

YOUNGSTOWN STATE UNIVERSITY



College of  
Science, Technology,  
Engineering &  
Mathematics

# Calibration of Optical Paints for Aerodynamic Testing

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Mechanical Engineering

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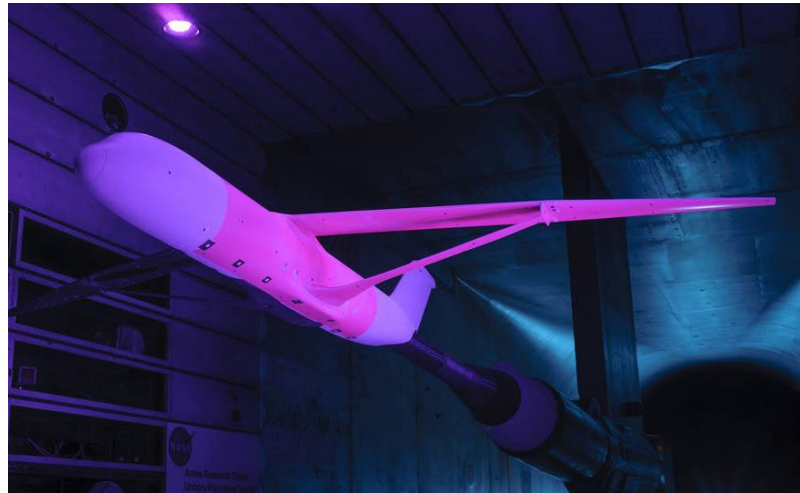
*Ohio Space Grant Consortium Student Symposium*  
*Ohio Aerospace Institute*

03 April 2020

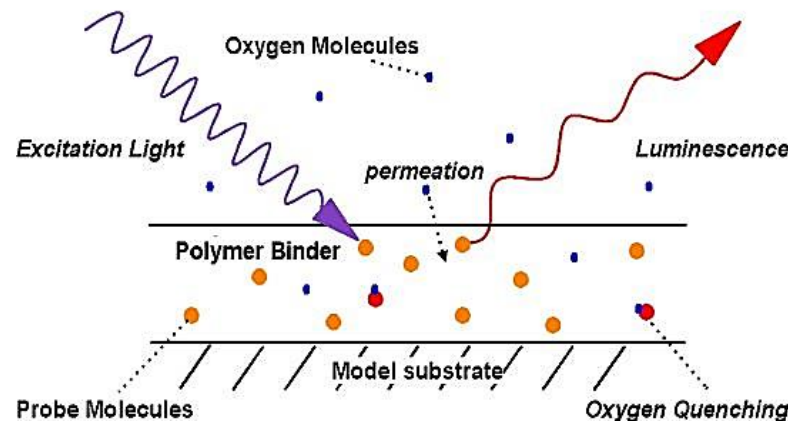


- Research Objective
- Background on Pressure/Temperature Sensitive Paints
- Apparatus Design
- Obtained Results
- Conclusions and Recommendations

- Objective:
  - Design and construct a Pressure/ Temperature Sensitive Paints static calibration apparatus for determining the Stern-Volmer relationship for a specific paint sample.

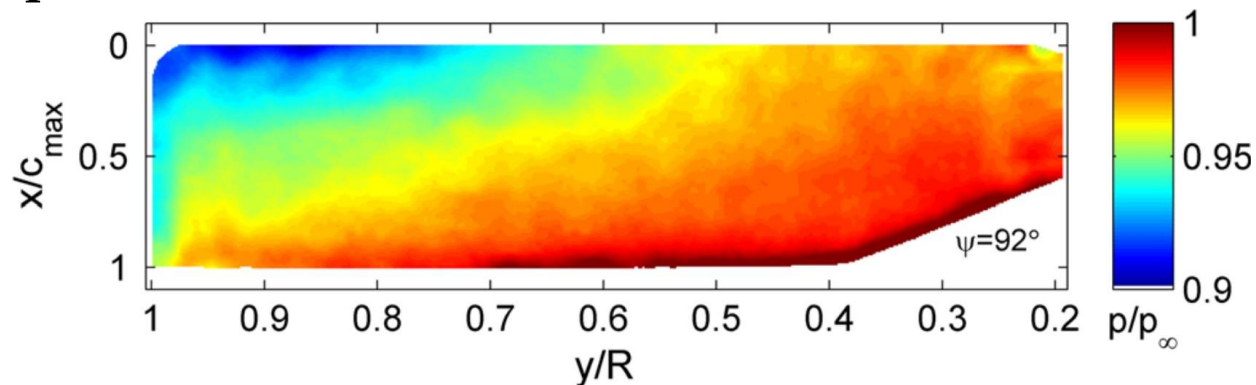


- Paints operate on process called “Luminescence Quenching”
  - When submitted to UV light, oxygen concentration in air correlates with intensity of emitted light from painted surface (luminescence)
  - For PSP, luminescence decreases due to oxygen quenching
  - For TSP, luminescence decreases due to thermal quenching
  - Emitted light can be recorded and correlated with pressure and temperature measurements



