 2021. These flow rates are subject to change depending on revised guidelines from GoI.

1.3 Daily Oxygen Consumption/requirement Based on Active Cases

<table>
<thead>
<tr>
<th>Column No</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr No</td>
<td>Active cases</td>
<td>O2 supported beds required (8% active cases)</td>
<td>ICU beds O2 requirement (4% active cases)</td>
<td>Total Oxygen consumption (Cubic Meters) @ 10 LPM flowrate</td>
<td>ICU beds oxygen consumption (Cubic Meters) @ 30 LPM flowrate</td>
<td>Total Oxygen Consumption (MT)</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Column no &quot;A&quot;@100</td>
<td>Column no &quot;A&quot;@100</td>
<td>Column no &quot;A&quot;@100</td>
<td>Column no &quot;A&quot;@100</td>
<td>Column no &quot;A&quot;@100</td>
<td>Column no &quot;D&quot;@100</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
<td>1000/60</td>
<td>1000/40</td>
<td>80/100</td>
<td>24/1000</td>
<td>40/330/60</td>
<td></td>
</tr>
</tbody>
</table>

Table 21: Daily oxygen requirement/consumption based on active cases

*As per the state trend/average total 12% of total active cases need medical oxygen support out of which 8% on O2 beds and 4% on ICU beds. Districts/Hospitals can use the actual percentage as per their patient data on oxygen support requirement.
1.4 Oxygen requirement, availability and Gap analysis

<table>
<thead>
<tr>
<th>Source of Oxygen in dedicated COVID Hospitals (DHHC &amp; DCH)</th>
<th>Calculation for O2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. No of cylinders available with he State/District/Hospital</td>
<td>D Type (7 cubic meter) No. of Cylinders x 7 cubic meter = 'A' in m³</td>
<td>A+B+C</td>
</tr>
<tr>
<td></td>
<td>B type (1.5 cubic meter) No. of Cylinders x 1.5 cubic meter = 'B' in m³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dura Cylinders (Capacity in Litre x 0.81734= Capacity in CuM), No. of Cylinders x Capacity in CuM = 'C' in m³</td>
<td></td>
</tr>
<tr>
<td>b. O₂ Generation through Pressure Swing Adsorption (PSA) if centralized manifold is available</td>
<td>Capacity in LPM (Litres per min) x 60 min x 24 hrs x 1000 (to convert litres to cubic meter) = 'D' in m³</td>
<td>D</td>
</tr>
<tr>
<td>c. Liquid Medical Oxygen if centralized manifold is available</td>
<td>Capacity in Kc x 877.8 = Capacity in CuM = 'E' in m³</td>
<td>E</td>
</tr>
<tr>
<td>Total</td>
<td>A+B+C+D+E (in m³)</td>
<td></td>
</tr>
</tbody>
</table>

Table 22: Oxygen availability at state district/hospital level

Gaps to be addressed for Oxygen Supply

Gap in O₂ Supply = Total Oxygen Required (X+Y) - Total availability (A+B+C+D+E) in m³

(Reference: Oxygen requirement, availability, and Gap analysis MOHFW, D.O. Letter dated 18th April 2020)

Imp. Note: The use of oxygen cylinders requires three times the inventory of cylinders consumed in a hospital on a single day (one set of cylinders in use, one set as backup and one set in refilling station).

1. BRIEF INTRODUCTION

Medical oxygen is the primary treatment for patients with hypoxia who are suffering with severe COVID-19 symptoms. That is why the storage and use of oxygen has increased at health facility level and it is very important to understand the risk associated with handling of medical oxygen. This guideline tries to highlight facts about medical oxygen and provide guidance on precautions to be taken during handling of medical oxygen and equipment.

1.1 Oxygen as a fire risk

- Oxygen is classified as an 'oxidizing agent', reacting with most elements.
- Oxygen is highly supportive of combustion (the reaction with oxygen to release heat and light/flame/glow).
- Oxygen enrichment = Amount of Oxygen content higher than in the air (i.e., >21%).
- Oxygen concentration higher than 23.5% could create greater fire hazards than normal air.
- Exposure to liquid oxygen can cause severe burns due to cold temperatures.
- There is possibility of a combustion reaction if the oxygen is permitted to contact a non-compatible material.
- Materials include clothing and hair, which have air spaces that readily trap the oxygen, not only become more susceptible to ignition, but also burn with added violence in the presence of oxygen.
- Any clothing that has been splashed or soaked with liquid oxygen or exposed to high oxygen concentrations should be removed immediately and aired for at least an hour.
- Personnel should stay in a well-ventilated area and avoid any source of ignition until their clothing is completely free of any excess oxygen.
- Do not permit liquid oxygen or oxygen-enriched air to come in contact with organic materials or flammable or combustible substances of any kind.
- Some of the organic materials that can react violently with oxygen when ignited by a spark or even a mechanical shock are oil, grease, asphalt, kerosene, cloth, tar, and dirt that may contain oil or grease.
  - Oxygen reacts with most materials. The higher the oxygen concentration and pressure in the atmosphere or in an oxygen system then
  - Combustion reaction or fire will be more vigorous.
  - Ignition temperature and the ignition energy to promote the combustion reaction is much lower.
  - Temperature of the flame is higher and consequently the destructive capability of the flame is greater.

Figure 29: The Fire Triangle
1.2 Most causes of oxygen fires can be categorized as follows
1. Oxygen enrichment of the atmosphere.
2. Improper use of oxygen.
3. Incorrect design of oxygen systems.
4. Incorrect operation and maintenance of oxygen systems.
5. Use of materials incompatible with oxygen service.

2 PREVENTION OF FIRES IN OXYGEN SYSTEMS

2.1 Information/training
- Any personnel using oxygen equipment should be informed of the hazards, properties, and risks of oxygen.
- All maintenance and repair work should be performed by trained and competent personnel.
- All persons who work in areas where oxygen enrichment can occur shall be given instructions as to the risks involved. Emphasis shall be given to the nature of the risks and to the almost immediate consequences. Training shall on ways of minimizing the risk, stressing the importance of identifying sources of oxygen enrichment and their isolation.

2.2 Design
- In oxygen systems only equipment that has been specifically designed for oxygen shall be used; for example, nitrogen regulators shall not be used in oxygen service. The design of equipment intended for oxygen service takes into account materials to be used and their configuration, in order to minimize any risk of ignition. The reasons for a particular design and choice of material are not always obvious and expert advice shall be sought before considering a change of materials.
- Oxygen equipment shall only be lubricated with lubricants specific to the application and service. Specialist advice shall always be sought, for example from the supplier or test facility.
- Oxygen systems shall be designed so that the flow velocity is as low as possible. If the velocity is doubled the energy of a particle in the gas stream will increase four times.
- Oxygen systems should be positioned in well-ventilated areas away from primary ignition sources such as boilers. Liquid systems should be located away from cable trenches, drains, and ditches.

2.3 Prevention of oxygen enrichment
- 2.3.1 Leak testing
  - For leakages newly assembled equipment for oxygen service shall 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.
  - Periodic retests to check for leaks are recommended.
- 2.3.2 Operation and practice
  - When the work period is over, 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.
- 2.3.3 Ventilation
  - Rooms under the risk of oxygen enrichment shall be well ventilated. Examples of such rooms include:
    - Filling stations.
    - Rooms in which oxygen vessels or cylinders are stored, handled, or maintained.
    - Rooms in which oxygen is used or analysed.
    - Rooms used for medical treatment with oxygen such as in hospitals, home care, and other healthcare facilities.
  - In many cases, natural ventilation can be sufficient such as in halls or rooms provided with ventilation openings. The openings should have a flow area greater than 1/100 of the room's floor area, be diagonally opposite each other, and should ensure free air circulation with no obstructions. Where natural ventilation is not possible, a ventilation unit with a capacity of approximately 6 air changes/hour shall be provided. Consideration shall be given to the ventilation of underground rooms, vessels, pits, ducts, and trenches.
  - There shall be a safety warning to indicate if the ventilation unit fails.

2.4 Vessel entry/blanking procedures
- Prior to entry into any vessel, which is connected to a gas source, the vessel shall be emptied and isolated from the source. Isolation can be accomplished, for example, by the removal of a section of pipe, by the use of a spectacle plate, by inserting blind flanges, or by double block and bleed valves. The space shall be thoroughly ventilated to maintain an atmosphere of no greater than 23.5% oxygen. Appropriate regulatory confined space entry procedures shall be followed.

2.5 Isolation equipment
- When an oxygen pipeline enters a building, an isolation valve shall be provided outside the building in an accessible position for operation. This valve and location shall be clearly marked and identified. The purpose is to enable operation of the valve from a safe location, in the event of an oxygen release inside the building.
- Disused oxygen lines should either be dismantled or completely severed and blanked off from the supply system.

2.6 Oxygen cleanliness
One of the fundamental safety procedures in preventing oxygen fires is to ensure that all equipment is cleaned before being put into or returned to oxygen service. There are several methods for cleaning oxygen equipment.
Oxygen equipment shall be free of solid particles. In order to remove particles, new oxygen equipment shall be purged with oil-free or nitrogen before start-up.

3 PROTECTION OF PERSONNEL

3.1 Clothes
Persons who have been exposed to an oxygen-enriched atmosphere shall not smoke or go near open flames, hot spots or sparks until they have properly ventilated their clothes in a normal atmosphere. A ventilation period of not less than 15 minutes with movement of the arms and legs and with coats removed is recommended.
3.2 Analysis
Before persons enter a space which can be subject to oxygen enrichment, the atmosphere shall be analysed for oxygen by a reliable and accurate analyser. Entry shall not be allowed if the oxygen concentration is greater than 23.5%. An oxygen concentration greater than 23.5% is potentially dangerous. As a warning against possible variations in concentration, the space may be monitored with a continuous automatic oxygen analyser that sounds an audible, visual, and/or tactile (vibration) alarm when the oxygen concentration in the atmosphere could exceed 23.5% or be less than 19.5%.

3.3 Firefighting equipment
The only effective way of dealing with oxygen-fed fires is to isolate the supply of oxygen. Under oxygen-rich conditions, appropriate firefighting media include water, dry chemical (powder), or carbon dioxide. The selection needs to take into account the nature of the fire, for example, electrical. Burning clothing shall be extinguished by water as covering the clothing with a fire blanket will still allow oxygen-enriched clothing to burn. Firefighting equipment shall be properly maintained and operating personnel should know where it is located, how to operate it, and which equipment to use for which type of fire.

3.4 Smoking
All personnel shall be informed of the dangers of smoking when working with oxygen or in an area where oxygen enrichment can occur. Many accidental fires and burn injuries have been initiated by the lighting of a cigarette; it is therefore imperative to emphasise the danger of smoking in oxygen-enriched atmospheres or where oxygen enrichment can occur. In such areas, smoking shall be prohibited.

3.5 Emergency response and rescue
The location’s emergency response procedures should contain provisions for entry into potentially oxygen-enriched areas. Victim rescue or entry to shut down the process shall not be attempted until levels of oxygen-enriched gases are determined to be less than 23.5% oxygen and it is safe to enter. Clothing materials include flame-resistant or treated materials can be susceptible to burning in an oxygen-enriched atmosphere. Emergency procedures may include the use of water spray to protect potential victims if it can be done from a safe distance until safe-entry verification can be made.

Effective emergency procedures provide for identifying where oxygen enrichment is a risk, as well as training personnel, conducting drills, and providing readily accessible emergency contact numbers for fire and medical response.

If a major release of liquid or gaseous oxygen-rich gases occurs, all electrical appliances and lighting systems in the affected area are potential sources for a spark and ignition can occur. The source of the oxygen-rich gases shall be shut off as soon as possible. Experience has shown that if liquid oxygen-rich gases are released in an open space, a hazardous oxygen concentration usually exists within the visible fog cloud associated with the spill. Personnel should never enter a visible fog cloud. A hazardous oxygen concentration can exist outside the cloud. A portable oxygen analyser should be used before entering the area near a release.

4 PRECAUTIONS DURING EQUIPMENT HANDLING TO REDUCE FIRE RISKS FROM OXYGEN

A. OXYGEN CYLINDER

1.1 General handling
- Personal protective equipment, such as eye and hand protection, should be worn when handling oxygen cylinders.
- All compressed medical oxygen gas cylinders (regardless of size) should be secured to racks, walls, work benches or hand trolleys by a strong chain or strap, capable of preventing the cylinder from falling or being knocked over.
- Secure in an upright position. Note that small cylinders, when used for patient transport, may be laid flat, but still need to be firmly secured.
- Do not drop cylinders or allow sharp impacts on cylinders.
- Cover the top of the oxygen cylinder with the cap when it is not in use or when being transported for delivery.
- Set up the cylinder for patient use a safe distance from the patient.
- After connecting the appropriate equipment, turn the flow control off, carefully open the main valve, then turn up the flow slowly to the desired rate.
- Do not place the cylinder on a patient’s bed.
- Before moving cylinders, they must be disconnected from any regulators or manifolds, applying any protective valve caps before the cylinders are released.
- Cylinders should be moved only on a hand truck or other cart designed for handling gas cylinders.
- No more than one cylinder should be handled at a time except on carts designed to transport more than one cylinder.
- All medical gas cylinders should be clearly labelled to identify the contents. A cylinder without a readable product label should not be used and should be returned to the supplier.
- All defective gas cylinders or equipment should be reported immediately to the supplier for correction or replacement.

1.2 Storage
- Always physically separate full and empty medical gas cylinders. Ambulatory organizations can do this by using separate racks, physical barriers or by colour coding the storage rack.
- Label the cylinders clearly (open/empty or full/unopened), to avoid confusion and delay in selecting between full, partial and empty cylinders.
- Store in well-ventilated, clean, dry conditions, not exposed to extremes of heat or cold.
- “DO NOT use oil or grease on the valve of cylinders or regulators/gauges, particularly those containing oxygen or oxidising agents, to avoid fire or explosion.”
- Never use a single-use and/or re-use an industrial gas cylinder for refilling medical oxygen.
1.3 When and how to change a cylinder

When to change a cylinder

- Check your pressure gauge on the regulator unit (or control panel in case of jumbo cylinders connected to manifold) frequently to make sure you do not run out of oxygen. Please be aware that some manifold systems may have a sound based-alarm system to alert low supply of oxygen in the cylinder.
- Always check the gauge (or control panel) when the valve is turned on.
- When the needle gets closer to zero on the gauge (or the pressure reading is low on control panel), it is time to change the cylinder.
- Be sure to change the cylinder before the needle gets below 56 psi (4 bar).
- If the pressure gauge is broken, please note the weight of an empty and a full cylinder. Regularly note the weight of a cylinder to ensure it is empty before changing it.

How to change a cylinder

- Turn off the oxygen flow.
  - Using the cylinder wrench (spanner/key), turn the cylinder on/off valve clockwise to close it.
  - Bleed off the pressure in the valve by opening the flow regulator knob.
  - When the gauge reads zero on the regulator, turn the flow regulator knob to zero.
- Change the cylinder.
  - Remove the regulator unit (including pressure gauge and flowmeter) from the empty cylinder and attach it to a filled cylinder.
- Turn on the oxygen flow.
  - Place the cylinder wrench on the cylinder’s on/off valve, located at the top of the cylinder.
  - Open the valve by turning it anti clockwise one full turn. As the valve opens, the gauge on the regulator will show the amount of pressure in the cylinder. Pressure in a full cylinder will read about 1880-2100 psi (120-150 bar).
  - Adjust the flow knob on the regulator until the gauge reaches the flow rate your doctor prescribed.
- Oxygen cylinders should have a labelling tag stating its status – Full or Empty or In-use. Moreover, the “date of service” should also be mentioned on the cylinder. Ideally, the cylinders should be periodically checked once every 5 years and the “date of test” should be stamped on the cylinders.

1.5 Precautions during equipment handling to reduce fire risks from oxygen

- Handle cylinders carefully, move in trolley.
- Keep cylinders clamped or chained to prevent from falling over. Must be well labelled.
- Only store as many cylinders as needed; return empties to suppliers.
- Open valves slowly and in the correct order. Close the valve when not in use. If the valve is hard to open, discontinue use and contact your supplier.
- Never insert an object (e.g. wrench, screwdriver, pry bar) into cap openings; doing so may damage the valve and cause a leak. Use an adjustable wrench to remove over-tight or rusted caps.
- Install valve protection cap, if provided, firmly in place by hand when the container is not in use. Store full and empty containers separately.
- Protect cylinders from physical damage; do not drag, roll, slide or drop.
- While moving cylinder, always keep in place removable valve cover.
- Never attempt to lift a cylinder by its cap; the cap is intended solely to protect the valve. When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport cylinders.
- Use a first-in, first-out inventory system to prevent storing full containers for long periods.

1.6 Precautions needed in using any of the methods of oxygen supply in corona virus infested environment

Liquid Medical Oxygen, Oxygen generators and in some cases cylinders are methods which use a MGPS to supply oxygen to a hospital facility. These equipment will need exactly the same sanitation as is been given to any other machinery in the hospital. All parts which are regularly and frequently touched or operated should be sanitized before and after use. Only relevant operators should handle the equipment.

Use of cylinders brings a need for a major change in procedure of handling them. Right from filtration, transportation, loading, unloading, use, exchange, carriage in the hospitals and in critical care facilities, cylinders see handling by various people, usage by patients and being very close to actual infected patients. The safe handling of cylinders is a major challenge which needs a very focused and concentrated effort by all involved.

The following guidelines may be adopted for handling Oxygen cylinders:

- The cleaning & disinfection procedure should be performed at the hospital.
- For initial cleaning, hot potable water with detergents, not exceeding 50 degrees Celsius (50 °C) should be used for cleaning cylinders/containers. Valves & inlets should be closed & covered so that the water doesn’t get inside the cylinders/containers. Under no circumstances medical gas cylinder/container should be immersed in water.
- After cleaning the cylinder/container with water and soap, the cylinder/container should be cleaned with Isopropyl Alcohol or Equivalent disinfectant wipes. The application of the alcohol based wipes should be limited otherwise it can cause a potential fire risk. Also, ensure that residual disinfection agents are removed from the Gas Cylinder/container.
- While cleaning the cylinder/container, avoid cleaning agents that contain ammonia, amine based compounds or chlorine based compounds as they can cause corrosion of
steel or aluminium alloy components or stress cracking of brass, including copper alloy components.

- In case the used cylinders have not been disinfected then the cylinders should be kept in an isolated area, with a tag clearly mentioning that the cylinder is infected. The cylinders should be sent to the supplier only after these steps are followed.
- Medical Gas Cylinders/containers should be quarantined till they are cleaned. The cylinders/containers should be filled with Medical Gas/Oxygen only after cleaning is done.
- Personnel involved in filling, storing, handling & transporting of Medical Gas Cylinder/container should be trained in this procedure and should be wearing protective gear at all times.
- These steps and method highlighted above is not the last word on precautions which can be taken while handling oxygen supply related equipment during the period of pandemic of corona virus. With more information and studies, the procedures can be improved and simplified.

1.7 Disposal
Cylinders and unwanted product should be returned to the vendor, not vented into the environment. Obsolete cylinders must be disposed of based on local regulations.

