# Lecture # 04 Pressure Measurement Techniques and Instrumentation

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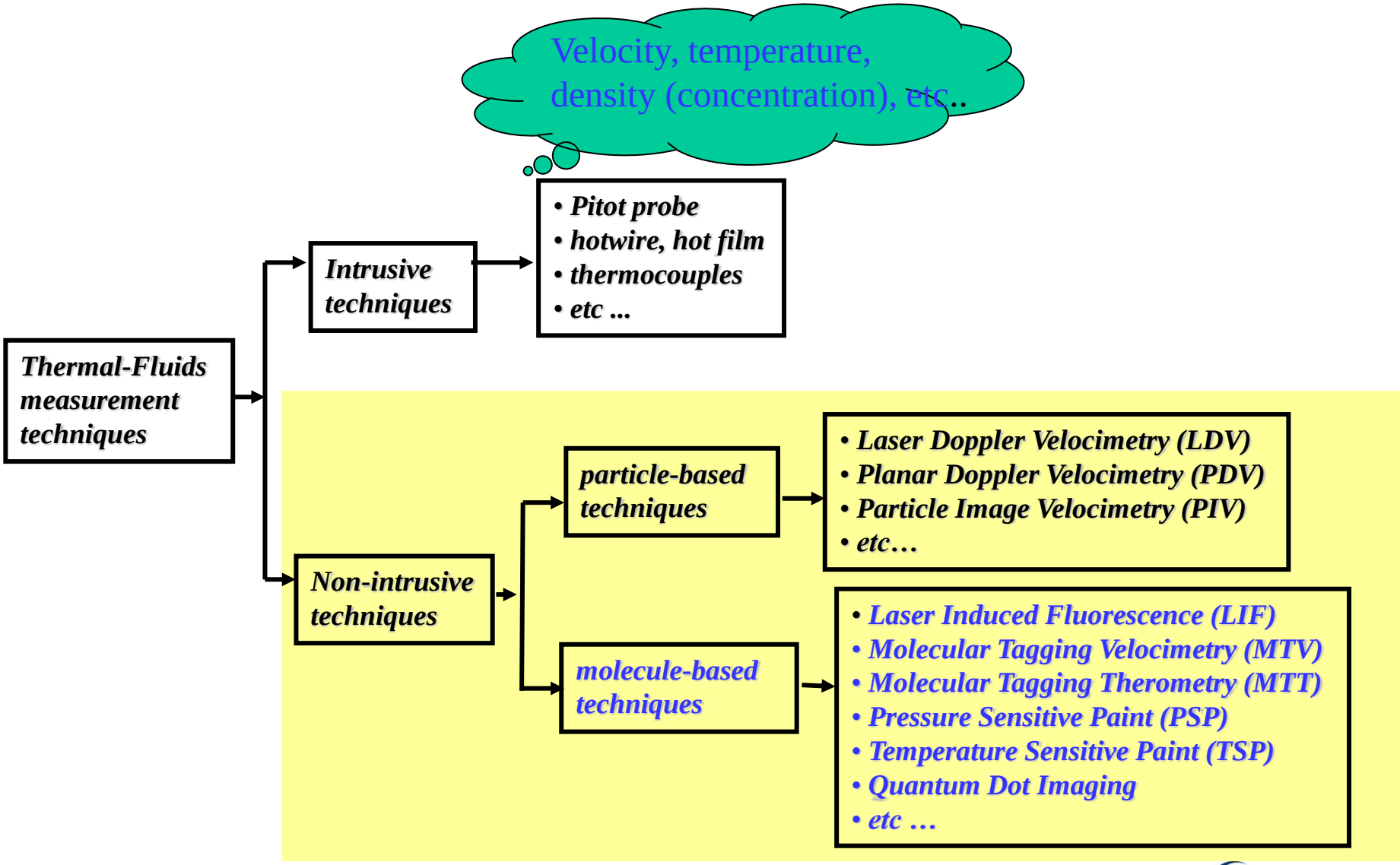
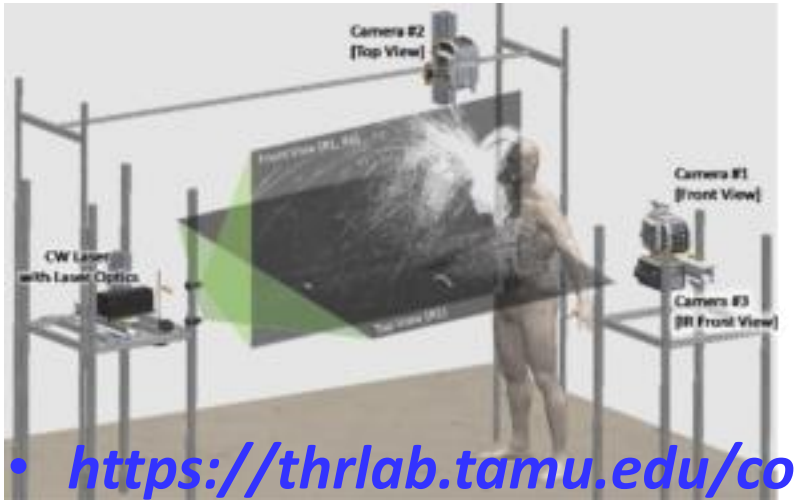
# Measurement Techniques for Thermal-Fluids Studies

