Labyrinth Seal Test Rig

Sponsored by Danfoss –Turbocor

Presentation to the

Mechanical Engineering Advisory Committee

Group 1

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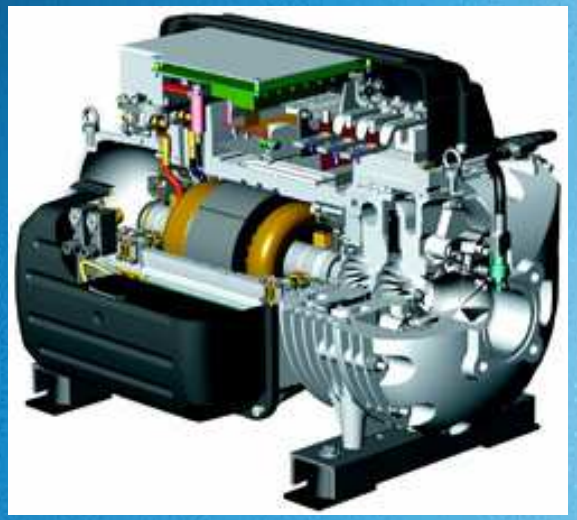
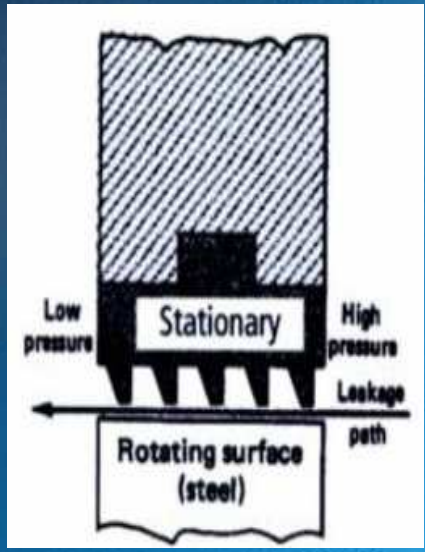
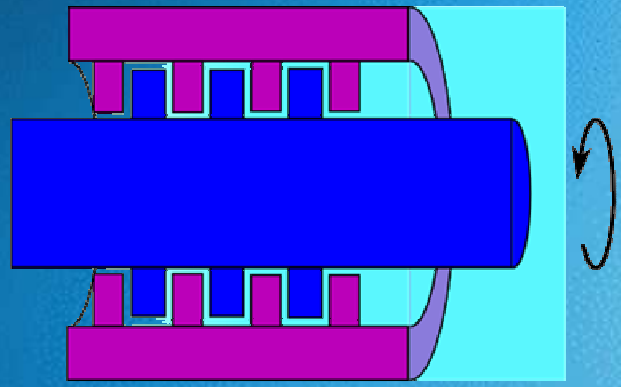


