B.Eng.-Experiment 1
Wind Tunnel Calibration

Objective

1. Survey the velocity at the inlet to the test section.
2. Become familiar with the operation of wind tunnel.
3. Check the uniformity of the velocity
4. Check the height of boundary layer

Theory

The velocity at the point of measurement is given by

1. Local air density (ρ_a : kg/m^3)

$$\rho_a = \frac{P_a \times 100}{RT_a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

(1 millibar =100 N/m^2 = 100 Pa)

2. Velocity (V : m/s)

$$V = \sqrt{\frac{2 \times \Delta P_l \times 9.81}{\rho_a}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where

$\Delta P_l =$ Dynamic pressure (mm H_2O)

T_a = Ambient air temperature (15°C = 288.15 K)

P_a = Ambient atmospheric pressure (millibar)

Standard sea level condition $\rightarrow$ $P_a = 1013.25$ millibar

R = Specific gas constant (air: $R = 287 \frac{J}{(kg)(K)}$)

(1 mm H_2O = 9.81 N/m^2 = 9.81 Pa)

Note:
In your report include the theory of Pitot Tube and Boundary layer

<u>Apparatus</u>

1. AF100 Subsonic wind tunnel
2. Manometer
3. Pitot probe

<u>Apparatus</u>

a. Start up
- Switch on the electrical isolator on the control and instrumentation frame.
- **<u>Set the speed control to the minimum position (fully anticlockwise)</u>**
- Press the green “START” button
- **<u>Gradually</u>** turn the speed control clockwise until the tunnel is operation at the speed needed for the experiment

b. Shut down
- Slowly turn the speed control fully anticlockwise
- Press the red STOP button.

c. Emergency Stop
- Press the red STOP button
- Turn the speed control fully anticlockwise

<u>Experimental Procedure (Reference velocity)</u>

1. Ensure that the Pitot tube is fitted to the front position (near to the inlet). Check that the mechanism allows the probe to traverse the entire section. If not, undo the screw holding the Pitot tube to the pointer and adjust it.

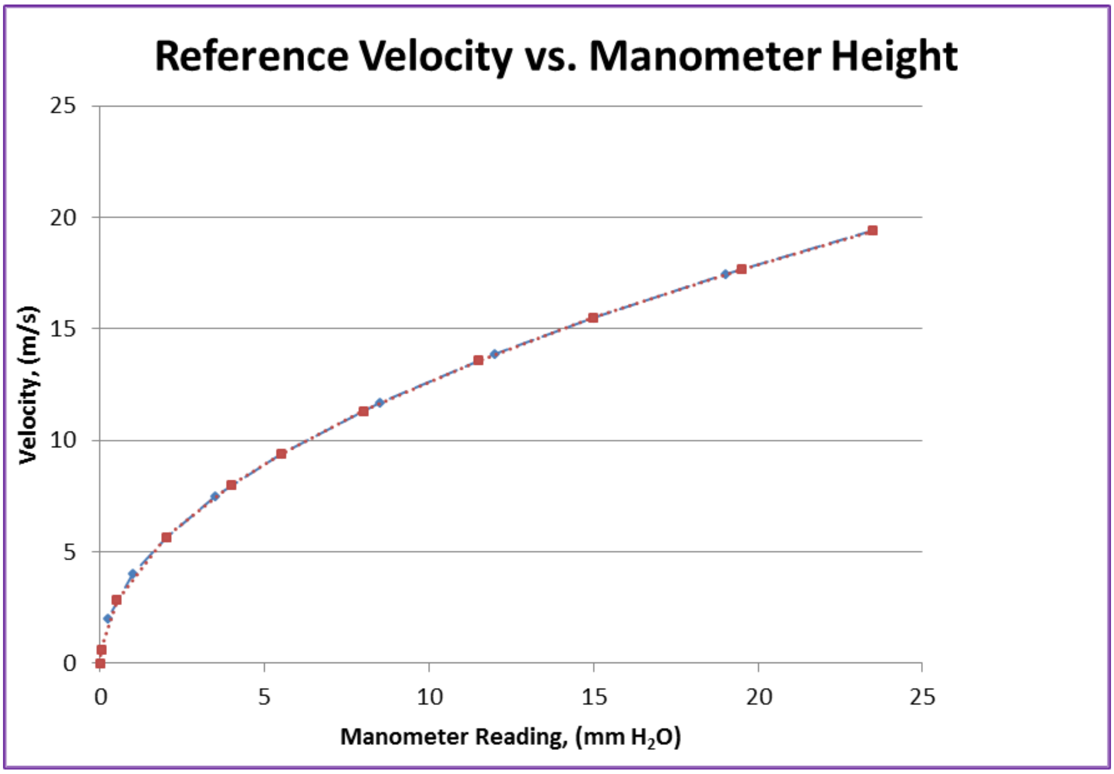
2. Connect the Pitot tube and wall tapping to the manometer ΔP_l. Connect the wall tapping to the left limb and the Pitot to the right limb.

