Thermo-anemometry - Hot-Wire Technique

key words: Constant temperature thermo-anemometry, Kings curve, convective heat transfer
goals: The objective of this exercise is to gain knowledge of velocimetry methods employing electro elements. Calibration of the device will be performed, velocity and angular characteristics of thermo-anemometer will be investigated.

1 Introduction

Thermo-anemometry technique is used to measure **instantaneous velocity** of a turbulent flow. It employs the fact that electrical resistance varies with the change in temperature. The main element of a thermo-anemometer is thin wire (1-5 μm) made of material with large resistance temperature dependence (e.g.. Platinum, Tungsten).

In general a heated element (a thin electrically heated wire) surrounded by the fluid will experience heat transfer to the surrounding. Energy exchange mechanisms are the **free convection**, **forced convection** and **radiation**. In case of a stationary fluid free convection would play the main role. As the velocity of the flow increases forced convection would dominate. The influence of radiation is eliminated by relatively low working temperature (below 200 °C) of the instrument.

2 Constance Temperature Anemometer

In this type of an anemometer the wire is kept at almost constant temperature ($T_w = const$), independent of the flow velocity. It is achieved through feedback loop of the electrical elements. With proper calibration high sensitivity of the probe might be achieved. Figure 1 shows schematics of the experimental setup used to calibrate the thermal probe.

For constant temperature anemometer the voltage drop due to the wire resistance and the flow velocity are related through the so called **King's equation**. It has the following form:

$$E^2 = E_0^2 + BV^n or V = \sqrt[n]{\frac{E^2 - E_0^2}{B}}$$

where:

E - voltage drop,

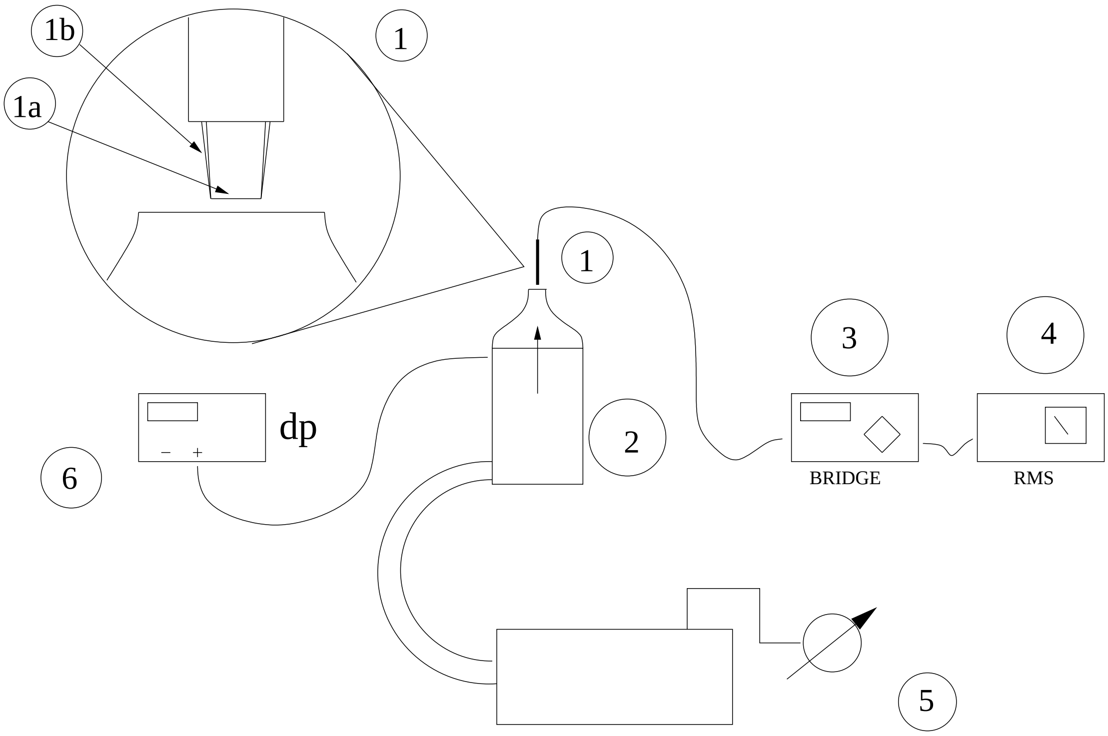

Figure 1: Experimental set-up. 1 - probe, 1a - wire, 1b - supports, 2 - wind tunnel , 3 - bridge, 4 - RMS voltmeter, 5 - flow control, 6 - manometer.

V - the flow velocity,

E_0 - voltage drop for stationary flow (V$\sim$0)

B, n - calibration parameters, assumed to be constant.

3 Velocity characteristics and calibration

1. Note the ambient pressure and temperature.
2. Perform around 15 measurements of the voltage drop at different speeds.
3. Plot the Kings curve with the measured values.
4. Plot $log(E^2 - E_0^2) = f(V)$ and determine n, and B parameters.
5. Using the King's equation calculate velocity for each measurement, plot the $V_{term} = f(V)$.
6. Estimate and plot the error according to the formula: $Er = \frac{V_{term}-V}{V}$

4 Angular characteristics

1. Note the ambient pressure and temperature.

2. For a chosen velocity perform measurements of the voltage drop changing the probe alignment.

3. Using the King's equation calculate velocity for each measurement, plot the $V_{term} = f(\alpha)$.

4. Estimate and plot the error according to the formula: $Er = \frac{V_{term} - V}{V}$