



USAID
FROM THE AMERICAN PEOPLE

RISE
Reaching Impact, Saturation,
and Epidemic Control

Reaching Impact, Saturation, and Epidemic Control (RISE)

Standard Operating Procedures

PSA Plant Operations and Preventive
Maintenance by the Facility Management

Contents

ABBREVIATIONS	3
INTRODUCTION	4
COMPONENTS OF A PSA PLANT	4
PSA PLANT OPERATIONS	5
FIRE SAFETY IN PSA PLANTS	8
PREVENTIVE MAINTENANCE FOR PSA PLANTS	8
ANNEXURE	10

Abbreviations

DG	Diesel Generator
LPM	Litre Per Minute
MCB	Miniature Circuit Breaker
MGPS	Medical Gas Pipeline System
NABL	National Accreditation Board for Testing and Calibration Laboratories
OEM	Original Equipment Manufacturer
PLC	Programmable Logic Controller
PSA	Pressure Swing Adsorption
PRV	Pressure Relief Valve

Introduction

Amid the ongoing COVID-19 crisis, especially, oxygen shortage in the second wave, brought out the need for improved management of oxygen generation and supply. In that context, pressure swing adsorption (PSA) oxygen plants have emerged as a viable option and widely used as a primary source of medical oxygen across hospitals in India. Moreover, to limit the dependency on refilling oxygen cylinders and procuring liquid oxygen from vendors, the Government of India has recommended that PSA plants should be used as an alternative and sustainable source of oxygen. Oxygen generated by PSA plants is now recognized and permitted by the Indian Pharmacopoeia Commission.

PSA plant technology is based on the phenomenon that, under high pressure, gases tend to be trapped on solid surfaces called adsorbents. The higher the pressure, the more gas is adsorbed. When the pressure drops, gas is released. Special adsorbent materials such as zeolites, activated carbon, etc. are used as trapping materials. The target gas is adsorbed at high pressure, and the process swings to low pressure to desorb the adsorbed gas. In the case of the PSA plant, 13X molecular sieves zeolites are used to adsorb nitrogen at high pressure to obtain 93% (+/-3%) pure oxygen for medical use.

Components of a PSA Plant

Air Compressor

The lubricated screw type air compressor is typically used in PSA plants to compress the air at approximately 5-6 bar.

Air Dryer

It is used to remove moisture from compressed air. The dried air eliminates operational issues in the molecular sieves and solenoid valve. Typically, refrigeration dryers are used in PSA plants.

Air Filters

In a PSA plant, various filters such as pre-filter, carbon filter, fine filter, bacterial filter, etc. are used to remove solid particles such as dust, dirt, and other foreign material; fine particles, oil particles of varying sizes (5 microns to 0.01 microns); and vapors, moisture, and bacteria across various stages of oxygen generation. Bacterial filters are used at the final stage of oxygen production just before the oxygen is allowed to pass through the medical gas pipeline system (MGPS).

Air Storage Tank/Receiver

It is a pressure vessel where the air from the dryer and filters is collected (at 4.5-5 bar pressure) before it is sent to the adsorption towers.

Adsorption Towers

There are two adsorption towers installed in the PSA plants. These towers contain zeolite molecular sieves and activated alumina. In the adsorption towers, nitrogen is removed from the air through adsorption and 93% (+/-3%) pure oxygen is supplied to the buffer storage tank which is connected to the MGPS. The pressure of gas is at 4.5 - 5 bar in the adsorption towers.

Valves

Different types of valves are used across a PSA plant. A ball valve is usually used at the inlet and outlet of the various components in the PSA. A pressure relief valve is fitted in all the pressure vessels and opens in the event of a serious malfunction. A non-return valve is fitted at the outlet of the absorption tower to avoid any backward flow of oxygen into the absorption tower. During the desorption phase, solenoid valves allow nitrogen from the two adsorbent towers to be exhausted.

