Design Review V

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Team 4: Visual Monitoring System for Danfoss Turbocor Compressor IGVs

Danfoss IGV Monitoring System

Team 4

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Engineer

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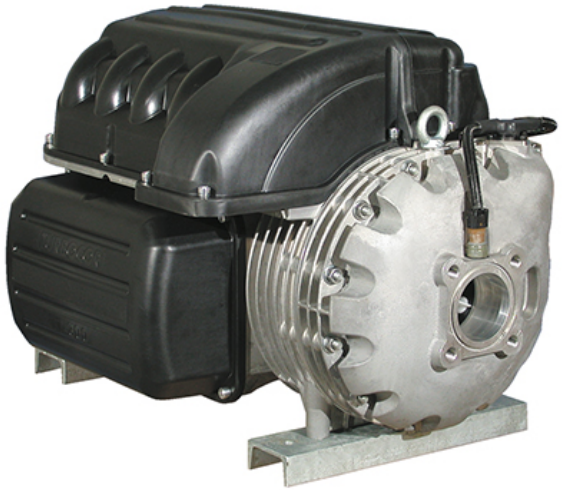
Presented by Brandon Klenck

BACKGROUND INFORMATION AND PROJECT INTRODUCTION

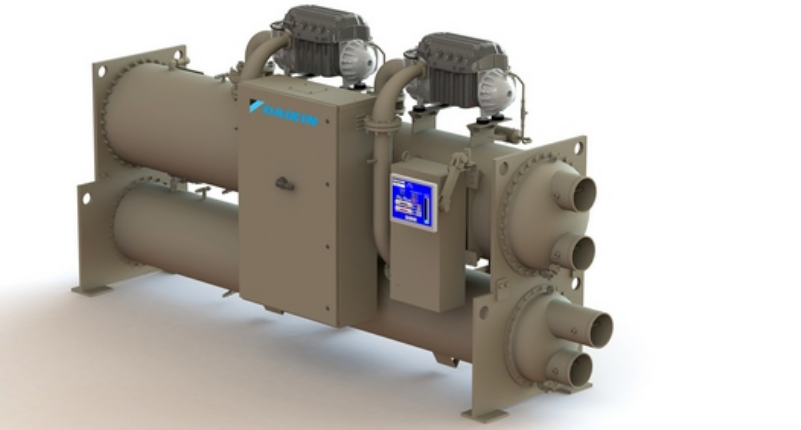
Danfoss Turbocor Compressors

- Refrigerant Compressors
  - TT Series
    - 4 Different Models
    - 300, 350, 400, 500
  - Magnetic Bearing, Oil-Free
  - Inlet Guide Vanes (IGVs)



Turbocor Oil Free Compressor

Chiller Application for Compressors



- Applied in Water Chillers
  - Air and Water Cooled Chillers
  - HVAC Applications
  - Comfort Cooling for Buildings
  - 60 - 200 Tons

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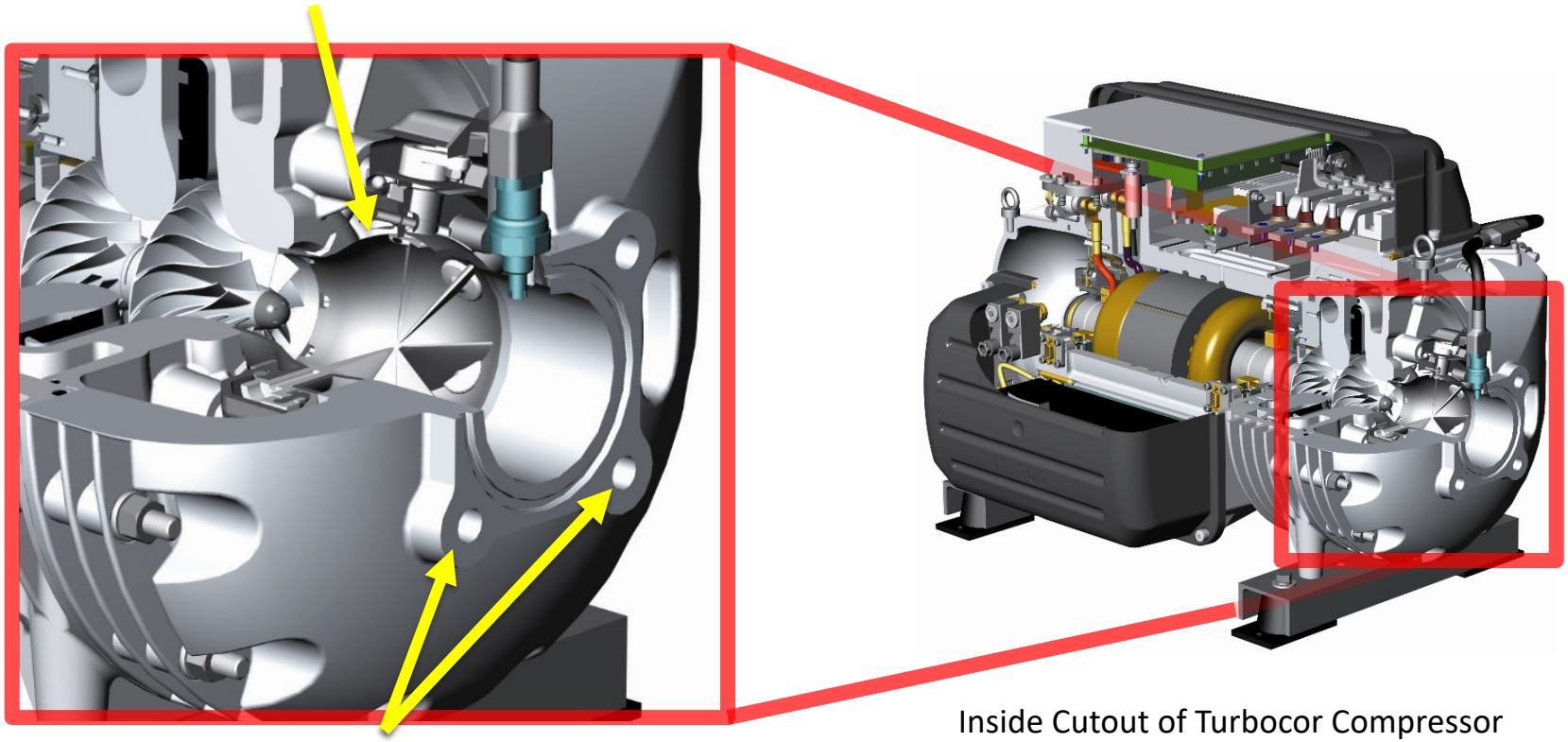
TT Series Compressor Detail

