SILESIAN UNIVERSITY OF TECHNOLOGY
FACULTY OF POWER AND ENVIRONMENTAL ENGINEERING
INSTITUTE OF POWER ENGINEERING AND TURBOMACHINERY

Pressure measurement

Metrology laboratory

(M - 4)

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1. PURPOSE OF EXERCISE

The purpose of this exercise is to learn the methods and instruments for measuring pressure taking into account to errors and irregularities that may occur during the measurement of pressure.

2. THEORETICAL INTRODUCTION

The tension occurring in fluids, caused by the action of external factors, such as changes of: volume, the thermal changes, speed, acceleration, etc., is characterized by a parameter called **pressure**.

The pressure value *p* is defined as the force *F* acting perpendicular to the surface *A*:

$$p = \frac{F}{A}$$

In the case of column of liquid or gas about the height *h*:

$$p = hg\rho$$

where:

ρ - density
g - acceleration due to gravity

The basic **unit** of pressure in the SI system is the pascal:

$$1Pa = 1\frac{N}{m^2} = 1\frac{kg}{m \cdot s^2}$$

unit		converter
$1bar$	bar	$1bar = 10^5 Pa$
$1\frac{kg}{m^2}$	kilogram per square meter	$1\frac{kG}{m^2} = 9{,}80665Pa$
$1at$	technical atmosphere	$1at = 1\frac{kG}{cm^2} = 98066{,}5Pa$
$1Atm$	physical atmosphere	$1atm = 760mmHg = 101325Pa$
$1mmHg$	milimeter of mercury	$1mmHg = 133{,}322Pa$
$1mmH_2O$	milimeter of water column	$1mmH_2O = 9{,}80665Pa$

The measurement technique distinguishes between the following **types of pressure**:

- atmospheric pressure (barometric) → p_{ot} → caused by the weight of the air column of Earth's atmosphere
- absolute pressure → p_a → total pressure affecting to the factor
- manometric pressure → p_m:

  - overpressure → positive different between the absolute pressure and the barometric pressure:

$$p_m = p_a - p_{ot} \qquad (p_a > p_{ot})$$

  - underpressure → negative different between the absolute pressure and the barometric pressure:

$$p_m = p_a - p_{ot} \qquad (p_a < p_{ot})$$

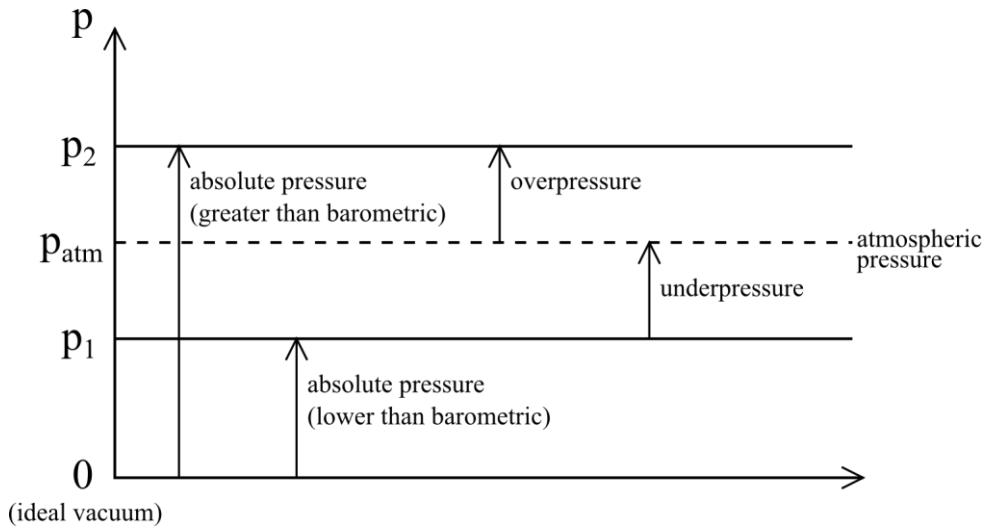


Fig.1. Types of pressure

Considering the moving factor, we can distinguish:

- static pressure → p_s → indicated by the manometer moving with the factor
- dynamic pressure →p_d → pressure increase caused by the factor deceleration to speed w = 0
- total pressure → p_c → the sum of the static and dynamic pressure

$$p_c = p_s + p_d$$

3. INSTRUMENTS FOR MEASURING PRESSURE (DIFFERENCE OF THE PRESSURE)

Hydrostatic manometers (U-tubes)

U-tube is the most simple instrument to measure the pressure. Usually consists of a glass tube bent in a U-shape. The manometric liquids is usually water, mercury or alcohol. Measuring range usually from 0 to 1000 mm column of liquid. Measurement accuracy is about 1 mm of liquid.

