NEST-ED

Technical Modules

February 2021

Newborn Essential Solutions and Technologies-Education (NEST-ED) Technical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre-and in-service settings and are not intended to be comprehensive technical guidelines or device-specific manuals.

FACILITATING THE CLINICAL USE AND TECHNICAL REPAIR OF TECHNOLOGIES FOR NEWBORN CARE IN LOW-RESOURCE SETTINGS
Newborn Essential Solutions and Technologies-Education
Technical Modules: Oxygen Cylinder

This series reflects the work of the NEST360° team through a joint effort with partner organisations. Some rights reserved. This work is available under the Creative Commons Attribution-ShareAlike 4.0 International license (CC BY-SA 4.0; https://creativecommons.org/licenses/by-sa/4.0/).

Under the terms of this license, you may copy, redistribute and adapt the work in any medium or format for any purpose, even for commercial purposes, provided you indicate whether any changes were made and that the work is appropriately cited, as indicated below. In any use of this work, there should be no suggestion that NEST360° endorses any specific organisation, products, or services. The unauthorised use of the NEST360° names or logos is not permitted. If you adapt the work, then you must license your work under the same or equivalent Creative Commons license. If you create a translation of this work, you should add the following disclaimer along with the suggested citation: “This translation was not created by Newborn Essential Solutions and Technologies (NEST360°). NEST360° is not responsible for the content or accuracy of this translation. The original English edition shall be the binding and authentic edition”.


Rights and licensing. For queries on rights and licensing, see the full legal code for the Creative Commons Attribution-ShareAlike 4.0 International license (CC BY-SA 4.0; https://creativecommons.org/licenses/by-sa/4.0/).

Please contact nest360@rice.edu to obtain a version of the series that may be more easily adapted and integrated into other materials.

Third-party materials. If you wish to reuse material from this work that is attributed to a third party, such as tables, figures or images, it is your responsibility to determine whether permission is needed for reuse and to obtain permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

General disclaimers. All reasonable precautions have been taken by NEST360° to verify the information contained in this publication. The mention of specific companies or of certain manufacturers’ products does not imply that they are endorsed or recommended by NEST360° in preference to others of a similar nature that are not mentioned. The published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall NEST360° or affiliated partner institutions be liable for damages arising from its use.

The authors have made every effort to check the accuracy of all information and instructions for use of any devices or equipment. As knowledge base continues to expand, readers are advised to check current product information provided by the manufacturer of each device, instrument, or piece of equipment to verify recommendations for use and/or operating instructions.

In addition, all forms, instructions, checklists, guidelines, and examples are intended as resources to be used and adapted to meet national and local health care settings’ needs and requirements.
# TABLE OF CONTENTS

**NEST-ED** ........................................................................................................................................... 1  
**TECHNICAL MODULES** ....................................................................................................................... 1  

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCLAIMER</td>
<td>2</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>3</td>
</tr>
<tr>
<td>PREFACE</td>
<td>4</td>
</tr>
<tr>
<td>ABBREVIATIONS</td>
<td>5</td>
</tr>
<tr>
<td>NOMENCLATURE</td>
<td>5</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>6</td>
</tr>
</tbody>
</table>

**RESPIRATORY SUPPORT** ....................................................................................................................... 9  

**OXYGEN THERAPY** ................................................................................................................................. 9  

**OXYGEN CYLINDER** .............................................................................................................................. 9 

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CLINICAL PROBLEM</td>
<td>10</td>
</tr>
<tr>
<td>2 ASSESSMENT</td>
<td>10</td>
</tr>
<tr>
<td>3 MANAGEMENT</td>
<td>15</td>
</tr>
<tr>
<td>4 INFECTION PREVENTION</td>
<td>16</td>
</tr>
<tr>
<td>5 COMPLICATIONS</td>
<td>18</td>
</tr>
<tr>
<td>6 CARE &amp; MAINTENANCE</td>
<td>19</td>
</tr>
<tr>
<td>7 TROUBLESHOOTING &amp; REPAIR</td>
<td>22</td>
</tr>
<tr>
<td>8 REFERENCES</td>
<td>24</td>
</tr>
</tbody>
</table>
This series has been designed with the intent of supporting the clinical use and technical repair of technologies in newborn care units.

