

Setting up a ward oxygen system: Installation Guide

This is a quick-reference guide to installing ward oxygen systems using oxygen concentrator (or cylinders), low-pressure plastic tubing, and flowmeter stands. This does not include advice on procurement, or technical specifications. This does not include advice on oxygen for intensive care.

Contents

| | |
|--|----|
| A) Pre-installation Checklist..... | 2 |
| B) Plan the installation | 2 |
| C) Installing the concentrator..... | 4 |
| D) Installing the oxygen cylinder | 5 |
| E) Installing the flowmeter stand..... | 6 |
| E) Installing the distribution tubing | 7 |
| Appendix 1 – General design guidelines..... | 11 |
| Severe Acute Respiratory Infection (SARI) wards, including COVID-19..... | 11 |
| Appendix 2 – Equipment list | 15 |
| Appendix 3 - Weekly Equipment Checklist | 17 |
| Appendix 4 – DIY Flowmeter stand..... | 20 |
| Acknowledgements..... | 24 |

Updates plus more technical and clinical resources and training materials can be found in the free online Oxygen Resources repository: <https://bit.ly/2XkxIFY>

For more detailed description and technical specifications:

- WHO-UNICEF technical specification and guidance for oxygen therapy devices (2019) https://www.who.int/medical_devices/publications/tech_specs_oxygen_therapy_devices/en/.
- WHO Technical Specifications for Oxygen Concentrators (2015) <https://apps.who.int/medicinedocs/en/m/abstract/Js22194en/>

For clinical guidance on pulse oximetry and oxygen use:

- WHO Oxygen therapy for children (2016) https://www.who.int/maternal_child_adolescent/documents/child-oxygen-therapy/en/
- WHO Severe Acute Respiratory Infections Treatment Centre (March 2020) - <https://www.who.int/publications-detail/severe-acute-respiratory-infections-treatment-centre>

For latest WHO COVID-19 Technical guidance

- <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance>

A) Pre-installation Checklist

This list of essential actions should be completed by the person in charge of the installation, ideally confirmed in a team meeting with hospital representatives.

- Recorded contact details for key hospital staff (e.g. director, chief medical officer, chief nursing officer, chief technician) and installation team (e.g. driver, technicians)
- Confirmed logistic details with hospital and installation team (e.g. date, time, wards, equipment, site access)
- Financial arrangements completed (e.g. payment for equipment and delivery)
- Oxygen equipment delivered and checked, and stored in a safe and dust free location
- Installation equipment prepared (including replacement of consumables)
- Power requirements have been identified and reliable power solution planned
- Installation documentation reviewed, including equipment and materials

Oxygen is a Team effort

Oxygen is a medicine that depends on technology and requires effective teamwork between healthcare workers, technicians and managers. This guide is targeted at biomedical engineers and technicians, but oxygen planning decisions should always involve both technical teams (biomedical engineers/hospital technicians) and clinical teams (nurses and doctors). We have found that creating multidisciplinary oxygen teams in hospitals is the best way to find context-appropriate solutions to the many challenges to reliable oxygen access.

B) Plan the installation

This can be drafted by the installation team prior to meeting the hospital, but will require adaptation during the site visit and in cooperation with individual ward nurses.

1. Use the General Design Guidelines (Appendix 1 – General design guidelines, p11) to estimate oxygen demand and work out what equipment is likely to be needed.

- a. Use local data on bed occupancy and hypoxaemia if available.
- b. See specific information for COVID-19 isolation wards (p12).
- c. Check power needs (see Appendix 2 – Equipment list, p15).
- d. This guide focuses on systems using oxygen concentrators with back-up oxygen cylinders but can be adapted for primary use of large oxygen cylinders.

2. Consult with the nursing and medical staff before commencing activities.

- a. You may be working in spaces that have sick patients receiving active medical treatment.
- b. Work with the healthcare workers to ensure your work does not interfere with patient care.
- c. Infection control is a priority in clinical areas (particularly in relation to COVID). Always check, and follow, local infection control procedures.

The patient comes first!

As works will be carried out in a medical facility, patients and healthworkers may be present at the time of installation. The installation team must remain sensitive at all times to the patient, their condition and needs, and must never compromise medical activity under way in the ward.

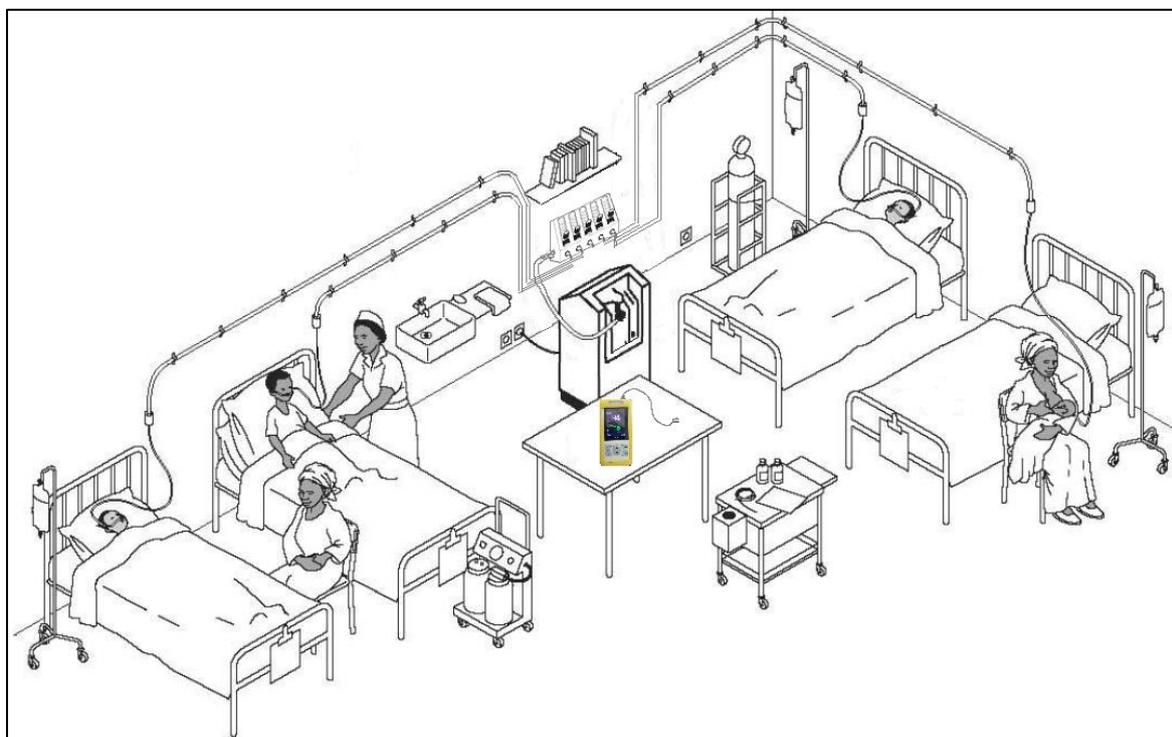
- 3. Discuss with the healthcare workers (especially nurses) to identify the best places for equipment and oxygen delivery positions.**
 - a. Oxygen concentrators should be located somewhere to keep them free from interference or accidental damage, and need an uninterrupted power source.
 - b. Oxygen cylinders need to be secured to prevent them falling over, and located somewhere to enable safe exchange when they are empty.
 - c. Flowmeter stand should be located somewhere convenient to nurses, free from interference or accidental damage¹.
 - d. Oxygen delivery points should be at designated 'high-dependency' beds, located close to the nurses for easy monitoring.

- 4. Sketch the plan on paper and check it with healthcare workers.**
 - a. See Figure 1 for example.