To measure low pressure, the manometers one- and two-armed are used.

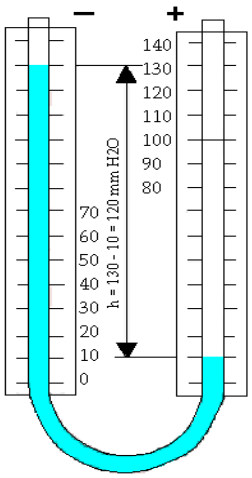


Fig.2. Two-armed liquid manometer (U-rurka)

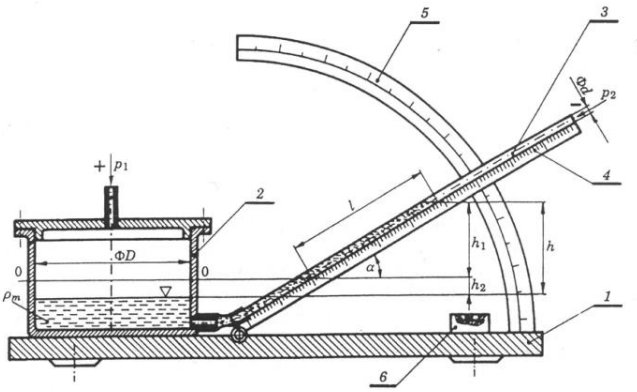


Fig.3. Manometer with an inclined tube

1 – base
2 – vessel
3 – measuring tube
4 – ruler with scale
5 – protractor
6 – buble level

The ring manometers (annular weight)

The basic element of the ring manometer is movable ring partially filled with liquid. The fulcrum point of ring is located slightly above the center of gravity.

In the neutral position, fluid is on both sides at the same height. Under influence of unilateral overpressure Δp , this pressure is disturbed, this balance is disturbed, on the opposite side the liquid is leaning out, and the torque acts on the chamber. It causes a torque opposite (off the center of gravity of the chamber) until to obtain the balance. The measured differential pressure is proportional to the sinus of the inclination angle α.

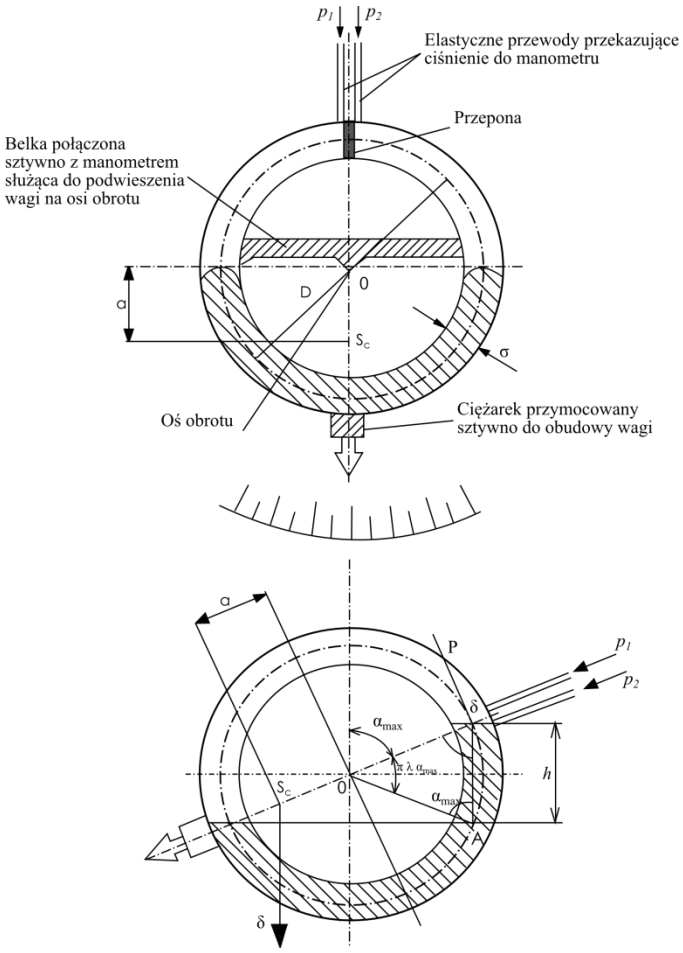


Fig.4. Annular weight

Float and bell manometers

They consist of a liquid filled casing and a diving bell, under which the impuls of pressure measurement is supplied. This apparatus is mainly used for measuring of low pressure as well as the registrars sensor. The float manometer is working similar.