Inlet Guide Vanes (IGVs)



Inside Cutout of Turbocor Compressor

Inlet Flange Attachment for Pipe and Monitoring System for Testing

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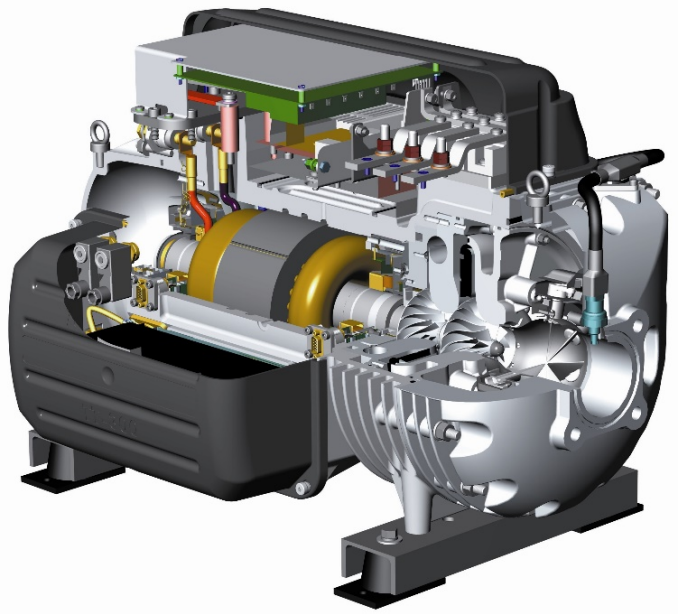
Project Overview

- Currently No Visual for Inlet Guide Vanes (IGVs)
- Limited Angle Measurement
  - Stepper motor is used for angle control
  - No feedback
- Problems with IGVs
  - IGVs might flutter or vibrate
  - Possible IGV breakdown
  - Single IGV latching or “sticking”
- IGV Misfunction has Caused Data Loss for Danfoss Turbocor



Inside Cutout of Danfoss Turbocor Compressor

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Project Goals

- Danfoss Turbocor Inlet Guide Vane (IGV) Monitoring System Goals:
  - Provide detailed visual monitoring of vane failure
  - Produce a system to detect position of individual IGVs
  - Minimize impact on the fluid flow

Compressor Inlet Cross-Section

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Notable Project Targets

Project Target Description	Target Value
Allowable Flow Impact	No Detectible Swirl
Minimum Visual Monitoring Rate	1 Hz
Minimum Sample Rate for Measuring Angle	1 Hz
Maximum Allowable Pressure Drop across Monitoring Device	0.2 psi
Maximum Monitoring System Length	50 cm
Minimum Angle Sensor Accuracy (In terms of percent open)	± 10%

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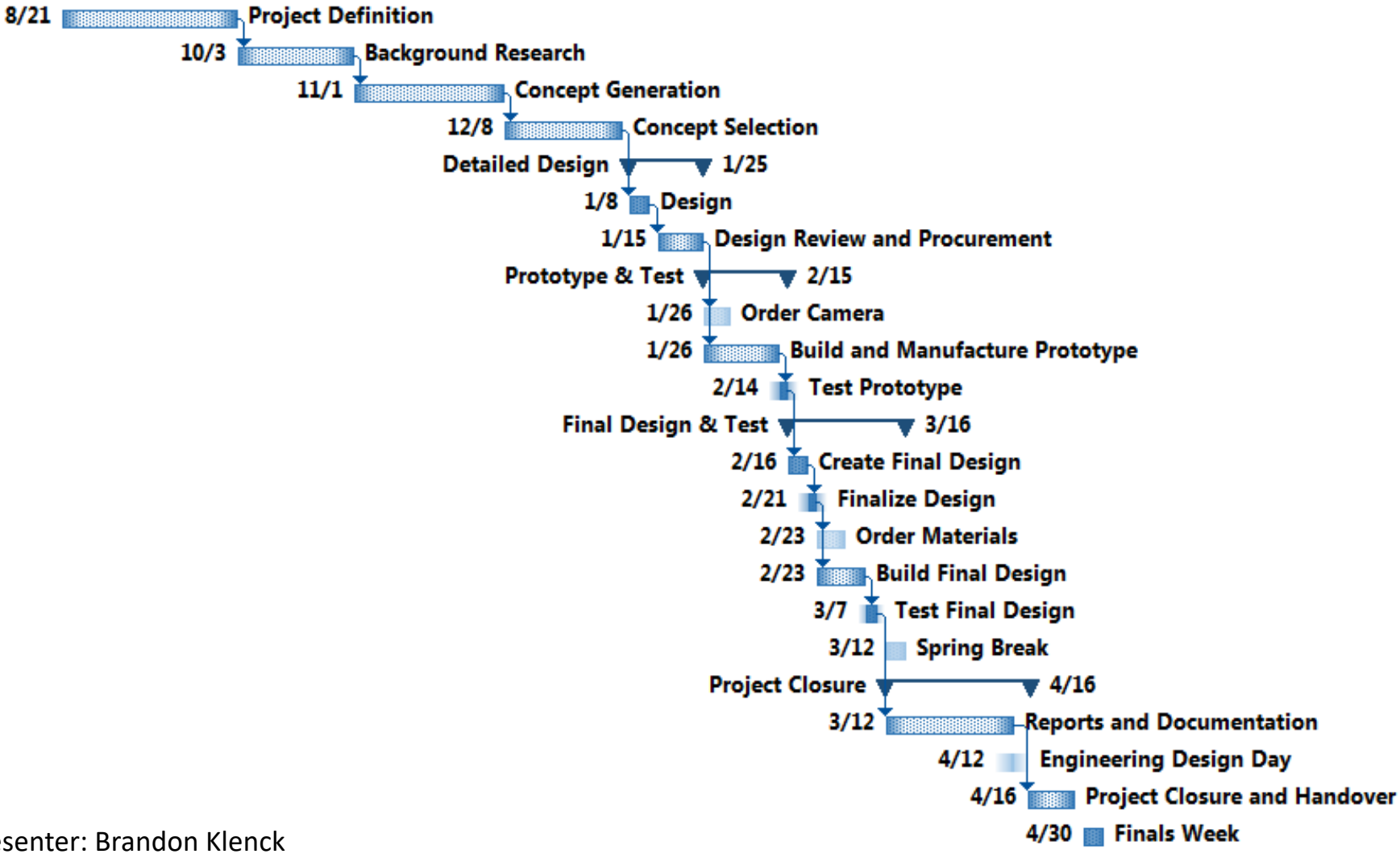
Project Timeline



