Conceptual Design

Group 1: Danfoss-Turbocor

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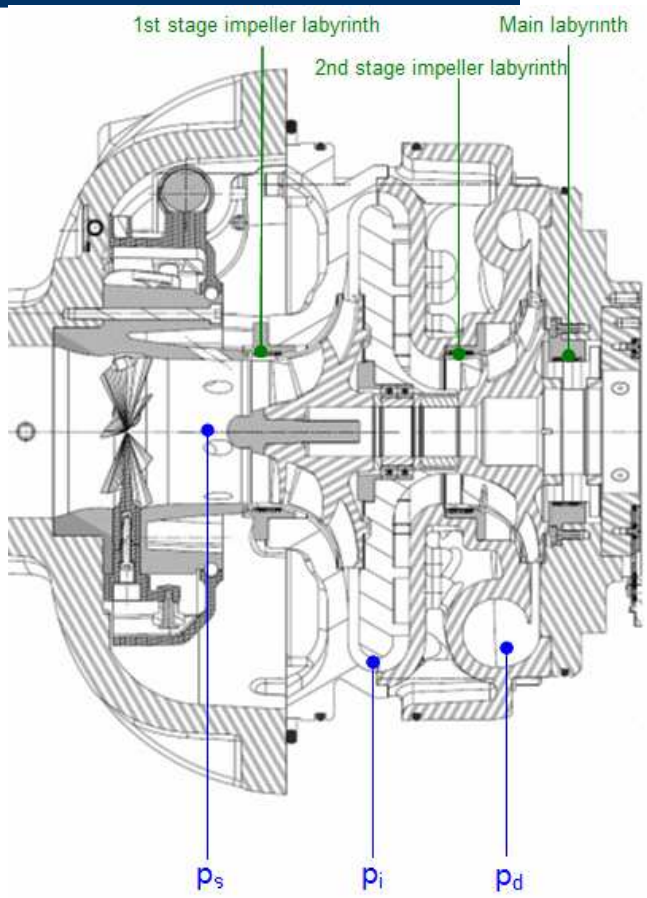
Danfoss-Turbocor: The Company

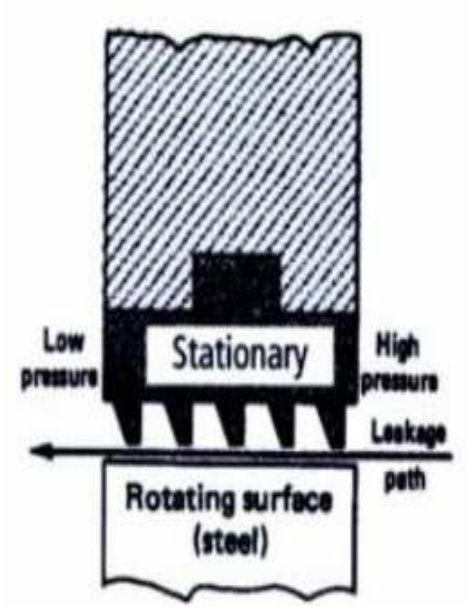
- Danfoss founded by Mads Clausen in 1933
- Manufactured automatic valves for refrigeration plants
- Turbocor started in Australia in 1993
- Headquarters is moved to Montreal in 1999
- Frictionless Compressors went on the market in 2002
- Denmark based Danfoss merges with Montreal based Turbocor in 2004
- Headquarters is moved to Tallahassee in 2007

Problem Definition

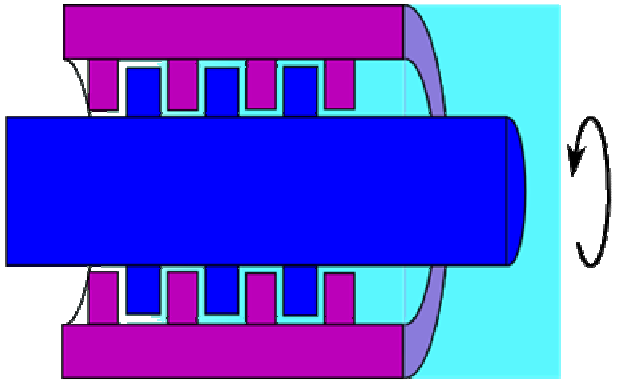
- Design and build a test rig that simulates conditions in a high speed centrifugal compressor
- The leakage flow through the seal must be measured to show which seal is superior
- Rig must allow for interchangeable seals for testing