- 5. Decide where you will run the tubing.**
 - a. Usually it is best to run it high along the wall, away from other equipment, benches, or people. Then drop it down to a convenient access point for each bed.
 - b. You may be able to run multiple tubes close together.
 - c. Measure distances for tubing and write on your plan.
 - i. From concentrator to flowmeter stand (x1)
 - ii. From flowmeter stand to beds (1 per flowmeter)

- 6. Check that you have all the right equipment, in adequate quantities.**

Figure 1 Illustration of ward oxygen system set-up



¹ A different approach is to mount individual flowmeters by patient beds.

C) Installing the concentrator

1. Put the concentrator in position and plug it to the power supply.

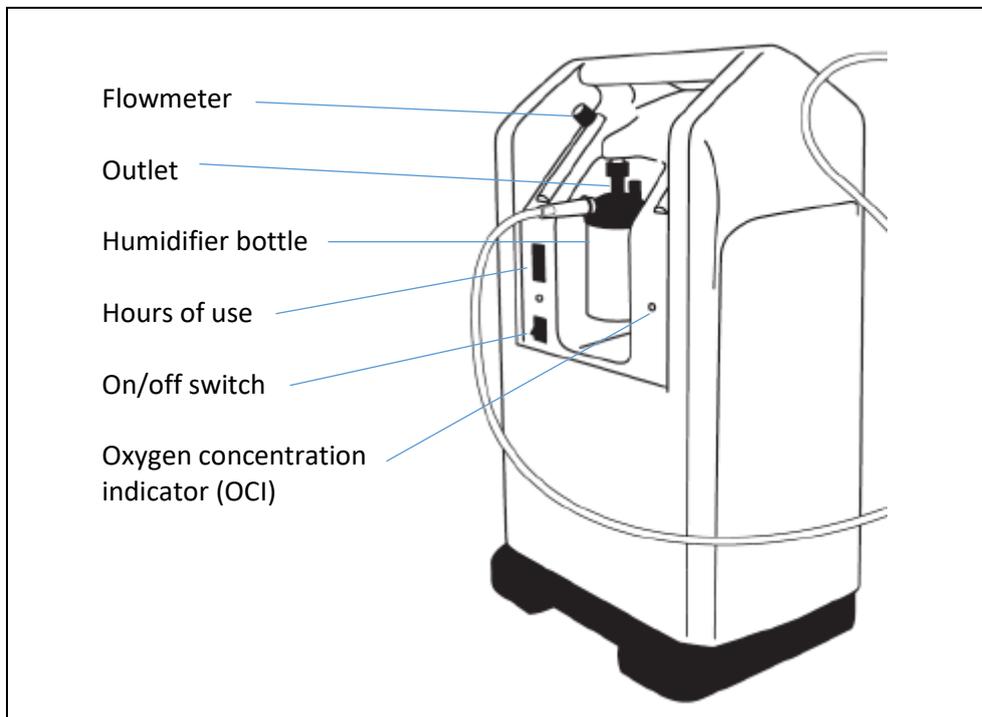
- a. Oxygen concentrators should be located somewhere to keep them free from interference or accidental damage, and need a power source. They should be in a well-ventilated area (not in a cupboard or against curtains) and protected from water (e.g. rain, flooding, spills).

2. Complete the concentrator checklist.

- a. Turn it on and turn the flowmeter to 5LPM (or maximum).
- b. Check the Oxygen Concentration Index (OCI) indicator/alarm. (E.g. Airsep OCI is an orange light which will be on initially, then off when the oxygen concentration has reached 85%).
- c. Use your oxygen analyser to manually check the oxygen concentration at the outlet.
- d. Check the filter is clean. Clean the body and filter as required.

3. Turn the concentrator off.

Figure 2 Oxygen concentrator (exact details will vary by model)



D) Installing the oxygen cylinder

1. Put the oxygen cylinder in position and secure it so that it cannot tip over.

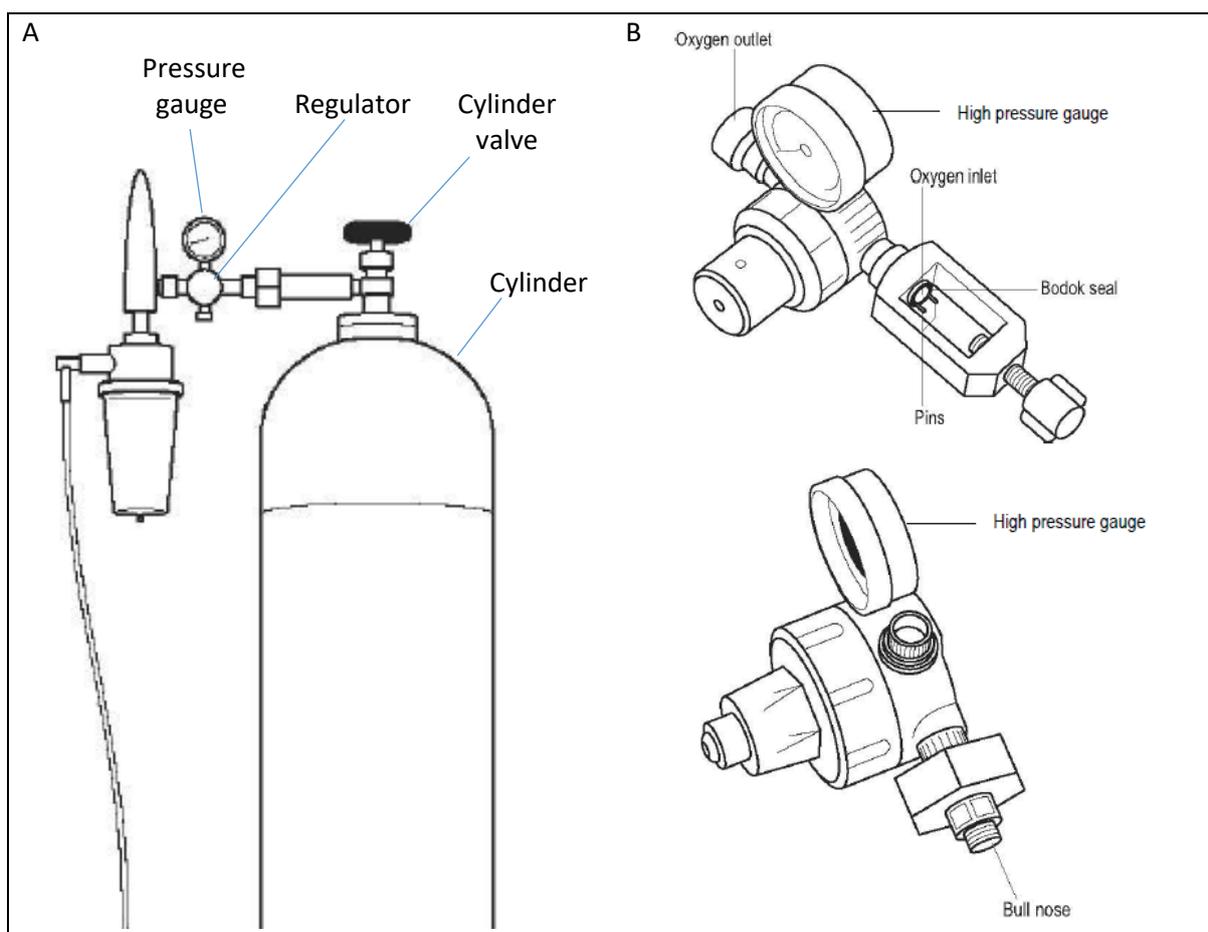
- Oxygen cylinders need to be secured to prevent them falling over, and located somewhere to enable safe exchange when they are empty.
- If using oxygen cylinders as the back-up oxygen source – ideally store cylinders (with regulator, pressure gauge and flowmeter attached) in a safe ward area where they can be readily accessed.
- If using oxygen cylinders as the primary oxygen source – ideally put the cylinders in one place, and run piping from them to each patient. If you use a manifold, cylinders will connect to the manifold, then you can run the tubing from the manifold to patients. Otherwise, you can attach oxygen distribution tubing directly to the flowmeter or pressure gauge.

