Overview: PSA Oxygen Plant Commissioning Guidelines

Date: 28 August 2024
This document was developed by Build Health International for the Global Fund's Project BOXER.

The purpose of this document is to serve as a guideline for Suppliers, PR's, technical staff and biomedical engineers on the minimum requirements to commission an oxygen plant. Though ideally documented at initial post installation commissioning, these requirements can be reconfirmed and documented at any point post installation including at routine, preventive and corrective maintenance by designated trained staff or the contracted supplier. Requirements can vary between plants with different operating conditions, models, and manufacturers, and it is best to cross check with additional or unique manufacturer-specific requirements when available. A plant would not be considered commissioned until these requirements are documented. This document is intended to be used as a minimum standard and does not include every procedural step required for commissioning.

General

1. Plant equipment specifications including Automatic Voltage Regulator (AVR) or other supplier provided components are confirmed via photo of nameplates and/or plant walkthrough video
2. All automatic and manual drains are tested and functionality is confirmed
3. Shut off valves, isolation valves, and alarms are tested and functionality is confirmed
4. Leak tests performed to confirm no leakages across the plant infrastructure (from compressor to bedside outlet)
5. All parts and accessories used to connect all equipment must be confirmed to be within manufacturers' specifications and industry standards.
6. Plant room ventilation functionality is confirmed (if relevant) and plant room temperature is between 5 - 40 degC or the manufacturer recommended temperature for the duration of testing

Air Compressor/Dryer

1. PDP Temperature is under 5 °C
2. Air compressor pressure output meets plant equipment requirements

Oxygen Concentrator

1. The plant is run uninterrupted for a minimum of 24 hours
2. Purity remains above 90% at all times
3. The flow rate is maintained at the rated maximum capacity of the plant for the duration of the 24 hour test
4. The onscreen purity is confirmed with a handheld analyzer. This purity must be confirmed at the following locations:
    a. Directly from the output of the oxygen tank
    b. Where available, at the bedside outlets
    c. Where filling manifolds are present, directly from a recently filled oxygen cylinder
5. Output pressure meets equipment requirements as indicated in the manufacturer's manual
6. If sensors are present, output CO and CO2 levels meet International Pharmacopeia standards

Booster Compressor

1. Cylinder filling rate is tested and confirmed to be within 10% of the manufacturer's stated output rate.
    a. BHI would expect this to be done by filling a full manifold, timing how long it takes to fill all the cylinders and then taking the average time per cylinder.
2. Booster compressor shuts off automatically when set shutoff pressure is reached (refer to manufacturer's manual for the exact set pressure)
3. Pressures at all stages including inlet pressure meet manufacturer specifications

Piping (if applicable)

1. Pipe material is confirmed to meet manufacturer specifications and industry standards
2. Pipe size is measured and confirmed to match design drawings or a rationale is provided for a change in sizing
3. Pipes are correctly labeled
4. 24 hour pressure test performed at 20% above operating pressure and confirmed to not fall more than 10%
5. Changeover system and low pressure alarm are tested (if present)
    a. Shut off supply to hospital from the oxygen tank to confirm the supply switches to the manifold
6. Zone valves/alarms are accessible by clinical staff and tested for functionality
7. Visual inspection of the piping is conducted for pipe deformations and unacceptable junctions
8. Bedside outlets are tested for leaks
9. Purity at outlets is measured at or above 90%
10. Where multiple gas pipelines are run, test to confirm no pipelines have been cross connected - This requires only pressurizing one gas at a time.
11. Test the last outlet in every branch for particulate by blowing oxygen into a white cloth.

Any deviations from the above requirements must be documented and confirmed with the manufacturer that they will not result in decreased performance, shortened lifespan, or voided warranty.