B. MEDICAL GAS PIPELINE SYSTEM (MGPS)

1.1 The safety of an MGPS is dependent on four basic principles

a. Identity- Identity is assured using gas-specific connections throughout the pipeline system, including terminal units, connectors etc., adhere to strict testing and commissioning procedures of the system.

b. Adequacy- Adequacy of supply depends on an accurate assessment of demands and the selection of plant appropriate to the clinical/medical demands on the system.

c. Continuity- Continuity of supply is achieved by- The specification of a system that (except for liquid oxygen systems which may include a secondary vessel) has duplicate components. The provision of a third means of supply for all systems except vacuum. The provision of alarm systems; and connection to the emergency power supply system. Surgical air systems are not considered to be life-support systems and therefore duplicate components are not normally required; an emergency/secondary supply is provided.

d. Quality of supply- Quality of supply is achieved using gases purchased to the appropriate Ph. Eur. Requirements or produced by plant performing to specific standards, by the maintenance of cleanliness throughout the installation of the system, and by the implementation of the various testing and commissioning procedures.

1.2 Fire Safety

Fire detection system such as smoke or heat detector heads should be installed in the plantrooms, medical gases manifold rooms and (when internal) medical gases cylinder stores in any hospital. An automatic shutdown system, linked to local smoke detectors, can be installed. If such a system is planned, it is essential that an automatic emergency supply manifold system is sited well away from the fire-risk area and is arranged to come on-line automatically in the event of plant shutdown.

2.1 Precautions during MGPS equipment handling to reduce fire risks from oxygen

- Formulating Standard Operating Procedures (SOPs), maintaining logbooks, preventive maintenance of equipment and leak test of pipeline should be ensured on quarterly basis.
- Twenty-four hours manning by trained personnel, periodic training of manifold personnel, daily checking of contingency plan, mock drills of pipeline failure, fire, and explosion should be regularly conducted.

<table>
<thead>
<tr>
<th>Do's</th>
<th>Don'ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure Cylinder is firmly secured.</td>
<td>Do not repair a cylinder.</td>
</tr>
<tr>
<td>Ensure connections are suitable and tightly connected.</td>
<td>Do not change marking on a cylinder.</td>
</tr>
<tr>
<td>Ensure cylinders are placed away from ignition sources.</td>
<td>Do not use oil or lubricants in cylinder valve.</td>
</tr>
<tr>
<td>Always keep gas filled and empty cylinders separately.</td>
<td>Do not tamper with gas cylinder test cap.</td>
</tr>
<tr>
<td>Ensure valve guards or caps are properly fitted when cylinders are not in use.</td>
<td>Do not tamper with or remove the bar code from a gas cylinder.</td>
</tr>
<tr>
<td>Use mechanical assistance when handling cylinders.</td>
<td>Do not roll cylinders on the ground.</td>
</tr>
<tr>
<td>Ensure adequate Ventilation is available.</td>
<td>Do not attempt to light fire invoking a gas cylinder.</td>
</tr>
<tr>
<td>Always keep the manifold plant room clean.</td>
<td>Do not use a cylinder that shows evidence of damage or corrosion.</td>
</tr>
<tr>
<td>Follow appropriate SOP (Standard Operating Procedure.)</td>
<td>Do not fill cylinder with any material.</td>
</tr>
<tr>
<td>Keep area around all equipment clear and without hindrance.</td>
<td>Do not stock areas around equipment with unwanted/unused articles.</td>
</tr>
<tr>
<td>In case of malfunction of any equipment inform service provider.</td>
<td>Do not try to rectify any malfunction or use services of unauthorized persons.</td>
</tr>
</tbody>
</table>

Table 23: Do’s and Don’ts - medical gas manifold room
2.2 Different sources of supply and key system components including alarms

The Medical supply system shall comprise of

- Primary supply.
- Secondary supply.
- In some cases, Reserve supply can be installed as per the national requirements.

Each supply system can be a combination of the following

a) Gas in cylinders or cylinder bundles.
b) Cylinders connected to a manifold.
c) Portable liquid cylinder.
d) Cryogenic liquid in stationary vessels.

Following figure shows how the above can be combined as acceptable sources of supply. It also shows the different sources of supply and key system components including alarms. This schematic is not a design drawing. A competent person should design the supply system after selecting a suitable source of supply.

C. LIQUID MEDICAL OXYGEN

1.1 Safety Considerations

- The hazards associated with liquid oxygen are exposure to cold temperatures that can cause severe burns; over-pressurization due to expansion of small amounts of liquid into large volumes of gas into inadequately vented equipment; oxygen enrichment of the surrounding atmosphere; and the possibility of a combustion reaction if the oxygen is permitted to contact a non-combustible material.

- It is important to note that fire chemistry starts to change when the concentration of oxygen increases to 23%. Materials easily ignited in air not only become more susceptible to ignition, but also burn with added violence in the presence of oxygen. These materials include clothing and hair, which have air spaces that readily trap the oxygen. Oxygen levels of 23% can be reached very quickly and all personnel must be aware of the hazard. Any clothing that has been splashed or soaked with liquid oxygen or exposed to high oxygen concentrations should be removed immediately and aired for at least an hour. Personnel should stay in a well-ventilated area and avoid any source of ignition until their clothing is completely free of any excess oxygen. Clothing saturated with oxygen is readily ignitable and will burn vigorously.

- Do not permit smoking or open flames in any areas where liquid oxygen is stored or handled. Do not permit liquid oxygen or oxygen-enriched air to come in contact with organic materials or flammable or combustible substances of any kind. Some of the organic materials that can react violently with oxygen when ignited by a spark or even a mechanical shock are oil, grease, asphalt, kerosene, cloth, tar, and dirt that may contain oil or grease. If liquid oxygen spills on asphalt or other surfaces contaminated with combustibles, do not walk on or roll equipment over the area of the spill. Keep sources of ignition away for 30 minutes after all frost or fog has disappeared.

- Systems used in oxygen service must meet stringent cleaning requirements to eliminate any incompatible contaminants.

1.2 Handling and storage

1.2.1 Handling

- Never use oxygen as a substitute for compressed air. Never use an oxygen jet for any type of cleaning, especially for cleaning clothing. Oxygen-saturated clothing may burst into flame at the slightest spark and be quickly consumed in an engulfing fire. Do not get liquid in eyes, on skin, or on clothing. Persons exposed to high concentrations of liquid oxygen should stay in a well-ventilated or open area for 30 minutes before entering a confined space or going near any source of ignition. Immediately remove clothing exposed to oxygen and air it out to reduce the likelihood of an engulfing fire. Prevent ignition sources, such as static electricity generated in clothing while walking.

- Wear leather safety gloves and safety shoes when handling cylinders. Protect cylinders from physical damage; do not drag, roll, slide or drop. While moving cylinder, always keep in place removable valve cover. Never attempt to lift a cylinder by its cap; the cap is intended solely to protect the valve. When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport cylinders. Never insert an object (e.g. wrench, screwdriver, pry bar) into cap openings; doing so may damage the valve and cause a leak. Use an adjustable strap wrench to remove over-tight or rusted caps. Slowly open the valve. If the valve is hard to open, discontinue use and contact your supplier. Close the container valve after each use; keep closed even when empty.
Never apply flame or localized heat directly to any part of the container. High temperatures may damage the container and could cause the pressure relief device to fail prematurely.

- 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 for moving smaller containers. Move larger containers by pushing, not pulling. Avoid mechanical and thermal shock.
- Never allow any unprotected part of the body to come in contact with uninsulated pipes or equipment containing cryogenic product. The extreme cold will cause flesh to stick fast and potentially tear on withdrawal.
- Use only oxygen-compatible materials and lubricants.
- If there is any difficulty in operating the container valve or container connections, discontinue use and contact the vendor. Do not remove or interchange connections. Use only the properly assigned connections.
- Do not use adapters.
- Use only transfer lines and equipment designed for use with cryogenic liquids. Some elastomers and metals, such as carbon steel, may become brittle at extremely low temperatures and may easily fracture. These materials must be avoided in cryogenic service.
- It is recommended that all vents be piped to the exterior of the building.
- On gas withdrawal systems, use check valves or other protective apparatus to prevent reverse flow into the container.
- On liquid systems, pressure relief devices must be used in lines where there is the potential to trap liquid between valves.

1.2.2 Storage

- Store in rooms where the temperature will not exceed 125°F (52°C). Post "No Smoking/No Open Flames" signs in storage and use areas. There must be no sources of ignition. Separate packages and protect against potential fire and/or explosion damage following appropriate codes and requirements. Always secure containers upright to keep them from falling or being knocked over. Install valve protection cap, if provided, firmly in place by hand when the container is not in use. Store full and empty containers separately. Use a first-in, first-out inventory system to prevent storing full containers for long periods.
- Store and use liquid containers with adequate ventilation. Do not store containers in a confined area or in an area unprotected from the 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 20 feet or a half-hour fire wall. Post "No Smoking" and "No Open Flames" signs.
- Liquid containers should not be left open to the atmosphere for extended periods. Keep all valves closed and outlet caps in place when not in use. If restriction results from freezing moisture or foreign material present in openings and vents, contact the vendor for instructions.

- Restrictions and blockages may result in dangerous over-pressurization. Do not attempt to remove the restriction without proper instructions. If possible, move the cylinder to a remote location.

1.3 Other precautions for handling, storage and use

- When handling product under pressure, use piping and equipment that is adequately designed to withstand the pressures to be encountered. Never work on a pressurized system. Use a back flow preventive device in the piping. Store and use with adequate ventilation. If a leak occurs, close the container valve and blow down the system in a safe and environmentally correct manner in compliance with all international, federal/ national, state/provincial, and local laws; then repair the leak. Never place a container where it may become part of an electrical circuit. When working with cryogenic/cold liquid or gaseous oxygen under pressure, avoid using materials that are incompatible with oxygen use. Some metals, such as carbon steel, may fracture easily at low temperature. Use only transfer lines designed for cryogenic liquids.
- Prevent liquid or cold gas from being trapped in piping between valves.

<table>
<thead>
<tr>
<th>Do's</th>
<th>Don'ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep all combustible materials away from possible contact with oxygen.</td>
<td>DO NOT permit smoking or an open flame in areas where oxygen is stored, handled, or used.</td>
</tr>
<tr>
<td>Keep all surfaces that may come in contact with oxygen clean.</td>
<td>DO NOT walk on or roll equipment over liquid oxygen spills.</td>
</tr>
<tr>
<td>Provide adequate ventilation in areas containing oxygen equipment.</td>
<td>DO NOT place liquid oxygen equipment on asphalt or any surface that may have oil or grease deposits.</td>
</tr>
<tr>
<td>Protect your eyes with safety goggles or face shield.</td>
<td>DO NOT lubricate oxygen equipment with oil, grease or unapproved lubricants.</td>
</tr>
<tr>
<td>Protect your ears with leather gloves.</td>
<td>DO NOT touch frostbitten pipes or valves with bare skin.</td>
</tr>
<tr>
<td>Use only equipment, cylinders, containers, regulators, and apparatus designed for oxygen service.</td>
<td>DO NOT spray water on liquid spill, allow it to evaporate.</td>
</tr>
<tr>
<td>Use Oxygens for medical purposes only. If it is labeled &quot;Oxygen UP.&quot;</td>
<td>DO NOT release gaseous oxygen indoors.</td>
</tr>
</tbody>
</table>

Table 24: Do's and Don'ts - liquid oxygen
D. PRESSURE SWING ADSORPTION (PSA)

Oxygen generators are very often operated inside closed buildings. Consequently, oxygen leakage can result in an oxygen-enriched atmosphere within the building. Areas where it is possible to have this condition shall be well ventilated. Oxygen vents should be piped outside of buildings or to a safe area. Where an oxygen-enriched atmosphere is possible, warning signs shall be posted and special precautions shall be taken such as installation of analyzers with alarms, ensuring a minimum number of air changes per hour, implementing special entry procedures, or a combination of these. Oxygen produced in generators is often used in areas remote from the generator itself. Therefore, it is important to recognize that accumulation of oxygen in these use areas can also result in an oxygen-enriched atmosphere.

Protective clothing and special equipment can serve to reduce fire hazards when working with oxygen, but prevention of the hazard should be the primary objective. Clothing should have minimum gap. The adsorbents used should be non-toxic. However, they may cause respiratory problems if they are inhaled in dust form. The use of a dust mask is sufficient to protect personnel.

Fire protection

Typically, the primary fire protection for generators is an ample water supply. Depending on the generator size, an adequate number of fire hydrants, chemical-type fire extinguishers, hoses, or a combination of these should be strategically located close to the generator(s) so a fire can be approached from any direction in an emergency.

On oxygen systems, automatic isolation valves or generator shutdown are frequently used to isolate oxygen sources from feeding a fire.

E. OXYGEN CONCENTRATOR

Operating hazards

Improper disposal of the vent and waste gases, which are produced by the generator, can be extremely hazardous.

All piping should be leak checked (soap test) immediately after the generator has been placed into operation, particularly if the generator is installed indoors. All leaks should be repaired before operating the generator to preclude the hazards of oxygen-enriched or oxygen-deficient atmospheres.

5. OXYGEN SAFETY SIGNS FOR GENERAL USE:

![Safety is everyone's responsibility!](image)

Figure 31: Oxygen safety signs

6. LABELING/SIGNAGE

Labeling and signs for medical gas systems, equipment and housing should be in accordance with the following

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Symbol description/Placed</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>SWIFT Keep equipment in well ventilated area and gases away from combustible material. On front of PSA generator.</td>
<td>Warning: Oxidizing gas. Keep equipment in well ventilated area and gases away from combustible material. See WARNINGS AND IMPORTANT INFORMATION.</td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>Equipment must be placed in a well-ventilated area. Avoid inhalation of gases. On exhaust silencer.</td>
<td>Warning: Equipment must be placed in a well area. Avoid inhalation of gases. See WARNINGS AND IMPORTANT INFORMATION concerning exhaust gases.</td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>On skid plate</td>
<td>Warning: See WARNINGS AND IMPORTANT INFORMATION. Voltage Turn off power and disconnect power supply before service or repair. Pressure: Decompress before service or repairs. Manual: See manual before service or repair.</td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>DEPRESSURIZES equipment before service.</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>See manual before service</td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>INLET - FEED AIR On piping near inlet</td>
<td>Information label, INLET - FEED AIR. Connect to feed air supply.</td>
</tr>
<tr>
<td><img src="image" alt="Symbol" /></td>
<td>OUTLET - OXYGEN On piping near oxygen outlet</td>
<td>Information label, OUTLET - OXYGEN. On PSA generator. Connect this oxygen outlet to product tank inlet. On product tank: Connect this oxygen outlet to your consumption.</td>
</tr>
</tbody>
</table>

Figure 32: Labeling and signs for medical gas systems
CHAPTER 10
GUIDELINES ON FACILITY BASED OXYGEN AUDIT

1. BRIEF INTRODUCTION

Medical oxygen is an essential medicine in the treatment of COVID-19 and other serious respiratory disorders among adults and children in a health facility. Regular and periodic facility-based audits by dedicated oxygen audit teams are needed to ensure rational use of oxygen, streamline the oxygen supply from different sources of oxygen and ensure safety measures in oxygen delivery systems at facility level. Regular audits, review of audit reports by the hospital authority and immediate follow up actions can ensure the medical oxygen supply service is smooth and hassle free.

During this unprecedented time of COVID-19 outbreak, it is often observed that many health facilities and in turn the districts are consuming oxygen more than the normative as mandated by clinical recommendations. There may be the case of wastage, leakage and lack of awareness on appropriate delivery system of medical oxygen among hospital staffs. Implementing a regular oxygen audit mechanism with constitution of audit teams at facility and district level could find the exact gap in medical oxygen delivery system and help the State in saving each RuM of life saving oxygen.

India and especially Meghalaya State had witnessed sudden surge of COVID-19 cases in almost all districts during second wave. This increase in number of patients led to increase in demand of oxygen, so being a scarce resource, it is very crucial to use oxygen judiciously. Therefore, guidelines for rational use of oxygen are being circulated to all the districts in the State. It is expected to implement these guidelines strictly in Govt and Private Health Facilities classified as DCH, DCHC and CCC (with oxygen beds).

2. INSTITUTIONAL MECHANISM FOR OXYGEN AUDIT

A. State level Oxygen monitoring Committee/ cell

At State level, one Medical Oxygen Monitoring Committee (MOMC) is to be constituted for regular review of medical oxygen supply system. Accordingly, MOMC should take all necessary measures to strengthen the health system of the State which is capable of delivering medical oxygen at bed side as per clinical need while ensuring all required safety measures. MOMC is to be constituted by taking State oxygen nodal officer, State bio medical engineer, State medical equipment procurement managers, respiratory medicine/anesthesia specialists, M&E specialists and heads of bio-medical research/ laboratory along with other appropriate administrative heads as members.

The MOMC should collect inputs from all districts and conduct weekly review of medical oxygen supply system in the state during the surge in COVID-19 case and monthly as a routine practice. The review should include

- Status of oxygen sources, storage capacity and availability at secondary and tertiary care facilities in various districts.
- District wise availability of oxygen suppliers/refillers and storage capacity.
- Reviewing the system for regular maintenance of oxygen sources such as PSA, LMO and oxygen concentrators, storage and maintenance of oxygen cylinders.
- Status of staff training on medical oxygen delivery procedures.
- Training status of clinical staff on rational use of oxygen as per clinical need assessment of patients etc.
- Reviewing the status of oxygen audit across the districts.

Accordingly, all districts should be provided feedback and be supported for strengthening the district medical oxygen supply system. MOMC should also develop a repository of suppliers of oxygen equipments (PSA, LMO, OC, Cylinder, oxygen flowmeter etc) for smooth procurement of these products as per need. Along with this a list of resource persons available for staff training may be maintained.

B. District level oxygen audit committees

District quality team members may constitute the district level oxygen audit team. At least one specialist doctor in respiratory medicine is to be nominated as the team member.

Role of district level oxygen audit committee:

a. Conduct a baseline and then periodic (preferably weekly during the surge in cases and then monthly) assessment of the oxygen supply system in health facilities of the district.

b. Accordingly, a need gap analysis is to be prepared for further sharing with the State MOMC.

c. Trend analysis of medical oxygen requirement and forecasting the need of the district would be helpful for appropriate planning of oxygen supply system in the district.

d. Ensure that each health facility of the district with medical oxygen service has constituted a facility level oxygen audit committee.

e. Ensure that the state approved oxygen audit checklist formats are available in relevant health facilities.

f. Provide initial orientation to facility level oxygen audit teams on their role, responsibilities, and appropriate use of state approved oxygen audit checklist formats.

g. Collect, review, and provide immediate feedback to health facilities as per the facility level oxygen audit reports received from the districts.

C. Hospital/Facility Oxygen audit committee

Hospital oxygen audit team is a facility level team ideally constituting of at least one respiratory medicine specialist/anesthesiologist or physician, staff nurse in-charge, pharmacist and attendants Group D employees. The audit team will also include the additional medical superintendent and heads of the anesthesia and respiratory medicine wings or head of the internal medicine wing in case there is no separate respiratory medicine wing along with the nursing superintendent. The audit committee members have to be identified and a facility level audit committee needs to be constituted by office order from the hospital superintendent.