2. Complete the cylinder checklist.

- Check the regulator and flowmeter connections are secure.
- Open the cylinder valve and check the pressure gauge (see Figure 2). Red zone = empty.
- Open the flowmeter to allow gas flow.
- Use your oxygen analyser to manually check the oxygen concentration at the outlet.

3. Close the cylinder valve.

Figure 3 Cylinder with regulator (A), and close-up image of pin-type and bull-nose regulator attachments (B)



E) Installing the flowmeter stand

To build your own flowmeter stand, see Appendix 4 – DIY Flowmeter stand, p20.

1. Put the flowmeter stand in position and mark locations for fixing screws.

- Mark flowmeter stand holes where drilling for hanging device to wall is required.
- Choose the correct wall plugs and screws. The weight of the object to hang will determine the screw gauge; and the screw gauge will determine the correct wall plug. (Recommended screw – 2" 10-15mm, flathead).
- Insert the wall plug into the hole. Gently tap the end of the plug to ensure that it is flush with the wall.
- Gently twist in the screw into the wall until **the head is 1-1.5mm outstanding**.
- Carefully hang the flowmeter stand onto the outstanding screws.
- Check that the flowmeter stand is correctly in place (use a spirit level) and ensure it is secure and cannot be accidentally dislodged.



2. Connect PVC tubing from the oxygen concentrator (or cylinder) outlet to the flowmeter stand inlet.

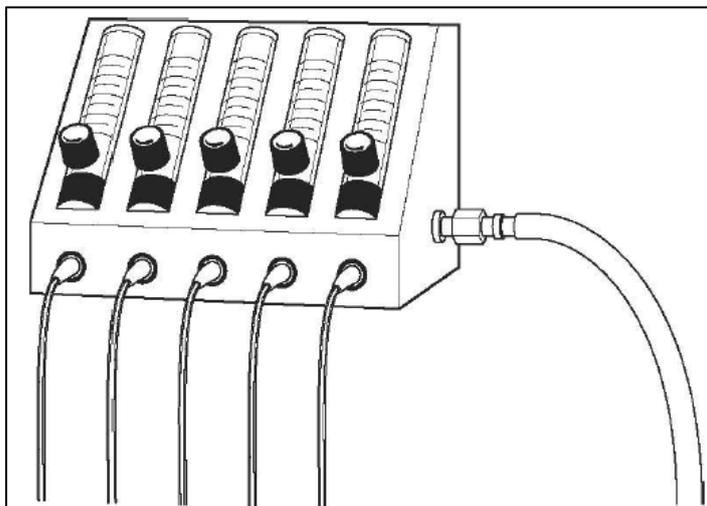
- Secure with tie wrap to prevent accidental disconnection or leak.

3. Complete the flowmeter stand checklist.

- Turn the concentrator (or cylinder) on.
- Open the concentrator (or cylinder) flowmeter.
(NB: if all the flowmeters on the flowmeter stand are closed, it will obstruct flow, and the flowmeter on the concentrator will not show any flow).
- Open each of the flowmeter stand flowmeters individually and check for flow.
- Open multiple flowmeter stand flowmeters and check that the total flow is roughly the same as the flow from the concentrator (or the cylinder flowmeter if available). If it is different, look for a leak.

4. Turn the concentrator (or cylinder) off.

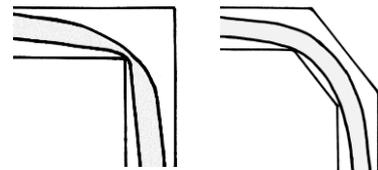
Figure 4 Flowmeter stand showing single inlet and five flowmeters with individual outlets.



E) Installing the distribution tubing

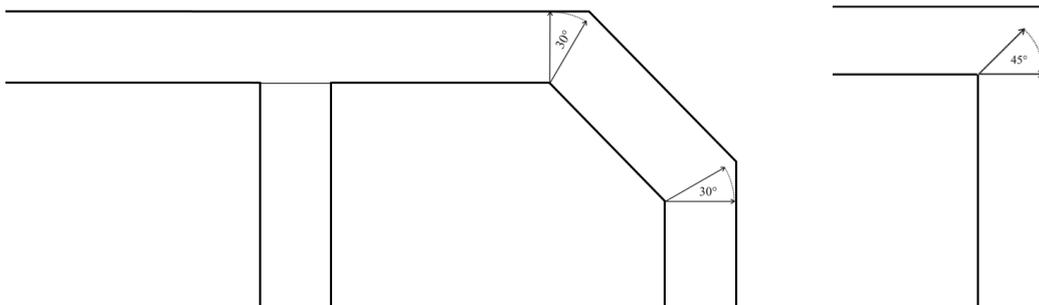
1. Map out the exact route for your distribution tubing from the flowmeter stand to each bed, using chalk to mark out the route.

- Use a spirit level to ensure that your chalk lines are level and neat.
- Check where you will be able to run multiple distribution tubes within the same trunking.
- Check for possible obstructions, such as electrical cables, shelves, doors, etc.
- Where possible, avoid going over obstructions. Look for an alternate route.
- If necessary, cut or drill holes in walls or other fixtures to pass the tubing through.
- Where possible, avoid right angle corners because the tubing may kink.



2. Cut the trunking and then fix the trunking to the wall².

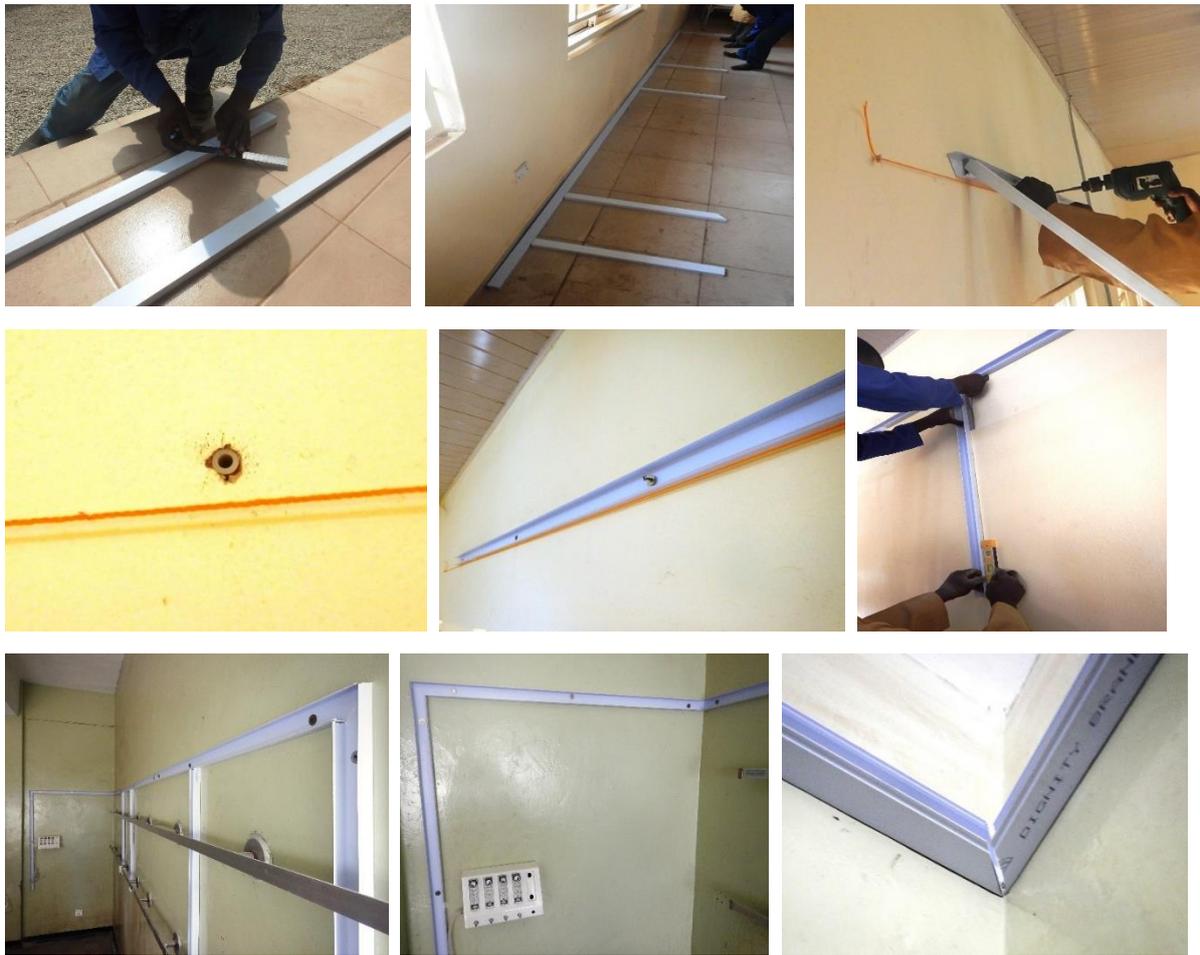
- Proceed sequentially. We suggest starting with the main long horizontal wall trunking, then connecting the vertical connections.
- Cut angular joints to ensure they conceal the tubes fully in the trunking without gaps.
 - Cut at 45 degrees to join at right angle, or ~30 degree for a gentler curve.
- Close up gaps to prevent insects, dust, and rodents getting into the trunking.



