Water Rennovation in Ukraine
Project no. 22320101

Water Rennovation in Ukraine

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The project is co-financed by the Governments of the Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.

Water Rennovation in Ukraine
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Mendel
University
in Brno

Practical seminar - Hydraulics

Pavel Zubík, Jaroslav Veselý

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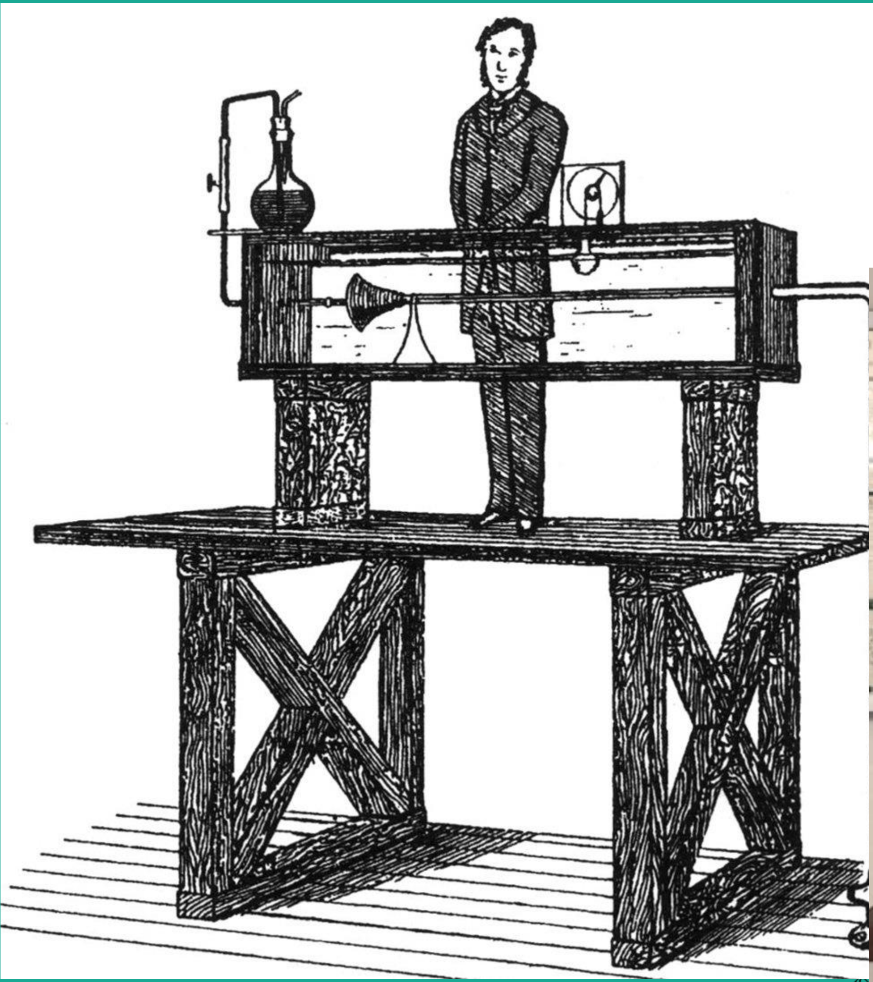
Experimental tasks of the laboratory exercise

1. Reynolds experiment (laminar and turbulent flow)
    - 1.1 Theory
    - 1.2 Experimental task
    - 1.3 Attachments

2. Energy losses in the pipe (local losses and frictional losses along the length)
    - 2.1 Theory
    - 2.2 Experimental task
    - 2.3 Attachments

1. Reynolds experiment (laminar and turbulent flow)

Osborne Reynolds (1842 Belfast – 1912 Watchet)



In 1883 he conducted an experiment with a glass tube into which he let water and colored it.

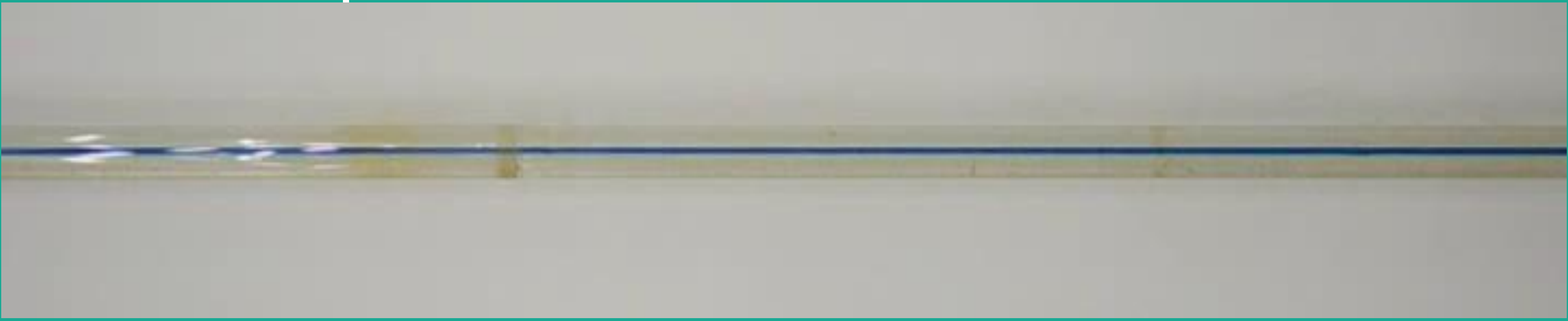
1. Reynolds experiment

1.1 Theory

Laminar flow - the liquid thread moves in a straight line and parallel to the walls, it is continuous and the particles that make it up do not change their position.

Flow in the transition regime - the fiber is continuous, but not straight, but is undulated into irregular undulations.v přechodné oblasti.

Fully turbulent flow - the fiber breaks up and the particles that formed it get into the entire flow profile.



1.2 Experimental task

A view of the workplace

3 vertical tubes:
D_1 = 15 mm;
D_2 = 25 mm;
D_3 = 35 mm.

