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Paper

ENVIRONMENTALLY RESPONSIBLE SURFACE PREPARATION WITH DRY ICE

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ABSTRACT

While traditional cleaning solutions can be time consuming, costly and ineffective, dry ice blast cleaning provides a completely dry solution that cleans faster and more efficiently, while reducing downtime and supporting environmental initiatives. This presentation will discuss the basic concepts of dry ice cleaning. Participants will learn the benefits of the process, as well as how it can benefit their production, improve quality and support an environmentally responsible production environment. By utilizing recycled frozen carbon dioxide as a cleaning media, end users benefit from an EPA approved media that is void of secondary waste. The dry ice media turns to gas (sublimates) upon contact with the surface being cleaned. Because there is no secondary waste generated, cleaning with dry ice addresses both environmental issues and advances sustainable development. Dry ice cleaning technology offers a safer and more efficient removal of overspill and buildup. Cleaning can be done in a fraction of the time compared to scraping and soaping.

1. BASIC PRINCIPLES OF OPERATION

Dry ice blasting uses solid CO_2, which is a non-abrasive, non-toxic, non-conductive and non-corrosive media for cleaning and surface preparation. Dry ice blasting works as a result of 3 factors during the process that work in tandem. The first is the kinetic energy effect. The CO_2 is accelerated by a pressurized air stream and directed toward the surface being cleaned at speeds ranging from 600 ft/s to 1,000 ft/s. The second aspect is the temperature. Dry ice is -109˚F (-79.5˚C). The third factor is the sublimation effect. Dry ice sublimates upon impact leaving no secondary waste or entrapment of blast media.

The dry ice is accelerated at very high speeds toward a targeted surface, and upon impact the CO_2 sublimates immediately. Sublimation is the transition of a substance from a solid to a gas while bypassing the liquid phase. This microsecond change from a solid to a gas state transfers kinetic energy and creates a micro-thermal shock at the surface. This thermal shock causes the contaminants being cleaned from the substrate to embrittle, which serves to break the bond between the substrate and the dirt, or in some cases, adhering coatings. The gas expands 800 times the volume of the solid particle within a few milliseconds. This rapid change in state from solid to gas also causes microscopic shock waves, which further assist in removing contaminants.

Dry ice is most commonly used in a solid 3mm pellet form, which is similar in size to an uncooked rice grain. In industrial applications it can also be shaved into a less dense, and thereby less aggressive, micro-particle form for more delicate cleaning operations. The sublimation process absorbs a large volume of heat from the surface, producing shear stresses due to the thermal shock, which also assists with the cleaning process. This improves cleaning through a combination of kinetic energy and heat transfer, de-bonding contaminants from the underlying substrate allowing material to flake off more easily. The efficiency and effectiveness of this process depends on the thermal conductivity of the substrate, CO_2 form and density, particle concentration pattern (flux density), velocity, nozzle selection and the pressure involved.

Compared to other media used for blast cleaning, dry ice blasting is a more attractive option for several reasons. Dry ice is a soft media. On a Mohs scale of hardness for minerals dry ice is approximately a 1.5-2. To put this number in perspective, baking soda is about 2.5, glass bead about 5.5 and garnet about 7.5. Due to the softness of the media, dry ice will not etch or profile substrates harder than itself. Furthermore, if you are cleaning a delicate surface that has the potential to be damaged by dry ice, the aggression can be controlled by a series of protocols of changing your blast pressure. Examples include switching the nozzle, increasing the distance of the nozzle from the substrate and switching from a more aggressive 3mm pellet to a less aggressive MicroParticle. This process is aggressive enough to cleaning heavy hydrocarbons from metal surfaces, or delicate enough to dust an electronic circuit board of debris without damage. This process is also dry and residue free, so it will not contribute to corrosion. Finally, this process creates no secondary waste or chemical residue. When the dry ice hits the surface, it sublimates into the atmosphere, only leaving the removed contaminant. The remaining dry ice at the completion of cleaning requires no disposal protocols. Unused dry ice sublimates at room temperature, returning to the atmosphere. In terms of waste and hazardous waste disposal, it is the most efficient blast cleaning process with regards to environmental responsibility, time and cost.

