Department of Engineering

Messiah College

the Collaboratory for strategic partnerships and applied research

OXYGEN CONCENTRATOR FILTER RE-DESIGN & TESTING

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CLIENT

- Macha Mission Hospital
  - Dr. John Spurrier
  - Mr. Melvin Mabeta
- DeVilbiss Healthcare- partnering organization

DeVilbiss HEALTHCARE

OXYGEN CONCENTRATORS

- Purpose: Delivering concentrated oxygen for patients
  - Elderly with respiratory issues
  - Infants and children with bronchiolitis

PROJECT IDENTIFICATION

- Problem: Premature concentrator failure
  - Average life is 43% lower than expected
  - Non-ideal conditions- humidity and dust
  - Irregular maintenance
- Goal: To sustain oxygen concentrator function
  - Increase longevity of machine
  - Maintain adequate oxygen output
  - Simplify maintenance procedures

WHAT ARE OXYGEN CONCENTRATORS?

- Oxygen concentrators vs. oxygen tanks
  - Access
- Sieve beds-filter out Nitrogen
  - Mode of failure

21% Oxygen
78% Nitrogen
1% Other gases

95% Oxygen
5% Other gases

HOW IT WORKS

Natural Air

Oxygen Gas

Nitrogen Purge

Pressurizes

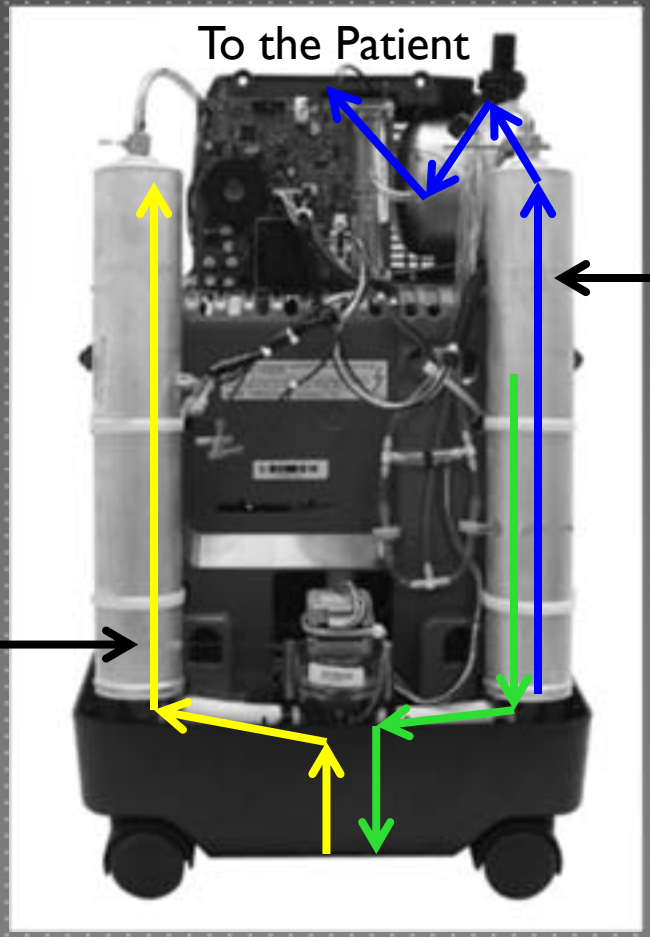


Photo: Devilbiss Healthcare

WHAT IS ZEOLITE?

- Zeolite
  - Separates gasses
- Crystal structure
  - Cage-like resemblance
  - Molecular exclusion