*Aerospaceweb.org*

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Disotell, K. J., Peng, D., Juliano, T. J., Gregory, J. W., Crafton, J. W., & Komerath, N. M. (2014). Single-shot temperature- and pressure-sensitive paint measurements on an unsteady helicopter blade. *Experiments in Fluids*, 55(2). doi: 10.1007/s00348-014-1671-2



- Calibration uses “Stern-Volmer Equation”:

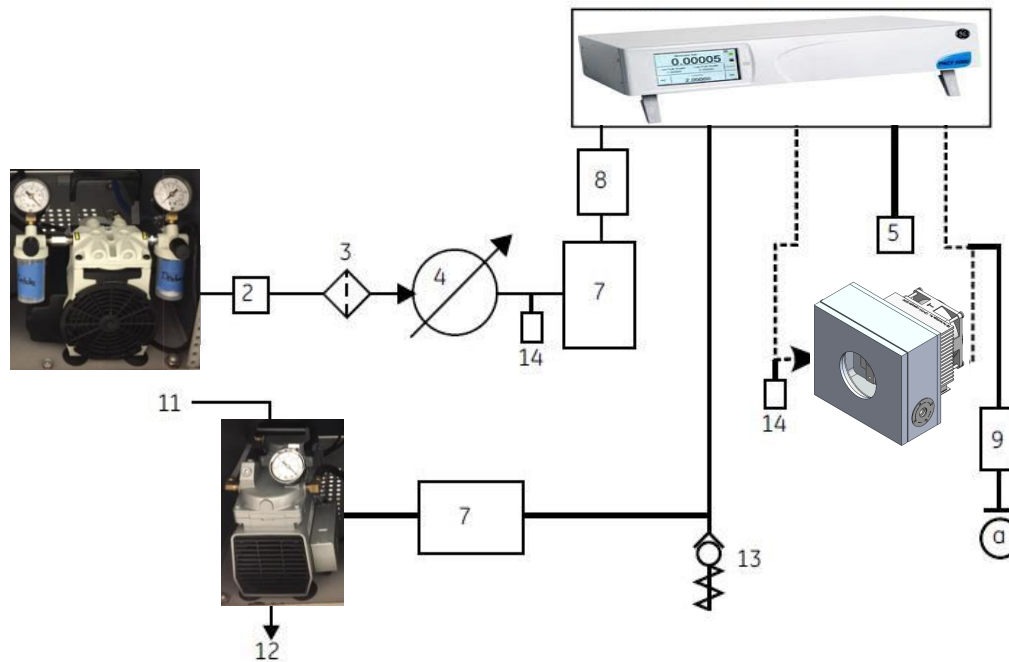
$$\frac{I_{ref}}{I} = A(T) + B(T) \left( \frac{P}{P_{ref}} \right)$$

- Where,
  - I = pixel intensity from camera image
  - P = local pressure
  - A & B = calibration coefficients as functions of temperature
  - Subscript *ref* denotes a reference condition (“wind-off”)
  - T = Temperature

# Apparatus

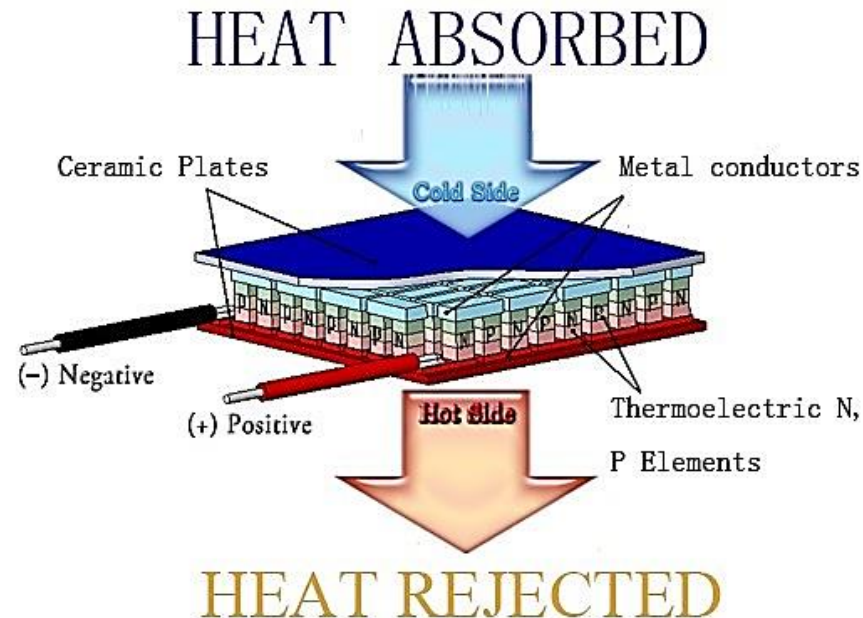


- Pressure Control
  - *GE Druck Pace 5000*
  - Pressure Range: -1 to 3.5 bar (-14.5 to 50.8 psi)
  - Accuracy: 0.005% reading



