What is Vacuum:
The Most Commonly Asked Questions

The application of vacuum generating equipment has many uses in industry today but unfortunately, vacuum remains a bit of a mystery. The objective of this article is to provide answers to the most commonly asked questions for when vacuum is used to make, move or transform a product or item.

1) What is vacuum?

Vacuum is the term used to describe the region of pressure below atmospheric pressure or the surrounding area:

1 Atmosphere @ sea level = 14.7 PSIA = 0 PSIG = 29.92″ Hg

When speaking of vacuum, remember that it is the opposite of pressure; high vacuum means low pressure.

2) How is vacuum measured?

There are a number of units of measure that can be used to describe the level of vacuum. Vacuum can be expressed in either gauge or atmospheric values. A simple rule of thumb is that gauge values start at zero while absolute values end at zero. In the US, the most common way that vacuum is referenced is in inches of mercury, gauge (“Hgv):

29.92: Hgv (gauge) = 0″ Hga (absolute)
0″ Hgv = 14.7 PSIA
0″ Hga = 0 PSIA

For process applications that run at higher (or deeper) vacuum levels, vacuum is often expressed in an absolute scale as the pressure level needs to be read in finer increments. Torr or millimeters of mercury (mmHga) are the most commonly used, both of which provide the same reading or indication:

1 Torr = 1 mmHga
760 Torr = 760 mmHga = 0″ Hgv = 29.92″ Hga = 14.7 PSIA

3) What is the function of a vacuum pump?

The main function of a vacuum pump is to:
1. Handle air leakage and/or non-condensables into the vacuum system in order to maintain a specific vacuum level.
2. To evacuate a volume or space from an initial pressure to a lower pressure.
3. A combination of the above.

4) How are vacuum pumps rated?

Depending on the pump manufacturer, vacuum pumps are usually rated in ACFM or SCFM. ACFM or Actual Cubic Feet per Minute measures the volume of air at a given pressure under actual vacuum conditions (i.e. expanded air). SCFM or Standard Cubic Feet per Minute measures the volume of air at a given pressure at atmospheric conditions (i.e. non-expanded air).

As a result of the measurement, ACFM values will always be greater than SCFM levels except at atmospheric pressure where they are the same (also called nominal capacity). In order then to accurately compare vacuum pump performance, advertised capacities should be converted into either ACFM or SCFM which is easily done by establishing the ratio of a volume at a specific vacuum level by using the following equation:

Ratio of a volume = P1/P2 where:
P1 = 29.92″ Hga
P2 = Vacuum level, "Hga

For example, suppose a pump has a rating of 5 SCFM @ 20″ Hgv. How do we determine ACFM? First, convert the gauge reading to absolute:

P2 = 29.92″ Hgv – 20″ Hgv = 9.92″ Hga

Then divide P1 by P2:

Ratio of a volume = 29.92/9.92 = 3

To convert to ACFM multiple the SCFM rating @ P2 by the ratio of a volume:

ACFM = 5 x 3 = 15

Note: To convert from ACFM to SCFM, divide the level of ACFM by the ratio of a volume.

See below for a chart of common ratio's.

"Hgv	"Hga	Ratio
0	30	1.0
5	25	1.2
10	20	1.5
15	15	2.0
20	10	3.0
25	5	6.1
27	3	10.3
28	2	15.6
29	1	32.6
29.5	0	71.4

5) What level of vacuum do I need for my application?

Most industrial vacuum applications require vacuum levels in the 10 – 25" Hgv range. For some process and production applications the operating range is higher, usually between 26 – 28" Hgv (50 – 100 Torr).

Too often, specifying higher than necessary vacuum levels results in higher vacuum pump capital and operating costs, not in higher performance/production/throughput. As a rule of thumb, the required vacuum level for a given process should be that level that is required to efficiently perform the "work" required (plus a safety factor).

