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 Concentrator

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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.
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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°.
Technical Education Modules

Respiratory Support – Oxygen Therapy

Oxygen Concentrator (Canta V8-WN-NS) NEST360°

ABBREVIATIONS

bCPAP Bubble continuous positive airway pressure
BMET Biomedical Equipment Technician
dL Decilitre
ESD Electrostatic Discharge
FiO₂ 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
O₂ Oxygen
OGT Orogastric tube
PCB Printed Circuit Board
ppm Parts per million
ROP Retinopathy of Prematurity
PSA Pressure Swing Adsorption
PSU Power Supply Unit
ROP Retinopathy of Prematurity
SpO₂ 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 Torx 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, ail90@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 Concentrator
1 Clinical Problem

Oxygen concentrators are used in multiple hospital settings. In newborn care units, oxygen concentrators are used as standalone or partner devices to deliver oxygen therapy.

Concentrators may be used to share oxygen between multiple patients using a flow splitter or used with other treatment devices such as continuous positive airway pressure (CPAP) devices. Supplemental oxygen is indicated for sick children, especially those with low blood oxygen saturation levels (typically $\text{SpO}_2<90\%$), which has many clinical causes.

2 Assessment

Oxygen concentrators (2.1) provide a source of oxygen with typical maximum cumulative output flow rates of 5, 8, 10 or 20 L/min. Both maximum and minimum flow capacity depend on device model.

Oxygen concentrators are one of the most commonly used sources of oxygen therapy, concentrating 85–95.5% oxygen from ambient air using two sieve beds containing a substance that adsorbs nitrogen at high pressures.

2.1 Typical oxygen concentrators.
Oxygen concentrators may have one or two oxygen output ports that may be used to supply oxygen directly to one or two patients or to multiple patients at low flows using a flow splitter. Each output port has an flowmeter that can be adjusted to regulate flow from that port. Oxygen can be delivered using both ports simultaneously.

Oxygen concentrators may provide oxygen via two types of flow:

- **Intermittent/pulse flow**: provides puffs of oxygen into nasal passageway at typical breathing rates.
- **Continuous**: provides constant oxygen delivery at a steady rate.

In intermediate care newborn units, concentrators with continuous oxygen delivery are required for most applications.

Typically, all flowmeters on an oxygen concentrator are graduated to the maximum capacity of the concentrator (e.g. if maximum flow capacity is 10L/min then there may be 2 flowmeters on the device each graduated to 10L/min flow, as in 2.2). However, while both flowmeter ports may be used simultaneously, the maximum flow rate at which the device can produce 85–95.5% oxygen remains the same (e.g., a 10 L/min oxygen concentrator can only produce 10 L/min of oxygen at a time, regardless of the number of ports or splitters in use). Combined flowrate from all ports during use must not exceed the total recommended flow rate. Should the combined flow rate go over the maximum capacity of the oxygen concentrator, the produced oxygen purity will drop, decreasing the oxygen delivered to the patient.

**HOW IT WORKS**

An oxygen concentrator operates on the principle of Pressure Swing Adsorption (PSA) using a microporous granulated molecular sieve material called zeolite. Zeolite has the property of selectively adsorbing (trapping) nitrogen from air at high pressure and desorbing (releasing)
Nitrogen at low pressure hence the name pressure swing (swinging between low and high). For the purposes of an oxygen concentrator, the zeolite is contained in two cylindrical canisters called molecular sieve beds.

Air at atmospheric pressure of 14.7 psi (101 kPa, 1.01 bar) is filtered and drawn into the concentrator by the cabinet fan and compressor. The compressor raises the air pressure to about 30 psi (206 kPa, 2.1 bar) and feeds it into one of the molecular sieve beds (controlled by the feed & waste valves). Nitrogen is adsorbed by the zeolite granules while oxygen is allowed to pass. The residual oxygen is collected at the molecular sieve bed outlet port into the product tank. After 10 to 15 seconds the zeolite will be saturated with nitrogen. At this point, it can no longer adsorb further and the supply of compressed air is automatically switched to the second molecular sieve bed where it undergoes the same sieving process.

