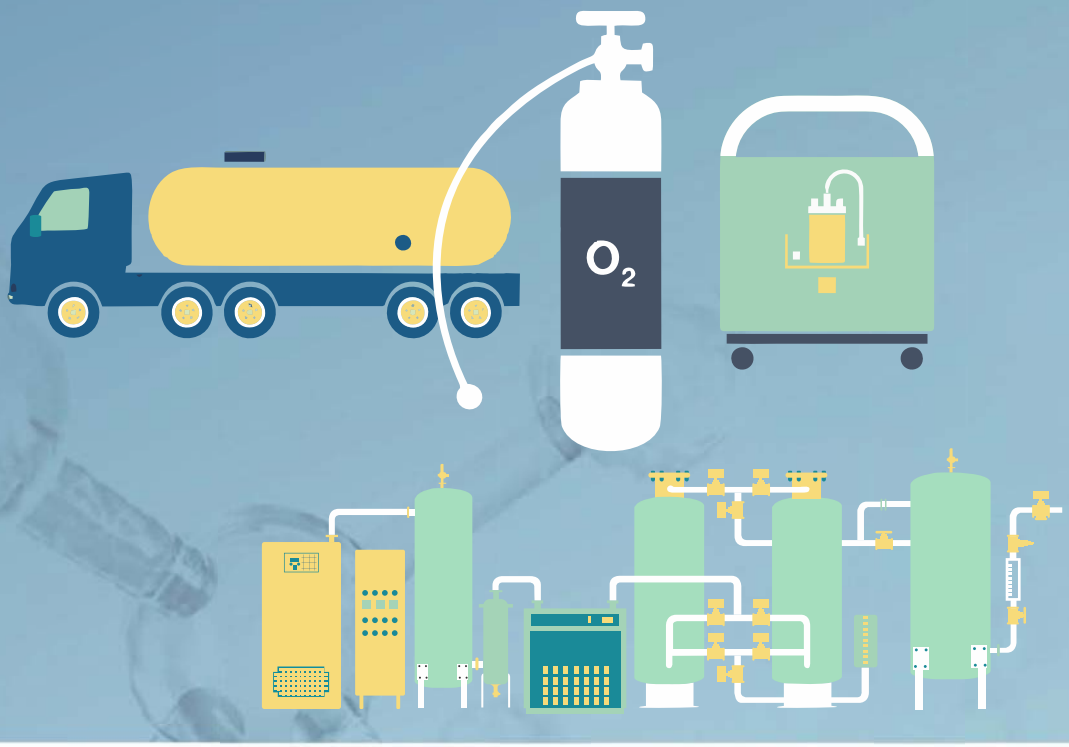
GUIDEBOOK ON

Medical Oxygen Management System



Department of Public Health
Government of Maharashtra

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Guidebook on

Medical Oxygen Management System

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FOREWORD

Since the onset of COVID-19 epidemic in Maharashtra, Public Health Department has remained committed and tirelessly working on various fronts to manage the epidemic. The Guidebook on Medical Oxygen Management System, the first of its kind in Maharashtra, lays the foundation for the improvement of management of medical oxygen in health facilities in the state. It also reinforces the commitment of the Government of Maharashtra to systematic and coordinated improvement in managing life-saving commodities, in this case, medical oxygen, at facility level.

This guidebook provides all required technical details for effective, efficient, and flawless oxygen management in Health Facilities. This document would serve as a ready reference book for the administrators, state and district level officers, procurement personnel, planning officers, program managers, biomedical engineers, and medical and paramedical staff handling oxygen devices for the storage-transport-distribution purposes. Additionally, the handbook also provides tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit.

The successful implementation of the Guidelines on Medical Oxygen Management System will require the sustained involvement and input of all stakeholders. I therefore urge all stakeholders to study the guidelines carefully and identify how they can contribute to achieving its aims and objectives.

With this Guidelines on Medical Oxygen Management System July 2021, I extend my heartiest congratulations to DHS Pune, Deputy Director (Transport) office, Pune, SHSRC, and PATH team for coming up with a comprehensive and the most relevant document of an hour. I sincerely hope that this document will be truly beneficial as a ready reference guide.

Best Wishes!

Pradeep Vyas

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PREFACE

Oxygen therapy proved to be the most effective lifesaving treatment in COVID-19 crisis. Therefore, medical oxygen management system is an important public health concern, especially in developing countries during the COVID-19 pandemic situation. India is currently observing second wave of the COVID-19 infection with increasing trend in patient case load after March 2021. This has led to sudden spike in patients requiring oxygen care and thus overfilling the hospitals for COVID-19 patient care.

The Government of Maharashtra worked on various strategies to fulfil the patient care needs with reference to medicines and oxygen. As a commitment to its people and considering long term systemic improvement, Government of Maharashtra is putting tireless efforts to improve production and supply of medical oxygen, a life-saving medicine, across the state.

The guidebook on Medical Oxygen Management System is an important tool to improve the technical skill of the administrators, and district level officers, procurement personnel, planning officers, program managers, biomedical engineers, and medical and paramedical staff handling oxygen devices for the storage-transport-distribution purposes. Additionally, the handbook also provides tools for proper functioning, maintenance, safety of the oxygen equipment and oxygen audit. I am sure that this document will definitely help various administrators and stakeholders at district level.

My sincere appreciation goes to Directorate, Health Services Pune office, Deputy Director (Transport), SHSRC, and PATH officials, who have contributed to the preparation for this document.

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save the girl child

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ACKNOWLEDGEMENT

During the second wave of COVID-19 world has experienced the devastating effects of sudden spike in COVID-19 cases leading to overburdened health systems and many times inadequate health care. Medical oxygen is the key factor in COVID-19 management and hence medical oxygen management system is one of the important key steps to accelerate the pace of managing the oxygen supply at facilities. This guidebook provides guidance to make informed decision about oxygen management system for proper usage of oxygen devices according to the requirement and the resources available in hospital setting in Maharashtra.

I express my sincere thanks to Dr. Pradeep Kumar Vyas, (Hon Additional Chief Secretary, Public Health Department, Gov. Maharashtra) for his guidance and motivation. I gratefully acknowledge the extensive support and co-operation received from Dr. Ramaswami (Commissioner, Health Services and Mission Director, NHM, Mumbai) who has provided committed engagement and detailed feedback on various aspects of this guidebook.

My sincere appreciation to Deputy Director (Transport), Pune office, SHSRC and PATH officials for their efforts & dedication for making this document. I would specially like to congratulate Mr. Magare (Biomedical Engineer, HEMR Aurangabad) and Mr. Kapare (Biomedical Engineer, HEMR Kolhapur) for their sincere efforts, dedication, and inputs for making this document possible. Lastly, I would like to acknowledge the hard work of all the contributors for their dedication and commitment in preparing this Guidebook on Medical Oxygen Management System.

I hope this guidebook will prove to be useful in the field for effective and efficient oxygen management system.

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TABLE OF CONTENT

Abbreviation	01
List of tables	03
List of figures	05
Introduction	07
Oxygen in medical terms	09
Oxygen ecosystem	10
Chapter 1: Liquid Medical Oxygen (LMO)	13
Chapter 2: Oxygen cylinder	23
Chapter 3: Pressure Swing Adsorption (PSA) plant	32
Chapter 4: MGPS- Medical Gas Pipeline System	39
Chapter 5: Oxygen concentrators	47
Chapter 6: Pulse oximeter and accessories	51
Chapter 7: Devices for oxygen delivery, regulation and conditioning	58
Chapter 8: Inventory management	69
Chapter 9: Medical oxygen handling and safety guidelines	73
Chapter 10: Guidelines on facility based oxygen audit	88
Annexure 1: Technical specifications of various oxygen systems	97
Annexure 2: ऑक्सिजन सिस्टीम दुरुस्ती करीता लागणारे अत्यावश्यक सुटे भाग	120
Annexure 3: Checklist for planning/installing/upgrading a cryogenic liquid supply system	123
Annexure 4: Checklist for daily inspection of various oxygen systems	127

TABLE OF CONTENT

Annexure 5: ऑक्सिजन समिती सदस्य यांचे करीता मार्गदर्शक सूचना 130

Annexure 6: Daily oxygen calculations 132

Annexure 7: Safety training checklists 133

Annexure 8: उपलब्ध ऑक्सिजनचा योग्य वापर करणेबाबत मार्गदर्शक सूचना 137

Annexure 9: Oxygen audit form 146

Annexure 10: Commonly needed tools for repair and maintenance of various oxygen systems 156

References 159

ABBREVIATION

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

ABBREVIATION

MOMC	Medical Oxygen Monitoring Committee
MT	Metric Ton
NFPA	National Fire Protection Association
NICU	Neonatal Intensive Care Unit
NIV FiO2	Non-invasive Ventilation Fraction of Inspired Oxygen
O2	Oxygen
NRBM	Non-Rebreather Mask
OC	Oxygen Concentrator
OLED	Organic Light-Emitting Diode
OT	Operation Theatre
P&ID	Piping and Instrumentation Diagram
PCC	Plain Cement Concrete
PESO	Petroleum And Explosives Safety Organization
PICU	Paediatric Intensive Care Unit
PPE	Personal Protective Equipment
PRV	Pressure Relief Valve
PSA	Pressure Swing Adsorption
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus-2
SMPV	Static and Mobile Pressure Vessels
SOPs	Standard Operating Procedure
SPO_2	Saturation of Peripheral Oxygen
TUV	Technischer Überwachungsverein, English translation: Technical Inspection Association
UNICEF	United Nations Children's Emergency Fund
UPS	Uninterruptible Power Supply
UTs	Union Territories
VIE	Vacuum Insulated Evaporator
WHO	World Health Organization

LIST OF TABLES

TABLE

Table 1: Oxygen system and the primary methods	11
Table 2: General characteristics of liquid oxygen tank	19
Table 3: Inspection and maintenance schedule of LMO	21
Table 4: Fault diagnosis/ troubleshooting of LMO	22
Table 5: Measurement of various sources in terms of jumbo cylinder	24
Table 6: User care and preventive maintenance cylinders (and associated accessories) recommendations for oxygen	31
Table 7: Troubleshooting for oxygen cylinders (and associated accessories)	31
Table 8: Troubleshooting other issues of PSA	37
Table 9: Various options for gas supply	41
Table 10: Pipeline testing	45
Table 11: Preventive maintenance oxygen concentrators	49
Table 12: Troubleshooting and corrective maintenance of oxygen concentrator	50
Table 13: Types pulse oximeter	51
Table 14: Common problems and remedies of pulse oximeter	55
Table 15: Description and comparison of flowmeters	58
Table 16: Description and comparison of flow splitting devices	61
Table 17: Description and comparison of humidifiers	62
Table 18: Description and comparison of oxygen delivery options	63
Table 19: Description and comparison of oxygen analysers	65
Table 20: Oxygen requirement/consumption based on bed strength	71
Table 21: Daily oxygen requirement/consumption based on active cases	71
Table 22: Oxygen availability at state, district/hospital level	72
Table 23: Do's and Don'ts - medical gas manifold room	81
Table 24: Do's and Don'ts - liquid oxygen	85
Table 25: Oxygen management system issues, causes and solutions	92

LIST OF TABLES

TABLE

Annexure Table 1: Technical specifications of Liquid Medical Oxygen	97
Annexure Table 2: Technical specifications for procurement- oxygen cylinders	100
Annexure Table 3: Technical specifications for medical gas pipeline system	105
Annexure Table 4: Capacity of the components of various plants	115
Annexure Table 5: Technical specifications for oxygen concentrators	117
Annexure Table 6: सेंट्रल ऑक्सिजन सिस्टिम दुरुस्ती करिता लागणारे अत्यावश्यक सुटे भाग	120
Annexure Table 7: लिक्विड टँक सिस्टीम दुरुस्तीकरिता लागणारे सुटे भाग	120
Annexure Table 8: Post operationalization PSA plant monitoring format	121
Annexure Table 9: Preventive maintenance checklists of PSA plant	122
Annexure Table 10: Checklist for planning/installing/ upgrading a cryogenic liquid supply system	123
Annexure Table 11: Daily oxygen calculation sheet based on oxygen storage sources	132
Annexure Table 12: Daily oxygen calculation sheet based on output sources	132

LIST OF FIGURES

TABLE

Figure 1: Oxygen Systems	10
Figure 2: Oxygen sources	10
Figure 3: Cryogenic oxygen distillation process	13
Figure 4: Typical vacuum jacketed dewar	14
Figure 5 a: Cryogenic liquid cylinders	15
Figure 5 b: Typical cryogenic liquid cylinders top view	15
Figure 6: A typical station with a cryogenic storage tank	16
Figure 7: Working and construction of LMO tank & dura cylinder	17
Figure 8: Oxygen Cylinder type	23
Figure 9: Differences in color coding of different gases between ISO colour coding standard and United States convention	25
Figure 10: Oxygen Cylinder labelling	25
Figure 11: Oxygen Cylinder with accessories	26
Figure 12: Oxygen Cylinder size	27
Figure 13: Pressure swing adsorption plant	32
Figure 14: Medical gas piping system configuration	42
Figure 15: Area valve service unit	43
Figure 16: Area alarm panel	43
Figure 17: Diamond-type oxygen outlet point	44
Figure 18: Chemetron-type oxygen outlet point	44
Figure 19: A set of medical gases outlets/inlets	44
Figure 20: Pipeline identification colours	45
Figure 21: Oxygen Manifold System	46

LIST OF FIGURES

TABLE

Figure 22: Oxygen concentrator	47
Figure 23: Types of probes	53
Figure 24: Coiled Probe Cable	54
Figure 25: Types of Thorpe Tube	60
Figure 26: Venturi mask	64
Figure 27: Types of ventilators	67
Figure 28: CPAP & BiPAP	67
Figure 29: The fire triangle	73
Figure 30: Different sources of supply and key system components including alarms.	82
Figure 31: Oxygen safety signs	87
Figure 32: Labeling and signs for medical gas systems	87
Annexure Figure 1: Commonly needed tools for repair and maintenance of various oxygen systems	160

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 Maharashtra implemented various strategies to fulfil the patient care needs for medicines and oxygen. As a commitment to its people and considering long term systemic improvement, the Government of Maharashtra 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 Maharashtra.

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 Maharashtra 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 linadequate 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.
- **Causes:** Lung disease, heart problems, anaemia, and COVID-19 (silent hypoxia).

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

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.

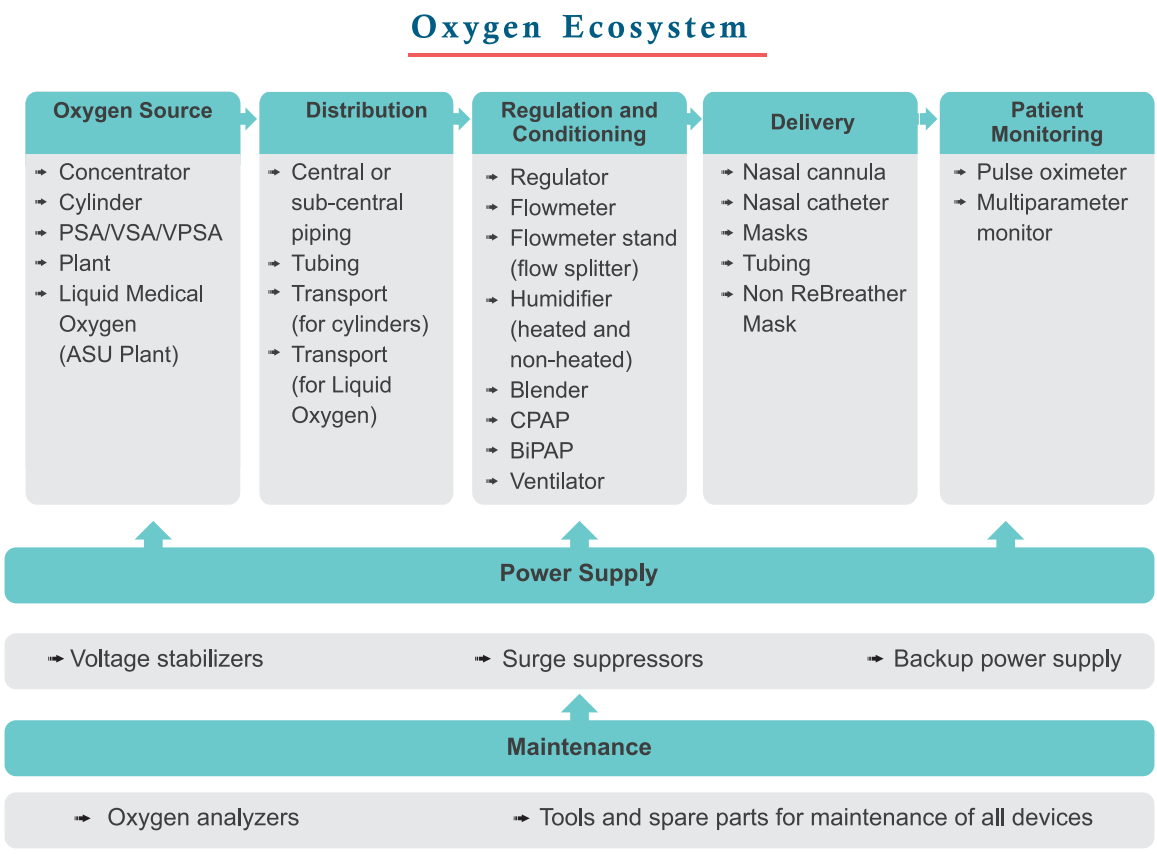


Figure 1: Oxygen System

Major sources of oxygen supply: Oxygen to medical facilities is supplied through four primary methods:

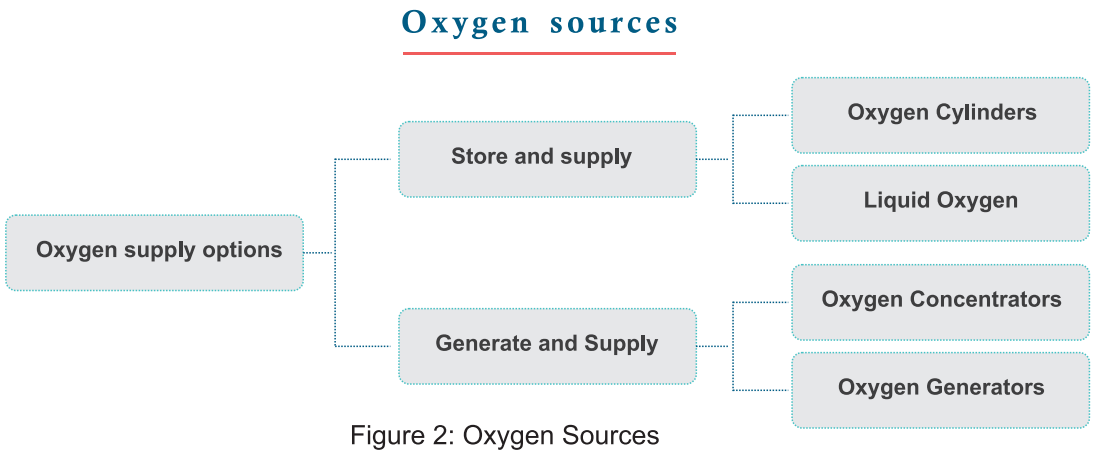


Figure 2: Oxygen Sources

To complete the oxygen system, the primary methods need following devices:

	Oxygen Sources		
	Cylinders (Stand alone or with manifold system)	**Concentrators**	**Oxygen plant (with central piping)**
Devices for distribution	Regulator Tubing	Tubing central or sub central piping	Central or sub-central piping
Devices for oxygen regulation and conditioning	Flowmeter (Thorpe tube, Bourdon gauge, Dial click) Humidifier (non-heated) Humidifier (heated) Blender CPAP	Flowmeter stand (flow splitter)	Flowmeter (wall-mounted) Humidifier (non-heated) Humidifier (heated) Blender CPAP Ventilator
Oxygen delivery devices	Nasal cannula Masks Tubing Nasal catheter High-flow nasal cannula (HFNC)	Nasal cannula Masks Tubing Nasal catheter	Nasal cannula Masks Tubing Nasal catheter HFNC
Pulse oximeter and patient monitoring devices	Self-contained fingertip Handheld Tabletop	Self-contained fingertip Handheld Tabletop	Self-contained fingertip Handheld Tabletop Multiparameter devices
Devices for quality power supply and oxygen analysis	Oxygen analyzer Voltage stabilizer Backup power supply Tools and spare parts	Voltage stabilizer Surge suppressor Oxygen analyzer Backup power supply Tools and spare parts	Voltage stabilizer Surge suppressor Backup power supply Tools and spare parts

Table 1: Oxygen system and the primary methods

Source: *WHO-UNICEF technical specifications and guidance for oxygen therapy devices.*

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., oxygen audit.

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.

Cryogenic Oxygen Distillation Process

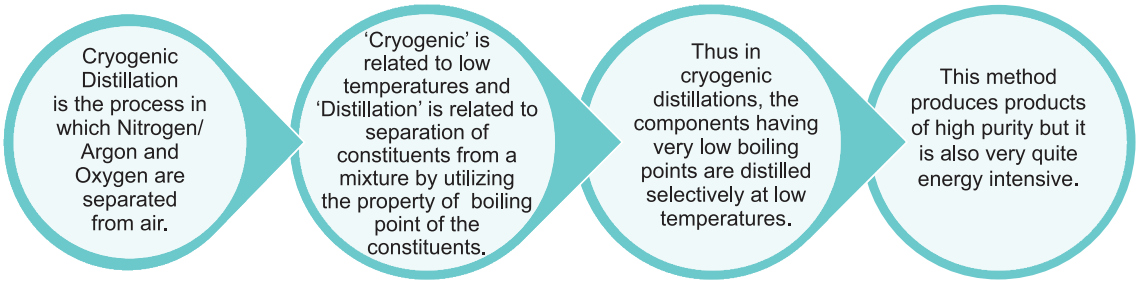


Figure 3: Cryogenic Oxygen Distillation Process

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.

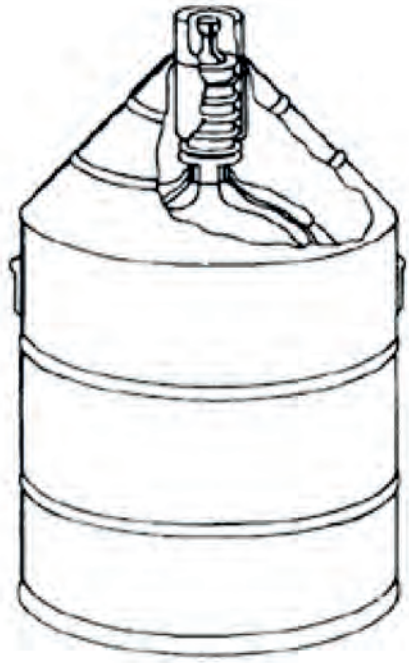


Figure 4: Typical vacuum jacketed Dewar

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.)

