SILESIAN UNIVERSITY OF TECHNOLOGY

FACULTY OF ENERGY AND ENVIRONMENTAL ENGINEERING

INSTITUTE OF POWER ENGINEERING AND TURBOMACHINERY

INSTRUCTION

for laboratory

"Metrology of the energetic quantities"

LABORATORY M-12

The measurement of mass flow and volume - part II

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The objective of laboratory:

The aim of laboratory is to learn the basic techniques to measure of the volume flow in open channels and experimental determination of the characteristics and calibration of measuring instruments.

1. Introduction

Flow control requires a measure of their intensity. It is also an indispensable part of the thermal energy measurement providing the greatest difficulties. The most common are measuring methods that use transmitters:
- Flow damming up,
- Rotary,
- Ultrasonic,
- Magneto-hydro-dynamic,
- Vibration.

Other methods turn out to be less useful for common applications, such as measuring water consumption and heat in the economy existentially - communal. In such cases, the fundamental role played by the following factors:
- Simplicity of design,
- Low cost,
- Reliability in the absence of supervision,
- Recording (integration time)
- Remote readings.
- form of numerical indications,
- Low threshold of insensibility.

Water is the fluid that flows is most often measured. Also in the largest number of positions to check and calibration of flow of the liquid is water.

2. Theoretical knowledge

If, on the horizontal section of stream (1-2), cross-sectional area is decreased from A_1 to A_2, it will also decrease the pressure p_1-p_2 = Δp. These changes are accompanied by energy losses determined by height h_s. Bernoulli equation for a line of stream:

$$\frac{\omega_1^2}{2g}+\frac{p_1}{\gamma}=\frac{\omega_2^2}{2g}+\frac{p_2}{\gamma}+h_s$$

The energy lost relative to the kinetic energy of the stream in the contraction:

$$h_s=\zeta_2\cdot\frac{\omega_2^2}{2g}$$

ζ_2- local loss factor

Using the equation of the stream continuity $A_1 \cdot \omega_1 = A_2 \cdot \omega_2$ and the ratio of $m = A_1 / A_2$:

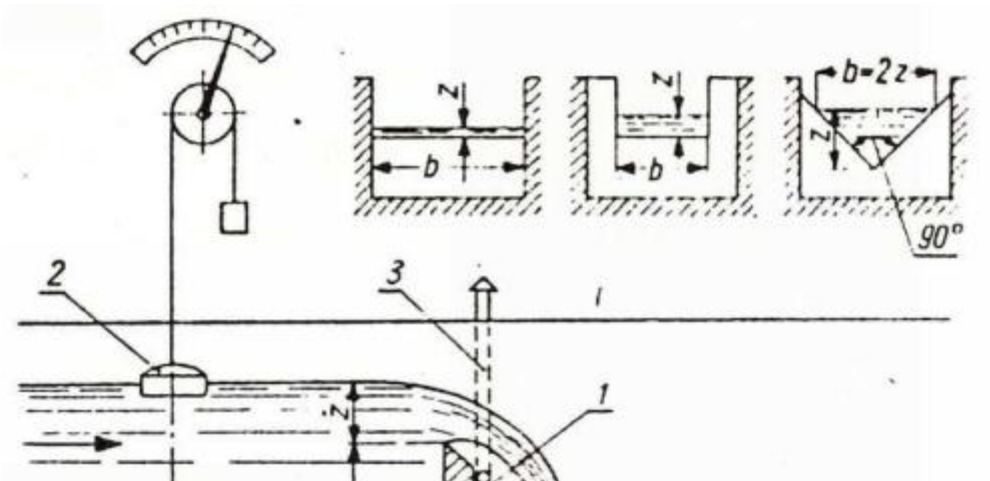
$$\Delta p = \frac{\gamma \cdot \omega_1^2}{2g} \cdot [(1 + \zeta_2) \cdot m^2 - 1]$$

$$\omega_1 = \sqrt{\frac{2g}{(1 + \zeta_2) \cdot m^2 - 1} \cdot \frac{\Delta p}{\gamma}}$$

The volumetric flow rate $q_v = A_1 \cdot \omega_1$

3. Measuring overflows

Measuring overflows are respectively formed baffle (throttle elements) embedded in open channels for measuring the amount of flux flowing through these channels. Throttle element, like in the closed channels, decreases the cross-sectional flow stream and increases the speeds of the liquid in the smaller section. Measurement of the liquid stream is determined by the relationship between the quantity of flow and the amount of accumulation induced by the barrier.