3. Zero the manometers and take readings of the ambient air temperature and barometric pressure, Position the pitot tube in the centre of the tunnel (152.5 mm from the bottom)

4. Start the fan and run it at 22 m/s. Take reading from the manometer. Reduce fan speed and take another manometer reading. Continue to take manometer readings for a range of fan speed.

5. Plot a graph of manometer reading versus reference velocity.

   Below is an example of how the plot should look like.



Reference velocity

T (°C) =…………………... R (J/kg.K) =…………………...
T (°K) =…………………... ρ (kg/m3) =…………………...
P (mb) =…………………...

V (pitot-static)	ΔP_l (mm H_2O)	V (pitot)	% Error
22		21.3	
20			
18			
16			
14			
12			
10			
8			
6			
4			
2			
0			

Note:

1. Use the following equation to find the Velocity measured using the Pitot Probe:

$$V(\text{pitot}) = \sqrt{\frac{2 \times \Delta P_l \times 9.81}{\rho_a}}$$

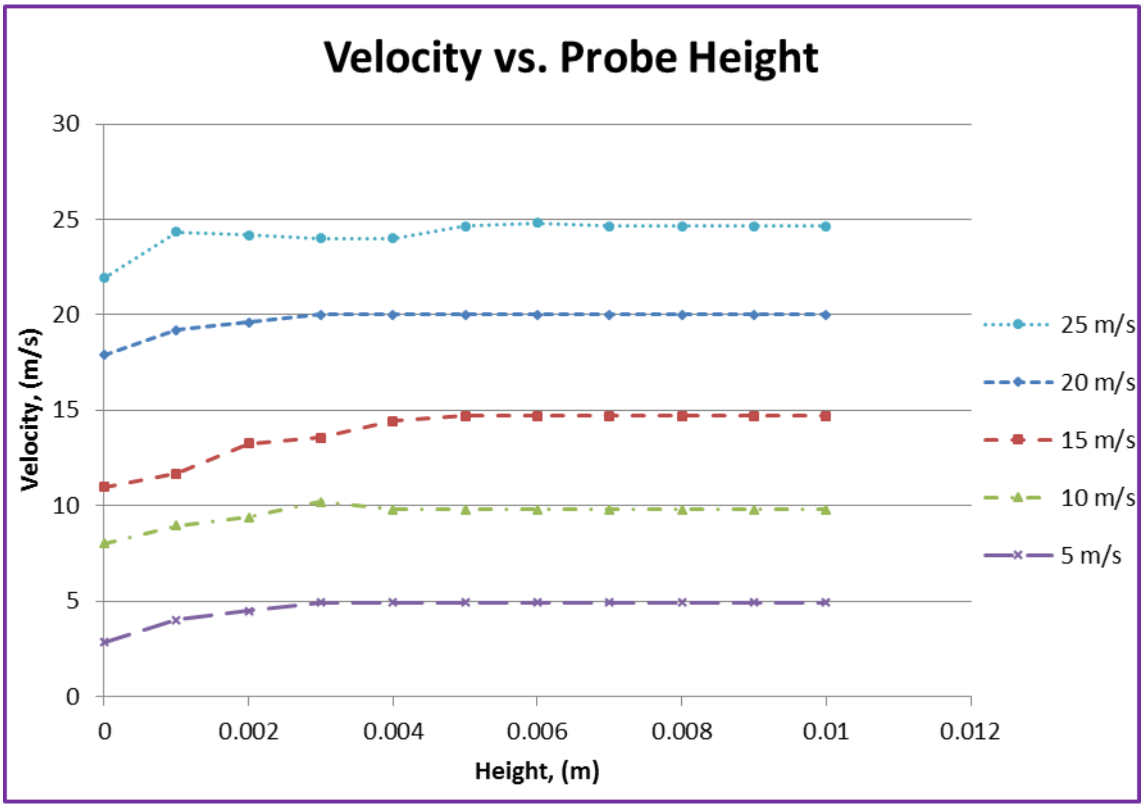
2. To find the %Error use the following equation