Newborn Essential Solutions and Technologies-Education (NEST-ED) Technical Modules provide educational support for each of the technologies included in the NEST360° bundle for newborn care. These materials are intended to strengthen locally developed neonatal and technical trainings in pre- and in-service settings. Of note, these materials are not intended to be comprehensive technical guidelines or to replace the use of device-specific user and service manuals or textbooks. They are to be used to facilitate the implementation of comprehensive newborn care, including bubble CPAP, in a resource limited setting.

The NEST-ED Technical Modules were developed through a combination of international standard review, international expert feedback, and multinational NEST360° expert consensus opinion. NEST-ED Modules form the backbone of all lectures, power points, job aids, and other supportive education materials supplied by NEST360°.

To view the full series, visit the NEST360° Resources website.
## Abbreviations

**bCPAP**  
Bubble continuous positive airway pressure

**BMET**  
Biomedical Equipment Technician

**dL**  
Decilitre

**ESD**  
Electrostatic Discharge

**FiO<sub>2</sub>**  
Increased Fractional Concentration of Oxygen

**Fr**  
French size

**HAI**  
Hospital acquired infections

**HCWs**  
Healthcare workers

**KMC**  
Kangaroo mother care

**LBW**  
Low birth weight

**LCD**  
Liquid Crystal Display

**LED**  
Light-Emitting Diode

**mm Hg**  
Millimeters of mercury

**NEST-ED**  
Newborn Essential Solutions & Technologies-Education

**NEST360°**  
Newborn Essential Solutions & Technologies

**nm**  
Nanometer

**O<sub>2</sub>**  
Oxygen

**OGT**  
Orogastric tube

**PCB**  
Printed Circuit Board

**ppm**  
Parts per million

**ROP**  
Retinopathy of Prematurity

**PSA**  
Pressure Swing Adsorption

**PSU**  
Power Supply Unit

**SpO<sub>2</sub>**  
Peripheral blood oxygen saturation

**UPS**  
Uninterruptible power supply

**WASH**  
Water, sanitation and hygiene

## Nomenclature

**Allen keys**  
Hex keys

**bCPAP prongs**  
bCPAP patient interface

**Christmas tree adapter**  
Barbed oxygen fitting, nipple and nut adapter

**Control PCB**  
Main PCB

**Cot**  
Bassinet, infant crib

**Flat head screwdriver**  
Slot head screwdriver

**Flow splitter**  
Oxygen splitter, flow meter stand

**Glucometer**  
Glucose meter

**Hospital Acquired Infection**  
Iatrogenic infection, nosocomial infection

**Multimeter**  
Digital multimeter, Avometer

**Nasal prongs**  
Oxygen catheter, oxygen cannula, oxygen prongs

**Positive Pressure**  
Positive end expiratory pressure, positive airway pressure

**Radiant warmer**  
Resuscitaire, resuscitation table

**Star screwdriver**  
Torrx screwdriver

**Suction pump**  
Suction machine
Introduction

The NEST-ED Technical Modules have been prepared to help technical staff and students understand the basics of when and how to use equipment essential to newborn care. More importantly, the Technical Modules support staff in troubleshooting common issues, as well as prepare staff to repair equipment when it breaks down or malfunctions. Modules may be used by teaching institutions, to supplement current newborn care curricula, or by hospitals, clinical departments and individuals to update their knowledge and to better facilitate the effective and safe use of newborn care equipment. Modules should be used alongside device user and service manuals to provide additional context as needed.

Whilst reading this series, navigate to the Table of Contents by clicking the NEST360° logo that appears at the bottom right corner of each page: NEST360°

Every module has a similar structure with sections and subsections. The sections have similar headings and subheadings to make it easy for the user to navigate them. However, words may have different meanings for the various cadres of staff reading them and so to reduce misinterpretation, the heading titles are explained below.

The NEST-ED Technical Modules are intended as a flexible resource that hospitals and partners can adapt to their specific needs. The Technical Modules consist of generic content that can be applied to any model within a device category, coupled with model specific device images that can be exchanged for alternative images depending on the devices available at your facility. Individuals who are interested in gaining access to the editable NEST-ED Technical Modules should contact the NEST Training Materials Coordinator (Anniina Lockwood, al90@rice.edu) or the NEST Biomedical Tech Training Director (Sara Liaghati-Mobarhan, slmobarhan@rice.edu).