Measurement procedure

Set the water flow using the valve to the lowest possible constant flow. Adjust the dye discharge from the nozzle with the ball valve so that the flow in the tube is not affected.

Set the highest flow through the tube when it is still possible to consider the flow as laminar, $Re < Re_{kr}$. Determine the water flow rate Q $[m^3/s]$ through the tube using the volumetric method (using a graduated cylinder and stopwatch).

Set the lowest flow through the tube when it is possible to consider the flow as fully turbulent, $Re > Re_{kr}$. Use the volumetric method to determine the water flow Q $[m^3/s]$ through the tube.

Insert the thermometer probe into one graduated cylinder and measure the temperature of the water T [°C] coming out of the tube.

Calculate the cross-sectional velocity of the water in the pipe [m/s] and determine the Reynolds number. Compare the result with the theory.

Check the effect of the inner diameter D [m] of the tubes using the above procedure.

Equations used

Volume flow rate

$$Q = \frac{V}{\Delta t} \qquad \left[m^3 / s\right]$$

Cross-sectional area

$$A = \pi\, r^2 = \pi\, \frac{D^2}{4} \qquad [m^2]$$

Cross-sectional Velocity

$$v = \frac{Q}{A} = \frac{4Q}{\pi\, D^2} \qquad [m / s]$$

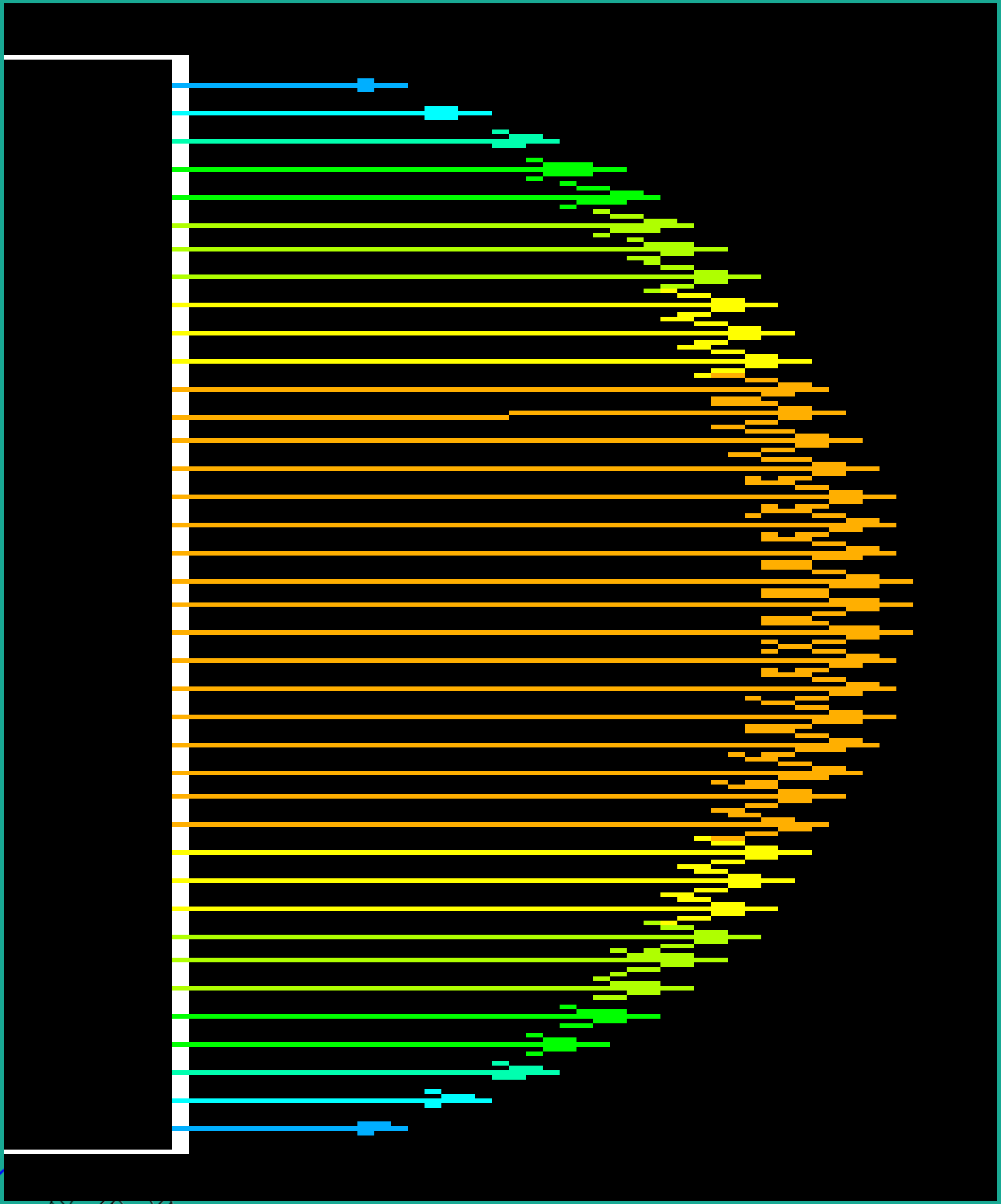
Reynolds number

$$\mathrm{Re} = \frac{v\, D}{\upsilon} \qquad [-]$$

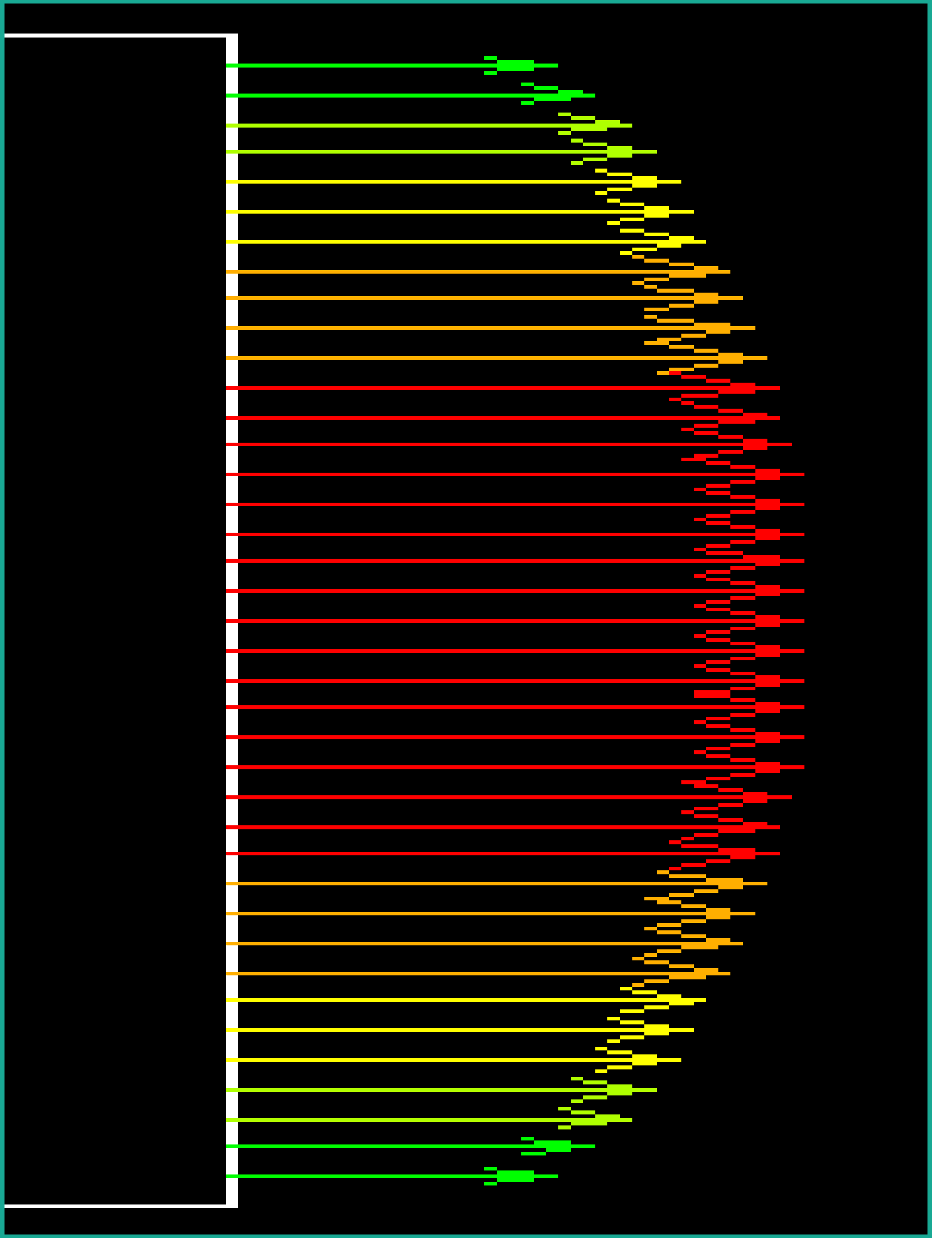
Kinematic viscosity of water

$$\upsilon = \frac{1{,}78 \cdot 10^{-6}}{1 + 0{,}0337 \cdot t + 0{,}000221 \cdot t^2} \quad [m^2 / s]$$