The volume flow:

- For rectangular overflow without lateral stenosis:

$$q_v = C \cdot b \int_{x=0}^{x=z} \sqrt{2gx}dx = \frac{2}{3} C \cdot b\sqrt{2g} \cdot z^{\frac{3}{2}}$$

C - number of flow, taking into account, inter alia, the impact of the velocity at the upstream channel depends on the barrier height of a = 100 [mm] and the height of the overflow,

b - channel width 0.145 [m],

z - the overflow height [m],

g - acceleration of gravity [m/s^2].

For water, the number of flow may be calculated using one of the following empirical formulas:

$$C = 0.605 + \frac{1}{1000z} + \frac{0,08z}{a} \quad (Rehbock - 1913)$$

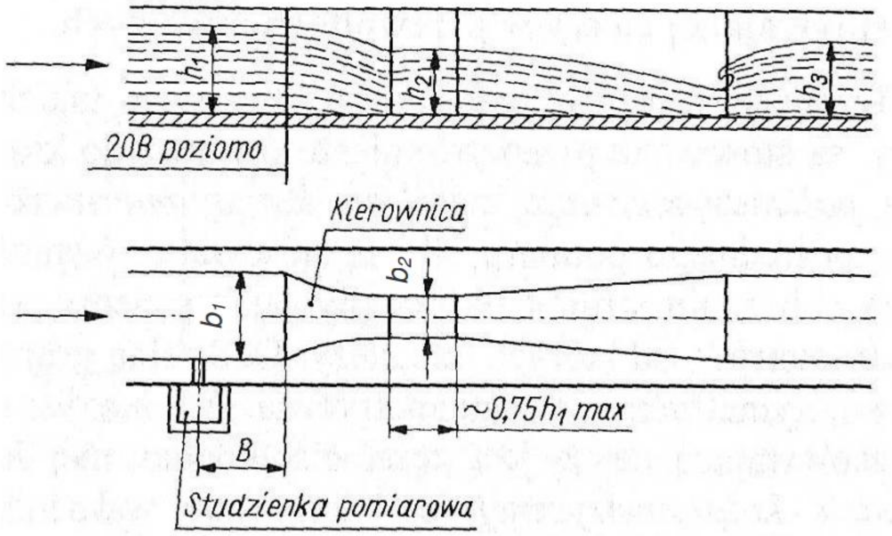
$$C = \left(0,6035 + 0,0813\frac{z}{a} + \frac{0,00009}{a}\right) \cdot (1 + \frac{0,0011}{z})^{3/2} \quad (Rehbock - 1924)$$

$$C = 0,615\left(1 + \frac{1}{1000z + 1,6}\right) \cdot \left[1 + 0,55\left(\frac{z}{z + a}\right)^2\right] \quad (szwajcarskie\ normy\ ISSA - 1924)$$

$$C = \left(0,615 + \frac{0,0045}{z}\right) \cdot \left[1 + 0,55\left(\frac{z}{z + a}\right)^2\right] \quad (Bazin)$$

4. Orifice measuring channels (constriction of the Venturi, Parshall)

The channel is triggered by a corresponding reduction of the cross sectional area of the open channel. Reduction in the shape of a Venturi nozzle is arranged in a trough of rectangular cross-section. In general, the side walls are in the shape of the nozzle; sometimes even the bottom may have the shape.



The volume flow can be calculated by the following formula:

$$q_v = C \cdot \frac{b_2 \cdot h_2}{\sqrt{1 - (m)^2}} \cdot \sqrt{2g(h_1 - h_2)}$$

b_1 - channel width 0.148 [m],

b_2 - constrictions width 0.048 [m],

h_1 - the height of the water level above the bottom in the cross section of the undisturbed flow [m],

h_2 - the height of water surface above the bottom in the middle of the contraction [m],

C - the number of flow, C = 0,97 - 1,0 (C = const, when $2b_2 \leq l \leq 5b_2$)

l - contraction length

m - Venturi channel module.

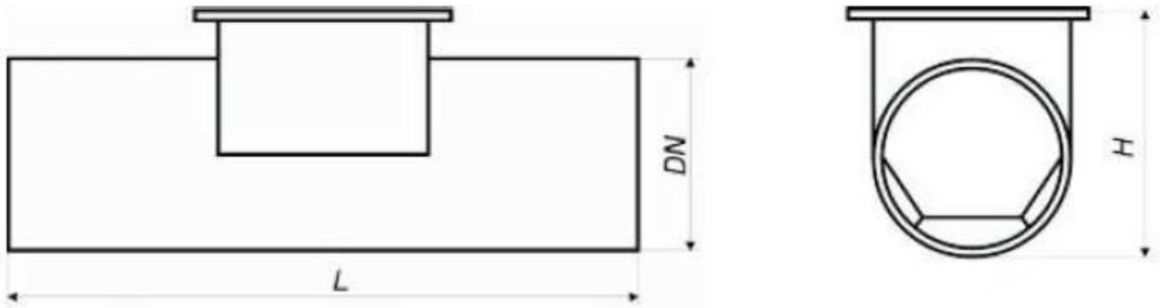
$$m = \frac{b_2 \cdot h_2}{b_1 \cdot h_1}$$