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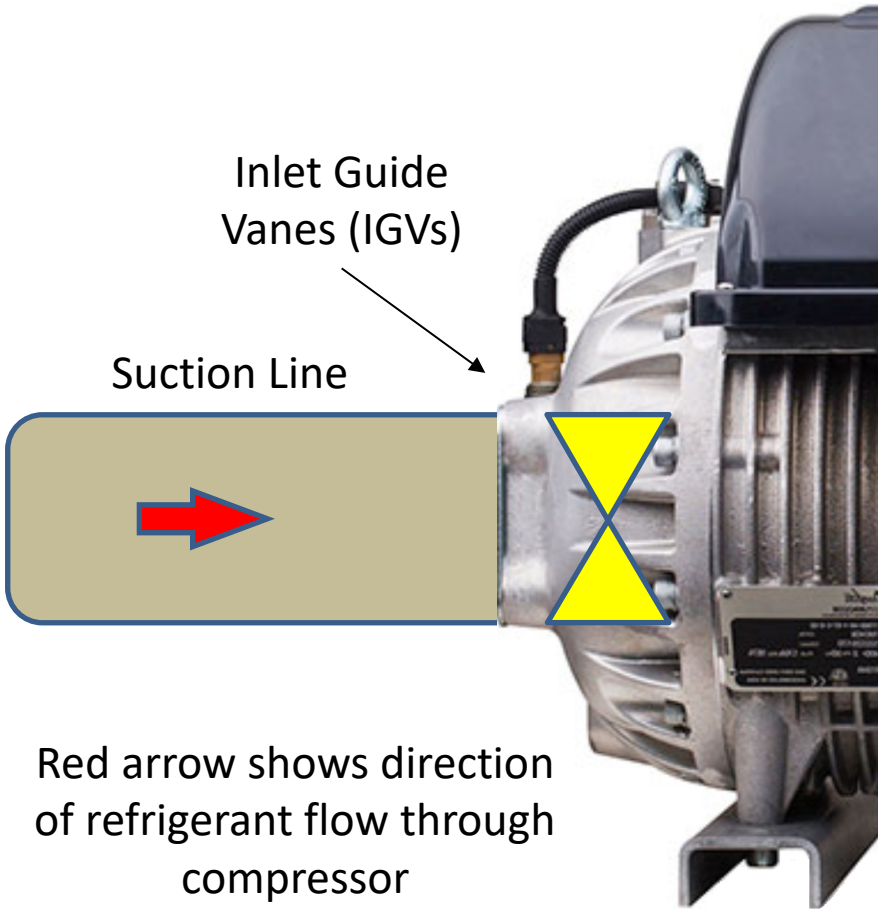
CONCEPT GENERATION AND SELECTION

Concept Generation for Each Subsystem

- Visual Monitoring
  - Mirror in central body with camera outside of pipe
  - Camera in elbow of pipe
  - Composite imaging
  - Camera in central body
- IGV Angle Monitoring
  - Potentiometer on string
  - Laser vibrometer
  - AprilTags with aspect ratio visual analysis
- IGV Lighting
  - Clear pipe with ambient lighting
  - Central body lighting
  - Lighting around inside of pipe



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Decision Matrix for Angle Measurement

Similar decision matrix completed for each subsystem

		Potentiometer with Integrator		Irrodescent Measurement		Camera with April Tags		Gyroscope/ Gyrometer		Digital Image Correlation	
Option	Weight Factor	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating
Image Clarity	13.4	0	0	7	94	6	80	0	0	6	80
Camera Frame Rate	5.7	0	0	7	40	7	40	0	0	7	40
Angle Measurement Accuracy	6.5	4	26	3	20	9	59	6	39	9	59
Angle Measurement Refresh Rate	5.5	8	44	7	38	7	38	8	44	7	38
System Stability	26.4	1	26	7	185	8	211	1	26	8	211
System Length	11.1	7	78	6	67	6	67	7	78	6	67
Ease of Integration	6.4	1	6	5	32	4	26	1	6	4	26
Pressure Drop across System	6.5	4	26	4	26	5	33	2	13	5	33
			206		501		553		206		553