Background Information

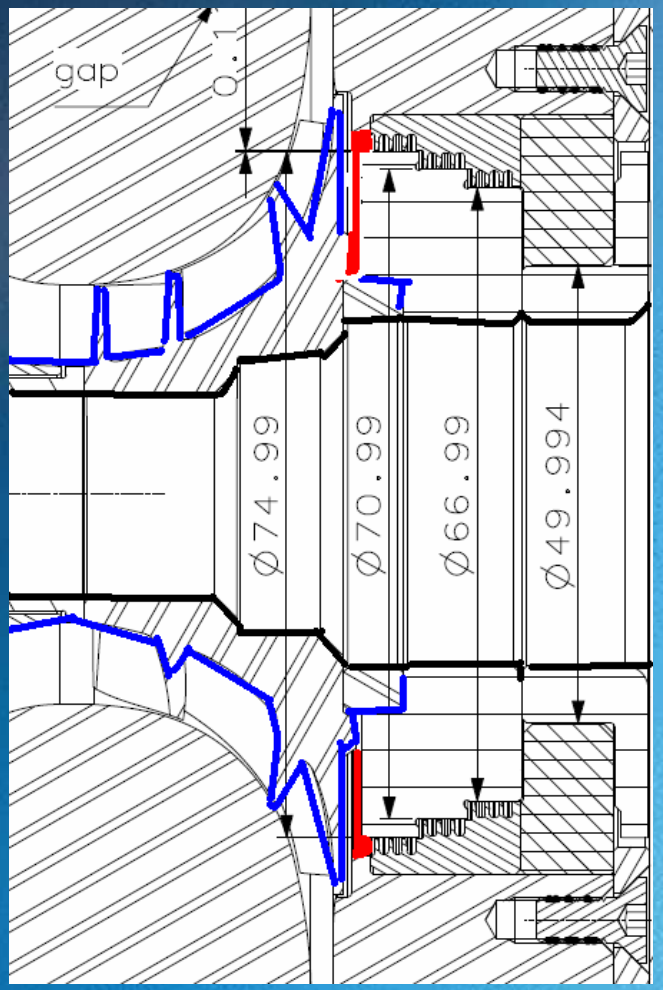
- **Labyrinth Seals**
  - Mechanical seal that fits around a shaft to prevent leakage of fluid
  - Provide non-contact sealing by controlling flow of fluid
  - Threads create a “maze” to induce turbulence and block flow
  - Typically used in high speed centrifugal applications





Problem Definition

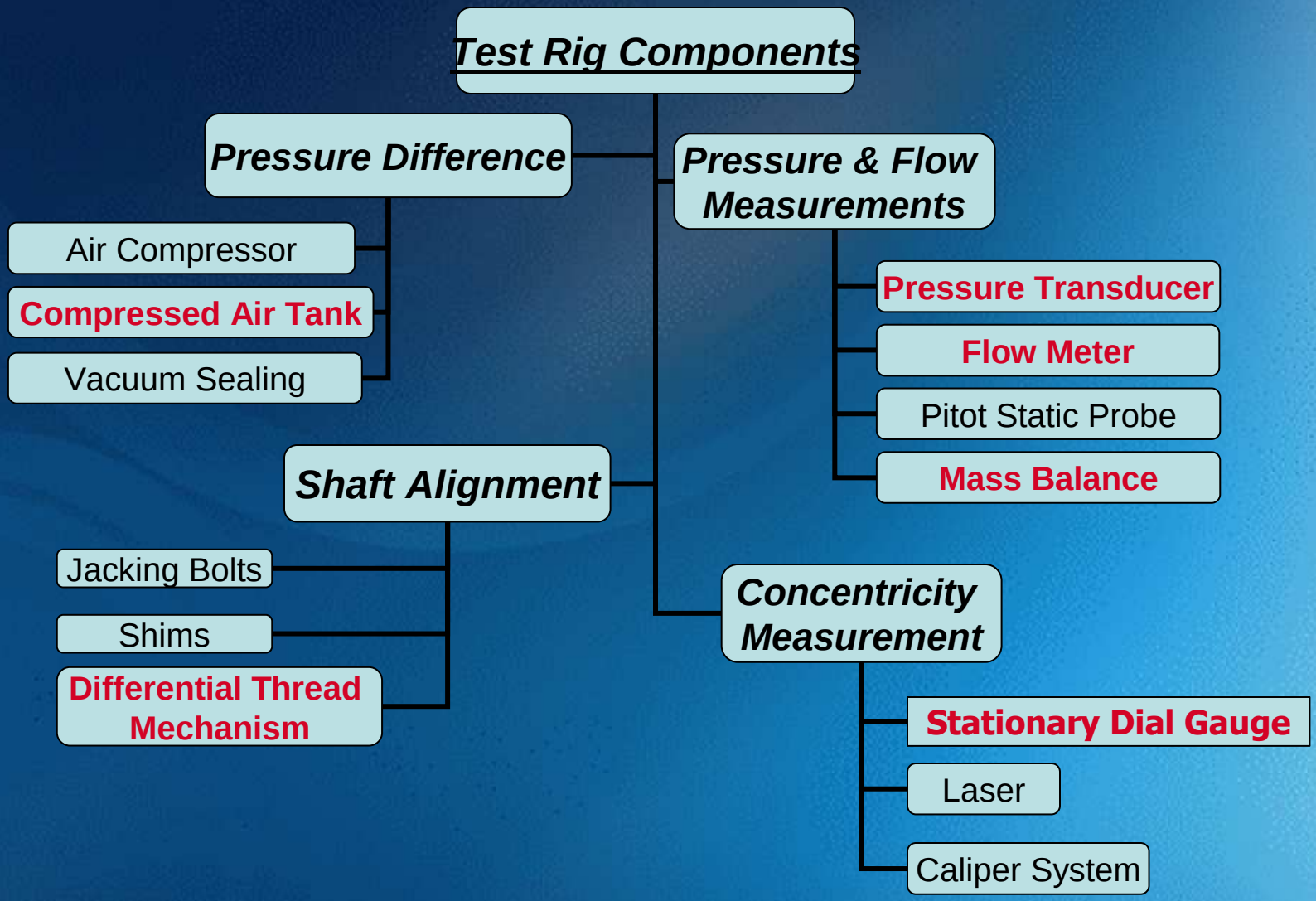
- Design and build a test rig that simulates conditions in a Danfoss – Turbocor compressor
- The leakage flow through the seal must be measured to show which seal is superior
- Rig must allow for interchangeable seals for testing
- The Concentricity of the shaft must be able to be adjusted