$$\%\, Error = \frac{V\ (\text{pitot}-\text{static}) - V\ (\text{pitot})}{V\ (\text{pitot}-\text{static})} \times 100$$

Experimental Procedure (Velocity profile)

1. Set the Pitot tube mid-way and set the fan running to give a speed of around 5 m/s, 10 m/s, 15 m/s, 20 m/s (use the pitot-static tube data display)
2. Position the pitot at the floor of the tunnel. Take a reading of the dynamic pressure and the position of the pitot from the scale
3. Move the Pitot away from the wall by approximately 1 mm and repeat the dynamic pressure reading. Continue to take readings of dynamic pressure every millimeter up to 15 mm and then every 20 mm up to the center line of the test section
4. Plot a graph of the height in the test section gains the velocity.(subtract the radius of the pitot tube for a true position relative to the tunnel floor)
5. The graph should show a reduced velocity near to the tunnel floor due to the boundary layer with a sensibly constant velocity over the remainder of the test section

   Below is an example of how the plot should look like.



Velocity profile (V= m/s)

T (°C) =…………………...
T (°K) =…………………...
P (mb) =…………………...
R (J/kg.K) =…………………...
ρ (kg/m³) =…………………...

Probe Height (mm)	Probe Height (m)	ΔP_l (mm H_2O)	V (pitot)
0	0		
1	0.001		
2	0.002		
3	0.003		
4	0.004		
5	0.005		
6	0.006		
7	0.007		
8	0.008		
9	0.009		
10	0.010		
11	0.011		
12	0.012		
13	0.013		
14	0.014		
15	0.015		
35	0.035		
55	0.055		
75	0.075		
95	0.095		
115	0.115		
135	0.135		
155	0.155		

Note:

1. Use the following equation to find the Velocity measured using the Pitot Probe:

$$V(\text{pitot}) = \sqrt{\frac{2 \times \Delta P_l \times 9.81}{\rho_a}}$$

<u>B.Eng.-Experiment 2</u>
<u>NACA 2412 Airfoil with variable flap</u>

Objective

Determine the effect of flap deflection angle to the aerodynamic characteristics of airfoil.

Analysis

The lift and pitching moment are automatically calculated by the AFA 3 from the equations:

Lift=Fore load cell force+ Aft load cell force

Pitching Moment=AFA3 Moment Arm Length × (Fore load cell force-Aft load cell force)

It is convenient to refer to the non-dimensional coefficients of lift, drag, and pitching moment as follows:

$$C_L = \frac{L}{\frac{1}{2}\rho V^2 S} \qquad C_D = \frac{D}{\frac{1}{2}\rho V^2 S} \qquad C_M = \frac{M}{\frac{1}{2}\rho V^2 Sc} \qquad \frac{L}{D} = \frac{C_L}{C_D}$$

Note:
In your report include the theory of the following; ***1.*** Forces on an airfoil, ***2.*** Lift Drag & Moment Coefficients, and ***3.*** High Lift Devices.