Trunking wall mounting steps

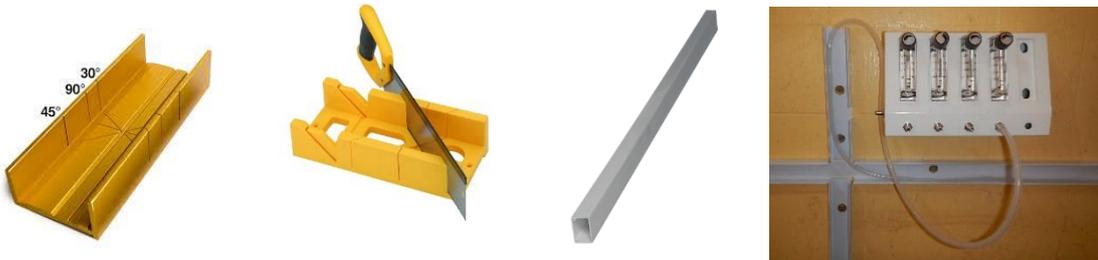
- Drill a hole through the trunking into the concrete/ brick wall.
- Remove the trunking and insert the plug directly into the hole. Using your fingers, push the wall plug into the hole. Gently tap the end of the plug to ensure that it is flush with the wall.
- Double check to ensure that all trunking openings (the openings where vertical runs branch off the main line) have been cut ahead of final wall mounting.
- Put the washer on the screw and gently twist in the screw.
- Visually check to ensure that the trunking is correctly in place (use spirit level) before firmly tightening the screws.
- Visually check that the trunking is installed to a satisfactory standard.

² Installing the plastic tubing inside protective housing will help prevent damage and leaks. However, you can attach the plastic tubing directly to the wall with nail clips



Trunking tips

- Cut the trunking outside the ward, away from clinical areas.
- Use a miter box for neat cutting of angles (image below). Cut at 45 degrees to join at right angle, or 30 degree for a gentler curve.
- After cutting, smooth the edges with sandpaper to remove sharp burrs.
- Avoid overlapping trunking.
- Use a minimum of 4 screws for each 2 metres of trunking (and at least 2 screws per mounted panel).



Drilling tips

- Do not drill close to windows frames or any other wall openings as you may break the window or cause structural damage.
- Use a hammer drill and masonry drill bit for drilling into concrete.
- Choose the correct drill bit. Measure by holding the screw directly behind the drill bit – it should hide the shaft of the screw but the screw threads should still be visible.
- Insert the required drill bit into a power drill, firmly locking it into place. Drill with steady pressure. Hold the drill steady and push it into the material (wall) to drill.
- Break through obstructions with a masonry nail. Sometimes, a drill does not go as expected. If you hit very hard concrete, insert a masonry nail into the hole and hammer it in to break up the concrete.
- A second person should hold a vacuum cleaner hose below the drilling hole to avoid dust pollution.
- Drill through the trunking at its final position to avoid unnecessary marking/ measuring effort.
- **SAFETY:** Wear safety goggles or glasses to prevent eye injury from flying debris. Wear ear protection if drilling regularly. Use a ladder or stable platform so that you can comfortably reach the drill site.

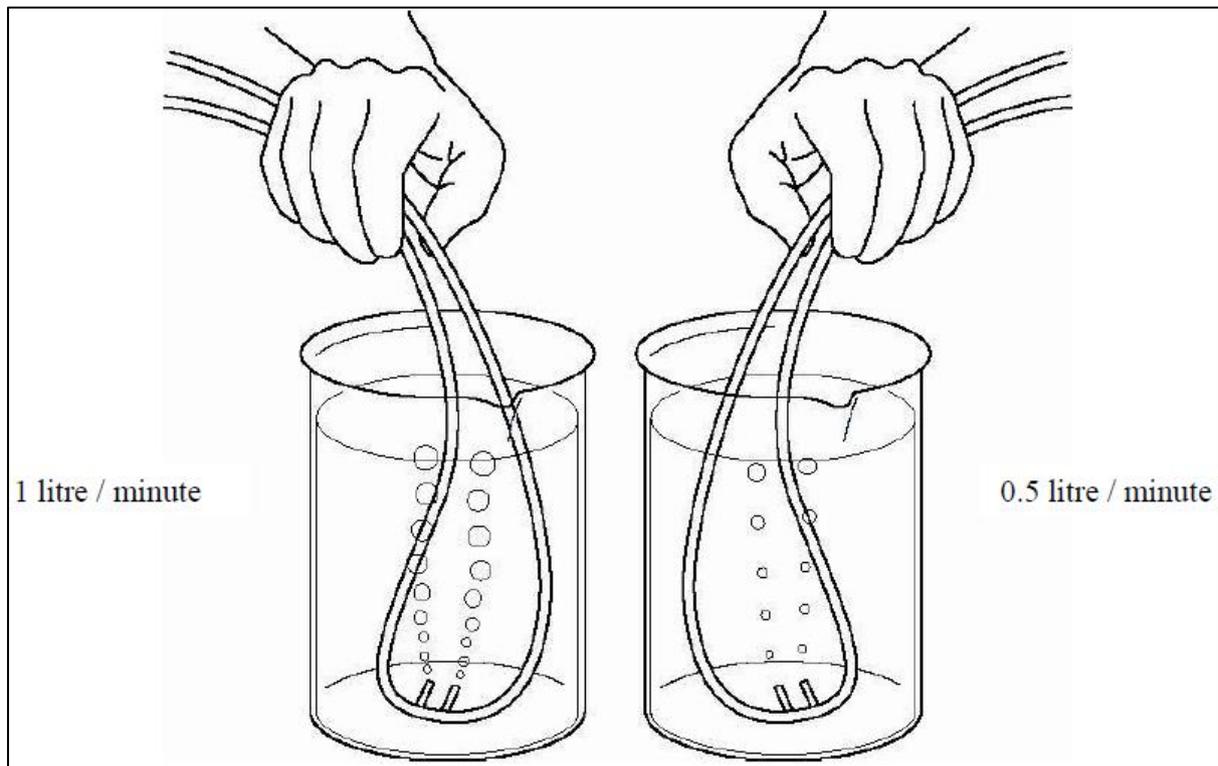
3. Starting from the flowmeter stand, fit the plastic tubing.

