

NASA Great Horned Owl (GHO) Combustor

SOUTHWEST RESEARCH INSTITUTE®

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Personal Background

About me:

- **Texas A&M University**
BS Mechanical Engineering, Graduation May 2024
Minor Computer Science
(Incoming) MS Aerospace Engineering



UTSR Summer Fellow:

- Hosted by:
Southwest Research Institute
(San Antonio TX)
- Division 18 Mechanical Engineering,
Machinery Department,
Propulsion & Energy Machinery Group



Background Experience:

- Tribology and Rotor dynamics
- Aircraft Structures and Airworthiness
- Cybersecurity and Vulnerability Assessment



TEXAS A&M
UNIVERSITY

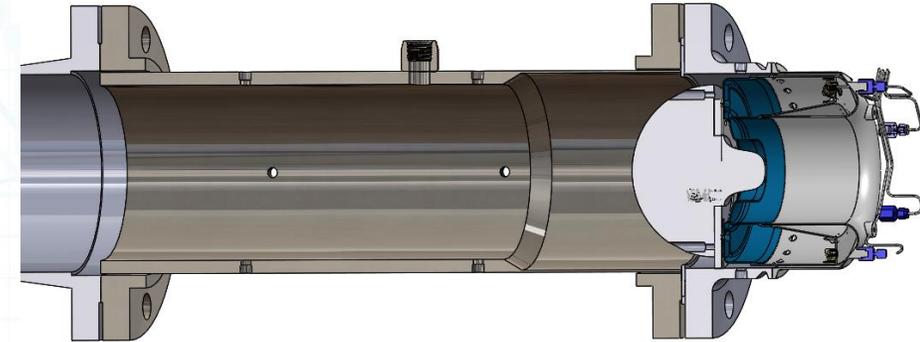
Outline

- Project Goals and Summer Goals
- P&ID & Design Features
- Previous Work
 - 2021 Cold Flow Testing
 - 2015 CFD
- Updated CFD
- Results and Future Work

Great Horned Owl (GHO)

Project Overview:

- Develop a small, lightweight gas turbine generator to provide power for electric or hybrid electric Unmanned Aerial Vehicles (UAVs).
- Low-cost, simple-to-operate capable of providing power to extend UAV range and operate at reduced noise levels



Project Goals:

- Understand why previous conditions in 2021 did not support light-off.
- Characterize the combustor pressure drop light-off characteristics, and other operational stability tests independent of the gas turbine rotating components.

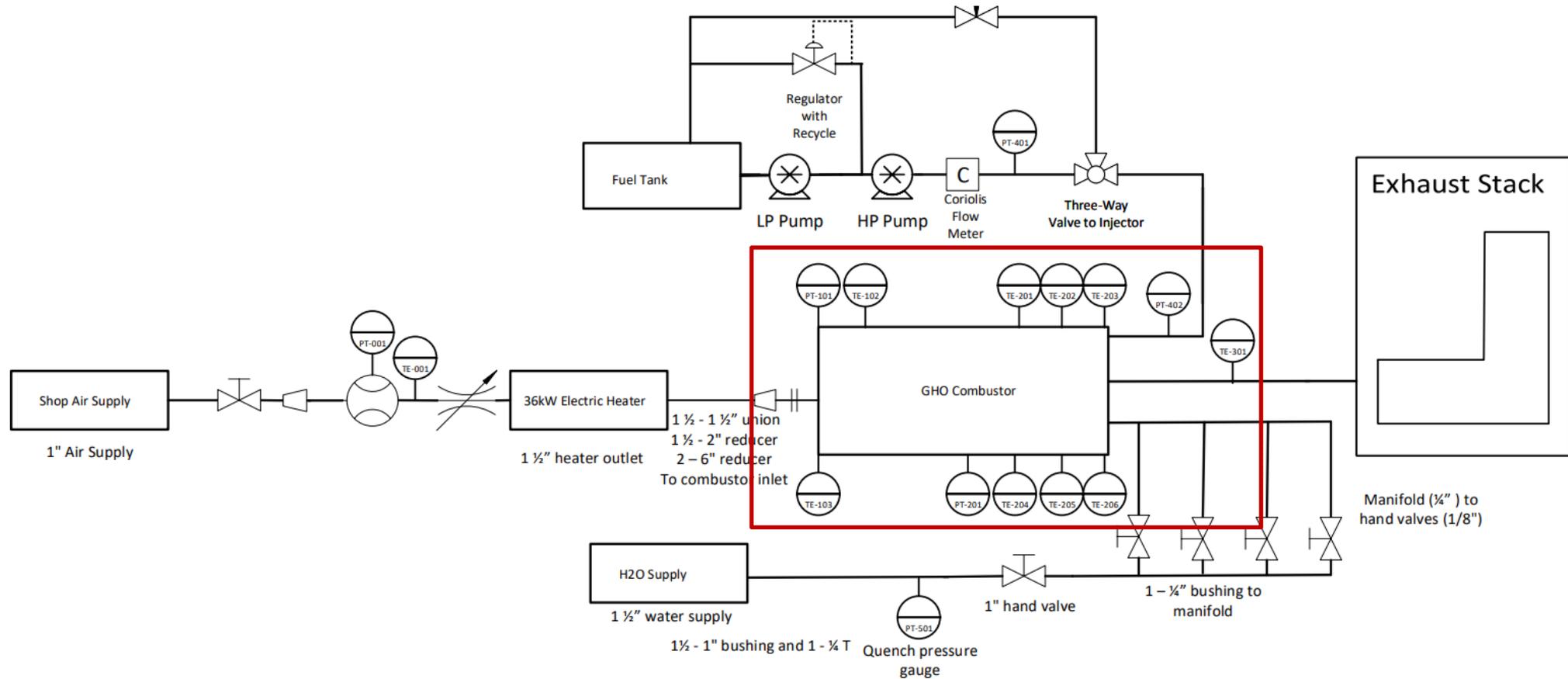
Summer 2023 Goals:

- Characterize combustor pressure drop

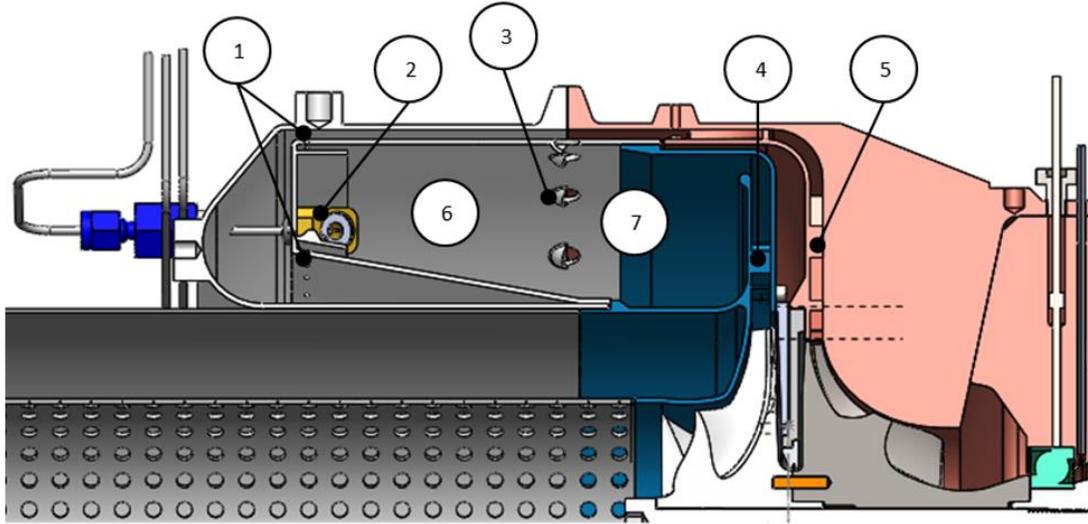
Characterize Combustor Pressure Drop (dP)

- Physical Measurements
 - Took combustor apart
 - Characterized hole sizes/compared to design
- CFD Modeling and Analysis
 - Implemented the model in ANSYS Fluent (old model in CFX)
 - Updated to match As-built Geometry
 - Updated boundary conditions from outdate CFD
 - Atmospheric discharge BC to match test rig
- Cold Flow Test
 - Previous deficiencies
 - Test rig fixture created non-realistic flow path
 - Inadequate instrumentation (i.e. no total pressure measurements)
 - Test rig updates
 - Inlet and outlet total pressure measurements
 - Reconfigure casing to better simulate flowpath in machine