CLINICAL PROBLEM

This section provides useful information on the clinical application of a device that would bear relevance to the biomedical team, not only to aid in their troubleshooting, but also for user training.

ASSESSMENT

This section explains how the device works, and what kinds of patients it is useful for. This section also includes comprehensive diagrams of internal and external views of the devices, including consumables that may be used with the device. This section also contains detailed descriptions of key device components (including alarms) and includes a diagram of typical device flow (including components and how they interact with each other, electrical current and fluid movement through the device if relevant).
MANAGEMENT

This section focuses on clinical management and provides step by step directions on how to set the device up for a patient, followed by instructions on starting the patient on the device and monitoring a patient whilst on the device. This section also describes how to remove the equipment from the patient when it is no longer needed. Although a biomedical engineer or a technician will not be responsible for providing care, understanding these steps will be useful in training and when assessing the device.

INFECTION PREVENTION

This section lays out the basic infection prevention measures that should always be taken when handling equipment, followed by directions for disinfecting the equipment both during and after use. This section also describes the crucial Infection Prevention and Control steps that are particularly relevant to biomedical engineers and technicians.

COMPLICATIONS

This section explains some of the common but serious clinical complications that relate to and can arise from the use of the equipment (e.g., complications that will be seen or directly apply to the patient). Biomedical engineers’ and technicians’ understanding of potential complications for the patient is crucial to ensure patient safety. This section also describes common device complications (e.g., complications that will be seen or directly apply to the device).

CARE & MAINTENANCE

This section describes where to place equipment for use, how to safely handle devices and their consumables, whether calibration is recommended, and how to decommission the equipment. Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure the equipment lasts to their potential lifetime; as such, this section also lists the necessary daily, weekly, monthly and annual preventive maintenance steps required to keep the device in good working condition. First-line care and maintenance is the responsibility of the user and is described in the NEST-ED Clinical Modules.

TROUBLESHOOTING & REPAIR

This section describes steps that should be taken when a device malfunctions and first-line troubleshooting efforts have failed to address the issue. This section describes tools and spare parts that might be required to prepare for repairs and to troubleshoot failures, and provides a list of components commonly provided with the device to ensure that all components return to the ward post-repair. Finally, this section also explains steps for testing, repairing, and replacing specific parts of the device.
REFERENCES & ALERTS

References & alert boxes are included within each module to provide clarity on areas where recommendations are governed by published standards, evidence, and/or expert opinion. This is included for the dual purpose of facilitating (1) feedback and continuous improvement of NEST-ED Technical Modules and (2) implementer review of content for incorporation in local trainings.

 QUERY ALERT BOXES appear where there may be controversy or disagreement. In these cases, alert boxes provide background to the recommendations that are made in the body of the document. Relevant documents are cited and brief explanation of reasoning for current module content provided.

 RECOMMENDATION ALERT BOXES appear where there are recommendations based largely on expert opinion or consensus, or to emphasize an important element of care. Relevant documents are cited and brief explanation of reasoning for current module content provided.
Respiratory Support

Oxygen Therapy

Oxygen Cylinder
1 Clinical Problem

Oxygen cylinders are used within multiple hospital settings. In newborn care units, an oxygen cylinder may be used as a standalone source of oxygen.

Oxygen cylinders may be used to provide supplemental oxygen directly to hypoxic patients, shared between patients using a flow splitter or used with other treatment devices such as continuous positive airway pressure devices. Supplemental oxygen is indicated for sick children, especially those with low blood oxygen saturation levels (SpO₂<90%) which has many clinical causes.

2 Assessment

Oxygen cylinders (2.1) may be used as backup to oxygen concentrators in case of power outage or transport, or as a primary means of delivering oxygen therapy to a patient. Cylinders may be piped to a particular area of the health facility using a walled oxygen system, or used directly within the patient area.

