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CASE STUDY ON OXYGEN MANUFACTURING AND BOTTLING PROCESS TO HELP THE SOCIETY IN THIS PANDEMIC SITUATION, COVID – 19

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ABSTRACT

Oxygen is the most essential element found in mother earth for the survival of the living organism. Humans, animal or maximum of the species on this earth requires oxygen for their survival. The availability of the oxygen(O_2) in the environment is by the natural process called as photosynthesis i.e. done by maximum number of plants. The O_2 is easily available in the atmosphere for breathing purpose, of the living species through their respiratory system. Human used mouth and the nose to take the air that contains O_2 from the atmosphere. The main organ involved in respiratory is Lungs in the human body, but now in this pandemic COVID-19 the virus is infecting the lungs of the human being which reduces its capacity of breathing. Thus, reducing the O_2 in the body which results in multiple organ failure and resulting ultimate death of the human. Already there are method for making of the medical oxygen here in the case study we have done study on various techniques can be used in manufacturing of the medical oxygen in India at the faster rate, with the major equipment's that are easily available in the country.

Keywords: *Oxygen Manufacturing, Medical Oxygen, Pandemic, Covid-19, Oxygen Cylinder.*

Introduction

Generally believed that we are breathing is what is 100% oxygen that is available in our atmosphere. But That's not true. The atmospheric air we breathe contains about 20.9%Oxygen (O_2) and 78.1%Nitrogen = 99% remaining 1% is the mixture of other gases i.e. Hydrogen (H), Carbon dioxide (CO_2), Argon and other gases, slightly it also depends on the altitude and the topography of the different areas of the earth and also vary with the change on the altitude.

One of the major misconceptions is human being & animals need high pureO_2i.e.100% oxygen for their survival and their growth. Oxygen is not only use for respiratory purpose but also used for oxidation of various metals. There are many other usages of oxygen in different purity form ranging from 16% to 100%. The human body in generally does their respiratory form the oxygen in air but at time of medical treatment they require extra oxygen similarly fire fighters, scuba divers, mountaineer, etc also requires the pure oxygen.

Requirement of Oxygen in Human Being

Not only Humans need oxygen to live, but also required for many other might think. The minimum O_2available for breathing & survival for human breathing which is 19.5 percent and that is easily available in many places of the earth. Air from the atmosphere is used for respiratory system. The lungs consume O_2available in the air, body's red blood cells carry this oxygen present in the lungs to the different parts of the body. Each cell uses and requires oxygen to thrive. Some time, the level of oxygen in air drops many be due to gases reaction making it toxic, high altitude, other topographic conditions, oxygen deficient areas. In these cases external oxygen is required and this requirement of external oxygen is fulfilled by medical oxygen which is manufactured by oxygen industries.

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When Human Require External/ Medical Oxygen

To overcome the oxygen deficiency, Medical Oxygen is provide to the oxygen deficient person. Eternal oxygen is given to a deficient person prescribed by the doctor, anaesthetist, dentist, ambulance officer or nurse via a mask or nasal prongs. When directed by a doctor, bottled Medical Oxygen / Medical concentrator can be used by patent in home also. Now in this pandemic situation COVID-19 as the population of the country is getting affected there is a huge requirement of the medical oxygen in the country to recover the covid patients. The patient or the sufferer of COVID -19 feels breathless as patient lungs get infected due to this COVID-19 virus. Depending on the symptoms or pneumonia caused by the covid virus, and depending on infection caused — the functioning of the lungs &the struggle of the lungs to get enough oxygen and transfer oxygen in the bloodstream. To over come the deficiency of the oxygen in the Covid patient body external oxygen is required.

Oxygen level in blood of human being varies between 75 and 100 milli-meters of mercury (mm Hg). When oxygen in blood goes below 60 mm Hg it is considered low and requires supplementary oxygen or medical oxygen – but this mainly depends on the decision of the doctor. When oxygen level in blood goes too low as to the average level of a healthy person, it can be a sign hypoxemia. Hypoxemia is that body is facing problem is delivering of oxygen to all cells, tissues and organs. The most efficient way to monitor blood oxygen levels is by an arterial blood gas or ABG test. For this test, a blood sample is taken from an artery, usually in the wrist. This procedure is very accurate, but it can be a little painful and time taking. An ABG test can be difficult to do at home, so a person may wish to do an alternative test, using a small device known as a pulse oximeter. It measures blood oxygen indirectly by light absorption through a person's pulse.