Infrastructure Works

The supplier is responsible for ensuring completeness of any site works under their scope. For site works **not** under supplier scope, the supplier shall document any observed infrastructure issues that may result in decreased performance, shortened lifespan, or voided warranty. At a minimum, the following shall be assessed:

1. Plant housing is confirmed to be at least 10 m from fire ignition sources and pollution sources.
2. Plant house has sufficient space around the PSA plant for access to operation and maintenance tasks
3. Plant housing ensures an acceptable noise level near the hospital wards
4. Fire prevention measures have been implemented including safety signage, fire extinguishers, and multiple entry and exit points in the PSA plant housing.
5. There is confirmed dedicated space for cylinder storage. This should include:
    a. Racks and chains for securing cylinders
    b. Well labeled dedicated spaces for storing empty and full cylinders
    c. Cylinder trolleys with chains from transporting cylinders. Where different sized cylinders are on site, trolleys for each cylinder size must be confirmed.
    d. Separate spaces with the above requirements should be made available in cases where gasses other than oxygen will also be stored in cylinders.
    e. Sloped entry (access ramp) for cylinder transport (if needed)

6. Review the base electrical infrastructure and verify conformance with the minimum requirements for acceptable plant operations. Special attention should be given to the following elements of the electrical system in order to ensure that plant equipment running and startup power requirements are met:
    a. Utility supply voltage across all phases entering plant is measured during start up and normal operation and meets plant equipment requirements
    b. Backup power supply is confirmed to meet plant equipment start up and running load requirements
    c. Grounding configuration of plant house equipment meets standards
    d. Feeders and breakers are confirmed to be appropriate size to meet plant equipment requirements
    e. Backup power supply has the same phase rotation as the primary power supply.

Training & Administrative Handover

The supplier shall provide basic training to the hospital's technical staff regarding the technical aspects of the PSA plant and how to operate the equipment. Proof of training should be made available. At a minimum, this training should include:

1. Basic operations and technical theory of the PSA plant and all components
2. Instruction on how to engage with the supplier and service provider to schedule preventive maintenance or address functionality issues with the plant
3. Details regarding any warranty voiding actions that hospital technical staff should not take while working with the plant
4. Detailed instructions for any service or maintenance activities that will be responsibility of the hospital technical staff, such as cleaning of equipment, daily checklist activities, drain cleaning, etc

At the conclusion of the plant commissioning, there should be a formal handover meeting between the PSA plant supplier or its representative and the hospital. This meeting should serve as the official conclusion of the commissioning effort and allow for both parties to sign-off on the completeness of the supplier's work. In addition, the following documents (in the country's lingua franca) should be handed over to the hospital for immediate use:

1. All manuals - instruction/user/operation and maintenance/service manuals, are confirmed delivered on site
2. If spare parts or cylinder provision is part of the supplier's scope, their delivery and quantities must be confirmed with written documentation of the supplied inventory
3. Detailed preventive maintenance schedule or plan, indicating the required service intervals for each piece of equipment, and the service parts or kits used at the specified intervals
4. Contact information and instructions for the party responsible for plant maintenance and service
5. PSA plant warranty and service contract

Additional resources:
WHO PSA plant commissioning checklist
WHO PSA plant Site readiness checklist
WHO Booster Compressor Performance Assessment

Appendix: PSA Plant Commissioning Checklist

Facility and Vendor Information			
Form Completed By	**Name**		**Title**
Supplier	**Company Name**		**Contact information**
Hospital/Facility Name			
Hospital Address (District, Town, Region)			
Date of visit(s)			
Hospital Contact Information	**Name**		**Title**
	Number (include country code)		**Email**
	Preferred contact method	☐	**Phone**
		☐	**WhatsApp**
		☐	**Email**
PSA Plant Operator / Technician or Engineer Contact Information	**Name**		**Title**
	Number		**Email**
	Best mode of contact	☐	**Phone**
		☐	**Whatsapp**
		☐	**Email**

General		
Take photos or record details of nameplates of all supplier provided equipment (including AVRs and in-line filters) for the hospital's future use and record	☐	Completed
Test and confirm functionality of all automatic and manual drains	☐	Completed
Test and confirm functionality of all shut off valves	☐	Completed
Test and confirm functionality of all general alarms	☐	Completed
Perform leak tests to confirm there are no leakages across the plant infrastructure.	☐	Completed
Record the plant room temperature during plant operation and confirm the temperature is within the manufacturer recommended temperature range for the duration of testing.		