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



Customer Needs

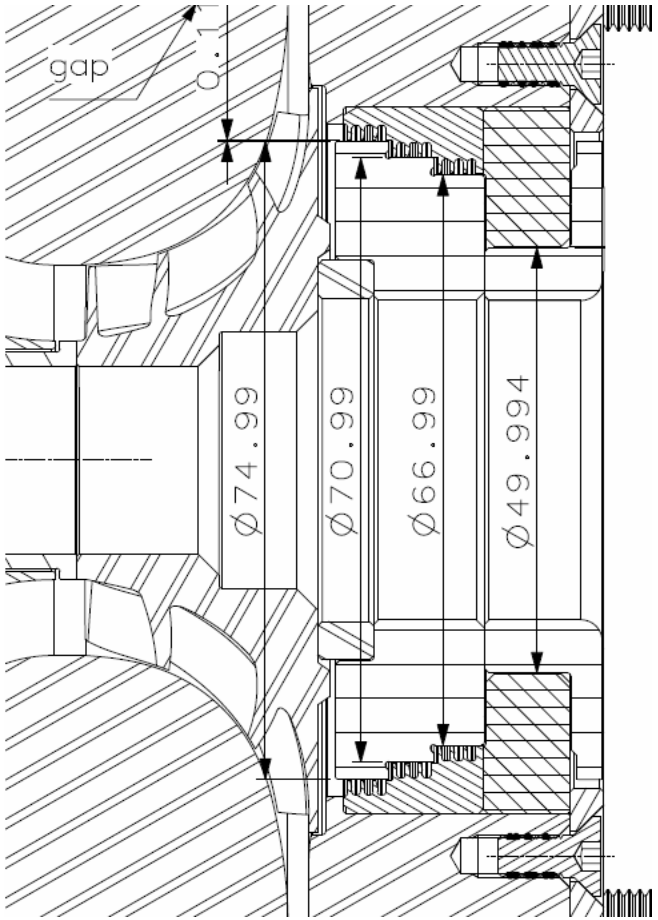
- Build a test rig that will quantitatively measure the leakage through a labyrinth seal
- Use air as the working fluid, and closely match the air with the properties of R-134a.
- A rotating shaft must be incorporated into the test rig
- The rig should be capable of adjusting to fit various seal designs and size

Product Specifications

- Set the Reynolds numbers of air and R134a equal to determine necessary conditions
  - The optimal inlet and outlet conditions are:
    In: 2 ˚C & 171 kPa
    Out: 55 ˚C & 1391 kPa
- The rig's shaft will operate at approximately 10,000 rpm
- The rig will be run with shaft concentricity varying at 100%, 90%, 80% and 70% centered
- 3 Labyrinth seal designs will be tested in various sizes
  - Impeller Labyrinths
  - Main Labyrinths
  - Interstage Labyrinths