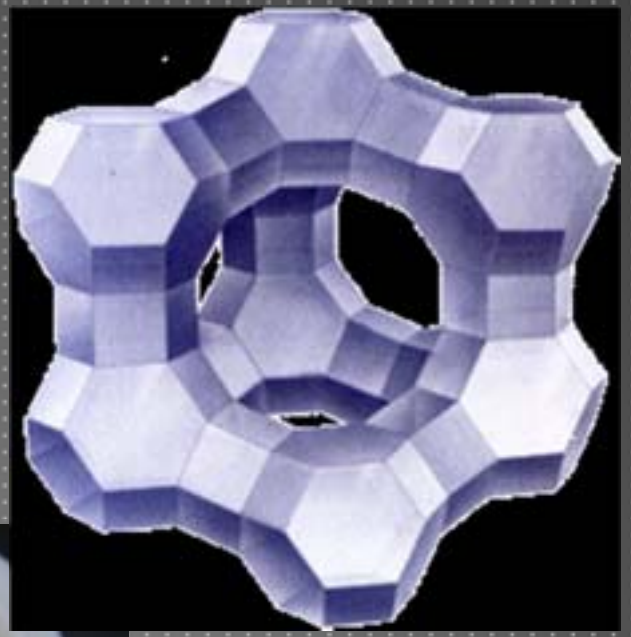
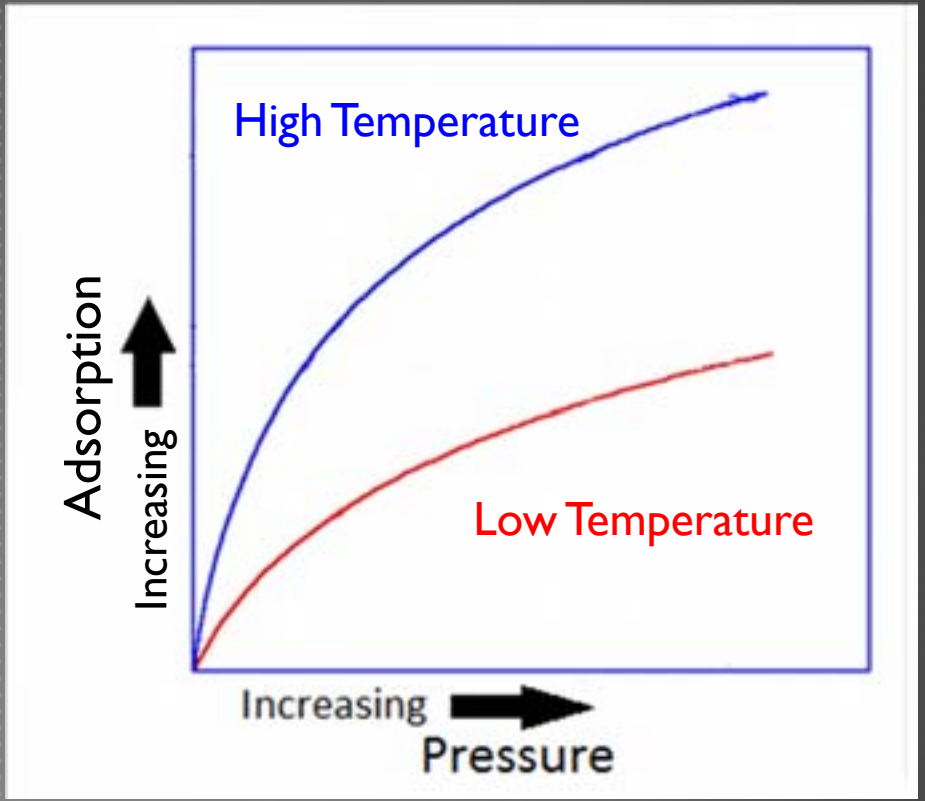


Photo: molecularsive.org

WHY IS PRESSURE IMPORTANT?

- Adsorption vs. Absorption
  - Adsorption = Physical bond (weak)
  - Absorption = Chemical Bond (strong)
- Pressure Swing Adsorption
  - High pressure = High adsorption
  - Low pressure = Low adsorption



FIRST SOLUTION

- Desiccant based filter
  - Removes humidity
  - Preserves zeolite functionality
  - Chose Silica Gel as desiccant