The dry ice used for this cleaning process is made from reclaimed CO_2, a natural byproduct of many industrial manufacturing processes. This involves collecting byproduct liquid carbon dioxide and expanding it to produce a snow-like, slurry substance that is compressed in a chamber and then extruded out of a die to make solid dry ice in 1mm-20mm diameters. Dry ice blasting does not produce CO_2, nor does it add CO_2 to the atmosphere. The CO_2 used in dry ice blasting is considered completely carbon neutral, which does not contribute to the greenhouse effect.

2. EQUIPMENT/MATERIALS

Dry ice blast cleaning machines can use pelletized dry ice or shaved dry ice. Both classes use a single hose system in which dry ice particles are loaded into an internal storage area (hopper). The pellet machines are gravity-fed dry ice pellets into the air-locked rotor and mixed directly into the compressed airstream, which feeds to the blast hose. The shaved dry ice MicroParticle machines are slightly different. A dry ice block is loaded into the hopper and then pushed horizontally into blades on a rotor, where the dry ice is shaved down to granular size. The MircoParticles fall into the air-locked rotor, where they mix into the compressed air stream and feed to the blast hose. The CO_2/compressed air mixture is fed directly into a single hose that connects to a trigger/handle mechanism with the nozzle attached on the opposite end. This single hose design allows for maximum energy retention for the blasting process and great flexibility for a wide range of conditions.

Both classes of machines operate fundamentally the same. The differences begins with the final form of CO_2 used. Pellet blast machines contain a hopper, which is loaded with premanufactured CO_2 pellets. The blast hose diameter and nozzle used will govern the final pellet size and blast flux density leaving the nozzle. These units have adjustable feed rates which also significantly influence the aggressiveness of the blasting operations.

The dry ice MicroParticle machines take various forms of dry ice such as 1-20mm diameters, block, slabs, etc. The dry ice is pushed horizontally into the blades on the rotor, which shaves off a thin layor of ice. This thin sheet shatters as it falls down the chamber to the air-locked rotor, where it becomes micro-particles. The MicroParticle machines deliver a blast with very high flux density at lower pressures allowing superior control of blasting operations. This ability to work at low pressures with greater control makes this equipment ideal for sensitive and delicate cleaning applications.

In addition to the machine, the equipment needed for dry ice blasting includes the applicator (trigger), hoses, nozzles, a supply of dry ice, compressed air and single phase 110/120 VAC electricity. All equipment is available in various sized and designs, which can be customized for specific dry ice blasting scenarios. Nozzles are available in low flow (50 CFM), medium flow (100 CFM) and high flow (>150 CFM) consumption rates. Nozzles are also available in various lengths, widths and angles. Some nozzles have fragmentation capabilities that allow the operator to fragment the 3mm pellet on a pellet machine to smaller, less aggressive particle sizes.

Compressed air is a major part of how the process works. When selecting an air compressor for use with a dry ice blasting system, equipment attributes such as achievable pressure range, volume and air dryness must be considered. Without appropriate volume, pressure or air quality the entire blasting system will not perform properly.

3. MARKETS AND APPLICATIONS FOR DRY ICE BLASTING RELATIVE TO THIS INDUSTRY

3.1 Maritime Industry

The maritime industry is plagued with the corrosive properties of salt water on metal structures in addition to those of oil, grease and contaminants associated with equipment operations. In many cases, protective coatings deteriorate due to normal wear and tear or harsh environmental conditions. Dry ice blasting is extremely effective for the removal of failing coating systems on both interior and exterior (weather deck) surfaces, as well as cleaning for equipment maintenance. The ability of this equipment to deep clean grease, oil, dirt, and contaminants from galley areas, engine rooms, living spaces and weather deck areas without producing a secondary waste stream make it ideal for use in the interdependent nature of shipboard equipment and machinery. The non-abrasive aspect of dry ice blasting does not damage the substrate material, so it will not induce a profile for coating adhesion. The removal of existing failing coatings fully exposes the original profile, ideal for re-coating. Before and after conductivity testing performed and verified by third party inspection prove dry ice blasting surfaces exposed to maritime contaminants are ready for immediate recoating upon the completion of cleaning.

3.2 Power Generation

Power generation, regardless of form, relies on electrical equipment, turbines, compressors, engines, cable ways and cable trays. Clean equipment is essential for peak performance. The industry constantly balances the cost of equipment downtime for cleaning operations with the demands to keep equipment running. When the power demand results in deferred cleaning and maintenance cycles the facility runs at diminishing efficiency levels, resulting in decreased supply that could lead to flashover; causing outages. Dry ice blasting is a non-conductive, non-abrasive, dry cleaning process that allows equipment to be cleaned in place without damage to cables or insulation. This also means that minimal disassembly is required in most cases. Minimizing potential damage caused by the disassembly/reassembly process greatly reduces labor costs. Secondary waste, solvents disposal and equipment drying time are eliminated.