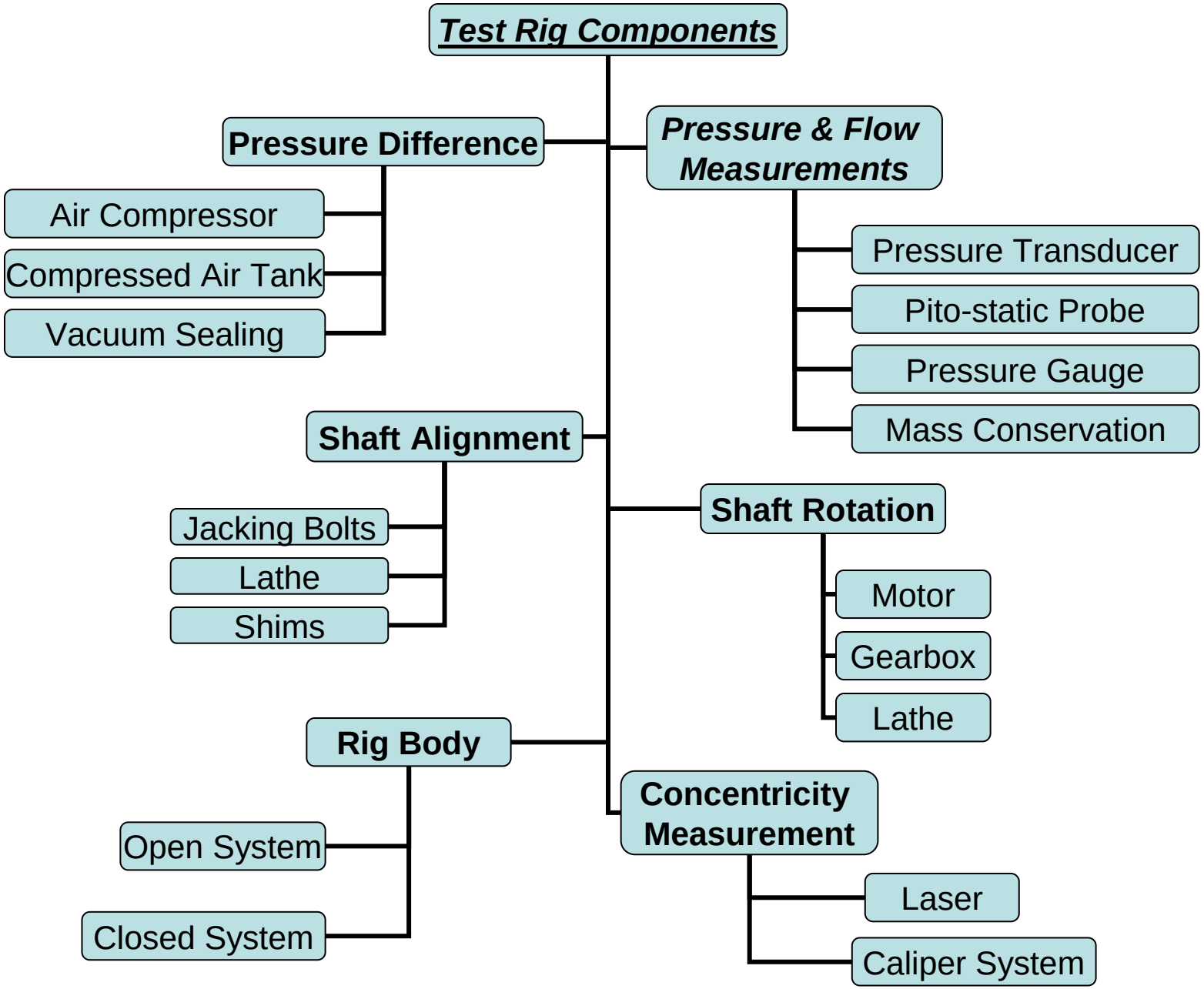
Some Analysis

- Iterative process to compare Reynolds number of air at various conditions to R134a
- Use “RefProp” to find conditions of air at varying Pressures and Temperatures
- Compare the Mach numbers of both fluids as a verification
- The tangential Velocity caused by the shaft is the dominant velocity



System Breakdown

- Shafting Considerations
  - Providing necessary rpm
  - Initial alignment
  - Variable concentricity
- Rig Body considerations
  - Maintaining a pressure gradient
  - Ability to test multiple designs and sizes of labyrinth seals
- Measurement Needs and Options
  - Air getting through the seal
    - Pitot-Static Probe
    - Pressure Transducers
    - Mass flow meter
  - Shaft Alignment
    - Calipers
    - Laser alignment


Test Rig Components
Pressure Difference
Air Compressor
Compressed Air Tank
Vacuum Sealing
Pressure & Flow Measurements
Pressure Transducer
Pito-static Probe
Pressure Gauge
Mass Conservation
Shaft Alignment
Jacking Bolts
Lathe
Shims
Shaft Rotation
Motor
Gearbox
Lathe
Rig Body
Open System
Closed System
Concentricity Measurement
Laser
Caliper System

Decision Matrix

Parameters Idea	Manufacturability (5)	Cost (3)	Rig versatility (2)	Effectiveness (4.5)	Ease of use (3.5)	Repeatability (4)	Total (22)
Shaft Rotation							
Lathe	4	3	1	4.5	3.5	2	18
Motor	3	1	2	4	3.5	3.5	17
Seal Mounting							
chuck	2	1	2	2.5	3	4	14.5
Multiple custom plates	4	2.5	1	4	2.5	4	18
Pressure Difference							
Vacuum Sealing	2	1	1	2	1	3.5	10.5
Compressed air tank	4.5	3	2	3	3	2.5	18
Air compressor	4.5	2	2	4	3.5	4	20

Conceptual Design 1: Enclosed Seal

Design 1 Continued

Conceptual Design 2: Lathe Attachment

Design 2 Continued

Schedule: Past, Present, and Future

- **Completed:**
  - Initial Client Meeting
  - Needs Assessment
  - Product Specifications
  - Initial Brainstorming
- **Currently Open**
  - Conceptual Development
  - Design Selection
- **Future Endeavors**
  - 3D and 2D system diagrams
  - Material and parts selection
  - Parts Procurement

Any Questions?