The above formula is right for the flow of the so-called. quiet, when h_2 / h_1 > 0.7. When the flow is "rushing", it is only correct height h1, and the formula for the volume flow takes the form:

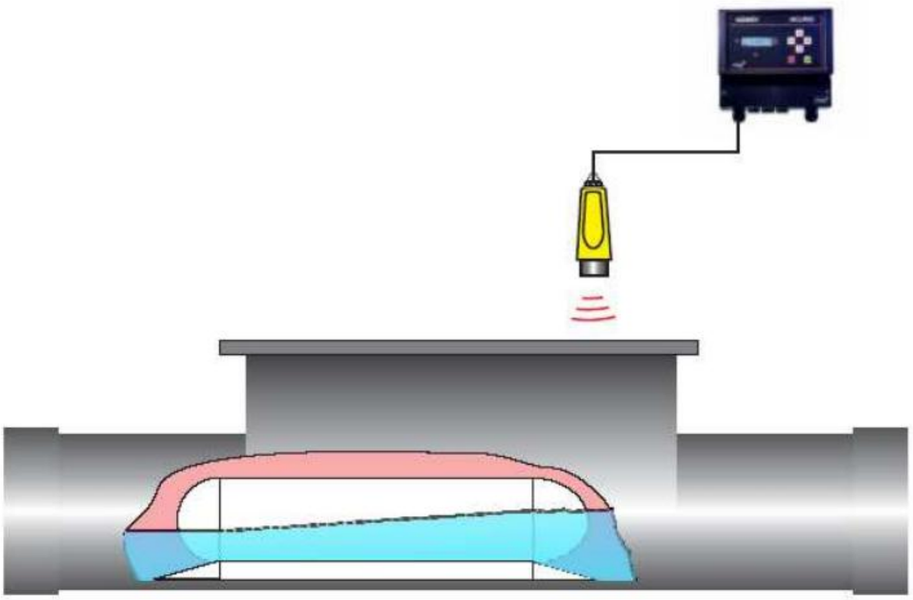
$$q_v = 0.385 \cdot C \cdot b_2 \cdot \sqrt{2g} \cdot h_1^{\frac{3}{2}}$$

5. Palmer & Bowlus orifice

The Palmer & Bowlus'a orifice is one of the prefabricated orifice measurement for flow measurement in pipes gravity. It is recommended for gravitational channels of circular cross section, as well as for pipelines operating at atmospheric pressure. Due to the construction, orifice has a self-cleaning properties, and can be used for the fluid carrying the solids. The orifice provides a close relationship between the level of the filling and the flow rate of fluid in the channel or pipeline.
The figures illustrate essential dimensions of the orifice P & B, and how to install an ultrasonic sensor.



In order to obtain a correct measurement of the substance stream, orifice must be installed horizontally without loss.



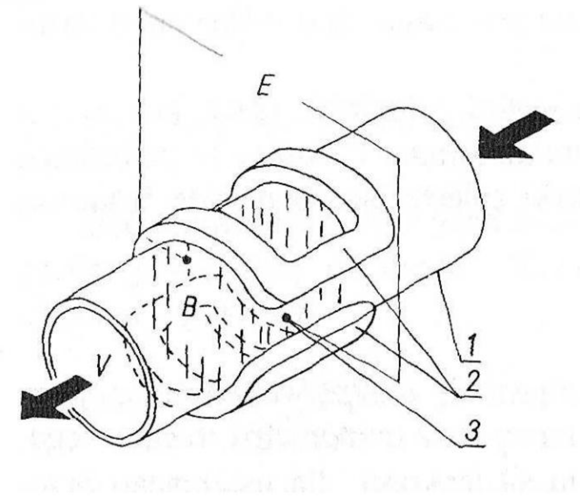
Advantages:
- optimal flow rate measurement accuracy,
- standardized dimensions of the orifice,

- ease of installation in channel with circular cross section or in pipeline.
- ease of orifice mounting

6. Electromagnetic Flow meter (inductive)

In this flow meter is used the induce phenomenon of the electromotive force in a conductor moving in a magnetic field. They are used to measure the volume flow of electrically conductive.

