EverAir

An Affordable, Safe and Effective Oxygen Concentrator for Use in Low-Resource Settings

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Clinical Need

Hypoxemia
- Respiratory diseases like chronic obstructive pulmonary disorder and pneumonia lead to hypoxemia
- Low blood-oxygen saturation
- ⅓ of hospital visits and 20-30% adults affected

Oxygen Supply
- Oxygen- one of the essential medicines by World Health Organization (WHO)
- Highly effective in treating hypoxemia
- Not widely available in low resource settings

Solution Profile

Existing solutions and their shortcomings include:

Oxygen Tanks
Difficult to transport

Oxygen Pipeline System
Very expensive

Oxygen Concentrators
Expensive
Require steady voltage supply

Needs Statement
An affordable, safe, and effective oxygen concentrator capable of handling power supply issues

Market Analysis and Cost

An at-home oxygen concentrator is sold for $735 on average. In addition to being expensive, the existing models are unable to handle fluctuating voltage input and performing maintenance on the devices is difficult.

EverAir is expected to be manufactured and assembled locally in Nepal within a university lab environment. Off-the-shelf components will be procured from India and China. The cost of a unit produced is expected to be $328. It is designed for the local environment and requires minimum maintenance.

Cost Per Oxygen Concentrator

$735	$328
Market Average	*EverAir*

Design Accomplishments

To address the lack of an affordable oxygen concentrator capable of dealing with the voltage fluctuations typical in Nepal, the team has designed and tested an oxygen concentrating subsystem and a voltage stabilizer, as well as developed an overall design for an easy-to-use oxygen concentrator.

- Key innovation is the voltage stabilizer
- Detects voltage differences above and below standard input voltage range and uses voltage transformers to maintain it within the acceptable range
- Also takes into account the functionality of the oxygen concentrating subsystem, voltage stabilizer, and exterior design

Voltage Stabilizer
- Designed a voltage stabilizing circuit that can interpret magnitude and direction of voltage fluctuations
- Simulated the circuit in LTSpice to prove that it can adequately handle voltage disturbances
- Researched fabrication methods and created list of components needed to actually make the device

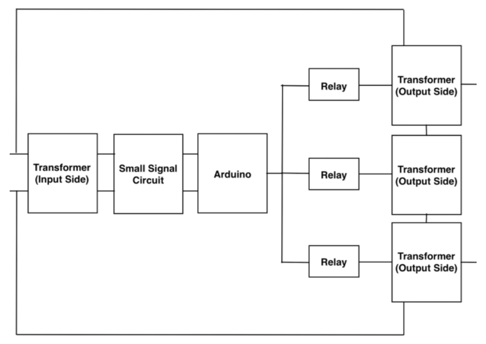

Fig. 1 - Diagram of the voltage stabilizer

Voltage input and outputs for Fig 2:
- V(in0) through V(in4) are inputs, ranging from 160V to 280V
- V(out0) through (V(out4)) are corresponding outputs, with the range limited to between 220V to 240V

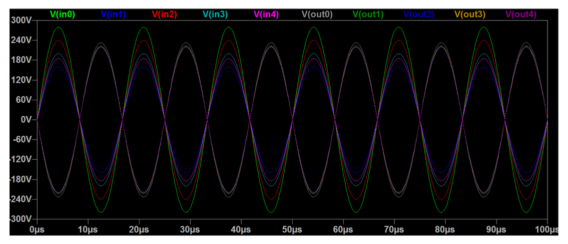

Fig 2 - Voltage inputs and outputs for the voltage stabilizer simulated in LTSpice

Pressure Swing Adsorption
- Designed a dual bed setup that would allow for continuous oxygen concentration via selective adsorption of nitrogen
- Physically implemented design (pressure vessels with zeolite, fittings, tubing, solenoid valves) and incorporated an Arduino controller and associated electronics to switch air flow between the two beds
- Performed calculations to determine mass balance, bed size, nitrogen adsorption, optimal pressure and flow rate
- Tested design using prototype
- Troubleshooted design and systematically tried to identify root cause for low oxygen concentration