This team is crucial in strengthening the in-house capacity for medical oxygen delivery system at hospital level. The team members have an important role to play in safe delivery and rational use of oxygen in their health facility. The oxygen audit committee members need to be oriented by district oxygen audit team on various elements of oxygen audit and importance of regular audit on appropriate usage of medical oxygen in the health facility.
This team will also serve as facility level mentoring team for clinical staff and attendants on appropriate handling of medical oxygen related equipments along with ensuring rational use of oxygen.

Role of facility level oxygen audit committee

- Supervise inventory planning and record oxygen consumption pattern (Maintain a record of daily stock of oxygen in hospitals, its use, and leftover stock).
- The audit committee will register details about the availability and use of oxygen in a hospital and report to the district oxygen nodal person on a daily basis.
- Ensure regular repair and maintenance of oxygen sources e.g., PSA plants, LMO tanks and gas pipelines along with wall mounted gas outlets.
- Support setting up of oxygen monitoring team in all shifts in hospitals as part of the committee. It should include a nurse and an operation theatre technician.
- Oxygen monitoring team should regularly monitor the places where oxygen is given to patients and inspect the gas pipeline, gas cylinders, wall mounted gas outlets and gas cylinders to detect and promptly address leakages, if any. Nurse in the team will check the oxygen mask on regular basis and ensure closure of valves during “no-use” at all times.
- The committee will be responsible for regular training to staff nurses, nursing attendants, ICU/OT technicians on appropriate procedures of oxygen administration, patient monitoring, oxygen weaning protocols, to detect leaks in oxygen supply systems and to follow oxygen prescription as directed by the treating physician. Sensitize nurses and technicians for conservation of oxygen.

3. PERIODICITY OF AUDITS AND REPORT SUBMISSION

Health facility level oxygen audit reports should be submitted on weekly basis to the district level oxygen nodal officer for review and feedback. The facility based oxygen audit report should be submitted in a structured checklist format which is approved by State health department. The weekly audit reports should include the number of leakages identified in oxygen supply systems, any breakdown of oxygen sources, proportion of admitted patients on HFNC, non-invasive ventilation, invasive ventilation, nasal cannula, simple face mask, NRBM etc., utilization of oxygen Vs clinical load of the facility, staff knowledge and skills related to oxygen equipment use etc.

District oxygen audit committee shall send a monthly report to MOMC with regard to details of audit conducted. The audit report should include facility wise details of key audit findings along with immediate action taken to ensure compliance to recommended practices. The audit report may also accompany a gap analysis of oxygen supply system and highlight any support requirement from State Health Department.

4. IMPORTANT FOCUS AREAS RELATED TO OXYGEN AUDIT

Various focus areas of oxygen audit are as follows:

- Oxygen prescription – Written like any other drug, mention flow rate, end points in terms of SpO2/PaO2.

<table>
<thead>
<tr>
<th>OXYGEN SHOULD NOT BE ADMINISTERED WITHOUT PRESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goals:</strong></td>
</tr>
<tr>
<td>• SpO2: 90-94% (COPD: 85-90%), if breathing work does not increase.</td>
</tr>
<tr>
<td>• PaO2: 60-70mmHg, (COPD: 55-65mmHg)</td>
</tr>
<tr>
<td>• Monitor SpO2 continuously and make necessary changes so as to meet the Oxgenation goals.</td>
</tr>
</tbody>
</table>

**IN THE CASE OF FLOW RATE AND TARGET SpO2 HAS TO BE CLEARLY MENTIONED**

- Triaging of patients as per their oxygen status should be done at regular intervals. De-escalate Oxygen therapy is needed as patient improves clinically. If SPO2 is more than 94% for 12 Hrs continuously, then patient should be switched over to intermittent oxygen therapy.
- If oxygen cylinders are in use, then it is important to see that the oxygen in the container is up to an appropriate level and timely changing of empty cylinders is done. This is essential to prevent sinking of the patients due to want of oxygen at proper pressure and percentage.
- HFNC use should be minimized. HFNC use at high flow rates should be minimized. When required, BiPAP should be preferred over HFNC. HFNC should be used only in ICU setting under supervision of respiratory physician/ physician. HFNC should be used at flow rate more than 30 l/min only after getting approval from senior most respiratory physician/ physician/ institutional critical care team. Staff should encourage patients to keep mouth closed during HFNC use.
- Awake repositioning protocol to be started in all hospitalized patients with hypoxemia. Prone positioning should be intermittently done in patients with COVID-19 / severe hypoxemia along with adjunctive physiotherapy to optimize respiratory status. If awake proning protocol is not followed, reason for the same has to be documented in the case sheet.
- Wastage of oxygen through leaks should be detected on daily basis and rectified at the earliest.
- Ensure closure of valves in pipeline system in “no-use” areas.
- Maintain base flow in ventilator to minimum if it can be adjusted.
- Use non-rebreathing bag with optimally fitting mask (Monitor for air hunger-if so, increase flow rate).
- Use CPAP machine/BiPAP machine with lower oxygen flow (higher mean airway pressure can increase oxygenation) instead of high flow oxygen devices.
- Ensure adequate fit of right size mask (use templates while selecting interface) in patients receiving non-invasive ventilation to avoid leakage.
- Ensure right size of endo-tracheal tube with optimal cuff pressure so as to minimise leaks.
5.2 Additional Tips

- Ensure a knowledgeable bio medical engineer is recruited for installation and maintenance of the oxygen storage devices.
- The hospital will have to conduct regular maintenance checks on oxygen storage devices to ensure there are no leaks.
- Substandard pressure releasing valves could cause damage to the surrounding. Ensure proper PRVs are fitted.
- The right kind of valves need to be fitted on oxygen cylinders.
- Use fire retardant material for shade for dura (Bison /heat resistant sheets below tin shade).
- There should not be any bends or cracks in pipes that are supplying oxygen from the facility to the hospital or when administering oxygen to the patient.
- Use good quality spanners. Do not hammer the oxygen cylinders.

5.1 Issues, causes and solutions for preventing oxygen loss

<table>
<thead>
<tr>
<th>Issue</th>
<th>Causes</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less manpower: Hospital staff consist of doctors, nurse and ward boys. Lack of manpower can lead to -</td>
<td>Patients would help themselves</td>
<td>Increase hospital manpower</td>
</tr>
<tr>
<td>Maintenance of dura cylinders: Dura cylinders store cryogenic oxygen at -183 degrees C or lower; Leaks from dura cylinders are caused due to</td>
<td>Stored for long periods of time</td>
<td>Rotate dura cylinders</td>
</tr>
<tr>
<td>Leaks from jumbo cylinders. These are caused due to the following factors:</td>
<td>Faulty valves</td>
<td>Rotate jumbo cylinders</td>
</tr>
<tr>
<td>Avoid HFNO – High-Flow Nasal Oxygen</td>
<td>Made patients lungs lazy</td>
<td>Replace with NIV (Non Invasive Ventilation) or BiPAP (Bi Level Positive Airway Pressure)</td>
</tr>
</tbody>
</table>

Table 25: Oxygen management system issues, causes and solutions
Annexure
# ANNEXURE 1: TECHNICAL SPECIFICATIONS OF VARIOUS OXYGEN SYSTEMS

## Annexure Table 1: Technical specifications of Liquid medical oxygen

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
<th>Liquid Medical Oxygen Plant</th>
</tr>
</thead>
</table>
| 1       | Liquid medical oxygen supply system | - Liquid medical oxygen tank (VIT) and allied equipment application:  
- Storage of liquid oxygen and supply of high purity oxygen gas for medical use after conversion of liquid to gas through ambient atmospheric vaporizer.  
- The system to be supplied as per relevant applicable standard and certification. |
| 2       | Liquid medical oxygen storage tank (VIT) | - The double walled vacuum insulated evaporator 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 particulate insulation material to insulate under vacuum.  
- The VIT 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 clearing regime suitable for medical grade liquid oxygen. |
| 3       | Liquid oxygen tank with required accessories | - Quantity: 10KL X 1 No.  
- Installation: Outdoor  
- Type: Double walled, vertical  
- Capacity: Minimum 19,000 liters water capacity- 2 No  
- Design code: ASME Sec. VIII-D1 & D2  
- Material of construction: Inner shell and welded parts of SS 304 outer shell/CSASTM A316 Gr. 70/CGA-341 2002/EN13485/257/305  
- Joint efficiency: 100%  
- Radiography: 100% for inner, for outer spot  
- External plumbing: From LMO tank to vaporizer SS304  
- From vaporizer to inlet of pressure reducing station SS304  
- From outlet of pressure reducing station to main header copper  
- Cryogenic valve: Non-ferrous (Imported)  
- Cryogenic safety valves: Imported  
- Pressure building regulator: Non-ferrous  
- Leak detection test: Helium leak detection  
- Painting: Primer and finish with white RAL 9010  
- Inspection: By 3rd party (SGS/LOYD/TV)  
- Clearing: Degreasing for oxygen service and pressure test with nitrogen.  
- Withdrawal rate: 1000 cu m per hr, at 12 Bar G |
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Accessories</td>
</tr>
<tr>
<td>5</td>
<td>Safety Fittings</td>
</tr>
<tr>
<td>6</td>
<td>Submittals</td>
</tr>
<tr>
<td>7</td>
<td>Liquid Medical Oxygen supply system</td>
</tr>
<tr>
<td>8</td>
<td>Product and service specification</td>
</tr>
<tr>
<td>9</td>
<td>LMO tank and existing oxygen manifold</td>
</tr>
</tbody>
</table>

**Liquid Medical Oxygen Plant**

- L MO tank along with FMD shall be fitted with the following accessories: Top fill valve, bottom fill valve, liquid charging line blow valve, liquid delivery valve, permeate valve, gas blow valve, fitting coupling, vaporizer coupling, liquid level gauge (Dial 100 mm), high level valve, equalizing valve, low level valve, pressure gauge (100 mm dia, Range 0-25 kg/cm^2), pressure gauge isolation valve, pressurizing valve, pressurizing coil, filter, pressure regulator, exponential, pressure relief valve, expansion port, vacuum gauge connection port/vacuum probe valve.

- Two safety valves for inner vessel fitted on pipeline with flow divert valve.
- Reusable disc for inner vessel.
- Safety valve for inlet pipeline.
- Safety valve for pipeline of pressurizing evaporator.
- One rupture disc safety device on outer vessel, the liquid medical oxygen tank shall accompany the original quality test certificate covering the following documents:
  - Approval letter from CCCEC along with approved drawing from CCOE.
  - Approval letter from CCOE for use of cryogenic vessels at site.
  - Certificate from the authorized inspection agency.
  - Heat chart for pressure parts.
  - Dimension checks report.
  - Dismantling report.
  - Mechanical properties test report for production test coupon.
  - Visual inspection report.
  - Radiography examination report.
  - Liquid penetrant examination.
  - Cleaning inspection report.
  - Hydrostatic test report.

- Two vessels of 1X10 KL liquid oxygen VESSEL system will be the primary (main) supply source. In case of failure in liquid oxygen supply, it should automatically switch over to an emergency oxygen manifold having 2 X 10 cylinders.
- Design shall be static-tight.
- The unit should consist of a double walled vertical vessel (inner pressure vessel made of stainless steel and outer vessel of carbon steel).
- It should be fitted with standard accessories and should be "passed" the standard inspection requirement at factory for VESSEL.
- The copy of the certificate should be forwarded to HPL prior to shipping and original should be encased along with the shipping documentation.
- Bidder should follow International Standards.

- Capacity of liquid oxygen storage tank: 10 KL.
- Gas outlet pressure to be maintained at 4.2 kg/cm^2.
- Space taken for installation should be as per regulations of Indian Explosive controller and having easy access for LMO tank.
- The site would be protected by fences around, wall by wall concrete upward, and demarcated with proper signage.
- Indication of liquid oxygen level and outlet gas pressure should be provided.

**Material of GB tank:**

- Stainless steel.

**LMO tank and existing oxygen manifold**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Specification of components</td>
</tr>
<tr>
<td>11</td>
<td>The requirement of the cryogenic vessel</td>
</tr>
<tr>
<td>12</td>
<td>Storage tank capacity</td>
</tr>
<tr>
<td>13</td>
<td>Safety</td>
</tr>
<tr>
<td>14</td>
<td>Statutory requirements</td>
</tr>
<tr>
<td>15</td>
<td>Maintenance</td>
</tr>
<tr>
<td>16</td>
<td>Training</td>
</tr>
</tbody>
</table>

**Liquid Medical Oxygen Plant**

- Product: The liquid medical oxygen (LMO) supplied at site should be of IP grade. LMO supplied should comply with all relevant ISM PV specifications and standards under per view of the Indian Drug and Cosmetic Act rules. They should also satisfy the IP 2007 specifications.
- The cryogenic vessel will be of cylindrical shape with vaporizer and the pressure control system. It should be provided with the essential components to fill the liquid, to build-up pressure, to relieve pressure to withdraw product and to evacuate the vessel. All protective, safety and alarm provisions mandatory to liquid medical oxygen plants should be supplied.

- Vacuum insulated evaporator vessel should have a capacity of 1X10 into litres. The AV coil should have adequate capacity to handle the gas flow requirements of the hospital.
- Vaporizer coil.
- Maximum operating Pressure: 20 kg/cm^2.
- Design Pressure: 22 kg/cm^2.
- Pneumatic test pressure: Greater than 24 kg/cm^2.
- Metal temperature: -195°C to +40°C.
- Duty cycle: Continuous duty.
- Flow rate: 1200 cubic meter/hour.
- The fence, foundation, lighting, signage, approach gate, approach road, etc., are to be designed and installed by the vendor.

**Liquid Medical Oxygen Plant**

- The vendor should ensure that all the safety norms and standards applicable as per the rules and regulations prescribed by the CCEC. Following are the mandatory provisions for vessel:
  - Vessel low liquid level alarm.
  - Vessel low pressure alarm.
  - Pipeline low pressure alarm.
  - Fire-rated valve.
  - Twin safety valve.
  - Non return valve and 3-way diverter (by-pass) valve.
  - Automatic changeover to manifolds with control panel.
  - Alarm on indicating manifold if use in case the vessels is not in use.
  - Alarm on low pressure back-up manifolds.

**Liquid Medical Oxygen Plant**

- All statutory requirements of the Chief Controller of Explosives of India and ISM PV rules need to be followed, besides, all regulations and guidelines prescribed by the Govt. of India from time to time should be followed.

<table>
<thead>
<tr>
<th>Sr. No.</th>
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</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Training</td>
</tr>
</tbody>
</table>

- Satisfactory Training to be provided at site to designated authorities for minimum 2 weeks.

**Source:** Technical Specifications – Liquid Medical Oxygen Plant

[David Medicine Building, Government Medical College & Hospital, Aurangabad]
Annexure Table 2: Technical specifications for procurement—oxygen cylinders

Oxygen and medical air cylinders are refillable containers for such gas, in a compressed form, available in international standard capacities/pressure and dimensions. The cylinders can be made of steel, aluminium/alu, carbon fibre or other composite material.

Nominal pressure should be 13 700 kPa (137 bar, 1987 psi) for standard cylinders and 23 000 or 30 000 kPa (220 or 300 bar, 3336 or 4351 psi) for cylinders fitted with integral valves.

Each cylinder is fitted and supplied with a valve. Multiple options for pressure regulators, various fitting and outlets, and integral valves should be available separately.

Specific ISO, American National Standards Institute (ANSI) and other international colour coding for oxygen and medical air should be available.

Accessories like holders, racks and trolleys should be available separately.

**Oxygen cylinders:**
- Refillable cylinders for compressed oxygen (all-free and compliant to ISO standards) or air (compliant to ISO standards) for medical use.
- Fitted with a primary valve, standard pin index or bundled pin, or integral refillable.
- Nominal pressure 13 700 kPa (137 bar, 1987 psi), for standard valve cylinders, or 23 000–30 000 kPa (220–300 bar, 3336–4351 psi) depending on the cylinder model, for integral valve cylinders.
- Compressed Gas Association (CGA) approved seamless steel/aluminium alloy composite body, colour coding according to ISO/ANSI/CSA/GP/NFA, class ISGUS standard.
- Cylinders supplied with optional pressure regulators, multiple fitting according to the international standard, safety over-pressure relief valve (if not built-in the integral valve fitted cylinders).

**Primary valve and pressure regulator assemblies:**
- Pin index or bulkhead primary valve and compatible pressure regulators, providing pressure regulated supply of oxygen (all-free and compliant to ISO standards) or medical air (compliant to ISO standards).
- Stainless steel/aluminium casing, brass valve.
- Nominal inlet pressure 13 700 kPa (137 bar, 1987 psi), maximum 20 000 kPa (200 bar, 2960 psi).
- Outlet pressure 345 kPa (5.0 bar, 50 psi).
- Integrated manometer, 0–20 000 kPa (0–200 bar, 0–2900 psi).
- Safety over-pressure relief valve.
- Pressure regulator supplied with flowmeter, if required; see configurations/option specifications, integral value:

  **Integral valves:**
  - All-in-one cylinder valve for oxygen (all-free and compliant to ISO standards) or medical air (compliant to ISO standards), providing direct attachment to the cylinder, pressure regulation and supply of medical gas with adjustable flow rate.
  - Steel/aluminium casing, brass valve.
  - 5 mm barbed and BS 5682 Schrader (if applicable depending on the size of the cylinder outlet).
  - Integrated open-close valve, outlet nominal pressure 400 kPa (4 bar, 58 psi).
  - Inter pressure 23 000–30 000 kPa (220–300 bar, 3336–4351 psi), depending on the cylinder model.
  - Integrated refillable ISO 5145/CGA 640 compliant.
  - Integrated manometer, covering the full nominal pressure range of the cylinder, standard 23 000–30 000 kPa (220–300 bar, 3336–4351 psi), for integral valve cylinders, or whatever applicable.
  - Integrated flowmeter.
  - Safety over-pressure relief valve.

  Capable of being stored in ambient temperature of at least 5–50 °C, relative humidity of at least 15–95% non-condensing.

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Suitable for continuous operation in ambient temperature of at least 5–45 °C, relative humidity of at least 15–90% non-condensing. Specific requirements for altitude may be required, depending on the installation site. Applicable regulations on transport and storage of cylinders may vary if the cylinders are empty or partially full.

Compliance with regulations on hazardous goods, flammable, explosive, compressed gas, according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and international standards, is mandatory.

**Oxygen cylinder configurations/options:**

- Standard and MRI-compatible versions.
- Specific ISO/ANSI/CSA/GP/NFA colour coding for oxygen and medical air.
- Seamless cylinders made of steel, aluminium/alu, carbon fibre or other composite material (CGA approved and compliant to ISO applicable standards).
- Pin index/bulkhead and integral valve options.
- OXYGEN and MEDICAL AIR cylinders with STANDARD VALVE available in all the ISO international standard sizes, including size AZ, C, D, E, F, G, H, I, and also U.S. sizes M2 to M 205 (not all sizes apply to both oxygen and medical air).

The type of standard valve has to be compliant to international ISO and U.S. standards, i.e., pin index ISO 40798 BS63/CGA 870 valve, CGA 540 valve, 5/16 inch BSF (F) bulkhead BS 341 valve, also according to the size/pressure of the cylinder and to any applicable regulation.

OXYGEN cylinders should be available also with INTEGRAL VALVE (with manometer and flow regulator, 400 kPa (6 bar) nominal outlet pressure, 6 mm barbed and BS 5682 Schrader outlet), in all the ISO international standard sizes, including size 2A, 2D, 2D, 2X and 2X, and also US sizes M2 to M 205 in a moulding system.