Concurrently, the pressure in the first molecular sieve bed is reduced to atmospheric pressure by venting it back to the atmosphere. This allows the trapped nitrogen to be released from the zeolite back to the atmosphere. By releasing nitrogen, the zeolite becomes regenerated and ready for the next cycle. By having two sieve beds a continuous supply of oxygen is ensured. There is no lag in production as the molecular sieve beds alternate between oxygen production and zeolite regeneration.

Standard external and internal device components are annotated below in Figures 2.5 and 2.6. Components should be similar regardless of model. However, specific locations, visual setup and component type may vary by brand and device model. Refer to service and user manuals if model in use is different from the displayed version.
2.4 (a) External components (front view).

2.4 (b) Internal components (front view).

2.5 Internal components (back and side view).
TYPICAL DEVICE FLOW

Ambient Air Intake

Power Supply

9V Power Supply, Alarm

Gross Particle Intake Filter

Intake Muffler

Fine Particle Intake Filter

Alarm Indicators

Display

000 Hours

Flow Meters

Product Tank

Product Filter

Molecular Sieve Bed 1

Molecular Sieve Bed 2

Pressure Equalization Valve

Cabinet Fan

Feed & Waste Solenoid Valves

Oxygen Concentrator (Canta V8-WN-NS)

Oxygen Monitoring PCB

Control PCB

Fan Control PCB

Heat Exchanger

Compressor

Piston

Piston

Capacitor

Thermal Switch

Exhaust Muffler

Nitrogen Exhaust

10 Patient Oxygen Output
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 for more device-specific information.

**Compressor**

Pressurises ambient air by reducing its volume. As the ambient air pressurises, heat is produced. A typical compressor assembly is displayed in 2.6. Compressor output refers to how much compressed air the compressor can produce. This depends upon the model of the compressor, stroke size, bore size and cup seal condition. Some compressors may have a pressure relief valve (an automatic, typically spring-loaded mechanism that opens when the compressor experiences increased pressure to discharge the excess air into the atmosphere).

**Starting capacitor**

Starts and runs the compressor and keeps the auxiliary compressor motor coil running.

**Heat exchanger**

Reduces the temperature of the compressed air which has heated during the compression process.
**Thermal switch**

Cuts power to the compressor once the compressor running temperature exceeds maximum heat threshold.

**Control PCB**

Controls the opening and closing of the solenoid valves. It also controls all electronic and electrical components of the unit including alarms, pressure transducers and oxygen monitor circuits.

**Molecular sieve beds**

Canisters that contain zeolite (typically aluminum silicate), which adsorbs nitrogen from air at high pressures. Compressed air enters the sieve beds from the compressor at high pressure which allows the zeolite to adsorb the nitrogen in air, leaving 85–95.5% oxygen-enriched gas.

**Oxygen monitoring PCB**

Consists of an in-built oxygen analyser, typically ultrasonic, which monitors oxygen concentration in produced airflow. The oxygen monitoring PCB also processes output signal of the analyser in a pass/fail fashion.

**Solenoid valves**

Solenoid valves are electrically controlled valves with two main components: a solenoid (an electric coil with a movable electromagnetic plunger) and a valve. Solenoid valves remain at their “normal” position (open or closed) until an electric current creates a magnetic field to force the plunger up and open or close the valve.

In oxygen concentrators, solenoid valves are used to control feed and waste processes through the molecular sieve beds. **Feed valves** direct and regulate the flow of ambient air from the compressor to the sieve beds, while **waste valves** direct and regulate the exhaustion of nitrogen out of the sieve beds.

**Equalisation valve**

The equalisation valve plays two critical roles in the Pressure Swing Adsorption process:

1. It facilitates pressurization and nitrogen purging of the sieve under depressurizing cycle.
2. It directs some of the oxygen produced in one sieve to the other thus reducing energy requirements and increasing efficiency.