GHO P&ID

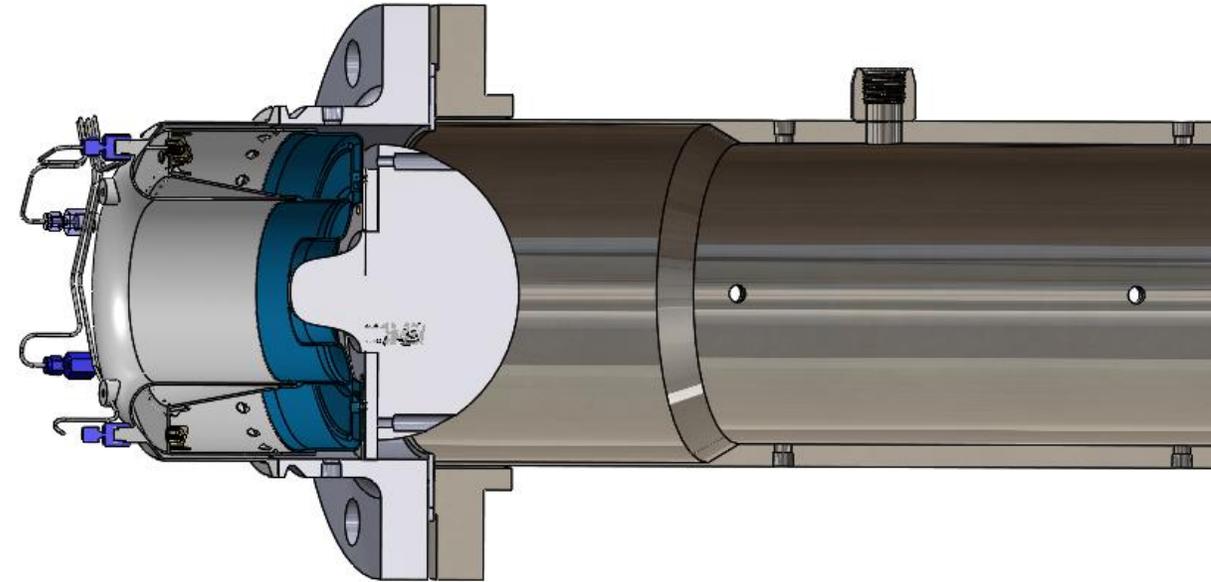


Design Features with Attention of Orifices

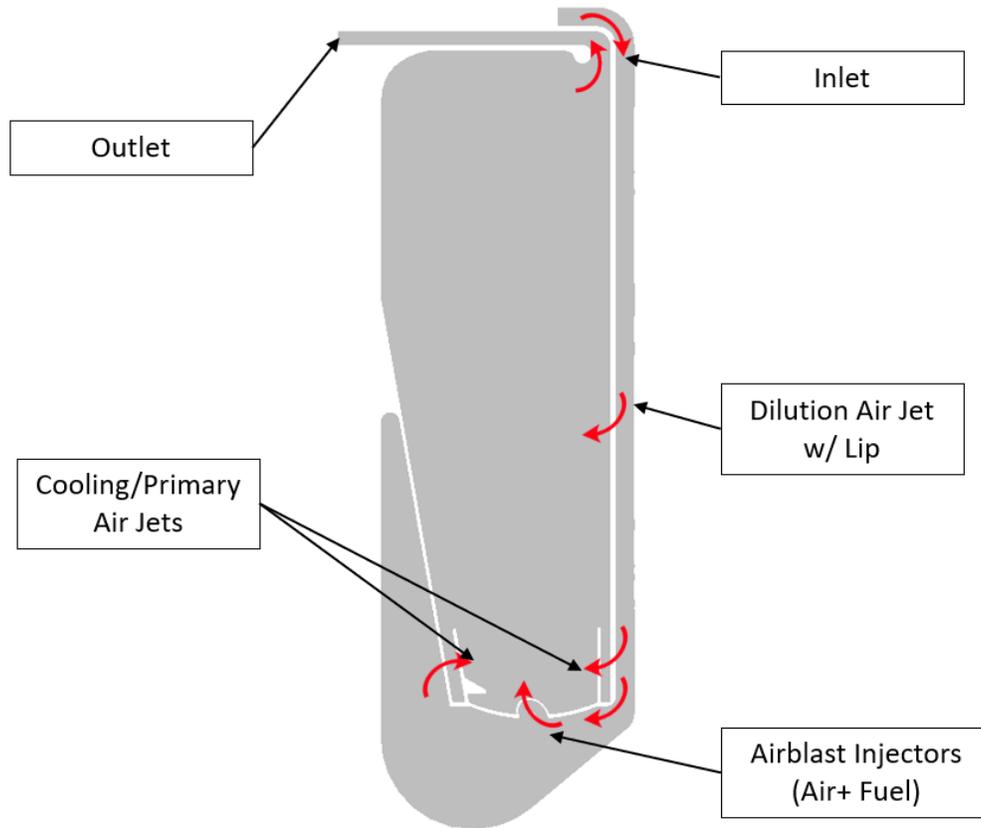


Key:

1. Cooling/Primary Air Jets
2. Airblast Injector (Air+Fuel)
3. Dilution Air Jet w/ Lip
4. Turbine Inlet Guide Vanes
5. Compressor Discharge Guide Vanes
6. Primary Combustion Zone
7. Dilution Zone

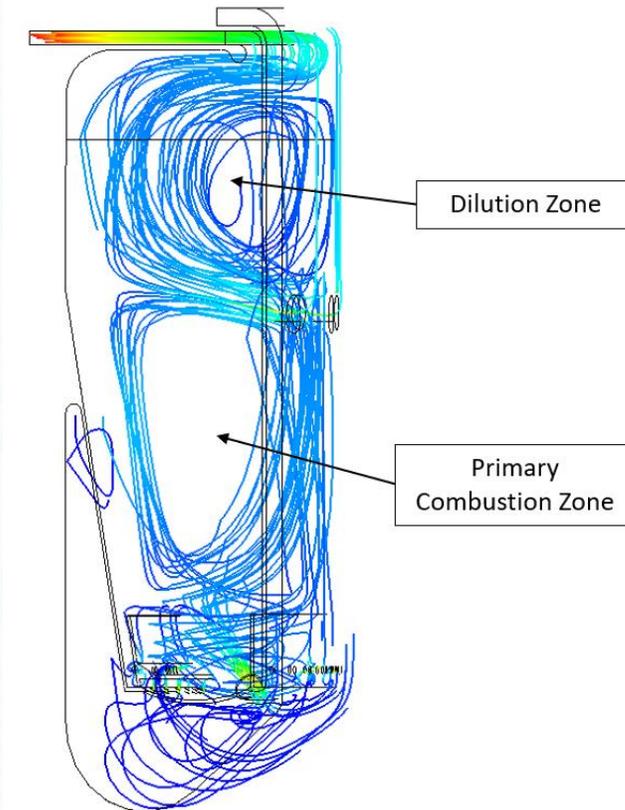


Combustor Flow Pattern



Induced swirl intended to:

- Maintain stable combustion, increasing residence time
- Recirculates hot products, reducing hot spots



dP Factors

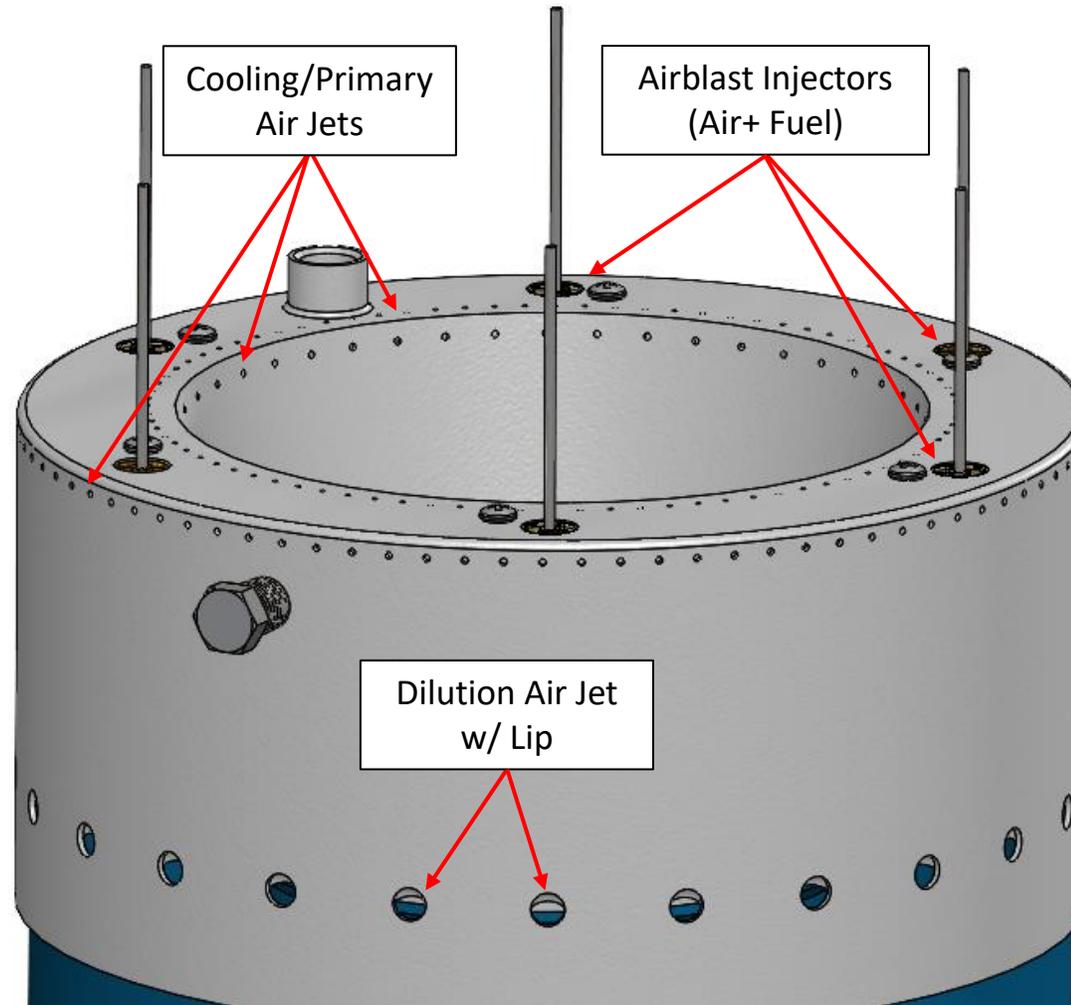
Flowrate:

- Air moves in direction of decreasing pressure

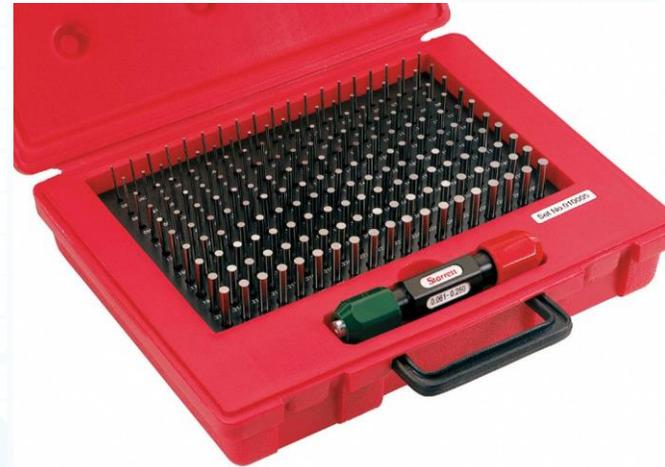
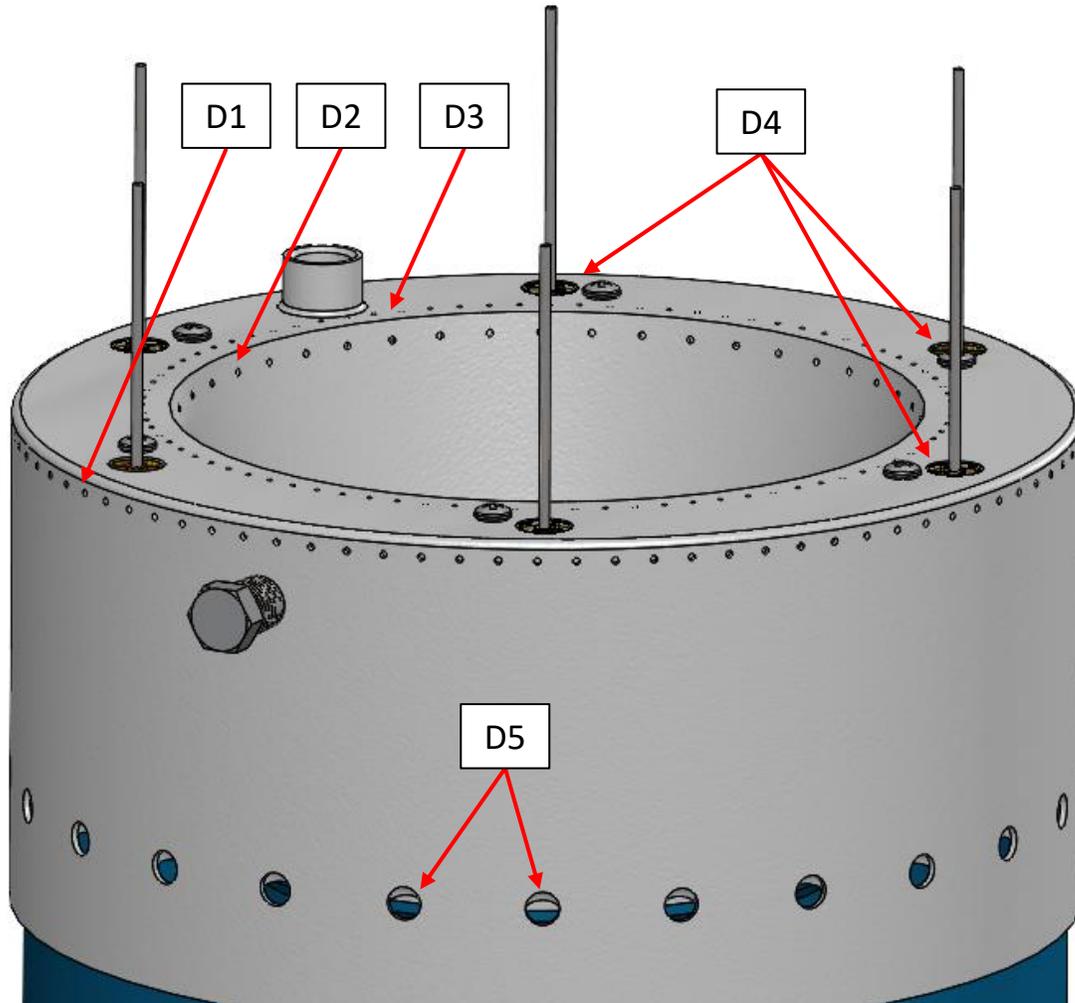
Design:

- Narrow channels/turns
- Flow Field Structure (i.e. recirculation)
- Orifice Sizes

Combustor Hole Locations



Physical Measurement of Orifices



Decreasing the hole sizes within the simulation would result in a higher dP

Location	D1	D2	D3	D4	D5
Original ANSYS Size [in]	0.0415	0.0415	0.0260	45 deg, 0.16 x 0.14	0.1970
Average Actual Size [in]	0.0328	0.0292	0.0280	0.2860	0.1933

Governing Equations and Boundary Conditions

Fan Law Calculation:

$$CFM_2 = CFM_1 \times \left(\frac{RPM_2}{RPM_1} \right)$$

$$\text{Massflow Rate} = \frac{\text{Compressor Suction Massflow} * \text{Speed}}{\text{Compressor Design Speed}}$$

$$\dot{m}_1 = \dot{m}_2 \frac{\omega_1}{\omega_2}$$

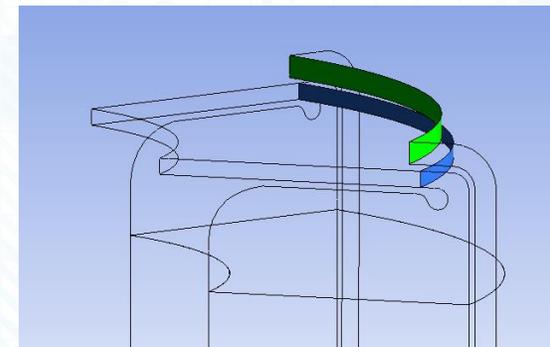
Speed [rpm]	Mass Flow [kg/s]
25000	0.0280
50000	0.0559
70000	0.0783
100000	0.1119
118000	0.1320

Pressure Drop:

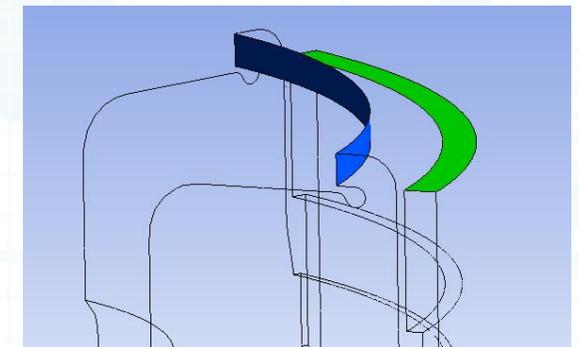
$$\frac{dP}{P} \% = \frac{\text{Total Inlet Pressure} - \text{Total Outlet Pressure}}{\text{Total Inlet Pressure}}$$

$$\frac{dP}{q} \% = \frac{\text{Total Inlet Pressure} - \text{Total Outlet Pressure}}{\text{Ref Dynamic Pressure}}$$