Regulator/integral valve configurations/options:

- Standard and MRI-compatible versions.
- Oxygen and medical air versions.

Pressure regulators and integral valves should be available with BDS and 6-mm barbed outlet.

Pressure regulators should be available in basic open-case model and fitted with integrated flowmeter, Thrope or Bourdon gauge. Pressure regulators and integral valves with Thrope or Bourdon flowmeter should be available at least in the following flow ranges, for oxygen and medical air:

- Low flow 0.3 to 4 L/min (only for oxygen), discrete (10% flow setting) 0.3, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0 L/min, accuracy 10%.
- Standard flow 0.15 L/min, discrete (10% flow setting) 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 15.0, 20.0 L/min, accuracy 10%.
- High flow 0.25 L/min minimum, discrete (10% flow setting) 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 15.0, 20.0 L/min, accuracy 15%.
- Standard flow 0.25–1.5 L/min, 10% flow setting (80%–120%), regulated flow 0.25–1.5 L/min, accuracy 10%.
- High flow 0.25–4.0 L/min, minimum, accuracy 10%.

Cylinder body, primary valve and pressure regulator or integral valve assembly, outlet connectors, safety pressure relief valve, valve/regulator knob, manometer and flowmeter (for integral valve), portable or stationary (depending on the size of the cylinder), Brass valve assemblies, Cylinders made of steel, aluminium/alu, carbon fibre or compound material, bronze/brass/synthetic sealings, all materials in contact with air certified for medical use.
Suitable for continuous operation in ambient temperature of at least 5–40 °C, relative humidity of at least 10–90% non-condensing. Specific requirements for altitude may be required, depending on the installation site.

Applicable regulations on transport and storage of cylinders may vary if the cylinders are empty or partially/fully filled.

Compliance with regulations on hazardous goods, flammable, explosive, compressed gas, according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and international standards, is mandatory.

Display parameters
- Pressure and flow (for integral valve cylinders only).

User adjustable settings
- Open/close control, pressure and flow (for integral valve cylinders only).

Accessories
- Cylinder holding, carts, trolleys, Supplied with keys and tools to operate valves and regulator.

Spare parts
- Common and frequently used spare parts, sensors/ transducers/ actuators, reusable probes/cables/patient connection accessories, periodic maintenance and calibration kits/materials, accessories that should be procured together with the equipment and in quantities sufficient for 2 years recommended (1 year at least) of typical use.
- These items should be supplied to each department where the equipment is installed and shipped to local and local maintenance division, loading set, maintenance kit, regulating unit (knob), adapters and connectors, keys and tools to operate the valves. Terms in the above-mentioned categories that are not frequently needed or require specialized skills to be used/used should be assessed by technical staff before procuring the main medical devices, and procured together. It is recommended to store and use them in central and local maintenance department.

Primary valve assembly, regulator valve assembly, pressure safety valve, inlet/outlet connections, full set of safety, integral valve assembly, manometer and flowmeter (for integral valves).

Mobility, portability (if relevant)
- Portable or stationary (depending on the size of the cylinder).

Documentation requirements (English language mandatory)
- User and maintenance manuals, hard and soft copies, in English (mandatory) and other languages (preferable). Certificate of calibration and inspection, Troubleshooting, calibration and routine maintenance. List of accessories and accessories, with part numbers and contact details for parts supply, Document with contact details of manufacturer, supplier and local service agent.

Transportation and storage and primary packaging labeling
- Applicable regulations on transport and storage of cylinders may vary if the cylinders are empty or partially/fully filled.
- Compliant with regulations on hazardous goods, flammable, explosive, compressed gas, according to GHS and international standards is mandatory.
- Sealed container.
- Capable of being transported and stored in ambient temperature of at least 5–40 °C, relative humidity of at least 10–90% non-condensing. Specific requirements for altitude may be required, depending on the installation site.
- Hazardous goods, flammable, explosive, compressed gas labelling according to GHS and international standards and regulations.

Primary packaging:
- Unit of use: one [1] cylinder or valve/regulator in a box or case with manufacturer's instructions for use, spare parts and accessories (when applicable). Cylinder type and content in litres, tare weight (weight when empty), maximum cylinder pressure, cylinder size code.
- Labelling on the primary packaging:
- Name and/or trademark of the manufacturer; manufacturer's product reference: type of product and main characterizations; lot number prefixed by the word "LOT" (or equivalent harmonized symbol) (if applicable), information for particular storage conditions (temperature, pressure, light, humidity, etc.), as appropriate (or equivalent harmonized symbol), information for handling, if applicable (or equivalent harmonized symbol).
- Over packaging:
- Packaging unit:
- Labelling to be the same as primary packaging. Extra information required: number of units.

Standards, for the manufacturer:
- Certified quality management system for medical devices (e.g., ISO 13485).
- General quality management (e.g., ISO 9001).
- Application of risk management to medical devices (e.g., ISO 14971).

Regulatory approval/ certification:
- Free sales certificate (FSC) or certificate for exportation of medical device provided by the authority in manufacturing country. Proof of regulatory compliance, as appropriate, per the product's risk classification (e.g., Food and Drug Administration [FDA] and/or Conformité Européenne [CE]).
- Compliance to the following international standards or to a regional or national equivalent (including the technical tests for safety and performance from accredited laboratory or third party) for:
  - Colour coding ISO or ANSI for medical gases.
  - Conforms to ISO, NFPA and/or CAN standards, and/or UL or CSA approved.
  - ISO 11144 Gas cylinders – Compatibility of cylinder and valve materials with gas contents.
  - ISO 10524 Pressure regulators for use with medical gases.
  - ISO 15002 Flow-metering devices for connection to terminal units of medical gas delivery systems.
  - ISO 15245 Gas cylinders – Parallel threads for connection of valves to gas cylinders.
  - ISO 15297 Gas cylinders – Cylinder valves – Specification and type testing.
  - ISO 17871 Gas cylinders – Quick-release cylinder valves – Specification and type testing.
  - ISO 17879 Gas cylinders – Swivel-coupling cylinder valves – Specification and type testing.
  - ISO 457 Screw medical gas cylinders – Pin-index yoke-type valve connections.
  - ISO 5145 Cylinder valve outlets for gasses and gas mixtures – Selection and dimensioning.
  - ISO 12299 Gas cylinders – Outlet connections for gas cylinder valves for compressed breathing air.
  - ISO 14245 Gas cylinders – Cylinder valves – Manufacturing tests and examinations.
  - ISO 22435 Gas cylinders – Cylinder valves with integrated pressure...
Annexure Table 3: Technical specifications for medical gas pipeline system

<table>
<thead>
<tr>
<th>Pipeline Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper Pipes</td>
<td>Will be Solid drawn, seamless de-oxidised, non-ferrous, half-hard, cold-drawn and de-greased materials conforming to BS 971/1981 (CuZnRP) manufactured as per BS 2971/1971 and dimension tolerances conforming to BS-EN 1057. Pipe fittings conform to BS-EN 1254-3:1998. Lloyd's certified</td>
</tr>
<tr>
<td>Fittings</td>
<td>End-feed type, made from the same grade of copper as the pipes, and in accordance with the requirements of BS-EN 1254-1:1998 Part 1.</td>
</tr>
<tr>
<td>Delivery to site</td>
<td>In degreased condition, plugged or capped at both ends and supplied sealed in protective polythene bags, accompanied by certificate from Lloyd’s certified</td>
</tr>
<tr>
<td>Joints, on site</td>
<td>To be brazed, except for mechanical joints used for components, employing a method that permits the joints to maintain their mechanical characteristics up to 500 deg C.</td>
</tr>
<tr>
<td>Brazing system</td>
<td>Fluxless brazing using a copper-phosphorus brazing alloy to BS-1845.</td>
</tr>
<tr>
<td>Pipe wall thickness</td>
<td>Copper pipe Ø22 (in mm) 12.15, 22.28, 42 Thickness (in mm) 0.9 1.2</td>
</tr>
<tr>
<td>Pipe damp</td>
<td>Shall be non-reactive to copper and be of non-ferrous or non-deteriorating plastic suitable for the diameter of the pipe.</td>
</tr>
<tr>
<td>Pipeline support</td>
<td>Spacing not to exceed 1.5M, irrespective of the pipe diameter.</td>
</tr>
<tr>
<td>Passage through walls &amp; floors</td>
<td>Through suitable sleeves.</td>
</tr>
<tr>
<td>Earthing</td>
<td>To be connected to one or more earth terminals.</td>
</tr>
<tr>
<td>Painting</td>
<td>All exposed pipes to be painted with two coats of synthetic enamel paint, the color codification complying with ISO 5359 / IS 2270.</td>
</tr>
<tr>
<td>Marking and colour coding</td>
<td>To mark with the name and / or symbol adjacent to shut-off valves, at the junctions and the changes of direction, before and after walls and partitions, etc. at the intervals of no more than 10M and adjacent terminal units.</td>
</tr>
<tr>
<td>Direction marks</td>
<td>Marking to include arrows denoting direction of flow and letters used for marking shall not be less than 6mm high.</td>
</tr>
<tr>
<td>Identification</td>
<td>All concealed pipes to have gas identification bands/ labels are at appropriate distance, similarly all pipes which need embedding in the wall will be tested painted/ painted and properly insulated in accordance with ISO 5359.</td>
</tr>
<tr>
<td>Post-installation</td>
<td>After erection, the pipelines are to be flushed and purged clean with dry nitrogen gas.</td>
</tr>
<tr>
<td>Testing</td>
<td>Pressure testing using dry nitrogen gas at 1.5 times the working pressure for atleast 24 hours. System should exhibit its integrity and no leakage. All contraindications, if any, to be carefully examined, problems diagnosed and necessary rectifications/ substitutions carried out, and test repeated after re-purging the lines.</td>
</tr>
</tbody>
</table>

**COLOUR CODE FOR MEDICAL GASES PIPES As per IS 2710-1983**

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>GROUND COLOUR</th>
<th>FIRST BAND</th>
<th>SECOND BAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Oxygen</td>
<td>Canary</td>
<td>White</td>
</tr>
<tr>
<td>Canopy</td>
<td>Yellow</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>


The technical specification for oxygen cylinder from WHO are available at: [https://apps.who.int/iris/bitstream/handle/10665/3387452/9789241516874-eng.pdf?ua=1](https://apps.who.int/iris/bitstream/handle/10665/3387452/9789241516874-eng.pdf?ua=1)
<table>
<thead>
<tr>
<th>GAS OUTLET POINTS FOR OXYGEN INLET:</th>
<th>GENERAL INSTRUCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Company personnel should visit the site for locating the site of gas bank and for estimating length of pipeline &amp; other details.</td>
</tr>
<tr>
<td>Type</td>
<td>Demonstration should be arranged by the company for the acceptance of specification.</td>
</tr>
<tr>
<td>Type of outlet</td>
<td>Per unit cost of each item should be quoted.</td>
</tr>
<tr>
<td>Valves</td>
<td>The quotation for the item should be given together and no separate cost of any nature will be entertained subsequently.</td>
</tr>
<tr>
<td>I/d</td>
<td>Company should have installed the system at 3 institutes in India and should produce certificate of satisfactory service reports from these institutes.</td>
</tr>
<tr>
<td>Front plate</td>
<td>The copy of the certificate of materials supplied must be produced along with the tender and at the time of delivery of the material. E.g., Lloyd’s certificate for copper pipe.</td>
</tr>
<tr>
<td>Compliance</td>
<td>Company who gets the contract must submit the AUTOCAD DRAWING of the system for final approval of technical committees.</td>
</tr>
<tr>
<td>Post-installation purging</td>
<td>Company should arrange for training of hospital staff and company personnel should be available till hospital staff is trained.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>Company personnel should visit the site for locating the site of gas bank and for estimating length of pipeline &amp; other details.</th>
</tr>
</thead>
<tbody>
<tr>
<td>As secondary/ reserve source, the primary source being the liquid oxygen tanks arranged through other contracts,</td>
<td>Demonstration should be arranged by the company for the acceptance of specification.</td>
</tr>
<tr>
<td>Main manifold configuration</td>
<td>Per unit cost of each item should be quoted.</td>
</tr>
<tr>
<td>2 x 10 cylinders</td>
<td>The quotation for the item should be given together and no separate cost of any nature will be entertained subsequently.</td>
</tr>
<tr>
<td>Emergency Manifold</td>
<td>Company should have installed the system at 3 institutes in India and should produce certificate of satisfactory service reports from these institutes.</td>
</tr>
<tr>
<td>2 x 2 cylinders with single regulator</td>
<td>The copy of the certificate of materials supplied must be produced along with the tender and at the time of delivery of the material. E.g., Lloyd’s certificate for copper pipe.</td>
</tr>
<tr>
<td>Pressure rating</td>
<td>Company who gets the contract must submit the AUTOCAD DRAWING of the system for final approval of technical committees.</td>
</tr>
<tr>
<td>145 kg/cm²</td>
<td>Company should arrange for training of hospital staff and company personnel should be available till hospital staff is trained.</td>
</tr>
<tr>
<td>Flow rate</td>
<td>(Source: <a href="https://www.gov.in/2018/12/10/2018-12-10%20OXYGEN%20MANIFOLD%20DESCRIPTION.pdf">https://www.gov.in/2018/12/10/2018-12-10%20OXYGEN%20MANIFOLD%20DESCRIPTION.pdf</a>)</td>
</tr>
<tr>
<td>[Specify] attach calculation</td>
<td></td>
</tr>
<tr>
<td>Formal</td>
<td></td>
</tr>
<tr>
<td>Wall mounting straight line</td>
<td></td>
</tr>
<tr>
<td>Top frame</td>
<td></td>
</tr>
<tr>
<td>High-pressure copper pipes of size ½” I/D, x 15swg, high pressure brass fittings made of high tensile brass, non-return valves &amp; high pressure copper bell pipes, made of high pressure copper pipes of size ½” I/D, x 15swg</td>
<td></td>
</tr>
<tr>
<td>Middle &amp; Bottom frames</td>
<td></td>
</tr>
<tr>
<td>To suit both round and flat bottom cylinders.</td>
<td></td>
</tr>
<tr>
<td>High pressure regulator</td>
<td></td>
</tr>
<tr>
<td>For both manifold systems for reducing the cylinder pressure suitable to the line pressure.</td>
<td></td>
</tr>
<tr>
<td>Source shut-off Valves</td>
<td></td>
</tr>
<tr>
<td>For ease of charging and positioning, without closing the bank.</td>
<td></td>
</tr>
<tr>
<td>Filter</td>
<td></td>
</tr>
<tr>
<td>Cylinder to be set in place using cylinder brackets and fixing chains, all zinc plated.</td>
<td></td>
</tr>
<tr>
<td>Fixity</td>
<td></td>
</tr>
<tr>
<td>All works to be powder coated, the color coding complying with ISO 5399: BS 2379.</td>
<td></td>
</tr>
<tr>
<td>Painting</td>
<td></td>
</tr>
<tr>
<td>Non-halogenated polymer materials only are permitted to be used in the non-return valves,</td>
<td></td>
</tr>
<tr>
<td>Specific requirement</td>
<td></td>
</tr>
<tr>
<td>Delivery to site</td>
<td>In degassed condition, plugged or capped at all ends and supplied sealed in protective polythene bags, accompanied by post-delivery test certificate.</td>
</tr>
<tr>
<td>Pre-delivery and post-installation pressure testing to 1.5 times the working pressure,</td>
<td></td>
</tr>
<tr>
<td>Testng</td>
<td></td>
</tr>
<tr>
<td>Pre-Delivery test certificate to accompany supply to site, Post-installation testing to be witnessed by the Engineer, who shall receive the documents,</td>
<td></td>
</tr>
</tbody>
</table>

(Source: https://www.gov.in/2018/12/10/2018-12-10%20OXYGEN%20MANIFOLD%20DESCRIPTION.pdf)
TECHNICAL SPECIFICATION FOR PSA PLANTS (AS PER GOI TENDER DOCUMENT)

1. Compressed Air system consisting screw type compressor (2 numbers to be supplied with each PSA system)

I. The oxygen concentrator should be supplied with Air compressor system to meet the peak load at atmospheric air and pressure requirement.

II. The compressor should be suitable as per site conditions, for working pressure of 7.5-8 Bar, fitted with electric motor, three phase, AC 415 ± 1% volts, 50 Hz frequency, rotary screw element complete with dry paper type suction air filter with silencer, conveniently located for easy replacement of filter element with integrated regulating valve for load/ unload control system, simple design with only one moving part, need no regular adjustment, three way solenoid valve required for load/ unload regulation of the compressor, air/ oil temperature sensor to sense the air oil temperature, electronic controlled that optimizes operations of the compressed system, should act as intelligent user interface for improved navigation, should monitors, controls, protect the compressed system.

III. Start/ Stop for starting/ stopping the compressor having build-in display unit with the keypad users interface for indicating the following messages,

IV. Operation Type: Automatic loading and unloading of Compressor Control Type: Local, Remote & Computer Timer Activated / not activated, Discharge Pressure, running hours, loading hours, reguAtrial hours, service Plan.

V. Compressor Package is enclosed in a powder coated acoustic canopy with sound absorbing material for limiting the noise level. Canopy is pressurized ensuring no pressure drop at suction filter and avoids entry for dust particles in the element in the anti-vibration mounts support electric motor and compressor unit and isolate the moving components from the rest of the structure. The desired working pressure of the compressed dry air should be 7.5-8.0 Bar.

VI. Compressed air system comprising of screw air compressor, air cooled with PLC based control panel coupled with motor assembly.

VII. The compressor should be capable of delivering air as required for PSA, pressure swing adsorption generator.

VIII. The compressor shall have to be with all standard accessories compatible with oxygen generator.

IX. The flow capacity of the compressor and delivery pressure shall be as specified by Core PSA Medical Oxygen Generator service provider. The motor rating shall be suitable for air compressor.

X. Average ambient conditions to be considered for air compressor with regards to temperature and site elevation. The site should be able to work in all weather conditions.

XI. The air compressor shall be manufactured to internationally acceptable standards with CE mark and ISO 9001 and ISO 13485 certification.
   a. ISO 8573-1: Compressed air – Part 1: Contaminants and purity classes
   b. ISO 8573-2: Compressed air – contaminant measurement – Part 2: Oil aerosol content
   c. ISO 8573-4: Compressed air – contaminant measurement – Part 4: particle content
   d. ISO 5011: Inlet air cleaning equipment for internal combustion engines and compressors – performance testing.

XII. Intake air temperature shall be conditioned to between (minus)10 to +55 deg C and 35% RH (or plant operating conditions as indicated by supplier).

XIII. It should be supplied with all accessories for full installation and operation -flywheel, foundation bolts, motor pulley, v-belts, belt guard, and slide rails for the motor.

XIV. EEF1 (CEMEP) rated totally enclosed fan-cooled, IP55 class F electric motors shall be used and incorporate maintenance-free greased forlife bearings. Motors with lower (equivalent) efficiency ratings are not acceptable.

