Liquid CO2 Immersion Cleaning: The User's Point of View

Among the many new cleaning technologies that have emerged in recent years is a dry cleaning technique called liquid carbon dioxide (LCO_2) immersion cleaning. Read on for some first-hand accounts of how this environmentally sound alternative is benefiting several manufacturing operations.

Over the past decade, concern for the environment, economic competitiveness, and technological advances all converged to cause both industry and government to re-evaluate manufacturing processes. Changes from traditional solvent cleaning to alternative methods set into motion recent trends toward zero discharge of pollutants into the air, water, and soil. Phase-outs of ozone-depleting solvents greatly impacted many manufacturers of both industrial and commercial products; in fact, many are still feeling the ramifications.

Equipment and bath maintenance, rinsing and drying issues, rust and corrosion problems, chemical disposal, and new environmental regulations-these are all concerns that arrived "on the tailcoat" of replacement chemistries.' Moreover, many interim alternative solvents and solvent formulations themselves have uncertain regulatory futures.*

Somewhere in all this transitioning, a new dry cleaning technology emerged called liquid carbon dioxide (LCO_2) immersion cleaning. It has since evolved into an effective and standardized cleaning alternative. But success came only after a carefully orchestrated development process: from invention to optimization of the LCO_2 process to the recycling component. This development included both regional and federal environmental agency technology demonstrations[3,4] and the issuance of several patents.[5] Nonetheless, the technology might still he on the drawing hoard were it not for the decision of leading manufacturers to apply it in actual production lines. This article highlights LCO_2 cleaning from the "user's point of view."

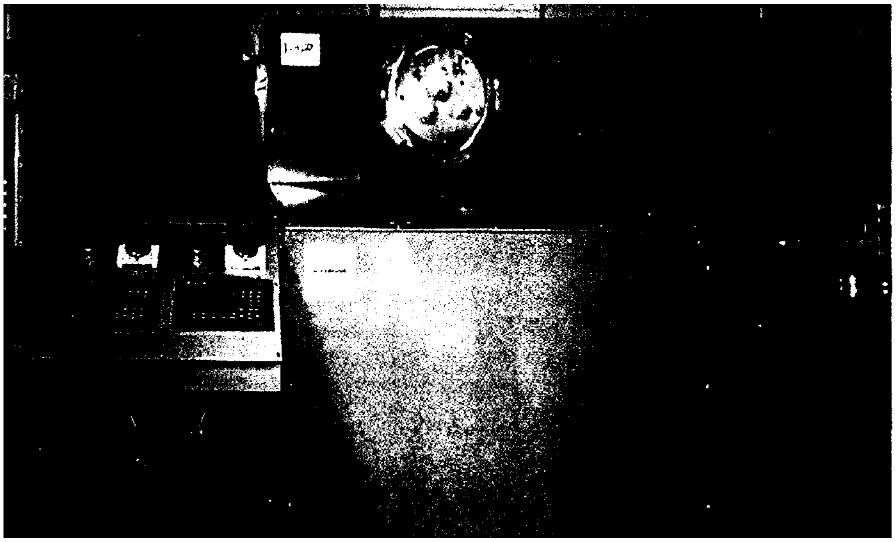

Figure 1. Centrifugal LCO_2 cleaning system.

liquid CO_2 Immersion Cleaning Technology

A commercial LCO_2 immersion system (Deflex Corporation, Burbank, Calif) is shown in Figure l.* The system utilizes the solvent power of liciuefied CO_2 in combination with patented hi-directional centrifugal cleaning action to effectively remove contaminants from products. The system is comprised of two modules: a centrifugal LCO_2 solvent cleaning module and a CO_2 recycling module. The principle of operation is similar to that of closed vapor and immersion cleaning systems.

As shown in Figure 1, the product to he cleaned is placed into the cleaning chamher and the lid is closed. The operator presses the start button on a graphical display console, and clean LCO_2 is automatically transferred from a supply vessel within the recycling system into the cleaning chamber (Figure 2). During and following the fill cycle, the LCO_2 system cleans the product using hi-directional centrifugal agitation for a predetermined cleaning cycle time. Following the cleaning cycle, contaminated LCO_2 is transferred from the cleaning chamber into the recycling system for separation and recovery operations. Clean, dry product is removed from the chamber, and the cleaning process is complete.