Dry ice blasting is an effective method for decontaminating semi-hot cells used for dissolving spent fuel in old reactors. Dry ice blasting can be used for decontaminating building surfaces and removing contaminated coatings during facility disassembly.

3.3 Refining & Petrochemical

The non-abrasive, nonflammable and non-conductive properties of dry ice blasting make this an appealing alternative to other blast cleaning methods in the oil, gas and petrochemical industries. Dry ice cleaning is an innovative technology that is an ideal replacement for pressure washing because it completely eliminates the burden of collection, transportation and disposal of the secondary waste stream created by the water and the associated costs. CO_2 blasting is a proven method for surface preparation of pressure vessels, cleaning of rotating equipment, production equipment, heat exchangers, reactor screens, shell side tube bundles, convection sections or re-boilers, fin-fans and sulfur removal. Dry ice is replacing solvents that cause damage to the environment and are workplace hazards such as acids and caustics.

3.4 Facility Maintenance

All industries requiring the use of a facility structure are subject to dirt, soot, grease, oil build-up, residual materials and grime. In order to keep equipment such as conveyors, cooling fans, pipes, forklifts, motors, walk-aways and ventilation ducting at peak efficiency, regular cleaning is required. Effective cleaning extends the life of rotating machinery and electric motors. Dry ice cleaning is a proven method for deep cleaning equipment mentioned above. Virtually all tooling and production fixtures can be cleaned utilizing dry ice blasting with minimal to no disassembly, and can often be cleaned while on-line or during production operations. Dry ice blasting deeply cleans the substrate, removing grease and oil among other contaminants making it an excellent method for cleaning equipment casings and support structures such as ceilings, walls, and pillars prior to maintenance painting. In the event the equipment requires complete rebuild, dry ice cleaning of the component parts quickly removes grease, oil, gasket residue, carbon deposit build-up and contaminants. The non-abrasive, non-corrosive elements of dry ice blasting make it a valid solution for graffiti removal without harming the underlying wall, ready for immediate repainting if desired.

3.5 Applications for Dry Ice Blasting

Other major markets that have found great benefits and cost savings from dry ice cleaning are disaster remediation (mold, fire, smoke), transportation, metal working, ventilation system cleaners and abatements organizations. Specific applications include, but not limited to:

- Surface preparation prior to painting or repainting
- Cleaning work surfaces near sensitive machinery
- Hazardous coatings and material removal such as lead paint, asbestos, radioactive coatings or coatings contaminated with PCBs
- Greasy factory ceilings
- Flaking paint removal
- Preparing machines, tools and equipment for repainting

3.6 Advantages of Dry Ice Blasting

Cost Reduction- The complete sublimation of the cleaning media eliminate the necessary collecting, containerizing, transportation and disposal costs associated with the secondary waste generated by all other blast cleaning technologies or chemical cleaning operations.

Scrap Reduction- Dry ice is non-abrasive and does not damage surfaces harder than it. This creates a reduction in downtime because cleaning can be done in place without disassembly.

Improved Productivity- In most cases, equipment does not require disassembly prior to dry ice cleaning. The labor intensive disassembly and reassembly of equipment no longer needs to be factored into the costs of cleaning and equipment maintenance. In many assembly line applications, dry ice blast systems can be fully integrated into production lines, performing cleaning during production periods savings shutdown and de-tooling time and costs.

Extension of Equipment's Useful Life- Dry ice blasting is non-abrasive, so it will not wear tooling, damage rotating equipment, scar bearings or machinery or harm textured surfaces. There is no sand or grit media that could get into tight tolerance areas or fine screens potentially causing damage. Dry ice cleaning efficiently removes grease, oil, dirt and contaminants without the introduction of abrasive media.

A Dry Process- Dry ice cleaning is considered a dry process, in that there is no introduction of water or water based chemicals. This and the non-conductivity property of CO_2 make it an effective cleaning method for electrical components such as switchboards, breakers, wiring, cabling, controls and switches. Because this process is dry and deeply cleans the substrate of metal surfaces, the formation of flash rust is virtually eliminated. When used in the food industry or for mold remediation in public and private buildings, dry ice significantly reduces the potential for bacteria growth inherent with any cleaning process using water.