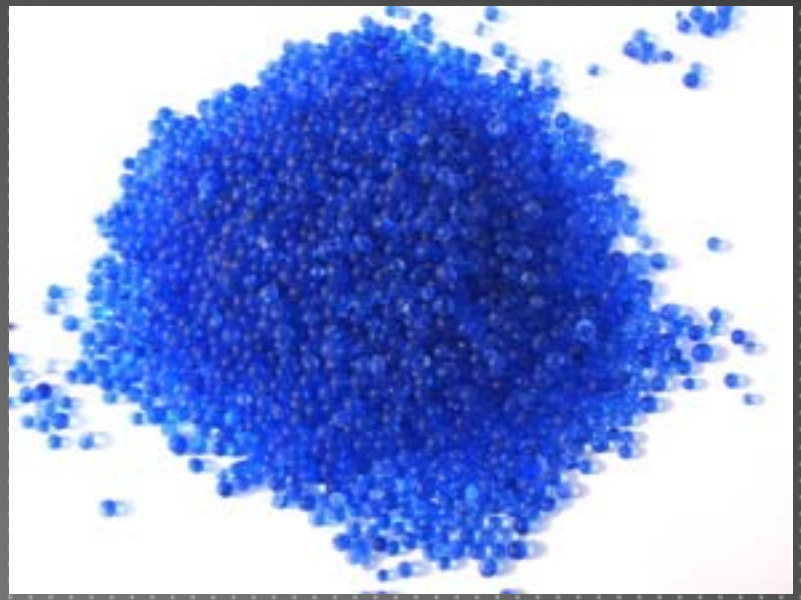
PAST WORK

- Designed Dehumidifying Filter
  - Desiccant based
- Site team trip May 2013
  - Evaluated prototype on site
  - Provided aid with repairs

George Mono and Steven Bandstra 2013

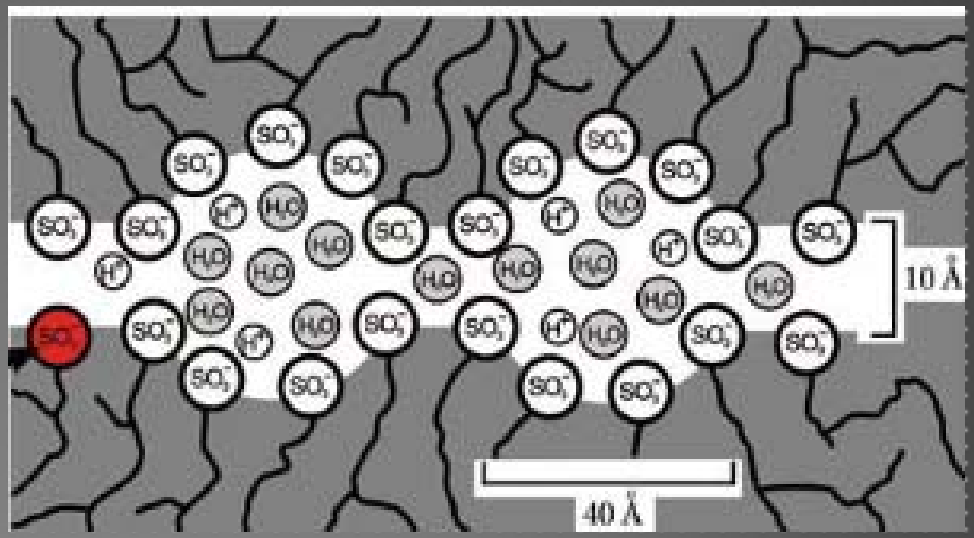
RESEARCH

- Desiccant vs. Membrane
- Desiccant
  - Cost effective
  - Effective over short time
  - Requires periodic maintenance
  - Regenerative
- Membrane
  - No maintenance required
  - Long lifespan
  - Expensive - $150/ft^2
  - Requires dry air source



