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Pressure measurement

Author: prof.dr. Hazim Bašić
Univerzitet Džemal Bijedić
Mašinski fakultet Mostar

Measuring in Energetics15.04.2025

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Partnership for Promotion and Popularization of Electrical Mobility through Transformation and Modernization of WB HEIs Study Programs/PELMOB
Call: ERASMUS-EDU-2022-CBHE-STRAND-2
Project Number: 101082860

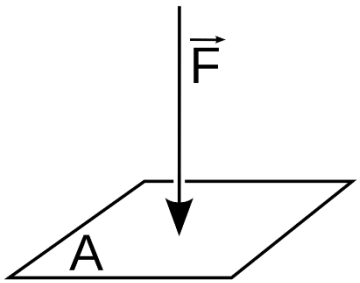
Contents

Introduction

- The development of pressure measurement methods and techniques began with Torricelli's experiment in 1643, which showed that the Earth's atmospheric mantle presses the Earth's surface with a pressure corresponding to approximately 760 mm of Hg.
- Pressure is a physical quantity needed to describe the thermodynamic state of a fluid
- Pressure or compressive stress is a special form of stress, defined as a force acting on a unit area
- Often, pressure is measured to indirectly obtain the values of some other physical quantities (e.g. flow rate and fluid level).

Pressure definitions

Mechanics

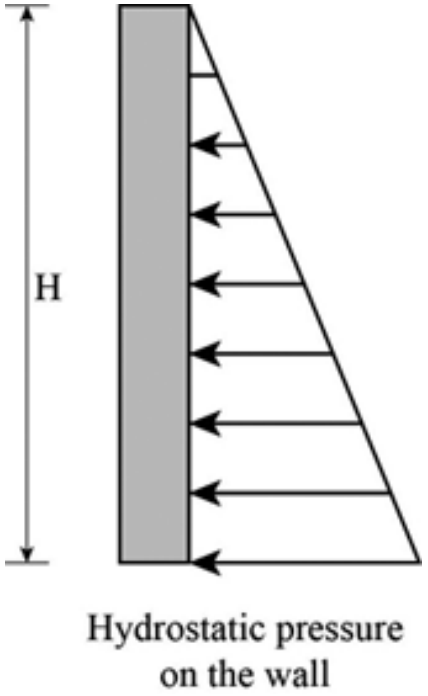


$$p = \frac{F}{A}$$

p, Pa – pressure
F, N – force
A, m^2 – area

Fluid mechanics (hydrostatic pressure)

$$p = \rho g h$$



ρ , kg/m^3 – fluid density
g , m/s^2 – gravitational acceleration
h , m – height of the liquid column (depth)

Pressure definitions

Thermodynamics:

According to the kinetic theory of gases, pressure is a measure of the total average kinetic energy of the translational motion of gas molecules in a volume V at a temperature *T*:

$$p = \frac{2}{3} Nk \frac{T}{V}$$

N – number of molecules

k – Boltzmann constant, *k* =1,38064852 × 10^{-23} m^2 kg s^{-2} K^{-1}

T , K – thermodynamic temperature

Pressure units

1) Pascal (Pa)
2) Bar atmosphere (atm)
3) Technical atmosphere (at)
4) Millimeter of water column
5) Millimeter of mercury column (mm Hg)
6) Inch of water column
7) Inch of mercury PSI (pounds per square inch)

Relationships between some pressure units

	Pa	bar	at	atm	mm Hg
Pa	1	1×10^{-5}	$1{,}0197 \times 10^{-5}$	$9{,}869 \times 10^{-6}$	**$7{,}501 \times 10^{-3}$**
bar	1×10^{5}	1	**1,0197**	$9{,}869 \times 10^{-1}$	$7{,}501 \times 10^{2}$
at	$9{,}807 \times 10^{4}$	$9{,}807 \times 10^{-1}$	1	$9{,}678 \times 10^{-1}$	$7{,}356 \times 10^{2}$
atm	$1{,}013 \times 10^{5}$	**1,013**	1,033	1	$7{,}60 \times 10^{2}$
mm Hg	**$1{,}333 \times 10^{2}$**	$1{,}333 \times 10^{-3}$	$1{,}360 \times 10^{-3}$	$1{,}316 \times 10^{-3}$	1