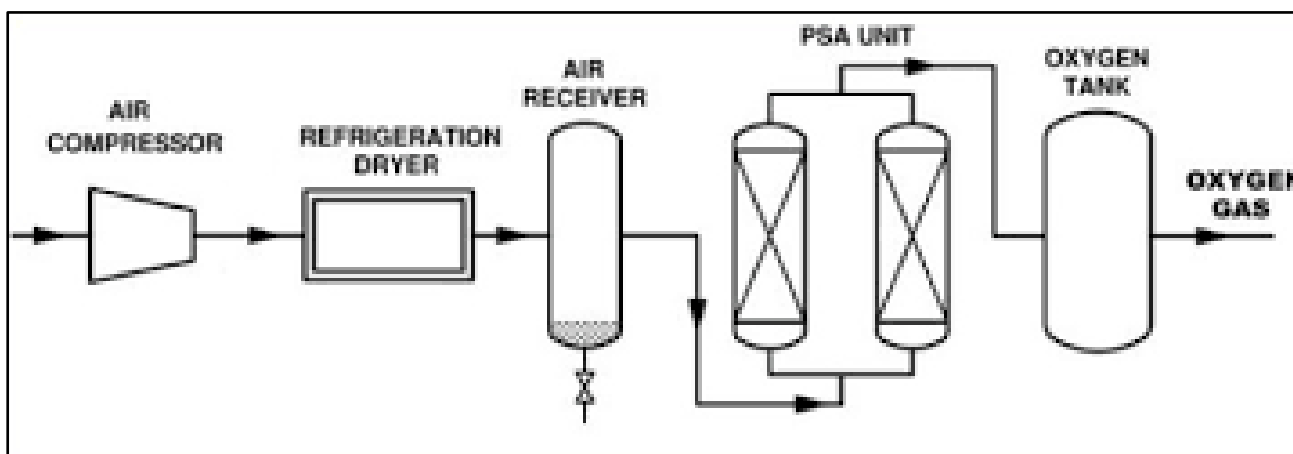


Figure 1: PSA plant line

PSA Plant Operations

Start Up Procedure of a PSA Plant

- The area near the unit should always be kept clean and well ventilated.
- Switch on the main power switch and check the voltage in the power panel as per requirement and as per the need of the plant.
- Ensure oxygen receiver tank inlet valves and outlet valves are closed.
- Ensure air receiver tank's outlet valve is in a closed position.
- Switch on the oxygen generator control panel's miniature circuit breaker (MCB), air dryer's MCB, and the air compressor switch at the power panel.
- Start the air dryer unit before starting the air compressor (where the air dryer is followed by the air receiver tank). Wait till the air dryer's dew temperature reaches its set value (usually less than <7 degrees centigrade).
- Start the air compressor.

- As soon as the air receiver tank pressure reaches (please check as per the original equipment manufacturer (OEM) manual, the time cycle of the PSA unit starts.
 - Once the pressure reaches around 70% of the required pressure, which is between 3.5-4.9 bar in the air receiver tank, open the drain/vent valve (which is located at bottom of air tank) for 5 seconds and check for any water/moisture discharge.
 - Check for any water/moisture discharge at the dust and coalescer filter through drain valve manually.
 - Continue the above two steps every 5 minutes for 5 cycles. If water/moisture is observed, do not proceed further to allow the air into the generator tank.
 - If traces of water/moisture are observed, then check the dryer and rectify as per the dryer manual.
- Gradually open the air receiver tank's outlet valve to equalize the air pressure and then open it fully.
- Switch on the button (it could be touch screen)
- Ensure all valves are operating as per the programmable logic controller (PLC) program in the control panel (as per the description in the manual).
- If any abnormality is found, please refer to the corresponding troubleshooting steps in the "OEM Installation & Commissioning Manual."
- Observe for any abnormalities such as the sound inside the generator towers operation, exhaust blowdown, dusting/powder discharge at silencers/mufflers. For any abnormalities, refer to the corresponding troubleshooting steps in the corresponding "OEM Manual."
- In the control panel display, go to the "Operator Screen" to see the oxygen purity and increase pressure gradually.
- Once the oxygen pressure reaches more than 4.2 bar and purity is $93\% \pm 3\%$ (to be checked in the display), wait for 5 minutes. Thereafter, open the outlet valve of the oxygen receiver tank fully if the plant is connected to the hospital's medical oxygen pipeline.

Note (warning):

- One may follow this starting procedure in PSA plants where the air dryer is followed by the air receiver tank.
- Never switch on the air compressor before switching on the air dryer when the air dryer is followed by the air receiver tank.
- Never operate the plant if water auto drain valves are malfunctioning or not draining properly. Residual water can be checked by opening the manual drain valve.
- Do not operate the plant when power (voltage) supply is unstable.
- Oxygen generator should only be used for only high purity (>90%) oxygen generation and at specific pressure as per the PSA manual and hospital needs.
- Ensure that the inlet air to the adsorption towers is dried and filtered.

Caution:

- Do not start or operate the PSA plant if there is a leak.
- Do not operate the generator at pressures and/or temperatures above the maximum, allowable limit mentioned in the datasheet/manual.
- Verify that incoming voltage matches the voltage marked as per the PSA plant manual.

- Emergency stop button should be used to stop the process in high-risk conditions.
- Do not overdraw the oxygen with flowrate (liter per minute) which is higher than its capacity as it leads to:
 - Drop in oxygen purity
 - Drop in oxygen pressure
 - Malfunction/permanent failures of critical parts such as valves, sensors, gauges, etc.