2. Refrigerant Air Dryer

i. Refrigerant type Air Dryer should have inlet pressure equal to outlet pressure from Air compressor, inlet air temperature less than 45°C, ambient temperature +20°C to +45°C, dew point temperature of maximum +3°C and inlet air capacity compatible to air delivery of 7.5-8Bar pressure.

ii. The dryer shall be provided with power supply as required by dryer vendor.

iii. It should be equipped with safety valves. It should be of simple plug and play concept.

iv. The pressure shall be self-regulating.

v. The dryer shall include the following components
   a) Refrigerant Circuit
      • Refrigerant separator and compressor
      • Maximum pressure switch and fan control switch (FX 13-21)
      • Condenser fan and condenser
      • Capillary filter and tube
      • Hot gas bypass
   b) Air Circuit
      • Air inlet to refrigerant heat exchanger
      • Air/heat exchanger
      • Water separator
      • Automatic drain
      • Air outlet

3. Air Receiver

i. The system should be provided with an Air Receiver having the specific capacity and should be designed in such a way to sustain pressure of 7.5-8Bar.

ii. The air receiver should be fabricated as per ASME Sec VIII Div.1 or IS 2825Code or equivalent and fitted with 2 Nos. auto drain-out moisture filters.

iii. A corrosion allowance of 3 mm shall be considered.

iv. The receiver vessel shall be provided with a pressure gauge, safety valve and auto drain valve.

v. Vertical floor mounted design equipped with pressure gauge, safety release valve,
manual and automatic, zero-loss drain valve (float-type are not acceptable).

vi. The receiver assembly shall be fitted with a pressure safety valve capable of passing the maximum flow output of the compressor at 10% receiver over pressure.

4. Filtration system for the compressed Air

i. Food air quality of the oxygen concentrator shall be conforming to ISO 8573Class 4 and is of filtration grade of 0.01 micron.

ii. The filtration system should include both inlet filtration comprising of micro filter and active carbon filter as well as outlet filtration comprising dust fine filter.

iii. Type of filters to be specified in terms of Prefilter (>5 micron); Fine filters, coalescing filter (0.1 micron); and coal filter (coal tower, alternatively activated carbon filter).

5. Molecular Sieve Units

i. The plant should comprise of duplexed air treatment/molecular sieve devices to permit continuous generation of oxygen: two sets of filters and a pair of molecular sieves.

ii. One of the pairs of duplex sieves will be in the adsorbing stage, whilst the other regenerates.

iii. Each vessel will have dual gas baffle and strainer assemblies to protect and contain the molecular sieve.

iv. Each molecular sieve shall be a high-performing chemically produced zeolite as the molecular sieve media which has been compacted to the correct

v. Density by means of vibration to adsorb specific types of molecules (such as water vapour or nitrogen).

vi. Pneumatic valves shall control the generation and regeneration process to ensure proper changeover between the two sieve devices.

vii. A vacuum pump may be required as part of the system. The vacuum pump, if provided, is utilized during the adsorption/regeneration process.

6. Oxygen Concentrator Module

i. Fully automated system Microprocessor based oxygen concentrator module, duplex process valve system with PSA (Pressure Swing Adsorption) Technology.

a. Each module should be able to produce medical grade oxygen purity of 93% ± 3%. The oxygen should be of medical grade and shall be supplied through oxygen outlet at minimum pressure of 4, 2-6 bar at all times of operations of the generator.

b. Automatic shut off valve should be installed to control the medical oxygen purity and pressure.

c. The oxygen concentrator system shall have PSA sieve beds with touchscreen for display of size not less than 5” for constant quality control by measuring oxygen purity, outlet pressure, instruction manual, curves of oxygen pressure, basic setting, alarm facility for process a cycle failure, low oxygen pressure, maintenance alerts, process overview with valve operation and an analogue values.

d. In case of valve malfunctioning the panel shall have diagnostic tool top in point exact values in question for fast service.

e. The plant should be able to deliver medical grade oxygen at Indian Pharmacopeia monograph quality standards.

ii. Medical Oxygen (As per Indian Pharmacopeia 2018- Oxygen 93%).

- Oxygen 93% contains not less than 90.0 percent and not more than 96.0 percent v/v of oxygen
- Oxygen Purity: 93% +/- 3%
- CO: <5 ppm
- CO2: <300 ppm
- Water Vapour< 67ppm
- SO2: 0 ppm
- NO2: 0 ppm

iii. Maintenance: Free self-lubricating, heavy duty valve section, angil seat pneumatic valve technology for constant availability of pure oxygen. The inlet pressure sensor shall be included in the scope of the contract.

iv. The oxygen concentrator should have built in Zirconium/Ultrasonic/Galvanic type oxygen sensor with Oxygen Analyzer with digital display having automatic backup control system also fitted with Medical sterile and bacterial filter.

v. Operating Temperature range (minus)50 C to +50°C

vi. Humidity: up to 95%

vii. Electrical Supply – 220-240VAC, single or 3 Phase. It may vary as per the requirement of the site and the plant size.

viii. Should be Automatic and designed for unattended operation (but to be strictly monitored by service provider with all safety measures required to ensure non-stop operation when power goes off and supply should have a backup tank for storage of oxygen in tank of proper capacity case power is off due to load shedding maintenance etc. 24X7 in 3 shifts)

ix. Should have silenced; Silencer reduces air discharge noise to less than 65dBA.

x. All the Certifications should be provided by Original Equipment Manufacturer

a. It should have ISO 9001:2008 certification – for organization

b. Oxygen Generator must have US FDA (United States, Food and Drug Administration) or CE Certificate/ CE (Conformity European) / EC (European certificate), certification of the Original Equipment Manufacturer.

c. ISO 13485: 2016 certification – for design of medical systems

d. ISO10083/ENISO7396-1/EN737-3European Standards and should be in accordance with medical device directives 93/42/EEC or Medical use international standard regarding the supply of oxygen via oxygen generators for a use in medical gases distribution networks.

xi. In case of the bidder supplying imported PSA Plant, he should give a certificate from the OEM that the generator offered by the bidder (its brand and its model number) is manufactured by the OEM as a medical grade oxygen generator and sold as such in INDIA.

7. Oxygen Analyser

The oxygen analyser should be from Core PSA/ Same OEM plant supplier only.

Local makes or after- market devices shall not be accepted. Analyser shall meet the following specifications to ensure long term reliability
a. Sensor —rated for use with PSA oxygen production (e.g. ultrasonic, galvanic, or equivalent), to be specified by bidder

8. Oxygen Product Receiver
   i. The oxygen receiver tank shall be of capacity as specified by Core PSA Medical Oxygen Generator or service provider.
   ii. Nominal operating pressure shall be based on maximum rated pressure for tank, both to be clearly indicated.
   iii. The vessel shall be designed and manufactured as per ASME Section VIII Div 1 Or Equivalent.
   iv. The Service provider shall maintain design calculations. A corrosion allowance of 1.6 mm shall be considered.
   v. The receiver vessel shall be provided with a pressure gauge, safety pressure release valve and auto drain valve.
   vi. Vertical floor mounted design equipped with pressure gauge, safety release valves.

9. Automatic change over Panel
   The automatic change over panel shall be compatible with oxygen plant. The cover of Panel shall be made of SS/MS duty powder coated. Automatic changeover panel should maintain the following:
   i. Continuous pressure
   ii. Continuous flow
   iii. Purity of oxygen
   iv. Power failure

10. Main Electrical Panel
    i. The Main electrical control Panel should be compatible with Oxygen plant and allied equipment.
    ii. The Panel should have automatic starter, overload protection, single phase preventer, timer assemblies, emergency stop buttons and indication lamps etc. for successful operation of all the components of the Oxygen plant.
    iii. Equipment shall be earthed in an approved manner as per I.E.E. rules and acceptable to the local authority.
    iv. Earthing station shall be provided by the Service Provider. No medical gases pipe shall be used for electrical earthing.
    v. Entire installation shall be done taking care to follow all safety regulations under BIS standards for electrical installation of oxygen generation plant.
    vi. Charging of the panel to be included in the scope of work (This requires Cable lying, electrification work from the main panel and earthing works). The entire cabling from the mains to the panel should be armored cable up to 30mtrs only.
    vii. The control panel provided with plant should have following features as minimum:
        • LCD illuminated display.
        • Meters
        • Pressure in product tank is visual on the display, Range is adjustable
        • Prepared for oxygen purity monitoring. Range is scalable in the control panel
        • Alarms - All alarms described on the controllers display for easy and fast recovery.

Alarms on air dryer and air compressor should be monitored by the controller (requires digital signals)

   • Drain Control - Automatic drain control for the air vessel to ensure proper air quality
   • Smart delivery - Intelligent delivery based on pressure and purity
   • Service indicator - The system should automatically detects when the service is needed (based on operating hours) and should display a message

11. Alarm System
    i. Providing and fitting of Main Alarm Panel to indicate any abnormality of gas pressure and other failures of the system. Job includes providing of Medical Gas Alarm System for 01 services viz. oxygen.
    ii. The Alarm System consists of an isolation valve box, pressure sensors, circuit plate with LED colour indicators for visual indications.
    iii. The Gas Alarm system is sensitive to detect any pressure drop in the supply pipelines.
    iv. The Alarm System is fitted with electronic hotter/audio siren for audio indications of pressure drop.
    v. The alarm is provided with the manual pressure gauge for indication of pressure in services. It shall have anti-microbial coating labels for touch control.
    vi. The alarm system shall be complete with digital display, sensor module and power supply. The alarm system shall be complete with all indication controls, wirings, accessories etc. as required.

12. Servo Voltage stabilizer
    Servo voltage stabilizer of suitable capacity for oxygen plant and allied equipment’s with input voltage range 300V-480V & output voltage 415+1% rating 3 phase 50Hz; micro processed based digital display suitable for unbalanced/balanced supply and unbalanced/balanced load copper wound with bypass switch, MCCB, selector switches, complete in all respect.

13. Online UPS of suitable capacity
    With at least 30 min backup for PLC of the concentrator plant or as per manufacturers standards.

14. Documents to be submitted along with Technical Bid
    i. Flow line diagram/Block Schematic Diagram, colored technical manuals scanned in original of the complete oxygen plant should be provided with the tender document.
    ii. Bidder should submit complete technical offer including Make, Model and certifications in accordance with technical specifications with Non Price BOM (Bill of Material) i.e. for each component or equipment installed with PSA Oxygen Generation Plant.
    iii. Copies of same documents to be submitted to the Hospital at the time of handing over the Plant to the Hospital after commissioning.

15. Erection of the plant should be under the scope of the bidders which includes masonry works required for plant erection and commissioning as per the Foundation layout.
    Any work beyond the scope of Hospital and necessary for successful installation, testing and commissioning of PSA Oxygen Plant shall be deemed to have been included within the scope of vendor with no extra cost.
16. **Oxygen pipeline works** (including fabrication/welding/jointing if required) from the Plant till the existing Oxygen supply system/manifold system/LMO system or 15m whichever is lower of the hospital shall be of vendor’s responsibility.

17. **Warranty and CAMC**

All the equipments including the accessories supplied as per the technical specification should carry comprehensive warranty for a period of THREE years and Comprehensive Annual Maintenance Contract (CAMC) for a period of SEVEN years. During this period, the successful bidder shall examine all defective parts and attend to all repairs/breakdowns and undertake stipulated number of preventive maintenance visits to every user installation site. The cost of spare parts for all replacements has to be borne by the successful bidder during the period of comprehensive warranty and Comprehensive Annual Maintenance Contract (CAMC). Maintenance of all the equipments for Ten (10) complete years (3 year Warranty + 7 Years CAMC) from date of commissioning of Oxygen Plant and comprise of consumable items, Consumable/ lubricants, filters, UPS, Batteries for complete servicing of equipments or replacement of any spare parts as well which may develop defect during said period. The servicing shall be carried strictly as per maintenance schedule of OEM. The replacement of Zeolites should be included in warranty and CAMC period. The Comprehensive Annual Maintenance Contract (CAMC) is otherwise an extended warranty. All the terms and conditions agreed by the successful bidder for executing the comprehensive warranty of the equipment shall be extended during the period of CAMC, only difference being the payment of CAMC charges is absent during the period of comprehensive warranty. Warranty as well as Comprehensive Maintenance contract will be inclusive of all accessories supplied as per Technical Specifications and it will also cover the following wherever applicable:

- Any kind of motor
- All kind of sensors
- All kind of coals
- Consumable items
- Consumable/lubricants
- Filters
- UPS including the replacement of batteries
- Replacement of Zeolites

18. **Life Span**

Minimum 15 years and certificate in this regard should be from OEM. Vendor should also certify the availability of all the parts/spares/accessories delivered with the equipment to be available for 15 years. Certification from the OEM should be produced in this respect.

19. **Documentation (included, minimum in English language)**

Hard and soft copies, in English language as requirement and local language as preference, of

- Life span of minimum 15 years; guaranteed by a letter from the manufacturer
- Certificate of quality, calibration and inspection
- User manual, detailing
  - Specific protocols for operation
  - List of equipment and procedures required for cleaning, disinfection, troubleshooting, calibration, and routine maintenance
- Service manual
- Contact details of manufacturer, and authorized distributors (if applicable), and local service agent.

**Quality Certificates**

a. Copy of ISO certification or GMP Certificate of its original equipment manufacturer.

b. ISO 13485: 2016 certification – for design of medical systems.

c. ISO 10083/ EN ISO 7396-1/ EN 737-3 European Standards and should be in accordance with medical device directives 93/42/EEC or Medical use international standard regarding the supply of oxygen via oxygen generators for a use in medical gases distribution networks.

d. The Medical grade oxygen concentrator/generator shall be either USDA approved or CE or should have CE Conformity European(EU)/European Certificate (EC) number and a certificate that the oxygen generated complies with Medical grade standard of the OEM be uploaded.

### Annexure Table 4: Capacity of the components of various plants

<table>
<thead>
<tr>
<th>PSA Plant Capacity in LPFM</th>
<th>Power supply required (KW)</th>
<th>Dimensions of room required (LxWxH) in metre</th>
<th>CIVIL Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-200 LPM</td>
<td>29KW</td>
<td>6x5x5</td>
<td>1. Plant room shall have PCC flooring (4-6 inches thickness) with even surface and area around plant room shall have proper drainage facility with s-</td>
</tr>
<tr>
<td>201-300 LPM</td>
<td>40KW</td>
<td>7x7x5</td>
<td>slopes for rain water to get collected inside the plant room and proper cross ventilation.</td>
</tr>
<tr>
<td>501-1000 LPM</td>
<td>80KW</td>
<td>8x8x6</td>
<td>2. Oxygen generators shall not be installed close to diesel generators (minimum distance 5M) or any other system which releases smoke or fire.</td>
</tr>
<tr>
<td>1001-1500 LPM</td>
<td>120KW</td>
<td>10x10x7</td>
<td>3. Cooling water is not required for these systems.</td>
</tr>
<tr>
<td>1501-2000 LPM</td>
<td>130KW</td>
<td>12x12x7</td>
<td></td>
</tr>
<tr>
<td>2001-2500 LPM</td>
<td>160KW</td>
<td>15x15x8</td>
<td></td>
</tr>
<tr>
<td>2501-3200 LPM</td>
<td>220KW</td>
<td>18x18x8</td>
<td></td>
</tr>
</tbody>
</table>

Ref: CMMSS, Govt Online Tender of SPTC of PSA Oxygen Generation Plant at Public Health Facilities on RAN India Basis

The technical specifications for PSA plants from WHO are available at:

https://apps.who.int/bdd/docs/pubdocs/106655958740979245158914_en.pdf?ua=1
20. Product labelling
Electrical power input requirements (voltage, frequency and socket type); labelling for medical use according to standards.

21. Primary packaging
Labelling on the primary packaging to include: name and/or trademark of the manufacturer; model or product’s reference.

Information for storage conditions (temperature, pressure, light, humidity).

22. User and Maintenance training
Manufacturer must indicate explicitly the following maintenance routines to match the dedicated staff capabilities within the health facility:

- Cleaning routines of the PSA plant considering the electrical safety precautions.
- Cleaning routines for the filters, if applicable (i.e. reusable).
- Testing of alarms.
- Testing of operating pressures.
- Testing of oxygen concentration.
- Frequency of the recommended maintenance routines.
- Safety precautions on management of oxygen.

23. Inspection and Testing after Installation
A joint team of Hospital staff and vendor/supplier will conduct the sample of oxygen output and get the sample analysis report of the PSA Oxygen Generation Plant output, from third party NABL approved Lab after commissioning & submit a copy of same signed by Hospital Authority along with the final acceptance certificate to CMSS for payment.

The Pressure of the output, concentration of the oxygen, alarms and automatic change over in case of failure need to be demonstrated by the supplier and certified by the User Hospital at the time of taking hand over and during Preventive maintenance also.

24. Service Level Agreement
i. Maximum time to attend any repair call- within 48 hours. In cases, where the down time increases beyond 48 hours the vendor would (keep arrangement ready) to make available the medical oxygen backup in shape of the oxygen cylinders to meet hospitals daily requirements failing which this requirement would be met by hospital/institution at risk and cost of the defaulting vendor.

ii. Frequency of visits to all user institution concerned during warranty/ CAMC—One visit every 3 months (4 visits in a year) or one visit after every 3000 hours of usage(whichever is earlier) for periodic/ preventive maintenance and any time for attending repairs / break down calls. Training and capacity building of one day has to be imparted every year after the installation, date and time to be decided on mutual agreement between the vendor and user department.

iii. Uptime in a year. The bidder shall ensure uptime of 95%. The bidder shall provide up-time warranty of complete equipment, the uptime being calculated on 24(hrs) X 7 (days) basis, failing which the extension of Warranty period will be extended by double the downtime period.

