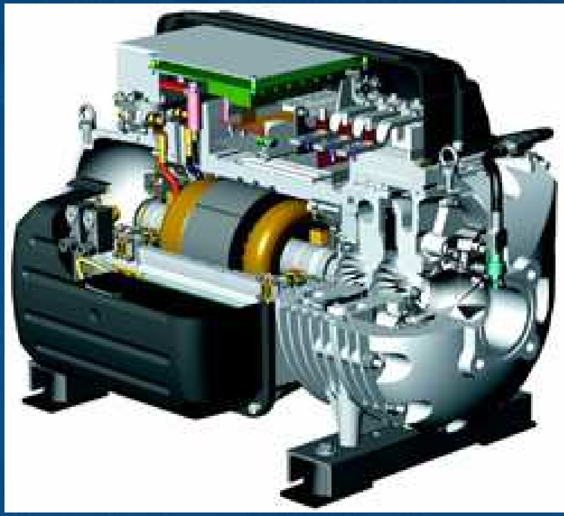
Labyrinth Seal Test Rig

Sponsored by Danfoss –Turbocor
Fall 2008 Final Design Review Presentation



Group 1

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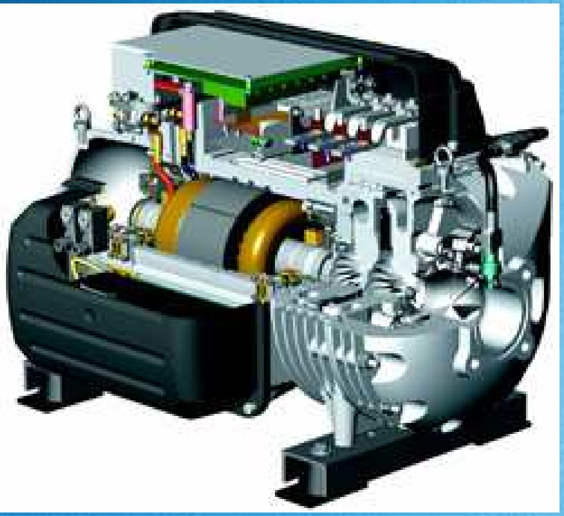
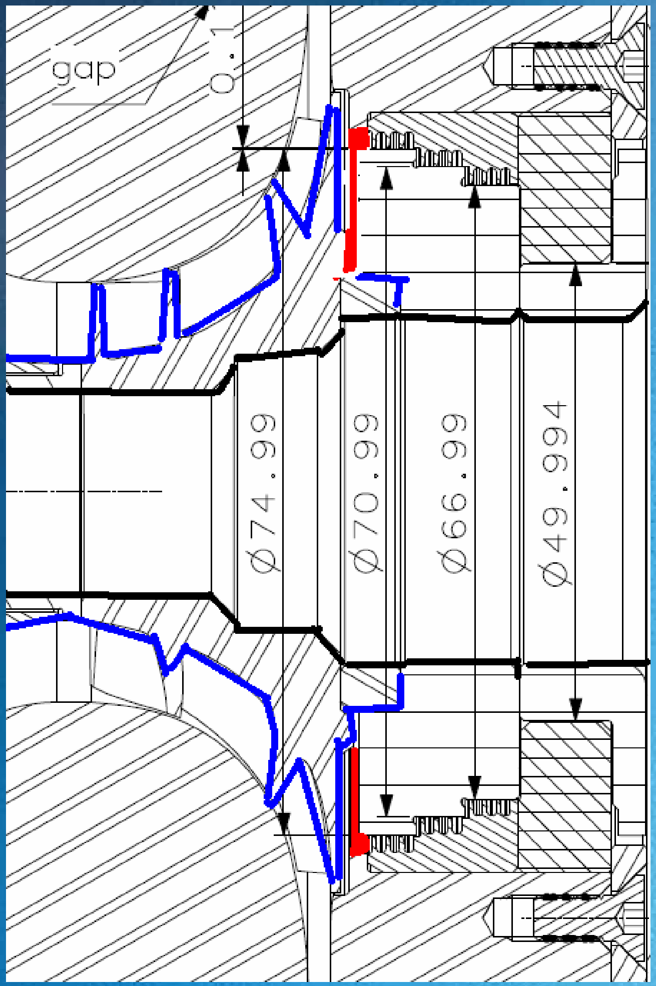