The equalisation valve may be a solenoid or mechanical valve.

**Cabinet fan**

The cabinet fan pulls ambient air into the unit and circulates air throughout insides of concentrator, cooling internal components. This component typically has its own PCB that controls power and rate information to the fan.
Pressure regulator

Controls the oxygen pressure as it leaves the product tank. This is typically set by the manufacturer to 20 psi (138 kPa, 1.4 bar).

Check valve

Prevents backflow of oxygen after air has been processed through the sieve beds.

Intake muffler

Minimises noise from compressor suction as air enters compressor.

Exhaust muffler

Minimises noise of nitrogen-rich air exhaust and discharges this air from concentrator.

Product tank

Reservoir where oxygen is kept before proceeding to the outlet ports. This tank stores a small amount of oxygen that is released when the device is turned off or power is lost.

Pressure relief valve

Reservoir where oxygen is kept before proceeding to the outlet ports. This tank stores a small amount of oxygen that is released when the device is turned off or power is lost.

Oxygen output ports

Product output ports; these ports may have free flowing oxygen or require a Christmas tree adapter to be connected to allow flow.

Fine particle intake filter

Internal to the machine, either composed of filter paper or thick white felt filter. Filters particles from air to protect the compressor.

Gross particle intake filter

External to the machine, very porous and only intended to filter out large particles.

Product filter

Filters fine particles from product oxygen stream prior to administration to patient. Unlike other filters, intended for use of unit lifetime.
**Hour meter**
Records the device's cumulative running time.

**Reset button**
Circuit breaker; resets the unit after electrical overload shutdown.

**Alarm battery**
Provides power to audible alarm speaker to ensure alarms sound during a power outage. Typically 9V.

**Alarms**
Alarms may be audible, visual or both. LED indicators may illuminate to indicate low oxygen output levels, flow restriction, high/low pressure, power supply failure, and high temperature. Some oxygen concentrators may have specific codes that designate each failure; refer to the model-specific user and service manual for more information.

**Flowmeter and regulator knobs**
Controls and displays the oxygen delivery rate to the patient(s) in L/min.

---

### 3 Management

Management covers how to use the oxygen concentrator, 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. Plug oxygen concentrator's power cable into the oxygen concentrator (3.1a) and into the wall and turn on power at socket. Turn on concentrator. (3.1b)
2 Set flow to desired rate. If machine has not been turned on, allow to run for five minutes or until indicator light (3.2) shows that concentrator is providing appropriate concentration of oxygen for treatment. Check that no alarms sound on the machine.

3 If the patient’s healthcare provider has determined the patient requires humidification, assist the healthcare worker to ensure humidifier is correctly connected to the concentrator. (Alert 3.1)

---

### 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.

---

4 Perform hand washing protocols. Connect appropriately sized nasal prongs to oxygen port on machine (3.3) or to humidifier (if using).

---

3.2 The “Low Oxygen” alarm indicates that produced concentrations are lower than 85.

3.3 Connect correctly sized nasal prongs to oxygen port.
5 Test that oxygen flow has begun by placing your finger near the nasal prongs, ensuring that flow commences. This can also be tested by submerging the nasal prongs in clean water and checking for bubbles (3.4), also known as the “Bubble Test.”

3.4 Submerging the nasal prongs in water should produce bubbles.

4 Infection Prevention

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

**CLINICAL INFECTION PREVENTION**

1. Housing of the oxygen concentrator should be cleaned according to ward guidelines for disinfecting surfaces.

2. 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.

3. 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)*

4. 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.
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.

**DISINFECTION AFTER USE**

1. Turn off and unplug the oxygen concentrator. If reusing tubing, immediately begin hospital protocol for disinfection.
2. Housing of the oxygen concentrator should be cleaned according to ward guidelines for disinfecting surfaces. Flowmeter controls and LEDs should be cleaned using 70% alcohol after every use. (Alert 4.2)

**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 concentrator 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.