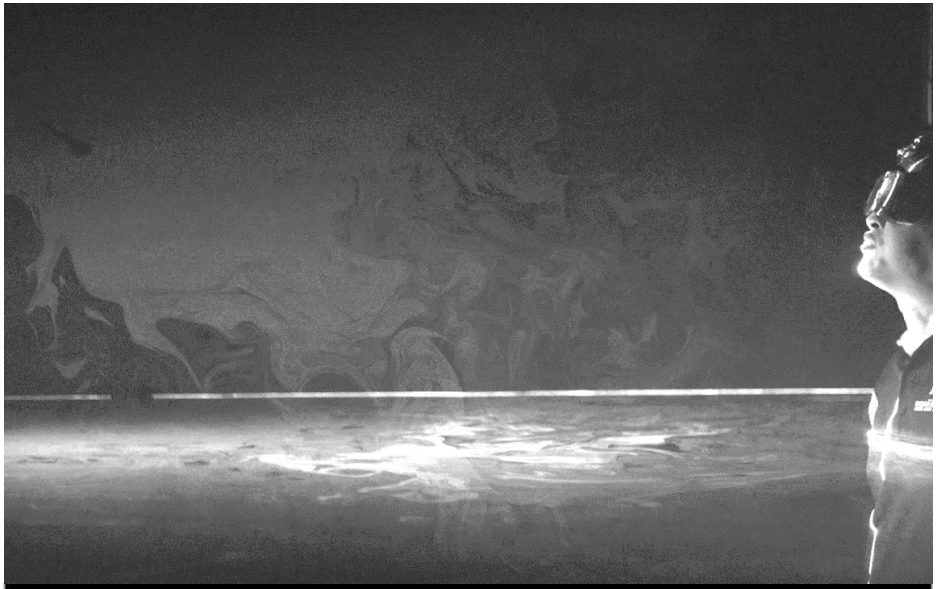


# PIV examples

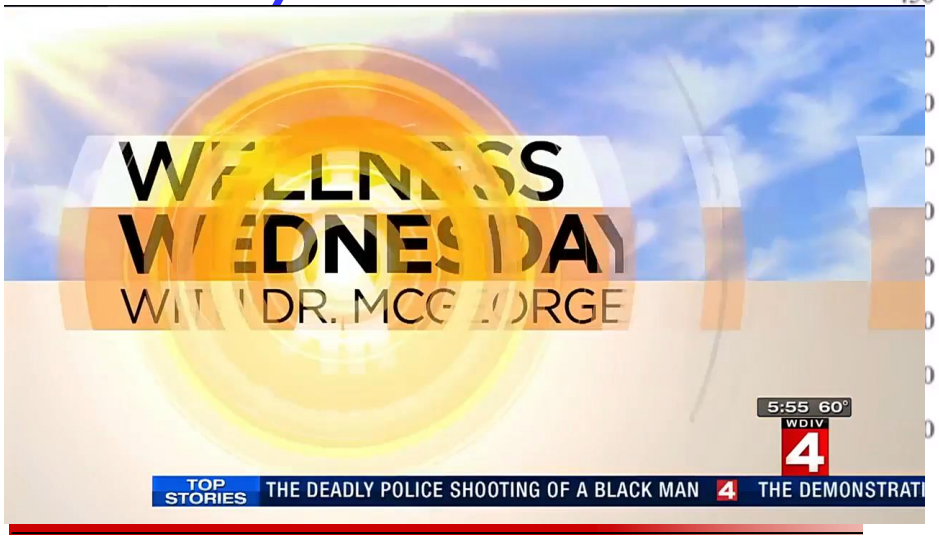
- *A supportive COVID-19 study: Experimental Investigation on a Human Sneeze*




- *https://thrlab.tamu.edu/covid-*



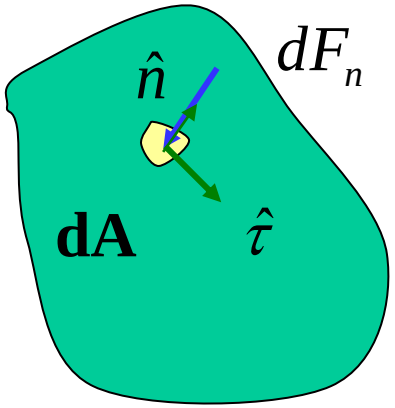
- *https://www.youtube.com/watch?v=9-ui6uFhUx0*

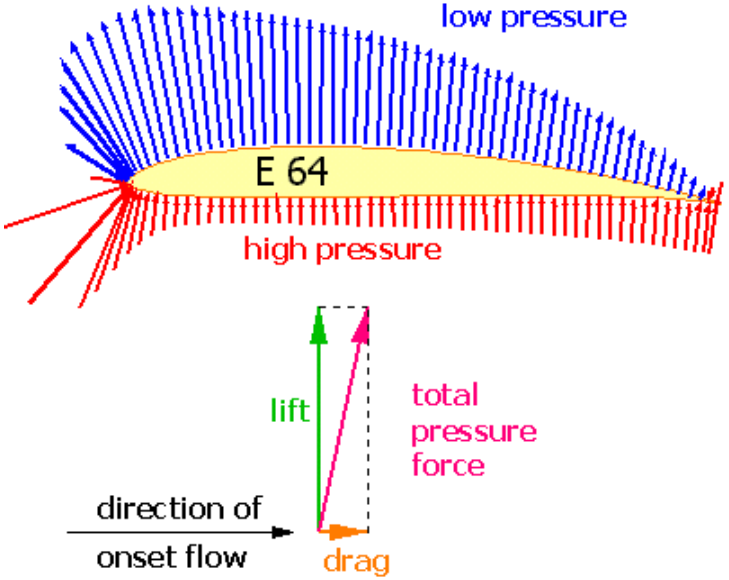


# Pressure measurements

- ***Pressure is defined as the amount of force that presses on a certain area.***
  - ***The pressure on the surface will increase if you make the force on an area bigger.***
  - ***Making the area smaller and keeping the force the same also increase the pressure.***
  - ***Pressure is a scalar***