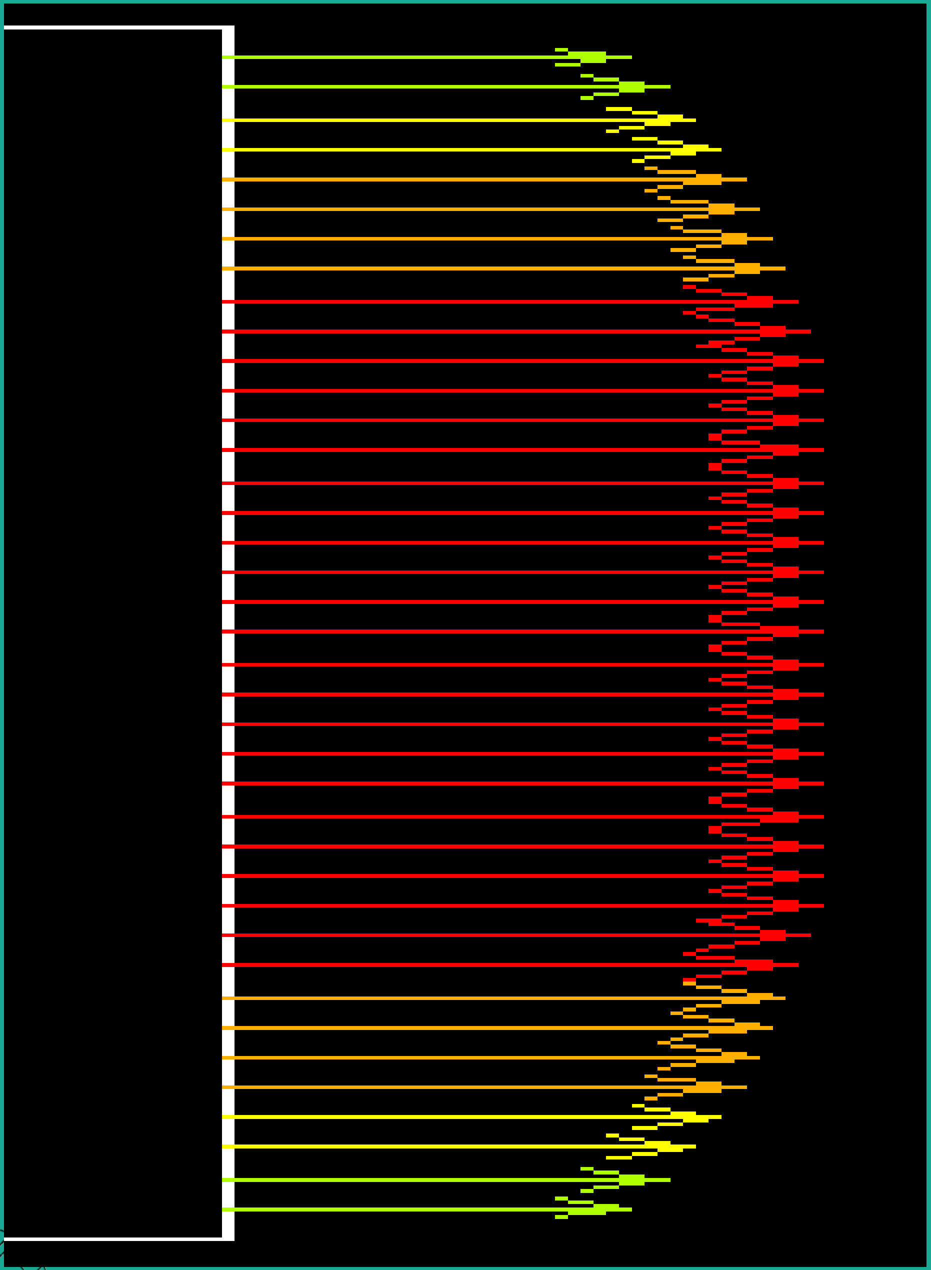
Laminar flow



Transient regime flow



Fully turbulent flow



Energy losses in the pipe

2.1 Theory

When a real liquid flows through a pipe, there is a loss of mechanical energy caused by the internal friction of the liquid and the friction of the liquid against the walls. Mechanical energy is transformed by friction into other energy (heat, acoustic waves, deformation...).

We divide energy losses (expressed by loss height h_z) into two components:

- Friction losses along the length - h_{zt}
- Local losses - h_{zm}

So it is true that:

$$h_z = \sum h_{zt} + \sum h_{zm}$$

Friction losses along the lengt (Darcy-Weisbach equation)

$$h_{zt} = \lambda \frac{L\,v^2}{D\,2\,g}$$