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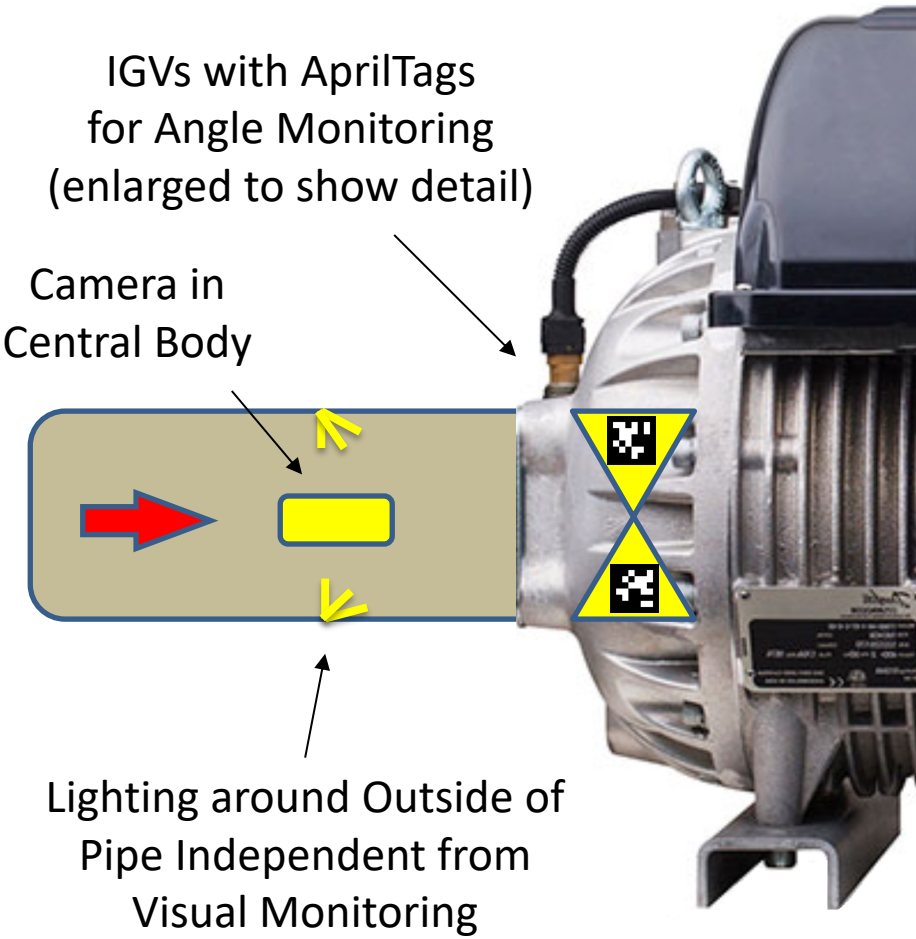
Subsystems with Concept Generation and Selection

- Visual Monitoring
  - Mirror in central body with camera outside of pipe
  - Camera in elbow of pipe
  - Composite imaging
  - **Camera in central body**
- IGV Angle Monitoring
  - Potentiometer on string
  - Laser vibrometer
  - **AprilTags with aspect ratio visual analysis**
- IGV Lighting
  - Clear pipe with ambient lighting
  - Central body lighting
  - **Lighting around inside of pipe**



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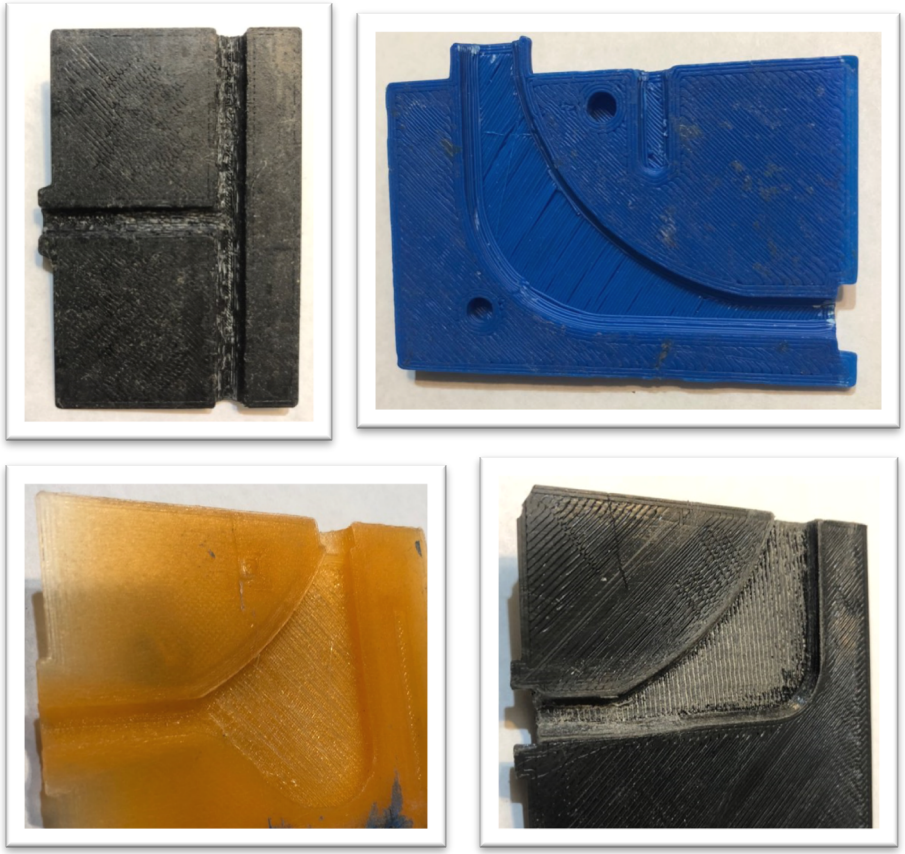
PROTOTYPE & TESTING