- Inlet
- Outlet



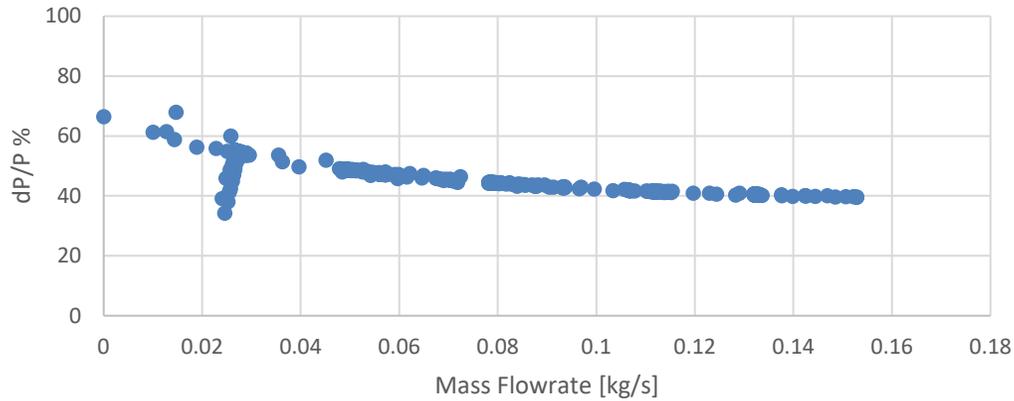
Ver1



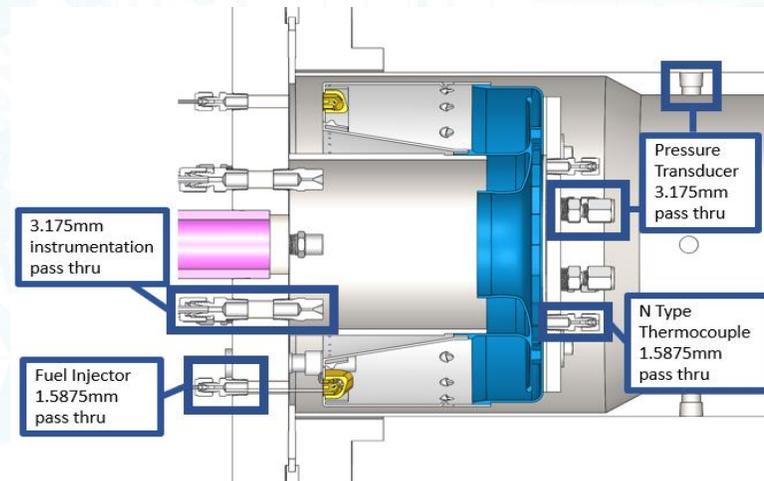
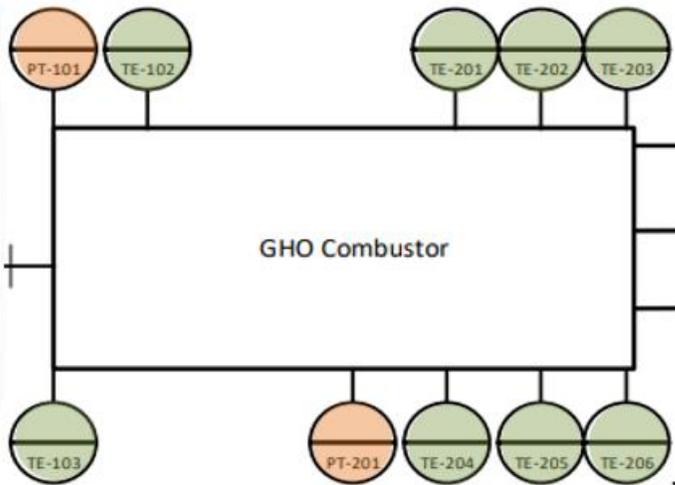
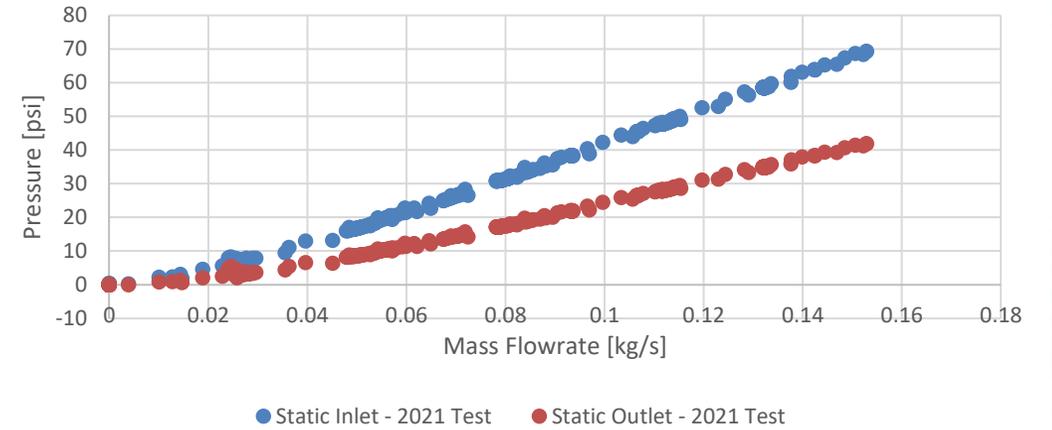
Ver2

2021 Cold Flow Testing Results: High dP

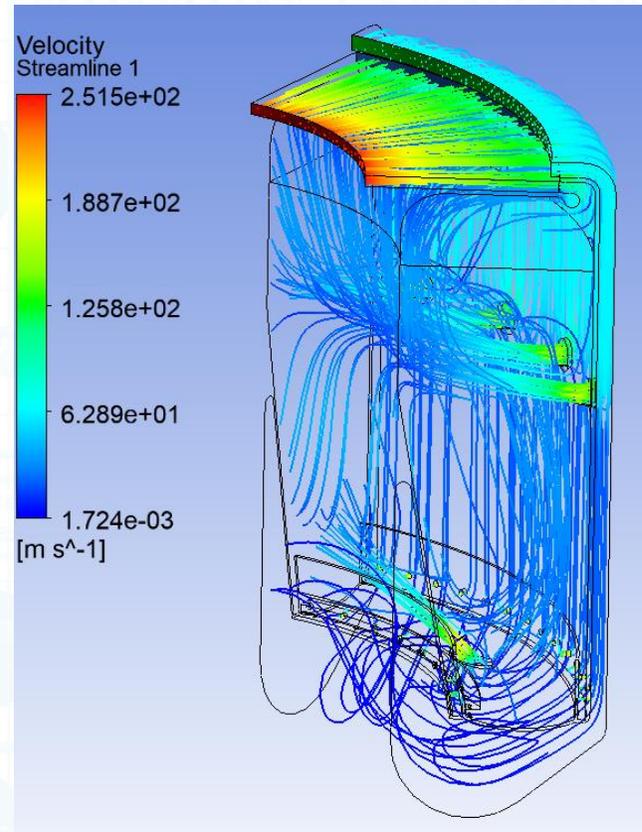
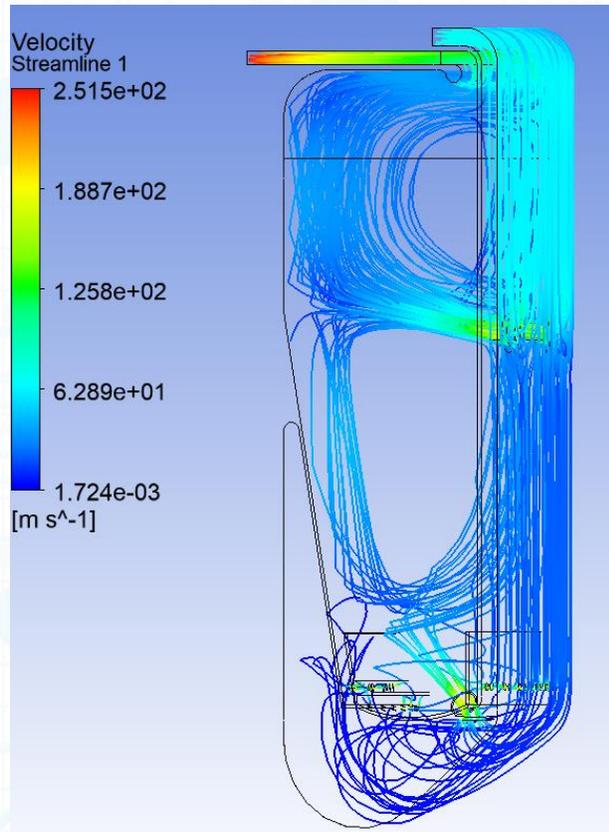
dP / P %
July 30, 2021