Atmospheric pressure

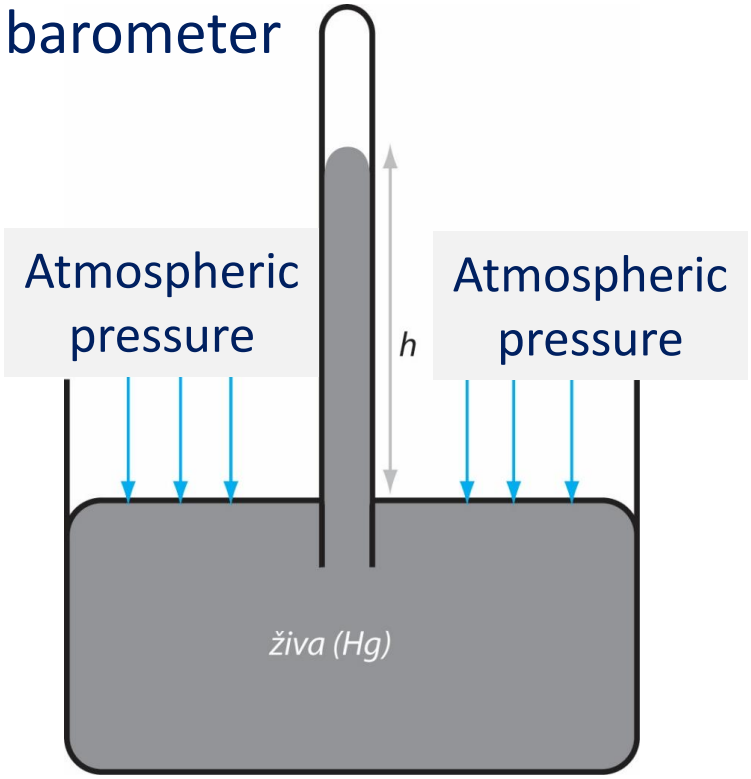
- Atmospheric pressure is the pressure on any part of the Earth's atmosphere
- It is equal to the hydrostatic pressure caused by the Earth's atmosphere located in the column above the point of measurement
- Areas of lower pressure have less mass of atmosphere above them, and areas of higher pressure have more
- With the increase in altitude, the column of atmosphere above decreases, and the atmospheric pressure is lower
- The weight of the air envelope is subject to many influences, so the atmospheric pressure changes constantly and irregularly
- At sea level, the atmospheric pressure is the highest, and the atmosphere is defined by that pressure

Measuring atmospheric pressure

Devices for measuring atmospheric pressure are called barometers

The working principle of a mercury barometer

1 atm = 760 mm Hg = 101325 Pa



Measuring atmospheric pressure

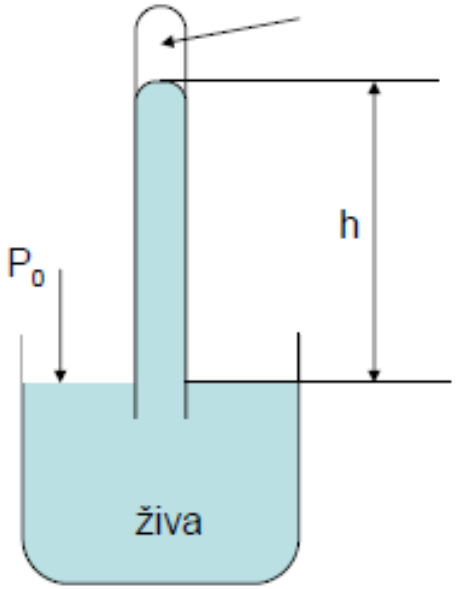
Torricelli's experiment

$$G = m \cdot g = V \cdot \rho \cdot g = A \cdot h\rho \cdot g$$

$$F = p_0 \cdot A$$

$$G = F$$

$$p_0 = h\rho \cdot g$$



$P_0 = \rho gh$

$p_a = \rho gh = 13\,595{,}103 \cdot 9{,}80665 \cdot 0{,}76 = 101325$ Pa

Measuring atmospheric pressure

- The standard atmosphere (symbol: atm) is an old unit of pressure
- It was originally defined as the pressure at which the height of the mercury column in the barometer is 760 mm
- This is also the air pressure measured at the mean altitude at the latitude of Paris
- This definition also depends on the density of mercury, which also depends on the pressure, it was later modified by prescribing the exact relationship according to Pascal

