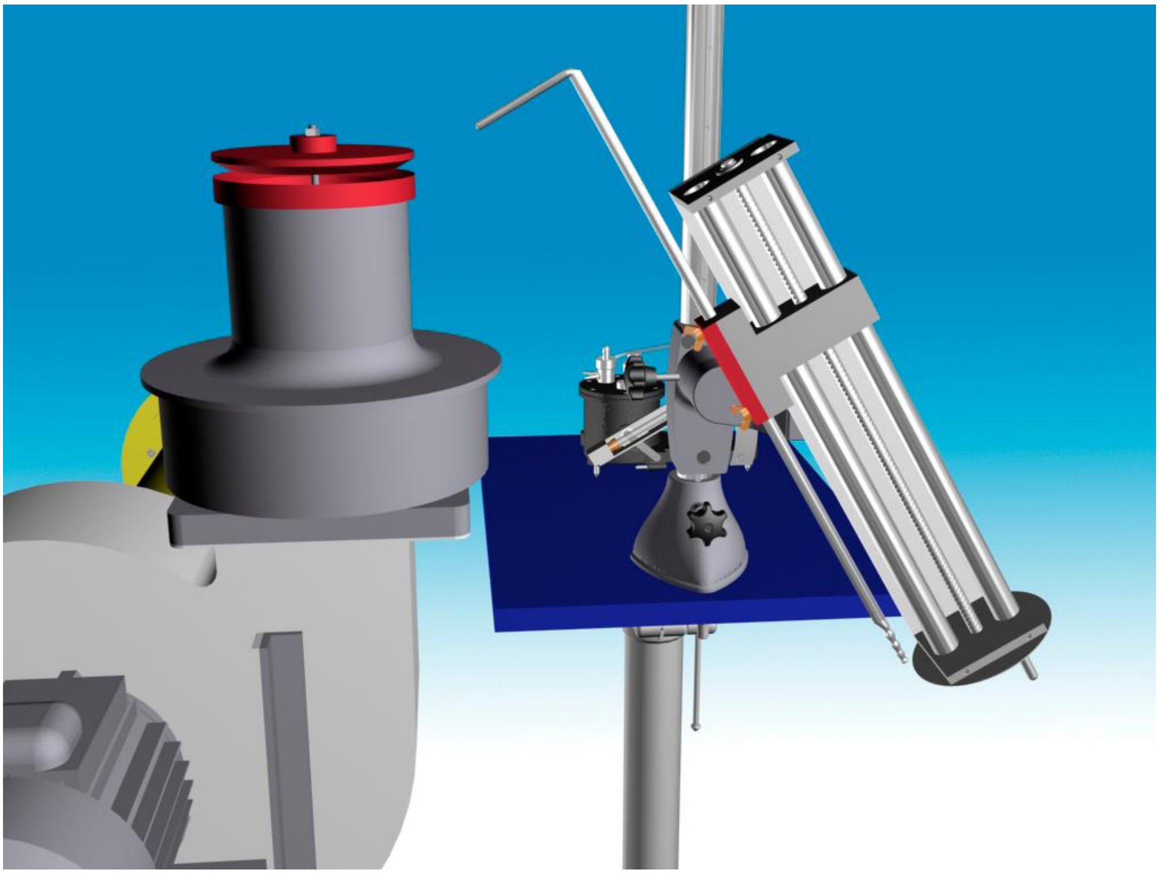


M5

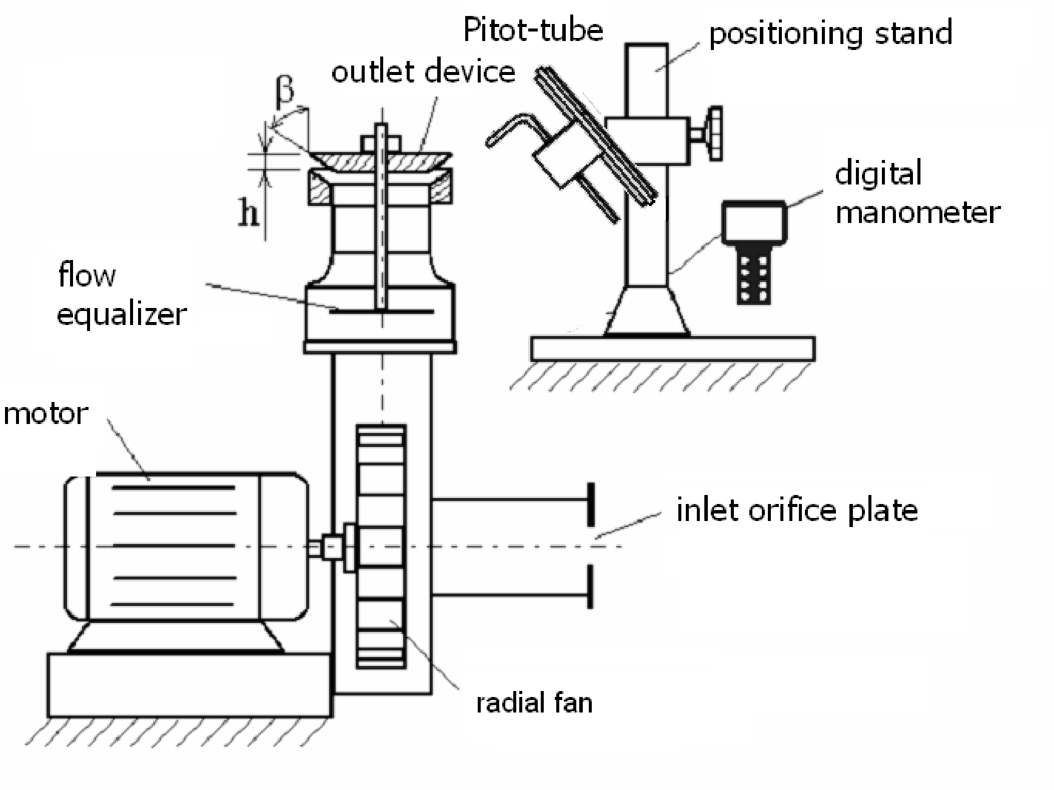
Analysis of a radial jet

1. The aim and practical aspects of the measurement

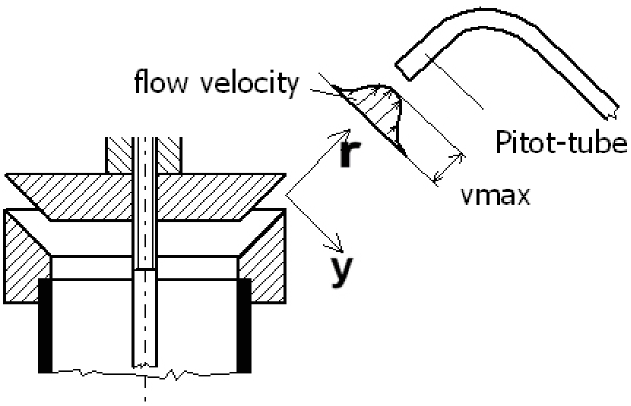
In ventilation systems radial free jets are often used for low-speed air introduction. In radial jets, just like in round jets, the velocity of the flow reaches its maximum value in the plane of symmetry. As we are getting farther from the air-outlet section the maximum value of the flow velocity is decreasing, while the jet is getting wider. The aim of the measurement is to get to know the properties of a radial jet by measuring its flow-field.

2. Description of the measurement

With the help of a radial fan, the air is sucked in through the inlet orifice plate and is let out in the form of a radial jet through the air outlet device, shown is Figure 1. At the air outlet four different types of nozzles can be used, where the angle β between the jet and the symmetry plane can take the values: β=30°, 45°, 60°or 90°. The opening of the nozzle (*h*) can be varied between h_{min} = 1mm and h_{max} = 4mm. Greater openings are not suggested, because it will cause an asymmetric flow pattern already in the outlet cross-section and the axis of the jet will greatly deviate from the geometrical axis given by β. The task is to measure the velocity field of the radial jet at **one** magnitude of *h* nozzle height and **one** angle of β.
The velocity of the air outflow is measured by a Pitot-tube and a digital manometer. The Pitot-tube can be positioned arbitrarily with the help of an adjustable stand.
The fan sucks air from the surroundings. The flow rate is measured on the suction side by an inlet orifice plate.