3.7 Limitations Compared to Abrasive Blasting

Because dry ice blasting in non-abrasive, coating removal rates are decreased when compared to abrasive blast methods. Because of its non-abrasive nature, dry ice cleaning will produce no surface or anchor profile on metal surfaces. If an etching or profiling is needed it must be created by mechanical means.

3.8 Safety and Environmental Considerations

Personal Protective Equipment (PPE) is required to be worn at all times during blasting operations.

- Hearing Protection – Dry ice blasting exceeds OSHA's safe working limits without hearing protection. Personnel performing blasting operations and those in close proximity must wear proper hearing protection.
- Eye Protection - Safety glasses with side-shield are required to be worn by the operator and personnel in the vicinity whenever high velocity air is in use, i.e. during blasting operations.
- Skin Protection - Gloves and long sleeves should be worn when handling dry ice. Leather insulated gloves with gauntlets are recommended due to the low temperature of dry ice (-109.3˚F (-78.5˚C)).
- Ventilation Requirements - Dust or breathing mask must be worn if there is a risk of dust or fine debris in the air, or if proper ventilation isn't located in the immediate area.

Carbon dioxide is a non-toxic gas that meeting EPA, FDA and USDA industry guidelines. By replacing toxic chemical processes with CO_2 as the cleaning media, employee exposure and corporate liability resulting from the use of dangerous chemicals can be substantially reduced or eliminated completely. CO_2 gas is completely non-toxic. It is an oxygen displacement gas, which can cause asphyxiation if not properly handled. When not used in a completely open environment, evacuation and ventilation protocols must be implemented. Because carbon dioxide is heavier than air, exhaust vents are required to be at or near ground level to efficiently remove the gas to an open area.

3.9 Weather Restrictions

Dry ice blasting is suitable for use in most weather considions. However, rain can become problematic in that the dry ice media must be kept dry when transferred from the storage container to the machine's hopper. Extreme heat and high humidity are also challenging when using dry ice, because of the desiccant properties of the media. Dry ice pulls moisture from the air while it is sublimating. This causes the dry ice to clump, which can interfere with acceleration rates and possibly block the machine's blasting stream.

3.10 Operating Costs

Dry ice is normally purchased on an as-needed basis and the media is either delivered to the work site or the end user picks it up from the supplier. The cost of dry ice used for this application varies by market supply and demand, as well as, substantial geographical price variations coupled with transportation distances involved. Figuring an average usage of 3 pounds per minute (1.36 kg/min) at an average cost of .43 cents per pound, operating costs would be $77.40 per hour of continuous blasting. Costs vary when factoring in the price of the media and equipment configuration and settings which greatly influences the rate of use.

3.11 Paint Removal

When removing a relatively new, properly applied finish, the removal rate expected is .25-.33 ft^2/min (.076-.101 m^2/min). When the removal rate is low, it will decrease over time as the substrate becomes extremely cold and the thermal effect diminishes. It may take one minute to break through the coating film with the nozzle remaining stationary over a single point. Primers often respond this way. On a coating that is weathered or was applied improperly, results can be significantly better. Improving to 1 ft^2/min (.304m^2/min) or more.

3.12 Surface Preparation

In order to apply any paint or coating, the surface to be painted must be free of all contaminants. When using dry ice blasting to clean previously painted surfaces to remove dirt, oil, grease, loose paint, rust or oxidation, etc., prior to repainting, the average rate of blasting is normally 3-6 ft^2/min (.91-1.83m^2/min). The cleaned area can be immediately repainted with no further treatment because dry ice blasting leaves no chemical residue. Since there is no water or liquid involved, the dry nature of dry ice blasting is especially valuable when cleaning and preparing metal surfaces, as it significantly lowers or eliminates the formation of flash rust.

3.13 Compatibility with Paint Types

Dry ice blasting is compatible with all types of paint in that there is no danger of a secondary compound being formed. It may not be able to remove all types of paint with significant removal rates, but it creates a clean, rinse free and water-break free surface ready to be coated.

3.14 Expected Advances in Dry Ice Blasting Technology

Dry ice blasting equipment will continue to evolve providing greater efficiency and flexibility of use with improved ergonomics, nozzle design and noise reduction. As more organizations in the global community move further toward environmentally responsible solutions and away from reliance on toxic chemicals and hazardous materials, the demand for this technology will increase.