Technical atmosphere

- Technical atmosphere (sign: at) is a unit of measurement for pressure from the old technical system of units (MKpS) According to the definition, it is equal to one kilopound per square centimeter:

$$1\ \mathrm{kp/cm^2}$$

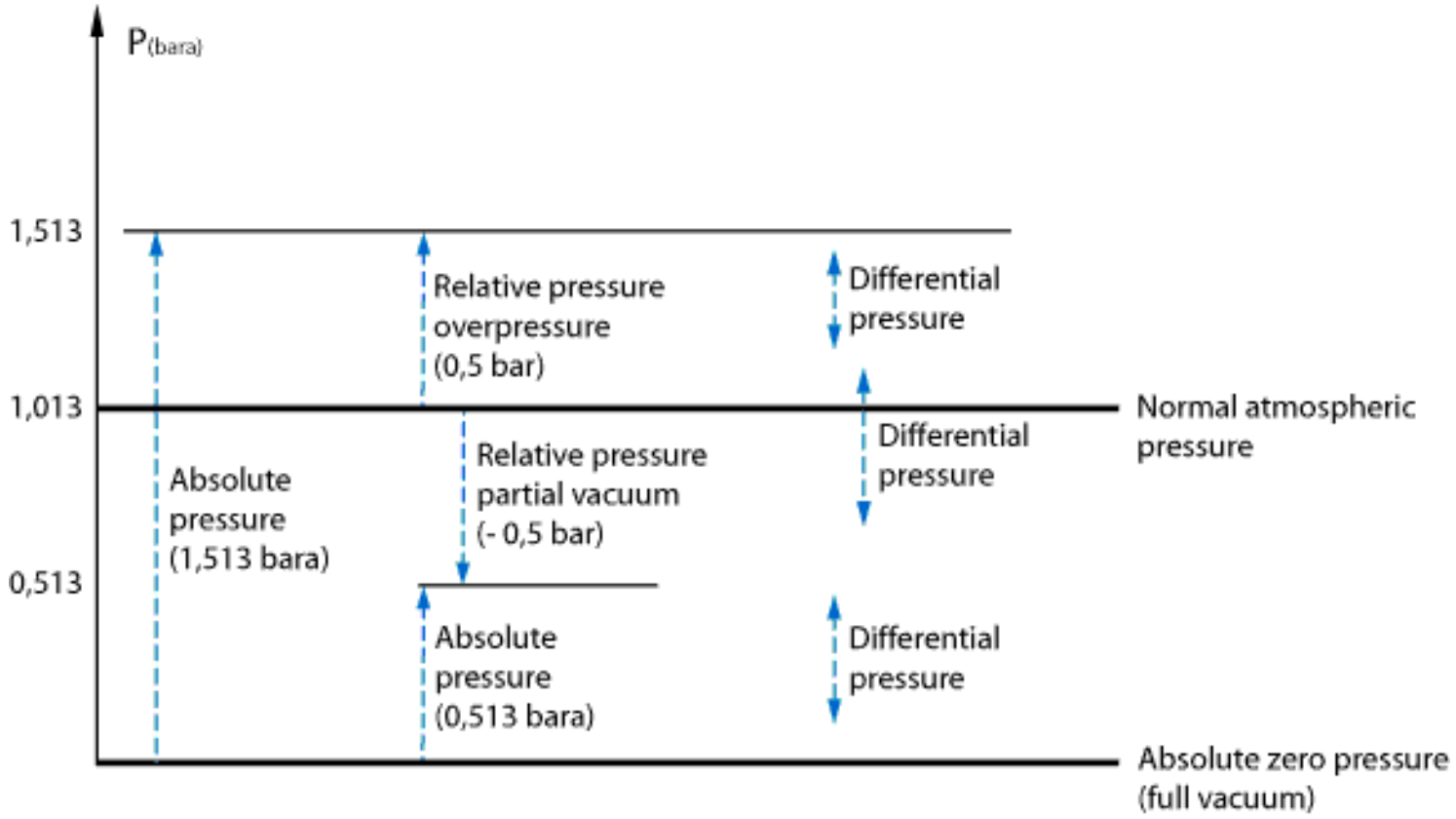
As this definition also depends on the density of mercury, which also depends on the pressure, it was later changed by prescribing the exact relation to Pascal.

