EML4551-2

Senior Design Team 509

Environment-Controlled Test Stand Chamber

Michael Stoddard, Meghan Fonda, Donald Laughlin, & Dai (Bill) Truong

Friday, March 6, 2020

Team Introductions

Michael Stoddard
Project Manager &
Validation Engineer

Meghan Fonda
Quality and Test Engineer

Donald Laughlin
Thermal Fluids Engineer

Dai (Bill) Truong
Design Engineer

Sponsor and Advisor

Sponsor

Jerry Huang

R&D Engineering Manager

Academic Advisor

Dorr Campbell, Ph.D.

Meghan Fonda

Objective

The objective of this project is to design and construct a temperature and humidity-controlled testing chamber for the TT and TG models of Danfoss Turbocor Compressors.

Project Background

Danfoss Turbocor Compressors

TT Model

- Can operate under standard water cooled and low lift chiller operation or at high lift for air cooled or heat recovery operation
- 788mm x 518mm x 487mm
- Capacity ranging from 60 tons/200 kW to 200 tons/700 kW

Refrigerant used:
HFC134a

TG Model

- Can operate under standard water cooled and low lift chiller operation or at high lift for air cooled or heat recovery operation
- 788mm x 518mm x 487mm
- Capacity ranging from 40 tons/140 kW to 150 tons/540 kW

Refrigerant used:
HFO-1234ze

Meghan Fonda

Project Scope

Goals

- Achieve a temperature range of 10 to 55°C
- Maintain a reasonable humidity range (from 10 to 95 percent)
- Keep lab personnel safe throughout the testing procedure
- Easy to assemble and disassemble

Assumptions

- Dimensions of compressors being tested inside the chamber are constant
- Device will be used inside a Danfoss facility
- Power comes from the testing rig
- The chamber will sit atop the rig
- Danfoss-Turbocor can provide machining services

Meghan Fonda

Markets and Stakeholders

Primary Market

- Danfoss-Turbocor
- R&D Test Facilities

Stakeholders

- Sponsor
  - Jerry Huang, Danfoss employee
- Facilitators
  - FAMU-FSU College of Engineering
  - Dr. Shayne McConomy