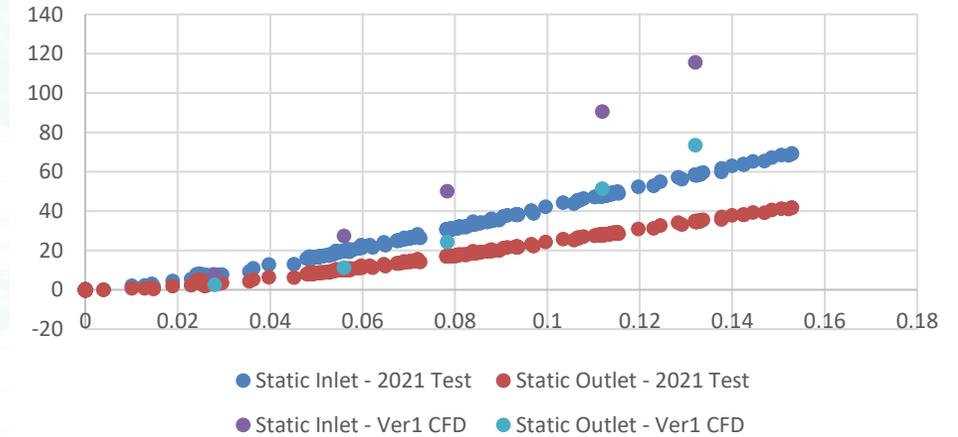
Static Pressure
July 30, 2021



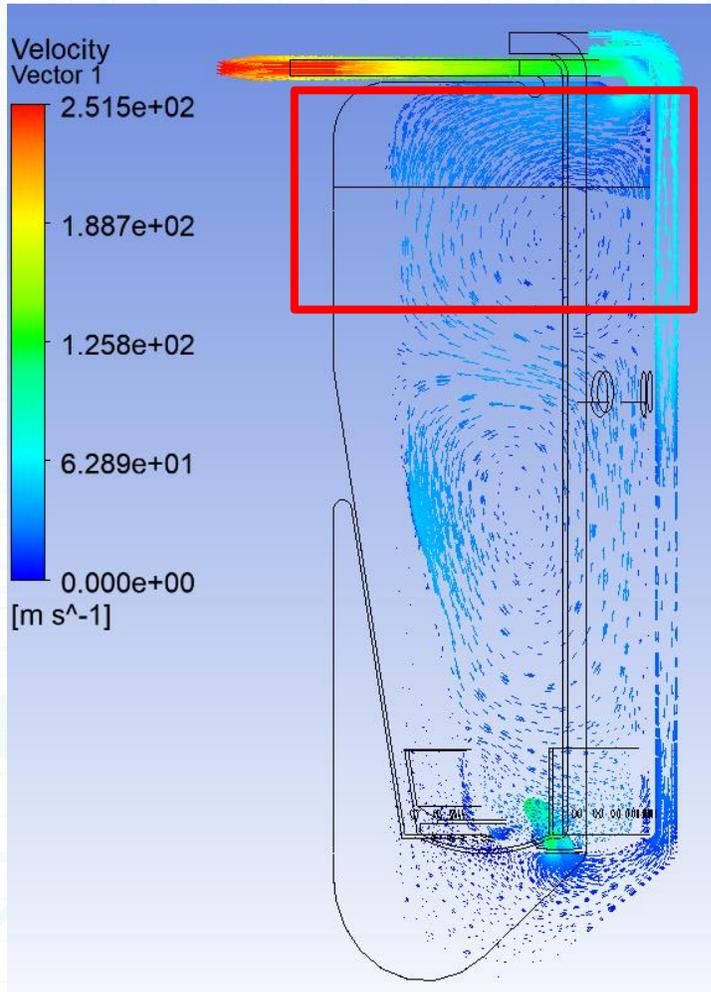
Ver1 CFD Does Not Match 2021 Data



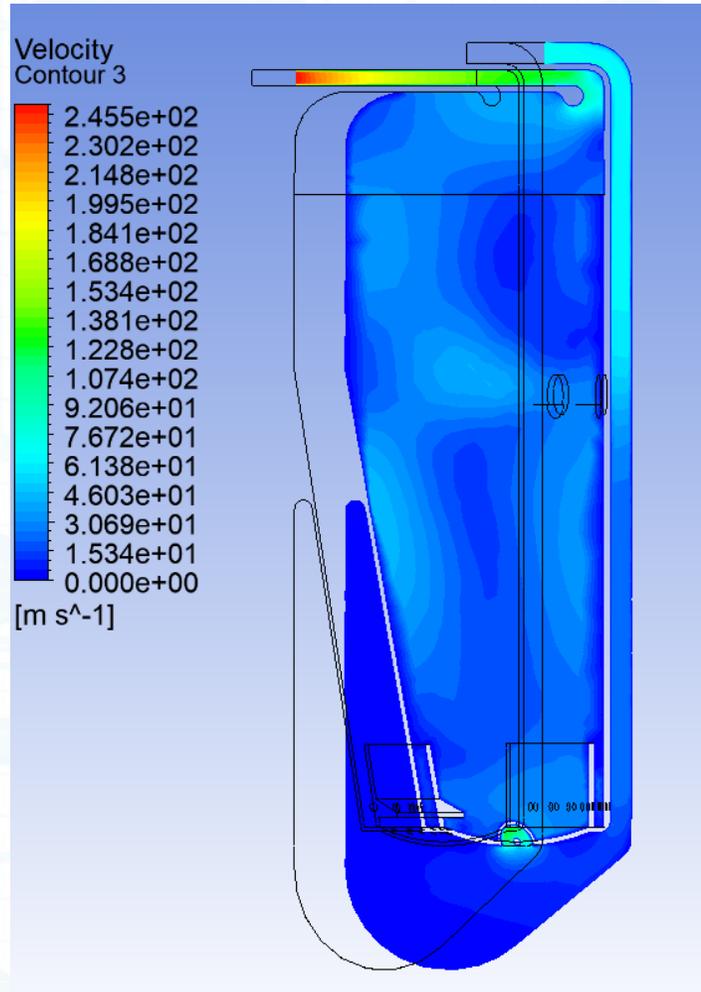
Static Pressure: Ver1 CFD vs 2021 Data



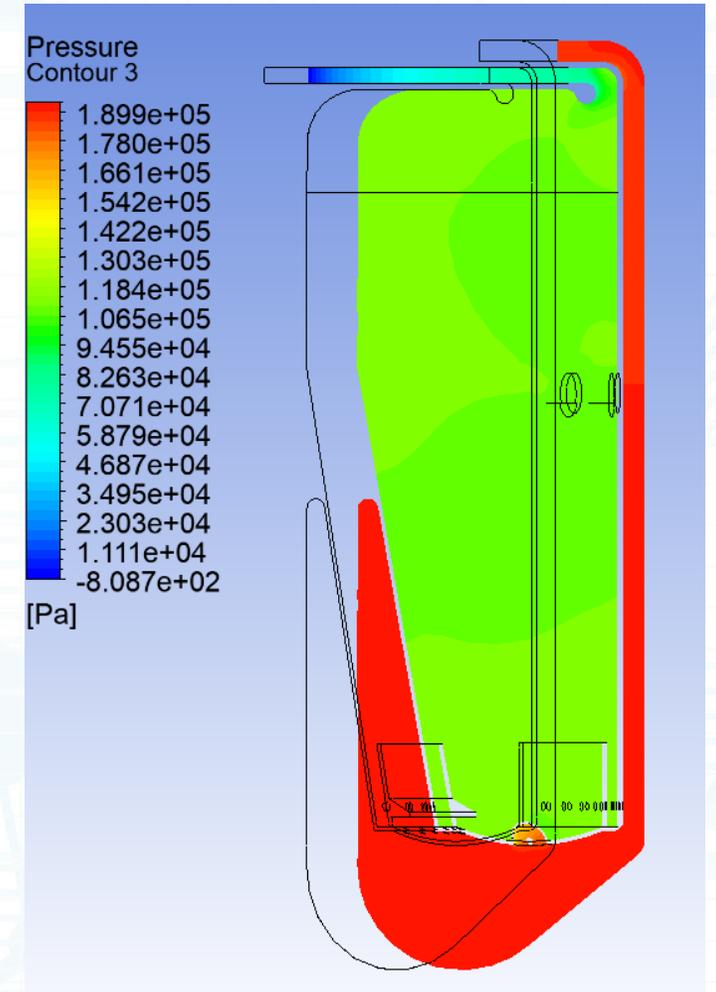
VerI CFD Results and Issues



Velocity Streamline

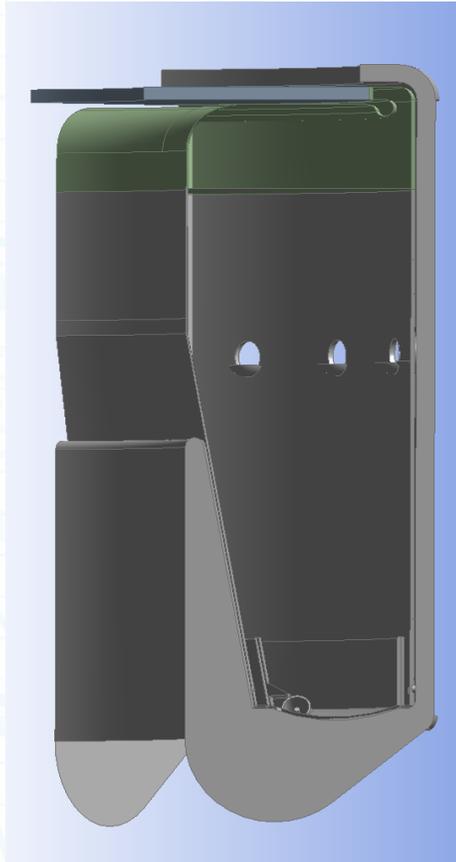


Velocity Contour

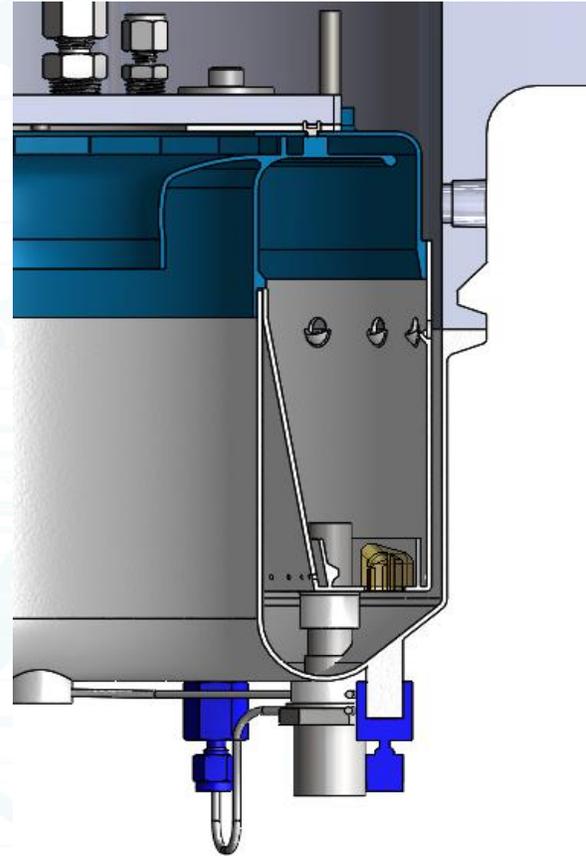


Static Pressure Contour

Ver2 CFD Model Created to Match As-Built Combustor



Ver1



Ver2

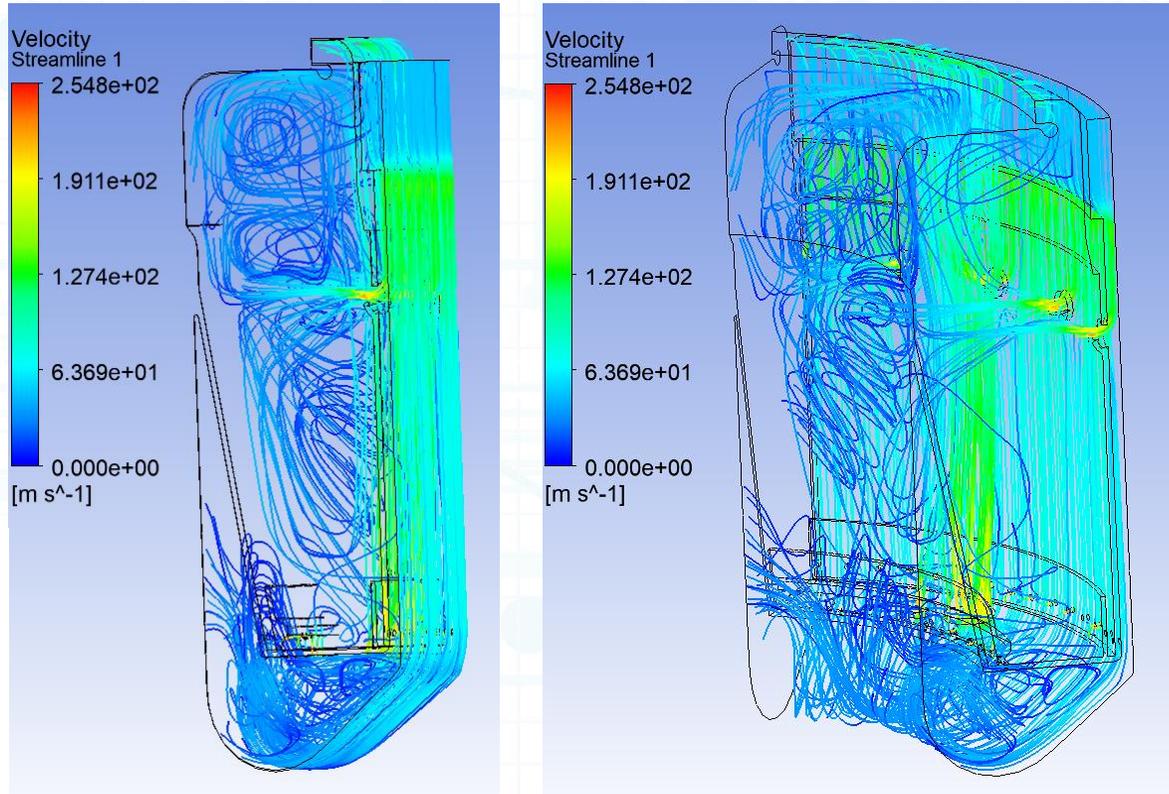