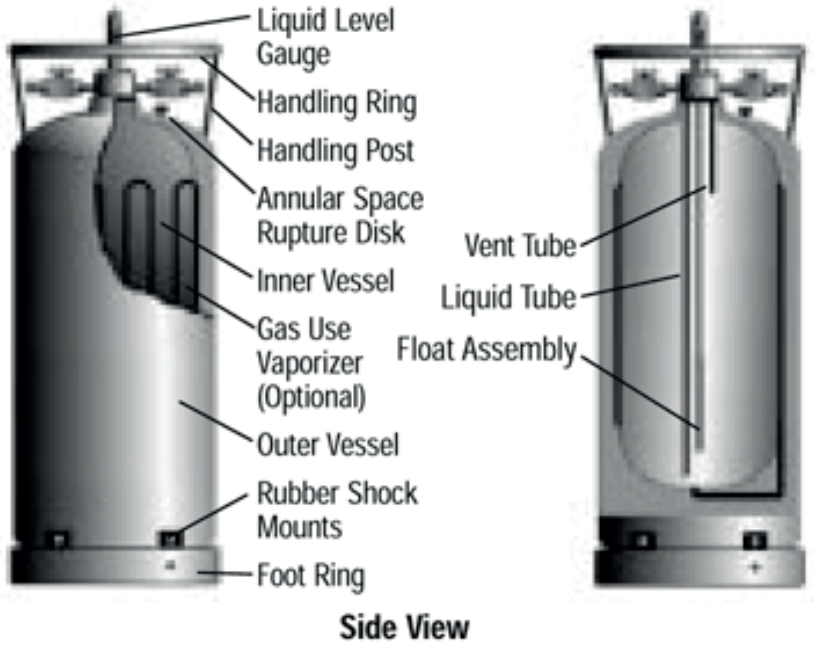


Figure 5a: Cryogenic liquid cylinders

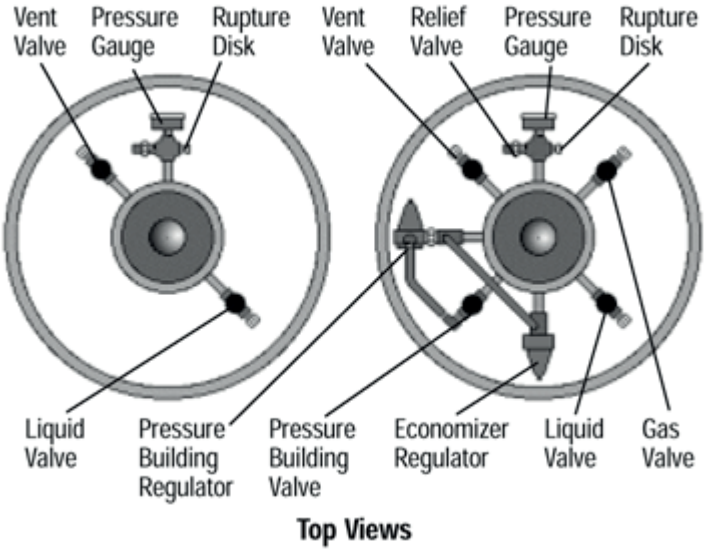


Figure 5b: Typical cryogenic liquid cylinder, top view

1.1.3 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.

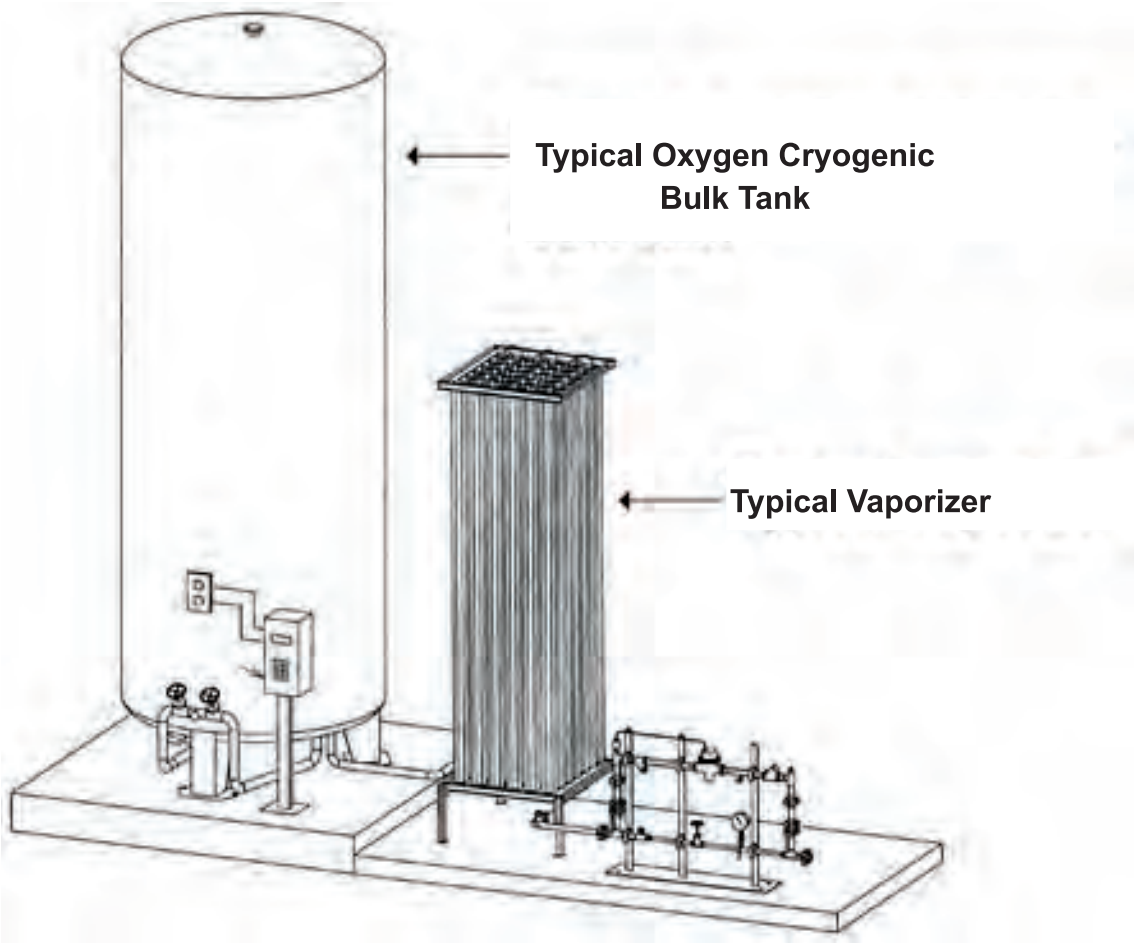


Figure 6: A typical station with a cryogenic storage tank

1.2 Working and construction of LMO tank

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

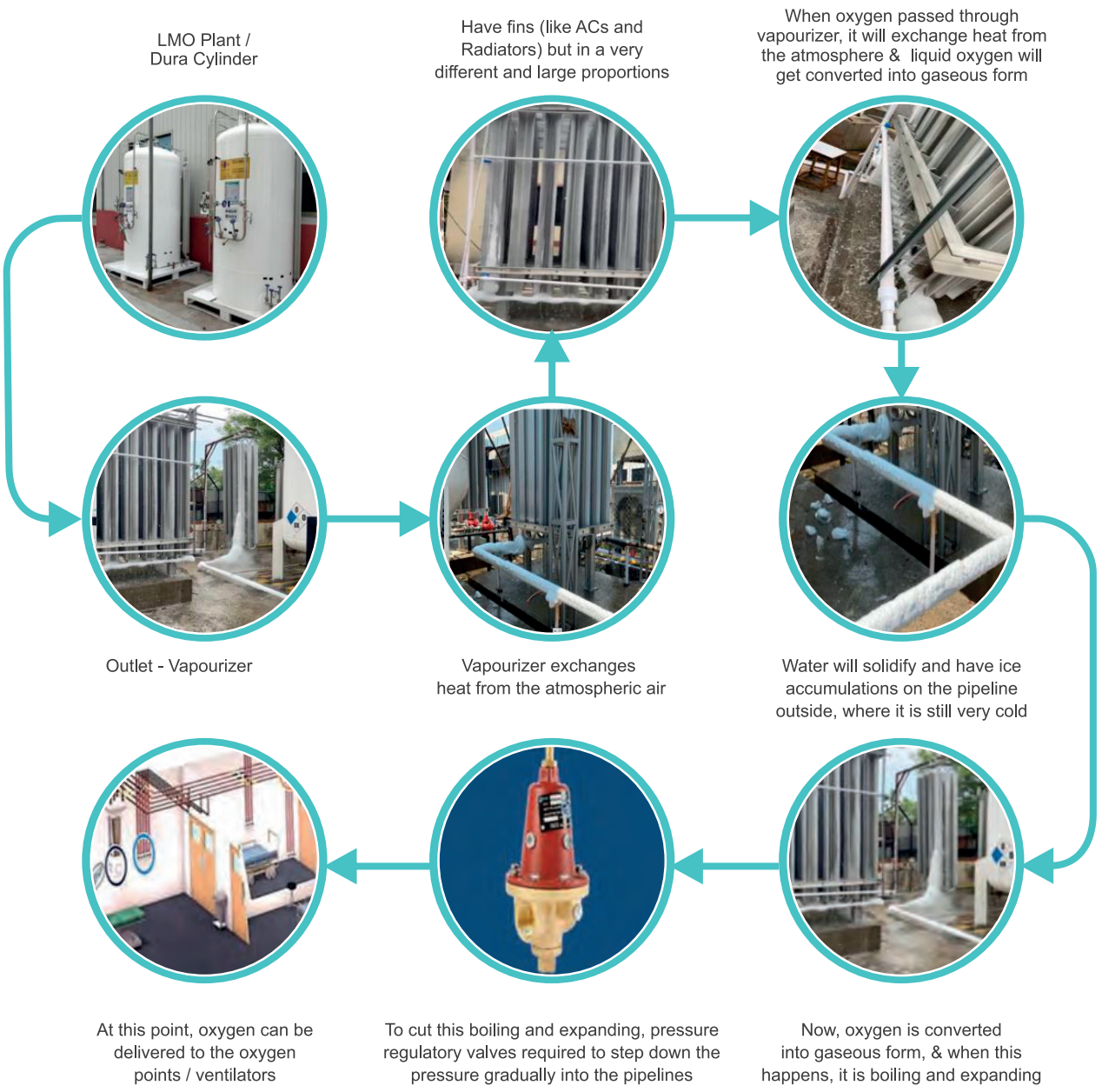


Figure 7: Working and construction of LMO tank & dura cylinder

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 Signages 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 –

1. PESO - *https://peso.gov.in/web/smpv-u-rules-2016*

2. Website of INOXINDIA -*https://www.inoxindia.com/inoxindia/covid19.php*

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.
- AIGA 049/17 Guideline to Medical oxygen supply system for Healthcare facilities.
- NFPA 55 – 2016 – Chapter 9, Bulk Oxygen Systems.

General Characteristics	Liquid Oxygen
Description	Bulk liquid oxygen generated off-site and stored in a large tank and supplied throughout a health facility via a central pipeline system. Tank requires refilling by liquid oxygen supplier.
Clinical application and/or use case	Can be used for all oxygen needs, including high-pressure supply and in facilities where power supply is intermittent or unreliable.
Appropriate level of health system	Secondary and tertiary.
Distribution mechanism	Central pipeline distribution system.
Electricity requirement	No.
Initial costs	Can be high; tank, pipeline installation and civil.
Ongoing operating costs	Moderate (can be high if tank is leased); refill costs, maintenance.
Maintenance requirement	Periodical maintenance of system and piping required by highly trained technicians and engineers, can be provided as part of contract.
User care	Minimal; at terminal unit only.
Merits	99% purity of oxygen obtained. High oxygen output for small space requirement.
Drawbacks	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.

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.

Actions	Commissioning	Monthly	Quarterly	Annually	5 Yearly
Inspection, checks and tests					
Ambient temperature	✓		✓		
Suitability of location	✓				
Adequate room for ventilation	✓				
Adequate access for maintenance	✓		✓	✓	✓
Visually inspect the unit for damage	✓	✓			
Planned preventive maintenance					
Complete commissioning procedure	✓			✓	✓

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 regulator 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
Failure to reach or maintain operating pressure	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 clogged	Clean
	Improper adjustment of regulator, or regulator defective	Correct adjustment or replace regulator-see Maintenance section
Erroneous or irregular contents gauge readings	Bypass valve not closed or leaking	Close or replace
	Wrong adjustment	Readjust
	Leaking in differential pressure pipes or connections	Seal
	Gauge damaged or leaking	Replace, or return to manufacturer for repair
Main safety valve leaking	Dirt or ice under disk cone	Repair / Replace
Inner vessel bursting disk has burst	Bursting disk with too low pressure	Replace
	Corrosion or material fatigue	Replace
Shut-off valves leaking	Valve seat loose	Tighten
	Damaged seat or cone	Replace seat
Loss of vacuum	Leak on vacuum bursting disk	Replace
	Leaking measuring socket	Seal
Wrong or incorrect vacuum gauge reading	Gauge not properly calibrated	Calibrate
	Batteries have no charge	Replace
	Defective vacuum gauge tube	Replace

Table 4: Fault diagnosis/ troubleshooting of LMO

CHAPTER 2

OXYGEN CYLINDER

Cylinders type
(Gaseous Medical Oxygen)

Dura Cylinder
(Liquid Medical Oxygen)

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, regulators, 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 numbered. In India and Maharashtra most commonly used cylinders are D type (Jumbo) and B type (Portable) cylinders which contains 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.

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

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.

Differences in colour coding of different gases between ISO colour coding standard and United States convention

Gas	ISO colour code	US colour code
Carbon dioxide	Grey	Grey
He-O2	Brown and white	Brown and green
Instrumental air		Red (USA only)
Medical air	Black and white	Yellow
Nitrogen	Black	Black
Nitrous oxide	Blue	Blue
O2-He	White and brown	Green and brown
Oxygen	White	Green
Vacuum (suction)	Yellow	White
WAGD(evac)	Purple	Purple

Figure 9: Differences in colour coding of different gases between ISO colour coding standard and United States convention

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.

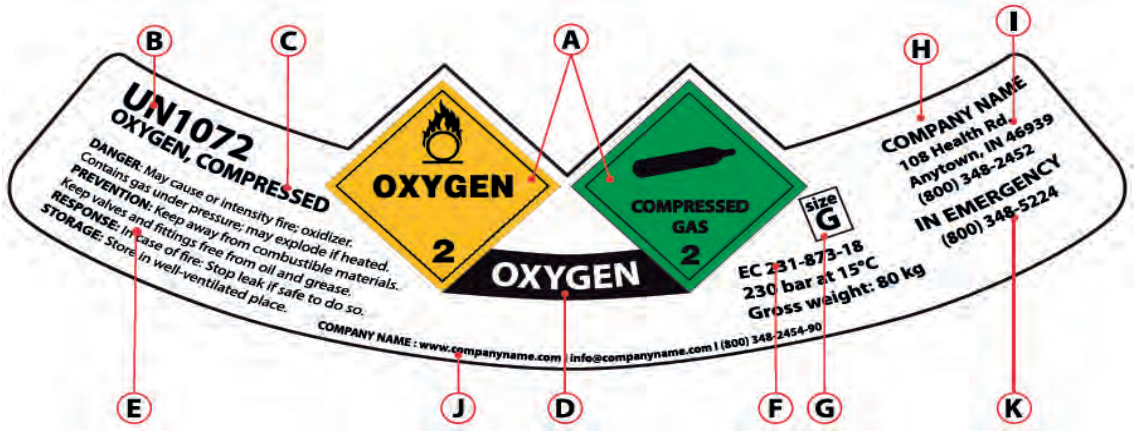


Figure 10: Oxygen cylinder labelling

A. Diamond hazard label: displaying the primary hazard with additional hazard labels displaying any subsidiary hazards. These labels will display the dangerous goods classification number.

B. UN number: preceded by the letters UN. The UN number is a number assigned by the United Nations Committee of Experts on the Transport of Dangerous Goods. The UN number for compressed oxygen is UN 1072.

C. Proper shipping name.

D. Product name (may be omitted if the proper shipping name is identical).

E. Signal word, hazard and precautionary statements.

F. EC number (if applicable).

G. Package size and pressure.

H. Company name.

I. Address of the gas company.

J. Additional company information.

K. Contact telephone number.

Note : See British Compressed Gases Association. Technical information sheet 6. Revision 2: 2012. Cylinder identification. Colour coding and labelling requirements; 2012

1.4 Oxygen cylinder accessories

The following figure shows the accessories required for the cylinder's installation. These are flowmeter, pressure gauge, humidifier, cylinder key, pressure regulator, and trolley.

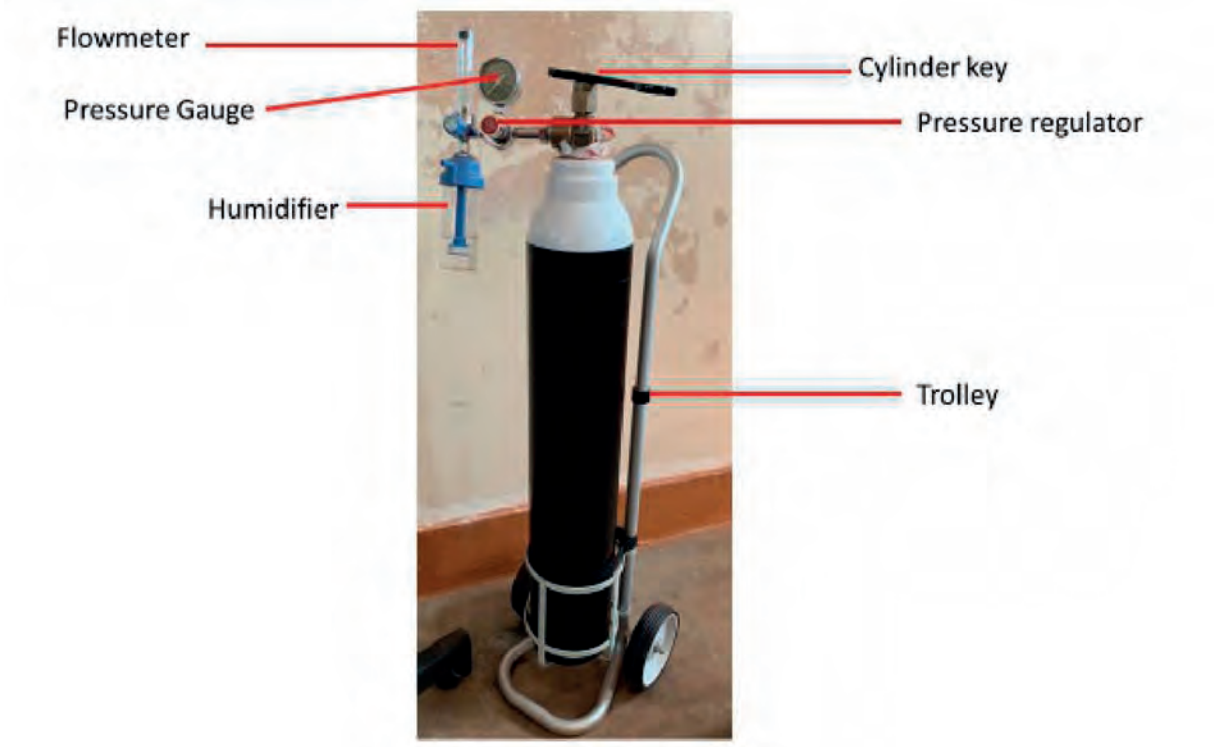


Figure 11: Oxygen cylinder with accessories

1.5 Oxygen cylinder description (Type B and D)

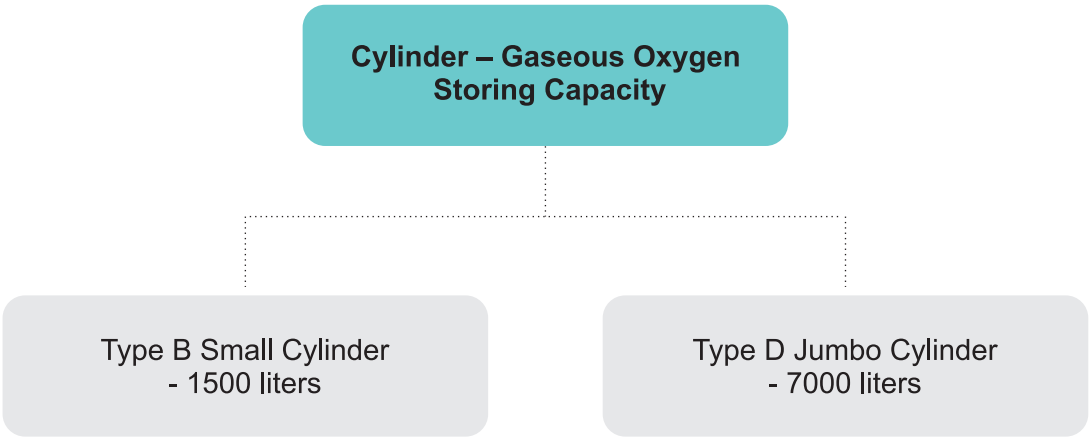


Figure 12: Oxygen cylinder size

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 (specially 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 crain 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 Nm^3/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 Nm^3 - 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 colored 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.

Schedule Period	Activities	Check
Daily	Cleaning	Ensure delivery tubes and masks are decontaminated. If humidifier bottle is used, disinfect and refill with clean water.
	Visual checks	Check cylinder is correct type and correctly labelled. Check all parts are fitted tightly and correctly
	Function	Before use, ensure cylinder has sufficient pressure. Ensure flow is sufficient for intended use. Close cylinder valve after each use
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 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.

Problem or fault	Possible cause	Solution
No oxygen is flowing	Empty cylinder	Replace cylinder.
	Flowmeter knob or cylinder flow valve is closed	Open the valves, and then check the meter registers flow.
	Faulty regulator	Close all the valves and replace the regulator.
Leakage from cylinder or flowmeter	Cylinder is not connected to pressure regulator properly.	Tighten all fittings.
	Faulty or missing washer between regulator and cylinder.	Replace the washer.
	Flowmeter seal damaged or loose.	Replace sealing of the washer and realign the flowmeter.
	Cylinder faulty.	Label faulty cylinder and take appropriate action.
Leakage cannot be located	Leakage too small to be heard	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.
Flowmeter ball not moving, yet oxygen is flowing	Faulty flowmeter.	Close all the valves, disconnect flowmeter, and clean the flowmeter. Reconnect and test. If problem persists, replace the flowmeter.
Pressure gauge does not show pressure, yet oxygen is flowing	Faulty pressure gauge	Replace pressure gauge.

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

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 GoI, 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.

- Generator should be secured by bolting it down. It is preferred that all components of the generator system should come in their own skids.
- By-pass valve system should be installed between the Generator inlet and outlet so the dryer can be serviced without having to interrupt the compressed air supply from the circuit. The upstream and downstream valves must be closed during installation.
- Ensure there are no leakages after all connections are completed. Also, ensure that the inlet, outlets and drain lines are fixed appropriately.
- Ensure generator is pressurized before power up.
- Ensure the digital screen, all the alarm systems, pressure regulator, oxygen analyser and digital audit systems are checked.

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 on 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 temparature. 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 performed regularly. A detailed check list 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 exists 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

Issue	Troubleshooting
Displays not showing up	Check the power supply connection and tension
Tower Status LED not changing	Change the controller
LEDS Status Change but Tower not Switching	Check the coil connection at DIN* and terminal connector in the controller Check the solenoid valve
No Purging	• Check the solenoid valve • Check the exhaust valve • Clean the silencer (muffler) continuous purging at tower 1A – Shuttle not closing • Check pilot air for exhaust valve • Check exhaust valve piston if it is stuck
High Purge Loss	• Check outlet shuttle closing • Check for silencer choke
High Pressure Drop across Generator	• Pre-filter may be clogged. Check and replace filter elements. • Check whether the generator is being overflowed.
Oxygen Analyser (Purity) issue	• Follow the flow diagram given by the manufacturer
Low Operating Pressure	Lower than normal operating pressure may indicate any of the following, • 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. • An improperly operating circuit board or solenoid valve. Confirm that the circuit board and solenoid valves function properly. • A leak in the unit, which allows system pressure to escape. Perform leak test in the unit. • A compressor with reduced output. Ensure that the oxygen concentration level at the desired liter flow is within Trident's specifications. If it is below specifications, replace or repair the compressor.