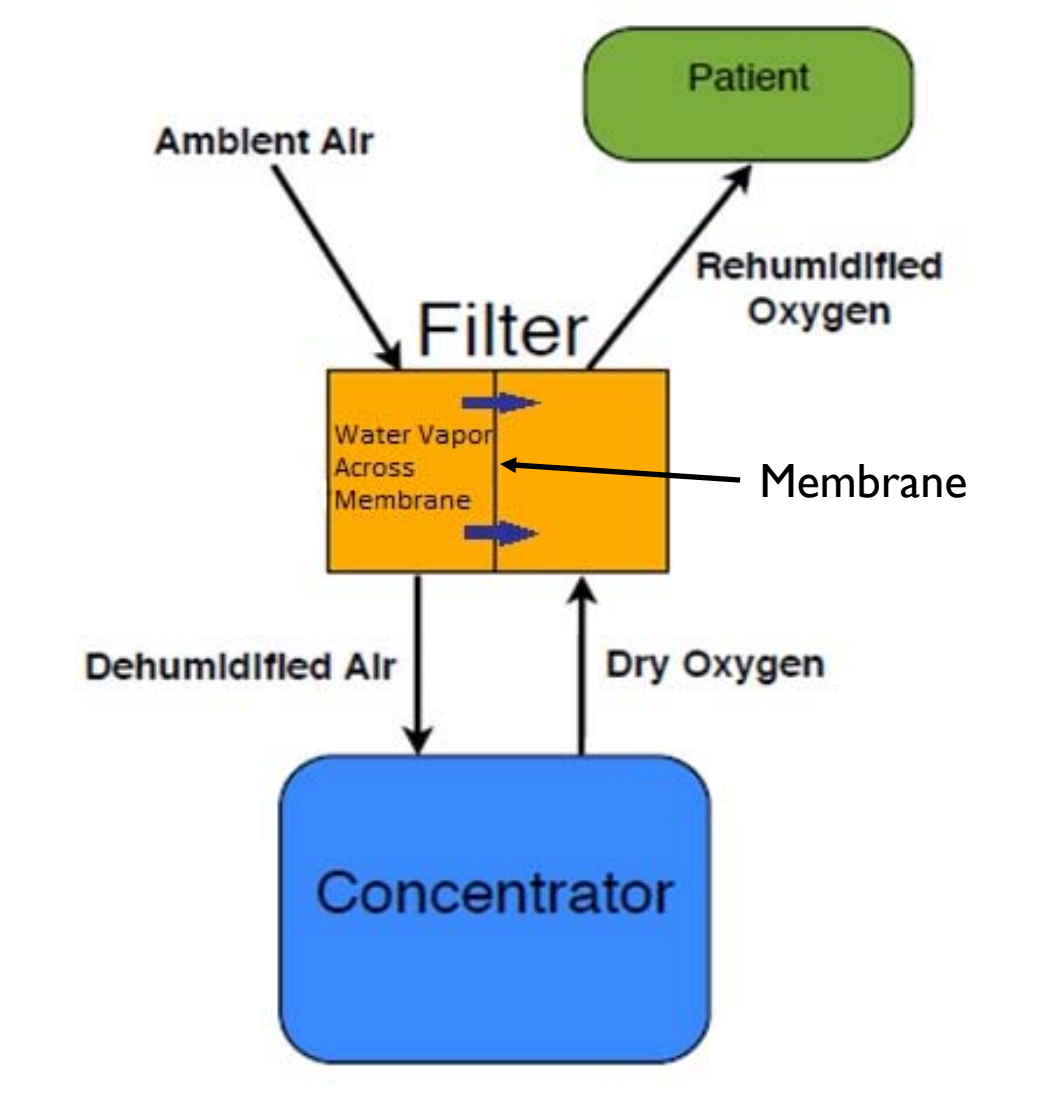
NAFION MEMBRANE

- Tetrafluroethylene – AKA Teflon
  - Bonded with Sulfonic Acids
- Transports water across
  - Acid Groups form channels
- Blocks all non polar molecules
  - O_2, N_2, ect.
- Passive transport
- Requires difference in water concentration



Credit: Eric Listor

MEMBRANE FILTER



HOUSING DESIGN

- Decided on a design based on cost, durability and manufacturability
  - 3D printed
  - Extruded ABS plastic
- 2 Halves sealed with rubber gasket