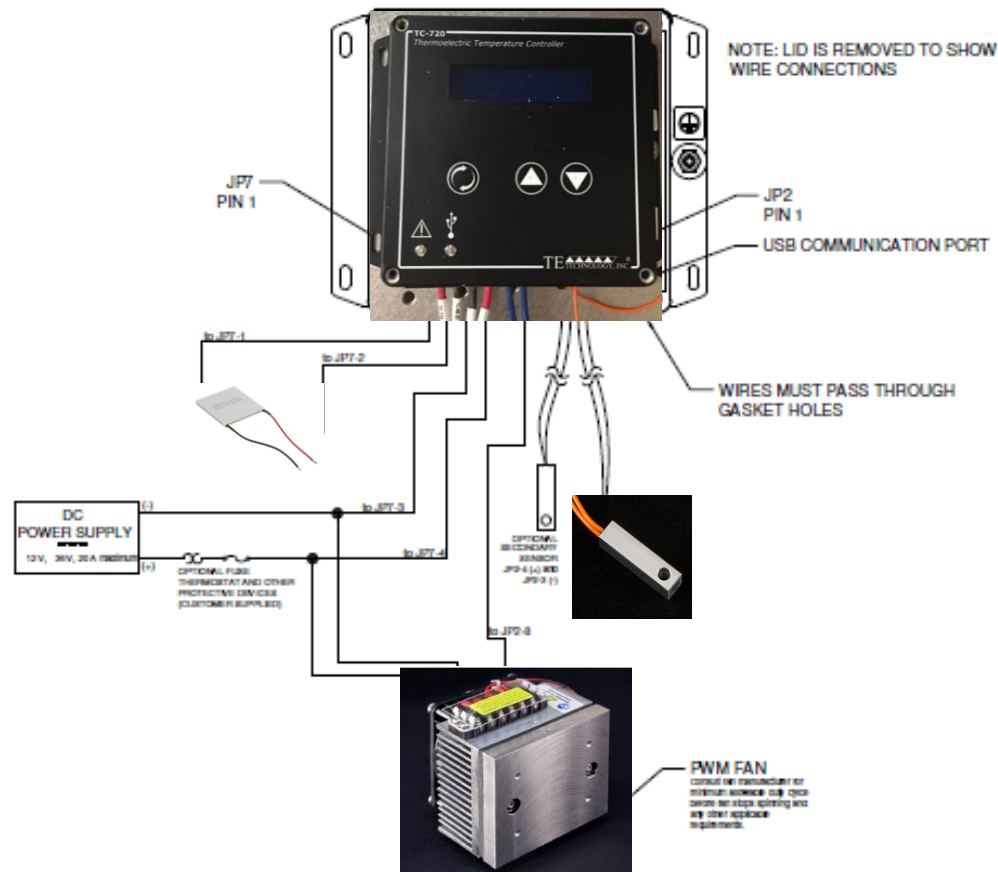
*GE Druck Pace 5000 User Manual*

- Temperature Control
  - *Peltier Heating Elements*
  - Temperature Range: -40 to 80 Celsius