1. Figure: Sketch of the measurement



2. Figure: Sketch of the coordinate-system

3. Principles of the measurement

According to the shape of the outlet device the jet is either plane or truncated cone-shaped, the streamlines are approximately parallel. As we move farther from the outlet orifice in the direction of *r*, v_{max} (the maximum velocity at a given *r*=const. cross-section) is getting smaller, while the q_v, volume flow rate of the air flowing in the free jet, is getting larger.
In free jets the static pressure is more or less the same as the atmospheric pressure, therefore the total pressure (p_t) measured by the Pitot-tube minus the atmospheric pressure (p_0) gives us the dynamic pressure (p_{din}) in the jet. From this the velocity of the flow at a given point can be calculated:

$$v_i = \sqrt{\frac{2}{\rho} p_{din,i}}$$

4. Measurement procedure

a./ Measuring the flow rate with the help of an inlet orifice plate.

b./ Moving the Pitot-tube along the outflow cross-section by 90° we measure the pressure in 4 different points along the circumference and we check whether the flow is symmetric or not. Supposing that the velocity distribution in the cross-section of the outflow is even, the outflow rate can be determined from the 4 measurement points and can be compared to the inflow rate. Because of continuity these flow rates should be more or less the same, before further measurements it should be checked.

c./ The Pitot-tube is held by a positioning stand. One rotation of the handle means a 1mm change in the *y* direction, so the velocity profile at an *r*=const. cross-section can be measured.

At least 10 velocity profiles should be measured at 5mm intervals, while moving further from the outflow cross-section (*r*=0mm) in the radial direction.

The so called initial section r_{ini} is the initial part of the free jet, when in the symmetry plane the v_0 velocity does not decrease (or it is still at least 95% of the outflow velocity). One task is to measure the length of the initial section, which according to literature values is r_{ini}=(5-6)h.

The measurement has to be planned in a way, that outside the initial section at least 4-5 velocity profiles have to be measured, since the analysis is focused on those profiles.

5. Evaluation of the measurement results

a) Sketch all velocity profiles measured at different *r* values in the same diagram. v*(r,y)*

b) Sketch all dimensionless velocity profiles in the same diagram $v_i/v_{max}=f(y/y_{0.5})$, where v_i is the velocity of a given point of a profile, v_{max} is the maximum velocity in the given profile, *y* is the vertical coordinate and $y_{0.5}$ the vertical coordinate of the point where the velocity is reduced to half of its maximum value.

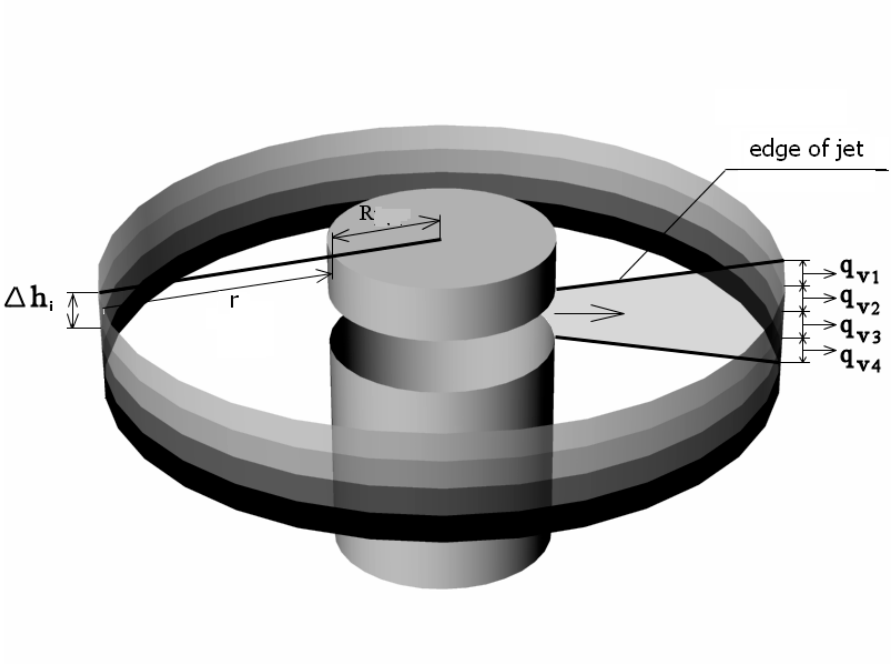
c) Sketch the maximum velocities of every velocity profile in the function of *r*. v(*r*)