In the recycling phase, the contamination is captured and filtered for reuse or disposal and the recovered CO, is transferred into the supply tank for reuse. The recycling system is capable of recovering 90 to 95% of the CO, for reuse. The system has several features, including additive injection and the capability of recovering CO_2 off-line (hatch system) or in-line (continuous system).

Temperature and pressure are among the parameters specific to the patented centrifugal technology of LCO_2 cleaning. Process temperatures generally range between 50 and 70°F, and process pressures range from 750 to 1200 psi. The LCO_2 cleaning system can he operated in a vertical (centrifugal) or horizontal (centrifugal/tumbling) orientation and can use either liquid or supercritical CO_2.

Liquid carbon dioxide used alone under these conditions is a solvent much like room temperature 1,l,l-trichloroethane (TCA). As such, it will remove many hut not all types of contaminants. Contaminants that are not soluble in LCO_2 alone can he solubilized or otherwise separated by employing proprietary additives, modifiers, or mechanical adjuncts in the process.

Finally, the LCO_2 immersion cleaning process can meet a variety of cleanliness requirements, ranging from visually clean to more rigorous quality standards requiring such sophisticated test methods as nonvolatile residue analysis, infrared spectroscopy, or scanning electron microscopy. Functional testing, such as that measuring weld joint porosity and adhesive strength, has also been conducted to evaluate the technology.

The User's Point of View

Several customers who own and use a centrifugal LCO_2 cleaning system shared their insights and perspectives regarding this cleaning method with the product manufacturer. Customer feedback generally related to the application and use of the technology in their production operations. Responses focused on the following factors: type of products manufactured, cleaning requirements, past cleaning methods, reason for evaluating and changing to LCO_2 cleaning, and results of the process change.

LCO_2 Wins Out Over Aqueous

"Like many companies, we were faced with the challenge of replacing our conventional vapor degreaser," stated Paul Lien of DoverTech-Weldcraft Corporation (Burhank, Calif). "Initially we looked into water-based cleaning, thinking it was the obvious solution to our cleaning problems. We tested several aqueous-based systems and found they did a good job.

"There were three main concerns with aqueous cleaning systems. The first concern was how to deal with the waste. We operate in a city that demands strict adherence with the air and water municipality's disposal guidelines. The second concern was the increase in maintenance costs of both the water-based equipment and all the support equipment. The third concern was bath life and bath maintenance. We also realize that current wastewater disposal regulations are subject to change at any time.

"We clean our parts in preparation for brazing and/or molding operations and, as such, cannot tolerate any residue/oil. We require consistently clean parts all day, every day, without an on-hoard chemist checking pH and concentration of the aqueous solutions. When we were introduced to a dry cleaning process that uses LCO_2, our initial thought was 'Even if it worked, could we afford it?' Well, as it turned out, we could not afford to not have it."

Lien explained that his company first tested an LCO_2 cleaning system four years ago. "Our goal was to eliminate the use of pollution-generating cleaning processes," he remarked. "We found the LCO_2 cleaning process to he more effective, extremely consistent, and less costly to operate than our TCA solvent process and the alternate aqueous systems we initially considered.

"Our analysis involved a detailed comparison of both capital equipment and ongoing operational costs of the various systems being considered. Our analysis confirmed that although the LCO_2 system was more capital-intensive than the water-based option, the operational cost difference between the two provided the necessary justification for the purchase of the LCO_2 equipment. The operational

"Ail subsequent discussion of LCO_2 cleaning in this article pertains to this type of system.

cost difference between the LCO_2 and water-based process was significant at approximately $2500 per month. After much testing and cost analysis, we purchased an LCO_2 system for our production operation.

"Four years ago we implemented the technology and, after some initial startup glitches, we have run successfully ever since. Our production demand requires us to clean medium-size brass and copper components 17 hours a day, 6 days a week. Our monthly operational cost to run the LCO_2 system is approximately $450. To date, we have experienced no real down-time with the LCO_2 system. Our concerns regarding bath maintenance were resolved since the LCO_2 process does not degrade over time. And finally, we now generate no pollution related to cleaning processes and enjoy consistently clean product a daily basis."

No Hazards, No Permits

Bill Fisch of Accra-Tronics Seals Corporation, also in Burbank, found the LCO_2 process to he a "perfect fit" for his company's cleaning requirements.

"Our cleaning requirements are basic: clean enough for inspection and for further processing internally or at various vendors," stated Fisch. "We have used TCA and, because of serious environmental issues in our area that have proven to he very expensive over many)-ears, we wanted a cleaning system with zero environmental concerns.