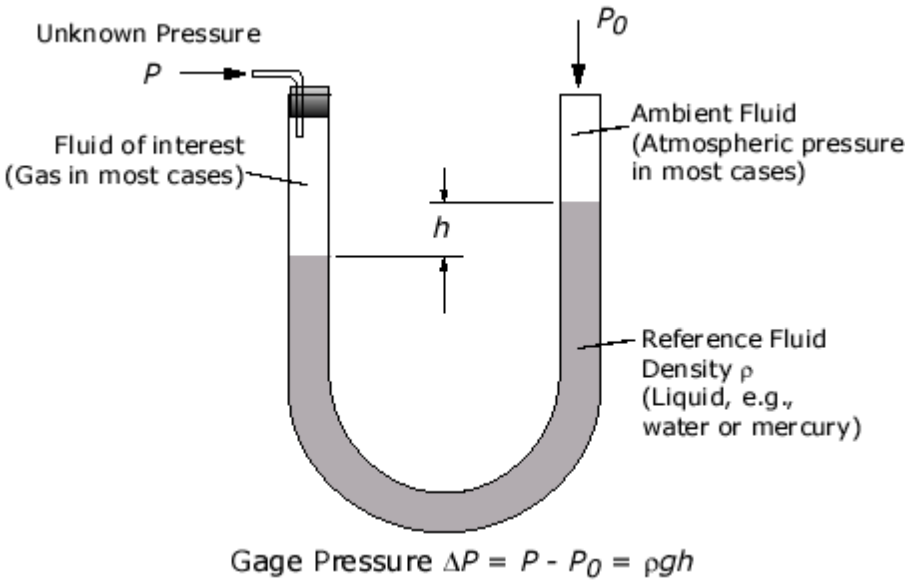
$$P = \frac{F_n}{A} = \frac{dF_n}{dA}$$



# Pressure measurements

$$P_{gauge} = P_{absolute} - P_{amb}$$

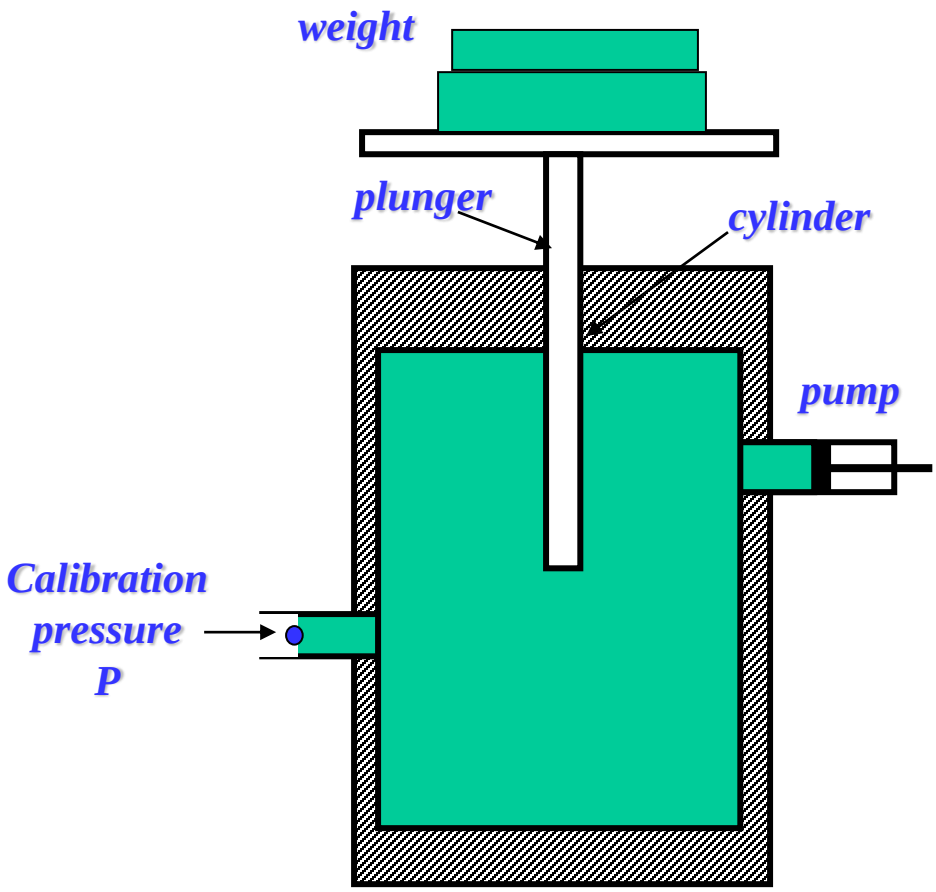



**Manometer**

# Mechanical Pressure Gauges -1

## *Deadweight gauges:*

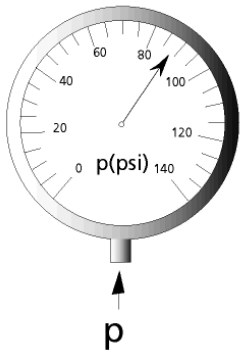
- *High accuracy*
- *Usually used for the calibration of other instruments*
- *Application range : 102~108 pa*
- *Uncertainty is within 0.01% ~0.05% of the reading*

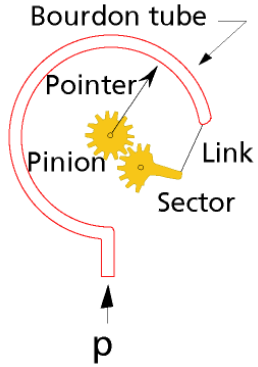


# Mechanical Pressure Gauges -2

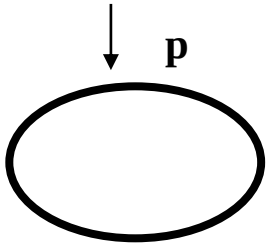
***Elastic-element gauges:***

- ***Contain an elastic elements that deforms under pressure and creates a linear or angular displacement***
- ***The displacement is either displayed on a dial by means of purely mechanical linkages or transformed to an electric signal that can be displayed or recorder at will.***
- ***They usually used for monitoring supply pressure***

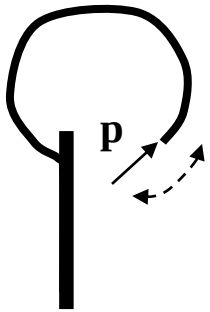


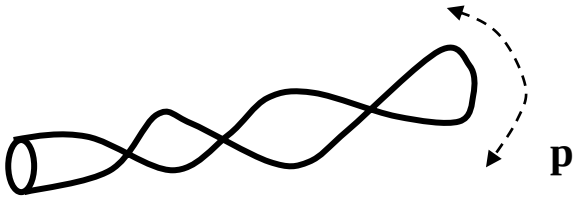



Cross sectional shape




Curved Bourdon tube

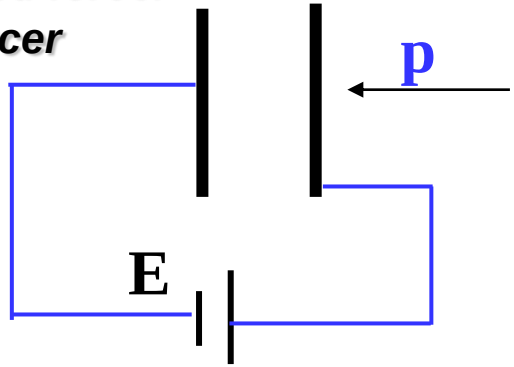



Twisted Bourdon tube

# Electrical Pressure transducers

- *These devices provides an electric output signal that is linearly or nonlinearly dependent on the absolute pressure or a pressure difference.*
- *They can be categorized as:*
  - *Molecular transducers:*
    - *Applied pressure or force produces a change (on the molecular level) of a electrical property of material.*
    - *Piezo-electric material such as quartz crystal: change in internal dipole moments of the molecules of the crystal when the pressure or force is applied.*
  - *Parametrical transducers:*
    - *The gross electrical parameter (resistance, inductance, capacitance) of an associate electrical parameter is altered by applied force.*
    - *Variable-capacitance transducer*