The medical oxygen is packet in the cylinder of different sizes and packings depending on the usages, installation areas.

Like small portable can (non refillable)

- Small in size
- Light weight (app 120 grm)
- Easy to carry
- Oxygen quantity =150 spray (99% oxygen)
- Can be used in first aid purpose, on high altitudes, sports requirement,

Aluminium Cylinder (Refillable)

- Seamless Aluminium High-Pressure Cylinders.
- also known as light weight portable cylinder
- Light weight-- Easy to carry
- Oxygen quantity 1.3 ltr to 10 ltr
- Working pressure = 126 bar to 150 bar
- Can be used in first aid purpose, on high altitudes, sports requirement, medical purpose also

Specification of Medical Oxygen Cylinder as per RMSC

A-type, B-type, D-type

- **A-type***:* High pressure seamless cylinder for medical oxygen cylinder gas, cylinder as per ISI market confirming to IS:7258 part 2, certified by BIS (Bureau of Indian Standards) and approved by COOE (Chief Controller of Explosive). Cylinder made of Manganese Steel. **5 ltrs** water capacity / 20 cuft. Fixed with **pin index flues** type valve for direct use on machine. Valve made of Brass & chrome plated. Working pressure 150 kgf/cm^2 at 15 degcelcius = 147.09 bar. Hydraulic test pressure 250 kgf/cm^2 = 245.166 bar. Colour code of the cylinder as per IS 3933-1966 with updating till date. Certificate manufacturing certificate, ISI certificate & department of explosion Government of India to be provided for each specified cylinder separately at the time of supply. Filled with medical oxygen gas of medical grade. Matching key spanner to release oxygen for each cylinder separately. Minimum 2-year guarantee cylinder.
- **B-type:** High pressure seamless cylinder for medical oxygen cylinder gas, cylinder as per ISI market confirming to IS:7258 part 2, certified by BIS (Bureau of Indian Standards) and approved by COOE (Chief Controller of Explosive). Cylinder made of Manganese Steel. **10 ltrs** water capacity / 40 cuft. Fixed with **bull nose** type valve as per IS:3224 and neck cap. Valve made of Brass & chrome plated. Working pressure 150 kgf/cm^2 at 15 degcelcius = 147.09 bar. Hydraulic test pressure 250 kgf/cm^2 = 245.166 bar. Colour code of the cylinder as per IS 3933-1966 with updating till date. Certificate manufacturing certificate, ISI certificate & department of explosion Government of India to be provided for each specified cylinder separately at the time of supply. Filled with medical oxygen gas of medical grade. Matching key spanner to release oxygen for each cylinder separately. Minimum 2year guarantee cylinder.
- **D-type:** High pressure seamless cylinder for medical oxygen cylinder gas, cylinder as per ISI market confirming to IS:7258 part 2, certified by BIS (Bureau of Indian Standards) and approved by COOE (Chief Controller of Explosive). Cylinder made of Manganese Steel. **46.7 ltrs** water capacity / 220 cuft. Fixed with **bull nose** type valve as per IS:3224 and neck cap. Valve made of Brass & chrome plated. Working pressure 150 kgf/cm^2 at 15 degcelcius = 147.09 bar. Hydraulic test pressure 250 kgf/cm^2 = 245.166 bar. Colour code of the cylinder as per IS 3933-1966 with updating till date. Certificate manufacturing certificate, ISI certificate & department of explosion Government of India to be provided for each specified cylinder separately at the time of supply. Filled with medical oxygen gas of medical grade. Matching key spanner to release oxygen for each cylinder separately. Minimum 2year guarantee cylinder.