*Huimao.com*





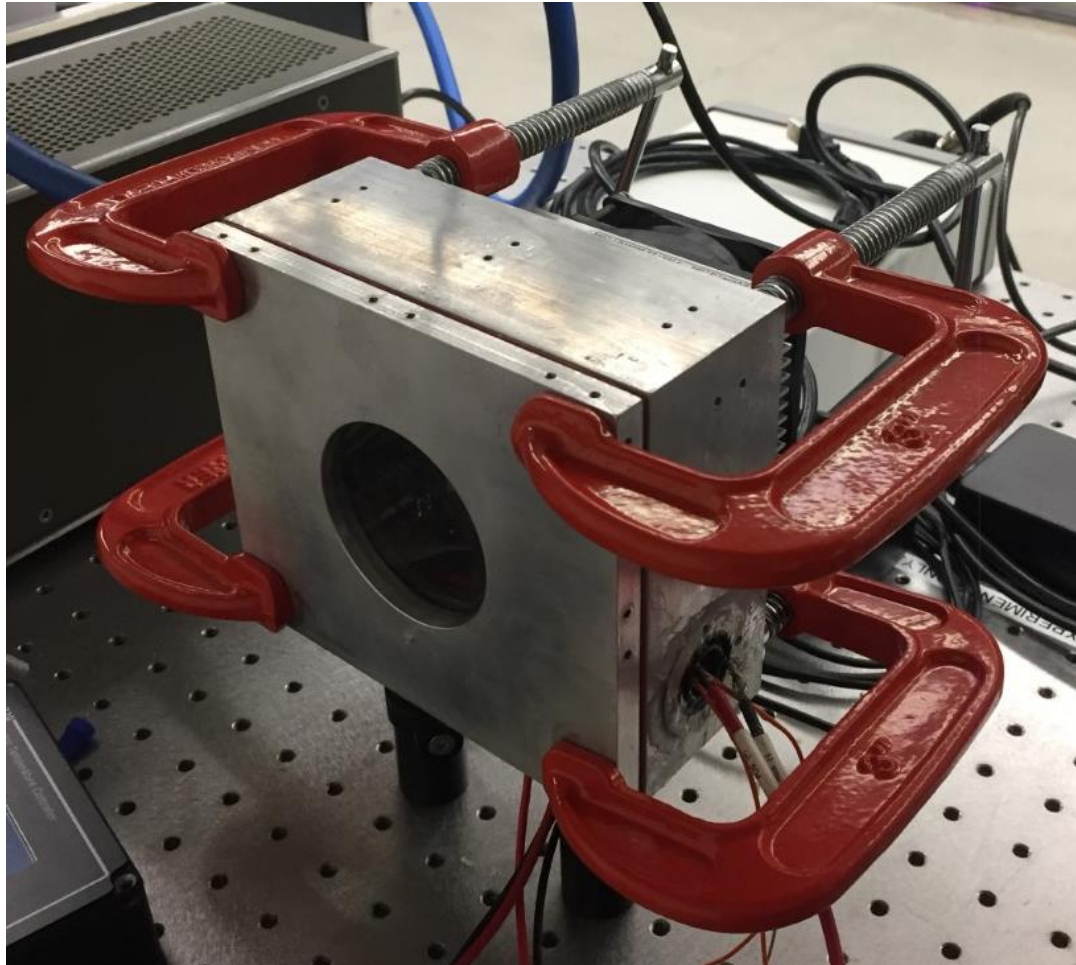
**Connections, Fan Speed Control**  
(connections and components may vary depending on the fan being used)

**TEtechnology, Inc.**

# Constructed Chamber



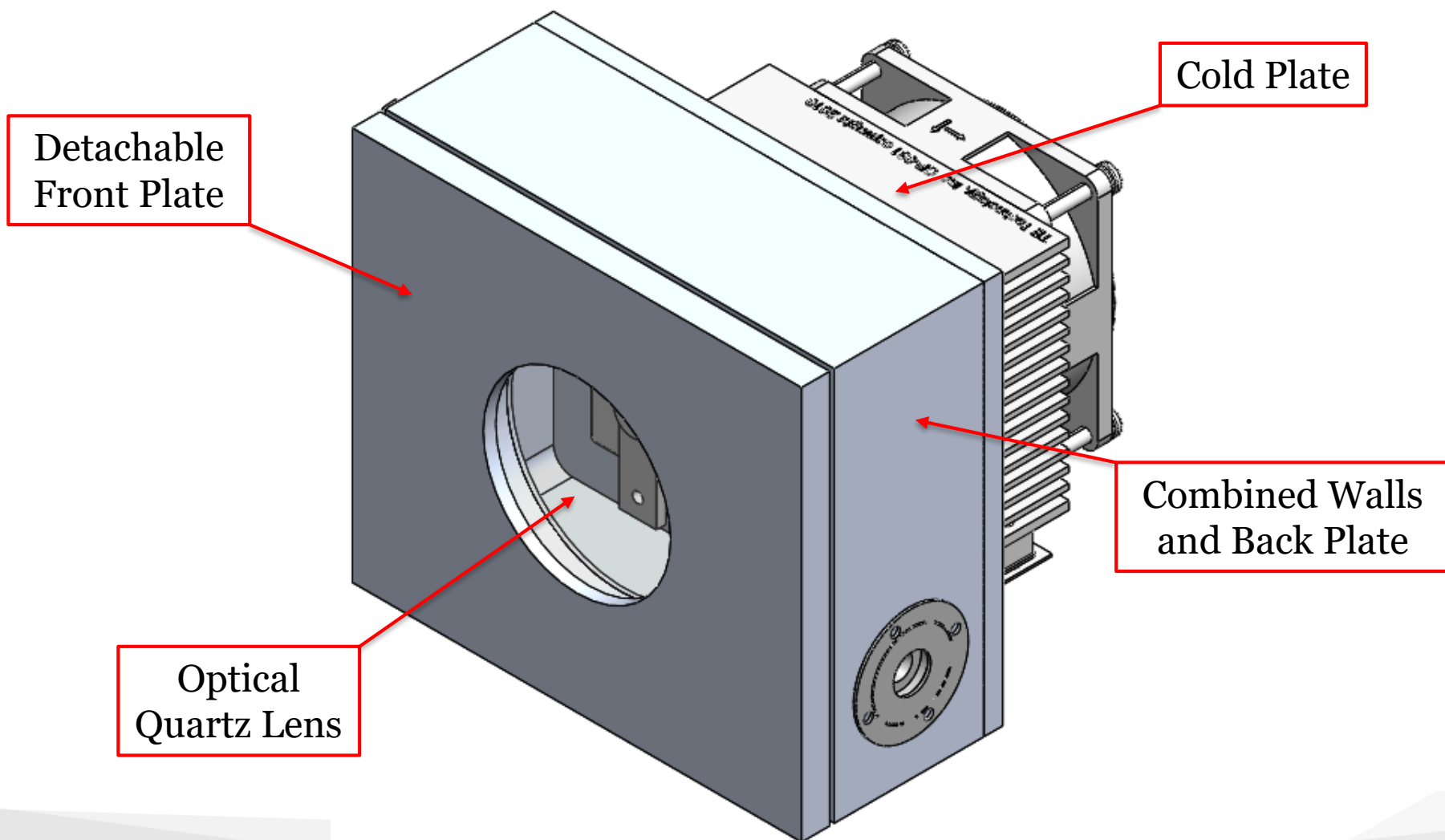
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# Constructed Chamber



