A Cooperative Project between the U.S. Environmental Protection Agency and the Garment and Textile Care Industry

design FOR THE ENVIRONMENT

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Design for the Environment U.S. EPA

Garment and Textile Care Program

Case Study: Liquid Carbon Dioxide (CO_2) Surfactant System For Garment Care

As part of a cooperative effort between the U.S. Environmental Protection Agency (EPA) and the garment and textile care industry, the EPA Design for the Environment (DfE) Program recognizes the liquid carbon dioxide (CO_2) cleaning process as one example of an environmentally-preferable technology that can effectively clean garments.

Currently, most of the Nation's 34,000 commercial drycleaners use perchloroethylene (PCE or perc) as a solvent to clean garments. Since 1992, in response to growing health and environmental concerns about perc, EPA has been working in a voluntary partnership with the drycleaning industry to reduce exposures to perc. EPA's DfE Garment and Textile Care Program (GTCP) encourages professional clothes cleaners to explore environmentally-preferable technologies capable of cleaning garments labeled "dryclean only." Several companies in the garment and textile care industry have begun using liquid CO_2 cleaning technologies for cleaning all types of fabrics. One company, Micell Technologies, Inc., has developed a process that utilizes liquid CO_2 in conjunction with cleaning agents (i.e., surfactants). This new technology, named the Micare™ System, effectively cleans clothes and is now in commercial use.

Company Background

Founded in 1995, Micell Technologies set out to develop a drycleaning process that would eliminate hazardous waste generation, use cleaning agents that do not pose the environmental and human health risks associated with perc, lower energy consumption, save money, improve cleaning performance, and reduce environmental regulatory burdens. With these criteria in mind, Micell explored the potential applications and capabilities of liquid CO_2 technology. Micell is funded by private and corporate investors and has raised over $20 million in equity financing. The headquarters of Micell Technologies is located in Raleigh, North Carolina.

The Micell Technologies Production Facility in Midland, Michigan

Micell works closely with the North Carolina State University (NCSU) College of Engineering and the College of Textiles. The company's research in the area of liquid CO_2 cleaning technology has resulted in the issuance of new patents to Micell. In addition, Micell has licensed patented cleaning agent components from the University of North Carolina at Chapel Hill and from Pacific Northwest National Laboratories. These cleaning agent developments have been extended by Micell's team of scientists and engineers, resulting in the high performance and cost effective liquid CO_2 cleaning solution used in the Micare™ system's $MICO_2$™ machine.

Service Counter at a Hangers™ Cleaners Store

The first drycleaning facility to offer the Micare™ system is Hangers™ Cleaners located in Wilmington, North Carolina. Hangers™ is owned and operated by the Williams family who have been in the drycleaning business since 1941. The Williams family's Hangers™ Cleaners has been cleaning customers' garments using the CO_2-based Micare™ system since late 1998. Micell plans to have approximately 60 machines in the mid-Atlantic, New England, and mid-West marketplaces by the end of 1999.

How the Liquid CO_2 Process Works

Traditional drycleaning systems use perc or petroleum-based chemicals as the primary cleaning solvent—with additives and detergents. Wetcleaning utilizes water as its primary solvent. The liquid CO_2 process employs liquid CO_2 as the primary solvent, with recyclable cleaning agents.

Carbon dioxide is a naturally occurring and generally benign substance. At room temperature, CO_2 can exist in the form of a gas and is therefore used to carbonate soft drinks and other beverages. In solid form, carbon dioxide is known as dry ice. At room temperature, CO_2 can also exist as a liquid if kept in a closed system at an elevated pressure. Liquid CO_2 has a gas-like consistency and a low surface tension allowing it to function as a very effective cleaning medium when combined with detergents.

The Micare™ system uses a large conventional rotating basket with a detergent system. The system utilizes a specially designed, 60-pound capacity $MICO_2$™ machine that houses liquid CO_2. It is similar to today's front-load, mechanical action machines and features gentle wash and extract cycles.