Issue	Troubleshooting
High Operating Pressure	Higher than normal operating pressure may indicate any of the following. • A restrictive muffler, which does not allow the waste (purge) gas to exit the system freely. Operate the unit with the muffler disconnected to see if the operating pressure returns to normal. • An improperly operating circuit board or solenoid valve. Confirm that the circuit board and solenoid valves function properly. • A restrictive diffuser, which does not allow the inlet feed air as well as exhaust air from the generator. Check the diffuser and correct it. • Contaminated sieve beds. Change the sieve beds.
Leak Test Operation	Shut off the oxygen application/consumption. Let the plant run in manual mode, until the oxygen tank pressure reaches a minimum of 5 bar. Turn the mode selector switch to stand-by/off, and the PSA generator will stop after a little while, when the actual operation cycle is completed. Shut off the feed air supply. If coal tower is installed, close of oil indication tube. If fitted with purity monitoring probe close of the pressure reduction valve on probe inlet. Read and note the pressure P1 in product tank, column 1, column 2, column 3 if present and feed air tank. Let the plant stand still (rest) and isolated in pressurized condition for an hour. After an hour read and note the pressure P2 in product tank, column 1, column 2, column 3 if present and feed air tank. Then determine an eventually pressure drop as the difference between P1 and P2 for each component. The Leak test is right, if the pressure drop after one hour pressurized isolation is less than 0.1 bar. In case of leaks they must not cause more than 0.1 bar pressure drop per hour. If closed open for coal tower oil indication tube and reset the pressure reduction valve on probe inlet 1.0 bar.

DIN (Deutsches Institut für Normung) - A DIN Connector is an electrical connector that was originally standardized in the early 1970s by the Deutsches Institut für Normung (DIN), the German national standards organization.

Table 8: Troubleshooting other issues of PSA

CHAPTER 4

MGPS- MEDICAL GAS PIPELINE SYSTEM

1. INTRODUCTION:

1.1 Medical gas pipeline system (MGPS)

Medical gases are used for patient's healthcare in multiple ways. In the early 1950s, 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, porterage, 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 quantity 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 medical applications. The MGPS provides vital medical gases for patient ventilation and various clinical applications. Commonly used medical gases in hospitals are,

a) Oxygen (O_2)
b) Nitrous oxide (N_2O)
c) Medical air 400 KPa or 4 bar (MA 4)
d) Medical air 700 KPa or 7 bar (MA 7)
e) Carbon dioxide (Co_2)
f) Nitrogen (N_2)
g) Medical vacuum

a. Oxygen (O_2)

Oxygen is the most important gas on the earth; it forms about 21 per cent 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 (N_2O)

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, Medical Air 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 (Co_2)

Carbon dioxide is a medical gas used for insufflation purpose in open heart surgery and laparoscopy procedures. Usually, portable cylinders are the source of CO_2 which are coded with grey color.

f. Nitrogen N_2

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.

Type of system	Primary supply	Secondary supply	Reserve supply (third source of supply)
Compressed gas cylinder manifold systems	Fully automatic manifold. Number of cylinders based on system design	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	Automatic/manual manifold supplying via non-interchangeable screw thread (NIST) connectors OR Locally based integral valved cylinders with regulators/flowmeters attached
Liquid cylinder systems	Liquid cylinder manifold system. NB: This is NOT a changeover manifold. All cylinders are on-line simultaneously.	Automatic manifold system. To come on-line in the event of plant failure.	Automatic manifold system. May be sited to support high dependency areas or whole site OR Locally based integral valved cylinders with regulators/flow meters attached.
PSA plant	Multiplex compressors and columns (adsorbers). Subject to design.	Automatic manifold system. To come on-line in the event of plant failure. May be fitted 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	Type and capacity of supply to be determined by risk assessment.

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
4.2 Piping networks
4.3 Valves
4.4 Warning and alarm systems
4.5 Outlets and inlets
4.6 Secondary equipment

These components explained as follows.

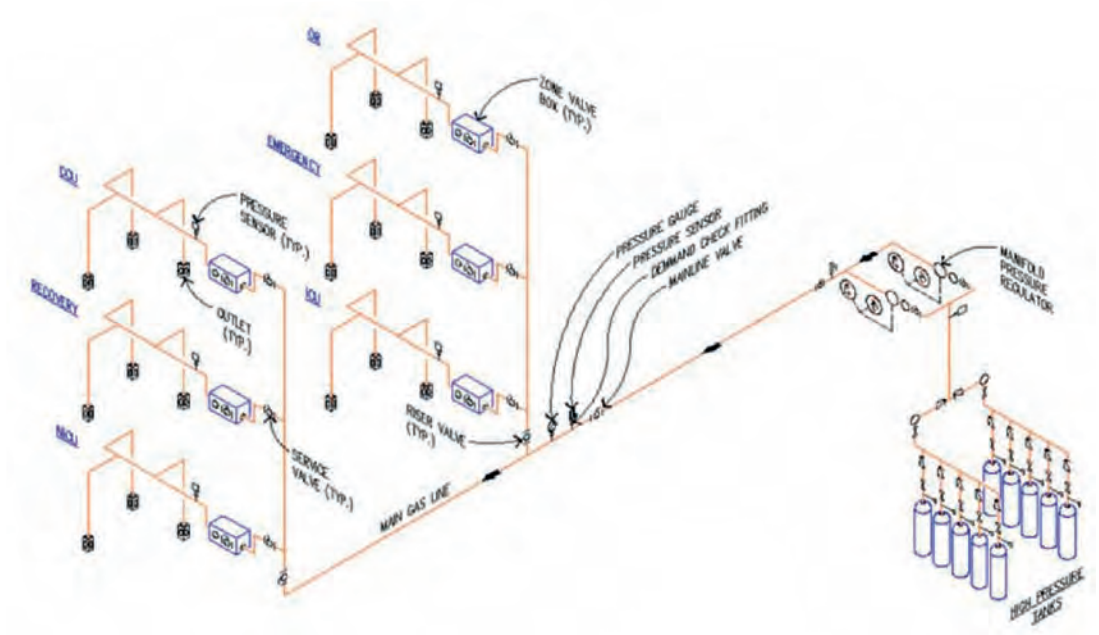


Figure14: Medical gas piping system configuration

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 rooms that they control. On the other hand, service valves are used to isolate certain part 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.

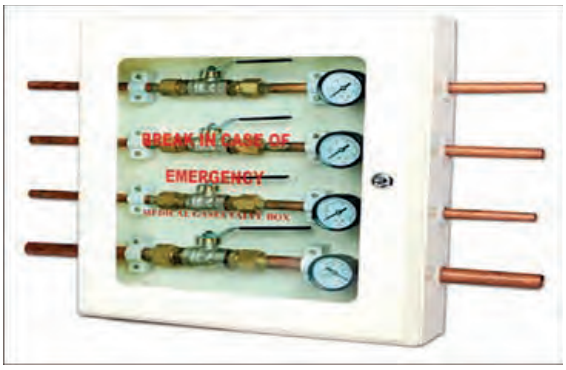


Figure 15: Area valve service unit

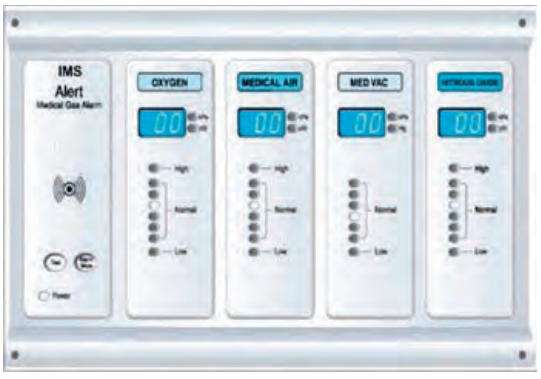


Figure 16: Area alarm panel

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

Figure 17: Diamond-type oxygen outlet point.

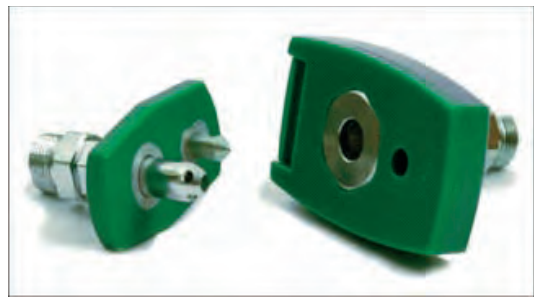


Figure 18: Chemetron-type oxygen outlet point.

Figure 19: A set of medical gases outlets/inlets

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.

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

Table 10: Pipeline testing

(Reference: Sarangi S, Babbar S, Taneja D. Safety of the medical gas pipeline system. J Anaesthesiol Clin Pharmacol.https://www.joacp.org/text.asp?2018/34/1/99/227571)

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 of vacuum pipeline failure can be tided 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.

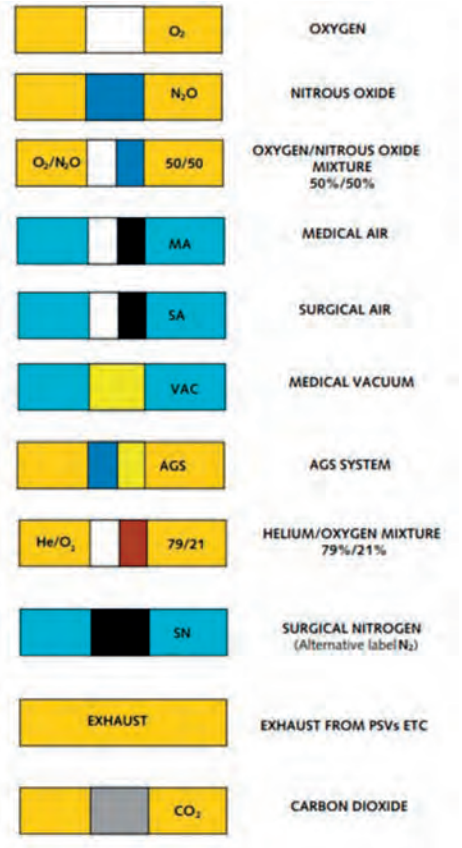


Figure 20: Pipeline identification colours

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.

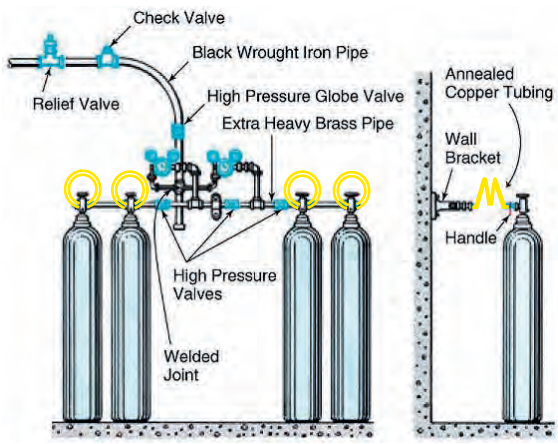


Figure 21: Oxygen Manifold System

- 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.

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.

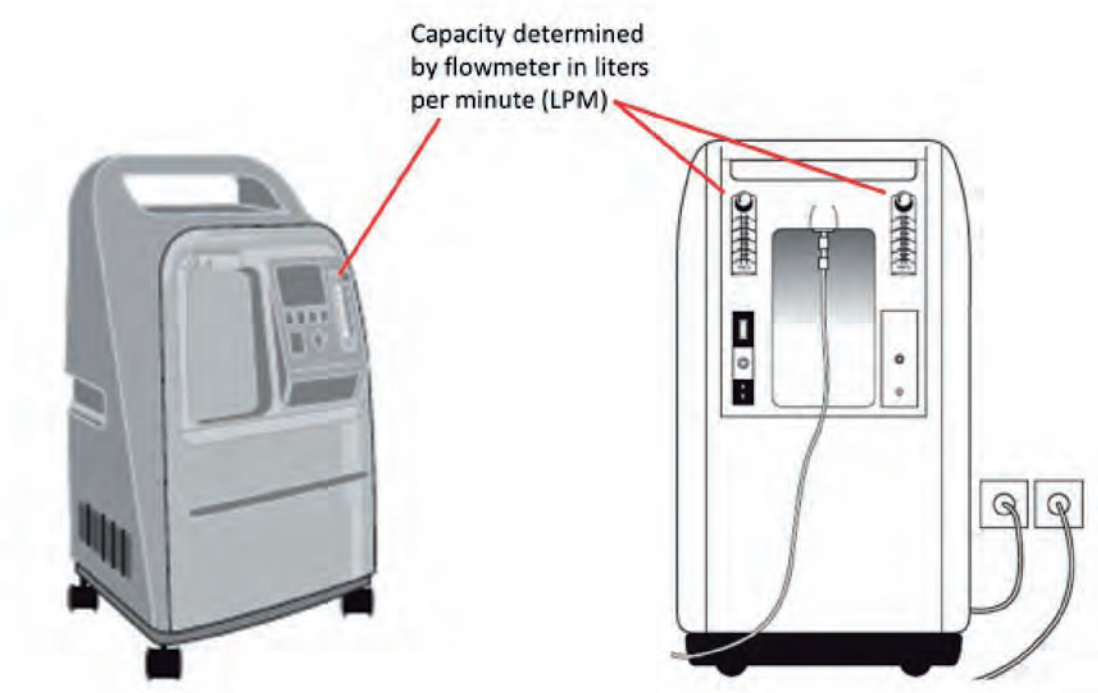


Figure 22: Oxygen Concentrator

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 by 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

Schedule Period	Activities	Check
Daily	Cleaning	Remove any dust / dirt with damp cloth and dry off. Fill humidifier bottle up to marker with clean distilled water.
	Visual checks	Check all screws, connectors, tubes and parts tightly fitted.
	Function	Check oxygen flow before clinically required.
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
No oxygen flow	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 light 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

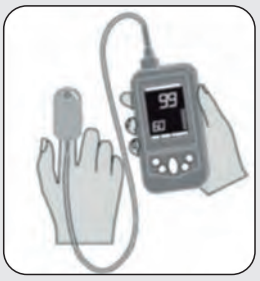
1.1 Purpose

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.

General Characteristics			
Illustration	Self-contained fingertip 	Portable handheld 	Tabletop 
Description	Portable device that has the sensor, analyser and display contained in a single unit.	Handheld portable device with display screen and attached sensor probe and cable.	Stationary device for continuous operation/monitoring. Some can be wall- or pole-mounted.

General Characteristics			
	Self-contained fingertip	**Portable handheld**	**Tabletop**
Clinical application and/or use case	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.	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).	Monitoring of pulse rate, SpO2 and plethysmography waveform to detect hypoxaemia, supporting the diagnosis of respiratory disorders. Suitable for longer term continuous monitoring.
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 RR).	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 (reusable 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 (reusable probes typically need replacing at least once per a year). Charging/power cable.
Merits	Low upfront cost. Portable. Self-contained unit; no external probes/cables.	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. Ideally have a port (or Wi-Fi) for downloading and/or printing data.	Multiple use-case options. May be pole mounted. Large internal memory to store patient IDs and records. Ideally have a port (or Wi-Fi) for downloading and/or printing data. Most accurate, in general.

Table 13: Types pulse oximeter

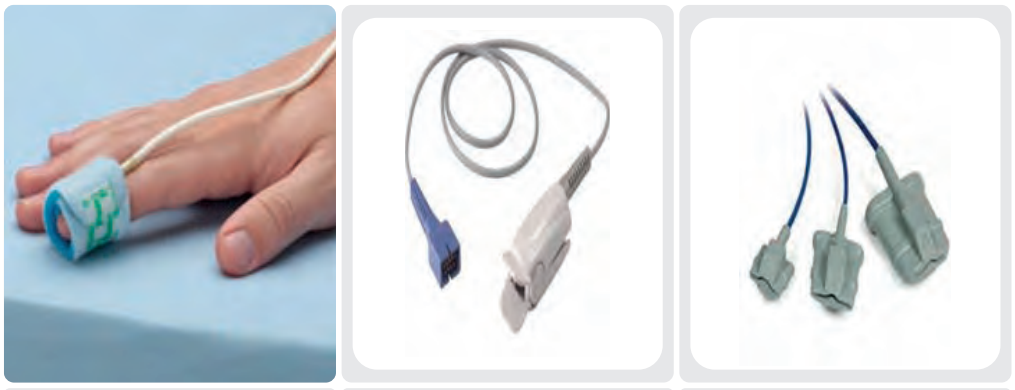
1.3 Controls on display

- 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.



Wrap around probe	Hinged probe	Rubber probes

Figure 23: Types of probes

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.

Tips to protect oximeter probe

When not in use, the oximeter probe cable may be loosely coiled for storage or carrying but should not be coiled too tightly as this will damage the wires inside the cable. The lens and detector should be kept clean. Use soapy water or an alcohol-soaked swab to gently clean dust, dirt or blood from the probe.

Figure 24 : Coiled Probe Cable

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

Problem	Possible cause	Solution
Oximeter will not power up	Battery is completely discharged	Charge the batteries for 6 hours by connecting to the AC mains.
	Battery is not getting charged	Check the AC mains socket for proper voltage. Check for Green LED on Oximeter If Green LED does not light, contact our dealer-circuit problem If Green LED lights up, contact our dealer -battery needs replacement
No pulse shown on the barograph	Sensor or patient cable is disconnected from the oximeter	Check sensor patient cable connections
	Sensor is incorrectly positioned on the patient	Reposition the sensor
	Poor patient perfusion	Reposition the sensor
	Defective sensor or patient cable	Try a new sensor or patient cable or contact our dealer.
Segments of SPO2 or pulse rate missing	Defective LED displays	Contact service provider for repairs.
Displayed pulse rate does not correlate with pulse rate on ECG monitor	Excessive motion at sensor site may be prohibiting the oximeter from acquiring a consistent pulse signal	Eliminate or reduce cause of motion artefact OR reposition sensor to new sensor site where motion is not present.
	Patient may have arrhythmia resulting in some heart beats that do not yield a perfusion signal at sensor site	Examine the patient: condition may persist even though both the monitors are functioning properly if patient's arrhythmia persists.
	ECG monitor may not be functioning properly.	Examine the patient: Replace ECG monitor OR refer to operator's manual of ECG monitor
Erratic pulse display and/or yellow perfusion LED during concurrent use of electrosurgical equipment (ESU)	ESU may be interfering with oximeter performance	Examine the patient: Move oximeter, cables and sensor as far away from ESU as possible OR refer to the ESU operator's manual
Perfusion is blinking yellow with each pulse	Perfusion signal at sensor site is marginal	Examine the patient: Reposition sensor OR select alternate sensor site

Problem	Possible cause	Solution
Unable to obtain green perfusion	Low patient pulse strength sensor site poorly perfused sensor not correctly positioned. Excessive cold condition	Reposition sensor on patient
	Sensor attached too tightly or tape is restricting perfusion at sensor site	Reposition sensor, select alternate site or remove restrictive material from sensor site
	Circulation reduced due to excess pressure between sensor and hard surface	Allow sensor and finger to rest comfortably on surface
	Excessive ambient light	Reduce ambient light
	Excessive patient motion	Reduce patient motion OR select alternate sensor site
	Sensor applied to polished fingernail	Remove fingernail polish
	Interference from: arterial catheter blood pressure cuff electrosurgical procedure infusion line	Reduce or eliminate interference
Perfusion LED is blinking red	Inadequate perfusion signal at sensor site	Examine the patient: Reposition sensor OR select alternate sensor site
	Excessive motion at sensor site may be prohibiting the oximeter from acquiring a consistent pulse signal	Eliminate or reduce cause of motion artefact OR reposition sensor to new sensor site where motion is not present
Sensor alarm sound continusly	Sensor problem	Check sensor connection to oximeter Check proper connection to patient Sensor faulty-needs replacement
Alarm sounds continuously	Alarm limit violation due to faulty alarm limits	Reset the alarm limits OR Reset the oximeter to factory default settings
Error "Oximeter Not Installed"	Unit not detecting oximeter module faulty sensor-Try replacing sensor	Contact your dealer for repairs

Table 14: Common problems and remedies of pulse oximeter

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.

CHAPTER 7

DEVICES FOR OXYGEN DELIVERY, REGULATION AND CONDITIONING

1. BRIEF INTRODUCTION

1.1 Devices for oxygen regulation and conditioning

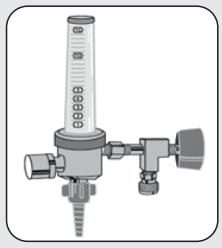
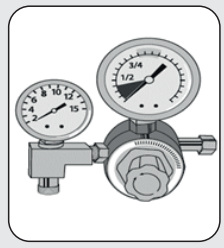
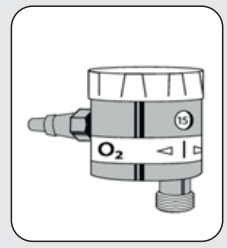
The oxygen therapy products covered in this section include flowmeters, flow-splitting devices and humidifiers. These devices play different roles in the regulation and conditioning of oxygen gas for the delivery of oxygen therapy to patients.

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.

	Thorpe tube (rotameter)	Bourdon gauge (single and multiple stage)	Dial/click (flow restrictor)
Illustration			
General characteristics			
Description	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.	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.	fixed-orifice flowmeter calibrated to deliver flow in specific increments, adjusted with a click dial. This device integrates a pressure-reducing valve.

Clinical application and/or use case	For all inpatient clinical areas in health care facilities where oxygen therapy is provided. Recommended for use with terminal units (wall outlets) of piped distribution systems or for large stand-alone cylinders.	Ideal for ambulance transportation. Recommended for use with smaller portable cylinders common for emergency and ambulance transportation.	For all inpatient clinical areas in health care facilities where oxygen therapy is provided (terminal units – either wall outlets or ceiling mount drops of piped oxygen distribution systems in hospitals). Also common with portable cylinders for intra facility, interfacility or air transport.
Product-specific characteristics			
Integrates a pressure-reducing valve	No	No	Yes
Inlet pressure	Always attached to a 345kPa (3.45 bar, 50 psig) source.	Variable.	Variable.
Oxygen source	Terminal unit (wall outlet) or cylinder with pressure -reducing valve.	Cylinder.	Terminal unit (wall outlet or ceiling mount drop), or cylinder.
Merits	Simple. Cost-effective. Wide variety of flow ranges available. Provides visual feedback of actual flow measurement. Can fine-tune flow rate. Pressure compensated: flow is accurate in the face of an obstruction downstream.	Unaffected by gravity; works in any position. Inbuilt with regulator and gauge.	Simple to operate. Unaffected by gravity; works in any position. Inbuilt with regulator and gauge. Compact.
Drawbacks	Affected by gravity; works in a vertical position only. Needs additional pressure regulator and gauge. Fragile. Uncompensated: can display an erroneously high flow rate.	Not back pressure compensated. As flow increases, the indicated flow reading becomes inaccurate.	Can only choose flow rates in fixed increments. Regulates but does not measure flow. Expensive. Accurate only at rated pressure.

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.