The coefficient of friction losses along the length λ is determined depending on the flow regime:

- Laminar flow –

$$\lambda = \frac{64}{\mathrm{Re}}$$

- Turbulent flow and transient regime flow –

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{2{,}51}{\mathrm{Re}\sqrt{\lambda}} + \frac{k}{3{,}71\,D}\right)$$ (Colebrook-White)

Local losses

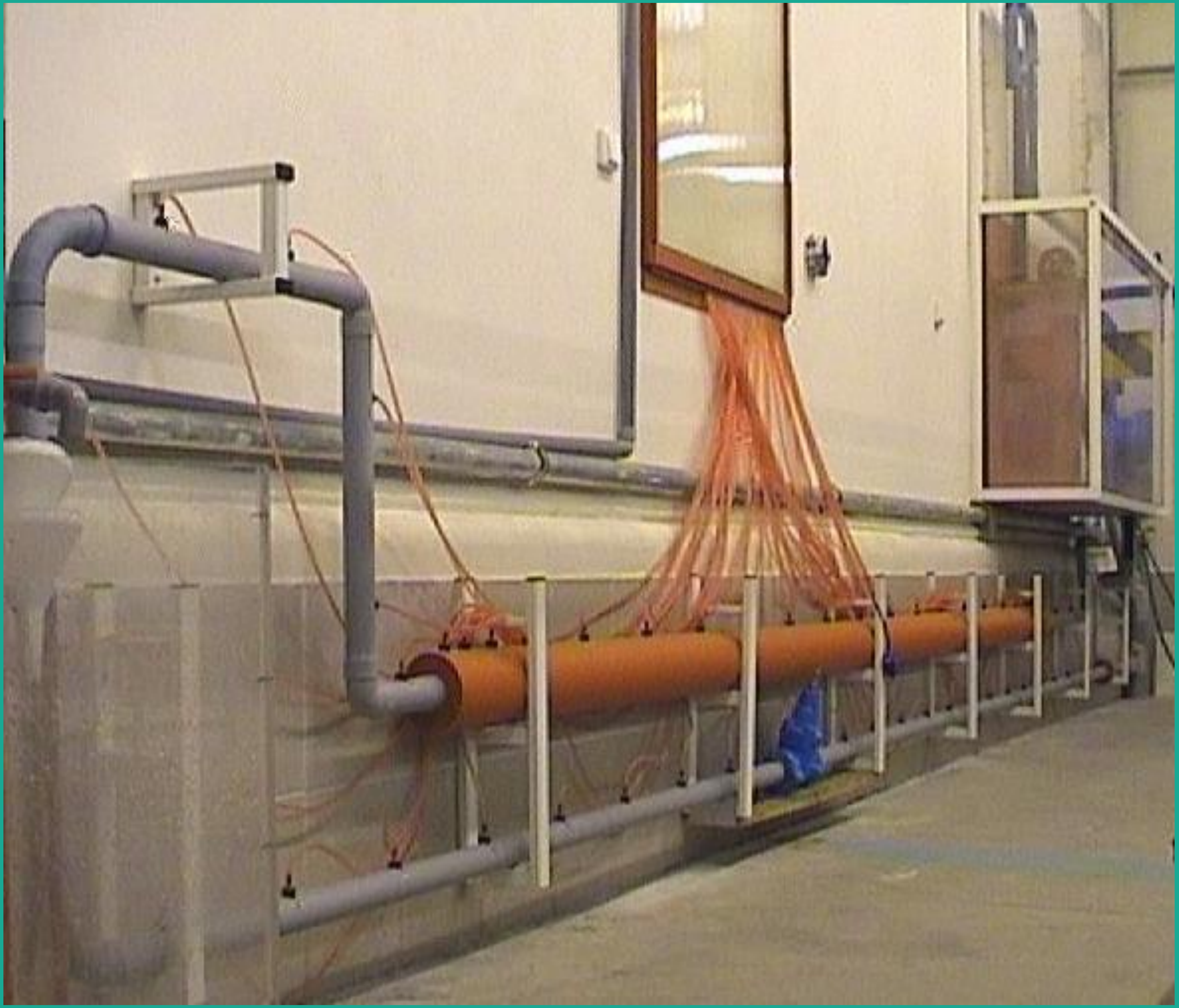
Local losses are characterized by the equation (Weisbach):

$$h_{zm} = \xi \frac{v^2}{2g}$$

The coefficient of local losses ξ depends on the type of losses, the geometry of the element, the roughness and the value of the Reynolds number (i.e. the flow velocity). For $Re > Re_{kr}$ (fully developed turbulent flow), the local loss factor ξ is constant.

