Pressure tubes velocimetry

key words: Dynamic, static and stagnation pressure, Bernoulli equation, water manometer, Pitot and Prandtl tubs.
goals: The objective of this exercise is to gain knowledge in velocimetry methods employing pressure tubes. Velocity and angular characteristics of pressure tube will be investigated.

1 Introduction

Reassure tubes are simple instruments used for local velocity measurements of the flow. By measuring static and stagnation pressure one might calculate flow velocity by employing the Bernoulli equation. For incompressible flow it takes the following form:

$$\frac{{V_A}^2}{2} + \frac{p}{\varrho} = \frac{p_0}{\varrho}$$

where: V - flow velocity, p,ϱ pressure and density, p_0 - total or stagnation pressure. (pressure achieved when the flow comes to a stop.) Modification of the Bernoulli equation yields the expression for velocity:

$$V_A = \sqrt{\frac{2(p_0 - p)}{\varrho}}$$

The Difference $\triangle p = p_0 - p$ is often referred to as dynamic pressure.

For an incompressible flows (e.g. water measurements) density might be found in appropriate scientific tables. For compressible flows density should be calculated using the equation of state.

$$\varrho = \frac{p}{RT}$$

where: T stands for temperature in Kelvins and R is a gas constant.

In case of gas flow the governing equation must be modified as to consider the compressibility effect. The equation of the following form is used:

$$\frac{{V_A}^2}{2} + \frac{\kappa}{\kappa - 1}\frac{p}{\varrho} = \frac{\kappa}{\kappa - 1}\frac{p_0}{\varrho}$$

Where κ is a heat capacity ratio (adiabatic index or ratio of specific heats).

Neglecting the compressibility effects might leads to measurement errors. For Mach numbers below 0.2 the error fall below 0.5%, while at M=0.4 it is around 2% and 12% for Mach number M=1.

2 Pressure tubes

Pressure tubes can be used to measure stagnation (total pressure), static pressure or both. Figure 1 shows a sketch of a tube capable of both stagnation and static pressure measurements (Static Pitot tube or Prandtl tube).

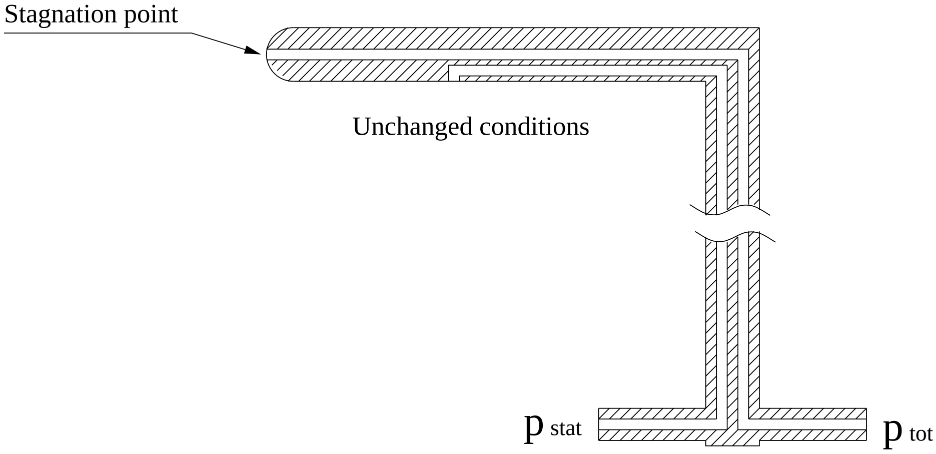

Figure 1: Sketch of a static Pitot tube.

3 Velocity characteristic

To find the velocity characteristics of the pressure tube an incompressible flow will be considered. The tube will be placed measurement space of an open wind tunnel. The flow speed will be measured with the pressure tube and a reference anemometer. Figure 2 illustrates the experiment.

3.1 what to do

1. Note the atmospheric pressure p_a and ambient temperature t_a. Calculate density. (Assume $R = 287\frac{m^2}{s^2K}$).
2. Calculate the Reynolds number for maximum and minimum velocity. ($Re = \frac{VD}{\nu}$ D tube diameter, ν kinematic viscosity)
3. Set the flow velocity at 20m/s, note the values of pressures and velocity.
4. Repeat previous point while decreasing the velocity of the flow.
5. For each measurement calculate dynamic pressure, velocity (from dynamic pressure) and error as compared to the reference anemometer.