Annexure Table 5 : Technical Specifications for oxygen concentrators

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Oxygen Concentrators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>A stationary mains electricity (AC-powered) device designed to concentrate oxygen from ambient air and deliver the concentrated oxygen, typically through an attached nasal cannula (or prongs), to a patient requiring oxygen therapy. It processes the air through an internal filtration system (e.g. a molecular sieve [zeolite granules or membranes]), which has a large total surface area to separate %2 from the air. A typical consists of an air compressor, filters, dual chambers, a reservoir and controls. The oxygen concentration is variable depending on the flow rate utilized. It is typically wheeled, but is designed to be placed in one location (e.g. an institution or a home setting).</td>
</tr>
<tr>
<td>Purpose Of Use</td>
<td>Delivery of low-flow, continuous, clean and concentrated oxygen (&gt; 82%) from room air (21%). With appropriate accessories, two or more hypoxemic patients can be treated with one concentrator.</td>
</tr>
<tr>
<td>Clinical or other purpose</td>
<td>Health centre, general hospital, district hospital, provincial hospital, regional hospital, specialized hospital.</td>
</tr>
<tr>
<td>Level of use (if relevant)</td>
<td></td>
</tr>
<tr>
<td>Accessories, Consumables, Spare Parts, Other Components</td>
<td>One or two oxygen outlets, each to be provided with separate controlable flowmeter. Audible and/or visual alarms for low oxygen concentration (&lt; 82%), low battery and power supply failure. Audible and/or visual alarms for high temperature, low/high flow rate and/or low/high pressure. Power efficiency ≤ 70 W/Lmin. User interface to be easy to operate; numbers and displays to be clearly visible. Digital or analogue meter that displays cumulative hours of device operation. Oxygen outlet(s) with 6 mm (1/4 inch) barbed fitting and O2S connector, or equivalent. Flowmeter minimum flow rate of 0.5 L/min or less. This may be achieved by a combination of concentrator and separately supplied flowmeter stand. Flowmeter continuously adjustable, with minimum markings at 0.5 L/min intervals (or lower for paediatrics). Noted level &lt; 95 dB(A), one or two.</td>
</tr>
<tr>
<td>Detailed requirements</td>
<td></td>
</tr>
<tr>
<td>Displayed parameters</td>
<td>Oxygen flow rate (on flowmeter). Cumulative hours of operation.</td>
</tr>
<tr>
<td>User adjustable settings</td>
<td></td>
</tr>
<tr>
<td>Utility Requirements</td>
<td>Electrical, water and/or gas supply (if relevant). Electrical source requirements to be locally compatible (voltage and plug type need to be specified). Capacity for safe operation on at least 10% of local rated voltage. Main power cable to have length &gt; 2.5 m. Electrical protection by resettable circuit breakers or replaceable fuses, fitted in both neutral and live lines.</td>
</tr>
<tr>
<td>Accessories, Consumables, Spare Parts, Other Components</td>
<td>The unit shall include internally and externally mounted filters for cleaning the air intake. All user-removable filters shall be cleanable. Cleaning instructions for filters shall be included in the instructions for use. For two or more simultaneous paediatric patients: 1 x flowmeter stand with maximum range from 0 to 2 L/min. 2 x intra-resistant oxygen tubing with standard connectors (16 mm each). 4 x infant cannula with 2 m intra-resistant oxygen tubing with standard connectors. 2 x adult cannula with 2 m intra-resistant oxygen tubing with standard connectors. 4 x medical cannula with 2 m intra-resistant oxygen tubing with standard connectors.</td>
</tr>
<tr>
<td>Sterilisation/sterilization process for accessories (if relevant)</td>
<td>Disinfection for nasal prongs.</td>
</tr>
</tbody>
</table>
Consumables/Reags (if relevant)
- 5 year supply recommended.
- 1 year supply at nominal quantities per patient lead and usage frequency.
- Nasal prongs or nasal catheters (each size for adult, child, infant).
- Child nasal prongs: distal diameter: 1–2 mm.
- Child infant catheters: 6 or 9 French gauge.

Spare parts (if relevant)
- Internal and external filters and spare parts for user filling (as described in the user manual), including:
  - parts supply, including all necessary filters, for 2 years’ operation at 15 hours per day.
  - 1 x spare battery set for alarm system (if applicable).
  - 1 x spare mains power cable, length ≥ 2.5 m.
  - 2 x replacement sets of spare fuses (if non-replaceable fuses are used).
  - DSS to 6 mm. tertial plug for each outlet (if relevant).
  - Bidet must give a complete list of the specific spare parts included in their bid.
  - Other spares that may be needed: circuit breaker, printed circuit board, seal, gasket, compressor service kit, valves, wheels, motor capacitor, flowmeters and fan.
  - (Spare parts are not interchangeable between devices of different brands and models, and can vary in their design and lifetime. Medical units to select spare parts ensuring compatibility with the brand and model of the equipment.)

Training, installation and utilization
- Pre-installation requirements (if relevant)
  - Verify plug electrical requirements with socket to be used.
  - Clinical and staff training on device use.
  - System for procuring spare parts.
- Requirements for commissioning (if relevant)
  - Note and report any signs of external or internal damage upon device delivery.
  - Record the number of hours on the hour meter.
  - Verify oxygen concentration level is within specifications when device is operated with all tubing and flowmeters installed.
  - Verify operation of oxygen concentration, battery and pressure failure alarms.
  - Spare parts for 1 year or 5000 hours (5 years or 15 000 hours ideally) if use are arranged.
- Training of users (if relevant)
  - Clinical staff training in oxygen therapy guidelines, device use and multi-patient use.
  - Technical staff training in device operation, safety and maintenance provided by manufacturer, supplier or experienced users.
  - Advanced maintenance tasks required shall be documented.
- User care (if relevant)
  - Device exterior to be wiped effectively with a mild solution of detergent or cleaning agent (weekly), without connection to mains power.
  - Cross particle filter to be cleaned effectively when removed and washed with soap and water (weekly).
  - Do not clean with alcohol.
  - (User care needed more often in very dusty environments.)

Warranty and Maintenance
- Warranty
  - 2 years or more (5 years ideally) to cover lifespan of equipment.
  - Manufacturers, supplier, ideally responsible for all costs for repairs and replacement covered under the warranty.
  - Extended warranty options specified by manufacturer.
- Maintenance tasks
  - Test power failure alarms.
  - Measure operating pressure with pressure test gauge.
  - Measure oxygen concentration with a calibrated oxygen analyser.
  - Repair internal components as needed.
  - Maintain spare-parts inventory.

Safety and Standards
- Risk classification
  - Class 1 (IHF Rule 11): FDA Class II (USA), Class IIA (EU and Australia), Class I (Canada).
- Regulatory approval/certification
  - Proof of regulatory compliance (e.g., registration, clearance, approval) must be provided as appropriate per the product’s risk classification (e.g., by a founding member of IMORF - EU, USA, Canada, Australia, Japan).
- Standards applicable to the manufacturer and the manufacturing process (compliance to the last available version is recommended, proof of compliance must be provided):
  - ISO 13485 Medical devices — Quality management systems — Requirements for regulatory purposes.
  - ISO 14971 Medical devices — Application of risk management to medical devices.
- Standards applicable to the product (where applicable, compliance to the last available version is recommended, proof of compliance must be provided):
  - IEC 60601-1-8: 2013 Medical electrical equipment — Part 1-8: General requirements for basic safety and essential performance — Coherent standard: General requirements, tests and guidelines for alarm systems in medical electrical equipment and medical electrical systems.
  - Compliance with ISO 8359 may be considered.
**Annexure 2: Essential spare parts needed to repair the central oxygen system and liquid tank system**

### Annexure Table 6: Essential spare parts needed to repair the central oxygen system

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Details of spare parts</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Copper Tail Pipe</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>02 NRV</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Tail Pipe washer</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Twine Gauge Regulator</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Teflon Tape</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Tail Pipe adaptor Nut</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Double Bore Butane Gas torch</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Butane Gas Cylinder</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Copper Rod</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>DIN Type Oxygen OUT LET Point</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Isolation Valve 15mm</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>BS Type Oxygen Outlet Points</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Self Sealing Valves EGV Sex seat</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Oxygen safety Key Plug</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3/8&quot; pipe Hose Clamp</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>VentAirlock Connector</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Copper Pipe Medical Grade 15 mm</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Copper Pipe Medical Grade 12 mm</td>
<td></td>
</tr>
</tbody>
</table>

### Annexure Table 7: Spare parts required for liquid tank system repair

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Details of spare parts</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Liquid tank valve of all type</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Safety relief valves, Internal valve, Excess flow valve</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SMPV, high flow regulator</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Nut, couplings, joints</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rubber/Metal diaphragms of regulator</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Rubber washers/Teflon washers’ “O” ring</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Teflon tapes</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Toolbox (Spanners, screw drivers, wrench, adjustable spanner)</td>
<td></td>
</tr>
</tbody>
</table>

**Post operationalization PSA Plant monitoring format**

(To be filled by the facility staff)

### Annexure Table 8: Post operationalization PSA plant monitoring format

<table>
<thead>
<tr>
<th>Regular Process functions to be monitored</th>
<th>Hourly*</th>
<th>Daily</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Whenever required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check Compressor Pressure</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Compressor Oil level</td>
<td></td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Oxygen Pressure</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check rated oxygen flow</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Oxygen Purity</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Dew point at dryer outlet</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Air Dryer condensate drain</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Tower pressure</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check drain on all Filters</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check pressure in Air tank</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check pressure in Oxygen tank</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check solenoid valves for corrosion</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Check pipes / hoses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replace desiccant</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant room has adequate ventilation</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust fans functioning properly</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant room is devoid of water seepage rainwater/water accumulation</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power back up generator is functioning properly with adequate diesel available for plant functioning throughout the day</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinders/LMO back up of 3-3 days available in case of PSA Plant breakdown and during emergencies</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Hourly indicators are mostly available on digital display or pressure gauge. These may also vary based on vendor/product. Following indicators to be monitored on semi-annual/annual frequency.*

**Semi-annual monitoring**
- Replace all filter elements
- Check pressure safety valve
- Calibrate all pressure gauge

**Annual monitoring**
- Service compressor according to supplier instructions
- Service air dryer according to supplier instructions
- Check tower pressure
- Calibrate oxygen sensor
### Annexure Table 9: Preventive maintenance checklists of PSA plant

<table>
<thead>
<tr>
<th>Spare</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
<th>Year 7</th>
<th>Year 8</th>
<th>Year 9</th>
<th>Year 10</th>
<th>Whenever required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas top-up</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️ (as per year)</td>
</tr>
<tr>
<td>Compressor</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Expansion valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>Controller</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>In/Out valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Keep 1 at site</td>
</tr>
<tr>
<td>Filter</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>Pre-Filter</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Fine Filter</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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</tr>
<tr>
<td>Carbon Filter</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
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</tr>
<tr>
<td>After Filter</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Back-up Filter</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
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<tr>
<td>Inlet valve</td>
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<td></td>
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<td>Keep 1 at site</td>
</tr>
<tr>
<td>Exhaust valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>Shuttle valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>Solenoid valve (2/2 way)</td>
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<td>Keep 1 at site</td>
</tr>
<tr>
<td>Filter</td>
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<td></td>
<td></td>
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<td></td>
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<td>Keep 1 at site</td>
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<tr>
<td>Deoxygenator</td>
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<td>Pressure gauge</td>
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<td></td>
<td>Keep 1 at site</td>
</tr>
<tr>
<td>Oxygen sensor</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
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</tr>
<tr>
<td>Pressure Transmitter</td>
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<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>Pressure Receiver</td>
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<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

### Annexure Table 10: Checklist for planning/installing/upgrading a cryogenic liquid supply system

1. Information given in this Appendix can be used to determine the need for a particular capacity or type of supply system. Many of the factors described will also apply to planning an upgrade to an installation by way of increase in system size or a change of system type.
2. Some factors that should be considered are outlined below.

#### Annexure Table 10: Checklist for planning/installing/upgrading a cryogenic liquid supply system

- **Delivery frequency**: Does current frequency cause logistical problems for the supplier/your site?

- **Calculating consumption**
  - Consumption is rising at approximately 10% per annum. It doubles in seven years.
  - Use pharmacy records for cylinder/liquid consumption. Look for peaks in demand, for example winter influenza epidemics.
  - When average and peak flow rates are known, calculate the required size of the emergency supply.

- **Age of the current system**
  - The secondary supply of older VE systems will be a compressed gas cylinder manifold, which may have very limited capacity. Consideration should be given to either a single VE plus fully automatic manifold or, preferably, a dual VE system.

- **Sitting of system and the site survey**
  - Whatever restrictions apply (vessel size, noise, etc.)?
  - What are convenient locations for cylinder/liquid delivery?
  - Advantages of separating primary and secondary supplies, if space is available.
  - Will other facilities be killed/reduced, for example car-parking space?
  - It will be less economical in terms of delivery charges and unit gas costs to deliver large load (for example 20 tons) using rigid vehicles (maximum 12 tons). Articulated vehicles will deliver the largest loads but may require roadways/access modifications.
  - Can storage access for vessels?
  - When choosing liquid cylinder systems, will adequate ventilation be available?
  - Emergency supply location.
  - Pipeline protection and possible need for dike/fence.
  - Pipeline extension into other sites if applicable, for example two hospitals supplied from the same VE system. There are possible insurance issues with this arrangement.
  - Modifications to the alarm system may have to be made.
  - Alarm panel in laveratory in waterproof enclosure.
  - Are alarms compatible with the existing system?
  - Alarm arrangement for dual (but separate) tank installations.
  - Cable ducts and trays: examine possibility routes.
  - Possible need to move gauging points into present pipework.
  - Clearance of trees/buildings.
  - Sealing windows of adjacent buildings.
  - Position of frame for valve tree (tie to fence for rigidity?).
  - Position of emergency gate.
  - Position of FV couplings must allow driver to see tank gauges.
  - Cabling and alarm runs for the emergency supply manifold (ESM).
  - Availability and presentation of alarms for ESM.
  - Power and lighting during work.
  - Drainage – catch pits, diversions, pond resuits.
- Make sure all costs are allowed for. For example:
- Site inspection.
- Cost of continuing delivery using rigid and non-articulated vehicles.
- Gas charge/HCIM (hundred cubic metres) and any inflation likely.
- Facility charges (initial).
- Delivery charge for equipment.
- Loan charges and changes in interest rate on any loan if the installer lends any part of the instalation.
- Road/ramp/compound loans will be seen as x added to gas price over 5 years.
- Climate change levy.
- Professional fees (consultancy).
- Planning permission.
- Building Regulations clearance.
- All civil engineering work.
- Gated price for gas/fees/delivery charges may be dependent on payment by direct debit.
- Introduction/modification and maintenance of services, for example lighting, power supplies, drainage.
- Engineering and pharmaceutical testing.
- Additional emergency provision and any associated cylinder charges.
- Modifications to alarm and telephone systems.
- Security.
- Charges for ESM cylinders during installation (may have to be charged and then recovered).
- Drainage charges.
- Contingency 10%.
- What, if any, commitment is required by the gas company?
- How will gas prices vary during this period?
- Is there any agreement to provide, for example, modified roadway facilities if rigid vehicular deliveries are too frequent to be convenient to supplier? Or if such roadway modifications take place within a defined timescale, new rates etc may need to be negotiated.
- Check defects liability (usually 12 months).

Cost

- Examine the vulnerability of current system and main feeds to hospital.
- Consider minimum size of manifold plus cylinder storage to meet four-hour supply requirement, Is a second VE a better option?
- Operational requirements of ESM.
- Protection/housing/security of ESM.
- Alarm/monitoring systems and power supplies for ESM and its accommodation.

Emergency provision

- Often it will be necessary to interrupt site supplies during connection of new plant. How will this be managed?
- Disruption of two hospitals simultaneously if plant is to be upgraded is supplying both sites.
- Examine planned plant and pipework systems carefully to ascertain the best way of minimising downtime and facilitating engineering and pharmaceutical testing.
- While installing, fit extra valves to allow for future expansion and emergency supply manifolds to protect vulnerable parts of the system.
- Fill NET fittings wherever this will facilitate system purging.
- Fill test points/emergency inlet ports as recommended in this guidance or investigate any likely requirement for additional (local) manifolds to support high-dependency areas.

System shutdown during installation

- Site survey details.
- Register of contractors with contact names/telephone numbers.
- Keep a record of all dates, for example:
- tender invitation;
- tender open;
- tender close;
- award and reject letters to tenderers.
- Copies of all letters to/from contractors.
- NICEIC (National Inspection Council for Electrical Installation Contracting) test certificates for electricians.
- Validation and verification results (engineering and pharmaceutical).
- Health and safety policies of contractors.
- Method statements from contractors.
- Insurance agreement with gas supplier for VE system(s).
- NSIPS operational policy protocols.

Paper work

- Health and safety policy (contractors and their employees, and subcontractors and their employees, must comply when employed by the trust and working on trust properties).
- Informs contractors of specific site hazards.
- Hazard notices on site and on final installation.
- Lighting during installation and for completed compound.
- Road markings and signage.

Health and safety

- Carefully plan phasing of building work to maximise efficiency of installation programme. (Remember concrete pits will take three days to harden before vessel can be sited.)
- Plan phasing of engineering and GC testing to avoid wasting APS/GCs' time.
- Consider methods of maintaining supplies during essential shutdowns. Cylinder supplies may be needed during commissioning. Gas supplier may be able to arrange multi-cylinder packs.
- Road base preparation, if required, must be completed in an early phase of the work to allow necessary access for cranes and, eventually, delivery vehicles.
- Road surfacing/kerb/ing/waiting/parking.
- Retaining walls around compound if required, for example on sloping sites.
- Maintaining rights of way.
- Oxygen compound civil engineering work.
- If you are changing supplier, your original supplier will need to remove old equipment before pit can be extended to fit new vessels.
- Electric fire alarms/tank, lighting and, possibly, vehicle pump, Floodlighting and telephone line.
- Plan vehicular parking during (and after) work.
- The old pit may require skimming to provide a reasonable surface.

Preparation
Annexure 4: Checklist for Daily Inspection of various oxygen systems

Daily/shift-wise check list for the Head of Institution, Sister In-Charge, Head of COVID-19 Care Centre and staff handling liquid oxygen tank

<table>
<thead>
<tr>
<th>Name of the health institution -</th>
<th>Date -</th>
<th>Time -</th>
<th>Name of the head of the health institution -</th>
<th>Mobile no. -</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Capacity of liquid oxygen tank (in KL)

2. Balance stock at the start of the shift (in litres)

3. Balance stock at the end of the shift (in litres)

4. Pressure of Liquid oxygen tank (in bar)

5. Output pressure of Liquid oxygen tank (in bar)

6. Is the vaporizer working properly?

7. Is the PRV system working properly?

8. Is the vaporizer shower working properly?

9. Does oxygen flow at 4.5 bar pressure from the PRV system panel?

10. Are all the jumbo cylinders full for backup if the liquid tank fails?

11. Are all filled jumbo cylinders attached to the manifold?

12. Are all filled jumbo cylinders attached to the manifold?

13. Are the BPC Flowmeter with Humidifier of all the oxygen outlet points on the patient's beds, working?

14. Is the central oxygen system alarm working properly?

15. Is there a leak in the pipeline from the liquid oxygen tank to the oxygen outlet point on the patient's beds?

Note: The above mentioned indicators should be filled everyday by the staff handling the liquid oxygen tank at the beginning of each shift and submit the completed checklist to the head of the institute. If there is a leak anywhere in the system, an equipment or a part is not working and needs to be replaced, or if there is an abnormality in the system, the head of the institute should immediately call the repairing contractor or the repairing technician. If there are any additional issues not mentioned in the checklist, they should be clearly stated separately as it will allow the concerned personnel to take appropriate action.