**Alert 4.2 Disinfecting Equipment**

Disinfection of equipment should always comply with manufacturer guidelines. WHO recommends 0.5% dilution of chlorine (0.5% or > 100ppm available sodium hypochlorite) as the standard disinfectant for materials and surfaces contaminated by blood or body fluids. For metal and rubber surfaces, which may be corroded by chlorine, 70% alcohol is also commonly utilised for low level disinfection.

Other appropriate low-level disinfectants include quaternary ammonium, improved hydrogen peroxide and Iodophor germicidal detergent. Phenolic germicidal detergent is also identified but should not be used in neonatal wards since affordable, effective alternatives are available; and, there are concerns it may cause hyperbilirubinemia and/or neurotoxicity in neonates.

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

- **Inadequate oxygen concentrations**: if the oxygen concentrator indicates inadequate concentrations of oxygen (Alert 5.1), oxygen concentration has dropped below 82% and machine maintenance is needed. Replace the concentrator or switch to backup oxygen cylinder supply if available; if not available, increase monitoring frequency to ensure clinical stability until concentrator can be replaced or maintained.

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 concentrators may be powered via mains or grid power with a voltage protector in line, or a rechargeable battery, depending on the model.

WARD LOCATION

The concentrator should be located in a clean, dry, well-ventilated space. The back of the concentrator should be 30–35 cm away from the nearest wall to ensure that air can freely flow into the concentrator. Ideally, the concentrator is placed close to oxygen splitters or other ancillary equipment in use. To facilitate access, it should also be placed in a location that is easily viewed and accessed by ward staff.
DEVICE CALIBRATION

Manufacturers do not recommend calibration for any oxygen concentrator components.

DECOMMISSIONING

Assuming appropriate use and consistent maintenance, an oxygen concentrator may last up to 7 years. Generally, it is more fiscally responsible to repair oxygen concentrators when necessary, although there are some low-cost models that may be cheaper to replace rather than repair. Most components on an oxygen concentrator can be repurposed; exceptions are typically molecular sieve beds, which will become contaminated over time with moisture in the air.
PREVENTIVE MAINTENANCE

After Each Use

☐ Turn off and unplug the oxygen concentrator. Use gauze and 70% alcohol or diluted chlorine to thoroughly wipe the oxygen flowmeter controls, control panel and power button. See **Oxygen Concentrator: Disinfection After Use** and **Alert 4.2** for more information.

☐ Visually inspect oxygen concentrator components and location.

Weekly

☐ Visually assess and clean the external gross particle intake filter.

☐ Visually assess the internal fine particle intake filter. Clean or replace if needed. See **Oxygen Concentrator: Troubleshooting & Repair: Assessing, cleaning & replacing intake filters** for more detail.

☐ Turn on and allow the oxygen concentrator to run for 15 minutes. Confirm that no alarms are audibly or visually activated.

☐ Document cumulative hours run and preventive maintenance actions taken.

Monthly

☐ Perform **Weekly** preventive maintenance steps.

☐ Test the **power loss alarm**: while the oxygen concentrator is plugged in and turned on, turn off the power at the wall socket. An alarm should sound.

☐ Test the **oxygen concentration output** at both the minimum and maximum flow range of the oxygen concentrator using an oxygen analyser:
  - Remove humidifier bottle if on device. Moisture can damage the analyser.
  - Turn on the oxygen concentrator. Allow the concentrator to run for 5 minutes.
  - Connect an oxygen analyser to the outlet port and wait for reading to stabilise.
  - Assess concentration and output flow rate at both minimum and maximum flow rates on all oxygen outlet ports.

If an analyser is not available, observe the ‘Low Oxygen’ LED indicator.

☐ Visually assess the internal housing and compartments for dust. Blow clean if necessary.

☐ Document cumulative hours run and preventive maintenance actions taken.

Quarterly

☐ Perform **Monthly** preventive maintenance steps.

☐ Audibly assess the concentrator for sounds outside of standard operation.