Airfoil Prototypes



Airfoil Prototypes

- Tested channel size and path for camera fit
- Learned from each prototype
  - The curvature of the channel
  - How to make the alignment pins
  - Thickness increase close to camera head
  - Tolerances for the front edge of the airfoil
- Provided communication of ideas to sponsor
- Final prototype fit camera and sight glass

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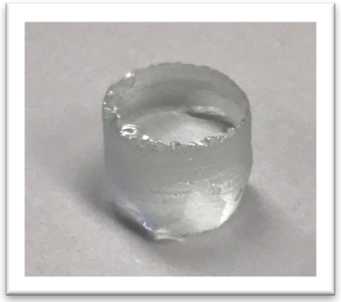
Sight Glass and Epoxy Tests

- Sight glasses of 4 different materials tested for reflection
- Application of epoxy was practiced
- Test of overflow of epoxy into camera housing
- Hole dimensional check for engineering drawings



Sight Glass

Sight Glass and Epoxy Testing

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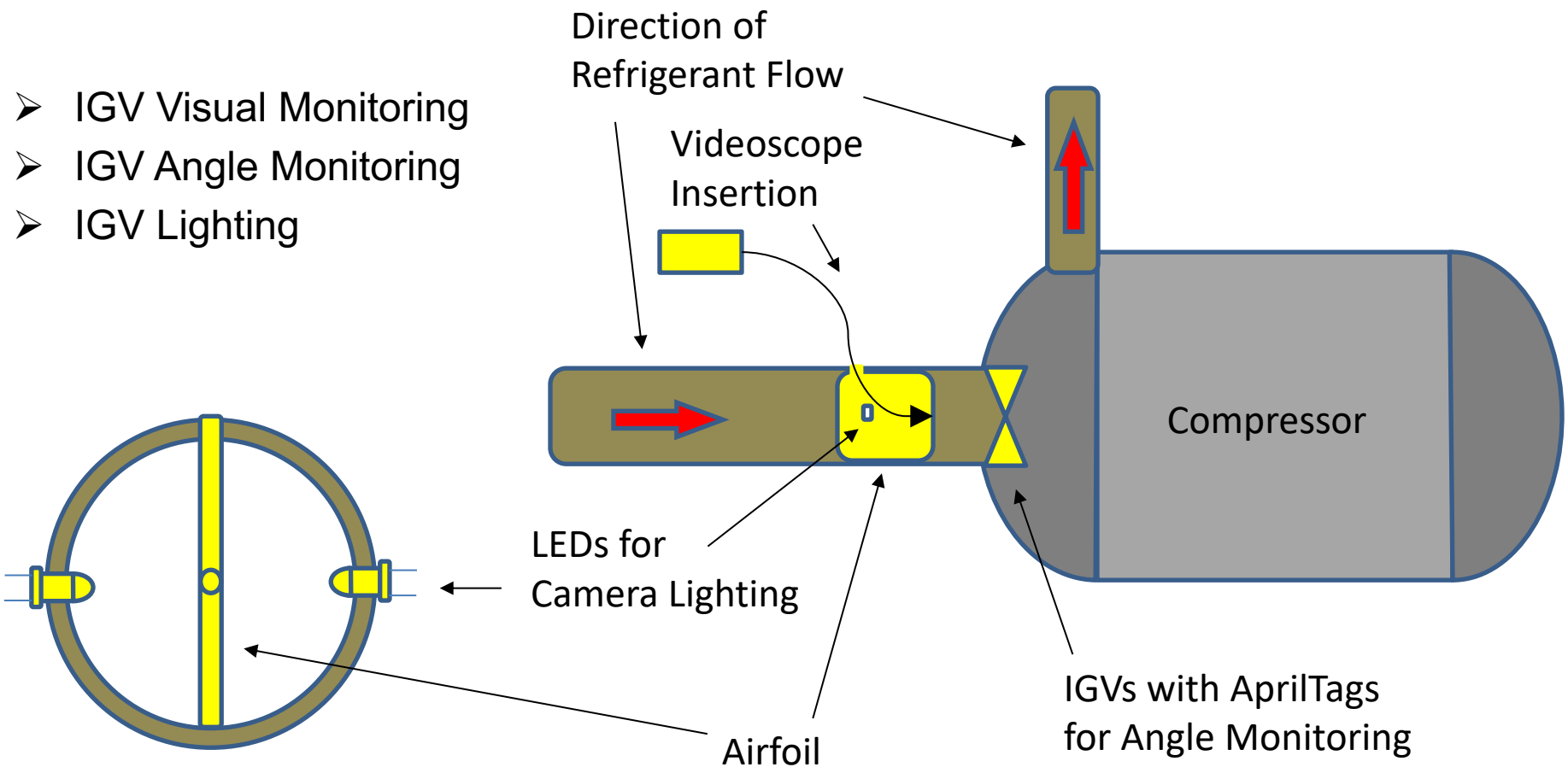
DETAILED DESIGN, FINAL DESIGN AND TESTING