Please immediately audit your hospital’s liquid oxygen tank and system

Mr. ……………………………
Name / Signature of the staff handling the oxygen system
Date
Time

Dr. ……………………………
Name / Signature of the Head of the Institution In-Charge
Date
Time
### Daily/shift-wise check list for the Head of Institution, Sister In-Charge, Head of COVID-19 Care Centre and staff handling the central oxygen system

<table>
<thead>
<tr>
<th>Name of the health institution</th>
<th>Date</th>
<th>Time</th>
<th>Name of the head of the health institution</th>
<th>Mobile no.</th>
</tr>
</thead>
</table>

1. **Total number of jumbo cylinders**
   - [ ] Yes / [ ] No

2. **Total number of empty jumbo cylinder**
   - [ ] Yes / [ ] No

3. **Total number of reserve jumbo cylinder**
   - [ ] Yes / [ ] No

4. **Are empty jumbo cylinder sent for refilling?**
   - [ ] Yes / [ ] No

5. **Is the concerned supplier informed that the vehicle is coming before sending the cylinder for refilling?**
   - [ ] Yes / [ ] No

6. **Does oxygen flow at 4.5 bar pressure from ox double gauge regulator/control panel?**
   - [ ] Yes / [ ] No

7. **Is there oxygen leakage anywhere in the manifold?**
   - [ ] Yes / [ ] No

8. **Are all tail pipe/VRV/valve/lid, functional?**
   - [ ] Yes / [ ] No

9. **Are all the oxygen outlet points on the patient’s bed, working?**
   - [ ] Yes / [ ] No

10. **Are the oxygen outlet points on the patient’s bed, OK?**
    - [ ] Yes / [ ] No

11. **Is the central oxygen system alarm working properly?**
    - [ ] Yes / [ ] No

12. **Is there a leak in the pipeline from the central oxygen system to the oxygen outlet point on the patient’s bed?**
    - [ ] Yes / [ ] No

---

**Note:** The above mentioned indicators should be filled everyday by the staff handling the liquid oxygen tank at the beginning of each shift and submit the completed checklist to the head of the institute. If there is a leak anywhere in the system, an equipment or a part is not working and needs to be replaced, or if there is an abnormality in the system, the head of the institute should immediately call the repairing contractor or the repairing technician. If there are any additional issues not mentioned in the checklist, they should be clearly stated separately as it will allow the concerned personnel to take appropriate action.

---

**Please immediately audit your hospital’s central oxygen system**

**Mr.**

Name / Signature of the staff handling the oxygen system

Date

Time

**Dr.**

Name / Signature of the Head of the Institution/In-Charge

Date

Time

---

**Daily/shift-wise check list for the Head of Institution, Sister In-Charge, Head of COVID-19 Care Centre and staff handling the pressure swing adsorption (PSA) system**

<table>
<thead>
<tr>
<th>Name of the health institution</th>
<th>Date</th>
<th>Time</th>
<th>Name of the head of the health institution</th>
<th>Mobile no.</th>
</tr>
</thead>
</table>

1. **Checking input and output voltage frequencies**
   - [ ] Yes / [ ] No

2. **Record the readings of the pressure gauge**
   - [ ] Yes / [ ] No

3. **Checking compressor oil level and leakage**
   - [ ] Yes / [ ] No

4. **Noting if there is an abnormal sound**
   - [ ] Yes / [ ] No

5. **Checking all types of alarms and taking appropriate action**
   - [ ] Yes / [ ] No

6. **Check air dryer’s filter indicator, due point, auto drain, condenser fan and take proper action**
   - [ ] Yes / [ ] No

7. **Check the inlet and outlet pressure alarms of the PSA system and take appropriate action**
   - [ ] Yes / [ ] No

8. **Checking the oxygen purity indicator and taking appropriate action**
   - [ ] Yes / [ ] No

9. **Check the generator by starting it manually**
   - [ ] Yes / [ ] No

---

Note: The above mentioned indicators should be filled everyday by the staff handling the liquid oxygen tank at the beginning of each shift and submit the completed checklist to the head of the institute. If there is a leak anywhere in the system, an equipment or a part is not working and needs to be replaced, or if there is an abnormality in the system, the head of the institute should immediately call the repairing contractor or the repairing technician. If there are any additional issues not mentioned in the checklist, they should be clearly stated separately as it will allow the concerned personnel to take appropriate action.

---

**Please immediately audit your hospital’s central oxygen system**

**Mr.**

Name / Signature of the staff handling the oxygen system

Date

Time

**Dr.**

Name / Signature of the Head of the Institution/In-Charge

Date

Time
Annexure 5: Guidelines for members of the Oxygen Committee

Guidelines for the Head of the Institution, Head of the COVID-19 Care Centre and Oxygen Committee Members of the institution

- All the jumbo oxygen cylinders and dura cylinders in the institute should always be filled with oxygen. The required reserves should be kept.
- If liquid oxygen tank is used in in the institute, then the required technical manpower should be available to monitor the tank 24x7.
- The tank should be inspected regularly by the manufacturer and the supplier.
- Regular oxygen security audits of the institute’s central oxygen system should be carried out by the relevant authority. If some corrections are suggested or any errors are detected, then these matters should be given top priority by the concerned authority.
- If oxygen leakage is found anywhere in the manifold system and in the copper pipeline that supplies oxygen, it should be repaired immediately by the concerned person.
- Spare parts should be readily available or immediately provided for maintenance and repair of the central oxygen system, manifold system, and liquid oxygen tank.
- Adequate BPC flowmeter with humidifier required to supply oxygen to the patients, should be made available.
- Contact numbers of oxygen supply agency, central oxygen system handling staff, driver or handler of cylinders carrying vehicle (including vehicle number), person/agency to contact during emergency should be displayed in the manifold room as well as the viewing area at the nursing station.
- If the institute is using an oxygen generation plant (PSA), manpower should be made available for regular monitoring. Regular inspections should be done by the manufacturer or supplier agency. Additionally, regular maintenance and repair should be done.
- A permanent 24x7 security system should be maintained for the institute central oxygen system and manifold system, liquid oxygen tank and oxygen generation plant (PSA).
- The list of spare parts required for all types of oxygen system repairs will be presented to the head of the institute by the technicians in the HEMR workshop and the head should ensure the availability of those spares at the institute.
- Measures should be taken in case of emergency and essential numbers should be posted in a prominent area.

Guidelines on maintenance and repair of central oxygen system, dura cylinder, liquid oxygen tank, oxygen generation PSA plant at all levels of health institutions by bio medical engineers of the Health Medical Equipment Maintenance and Repair (HEMR) department.

- The biomedical engineers of the HEMR workshop will regularly inspect the central oxygen system, dura cylinder, liquid oxygen tank, oxygen generation PSA plant in all the health institutions of all the divisions and take appropriate action accordingly.
- In addition, the bio medical engineers will be in constant touch with the head of the health facility to ensure that the oxygen system in the institute will continue to function.
- The technicians from the HEMR workshop will go directly to the respective health facility and train the staff to handle all the oxygen systems in the institute.
- The technicians in the HEMR workshop will make monthly visits to the districts that have been assigned to them and will visit the respective health institutes. If there are any defects in the oxygen system or if there is a need for maintenance and repair, the technicians will bring the matter to the notice of the head of the institution. In coordination with the head of the institution and the concerned service provider, the defects will be immediately rectified.
- The technicians from the HEMR workshop will plan a quarterly audit of the oxygen system in the health institution in the district assigned to them and conduct a joint audit with the concerned institution head and the staff managing the oxygen system.
- If any error is found during the oxygen audit, it will be rectified as soon as possible by the concerned Bio medical engineer technician with the help of the head of the institute and the concerned repair and maintenance service provider.
- The technicians at the HEMR workshop will provide details to the Deputy Director of Health Services, Transport, Pune on monthly basis on oxygen system’s inspection, maintenance, and repair as well as the number of staff trained in the health institute on oxygen system handling.
- If the technicians in the HEMR workshop have any problem or need guidance in this regard, biomedical engineers or Honourable Deputy Director of Health Services should be contacted.
- The technicians in the HEMR workshop should coordinate with the heads of the institutes in the respective districts to ensure that the oxygen system continue to function.

The updated list of names and contact numbers of the heads of health facility, oxygen system handling staff as well as oxygen system repair and maintenance service providers of the designated district health institutions will be kept in the HEMR workshop.
### Annexure 6: Daily oxygen calculations

#### Annexure Table 11: Daily oxygen calculation sheet based on oxygen storage sources

<table>
<thead>
<tr>
<th>Sources of oxygen storage</th>
<th>Approximate availability of liquid medical oxygen in liters</th>
<th>QTY of cylinders</th>
<th>Approximate availability of oxygen in gaseous form</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid medical oxygen tank-1</td>
<td>5</td>
<td>5000</td>
<td>NA</td>
<td>43,50,000 For converting LMG/O2/Lab/Lietar in gaseous form multiply by 1.05, 1 liter=1600 liters gaseous oxygen</td>
</tr>
<tr>
<td>Liquid medical oxygen tank-2</td>
<td>2</td>
<td>2000</td>
<td>NA</td>
<td>17,40,000</td>
</tr>
<tr>
<td>Liquid medical oxygen Reservoir-1</td>
<td>0</td>
<td>0</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>Dura Cylinder-1</td>
<td>NA</td>
<td>200</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dura Cylinder-2 Filled</td>
<td>NA</td>
<td>240</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D- type Jumbo cylinder (Filled)</td>
<td>NA</td>
<td>16</td>
<td>1,12,000</td>
<td>For jumbo cylinder type D 7000 liters</td>
</tr>
<tr>
<td>B- type, small cylinder(Filled)</td>
<td>NA</td>
<td>0</td>
<td>0</td>
<td>For cylinder type B 1500 liters</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>62,02,000 Total Usable Oxygen after considering residual oxygen requirement to maintain pressure</td>
</tr>
</tbody>
</table>

### Annexure 7: Safety training check lists

Checklist for ensuring training on following aspects:

<table>
<thead>
<tr>
<th>Training topic</th>
<th>Training done</th>
<th>Training date</th>
<th>Trainer Signature</th>
</tr>
</thead>
</table>

1. **SAFETY EQUIPMENT**
   - Has the appropriate Personal Protective Equipment been given to the employee?
     - appropriate work clothes
     - boots/shoes
     - gloves
     - eye protection
     - hearing protection
     - hard hat

2. **HAZARDS**
   - Have the Work Instructions which concern employee’s particular work and general matters been pointed out to him?
     - Has employee read and understood them?
   - Have the Your Instructions which concern employee’s particular work and general matters been pointed out to him?
     - Has employee read and understood them?

3. **HAS THE MEANING OF ALL RELEVANT SAFETY SIGNS BEEN EXPLAINED?**
   - Any relevant safety booklets, videos, etc should be used at this stage.
<table>
<thead>
<tr>
<th>Training topic</th>
<th>Training done</th>
<th>Training date</th>
<th>Trainer Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5. Does employee know the hazards associated with:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Oxygen plus oil, grease or other flammable or organic substances?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Acetylene or hydrocarbons in liquid oxygen (air separation plants only)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Liquid oxygen spills (black top asphalt)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Oxygen deficiency which can be created by spillage or venting of nitrogen or argon or confined spaces?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Oxygen enrichment due to spillage or venting?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improper use of plant utilities, such as steam and compressed air?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.6. Does he/she know that hot work, including the use of raised flames may only be carried out in certain specified areas which have been pointed out to him/her, or after the issue of the appropriate Work Permit?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7. Does employee fully understand hazards associated with flames / sparks and that smoking is only allowed in certain areas which have been pointed out to him</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.8. Does employee know that he/she must not bring matches, transistor, radios or other unapproved electrical devices, lighters or smoking materials within the boundary of DA and hydrogen storage and production areas?(DA = Dissolved Acetylene).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.9. Is employee aware of the instructions for action in case of fire? Does employee know the location of fire extinguishers, hydrants and hoses? Has employee been given a demonstration of the use of appropriate fire extinguishers and hoses? Does the employee know the location and sound of the fire and evacuation alarm?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.10. Have instructions been given in emergency procedures relevant to employee's job and does employee know the position of emergency stop buttons and emergency shut-off valves?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.11. Has the site emergency plan been explained including employee's particular role?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.12. Does employee know his/her meeting point in case of emergency?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.13. Record have when present at a site emergency drill or training session.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.14. Does employee know how to identify the contents of cylinders by:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- The written word (label)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Colour code?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Valve type?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Pressure test dates?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Max. allowed working pressure?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.15. Have the dangers of lifting damaged cylinders been explained to him?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.16. Have the dangers of overpressuring cylinders been explained?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.17. Have the dangers of allowing an out of standard cylinder to be dispatched been explained (i.e., empty, unscraped, incorrect labels,...)?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.18. Has the procedure for reporting safety hazards been explained to employee?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.19. Has employee been instructed to report gas leaks on equipment and faulty connections?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3. MECHANICAL & ELECTRICAL HAZARDS**

<table>
<thead>
<tr>
<th>Training topic</th>
<th>Training done</th>
<th>Training date</th>
<th>Trainer Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.20. Does employee know what to do when cryogenic transfer hoses and/or high pressure filling hoses rupture?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.21. Does employee know the dangers of continued exposure of hands and other parts of the body to solvents?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.22. Does employee know that there are approved skin disinfectors, and where to find them?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.23. Is employee aware of the role he/she is expected to play in housekeeping of the area or section in which he/she works and the importance of it in prevention of accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**4. TRAFFIC HAZARDS**

<table>
<thead>
<tr>
<th>Training topic</th>
<th>Training done</th>
<th>Training date</th>
<th>Trainer Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1. Has employee been told that a speed limit exists for all vehicles in the factory?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2. Has employee been told that only trained and authorized personnel are allowed to drive or operate forklift trucks?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3. Has employee been told that riding as a passenger on a forklift truck or the back of a lorry is forbidden?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4. Has employee been advised to keep clear of vehicles which might move without warning?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5. Has employee been instructed to report all unsafe conditions at customer's premises as well as in the factory?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6. Does employee know that he/she should use pedestrian walkways when they are available/identified?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Annexure 8: Guidelines on Oxygen Management for COVID19 -
Clinical Protocol Rational use

5. SAFETY ORGANISATION

5.1. Has the employee been given a copy of the Site Safety Policy?

5.2. Has the Safety Policy been explained to employee?

5.3. Has Safety organisation (Company and operating unit) been

5.4. Does employee know to whom he/she should address queries on

5.5. Has employee been advised about the function of the Safety

Committee?
The Ministry of Health and Family Welfare had issued an advisory on the rational use of oxygen vide D.O. letter/1830290/Immunization/2020 dated 26.09.2020. In the wake of rising cases of COVID-19 and an escalated need to ensure rational use of oxygen, a need was felt to review the advisory and issue updated comprehensive guidelines.

These guidelines are based on the recommendations of the leading clinical teams of the country who participated in a consultation as held on 22/04/2021, chaired by Dr. V.K. Paul, Member, NITI Aayog. Additionally, inputs of the Joint Monitoring Group (JMG) headed by Director General of Health Services (DGHS) MoHW and Prof. (Dr.) Randeep Guleria, Director, AIIMS, New Delhi and Prof. (Dr.) Balram Bhargav, DG ICMR cum Secretary, Department of Health Research are included.

These guidelines aim to promote judicious use of oxygen therapy in individual cases, and to enhance accountability for oxygen conservation through monitoring and audit without compromising quality of care.

The majority of patients of COVID-19 have mild illness. Out of 100 patients, 80 are treated at home or COVID care centres. Out of the remaining 20, about 17 have moderate disease needing oxygen beds. Only 3 are in ICUs and are treated with oxygen therapy by Non Rebreathing mask (NRSB), Non Invasive ventilation (NIV), High Flow Nasal Cannula (HFNC), and Invasive ventilation.

Oxygen is a precious drug that should be used judiciously, and the following action points are necessary to achieve this objective. These guidelines should be implemented by all the states and Uts.

RESPONSIBILITY OF THE HEALTH TEAM: Judicious use

1. The flow of oxygen should be adjusted to the lowest permissible level to target an oxygen saturation of 92°8-94°7° for the hospitalized COVID 19 patients.

2. Indiscriminate use of BIPAP/HFNC should be avoided. When required, BIPAP should be preferred over HFNC, the latter consumes enormous amount of oxygen. HFNC device should be used only in the ICU setting under supervision of a respiratory physician/physician. Patient should be put on HFNC only after approval of the senior most respiratory physician/physician.

3. Prone positioning should be intermittently done in patients of COVID-19, along with adjunctive physiotherapy. This optimizes the respiratory status.

4. Individualization of oxygen therapy should be done taking into account the clinical signs like respiratory rate etc. and not just the saturation level. Once the desired saturation is achieved, flow of oxygen should not be increased as it may not provide any additional benefit to the patient. Up-titration instead of down titration of oxygen flow levels should be the norm.

5. Triaging of patients as per their oxygen status should be done at regular intervals.

6. An audit of the oxygen use by the ICU ward should be done by the clinical team leader on a daily basis.

RESPONSIBILITIES OF STATE/HOSPITAL ADMINISTRATORS:
Monitoring and Audit

1. A team of one Nurse and one OT Technician may be designated as Oxygen Monitoring Team for each shift at each hospital/hospital facility level. The team will visit all areas where oxygen supply I therapy is instituted.

   a. Inspect the gas pipeline, wall mounted gas outlets, as well as gas cylinders to detect and promptly address leakages, if any. Nurse in the team will check the oxygen mask on a regular basis.

   b. Ensure closure of valves during ‘no-use’ at all times.

   c. Sensitize nurses and technicians for conservation of oxygen.

2. At the facility level, an Oxygen Audit Committee may be formed in every hospital which may consist of Additional Medical Superintendent, Head of Anesthesia, Head of Respiratory Medicine (Head of Internal Medicine incase Respiratory Medicine department does not exist) and Nursing Superintendent.

3. The Oxygen Audit Committee will be mandated to supervise inventory planning, oxygen consumption pattern, regular repair and maintenance of gas pipelines, gas plant, and wall mounted gas outlets etc. It should review the consumption pattern of oxygen twice a week and conduct and audit and reduce oxygen consumption if found to be in excess.

4. The hospital management should reduce all elective and emergency services to a minimum in view of the present pandemic situation

5. Regular training of OT Technicians and Nurse should be undertaken on proper oxygen administration and monitoring, and on conserving oxygen.

6. District Magistrate (DM) assisted by the Chief Medical Officer (CMO) of the district must also monitor the consumption including the rational use of oxygen in all facilities of the district on a weekly basis. Home oxygen cylinders should not be encouraged but the use of oxygen concentrators at home should be promoted whenever required.
GUIDELINES FOR RATIONAL USE OF OXYGEN FOR MANAGEMENT OF COVID-19

These guidelines are being issued based on the recommendations of The Empowered Group 1 (EG -1) chaired by Dr. V.K. Paul, Member, NITI Aayog, the Joint Monitoring Group (JMG) headed by Director General of Health Services (DGHS) MoHFW and the inputs provided by Prof. (Dr.) Randeep Guleria, Director, AIIMS, New Delhi and Prof. (Dr.) Balram Bhargav, DG ICMR cum Secretary, Department of Health Research.

1. It is assumed that out of the 100 confirmed cases of Covid-19;
   a. 80 cases will be Asymptomatic I Pre-Symptomatic or with "Mild" disease requiring home isolation or admission to Covid Care Center (CCC).
   b. Out of remaining 20 cases:
      i. 17 cases will be of "Moderate" disease requiring hospitalization for 7 days on Non ICU Oxygen Supported Beds. States I UTs would require to have oxygen storage capacity for all 17 Beds. However, for the purpose of calculation of Daily Oxygen consumption requirement, 50% of these Beds (i.e. 8.5) would be considered for computation purpose.
      ii. 3 will be "Severe" cases requiring ICU Beds for 18 days in ratio of 20% for Invasive Ventilation, 40% for Non-Invasive Ventilation (NIV) I High Flow Nasal Cannula (HFNC) and remaining 40% for oxygen therapy by Non-Re Breathing Mask (NRBM) etc. For the purpose of calculation of Daily Oxygen consumption requirement at each health facility, all the Beds (i.e. 3) would be considered for computation purpose.

2. For Moderate cases (SpO2 level between 94%-90%), the indicative oxygen flow rate is 2.4 Liters/minute by nasal prongs; 6-10 Liters/minute by facemask and 1-15 Liters/minutes by Non-Re-breathing Mask (NRBM).