Air Compressor/Dryer					
	1 Hr	3 Hr	6 Hr	12 Hr	24 Hr
Record the Pressure Dew Point (PDP) temperature during plant operation and confirm the PDP is within the manufacturer recommended limits for the duration of testing					
Record the air compressor pressure output					
If possible, record the air outlet temperature					

Oxygen Concentrator			
Run the plant uninterrupted for a minimum of 24 hours (3 days is recommended) at the maximum flow rate of the system, noting if the purity drops below the minimum tolerance per the plant specifications. Note the minimum tolerance here is (93 +/-3%) Note if flow rate is being measured by an air flow meter instead of any oxygen meter, the reading must be multiplied by 1.17		**Constant Rate of Flow During Testing (Nm3/hr)** (if flow meter is present)	
	%	1 Hr	
	%	3 Hr	
	%	6 Hr	
	%	12 Hr	
	%	24 Hr	
Confirm the on-screen purity reading with a recently calibrated handheld oxygen analyzer. Record the oxygen purity at the following locations:	**On-screen Purity**	**Handheld Analyzer purity directly from the output oxygen generator or oxygen tank:**	
	%	%	
	If available, at Bedside outlets		
	%	☐	**N/A**
	If filling manifolds are present, directly from a recently filled		

	oxygen cylinder:			
	%		☐	**N/A**
Record the oxygen concentrator output pressure				
Record the Input Pressure from the air receiver tank				
Record the minimum, maximum, and equalization pressures of both sieve beds	**Bed A Min.**		**Bed B Min**	
	Bed A Max		**Bed B Max**	
	Bed A Equal.		**Bed B Equal.**	
If CO sensors are present, record the maximum displayed CO output level	☐	**N/A**	**CO Levels:**	**ppm**
If CO2 sensors are present, record the maximum displayed CO2 output level	☐	**N/A**	**CO2 Levels:**	**ppm**

Booster Compressor *If more than one booster compressor is present, this table should be filled out once for each compressor*		
Fill a full manifold of cylinders and record how long it takes to fill all of the cylinders		**Time taken to fill cylinders**
		Number of Cylinders filled
		Size of Cylinders (water volume)
Calculate the actual cylinder filling rate		
Record the manufacturer's stated output rate		
Confirm the actual cylinder filling rate is within 10% of the manufacturers stated output rate	☐	**Yes**
	☐	**No**
Does the booster compressor shut off automatically when the set shutoff pressure is reached? (refer to manufacturers manual for the exact set pressure)		**Shut off Pressure**
	☐	**Yes**
	☐	**No**
When in automatic mode, does the booster compressor turn on automatically when the set start up pressure is reached? (refer to manufacturers manual for the exact set pressure)		**Start up Pressure**
	☐	**Yes**
	☐	**No**
Record the operating pressure at all stages and confirm interstage operating pressures meet manufacturer specifications		**Inlet Pressure**
		Stage 1
		Stage 2
		Stage 3
		Outlet Pressure

If possible, record the maximum booster compressor temperature reached during cylinder fill rate testing	

Piping (if applicable) *Any deviations from the below requirements must be confirmed with the manufacturer that they will not result in decreased performance, shortened lifespan, or voided warranty*			
Confirm piping material meets manufacturer specifications and industry standards	☐	**Completed**	
Does the pipe size match design drawings? IF NO provide a rationale for the change in sizing	☐	**Yes**	
	☐	**No**	
	☐	**Drawings not available**	
Are the pipes correctly labeled? (labeled oxygen with flow direction arrows)	☐	**Yes**	
	☐	**No**	
Perform a 24 hour pressure test at 20% above operating pressure. Record the pressure drop.			**Initial Pressure**
			Final Pressure
Record the pressure drop across the furthest point of the piping system. Is the pressure drop within 10% of the total initial pressure?	☐	**Yes**	
	☐	**No**	
Test the changeover system and low pressure alarm by shutting off the oxygen tank supply to the hospital. Does the supply switch to the back up manifold?	☐	**Yes**	
	☐	**No**	
	☐	**N/A**	
Are there zone valves and alarms provided in each ward with bedside oxygen outlets?	☐	**Yes**	
	☐	**No**	
Are the zone valves and alarms accessible by clinical staff? (no ladder required for access)	☐	**Yes**	
	☐	**No**	
Visually inspect the piping. Are there any deformations or unacceptable junctions? Take photos of any issues observed	☐	**Yes**	
	☐	**No**	
Confirm all bedside outlets have been tested for leaks. Record the number of leaking outlets.	☐	**Completed**	**# of leaking outlets:**
Measure the purity at the outlets in each ward. Is the purity at or above 90%?	☐	**Yes**	
	☐	**No**	
If multiple gas pipelines are run, pressurize each gas at a time to confirm that no pipelines have been cross connected	☐	**Completed**	
Test the last outlet in every branch for particulate by blowing oxygen into a white cloth. Was any particulate present?	☐	**Yes**	
	☐	**No**	

