Briefing Note: Pressure Swing Adsorption, Vacuum Pressure Swing Adsorption, and Vacuum Swing Adsorption

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1. Introduction

The objective of this document is to define the three different systems commonly used to produce oxygen at a hospital level:
1. Pressure Swing Adsorption (PSA).
2. Vacuum Pressure Swing Adsorption (VPSA).
3. Vacuum Swing Adsorption (VSA).

Similarities of the Three Systems
PSA, VPSA, and VSA all produce high purity (approximately 93%) oxygen by separating the oxygen from nitrogen in atmospheric air. All three systems achieve this by passing compressed air through a granular bed specialized material known as zeolite. Under pressure, nitrogen will stick to the surface of zeolite. Thus, the zeolite acts as a filter removing most or all of the nitrogen from the air stream, leaving high purity oxygen at the output. In an oxygen generator, many small pieces of zeolite fill a tank, called a sieve bed. Pressurized air passes through the sieve bed in the oxygen generator, and nitrogen sticks to the zeolite. Once the zeolite has become saturated with nitrogen, the nitrogen can be removed by lowering the pressure in the oxygen generator. At low pressure, the nitrogen will detach from the surface of the zeolite. Once the nitrogen has been removed from the zeolite, the zeolite is ready to repeat the process to filter more air and produce more oxygen in a continuous cycle.

This fundamental process of air separation is identical between PSA, VPSA and VSA. The three systems differ in their pressure levels and the equipment they use to achieve the separation.

Pressure Swing Adsorption (PSA)
In a PSA plant, there are two sieve bed tanks in the oxygen generator. An air compressor pressurizes the incoming air to a high pressure (4.5-7 bar). An air dryer is needed because moisture in the air condenses at high pressures. The two sieve bed tanks alternate producing oxygen and

releasing nitrogen back to the outside air to create a near continuous production of oxygen. Because the incoming air pressure is high, the oxygen pressure at the end of the system is high enough to be delivered directly to wall-mounted oxygen outlets (3.5-5 bar).

Vacuum Pressure Swing Adsorption (VPSA)

In a VPSA plant, there are two sieve bed tanks in the oxygen generator. There are two air-handling elements: a lobe compressor and a vacuum pump (generally an additional lobe compressor that is pulling). The air enters the two sieve bed tanks under low pressure (approximately 1 bar gauge) from the lobe compressor. Nitrogen is exhausted from the beds via the vacuum pump at below ambient pressures. The oxygen pressure at the end of the system is not high enough to be delivered directly to wall-mounted oxygen outlets. An additional oxygen compressor is needed to increase the pressure for direct piping.

Vacuum Swing Adsorption (VSA)

In a VSA plant, there is one sieve bed tank in the oxygen generator. A lobe compressor is the sole air-handling element. The air enters the single sieve bed tank under low pressure (approximately 0.7 bar gauge) from the lobe compressor. Nitrogen is exhausted from the bed via the same lobe compressor (either running backwards or using valves to switch the inlet/outlet). The oxygen pressure at the end of the system is not high enough to be delivered directly to wall-mounted oxygen outlets. An additional oxygen compressor is needed to increase the pressure of the oxygen for direct piping.