Needs Assessment & Product Specifications

Customer Needs	Product Specifications
Environmentally friendly	Replace R134a w/ air
Accurately model conditions in compressor	Numerical analysis to match Re of both fluids
Vary shaft concentricity	Differential threading mechanism to adjust seal w.r.t. the shaft
Measure leakage through seal	Mass balance, pressure transducers, & flow meter
Interchangeable labyrinth seals	Multiple removable seal plates

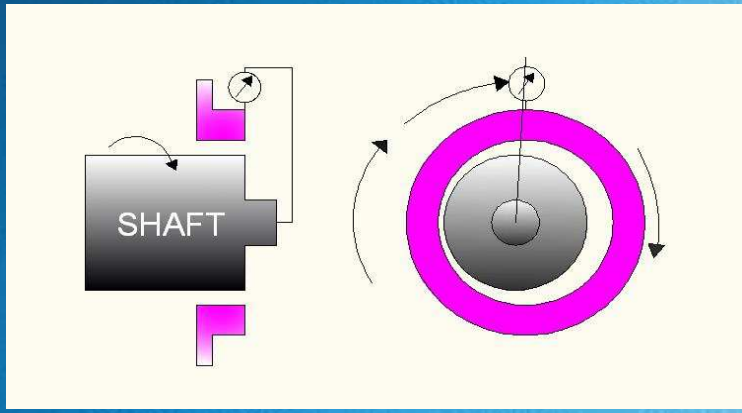
System Breakdown



Instrumentation

- **Flow: Redundant Measurements**
  - **Flow Meter**
  - **Mass Balance**
  - **Pressure drop over time**

- **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



Pertinent Calculations

- Expected Mass Flow Through Seal
  - Use mass flow rate to find the fluid velocity through the seal
  - Use the velocity to find Re
- Reynolds Number
  - Match Re of air and R134a to determine pressure of the test rig
- Pressure force analysis
  - Under determined conditions find the hoop and longitudinal stresses acting inside the test rig
  - Analyze the factor of safety

