Lesker Tech

"...vacuum science is our business."

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Basic Vacuum Concepts

Vacuum & Suction

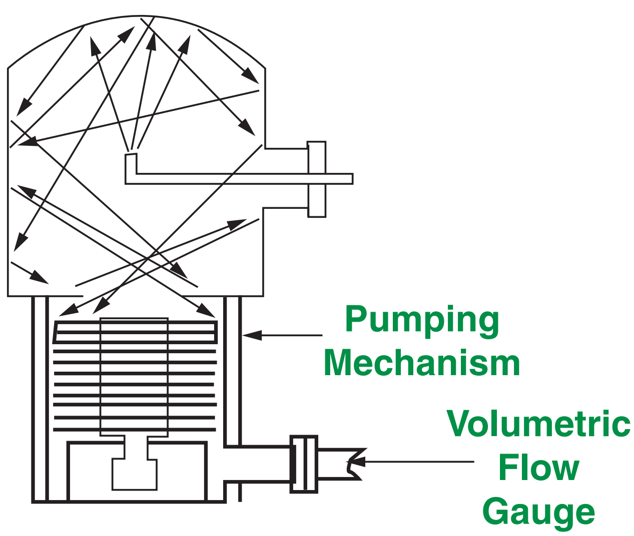
It is a common mistake to think a vacuum pump sucks gas from a chamber. There is no such force as suction. If gas molecules in one "section" of an enclosed volume are (for this discussion, mysteriously) removed, then molecules from the remaining volume, in their normal random, high-speed flight, collide and bounce off walls until they fill the total space at a lower pressure.

In other words, until a molecule, propelled by random collisions, enters the pump's pumping mechanism, it cannot be removed from the chamber. The pump does not reach out, grab a molecule and suck it in. Grasping that basic fact makes other aspects of vacuum easy to understand. So, the first great principle of vacuum technology is:

Vacuum Doesn't Suck!

Pumping Speed

Pumping speed is formally defined as the ratio of the throughput of a given gas to the partial pressure of that gas at a specific point near the inlet port of the pump. With less formality, but more clarity, it is the volume of gas (at any pressure) that is removed from the system by the pump in unit time. In short, pumping speed is a measure of the pump's capacity to remove gas from the chamber. It is measured in: *liters per second (L/sec); cubic feet per minute (cfm);* or *cubic meters per hour (m^3/hr).*



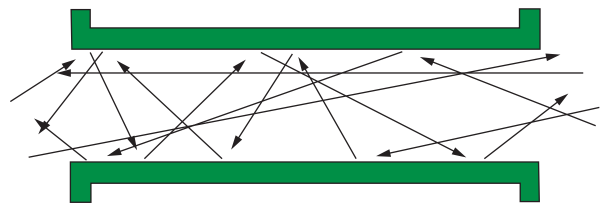
Measuring Pumping Speed

Conductance

The formal definition of conductance is the ratio of throughput, under steady-state conservation conditions, to the pressure differential between two specified isobaric sections inside the pumping system. Informally, the conductance of a tube is its capacity to let a volume of gas (at any pressure) pass from one end to the other in a unit of time. It too is measured in: *liters per second (L/sec); cubic feet per minute (cfm);* or *cubic meters per hour* (m^3*/hr)*.

The conductance of a passive (non-pumping) component has the same relationship as pumping speed has to a pump. It is a measure of its effectiveness at transferring gas rather than pumping it.

Although both conductance and pumping speed measured in the same units, the terms should not be used interchangably. However, it is very relevant to see how a pump's pumping speed is affected by adding the conductance of passive devices such as ports, traps, and valves between pump and chamber. (See *Lesker Tech* Volume 1, Issue 2.)



Gas Conductance of a Passive Component

Outgassing Rate

Outgassing rate is, informally, the quantity of gas evolving from a unit area of a surface in unit time. Typical measurement units are: *atm cc/sec/sq cm; torr.liter/sec/sq cm;* or *watts/sq meter.*

Although the last form may seem strange, it is the unit quoted in modern text books, such as O'Hanlon's "Users Guide to Vacuum Technology." (See below for explanation.)

The outgassing rate is a critical factor since, in an ideal leak-free vacuum system, the gas load (amount of gas entering the gas phase due to outgassing) divided by the effective pumping speed, gives the base pressure of the chamber. Methods of reducing outgassing rates will be discussed in a later *Lesker Tech*.

Throughput and Gas Load

Throughput and gas load are informally defined as the quantity of gas in pressure-volume units flowing in unit time past some location in the system. They are frequently expressed in: *torr.liters/sec;* or *atm cc/sec*.

Although throughput and gas load are sometimes used interchangeably, it is preferable to reserve throughput as a pump property and gas load as a chamber property. This allows the second great principle of vacuum technology to be stated as:

Gas In = Gas Out

or, more formally: at constant chamber pressure, the gas load into the chamber equals the throughput of the pump.

While this concept is easily accepted for a garden hose (the flow into the hose must equal the flow out of the hose) it is sometimes difficult to grasp why it should be true for gases. *(continued page 3)*

Aren't liquids incompressible and gases compressible? Yes, that's true. But for both liquids and gases we are describing here mass flow, not volumetric flow. Think of it at the molecular level. Gas load means the number of gas molecules entering the gas phase from all sources: gas leaks; wall outgassing; permeation through gaskets; evaporation of volatile materials; and backstreaming of gases and vapors from pumps. Pump throughput means all the molecules that enter the mechanism and never return to the chamber.

The pump's throughput is found by multiplying the Effective Pumping Speed (a concept discussed in a later *Lesker Tech*) from the chamber by the pressure in the chamber.

As stated earlier, most pumps have a constant pumping speed over a large pressure range. While in this range, clearly as the pressure decreases, the pump's throughput decreases. If the gas load can be considered almost constant (after several hours at high vacuum) then when the throughput equals that gas load, the chamber pressure stabilizes at what we call the base pressure.

Footnote: SI Units for Outgassing

Outgassing rate is measured in units of $Pa.m^3/sec/m^2$.

However,

$1 \text{ Pascal} = 1 \text{ Newton/meter}^2$

$1 \text{ Newton.meter} = 1 \text{ joule}$

$1 \text{ Joule/sec} = 1 \text{ watt}$

Therefore, outgassing units are watts/m^2.

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