Oxygen cylinders are usually made of a steel or aluminium alloy and are distinguished from other cylinders by having a black body with white shoulders and top. The capacity of oxygen is rated in litres which indicates the amount of oxygen the tank can store. Cylinder sizing follows an alphabetical system. Each letter corresponds to the capacity in litres of that particular cylinder; cylinder sizes include D, E, F, G, J and corresponding capacities are 340, 680, 1360, 3400 and 6800 litres, respectively.¹

¹ Typical oxygen cylinders.  2.2 Typical transport cylinder.
HOW IT WORKS

Oxygen cylinders are durable vessels filled with **medical grade oxygen** from an external source (e.g., a generation plant at a health facility or privately-owned company). In oxygen generation plants, oxygen cylinders are filled with oxygen at high pressures of 137 bar (13 700 kPa, 1987 psi) to 200 bar (20 000 kPa, 2 901 psi). This pressure acts as a driver to push oxygen out of the cylinder when opened for use.

From the oxygen cylinder body, the oxygen passes through a **pressure gauge**. The pressure gauge indicates both the pressure and the contents; as the content pressure drives the oxygen release, the pressure decreases as the contents decrease. The indicated pressure is thus directly proportional to the amount of oxygen remaining in the cylinder.

Before being given to a patient, the highly compressed oxygen passes through a **pressure regulator** to reduce its pressure to suitable levels for treatment. From the pressure regulator, the oxygen passes through the **flow regulator** (or flowmeter) where the flow is set and delivered to the patient or another oxygen delivery device (e.g., a CPAP, flow splitter, nebulizer). The flowmeter should be read in the correct orientation and angle; if the flowmeter is vertical, it should be installed in a vertical orientation and read at eye level.

Some oxygen cylinders may also be made of different materials so they can be used as transport cylinders (smaller and on castors or wheels) or MRI cylinders (smaller, on wheels, and made of a material that will not interact with the MRI).

Oxygen cylinders may also be stored in oxygen distribution manifolds (groups of cylinders linked in parallel), which are largely used for piping oxygen for small patient loads. A distribution manifold is a bank that can hold more than one cylinder simultaneously (particularly useful for piped systems). Distribution manifolds are defined by both the number of cylinders and banks they have (e.g., a 2x2 manifold has two banks with two cylinders on each bank).

Distribution manifolds typically have two equal banks (sets) of cylinders attached; one is the primary manifold which is used first and the other is on standby for use when the primary manifold runs out. This ensures a continuous supply of oxygen to the pipeline. Manifolds are usually semi-automated or manually operated, although back-up manifolds may be automated (with a pressure transducer for change-over between the banks).
Between the two banks, there is a double-stage regulator to adjust the pressure going into the lines according to the number of outlets installed (capped between 0 to 13 bar). Each cylinder has its own valve that connects it to the main line and is connected to this main line valve using a pigtail with a safety wire (a high-pressure hose); in the event the hose ruptures, the wire will stay in place rather than hitting someone at high speeds due to the pressure. The pigtail is connected to the cylinder with a bullnose or pin index connection. **All cylinders are chained or strapped into place to reduce potential for projectile hazards.**
The following device components should be similar regardless of model. However, specific locations, visual setup and component type may vary by brand and device model. Refer to model service and user manuals if different from the displayed model for more device-specific information.

### Housing

Oxygen cylinder housing is usually made of steel or aluminium alloy and distinguished from other gas cylinders by a black body and white collar.²

### Label

Identifies contents and provides safety and sizing information.

### Primary valve

Manually operated; opens the oxygen outlet port for oxygen flowing to the patient through pressure and flow regulators.

### Cap

Safety covering for the primary valve.

### Safety harness

The safety harness secures the oxygen cylinder to a specific location for added protection against compressed gas projectile safety.

### Inlet pressure gauge

Indicates the real time pressure value in the oxygen cylinder. The pressure gauge reading is directly proportional to the amount oxygen in the cylinder.