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

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

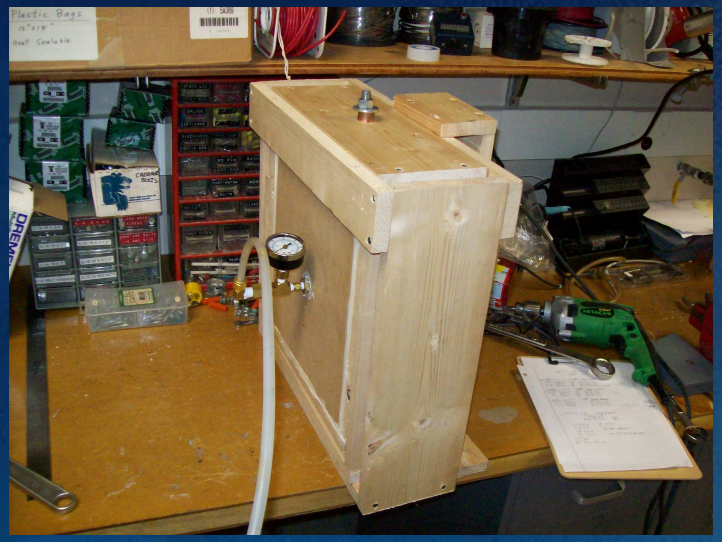
$$\mathrm{Re} = \frac{\rho V \delta}{\mu} = \frac{V \delta}{\nu}$$

$$\sigma_1 = \frac{P \cdot r}{t}$$

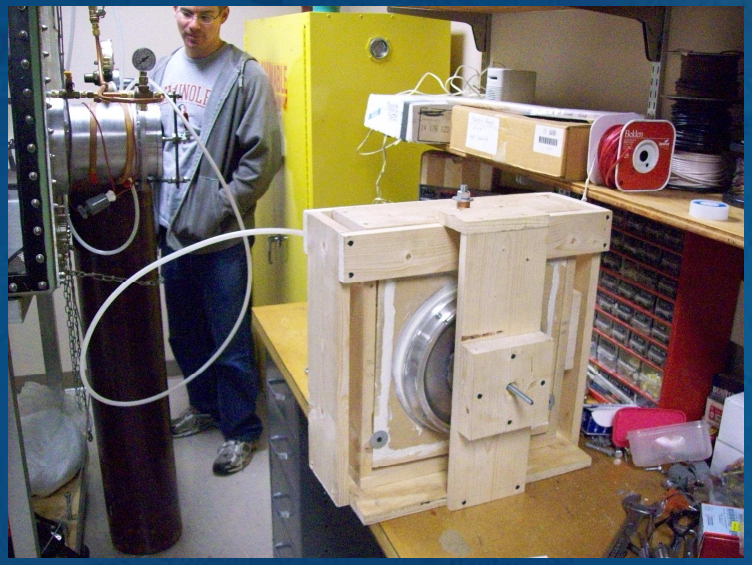
$$\sigma_2 = \frac{P \cdot r}{2t}$$

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

Prototype Testing

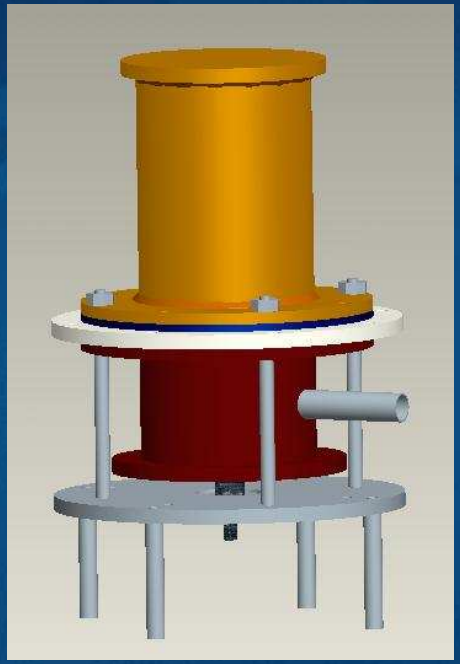


- A test was needed to verify mass flow calculations
- Prototype material: Wood
- Maximum Pressure: 8 psi estimated
- 4 tests were conducted:
  - 2, 3, 4, and 5 psi
  - Each with flow rate of 0.00x kg/s
  - Exit volumetric flow rate between 200 to 500 liters/min