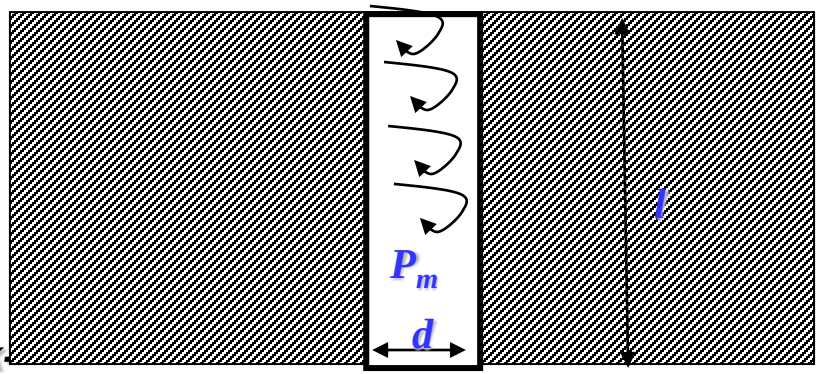
DSA3217 (Shown)




# Wall Pressure measurements -1

- *Making small orifice (pressure tap) facing the flow.*

$$\Delta p = P_m - P > 0$$

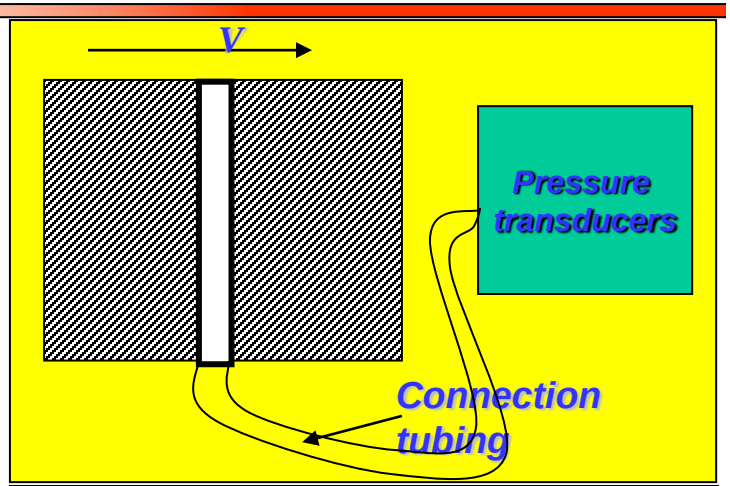



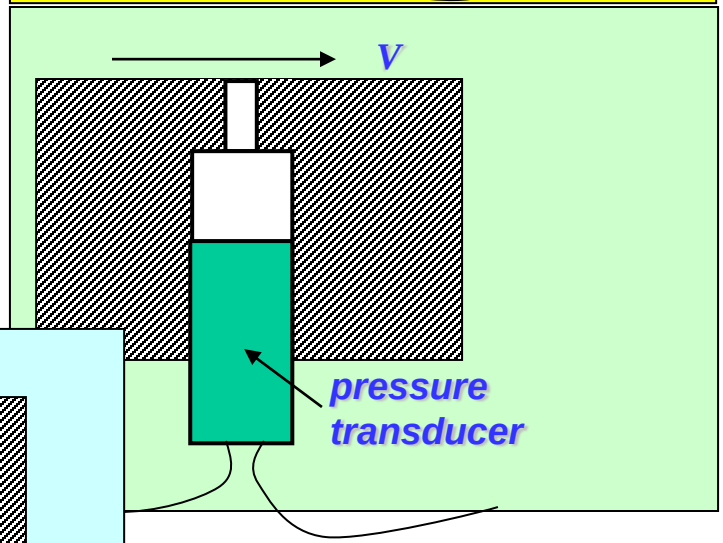

- *Machining small hole could be difficult*
- *d = 0.5~3.0mm in practice*
- *l/d = 5 ~ 15 is common used*

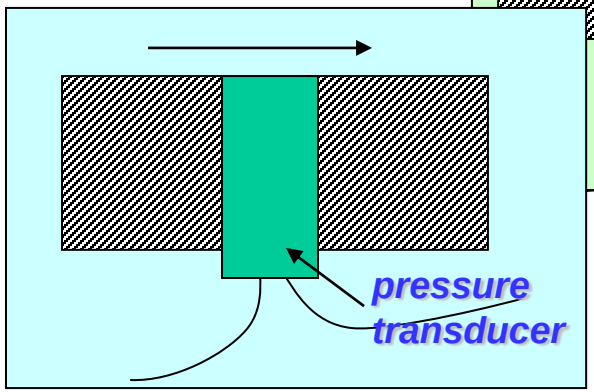
- *Potential effect on the wall roughness*
- *Effects of unsteady shock wave, and shock-boundary-layer interactions for transonic and supersonic flows:*
- *PSP method to be introduced later*

# Wall Pressure measurements - 2

- *For a unsteady flow, the dynamic response of a pressure acquisition system is a key issue!*
  - *Dynamic response of the pressure transducers*
  - *Dynamic response of the connection tubing*
- *Remote connection*
  - *Dynamic response is low*
  - *Spatial resolution is high*
- *Cavity mounting*
  - *Dynamic response is good*
  - *Spatial resolution is high*
- *Flush mounting*
  - *Dynamic response is high*
  - *Spatial resolution is low*