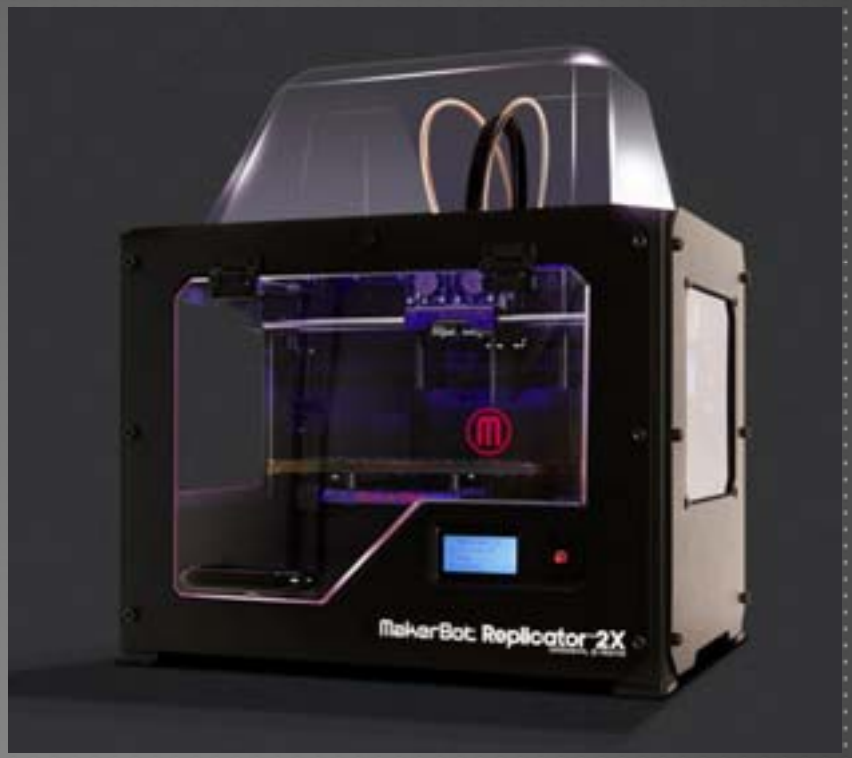
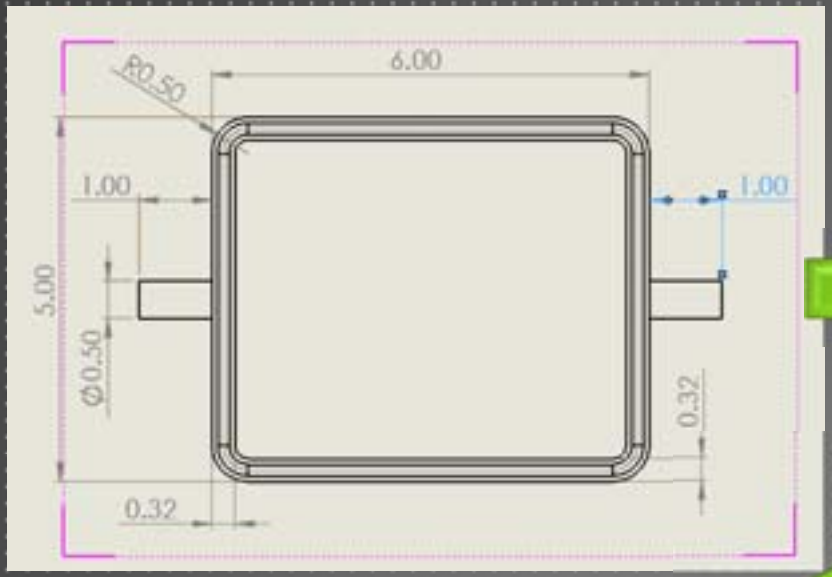
