BEng Architectural Environmental Engineering

Thermofluids 1 (ABEE1027) Laboratory

Air Flow Measurement using the AF10 Flow Bench

Wake Traverse Experiment

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Aims

- To measure air flow using a Pitot Static Tube
- To develop skills in analysis and report writing

Theory

Aerodynamics is the branch of fluid dynamics concerned with the study of motion of air, particularly when it interacts with a moving object is known as aerodynamics. The forces acting on bodies moving through the air are termed aerodynamic forces.

Boundary layers on bluff bodies often separate or break away from the body, forming a wake of rotational, retarded flow behind the body, and it is these wakes that are associated with the drag on the body. For example, flow past a circular cylinder has important consequences for the flow downstream. At points on the downstream side of the cylinder the flow separates and there is an unsteady turbulent wake behind it (See Figure 1). The existence of the wake destroys the symmetry in the pressure field predicted by the inviscid theory and there is net pressure force or form drag acting on the cylinder. Viscous stresses at the boundary itself cause additional drag on the body. Upstream of the cylinder the flow is similar to that predicted by the inviscid theory, except in a thin viscous boundary-layer adjacent to the cylinder. Wake is a region of disturbed flow downstream of a solid body, which is caused by the movement of this body or by movement of the fluid around this body.

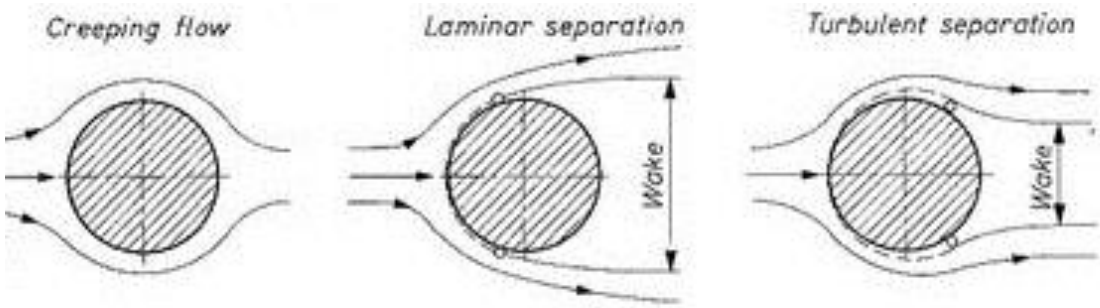


Figure 1 Wake Effect on a Spherical Body

Apparatus

The AF10 flow bench consists of a fan which draws air from the atmosphere and delivers it along a pipe to an airbox (plenum) which is above the test area. In the pipe is a valve which is used to regulate the discharge from the fan. From the plenum the air flows through a contraction (which accelerates the flow and flattens the flow profile) and into the parallel working section before exiting to the ambient surroundings. Discharge from the test section is directed towards the bench-top in which a circular hole is provided to collect the air so that it may be led through the duct to the rear of the bench. Care should be taken not to block the flow between working section discharge and exit duct as this will affect the measurements taken. Pressure tappings (See Figure 2) on the plenum and at the start of the working section are attached to a multitube manometer, shown in Figure 3a. This is filled with dyed water and graduated in mm.