The magnetic field lines (fixed or variable) are directed perpendicular to the direction of fluid flow. Electromagnetic flow meters with constant magnetic field were not applicable due to the polarity of the electrodes. Alternating field of low frequency is applied.



1 - internally insulated pipeline section
2 - coil in which a magnetic field is generated
3 - electrode

The voltage in the transmitter is measured in accordance with the expression:

$$U = \frac{1}{D}\int_0^D U(x)dx$$

D - The distance between the electrodes equal to the inner diameter of the pipeline
$U(x)$ - The voltage relative to the voltage generated across the section of the pipeline

$$U(x) = k(x,y)B(x,y)v(x,y)$$

$B(x, y)$ - Magnetic induction inside the pipeline at the point with coordinates x, y
$v(x, y)$ - Fluid velocity at the point with coordinates x, y
$k(x, y)$ - The influence factor the voltage generated (at the magnetic field of the moving carriers of electric current) at the location on the voltage delayed by the integral according to formula U.

7. Test bench description

In this exercise the Venturi measurer canal and the simple overflow measurer is carried out. The test devices are in the experimental channel with the rectangular cross section and constant slope of the bottom. The water is provided to the channel by the pipe on which is mounted a valve and a Venturi-type orifice used for measuring the reference volume flow. The level gauges in the form of glass tubes are used for the measurement of the level of liquid in the channels.

Course of exercise

1) Establish the desired flow in the channel by the valve. Wait approximately 5 minutes till to establish the flow in the installation.

2) Measure the volume flow q_{Vodn} in the Venturi canal, by the measuring the pressure drop h.

3) Read the liquid levels h_1 and h_2 in the Venturi canal and level ($h = a + z$) in simple overflow.

4) Change flow rate regulating the level of closure of the valve. After establishing a flow (wait approx. 2 minutes) repeat steps 2) and 3). The measurements performed for 6 different flow rate.

Development of measurement results

1) Calculate the reference flow rate measured on the orifice for all measuring points

$$q_{V_{odn}} = \frac{C}{\sqrt{1-\beta^4}} \cdot \frac{\pi}{4} d^2 \cdot \sqrt{\frac{2\Delta p}{\rho}} \quad [m^3/s]$$

Pressure calculation

$$\Delta p = \Delta h \cdot \rho_o [1 - \beta \cdot t_{ot}] \cdot 9{,}81 \quad [N/m^2]$$

The density of mercury at 0°C - ρ_o = 13,595 [kg/dm^3]

Volume expansion coefficient of mercury - β = 0,00018 [°C^{-1}]

Assume: C = 0,6; d = 0,06 m; β = 0,6; ρ - read from the tables for ambient temperature t_{ot}.

2) Calculate the flow coefficients of the simple overflow measurer for each measuring point from the relationship:

$$C_1 = \frac{q_{v_{odn}}}{\frac{2}{3} \cdot b \cdot \sqrt{2 \cdot g} \cdot z^{\frac{3}{2}}}$$

3) Make check the condition of the calm flow $h_2 / h_1 > 0.7$. Using a suitable dependence on the flow rate for the flow of "calm" or "rushing", for each stream determine the flow rate for Venturi measurer canal C_2.

4) On the basis of the results of measurements and calculations to plot the characteristics of the respondents flowmeters: $q_{Vodn} = f(z)$, $q_{Vodn} = f(h_1)$ - called. taring curve or marking curve.

8. Report

The report should include:

1. Front page

2. Sketches of the measurement stations specifying the location of the measurement points and an indication of the characteristic dimensions of the instrument.

3. The table of measurements results, calculations and formulas used for calculation.

4. The characteristics of the measuring overflow and venturi channel.
5. Comments and conclusions.

LIST OF LITERATURE

1. Praca zbiorowa pod redakcją Cz. Graczyka*: Laboratorium miernictwa cieplnego,* Skrypty uczelniane Nr 801, Politechnika Śląska, Gliwice 1981.
2. Polska norma PN-93/M-53950/01, Pomiar strumienia masy i strumienia objętści płynów za pomocą zwężek pomiarowych.
3. Józef Śmigielski: Niekonwencjonalne metody i urządzenia do pomiaru energii cieplnej i natężenia przepływu, Ossolineum, Wrocław1996.
4. Norma ISO 1438/1-1980
5. PN-ISO 9826:2004 Pomiary przepływu w korytach otwartych. Koryta pomiarowe Parshalla i SANIIRI.
6. http://mobrey.com.pl

Measurement table

No.	Measurement				Calculations		
	h	h_1	h_2	Δh	q_{Vodn}	C_1	C_2
	[mm]	[mm]	[mm]	[mm Hg]	[m3/m]	-	-
1							
2							
3							
4							
5							
6							