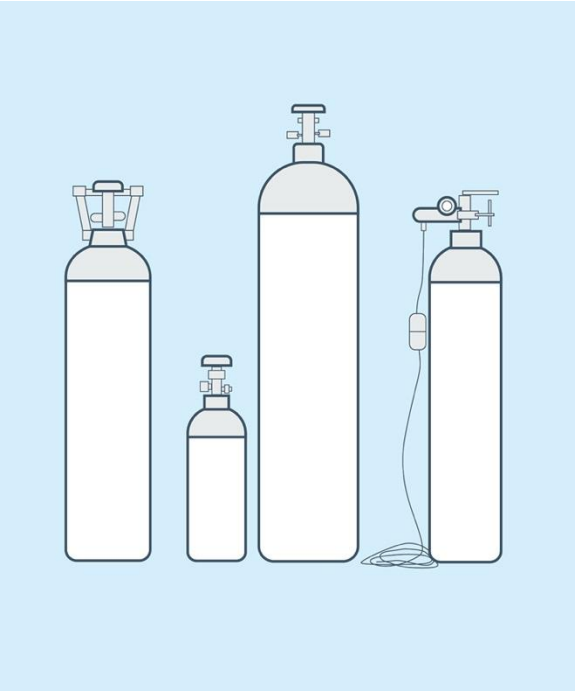
Oxygen Generation and Storage: Oxygen Cylinders

Technical overview



Cylinders are durable and refillable containers that hold compressed gases, such as oxygen, in a high-pressure (between 725 and 2,900 psig), non-liquid state. Portable cylinders range in size from approximately 50 to 1,000 L of compressed gas, while larger stationary tanks can store up to about 10,000L of compressed gas. Gas used to fill cylinders can be produced in multiple ways, including pressure swing adsorption (PSA), vacuum swing adsorption (VSA), or cryogenic distillation at an air separation unit (ASU).

Oxygen cylinders are graded according to liquid capacity (by liter) and fill pressure (kPa) and are color-coded to specify the contents (typically black with white shoulder per ISO standards; some geographies denote medical oxygen cylinders in green or blue). They should be transported to health facilities with their valve head protected by a steel cover or a carrying handle. A regulator and flowmeter assembly is used to access the oxygen supply, whether direct or to other medical devices. Oxygen cylinders may be the primary oxygen source or serve as a back-up supply for health facilities with another primary source for oxygen. Review the specifications and technical requirements as listed in the *WHO-UNICEF Technical Specifications and Guidance for Oxygen Therapy Devices*.

Key specifications

- Oxygen cylinders that store compressed oxygen are typically constructed of steel or an aluminum alloy.
- Standard cylinder sizes under ISO international standard are size AZ, C, D, E, F, G, H, and J, and United States (US) sizes are M2 to M265.
- Cylinders must be used with a pressure regulator in order to release oxygen at the correct working pressure.
- Standard (bullnose or pin-index) or integral valves are compatible to use with oxygen cylinders. If a standard valve is selected, it must comply with international ISO and US standards, which are ISO 407/BS 850/CGA 870 valve, CGA 540 valve, or ⅝ inch BSP (F) Bullnose BS 341 valve.
- If the cylinder employs an integral valve, a manometer and flow regulator (with 4 bar or 400 kilopascals [kPa] nominal outlet pressure) are already affixed to some but not all cylinder heads, and typically have a 6 millimeter (mm) barbed fitting, and BS Schrader outlet. Available sizes for integral valves under ISO are ZA, CD, ZD, HX, ZX, and US sizes in the M coding system. The nominal pressure for an integral valve cylinder ranges from 23,000 to 30,000 kPa (3,336 to 4,351 psi) depending on the cylinder capacity, and a standard valve cylinder nominal pressure is 13,700 kPa (1,987 psi).

Regulatory considerations

Oxygen cylinders are required to provide proof of regulatory compliance and risk classifications per product. They must have the correct labels at all times and need to be color-coded accordingly. Transport and storage regulations for oxygen cylinders vary depending on the cylinder's current capacity status (e.g., empty, partially filled, or full) and require hydrostatic pressure testing every five years. Oxygen cylinders must comply with international standards and with the Globally Harmonized System of Classification and Labeling of Chemicals regulations on hazardous goods, flammable, explosive, and compressed gas (usually black, red, orange, and green diamonds, respectively). Local fire codes may also dictate requirements for storage and handling of oxygen cylinders, such as ventilation, separation from flammables or ignition sources, and protection against tipping.

Infrastructure requirements

Oxygen cylinders require no electricity to be functional. They can provide oxygen to patients in two primary ways:

- ***Directly within patient care areas:*** Cylinders can be placed at or close to the patient and need to be accompanied with pressure regulators, associated gauges, and flowmeters.
- ***Piped into a health facility via a distribution manifold system:*** Distribution manifolds supplying piped systems are permanent installations of copper piping (typically type L) with brazed copper fittings. Manifolds have pressure regulation built into the header of both banks to ensure that pressure entering the system will be adequate to reach the bedside terminal unit. These piped systems need only a flowmeter with the appropriate connection fitting at the wall outlet (also known as bedside or terminal unit).