- Fix the plastic tubing onto the flowmeter stand outlet and secure with tie wrap.
- Put the plastic tubing into the housing, keeping it loose and preventing kinks.
- Where possible, use a single long length of plastic tubing for each patient connection (rather than joining short pieces and risking leaks).
- Install one firesafe connector at the patient end of each delivery tube, and secure with tie wrap.
- Connect nasal prongs to the firesafe connector. [Optional for installation]



4. Complete the distribution tubing checklist

- Check the plastic tube connections at the concentrator and flowmeter stand are secure.
- Turn the concentrator (or cylinder) on and open the flowmeter.
- Submerge the nasal prongs (or tubing end) in a cup of water and check the bubbles as you adjust the flow rate on the flowmeter stand.
- Repeat for every flowmeter.
- Turn the concentrator (or cylinder) off.



Appendix 1 – General design guidelines

Oxygen is a Team effort

Oxygen is a medicine that depends on technology and requires effective teamwork between healthcare workers, technicians and managers. This guide is targeted at biomedical engineers and technicians, but oxygen planning decisions should always involve both technical teams (biomedical engineers/hospital technicians) and clinical teams (nurses and doctors). We have found that creating multidisciplinary oxygen teams in hospitals is the best way to find context-appropriate solutions to the many challenges to reliable oxygen access.

This guidance is intended for **oxygen use on general wards** (adult and paediatric). They do not cover intensive care (ICU, e.g. mechanical ventilation), where oxygen requirements are much greater and different solutions are required.

General guidance

- Patients require different flow rates of oxygen over the course of their illness, so you need capacity to give higher flow rates to some patients while giving lower flow rates to others.
- Oxygen therapy should always be guided by pulse oximetry (to measure blood oxygen level), adjusting flow rates to the lowest rate required.
- Use local data on hypoxaemia and bed occupancy to estimate demand if available. Otherwise, use the following guide to get the most from your concentrators and cylinders.
- Our recommended solutions should provide adequate supply to cover 99% of demand (using the back-up cylinder less than 10% of the time). See for page 15 further explanation.

Severe Acute Respiratory Infection (SARI) wards, including COVID-19

Dedicated severe acute respiratory infection wards (e.g. COVID) will have much higher oxygen needs. Our guidance on Severe Acute Respiratory Infection (SARI) wards, should align with WHO and UNICEF guidance. However, we do not include oxygen for ICU (e.g. mechanical ventilation).

UNICEF has developed draft guidance (unpublished) on using oxygen concentrator-based solutions for treatment of severe COVID-19 (excluding critical patients requiring ICU).

ADULTS: 1 x 10LPM concentrator (or large cylinder) per 1-2 beds (or 1 x 5LPM concentrator per bed)

CHILDREN: 1 x 10LPM concentrator (or large cylinder) per (up to) 5 paediatric beds (or 1 x 5LPM concentrator per 2 beds)

WHO has produced guidance on setting up COVID-19 isolation wards and the clinical management of severe acute respiratory infection, including estimations of oxygen requirements for intensive care.

- WHO Severe Acute Respiratory Infections Treatment Centre (March 2020) - <https://www.who.int/publications-detail/severe-acute-respiratory-infections-treatment-centre>
- WHO Clinical care of severe acute respiratory infections (COVID-19 adaptation, April 2020) - <https://www.who.int/publications-detail/clinical-care-of-severe-acute-respiratory-infections-tool-kit>
- Latest WHO COVID-19 Technical guidance - <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance>

| GENERAL WARD | Small (~5-10 beds) 60 admissions per month (2/day) | Medium (~10-20 beds) 120 admissions per month (4/day) | Large (~30 beds) 240 admissions per month (8/day) |
|---|---|--|---|
| ADULT WARD | | | |
| Estimated number of ADULT patients requiring oxygen each day | 0-2 | 1-3 | 1-5 |
| Recommended solutions | 1 x 10LPM concentrator (or large cylinder) (split flow to 2 individual flowmeters) + 1 x large cylinder (available on demand) | 1 x 10LPM concentrator (or large cylinder) (split flow to 2-4 individual flowmeters) + 1 x large cylinder (available on demand) | 2 x 10LPM concentrators (or large cylinders) (split flow to 2-4 individual flowmeters) + 1 x large cylinders (available on demand) |
| PAEDIATRIC WARD | | | |
| Estimated number of PAEDIATRIC patients requiring oxygen each day | 1-3 | 1-5 | 2-8 |
| Recommended solutions | 1 x 5LPM concentrator (or large cylinder) (split flow to 4-5 individual flowmeters) + 1 x large cylinder (available on demand) | 1 x 10LPM concentrator (or large cylinder) (split flow to 4-5 individual flowmeters, including one 0-5LPM flowmeter) + 1 x large cylinder (available on demand) | 2 x 10LPM concentrators (or large cylinders) (split flow to 4-5 individual flowmeters, including two 0-5LPM flowmeters) + 1 x large cylinder (available on demand) |
| NEONATAL WARD | | | |
| Estimated number of NEONATAL patients requiring oxygen each day | 1-5 | 2-8 | 4-14 |
| Recommended solutions | 1 x 5LPM concentrator (or large cylinder) (split flow to 4-5 individual flowmeters) + 1 x large cylinder (available on demand) | 1 x 10LPM concentrator (or large cylinder) (split flow to 8-10 individual flowmeters) + 1 x large cylinder (available on demand) | 2 x 10LPM concentrators (or large cylinders) (split flow to 16-20 individual flowmeters) + 1 x large cylinder (available on demand) |

Note: Some 8-10LPM oxygen concentrators will have 2 oxygen outlets, each with maximum 5LPM flow. Use 0-5LPM or 0-8LPM individual flowmeters for adults; 0-2LPM individual flowmeters for children/neonates. For paediatrics, can also use 5LPM rather than 10LPM (but will require increased quantity).

| SEVERE ACUTE RESPIRATORY INFECTION (SARI) WARD (e.g. COVID) | Small (~4 SARI beds) 8 admissions per month (2 per week) | Medium (~15 SARI beds) 30 admissions per month (1/day) | Large (~30 SARI beds) 60 admissions per month (2/day) |
|--|--|---|---|
| ADULT SARI WARD | | | |
| Recommended solutions | 2 x 10LPM concentrators (or large cylinders) (split flow to 4-8 individual flowmeters) + 1 x large cylinder (available on demand) | 4 x 10LPM concentrators (or large cylinders) for severe patients + 4 x 10LPM concentrators (or large cylinders) (split to 8-16 individual flowmeters) + 2 x large cylinder (available on demand) | 8 x 10LPM concentrators (or large cylinders) for severe patients + 8 x 10LPM concentrators (or large cylinders) (split to 16-32 individual flowmeters) + 4 x large cylinders (available on demand) |
| PAEDIATRIC SARI WARD | | | |
| Recommended solutions | 1 x 10LPM concentrator (or large cylinders) (split to 4-5 individual flowmeters, including one 0-5LPM flowmeter) + 1 x large cylinder (available on demand) | 2 x 10LPM concentrators (or large cylinders) for severe patients (split flow to 4 individual flowmeters) + 2 x 10LPM concentrators (split to 8-10 individual flowmeters) + 1 x large cylinder (available on demand) | <i>Not applicable</i> |

Note: This is based on severe acute respiratory infections, such as COVID-19, requiring long inpatient admissions stays. Respiratory wards in general may have substantially lower requirements. Some 8-10LPM oxygen concentrators will have 2 oxygen outlets, each with maximum 5LPM flow. Use 0-5LPM or 0-8LPM individual flowmeters for adults; 0-2LPM individual flowmeters for children/neonates. For paediatrics, can also use 5LPM rather than 10LPM (but will require increased quantity).