3. For Severe cases (SpO2 level less than 90%), the indicative oxygen flow rate is 10 Liters/minute by invasive Mechanical Ventilation; 25-60 Liters/minute by Non-Invasive Ventilation and 10-15 Liters/minutes by NRBM.

4. Regular training of OT Technicians and Nurse should be undertaken on proper oxygen administration and monitoring.

5. District Magistrate (DM) assisted by the Chief Medical Officer (CMO) of the district must also monitor the consumption including the rational use of oxygen in all facilities of the district on a weekly basis.
Annexure 9: Oxygen Audit Form

HEALTH FACILITY INSPECTION / OXYGEN AUDIT FORM:

SELF CERTIFICATION TO BE DONE BY HOSPITAL MANAGEMENT

A. GENERAL INFORMATION OF HOSPITAL

1. Name of Covid Hospital: ____________________________

2. Type of Hospital: Government/Private  3. Hospital Category: CCC/DCHC/DCH

4. Dr. In charge of Covid Hospital: Name: ________________________ Mobile No.: ________________________

5. Designation of Dr. Incharge: Medical Superintendent / Dean / Administrative Officer / Head of Hospital

6. Hospital Address: ____________________________________________

   Hospital Telephone No.: ________________________ Pin code: ______________

7. Total beds in Hospitals: For Covid ______ For Non Covid: ______

<table>
<thead>
<tr>
<th>Type of Covid Bed</th>
<th>No. of beds</th>
<th>Currently Patient on</th>
<th>For Covid</th>
<th>For Non-Covid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O2 Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remaining ICU Beds (Except ventilator)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The HFNO’s should be phased out for large consumption of oxygen.

8. Total No. of Patients on Oxygen: ________________________

---

Details of Oxygen Use

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Device</th>
<th>Lit/Min</th>
<th>No. of Patients</th>
<th>Total Consumption Lit/min</th>
<th>Total Consumption Lit/Day</th>
<th>Total Consumption KL/Day (Total Consumption Lit/day / (1000*880))</th>
<th>Total Consumption In Ton (KL/Day*0.871)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nasal Prongs</td>
<td>(3 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Nasal Mask</td>
<td>(6 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Non-Rebreathable Mask (NRM)</td>
<td>(8 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Invasive Ventilation (Intubation)</td>
<td>(20 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BIPAP</td>
<td>(12 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NIV (Ventilator)</td>
<td>(60 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>HFNO</td>
<td>(60 LPM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 1) 1000L = 1 KL  2) 1 KL = 1.14 Ton

---

Jumbo Oxygen Cylinder General Information:

- Type of Jumbo System Installed:
  - I) Capacity of Manifold: __________ e.g. (8 x 8)
  - II) Capacity of reserved Manifold: __________ e.g. (4 x 4)
  - Total: __________

- Available Oxygen Cylinder in hospitals:
  - I) Type D (7 CuM) __________
  - II) Type B (1.5 CuM) __________
  - Total: __________

Source of Oxygen

<table>
<thead>
<tr>
<th>Source of Oxygen: Jumbo / Dura / LMO</th>
<th>1st Agency Name: ________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of Supply:</td>
<td>Address: ________________________</td>
</tr>
<tr>
<td>Quantity of Supply in last delivery (in CuM):</td>
<td>Pin Code: __________ Mob. No. ______________</td>
</tr>
</tbody>
</table>

Source of Oxygen

<table>
<thead>
<tr>
<th>Source of Oxygen: Jumbo / Dura / LMO</th>
<th>2nd Agency Name: ________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of Supply:</td>
<td>Address: ________________________</td>
</tr>
<tr>
<td>Quantity of Supply in last delivery (in CuM):</td>
<td>Pin Code: __________ Mob. No. ______________</td>
</tr>
</tbody>
</table>

Source of Oxygen

<table>
<thead>
<tr>
<th>Source of Oxygen: Jumbo / Dura / LMO</th>
<th>3rd Agency Name: ________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of Supply:</td>
<td>Address: ________________________</td>
</tr>
<tr>
<td>Quantity of Supply in last delivery (in CuM):</td>
<td>Pin Code: __________ Mob. No. ______________</td>
</tr>
</tbody>
</table>

Sources of Oxygen Storage

<table>
<thead>
<tr>
<th>Sources of Oxygen Storage</th>
<th>Approximate Availability of liquid medical oxygen in KL</th>
<th>Approximate Availability of liquid medical oxygen in liters (X 1000)</th>
<th>Quantity of Cylinder</th>
<th>Approximate Availability of oxygen in gaseous form</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Medical Oxygen Tank-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For converting LMO/Dura Lites in gaseous form multiply by 860. 1 Lte=860 Lites gaseous form</td>
</tr>
<tr>
<td>Liquid Medical Oxygen Tank-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid Medical Reservoir-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dura Cylinder-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dura Cylinder-2 (Filled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-Type, Jumbo Cylinder (Filled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For jumbo cylinder type D 7000 Litres</td>
</tr>
<tr>
<td>B-Type, small Cylinder (Filled)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For small cylinder type B 1500 Liters</td>
</tr>
</tbody>
</table>

Total: ________________________
## B. GENERAL CHECKLIST FOR OXYGEN SYSTEM

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/ NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All oxygen sources or plants should be erected in open spaces and not within the building premises.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>All the materials used in the construction of storage facility should be fire retardant. (Eg. Steel, Bison board, Cement paints which are fire retardant, tiles, mud tiles, Steel Fencing, Jali) Example of flammable material that should not be used are plastic, pvc, flammable plastic Jali, Plywood.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 3       | Tank Safety Measures taken:  
  i. Safety Net around tank  
  ii. CCTV  
  iii. Ventilation  
  iv. Prohibition of fire explosive elements  
  v. Security guard (24 X 7) |   |          |
| 4       | Fire Prevention Measures  
  i. Fire extinguishers  
  ii. Water hydrants / Taps  
  iii. Sand bucket |   |          |
| 5       | Access control arrangements with manual pad locks to entry gates to ensure entry of authorized person only in Oxygen Storage area. |   |          |
| 6       | Clear Signage indicating access to authorized person only should be displayed prominently around Periphery of Storage area. |   |          |
| 7       | In case of LMO facility separate gate for vehicle to unload and separate entry for the technical staff should be created. |   |          |
| 8       | At all given point the gates should be closed unless it is in use. |   |          |
| 9       | If padlocks are used to secure the gate, then spare key sets should be easily accessible and available with administration, Fire Department, Security Department and technical man power operating the Oxygen Facility. |   |          |
| 10      | Ensure CCTV monitoring of storage areas and such installation should be operating on low voltage systems like DC supply or in a manner where no nearby electrical points are utilized. |   |          |
| 11      | The CCTV system should operate from reasonably safe distance as per the layout of storage facility, Farther the better. |   |          |
| 12      | Ensure Assembly Points should be far away from Oxygen storage area unless the Oxygen storage facility is reasonably secured by Retainer walls of RCC in case of space constraints. |   |          |
| 13      | All Points in Fire safety as per the prevailing policy of local/state and central Govt. authorities are complied |   |          |
| 14      | Proper Fire Extinguishers, Sand Buckets, Fire Hydrant arrangements are available in the area as per the prevailing guidelines. |   |          |
| 15      | Ensure Mock Drill are conducted regularly covering incidents like Fire, Leakage and other Emergency situations. |   |          |

### Sources of Oxygen Generation

<table>
<thead>
<tr>
<th>Sources of Oxygen Generation</th>
<th>No. of Plants</th>
<th>Approximate Capacity of Plants in Litres/Minute</th>
<th>Approximate total availability of Oxygen in Gaseous form Litres/Minute</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen PSA Plant: 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen PSA Plant: 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** This information is to be collected from Hospital administration by discussion and examining report of fire and electrical audit.
### C. OXYGEN PIPELINE GENERAL INSPECTION CHECKLIST

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>DESCRIPTION</th>
<th>YES/ NO/NA</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leaks found at pipeline, Valve &amp; Joints</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>If leaks found, then repairing done immediately</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Is there Ending of Oil / Grease on pipeline</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Are there explosive elements found near Pipeline</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

### D. GENERAL OXYGEN WEANING PROTOCOL

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Description</th>
<th>Compliance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establish Oxygen weaning protocol as per the guidelines of Mahanarshana Task Force for Covid 19</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Conduct staff training for Oxygen Weaning protocol</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Display boards and sign ages for oxygen weaning protocol at Patient Bedside</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Display sign boards so Patient should be aware that they do not touch and change Oxygen LPM delivery settings</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Take good quality branded oximeter and SPO2 has to be measured every 2 hours as per chart given. (Preferable to oximeter with respiratory rate)</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Step Up and Step Down of Oxygen to be done as per established Oxygen Weaning Protocol</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Ensure that LPM delivery settings changes are carried with precautions and staff is trained for same. (Accidently increasing pressure above 1.5 LPM will cause breakage of humidifier bottle which are in short supply)</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Is there patient briefing taken for Oxygen Usage?</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Are staff Checking carefully leakages of Oxygen pipeline Cylinder &amp; Cryogenic tank daily?</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Is patient Oxygen requirement finalized carefully by using prone position after giving sufficient time by the Doctor? (Left Lateral, Right Lateral, Lying on belly, Sitting up)</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Are Reclining beds being used to reduce oxygen requirement and better saturation levels in patients</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
</tbody>
</table>

### F. JUMBO OXYGEN CYLINDER OPERATION & MAINTENANCE CHECKLIST

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>DESCRIPTION</th>
<th>YES/ NO/NA</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Are cylinders stored in upright positions and immobilized by chains or other means to prevent them from falling?</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Are cylinders stored away from electrical connections, sources of ignition, combustible waste material?</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Are charged or full cylinders labeled and stored away from empty cylinders?</td>
<td>Yes/No/NA</td>
<td></td>
</tr>
</tbody>
</table>

### E. OXYGEN CYLINDER WEANING PROTOCOL

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>DESCRIPTION</th>
<th>YES / NO / NA</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Are storage rooms for Oxygen cylinders dry, cool, and well-ventilated? (Note: The storage rooms should be fire-resistant, and the storage should not be in subsurface locations.)</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Are cylinders stored away from incompatibles, excessive heat, continuous dampness, salt, or other corrosive chemicals, and any areas that may subject them to damage?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Are cylinders maintained at temperatures below 51 Degree C or 125 degrees Fahrenheit? (Check with thermal gun)</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Are only Oxygen gas cylinders separately stored?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Are procedures established when a Oxygen cylinder leak cannot be remedied by tightening the valve? The procedures should include: (a) Attach tag to the cylinder stating it is unserviceable. (b) Remove cylinder to a well-ventilated outdoor location. (c) Place an appropriate sign on a flammable or toxic gas cylinder warning of these hazards. (d) Notify the Oxygen gas supplier and follow his/her instructions regarding the return of the cylinder.</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Are all Oxygen cylinders subjected to periodic hydrostatic testing and interior inspection by suppliers?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Are cylinder valves closed at all times, except when the valve is in use?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Are all Oxygen cylinder valve covers in place when cylinders are not in use?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Is using wrenches or other tools for opening and closing valves prohibited? (Note: Hammering on valve wheels to open them should be strictly prohibited. For hand-tighten valves, contact the supplier for instruction.) Ask Questions to field staff</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Are all Oxygen cylinders subjected to periodic hydrostatic testing and interior inspection by suppliers?</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Is repair or alteration to the cylinder, valve, or safety relief devices prohibited? (Note: All alterations and repairs to the cylinder and valve must be made by the compressed gas vendor. Modification of safety relief devices beyond the tank or regulator should only be made by a competent person appointed by management.) Ask Questions to field staff</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Are Oxygen cylinders always moved, even short distances, by a suitable hand trolley? (Note: They must never be dragged across the floor.) Check visually</td>
<td>Yes / No / NA</td>
<td></td>
</tr>
</tbody>
</table>
G. PRECAUTION FOR EFFICIENT UTILIZATION AND STORAGE OF JUMBO CYLINDERS (JUMBO SECTION)

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Precautions for efficient utilization of Jumbo Cylinders.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Every Type of Oxygen Container depletes in small quantities through valves

Note: Jumbo Cylinders stored eventually will deplete and, in few weeks, months will be empty due to the time of emergency such cylinders become useless, following precautions need to be taken up by hospital administration to avoid the above condition

1.1 The Hospital administration should establish a date based on the weekly check with the help of flow meter and the percentage loss observed. This needs to be done as every cylinder manufacturer uses different components, thus there is no other alternatives to establish it manually over a period of two to three months. Immediately hospital should maintain the last refill date on tag.

1.2 Check all humidifiers bottles and Gauges on arrival for leakages and reject faulty ones.

1.3 Check all spanners and replace all spanners which have lost grip because of wear and tear. Using them may not fine tune the fitting of gauges and humidifiers bottles.

1.4 Rotate all Jumbo Cylinders regularly which are kept in reserved stock.

1.5 All Jumbo cylinders should be marked with permanent paint and numbered.

1.6 All such Jumbo cylinders should be tagged with an non tearable tag.

1.7 Last jumbo refilling date should be mentioned by Refiller with help of clearly legible stickers on the tag.

1.8 Next refilling date if cylinders stay unused like the fire extinguisher should be maintained.

H. DURA OXYGEN SYSTEM

Tank Inspection Checklist

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do all cylinders have safety valves?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Are safety relief devices in the valve or on the cryogenic tank free from any indication of tampering?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Dura Cylinders handled only by experienced and professionally trained people? (Ask Questions to filled staff)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>If LMO Supply Fails / Breakdown, then alternative system is ready? Then is backup system available? Is Manifold system for Oxygen Cylinders Ready? (4 to 8 hours backup as per location (Urbane/Rural)).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>If LMO and Manifold System Fails, then are refilled cylinders kept in wards with regulators (Conversion kit)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Storage

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All oxygen sources or plants should be erected in open spaces and not within the building premises.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Dura oxygen storage facility should be covered from top and ensured that it is not exposed to sunlight and any source of heat directly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>All the materials used in the construction of storage facility should be fire retardant. (Eg. Steel, Bisle, Bisle board, Cement prints which are fire retardant, tiles, mud tiles, Steel Fencing Jali - example of flammable material that should not be used are plastic, nylon, flammable plastic)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Precautions for efficient utilization of Dura Cylinders

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Importance and when during cylinders are being used for backup for their own use for large number of days all Oxygen will be lost.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Rotate all Dura Cylinders regularly which are kept in reserved stock.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Check all spanners and replace all spanners which have lost grip because of wear and tear. Using them may not fine tune the fitting of gauges and humidifiers bottles.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>All Dura cylinders should be marked with permanent paint and numbered.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>All such Dura cylinders should be tagged with non tearable tag.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>Last Dura refilling date should be mentioned by Refiller on clearly legible Tag.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>Next refilling date of cylinders if it stays unused like the fire extinguisher should be maintained.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.7</td>
<td>Faster the spanners near work area with rope in a manner that they can be easily used and are readily available.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>Ensure spare spanner stocks are maintained in store in sufficient numbers.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. LMO OXYGEN SYSTEM

Tank Inspection Checklist

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If LMO Supply Fails / Breakdown, then alternative system is ready? Is Manifold system for Oxygen Cylinders Ready? (4 to 8 hours backup as per location (Rural/Remote))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>If LMO and Manifold System Fails then are filled cylinders kept in wards with regulators (Conversion kit)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Storage

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All LMO Plants should be erected in open spaces and not within building premises</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>All Materials used in the construction of storage facility should be fire retardant. (Eg, steel, bison board, cement paints which are fire retardants, tiles, mud tiles, steel fencing jail. Example of flammable material that should not be used are plastic, nylon, flammable plastic jail, plywood)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Are there separate entrances for operational persons and the LMO tankers?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Is the LMO facility secured by using padlock?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Are the keys of LMO easily available with fire / security / administration / operation staff?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Is there a mechanism to de-ice the vaporizer by using water showers?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Is the water being recycled by creating underground tanks or collecting it in any way?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Is the pipeline from LMO tank to vaporizer also getting de-ice?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Is the flooring in the LMO decanting perfectly horizontal? so all the LMO is properly decanted in the tank,</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

J. DURA OXYGEN SYSTEM PRECAUTION FOR HUMIDIFIER BOTTLES AND OXYGEN POINTS

Precautions

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is clean distilled water/ boiled water being used in humidifier bottles? (No Saline water should be used)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Are the humidifier bottles cleaned and made sterile every 3-4 days?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Are humidifier bottles being cleaned and made sterile after every patient is discharged</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

K. RECYCLING OF CONSUMABLES

Note: Sterile- Cidex or equivalent solution (Phthalaldehyde) and UV chambers can be used for sterilization. Sterilization must be carried out meticulously.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Descriptions</th>
<th>Yes/ No/NA</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Are the NIV masks being recycled by making them sterile?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Are the Nasal Prongs / NRBM being recycled by making them sterile for at least 1 or 2 times?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Are Safety Goggle being reused by the staff and not thrown away?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

L. INVENTORY REPORT

Inventory of Tools and Spares required for Each Liquid tank

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Required</th>
<th>Actual Available</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Liquid Tank Valves of all type</td>
<td>3 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Safety relief valves, Internal valves, Excess flow Valves</td>
<td>3 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SMPV High Flow Regulators</td>
<td>3 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Liquid Tank gauges</td>
<td>3 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Nut, Couplings, Joints</td>
<td>3 times of fitted Quantity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Rubber / Metal Diaphragms of Regulator</td>
<td>4 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Rubber washers / Teflon washers 'O' Rings</td>
<td>10 times of fitted Quantity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Teflon Tapes</td>
<td>10 Nos.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Tool Box (Spanners, wrench, screwdrivers, Adjustable spanners etc)</td>
<td>3 sets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* All these spares and tools should be kept in separate store in lock and key. 4 Nos. of keys should be available & distribute to four different person.

(Name & Sign of Auditor)  (Name & Sign of Authorised Person of Hospital)

Date of Inspection / Audit: ____/____/2021
Annexure 10: Commonly needed Tools for repair and maintenance of various oxygen systems:

- Cycle pressure gauge
- Axial / angle seated valves for cycle operation, Angle seat valve for cycle operation
- Outlet to product tank
- Feed air pressure regulator (without or with filter)
- Brazing Torch
- Safety relief valves
- Exhaust pipe - super silencer
- Brazing Torch

Cylinder Keys

- Pipe Wrench
- Adjustable Spanner
- Spanner Set
- Screw Drivers

Spanner & Tools

- Gas Outlets Regulators
- Shut - off Valve
Annexure Figure 1: Commonly needed Tools for repair and maintenance of various oxygen systems

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8. Technical specifications for Pressure Swing Adsorption (PSA) Oxygen Plants, Interim guide, WHO
9. Online tender for PSA Oxygen Generation plant at public facilities, Central Medical Services Society, MOHPW, GOI
10. Installation, Operation and maintenance manual – PSA type Oxygen Generating Plant, Trident
17. https://arogyay.Meghalaya.gov.in/Site/Uploads/Tenders/eb34f3eae-a081-a05e-a9c0-f7338b688c86%20CENTRALIZED%20OXYGEN.pdf
Medical Oxygen Management System

Health and Family Welfare Department
Government of Meghalaya

OCTOBER, 2021