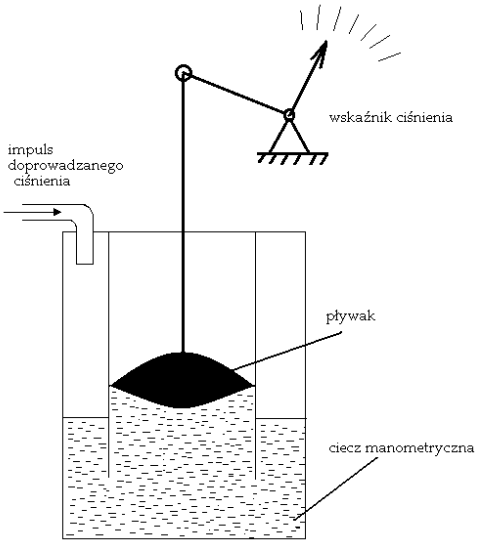


Fig.5. Float manometer

Spring loaded manometers

The measurement sensor is a metal spring, usually. In this group of manometers, we can point out:

- membrane manometers
- tubular manometers
- cased and pilaris manometes.

Advantage of these manometers is insensitivity to shakes, low cost of production and the ability to high pressures measurement. Disadvantage is the need for calibration and use of appropriate building conditions for measuring of pressure hot liquids (such as water vapor).

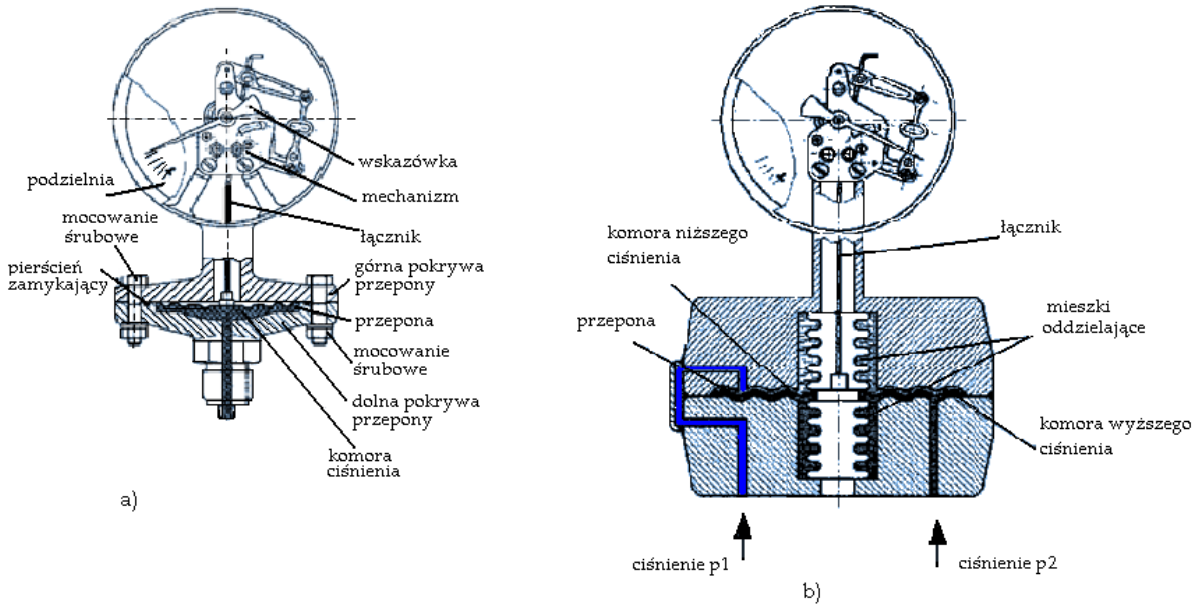
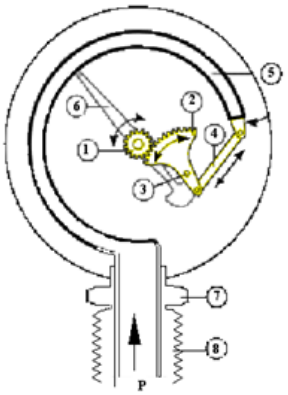