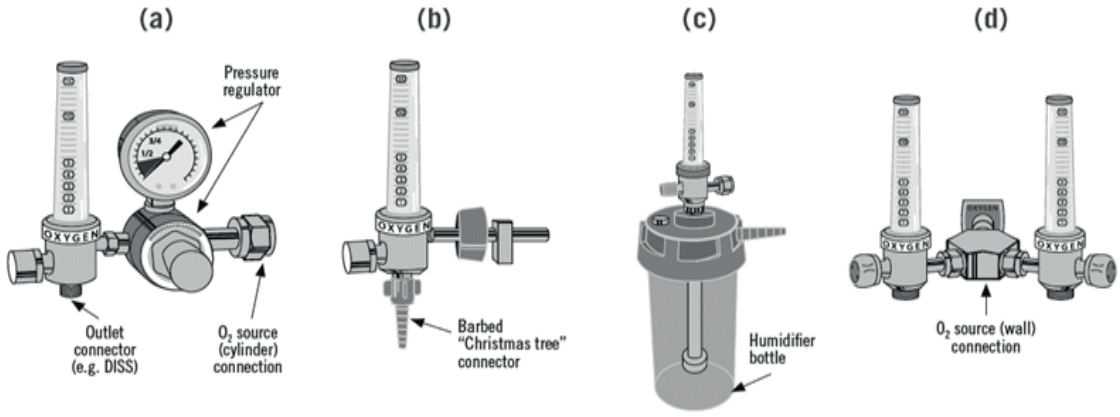


Figure 25: Types of Thorpe Tube

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 Thorpe tube flowmeters to measure and regulate the flow at each outlet. Each flowmeter is adjusted separately to ensure precise control with a visual indication of flow for 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 Thorpe 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.

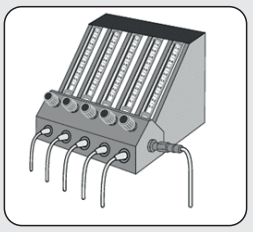
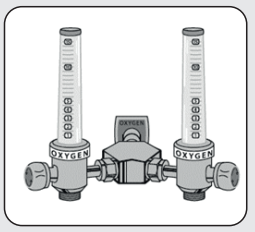
	Flowmeter stand	Dual Flowmeter
Illustration		
General characteristics		
Description	A device that distributes medical oxygen by splitting output flow from a single oxygen source to multiple outlets through independently regulated flowmeters, to individual patient needs.	A device that distributes medical oxygen by splitting output flow from a terminal unit (wall outlet) oxygen source through two independently regulated flowmeters, to meet individual patient needs.
Clinical application and/or use case	Splitting oxygen flow for inpatient oxygen therapy, particularly paediatric or neonatal wards where lower flow rates are used. One inlet can be divided into several independently regulated outlets for up to five patients. Set flow rates cannot exceed output flow rate of the concentrator.	Splitting oxygen flow for inpatient oxygen therapy. One inlet can be divided into two independently regulated outlet for up to two patients.
Appropriate level of health system (and relevant medical units)	Primary, secondary, tertiary (anywhere oxygen therapy is provided; health centre, general hospital, district hospital, provincial hospital, regional hospital, specialized hospital).	Secondary, tertiary (requires piped terminal unit).
Product-specific characteristics		
Flow regulation	Yes; via the mounted flowmeters.	Yes; via the two flowmeters.
Oxygen source	Concentrator or cylinder (on the downstreamside of a pressure regulator at 345 kPa (3.45 bar, 50 psig)).	Terminal unit of centralized piped system.
Merits	Simple. Can serve multiple patients who need oxygen therapy at different flow rates. Can be securely mounted to a terminal unit within easy reach of health care workers and without disturbances. Flowmeters are generally easy for health care workers to read. Suitable for primary care settings without centralized piped oxygen.	Simple. Can serve two patients who need oxygen therapy at different flow rates. Can be securely mounted to a terminal unit within easy reach of health care workers and without disturbances. Less costly than flowmeter stand, in general. Easier installation.
Drawbacks	Costly. Require space for health care workers to easily access the flowmeters. Usually mounted in a fixed position, which may restrict where patients can be placed. A clear outlet-to-bedside identification system must be established, otherwise there can be confusion about which outlet serves which bedside.	Requires centralized piped system and terminal unit adapter (which is not available in many primary care settings). Can only divide flow for up to two patients.

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 three main principles related to humidification:

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

	Bubble humidifier – Non heated (reusable)	Bubble humidifier – Non heated (single use)	Bubble humidifier – heated
Illustration			
General characteristics			
Description	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.	A single-use bottle that reduces the dryness of oxygen by bubbling the gas through distilled water at room temperature.	A device consisting of a heat source and a humidification chamber whereby the built-in heater warms the water in the chamber to add moisture to the airstream as it passes over the surface.
Clinical application and/or use case	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 asopharyngeal catheters are used.		Heated humidification is needed for CPAP and for HFNC oxygen therapy.
Appropriate level of health system (and relevant medical units)	Primary, secondary and tertiary level.		Secondary and tertiary level.

	Bubble humidifier – Non heated (reusable)	Bubble humidifier – Non heated (single use)	Bubble humidifier – heated
Product-specific characteristics			
Merits	Simple. No power required. Low cost. Reusable.	Simple. No power required. Low cost. Reusable.	Adjustable heat for more or less moisture. More efficient at humidifying gas.
Drawbacks	High risk of contamination (reduced by changing the water frequently) Decontamination required.	Disposable/single-use. More costly.	Risk of "rainout". High risk of contamination (reduced by changing the water frequently). Needs power source.
General comments	Works best at a water temperature of at least 30 °C.	Works best at a water temperature of at least 30 °C.	Works best at a water temperature of at least 37 °C.

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.

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

	Nasal Cannula (prongs)	Nasal Catheter	Other noninvasive options (face mask, head box, incubator, tent)
Appropriate level of health system (and relevant medical units)	All levels including primary, secondary and tertiary levels. All departments where oxygen therapy is delivered, including, but not limited to, ICUs, inpatient ward, emergency, operating theatre, recovery room, observation, emergency vehicles, etc.		(Note: Not recommended for neonates, infants and children. For risks, see Drawbacks below.)
Product-specific characteristics			
Achievable FiO2 (%)	Depends on the patient, but up to 50–55% can be achieved.		Depending on the device, can be varied from 21–100%.
Merits	Causes less interference with eating, drinking, speaking.	Lower cost alternative to nasal cannulae. Less likely to be dislodged.	Non-invasive. No increased risk of airway obstruction by mucus or of gastric distention.
Drawbacks	More costly than nasal catheters. a risk of dislodgement. Poor-quality tape can cause skin trauma, particularly in neonates, causing the skin to break and thus become open to infection.	More invasive than nasal cannulae. Insertion requires skilled trained nurse. Can become blocked with mucus	Can interfere with eating, drinking and speaking. Wasteful of oxygen. Potentially harmful due to risk of carbon dioxide accumulation (hypercapnia).

Table 18: Description and comparison of oxygen delivery options

2.1 Venturi mask

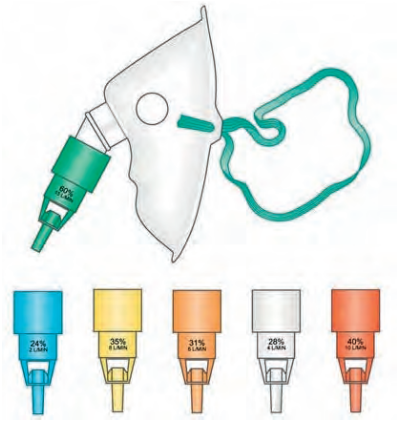


Figure 26: Venturi mask

- Delivers 24-60% 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 = 8-10L/min = 35% Oxygen
- RED = 10-12L/min = 40% Oxygen
- GREEN = 12-15L/min = 60% Oxygen

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

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.

	Oxygen analyzer for testing concentration-Electrochemical	Oxygen analyzer for testing concentration-Ultrasonic	Multiparameter analysers (Concentration, flow and pressure)
Illustration			
General characteristics			
Description	A device that measures and displays oxygen concentration using electrochemical sensing technology.	A device that measures and displays the oxygen concentration using ultrasonic oxygen sensing technology.	A device designed to test all types of gas flow equipment especially those requiring high accuracy.
Clinical application and/or use case	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.	Spot checking and servicing of PSA-generated oxygen, from concentrators. All clinical departments that use concentrators should have an analyser and use it regularly.	Equipment spot checking and servicing.
Appropriate level of health system	Primary, secondary, tertiary.	Primary, secondary, tertiary.	Secondary, tertiary.

Product-specific characteristics

Principle of operation	Electrochemical process whereby the electrical potential (voltage) changes with the concentration of oxygen.	Piezoelectric ceramics are used for ultrasonic transmission and reception. Ultrasonic technology accurately measures the speed of sound through the gas.	Varies depending on device.
Sensor material	Galvanic cell sensor consists of an anode, a cathode and an electrolyte	Electronic sensor.	Varies depending on device.
Parameters measured	Oxygen concentration.	Oxygen concentration. Flow rate (for some).	Oxygen concentration. Flow rate. Pressure.
Detection range	0–99.9%	21–95.6%	0–99.9% depending on device
Merits	Works for concentrator and lowpressure side of cylinder supply. Works for cryogenically generated cylinder oxygen. Cheapest initial cost, in general.	Accurate and stable. No need for calibration. Compact and easy to use. No need to replace sensor. Can also measure flow rate. Lifetime: ≥ 5 years.	Multiple parameters measured by one device.
Drawbacks	Lifetime: < 1–2 years. Influenced by the temperature and pressure. Needs calibration. Needs sensor spare parts.	Works only for PSA-generated oxygen (< 96%). Higher initial purchase cost, in general. Can be damaged by humidity.	High cost.
General comments	Recommended if the sensors are available and in proper supply.	Recommended for testing PSA-generated oxygen.	

Table 19: Description and comparison of oxygen analysers

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.

Intensive care

Transport, portable Ventilator

Figure 27 : Types of ventilators

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.

Figure 28 : CPAP / BiPAP machine

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 lighter 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.

CHAPTER 8

INVENTORY MANAGEMENT

1.1 OXYGEN CALCULATION

1.1.1 Oxygen Calculator Purpose

- Evaluating the capacity of oxygen available in the hospital.
- Determine total litre 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 Maharashtra 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 (m^3) = 1,000 liters (Gaseous O_2)
- 1 Metric Ton (MT) = 770 CuM (m^3) = 7,70,000 liters (Gaseous O_2)
- 1 Metric Ton (MT) = 876 litres of Liquid Oxygen
- 1KL Liquid O2 = 877.8 CuM
- 1 Litre Liquid O2 = 861 litres of gaseous O_2

1. Gaseous oxygen litres to cubic meters (m3) to metric ton (MT)

Qty in liter of gas	Qty in CuM	Qty in kg	Qty in MT
1000	1	1.429	0.001429

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

	Qty in liter of gas per day (LPM x 60 mins x 24 hours)	Qty in kg per day (Litres of gas x 0.001429)	Qty in MT per day (Qty in kg / 1000)
1 LPM	1440	2.05776	0.00205776
100 LPM	144000	205.77600	0.20577600
500 LPM	720000	1028.88000	1.02888000
1000 LPM	1440000	2057.76000	2.05770000

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

	Qty in litres of liquid oxygen	Qty in KL	Qty in kg	Qty in MT
Directly form liquid oxygen to MT	1000	1	1141.7	1.1417

Ref: Unit Conversion Data for Oxygen. Universal Industrial Gases Inc. Accessed at http://www.uigi.com/o2_conv.html in December 2020.

1.2 Oxygen Requirement/Consumption based on bed strength

Oxygen requirement for oxygen beds (excluding ICU beds) in Dedicated COVID Hospital (DCH) and Dedicated COVID Health Centre facilities (DCHC)					
Column No	A	B	C	D	Total requirement of the State for Oxygen in m^3 for dedicated COVID facilities="X+Y" (e. g. 1440 + 2160 = 3600 m^3)
1	Oxygen beds	Oxygen flowrate (LPM)	Oxygen requirement per day in Cubic meter	Total oxygen requirement	
2	100	10 litres/min	60 minutes x 24 hrs /1000 (to convert litres to m^3)	"X"=Column(A*B*C) e. g. 100 x 10 x 60 x 24 /1000 = 1440 m^3	
Oxygen requirement for ICU beds in DCH facilities					
Column No	F	G	H	I	
Sr No	ICU beds	Oxygen flowrate (LPM)	Oxygen requirement per day in Cubic meter	Total oxygen requirement	
1	50	30 litres/min	60 minutes x 24 hrs / 1000 (to convert litres to m^3)	"Y"=Column(F*G*H) (e. g. 50 x 30 x 60 x 24 /1000 = 2160 m^3)	

Table 20: Oxygen requirement/consumption based on bed strength

Note: Flow rate of 10 LPM/O2 bed and 30 LPM/ICU bed are considered for consumption calculation as per latest GoI guideline D.O.No. T-20017/03/2021-NCD (FTS- 8110554) 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

Column No	A	B	C	D	E	F	G
Sr No	Active cases	O2 supported beds required (8%* active cases)	ICU beds O2 requirement required (4%* active cases)	Total Oxygen consumption (In Cubic Meters) @ 10 LPM flowrate	ICU beds oxygen consumption @ 30 LPM flowrate	Total Oxygen consumption (Cubic Meters)	Total Oxygen Consumption on (MT)
	X	Column no "A"*8/100	Column no "A"*4/100	Column no "B"*10*60* 24/1000	Column no "C"*30*60* 24/1000	Column no "D+E"	Column no "F/770"
e. g	1000	1000*8/ 100=80	1000*4 /100=40	80*10*60* 24/1000= 1152	40*30*60* 24/1000= 1728	1152 + 1728 = 2880	2880 / 770 = 3.74

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. District/Facility can use the actual percentage as per their patient data on oxygen support requirement.*

1.4 Oxygen requirement, availability and Gap analysis

Source of Oxygen in dedicated COVID Hospitals (DCHC & DCH)	Calculation for O2	Total
a. No of cylinders available with he State/District/Hospital	D Type (7 cubic meter) No. of Cylinders x 7 cubic meter = 'A' in m^3	A+B+C
	B type (1.5 cubic meter) No. of Cylinders x 1.5 cubic meter = 'B' in m^3	
	Dura Cylinders (Capacity in Litre x 0.8778= Capacity in CuM), No of Cylinders x Capacity in CuM = 'C' in m^3	
b. O_2 Generation through Pressure Swing Adsorption (PSA) If centralized manifold is available	Capacity in LPM (Litres per min) x 60 min x 24 hrs/ 1000 (to convert litres to cubic meter) = 'D' in m^3	D
c. Liquid Medical Oxygen if centralized manifold is available	Capacity in KL x 877.8 = Capacity in CuM = 'E' in m^3	E
Total		A+B+C+D+E (In m^3)

Table 22: Oxygen availability at state district/hospital level

Gaps to be addressed for Oxygen Supply

Gap in O_2 Supply = Total Oxygen Required (X+Y) - Total availability (A+B+C+D+E) in m^3

(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).

CHAPTER 9

MEDICAL OXYGEN HANDLING AND SAFETY GUIDELINES

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.

Figure 29: The Fire Triangle

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.

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 those 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 air 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 1680-2100 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.

1.4 Fire safety

- Ensure appropriate fire extinguishers are kept nearby and are regularly inspected.
- Keep oxygen cylinders at least several meters from a heat source, open flames, electrical devices, or other possible sources of ignition.
- Put a “no smoking” sign near oxygen sources in the hospital.
- Check that all nearby electrical circuit breakers and devices are in safe working condition and free from sparking to prevent a serious fire occurrence.

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 strap 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 sanitization 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 filling point to 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.

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

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.

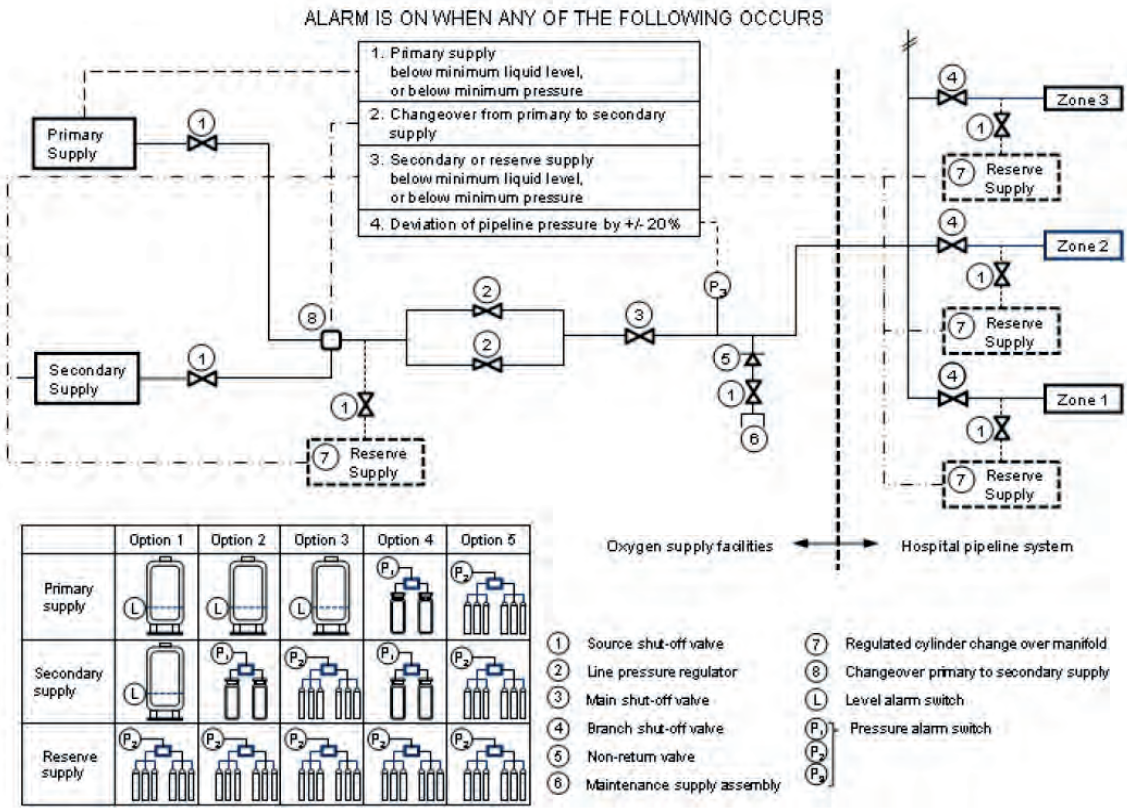


Figure 30 : Different sources of supply and key system components including alarms

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-compatible 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 premature.

- 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 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.

✔ Do's	✘ Don'ts
Keep all combustible materials away from possible contact with oxygen.	DO NOT permit smoking or an open flame in areas where oxygen is stored, handled, or used.
Keep all surfaces that may come in contact with oxygen clean.	DO NOT walk on or roll equipment over liquid oxygen spills.
Provide adequate ventilation in areas containing oxygen equipment.	DO NOT place liquid oxygen equipment on asphalt or any surface that may have oil or grease deposits.
Protect your eyes with safety goggles or face shield.	DO NOT lubricate oxygen equipment with oil, grease or unapproved lubricants.
Protect your arms with leather gloves.	DO NOT touch frosted pipes or valves with bare skin.
Use only equipment, cylinders, containers, regulators, and apparatus designed for oxygen service.	DO NOT spray water on liquid spill, allow it to evaporate.
Use Oxygen for medical purposes only if it is labelled "Oxygen I.P."	DO NOT release gaseous oxygen indoors.
Dispose liquid oxygen by discharging into remote outdoor pit filled with clean, oil-free, grease free gravel and allow it to evaporate safely.	

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 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:

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

Symbol	Symbol description/Placed	Explanation
	S9/17 Keep equipment in well ventilated area and gases away from combustible material. On front of a PSA generator	Warning: Oxidizing gas. Keep equipment in well ventilated area and gases away from combustible material. See WARNINGS AND IMPORTANT INFORMATION
	Warning Equipment must be placed in a well-ventilated area. Avoid inhalation of gases. On exhaust silencer.	Warning Equipment must be placed in a well area. Avoid inhalation of gases. See WARNINGS AND IMPORTANT INFORMATION concerning exhaust gases.
	On skid plate VOLTAGE Turn off power and disconnect before service. PRESSURE Depressurizes equipment before service. MANUAL See manual before service	Warning: See WARNINGS AND IMPORTANT INFORMATION Voltage Turn off power and disconnect power supply before service or repair. Pressure- Depressurize before service or repairs. Manual- See manual before service or repair.
INLET – FEED AIR	On piping near inlet	Information label, INLET – FEED AIR: Connect to feed air supply.
OUTLET - OXYGEN	On piping near oxygen outlet	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.

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 team is needed to ensure rational use of oxygen, streamline the oxygen supply from different sources of oxygen and ensure safety measures in oxygen delivery system 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 CuM of life saving oxygen.

India and especially Maharashtra 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/anaesthesia 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, oxy 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/anesthetist 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.

  OXYGEN SHOULD NOT BE ADMINISTERED WITHOUT PRESCRIPTION

  Goals:

  - SpO2›: 90-94% (COPD: 88-90%), if breathing work does not increase.
  - PaO2: 60-70mmHg, (COPD: 55-65mmHg)
  - Monitor SpO2 continuously and make necessary changes so as to meet the Oxygenation goals.

  IN THE CASE SHEET 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.

- Switch to standby mode when disconnecting the ventilator from patient as required during feeding. (supplement oxygen with nasal prongs/cannula while feeding as needed may be used).
- Use closed suction device thus preventing de-recruitment during open suctioning.

5 REASONS FOR OXYGEN LOSS

Oxygen is an important resource, any wastage or leakage needs to be prevented. Below are the major reasons for oxygen loss.

- Inadequate manpower to handle oxygen management system.
- Improper maintenance of dura cylinders.
- Leaks in jumbo cylinders.
- Avoid HFNO (High Flow Nasal Oxygen).

5.1 Issues, causes and solutions for preventing oxygen loss

Issue	Causes	Solutions
Less manpower: Hospital staff consist of doctors, nurses and ward boys. Lack of manpower can lead to -	• Patients would help themselves • NPM (None per mouth) settings would not be changed	• Increase hospital manpower • Ensure staff is well trained
Maintenance of dura cylinders: Dura cylinders store cryogenic oxygen at - 183 degrees C or lower. Leaks from dura cylinders are caused due to	• Stored for long periods of time • Oxygen converts from liquid to gaseous form and releases in to the air	• Rotate dura cylinders • Increase pressure of dura cylinder more than the oxygen pressure
Leaks from jumbo cylinders: These are caused due to the following factors:	• Faulty valves • Handle is not tight • Washer is not properly placed	• Rotate jumbo cylinders • Stick tags mentioning last filling date • Keep checking pressure gauges • Use good quality spanners during maintenance • Avoid hammering oxygen cylinder valves
Avoid HFNO – High-Flow Nasal Oxygen	• Make patients lungs lazy • Uses more oxygen	• Replace with NIV (Non Invasive Ventilation) or BiPAP (Bi level Positive Airway Pressure) • Better health effect on patients health

Table 25: Oxygen management system issues, causes and solutions

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.