### Pressure regulator

Used to reduce the oxygen cylinder outlet pressure to a level that is safe for patient use. It can be adjustable or fixed and is usually set at 3.45 bar (345 kPa, 50 psi).¹

### Flow regulator

Flowmeter, controls and displays the oxygen delivery rate to the patient(s) in L/min. Since neonates require low flows, flow meters with precision of at least 0.1 L/min should be used. There are special ultra-low flowmeters available for use with neonates with precision adjustments of 0.02–0.03 L/min which, especially in settings which do not utilise blenders, can be particularly useful to provide necessary oxygen to neonates and minimising hyperoxia. However, ultra-low flowmeters are not
Great care should be taken to ensure safe oxygen administration when adjusting the oxygen flow through a standard flowmeter to monitor saturations and avoid hyperoxia, because the standard flowmeter does not allow for very low flow titrations. When possible, cylinder oxygen intended for neonatal patients should be blended with ambient air to prevent harm, through an oxygen blender attachment or blending mask (e.g., a Venturi mask or blender).

SAFETY SYSTEMS

Since cylinders may be used to store a range of different gases, several different safety systems are employed to avoid interchanging cylinders that can lead to administering wrong gases to a patient or refilling a cylinder with a wrong gas:

- **Labelling:** Identifies contents and provides safety and sizing information. Cylinder labels typically contain the name and chemical symbol of the gas, cylinder contents in litres, tare weight (weight when empty), maximum cylinder pressure, cylinder size code and directions for use. (2.4) Cylinder sizing follows a standard alphabetical order with each letter indicating its oxygen capacity. Each letter corresponds to the capacity in litres of that particular cylinder; cylinder sizes include D, E, F, G, J and corresponding capacities are 340, 680, 1360, 3400 and 6800 litres, respectively.

- **Colour-coding:** cylinders can be distinguished by colour. ISO standards specify that an oxygen cylinder can be distinguished from other cylinders by a black body and white shoulders and top, although colour-coding varies by context and should be confirmed for local standards. Colour should not be used as a primary way of differentiating cylinders due to this lack of universal standardisation and colour variation due to chemical changes of paint pigments with time.

- **Pin index:** usually employed in smaller cylinders, the pin index safety system identifies gas cylinders with specifically positioned holes below the outlet port. The valve can then only be connected to a yoke or pressure regulator with a matching pair of pins. (2.5)

- **Diameter index or bullnose:** most commonly employed in bigger cylinders, the pressure regulator bullnose of a particular gas will only connect to a bullnose valve of a cylinder of a similar gas. The nip and nut assembly of the bullnose connector is different for each type of gas. (2.6) Oxygen (DISS 1240) has been assigned 9/16”-18 thread connections as its DISS identifier.
Management covers how to use the oxygen cylinder, including set up for a patient, patient commencement, care whilst on the device and removal of the patient from the device. These instructions are helpful for a biomedical engineer or technician both in user training and in assessing the appropriate functionality of the device.

**SETTING UP FOR A PATIENT**

1. Clean hands with soap and water or 70% alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.

2. Make sure the oxygen cylinder is in an upright position and is secured to a wall or stable object.

3. Assemble the pressure regulator and the flowmeter and connect them to the cylinder using the pin index connector. The flowmeter must be upright (vertical to the floor) to be read correctly. Tighten all connections and make sure there are no leaks. Ensure that the cylinder’s flowmeter is closed.

4. Slowly open the primary valve (using the cylinder key or hand-wheel). Check the amount of oxygen in the cylinder by reading the pressure gauge.

5. Connect the oxygen delivery device (e.g., nasal cannula, Venturi mask, bCPAP, etc.). Adjust the flowrate required with the flowmeter regulator.

6. If the patient’s healthcare provider has determined the patient requires humidification, assist the healthcare worker to ensure a humidifier is correctly connected to the concentrator. If oxygen needs are greater than 4 L/min, a humidifier is recommended.\(^5,6\) (Alert 3.1)
Per WHO recommendation in *WHO Oxygen Therapy for Children* and *WHO Technical Specifications and Guidance for Oxygen Therapy Devices*, when oxygen is delivered at higher than standard flow rates (> 1L/min for neonatal and 2L/min for infant patients), humidification is necessary. Ultimately, the decision to humidify low flow oxygen or not is a clinical one which is influenced by oxygen source (tank, concentrator), oxygen flow, climate, patient age, resource availability and clinical status. If used in series with another device, humidification should be added after the device and just prior to the patient interface to prevent moisture build-up in the ancillary device.

Test that oxygen flow has begun by listening for a hissing sound at the patient end of the delivery device (e.g., nasal prongs). This also can be tested by submerging the nasal prongs in clean water and checking for bubbles (3.1), also known as the “Bubble Test”.