Shut Down Procedure of a PSA plant

For regular maintenance activities, please follow the procedure to shut down the PSA plant as given below:

- Close the oxygen outlet valve. It is after the bacteria filter of oxygen storage tank.
- Close the air receiver tank's outlet valve and oxygen receiver tank's inlet valve.
- Wait (for 5 to 10 minutes) until the dial gauges readings on both the adsorption tank towers show zero. (Run the plant for a few cycles till the pressure gauge in the generator towers reaches zero).
- Switch off the air compressor.
- **Only for maintenance (otherwise, skip this step):** Drain the pressure inside the air receiver tank and oxygen receiver tank by opening the drain valves available at the bottom of these tanks. Pressure in the oxygen receiver can be seen on the "Operator Screen" of the oxygen generator control panel.
- Switch of oxygen generator control panel's display.
- Switch off the air dryer.
- Close the outlet valve of the air compressor.
- Switch off the oxygen generator control panel's MCB, air dryer's MCB, and the air compressor's switch at the power panel.
- Switch of the main electrical power source.

Handling Power Failure or Disruption

Whenever there is a power cut, the power backup supply source such as the diesel generator (DG) should automatically switch on, continuing the operation of the PSA plant. In case there is no DG or any other power backup supply source, please follow the below listed procedure:

- Monitor the secondary source of oxygen supply.
- Completely close the oxygen receiver tank's inlet valves and outlet valves.
- Completely close the air receiver tank's outlet and inlet valves.
- Switch off the oxygen control panel (if it runs on the UPS source).
- Turn off the oxygen generator control panel's MCB, air dryer's MCB & the air compressor's switch at the power panel.
- Switch off the power panel.

When the power supply resumes and is stable, please repeat the start-up procedure as mentioned above.

Fire Safety in PSA plants

First, all fire safety measures (including prevention, suppression, evacuation, and training drills) should be taken to prevent any fire incidents. In case of fire, please alert others immediately and only attempt to suppress the fire if it is safe to do so, otherwise, please evacuate immediately to a safe location, and if possible, help others to do so. Please follow the below listed instructions only if it is safe, otherwise please evacuate immediately:

1. Close the oxygen outlet valve which is placed after the bacteria filter (after the oxygen receiver tank).
2. Press the emergency stop button on the PSA control panel.
3. Press the emergency stop button of the air compressor and close the compressor outlet valve.

Preventive Maintenance for PSA Plants

PSA plant preventive maintenance is an important part of a successful facility management program. It requires an additional budget for equipment maintenance and operations. Preventive maintenance keeps the PSA plant operating efficiently, increases the safety of the organization's employees, and helps to avoid large-scale and expensive repairs. Preventive maintenance should be carried out only by an experienced and properly trained personnel.

Steps for Preventative Maintenance

- The PSA plant should be secured to prevent vandalism and unauthorized access. The plant should be protected with a lockable door.
- The vessels installed in the plant should be in good condition without any dents, rust, or any other type of damage. The pressure of the vessels should be maintained as per the manufacturer's recommendation. Operators can refer to the manufacturer's maintenance and operations manual.
- All the pipework should be free of corrosion and painted in white or yellow as per the original color code. The valves installed in pipelines should be functional and flexible enough to move or rotate. All the fittings and valves must be leak tested as per the procedure provided in Annexure A.
- The pressure regulator and gauges should be calibrated from time to time as per the manufacturer's recommendation. Normally, it must be done every quarter or half-yearly. The operator must refer to the operation and maintenance manual or contact the manufacturer or supplier for required assistance.
- The PSA plant foundation should be in good condition and the plant must be supported well with the help of nuts and bolts drilled into the foundation.
- The operator is responsible for keeping the PSA plant room well-ventilated, clean, and free of fire hazards and debris inside and outside the facility.
- The operator shall clear the vessels' drains as per the manufacturer's recommendation and at the time of troubleshooting. When the plant is in operation, drain valves must be secured in the normal close position. In the case of an automatic drain system, ensure that it is operational (check this function by pressing the DRAIN test button in the PSA controller menu).
- The operator should be sure to wear all the personal protective equipment while carrying out any type of preventive maintenance. He/she should also ensure the nearest fire safety equipment (fire hose or

fire extinguisher) is in place and is operational. There is a need to ensure that they regularly conduct fire safety drills and inspect the functioning of fire safety equipment as per the local authorities' requirements.