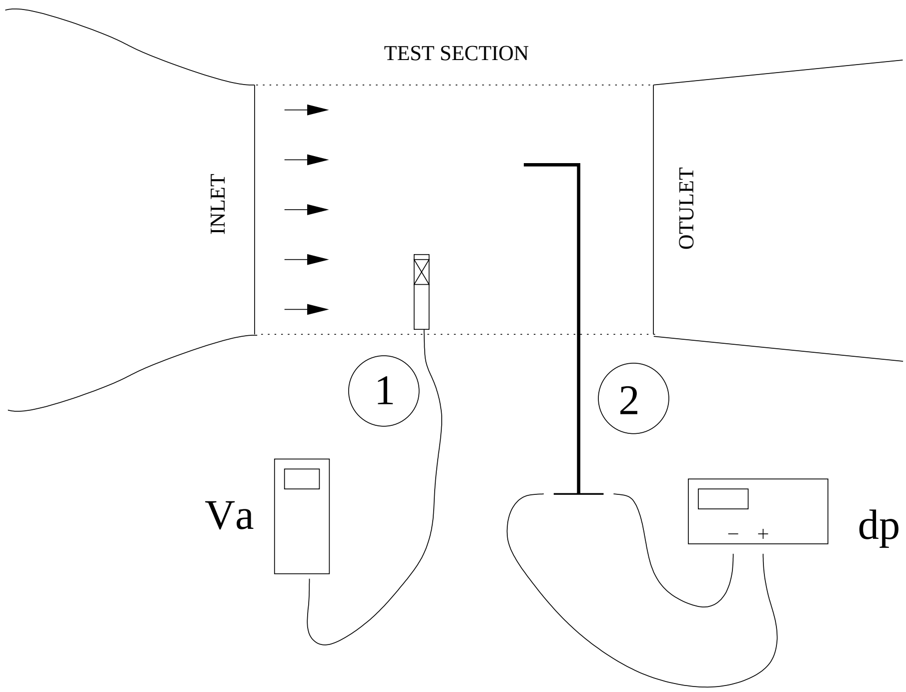

Figure 2: Experimental set-up used for velocity characteristic measurements. 1 - reference anemometer, 2 - Prandtl tube.

6. Prepare an appropriate rapport.

4 Angular characteristic

Angular characteristic will be investigated at a constant flow velocity. Measurements will be performed at different angles. Figure 3 illustrates the experimental set up.

4.1 what to do

1. Set proper flow velocity.
2. Do pressure measurements for different angular alignments.
3. For each measurement calculate dynamic pressure, velocity (from dynamic pressure) and error as compared initial measurements.
4. Prepare an appropriate rapport.

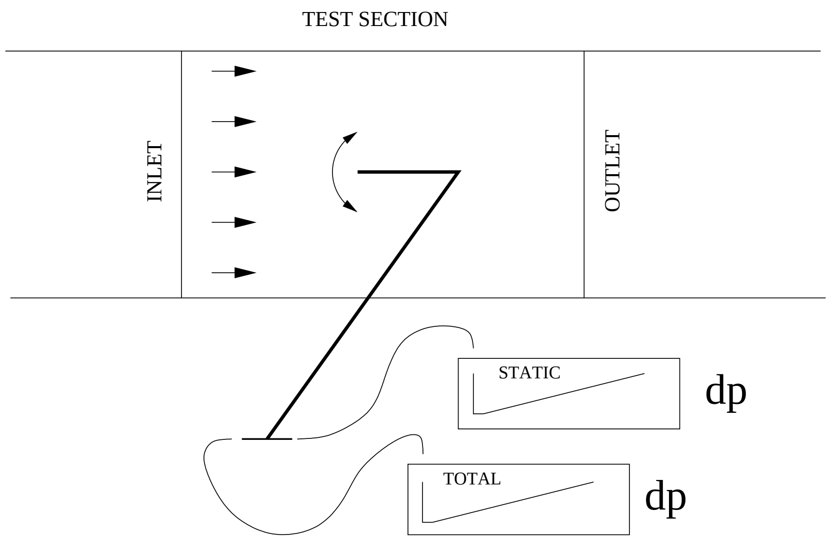

Figure 3: Experimental set-up used to measure angle characteristic.