

Inches of Water as a Pressure Unit

About Inches of Water units

Unlike other measurement units of pressure, the *Inches of Water* unit is inconsistent in its representation and requires some understanding to ensure that it is correctly used.

The *Inches of Water* (*inH₂O*) unit was derived from early pressure-measuring devices – manometers – where the pressure is related to a column of fluid (Figure 1). The manometer is considered a primary standard since the pressure exerted by the liquid column can be determined by measuring the basic physical properties; the height of the column and the density (specific gravity) of the fluid.

$$\text{Pressure} = \text{Density} \times \text{Height}$$

In order to determine the pressure that is indicated by the height of the water column, you need to determine the density of water which is affected by the local gravity and local temperature. Thus, the pressure equation becomes:

$$\text{Pressure} = (G_L / G_S) \times (D_W - D_A) \times \text{Height}$$

where:

G_L = Local gravity

G_S = Standard gravity (9.80665 m/s²)

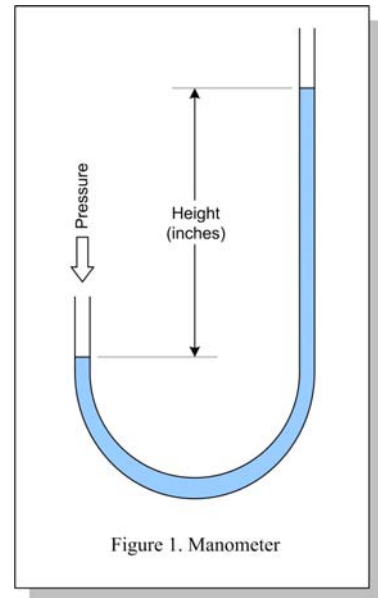
D_W = Density of water at the observed temperature

D_A = Density of air at the observed temperature

We will not go into the correction for gravity here since *Inches of Water* units typically reference the standard acceleration of gravity.¹ However, we want to stress that the pressure reading varies with location (gravity) and fluid density (i.e. temperature). In order to have comparable readings *Inches of Water* units must be reported at the same gravity and temperature.

Inches of Water is properly defined as the pressure exerted by a column of water of 1 inch in height at a *defined or reference condition*, such as 39 °F (4 °C) and the standard acceleration of gravity.

Because the fluid density and local gravity vary from one reading to another, the height of a fluid column does not define pressure precisely. No manometer can be read more accurately than the accuracy with which the specific gravity of the fluid is known. Since the pressure exerted by one inch of water is dependent on its density and the local gravity it is not a fundamental unit of measure for pressure but a derived one which is called a manometric unit.



¹ See [Understanding and Calculating Local Gravity Corrections](#)

Specific gravity is a ratio of the mass of a material to the mass of an equal volume of water at 4 °C (39 °F). Because specific gravity is a ratio, it is a unitless quantity. For example, the specific gravity of water at 4 °C is 1.0 while its density is 1.0 g/cm³.

Unlike mercury, water-based units depend on the density of water which is a measured rather than defined quantity. Pressures given as millimeters or inches of mercury are not based on a physical column of mercury, but rather are precise definitions that may be expressed in terms of SI units. There is only one commonly used reference for mercury; 0 °C (32 °F).

As shown in Figure 2, the maximum relative density of water is at about 39.2 °F (4 °C). That is, the density of water is less than its value at 39.2° both above and below this temperature. For this reason, scientists and physicists use 39.2 °F (4 °C) as the reference temperature for water in pressure calculations.

If all *inH₂O* pressure units were based on the same reference temperature, there would be no problem in making the measurement conversions. The problem is that the reference temperature for *inH₂O* pressure units varies...considerably.

Following is a discussion of the three reference temperatures in common use.

1. Scientific standard

Because water has a maximum relative density at about 39.2 °F (4 °C), the physics and scientific communities have adopted 39.2 °F (4 °C) as the reference temperature for water in pressure determinations. At this reference temperature and standard gravity, 1 (one) inch of water is equivalent to 0.036126 pounds per square inch.