Annexure

ANNEXURE 1: TECHNICAL SPECIFICATIONS OF VARIOUS OXYGEN SYSTEMS

Annexure Table 1: Technical specifications of Liquid medical oxygen

Sr. No.	Particulars	Liquid Medical Oxygen Plant
1	Liquid medical oxygen supply system	Liquid medical oxygen tank (VIE) 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 (VIE)	• 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 perlite insulation material to insulate under vacuum. • The VIE should be self-pressurizing type by partial evaporation of liquid oxygen through a pressure building coil by a non-ferrous imported pressure regulator. The vessel shall be supplied as a functional whole with all materials of construction & the cleaning regime suitable for medical grade liquid oxygen.
3	Liquid oxygen tank with required accessories	• Quantity: 10 KL X 1 No. • Installation: Outdoor • Type: Double walled, vertical • Capacity: Minimum 10,000 litres water capacity- 2 No • Design code: ASME Sec. VIII Div. I latest edition / EN - 13458-2 • Annexure-C/ AD2000 MARKBLATTER 2004 Edition • Max. working pressure: 17 Bar G • Design temperature: –196°C to +50°C • Hydraulic Test Pressure: 26 bar G • Type of Insulation: Vacuum, Perlite filled • Safety Valve Set pressure: 17 Bar G (dual safety valve with three-way diverter valve) • Bursting Disc Set Pressure: 23 Bar G (Bursting disc) • Standard fittings: Pressure rising coil, pressure building regulator of adequate capacity and size, dual safety valve with imported three-way diverter valve, bursting disc., pressure gauges, liquid over-flow line, Liquid level gauge and adequate numbers of extended spindle glove valve etc. • Maximum evaporation rate: <0.35% of net value. • Material of construction: Inner shell and wetted parts of SS 304 outer shell of CS ASTMA 516 Gr. 70 / CGA 341 2002 EN13455 S275/S355 • Joint efficiency: 100% • Radiography: 100% for inner, for outer spot • External piping: From LMO tank to vaporizer SS304 • From vaporizer to inlet of pressure reducing station SS304 • From outlet of pressure reducing station to main header copper • Cryogenic valves: 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/LLOYDS/TUV) • Cleaning: Degreasing for oxygen service and pressurize with nitrogen. • Withdrawal rate: 1000 cum per hr. at 12 Bar G

Sr. No.	Particulars	Liquid Medical Oxygen Plant
4	Accessories	• LMO tank along with P&ID shall be fitted with the following accessories: Top fill valve, bottom fill valve, liquid charging line blow valve, liquid delivery valve, overflow valve, gas blow valve, filling coupling, vaporizer coupling, liquid level gauge (Dial 100 mm), high level valve, equalizing valve, low level valve, pressure gauge (100mm dial, Range 0-25 kg/cm2), pressure gauge isolation valve, pressurizing valve, pressurizing coil, filter, pressure regulator, economizer, check valve, evacuation port, vacuum gauge connection port/ vacuum probe valve.
5	Safety Fittings	• Two safety valves for inner vessel fitted on pipeline with flow divert valve. • Rupture disc for inner vessel • Safety valve for inlet pipeline • Safety valve for pipeline of pressurizing evaporator • One rupture disc/ safety device on outer vessel.
6	Sub mittals	The liquid medical oxygen tank shall accompany the original quality test certificate covering following documents: • Approval letter from CCOE along with approved drawing from CCOE. • Approval letter from CCOE for use of cryogenic vessel(s) at site. • Certificate from the authorized inspection agency • Heat chart for pressure parts • Dimension checks report • Dished end reports • Mechanical properties test report for production test coupon. • Visual inspection report. • Radiography examination report. • Liquid penetrant examination • Cleaning inspection report • Hydro-pressure test report.
7	Liquid medical oxygen supply system	• Two vessel of 1X10 KL liquid oxygen VIE 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 should be state-of-the-art. • 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 VIE. • The copy of the certificate should be forwarded to HLL prior to shipping and original should be enclosed along with the shipping document. • Bidder should follow International Standards
8	Product and service specification	• Capacity of liquid oxygen storage tank: 10 KL • Gas outlet pressure to be maintained at 4.2 kg/cm2. • 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 fence around, well it by sodium vapour lamps and demarcated with proper signage. • Indication of liquid oxygen level and outlet gas pressure should be provided.
9	LMO tank and existing oxygen manifold	Automatic change over should be provided between the LMO tank and existing oxygen manifold. (Existing manifold is of 2 x 10 cylinders)

Sr. No.	Particulars	Liquid Medical Oxygen Plant
10	Specification of components	• Product: The liquid medical oxygen (LMO) supplied at site should be of IP grade. The LMO supplied should comply with all relevant SMPV regulations and standards under per view of the Indian Drugs and Cosmetic Act rules. They should also satisfy the IP 2007 specifications. • Storage tank specifications: The storage tank and the vaporizer coils should be designed as per the ASME Sec. VIII Div. I latest Edition / EN -13458-2 Annexure-C/ AD2000, MARKBLATTER 2004 Edition • 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.
11	The requirement of the cryogenic vessel	Configuration: Vertical • Inner vessel maximum allowable working pressure: 17 kg/cm2 • Inner vessel hydrostatic test pressure: Greater than 26 kg/ cm2 • Outer vessel material of construction: Carbon steel • Inner vessel material of construction: Stainless steel • Independent AV coil should be provided with each vessel
12	Storage tank capacity	• Vacuum insulated evaporator vessel should have a capacity of 1X10 kilo litres. The AV coil should have adequate capacity to handle the gas flow requirements of the hospital. • Vaporizer coil • Maximum operating Pressure: 20 kg/cm2 • Design Pressure: 22 kg/cm2 • Pneumatic test pressure: Greater than 24 kg/cm2 • Inlet temperature: - 196 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.
13	Safety	The vendor should ensure that all international safety norms and standards applicable as implemented and certified by the CCE. Following are the mandatory provisions for vessel: • Vessel low liquid level alarm • Vessel low pressure alarm • Pipeline low pressure alarm. • Twin regulator • Twin safety valve • Non return valve and 3-way diverter (bypass) valve • Automatic changeover to manifolds with control panel. • Alarm on indicating manifold in use in case the vessel is not in use. • Alarm on low pressure back-up manifold cylinders
14	Statutory requirements	All statutory requirements of the Chief Controller of Explosives of India and SMPV rules need to be followed; besides all regulations and guidelines put forward by the Govt. of India from time to time should be followed.
15	Maintenance	• All routine preventive maintenance and break-down maintenance of the liquid oxygen plant should be done by the vendor. Experienced personnel should be readily available. • Log of all works undertaken in the plant should be meticulously maintained by the vendor. • Bulk cylinders for the manifold will be arranged by the hospital. The hospital will ensure that the cylinders are full and ready to use during emergencies.
16	Training	• Satisfactory Training to be provided at site to the designated authorities for minimum 2 weeks

Source - Technical Specifications- Liquid Medical Oxygen Plant
[Covid Medicine Building, Government Medical College & Hospital, Aurangabad]

Annexure Table 2: Technical specifications for procurement- oxygen cylinders

1	**General technical requirements**	Oxygen and medical air cylinders are refillable containers for such gas, in a compressed form, available in international standard capacity/pressure and dimensions. The cylinders can be made of steel, aluminium/alloy, carbon fiber 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 (230 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 (oil-free and compliant to ISO standards) or air (compliant to ISO standards) for medical use. • Fitted with a primary valve, standard (pin index or bullnose) or integral, refillable. • Nominal pressure 13 700 kPa (137 bar, 1987 psi), for standard valve cylinders, or 23 000–30 000 kPa (230–300 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/CGA/NFPA, sizes ISO/US standard. • Cylinders supplied with optional pressure regulators, multiple fitting according to all the international standards. • Safety over-pressure release valve (if not built-in in the integral valve fitted cylinders). Primary valve and pressure regulator assemblies: • Pin index or bullnose primary valve and compatible pressure regulators, providing pressure regulated supply of oxygen (oil-free and compliant to ISO standards) or medical air (compliant to ISO standards). • Steel/plated brass/aluminium casing, brass valve. • Nominal inlet pressure 13 700 kPa (137 bar, 1987 psi), maximum 20 000 kPa (200 bar, 2901 psi). • Outlet pressure 345 kPa (3.5 bar, 50 psi). • Integrated manometer, 0–20 000 kPa (0–200 bar, 0–2901 psi). • Safety over-pressure release valve. • Pressure regulator supplied with flowmeter, if required – see configurations/options for specifications. Integral valves: • All-in-one cylinder valve for oxygen (oil-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/plated brass/aluminium casing, brass valve. • 6 mm barbed and BS 5682 Schrader (if applicable depending on the size of the cylinder) outlets. • Integrated open/close valve, outlet nominal pressure 400 kPa (4 bar, 58 psi). • Inlet pressure 23 000–30 000 kPa (230–300 bar, 3336–4351 psi), depending on the cylinder model. • Integrated refill valve ISO 5145/CGA 540 compliant. • Integrated manometer, covering the full nominal pressure range of the cylinder, standard 23 000– 30 000 kPa (230–300 bar, 3336–4351 psi), for integral valve cylinders, or whatever applicable. • Integrated flowmeter. • Safety over-pressure release valve. Capable of being stored in ambient temperature of at least 5–50 °C, relative humidity of at least 15–95% non-condensing.

		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/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.
2	**Configurations / options**	Oxygen cylinder configurations/versions/options: Standard and MRI-compatible versions. Specific ISO/ANSI/CGA/NFPA colour coding for oxygen and medical air. Seamless cylinders made of steel, aluminium/alloy, carbon fibre or other composite material (CGA approved and compliant to ISO applicable standards). Pin index/bullnose 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, J, and also US sizes M2 to M 265 (not all sizes apply to both oxygen and medical air). The type of standard valve has to be compliant to international ISO and US standards, i.e. pin index ISO 407/BS 850/CGA 870 valve, CGA 540 valve, 5/8 inch BSP (F) Bullnose 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 (4 bar) nominal outlet pressure, 6 mm barbed and BS 5682 Schrader outlets), in all the ISO international standard sizes, including size ZA, CD, ZD, HX and ZX, and also US sizes in M coding system. Regulator/integral valve configurations/versions: Standard and MRI-compatible versions. Oxygen and medical air versions. Pressure regulators and integral valves should be available with DISS and 6 mm barbed outlet. Pressure regulators should be available in basic open/close model and fitted with integrated flowmeter, Thorpe tube or Bourdon gauge. Pressure regulators and integral valves with Thorpe or Bourdon flowmeter should be available at least in the following flow ranges, for oxygen and medical air: • Low flow 0–3 or 4 L/min (only for oxygen), discrete (dial) flow setting (indicative steps 0, 0.03, 0.06, 0.12, 0.25, 0.50, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0), accuracy 10%. • Standard flow 0–15 L/min, discrete (dial) flow setting (indicative steps 0, 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 15.0), accuracy 10%. • High flow 0–25 L/min minimum, discrete (dial) flow setting (indicative steps 0, 0.25, 0.50, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 25.0), accuracy 10%. Pressure regulators and integral valves with Thorpe or Bourdon flowmeter should be available at least in the following flow ranges, for oxygen and medical air: • Low flow 0–3 or 4 L/min (only for oxygen), accuracy 10%, indicative graduation (L/min) 0.03, 0.06, 0.12, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0. • Standard flow 0–7 or 8 and 0–15 or 16 L/min, accuracy 10%, graduation 0.5 L/min (0.5–3 range) and 1 L/min (3–max range). • High flow 0–25 L/min minimum, accuracy 10%, graduation 0.5 L/min first increment and 1 L/min full range. Cylinder body, primary valve and pressure regulator or integral valve assembly, outlet connectors, safety pressure release 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/alloy, 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 5–45 °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/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.
3	**Displayed parameters**	Pressure and flow (for integral valve cylinders only).
4	**User adjustable settings**	Open/close control, pressure and flow (for integral valve cylinders only).
5	**Accessories**	Cylinder holding, carts, trolleys. Supplied with keys and tools to operate valves and regulators. Complete set of tubing and adapters to use the pressure regulator and the integral valve with all common international standard fittings, for medical gas sources, patient circuits and other medical devices.
6	**Spare parts**	Common and frequently used spare parts, sensors/ transducers/ actuators, reusable probes/cables/patient connection accessories, periodic maintenance and calibration kits/materials, renewables that should be procured together with the equipment and in quantity 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 also to central and local maintenance department. Sealing set, maintenance kit, regulating unit (knob), adapters and connectors, keys and tools to operate the valves. Items in the above-mentioned categories that are not frequently needed or require specialized skills to be used/replaced. The need and the quantity of these items 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 connectors, full set of sealings, integral valve assembly, manometer and flowmeter (for integral valves).
7	**Mobility, portability (if relevant)**	Portable or stationary (depending on the size of the cylinder).
8	**Documentation requirements (English language mandatory)**	Set: 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 all spare parts and accessories, with part numbers and contact details for parts supply. Document with contact details of manufacturer, supplier and local service agent.
9	**Transportation and storage and primary packaging labelling**	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 with GHS and international standards is mandatory. Sealed container. Capable of being transported and stored in ambient temperature of at least 5–50 °C, relative humidity of at least 15–95% non-condensing. Specific requirements for altitude may be required, depending on the installation site. Hazardous goods, flammable, explosive, compressed gas labelling according with 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 instruction 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 characteristics; 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 on the packaging unit: Labelling to be the same as primary packaging. Extra information required: number of units.
10	**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).
11	**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]).
12	**Standards, for product performance**	Compliance to the following international standards or to 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 CGA standards, and/or UL or CSA approved. ISO 11114 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 pipeline systems. ISO 15245 Gas cylinders – Parallel threads for connection of valves to gas cylinders. ISO 10297 Gas cylinders – Cylinder valves – Specification and type testing. ISO 17871 Gas cylinders – Quick-release cylinder valves – Specification and type testing. ISO 17879 Gas cylinders – Self-closing cylinder valves – Specification and type testing. ISO 407 Small medical gas cylinders – Pin-index yoke-type valve connections. ISO 5145 Cylinder valve outlets for gases and gas mixtures – Selection and dimensioning. ISO 11117 Gas cylinders – Valve protection caps and valve guards – Design, construction and tests. ISO 11363 Gas cylinders – 17E and 25E taper threads for connection of valves to gas cylinders. ISO 12209 Gas cylinders – Outlet connections for gas cylinder valves for compressed breathable air. ISO 14246 Gas cylinders – Cylinder valves – Manufacturing tests and examinations.

		ISO 22435 Gas cylinders – Cylinder valves with integrated pressure regulators. ISO 7866 Gas cylinders – Refillable seamless aluminium alloy gas cylinders – Design, construction and testing. ISO 20701 Gas cylinders – Refillable welded aluminium-alloy cylinders – Design, construction and testing. ISO 9809 Gas cylinders – Refillable seamless steel gas cylinders – Design, construction and testing. ISO 11119 Gas cylinders – Refillable composite gas cylinders and tubes – Design, construction and testing. ISO 13341 Gas cylinders – Fitting of valves to gas cylinders. ISO 32 Gas cylinders for medical use – Marking for identification of content. ISO 7225 Gas cylinders – Precautionary labels. ISO 10461 Gas cylinders – Seamless aluminium-alloy gas cylinders – Periodic inspection and testing. ISO 11623 Gas cylinders – Composite construction – Periodic inspection and testing. ISO 15223-1 Medical devices – Symbols to be used with medical device labels, labelling and information to be supplied – Part 1: General requirements. ISO 15996 Gas cylinders – Residual pressure valves – Specification and type testing of cylinder valves incorporating residual pressure devices. ISO 15001 Anaesthetic and respiratory equipment – Compatibility with oxygen.
13	**Warranty**	5 years recommended for the cylinders, 3 years recommended for the pressure regulators and valves (2 years at least).

(Source- WHO Priority medical devices list for the COVID-19 response and associated technical specifications-19 November 2020
https://www.who.int/publications/i/item/WHO-2019-nCoV-MedDev-TS-O2T.V2)

The technical specification for oxygen cylinder from WHO are available at -
https://apps.who.int/iris/bitstream/handle/10665/329874/9789241516914-eng.pdf?ua=1

Annexure Table 3: Technical specifications for medical gas pipeline system

COPPER PIPES	Pipe material	Copper Pipes will be Solid drawn, seamless, de-oxidized, non-arsenical, half hard tempered and degreased, materials conforming to BS: 6017/1981 (Cu-DHP) manufactured as per BS:2871/1971 and dimension tolerances conforming to BS-EN 1057. Pipe fittings conform to BS-EN 1254-3:1998. Lloyd's certified
	Fittings	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.
	Delivery to site	In degreased condition, plugged or capped at both ends and supplied sealed in protective polythene bags, accompanied by certificate from Lloyd's certified
	Joints, on site	To be brazed, except for mechanical joints used for components, employing a method that permits the joints to maintain their mechanical characteristics upto 600 degC.
	Brazing system	Fluxless brazing using a copper-phosphorous brazing alloy to BS-1845.
	Pipe wall thickness	Copper pipe OD (in mm) 12,15,22,28 42 Thickness (in mm) 0.9 1.2
	Pipe clamps	Shall be non-reactive to copper and be of non-ferrous or non-deteriorating plastic suitable for the diameter of the pipe.
	Pipeline supports	Spacing not to exceed 1.5M, irrespective of the pipe diameter.
	Passage through walls & floors	Through suitable sleeves.
	Earthing	To be connected to one or more earth terminals.
	Painting	All exposed pipes to be painted with two coats of synthetic enamel paint, the color codification complying with ISO 5359 / IS 2379.
	Marking and colour coding	To marked 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 that 10M and adjacent terminal units.
	Direction marks	Marking to include arrows denoting direction of flow and letters used for marking shall not be less than 6mm high.
	Identification	All concealed pipes to have gas identification bands/ labels are at appropriate distance, similarly all pipes which need embedding in the wall will to be tested/ painted/ labled and properly insulated in accordance with ISO 5359.
	Post-installation	After erection, the pipelines are to be flushed and purged clean with dry nitrogen gas.
	Testing	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.
COLOUR CODE FOR MEDICAL GASES PIPES As per IS 2379-1963	SERVICE	Oxygen
	GROUND COLOUR	Canary, Yellow
	FIRST BAND	White
	SECOND BAND	NA

GAS OUTLET POINTS FOR OXYGEN INDIAN: [Approx. Quantity in No: Oxygen (147)]	Type	Oxygen
	Type of outlet	Canary, Yellow
	Valves	White
	Inlet	NA
	Front plate	Colour-coded
	Compliance	NFPA-99 & EN-737
	Post-installation purging	After erection, to be flushed and purged clean with dry nitrogen
OXYGEN MANIFOLD SYSTEM	Service	As secondary/ reserve source, the primary source being the liquid oxygen bullets arranged through other contracts.
	Main manifold configuration	2 x 10 cylinders
	Emergency Manifold	2 x 2 cylinders with single regulator
	Pressure rating	145 kg/sq.cm.
	Flow rate	[specify] attach calculation
	Format	Wall-mounting straight line.
	Top Frame	High pressure copper pipes of size ½ " I.D. x 15swg, high pressure brass fittings made of high tensile brass, non-return valves & high pressure copper tail pipes, made of high pressure copper pipes of size ¼ " I.D. x 15swg
	Middle & Bottom frames	To suit both round and flat bottom cylinders.
	High pressure regulators	For both manifold systems for reducing the cylinder pressure suitable to the line pressure.
	Source shut-off Valves	For ease of changing and positioning, without closing the bank.
	Filter	Pore size of not exceeding 100um, between the cylinder(s) and the first pressure regulators.
	Fixity	Cylinder to be set in place using cylinder brackets and fixing chains, all zinc plated.
	Painting	All works to be powder coated, the color codification complying with ISO 5359/ IS 2379.
	Specific requirement	Non-halogenated polymer materials only are permitted to be used in the non-return valves.
	Delivery to site	In degreased condition, plugged or capped at all ends and supplied sealed in protective polythene bags, accompanied by pre-delivery test certificate.
	Testing	Pre-delivery and post installation pressure testing to 1.5 times the working pressure.
	Test documentation	Pre-delivery test certificate to accompany supply to site. Post-installation testing to be witnessed by the Engineer, who shall receive the documents.

GENERAL INSTRUCTIONS	
	Company personnel should visit the site for locating the site of gas bank and for estimate for calculating length of pipeline & other details.
	Demonstration should be arranged by the company for accepting the specification
	Per unit cost of each item should be quoted.
	The quotation for all the items should be given together and no separate cost of any nature will be entertained subsequently
	Company should have installed the system at 3 institutes in India and should produce certificate of satisfactory service report from these institutes
	The copy of all certificates relevant to 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
	Company who gets the contract must submit the AUTOCAD DRAWING of the system for final approval of technical committees.
	Company should arrange for training of hospital staff and company personnel should be available till hospital staff is trained.

(Source: https://arogya.maharashtra.gov.in/Site/Uploads/Tenders/db34f3ee-d081-405e-a6c0-f76388b688c586%20CENTRALIZED%20OXYGEN.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 inbuilt 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, regulator 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 7.5-8.0bar.

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 ≤95% 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. EFF1 (CEMEP) rated totally enclosed fan-cooled, IP55 class F electric motors shall be used and incorporate maintenance- free greased for life 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 +0°C to +45°C, dew point temperature of maximum +3°C and inlet air capacity compatible to air delivery of 7.5-8 Bar 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 playconcept.

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. Feed air quality of the oxygen concentrator should 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 that 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 of4. 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 96.0percent v/v

of oxygen

- Oxygen Purity: 93% +/- 3%
- CO: <5 ppm
- CO_2: < 300 ppm
- Water Vapour< 67ppm
- SO_2: 0 ppm
- N_2O : 0 ppm

iii. Maintenance Free self-lubricating, heavy duty valve section, angle 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 +550C

vi. Humidity: up to95%

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 silencer: 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 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 duly 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 equipments.

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 or15m 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/break downs 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 spares as well which may develop defect during said period. The servicing shall be carried strictly asper 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 coils.
- 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 USFDA approved or CE or should have CE(Conformity European)/European Certificate(EC) number and a certificate that the oxygen generated complies with Medical grade standard of the OEM be uploaded.

PSA Plant Capacity in LPM	Power supply required (KW)	Dimensions of room required in (LxWxH) in metre	CIVIL Work
100-200 LPM	20KW	6x6x5	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 no slopes for rain water to get collected inside the plant room and proper cross ventilation. 2. Oxygen generators shall not be installed close to diesel generators (minimum distance 5M) or any other system which releases smoke or fire. 3. Cooling water is not required for these systems.
201-500 LPM	40KW	7x7x5	
501-1000 LPM	80KW	8x8x5	
1001-1500 LPM	120KW	10x10x7	
1501-2000 LPM	130KW	12x12x7	
2001-2500 LPM	160KW	15x15x8	
2501-3200 LPM	220KW	18x18x8	

Annexure Table 4: Capacity of the components of various plants

Ref: CMSS, GoI Online Tender of S/I/T/C of PSA Oxygen Generation Plant at Public Health Facilities on PAN India Basis

The technical specification for PSA plants from WHO are available at -

https://apps.who.int/iris/bitstream/handle/10665/329874/9789241516914-eng.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 collect 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

Particulars	Oxygen Concentrators
Description	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 N2 from the air. It typically 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).
Purpose Of Use	
Clinical or other purpose	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.
Level of use (if relevant)	Health centre, general hospital, district hospital, provincial hospital, regional hospital, specialized hospital.
Accessories, Consumables, Spare Parts, Other Components	
Detailed requirements	One or two oxygen outlets, each to be provided with separate controllable flowmeter. Audible and/or visual alarms for low oxygen concentration (< 82%), low battery and power supply failure. Audible and/or visual alarms for high temperature, low/high/no-flow rate and/or low/high pressure. Power efficiency ≤ 70 W/L/min. 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 DISS 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). Noise level < 60 dB(A).
Displayed parameters	Oxygen flow rate (on flowmeter). Cumulative hours of operation.
User adjustable settings	Oxygen flow rate.
Utility Requirements	
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. 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.
Accessories, Consumables, Spare Parts, Other Components	
Accessories (if relevant)	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 minimum range from 0 to 2 L/min; Kink-resistant oxygen tubing with standard connectors (15 m each). 2 x adult cannula with 2 m kink-resistant oxygen tubing with standard connectors. 4 x infant cannula with 2 m kink-resistant oxygen tubing with standard connectors. 4 x neonatal cannula with 2 m kink-resistant oxygen tubing with standard connectors.
Sterilization/disinfection process for accessories (if relevant)	Disinfection for nasal prongs.