Types of pressures

- Atmospheric pressure
- vacuum (empty space)

  If the container does not contain a single molecule, the pressure in it is zero (absolute zero = 100% vacuum). It is also used as a term for a very small pressure reduced to the smallest achievable value.
- Relative pressure - pressure measured with respect to some reference pressure (often atmospheric)
- Absolute pressure – pressure measured on a scale that uses absolute zero as a reference value
- Overpressure
- Negative pressure

Atmospheric, absolute and relative pressure



Pressure measurement methods

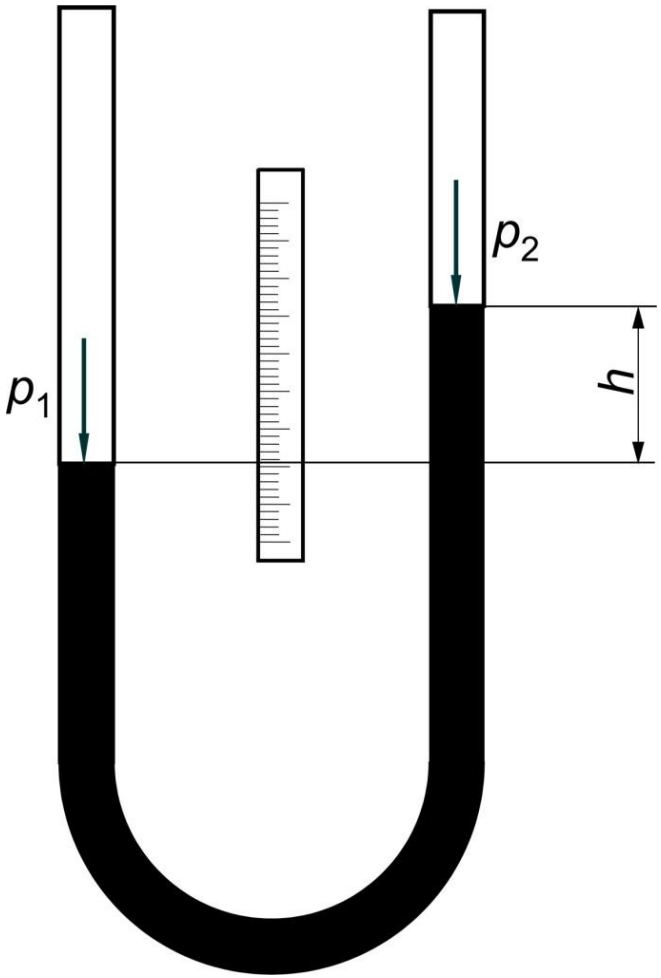
Categorization of pressure measurement methods:

1. Liquid manometers (U-manometers, piezometers, U-tubes)
2. Manometers with elastic transducers (tubes, membranes, bellows)
3. Sensors (inductive, capacitive, resistive, piezoelectric)

Liquid pressure gauges

- This group includes manometers that contain liquid
- A liquid column of certain height and cross-section acts as a "liquid weight" of known weight
- The weight of such a weight is usually measured by its height in a calibrated glass tube
- The weight of the weights, i.e. the force, is used for comparison with the force with which the measured pressure acts on a certain surface
- Thus, the height of the liquid column can be considered a measure of pressure

‘U’ – pressure gauge



Pressure difference:

$$\Delta p = p_1 - p_2 = \rho g h$$

- ρ – density of manometer liquid
  g – gravitational acceleration
- h – height difference between the liquid columns in the left and right arms