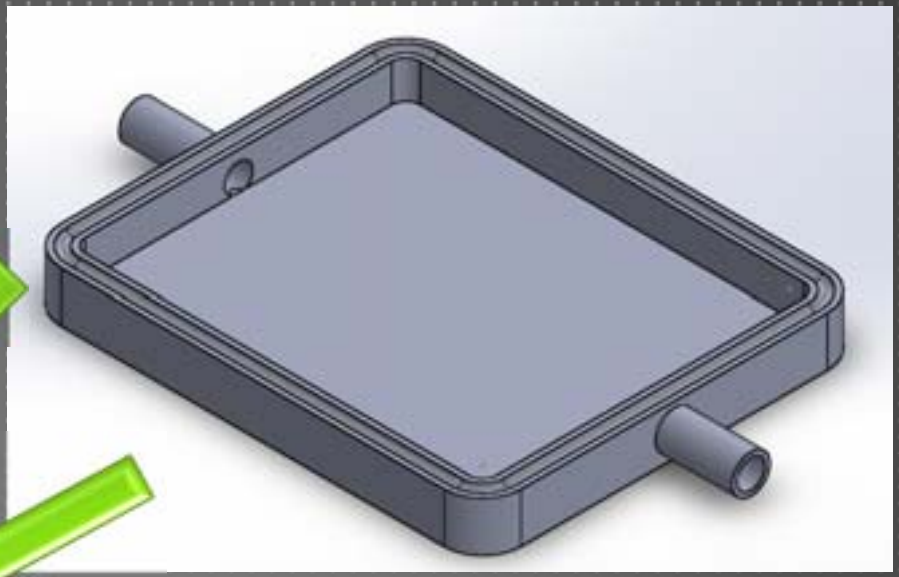
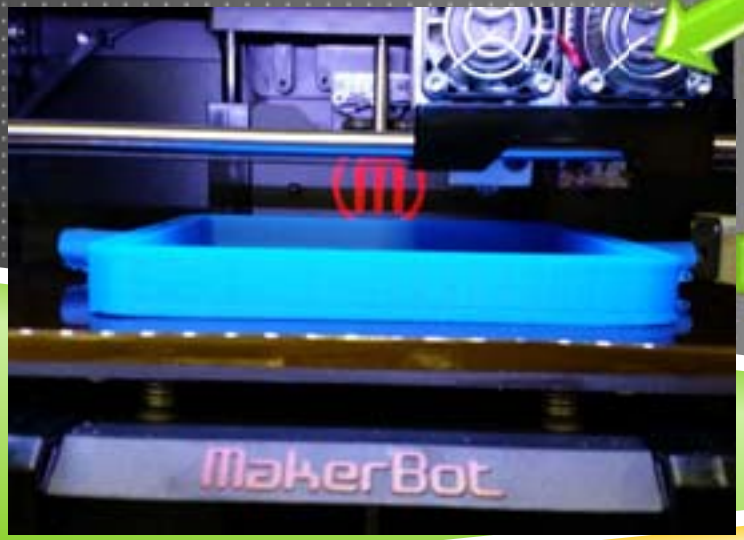