Assumptions for local equilibrium model for pressure swing adsorption:
- No flow maldistribution or dead volume axial dispersion term is negligible
- No concentration gradients within zeolite particles or film surrounding particles
- Isothermal plug flow with constant velocity

ρB = density of zeolite = 650 kg / m3
ε = void fraction = 0.3
ΔqN2 / ΔCN2 = adsorption isotherm = 0.0228 m3 / kg
Vbed = volume of zeolite bed = 0.00117 m3
Qair = volumetric flowrate of air = 0.0425 m3 / min

tc = cycle time = 0.415 min = 24.9 sec

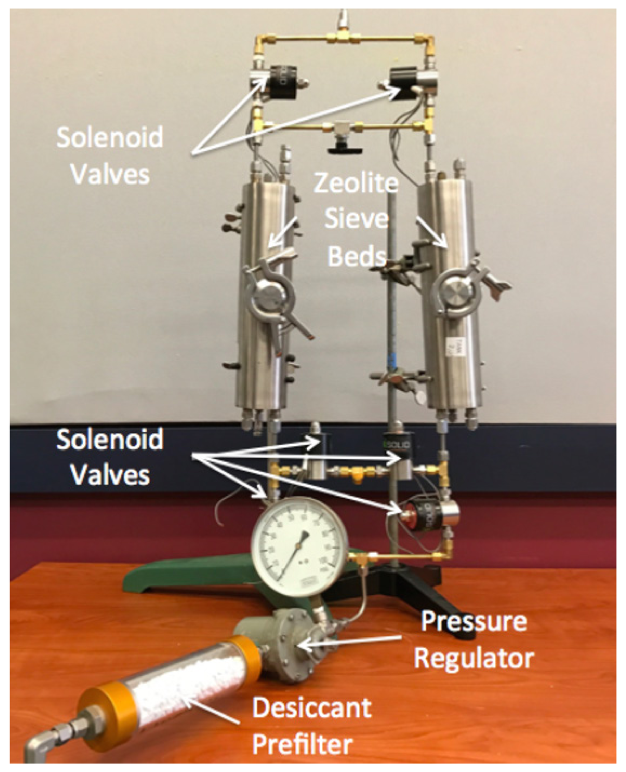

Fig. 3- Experimental setup used to test its oxygen concentrating efficacy

$$\varepsilon\frac{\partial C_{N2}}{\partial t}+\rho_B\frac{\partial q_{N2}}{\partial t}+\frac{Q_{air}}{A_{bed}}\frac{\partial C_{N2}}{\partial t}=D_Z\frac{\partial^2 y}{\partial^2 x}$$

$$t_C=\left[\varepsilon+\ \rho_B\frac{\Delta q_{N_2}}{\Delta C_{N_2}}\right]\frac{V_{bed}}{Q_{air}}$$

Fig. 4 - Local equilibrium model for pressure swing adsorption

External Design and Interior Layout
- Designed exterior with wheels and a handle, mass around 30 lbs and size of a big suitcase
- CAD model all main components for the interior and exterior of the device

Fig. 5- Rendering of the interior layout of the components

Fig. 6- Rendering of the exterior design

Future Work

This project will be continuing on for another year of development, with teams from the College of Biomedical Engineering and Applied Sciences in Nepal and Carnegie Mellon University both working on components of the system.

Pressure Swing Adsorption
- Improve upon testing set-up with additional monitoring instrumentation, surge tanks and push-to-connect fittings for the single bed system
- Perform dual-bed testing to determine optimal cycle time of zeolite regeneration for highest oxygen concentration
- Calculate specifications for producing enough oxygen to treat multiple patients

External design
- Analyze manufacturability of design and include easy-to-understand instructions

Voltage Stabilizer
- Integrate voltage stabilizer with other electronic components of device
- Physically test the voltage stabilizer in Nepal and adjust design based on results

Overall
- User testing, adjust design based on feedback from clinical studies
- Integrate all subsystems of the device together

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