**Alert 3.1**

Infection Prevention

Routine and adequate cleaning of medical devices is critical to prevent hospital-acquired infections in newborn care units.

**CLINICAL INFECTION PREVENTION**

1. Clean hands with soap and water or 70% alcohol before and after placing a patient on oxygen or handling any tubing that will be used on a patient.
2. Ensure that all patient-related tubing or interfaces are new or has been cleaned thoroughly and dried as per re-use guidelines. Any patient-related tubing or interfaces must be cleaned immediately after use; if reusing, immediately begin hospital protocol for disinfection of any patient-related tubing or interfaces. Delay in initiating cleaning of reused medical devices can lead to the need for more intensive cleaning procedures to remove pathogens. If not reusing, discard appropriately. (Alert 4.1)
3 Tubing should be hung to dry after disinfection and should not touch the floor or other unsanitary surfaces whilst drying. Any item falling on the floor is contaminated and must be thoroughly recleaned.

**Alert 4.1**

Respiratory circuits and humidifiers associated with oxygen delivery are generally intended as single use devices. However, in areas with limited resources or challenging supply chains, this equipment is often re-used. When re-processing single use devices it is extremely important that the cleaning process is not delayed following completion of use. If equipment is not re-processed promptly or adequately between patients, it poses a significant infection risk. Please refer to the Reference Manual for Health Care Facilities with Limited Resources Infection Prevention and Control, Module 6 for more detailed guidance on the re-processing of single use devices.

4 The housing of the oxygen cylinder should be cleaned according to ward guidelines for disinfecting surfaces, or by wiping down with soapy water.

5 Ensure the primary valve is tightly shut in between patients and whilst being stored.

### DISINFECTION AFTER USE

1 Close the flowmeter on the cylinder. Clean the flowmeter, gauge and dials using 70% alcohol after every use. (**Alert 4.2**)

2 Dispose of water within humidifier bottle and, if reusing humidifier and tubing, immediately remove and begin hospital protocol for disinfection. (**Alert 4.1**)

### BMET INFECTION PREVENTION

1 Any piece of equipment used in providing patient care must be handled carefully, as it may be contaminated and have the potential to spread infection.

2 Clean and disinfect oxygen cylinder housing and components whilst wearing PPE as appropriate (e.g., rubber gloves, apron, face protection, etc.) before any repairs or maintenance are made. Avoid any contact between used piece of equipment and skin, mucosa or clothing.

3 Post-maintenance, decontaminate all tools and surfaces used with 70% alcohol or according to manufacturer guidelines. Do not use equipment until it has fully dried following decontamination.
5 Complications

Equipment in newborn care units are highly specialised. Without proper knowledge and skills, this equipment can be potentially dangerous for the infants, families and care providers.

DEVICE COMPLICATIONS

- **Fire**: oxygen is an agent of combustion, meaning fire will burn more readily in its presence. Never use grease or oil to lubricate parts of the oxygen cylinder.

- **Pressurised gas**: oxygen cylinders are filled at very high pressures and must be chained to secure in place. (5.1) Accidentally tipping over a high-pressurised oxygen cylinder can easily dislodge the valve stem, creating a high-speed projectile. This projectile can move with sufficient speed and strength to break through cement walls, posing an extreme danger to surrounding patients, health staff and hospital infrastructure. (5.2) The safety cap must be on the cylinder when the pressure regulator is not attached. (Alert 5.1)
- **Cylinder empty**: the primary valve on the cylinder must be turned off completely when the cylinder is not in use. It is not uncommon for the valve to be left partially open, slowly emptying the cylinder. Excessive force in closing the valve should be avoided as it may result in stripping the threading.

**Alert 5.1**

Irresponsible use of high pressurised oxygen cylinders could easily result in a disaster, serious injury or death for patients or staff on the ward. Strict adherence to safety protocol, maintenance and proper use is critical when using oxygen cylinders.

---

### 6 Care & Maintenance

Biomedical engineers and technicians are responsible for second-line care and maintenance to ensure equipment lasts to their potential lifetime.

**POWER SOURCE**

Oxygen cylinders are not powered.

