# Pressure measurement explained

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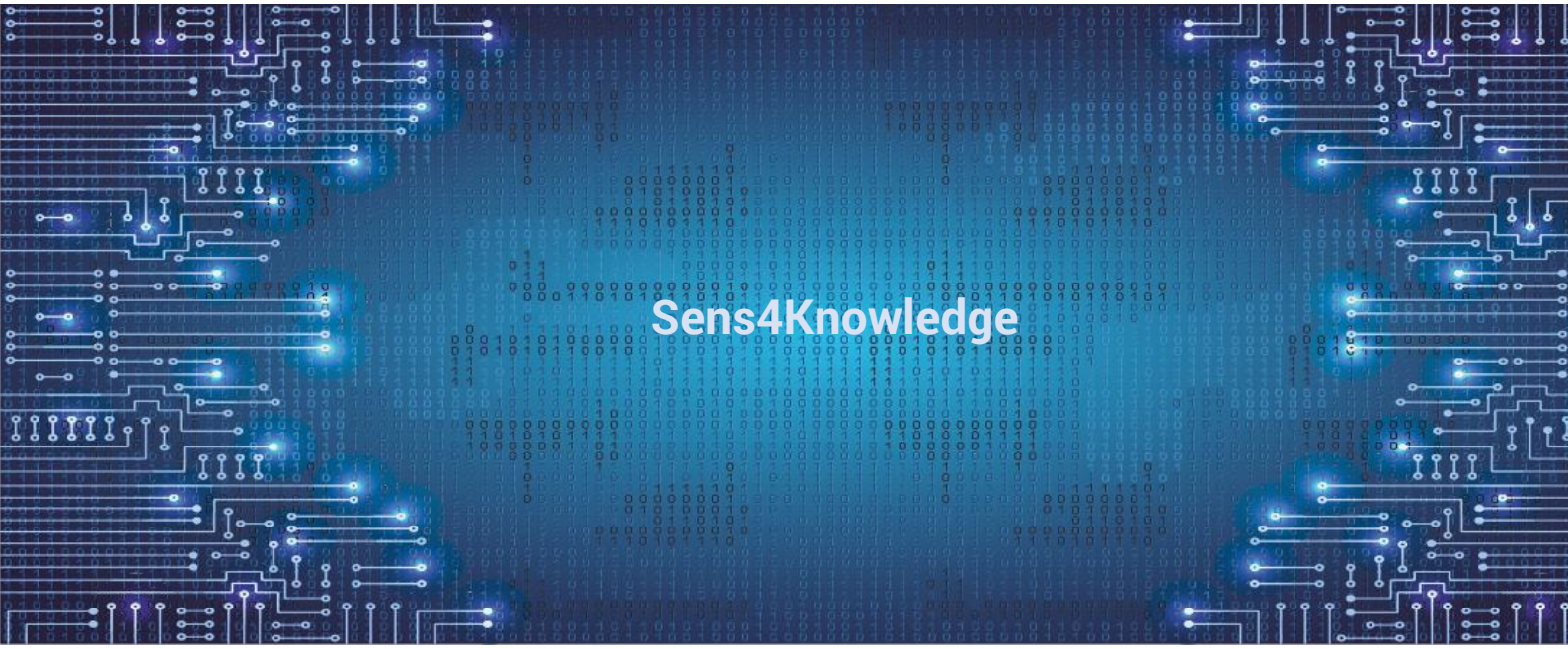


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## Introduction

Pressure is defined as the force per area that can be exerted by a liquid, gas or vapor etc. on a given surface. The applied pressure can be measured as absolute, gauge or differential pressure.

Pressure can be measured directly by measurement of the applied force or indirectly, e.g. by the measurement of the gas properties. Examples of indirect measurement techniques that are using gas properties are thermal conductivity or ionization of gas molecules.

Before mechanical manometers and electronic diaphragm pressure sensors were invented, pressure was measured by liquid manometers with mercury or water.

## Pressure standards

In physical science the symbol for pressure is p and the SI (abbreviation from French Le Système. International d'Unités) unit for measuring pressure is pascal (symbol: Pa). One pascal is the force of one Newton per square meter acting perpendicular on a surface. Other commonly used pressure units for stating the pressure level are psi (pounds per square inch), torr and bar. Use of pressure units have regional and applicational preference: psi is commonly used in the United States, while bar the preferred unit of measure in Europe. In the industrial vacuum community, the preferred pressure unit is torr in the United States, mbar in Europe and pascal in Asia.

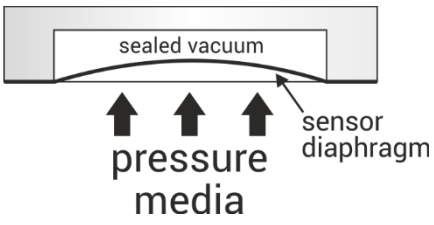
| Unit conversion | Pa | bar | psi | torr | atm |
|---|---|---|---|---|---|
| **1 Pa =** | 1 | $1\times10^{-5}$ | $1.45038\times10^{-4}$ | $7.50062\times10^{-3}$ | $9.86923\times10^{-6}$ |
| **1 bar =** | 100,000 | 1 | 14.5038 | 750.062 | 0.986923 |
| **1 psi =** | 6,894.76 | $6.89476\times10^{-2}$ | 1 | 51.7149 | $6.80460\times10^{-2}$ |
| **1 torr =** | 133.322 | $1.33322\times10^{-3}$ | $1.933768\times10^{-2}$ | 1 | $1.31579\times10^{-3}$ |
| **1 atm (standard) =** | 1013.25 | 1.01325 | 14.6959 | 760.000 | 1 |

According to the International Organization for Standardization the standard ISO 2533:1975 defines the standard atmospheric pressure of 101,325 Pa (1 atm, 1013.25 mbar or 14.6959 psi). The ambient atmospheric barometric pressure is dynamic on the Earth and varies with weather, climate and altitude. The typical sea-level barometric pressure variations range from 925 to 1,050 hPa. The Earth surface pressure decreases by approximately 0.1 hPa per meter (up to around 6 km altitude). For a more accurate calculation of atmospheric pressure dependency as function of altitude, the air temperature also needs to be considered.