A detergent system (containing patented cleaning agents) enhances the cleaning ability of the liquid CO_2, allowing it to remove soils from the garments. After the cleaning cycle, the machine pulls the mixture of liquid CO_2 and cleaning agents (i.e., the wash fluid) away from the clothes and then cleans and reuses the solution. The Micare™ process does not require heating of the clothes and is therefore gentle to fabric.

Specifically, the Micare™ System works in the following stepwise fashion:

- Approximately 60 pounds of garments are placed inside a large rotating basket in the $MICO_2$™ machine and the door is closed, sealing the system. Vacuum is applied to remove the majority of the air in the system and CO_2 gas is added to pressurize the wash tank.
- Liquid CO_2 is then added from the storage tank along with the Micare™ detergent system in order to form the wash fluid. The clothes are agitated for a pre-set time period and with a selected degree of agitation depending on the nature of the garments (e.g., delicate, normal, and heavy cycles). Similar to perc drycleaning machines, the wash fluid is circulated out of the wash tank through a lint filter to capture loose fibers and vestige lint. It then passes through a carbon filter and returns to the wash tank. At this point, the wash cycle is complete.
- The liquid CO_2 and detergent mixture (i.e., the wash fluid) is pumped out of the wash tank to the storage tank. The excess wash fluid (that fluid left clinging to the garments) is further removed by a spin extract cycle. A portion of the wash fluid is then cleaned via a distillation process that removes excess dirt and detergent. The residue from the distillation process is automatically eliminated from the machine and collected for shipment back to Micell for recycling. Carbon dioxide gas is removed from the wash tank using a compressor and the gas is sent back to the storage tank for reuse. The Micare™ system is able to efficiently convert CO_2 from a gas to a liquid, thereby permitting 98 percent of the CO_2 to be recycled. A nominal amount (10 lbs) of CO_2 gas is then vented to the atmosphere.
- After a cycle time of 35 to 45 minutes, the cleaned garments are removed from the wash tank.

Performance

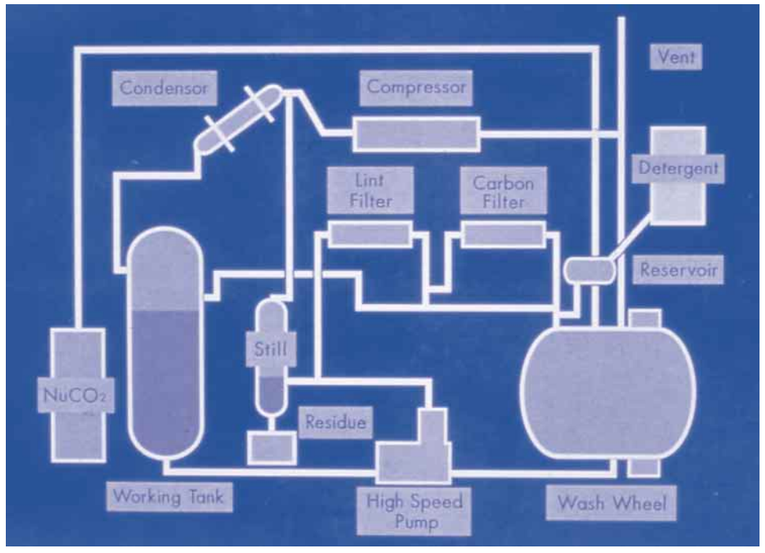
No independent performance testing has been conducted to date. The performance information that is presented in this case study was provided by representatives of Micell Technologies.

Cleaning

Micell Technologies asserts that the Micare™ system offers excellent cleaning performance across most garment components and a wide range of stains and soils. Also, since liquid CO_2 technology operates at room temperature, any stains that may remain on a garment after the wash cycle are not heat-set as can occur with traditional drycleaning systems. Because stains are not heat-set, post-spotting is very effective. In addition, the company has developed effective pre-treatments to further facilitate cleaning performance.