Problem Definition

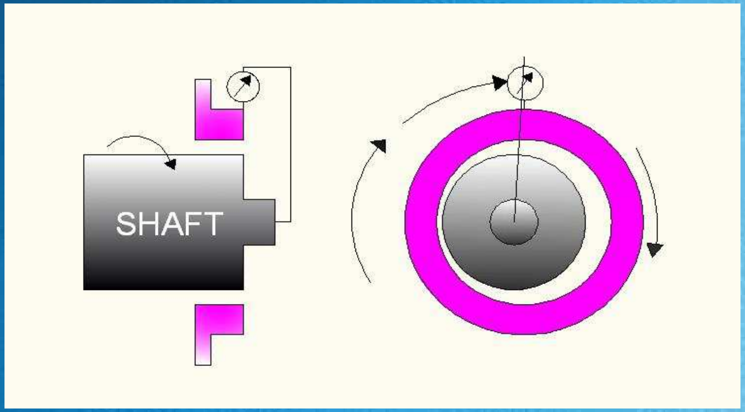
- Design and build a test rig that simulates conditions in a Danfoss – Turbocor compressor
- The leakage flow through the seal must be measured to show which seal is superior
- Rig must allow for interchangeable seals for testing
- The Concentricity of the shaft must be able to be adjusted



Instrumentation

- **Flow Measurements:**
  - **Flow Meter**
    - **Digital Omega Brand**
  - **Mass Balance of gas cylinder**
    - **Used as a check to the flow meter readings**

- **Concentricity: Dial Gauge**
  - Magnetic gauge connected to either shaft or rig body
  - Roll shaft
  - As the shaft rolls, gauge measures concentricity w.r.t. it's location



Differential Thread Mech.

- Uses 2 different sized screws, one of which is dual threaded (DTS)
- Smaller screw is indirectly attached to seal as well as screws into the DTS
- Screws have slightly different pitches so when the DTS is turned the smaller screw will unscrew but the seal will move a distance that is the difference between the pitches

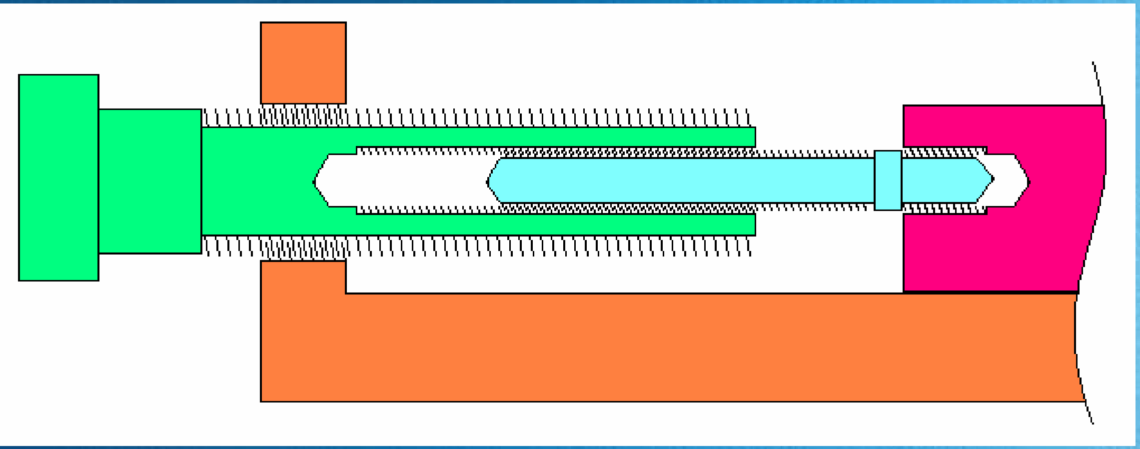
Thread Size:

Large screw:

3/8"diam.
24 thread
1.058 mm pitch

Small Screw:

1/4"diam.
28 thread
.907 mm pitch



Fluid Calculations

- Expected Mass Flow Through Seal
  - Use mass flow rate to find the fluid velocity through the seal
  - Use the velocity to find Re

$$\dot{m} = \pi 2 r_o \delta C_t C_c C_r \rho \sqrt{RT}$$

$$\dot{m} = \rho V A$$

$$\mathrm{Re} = \frac{\rho V \delta}{\mu} = \frac{V \delta}{\nu}$$

•The Reynolds numbers differed by several orders of magnitude

•Unable to be matched at ambient temperature

•Scaling the rig is impractical

•A heating cooling element is not desired by the client

•The calculations are being used to set up a relationship between air and R134a so numerical analysis and comparisons can be done

•The actual temperature may run colder than initially expected, this may influence the actual Re

Rig Conditions

- **Operating Conditions:**
- The rig will be pressurized to 400 kPA (60 psi)
- Pressure chosen based on relationship found between Pressure and mass flow rate during prototype testing
- Assumed temperature to be 24 deg C

$$\sigma_1 = \frac{\Pr}{t}$$

$$\sigma_2 = \frac{\Pr}{2t}$$

$$FS = \frac{\tau}{\sigma}$$

Force Analysis:

High pressure side:

$\sigma 1$ = 5.51MPa $\sigma 2$= 2.76MPa

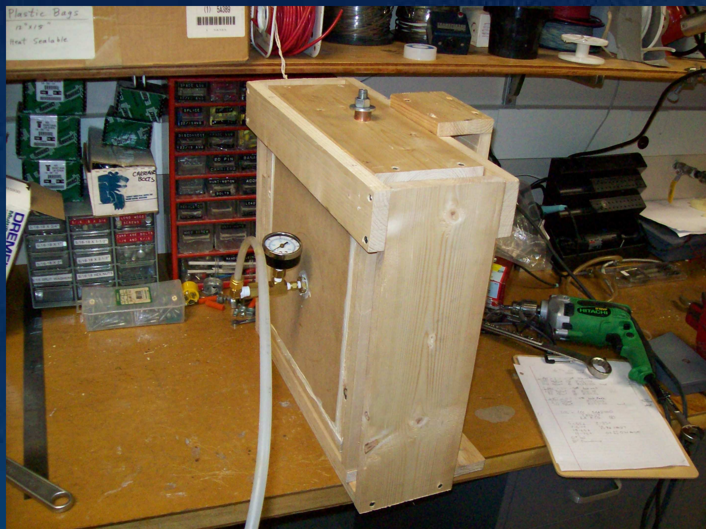
FS1= 32.6 FS2= 65.3

Low Pressure side:

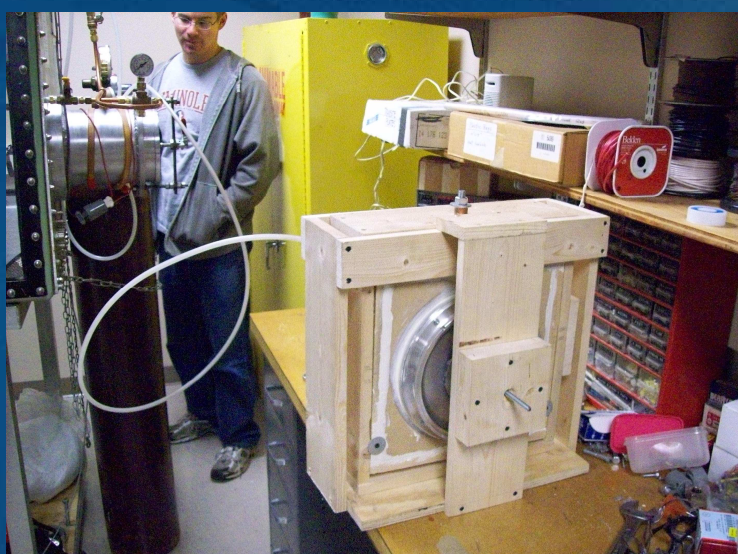
$\sigma 1$ = 2.22MPa $\sigma 2$= 1.11MPa

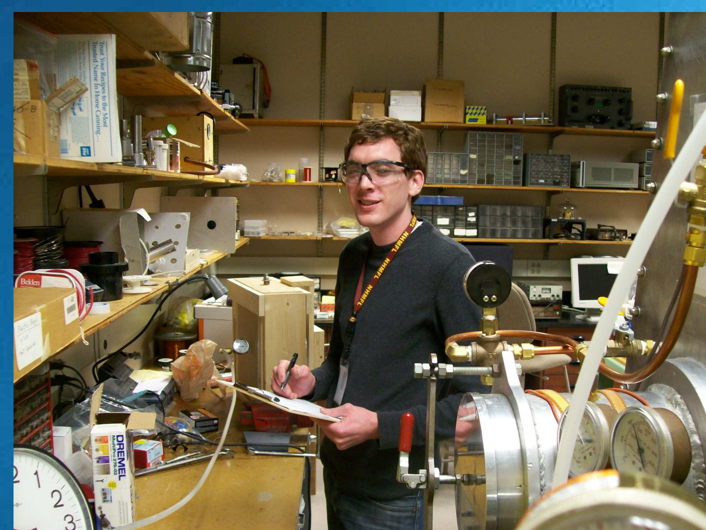
FS1= 80.8 FS2= 161.5

Prototype Testing



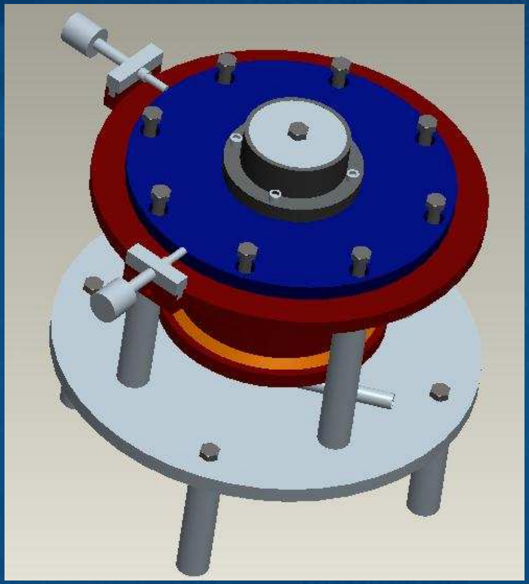
- A test was needed to verify mass flow calculations
- Prototype material: Wood
- Maximum Pressure: 8 psi estimated
- 4 tests were conducted:
  - 2, 3, 4, and 5 psi
  - Each with flow rate of 0.00x kg/s
  - Exit volumetric flow rate between 200 to 500 liters/min