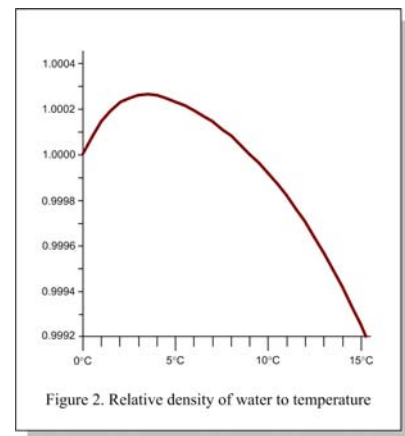


Figure 2. Relative density of water to temperature

2. ASME standard

ASME-3M provides standards used by many industries for the metering of many fluids and in particular steam and water flow measurements. ASME-3M has adopted 68 °F (20 °C) as the reference temperature for water in pressure determinations. At this reference temperature and standard gravity, 1 (one) inch of water is equivalent to 0.036063 pounds per square inch.

3. Industrial standard

ANSI 2530 and AGA 3 provide standards for the use of orifice meters used to meter natural gas and other fluids. These standards have adopted 60 °F (15.6 °C) as the reference temperature for water in pressure determinations. At this reference temperature and standard gravity, 1 (one) inch of water is equivalent to 0.036092 pounds per square inch.

Error differences

Since there is no universal standard for the reference temperature for *Inches of Water* measurement units, the user must pay close attention to the standard under which measurements are being taken and converted. The following table shows the potential errors (differences) when misusing *Inches of Water* pressure units.

Reference temperature comparison	Pressure Difference
39.2 °F (4 °C) versus 60 °F (15.6 °C)	0.094 %
39.2 °F (4 °C) versus 68 °F (20 °C)	0.174 %
60 °F (15.6 °C) versus 68 °F (20 °C)	0.08 %

Nearly every pressure conversion table and calculator on the Internet either does not indicate any temperature reference associated with Inches of Water pressure conversions or perhaps only one, such as 39.2 °F (4 °C). And yet, the differences in these unit references are significant.

Conversions

The following table provides some conversions for the three common *Inches of Water* pressure units.

This...	Times this...	Equals this...
<i>inH₂O</i> (39.2°F / 4°C)	0.00254	<i>atm</i> (metric)
"	0.00246	<i>atm</i> (standard)
"	0.00249	<i>bar</i>
"	2.540	<i>cmH₂O</i> (4 °C)
"	1.000942	<i>inH₂O</i> (60 °F)
"	1.001747	<i>inH₂O</i> (68 °F)
"	0.0736	<i>inHg</i> (32 °F)
"	0.00254	<i>Kg/cm²</i>
"	0.2491	<i>kPa</i>
"	0.0361	<i>PSI</i>
"	1.8683	<i>Torr / mmHg</i> (0 °C)
<i>inH₂O</i> (60°F / 15.6°C)	0.00254	<i>atm</i> (metric)
"	0.00246	<i>atm</i> (standard)
"	0.00249	<i>bar</i>
"	2.540	<i>cmH₂O</i> (4 °C)
"	0.9990	<i>inH₂O</i> (39.2 °F)
"	1.0018	<i>inH₂O</i> (68 °F)
"	0.0735	<i>inHg</i> (32 °F)
"	0.00254	<i>Kg/cm²</i>
"	0.2488	<i>kPa</i>
"	0.0361	<i>PSI</i>
"	1.8664	<i>Torr / mmHg</i> (0 °C)

Inches of Water as a Pressure Unit

This...	Times this...	Equals this...
<i>inH₂O</i> (68°F / 20°C)	0.00254	<i>atm (metric)</i>
"	0.00246	<i>atm (standard)</i>
"	0.00249	<i>bar</i>
"	2.5355	<i>cmH₂O</i> (4 °C)
"	0.9982	<i>inH₂O</i> (39.2 °F)
"	0.9992	<i>inH₂O</i> (60 °F)
"	0.0734	<i>inHg</i> (32 °F)
"	0.00254	<i>Kg/cm²</i>
"	0.2486	<i>kPa</i>
"	0.0361	<i>PSI</i>
"	1.8650	<i>Torr / mmHg</i> (0 °C)