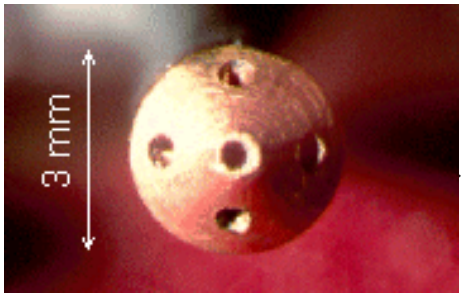


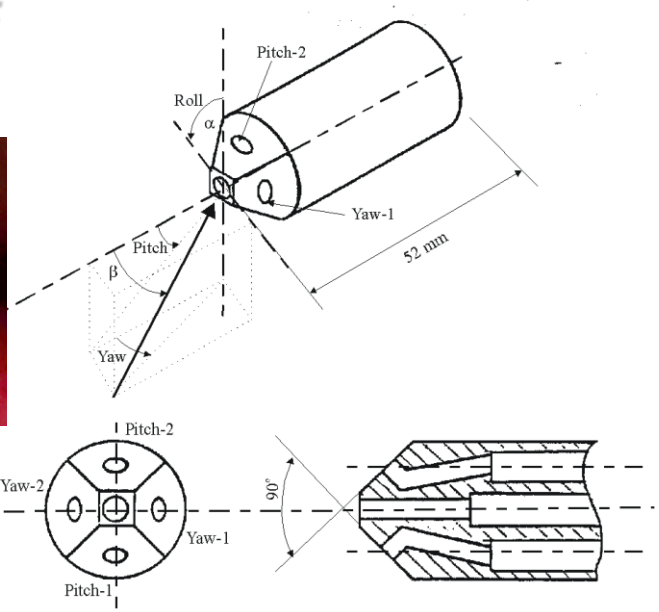



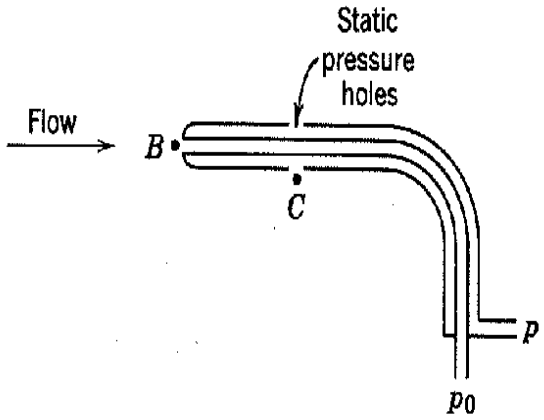



# Pressure Measurements inside Flow Field

- *Non-intrusive technique is unavailable for direct pressure measurements*
  - *Based on N-S equation to calculate pressure field using the measured (PIV) velocity field.*
- *Static probe: for static pressure measurements*
- *Pitot probe: for total pressure measurements*
- *Pitot-static probe: for static and total pressures measurements (velocity measurements)*
- *Multi-hole probe:*

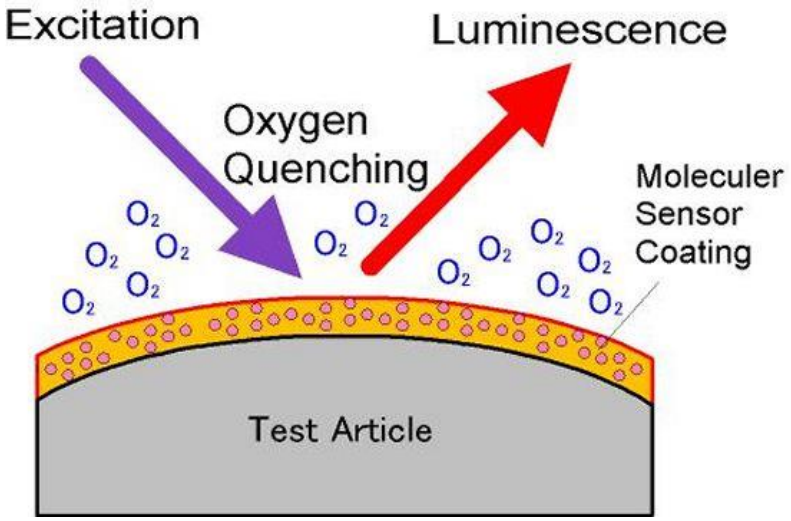


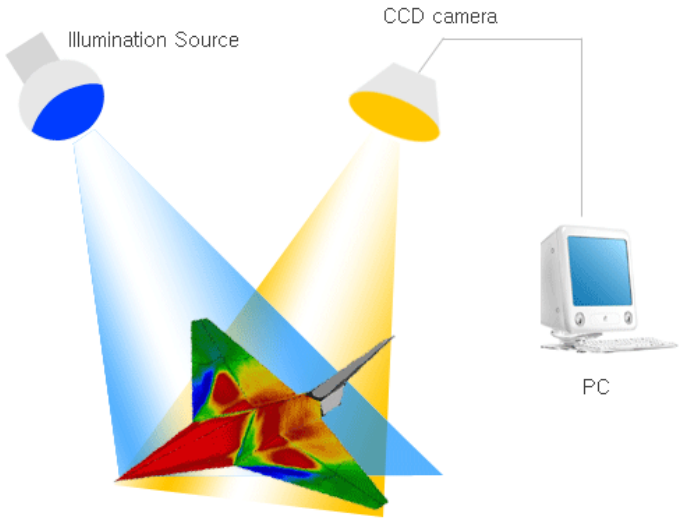



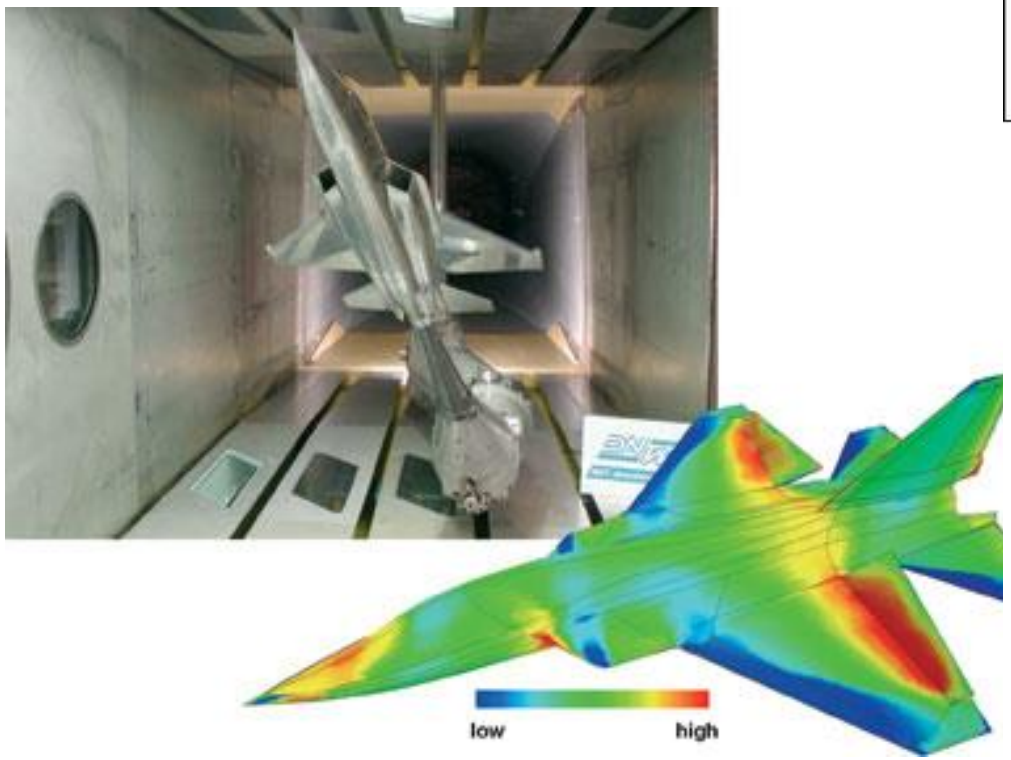
# Pressure Sensitive Paint (PSP) technique