**WARD LOCATION**

Oxygen cylinders should always be kept well-secured and safe from tipping or dropping, ideally along a wall with securing chains anchored into the wall. **Oxygen cylinders should not be placed precariously, tilted or located without securing chains in the middle of walking areas.** Store in well ventilated, clean and dry conditions. Oxygen cylinders should be well labelled and easily distinguishable from other cylinders. Keep away from contaminants like oil and grease and sources of heat or ignition. **Always use a secure trolley when transporting cylinders.** Oxygen cylinders may also be stored in oxygen manifolds for smaller patient loads. Equivalent requirements for safe securing of cylinders apply.

**DEVICE CALIBRATION**

Pressure gauges require yearly calibration. This should be completed by calibration professionals in accordance with the accuracy class of the pressure gauge. Low pressure gauges may be calibrated with air or gas; however, due to the high pressure range in oxygen cylinders, it may be safer to use liquid.

Oxygen cylinders require hydrostatic testing every 3, 5 or 10 years to ensure that the cylinder can safely hold maximum fill pressure. Hydrostatic testing checks the structural integrity of the oxygen
cylinder by filling the cylinder with water and pressuring it above its normal operating limit. If the cylinder expands under pressure beyond acceptable limits, the cylinder must be decommissioned.¹⁰

**DECOMMISSIONING**

Oxygen cylinders are usable as long as they are in physically good condition. As the use of oxygen cylinders is high-risk, physical damage should be taken seriously and cylinders decommissioned if structural integrity is compromised or if they fail hydrostatic testing. In these cases, if the primary valve stem is still in good condition, it may be reused and the cylinder housing repurposed. Components used with oxygen cylinders may also be reused or repurposed (e.g., oxygen regulators, flowmeters).
# PREVENTIVE MAINTENANCE

## After Each Use

- Turn the primary valve to close the oxygen cylinder. Use gauze and 70% alcohol or diluted chlorine to thoroughly wipe the oxygen flowmeter controls and primary valve.
  
  See Oxygen Cylinder: **Disinfection After Use** and **Alert 4.1** for more information.
  
- Visually inspect oxygen cylinder components and location. Ensure that cylinder is securely chained in place.

## Weekly

- **Check the regulator:**
  - Assemble the pressure regulator and the flowmeter and connect them to the cylinder using the pin index connector. Tighten all connections and make sure there are no leaks. Ensure that the cylinder’s flowmeter is closed.
  - Slowly open the primary valve (using the cylinder key or hand-wheel). Check the amount of oxygen in the cylinder by reading the pressure gauge.
  - Open the flowmeter its lowest setting and flush the pressure gauge and flow meter with oxygen for 2 minutes.
  - Confirm that there are no audible sounds of leakage and that the flow meter can go up to its maximum delivery rate.

- Examine the outside of the cylinder for dents, burns or grease.
- Document pressure reading and preventive maintenance actions taken.

## Monthly

- Perform **Weekly** preventive maintenance steps.
- Visually assess the filling port for debris, grease and signs of corrosion.
- Document pressure reading and preventive maintenance actions taken.

## Quarterly

- Perform **Monthly** preventive maintenance steps.
- Assess oxygen cylinder infrastructure in ward for accessibility of securing chains and patient access.
- Document pressure reading and preventive maintenance actions taken.

## Annually

- Perform **Quarterly** preventive maintenance steps.
- Request **Pressure Gauge Calibration**
- Check dates for hydrostatic testing for all cylinders. If necessary, request **hydrostatic testing**.
- Confirm supply of spare pressure gauges, pressure regulators, O-ring/sealing gaskets, securing chains and oxygen tubing are adequate to support estimated replacement for next year.
- Document pressure reading and preventive maintenance actions taken.
7 Troubleshooting & Repair

Biomedical engineers and technicians are responsible for providing rapid maintenance, troubleshooting and repair support for users.