The health facility will need to have a system for organizing filled, partially filled, and empty cylinders regardless of system so that they may be replaced rapidly in case of emergency.

Supply/shipping

Transport of cylinders: Cylinders are usually transported via flatbed trucks, but the mode of transportation can vary within different companies. Trucks should include placards or appropriate signage with hazard statements, signal words, and pictograms in accordance with local regulations for the transport of flammable compressed gas (see *Regulatory considerations* above). Companies also use different distribution networks, which can influence a supplier's response time from hours to days and their logistical costs. Depending on local supply conditions, health facilities may contract delivery for cylinder refills or transport to and from supply depots themselves or via third party logistics services.

Supply of cylinders to a health facility: In normal conditions where there are only moderate fluctuations in demand (unlike pandemic situations), cylinder delivery can be prompt as suppliers draw from their reserve inventory.

Purchasing new cylinders from a manufacturer: When medical demand exceeds available inventory, suppliers may procure additional cylinders and, in medical emergencies, recall cylinders from industrial customers. Increased demand may lead to bottlenecks in either production or raw material[1] access, contributing to substantial delays. Shipping lead time varies depending on the port of origin and destination, which typically requires 2 to 12 weeks.

[1] The primary raw materials for cylinders are aluminum (aluminum alloy 6061) and steel. Aluminum is used to manufacture a range of cylinder sizes, but larger cylinders may also be manufactured from steel. Stainless steel is used almost exclusively for liquid oxygen storage (such as vacuum-insulated evaporator).

Dependencies for use

Oxygen cylinders require a variety of accessories to ensure effectiveness. At an operational level, cylinders will need the following accessories to be functional: cylinder-holding carts or trolleys; keys (or spanners/wrenches) to open valves; pressure regulators; tubing adapters for use with pressure regulators and/or integral valve with all common international standard fittings; flowmeter; non-heated bubble humidifier; and common and frequently used spare parts such as sealing set, maintenance kit, regulating unit (knobs), adapters, and connectors.

Upon delivery of the oxygen to a patient, oxygen cylinders will require nasal cannulae, masks, tubing, nasal catheter or high-flow nasal cannulae, pulse oximeter, heated humidifier, blender, and continuous positive airway pressure machines. If cylinders are attached to a manifold system, a flowmeter is needed at the bedside terminal.

Maintenance

With proper maintenance and repair, a cylinder lifespan is around 20 to 25 years; valves and flowmeters last approximately 7 to 10 years. Preventive (scheduled) maintenance for oxygen cylinders consists of conducting a visual evaluation and a function check prior to use to ensure sufficient pressure. These tasks should be performed daily. In addition, valves and regulators require periodic checks for functionality. Planned maintenance with regular cleaning and functionality checks should be performed by a certified service provider for compressed medical gases, and cylinders themselves should include hydrostatic pressure testing every five years. For safety purposes, broken or defective cylinders should be replaced immediately.

Cost

Cost of cylinders from a manufacturer: The price of a "J" or equivalent-sized cylinder (6,800-L nominal content/oxygen capacity) can range from US$54 to US$229, with a median of US$71, from a manufacturer. However, in situations of high demand, such as the COVID-19 pandemic, prices can increase substantially or fluctuate rapidly with global demand.

Cost of leasing from a medical oxygen provider: Medical oxygen providers generally take on the responsibility of cylinder procurement, filling, and maintenance as part of a leasing agreement with the health facility or health system. The lessee will put up collateral to the provider against the risk of damage to or loss of a cylinder tank. Thus, an initial deposit is typically paid prior to a monthly rental fee, which is approximately US$25 per cylinder (in addition to deposit) but can vary widely depending on the service provider. Costs of necessary accessories, such as regulators, are also born by the lessee.

Cost of cylinder filling: Filling fees for standard "J" cylinders, 6.8 cubic meters of gas, can vary broadly due to differences in production costs, with a spread of roughly US$23 to US$112 depending on geography. Transport, inspection, and maintenance costs are often bundled with the refill cost.[2]

COVID-19 considerations

In the context of a global pandemic like COVID-19, additional considerations should be raised. For example, to reduce the spread of COVID-19 through surface contamination, cylinders and associated accessories should be cleaned regularly. This cleaning should take place in a "decontamination zone" before leaving any area of known contamination. If there is any suspected contaminated contact to the cylinder, decontaminate it immediately.

[2] This information comes from: Davies M, Onwuzoo A, Mednick S. Fighting for breath: How the medical oxygen industry is failing African hospitals. *The Guardian.* August 10, 2020. https://www.theguardian.com/global-development/2020/aug/10/fighting-for-breath-how-the-medical-oxygen-industry-is-failing-african-hospitals.

Acknowledgements

This brief is part of a larger series on technologies and equipment related to ***Oxygen Generation and Storage***. It is intended to serve as a concise primer for decision makers that govern, lead, support, or manage health systems and provide a starting point for understanding the solutions available to meet a health system's need for medical oxygen and its delivery.

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For more information

path.org/programs/market-dynamics/covid-19-and-oxygen-resource-library

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