- *Composition of Air: 78.08% $N_2$, 20.95% $O_2$, 0.93% Ar, 0.03% $CO_2$, 0.002% Ne, plus lesser amounts of Methane, Helium, Krypton, Hydrogen, Xenon.*
- *The pressure of air can be determined if the particle pressure of oxygen (i.e. oxygen concentration) can be measured.*
- *A typical pressure sensitive paint is comprised of two main parts: an oxygen sensitive fluorescent molecule and an oxygen permeable binder*

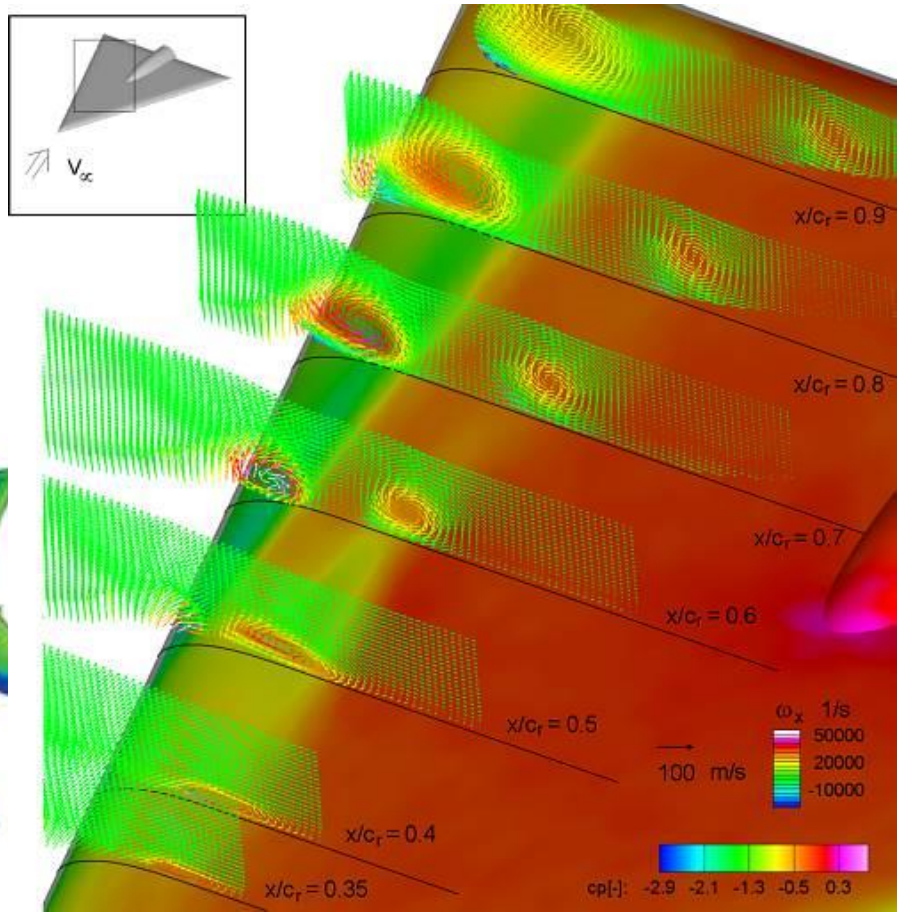


# Applications of PSP Technique




*PSP measurement result*



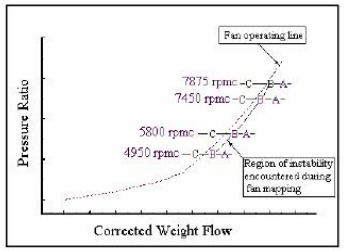

*PSP combined with PIV*

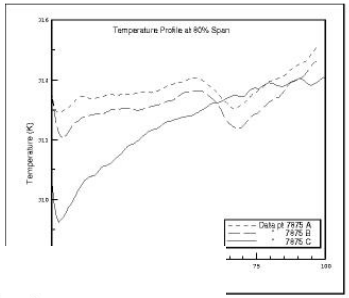
# Applications of PSP Technique

National Aeronautics and Space Administration Glenn Research Center

## Rotating PSP/TSP on 22" Fan Model

GRC 9'x15'LSWT

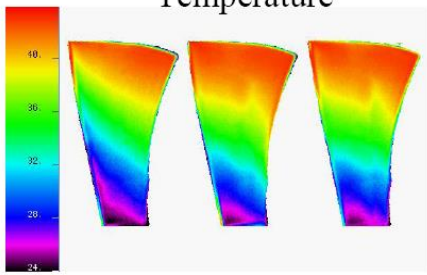


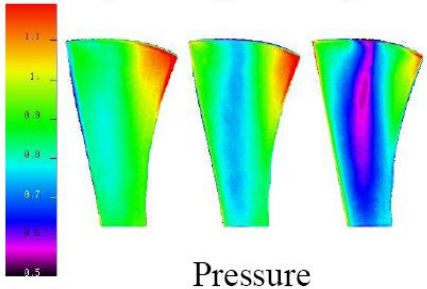

National Aeronautics and Space Administration Glenn Research Center

## Rotating PSP/TSP

Temperature

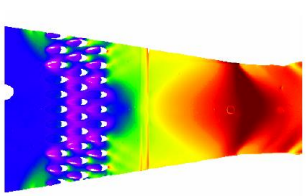


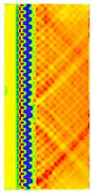
7875 RPM C B A



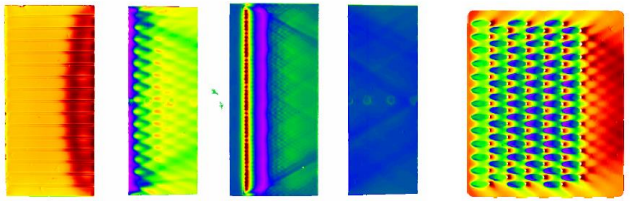
Pressure