2.2 Experimental task

A view of the workplace



Measurement procedure:

A. Friction losses along the lengt

Measure the length of the selected straight pipe section *L*.

Measure the level difference Δh in the piezometers delimiting the selected section.

Calculate the value of the friction loss coefficient along the length λ .

B. Local losses

Measure the level difference Δh in the piezometers bounding the selected elements.

Calculate the value of the local loss factor ξ.

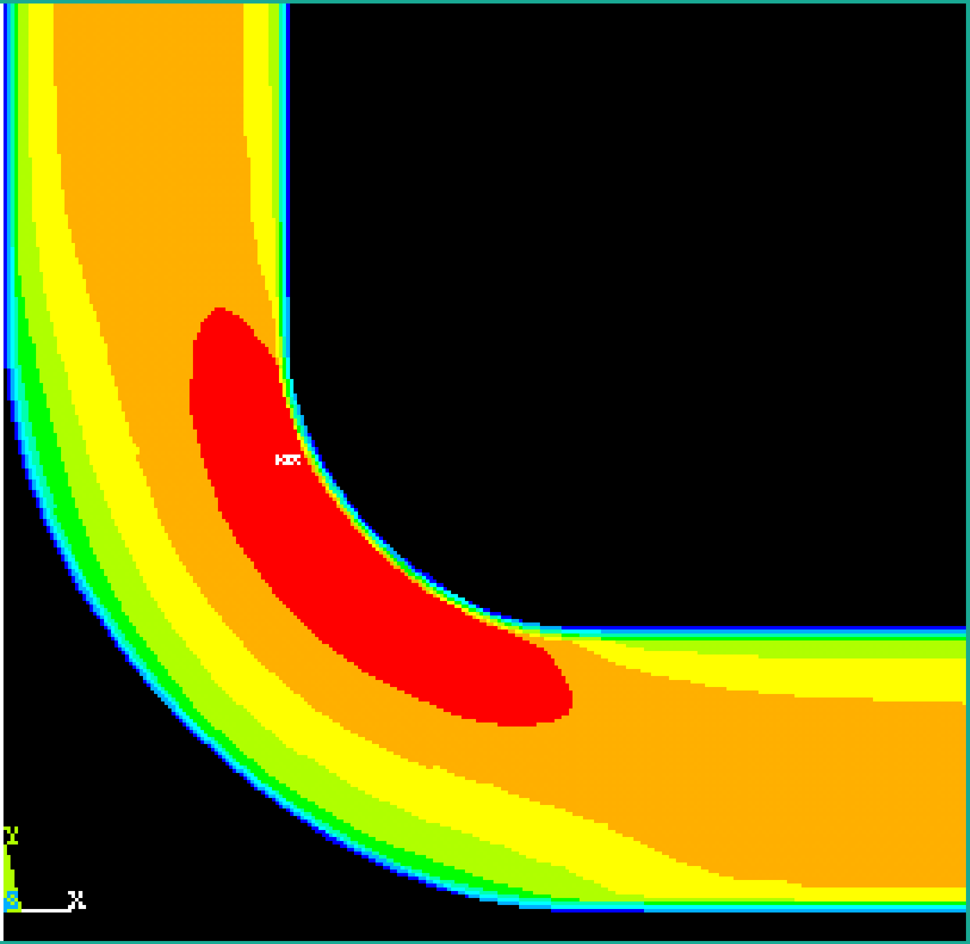
C. Determination of flow rate

From the pressures before and after the measuring orifice, calculate the flow rate Q.

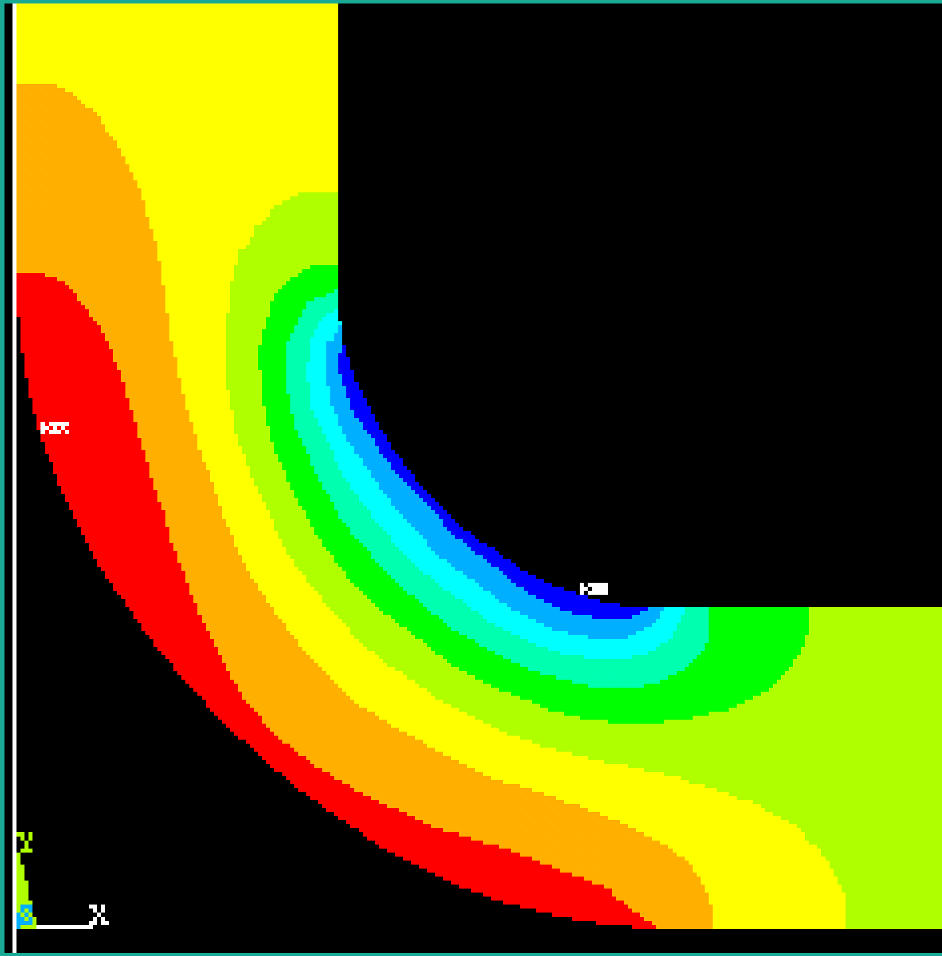
Determine the flow regime in the pipe (Reynolds number).