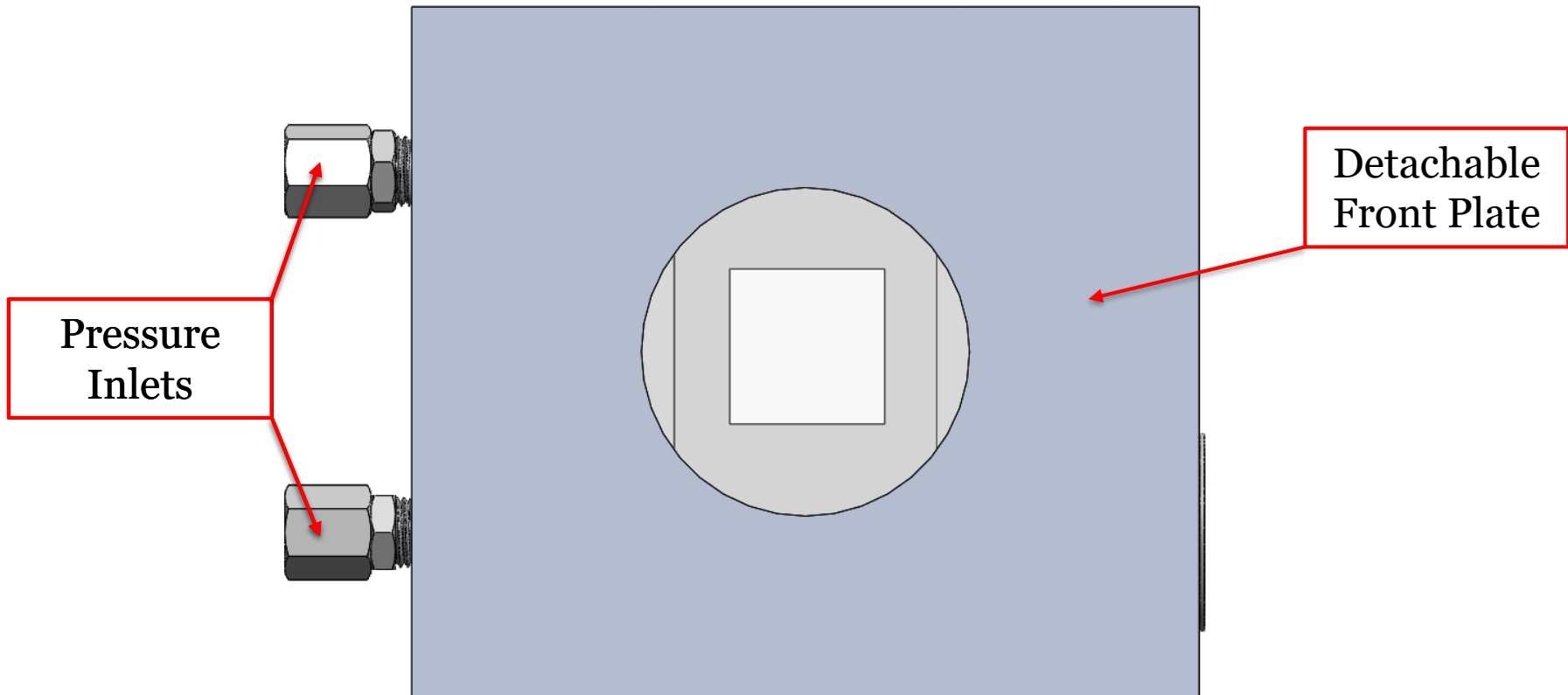
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# Constructed Chamber