Final Design Layout

- IGV Visual Monitoring
- IGV Angle Monitoring
- IGV Lighting



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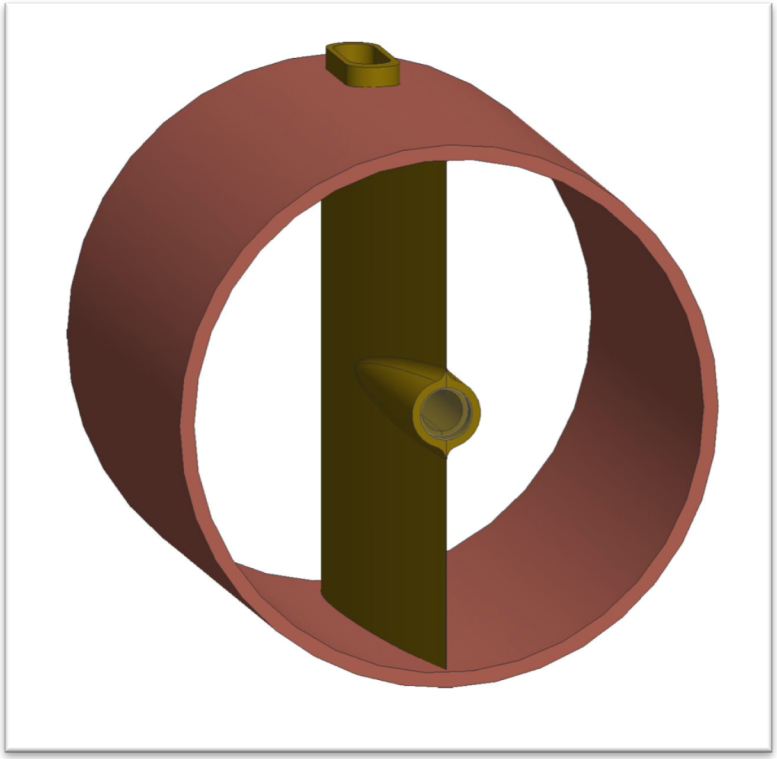
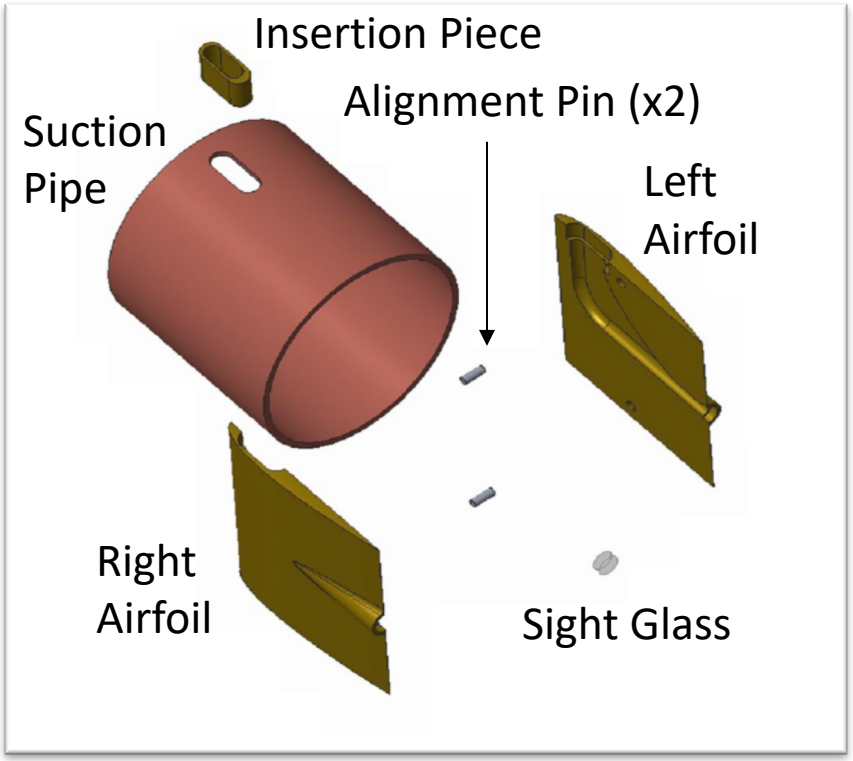
Final Design Assembly and Parts



Finished Assembly View



Exploded Assembly View

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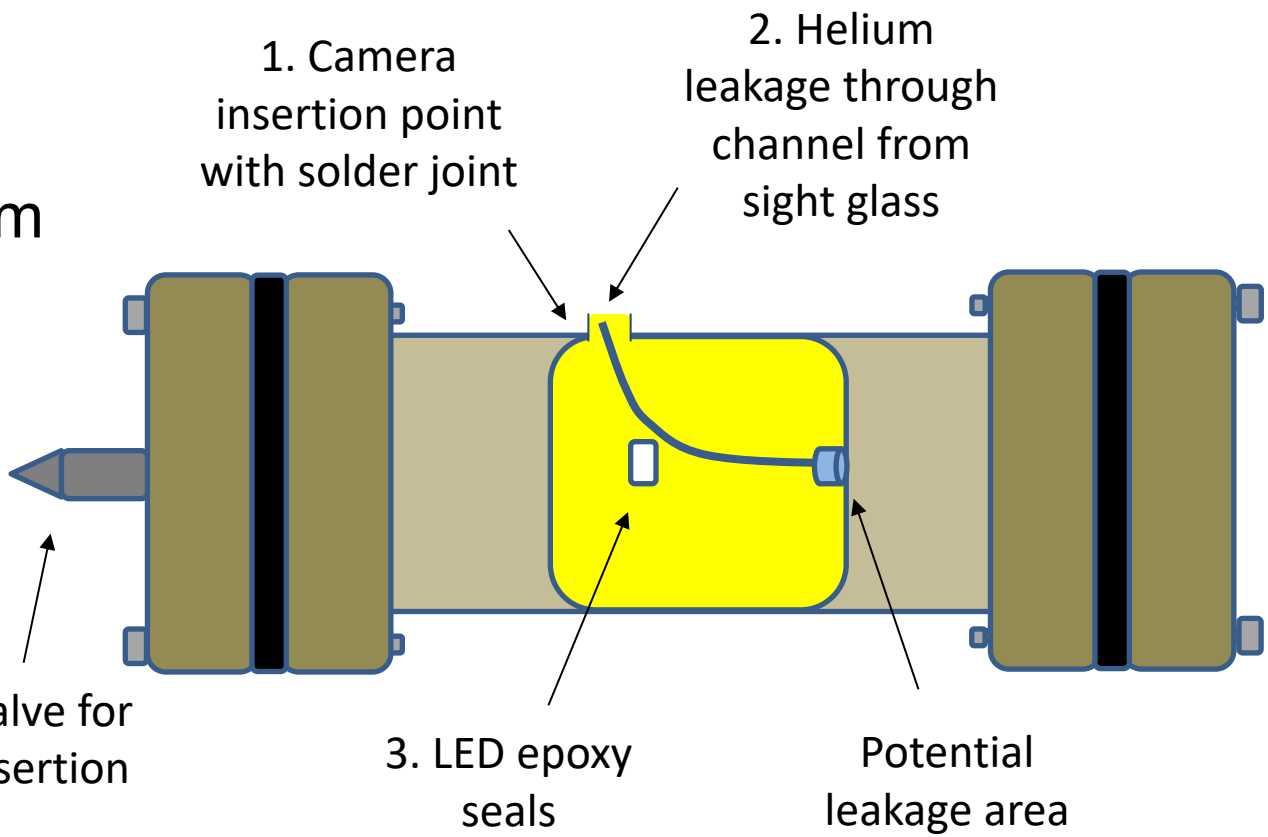
Pressure and Leakage Test