FAMU-FSU COLLEGE OF ENGINEERING

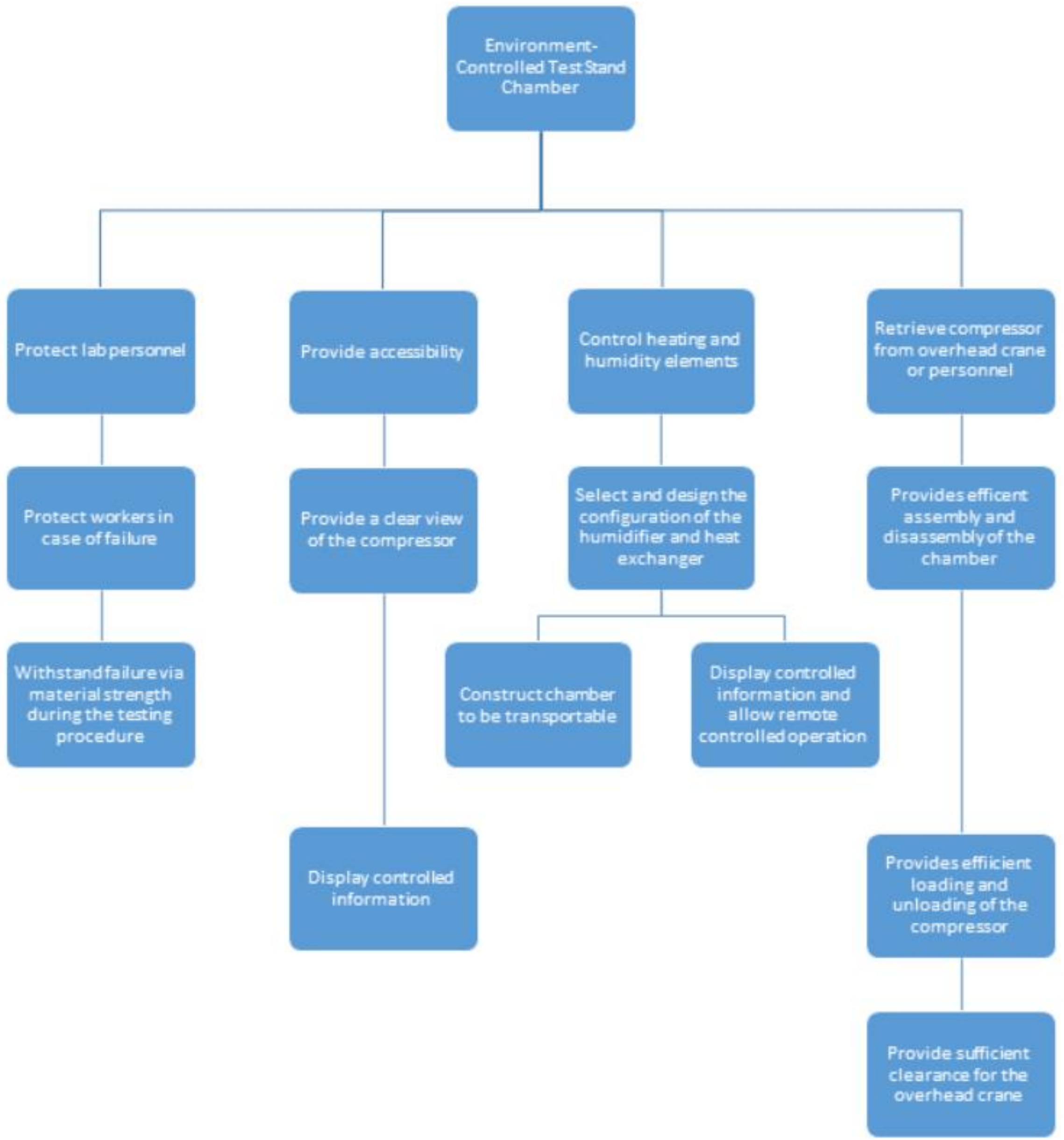
Meghan Fonda

Customer Needs

Are there any pressure specifications?	No pressure requirements	No considerations for high pressure in material selection
How does Danfoss switch the compressors into and out of the chamber?	An overhead crane with wheels is used	The chamber provides sufficient clearance
What is our budget?	The estimated cost is $10,000	Total material and labor costs should not exceed $10,000
Will humidity and temperature fluctuate throughout the testing?	Controlling elements are pre-set and remain constant until changed	Controlling elements will not fluctuate throughout the duration of a test

Meghan Fonda

Functional Decomposition



Meghan Fonda

Concept Generation

Morphological Chart

Size of the chamber	Wall Material	Frame Material	Sealant Design for enclosure	Door Design	Piping Enclosure Design
Extends to the far end of the rig	Acrylic	6000 Series Aluminum	Magnetic	Full double doors on one side of enclosure and half double doors on the opposite side	Separate panes on back wall horizontally
Shorten the width in order to exclude the opening in the stand from the enclosure	Polycarbonate	3000 Series Aluminum	Toggle Latches	Sliding door	Separate panes on back wall vertically
Keep the current dimensions of the existing prototype	Glass	5000 Series Aluminum	Window Latches	Full double doors on both sides of the enclosure	Cut holes in back pane then seal around pipes
Shape is adjusted to exclude most of the piping from the enclosure			Both Magnetic and Window Latches	Bifold doors	
Extends to far end of rig and sits on the ground			Both Magnetic and Toggle Latches	Full double doors on one side of enclosure and half double doors on the opposite side	

Size of the chamber	Wall Material	Frame Material	Sealant Design for enclosure	Door Design	Piping Enclosure Design
Extends to the far end of the rig	Acrylic	6000 Series Aluminum	Magnetic	Full double doors on one side of enclosure and half double doors on the opposite side	Separate panes on back wall horizontally
Shorten the width in order to exclude the opening in the stand from the enclosure	Polycarbonate	3000 Series Aluminum	Toggle Latches	Sliding door	Separate panes on back wall vertically