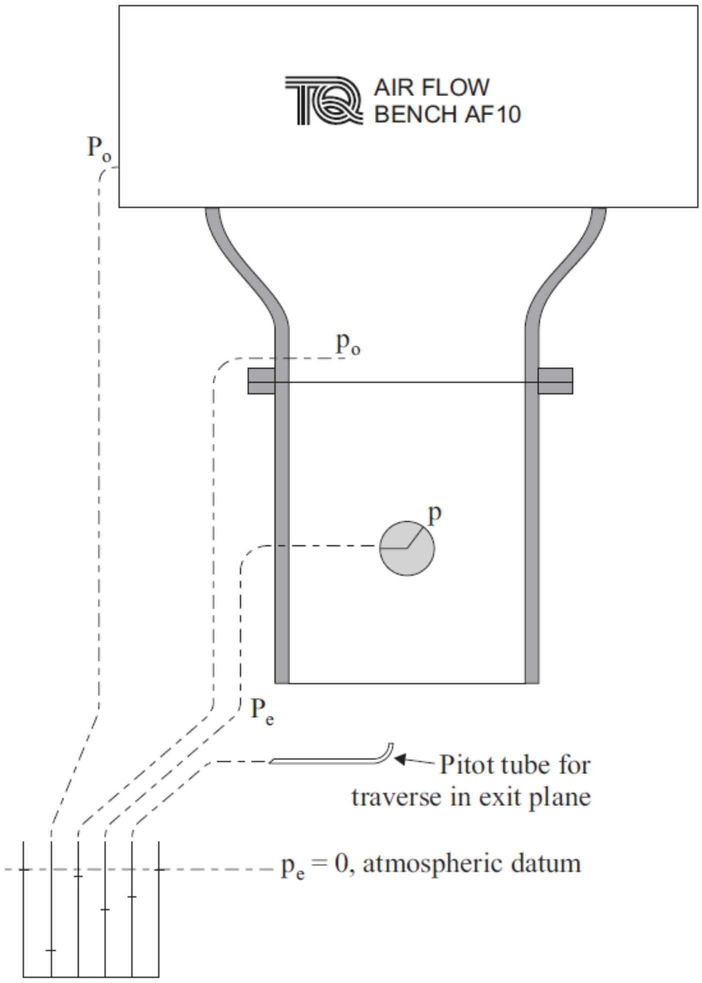


Figure 2 Pressure Tappings

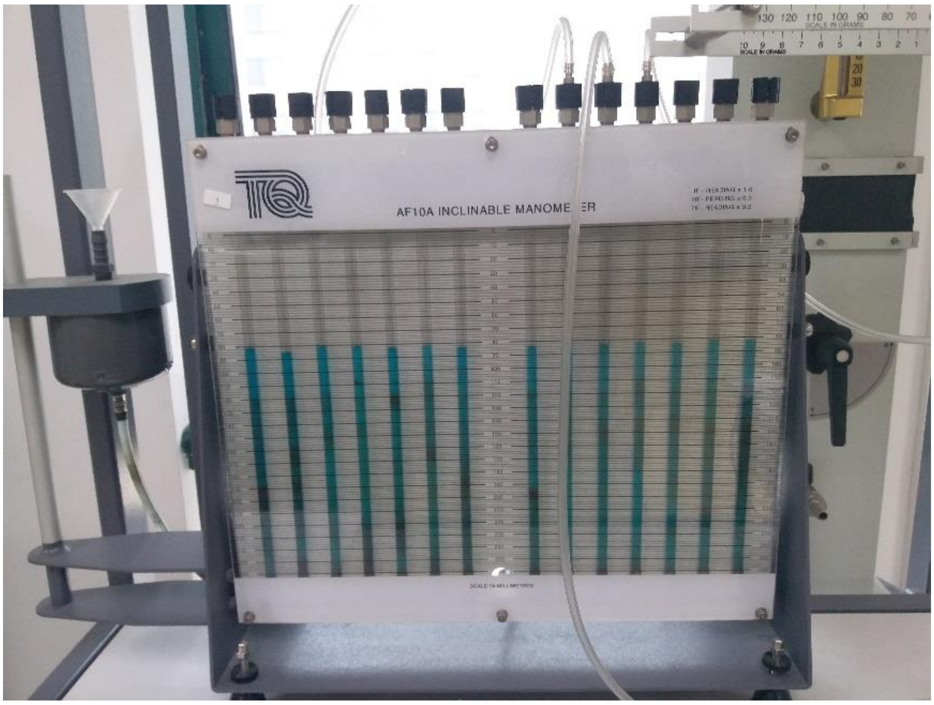


Figure 3a AF10 Inclinable Multitube Manometer

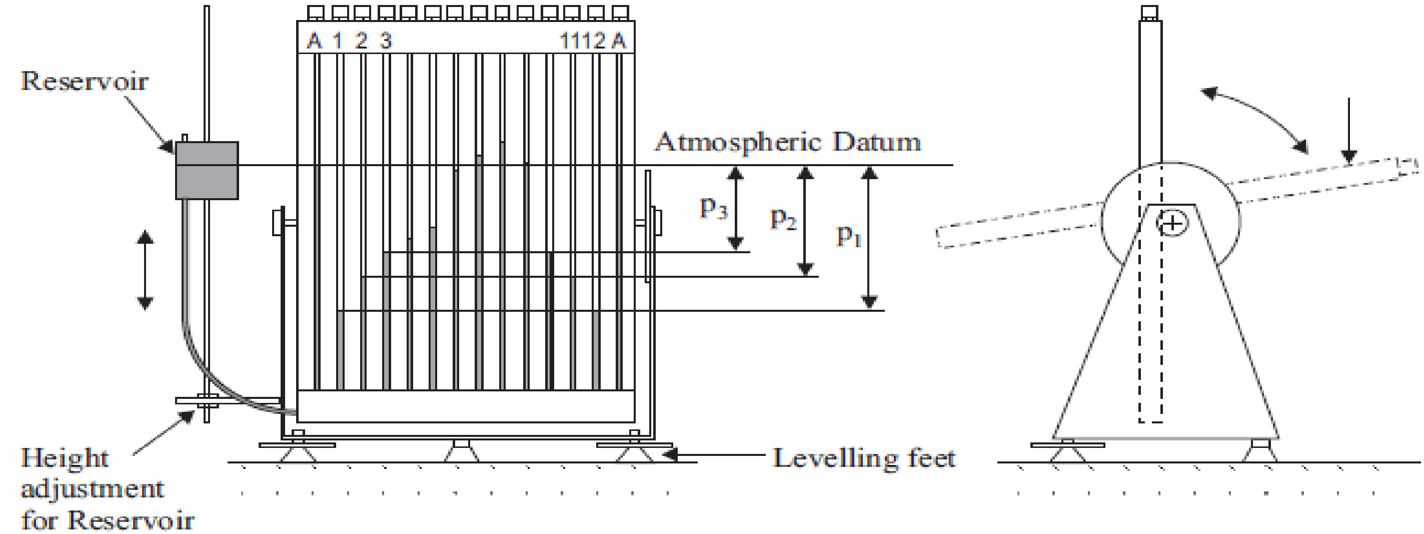


Figure 3b Schematic of the AF10 Inclinable Multitube Manometer

The reservoir of the manometer liquid is mounted on a vertical rod so it maybe set at a conveninet height (See Figure 3b). The manometer tubes at the sides marked A and B and reservoir connection be normally left exposed to the atmosphere. Pressures p1, p2, p3 in tubes 1,2,3 are the guage pressures measured relative to an atmospheric datum.

Experimental Procedure

a) Ensure the retaining screw is to the left of the cylinder.

b) Ensure the Pitot tube is vertical and aligned at the centre position on the scale (NB you must line up front and back scales for each reading). Lightly tighten the Pitot tube clamp screw (See Figure 4a and b).

c) Switch on the fan and open the valve so that you have a pressure difference of about 40-45 mm of water between total pressure (P_o or P_T) and atmosphere (any of the open columns).

d) Record the manometer reading for total pressure (P_o or P_T) and working section static pressure (p_o or p_s) along with any observations of the measurement.

e) Traverse the Pitot tube from zero to 50mm starting with increments of 2mm (you may use increments of 2mm near the centre, increasing to 5mm or 10mm in regions where the total pressure is seen to be substantially constant).

f) At each point record the scale reading for the Pitot tube and for one of the open tubes.

g) Please note that the liquid level in the open tubes is simply a datum point. You cannot calculate atmospheric pressure from this number.

h) Traverse the pitot tube from zero to minus 50mm taking enough points to establish whether the profile is symmetric (you will need far fewer points if there is symmetry)

i) Switch off the fan after the experiment.