Consumables/reagents (if relevant)	5 year supply recommended. 1 year supply (adjust quantities per patient load 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 8 French gauge.
Spare parts (if relevant)	Internal and external filters and spare parts for user fitting (as described in 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-resettable fuses are used). DISS to 6 mm barbed adaptor for each outlet (if relevant). Bidder 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, sieve beds, 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 power failure alarms. Spare parts for 1 year or 5000 hours (5 years or 15 000 hours ideally) of use are arranged.
Training of user/s (if relevant)	Clinical staff training in oxygen therapy guidelines, device use and multiple-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. 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.)

Warranty And Maintenance

Warranty	2 years or more (5 years ideally) to cover lifespan of equipment. Manufacturer/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.

Risk classification	Class C (GHTF Rule 11); FDA Class II (USA); Class IIA (EU and Australia); Class II (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 IMDRF - EU, USA, Canada, Australia, Japan).
International standards	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): ISO 80601-2-69: 2014 Medical electrical equipment – Part 2-69: Particular requirements for basic safety and essential performance of oxygen concentrator equipment. IEC 60601-1: 2012 Medical electrical equipment – Part 1: General requirements for basic safety and essential performance. IEC 60601-1-2: 2014 Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral Standard: Electromagnetic disturbances – Requirements and tests. IEC 60601-1-6: 2013 Medical electrical equipment – Part 1-6: General requirements for basic safety and essential performance – Collateral standard: Usability. IEC 60601-1-8: 2012 Medical electrical equipment – Part 1-8: General requirements for basic safety and essential performance – Collateral Standard: General requirements, tests and guidance for alarm systems in medical electrical equipment and medical electrical systems. IEC 60601-1-9: 2013 Medical electrical equipment – Part 1-9: General requirements for basic safety and essential performance – Collateral Standard: Requirements for environmentally conscious design. IEC 60601-1-11: 2010 Medical electrical equipment – Part 1-11: General requirements for basic safety and essential performance – Collateral Standard: Requirements for medical electrical equipment and medical electrical systems used in the home health-care environment. Compliance with ISO 8359 may be considered.

Annexure Table 4: Technical Specifications for Oxygen Concentrators

The technical specification for oxygen concentrators from WHO are available at –
WHO Priority medical devices list for the COVID-19 response and associated technical specifications-19 November 2020.
https://www.who.int/publications/i/item/WHO-2019-nCoV-MedDev-TS-O2T.V2

Annexure 2: सेंट्रल ऑक्सिजन सिस्टिम दुरुस्ती करिता लागणारे अत्यावश्यक सुटे भाग

अ.क्र.	सुटेभाग विवरण	नग
१	Copper Tail Pipe	
२	O2 NRV	
३	Tail Pipe washer	
४	Tween Gauge Regulator	
५	Taflone Tape	
६	Tail Pipe adoptor Nut	
७	Double Bore Buten Gas torch	
८	Buten Gas Cylinder	
९	Copper Rod	
१०	DIN Type Oxygen OUT LET Point	
११	Isolation Valve 15mm	
१२	BS type Oxygen Outlet Points	
१३	Self-Sealing Valves SSV Ssv seat	
१४	Oxygen safety Key Plug	
१५	3/8" pipe Hose Clamp	
१६	Ventilator Connector	
१७	Copper Pipe Medical Grade 15 mm	
१८	Copper Pipe Medical Grade 12 mm	

Annexure Table 6: सेंट्रल ऑक्सिजन सिस्टिम दुरुस्ती करिता लागणारे अत्यावश्यक सुटे भाग

अ.क्र.	सुटे भाग विवरण	नग
१	Liquid tank valve of all type	
२	Safety relief valves, Internal valve, Excess flow valve	
३	SMPV high flow regulators.	
४	Nut, couplings, joints	
५	Rubber/Metal diaphrams of regulators	
६	Rubber washers/Teflon washers/ "O" ring	
७	Teflon tapes	
८	Toolbox (Spanners, screw drivers, wrench, adjusant spanner)	

Annexure Table 7: लिक्विड टँक सिस्टीम दुरुस्तीकरिता लागणारे सुटे भाग

Post operationalization PSA Plant monitoring format

(To be filled by the facility staff)

Regular Process functions to be monitored:

Activities / frequency	Hourly*	Daily	Weekly	Monthly	Whenever required
Check Compressor Pressure	✓				
Check Compressor oil level		✓			
Check Oxygen Pressure	✓				
Check rated oxygen flow	✓				
Check Oxygen Purity	✓				
Check Dew point at dryer outlet	✓				
Check Air Dryer condensate drain	✓				
Check Tower pressure	✓				
Check drain on all Filters		✓			
Check pressure in Air tank	✓				
Check pressure in Oxygen tank	✓				
Check solenoid valves for corrosion			✓		
Check pipes / hoses				✓	✓
Replace desiccant					✓
Plant room has adequate ventilation		✓			
Exhaust fans functioning properly		✓			
Plant room is devoid of water seepage rainwater/water accumulation		✓			
Power back up generator is functioning properly with adequate diesel available for plant functioning throughout the day		✓			
Cylinders/LMO back up of 2-3 days available in case of PSA Plant breakdown and during emergencies		✓			

Annexure Table 8: Post operationalization PSA plant monitoring format

*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

	Spares	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Whenever required	Require-ment
Air dryer	Gas top up		✓										Keep 2Kg as spare
	Compressor											✓	
	Expansion valve											✓	Keep 1 as spare
	Controller											✓	Keep 1 as spare
	HP/LP switch											✓	Keep 1 as spare
Filters	Pre-Filter		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Fine Filter		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Carbon Filter		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	After Filter		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Bacterial Filter					✓					✓	✓	
Oxygen generator	Inlet valve seal kit			✓			✓			✓		✓	Keep 1 as spare
	Exhaust valve seal kit			✓			✓			✓		✓	Keep 1 as spare
	Shuttle valve seal kit			✓			✓			✓		✓	Keep 1 as spare
	Solenoid valve (3/2 way)											✓	Keep 1 as spare
	Desiccant												
	Pressure gauge											✓	Keep 1 as spare
	Oxygen sensor			✓			✓			✓			
	Pressure Transmitter				✓						✓	✓	
	Pressure Regulator											✓	

Annexure Table 9: Preventive maintenance checklists of PSA plant

Annexure 3: 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.

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 current system	• The secondary supply of older VIE systems will be a compressed gas cylinder manifold, which may have very limited capacity. Consideration should be given to either a single VIE plus fully automatic manifold or, preferably, a dual VIE system.
Sitting of system and the site survey	• What planning 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 lost/reduced, for example car-parking space? • It will be less economical in terms of delivery charges and unit gas costs to deliver large loads (for example 20 tons) using rigid vehicles (maximum 12 tons). Articulated vehicles will deliver the largest loads but may require roadway/access modifications. • Cranage access for vessels. • When choosing liquid cylinder systems, will adequate ventilation be available? • Emergency supply location. • Pipeline protection and possible need for dual feeds. • Pipeline extension into other sites if applicable, for example two hospitals supplied from the same VIE system. There are possible insurance issues with this arrangement. • Modifications to the alarm system may have to be made. • Alarm panel + telemetry in waterproof enclosures. • Are alarms compatible with the existing system? • Alarm arrangement for dual (but separate) tank installations. • Cable ducts and trays: examine possible routes. • Possible need to move gates/fences to install new pipework. • Clearance of trees/building. • Sealing windows of adjacent buildings. • Position of frame for valve tree (fix to fence for rigidity?). • Position of emergency gate. • Position of fill 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, pad resizing.

Cost	• Make sure all costs are allowed for, for example: • Site inspection. • Cost of continuing delivery using rigid and non-articulated vehicles. • Gas charge/HCM (hundred cubic metres) and any inflation likely. • Facility charges (rental). • Delivery charge for equipment. • Loan charges and changes in interest rate on any loan if the installer funds any part of the installation. • Road/compound loans will be seen as x added to gas price over y years. • Climate change levy. • Professional fees (consultancy). • Planning permission. • Building Regulations clearance. • All civil engineering work. • Quoted price for gas/facilities/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). • Cranage 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).
Emergency provision	• 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 VIE a better option? • Operational requirements of ESM. • Protection/housing/security of ESM. • Alarm/monitoring systems and power supplies for ESM and its accommodation.
System shutdown during installation	• 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 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. • Fit NIST fittings wherever this will facilitate system purging. • Fit test points/emergency inlet ports as recommended in this guidance or investigate any likely requirement for additional (local) manifolds to support high-dependency areas.

Paper work	• 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 regret letters to tenderers. • Copies of all letters to/from contractors. • NICEIC (National Inspection Council for Electrical Installation Contracting) test certificate for electrics. • Validation and verification results (engineering and pharmaceutical). • Health and safety policies of contractors. • Method statements from contractors. • Insurance agreement with gas supplier for VIE system(s). • MGPS operational policy protocols.
Health and safety	• 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). • Inform contractors of specific site hazards. • Hazard notices on site and on final installation. • Lighting during installation and for completed compound. • Road markings and signage.
Preparation	• Carefully plan phasing of building work to maximise efficiency of installation programme. (Remember concrete plinths will take three days to harden before vessels can be sited.) • Plan phasing of engineering and QC testing to avoid wasting APs'/QCs' 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 pallets. • 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/kerbing/drainage/lighting. • 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 plinth can be extended to fit new vessels. • Electrics for alarms, tank, lighting and, possibly, vehicle pump. • Floodlighting and telephone line. • Plan vehicular parking during (and after) work. • The old plinth may require skimming to provide a reasonable surface.

Installation	• If an ESM (as a third means of supply) is installed first, this can be used to supply the hospital system during vessel replacement. • Decide who arranges emergency cylinder supplies for ESM. When plinth extensions are required, specify oxygen-compatible sealant for gaps between old and new plinth sections. • Remember to post health and safety notices during the work. • Alarm systems will not be fully functional until system is fully commissioned. Therefore, all staff must be kept aware of the different alarm situation. • Concrete will need two to three days to harden on any pad extension. • The first vessel filling is a very noisy procedure with much vapour and can take several hours (consider restrictions). • Concrete sample testing will be required during new plinth construction. • Use temporary steel sheeting to support a new vessel on tarmac alongside the plinth. • Access for cranage must be kept open (car parking control). • Drainage (may have to move existing drains/ soak aways and create new pipe runs; remember oxygen separation distances). • Road markings and signage. • Possible new kerbs/footpaths. • Electrical supplies: single phase can be used for lighting, alarms etc but three-phase 60 A supply will be needed for delivery vehicle pump if appropriate. • Earth bonding/lightning protection for fences. • Alarm interface/telemetry boxes at a sensible height for viewing. • Lagging of liquid lines. • If using 200 bar unregulated cylinders for supply during installation or on ESM, take care that they are not mixed up with 137 bar cylinders. • Proximity of flammables and vital services during installation – vulnerability to mechanical damage (cutting discs etc), welding and cutting flames/sparks. • Power and lighting supplies during work. • Water supply (washing and concrete) during work.
Follow up	• Routine maintenance and monitoring of complete installation. • Cylinder changes and stock management for ESM. • Establish system management arrangements for vessels supplying more than one site. • Update MGPS operational policy and any relevant insurance policies.

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

Annexure 4: Checklist for Daily Inspection of various oxygen systems

आरोग्य संस्था प्रमुख, आणि प्रत्यक्ष लिक्विड ऑक्सिजन टँक हाताळणारे सनियंत्रण करणारे कर्मचारी यांचे करीता दैनंदिन/प्रत्येक शिफ्ट चेक लिस्ट

आरोग्य संस्थेचे नांव - **दिनांक-** **वेळ-**

संस्था प्रमुखाचे नाव - **मोबाईल नं. -**

१.	लिक्विड ऑक्सिजन टँक क्षमता (KL.....)	
२.	शिफ्ट सुरु होताना शिल्लक साठा लि.....	
३.	शिफ्ट संपताना शिल्लक साठा लि.....	
४.	लिक्विड ऑक्सिजन टँक प्रेशर बार.....	
५.	लिक्विड ऑक्सिजन टँक आउटपुट प्रेशर बार	
६.	व्हेपोरायझर व्यवस्थित कार्यरत आहे?	होय / नाही
७.	PRV सिस्टिम व्यवस्थित कार्यरत आहे?	होय / नाही
८.	व्हेपोरायझर शॉवर व्यवस्थित कार्यरत आहे?	होय / नाही
९.	PRV सिस्टिम पॅनल मधून ४.५ बार प्रेशर ने ऑक्सिजन फ्लो होतो काय?	होय / नाही
१०.	लिक्विड टँक फेल झाल्यास बॅकअप करीता असणारे सर्व जम्बो सिलेंडर भरलेले आहेत काय?	होय / नाही
११.	सर्व भरलेले जम्बो सिलेंडर मेनिफोल्डला जोडलेले आहेत काय?	होय / नाही
१२.	रुग्णाच्या बेड वरील सर्व ऑक्सिजन आउटलेट पॉईंट ओके आहेत काय?	होय / नाही
१३.	रुग्णाच्या बेड वरील सर्व ऑक्सिजन आउटलेट पॉईंटचे BPC Flowmeter with Humidifier ओके आहेत काय?	होय / नाही
१४.	सेंट्रल ऑक्सिजन सिस्टिम अलार्म व्यवस्थित कार्यरत आहे काय?	होय / नाही
१५.	लिक्विड ऑक्सिजन टँक ते रुग्णाच्या बेड वरील ऑक्सिजन आउटलेट पॉईंट पर्यंतची पाईपलाईन मध्ये लिकेज आहे काय?	होय / नाही

टिपः- वरील प्रमाणे सर्व बाबींची दररोज - प्रत्येक पाळी - शिफ्टच्या सुरवातीस प्रत्यक्ष लिक्विड ऑक्सिजन टँक हाताळणारे कर्मचारी यांनी सदर चेक लिस्ट भरुन संस्थाप्रमुखांना सादर करावी. सिस्टिममध्ये कोठेही लिकेज असेल, एखादा पार्ट खराब असेल आणि बदलणे गरजेचे असेल किंवा सिस्टिमध्ये काही अबनॉर्मल वाटत असेल तर तात्काळ दुरुस्त करणारा ठेकेदार अथवा दुरुस्त करणारा तंत्रज्ञ यास बोलावून संस्थाप्रमुखाने तात्काळ दुरुस्ती करून घ्यावयाची आहे. या व्यतिरिक्त आपली काही अडचण असेल तर तसा स्वतंत्रपणे उल्लेख करावा, त्या प्रमाणे पुढील कार्यवाही करणे सुकर होईल.

आपल्या रुग्णालयातील लिक्विड ऑक्सिजन टँक आणि सिस्टिमचे तात्काळ ऑडीट करुन घ्यावे

श्री.....
सेंट्रल ऑक्सिजन सिस्टिम हाताळणारा कर्मचारी,
नाव / सही / दिनाक / वेळ

डॉ. .....
आरोग्य संस्थाप्रमुख / I/C
नाव / सही / दिनाक / वेळ

आरोग्य संस्था प्रमुख, इन्चार्ज सिस्टर,कोविड केअर सेंटर प्रमुख आणि प्रत्यक्ष सेंट्रल ऑक्सिजन सिस्टिम हाताळणारे कर्मचारी यांचे करीता दैनंदिन / प्रत्येक शिफ्ट चेक लिस्ट

आरोग्य संस्थेचे नांव - **दिनांक-** **वेळ-**

संस्था प्रमुखाचे नाव - **मोबाईल नं. -**

१.	एकूण जम्बो सिलेंडर संख्या	
२.	भरलेले एकूण जम्बो सिलेंडर संख्या	
३.	रिकामे एकूण जम्बो सिलेंडर संख्या	
४.	एकूण जम्बो सिलेंडर संख्या राखीव साठा संख्या	
५.	रिफिल करीता पाठविलेले एकूण जम्बो सिलेंडर संख्या	
६.	रिकामे जम्बो सिलेंडर संख्या रिफिल करीता पाठविले आहेत का?	होय / नाही
७.	रिफिल करीता सिलेंडर पाठविताना संबंधित पूरवठादारास वाहन येत असल्याची पूर्व कल्पना दिली आहे काय?	होय / नाही
८.	मेनिफोल्ड मध्ये कोठेही ऑक्सिजन लिकेज आहे काय?	होय / नाही
९.	मॉक्स डबल गेज रेग्युलेटर / कंट्रोल पॅनल मधून ४.५ बार प्रेशरने ऑक्सिजन फ्लो होतो काय?	होय / नाही
१०.	सर्व टेल पाईप / एनआरव्ही / सिलेंडर नट ओके आहेत काय ?	होय / नाही
११.	रुग्णाच्या बेड वरील सर्व ऑक्सिजन आउटलेट पॉईंट ओके आहेत काय ?	होय / नाही
१२.	रुग्णाच्या बेड वरील सर्व ऑक्सिजन आउटलेट पॉईंटचे BPC Flowmeter with Humidifier ओके आहेत काय ?	होय / नाही
१३.	सेंट्रल ऑक्सिजन सिस्टिम अलार्म व्यवस्थित कार्यरत आहे काय?	होय / नाही
१४.	सेंट्रल ऑक्सिजन सिस्टिम ते रुग्णाच्या बेड वरील ऑक्सिजन आउटलेट पॉईंट पर्यंतची पाईपलाईन मध्ये लिकेज आहे काय?	होय / नाही

टिपः- वरील प्रमाणे सर्व बाबींची दररोज - प्रत्येक पाळी - शिफ्टच्या सुरूवातीस प्रत्यक्ष सेंट्रल ऑक्सिजन सिस्टिम बँक हाताळणारे कर्मचारी यांनी सदर चेक लिस्ट भरुन संस्थाप्रमुखांना सादर करावी. सिस्टिममध्ये कोठेही लिकेज असेल, एखादा पार्ट खराब असेल आणि बदलणे गरजेचे असेल किंवा सिस्टिमध्ये काही अबनॉर्मल वाटत असेल तर तात्काळ दुरुस्त करणारा ठेकेदार अथवा दुरुस्त करणारा तंत्रज्ञ यास बोलावून संस्थाप्रमुखाने तात्काळ दुरुस्ती करुन घ्यावयाची आहे. या व्यतिरिक्त आपली काही अडचण असेल तर तसा स्वतंत्रपणे उललेख करावा, त्या प्रमाणे पुढील कार्यवाही करणे सुकर होईल.

आपल्या रुग्णालयातील सेंट्रल ऑक्सिजन सिस्टिमचे तात्काळ ऑडीट करुन घ्यावे

श्री.....
सेंट्रल ऑक्सिजन सिस्टिम हाताळणारा कर्मचारी,
नाव / सही / दिनाक / वेळ

डॉ. .....
आरोग्य संस्थाप्रमुख / CCC I/C
नाव / सही / दिनाक / वेळ

आरोग्य संस्था प्रमुख, इन्चार्ज सिस्टर, कोविड केअर सेंटर प्रमुख आणि प्रत्यक्ष PSA सिस्टिम हाताळणारे कर्मचारी यांचे करीता दैनंदिन / प्रत्येक शिफ्ट चेक लिस्ट

आरोग्य संस्थेचे नांव - **दिनांक-** **वेळ-**

संस्था प्रमुखाचे नाव - **मोबाईल नं. -**

१. इनपुट आणि आऊटपुट व्होल्टेज फ्रिक्वेंसी तपासणी करणे -	
२. प्रेशर गेजच्या रिडिंगची नोंद करणे -	
३. कॉम्प्रेसर ऑईल लेवल व लिकेज चेक करणे -	
४. ॲबनॉर्मल आवाज असल्यास त्याची नोंद करणे -	
५. सर्व प्रकारचे अलार्मची तपासणी करुन योग्य ती कार्यवाही करणे -	
६. Air dryer फिल्टर इंडिकेटर, ड्यू पॉईंट, ऑटो ड्रेन, कंडेन्सर फॅनची तपासणी करुन योग्य ती कार्यवाही करणे -	
७. PSA सिस्टिमचे इनलेट व आउटलेट प्रेशर अलार्मची तपासणी करुन योग्य ती कार्यवाही करणे -	
८. ऑक्सिजन प्युरीटी इंडिकेटरची तपासणी करुन योग्य ती कार्यवाही करणे -	
९. जनरेटर मॅन्युअली सुरु करुन तपासणी करणे -	

टिपः- वरील प्रमाणे सर्व बाबींची दररोज - प्रत्येक पाळी - शिफ्टच्या सुरफवातीस प्रत्यक्ष PSA सिस्टिम हाताळणारे कर्मचारी यांनी सदर चेक लिस्ट भरून संस्थाप्रमुखांना सादर करावी. सिस्टिममध्ये कोठेही लिकेज असेल, एखादा पार्ट खराब असेल आणि बदलणे गरजेचे असेल किंवा सिस्टिमध्ये काही अबनॉर्मल वाटत असेल तर तात्काळ दुरुस्त करणारा ठेकेदार अथवा दुरुस्त करणारा तंत्रज्ञ यास बोलावून संस्थाप्रमुखाने तात्काळ दुरुस्ती करुन घ्यावयाची आहे. या व्यतिरिक्त आपली काही अडचण असेल तर तसा स्वतंत्रपणे उललेख करावा, त्या प्रमाणे पुढील कार्यवाही करणे सुकर होईल.

आपल्या रुग्णालयातील सेंट्रल ऑक्सिजन सिस्टिमचे तात्काळ ऑडीट करुन घ्यावे

श्री.....
सेंट्रल ऑक्सिजन सिस्टिम हाताळणारा कर्मचारी,
नाव / सही / दिनाक / वेळ

डॉ. .....
आरोग्य संस्थाप्रमुख / CCC I/C
नाव / सही / दिनाक / वेळ

Annexure 5: ऑक्सिजन समिती सदस्य यांचे करीता मार्गदर्शक सूचना

आरोग्य संस्था प्रमुख, कोविड केअर सेंटर प्रमुख आणि संबंधित आरोग्य संस्थेतील ऑक्सिजन समिती सदस्य यांचे करीता मार्गदर्शक सूचना

आरोग्य संस्थेचे नांव - **दिनांक-** **वेळ-**

संस्था प्रमुखाचे नाव - **मोबाईल नं. -**

१. आपल्या संस्थेतील सर्व जम्बो ऑक्सिजन सिलेंडर्स व डयुरा सिलेंडर्स नेहमी ऑक्सिजने भरुन ठेवलेली असावीत. तसेच आवश्यक तो राखीव साठा ठेवण्यात यावा.

२. आपल्या संस्थेमध्ये लिक्विड ऑक्सिजन टॅंकचा वापर होत असेल तर सदर टॅंकचे २४ x ७ संनियंत्रण करणेसाठी आवश्यक तांत्रिक मणुष्यबळ उपलब्ध असले पाहिजे.

३. सदर टॅन्कची उत्पादक कंपनी आणि पुरवठादार यांचे कडून नियमित तपासणी करुन घ्यावी.

४. आपल्या संस्थेतील सेंट्रल ऑक्सिजन सिस्टिमचे नियमित ऑक्सिजन सिक्युरीटी ऑडीट संबंधित ऑथॉरिटी कडून करुन घेण्यात यावे. त्यामध्ये काही सुधारणा करणेस सुचविले असेल, काही त्रुटी असतील तर सदर बाबीस सर्वोच्च प्राधान्य देऊन सदर त्रुटी संबंधित यंत्रणे कडून दूर कराव्यात.

५. मेनिफोल्ड सिस्टिम आणि ऑक्सीजन पुरवठा करणारे कॉपरच्या पाईपलाईन यामध्ये कोठेही ऑक्सिजन गळती आढळून आल्यास तात्काळ संबंधिता कडून दुरुस्ती करण्यात यावी.

६. सेंट्रल ऑक्सिजन सिस्टिम आणि मेनिफोल्ड सिस्टिम, लिक्विड ऑक्सिजन टॅन्क यांचे देखभाल व दुरुस्ती करीता लागणारे अत्यावश्यक सुटे भाग सदैव उपलब्ध करुन ठेवावेत.