☐ Measure grounding integrity and casing leakage current.

☐ Document cumulative hours run and preventive maintenance actions taken.

Annually

☐ Perform **Quarterly** preventive maintenance steps.

☐ Confirm supply of spare power supply units, sieve beds, control PCBs, solenoid valves, compressor rebuild kit, intake filters and power cables are adequate to support estimated replacement for next year.

☐ Document cumulative hours run and preventive maintenance actions taken.
# 7 Troubleshooting & Repair

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

## PREPARE FOR REPAIR

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<td>Permanent marker</td>
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<tr>
<td>Pressure gauge</td>
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## TROUBLESHOOTING FAILURES

### The oxygen concentrator is not turning on.

**Probable Cause:** Faulty power supply

**Components to Check:**
- Power cable continuity
- Reset button/circuit breaker activation & continuity
- Power switch physical integrity & continuity
- Power entry module fuse(s) physical integrity & continuity
- Power supply unit continuity & voltage
- Control PCB physical & electrical integrity and continuity
<table>
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<tr>
<th>Probable Cause</th>
<th>Components to Check</th>
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<td>The concentrator turns on, but a ‘Low Oxygen Concentration’ indicator is activated.</td>
<td>Contaminated sieve beds, worn compressor or blocked filters leading to low internal pressure</td>
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<td></td>
<td>Cumulative flow delivered</td>
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<tr>
<td></td>
<td>Gross and fine particle intake filter condition</td>
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<td></td>
<td>Sieve bed operating pressure</td>
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<td></td>
<td>Compressor physical condition</td>
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<tr>
<td></td>
<td>Control and Oxygen Monitoring PCB physical &amp; electrical integrity &amp; continuity</td>
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<td></td>
<td>Solenoid valves resistance &amp; magnetisation</td>
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<td>The concentrator turns on, but no flow comes from the oxygen ports.</td>
<td>Blocked oxygen port or displaced internal tubing</td>
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<td>Probable Cause:</td>
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<td>Components to Check:</td>
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<td>The concentrator turns on, but the compressor periodically shuts down.</td>
<td>Overheated compressor or restricted airflow</td>
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<td>Probable Cause:</td>
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<td>Components to Check:</td>
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<td>Internal tubing condition</td>
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<td>The concentrator turns on, but a loud popping sound is emitted from the device.</td>
<td>Compressor relief valve release due to high system operating pressure</td>
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<td>Probable Cause:</td>
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<td>Components to Check:</td>
<td>Sieve bed operating pressure</td>
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<td></td>
<td>Solenoid valves resistance</td>
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<td>Compressor &amp; compressor relief valve condition</td>
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<td>Control PCB physical &amp; electrical integrity &amp; continuity</td>
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<td>The concentrator turns on, but the compressor does not start.</td>
<td>Overheated or cold compressor</td>
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<td>Probable Cause:</td>
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<td>Components to Check:</td>
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<td>Internal electrical connections</td>
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<td></td>
<td>Control PCB physical &amp; electrical integrity &amp; continuity</td>
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</table>
Reset button trips repeatedly when power switch is ‘On’.

**Probable Cause:** Poor mains power quality or faulty reset button

**Components to Check:**
- Mains power quality
- Internal electrical connections
- Compressor electrical integrity
- Control PCB electrical integrity & continuity
- Reset button electrical integrity

The concentrator flow meter bead(s) fluctuate more than ¼ L/min.

**Probable Cause:** Leakage or loose internal connection

**Components to Check:**
- Cumulative flow delivered
- Internal tubing condition
- Flowmeter physical condition
- Gross and fine particle intake filter condition
- Sieve bed operating pressure
- Compressor physical condition
- Control & Oxygen Monitoring PCB physical & electrical integrity & continuity
- Solenoid valves resistance

**REPAIR & REPLACE**

Where technically possible and not likely to obstruct clinical care, repairs may be made within the newborn care ward. Use discretion to determine if this is appropriate or if the device should be removed to the biomedical workshop for more testing or repair. *Always refer to the manufacturer’s user and service manual before beginning any repair procedures.*

### Alert 7.1

All testing, repair and replacement steps should be conducted with the power to the device switched off and the power cable removed from mains power, unless otherwise stated.