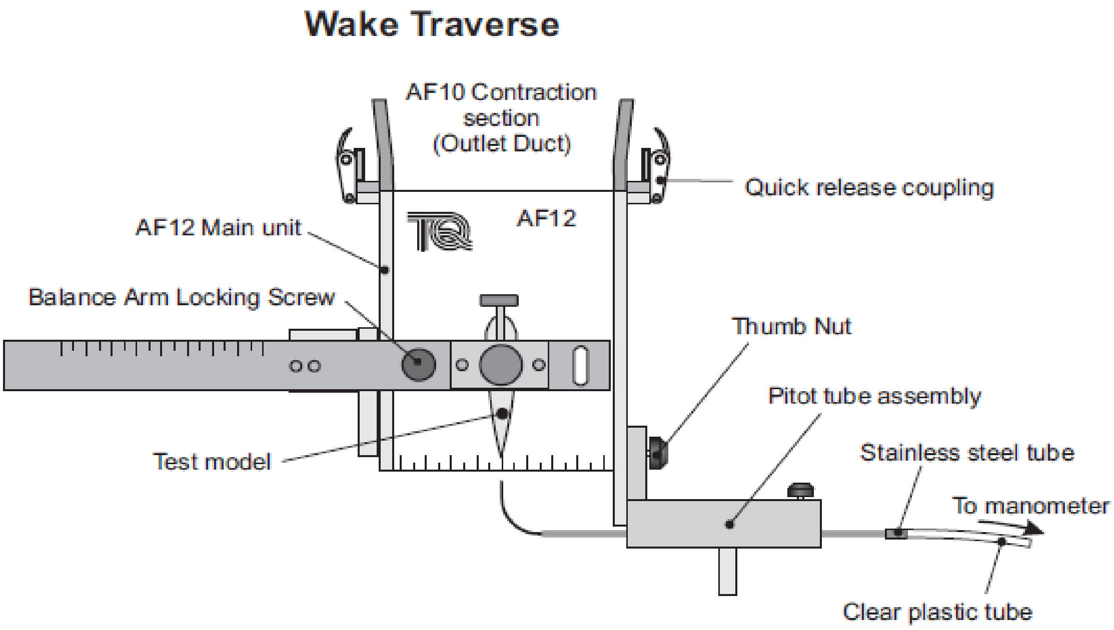


Figure 4a Schematic of Pitot Tube Assembly

Figure 4b Image of Pitot Tube Assembly

Task 1: Experimental Data Tables

1. Provide table of results for both experimental and derived data. Use Tables 1 and 2 as guide.

Table 1 Wake Traverse Measurement Data

Pitot Position(mm)	$\frac{l}{d}$	Pitot Pressure(mmH$_2$O)	Static Pressure(mmH$_2$O)	ΔP	Velocity(m/s)	$\frac{U_2}{U_1}\left(1-\frac{U_2}{U_1}\right)$

Table 2 Experimental Condition			
Parameter	**Value**	**Units**	**Comments**
Atmospheric Pressure			
Air Temperature			
Manometer reference reading point			
Cylinder dimensions			

Task 2: Calculations

1. Determine the free stream velocity. The velocity is determined by, $U = \sqrt{\frac{2g\Delta P}{\rho}}$
2. Plot $\frac{U_2}{U_1}\left(1 - \frac{U_2}{U_1}\right)$ against $\frac{l}{d}$ and determining the area under the curve using the trapezoidal rule. This determines the drag coefficient (C_D).
3. Compare the drag coefficient obtained by
   i. Plotting $\frac{U_2}{U_1}\left(1 - \frac{U_2}{U_1}\right)$ against $\frac{l}{d}$
   ii. Using $C_D = 2\int_{-l/d}^{l/d}\left(\frac{U_2}{U_1}\left(1 - \frac{U_2}{U_1}\right)\right) d\,\frac{l}{d}$
4. Calculate the uncertainty in the measurement of the pressure and velocity