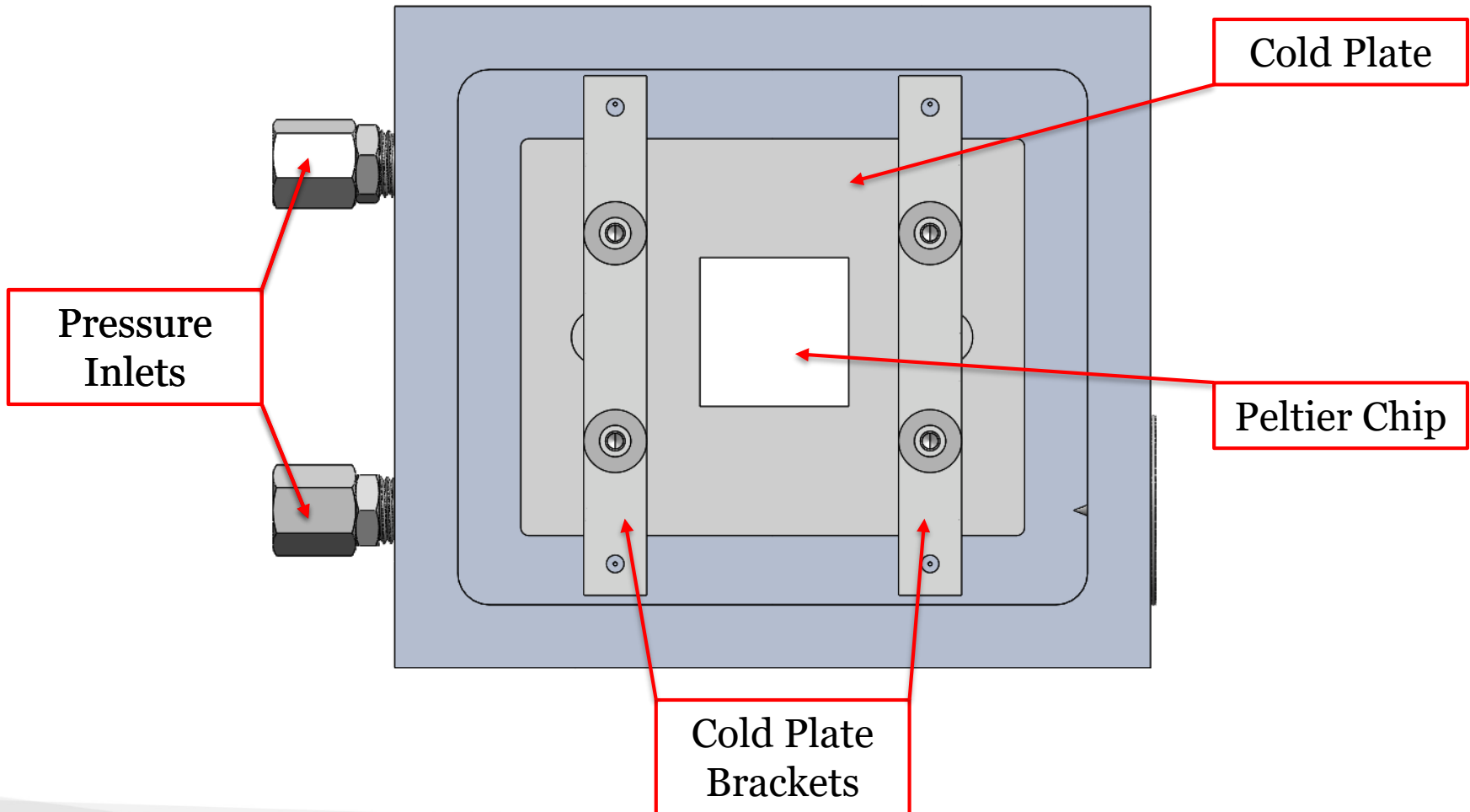
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# Constructed Chamber



