Perspectives on Surface Preparation with CO_2 Blasting

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Until recently, CO_2 blasting has been used primarily as an industrial cleaning technology to remove manufacturing process residues. Common applications include cleaning molds, ovens, conveyors, extruders, and presses. However, there has been increasing interest in using CO_2 blasting for paint stripping and surface preparation because the cleaning agent, small pellets of dry ice, immediately disappears upon impact and returns to its natural state in the atmosphere.

The performance of CO_2 blasting has been overstated in both positive and negative terms for a variety of reasons. The net result has been confusion among end users. Dry ice blasting is not a panacea that will solve all your surface preparations needs, but what it does well, it does better than any other technology available.

The concept of using dry ice pellets to clean surfaces is relatively new. In 1977, Lockheed Corporation filed a patent on a single hose system that used a supersonic venturi. The system configuration was later improved to a two-hose system, which was the basis for the second Lockheed patent.

Dry ice blasting was not available as an off-the-shelf product until 1986. Two companies in the United States manufacture CO_2 blasting equipment, one of which is Alpheus. We purchased the exclusive rights to the technology from Lockheed. A third company is located in Europe.

Dry Ice Blasting Process

Although each uses dry ice as the cleaning media, these companies have distinctly different ideas about surface cleaning and have designed their systems to reinforce these concepts. Because of these engineering differences, it is not possible to generalize one system's approach with the other two.

The core system is connected to both an air compressor and a liquid CO_2 storage vessel. Liquid CO_2 is used to make snow, which is then extruded into pellets of a predetermined size from 1/4 inch down to snow. The pellets are fed through an airlock out to the nozzle, where they are accelerated toward the object to be cleaned.

To evaluate the advantages and limitations of CO_2 blasting, it is necessary to understand the mechanics of surface cleaning with dry ice pellets. Visually, CO_2 blasting appears similar to the traditional process with grit. However, the actual cleaning dynamics differ significantly. Grit works through a chiselling action that not only slashes or cuts the coating but also the underlying surface. In contrast, CO_2 blasting can best be described as an impact-flushing process. As it impacts, the pellet causes surface and subsurface fractures in the coating. The pellet breaks apart and creates a high-velocity flow of dry ice particles that mushroom out from the point of impact, creating a lifting and shearing effect. When viewed with high speed film, the paint seems to be lifted from the inside out.

Intuitively, the idea of helping the cleaning process with a large thermal drop is both logical and appealing. However, the belief that cold weakens the coating system through embrittlement and/or the differential contraction between the coating and substrate just is not true in most cases.

With the Alpheus system, it is possible to adjust the temperature of blast air between -100° and +100°F. Our testing has shown that, with the exception of some paraffins, release agents, and sealants, there is no benefit from cooling the surface. In fact, with some coatings (such as coal tar epoxy), supercooling the surface drops the cleaning speed to less than one-fifth of that attainable at ambient or heated temperatures.

Another consideration is the excellent solvent characteristics of liquid CO_2. It has been hypothesized that—at the moment of impact—a thin layer of liquid CO_2 instantaneously appears and then disappears and that this assists the cleaning process.

CO_2 is a natural component of our atmosphere. Blasting with dry ice pellets does not create any additional CO_2, it only uses what is already there and thus does not contribute to the Greenhouse Effect. The equipment is reliable, easy to use, and requires only a half-day of operator training. Alpheus has units in robotic applications running 22 hours a day, seven days a week.

CO_2 is heavier than air and as such displaces oxygen. In most workplaces, the amount of CO_2 coming from the nozzle is not a problem; it is easily handled by the facility's ventilation system. In closed areas such as storage tanks, operators should use ventilation and respirators. Inexpensive CO_2 monitors can be installed to automatically shut down equipment if the levels of concentration exceed Occupational Safety and Health Administration standards.

Advantages

Since there is no incremental waste from the pellets, cleanup is confined to the residue removed. There is no danger of grit entrapment or sedimentation, which reduces or even eliminates the need to mask or disassemble the area being cleaned. The process will not affect water usage restrictions and has been safely used to clean live electrical subsystems. The pellets will not change the surfaces of precision-machined parts. By varying the blasting parameters, we have successfully cleaned everything from circuit boards to I beams.

Limitations

Dry ice pellets disintegrate upon impact and therefore do not ricochet off the target surface to clean hidden backsides in complex structures. Cleaning performance is generally best when the angle of impingement is between 75 to 90 degrees to the working surface; more glancing blows are ineffective for paint stripping. Lastly, CO_2 blasting cleans down to the original surface geometry. If a new anchor pattern is needed, another method must be used.

Although removal rates can equal traditional grit blasting in some applications, dry ice blasting is often much slower. Noise levels generated when operating blasting equipment at high pressure (>150 psi) range from 105 to 120 dbA, depending on the working environment.

Basic systems start at $100,000.

Good Applications

Surface preparation is rarely limited to the act of cleaning. As the time and cost of the pre- and post-cleaning activities increase for any given application, so does the attractiveness of CO_2 blasting. Two other favorable application conditions where CO_2 excels are when (1) the surface must not be damaged or altered, or (2) a company requires an exceptionally clean, residue-free surface.