Photo: Makerbot.com

HOUSING MANUFACTURING





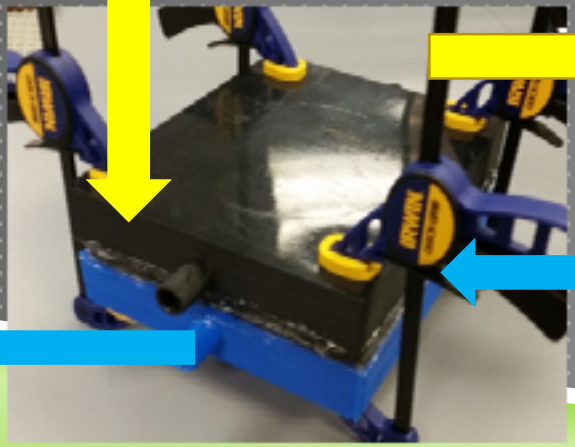


TESTING OF DESIGN

- Questions to answer
  - Will design reduce humidity?
  - How much membrane material is needed?

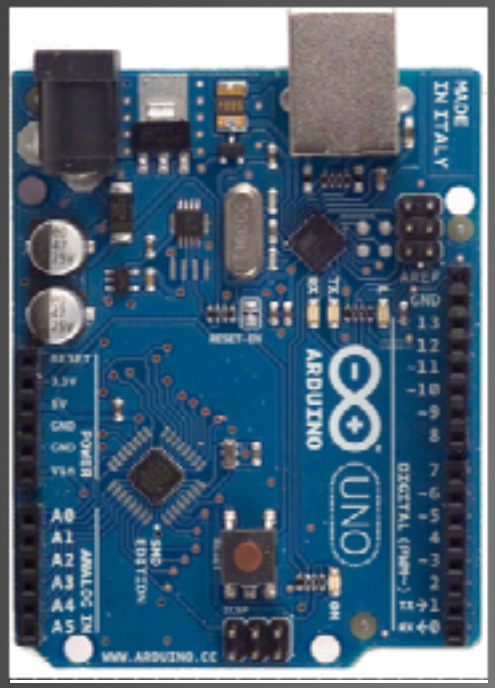
TESTING APPARATUS

Humidity Chamber

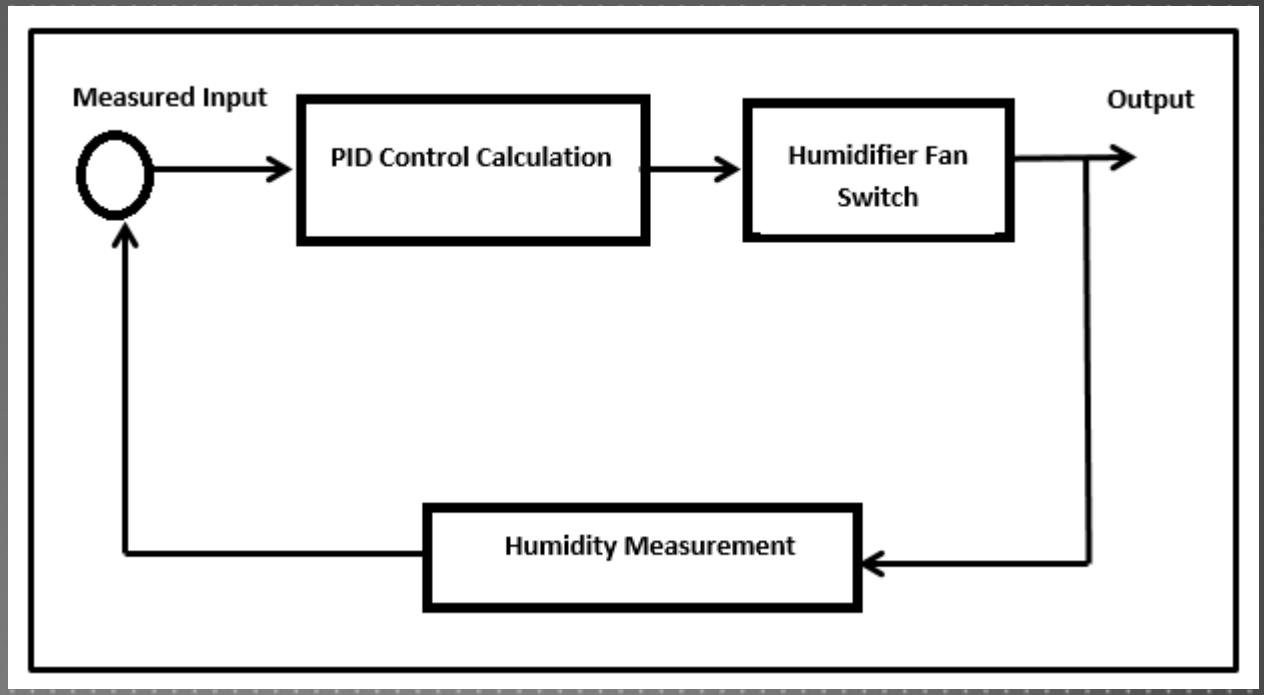


Oxygen Concentrator

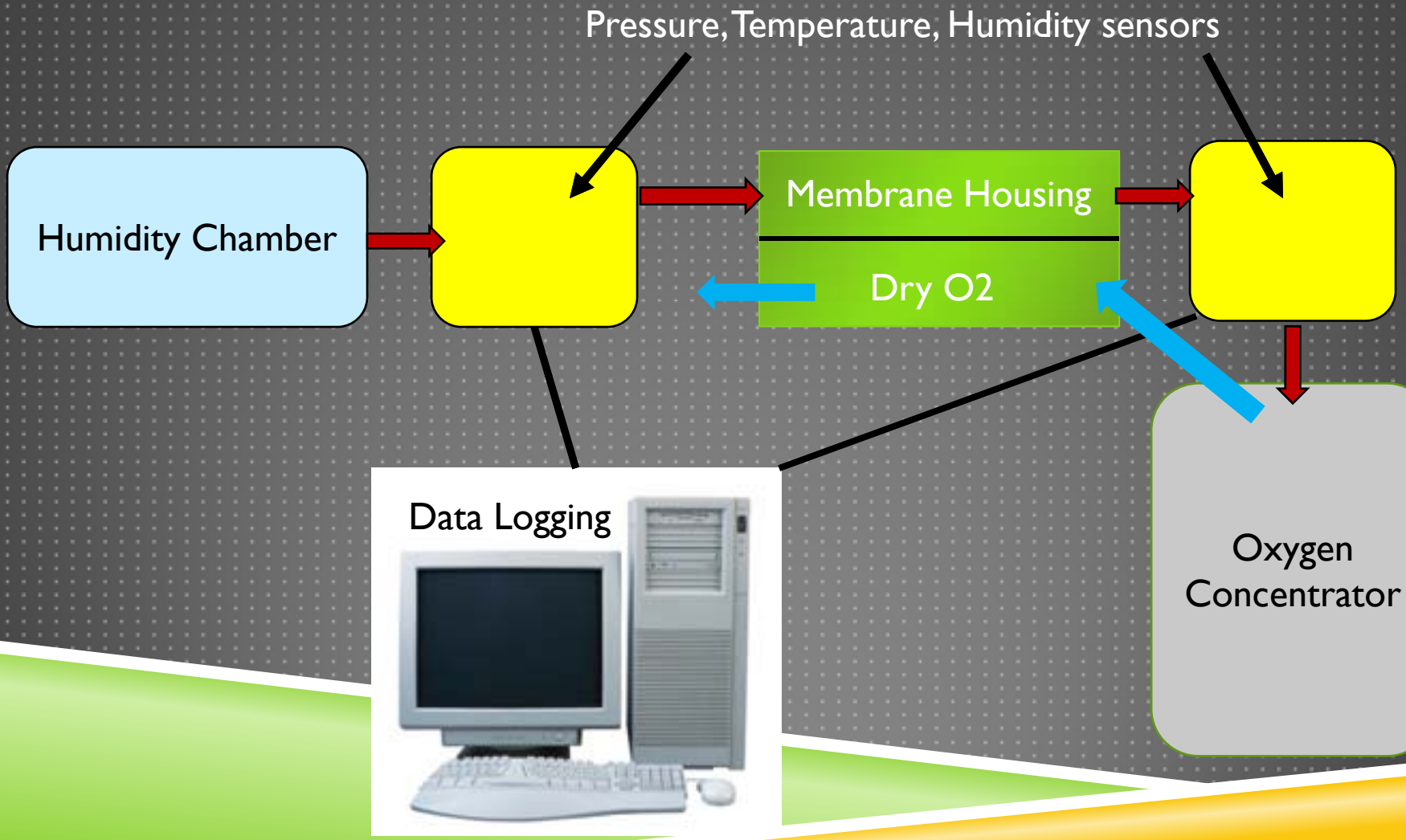
HUMIDITY CONTROL SYSTEM



www.arduino.com



RECORDING DATA



INITIAL RESULTS

- Encountered Sensor Error
  - Not calibrated for varying pressure
- Relative Humidity = Function of pressure and temperature
  - Sensors not compensated for pressure

CONCLUSIONS

- Initial tests indicate membrane does work
- Membrane filter can provide a self-sustaining solution
- Testing procedure adequate to benchmark prototype
- Need better procedure for collecting humidity data

FUTURE WORK

- Test membrane material in multiple conditions
- Rework data collection
- Revise filter design
- Site team trip in January

ACKNOWLEDGEMENTS

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- Eric Listor
- Chris Scheib