Where,

- C_D=drag coefficient (force)
- d= diameter of cylinder (12.5mm) (See Figure 5)
- l= length of the Pitot Traverse (Pitot Position) (mm)
- $P_o or P_T$ = Total pressure (Pa)
- $p_o or p_s$ = Static pressure (Pa)
- U = velocity (m/s)
- ρ = density (kg/m^3)

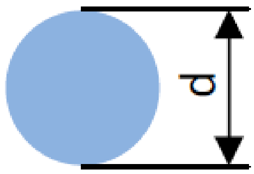
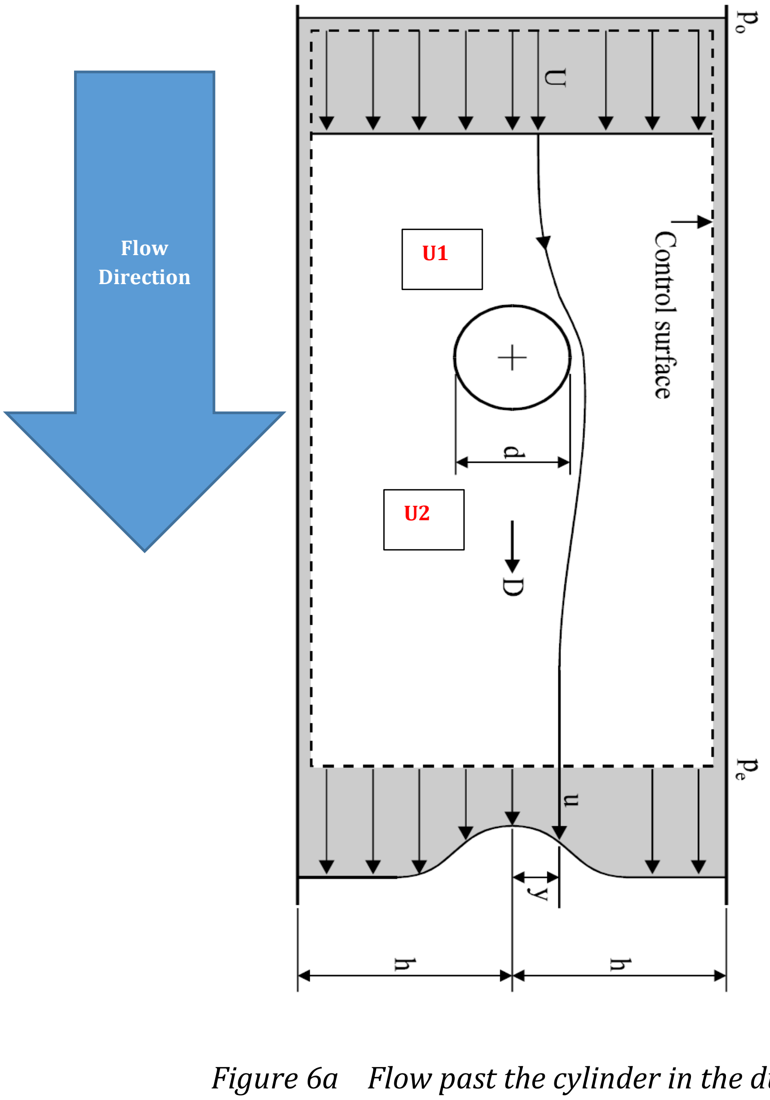


Figure 5 Diameter of Cylinder

Guidance on Determining U_1 and U_2

For U_1 and U_2 consider the Figures 6a and 6b below:



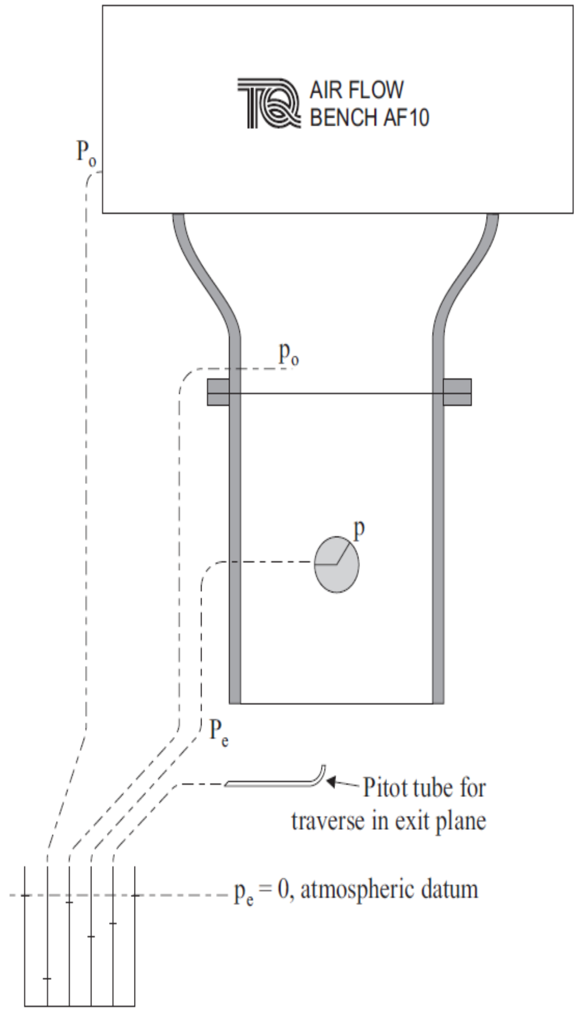


Figure 6a Flow past the cylinder in the duct *6b) Pressure Tappings*

- *Since you are calculating the values of the drag coefficient from the wake traverse, you will need to take the effects of the duct into consideration.*
- ***U_1 is the free stream velocity*** *(the area outside the wake of the cylinder).*
- *You can determine U_1 from the constant pressure difference away from the centre line of the cylinder.*
- *The free stream flow region can also be identified as the stable region in the data you collected. In this case you can have:*

$$U_1 = \sqrt{\frac{2g(P_e - p_e)}{\rho}}$$

As shown in Figure 6b.

- *P_e= average static pressure*
- *p_e=pressure across the downstream section*

So in your data the values of P_e and p_e occur where the total pressure is seen to be substantially constant.

Discussions & Conclusions

1. In not more than 300 words compare and discuss the two drag coefficients obtained by calculation and the graphical plot.
2. In not more than 300 words comment on the plot $\frac{U_2}{U_1}\left(1 - \frac{U_2}{U_1}\right)$ against $\frac{l}{d}$.
3. In not more than 300 words discuss any possible sources of errors in your results and how they could be corrected.
4. Provide concluding remarks for your investigations.

Assessment criteria

- Results (Task 1 and 2) 50%
- Discussions & Conclusions 30%
- Communication & Presentation 20%

References

- Markland, E (2011) A First Course in Airflow: Drag Measurement on Cylindrical Bodies. TecQuipment.EM/PE/djb/0511
- Smith, Roger K. (2008) Introductory Lectures on Fluid Dynamics. Version: June 13, 2008
- Rathakrishnan, Ethirajan. Theoretical Aerodynamics, edited by Ethirajan Rathakrishnan, John Wiley & Sons, Incorporated, 2013. ProQuest Ebook Central. Created from unnc-ebooks on 2017-02-28 21:13:26.
- FLANDRO, Gary A., Howard M. McMahon and Robert L. Roach. (2012) Basic Aerodynamics - Incompressible Flow. Cambridge: Cambridge University Press.