The Micare™ System $MICO_2$™ Machine

Diagram of the Micare System Cleaning Process



Micell Technologies recently conducted a study of how well the Micare™ system performed in an actual commercial setting. The study addressed the performance of the Micare™ system in cleaning approximately 3,000 pounds of garments that were brought by customers during a one and a half week period in January 1999 to the Williams Hangers™ Cleaners in Wilmington, North Carolina. The key results of the study are as follows:

- The average wash load weight was 42 pounds (not machine capacity-limited) and the average number of garments per pound was 1.13.
- Of the 3,000 pounds of garments, 61 percent or 1,830 pounds were dark-colored (with 58 percent or 1,061 pounds of the dark-colored garments having visible soil) and 39 percent or 1,170 pounds were light-colored (with 28 percent or 328 pounds of the light-colored garments having visible soil).
- Overall, 39 percent or 1,170 pounds of the total 3,000 pounds of garments had visible soil.
- Subsequent to cleaning, 12 percent or 360 pounds of the total 3,000 pounds of garments required post-spotting treatment.

Color Fastness

One of the most important attributes of any cleaning system is color fastness. According to Micell Technologies, the Micare™ cleaning system has color retention performance characteristics that equal or exceed those for perc drycleaning for a wide variety of colored fabric combinations. Scientists from the College of Textiles at North Carolina State University, working with Micell scientists, have compared Micare™ system color fastness with that of perc drycleaning for three pairs of black 100 percent cotton men's chino pants, and three red sweater vests composed of 90 percent silk and 10 percent cotton. One of each was drycleaned 20 times in perc, one of each was cleaned 20 times in the Micare™ liquid CO_2 system, and one of each was used as a standard control sample and thus was not cleaned. The color changes in the cleaned garments were measured using a high-resolution color reflectometer and the changes were compared to the non-cleaned identical garment. The black pants and red vest cleaned 20 times in the liquid CO_2 Micare™ System were virtually indistinguishable from the identical garments that were not cleaned. However, the red vest and black pants cleaned 20 times in perc resulted in noticeable color loss and fading. Micell has observed similar trends for many other colors.

The garments that appear to have less than ideal performance in the Micare™ System are garments that are primarily composed of triacetate and some acetate fabrics with specific dispersive dyes (yellow in particular). No abnormal shrinkage has been observed for acetate garments cleaned in the Micare™ liquid CO_2 system. Some shrinkage has been observed for triacetate-based garments only. Fortunately, triacetate garments are rare and are found in less than 0.5 percent of the garments that customers brought to the Hangers™ Cleaners store in Wilmington, North Carolina. Micell recommends that triacetate garments be wetcleaned and that the operator use the gentle Micare™ short cycle for the cleaning of acetate garments that contain the yellow dye.

Relative to traditional drycleaning solvents, fewer dye-bleeding situations have been observed with use of the Micare™ system. Micell reports that if a garment is poorly dyed at the manufacturers facility, there is some chance that it will bleed, although experience to date shows that such bleeding is much less likely with the Micare™ system than with conventional solvents. According to Micell, in the few observed cases where a garment has bled even slightly, dye transfer to other garments in the load did not occur. One example was a red dress with white cuffs. The dress was processed with a load of light khakis, and no color was transferred to other garments in the load. However, the red dye bled onto the cuffs of the dress, imparting a pink tint. The cuffs on the dress were restored by hand and the garment was returned to the customer in good condition.

While most leather goods are compatible with the Micare™ process and can be cleaned in the MICO$_2$™ machine, quality leather care typically requires more than just cleaning the garment. Leather goods incorporate a variety of dyes, softeners and paints. In many instances, to restore a leather garment to near original condition, re-dyeing or re-painting is necessary. The Micare™ cleaning process can be employed to clean such garments in preparation for further restoration, but cannot substitute for the dyeing and painting techniques offered by specialized leather processors. Finally, further testing is necessary in order to determine how broadly the Micare™ process can be applied to cleaning delicate fur items.

Environmental, Safety, and Health Impacts

Carbon dioxide is a naturally occurring and generally benign substance that is routinely ingested in food products such as soft drinks. The use of liquid CO_2 technology allows consumers and machine operators to avoid exposure to traditional drycleaning solvents. A company named "NuCo$_2$" supplies liquid CO_2 to Micell's professional clothes cleaning customers. The Micare™ system uses the same beverage-grade bulk CO_2 that NuCo$_2$ delivers to more than 50,000 restaurants and other fountain beverage dispensers located across the nation.