Explanation

Our estimates on oxygen need are based on assumptions about the proportion of admitted patients who need oxygen, and what flow rates they are likely to need. This recognises that some patients will need higher flow during resuscitation or because they are extremely well, but most will start on standard flow rates and be weaned off over time.

Data from low- and middle-income countries suggest that ~5% of adults, ~10% of children, and ~20% of neonates admitted to hospital with acute illness will have hypoxaemia (low blood oxygen levels, SpO₂<90%) – including 25-50% of those with pneumonia.

Typically, children hospitalised with pneumonia start on 0.5-2 litres per minute (LPM) oxygen therapy, and rarely require more than 4-5LPM. We expect children on oxygen to need oxygen for ~3 days, at an average flow rate of 0.5-1LPM. This means that a 5LPM or 10LPM concentrator can be shared between multiple children, ideally using 0-2LPM individual flowmeters. Large paediatric wards may use a second oxygen source to provide higher flows to severely unwell children until they are stable.

Adults will typically start on 2-5LPM, but may need up to 10-15LPM if severely unwell. We expect adults on oxygen to need oxygen for ~3 days, at an average flow rate of <5LPM. This means that a 10LPM oxygen concentrator can be shared between multiple adults, ideally using 0-5LPM individual flowmeters. However, very severely ill adults will need a dedicated oxygen source (e.g. cylinder or 10LPM concentrator). Note: patients with COVID-19 may require longer on oxygen (often 7-10 days), but we assume similar average flow rates to other pneumonias.

Based on this, we can estimate the average expected oxygen requirements, but random variability means that this could vary substantially day-to-day (particularly in less busy facilities). Factoring in variability can give us the estimated *total peak patient oxygen days per month*. We can then estimate the *daily peak flow rate*, with assumptions on the necessary flow rates.

Our **recommended solutions** should provide adequate supply to cover 99% of demand (using the back-up cylinder less than 10% of the time). Actual oxygen usage will be much less (1/3) most days, but we always expect significant variation from day to day. Please contact me directly if you would like to see more details.

Total peak patient oxygen days per month = average monthly admissions X hypoxaemia prevalence X 3 days X 3 variability factor

Daily peak flow rate assumes that 20% of patient oxygen days will be high demand, 30% moderate demand, 50% low (using age-specific mean flow rates).

Note on cylinders: Large (G-type) oxygen cylinders can hold up to 3400 litres of oxygen (however, actual maximum volume may depend on what pressure the filling stations fills cylinders to). This will last up to 2 days if a patient is on 1LPM; 1 day if a patient is on 2LPM; 14 hours if a patient is on 4LPM; 5 hours if a patient is on 10LPM.

Appendix 2 – Equipment list

The following is a list of suggested essential equipment, however exact requirements may vary.

Equipment³

- Oxygen concentrators, 5 or 10LPM maximum capacity.
- Flowmeter stand, with appropriately sized individual flowmeters
- Pulse oximeters
- Oxygen analyser
- Oxygen cylinder (large, size G or J)
- Good quality power supply⁴

Installation materials

- Plastic tubing ~6mm internal diameter
- PVC trunking and fixtures
- Tie wraps (cable tie)
- Fire-safe connectors (1 per patient)
- If installing additional power: power cable, sockets, PVC electrical pipe and fixtures.

Installation tools

- Ladders (x2)
- Hack saw and extra blades
- Miter box (for cutting neat angles) and/or combination square ruler
- Drill and bit set (including masonry drill bit for concrete walls if required)
- Screwdrivers, screws, and screw anchors
- Hammer
- Pliers
- Digital multimeter
- Utility knife
- Spirit level
- Permanent marker
- Vacuum cleaner (for dust)
- Cleaning materials: cloth, sponge, soap, alcohol, water
- Torch (e.g. head torch for working in ceiling spaces)

Essential spares and consumables

- Christmas tree connectors
- Concentrator filters (internal and external)
- Oximeter probes
- Nasal prongs

SAFETY: Always use equipment correctly and with appropriate safety gear.
Misuse of tools may risk injury or damage to facilities.

³ All equipment should meet WHO/UNICEF Technical Specifications and be appropriate for local requirements (e.g. able to operate in hot, humid, dusty conditions).

⁴ Power supply may be from any source, but must have good voltage stabilisation. See WHO-UNICEF Technical Specifications for additional information about power options.

Power supply

Oxygen concentrators require a reliable power source. If concentrators are connected to an unreliable or poor quality power supply, voltage fluctuations and power cuts will damage the compressor and cause equipment failure. Always check that your concentrator (and other electrical equipment) is appropriate for your local power supply⁵.

Many hospitals have unreliable mains power supply and use a variety of other power sources. Most of these sources will require you to use a voltage stabiliser and/or uninterruptible power supply to protect the concentrator from voltage fluctuations or power cuts. The best option will depend on your baseline power supply, and cost (which will vary locally).

- **Mains power supply** – supplied from power plant to facilities via high voltage power lines. Voltage fluctuations and outages are common in many places. Always use voltage stabilisation.
- **Diesel generator** – large generator on site, often used as core supply to main hospital (but may be switched off overnight). Always use voltage stabilisation.
- **Petrol generator** – small generator on site that can be used to power specific equipment (such as concentrator), and useful back-up power supply (e.g. overnight). Always use voltage stabilisation.
- **Solar power with batteries and inverter** – very reliable option where sun is readily available, but solar yield varies with weather (e.g. clouds) and seasons (e.g. shorter hours of daylight). Always need battery storage (+/- alternate power source) to power outside daylight hours. Hybrid option (combining solar with other source to charge batteries) is more cost-effective and efficient than stand-alone solar.
- **Batteries with inverter** - Batteries provide reliable storage and can be recharged from solar or mains or generator (i.e. any source). Quality inverter should provide high quality power supply so do not need separate voltage stabiliser. You need a large battery pack to power concentrators for >24 hours.

Voltage stabilisers come in a variety of capacities, and must be selected according to need (particularly the input voltage and expected load). See additional detail on devices for quality power supply in the WHO-UNICEF technical specification and guidance for oxygen therapy devices (2019) https://www.who.int/medical_devices/publications/tech_specs_oxygen_therapy_devices/en/.

⁵ Check power supply and plugs online - https://en.wikipedia.org/wiki/Mains_electricity_by_country. Africa generally uses 220-240V 50Hz with UK-style sockets, Americas 120V 60Hz, Asia 220-240V 50Hz, but there are many exceptions and variations.

Weekly Equipment Checklist

Appendix 3 - Weekly Equipment Checklist

To keep the Oxygen Concentrator, Pulse Oximeter, and other equipment functioning effectively please perform these basic checks every week, and record on the Checklist. If there are any problems, report them to the Engineer/Technician responsible within 24 hours.

1. **Turn the Concentrator on.** If the concentrator has no power supply, an alarm may sound. If the power failure alarm does not alarm, inform the responsible technician.
2. **Turn the Concentrator flowmeter to 5LPM (or maximum).**
3. **Use the Oxygen Concentration Indicator (OCI), or oxygen analyser, to test oxygen purity.** If the OCI stays on, the concentrator is not producing adequate oxygen. Contact the Engineer/Technician responsible.
4. **Check the tubing connections of the Concentrator and Flowmeter stand.** Tighten loose connections, and if there are cracks or leaks inform the Engineer Responsible.
5. **Submerge the nasal prongs in water and adjust the flow rate on the Flowmeter stand.** If bubbles are not produced appropriately at flow rates of 0.5-2.0 LPM, contact the Engineer/Technician responsible. Repeat for every flowmeter. (You can now turn the concentrator off)
6. **Clean the concentrator body, check for damage, and record the hours of use.**
7. **Remove the external filter and replace with a clean, dry filter.** Wash the old filter and allow to dry.
8. **Check the Pulse Oximeter on your finger, and check that each of the probes are working.** If any are not working, contact the Engineer/Technician responsible.