Infrastructure Works

*The supplier is responsible for ensuring completeness of any site works under their scope. For site works **not** under supplier scope, the supplier shall document any observed infrastructure issues that may result in decreased performance, shortened lifespan, or voided warranty.*			
Is the plant housing at least 10 m away from fire ignition sources and pollution sources?	☐	**Yes**	
	☐	**No**	
Is there sufficient space around the PSA Plant for access to conduct operation and maintenance tasks? (Refer to Manufacturer's Site Requirements Drawing)	☐	**Yes**	
	☐	**No**	
Is the noise level of the PSA plant acceptable at nearby wards?	☐	**Yes**	
	☐	**No**	
Is there proper signage to mitigate fire risk (e.g. "Medical Gases - NO Smoking or Open Flame")?	☐	**Yes**	
	☐	**No**	
Is there a fire extinguisher present in the plant room?	☐	**Yes**	
	☐	**No**	
Is there more than one point of entry and exit from the PSA Plant room?	☐	**Yes**	
	☐	**No**	
Cylinder Storage			
Are there racks and chains for securing cylinders?	☐	**Yes**	
	☐	**No**	
Are there well labeled dedicated spaces for storing empty and full cylinders?	☐	**Yes**	
	☐	**No**	
Are there cylinder transport trolleys for each size cylinder onsite	☐	**Yes**	
	☐	**No**	
If other gasses are stored in cylinders onsite are they stored in separate spaces from the oxygen cylinders?	☐	**Yes**	
	☐	**No**	
Is there a sloped entry (access ramp) for cylinder transport between storage location, manifolds, and hospital wards?	☐	**Yes**	
	☐	**No**	
	☐	**N/A**	
Electrical Infrastructure			
Measure primary power supply across all phases entering the plant during start up and normal operation.		**Start up**	**Normal Operation**
	L1-L2		
	L2-L3		
	L1-L3		
	L1-N		
	L2-N		
	L3-N		
Does this voltage meet plant equipment requirements?	☐	**Yes**	
	☐	**No**	
Does the backup power supply meet the plant equipment start up and running load requirements?	☐	**Yes**	
	☐	**No**	

Does the plant house grounding configuration meet minimum standards?	☐	**Yes**
	☐	**No**
Are the feeders and breakers supplying the plant appropriately sized?	☐	**Yes**
	☐	**No**

Training and Administrative Handover *The supplier shall provide basic training to the hospital's technical staff regarding the technical aspects of the PSA plant and cylinders and how to operate the equipment. Proof of training should be made available*		
Train the technicians on basic operations and technical theory of the PSA Plant and all components.	☐	**Completed**
Provide the technical staff with detailed instructions for any service or maintenance activities that will be their responsibility, such as cleaning equipment, daily checklist activities, drain cleaning, etc	☐	**Completed**
Provide direction to hospital staff on how to engage with the service provider to schedule preventive maintenance or address functionality issues with the plant.	☐	**Completed**
Provide direction and guidance to the staff for any specific warranty voiding actions that should not be taken while working with the plant.	☐	**Completed**
Handover		
Conduct a formal handover meeting between the plant installer and the hospital where both parties sign off on the completeness of the supplier's work	☐	**Completed**
Deliver all manuals (instruction/user/operation) onsite and digitally to the responsible hospital staff (in the country's lingua franca)	☐	**Completed**
If spare parts and consumables are to be stored on site at the hospital, confirm their delivery and quantities with written documentation of the supplied inventory (in the country's lingua franca)	☐	**Completed**
Provide a detailed preventive maintenance schedule or plan, indicating the required service intervals for each piece of equipment, and the service parts or kits used at the specified intervals (in the country's lingua franca)	☐	**Completed**
Provide contact information and instructions for the party responsible for plant maintenance and service	☐	**Completed**
Provide a written PSA plant warranty and service contract to the onsite staff (in the country's lingua franca)	☐	**Completed**