Fig 6. Spring loaded manometers: a) membrane b) pilaris



1 - koło zębate sprzężone ze wskazówką

2 - dźwignia zębata

3- oś obrotu dźwigni zebatej

4 - cięgno

5 - sprężysta rurka

6 - wskazówka

7 - uchwyt

8 - gwint

Fig. 7. Spring loaded tubular manometer (with Bourdon's tube)

Electric converters of differential pressure

They use different physical / electrical properties in order to determine the pressure. In this group, there are multimeters: resistive, piezoelectric and tensometric. These are characterized by high accuracy of processing and the ability to measuring the rapidly changing quantities (the low inertia of sensor). Most frequently, these manometers are integrated with processing circuit, where the unified signal of voltage or current is the input signal.

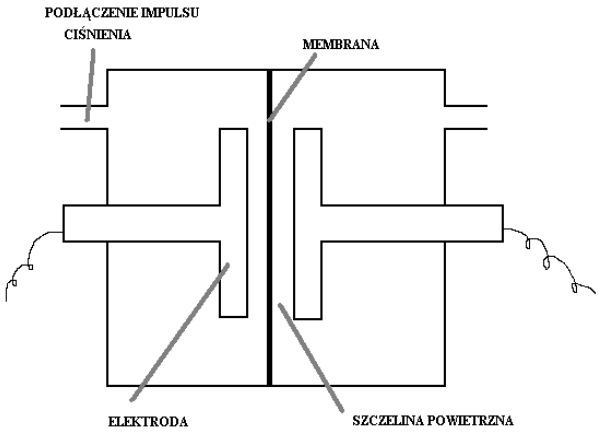


Fig. 8. Electric converters of differential pressure

Damming tubes

Damming tubes (Prandtl tube and Pitot tube) are used for measuring the dynamic pressure and/or total pressure. The principle of operation of these tubes is based on the transformation of energy of dynamic stream of fluid (by the deceleration) into the potential energy of pressure, which is then measured (eg, using an U-tube manometer).

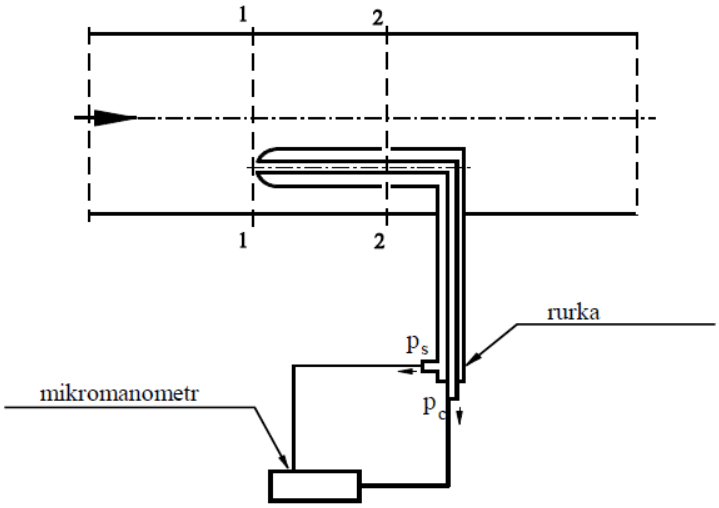
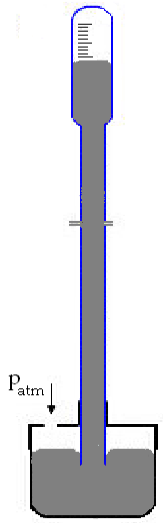


Fig.9. Prandtl tube manometer



BAROMETER – A vertical glass tube filled with mercury (a liquid with a large density), closed at one end. Above mercury is a vacuum. Atmospheric pressure acting on the mercury through the open end of the tube, changes the altitude of mercury, readed in mmHg.

Fig.10. Barometer

4. MEASURING SYSTEM

Proper installation of pressure gauges is a prerequisite to obtain reliable results. Before each pressure gauge should be a three-way tap, which will allow:

- disconnect the pressure gauge
- the switching of the pressure
- checking the resetting of the pressure gauge
- connection of control manometer
- purging the line supplying the pressure.

When transmission the pressure on some distance, pipes with a diameter of Φ 4-6mm for a gas i Φ 10-12mm for a liquid, are used.