Flow in the elbow (mathematical model)

Velocitys

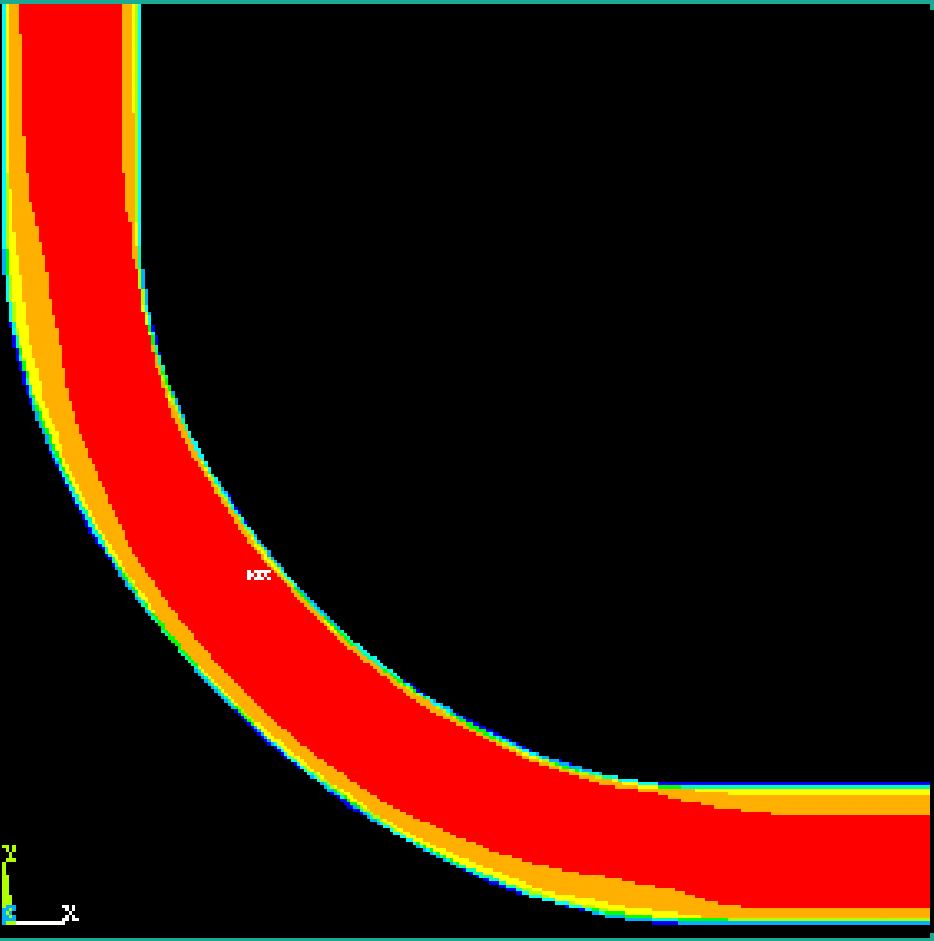


Pressure field

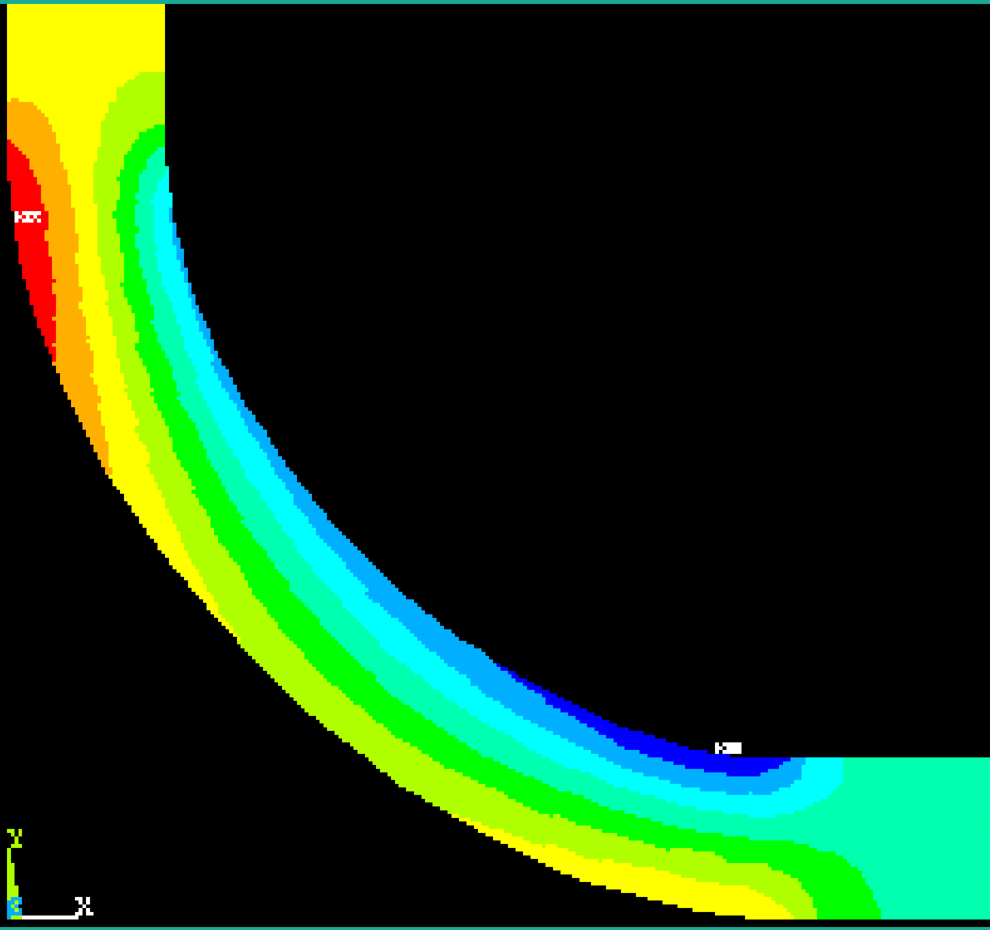


Flow in the Arc (mathematical model)

Velocitys

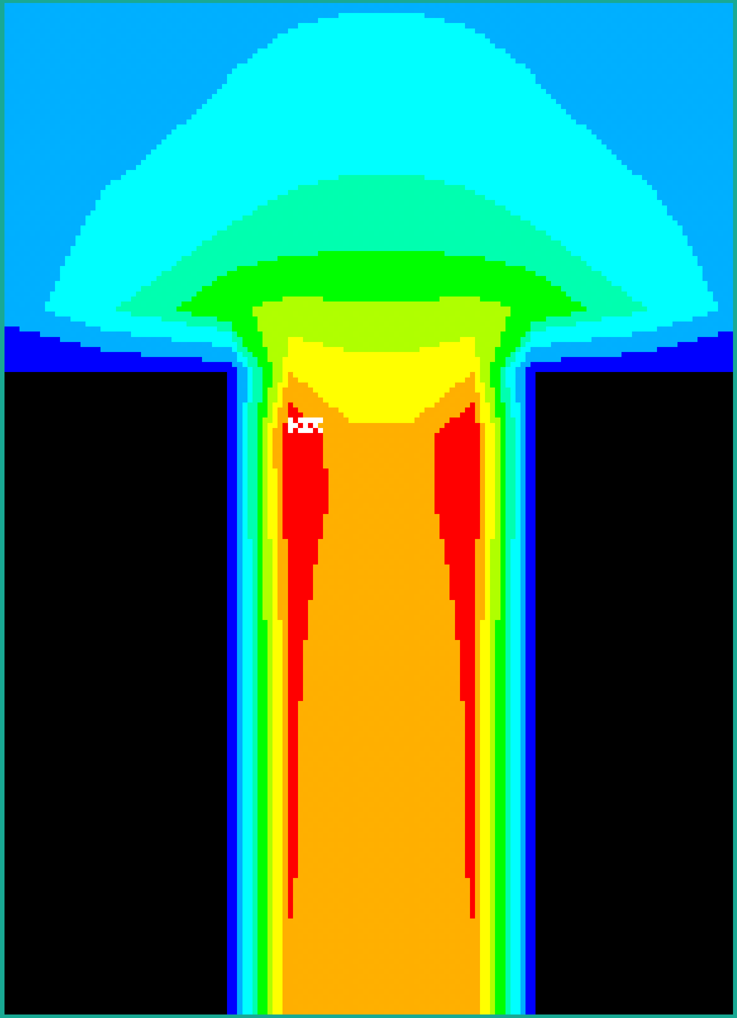


Pressure field



Flow in a constriction (mathematical model)