Design Continued

- Vertical Design, with top-down flow
- Has the capability to include a motor
- Pressure Vessels are welded closed to ensure seal



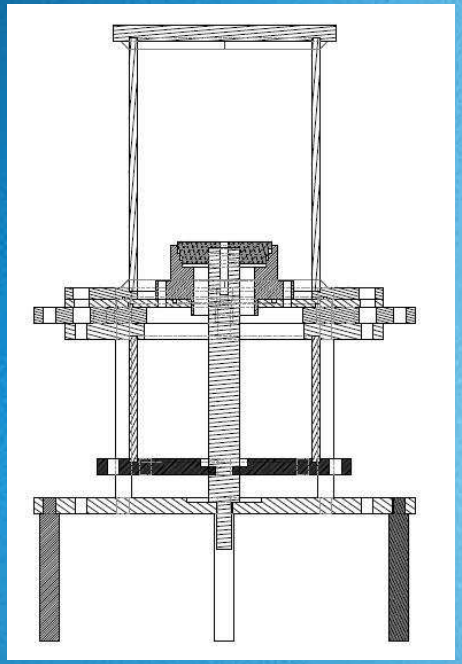
Dimensions

Height: 2 ft

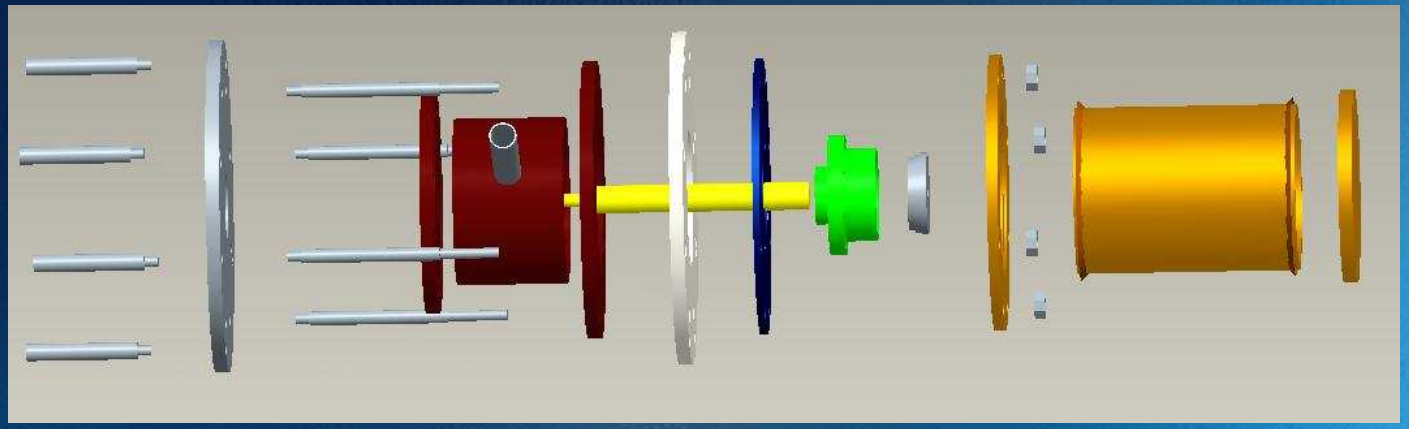
Total Width: 1 ft

Max Seal Diameter Needed: 8.9 cm ~ 3.5”

Max Seal Diameter Capable: 5.5”



Detailed Design



- Utilizes a constant area outlet for mass flow meter
- Components with same colors will be welded together

Garnet	Low P Side
Gold	High P Side
Green	Labyrinth Seal
White	Seal Ref.
Silver	Balancing Piston
Yellow	Shaft
Blue	Adjustable Seal Mount
Gray	Misc. Housing supports

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, Seal Plates, and Shaft are all manufactured in house by Danfoss –Turbocor and made of steel.**

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
S&H estimate	$95.82
Total	**$1217.76**

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:**
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  - **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 ?