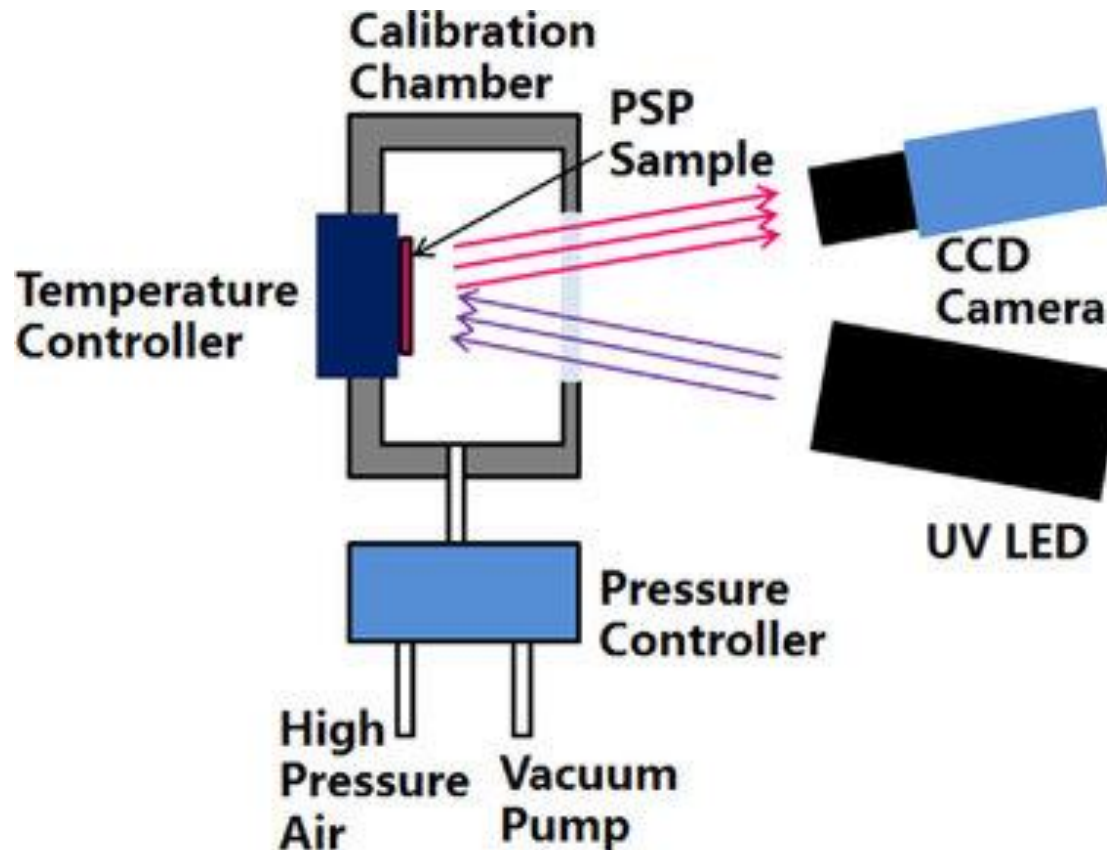
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# Experimental Setup



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*Peng, D. & Chen, J. & Jiao, L. & Liu, Y. (2018). A Fast-Responding Semi-Transparent Pressure-Sensitive Paint Based on Through-Hole Anodized Aluminum Oxide Membrane. Sensors and Actuators A Physical. 274. 10.1016/j.sna.2018.02.026.*

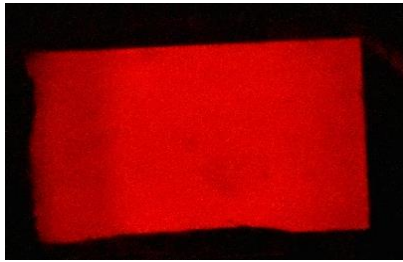


<b>Pressure Calibration</b>		
Trial	Temperature (°C)	Pressure (psig)
1	20	-5
2	20	20
3	20	40
<b>Temperature Calibration</b>		
Trial	Temperature (°C)	Pressure (psig)
4	15	0.0181
5	20	0.0181
6	30	0.0181

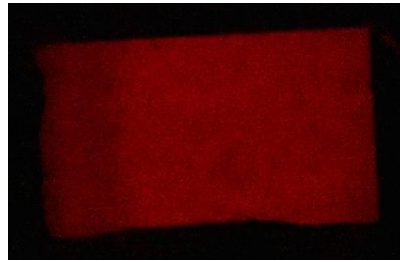
# Results



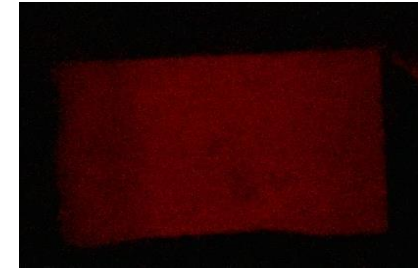
- Pressure Images (T = 20 C)