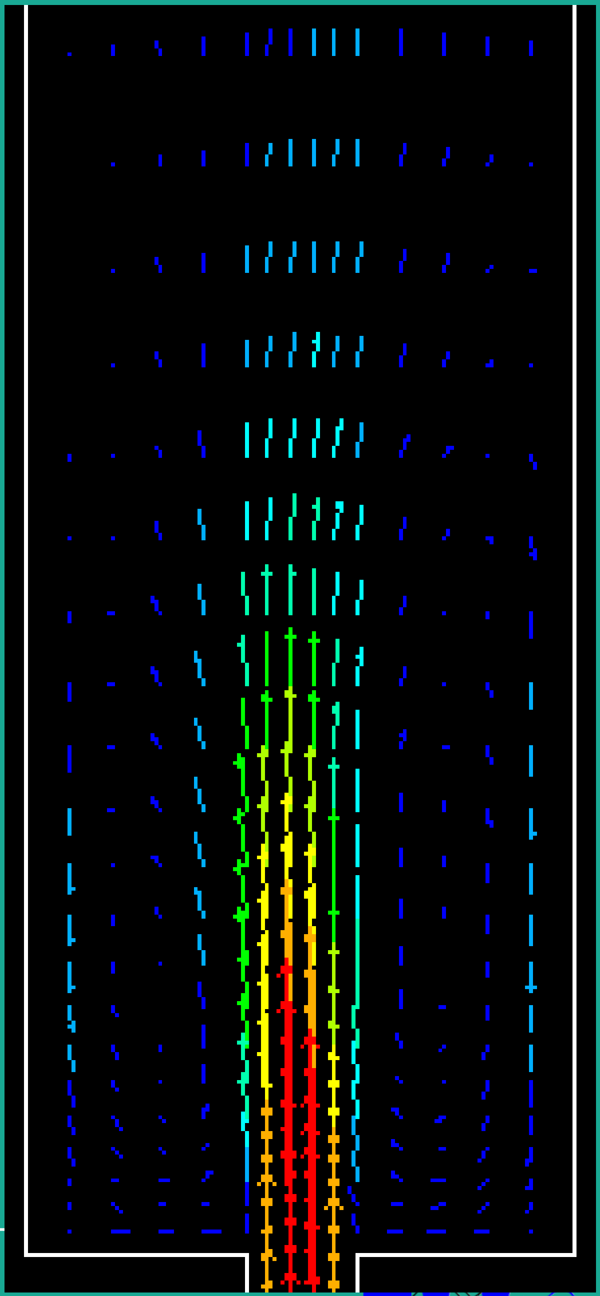
Velocitys



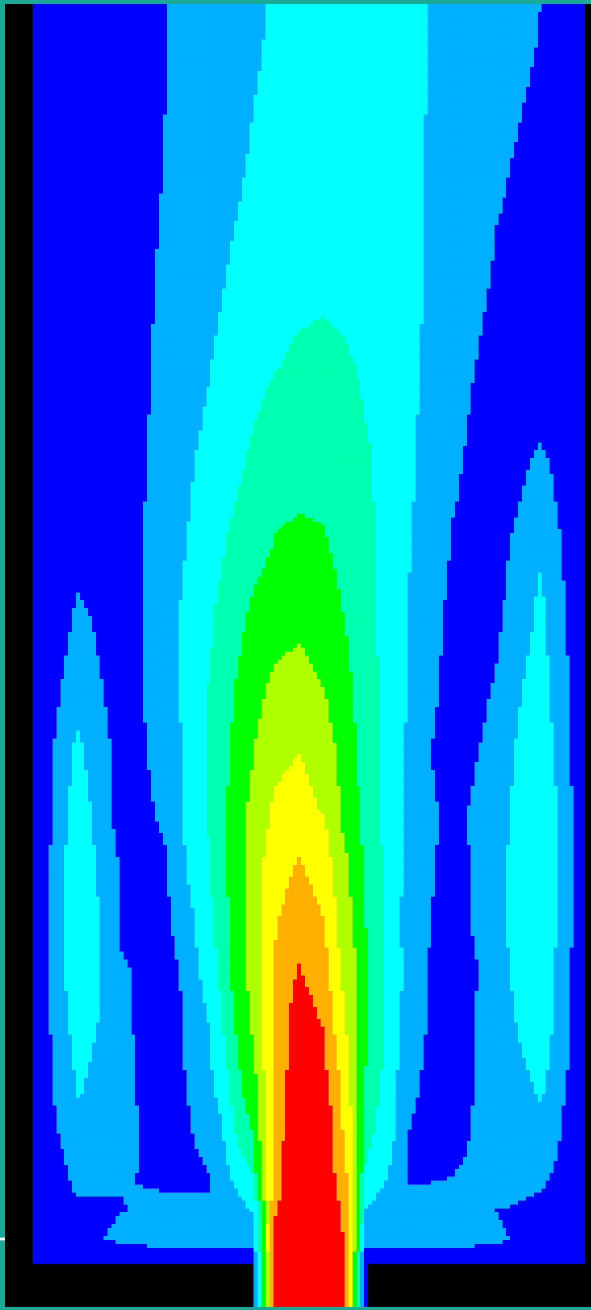
Pressure field

Flow in expansion (mathematical model)

Velocity vectors

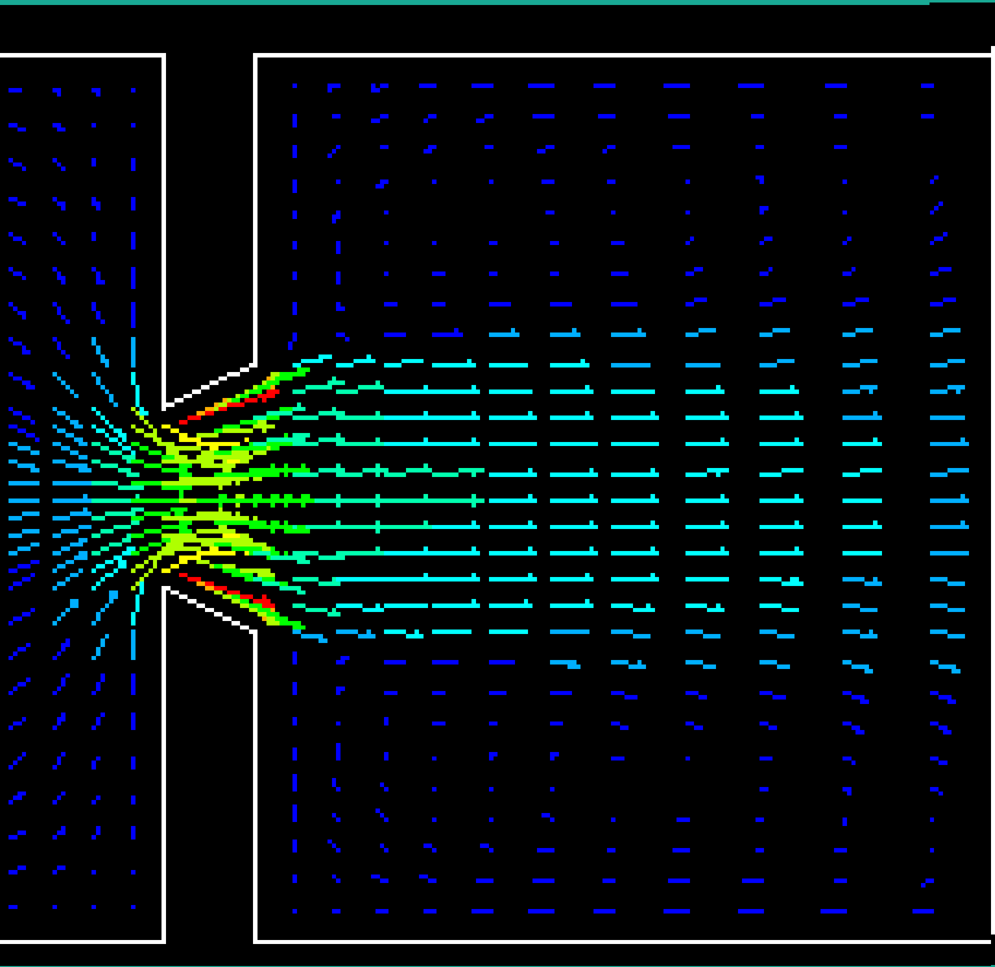


Velocity field



Flow in a measuring orifice (mathematical model)

Velocity vectors



Turbulent kinetic energy