Pressure

FUNDAMENTALS

For a fluid at rest, pressure can be defined as the force exerted perpendicularly by the fluid on a unit area of any bounded surface. That is, P=F/A.

To understand the definition of pressure, it is useful to look at an example of force and pressure. If a 2 inch square cube weighs 10 pounds and it is set on a table, the force on the table would be 10 pounds. However, the pressure exerted on the table under the cube would be 10/4 or 2.5 pounds/inch.

A similar example can be made with two columns of water. Suppose you have a vertical column of water 27.73 inches in two pipes. One pipe is 1 inch in diameter and one pipe is 5 inches in diameter. For each pipe, the downward force on the table is the same as the weight of the liquid in the pipe (ignoring the weight of the pipe). For the one inch pipe, the weight is 0.785 pounds and the weight in the 5 inch pipe is 19.636 pounds. The pressure at the bottom of the tube is 1 pound per square inch. This is because pressure depends on the height of the water, not the volume. Figure 1 shows this example. The height of liquid is known as head.

Pressure is commonly referred to with various units of measure. One of the most frequent measures of pressure is pounds per square inch, which is abbreviated as psi. For low pressures, it is common to express pressure in inches of water which is symbolized by in. WC, meaning water column, or in. H_2O. One vertical inch of cold water equals 0.0361 psi at room temperature.

Pressures for pumps are commonly given in feet of head, shown as ft head. This refers to the theoretical column of liquid that the pump pressure could support. Barometric pressure is usually expressed in inches of mercury, in Hg or as millimeters of mercury, mm Hg. Here, we refer to a vertical column of mercury just like we refer to the vertical column of water in the previous examples.

Table 1 lists conversion factors between common pressure scales. Multiply known pressure by factor to obtain unknown pressure in different units.

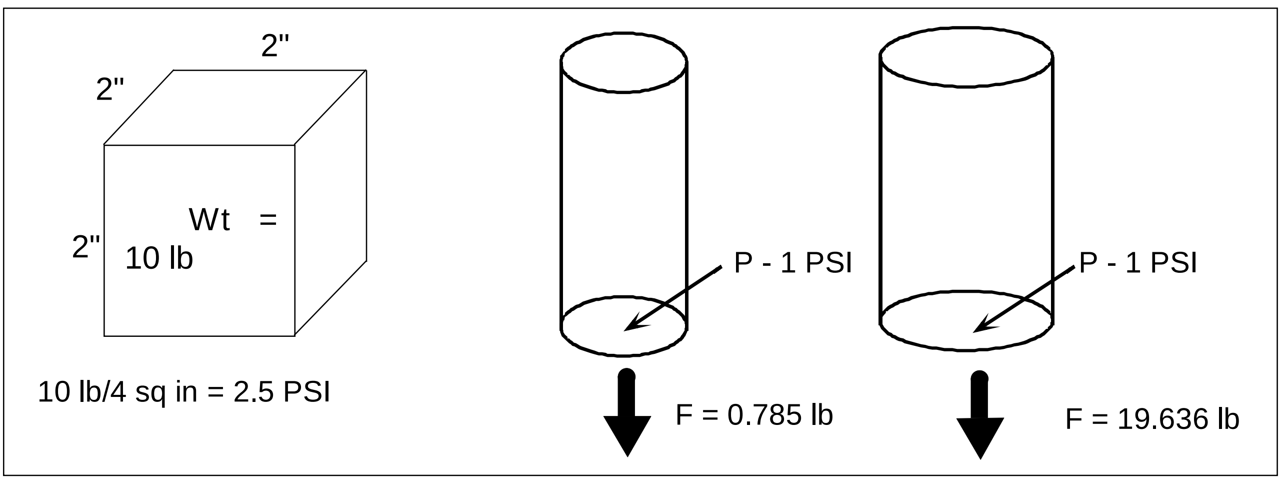

FIGURE 1 Pressure vs. Force Example

TABLE 1 Conversion Factors for Pressure Scales

UNKNOWN →

KNOWN ↓

Pressure	lbm/in²	lbm/ft²	Atm.	in H_2O (68°F)	ft H_2O (68°F)	in Hg (32°F)
lbm/in2	1	144.0	0.068046	27.730	2.3108	2.03602
lbm/ft2	0.0069444	1	0.000473	0.19257	0.016048	0.014139
Atm.	14.696	2116.22	1	407.520	33.960	29.921
in H_2O	0.036062	5.1929	0.002454	1	0.08333	0.073423
ft H_2O	0.432744	62.315	0.029446	12	1	0.88108
in Hg	0.491154	70.7262	0.033420	13.6197	1.1350	1

TYPES OF PRESSURE

There are several common ways to measure pressure. Each method measures the applied force over an area. The difference is the reference point for the measurement. There are two reference points; zero absolute pressure and standard atmospheric pressure.