## Boundary Layer Control Tests in the 1'X1'SWT





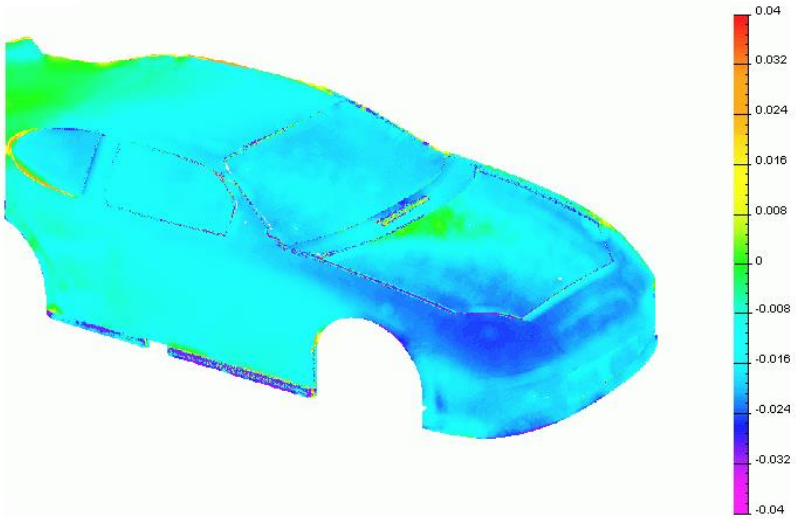
Methods using suction and blowing for boundary layer enhancement



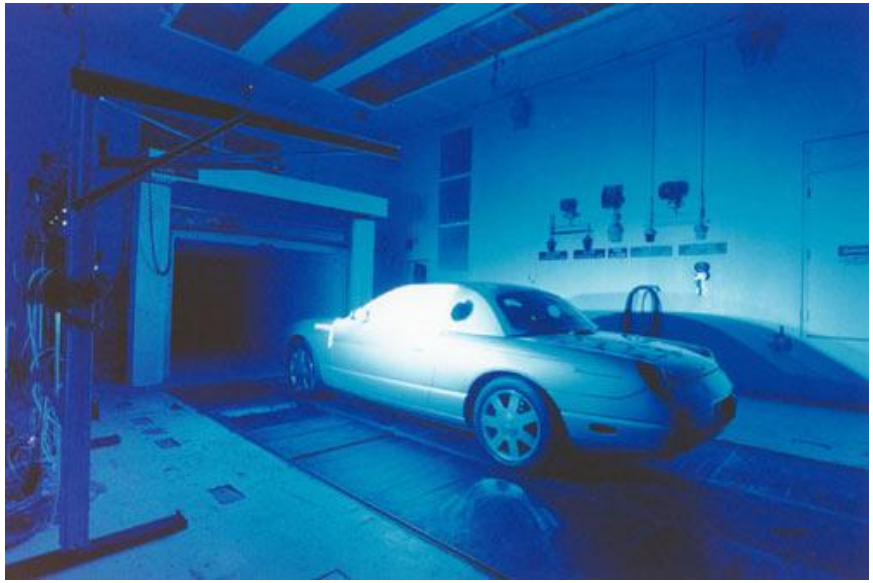


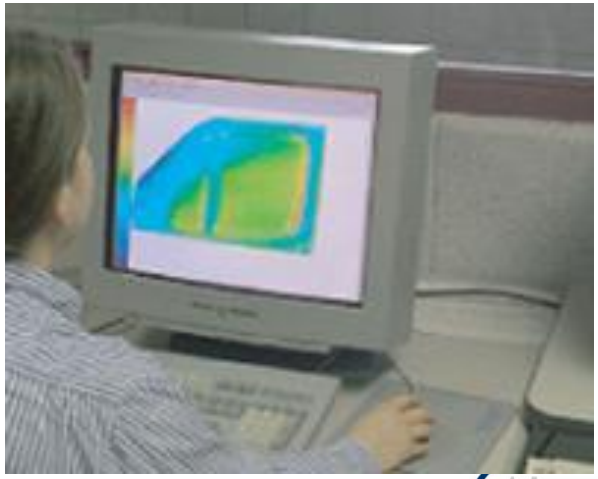
AerE Aerospace Engineering

# PSP Technique for Low Speed Applications




$V_\infty$=50m/s

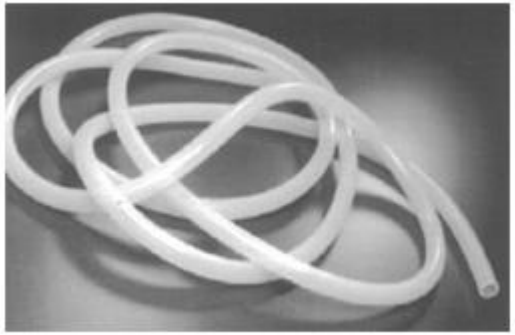




*PSP measurements of a 2002 Ford Thunderbird*

# AerE344 Lab #03: Pressure Sensor Calibration and Measurement Uncertainty Analysis

- ***Task #1:*** ***Pressure Sensor Calibration experiment***
  - ***A pressure sensor – Setra pressure transducer with a range of +/- 5 inH2O***
    - ***It has two pressure ports: one for total pressure and one for static (or reference) pressure.***
  - ***A computer data acquisition system to measure the output voltage from the manometer.***
  - ***A manometer of known accuracy***
    - ***Mensor Digital Pressure Gage, Model 2101, Range of +/- 10 inH2O***
  - ***A plenum and a hand pump to pressurize it.***
  - ***Tubing to connect pressure sensors and plenum***
- ***Lab output:***
  - ***Calibration curve***
  - ***Repeatability of your results***
  - ***Uncertainty of your measurements***