- All the pressure relief valves, and vent pipes should be cleaned and free of any clogging or rust.
- The operator must ensure that all rubber seals are in good working condition and do not leak.
- The operator should check the physical condition of the earthing connection and the earth's resistivity.
- The operator should ensure that all types of filters are replaced timely as per the manufacturer's recommendation. If the recommendation is not clear in the operation and maintenance manual, then the operator may contact the manufacturer or supplier for immediate assistance.
- The operator should ensure the required impurity level is within the permissible limit. It is recommended to get oxygen samples tested by a National Accreditation Board for Testing and Calibration Laboratories (NABL)-accredited laboratory, preferably once every six months to validate the functioning of the PSA plant as well as the oxygen analyzer fitted in the plant.
- The operator should ensure that appropriate oil level is maintained in the air compressor. In the event of spillage, the operator should immediately contact the manufacturer or supplier for assistance.
- The operator should ensure good condition of fences/boundary walls/gates with proper signage.
- The operator should ensure availability of at least two compressors with each PSA plant.
- The operator should conduct regular inspection (daily, monthly, and yearly) and should be well-versed in routine maintenance and minor fault resolutions (such as electrical and technical). Please see Annexure B for more details.

Please note that the basic toolkit and spare parts should be made available at the site for preventive maintenance.

Troubleshooting Techniques

Problems	Tips	Recommended Escalations
LED not glowing or/and nor reading on display	<ul style="list-style-type: none"> - Check the power supply connection. - Check connection in between the equipment. 	If not sorted with the tips, manufacturer/supplier should be contacted.
Low pressure in oxygen tank	<ul style="list-style-type: none"> - Check any obstruction to the air flow near the compressor. - Ensure all the pre-filters are clean/changed. - Ensure all the valves are fully opened. - Check the consumption rate. Production v/s consumption. - Check the pressure gauge/transmitter of the oxygen tank which may require calibration. - Check the leaks as per the procedure in Annexure A. 	If not resolved with the tips, manufacturer/supplier should be contacted.
Low oxygen purity	<ul style="list-style-type: none"> - Ensure all the valves are fully opened. - Check that the equalization valve is closed during oxygen production and regeneration of other beds. 	If not sorted with the tips, manufacturer/ supplier should be contacted.

	<ul style="list-style-type: none"> - Ensure all the valves are cleaned as per the operation and maintenance manual. - Purge the whole plant as per operation and maintenance manual. Refer to the OEM. - Faulty sensor. - Faulty PLC reading - must be calibrated as per the manufacturer recommendation. 	
Not able to purge the plant	<ul style="list-style-type: none"> - Ensure that the compressor is working. - Check the solenoid valve and ensure all the manual valves are in opened position including exhaust valve. - Clean if the silencers of the vent pipe are clean. 	If not resolved with the tips, manufacturer/supplier should be contacted.

Annexure

Annexure A: Leak Testing Procedure

- Shut off the PSA oxygen plant by switching off the main power supply.
- Shut off the manual valve at feed air supply and the valve at the outlet before the MGPS.
- Read and note the pressure P1 in each vessel using the pressure gauges installed in line.
- Let the plant stand still (rest) and isolated in pressurized condition (e.g., 5 bar) for one hour.
- After one hour, read and note the pressure P2 in each pressure gauge.
- Determine an eventually pressure drop as the difference between P1 and P2 for each component.
- Any drop in pressure per hour should be investigated with the leak test procedure.
- Apply soapy water on the entire suspected (joints and fittings) portion of the pressure drop, including the valves and regulators, using a spray bottle or sponge. Pressurize the system without turning on any appliances. If the operator sees bubbles, then there is a leak at that point.

Annexure B: Daily, Monthly and Yearly Inspections

- Daily inspections
 - Inspection of the pre-filter, oxygen purity, compressor pressure and oil level, oxygen pressure in air receiver tank, adsorption towers and oxygen buffer tank, and dryer dew point. Check drains of the filter to ensure that the condensate outlet and tubing for the drain valve is not obstructed. Condensate should discharge from the outlet or tubing for approximately three to five seconds every ten minutes when the ON/OFF switch on the control panel is set to ON and the green indicator light on the switch illuminates. Press the MANUAL DRAIN button on the control panel and observe the discharge. The discharge should flow freely and be clear of oil and water within five seconds.

- Monthly inspections
 - Check pipes and hoses for leakages.
 - Check solenoid valves for corrosion.
 - Inspect filters such as carbon filter, fine filter, bacterial filter.
 - Test the performance of automatic drain valve.

- Annual inspections
 - Check drying and regeneration cycles functioning.
 - Check for clogging of silencer.
 - Replace filter elements.
 - Check the condition of all the valve seals.
 - Calibrate the oxygen sensor.
 - Check the servicing requirement of compressor and air dryer.