Resulting Design

- Chamber extends to far end of the rig
- Wall material is polycarbonate
- Frame material is 600 series aluminum
- Magnetic sealant is used for enclosure
- The chamber doors are a sliding design
- Piping is enclosed by using separate, vertical panes

Meghan Fonda

Morphological Chart Math

Size of the chamber	Wall Material	Frame Material	Sealant Design for enclosure	Door Design	Piping Enclosure Design
Extends to the far end of the rig	Acrylic	6000 Series Aluminum	Magnetic	Full double doors on one side of enclosure and half double doors on the opposite side	Separate panes on back wall horizontally
Shorten the width in order to exclude the opening in the stand from the enclosure	Polycarbonate	3000 Series Aluminum	Toggle Latches	Sliding door	Separate panes on back wall vertically
Keep the current dimensions of the existing prototype	Glass	5000 Series Aluminum	Window Latches	Full double doors on both sides of the enclosure	Cut holes in back pane then seal around pipes
Shape is adjusted to exclude most of the piping from the enclosure			Both Magnetic and Window Latches	Bifold doors	
Extends to far end of rig and sits on the ground			Both Magnetic and Toggle Latches	Full double doors on one side of enclosure and half double doors on the opposite side	

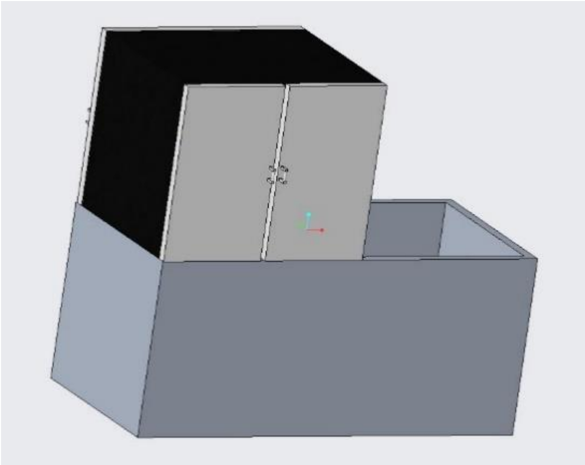
5 x 3 x 3 x 5 x 5 x 3 = **3,375**

1. Sum the concepts in each column
2. Multiply the sum of the column by each subsequent column
3. The resulting product is the total number of concepts generated by the chart

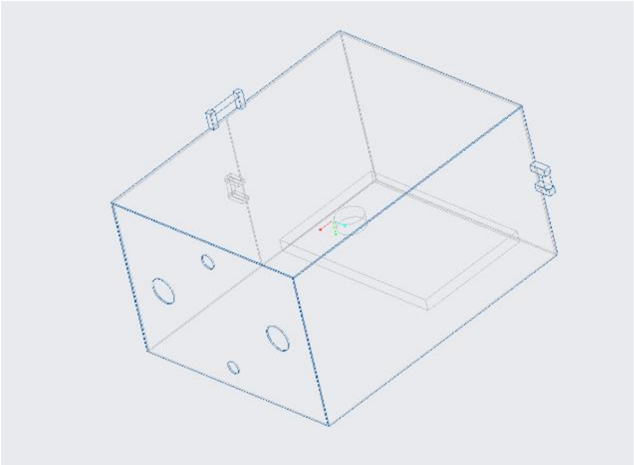
Our chart generated 3,375 possible concepts