७. रुग्णांना ऑक्सिजन पुरवठा करण्यासाठी लागणारे BPC Flowmeter With Humidifier हे पुरेशा प्रमाणात उपलब्ध करुन ठेवावेत.

८. ऑक्सिजन पुरवठा करणारी एजन्सी, सेंट्रल ऑक्सिजन सिस्टिम हाताळणारे कर्मचारी, जम्बो ऑक्सिजन सिलेंडर्स याचे वाहतूक करणारे कर्मचारी व वाहन यांचे क्रमांक आणि आपत्कालीन परिस्थिती उदभवल्यास संबंधित व्यक्ती, एजन्सी यांचे संपर्क क्रमांक. मेनिफोल्ड रुम तसेच, नर्सिंग स्टेशन येथिल दर्शनी भागात लावावेत.

९. तसेच आपले संस्थेत Oxygen Generation Plant (Pressure Swing Adsorption - PSA) वापरात असल्यास नियमित मोनिटरिंग करण्या करीता मणुष्यबळ उपलब्ध ठेवण्यात यावे. तसेच उत्पादक अथवा पुरवठादार एजन्सी यांचे कडून नियमित तपासणी करणयात यावी. तसेच नियमित देखभाल व दुरुस्ती करुन घेण्यात यावी.

१०. आपल्या संस्थेतील सेंट्रल ऑक्सिजन सिस्टिम आणि मेनिफोल्ड सिस्टिम, लिक्विड ऑक्सिजन टॅन्क, आणि Oxygen Generation Plant (Pressure Swing Adsorption - PSA) या करीता कायम स्वरुपी २४ X ७ सुरक्षा व्यवस्था ठेवण्यात यावी.

११. सर्व प्रकारच्या ऑक्सिजन प्रणाली दुरुस्ती करीता लागणारे सुटे भागांची यादी एचईएमआर कार्यशाळेतील तंत्रज्ञ हे संस्था प्रमुखास सादर करतील त्या प्रमाणे सुटे भाग संस्थाप्रमुखाने संस्थेमध्ये उपलब्ध करुन ठेवावयाचे आहेत.

१२. अपातकालीन व्यवस्थेमध्ये करावयाची उपाय योजना आणि अत्यावश्यक क्रमांक दर्शनीय भागावर लावण्यात यावेत.

आरोग्य साधन सामुग्री देखभाल व दुरुस्ती (HEMR) विभागातील जीव वैद्यकीय अभियंता आणि तंत्रज्ञ यांनी सर्व स्तरावरील आरोग्य संस्थेतील सेंट्रल ऑक्सिजन सिस्टिम, डयुरा सिलेंडर, लिक्विड ऑक्सिजन टॅन्क, ऑक्सिजन जनरेशन झड प्लॅन्ट यांच्या देखभाल व दुरफस्ती बाबत मार्गदर्शक सूचना

१. एचईएमआर कार्यशाळेत जीव वैद्यकीय अभियंता हे मंडळातील सर्व आरोग्य संस्थांमधिल सेंट्रल ऑक्सिजन सिस्टिम, ड्युरा सिलेंडर, लिक्विड ऑक्सिजन टॅन्क, ऑक्सिजन जनरेशन PSA प्लॅन्ट यांचा नियमित आढावा घेतील आणि त्या प्रमाणे उचित कार्यवाही करतील.

२. तसेच सर्व आरोग्य संस्था प्रमुखांशी सतत संपर्क ठेऊन संस्थेतील ऑक्सिजन प्रणाली सतत कार्यरत राहील याबाबत संस्था प्रमुखास सहाय्य करतील.

३. एचईएमआर कार्यशाळेतील तंत्रज्ञ हे प्रत्यक्ष संबंधित संस्थेमध्ये जाऊन संस्थेतील सर्व प्रकारची ऑक्सिजन प्रणाली हाताळणारे कर्मचारी यांना प्रशिक्षण देतील.

४. एचईएमआर कार्यशाळेतील तंत्रज्ञ यांना मंडळातील ज्या जिल्ह्याची जबाबदारी देण्यात आलेली आहे त्या जिल्ह्यांचा दरमहा नियमित दौरा करुन सबंधित संस्थेस भेटी देतील. तेथिल ऑक्सिजन प्रणालीमध्ये काही त्रुटी असतील किंवा देखभाल व दुरुस्ती करावयाची असेल तर सदर बाबत संबंधित संस्था प्रमुखांच्या निदर्शनास आणून देतील आणि संस्थाप्रमुख आणि संबधित सेवा पुरवठादार यांचेशी समन्वय साधून सदर ऑक्सिजन प्रणालीमधील दोष तात्काळ दूर करतील.

५. एचईएमआर कार्यशाळेतील तंत्रज्ञ यांनी त्यांना नेमुन दिलेल्या जिल्ह्यांतील आरोग्य संस्थेमधील ऑक्सिजन प्रणालीचे त्रैमासिक ऑडीटचे नियोजन करुन संबंधित संस्थाप्रमुख व ऑक्सिजन प्रणाली हाताळणारे कर्मचारी यांचेसह एकत्रितपणे ऑडीट करतील.

६. ऑक्सिजन ऑडीटच्या वेळी काही त्रुटी आढळल्यास त्याचे निराकरण संबंधित तंत्रज्ञ संस्थाप्रमुख आणि संबंधित दुरुस्ती व देखभाल सेवा पुरवठादार यांच्या सहाय्याने लवकरात लवकर निराकरण करतील.

७. एचईएमआर कार्यशाळेतील तंत्रज्ञ यांनी ऑक्सिजन प्रणाली तपासणी, देखभाल व दुरुस्ती तसेच किती संस्थेतील कर्मचाऱ्यांना ऑक्सिजन प्रणाली हाताळणी संबंधी प्रशिक्षण दिले याबाबतचा तपशिल दरमहा मा. उपसंचालक आरोग्य सेवा, परिवहन पुणे यांना सादर करावयाचा आहे.

८. एचईएमआर कार्यशाळेतील तंत्रज्ञ यांना या बाबत काही अडचण असल्यास किंवा मार्गदर्शन हवे असल्यास, जीव वैद्यकीय अभियंता किवा मा. उपसंचालक आरोग्य सेवा, परिवहन यांचेशी संपर्क करावा.

९. एचईएमआर कार्यशाळेतील तंत्रज्ञ यांनी संबंधित जिल्ह्यातील संस्थाप्रमुखांशी सतत समन्वय साधून ऑक्सिजन प्रणाली सतत कार्यरत राहील या बाबत दक्ष रहावे.

१०. नेमुन दिलेल्या जिल्ह्यांतील आरोग्य संस्थेमधील आरोग्य संस्था प्रमुख, ऑक्सिजन प्रणाली हाताळणी करणारे कर्मचारी तसेच ऑक्सिजन प्रणालीचे संबंधित दुरुस्ती व देखभाल सेवा पुरवठादार यांची नावे आणि संपर्क क्रमांक यादी एचईएमआर कार्यशाळेत अद्ययावत ठेवतील.

Annexure 6: Daily oxygen calculations

Sources of oxygen storage	Approximate availability of liquid medical oxygen in kilo liters	Approximate availability of liquid medical oxygen in liters (x1000)	Qty of cylinders	Approximate availability of oxygen in gaseous form	Remarks
Liquid medical oxygen tank-1	5	5000	NA	43,50,000	For converting LMO/Dura Liters in gaseous form multiply by 860. 1 Litre=860 Liters gaseous oxygen
Liquid medical oxygen tank-2	2	2000	NA	17,40,000	
Liquid medical oxygen Reservoir-1		0	NA	0	
Dura Cylinder- 1	NA	200		0	
Dura Cylinder- 2 Filled	NA	240		0	
D-Type, Jumbo cylinder (Filled)	NA	NA	16	1,12,000	For jumbo cylinder type D 7000 Liters
B- Type, small cylinder (Filled)	NA	NA		0	For cylinder type B 1500 Liters
Total				62,02,000	
Total Usable Oxygen after considering residual oxygen requirement to maintain pressure				48,37,560	

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

Output calculations	Approximate average consumption of devices in LPM	Nos. of Patients	Approximate Total consumptions in gaseous form in LPM
O_2 Prong	3	10	30
O_2 Mask	4	10	40
Non-Rebreather mask	6	10	60
BiPAP	12	10	120
NIV FIO_2	50	10	500
Intubation FIO_2	25	10	250
HFNO (Not recommended and should be phased down)	50	10	500
Total		70	1500

Annexure Table 12: Daily oxygen calculation sheet based on output sources

(Note : Calculation sheet will be provided as per user demand)

Annexure 7: Safety training check lists

Checklist for ensuring training on following aspects:

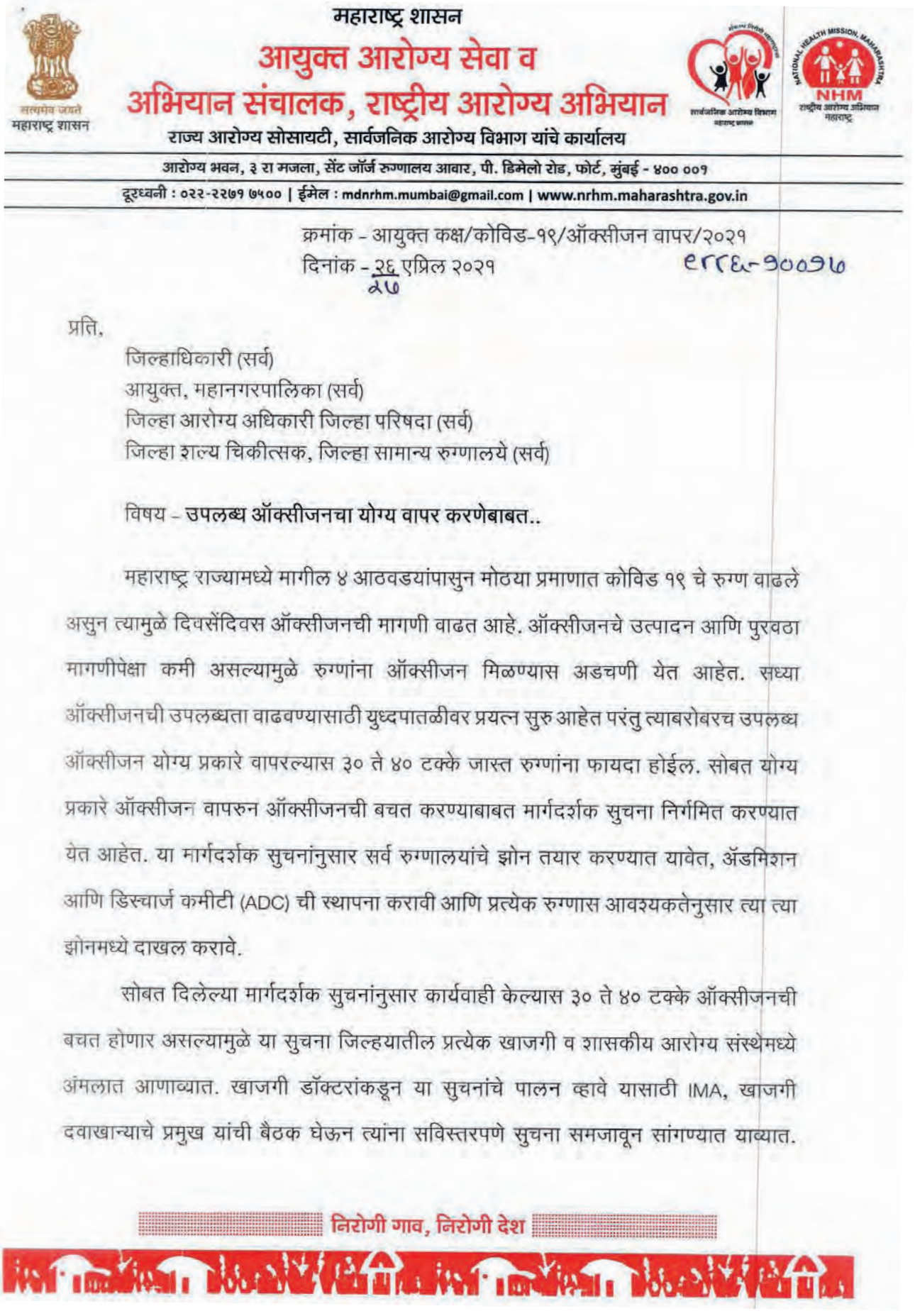
Training topic	Training done	Training date	Trainer Signature
1. SAFETY EQUIPMENT			
1.1. Has the appropriate Personal Protective Equipment been given to the employee? - appropriate work clothes - boots/shoes - gloves - eye protection - hearing protection - hard hat			
1.2. Have the rules regarding wearing of personal protective equipment been explained?			
1.3. Does employee know that special protective clothing impermeable gloves, apron or suit, boots, goggles, face shield) must be worn when work is being done on caustic/acid installations or with solvents and where it can be obtained?			
1.4. Does employee know that clothing contaminated with caustic or acid has to be removed carefully?			
1.5. Has employee been told that damaged or unserviceable personal protective equipment must be replaced and that any damage to safety equipment must be reported to his/her supervisor?			
1.6. Has employee been told that emergency equipment must not be used for routine jobs?			
1.7. Has employee been shown where emergency showers and eyewash devices are located and how to use them?			
1.8. Does employee know why showers and eyewash bottles are provided in some plant areas and the importance of preventing their misuse?			
1.9. Has employee been told that it is dangerous to wipe his/her eyes or face with hands which may have come into contact with chemicals or solvents?			
1.10. Does employee know where self contained breathing apparatus, canisters and safety harness are kept and that they can only by used by trained personnel?			
2. HAZARDS			
2.1. Have all specific documents relevant to the job been given to employee. i.e. Risk evaluations, Emergency instructions?			
2.2. Have the Work Instructions which concern employee's particular work and general matters been pointed out to him? Has employee read and understood them?			
2.3. Has the meaning of all relevant safety signs been explained?			
2.4. Have the applicable leaflets been commented? Have respective test been already filled? The minimum percentage of right answers has been reached? Failed questions have been commented? Any relevant safety booklets, videos.. etc should be used at this stage.			

Training topic	Training done	Training date	Trainer Signature
2.5. Does employee know the hazards associated with: • Oxygen plus oil, grease or other flammable or organic substances? • Acetylene or hydrocarbons in liquid oxygen (air separation plants only)? • Liquid oxygen spillages on black top (asphalt)? • Oxygen deficiency which can be created by spillage or venting of nitrogen or argon or confined spaces? • Oxygen enrichment due to spillage or venting? • Improper use of plant utilities, such as steam and compressed air?			
2.6. Does he/she know that hot work, including the use of naked 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?			
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			
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).			
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 alarms?			
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?			
2.11 Has the site emergency plan been explained including employee's particular role?			
2.12 Does employee know his/her meeting point in case of emergency?			
2.13 Record here when present at a site emergency drill or training session.			
2.14 Does employee know how to identify the contents of cylinders by: • The written word (label)? • Colour code? • Valve type? • Pressure test dates? • Max. allowed working pressure?			
2.15 Have the dangers of filling damaged cylinders been explained to him?			
2.16 Have the dangers of over pressurizing cylinders been explained?			
2.17 Have the dangers of allowing an out of standard cylinder to be dispatched been explained (i.e. empty, uncapped, incorrect labels...)?			
2.18 Has the procedure for reporting safety hazards been explained to employee?			
2.19 Has employee been instructed to report gas leaks on equipment and faulty connections?			

Training topic	Training done	Training date	Trainer Signature
2.20 Does employee know what to do when cryogenic transfer hoses and/or high pressure filling hoses rupture?			
2.21 Does employee know the dangers of continued exposure of hands and other parts of the body to solvents?			
2.22 Does employee know that there are approved skin cleansers, and where to find them?			
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			
3 MECHANICAL & ELECTRICAL HAZARDS			
3.1. Has employee been instructed in the proper methods of breaking into lines?			
3.2. Does employee know where low voltage hand tools should be used?			
3.3. Does employee know the rules governing the use of standard voltage hand tools?			
3.4. Is employee familiar with the hazards associated with soldering, welding and flame-cutting and the correct precautionary measures?			
3.5. Does employee know that he/she is required to wear additional eye protection for certain tasks and/or in certain locations and have these tasks and locations been explained to him?			
3.6. Does employee know that special precautions are required for working on roofs or in excavations?			
3.7. Have rules relating to the use, care and return of ladders and lifting equipment been explained?			
3.8. Has employee been told that access to fire equipment, emergency exits and electrical switchboards must be kept clear at all times?			
3.9. Has employee been instructed how to handle cylinders and other heavy objects correctly?			
3.10 Does employee understand that only trained personnel can use cranes and lifting equipment?			
3.11 Is employee aware that only qualified electricians can carry out electrical repairs, even though apparently trivial?			
4 TRAFFIC HAZARDS			
4.1. Has employee been told that a speed limit exists for all vehicles in the factory?			
4.2. Has employee been told that only trained and authorized personnel are allowed to drive or operate forklift trucks?			
4.3. Has employee been told that riding as a passenger on a forklift truck or the back of a lorry is forbidden?			
4.4. Has employee been advised to keep clear of vehicles which might move without warning?			
4.5. Has employee been instructed to report all unsafe conditions at customer's premises as well as in the factory?			
4.6. Does employee know that he/she should use pedestrian walkways when they are available/identified?			

Training topic	Training done	Training date	Trainer Signature
4.7. Does employee know who his/her department first-aider is and where he/she is located?			
4.8. Does employee know that all injuries must be reported to his/her supervisor and a record made in the Accident Logbook as soon as possible?			
4.9. Does employee know that if an injury occurs which necessitates his absence from work, he/she must, as soon as possible before the first day or shift of absence, inform his/her supervisor?			
4.10. Does employee know that, during absence from work, he/she may be requested to attend medical examination by an appointed Doctor?			
4.11. Does employee know that, on return to work, he/she may be required to be examined by an appointed Doctor?			
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 explained to employee?			
5.4. Does employee know to whom he /she should address queries on Safety?			
5.5. Has employee been advised about the function of the Safety Committee?			

Annexure 8: उपलब्ध ऑक्सिजनचा योग्य वापर करणेबाबत मार्गदर्शक सूचना



महाराष्ट्र शासन

आयुक्त आरोग्य सेवा व अभियान संचालक, राष्ट्रीय आरोग्य अभियान

राज्य आरोग्य सोसायटी, सार्वजनिक आरोग्य विभाग यांचे कार्यालय

आरोग्य भवन, ३ रा मजला, सेंट जॉर्ज रुग्णालय आवार, पी. डिमेलो रोड, फोर्ट, मुंबई - ४०० ००१

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क्रमांक - आयुक्त कक्ष/कोविड-१९/ऑक्सीजन वापर/२०२१

दिनांक - २६ एप्रिल २०२१ (२७) ERRE-90096

प्रति,

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जिल्हा शल्य चिकीत्सक, जिल्हा सामान्य रुग्णालये (सर्व)

विषय - **उपलब्ध ऑक्सीजनचा योग्य वापर करणेबाबत..**

महाराष्ट्र राज्यामध्ये मागील ४ आठवडयांपासुन मोठया प्रमाणात कोविड १९ चे रुग्ण वाढले असुन त्यामुळे दिवसेंदिवस ऑक्सीजनची मागणी वाढत आहे. ऑक्सीजनचे उत्पादन आणि पुरवठा मागणीपेक्षा कमी असल्यामुळे रुग्णांना ऑक्सीजन मिळण्यास अडचणी येत आहेत. सध्या ऑक्सीजनची उपलब्धता वाढवण्यासाठी युध्दपातळीवर प्रयत्न सुरु आहेत परंतु त्याबरोबरच उपलब्ध ऑक्सीजन योग्य प्रकारे वापरल्यास ३० ते ४० टक्के जास्त रुग्णांना फायदा होईल. सोबत योग्य प्रकारे ऑक्सीजन वापरुन ऑक्सीजनची बचत करण्याबाबत मार्गदर्शक सुचना निर्गमित करण्यात येत आहेत. या मार्गदर्शक सुचनांनुसार सर्व रुग्णालयांचे झोन तयार करण्यात यावेत, ॲडमिशन आणि डिस्चार्ज कमीटी (ADC) ची स्थापना करावी आणि प्रत्येक रुग्णास आवश्यकतेनुसार त्या त्या झोनमध्ये दाखल करावे.

सोबत दिलेल्या मार्गदर्शक सुचनांनुसार कार्यवाही केल्यास ३० ते ४० टक्के ऑक्सीजनची बचत होणार असल्यामुळे या सुचना जिल्हयातील प्रत्येक खाजगी व शासकीय आरोग्य संस्थेमध्ये अंमलात आणाव्यात. खाजगी डॉक्टरांकडून या सुचनांचे पालन व्हावे यासाठी IMA, खाजगी दवाखान्याचे प्रमुख यांची बैठक घेऊन त्यांना सविस्तरपणे सुचना समजावून सांगण्यात याव्यात.

निरोगी गाव, निरोगी देश

वारंवार कळवुनदेखील कार्यवाही न करणा-या रुग्णालयांवर आपत्ती व्यवस्थापन कायदा आणि साथरोग कायदा यामधील तरतुदींनुसार कार्यवाही करावी.

26.04.2021

आयुक्त आरोग्य सेवा तथा
संचालक, राष्ट्रीय आरोग्य अभियान
मुंबई

प्रत माहितीस्तव सादर - मा. प्रधान सचिव, सार्वजनिक आरोग्य विभाग, मुंबई
प्रत - संचालक, आरोग्य सेवा, मुंबई व पुणे

RATIONAL USE OF O_2 IN COVID-19 HOSPITALS

Maharashtra State is witnessing sudden surge of Covid-19 cases in almost all districts since last 3 weeks. This increase in number of patients is now leading to increase in demand of Oxygen. It has been informed to all the districts treat O_2 as scares resource and use judiciously. However, consumption of Oxygen has not reduced as expected. Therefore, guidelines for rational use of Oxygen are being circulated to all the districts in the State. District Collectors are expected to implement these guidelines strictly in Govt and Private Health Facilities classified as DCH, DCHC and CCC (with Oxygen beds).

A) CLASSIFYING AREA AS PER NEED OF OXYGEN

Every patient admitted to Covid health facility will not require Oxygen. Also Oxygen requirement of some patient will be initially low but will increase over period of time and also may reduce after some time. Mixing the patients requiring different need of Oxygen may lead to wastage of these scarce resources. Therefore there is need to classify the hospital into 6 areas as mentioned below. This could be floor of hospital or wards physically separated from each other.

1. Zone – A : Ward or Floor for patients who do not require Oxygen (e.g. patients maintaining Oxygen saturation 94% or above in room air).
2. Zone – B : Ward or Floor for patients who require O2 – 1 to 5 litres per minute
3. Zone – C : Ward or Floor for patients who require O2 – 6 to 10 litres per minute
4. Zone – D : Ward or Floor for patients who require O2 – 11 to 15 litres per minute
5. Zone – E : Ward or Floor for patients who require O2 – 16 to 30 litres per minute
6. Zone – F : Ward or Floor for patients who require O2 – 30 + litres per minute

Districts are not expected to make large reshuffle in hospital beds but to designate the zones considering the available infrastructure in each ward / floor such as Oxygen pipe supply facility, distance from cylinder storage, etc.

B) ESTABLISHMENT OF ADMISSION & DISCHARGE COMMITTEE

It is important to correctly identify and reclassify the patients continuously and put them in appropriate zone to save and use the Oxygen judiciously. Every Hospital should have one Admission and Discharge Committee (ADC) under Chairmanship of Head of the Hospital. Composition of committee will be as follows:

1. Head of the Facility
2. Senior Physician / Anaesthetist
3. I/c of DCH/DCHC
4. FDA representative
5. District Collector representative

Member no. 4 and 5 will not be involved in admission, zone allotment and discharge of patients. They will facilitate committee in Oxygen utilisation audit and Oxygen supply.