Weekly Equipment Checklist

Equipment Serial Numbers

- Insert the serial numbers for all Oxygen equipment below and the date it was received.

Local Technician:

Contact:

Engineer/Technician (referral):

Contact:

Oxygen Concentrators

| Date received | Concentrator Serial Number |
|---------------|----------------------------|
| | |

Oximeter Probes

| Date received | Probe Serial Number |
|---------------|---------------------|
| | |

Pulse Oximeters

| Date received | Oximeter Serial Number |
|---------------|------------------------|
| | |

Complete this EVERY WEEK. Check every item of equipment. Indicate correct function of all equipment with ✓, and any problems with ✗. Describe problems identified and action taken (including equipment serial number).

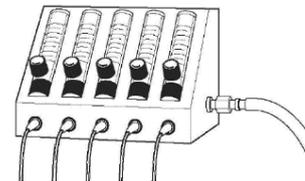
| Checklist item -> | Concentrators | | | | Oximeters | | Document problems identified and action taken (include serial number) | Sign | |
|-------------------|---------------|--------|------|-------|-----------|----------|---|--|------|
| | ①②③ | ④⑤ | ⑥ | ⑦ | ⑧ | | | | |
| Week | Date | Alarms | Flow | Hours | Filter | Oximeter | Probes | Problems & Actions | Sign |
| E.g. | 20/02/20 | ✓ | ✓ | 4 | ✓ | ✓ | ✗ | Probe #1234567 broken, contacted Engineer for replacement. | HG |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |
| 9 | | | | | | | | | |
| 10 | | | | | | | | | |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |
| 13 | | | | | | | | | |

Appendix 4 – DIY Flowmeter stand

Introduction

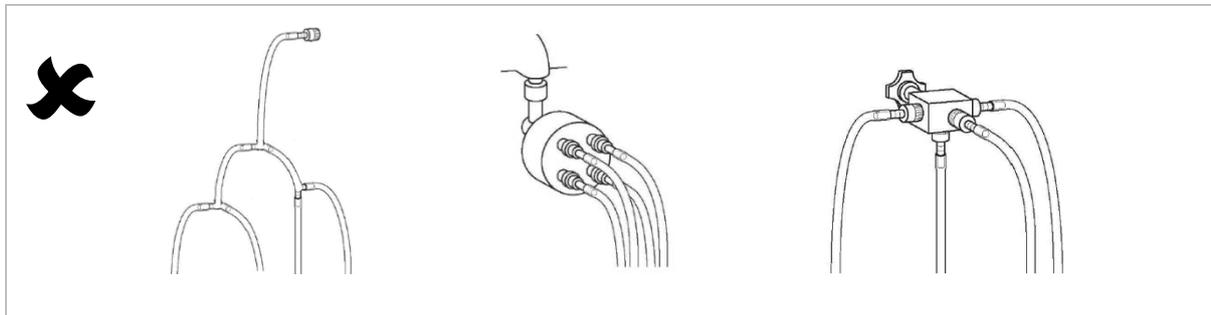
Flowmeters allow individual titration of oxygen to patients. Flowmeters have a dial that controls oxygen flow, flow markers to read the flow rate, and a ball that rises with higher flow. Flowmeters are important for the safe delivery of the right amount of oxygen (typically the lowest flow required to maintain adequate blood oxygen level).

Flowmeter stands enable you to give oxygen to multiple patients from a single oxygen source, with individual flowmeter control. This helps you provide oxygen more efficiently. Flowmeter stands are better than using flow splitters that do not have individual flowmeters (Box 1).



This guide shows you how to build your own flowmeter stands, providing oxygen to multiple patients from a single oxygen with individual flowmeter control.

Box 1 Non-preferred ways to split flow



Equipment

All the parts can be recycled from broken concentrators. You will also need pliers.

| | |
|--|---|
| <ul style="list-style-type: none"> • Flowmeters (with connecting barb at back) – choose the appropriate number of flowmeters and flow range for your use. <ul style="list-style-type: none"> ○ 0-2LPM for neonates and children (X4) ○ 0-5LPM for older children and adults (X2) |  |
| <ul style="list-style-type: none"> • Connectors (T-piece or Y-piece) <ul style="list-style-type: none"> ○ X3 for a stand with 4 flowmeters ○ X1 for a stand with 2 flowmeters |  |
| <ul style="list-style-type: none"> • Plastic tubing <ul style="list-style-type: none"> ○ Short length (~20cm). Diameter size to fit to connectors. |  |
| <ul style="list-style-type: none"> • Tie wrap (cable ties) (to secure the connections) <ul style="list-style-type: none"> ○ X1 per connection |  |
| <ul style="list-style-type: none"> • Firesafe cannula (or other joining piece to connect patient tubing) <ul style="list-style-type: none"> ○ X1 per flowmeter |  |

Instructions

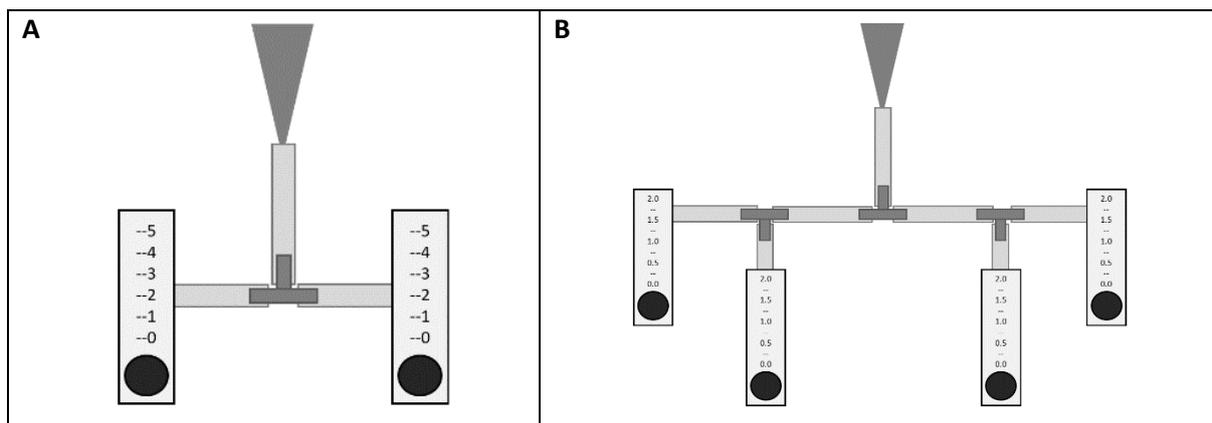
1. Prepare the equipment

- Take parts from broken concentrators if needed. A single broken concentrator contains enough tubing and connectors to make multiple flowmeter stands (if you have additional flowmeters).

2. Work out the configuration

- For adults, you may ideally use 2-3 flowmeters with 0-5LPM range.
- For children, you may ideally use 4-5 flowmeters with 0-2LPM range.