a.) P = 65 kPa

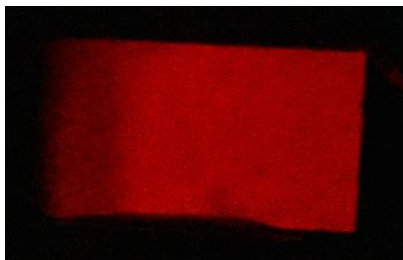


b.) P = 238 kPa



c.) P = 376 kPa

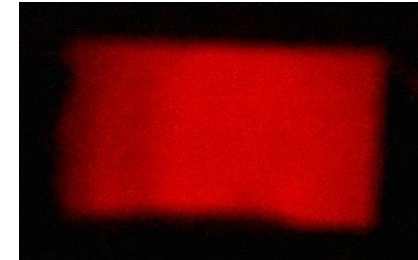
- Temperature Images (P = 100 kPa)



a.) T = 15 °C



b.) T = 20 °C



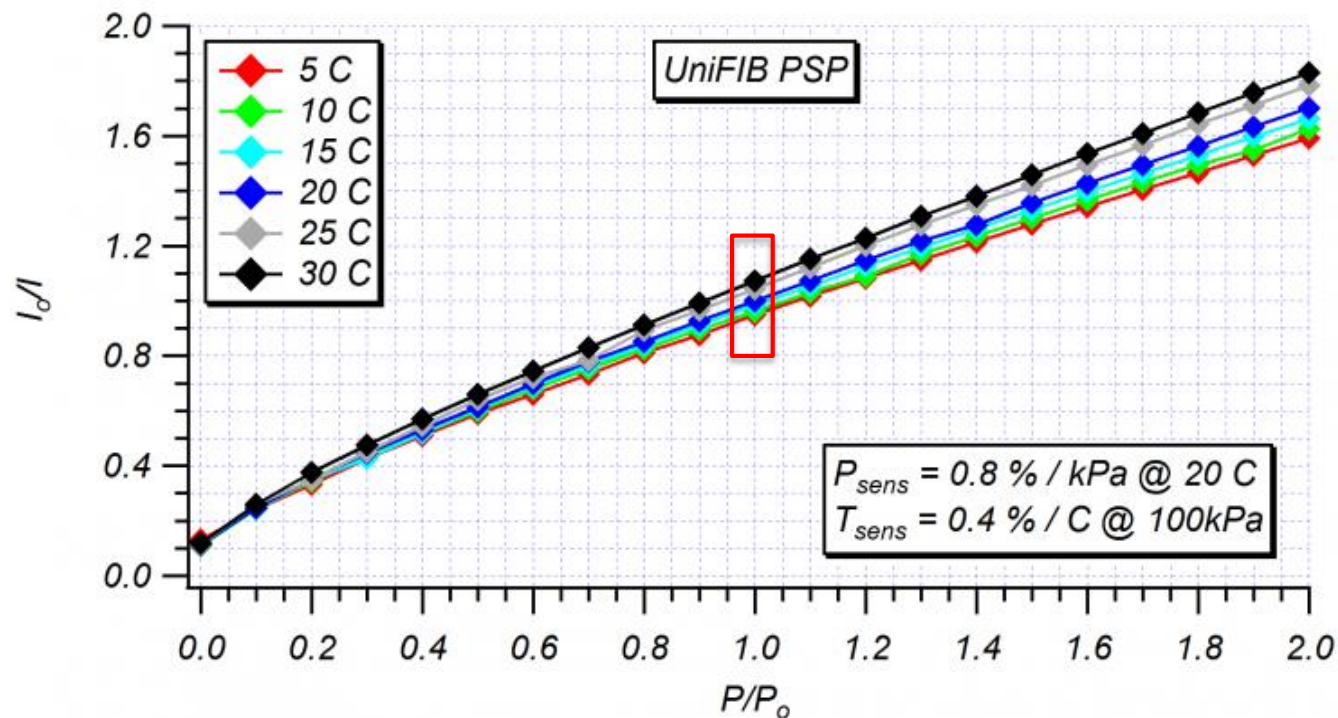
c.) T = 30 °C



# Results



- Paint used is known as UniFIB
  - Small temperature sensitivity leads to small differences in light intensity at constant pressure



*Innovative Scientific Solutions Incorporated (ISSI)*



- **Conclusions**
  - Calibration images match anticipated trends for a given paint sample (UniFIB PSP)
  - Constructed apparatus is viable method for PSP & TSP calibrations
- **Recommendations**
  - Reseal grommet to repair air leak or replace with bulkhead
  - Research adjustable latches for sealing instead of C-clamps

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