Figure 1: PSA Plant

Figure 2: VPSA Plant

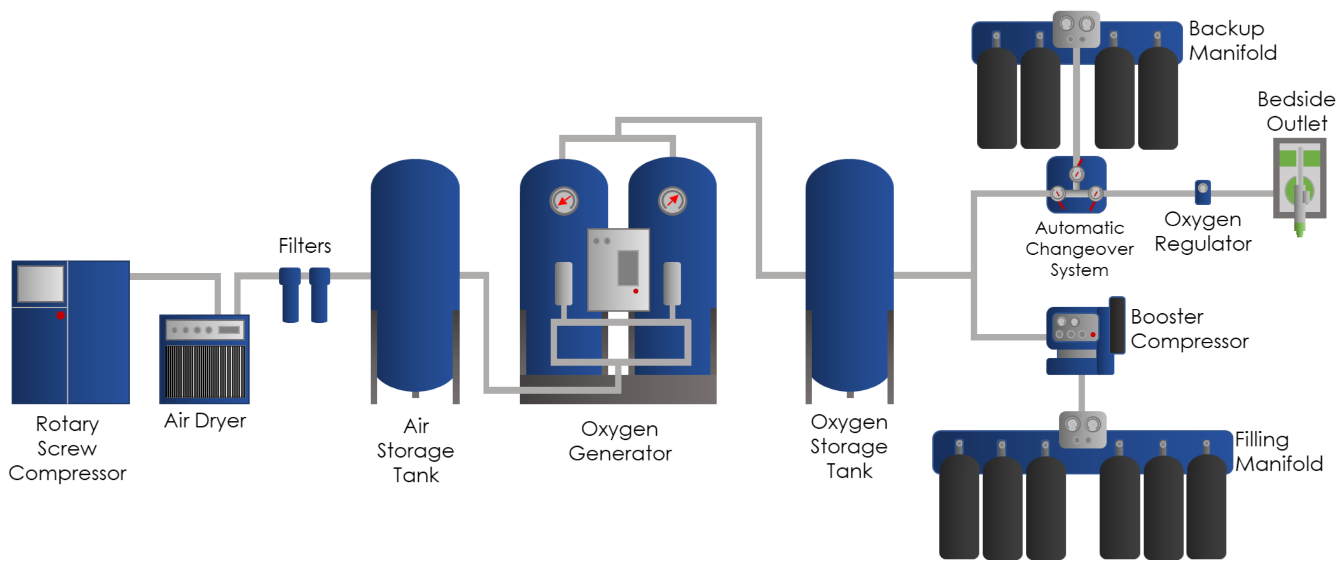
Figure 1: VSA Plant

2. Technology Comparison

The following table compares three oxygen generating technologies:

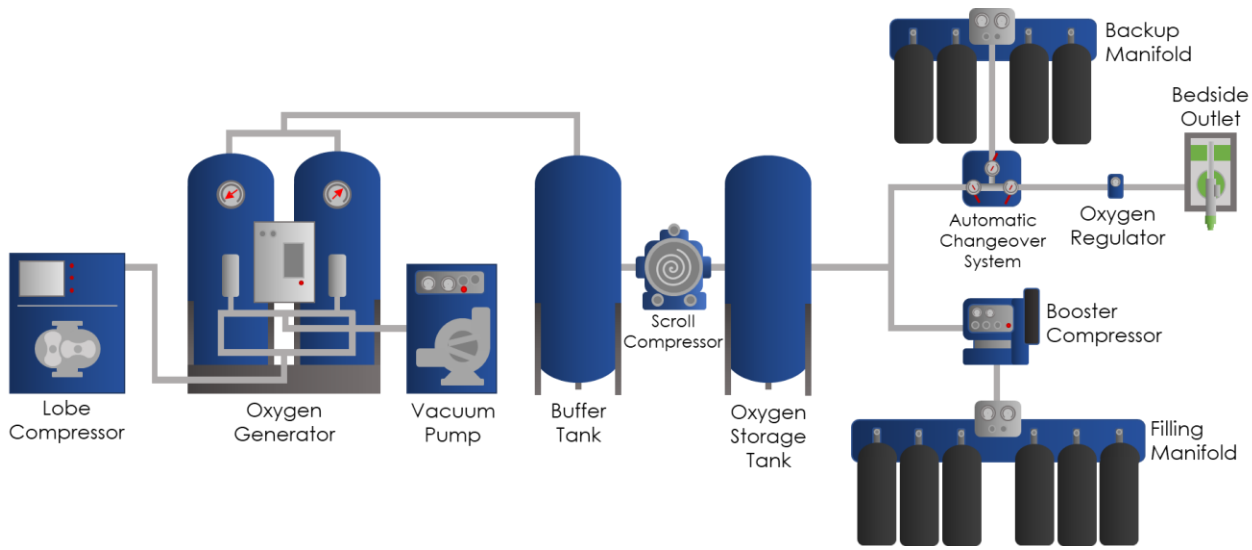
Technology	Number of Sieve Bed Tanks	Air Handling	Exit Pressure for Piping
PSA	2	Rotary screw compressor and air dryer	Exit pressure from the oxygen generator is sufficient to pipe.
VPSA	2	Lobe compressor and vacuum pump	Exit pressure from the oxygen generator is low. An additional high pressure compressor is needed for piping
VSA	1	Lobe compressor (also called a reversible blower)	Exit pressure from the oxygen generator is low. An additional high pressure compressor is needed for piping.