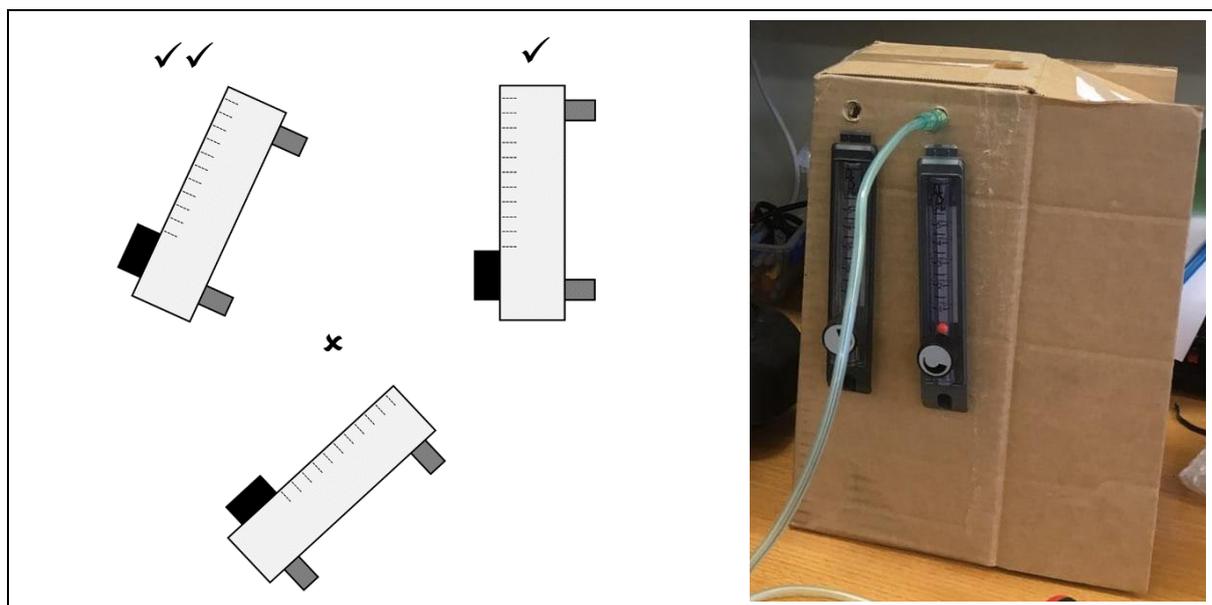
Box 2 Basic configuration for (A) 2 X 0-5LPM and (B) 4 x 0-2LPM configuration



3. Mount the flowmeters on a cardboard box (or similar)

- Mark the inlet and outlet holes on the box and cut appropriately sized holes.
- Secure with tape (or wire or tie wrap), being careful not to cover the flow markings.
- NOTE: Flowmeters are calibrated to be mounted 30 degrees from vertical. Vertical mounting is acceptable (and will underestimate actual flow rate by less than 10%). However, greater than 30 degrees from vertical will result in significant overestimation of the actual flow rate.

Box 3 Mounting of flowmeter at 30°, vertical, and greater than 30° from vertical, and mounting on cardboard box.

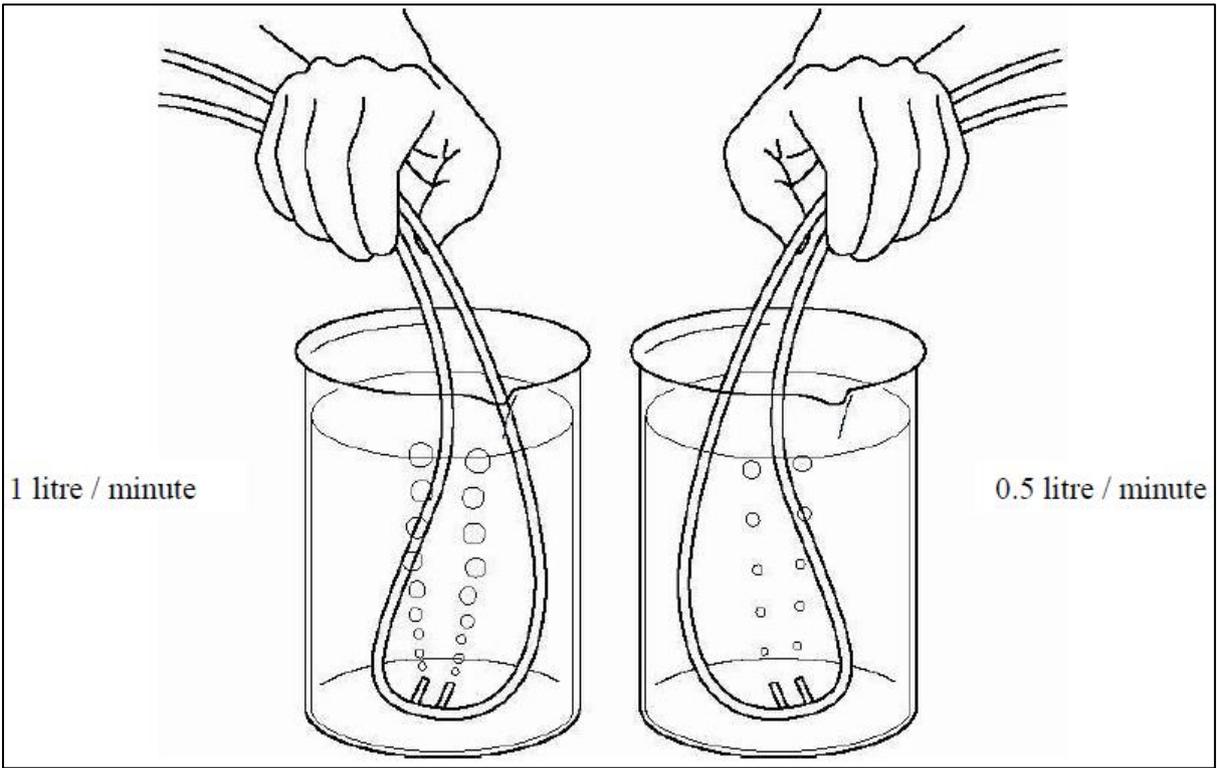


- 4. Connect the connectors to the tubing to create the tree configuration.**
 - a. Use short pieces of plastic tubing between the connectors so that it can all be neatly contained in a small box.
 - b. Use longer plastic tubing from the connector to the oxygen source.
 - c. Double check that you have arranged the configuration correctly, before securing every connection tightly with tie wraps.

- 5. Connect the tubing to the flowmeter inlet.**
 - a. The flowmeter inlet is always at the bottom (regardless of where the dial is located). Oxygen flows through the inlet, pushing the ball upwards, exiting at the top.
 - b. Double check that you have arranged the configuration correctly, before securing every connection with tie wraps.

- 6. Connect tubing to the flowmeter outlets and run to patient beds.**
 - a. Option 1 (preferred): connect a long length of tubing from the flowmeter outlet (inside the box), running out of the box towards the patient bed. Put a firesafe cannula (or similar joiner) to connect the patient nasal prongs/mask.
 - b. Option 2: connect the nasal prong (or mask) tubing directly to the flowmeter outlet that is inside the box. (NB: this requires interfering with the flowmeter and potentially contaminating it at every tubing change)

- 7. Check each individual flowmeter.**
 - a. Connect to an oxygen source and turn on the flow.
 - b. Connect tubing (or nasal prongs) to each flowmeter to check there is flow.
 - c. Submerge the nasal prongs (or tubing end) in a cup of water and check the bubbles as you adjust the flow rate on the flowmeter stand.
 - d. Repeat for every flowmeter.



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- Bev Bradley, Cindy McWhorter and the UNICEF Supply Division technical team
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- Trevor Duke and colleagues in Papua New Guinea
- Dr David Peel
- Doctors, nurses, and technicians in all our past and present oxygen projects
- Oxygen champions everywhere

See more resources in the free online Oxygen Resources repository – <https://bit.ly/2XkxIFY>

We welcome your feedback (hamish.graham@rch.org.au).



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