- Barbara Ressler, Former Advisor

QUESTIONS

DRYING AGENT COMPARISON CHART

Solution	Cost	Size	Implementation	Availability	Power requirements	Transportation	Maintenance
Aftercooler	High	Intermediate	Hard	Fairly Common	Large	Varies	Minimal
Mechanical Water Separator	Low	Small	Easy	Common	None	Simple	Daily
Deliquescent Dryer	Fairly Low	Large	Hard	Not Common	Varies	Difficult	Weekly
Condenser	High	Large	Hard	Fairly Common	Varies	Difficult	Monthly
Membrane Air Dryer	High	Small	Easy	Fairly Common	None	Easy	Minimal
Desiccant	Low	Small	Easy	Common	None	Easy	Moderate

DETERMINATION OF FAILURE MODE

	Temperature	Humidity	Altitude	Dust Level
DeVilbiss specifications	50 to 96 F	50 to 90%	10,000ft	Minimal
Conditions in Zambia	43 to 104F	60 to 95%	3000 to 10,000ft	High

- Analysis and collaboration with DeVilbiss led us to conclude *cause of failure is contamination of the sieve beds*-through dust and humidity

- The humidity in Macha is typically below 80% relative humidity so as long as we are able to reduce the humidity by 30% we believe we will not have problems with reduced concentrator lifetime