PREPARE FOR REPAIR

<table>
<thead>
<tr>
<th>ACCESSIBLE TOOLS</th>
<th>SPARE PARTS</th>
<th>DEVICE CHECKLIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phillips, star &amp; flathead screwdrivers</td>
<td>Primary valve</td>
<td>☐ Oxygen cylinder</td>
</tr>
<tr>
<td>Allen keys</td>
<td>Pressure gauge</td>
<td>☐ Pressure regulator</td>
</tr>
<tr>
<td>Adjustable wrench</td>
<td>Pressure regulator</td>
<td>☐ Pressure gauge</td>
</tr>
<tr>
<td>Needle nose pliers</td>
<td>O-ring / sealing gasket</td>
<td>☐ Flow regulator</td>
</tr>
<tr>
<td>Soapy water</td>
<td>Tubing</td>
<td></td>
</tr>
<tr>
<td>Oxygen analyser</td>
<td>Crimp or zip ties</td>
<td></td>
</tr>
<tr>
<td>Pressure gauge</td>
<td>Flow regulator</td>
<td></td>
</tr>
</tbody>
</table>

TROUBLESHOOTING FAILURES

No oxygen is emitted from the oxygen cylinder.

**Probable Cause:** Faulty pressure regulator or loose connection

**Components to Check:**
- Pressure gauge and regulator physical condition
- Remaining gas volume
- O-ring / sealing gasket physical condition

The oxygen cylinder is emitting an audible hiss.

**Probable Cause:** Leakage or loose connection

**Components to Check:**
- Tubing & component physical condition
- O-ring / sealing gasket physical condition

Oxygen is flowing, but flowmeter ball is not moving or the pressure gauge does not show any pressure.

**Probable Cause:** Debris in flowmeter connection circuit or pressure gauge fault

**Components to Check:**
- Flowmeter physical condition
- Pressure gauge and regulator physical condition
Oxygen cylinders should be removed to the biomedical workshop for testing or repair. (7.1)

### Alert 7.1

All testing, repair and replacement steps should be conducted with the oxygen cylinder secured to a wall or bracket, unless otherwise stated.

### Testing & replacing the pressure regulator

Close the primary valve and remove the pressure regulator. Visually inspect the pressure regulator for physical damage on the external housing and the valve outlet for debris that may be obstructing flow or allowing leaks. Remove any debris with a clean, dry cloth. Connect the regulator with another oxygen cylinder to test its functionality. If a replacement regulator is needed, check the oxygen cylinder specifications before purchasing and installing a replacement. Tape, epoxy and other glues should not be used to prevent leaks on oxygen cylinder connections. Assess that the pressure displayed is as expected for the cylinder contents; if this reading is low, the pressure regulator and cylinder connection may be leaking.

### Testing & replacing the tubing components

Leaks may contribute to both low oxygen flow delivery and accelerated oxygen use. Tubing can be assessed for leaks by running soapy water or foam along the suspected tubing, pipes and fittings during operation and checking for bubbles or movement of the liquid.

### Testing & replacing O-rings/sealing gaskets

Sealing gaskets are present at various points in the oxygen cylinder circuit and should be checked if leaks are present in the system. Remove the pressure regulator and check the condition of the Bodok seal fitted between the cylinder and the regulator. If deteriorated, replace. If a humidifier or flowmeter is in circuit, check the O-rings at each of these points for deterioration.

### Testing & replacing the flowmeter

The flowmeter may be damaged through user error or through lack of use and preventive maintenance over time. User error is design dependent; if the flowmeter is not designed to prevent the flowmeter bead from falling into the regulating knob channel, the flowmeter bead can be damaged or crushed as the flowmeter is closed. In most cases, the flowmeter bead is not a spare part and this damage will require the entire flowmeter assembly to be replaced.

The flowmeter may also develop debris or deposits that affect the movement of the flowmeter bead within the flowmeter channel. This can be repaired by taking apart and cleaning the flowmeter.

### Alert 7.2

Correct parts must be used when repairing or replacing components of the oxygen cylinder. If correct parts are unavailable, liaise with a local oxygen cylinder supply company for appropriate replacement parts. Using incorrect parts can lead to fire, physical damage and oxygen waste.
8 References

8. World Health Organization, Regional Office for the Western Pacific, World Health Organization, & Regional Office for South-East Asia. Practical guidelines for infection control in health care facilities. (World Health Organization, Regional Office for Western Pacific; World Health Organization, Regional Office for South-East Asia, 2004).
11. BOC Limited. PTFE tape and oxygen service. https://www.boconline.co.uk/.