**Testing & replacing the power supply fuses**

Fuses may be located both on the oxygen concentrator housing and on the power supply cable. Fuse integrity may be visually assessed or evaluated by testing the continuity across the fuse. Always refer to the manufacturer specifications for replacement fuses to ensure that the device remains electrically sound in standard operation.

**Testing & replacing the power switch**

Power switches should be tested in both the off and on positions to confirm functionality. In the **On** position, the switch terminals should be continuous. In the **Off** position, the switch terminals should show a high resistance, or **OL** in most multimeters.

If the switch shows continuity or discontinuity inappropriately, assess the switch for visible physical or electrical damage. If the switch is visibly damaged or dislodged, assess whether the part can be
repaired with glue or solder. If it cannot be easily repaired, replace the switch. Always refer to the manufacturer specifications for replacement switches to ensure that the device remains electrically sound in standard operation.

**Testing & replacing the power supply unit or module**

Testing the power supply unit cannot be completed appropriately without checking the alternating voltage at the power supply unit. **This should be completed with caution**, as the power to the device must be switched on to accurately measure the voltage delivered. If the power supply unit or module is damaged, contact the manufacturer to request a replacement part.

**Testing & replacing control PCB and associated components**

In most cases, if one element of the control PCB has malfunctioned, the entire control PCB should be replaced. Visually assess the PCB for burnt or damaged components. *(7.1 – 7.6)* Internal wiring continuity leading from the power supply to the control PCB and from the control PCB to the other components may also be assessed for replacement. *(Alert 7.2, Alert 7.3)*

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### Alert 7.2

Printed Circuit Boards (PCBs) contain components that are sensitive to electrostatic discharge (ESD) and can damage the board if not handled properly. As when handling any ESD-sensitive PCB, observe standard ESD safety procedures.

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7.1 Unscrew the housing.

7.2 Remove the housing to access internal components.

7.3 Unscrew and slide the front housing off of the device.
When disassembling and reassembling devices, it is critical that all parts are connected back to the sections of the circuit board that they were initially in. For more complicated devices, it is best to take photographs of the repair process as steps are conducted. These photos can then be used as a reference with the manufacturer’s service manual when putting the device back together. Connecting and turning on a device in the wrong component orientation can cause permanent damage to a device.

Alert 7.3

Assessing cumulative flow delivery

Although both oxygen flowmeters on an oxygen concentrator are graduated to the maximum capacity of the machine and may be used simultaneously, the maximum flowrate at which the device can produce recommended purity of oxygen remains the same (e.g., a 10 L/min oxygen concentrator can only produce 10 L/min of oxygen at a time, regardless of the number of ports or splitters in use). Should the combined flowrate go over the maximum capacity of the oxygen concentrator, the produced oxygen purity will drop, decreasing the oxygen delivered to the patient. Users should be oriented on cumulative flow and a safety label placed on the oxygen concentrator to facilitate safe use. (7.7)

To assess the cumulative flow delivery, oxygen flow rates from all oxygen ports (in L/min) should be summed and compared to the maximum oxygen capacity for the concentrator model (in L/min). If this exceeds the maximum oxygen capacity, the oxygen flow rates must be decreased until their cumulative flow is within model specifications.

Over the oxygen concentrator’s lifetime, the maximum output flow rate that can be produced whilst retaining 90% to 95% oxygen concentrations may decrease by 1 or 2 L/min. This can be improved by replacing or rebuilding the compressor and sieve beds but indicates that the oxygen concentrator is nearing the end of its usable lifetime and should be considered for decommission.
Testing & repairing the oxygen outlet ports

Over time, oxygen outlet ports may accumulate deposits or debris that block oxygen flow from the concentrator. Ports should be visually inspected using a penlight and cleaned using ear swabs or forceps wrapped in gauze soaked in 70% alcohol.