For example, with an application that requires a vacuum level of 20" Hgv and has a constant leak rate of 5 SCFM at atmospheric pressure, the calculated inlet capacity at the vacuum pump to maintain the vacuum level would be 15 ACFM (5 SCFM x Ratio of 3). If using a rotary vane style vacuum pump this would translate into a motor size of approximately 1.5 HP.

However, if a higher vacuum level is specified (let's assume 25" Hgv) with the same 5 SCFM leak rate, the size of the pump increases as the calculated inlet capacity at the vacuum pump doubles in volume to 30.5 ACFM (5 SCFM x Ratio of 6.1) to maintain the higher vacuum level. This now means that the same rotary vane style pump would require a 5.0 HP motor in order to meet the increased capacity requirement at the higher vacuum level. Higher costs will always be realized when higher than necessary vacuum levels are specified.

6) How do I know which style of pump to use?

In today's marketplace there are many different styles and types of vacuum pumps available. Mechanical or motive fluid powered, rotary or reciprocating, oil-less or lubricated; there are many choices to choose from.

The first step in selecting a vacuum pump suitable to the process is to ensure that the pump is designed to operate at the required vacuum level or vacuum range. For instance, pumps designed specifically for high vacuum service should never be applied or operated on applications in the rough vacuum range (as they are not designed to handle the larger volumes of airflow at lower vacuum levels).

The shape of the pump performance curve in relation to the required vacuum level is also a consideration. Never select a pump where the required vacuum level falls into or past the "knee" of the curve, as pump efficiency at that point is reduced. (Note that the shape of the curve and the position of the knee of the curve are dependent on the selected pump technology.)

Next consider the condition of the incoming airstream. In vacuum cooking for example, large amounts of water vapor are removed under vacuum so as to reduce the level of moisture in the product. This highly saturated air would quickly foul an oil lubricated style of pump as the vapor can condense prior to or within the pump itself. A water sealed liquid ring pump however, which also acts as a condenser, would not suffer any ill effects – its performance would actually be enhanced by the condensing vapor.

Finally, consider the total cost of ownership of a vacuum pump, not just its initial purchase price. Vacuum pumps have different levels of efficiency (ACFM/kW) depending on the pump design and technology. Too often, the cheapest pump to purchase turns out to be the most expensive pump to own, long term.

7) Do I use individual pumps or a central system?

For companies that have multiple machines that use vacuum pumps, the question is often raised, "should I stay with individual pumps or should I move to a central vacuum system?"

Either method has its advantages and disadvantages. Individual pumps, usually located on or near the machine, are less expensive to purchase when compared to a central system. Their location at the machine also eliminates the need for a plant wide vacuum piping system to connect all of the vacuum use points to the central system.

Individual pumps can require more maintenance than central systems (as there are more pumps to service). In addition, noise, heat, oil or smoke emitted by the pump(s) can make for an undesirable situation for workers on those machines.

Central systems, when properly applied, can provide for all current and future vacuum requirements. When supplied as a duplex system, the individual pumps can be sized to continuously provide 100% of the required plant capacity (with 100% backup) or to provide 100% of peak load capacity (where each pump covers say 60% of total load), and where the pumps run "on demand," they provide for energy and operating cost savings. Central systems can also be supplied in an expandable configuration where additional pumps/controls can be easily integrated as future demand increases.

8) What about using receivers or tanks?

A common misconception with vacuum is that the addition of a receiver or tank will help to increase the performance of the machine/pump/system. This of course is not always 100% correct as it depends on a number of factors and sizing considerations.

For certain applications, like vacuum thermoforming, the receiver actually does the work by quickly evacuating the mold volume once the control valve is energized. The vacuum pump in these applications simply is used to evacuate the tank between forming cycles, not specifically to do the mold evacuation.

For many applications, simply adding a receiver will only add to the overall volume of the vacuum system and can actually hinder performance. As there is no storage effect realized (which is the opposite of compressed air), the use of a receiver volume should generally be limited to those applications that require evacuation of a volume, or where the receiver is used as a part of a central vacuum system, acting as a ballast to help stabilize the vacuum level (as vacuum demand changes).