SVC Topics



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The Return of the Piston Pump

Historically, the major role for vacuum pumps in industrial processing was to generate and maintain a good vacuum for such processes as vacuum heat treating, vacuum melting, vacuum drying and film deposition, as well as producing light bulbs and electron tubes, etc. These applications generally only required mechanical vacuum pumps to compress and pump large amounts (molecules) of gas for only a short time during the process. This meant that the internal heat generated as a result of the gas compression was restricted to a short period of time.

Recently, vacuum pumps have been used more and more to control the flow of gases at an appreciable flow rate (high mass throughput) over a long period of time in processes such as subatmospheric chemical vapor deposition (SA-CVD), plasmaenhanced CVD (PECVD), plasma etching, plasma deposition, etc. In addition, the processing gases and the reaction products can be toxic, corrosive or flammable, and may contain particulates. Also of concern are contaminants, such as oil from the vacuum pump returning to the processing chamber by back-streaming and wall creep, or because of power or operator failure.

Piston-type Pumps

The reciprocating piston-type vacuum pump had its beginning with the piston-type water pump, which is thousands of years old. Around 1648, von Guericke first began experimenting with the piston-type suction pump. He demonstrated the power of vacuum (really atmospheric pressure) using the famous Magdeburg hemi-



spheres in 1657. (Torricelli had demonstrated the mercury barometer in 1643). In the mid-1800s, all-glass vacuum pumps, using moving mercury columns as the piston in glass cylinders, were developed (Geissler, Töpler, Sprengel). The moving mercury column formed a good hermetic seal with a clean glass surface. These mercury piston pumps allowed the generation of better vacuums than did the solid-piston mechanical pumps, and were used by Edison in evacuating the first light bulbs in 1879. Various types of manually operated piston pumps remained the primary type of mechanical vacuum pump until about 1910, when the oil-sealed rotary vane pump had developed to nearly its present-day design (Gaede, 1907). About this time, the first high-vacuum mercury diffusion (vapor jet) pumps were invented (Gaede, 1915; Langmuir, 1916), and they replaced the mercury piston pumps.

Rotary Pumps

Rotary vane pumps had been used for pumping water since at least 1588 (Rumelli woodcut) and were in some use as vacuum pumps in the late 1800s, but were not very effective because of poor seals (oiled leather was the principal flexible sealing material), high-vapor-pressure oils and slow rotation speeds. Rotary pumps evolved rapidly once the newly developed electric motors were applied to vacuum pumps (Kaufman, 1905; Gaede, 1905). This allowed high rotation speeds, along with better sealing materials and low-vaporpressure oils (Burch, 1928). Because the rotary pump was much simpler and more easily maintained than the piston pump, the rotary pumps rapidly replaced the piston-type vacuum pumps for industrial applications, though manually operated piston pumps were still used for laboratory demonstrations (e.g., CENCO Scientific catalog) for many years. The first "vacuum cleaner" (Booth, 1901) was a hand-operated piston pump drawing air through a cloth filter.

The oil-sealed rotary vane pump has the advantage, in high-throughput pumping applications, that the oil can be circulated, cooled, chemically neutralized and filtered during operation. Disadvantages are:

- The oil can migrate back to the processing chamber
- The oil can accumulate chemicals and particulates from the processing
- The compression of vapors can lead to condensation of vapors, which can inhibit the sealing properties of the oil (especially a problem when pumping large amounts of water vapor).

Water in the oil causes the oil to froth and poor sealing results until the water is vaporized from the oil. Chemicals can react with and degrade the oil, and chemical retention in the oil can pose a significant maintenance and waste-disposal problem. In some cases, chemical-resistant oils are used in the pump but, generally, they have poor lubrication properties that can increase maintenance problems.

Other types of mechanical pumps, such as the "blowers," use much less oil and are sometimes called "dry pumps." The lobe (Roots) and claw blower designs have poor internal heat dissipation and will heat up in long-term, high-throughput pumping conditions. This can lead to oil vaporization from bearings and internal gear boxes, as well as problems with maintaining the close mechanical tolerances required for operation and efficient pumping.

Initially, the pistons in pistonpumps were oil-sealed, but the demands of surface science and vacuum analytical techniques, such as transmission electron microscopy (TEM), required oil-free vacuum chambers (because electron bombardment polymerizes oils and hot surfaces decompose oils). In the late 1960s and early 1970s, the newly developed low-friction, high-temperature, polymer materialpolyfluoroethylene (PTFE)-often "filled" with a harder material, began being used for the chamber and piston walls (Farrant). By the mid-1980s, oil-free piston pumps were commercially available and were being used in the semiconductor-processing industry. In the piston pump, there

can be several stages in series. The accompanying figure shows a two-stage reciprocating piston pump.

The piston pump has many attributes for some application of vacuum pumping. The modern piston pump uses no oil in contact with the pumping chambers, so oil contamination and chemical retention are not a problem. The surfaces exposed to chemicals can be made of, or coated with, a corrosion-resistant material. The design allows for good heat dissipation by having large surface areas in contact with the pumping chamber. The temperature of the chamber walls can be controlled to minimize vapor condensation by compression. Disadvantages of the piston pump, in some cases, are its noise and vibration. PASF

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