Ver2 Geometry Changes:

- Larger passage ways
- Smaller chamber size
- Fuel nozzles angle

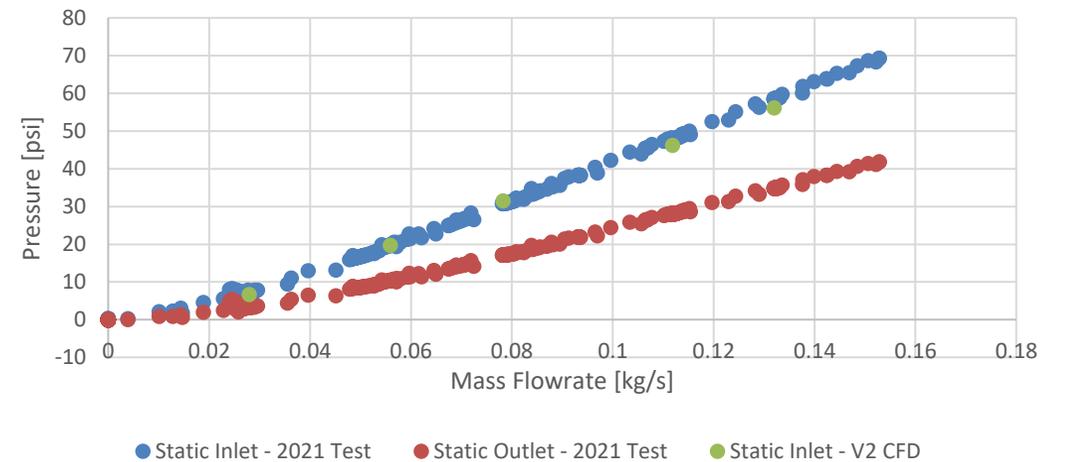
Ver2 CFD Model with Mass Flowrate Inputs

Matches 2021 Inlet Data

Outlet Pressure [psi]	Inlet Air Mass Flow [kg/s]	Inlet Temperature [K]
14.696	0.02797	300
14.696	0.05593	300
14.696	0.07830	300
14.696	0.11186	300
14.696	0.13200	300



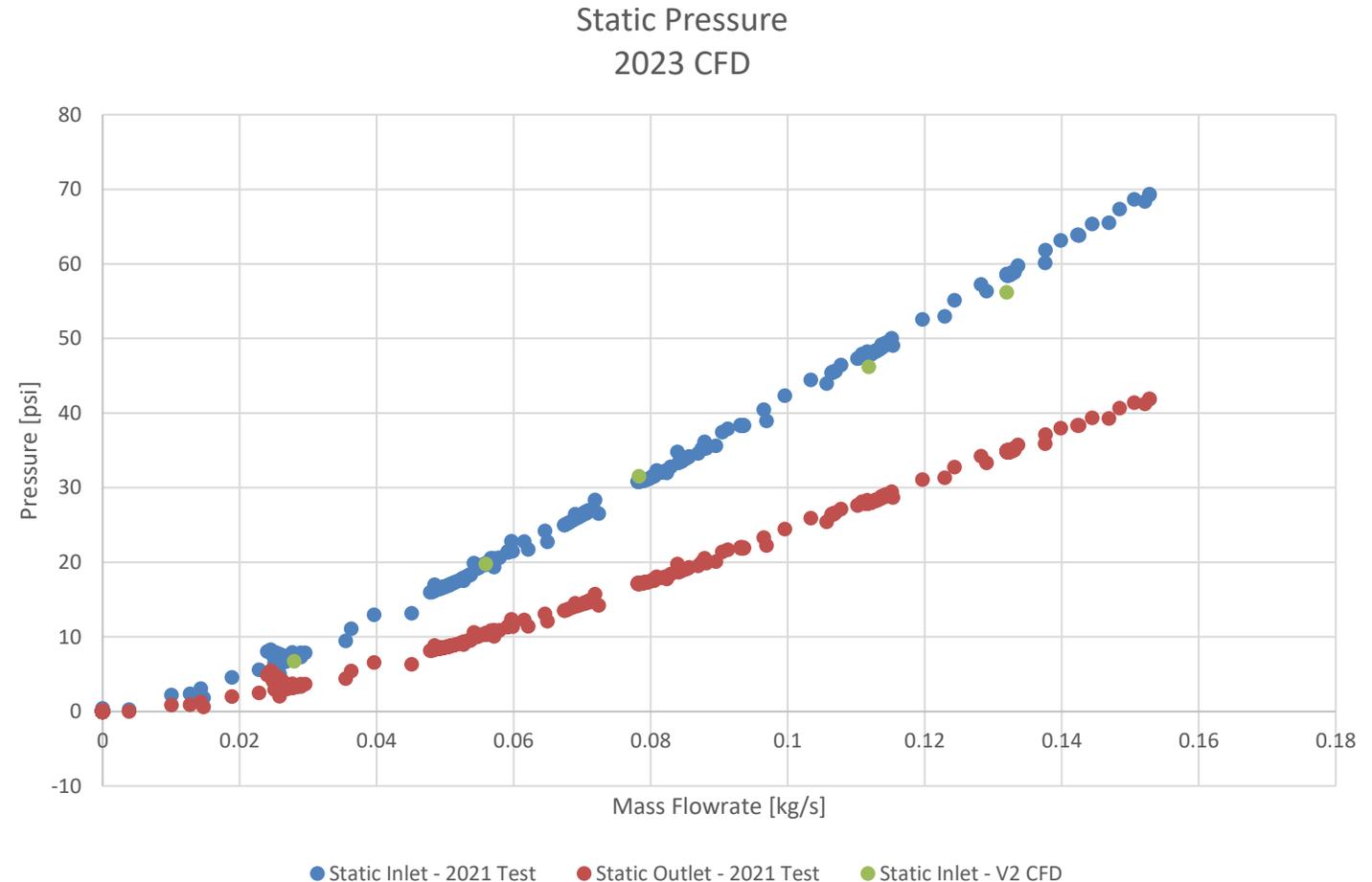
Static Pressure
2023 CFD



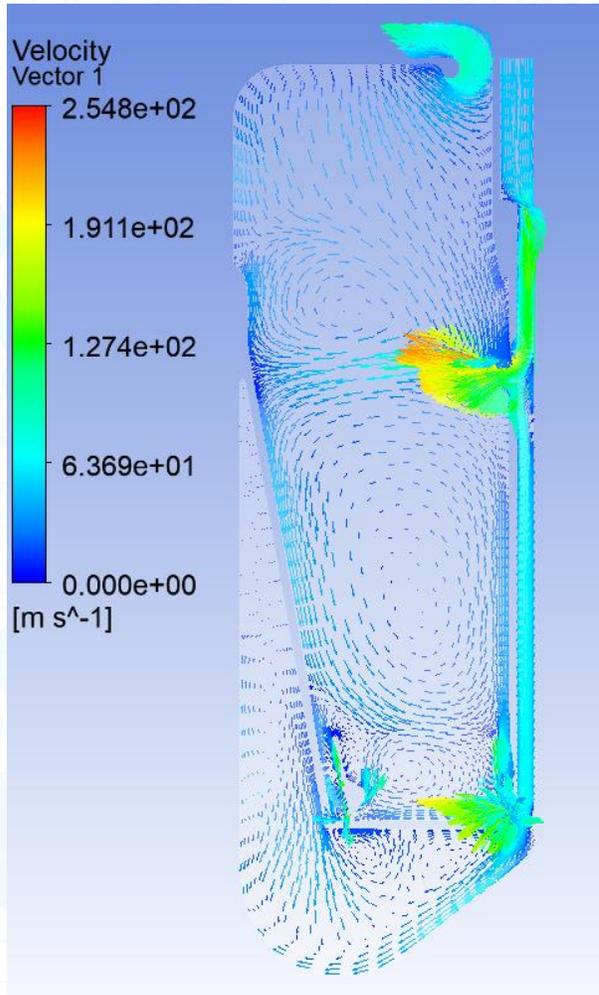
Ver2 CFD Model Discrepancies

Reasons for CFD Outlet not Matching:

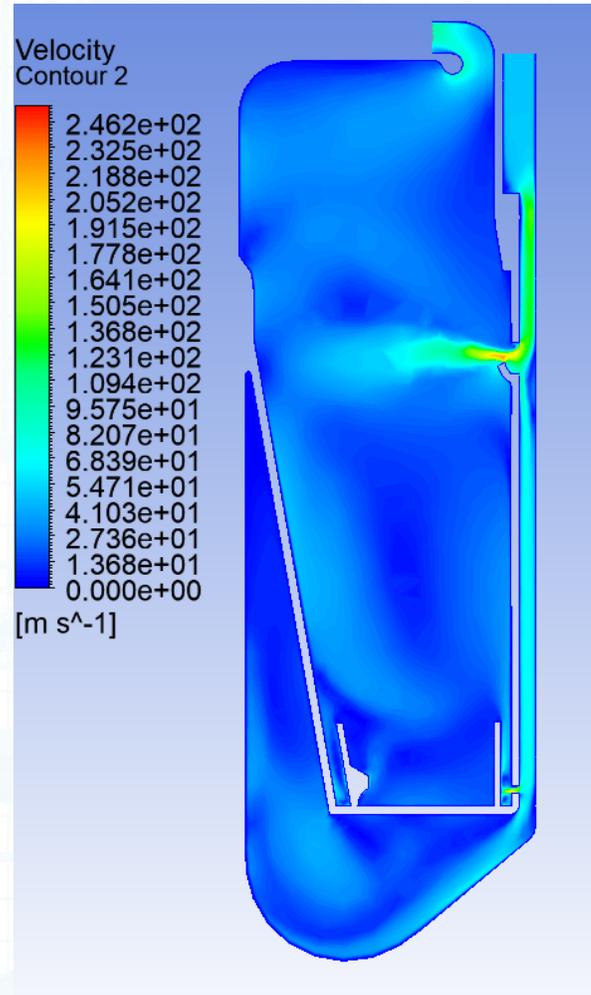
- Did not take into consideration for inlet guide veins
- Relative to atmospheric as part of BC
- Unknown location for outlet on previous data