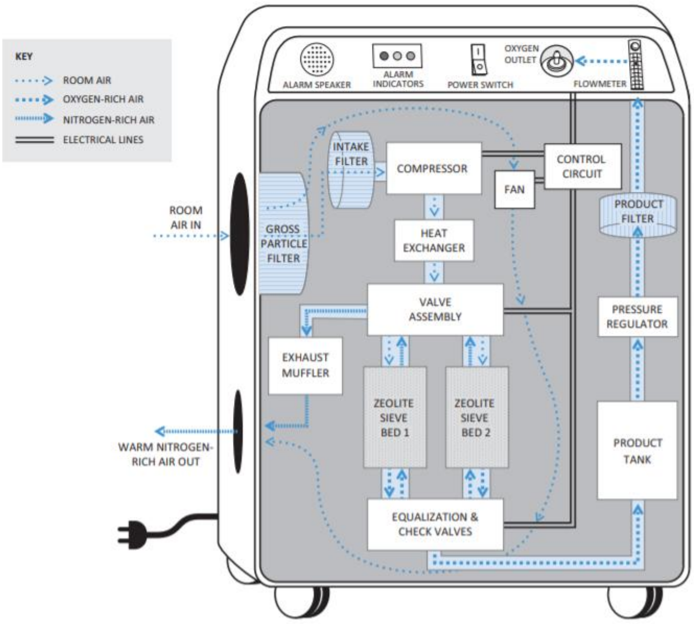
Alternate of Oxygen Cylinder = Oxygen Concentrator

Oxygen concentrator is manufactured by many companies with different models and sizes depending in their uses and the requirement of Oxygen flow rate. Oxygen concentrator works on the phenomena of making oxygen from the atmospheric air. The rate of oxygen making with the help of concentrator is 1 ltr. to 5 ltr/ min.oxygen concentrator basically comprises of –

- Small air compressor
- 2-cylinerical vessels connected with pressure valves & tubes
- One Pressure container.
- a pressure equalizing reservoir.
- with electrical supply / battery operated.

The working of the oxygen concentrator is very simple and it takes the air as its raw material to produce oxygen that can be useful to the patient.

After the plug in of the concentrator the compressor starts and sucks the air from the room. The first half-cycle the first cylinder receives air from the compressor passing through the heat exchanger.From there the air is passed to the first cylinder rises from atmospheric to about 2.5 times i.e.20 psi/ to 138 kPa gauge, or 2.36 atmospheres absolute i.e. the nitrogen is adsorbed on the surface of the zeolite. After this the air passes to the next cylinder where the remaining gas like water vapour, CO_2, argon removed. The pure oxygen is then passed product tank. The complete process is maintained by the pressure valves. The filtered oxygen is then passed to the patient connected pipe.



Source: Provided by PATH (2015).

Simultaneously, the second half of the cycle, there is another valve position change to vent the gas in the first cylinder back into the ambient atmosphere, keeping the concentration of oxygen in the pressure equalizing reservoir from falling below about 90%. The filtered oxygen flow rate can be easily controlled by the regulator.

Oxygen concentrator is a small working model of Oxygen manufacturing plant only the main difference is high pressure bottling is not possible with the concentrator, the oxygen manufactured by the concentrator is directly supplied to the patient.

System	Central oxygen (pipeline system)	Oxygen cylinders	Oxygen concentrators
Power source required	No	No	Yes, continuously (100–600 W, depending on model)
Transport requirement	Those associated with cylinders	Regularly; heavy and costly to transport	Only at time of installation
Exhaustible supply	Yes, if pipes are refilled from an offsite supply facility	Yes, depending on the size, storage pressure and patient needs	No, continuous supply as long as power remains uninterrupted
Operational costs[a]	Small to moderate: maintenance, continuous refill of pipeline by bank or tanks	High: cylinder refills and transport from refilling station to hospital	Small: electricity and maintenance
User care	Minimal	Minimal: regular checking, minimizes fire hazard (no grease or flammables)	Moderate: cleaning of filters and device exterior, and minimizes fire hazard
Maintenance	Moderate: check for pressure leaks with manometer Maintenance of oxygen pipelines to prevent leaks and oxygen wastage Significant: if supply facility is onsite	Moderate: check for pressure leaks with gauge	Moderate: check for low oxygen output with analyser

Differences Between Medical Oxygen & Industrial Oxygen?

Medical oxygen is highly pure oxygen with 99% purity no other toxic gas is present in it. This oxygen is used in medical treatment at time of operations or to the patient suffering from lack of oxygen. Medical oxygen is supplied in the hospitals or to the patient as per the guidelines prescribed by the ministry of health of India. The medical oxygen is given after the prescription of the doctor.

Industrial oxygen may not be 100% pure as its usage varies from industry to industry. The industrial oxygen may contain some of the impurities. The oxygen in industries are use mainly to enhance the heating, oxidation, chemical reactions, cutting. The industrial oxygen purity levels may vary depending on the need and the cost incurred to manufacture the oxygen.