- Three main areas for to check for potential leakage
- Tested with Helium
- Mechanism is reused for two separate tests



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Summary

- Total Project Materials Budget
  - $3,000 - $5,000
- Total Material Cost
  - $1,460
  - Main cost was the videoscope
  - Other costs included the brass and epoxies

- Project Steps
  - Project Definition
  - Concept Generation
  - Concept Analysis
  - Concept Selection
  - Prototype & Testing
  - Detailed Design
  - Final Design & Testing
  - Reports and Documentation

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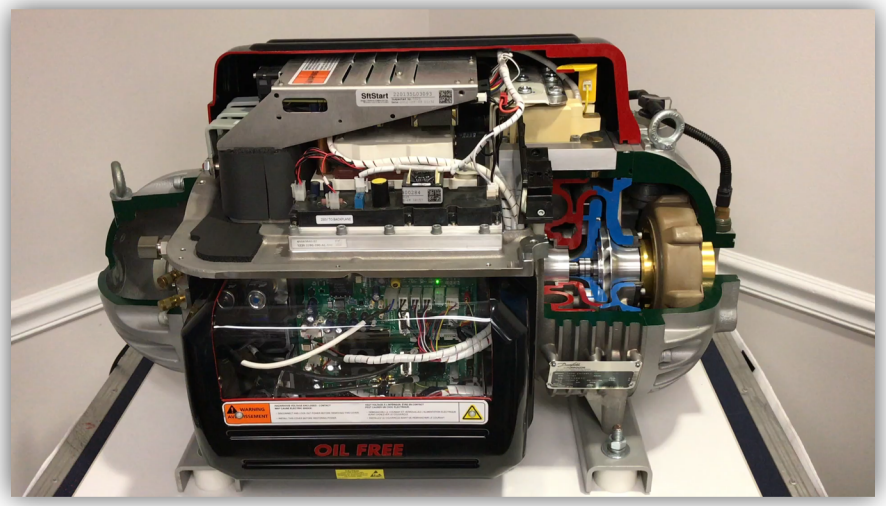
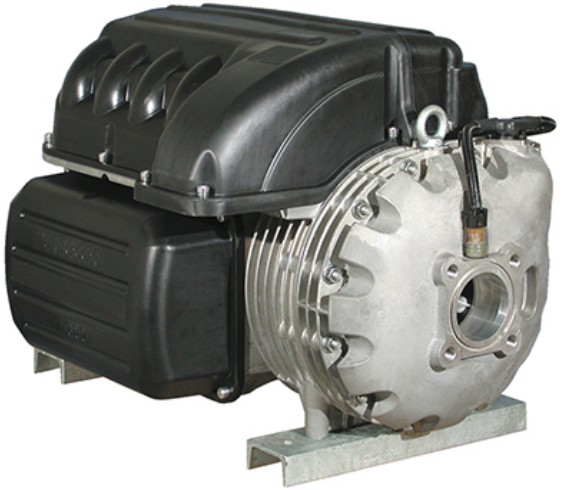
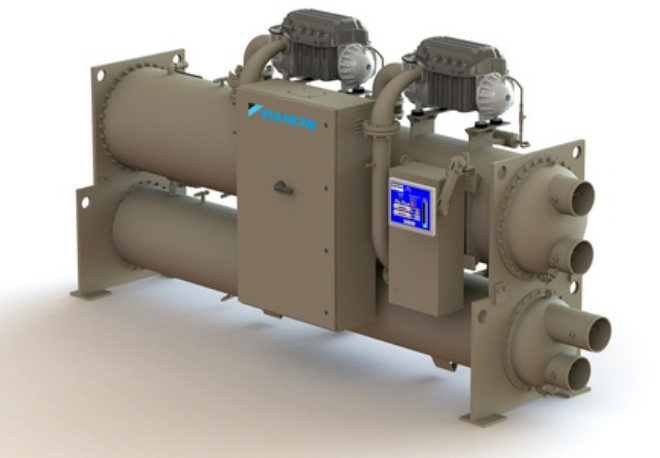
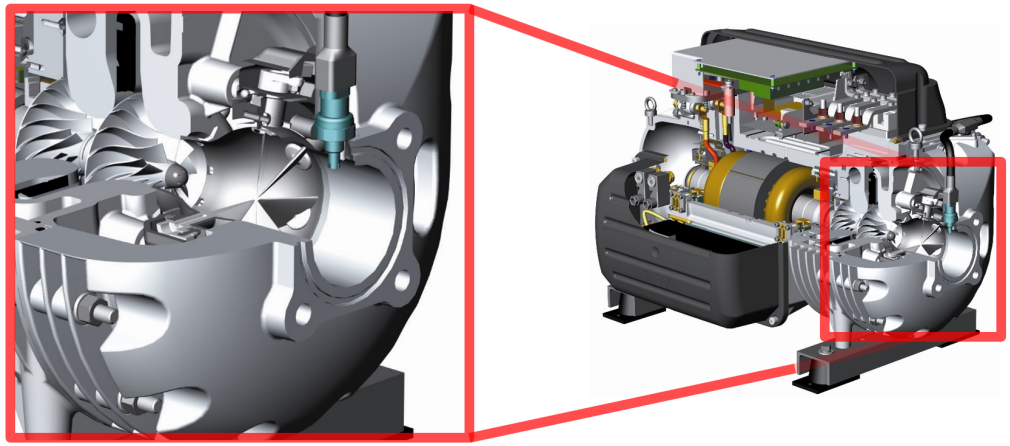
Thank You for Your Time. Questions?