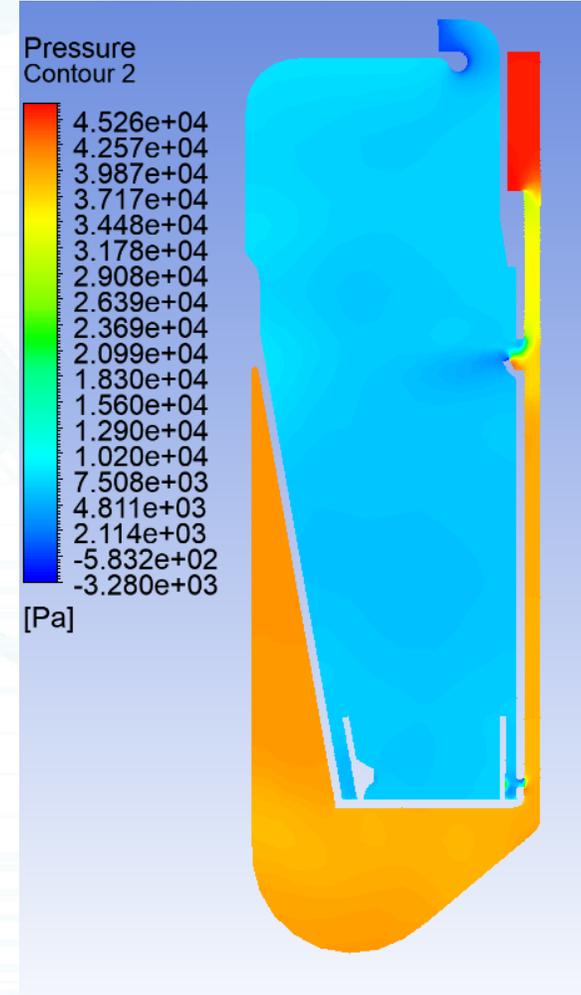
Ver2 CFD Results



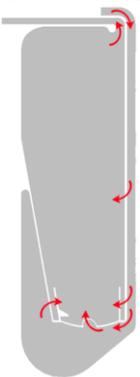
Velocity Streamline



Velocity Contour

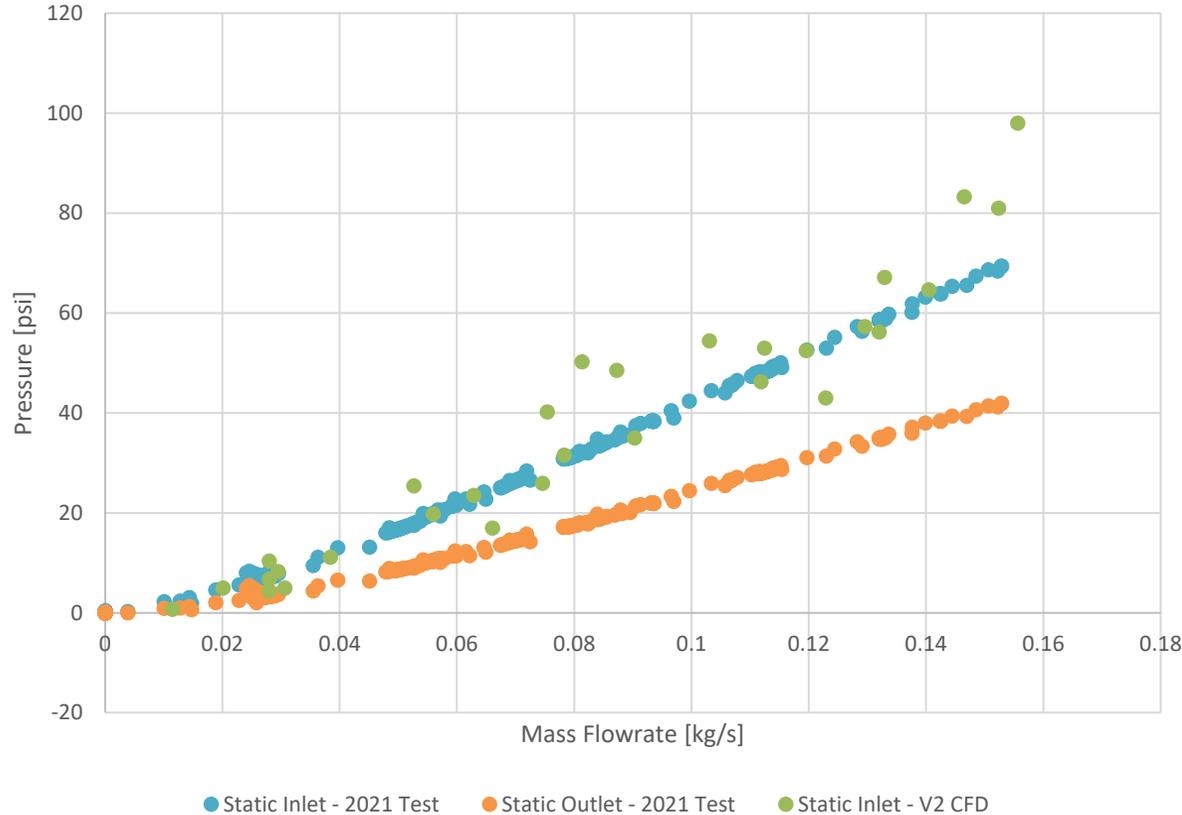


Static Pressure Contour



Ver2 CFD in Realistic Combustor Operation

Static Pressure at High Temperatures: V2 CFD vs Data

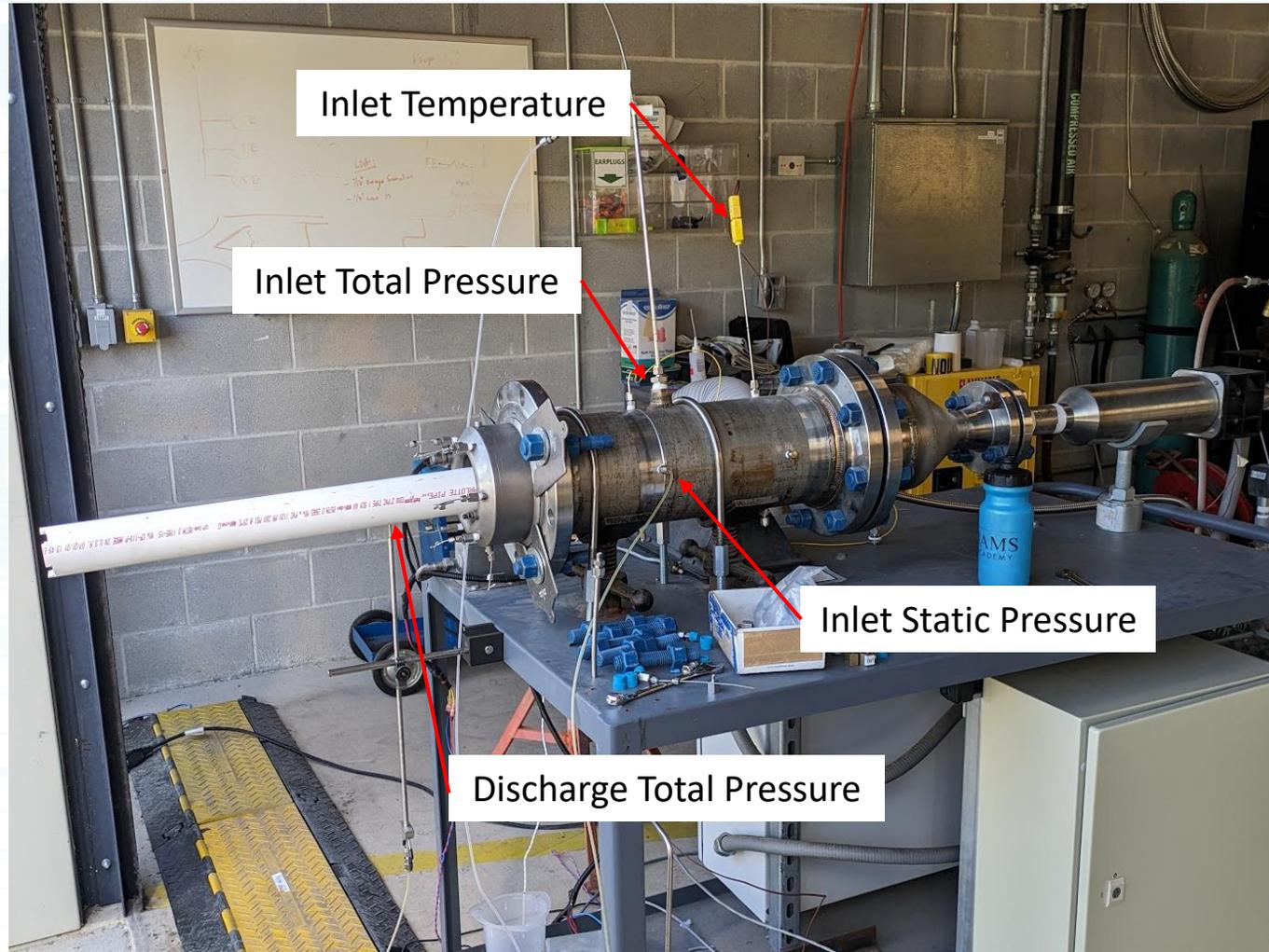


How the pressure losses might perform with high temperature inlet flow (300-550 K):

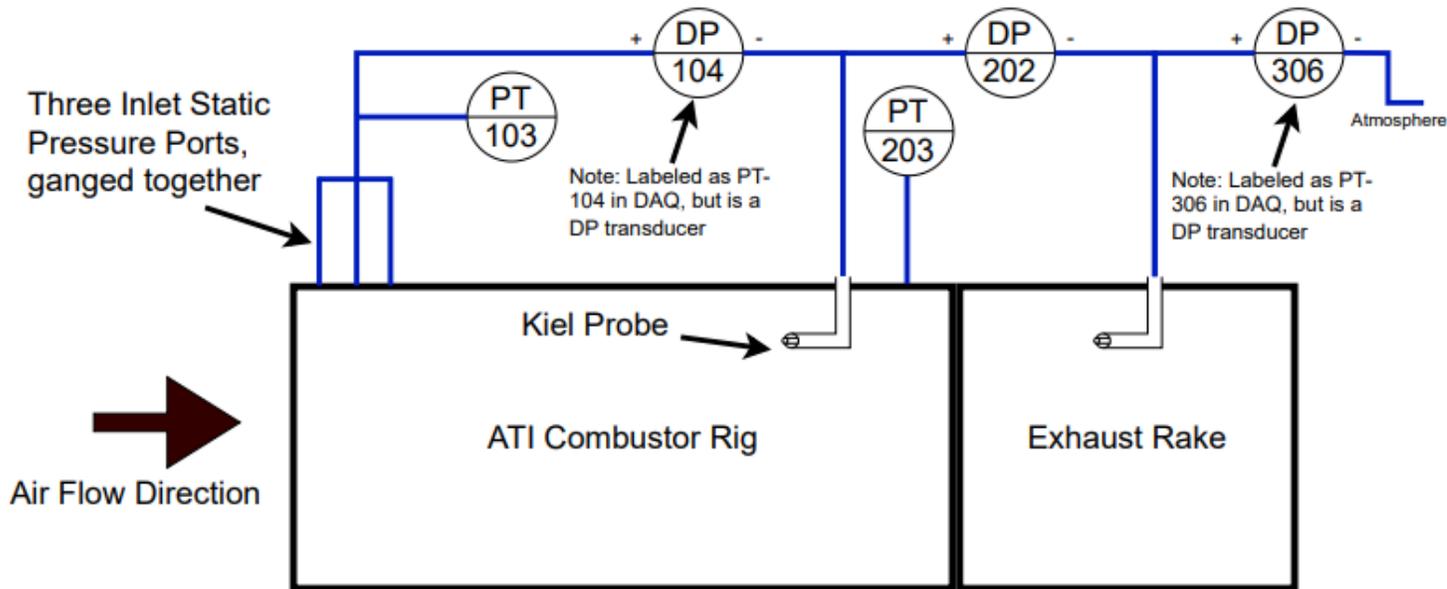
- Air going through a compressor undergoes isentropic compression, which means it will heat up

Result: not much variance from inlet test data

2023 Cold Flow Testing Rig



Updated P&ID for 2023 Testing



Measurement	Title
PT-103	Inlet air static pressure [psig]
DP-104	Inlet air total pressure [psid]
PT-203	Combustor static pressure [psig]
DP-202	Combustor pressure delta [psid]
DP-306	Exhaust total pressure [psig]

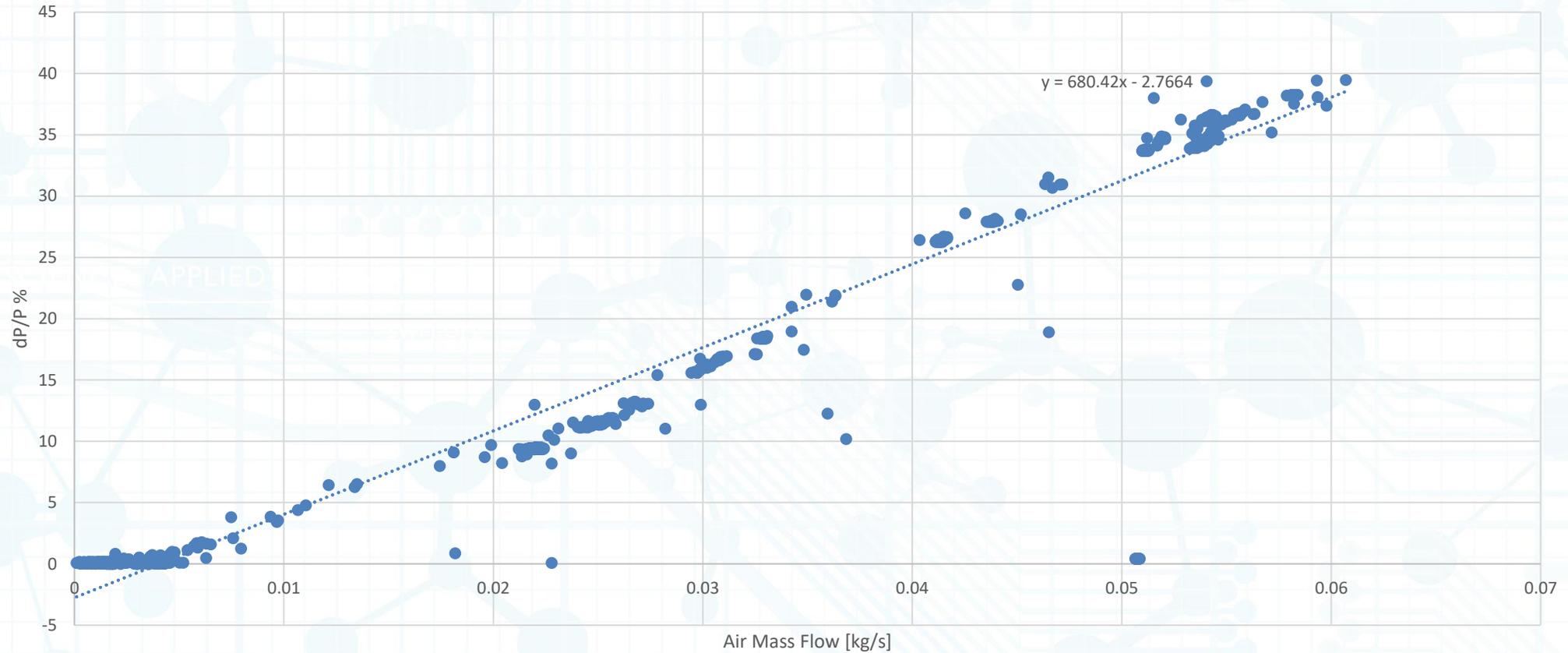
2023 Testing: Total Pressure Transducers for Pressure Loss Factor

- Ratio the total pressure drop across the combustor to the reference dynamic pressure
 - represents velocity and density of the flow
- dP/P % depends on operating condition

$$\frac{dP}{P} = \frac{P_{in} - P_{out}}{P_{in}}$$

Measured Pressure Drop is Very High!

Combustor dP/P %
July 26, 2023



GHO Conclusions

- Good %dP/P validation data acquired
 - Measured dP/P is very high
- CFD advanced to match as-designed combustor geometry
- Cooling hole geometry verified vs as-designed
- Next Steps:
 - Progress test rig design
 - Pressure measurement inside combustor liner
 - Hardware modifications required
 - Progress CFD to validate vs cold flow results

Acknowledgements

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