PSA



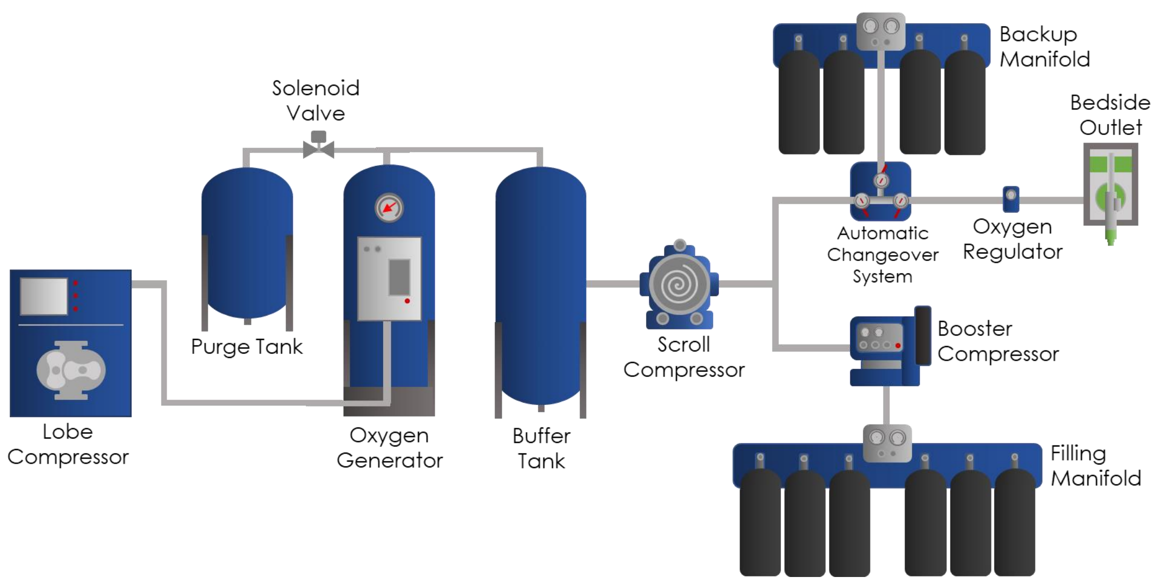
In a PSA plant, the air intake system is the rotary screw compressor, air dryer, and filters. These components pressurize the air to 4.5-7 bar and remove oil and water. There is an air storage tank before the oxygen generator. The air enters the oxygen generator, passes through the zeolite, and oxygen exits the sieve bed tanks on its own accord because it is at a high pressure. The oxygen is stored in a storage tank at 3.5-5 bar. From this point, the oxygen can be fed to the hospital oxygen network or to the high-pressure booster to fill cylinders.

VPSA



In a VPSA, there is a lobe compressor before the oxygen generator to push air into the oxygen generator. There is a vacuum pump after the oxygen generator to pull the oxygen out of the sieve bed tanks. The oxygen then goes to a buffer tank at approximately 1 bar. The oxygen is then pressurized to 5 bar by a scroll compressor and is stored in a 5 bar oxygen storage tank. If additional pressure is needed (for example, for systems operating at 10-12 bar), additional pressurizing equipment is added here. From this point, the oxygen can be fed to the hospital oxygen network or to the high-pressure booster to fill cylinders.

VSA



In a VSA, there is a lobe compressor that pushes air into the oxygen generator and pulls oxygen out of the oxygen generator. Following the oxygen generator, the oxygen is stored in a buffer tank at approximately 0.7 bar. The oxygen exits the buffer tank and is pressurized to 3-7 bar by a scroll compressor. From this point, the oxygen can be fed to the hospital oxygen network or to the high-pressure booster to fill cylinders.

3. Benefits and Drawbacks

Technology	Benefits	Drawbacks
PSA	● Oxygen exits the oxygen generator at the pipeline delivery pressure, at approximately 4 bar, which is often suitable for delivery pressure. An additional oxygen booster is not needed. ● Wider knowledge base due to more common components. ● More established supply chains and service networks.	● Large PSA plants can have high air compressor electrical in-rush currents. The generator and switchgear must be sized for this in-rush current. ● More filters are required in the system due to the presence of oil in the rotary screw compressor, and these filters will require filter replacements.
VPSA	● Lower average power consumption (generally applies at larger scale, minimum 60 Nm3/h) when compared to PSA plants. ● Lower risk of condensate due to lower operating pressures when compared to PSA plants.	● Requires an oil-free oxygen booster compressor for distribution, which can be more challenging to maintain. ● There have been reports of low purity with these systems. From this, some manufacturers note that this technology is more appropriate for **larger industrial applications.** ● In countries where such plants are not common, spare parts supply chains and maintenance support may not be optimal.
VSA	● Lower average power consumption when compared to PSA plants. However, power savings may not be realized for smaller plants. ● Lower risk of condensate due to lower operating pressures when compared to PSA plants.	● Peak operating power is the same as PSA plants. VSA requires the same size generator and switchgear as PSA. ● Requires an oil-free oxygen booster compressor for distribution. ● Highly specialized maintenance tools are required. ● In countries where such plants are not common, spare parts supply chains and maintenance support may not be optima.l

4. General Recommendation

When deciding which technology is the best fit for a particular context, the most important factor to consider is the type of oxygen generating technology already common and functional in the region. If there are existing oxygen plants that are functioning well, BHI recommends pursuing more oxygen plants of the same technology to standardize the tools, skills, and expertise needed to maintain the equipment. Functioning oxygen plants indicate that there are technicians in the region with the knowledge to maintain that particular technology. Additionally, it indicates an established supply chain for spare parts. In general, recipients of oxygen plants should procure familiar technology that has a history of success in their country and in the region.