If the pressure measurement is referenced to atmospheric pressure (approximately 14.7 psia), the measured pressure is referred to as gauge pressure. Positive gauge pressures are always above atmospheric pressure. Negative gauge pressure, or vacuum pressure, is always below atmospheric pressure. The maximum vacuum pressure theoretically achievable is then -14.7 psig, which correlates to 0.0 psia.

If zero absolute pressure is used as the reference, the measured pressures are referred to as absolute pressures.

ABSOLUTE PRESSURE

The pressure is referenced to zero absolute pressure and has units of psia. Absolute pressure can only have a positive value.

GAUGE PRESSURE

The pressure is referenced to atmospheric pressure and by convention is measured in the positive direction, i.e. 7 psig.

COMPOUND PRESSURE

The pressure is referenced to atmospheric pressure and has both a positive and negative component, i.e. -0.5" H_2O to +0.5" H_2O.

VACUUM PRESSURE

The pressure is referenced to atmospheric pressure and by convention is measured in the negative direction, i.e. -50 mm Hg.

Figure 2 shows the different types of pressure in a graphical form.

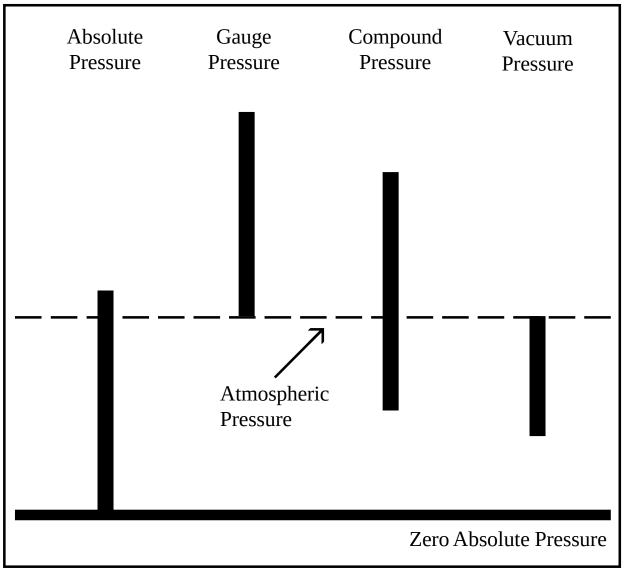

FIGURE 2 Definitions of Pressure

HYDROSTATIC PRESSURE

Hydrostatic pressure is the pressure that a fluid exerts on an object or container walls. Hydrostatic pressure can be used to determine the level of liquid in tanks. The pressure at any height in the tank is given by:

$P = \rho H$

where P = Hydrostatic pressure

ρ = density of the liquid

h = height of the liquid in the tank above the pressure tap.

Figure 3 shows a typical application of measuring hydrostatic pressure.

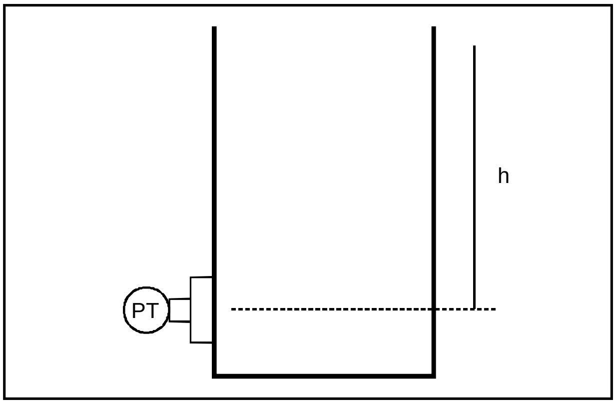

FIGURE 3 Hydrostatic Pressure

DENSITY MEASUREMENT

By using the same equation that was used to determine level, $P = \rho h$, it is possible to measure density. If both the low and high pressure taps of the transmitter are connected to the tank, it is possible to measure density. In this case, h is determined by the distance between the pressure taps and is typically designated by an H. This yields:

$P = \rho H$

In this application, it is desirable to have H as large as possible because this will result in the larger change in P for a given change in ρ.

Figure 4 shows a typical application of density measurement.

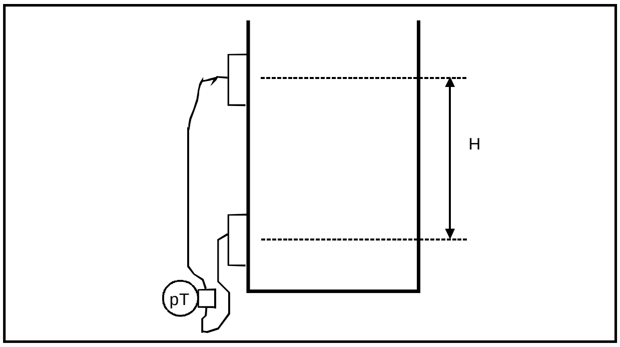

FIGURE 4 Density Measurement