Work Cited

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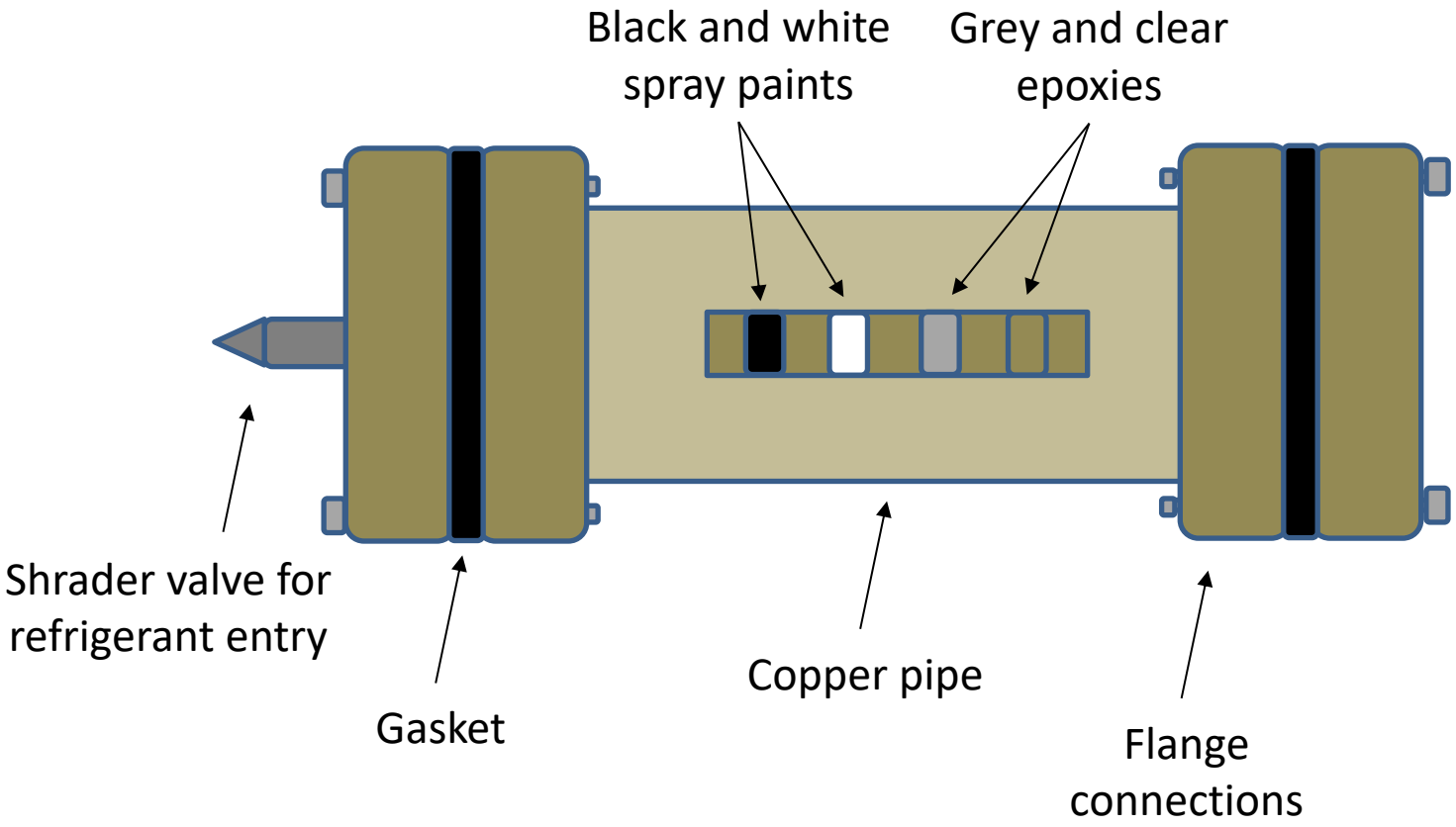
AprilTag Testing

Refrigerant Compatibility Test



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Future Work

- High-Cycle Monitoring System
  - Measure the vibrations of the vanes
  - Vibrometer or high speed camera
- Mechanically Implemented Sight Glass and Lighting Subsystem
  - Epoxy-free seals
  - Longer lasting solution with added reliability
- Remove Lighting around Videoscope Head
  - Reduce thickness of the airfoil in half
  - Less pressure drop and reduced flow impact
- Include Lighting Subsystem into Airfoil
  - Less intrusions in the suction pipe
- Alarms for IGV Malfunction
- Add Pressure, Temperature, and Airflow Sensors
  - Create a sellable package to other manufactures
  - All-in-one system without need for additional sensors in suction pipe

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