Testing & replacing internal tubing components

Leaks may contribute to both low operating pressure and accelerated failure of molecular sieve beds. Internal tubing can be assessed for leaks by running oil-free, mild or diluted soapy water or leak-testing foam along the suspected tubing, pipes and fittings during operation and checking for bubbles or movement of the liquid.

Internal tubing may have springs in place to protect from kinks or bends. When replacing tubing, remember to remove the springs and replace in the new tubing.

Assessing, cleaning & replacing intake filters

Frequency of maintenance increases in hot, humid and/or dusty operating environments. As the gross (7.8) and fine (7.9) particle intake filters become clogged with dust or other debris, intake airflow to the compressor becomes constricted and decreases the efficacy of the PSA process. Intake filters should be assessed and cleaned regularly whilst wearing appropriate PPE (including gloves, a face mask and safety glasses, if available). The fine particle intake filter should be replaced after every 5 000 hours of use.

7.7 Sample safety labels for (A) 10 L/min and (B) 8 L/min concentrators: delivered oxygen from all oxygen ports should not exceed maximum oxygen capacity.
Clean the gross particle intake filter:

1. Pull gross particle intake filter gently from the back of the oxygen concentrator. Replace with spare.
2. Put the filter in warm, soapy water and swirl gently to remove debris.
3. Remove from soapy water and rinse with clean water. Place in shaded area until completely dry. Store as spare filter until next cleaning is required.

Cleaning the fine particle intake filter:

1. Open the oxygen concentrator housing. The fine particle intake filter is internal to the device, although the exact position varies by oxygen concentrator model.
2. Remove the fine particle intake filter. Replace with spare filter. (7.10 – 7.12)
3. Take the filter to an outside or well-ventilated area. Hold the filter firmly a distance away from and downwind of any individuals. Use compressed air to blow dirt and debris off the filter. If compressed air is not available, a pen or pencil may also be used to firmly strike the internal filter. (7.13 – 7.14)
4. Dust clouds will rise off the filter. Continue striking or blowing compressed air until dust no longer comes off and the colour has visibly lightened.
5. Assess the condition of the fine particle intake filter. If the filter is not damaged, store as spare filter until next cleaning is required. **The fine particle intake filter should be replaced after every 5 000 hours of use.**
Testing & replacing sieve beds

With lack of use or with age, the molecular sieve materials within sieve beds may become contaminated with water molecules. This decreases the amount of open space for the nitrogen in ambient air to bind to during PSA cycles and obstructs airflow over the molecular sieve. This contamination decreases the efficacy of the oxygen concentrator. High operating pressure and low oxygen concentration levels may indicate that the sieve beds have been contaminated and need to be replaced. (7.15 – 7.18)

Sieve beds should be replaced in pairs. While replacing, sieve bed spares should be temporarily sealed with tape until installation is complete to prevent contamination of the molecular sieve from the moisture in the ambient air. After installation of the spare sieve beds, careful leak testing should be conducted to ensure that there are no small leaks that may contaminate the newly installed sieve beds. See Oxygen Concentrator: Troubleshooting & Repair: Testing & replacing internal tubing components for more information.
Testing & replacing the compressor and its components

Compressor output depends upon the model of the compressor, stroke size, bore size, and cup seal condition. The cup seals form the seal between the piston and the cylinder wall. As the cup seals wear, the compressor’s output begins to gradually decrease. This reduction in compressor output results in less air for the sieve beds and decreases the production of oxygen. The condition of the compressor’s cup seals, bearings, and other components can also result in a noticeably louder running sound.