Environmental stewardship is one of the hallmarks of the Micare™ system. The residue generated by the Micare™ system distillation process (i.e., the liquid CO_2 cleaning and reuse process) is returned to Micell Technologies for recycling or recovery. Even though CO_2 and the Micare™ system chemistry are environmentally benign, the MICO$_2$™ cleaning machine has multiple safeguards and process controls that minimize the potential for leaks and spills. The Micare™ system produces no hazardous waste, eliminates exposures to traditional drycleaning solvents, and does not use ozone-depleting compounds.

Because the Micare™ system liquid CO_2 is stored under pressure, the MICO$_2$™ machine is designed and constructed in accordance with the American Society of Mechanical Engineers (ASME) code for pressurized vessels and systems. In addition, Micell has considered all applicable National Fire Protection Association (NFPA) and Occupational Safety and Health Administration (OSHA) guidelines.

All MICO₂™ machine components that hold liquid CO_2 over long time periods have relief devices which protect the system against over-pressurization. In addition, automated control logic maintains safe operating conditions and the MICO₂™ machine is self-regulating through redundant levels of safeguards and relief devices. Operating pressure for the MICO₂™ machine is actually lower than that associated with various commercial equipment such as scuba gear and welding gas systems.

Insurance underwriters have insured Micare™ systems (in commercial use) through a 100 dollar per year rider on the boiler policy. This insurance cost is lower than coverage commonly necessary for traditional drycleaning processes.

Capital Costs

A primary concern for individuals considering the use of a liquid CO_2 cleaning system is the capital required to purchase machinery. The 60-pound MICO₂™ machine, which has a 35 to 45 minute cycle time, has a retail cost of $150,000, excluding pressing and finishing equipment. As a comparison, Micell states that the capital cost for perc cleaning equipment can range from $40,000 to $65,000, while the capital cost for petroleum cleaning equipment with fire suppression systems and oxygen sensors can range from $75,000 to $110,000. Micell bases the capital cost ranges for perc and petroleum equipment on equivalent throughput capacity. That is, perc and petroleum machines have a cycle time of approximately 70 minutes, while the MICO₂™ machine operates with a 35 to 40 minute cycle. Nearly twice as many perc or petroleum machines would be necessary to achieve the same throughput as one MICO₂™ machine. Low operating costs and the high productivity associated with the Micare™ system ensure adequate return on investment. In addition, the life expectancy of the MICO₂™ machine could be at least twice that of perc drycleaning machines because it is manufactured primarily with stainless steel.

There are additional business costs associated with franchising. Micell Technologies is offering the Micare™ technology to the garment care industry through a franchise affiliation with its Hangers™ brand national clothes cleaning chain. The company believes that it is bringing this franchise offering to the marketplace at rates that are similar to franchising in other retail categories. Total franchising costs will vary from cleaner to cleaner and need to be worked out for an individual by a Micell representative.

Operating Costs

Micell asserts that the operating costs per pound of clothes cleaned via the Micare™ system are competitive with conventional drycleaning technologies. Micell gathered detailed operating cost information from three drycleaning establishments that use perc, one establishment that uses Stoddard solvent, and three establishments that use Exxon's DF-2000 petroleum solvent. This information was compared to the operating costs of the Micare™ system for cleaning approximately 20,000 pounds of clothes.

The analysis was designed to derive the total operating cost per pound of clothes cleaned. Individual operating cost items included in the analysis are: cleaning cycle time; detergent costs; solvent cost and usage; labor and chemical costs associated with pre- and post-spotting; labor costs for garment finishing; filter cartridges; waste disposal costs; and equipment maintenance costs.

As shown in the chart on the previous page, at $0.61 per pound of clothes cleaned, the total Micare™ system operating cost is competitive with the total operating costs associated with cleaning with perc, cleaning with Stoddard solvent, and cleaning with DF-2000 petroleum solvent.