Detailed Design

- Vertical Design, with top-down flow
- Versatile design allows for various high pressure air supply sources
- Has the capability to include a motor



Dimensions

Height: 2 ft

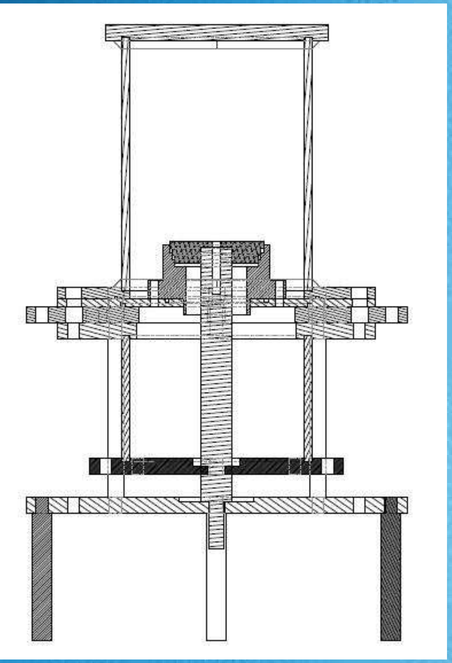
Total Width: 1 ft

Max Seal Diameter

Needed: 8.9 cm ~ 3.5”

Max Seal Diameter

Capable: 5.5”



Detailed Design

Garnet	Low P Side
Gold	High P Side
Blue	Adjustable Seal Mount
Gray	Misc. Housing supports

Utilizes a constant area outlet which will connect to a digital mass flow meter

Each pressure housing will be welded in order to achieve an airtight enclosure

O-rings will be incorporated into the seal mount to provide an airtight connection between each of the housings

Materials Selection

- **High & Low Pressure Chambers: Carbon Steel Tube**
  - ***D = 6" & L= 2' t = ½"***
  - Circular in order to withstand high internal pressure
  - Circular shape allows for greater precision machining
  - Allows for welding to ensure that no unplanned leaks will occur
- **Chamber "Covers": A36 Steel Plate**
  - ***Lx w x h = 1' x 2' x ½" & L x w x h = 2' x 2' x ¼"***
  - Used to cover tube ends to form pressure chambers
  - Can be welded to pressure chamber tubes
- **Structural Components: Steel Rod**
  - ***L = 6'***
  - Used for legs, spacers, etc
- **The Seals, Balancing Pistons, and Shaft are all manufactured from steel by Danfoss –Turbocor.**

Cost Analysis

Item	Cost
Steel Tube	$138.14
Steel Plating (total)	$168.82
Steel Rod	$25.98
Flow Meter	$664.00
Pressure Gauge	$125.00
Dial Gauge	$0.00
Pressure Regulator	$0.00
Pressure Transducers	$0.00
Differential Thread rods (2)	$12.00
S&H estimate	$95.82
Total	**$1229.76**

Conclusion

- Measurements:
  - Omega digital mass flow meter is primary method
  - Concentricity measured using a dial gauge
- Rig Conditions:
  - 400 kPa
  - Approx. 24 deg C
  - Sufficient factors of safety for internal pressure forces
- Material Selection: A36 steel
  - Easy to machine and weld, magnetic
- Cost Analysis:
  - Approximately $1230
  - Will be under budget or right at $1500

Future Work

- Acquire shop-time at Turbocor
- Shape rig housing (Cut bulk steel)
- Assemble Rig
- Begin Testing of various seals provided by Turbocor
- Rate the seals based on the flow rate measured through them

Thanks to

- **Danfoss – Turbocor Staff:**
  - Jesper Nielsen
  - Marius Dragut
  - Lin Sun
  - Joost Brasz
- **FAMU-FSU College of Engineering Faculty**
  - Dr. Chiang Shih
  - Dr. Daudi Waryoba
  - Mr. Bill Starch , Shop Supervisor at ASC, NHMFL

References

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  - Classical Concepts and Papers by Egli 1935
  - Piotrowski, John. Shaft Alignment Handbook. Danbury: NetLibrary, Incorporated, 1995.

- **Vendors:**
  - www.Metalsdepot.com
  - www.Omega.com

? Questions ?