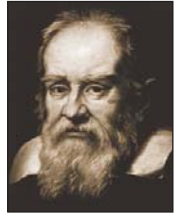


History of Pressure

1594



Galileo Galilei, born in Pisa (Italy), obtains the patent for a machine to pump water from a river for the irrigation of land. The heart of the pump was a syringe. Galileo Galilei found that 10 meters was the limit to which the water would rise in the suction pump, but had no explanation for this phenomenon. Scientists were then devoted to find the cause for this.



1644



Evangelista Torricelli (Torr), Italian physicist, filled a tube 1 meter long, hermetically closed at one end, with mercury and set it vertically with the open end in a basin of mercury. The column of mercury invariably fell to about 760 mm, leaving an empty space above its level. Torricelli attributed the cause of the phenomenon to a force on the surface of the earth, without knowing, where it came from. He also concluded that the space on top of the tube is empty, that nothing is in there and called it a "vacuum".



1648



Blaise Pascal, French philosopher, physicist and mathematician, heard about the experiments of Torricelli and was searching for the reasons of Galileo's and Torricelli's findings. He came to the conviction that the force, which keeps the column at 760 mm, is the weight of the air above. Thus, on a mountain, the force must be reduced by the weight of the air between the valley and the mountain. He predicted that the height of the column would decrease which he proved with his experiments at the mountain Puy de Dôme in central France. From the decrease he could calculate the weight of the air. Pascal also formulated that this force, he called it "pressure", is acting uniformly in all directions.



1656



Otto von Guericke, born in Magdeburg/Germany. Torricelli's conclusion of an empty space or "nothingness" was contrary to the doctrine of an omnipresent God and was thus attacked by the church. Guericke developed new air pumps to evacuate larger volumes and staged a dramatic experiment in Magdeburg by pumping the air out of two metal hemispheres which had been fitted together with nothing more than grease. 8 horses at each hemisphere were not strong enough to separate them (see title page).



1661



Robert Boyle, an Anglo-Irish chemist, used "J"-shaped tubes closed at one end to study the relationship between the pressure and volume of trapped gas and stated the law of $P \times V = K$ (P: Pressure, V: Volume, K: Constant) which means that if the volume of a gas at a given pressure is known, the pressure can be calculated if the volume is changed, provided that neither the temperature nor the amount of gas is changed.



1820



Almost 200 years later, Joseph Louis Gay-Lussac, French physicist and chemist, detects that the pressure increase of a trapped gas at constant volume is proportional to the temperature. 20 years later, William Thomson (Lord Kelvin) defines the absolute temperature scale with the zero point at $-273\text{ }^{\circ}\text{C}$ (or 0 Kelvin).



History of Pressure Measurement

Mechanical Measurement Technologies

1843 Lucien Vidie, French scientist, invented and built the aneroid barometer, which uses a spring balance instead of a liquid to measure atmospheric pressure. The spring extension under pressure is mechanically amplified on an indicator system. Employing the indicator method of Vidie, Eugène Bourdon (founder of the Bourdon Sedeme Company) patented 1849 the Bourdon tube pressure gauge for higher pressures.



Aneroid Barometer

Electrical Measurement Technologies

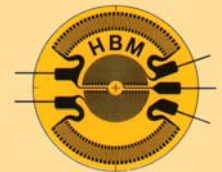
1930 The first pressure transducers were transduction mechanisms where the movements of diaphragms, springs or Bourdon tubes are part of an electrical quantity. Pressure diaphragms are part of a capacitance, the indicator movement is the tap of a potentiometer.



Bourdon Tube

1938 The bonded strain gauges were independently developed by E. E. Simmons of the California Institute of Technology and A.C. Ruge of Massachusetts Institute of Technology. Simmons was faster to apply for a patent.

1955 The first foil strain gauges came up with an integrated full resistor bridge, which, if bonded on a diaphragm, see opposite stress in the center and at the edge.



Foil Strain Gauge

1965 The bonding connection of the gauges to the diaphragm was always the cause for hysteresis and instability. In the 1960's, Statham introduced the first thin-film transducers with good stability and low hysteresis. Today, the technology is a major player on the market for high pressure.

1973 William R. Poyle applied for a patent for capacitive transducers on glass or quartz basis, Bob Bell of Kavlico on ceramic basis a few years later in 1979. This technology filled the gap for lower pressure ranges (for which thin film was not suited) and is today, also with resistors on ceramic diaphragms, the widest spread technology for non-benign media.



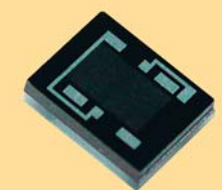
Thin Film

The Sensor Age

1967 Honeywell Research Center, Minneapolis/USA, 1967: Art R. Zias and John Egan applied for patent for the edge-constrained silicon diaphragm. 1969, Hans W. Keller applied for patent for the batch-fabricated silicon sensor. The technology is profiting from the enormous progresses of IC-technology.

A modern sensor typically weighs 0.01 grams. If all non-crystalline diaphragms have inherent hysteresis, the precision limit of this item is not detectable by today's means.

The piezoresistive technology is the most universal one. It applies for pressure ranges from 100 mbar to 1500 bar in the absolute, gauge and differential pressure mode. The slow spread of the technology in high volume applications for non-benign media resulted from the inability of US-companies to develop a decent housing. In 30 years, KELLER has perfected it at costs comparable to any other technology.



Piezoresistive Silicon Pressure Sensor

2000