Medical Oxygen

Medical oxygen comprises of 92% to 95% oxygen with 4% to 3 % nitrogen and 4% to 2% argon. There are different ways of making oxygen but two are main prevailing in India, in all the techniques there is removal of nitrogen, hydrocarbons, moisture, and CO2 are removed leaving behind only oxygen (O_2).

Medical Oxygen Manufacturing

The *raw material* for the Oxygen manufacturing is atmospheric air. Different method used for manufacturing of the oxygen used in medical purpose or industrial purpose. The following methods used for oxygen manufacturing also known as Air Separation Units (ASU)

- **Cryogenic distillation process / Cryogenic Air Separation Units:** Cryogenic distillation process is the most common method (commercial)to producing **Oxygen (O_2)** separation it from air *(cryogenics is the production and behaviour of materials at very low temperatures. As*

Oxygen boiling point is 90.18 K.). Nitrogen is also produced by separating it from atmospheric air. Argon is also produced from the same process. (that is how a plant of Nitrogen can be converted in Oxygen plant also with slight modification).

Process

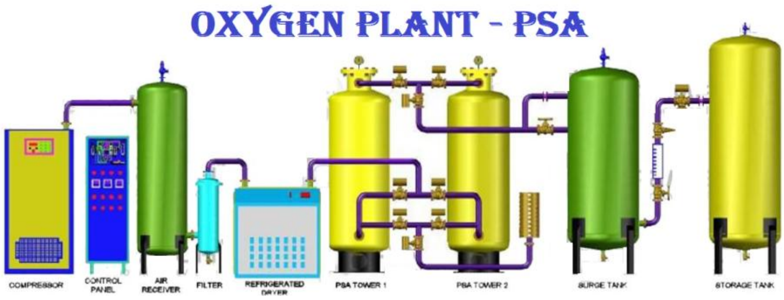
The following major gas can be produced and separated gases can be separately bottled in same plant

- First air is compressed by 3 stage compressors (high pressure compressor) to a pressure of 30kg/cm2 = 29.42 bar.
- Then removal of water vapor and carbon dioxide take place in a battery of molecular sieves. The out-going carbon dioxide and water vapor free air is compressed upto pressure of 100 kg/cm2 = 98.07 bar and cooled substantially by external refrigeration. This high-pressure air is cooled further in heat exchangers by the outgoing product gases. Bulk of this cold air is allowed to expand through an expansion engine and the remaining air is routed through an expansion valve.
- The downstream air of the expansion engine attains a pressure of 5 kg/cm2 = 4.9bar and a considerably reduced temperature.
- The other stream of air going through the expansion valve is expanded to also attain a pressure of 5kg/cm2) whereby partial liquefaction of air takes place. Both the streams of air are mixed and introduced as a liquid vapor mixture to the bottom column of the double rectification column (fractional Distillation Column).
- Due to mass and heat transfer at every perforated tray in the column the nitrogen rich liquid vapor accumulate at the top trays and an oxygen rich liquid-vapor mixture collect in the bottom of the column.
- The liquid nitrogen accumulating at the upper portion of the bottom column is drawn out as product for storage in Vacuum insulated cryogenic tanks.
- For Nitrogen gas, this liquid nitrogen is pumped from the storage tank through vaporizers for gasification and bottling into cylinders.
- The oxygen rich liquid-vapor mixture at the sump of the bottom column is routed to the top column of the distillation column, which is at a lower pressure of 0.5kg/cm2. In this low-pressure column further separation of oxygen and nitrogen vapor, take place through a mass and heat transfer process at the various trays within the column.
- The separated oxygen vapours again settle at the bottom of this column and condense to form liquid oxygen due to exchange of heat with the colder liquid nitrogen formed at the top of the bottom column. This liquid oxygen accumulating at the bottom portion of the top column is drawn out as product for storage in Vacuum insulated cryogenic tanks.
- For Oxygen gas, this liquid oxygen can be vaporized by the heat exchange between the incoming process air and compressed by oxygen compressors for bottling into cylinders.

Depending on the requirements, the production modes of the plant can be altered to produce: 1) liquid nitrogen and compressed oxygen where the in-built vaporizers are used to fill compressed oxygen and 2) liquid oxygen only, where external vaporizers are used to fill compressed oxygen.