Compressor units may be serviced by replacing internal cup seals and bearings using a compressor rebuild kit (7.19 – 7.26). If rebuilding the compressor using a rebuild kit is not sufficient to repair the compressor, the entire compressor unit may also be replaced.
Alert 7.4

When reassembling the compressor after replacing the compressor kit, assemble the compressor sleeve, plates and cups before reattaching. It is important that the compressor plates and cups have adequate purchase in the compressor sleeves; if this is not done in the first attempt, push the compressor plate and cup through the sleeve and try again. Always nest the plate within the cup before pushing into the compressor sleeve.

Compressor segments are directional. Always label the sides of the compressor with permanent ink to ensure the correct pieces are installed for the correct side.

7.19 Slide panel up to access compressor.

7.20 Mark sides of the compressor.

7.21 Use a ratchet to remove the bolts securing compressor head.

7.22 Lift off compressor head & assess head gaskets for damage.

7.23 Turn over valve plate and assess o-rings and reeds for damage. Replace if necessary.

7.24 Remove compressor sleeves & assess for visible damage. Clean interior with alcohol & cotton swab.
The compressor relief valve and starting capacitor may also need replacement. These parts should be interchangeable with components of equivalent specifications, which can usually be determined from the component housing or device service manual.

### Testing & replacing solenoid valves

Solenoid valves may be tested using a multimeter or by checking the magnetisation of the coils during operation. Valve coil resistance specifications for feed, waste and equalisation valves should be available from the manufacturer or service manual for a specific model. Coil specifications may vary within a model or between AC ratings.

Magnetisation can be tested by holding the metal tip of a magnetized screwdriver over the exposed top of the valve stem in the centre of the coil. When the coil becomes energized (magnetized) the tip of the screwdriver should be pulled down onto valve stem, indicating the valve coil is functional.

Solenoid valves may be serviced by replacing the internal coil or the entire solenoid valve assembly. The internal coil is directional and must be replaced in the same orientation as it was removed.

### Assessing & replacing the fan

Most fan-related failures are due to physical damage to the fan itself or electrical damage to the fan PCB. The fan can be visually assessed for repair and replacement. The most common electrical damage to the fan PCB is the burnout of the fan transformer, which can be visually or electrically assessed. As in most PCB-based repairs, if one element of the PCB has been damaged, the entire PCB should be replaced.

### Testing & replacing the thermal switch

The thermal switch shuts down the compressor when it exceeds a high temperature threshold. The oxygen concentrator may keep running the fan to allow for more rapid cooling, but it will not be able to fully turn on until cooler temperatures are reached within the concentrator. The thermal switch may become faulty over time due to poor power quality or consistently high running temperatures. A faulty thermal switch will prevent the compressor from running even during
standard operating temperatures. Test the electrical integrity of the thermal switch using a multimeter; if a replacement is needed, contact the manufacturer for appropriate spares.

**Assessing, repairing & 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. (7.27)

![Image: Points to remove flowmeter for replacement, cleaning or repair.](image)

**Assessing power quality**

A qualitative measurement of power quality can be taken using an oscilloscope to observe the shape of the AC voltage delivered at the mains socket. If noise or other interference is visible on the voltage sine wave, the power quality is poor. Poor power quality contributes to the general accelerated failure of electrical components in medical devices, as do frequent differences in voltage delivered (e.g., lags and surges). If poor power quality is noted (either through observation or qualitative measurement) an in-line voltage stabilizer can be installed at a facility or ward level.

**Assessing & replacing the reset button**

The reset button is a circuit breaker that shuts down the concentrator completely when it experiences an electrical overload. The reset button may become faulty over time due to poor power quality. A faulty reset button will continuously shut down the concentrator repeatedly on any circuit it is plugged into, regardless of the power quality. This can be tested by assessing the power quality or voltage delivered from the mains power circuit the concentrator is on. If the power quality is acceptable, the reset button should be replaced. (7.28 – 7.30)
In some cases, parts on the unit may be replaced with a repurposed or recycled part from another piece of equipment being used for parts. Repurposed parts should be considered with caution and guidance from the manufacturer to ensure specifications of the repurposed part is compatible with the equipment. This includes spare parts and accessories that may not be compatible with multiple systems.
8 References

5. 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).