d) Sketch the flow rate of the flow in the free jet in the function of *r*. $q_v(r)$

At the examined *r*=const. cross-sections the flow rates have to be determined by simple numerical integration.

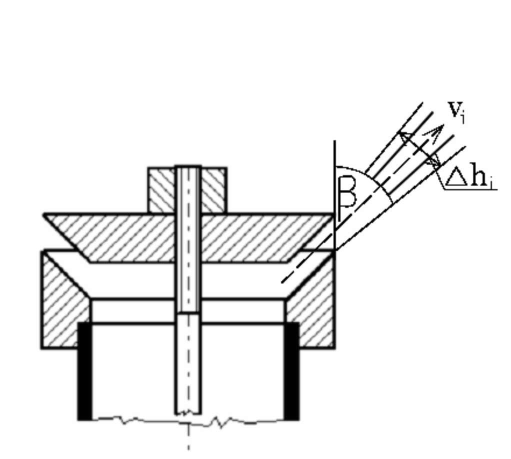
Calculation in the case of : β=90°

The area of the examined cross-section of the free jet is the surface area of a cylinder, which can be calculated as follows: $A_i = 2(R+r)\pi \cdot h_i$, where *R* is the radius of the air outlet device and h_i is the height of the cylinder section at the given profile. Adding up the flow rates $q_{v,i} = A_i \bar{v}_i$ for the whole cylindrical surface at the given profile on gets the flow rate of the free jet at r=const. The flow rate should be calculated at every velocity profile.



3. Figure: Schematic drawing for the understanding of the numerical integration

Numerical integration for β≠90° cases:



4. Figure: Schematic drawing for the understanding of the numerical integration

$$q_v = \sum A_i \bar{v}_i = \sum_{i=1}^{n} 2\left(R + r_i \sin\,\beta\right) \cdot \pi \cdot \Delta h_i \cdot v_i$$

Error calculation

Error calculations should be carried out at all velocity measurement points in one velocity profile, outside of the initial section. For a given point in the given profile you have:

The velocity:

$$v_k = \sqrt{\frac{2 \cdot p_{din,k}}{\rho_{air}}}$$

The absolute error:

$$\delta v_k = \sqrt{\sum_{i=1}^{n}\left(\delta X_i \cdot \frac{\partial v_k}{\partial X_i}\right)^2}$$

The relative error:

$$\frac{\delta v_k}{v_k} = ?$$

where X_i are the measured quantities and δX_i are the related errors:

$X_1=p_0$ $\delta p_0=100$ Pa

$X_2=T_0$ $\delta T_0=1$ K

$X_3=p_{din}$ $\delta p_{dig,man}=2$ Pa

Remember that during the labs:

- Before turning any measurement device on or in general during the lab, make sure that safe working conditions are ensured. The other participants have to be warned of the starting of the machines and of any changes that could endanger the members of the lab.
- The atmospheric pressure and room temperature should be recorded before and after every measurement.
- The measurement units and other important factors (e.g. data sampling frequency, date of calibration) of every recorded value of the applied measurement devices should be recorded.
- Type and construction number of the applied measuring instrument should be included in the final report.
- Checking and harmonizing of the units of the recorded values with those used in further calculations.
- Manometers should be calibrated if necessary.
- The measurement ports of the pressure meter should be carefully connected to the correct pressure ports of the instrument.
- If inlet or outlet tubes are to be assembled with fans, connections should be airtight as escaping/entering air can significantly modify the measurement results.

Bibliography:

Lajos Tamás: Az áramlástan alapjai, Műegyetemi Kiadó, Budapest 2004