A few examples of good applications are given in the following paragraphs.

- **Nuclear test cells:** Radioactive epoxy paint was removed from high density concrete in nuclear test cells. This two-week job resulted in disposal savings of $500,000.

- **Water storage tanks:** A company wanted to replace a coal tar epoxy coating in a potable water storage tank. Power tools removed most of the coating but were unable to clean the seams, which was done quickly by CO_2 blasting.

- **Food processing areas:** A cracker plant wanted a multi-layered, industrial alkyd coating removed. Grit blasting or solvents could be used in the food production areas, and the plant's wood floors eliminated use of water blasting. CO_2 blasting cleanly eliminated the coating.

- **Chemical refineries:** Pressure vessels at a chemical refinery must have the coating over welds periodically stripped to permit inspection for fatigue cracking. Grit blasting will fold the metal over any cracks, making suspect the results of a dye penetrant inspection. CO_2 will clean and strip without hiding the cracks and can also remove the dye penetrant after the inspection is completed.

- **Metal plating facilities:** Corrosive deposits form on equipment, walls, and ceilings at a metal plating plant. Grit can become contaminated, creating a disposal problem, and water would activate the chemical nature of the deposits. CO_2 blasting successfully removed deposits and old paint, thus providing a residue-free surface for repainting.

Steel Structures Painting Council Standards

Dry ice blasting meets or exceeds the following SSPC standards.

- SP-1 (Solvent cleaning)*
- SP-2 (Hand tool cleaning)
- SP-3 (Power tool cleaning)
- SP-6 (Commercial blast)*
- SP-7 (Brush-off blast)

SP-1 and SP-6 have asterisks, which I will explain.

- **SP-1:** Dry ice blasting does an excellent job of removing oil, grease, and dirt. Alpheus has a unit in the Space Shuttle Program that high-performance cleans oils and particulates down to the microcontaminant level, even to the point of removing fingerprints. However, all cleaning is simply the relocation of dirt from an unacceptable location to another one that is more acceptable. With complex structures, such as printing presses, care must be taken not to relocate the dirt to a previously cleaned area. Operator skill comes into play here.

- **SP-6:** CO_2 blast cleaning meets the SP-6 standard when there is no heavy corrosion and the existing anchor pattern under the old coating is acceptable. CO_2 blasting cannot meet this standard with new steel because it will not remove mill scale.

Cleaning Results

Now, how fast does CO_2 blasting clean? Surface preparation experts would say that the outcome depends on such things as the coating's thickness, age, original anchor pattern, and structure complexity—and they would be right. Nevertheless, laboratory test specimens can be a good starting point for discussion.

KTA-Tator prepared multiple test panels of eight different paint systems. Each panel was grit-blasted to an SP-10 near-white finish with a nominal anchor pattern of 2 mils. Paint was applied and cured according to the manufacturer's specifications. A Taguchi test structure was established to optimize the blasting parameters for each paint system using nine variables, including pellet size, velocity, quantity, and temperature. The panels were cleaned with CO_2 blast equipment until all paint had been removed and the original SP-10 standard was again achieved. The results are shown in Table 1.

Table 1.—Cleaning results for test specimens.

>200 FT^2/HR	40–80 FT^2/HR	<20 FT^2/HR
• Inorganic zinc	• Acrylic latex	• Coal tar epoxy (2 coats)
• Vinyl (2 coats)	• Industrial alkyd (2 coats)	• Polyamide epoxy (2 coats)
	• Baked enamel	• Epoxy mastic polyurethane

Some of the information presented in Table 1 requires further explanation. Let's start with the inorganic zinc. The removal rate was higher than we expected. We checked the curing of the sample and found it was in accordance with the manufacturer's guidelines. We are now awaiting receipt of additional panels to replicate the test.

The test removal rates for the latex, alkyd, and coal tar epoxy were all much slower than those in Alpheus' field experience. For coal tar epoxy and industrial alkyd, we attribute this to the fact that, as paint ages, it loses adhesion and thus CO_2 pellets remove it more easily. Also, we have had removal rates in excess of 300 square feet per hour for latex paint. We plan to explore the reasons for the slower removal rate in the test.

The two epoxy systems really are that slow. For these coating systems, we are testing CO_2 used in tandem with other technologies. Maxwell Laboratories and Polygon Industries are working with Alpheus to explore CO_2 blasting with their flashblasting technology for paint removal. Laboratory removal rates of 800 square feet an hour have been achieved. Alpheus has also worked with various chemical companies on pretreatments. These are sprayed on the painted surface, weakening the adhesive bonds chemically. Then the paint is removed quickly with CO_2 blasting.

Conclusion

Alpheus has committed significant resources to furthering the science of CO_2 blasting. At our test center, a number of projects are being conducted, including:

- Quantification of pellet flow upon exiting from the nozzle,
- Effects of supercooled, ambient-heated drive air, and
- Effects of pellet impact energy on coatings and substrates.

Many of the results will be published to help the industrial community better understand and use the unique characteristics of CO_2 blast cleaning.