- *Adsorption Technology / PSA* -- with advancement of the technology day by day, limitation of the area *available* to set up plant, to decrease the cost of transportation, PSA technology of oxygen manufacturing is now mostly in demand. Due to this these oxygen plant can be installed in the hospital area also. It is safe for their installation also the time require for installation is less. Power consumption is also low. Different parts of the oxygen plant based on PSA technology.
  - **Air Compression:** Used for building up the air pressure sucking it from the atmosphere. This is low pressure compressor, single stage compressor, with flow rate depending in the size of the plant.
  - **Air Buffer Tank:** Holds the air of the atmosphere at 10 to 16 bar pressure and having a storage depending on the size of the plant. The tank is made of MS sheet with inlet and outlet values and pressure indicator.
  - **Air Filtration:** Do the work of air purification by removes the suspended particles present in the air, air drying i.e by removing of the moisture, also removes the oil traces present in the air.
  - **Refrigerant Air Drying:** Use to bring down the temperature of the air coming from the filter.

- **PSA Towers:** The air from the dryer is passed in the MS vessels contains the sieve molecules to act as adsorbers (generally Zeolite is used)***A)*** First Absorbing Tower A, Second Absorbing Tower B. The adsorbed nitrogen is released in atmosphere with negative pressure.
- **Surge Tank:** Rotameter is used to check the oxygen flow rate and the quality of the oxygen.
- **Oxygen Storage Tank:** The pure oxygen is storage in the storage tank at a particular pressure. After then the oxygen is used to directly supply in the piping of the hospital or supplied to the compressor for bottling.
- **High Pressure Compressor:** A 3 stage compressor to compress the oxygen from 120 bar to 150 bar to fill in the oxygen cylinder to be used for the patients. Technical details of the cylinder are discussed above.



- In technical language - the process of PSA is based on “different gases have the propensity to be attracted to different solid surfaces more or less strongly” or in simple language “the atmosphere air contains Oxygen, Nitrogen and other gases – major gas i.e Nitrogen is first adsorbed on the surface of the solid molecules and filled in the filtration vessel at particular pressure and allowing other gases to pass in another vessel and the other gases are adsorbed in the second vessel and at last we get oxygen 99% $^{+-}$ 1%.

Nitrogen is attracted to the Zeolite surface at particular pressure and will be released from the zeolite at negative pressure. Due to this the operating cost of this plant is very less, the degradation of zeolite is very less and sustain for many years. 2 vessels of Zeolite are use for more pure oxygen recovery. The air is first passed from the 1st vessel and from there it is passed to 2nd vessel. In some of the plants to achieve more purity Carbon Molecular Sieve (CMS) is also used to get more pure oxygen. The whole process is intelligently controlled with help of automated valves.

The maximum purity achievable in such systems is 99.3%. Typically, the system is operated at a design point of 99.1% to optimize the output. In such a system there is about a 35% loss in the 94% feed product gas. This loss of product is sensitive to the purity level that is lower purity, less product loss.

TABLE 1. Comparison of air separation technologies

Technology & development stage	O_2 purity %	Capacity, tons per day	Possible by-products, Quality	Energy demand kWh/ton O_2	Driving force	Start-up time
Cryogenic Matured	99 +	up to 4 000*	Nitrogen, Argon, Krypton, Xenon, Very good	200$^{(1)}$	Electricity	hours/ days
Adsorption Matured	95 +	up to 300	Nitrogen, Bad, ca. 11% O_2	500$^{(2)}$	Electricity Heat (70-90 °C)	minutes/ hours
Membrane (polymer) Matured	~ 40	up to 20	Nitrogen, Bad	–$^{(4)}$	Electricity	minutes
Membrane (ITM) R&D phase	99 +	laboratory scale	Nitrogen, Bad	400$^{(3)}$	Electricity Heat (800 °C)	hours

* – from a single train
(1) – data from existing installations,
(2) – laboratory-based estimation,
(3) – literature data,
(4) – not applicable due to low oxygen purity

- *Membrane Technology*: The suction system is same with help of the air compressor single stage, the air from the compressor is passed through the filters to remove the suspended particles of the air. Oxygen up to the concentration of 30-45%. The technology is involved is only change of filtration technique, I this process the gas separation is achieved in the gas separation module composed of hollow-fiber membranes and representing the plant critical and high-technology unit. The adoption of membrane systems for air enrichment purposes promises multiple oxygen savings where the oxygen concentration of 30-45% is sufficient to cover process needs. In addition to customer saving on the product oxygen cost, there is a collateral economic effect based on extremely low operating costs. With the incorporation of the membrane technology, oxygen plants have outstanding technical characteristics. Membrane oxygen plants are highly reliable due to the absence of moving parts in the gas separation module. The systems are very simple in operation – control of all operating parameters is carried out automatically. Membrane oxygen plants are best suitable for vaiour industries and their application. With moderate requirements to oxygen purity in product up to 30-45%, membrane systems generally prove more economically sound than adsorption and cryogenic systems. This system is not recommended for medical oxygen.