Indications pressure gauges during the measurements may be subject to errors due to, inter alia:

- the use of untested manometers
- clogged or leaked of impulse tube, which supply the pressure to the manometer
- geodetic height difference, between the point of the pressure measurement and place of a pressure gauge install when the wires are flooded by liquid or condensate (this is a systematic error)
- incomplete filling of the lines by an intermediate liquid (in this case of measurement, error is classified as accidental)
- condensation of the moisture, and flooding of placed lower lines, in the case of gas pressure measurement.

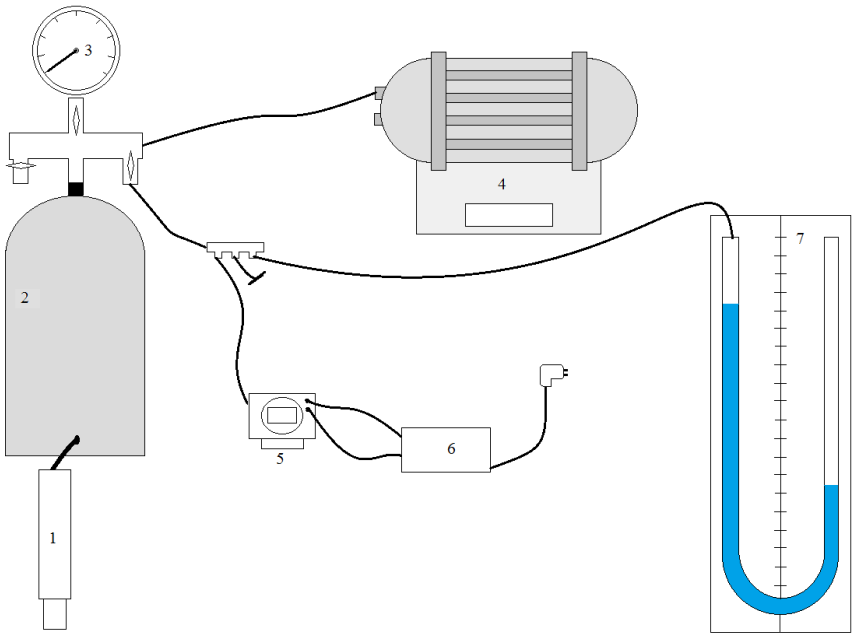


Fig.10. Scheme of measuring system

1 - pump
2 - reservoir
3 - membrane manometer
4 - differential pressure manometer
5 - differential pressure converter
6 - power supply
7 - U-tube manometer

5. EXERCISE RALIZATION

A) Learning the structure and principles of operation of the various types of manometers
B) Writing down the measurement ranges
C) Reading of the height of mercury and an ambient temperature on the barometer
- calculating the atmospheric pressure (based on the read of the mercury in the barometer and the current ambient temperature)
- taking into account of the temperature correction
- calculation of measurement uncertainty caused by the inaccuracy of measurement of liquid height in the manometer.

D) Determination of the static characteristics of manometers
E) Writing down of measurements in the respective tables

6. DRAFTING OF MEASUREMENT RESULTS

- calculation of atmospheric pressure value, based on the series of mercury column measurement, and ambient temperature + determine the accuracy of the result obtained

- Drafting of the characteristics of the manometers (membrane manometer, electric differential pressure converter, using a U - tube)
- (Calculation of accuracy of the pressure measured)

7. REPORT

In a report of laboratory exercise should be:

1. front page
2. Data of measuring instruments
3. Scheme of the measurement system (with the description)
4. Tables of values of results
5. The calculation of these values and their graphs
6. Conclusion (+ comments)

SOURCES

1. Previous version of „Instrukcja do ćwiczenia laboratoryjnego M-4 Pomiar ciśnień" (dr inż. Jacek Łyczko, dr inż. Jan Około-Kułak, dr hab. inż. Janusz Kotowicz)
2. Taler D., „Pomiar ciśnienia, prędkości i strumienia przepływu płynu", Uczelniane Wydawnictwa Naukowo – Dydaktyczne, Kraków 2006

ANNEX: MEASURING TABLES

Atmospheric pressure measurement

Lp.	Name and Surname	Height of mercury [mmHg]	Ambient temperature [°C]
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

- accuracy of ambient temperature measurement: Δt_{ot} [°C]
- accuracy of the height of mercury measurement: Δh_{Hg} [mmHg]

Static characteristics of different types of manometers

Lp.	U-tube manometer [mmH_2O]			Membrane manometer [mmH_2O]	Differential pressure converter [mV]	
	L	P	Δh			
1.						
2.						
3.						
4.						
5.						
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9.						
10.						
11.						
12.						
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