ADC should be established in all Govt and Private health facility engaged in treatment of Covid-19 patient. There can be more than one committee in one hospital considering the capacity and load of patients. Regarding Private Hospitals, one doctor nominated by District Collector will be included in committee.

District level committee of District Hospital / Medical College can visit any of the private hospital at district HQ consuming Oxygen. At block level, Medical Superintendent of RH/SDH and representative of District Collector will visit private health facility for Oxygen Utilisation Audit.

ToR of Admission & Discharge Committee

1. Ensure that no un-necessary admission is done in hospital
2. Correctly identify and re-classify each patient daily as per O2 requirement and allot the zone.
3. Review of zone of all admitted patients once a day and re-allocation of zone to patient
4. Segregating patients not requiring O2 to separate floor (Zone - A) and discharge based on clinical conditions and GoI guidelines
5. Review of treatment, check whether treatment is given as per protocol decided by State.
6. Daily review of Oxygen requirement, actual consumption, availability, etc.

7. Understanding the O2 supply pattern and eliminating unnecessary wastage of O2 (Oxygen Utilisation Audit)
8. Suggesting control measures to reduce Oxygen consumption in the hospital.

C) ADMISSION & TREATMENT OF PATIENT IN APPROPRIATE ZONE

Following procedure should be adopted while admitting the patient in covid hospital :

1. Admitting and providing medical services to patient in appropriate zone is very important for conservation of Oxygen.
2. The admission committee will review condition of patient and admit the patient in appropriate zone. Alternatively, the Casualty Medical Officer will be given criteria for admission and allotment of zone and committee will examine the admitted patients once a day and make change of zone if necessary.
3. There should not be oxygen cylinders, oxygen concentrators, etc. in Zone- A.
4. Oxygen to all the patients in Zone – B should be preferably administered through Oxygen Concentrators. No Oxygen cylinder or pipe oxygen should be used in Zone –B if Oxygen Concentrators are available in sufficient quantity. Sufficient number of Oxygen Concentrators should be procured for this.
5. No high flow nasal Oxygen will be used for patients unless it is approved by the ADC.
6. No patient will be admitted on Oxygen bed if saturation on admission is 94% or above in room air.
7. Each patient should be examined hourly whether mask / cannula is correctly put on patient.

D) IMPROVING AVAILABILITY OF OXYGEN

It is important to increase the Oxygen storage capacity of hospital as well as have mechanism to get in-house Oxygen in emergency.

1. Oxygen storage capacity

Hospital should have capacity to store Oxygen of at least 3 days requirement if all the beds are full. Requirement can be calculated by calculating demand as 10 litres/minute/bed for 24 hours.

Oxygen storage can be increased by following

i. Type – D cylinders (Jumbo cylinders)
ii. Dura cylinders (Bulk cylinders)
iii. Oxygen tank

Number of cylinders required and capacity of Oxygen tank required should be decided based on demand and three days storage. On an average, if there is no Oxygen tank installed, there should be 4 Jumbo cylinders per Oxygen bed or one dura cylinder for every six Oxygen beds. If facility of refilling is away from the hospital and not reliable, then 10% to 25% quantity should be added to this.

Considering Nashik incidence, if Oxygen is being supplied by tank, at least 6 hours capacity dura cylinders should be connected to Oxygen system by manifold parallel to the tank for emergency purpose with appropriate connection system.

2. Oxygen generation system

Considering the crisis, all the DCH are advised to establish one Oxygen generation plant of one day requirement capacity.

All the hospitals should have Oxygen concentrators of 25% bed capacity excluding ventilator beds. Oxygen concentrators of 10 litres/min output capacity may be preferred if available for purchase in the market.

It has been observed that many patients requiring Oxygen are kept in CCC because Oxygen beds in higher centres are full, it is advised to keep Jumbo cylinders and Oxygen concentrators in all CCC in the district.

3. Oxygen distribution system

Good quality pipe Oxygen distribution system saves Oxygen wastage. Therefore Oxygen pipe line should be installed in all the DCH and DCHC. Oxygen pipeline should be installed even if the DCHC is established in Govt buildings, Govt hostels, etc.

Oxygen tanks, Dura cylinders also save Oxygen as compared to Jumbo cylinders. Therefore as far as possible, Oxygen tanks and Dura Cylinders should be used for Oxygen supply.

4. Maintenance of Oxygen delivery system

At least 2 technicians with knowledge of Oxygen delivery system, from source to user point should be available 24 hours and hospitals with 100 or more Oxygen beds. At least one person should be available at other places. In CCC, one staff should be trained in maintenance of Oxygen delivery system and one technician should be on call.

Oxygen system should be checked daily at 8 am and 6 pm from source to point of use. Register should be maintained to record findings of the inspection. The technician should inform findings to i/c of Oxygen supply and head of the institution.

Stop cock can be installed at entrance of each Ward so that if no patient requiring Oxygen is admitted in ward, this can be closed.

E) MONITORING OF OXYGEN USE

It is important to monitor use of Oxygen by each patient and make corrections accordingly. As per guidelines, each patient is to be examined every four hour and further action is to be taken as per Oxygen saturation of the patient. Following actions are to be taken in this regard:

1. Each patient should be examined four hourly for Oxygen saturation and flow of Oxygen should be adjusted based upon the Oxygen saturation. At least 10% of bed capacity Pulse Oximeter should be available in each ward to monitor the Oxygen saturation.
2. One i/c Doctor to be appointed for each zone to monitor the Oxygen consumption of the zone. Daily zone wise audit of Oxygen use should be done by Zone in charge. Use of Oxygen from cylinder/tank should be compared with actual consumption by patient with the help of Form – A. If there is discrepancy, it should be immediately brought to notice of ADC.

3. One Staff Nurse called as **"Oxygen Sister"** to be appointed for every 50 beds. She will go to each patient, check the Oxygen saturation by pulse oximeter, record on the patient indoor paper and adjust the Oxygen flow of patient. If the saturation is 95% or above, she will reduce the flow, if the saturation is below 95% she will increase the Oxygen flow. If the saturation is not attending 93% level even after 15 Litre/Min, she will inform doctor for further action.

   Her one cycle of 50 patients will finish in 3 to 4 hours. One Oxygen sister will have two rounds in her duty. This duty will be 24X7.
4. If patient is improved and maintaining 94% or higher saturation at room air, patient should be shifted to Zone – A.
5. There will be daily count of patients in each zone, estimated Oxygen consumption and actual Oxygen consumption. In case of discrepancy, instigations should be done whether Oxygen is wasted in any zone.
6. Following monitoring format should be used for checking consumption. Format should be filled in zone wise by i/c doctor of each zone.

Form – A : Monitoring of Oxygen use

Name of Hospital : ..... Type : DCH/DCHC/CCC

Zone : ..... I/c

Zone:.....

Bed No.	Name	Age	Sex	D/o admission	Temp	SpO_2	BP	Pulse	RR	O2 supplied*	O2 lit/min	Condition of patient**

*O2 supplied via - Mask / Nasal / BiPAP / High Flow / Ventilator

** Condition of patient – Good / Poor / Very Poor / Critical

Signature of the i/c of ward/Zone

F) TRAINING OF HR

Two types of HR are required for O2 supply and use monitoring. First is engineering HR and second is medical HR.

1. Engineering HR will be trained in
   - i. Functioning and maintenance of Oxygen supply system
   - ii. Periodically report amount of Oxygen consumed, time left to replenish and accounting of cylinders
   - iii. Check the pipeline for leakages
   - iv. Maintaining the tanks for continuous flow – checking the ice on tubes

2. Medical HR
   - i. Monitoring the bed wise O2 supply
   - ii. Periodic checking vitals change in O2 flow
   - iii. Work distribution amongst available staff
   - iv. Discharge unruly patients

G) OTHER ACTIONS

1. No entry to patient relatives: It is observed that lot of patient relatives enter the hospital without permission. They quarrel with the security and do not listen to them. This leads to spreading of infection and also making difficulty for doctors and staff to transfer the patients to appropriate zone. Barricading should be done at the entrance of hospital and only the staff and patients will be allowed. No relative of any patient will be allowed inside hospital.
2. Mechanism to communicate status of each patient to relatives should be developed with the help of local NGO or govt officials of other departments.
3. Cylinders should not be given to patients relatives.

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:** _____

Type of Covid Bed	No. of beds
• Isolation	
• O2 Support	
• Ventilator	
• Remaining ICU Beds (Except ventilator)	

NOTE: *The HFNO's should be phased out for large consumption of oxygen*

8. **Total No. of Patients on Oxygen:** _____

Currently Patient on	For Covid	For Non-Covid
• Oxygen Cylinder		
• Oxygen Piped Bed		
• NIV (Ventilator)		
• Intubation (Ventilator)		
• Bi-PAP		
• HFNO		

Details of Oxygen Use

Sr. No.	Device	Lit/Min	No. of Patients	Total Consumption Lit/min	Total Consumption Lit/Day	Total Consumption KL/Day (Total Consumption Lit/day / (1000*860))	Total Consumption in Ton (KL/Day*0.871)
1	Nasal Prongs	(3 LPM)					
3	Nasal Mask	(4 LPM)					
4	Non Re-breathable Mask (With Bag)	(6LPM)					
5	Invasive Ventilation (Intubetion)	(20 LPM)					
6	BiPAP	(12 LPM)					
7	NIV (Ventilator)	(50 LPM)					
8	HFNO	(50 LPM)					
Total							

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

Jumbo Oxygen Cylinder General Information:

Type of Jumbo System installed:	Available Oxygen Cylinder in hospitals:
i) Capacity of Manifold : _____ **e.g. (8 x 8)** **ii)** Capacity of reserved Manifold: _____ **e.g. (4 x 4)** **Total:** _____	**i) Type D** (7 CuM) :_____ **ii)** Type B (1.5 CuM) : _____ **Total:** _____

Source of Oxygen

Source of Oxygen: Jumbo / Dura / LMO **Frequency of Supply:** _____ **Quantity of Supply in last delivery (in CuM):** _____	**1st Agency Name**: _____ **Address**: _____ _____ **Pin Code:** _____ **Mob. No.** _____
Source of Oxygen: Jumbo / Dura / LMO **Frequency of Supply:** _____ **Quantity of Supply in last delivery (in CuM):** _____	**2nd Agency Name**: _____ **Address**: _____ _____ **Pin Code:** _____ **Mob. No.** _____
Source of Oxygen: Jumbo / Dura / LMO **Frequency of Supply:** _____ **Quantity of Supply in last delivery (in CuM):** _____	**3rd Agency Name**: _____ **Address**: _____ _____ **Pin Code:** _____ **Mob. No.** _____

Sources of Oxygen Storage

Sources of Oxygen Storage	Approximate Availability of liquid medical oxygen in KL	Approximate Availability of liquid medical oxygen in liters (X 1000)	Quantity of Cylinder	Approximate Availability of oxygen in gaseous form	Note
Liquid Medical Oxygen Tank-1					For converting LMO/Dura Litres in gaseous form multiply by 860. 1 Litre=860 Litres gaseous form
Liquid Medical Oxygen Tank-2					
Liquid Medical Reservior-1					
Dura Cylinder-1					
Dura Cylinder-2 (Filled)					
D-Type, Jumbo Cylinder (Filled)					For jumbo cylinder type D 7000 Litres
B-Type, small Cylinder (Filled)					For small cylinder type B 1500 Litres
Total					

Sources of Oxygen Generation				
Sources of Oxygen Generation	**No. of Plants**	**Approximate Capacity of Plants in Litres/Minute**	**Approximate total availability of Oxygen in Gaseous form Litres/Minute**	**Note**
Oxygen PSA Plant-1				
Oxygen PSA Plant-2				
Total				

Note: This information is to be collected from Hospital administration by discussion and examining report of fire and electrical audit.

FIRE AUDIT	
1. Fire Audit of Hospital has been done?	Yes / No
If yes, pls mention Date of fire Audit	/ /
Faults found (if any)	
Corrective action taken	
If No audit done, please mention What is the Plan for Audit?	

ELECTRICAL AUDIT	
1. Electrical Inspection of Hospital has been done?	Yes / No
If yes Pls. mention Date of Electrical Inspection	/ /
Faults found (if any)	
Corrective action taken	
If No, electrical inspection done, please mention What is the Plan for inspection?	
Are Lightening Arresters available and installed on building?	Yes / No
If available, where is it?	At Hospital / At Oxygen Cryogenic Tank area

1. Appointment of dedicated technical persons round the clock to check / Monitor Oxygen Pipeline, Cylinders & Tank (24 X 7) :-														Yes / No
If yes	Name:		Mobile No.											
2. Name of technical Engineer		Name:												
Address:			Mobile No.											
			Alternate Mobile No.											
3. Daily Oxygen Requirement by Hospital (In MT) Before Audit														
4. Projected requirement of Oxygen by Hospital (In MT) As per Audit														
5. Saving of Oxygen Requirement (In MT) which is possible														

B. GENERAL CHECKLIST FOR OXYGEN SYSTEM

Sr. No.	Descriptions	Yes/ No/NA	Comments
1	All oxygen sources or plants should be erected in open spaces and not within the building premises.		
2	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, nylon, flammable plastic Jali, Plywood)		
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	The 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.		

C. OXYGEN PIPELINE GENERAL INSPECTION CHECKLIST

Sr. No.	DESCRIPTION	Yes/ No/NA	COMMENTS
1	Leakages found at pipeline, Valve & Joints		
2	If leakages found, then repairing done immediately		
3	Is there finding of Oil / Grease on pipeline		
4	Are there explosive elements found near Pipeline		

D. GENERAL OXYGEN WEANING PROTOCOL

Sr No.	Description	Compliance Yes/No/NA	Comments
1	Establish Oxygen weaning protocol as per the guidelines of Maharashtra Task Force for Covid 19		
2	Conduct staff training for Oxygen Weaning protocol.		
3	Display boards and sign ages for oxygen weaning protocol at Patient Bedside		
4	Display sign boards so Patient should be aware that they do not touch and change Oxygen LPM Delivery settings.		
5	Take good quality branded oximeter and SPO2 has to be measured every 2 hours as per chart given. (Preferable to oximeter with respiratory rate)		
6	Step Up and Step Down of Oxygen to be done as per established Oxygen weaning Protocol		
7	Ensure that LPM delivery settings changes are carried with precautions and staff is trained for same, (Accidentally increasing pressure above 15 LPM will cause breakage of humidifier bottles which are in short supply)		
8	Is there patient briefing taken for Oxygen Usage?		
9	Are staff Checking Carefully leakages of Oxygen Pipeline Cylinder & Cryogenic tank daily?		
10	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)		
11	Are Reclining Beds being used to reduce Oxygen requirement and better saturation levels in patients		

E.

SR.NO.	DESCRIPTION	YES / NO/NA	COMMENTS
1	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.)		
2	Are cylinders stored away from incompatibles, excessive heat, continuous dampness, salt or other corrosive chemicals, and any areas that may subject them to damage?		
3	Are cylinders maintained at temperatures below 51 Degree C or 125 degrees Fahrenheit? (Check with thermal gun)		
4	Are only Oxygen gas cylinders separately stored?		

SR.NO.	DESCRIPTION	YES / NO/NA	COMMENTS
5	Are cylinders stored in upright positions and immobilized by chains or other means to prevent them from falling?		
6	Are cylinders stored away from electrical connections, sources of ignition, combustible waste material?		
8	Are charged or full cylinders labeled and stored away from empty cylinders?		

F. JUMBO OXYGEN CYLINDER OPERATION & MAINTENANCE CHECKLIST

SR.NO.	DESCRIPTION	Yes/ No/NA	COMMENTS
1	Are all Oxygen cylinders subjected to periodic hydrostatic testing and interior inspection by suppliers?		
2	Are all Oxygen cylinders regularly inspected for corrosion, pitting, cuts, gouges, digs, bulges, neck defects and general distortion?		
3	Are suitable pressure-regulating devices in use whenever the gas is emitted to systems with pressure-rated limitations lower than the cylinder pressure.		
4	Are all Oxygen cylinder connections (pressure regulators, manifolds, hoses, gauges, and relief valves) checked for integrity and tightness?		
5	Are all Oxygen cylinders regularly subjected to leak detection using an approved leak detecting liquid?		
6	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.		
7	Are Oxygen handled only by experienced and properly trained people?		
8	Is the bottom of the cylinder protected from the ground to prevent rusting?		
9	Are cylinder valves closed at all times, except when the valve is in use?		
10	Are all Oxygen cylinder valve covers in place when cylinders are not in use?		
11	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 hard-to-open valves, contact the supplier for instruction.) (Ask Questions to field staff)		
12	Are all Oxygen cylinders subjected to periodic hydrostatic testing and interior inspection by suppliers?		
13	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)		
14	Are Oxygen cylinders always moved, even short distances, by a suitable hand trolley? (Note: They must never be dragged across the floor.) (Check visually)		

G. PRECAUTION FOR EFFICIENT UTILIZATION AND STORAGE OF JUMBO CYLINDERS (JUMBO SECTION)

Sr.No.	Descriptions	Yes/ No/NA	Comments
Note: Every Type of Oxygen Container depletes in small quantities through valves			
1	**Precautions for efficient utilization of Jumbo Cylinders.**		
Note: Jumbo Cylinders stored eventually will deplete and, in few weeks, or months will be empty, during 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 this date based on weekly check with the help of flow meter and the percentage loss observed. This needs to be done as every cylinder manufacturer as uses different component, thus there is no other alternatives to establishing it manually over a period of two three months. Intermittently hospital should maintain the last refill date on tag.		
1.2	Check all humidifier 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 tear able 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

Sr. No.	Descriptions	Yes/ No/NA	Comments
1	Do all cylinders have safety valves?		
2	Are safety relief devices in the valve or on the cryogenic tank free from any indication of tampering?		
3	Dura Cylinders handled only by experienced and professionally trained people? (Ask Questions to filed staff)		
4	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 (Urban/Rural)		
5	If LMO and Manifold System Fails, then are refilled cylinders kept in wards with regulators (Conversion kit)		

Storage

Sr. No.	Descriptions	Yes/ No/NA	Comments
1	All oxygen sources or plants should be erected in open spaces and not within the building premises.		
2	Dura oxygen storage facility should be covered from top and ensured that it is not exposed to sunlight and any source of heat directly.		
3	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, nylon, flammable plastic Jali, Plywood)		

Precautions for efficient utilization of Dura Cylinders

Sr. No.	Descriptions	Yes/ No/NA	Comments
Note: Dura Cylinders are also also susceptible to the leakages and if the dura cylinders are not used for 2 to 3 days they will vaporize and the Oxygen will be released to through the safety valve into atmosphere, while this happens there is a big whistling sound that accompanies it. To avoid such wastage of oxygen the dura cylinders should be used when they are bought in the hospital premises within 48 hours. They should be avoided stored in an area where the temperature is high. In dura cylinders the oxygen is stored in cryogenic form as the temperature increases it vaporizers and if not attended all the oxygen is lost the atmosphere does if the dura is being used as a backup facility to the main element tank then every 2 days the dura pressure has to be increased more than the oxygen pressure the LMO pressure and using the pressure differential the standby bank should be made as the primary bank and emptied and refilled again this is of utmost importance and when during cylinders are being used for backup for their own use for large number of days all Oxygen will be lost.			
1	Importance and when during cylinders are being used for backup for their own use for large number of days all Oxygen will be lost.		
1.1	Rotate all Dura Cylinders regularly which are kept in reserved stock		
1.2	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.		
1.3	All Dura cylinders should be marked with permanent paint and Numbered		
1.4	All such Dura cylinders should be tagged with an non tearable tag.		
1.5	Last Dura refilling date should be mentioned by Refiller on clearly legible Tag		
1.6	Next refilling date of cylinders if it stays unused like the fire extinguisher should be maintained		
1.7	Fasten the spanners Near work area with rope in a manner that they can be easily used and are readily available		
1.8	Ensure spare spanner stocks are maintained in store in sufficient numbers.		

I. LMO OXYGEN SYSTEM

Tank Inspection Checklist

Sr. No.	Descriptions	Yes/ No/NA	Comments
1	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))		
2	If LMO and Manifold System Fails then are filled cylinders kept in wards with regulators (Conversion kit)		

Storage

Sr. No.	Descriptions	Yes/ No/NA	Comments
1	All LMO Plants should be erected in open spaces and not within building premises		
2	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 jali. Example of flammable material that should not be used are plastic, nylon, flammable plastic jali, plywood)		
3	Are there separate entrances for operational persons and the LMO tankers?		
4	Is the LMO facility secured by using padlock?		
5	Are the keys of LMO easily available with fire / security / administration / operation staff?		
6	Is there a mechanism to de-ice the vaporizer by using water showers?		
7	Is the water being recycled by creating underground tanks or collecting it in any way?		
8	Is the pipeline from LMO tank to vaporizer also getting de-ice?		
9	Is the flooring in the LMO decanting perfectly horizontal? so all the LMO is properly decanted in the tank.		

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

Precautions

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

4	Is the water level in humidifier bottles being properly maintained between minimum and maximum?		

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.

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

L. INVENTORY REPORT

Inventory of Tools and Spares required for Each Liquid tank				
Sr. No.	**Description**	**Required**	**Actual Available**	**Remarks**
1	Liquid Tank Valves of all type	3 Nos. each		
2	Safety relief valves, Internal valves, Excess flow Valves	3 Nos. each		
3	SMPV High Flow Regulators	3 Nos. each		
4	Liquid Tank gauges	3 Nos. each		
5	Nut, Couplings, joints	3 times of fitted Quantity		
6	Rubber / Metal Diaphragms of Regulator	4 Nos. each		
7	Rubber washers / Teflon washers 'O' Rings	10 times of fitted Quantity		
8	Teflon Tapes	10 Nos.		
9	Tool Box (Spanners, wrench, screwdrivers, Adjustable spanners etc)	3 sets		
* 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)**

_____ _____

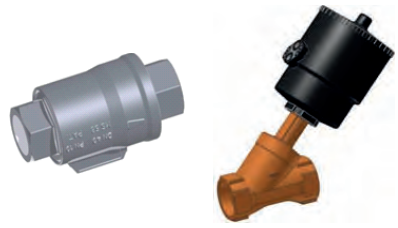
_____ _____

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

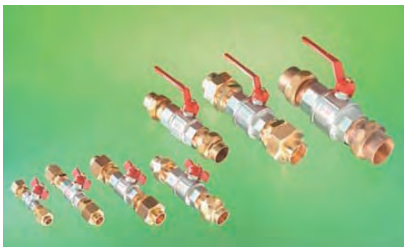
Adjustable Spaner

Spanner Set

Screw Drivers

Spanner & Tools

Gas Outlets Regulators

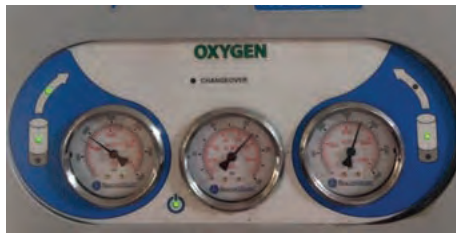


Shut -off Valve

Coper Pipe & Its Joints

Coper Pipe & Its Joints

Manifold Gauges for MGPS System



Pressure Release Valve for LMO

Cryogenic Valves

Cryogenic Vacuum valves

Cryogenic Liquid Transfer Line

Cryogenic Gloves

Annexure Figure 1: Commonly needed Tools for repair and maintenance of various oxygen systems

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Medical Oxygen Management System

Department of Public Health
Government of Maharashtra

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