Meghan Fonda

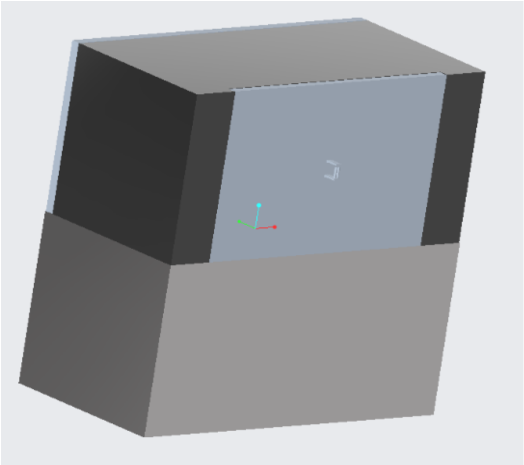
Generated Concepts



Concept 1



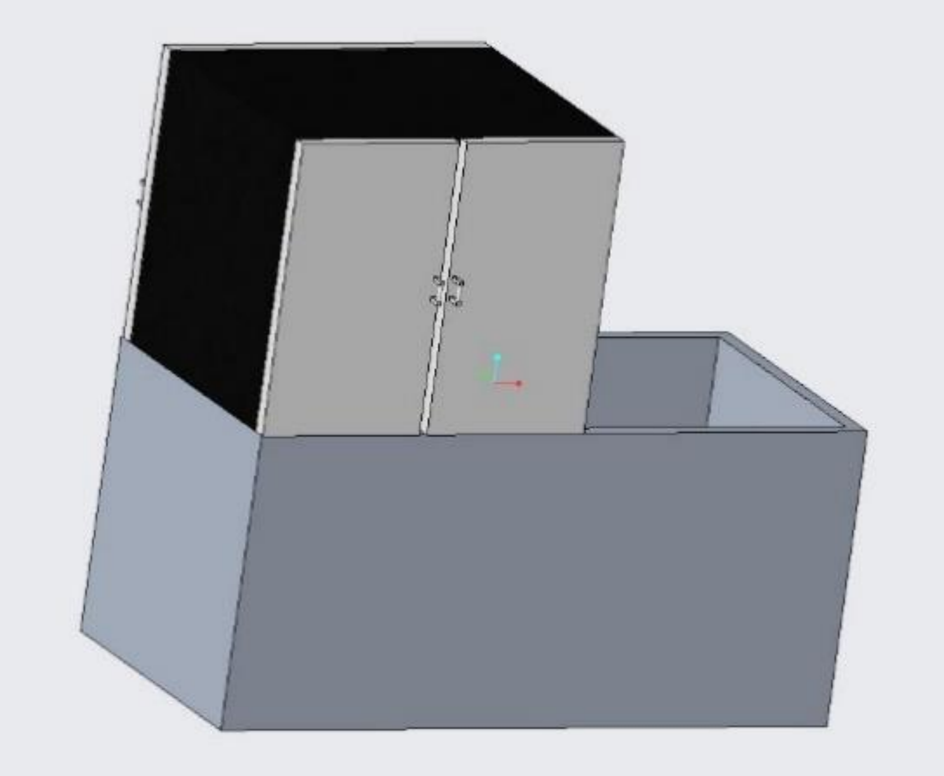
Concept 2



Concept 3

Meghan Fonda

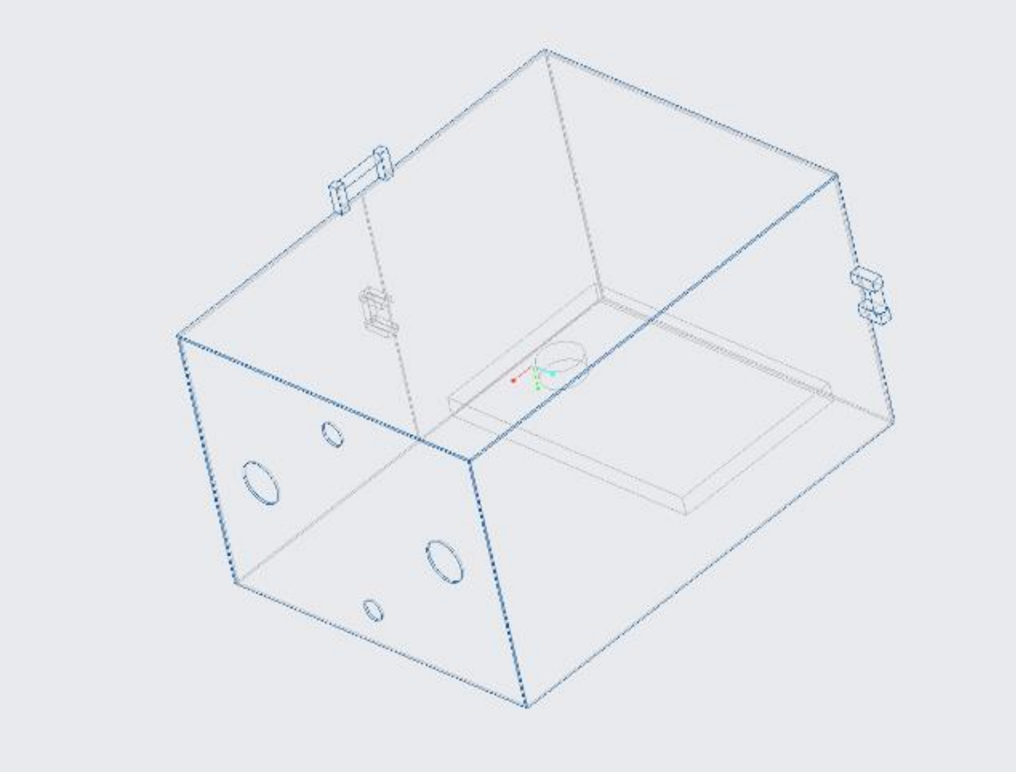
Concept 1



- Shorten the length of the existing chamber
- Polycarbonate chamber wall material
- 6000 series aluminum framing material
- Magnetic and toggle latches
- Full-sized double doors on one side of enclosure and half-sized double doors on the opposite side
- Cut holes in back wall and seal around piping

Meghan Fonda

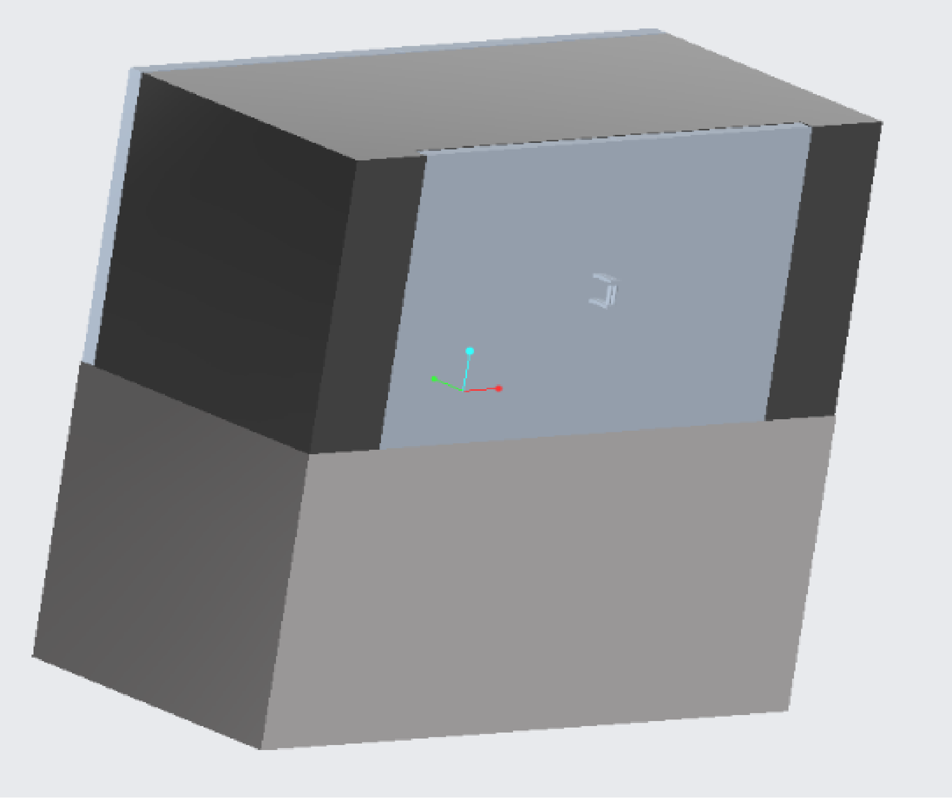
Concept 2



- Keep the dimensions consistent with the existing chamber
- Polycarbonate chamber wall material
- 6000 series aluminum framing material
- Magnetic and toggle latches
- Full-sized double doors on one side of enclosure and half-sized double doors on the opposite side
- Cut holes in back wall and seal around piping

Meghan Fonda

Concept 3



- Chamber extends to the far end of the rig and sits on the ground
- Acrylic chamber wall material
- 6000 series aluminum framing material
- Magnetic and toggle latches
- Sliding doors
- Design completely encloses pipes – no need for sealant

