

# This IS Vacuum

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## U.N.I.T.S O.F M.E.A.S.U.R.E.M.E.N.T

A confusing aspect of vacuum engineering are the units of measurement used in the industry. Depending on the origin of product catalogues or indeed the intended target industry, the units of measurements will vary widely.

### Vacuum Level

Understand this. There is no such thing as vacuum measurement. It is *atmospheric pressure* you are measuring. The two differences in the vacuum industry are either the measurement of differential or absolute pressure. In North America and in particular the United States, general industry uses inches of mercury ("Hg) and is by far the most common terminology in use. This is a differential unit of measurement. This means that it is a measurement of pressure (but always referred to as vacuum) with the datum point taken from the existing atmospheric pressure. The higher the number, the higher the vacuum. For example, when a vacuum pump or venturi starts to create a vacuum in a known, fixed volume, the "Hg scale starts to increase, rising from zero to the final pressure (vacuum) level, which has been determined by the performance of the pump or the application itself. The standard maximum number for "Hg is 29.92, as this is a standard "atmospheric pressure."

Atmospheric pressure is created by a column of air pressing down onto the surface of the earth. In real world terms, imagine a square inch of surface area. This will have a force of 14.7 psi pressing down on it. This pressure is what vacuum engineers are reducing in a known volume. Of course, atmospheric pressure varies based on weather activity, or what is more comprehensible, the altitude of the machinery compared to sea level. At sea level, which is a constant height across the globe, the following standard atmospheric pressures are applicable: 29.92"Hg, 14.696 psi, 760 mmHg (Torr), 1013 mbar, and 100 kPa. Fig. 1 demonstrates these values and shows if they are normally used in a differential (starts from zero) or an absolute (ends in zero) scale in our industry.

The industrial application normally dictates the unit of vacuum level. In a simple vacuum cup pick-and-place system, "Hg is the most common, certainly in North America, whereas in Europe, kPa is the preferred choice. This is because the amount of vacuum required is generally low, peaking at <27"Hg or -90 kPa. However, if the user must know the final atmospheric pressure, an absolute scale should be used. Industries such as vacuum deposition (coating) or semiconductor manufacturing where the atmosphere must be clean (as few gas molecules as possible), a much higher vacuum is required. Therefore, an absolute measurement should be used such as mbar (millibar). It is not uncommon

for this industry to use a sliding vane pump to create an initial vacuum of 0.02 mbar(a) and then a turbomolecular pump to generate in excess of 0.00001 mbar(a). Notice the (a) after the number. This dictates it is a measurement based on absolute zero atmospheric pressure, which is always a constant unlike the atmospheric pressure, which a differential measurement uses as its datum point. Mbar(a) is common in European countries whereas in North America, Torr (mmHg) is the preferred choice. Both are absolute scales and offer the same accuracy of absolute pressure measurement.

### Vacuum Flow

Flow in a vacuum system is always confusing to people as they can't visualize the air in a vacuum system. Think of it like this: air is made up of gas molecules, microscopic of course but a physical mass nonetheless. It is these gas molecules that you are removing. Pressure is created by the density of gas molecules in a known volume. If you double the amount of gas molecules in a volume (using a compressor), then you have doubled the pressure. Consequently, if you extract half of the gas molecules in a known volume, then you will half the pressure, or in the case of vacuum, if the initial pressure was one atmosphere, you have now created a vacuum of -50kPa or 15 "Hg or 380 Torr, etc.

The units of measurement used to measure vacuum flow vary as much as vacuum level measurement. In North America, the most common by far is **CFM** or cubic feet per minute. This means that the pump or venturi will extract so many CFM in a known volume. There is also much confusion as to the difference between SCFM and ACFM. SCFM is a volume of air assumed at a standard condition based on atmospheric pressure, temperature, and humidity. This standard varies even within the same countries, let alone continents, so always refer to the manufacturers' data sheets to see what they are basing their SCFM units on. However, 1 scfm is a standard "lump" of air full of the normal amount of gas molecules found in a cubic foot of air at sea level. As the vacuum level increases, the SCFM decreases with it at a near linear rate (Fig. 2) as there are less and less gas molecules in the application. This is why when a vacuum pump first starts to evacuate a volume, there is a lot of flow out of the pump exhaust, but as the vacuum pump decreases the pressure (increases the vacuum), the flow from the exhaust decreases. Therefore at a vacuum of 29 "Hg, there is hardly any flow (SCFM) at all.

