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PVD Processes: Cleaning With CO_2

Pollution concerns with typical solvents have spurred the search for alternative cleaning materials and processes. One promising material is carbon dioxide (CO_2), which is a naturally occurring, nontoxic, inert gas that is not ozone-depleting.

If a gas, such as CO_2, is compressed to its "critical pressure" (CO_2 = 1077 psi), it liquefies to become a "critical fluid." If it is also heated above its "critical temperature" (CO_2 = 31.1 °C), it becomes a supercritical fluid (SCF) as shown in the figure. By increasing the pressure further, the fluid can be made more dense with a greater solvating ability.

Supercritical Fluid-CO_2

Carbon dioxide has been shown to have a Hildebrand solubility parameter that can vary from 0 in the gas to 10 under high-pressure, supercritical conditions. Values of 6–8 are typical for SCF-CO_2, which is about the same as for hexane and carbon tetrachloride. The SCFs have gas-like viscosity and high diffusivity, which enable them to penetrate confined spaces. SCF-CO_2 fluids are good solvents for many medium-molecular-weight, nonpolar or slightly polar organic materials, but are not good solvents for salts or polar organic molecules. They are also poor solvents for removing particulates.

Cleaning Parameters

SCF-CO_2 is compatible with metals, ceramics and most polymers, although it can cause swelling in acrylates, styrene, neoprene, polycarbonates and urethanes. SCF-CO_2 cleaning is particularly useful for cleaning the last small amount of contaminants (precision cleaning) from critical surfaces.

A typical commercial cleaning facility consists of a CO_2 chiller-compressor, a cleaning chamber (autoclave), and a separator vessel where the CO_2 is expanded and releases the contaminants that it has taken up. The table gives typical operating parameters for SCF-CO_2 cleaning.

Operating Conditions For SCF-CO_2 Cleaning

Parameter	Range
Pressure	1450–4350 psi
Temperature	100–185 °F
SCF-CO_2 density	30–50 lb/ft^3
SCF-CO_2 flow rate	2–11 lb/hr
Cleaning time	0.5–3 hr

Carbon dioxide "snow" can be formed by adiabatic cooling of compressed CO_2 gas, expanded from a small diameter orifice. The size of the snow particles depends on the geometry of the expansion nozzle, and the gas flow and size can be varied over a wide range. The CO_2 snow is soft and provides a mild abrasive action. Solubility at the surface-liquid interface, during the impact, allows solvation, as well as abrasion. The CO_2 snow can be combined with alcohol to improve the cleaning ability. It can also penetrate confined spaces and clean complex surfaces.

This technique removes particulates, fingerprints and silicone oil from surfaces, and is effective as a solvent cleaner for the removal of hydrocarbons in many cases. It does not readily remove heavier oils. The CO_2 snow does not damage sensitive surfaces, such as mirrors and other optics. If the snow is made from high-purity CO_2, it will leave no residue on the surface. A major processing variable is the purity of the compressed CO_2 gas, and a purifier should be included in the cleaning system. Commercial CO_2 snow-cleaning units are available. ❑

Plating Diagram for Pure CO_2