Meghan Fonda

Concept Selection

Selection Process

- 8 concepts were pulled from our concept generation
  - 5 medium fidelity concepts
  - 3 high fidelity concepts
- Many tools were used to choose the best concept
  1. House of Quality - choose which target to prioritize.
  2. Pugh Matrix – which concepts provide improvement
  3. Analytic Hierarchy Process (AHP) – Pairwise Comparison, avoid biases
  4. Pick an optimal concept

Dai Truong

House of Quality

House of Quality												
	Improvement Direction	↑			↑	↑		↓	↓	↑	↑	↑
	Units	MPa	°C	°C	%	m	m^3	kg	W/(m^2*K)	%	m^2	m
Customer Requirments	**Priority**	Impact Strength	Outer Temp	Inner Temp	Visible Light Transmittance	Clearance	Inner Volume	Weight	U-factor	Relative Humidity	Loading Area	Minimum clearance height
Protect lab personnel	**5**	9	3	1				3	1	1		
Maintain temperature range between 10 and 55°C	**3**		3	9			9		9	9		
Maintain humidity range of 0 to 95%	**3**		1	9			9		3	9		
Chamber provides sufficient clearance for the overhead crane	**5**	1				9	3	1			9	9
Chamber is easily assembled and disassembled by lab personnel	**1**	3					1	9			3	3
Chamber is constructed with lightweight material	**1**	3		3				9			3	
Chamber material is transparent and provides sufficient visibility within	**5**	3		3	9							
Total material cost is under $10,000	**5**	3		9	3	1	9	9			3	3
772	**Raw Score**	86	27	122	60	50	115	83	41	59	66	63
	Relative Weight %	11.1399	3.497409	15.80311	7.772020725	6.476684	14.89637	10.7513	5.31088083	7.642487	8.549223	8.160622
	Rank Order	3	11	1	7	9	2	4	10	8	5	6

Dai Truong

House of Quality

House of Quality												
	Improvement Direction	⬆			⬆	⬆		⬇	⬇	⬆	⬆	⬆
	Units	MPa	°C	°C	%	m	m^3	kg	W/(m^2*K)	%	m^2	m
Customer Requirments	**Priority**	Impact Strength	Outer Temp	Inner Temp	Visible Light Transmittance	Clearance	Inner Volume	Weight	U-factor	Relative Humidity	Loading Area	Minimum clearance height
Protect lab personnel	**5**	9	3	1				3	1	1		
Maintain temperature range between 10 and 55°C	**3**		3	9			9		9	9		
Maintain humidity range of 0 to 95%	**3**		1	9			9		3	9		
Chamber provides sufficient clearance for the overhead crane	**5**	1				9	3	1			9	9
Chamber is easily assembled and disassembled by lab personnel	**1**	3					1	9			3	3
Chamber is constructed with lightweight material	**1**	3		3				9			3	
Chamber material is transparent and provides sufficient visibility within	**5**	3		3	9							
Total material cost is under $10,000	**5**	3		9	3	1	9	9			3	3
772	**Raw Score**	86	27	122	60	50	115	83	41	59	66	63
	Relative Weight %	11.1399	3.497409	15.80311	7.772020725	6.476684	14.89637	10.7513	5.31088083	7.642487	8.549223	8.160622
	Rank Order	3	11	1	7	9	2	4	10	8	5	6

