VACUUM

The Italian physicist Torricelli (1608-1647), inventor of the barometer, is credited with beginning the study of vacuum techniques by his experiments on the existence of a pressure due to air. Pascal (1623-1662) continued this research by showing the reduction of air pressure at different altitudes. Boyle (1602-1686) invented the first mechanical vacuum pump.

The classical definition of a vacuum is an enclosed space devoid of any gases or vapors. This definition, of course, is impossible to achieve. The best that can be accomplished is an area of low pressure where most of the gases and vapors have been removed.

James Dewar (1848-1923) was the first to use vacuum insulation. His invention, the double-walled glass vessel with a high vacuum in the space between the walls, is now a common article in research laboratories. Any vessel that utilizes vacuum insulation to prevent heat flow is called a Dewar.

Dewar designed his vessel after studying the 1820s research of Dulong and Petit who discovered the following two properties of insulation:

1. There is no convective transfer of heat between walls confining gas at sufficiently low pressure.
2. The emission or absorption of thermal radiation by the surface of a material grows weaker as the reflectivity increases. (Scurlock 155)

Vacuum insulation alone can nearly eliminate two of the principal modes of heat transfer, that of **conduction** and **convection**. When appropriate measures are taken also to minimize heat transfer by **radiation**, and conduction by solid structural members, then vacuum insulation is by far the most effective known(Scott 143).

A high-vacuum system usually consists of several items working together:

1. A mechanical pump called the fore pump, which exhausts to the atmosphere and maintains an inlet pressure in the range of 1 to about 100 microns of mercury.
2. A pipe connecting this pump to the outlet of a diffusion pump capable of reducing the pressure several orders of magnitude more.
3. A pipe of a larger diameter connecting the diffusion pump to the volume being evacuated.
4. Sometimes a second pump, called a booster pump, is used between the high-vacuum diffusion pump and the mechanical pump.
5. It is also customary to provide a cold trap to remove condensable vapors(Scott 155).

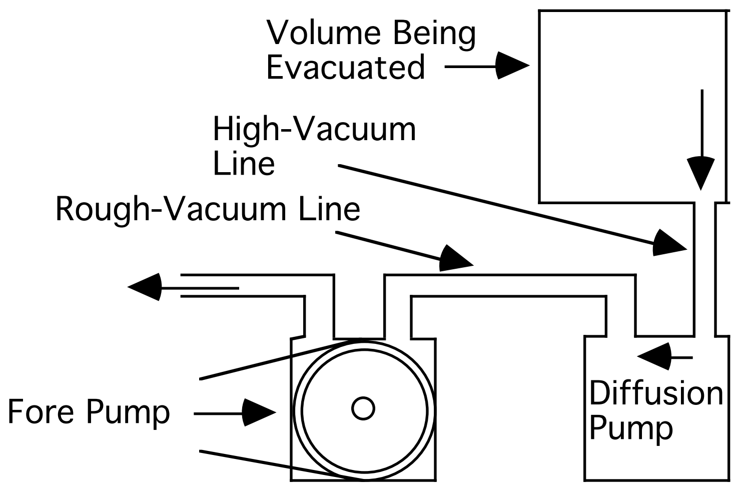

Diagram of a Simple Vacuum System

Some of the different types of vacuum pumps are diffusion pumps, ion pumps, cryogenic pumps, and turbo-molecular drag pumps.

CRYOPUMPING

Gas will condense on a cryogenically cooled surface. If this surface is in an evacuated enclosure, such as a vacuum shield for liquid helium, it will produce a better vacuum. This phenomenon involves not only phase change from gas to solid at the cold surface but also adsorption of the gas molecules. (Adsorb: to collect a gas, liquid, or dissolved substance, in condensed form on a surface.) The attractive feature of cryopumping is the extremely large pumping speeds that can be attained. The effect of this "pump" is that it occurs wherever there's liquid helium (or gas if the temperature is below 20°K) across a surface in conjunction with a vacuum line (all transfer lines). The surface of the pipe becomes the pump's collection point.

VACUUM VALVES

Of the many valves designed for high-vacuum use, the most reliable are those that do not depend on packing to separate the vacuum region from the atmosphere. Some valves use metal bellows and others have an elastic diaphragm of synthetic rubber pressed onto a seat by a metal member that is on the atmospheric side of the diaphragm. These are not very suitable due to air diffusion through the diaphragm.

HIGH-VACUUM VALVES

The Richards seal-off valve, developed by NBS Cryogenic Engineering Laboratory, has proved very useful. After pumping is completed, the valve is closed and then the valve handle and bonnet can be removed, leaving only the closed valve seat on the evacuated apparatus(Scott 181).

VACUUM GAUGES

Since pressures measured by vacuum gauges are several orders of magnitude smaller than atmospheric pressure, most of the ordinary pressure gauges cannot be easily used in vacuum work. In fact, most vacuum gauges are secondary gauges — the pressure is not measured directly, but is inferred from measurement of other properties.

So, if pressure can't be measured directly, how is it measured?

In the free molecular flow range of low pressure, the thermal conductivity of a gas decreases as the pressure of the gas is reduced. Therefore, if a heated surface is placed within the area of this pressure range, the thermal conductivity of the gas at the prevailing pressure will determine the rate which heat is dissipated form this surface. Vacuum gauges operating on this principle use a fine wire as the heated surface. If the wire is kept at a constant wattage, the temperature of the wire can be used to indicate the pressure.

The reliability of any hot-wire vacuum gauge will suffer if the wire surface becomes too contaminated.

MKS CAPACITANCE MONOMETER

This gauge measures the true partial pressure regardless of the thermal conductivity of the gas.

THE PIRANI GAUGE

The Pirani gauge operates on the principle that the thermal conductivity of a low-pressure gas depends upon pressure, and that the resistances of most metallic conductors increase whenever the temperature of the conductor is raised. By using a metal with a high coefficient of resistance and a Wheatstone bridge for balance, pressure can be determined by measuring linear resistance. The usable pressure range for this gauge is from 1 mm Hg down to 1 x 10^{-3} mm Hg.

THE THERMOCOUPLE GAUGE

The thermocouple gauge also responds to changes in thermal conductivity by measuring the temperature of a heated wire. A small thermocouple mounted on the wire generates a nonlinear voltage that can be read by a galvanometer graduated into units of pressure. The pressure range for this gauge is from 1 mm Hg down to 1 x 10^{-3} mm Hg.

This gauge, though not as accurate as the Pirani, is more physically resilient. The thermocouple gauge can be read continuously, and further, it's not affected by operation at atmospheric pressure for short periods. It measures total pressure (pressure due to vapor as well as pressure due to permanent gas). The gauge can be read remotely and it can be used to provide a control signal for other circuits. The disadvantage of this gauge is that it must be calibrated for each different gas.

THE IONIZATION GAUGE

The ionization gauge is probably the most widely used high-pressure vacuum gauge. It operates by supplying a constant current flow to an anode that ionizes any residual gas molecules. These ions are drawn to the ion collector, producing a current measured with a microammeter. Since the supply current is fixed, the ion current is proportional to the molecular concentration(Scott 179). The pressure range for this gauge is from 1 mm Hg down to 1 x 10^{-6} mm Hg.