Difference between Liquid & Gas Oxygen

Liquid oxygen takes up much less space in a canister than oxygen in a gaseous state (also known as concentrated oxygen), making liquid oxygen containers lighter and smaller than oxygen gas Container in Gases form. Vaporizers convert the liquid oxygen into a gaseous state. A pressure control manifold then controls the gas pressure that is fed to the process or application. Vessels used in liquid oxygen service should be designed for the pressure and temperatures involved.

1 ltr of liquid oxygen = 860 Liters of gaseous oxygen.

Liquid oxygen is pale blue in color and is paramagnetic (strong): it can be suspended between the poles of two powerful magnet. Characteristics of Liquid Oxygen are -

- Density of 1.141 g/cm^3 = 1.141 kg/L = 1141 kg/m^3,denser than liquid water,
- freezing point of 54.36 K = −218.79 °C = −361.82 °F
- boiling point of 90.19 K = −182.96 °C = −297.33 °F (at 101.325 kPa = 1.01 bar = 760 mmHg)
- Expansion ratio of 1:861 under 1 SAP = 100 kPa / 750 mmhg/ 1 bar and 20 °C /68 °F and because of this,
- it is used in some commercial and military aircraft as a transportable source of breathing oxygen.

Oxygen turns to liquid only when it is kept at very cold temperatures and when it is released under pressure from cold storage, it willbe converted to a gas.

Unit Conversion Data for Oxygen

	Weight		Gas		Liquid	
	pounds (lb)	kilograms (kg)	cubic feet (scf)	cu meters (Nm^3)	gallons (gal)	liters (l)
1 pound	1.0	0.4536	12.076	0.3174	0.105	0.3977
1 kilogram	2.205	1.0	26.62	0.6998	0.2316	0.8767
1 scf gas	0.08281	0.03756	1.0	0.02628	0.008691	0.0329
1 Nm^3 gas	3.151	1.4291	38.04	1.0	0.3310	1.2528
1 gallon liquid	9.527	4.322	115.1	3.025	1.0	3.785
1 liter liquid	2.517	1.1417	30.38	0.7983	0.2642	1.0
1 short ton	2000	907.2	24160	635	209.9	794.5

Scf (standard cubic foot) gas measured at 1 atmosphere and 70°F.
Nm3 (normal cubic meter) gas measured at 1 atmosphere and 0°C.
Liquid measured at 1 atmosphere and boiling temperature.

Oxygen Transportation and Packing for Consumers

Oxygen is transported in 2 forms Liquid or gases form. The oxygen is generally transported in soil cylindrical containers or oxygen cylinder as discussed above.

Suggestion & Recommendation

Caution: Oxygen is not a flammable gas, but supports combustion as well as oxidation. Many materials are flammable in air and burns vigorously in contact or supply of oxygen. Some fuels when combined with oxygen, such as oil and grease, burn with almost explosive violence. Cylinders with fissures can be projected with force. All elements, except inert gases, in direct combination with oxygen, form oxides. Proper international signs and symbols for hazard management should be on the compress oxygen containers.

Medical grade oxygen 93 is defined as follows:

- Ph Eur: Contains between 90% to 96% O2. Reaming volume consists of Nitrogen & Argon. This monograph applies to oxygen used on site where it is produced. It does not apply to individual concentrators. The continues supply of the pure oxygen is also dangerous to the patient, so the supply of the oxygen to the patient must be under doctor recommendation and observation.

Conclusion

This case study will help the society to understand the use of the oxygen and the type of cylinder they can choose as and when required. In this pandemic situation this will help the government of the country to decide the establishment of the oxygen plant in different parts of the country working on the quantity of the oxygen required and also the establishment time required in set up of the oxygen plant.

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