

2.3 Oxygen Concentrators

2.3.1 Clinical Use and Principles of Operation

Oxygen is a widely prescribed medication in both the hospital and home setting. Hypoxia, or an inadequate amount of oxygen, is the main physiological state requiring this medical technology and is present in a number of life-threatening conditions. These include chronic obstructive pulmonary disease (COPD), which refers to the restriction, inflammation, or infection of bronchioles or alveoli whereby oxygen supply or transfer to the blood is limited. Cardiovascular insufficiency also causes hypoxia when an irregular rhythm, decreased flow, or inefficient transport prevents adequate oxygen delivery to peripheral tissues.

In addition to these medical conditions, a reliable source of oxygen is essential wherever anesthetics are administered, both to supplement the inspired gas mixture and also for resuscitation, though other machines such as ventilators may be selectively used.

Oxygen has traditionally been supplied in cylinders in the developing world. However, cylinders are both bulky and expensive. In isolated areas transportation of cylinders is difficult and may be unreliable. For these reasons, The World Health Organization recommends oxygen concentrators as a better long-term investment for smaller, remote hospitals in the developing world.

Engineering Details

Ambient air contains 78% N, 21% O₂ and 1% trace gases. An oxygen concentrator works by separating and removing the nitrogen from the ambient air, leaving nearly pure (95%) oxygen. At high flow rates the oxygen concentration may drop.

Most machines now operate using pressure swing adsorption (PSA). Ambient air is compressed and passed through a synthetic aluminum silicate (zeolite). Zeolite acts as a molecular sieve by binding to nitrogen, but only at high pressures. The zeolite is designed with a porous configuration to maximize surface area.

The high pressure, concentrated, oxygen is stored in a tank. A pressure regulator is used to step down the pressure to the desired range.

After the zeolite is saturated with nitrogen, the valve leading to the oxygen tank is closed and the pressure is decreased in the zeolite tank. As the pressure drops the zeolite releases nitrogen which is vented into the air. A small quantity of enriched oxygen is then passed backwards through the zeolite canister to completely purge the zeolite of nitrogen. Since the patient probably needs a continuous supply of oxygen, a typical concentrator will have two zeolite canisters. One is concentrating oxygen while the other is being purged.

An oxygen concentrator is easy to operate with only a power switch and a flow meter. An alarm sounds if the pressure in the compression chamber falls below 20 psi. Some models include a built-in device called an OCSI (oxygen concentration status indicator) that measures the oxygen concentration just before the outlet. An alarm would sound if the concentration is low in these devices. Some machines automatically shut down if the concentration of oxygen falls below 70%.

2.3.2 Common Problems

Concentrators do malfunction occasionally, and their repair can require considerable expertise; worn parts on the compressor and valves may need replacement. Assuming that all other parts function optimally, the machine is only limited by the life of the zeolite crystals, which is expected to be at least 20,000 hours.

The primary complaints are low oxygen concentrations and decreased gas flows. Since this machine is so widely used and has few options on the interface, user error is unlikely. A clogged filter may be the cause. The filter is located between the air source and the zeolite containers. Some models may have multiple filters. A dirty filter can lead to a decreased oxygen concentration and/or a decreased flow rate.

If the flow to the patient is insufficient, the tubing and connectors should be checked for leaks. Remember that part of the oxygen-providing pathway from the zeolite canisters can be inside of the machine.

If the motor or compressor is not functioning properly, air in the zeolite canisters will not be pressurized enough to remove an adequate amount of nitrogen from the air. It is necessary in this case to check any seals/gaskets associated with these systems. Inside the chambers, 20psi is the standard pressure.

The valves at the inlet and outlet of the zeolite canisters must be tight and timed correctly. During pressurization, the inlet valve should be opened and the outlet valve should be closed. During filtering, which normally takes 8 to 20 seconds, both valves should be closed as nitrogen binds to the zeolite. During release of oxygen-concentrated air to the patient, only the outlet valve should be opened. Remember that in the regeneration stage a small amount of oxygen is released back into the canister to expel leftover nitrogen. Most models have valves that are coordinated between chambers. However, check the timing of valve opening and closing. Canisters will be in different stages of the pressure swing cycle so that while one canister is filtering, the other is regenerating.

2.3.3 Suggested Minimal Testing

It is important that this machine achieve oxygen concentrations near 90% or above and provide gas flows in the manufacturer's range, keeping in mind that for high flow rates (around 5 liters/minute) oxygen concentration will be lower. In addition, it is not safe to trust flow meters and oxygen concentration indicators on the machine when releasing an oxygen concentrator to the floor. These variables need to be checked using a separate oxygen analyzer and flow meter, respectively. It is not typically difficult to determine the flow rate in the developing world, as there is an abundance of flow meters. However, measuring oxygen concentration can be challenging. If you are unable to locate an oxygen concentration meter, discuss the problem with the physician before releasing the device to the floor without an oxygen concentration test. The measurement must be performed 10 minutes after switching the concentrator on to give the machine time to build up the concentration of oxygen.