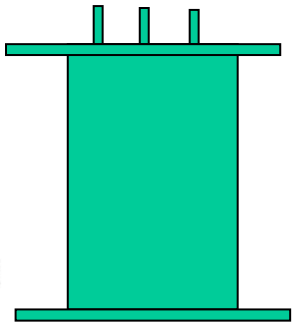


*tubing*


*Setra pressure transducer (to be calibrated)*


*Mensor Digital Pressure Gage*

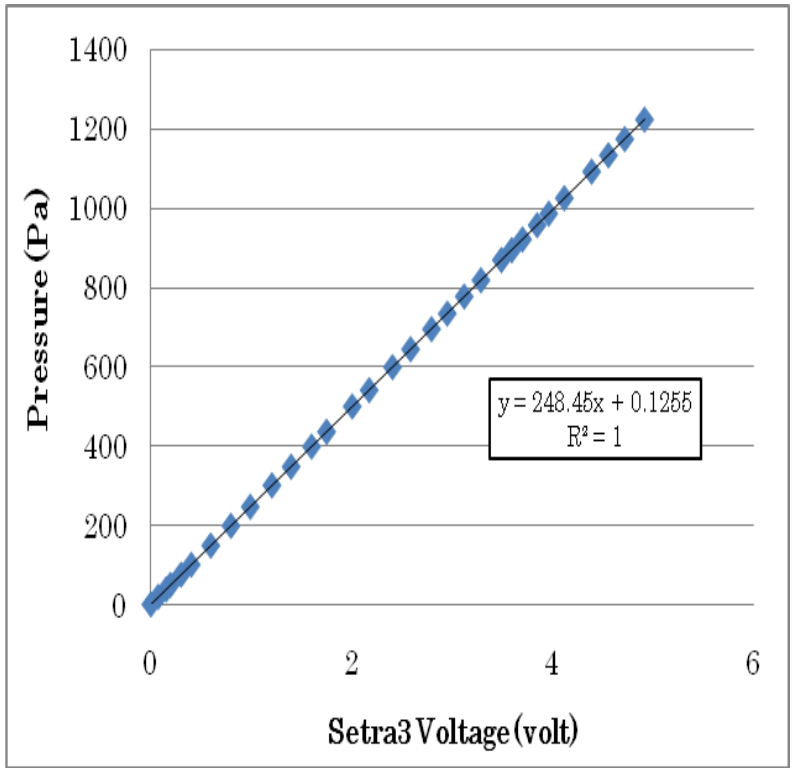
*A computer*

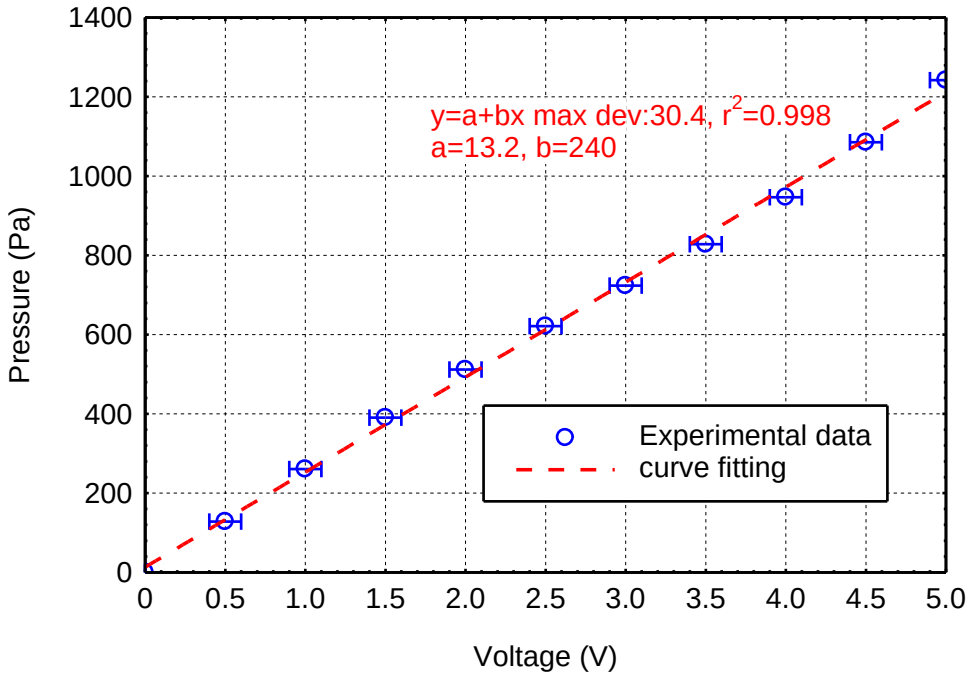


*A plenum*

*hand pump*

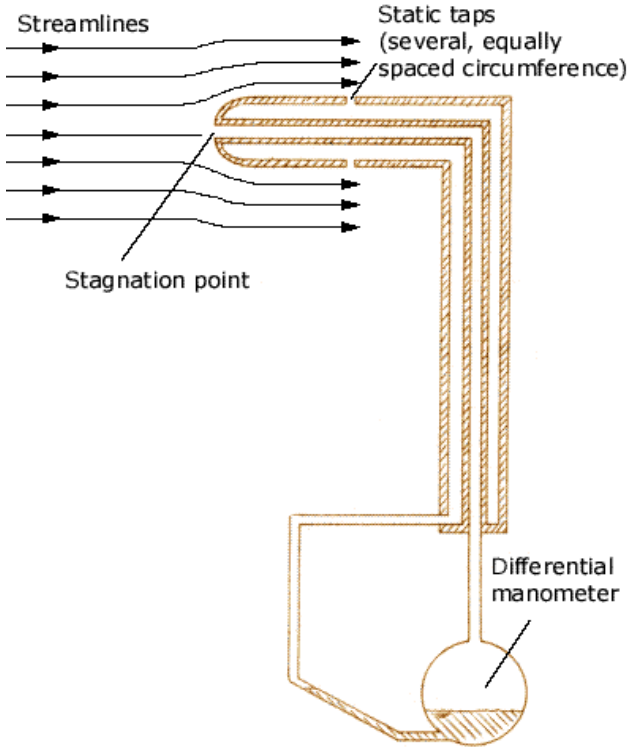
# Calibration curves



# AerE344 Lab #03: Pressure Sensor Calibration and Measurement Uncertainty Analysis

- *Task #2: velocity profile measurements of a Wind tunnel*
  - *A Setra manometer to be used with a Pitot-static probe.*
  - *A Pitot-static probe mounted to a traverse for measuring velocity profiles in the wind tunnel.*
  - *A thermometer and barometer for observing ambient lab conditions (for calculating atmospheric density).*
  - *A computer with a data acquisition system capable of measuring the voltage from your pressure transducer.*




- *Lab Output*
  - *Velocity profiles across the wind tunnel test section.*

$$p_0 = p_{stat} + \frac{1}{2}\rho V^2, (Bernoulli)$$

$$V = \sqrt{\frac{2(p_0 - p_{stat})}{\rho}}$$

# Velocity profile in the Bill James wind Tunnel