"We manufacture hermetically sealed connectors and precision component parts for the ordinance industry. Our components vary in size between 1 and 8 cubic inches. We consumed 55 gallons per month of TCA and, although the material, even at the current rate, is not that expensive, the risks and adjunct costs are exorbitant.

"All existing solvent- or water-based methods require the use of hazardous materials and require permits from water and/or air regulatory agencies," Fisch continued, adding that their LCO_2 system "does not suffer from any of these deficiencies. We have had a comprehensive number of production parts tested prior to our purchasing the system and found that it meets all of our needs, including the elimination of potential etching of aluminum or rusting of steel.

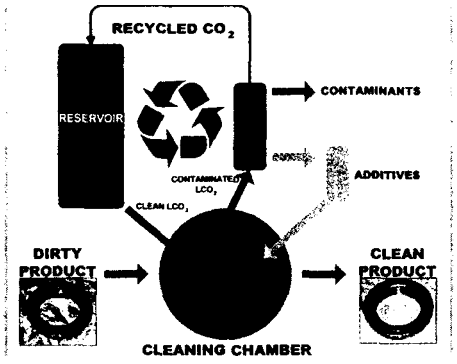

Figure 2. Schematic of LCO_2 immersion cleaning process.

"The mental and financial relief of not having to deal with hazardous materials accidents, against which we can no longer buy insurance, is also of significant importance," Fisch added in closing.

Making the Switch for Switch Components

Victor Wagner of THERM-O-DISC, Incorporated, a subsidiary of Emerson Electric, described his company's acquisition of an LCO_2 unit and its CO, recycling counterpart module.

"We went on-line in our London, Kentucky, facility on December 1, 1997," said Wagner. "The assemblies we clean are electrical switch components with silver contacts. The contacts tend to attract contaminates during the manufacturing and assembly processes, and, if improperly cleaned, will result in a rejected component. The LCO_2 cleaning system was acquired to replace vapor degreasing units.

"Our process engineers tested many alternatives to solvent cleaning," Wagner remarked. "Based on the cleanliness results, operating costs, and environmental benefits, they felt the CO_2 cleaning system presented an excellent opportunity for us to move away from chemicals into a dry cleaning process with no future environmental risks. The system cleans our parts as good as or better than our past vapor degreasing process.

"Since going on-line we have not encountered any significant maintenance problems with the CO. system. The typical maintenance situation involves the replacement of "0" ring seals in the two pumps. We drive the pumps with nitrogen gas generated from an on-site liquid nitrogen tank. Currently, we consume approximately 600 pounds of CO_2 every 10 to 14 days - depending on production - and have no disposal or environmental concerns related to our cleaning process (average cost of CO_2 is $0.14 per pound)."

In summary. Wagner stated that his company is "very pleased" with their transition to LCO_2 cleaning. "I should add that we found the system to be very operator-friendly," he noted. "We have trained five different operators, and none of them had any trouble learning the functions and cleaning procedures."

> The technology provides significant environmental benefits and eliminates such concerns as wet chemistries, environmental permits, hazardous waste, bath degradation, bath maintenance, water and air pollution, and toxic chemicals.

A Promising Process

The LCO_2 immersion process is currently being used in many different cleaning applications. The method has enjoyed much success in cleaning components used in automotive fuel injections, safety restraint systems (air hags), and turn-signal sensors. Other applications include cleaning aircraft fuel injection components, climate control devices, home appliance switching components, and stationary products (eg, ballpoint pen components [tips, barrels, halls]).

Like all cleaning: technologies, the LCO_2 immersion cleaning process is not for every company or parts cleaning application. A correct application of the technology is based on a combination of factors, including capacity needs, cleaning quality desired, equipment cost, cost of ownership, and environmental issues. In applications where both cleanliness and production objectives must he met, the technology, for many end-users, has proven itself mechanically reliable, consistently efficient, and cost-effective.

The technology also provides significant environmental benefits and eliminates such concerns as wet chemistries, environmental permits, hazardous waste, bath depadation, bath maintenance, water and air pollution, and toxic chemicals.

Many manufacturing companies have implemented this new dry cleaning technology, hoping that the financial risk of doing so will he balanced by the unique features and benefits the systems promise. Given that many innovative technologies take flight from early trials by market leaders, the LCO_2 immersion process seems well on its way to becoming a viable alternative for many companies on the verge of change in terms of cleaning practices. n

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