However ACFM is the flow at the vacuum level. Therefore, theoretically, 100 acfm at 15 "Hg is the same as 50 scfm because at 15 "Hg, there is half the amount of gas molecules. Therefore, when you specify a vacuum pump on a customer request, make sure he is quoting you either ACFM or SCFM.

The other common units of measurement are cubic meters, liters, or milliliters (metre, litre, and millilitre in European spelling). Therefore on European pump data sheets, you will see m<sup>3</sup>/hr, m<sup>3</sup>/min or l/min or l/sec--quite the variation and based upon the manufacturer's preference. The good thing about the European

system is that it's all divisible by 60 (minutes to seconds or hours to minutes) or 1000 (meter cubed to liters). So jumping between one manufacturer and the next is relatively easy. Fig. 2 demonstrates the difference in m<sup>3</sup>/hr, actual m<sup>3</sup>/hr (ACFM), and standard m<sup>3</sup>/hr (SCFM). Also, as you can see from the graph in Fig. 2, manufacturers give a time curve as well for a given volume to assist the user in sizing the equipment for a given application.

Vacuum pumps or venturi are used for one thing and one thing only. To “pump” down a volume to a particular vacuum level in a certain amount of time, and the reason for one pump being larger than the other is simply to do it faster. This volume might be the internal volume of a vacuum cup and associated hoses or a space simulation vessel some 100 feet in diameter. Either way, an application engineer needs to know three things: the vacuum level required, the volume to be evacuated, and the time in which it is to take. The fourth and generally the most important thing they need to know is what the application is. That will determine what type of pump is required and all the accessories needed to ensure a safe, reliable, and correct application of vacuum equipment.

*This article is intended as a general guide and as with any industrial application involving machinery choice, independent professional advice should be sought to ensure correct selection and installation.*

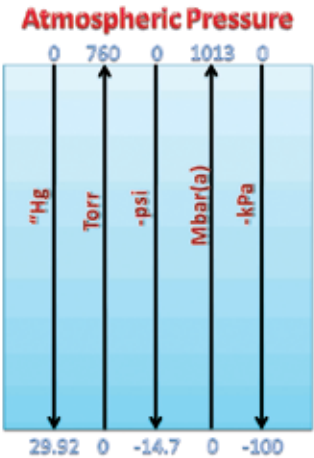


Fig. 1 100% Vacuum

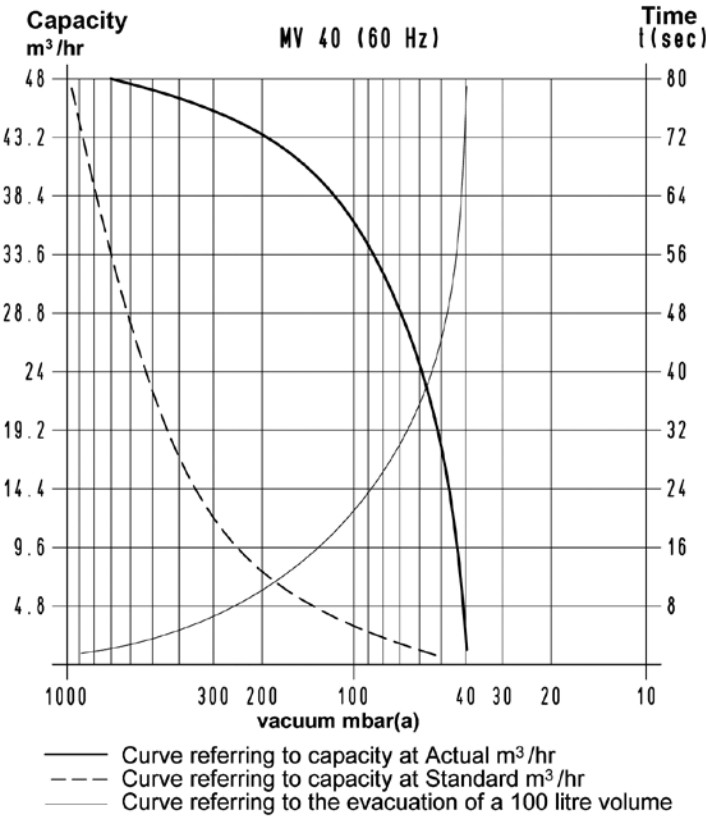


Fig. 2

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