Why Pressure Scales Cause So Much Confusion

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Pressure scales can be extremely confusing to new operators. This is not surprising. To my mind, there are three primary areas of confusion.

Firstly, the pressure of gas inside an instrument changes over many orders of magnitude during pump-down. The change is about 9 orders of magnitude for a traditional Scanning Electron Microscope and about 13 orders of magnitude for an ultra-high vacuum instrument such as a Scanning Auger Microprobe.

To give an idea about the scale of change involved in vacuum, consider that the change in going from ambient pressure to that inside a typical ultra high vacuum system is like comparing one meter with the mean radius of the planet Pluto's orbit. The fact is that we don't often get to play with things on that scale. As a consequence, many of us have to keep reminding ourselves that 1×10^{-3} is one thousand times the value of 1×10^{-6} - not twice the value.

The second source of confusion has to be the design of pressure gauge displays. Although modern gauges are digital and consequently trivial to read, most instruments have older, moving coil gauges in which a needle indicates the value of pressure. The visual layout of these gauge displays can be extremely confusing. Many instruments use a single gauge display, which not only indicates different pressure ranges, but also has the scales so arranged that, on one scale, the needle sweeps right for falling pressure, but on another scale, the needle sweeps left.

A third source of confusion has to do with the units we use to characterize pressure. There are an incredible variety of pressure scales. Although most of us will not encounter all of these scales except in textbooks, all of us will encounter enough of them to marvel at technologies' ability to make life "interesting".

The fact is that 1 Torr of gas pressure equals:

1333 dyne per square centimeter	1.35 Guericke
1333 microbar	0.0393 inches of mercury
1333 Bayre	0.0193 pounds per square inch
1000 microns of mercury	0.1333 Pieze
133.3 Newton per square meter	0.00135 technical atmosphere
1333333 Gaede	0.00 kilograms per square centimeter
13.59 millimeters of water	0.00135 Bar
13.59 kilograms per square meter	0.00131 physical atmosphere
1.33 millibar	133.3 Pascal
1.35 centimeters of water	

One might ask why there is such a variety of scales?

Well, pressure is force per unit area so we can pick out the units that are consistent with this (for example, dyne per square centimeter and the Newton per square meter).

In addition, we used to describe a force as a mass unit acted on by gravity, so we can pick out those units that describe pressure as a mass per unit area (for example, kilograms per square meter, pounds per square inch, and kilograms per square centimeter).

Now, we can also characterize pressure by the height of a column of liquid that it can support (for example, microns of mercury, millimeters of water, centimeters of water and inches of mercury).

Some are "honorary" scales where a scale is renamed in honor of a significant vacuum scientist (Pascal, for Blaise Pascal, which is the same as the Newton per square meter scale; Torr, for Evangelista Torricelli, which is the same as the millimeters of mercury scale; Gaede, for Wolfgang Gaede, which is the same as the Newton per square meter scale, and Guericke, for Otto von Guericke, which is the same as the centimeters of water scale).

Mix in the fact that some countries used pounds and inches, giving pounds per square inch, while other countries used kilograms and meters giving kilograms per square meter and kilograms per square centimeter.

Finally, as all had access to mercury and water, many measured in microns of mercury, millimeters of water, centimeters of water, and inches of mercury.

Pretty soon 20 pressure scales seems like a shortlist of options.

In the end, pressure units are like antiques. They give us a taste of how vacuum technology developed. Each scale has it's story and was someone's contribution. We are left with the clutter or, if we prefer, the charm.

In the U.S. we traditionally use the Torr scale when characterizing gas pressure inside a vacuum system. Nevertheless, the designated Standard Industrial Unit (SI) is the Pascal scale. As above noted, 1 Torr is equal to 133.3 Pascal.

So, the next time someone brags about being in the "low negative sevens", ask them is that's in Pieze, Guerickes, Gaedes, Bayres or just plain Torr. ■

(Dr. Anthony Buonaquisti is an independent consultant specializing in "At-Your-Site" Training)

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