## Absolute pressure

Absolute pressure is the pressure quantity measured relative to zero which in pressure terms is a perfect vacuum. As an example, absolute pressure measurement is used for measuring barometric pressure variations due to changes in weather patterns.

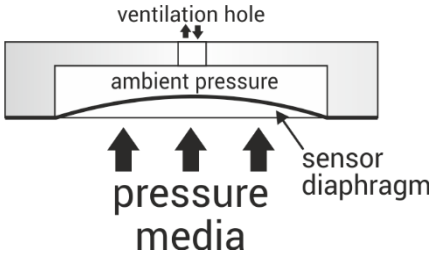
A diaphragm based absolute pressure sensor has one side of the diaphragm exposed to a permanently sealed vacuum cavity integrated in the sensor element and the other side of the diaphragm exposed to the applied pressure media to measure.



**Gauge pressure**

Gauge pressure is the pressure quantity measured relative to the ambient atmospheric pressure. Pressure transducers with a diaphragm-based gauge pressure sensor has one side of diaphragm exposed to the ambient atmospheric pressure and the other side of the diaphragm is exposed to the applied pressure.

Gauge pressure sensors will provide a negative pressure reading when exposed to vacuum and a positive reading when exposed to a pressure higher than the atmospheric pressure. At atmospheric ambient pressure the pressure is equalized between the two sides of the diaphragm and the sensor will provide a zero reading.

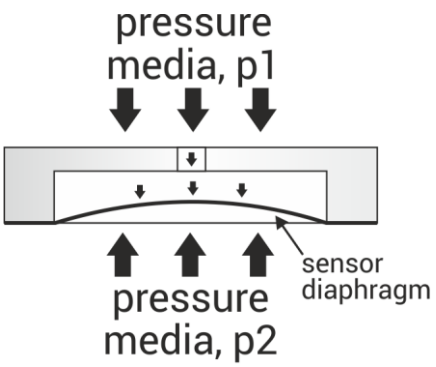



A variation of the gauge pressure sensor is the sealed gauge pressure sensor where one side of the diaphragm is exposed to a sealed cavity with a static pressure of 1 bar equivalent to the standard atmospheric pressure. Sealed gauge sensors are typically used for high pressure sensors where it is not practical, from a safety perspective, to have the high-pressure media separated from the atmosphere by only a thin diaphragm.

**Differential pressure**

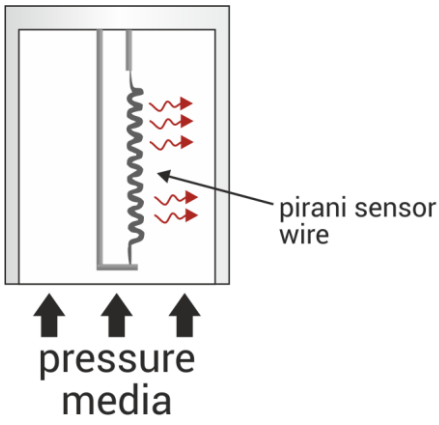
Differential pressure is a pressure measured between two independent pressure forces.

Pressure transducers with a diaphragm differential pressure sensor with one side of the diaphragm exposed to one pressure media and the other side of the diaphragm to a second pressure media. The differential pressure value is the pressure difference between the two pressure medias.




**Indirect pressure**

Gas pressure levels below atmospheric pressure is called vacuum. In vacuum applications it is common to measure the pressure indirectly. Because of the low gas density at pressures lower than $1 \times 10^{-5}$ hPa (high vacuum), the force exerted by the gas cannot be measured by direct methods such as the deflection of a diaphragm. Instead, pressure is measured in high vacuum applications by indirect pressure measurement techniques. As an example, the pressure can be determined in-directly by measurement of the thermal conductivity to the gas pressure media from a hot wire suspended in a tube or a hot resistive element on a micromachined silicon diaphragm. The hot wire Pirani or MEMS Pirani gauge can be used to measure pressure down to $1 \times 10^{-5}$ hPa.



For pressure measurement in the ultra-high vacuum range, hot or cold cathode ionization gauges are used. These type of gauges measures indirectly by ionization of gas molecules and can be used to measure pressure down to $1 \times 10^{-12}$ hPa.

**Conclusions**

Pressure and vacuum measurement is widely used in industrial and scientific applications. It can be measured with many different types of sensors, techniques and measurement technologies. The selection of measurement technique and sensor type depends on the application and requirements.

**Literature references**

1. A. Brenan; Total Pressure Measurement in Vacuum Technology
2. International Organization for Standardization; ISO 2533:1975, Standard Atmosphere
3. O. Wenzel, C. K. Bak; The Micro Pirani: A solid-state vacuum gauge with wide range; Vakuum in Forschung und Praxis, Volume10, Issue4, 1998
4. Béla G. Lipták; Instrument Engineers' Handbook

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