Operating Costs Per Pound of Clothes Cleaned for Four Technologies Across Eight Commercial Establishments

Benefits of the Micare™ System

The Micare™ sytem:

- Eliminates exposures to perc.
- Cleans effectively with no unpleasant odors.
- Treats garments gently.
- Eliminates the risk of groundwater contamination from conventional drycleaning solvents.
- Utilizes a traditional rotating basket design which is gentle to fabrics.
- Eliminates the risk of heat-related damage or heat-setting of stains, as there is no drying cycle.
- Costs less to operate than today's perc systems, thereby allowing drycleaning operators to offer the same prices to customers and improve their operating margins.
- Requires a 35 to 45 minute cleaning cycle for a 60-pound load — faster than traditional 'dry-to-dry' processes.
- Eliminates the time and money that operators typically must spend to comply with environmental and safety regulations associated with the use of perc and petroleum.

Impact on Businesses

Professional clothes cleaning with the use of liquid CO_2 technology in conjunction with Micell's specially formulated cleaning agents represents one of the latest technological advances in garment and fabric care. It appears as though initial capital costs may be impractical for some small businesses. However, savings exist in the form of reduced regulatory burden and lower waste handling and disposal costs. Because the wash fluid distillation residue is not a hazardous waste, the need for professional cleaners to comply with federal and state hazardous waste regulations [under the Resource Conservation and Recovery Act (RCRA)] is eliminated. Additional cost savings result from reduced machine and labor processing time. As a result of its cost and performance characteristics, the Micare™ liquid CO_2 process is both a commercially viable and environmentally-preferable fabricare system.

As mentioned previously, in order to utilize the Micare™ clothes cleaning technology, there is a cost associated with franchising. Micell Technologies is offering the Micare™ technology to the garment care industry through a franchise affiliation with its Hangers™ brand national clothes cleaning chain at rates that are similar to franchising in other retail categories. The Hangers™ franchise is available either as a single-site, or as multi-site, area-development package.

Hangers™ offers a state-of-the-art marketing and advertising package, territory protection, customer service, and a "Hangers' Express Service" program which creates a computerized profile of its customers allowing the franchise to meet individual customer preferences for clothing

handling and preferred pick-up location. The marketing and advertising package includes name, logo, packaging, uniforms, and point-of-sale, direct mail, print, radio, outdoor, and television advertising.

Other Information

Another company, Global Technologies, Inc., has developed a liquid CO_2 clothes cleaning system termed DryWash. EPA plans to develop a case study on the DryWash system when commercial performance information becomes available.

Further, both Micell and Global are exploring other applications of liquid CO_2 cleaning such as textile processing and metal cleaning and degreasing.

What is Design for the Environment?

EPA's Design for the Environment (DfE) Program is a voluntary initiative that forges cooperative partnerships among government, industry, academia and environmental groups. One of the primary objectives is to incorporate environmental concerns into the design and redesign of products, processes, and technical management systems.

One of the goals of the DfE Garment and Textile Care Program (GTCP) is to provide cleaners with information that can help them run their facilities in a way that is safer for workers, more environmentally sound, and more cost effective. To accomplish this goal, the program utilizes EPA expertise and leadership to evaluate the environmental and human health risks, performance, and cost tradeoffs among clothes cleaning technologies. DfE disseminates information to all interested parties and assists businesses in implementing cleaner technologies.

The GTCP is preparing several documents addressing environmentally-preferable and commercially viable clothes cleaning technologies. In the near future, these and other case studies will be available on the GTCP website and in hardcopy and include:

- *Case Study: Water-Based Cleaning System for Suede and Leather* (EPA 744-K-98-017)
- *Case Study: Wetcleaning Systems for Garment Care* (EPA 744-K-98-016)

For More Information

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- Contact the EPA Pollution Prevention Information Clearinghouse (PPIC) to receive an information packet about EPA's DfE Program or the Garment and Textile Care Program, or to request single copies of DfE documents, or a revised DfE Publications List:

  Pollution Prevention Information Clearinghouse (PPIC)
  U.S. Environmental Protection Agency
  401 M Street, SW (7407)
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  Telephone: (202) 260-1023
  Fax: (202) 260-4659
  E-mail: ppic@epa.gov

- Visit the EPA DfE Garment and Textile Care Program web site: **http://www.epa.gov/dfe/garment/garment.html**

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