Dai Truong

Decision Matrix

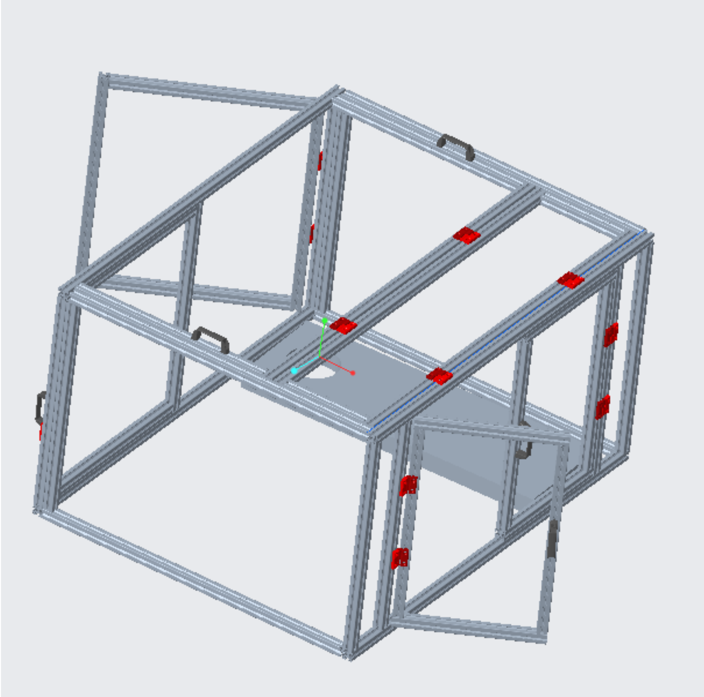
Decision Matrix				
Selection Criteria	Concept 1	Concept 2	Concept 3	Concept 5
Safety	Datum	S	-	S
Cost		S	-	S
Construction feasibility		+	+	-
Weight of material		+	+	+
Controlling elements		+	+	+
Minimize heat loss		+	+	+
Accessibility		+	+	-
Clearance		+	S	S
Clarity		S	S	S
Portability		S	+	+
# of pluses		5	5	4
# of Minuses		0	2	2

Concept 2
Concept 3
Concept 5

Dai Truong

The Selected Concept

- During design, concept 2 was optimized and now has more features
- The final CAD allows volume to be calculated
- Can now determine
  - Appropriate heating/cooling device
  - Appropriate humidity control device



Concept 2

Dai Truong

The Control System

- The AC unit is provided by EIC Solutions
- It can provide 400 BTU of heat and uses a 120 VAC power supply
- The Humidifier is a separated unit with its own controller
- We will select a fan-powered humidifier

Solid State Thermoelectric AC unit

HONEYWELL Humidifier and HumidiPRO Digital Controller

Dai Truong

5 Most Important Points

1. We are designing the test chamber for the test rig, not the test rig itself.

Dai Truong

5 Most Important Points

1. We are designing the test chamber for the test rig, not the test rig itself.
2. Heat and humidity system solution was discussed and decided; we will use a fan heater/cooler and the HONEYWELL humidifier. Calculations now can be done to confirm.

Dai Truong

5 Most Important Points

1. We are designing the test chamber for the test rig, not the test rig itself.
2. Heat and humidity system solution was discussed and decided; we will use a fan heater/cooler and the HONEYWELL humidifier. Calculations now can be done to confirm.
3. A bill of materials was made, project is under the budget after first revision.

Dai Truong

5 Most Important Points

1. We are designing the test chamber for the test rig, not the test rig itself.
2. Heat and humidity system solution was discussed and decided; we will use a fan heater/cooler and the HONEYWELL humidifier. Calculations now can be done to confirm.
3. A bill of materials was made, project is under the budget after first revision.
4. Request to order materials and equipment.

Dai Truong

5 Most Important Points

1. We are designing the test chamber for the test rig, not the test rig itself.
2. Heat and humidity system solution was discussed and decided; we will use a fan heater/cooler and the HONEYWELL humidifier. Calculations now can be done to confirm.
3. A bill of materials was made, project is under the budget after first revision.
4. Request to order materials and equipment.
5. The spring project plan is being made.

Dai Truong

References

- Danfoss. (n.d.). *Turbocor - TG*. Retrieved from Highly energy efficient and environmentally friendly compressor: https://www.danfoss.com/en/products/compressors/dcs/turbocor/turbocor-tg/#tab-overview
- Danfoss. (n.d.). *Turbocor - TT*. Retrieved from Danfoss Turbocor® TT series: Oil free compressors using HFC134a refrigerant: https://www.danfoss.com/en/products/compressors/dcs/turbocor/turbocor-tt/#tab-overview
- Danfoss. (n.d.). *Turbocor – Danfoss Turbocor Compressor Specification Sheet.*

Dai Truong

Questions?

Dai Truong