Apparatus

4. AF100 Subsonic wind tunnel
5. Digital manometer
6. AF103 airfoil with variable flap
7. AFA3 Three component balance

Specification of AF103 Aerofoil model

Item	**Details**
Dimensions	300mm span & 150 mm chord
Airfoil	NACA 2412
Weight	2 kg
Notch increment	2.5°
Flap deflection angle	$\pm$ 2.5°

Wind tunnel operation

a) Start up

- Switch on the electrical isolator on the control and instrumentation frame.
- Set the speed control to the minimum position (fully anticlockwise)
- Press the green “START” button
- **Gradually** turn the speed control clockwise until the tunnel is operating at the speed needed for the experiment

b) Shut down

- Slowly turn the speed control fully anti-clockwise
- Press the red STOP button.

c) Emergency Stop

- Press the red STOP button
- Turn the speed control fully anti-clockwise

Model installation

1. Make sure the electrical supply to the wind tunnel is disconnected.

2. Remove the side window opposite the three component balance.

3. Make sure that any pitot tubes in the test section are out of the way.

4. Fit the airfoil model into the collect of the AFA3 so that the flattest side is to the top. (The airfoil is flying upside down, so that the load cells and connecting wires on the AFA3 are intension. Pitch is positive, with the leading edge toward the floor.)

5. Adjust the variable flap so that it is in line with the main part of the airfoil and the metal plate at the support shaft end of the airfoil. The flap angle is now zero.

6. Set the scale on the AFA3 to zero and lock it in position. Rotate the airfoil so that the trailing edge is 2.6 mm higher than the center line of the support shaft. Lock the support shaft in position on the AFA3. The 2.6 mm offset allow for the camber of the airfoil. The airfoil angle is not set to zero.

7. Refit the clear panel that you removed in step 2.

<u>Wind Tunnel test procedure</u>

1. Record the ambient temperature and pressure.

2. **<u>Release balance lock before test</u>**

3. Start the wind tunnel, set free-stream velocity as assigned to each team. Note that the pressure difference used to calculate the wind velocity varies due to ambient conditions.

4. Record the Lift, Drag and Pitching moment readings from the Three component balance display unit

5. Adjust the angle of attack in steps of 3º from -9º (351º) upwards until the lift passed its maximum magnitude due to the stall.

6. The airfoil is flown "upside down" in the three component balance. This is normal and allows more accurate balance design. (The sign of angle of attack in this balance is the opposite which appears in your text book)

7. In step of 3º, take readings of Fore and Aft drag forces at aerofoil angles from -9º to the stall angle. Make sure to take 5 readings for each angle of attack as this will reduce the error from the fluctuations.

8. The stall angle of attack changes with flap deflection angle. The wing is at stall when the lift starts to decrease as the incidence angle increases.

9. Stop the wind tunnel, remove the clear panel opposite the AFA3 and adjust the flap angle to 22.5 degrees and repeat the experiment. In this case you will start at -12º (348º).

10. Repeat the experiment with a flap angle of 45 degrees. In this case you will start at -15º (345º).

11. **<u>Tighten balance lock after test.</u>**

<u>Important Note:</u>
After adjusting the angle of attack make sure that you give the balancer an amount of time to display the actual readings of the airfoil forces. This should be done as you were applying force to the balancer while changing the angle of attack which will add a huge error to your readings if you immediately started recording readings.

NACA 2412 airfoil

Flap deflection angle	°
Manometer	$mm\ H_2O$
Air density	kg/m^3
Ambient Temperature	$°C$
Airfoil area	m^2
Wind velocity	m/s
Ambient pressure	$mbar$
Chord	m
$\frac{1}{2}\rho V^2 S$	N

AoA (deg)	Lift (N)	Drag (N)	Pitching Moment (Nm)	C_L	C_D	C_M	C_L/C_D

Below is an example of how the plots should look like.