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DRY ICE BLASTING
A NEW CLEANING TEHNOLOGY IN MACHINERY MANUFACTURING

BY

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Abstract. The paper presents general information about history of dry ice, how it made, store and short presentation of work procedure in dry ice blasting with the main industrial sectors where it is use. Dry ice blasting is an efficient and cost-effective way for industries to maximize production capability and quality. Dry ice blasting is similar to sand blasting, plastic bead blasting or soda blasting where media is accelerated in a pressurized air stream to impact a surface to be cleaned or prepared. But that's where the similarity ends. Instead of using hard abrasive media to grind on a surface (and damage it), dry ice blasting uses soft dry ice, accelerated at supersonic speeds, and creates mini-explosions on the surface to lift the undesirable item off the underlying substrate.

Key words: dry ice; blasting; environment; non abrasive.

1. Introduction - Safety

If you ever have a chance to handle dry ice, you want to be sure to wear heavy *gloves*. The super-cold surface temperature can easily damage your skin if you touch it directly. For the same reason, you never want to taste or swallow

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dry ice, either. Another important concern with dry ice is *ventilation*. You want to make sure the area is well-ventilated. Carbon dioxide is heavier than air, and it can concentrate in low areas or enclosed. Normal air is 78% nitrogen, 21% oxygen and only 0.035% carbon dioxide. If the concentration of carbon dioxide in the air rises above 5%, carbon dioxide can become toxic. Be sure to ventilate any area that contains dry ice, and do not transport it in a closed vehicle.

2. The Manufacturing Process of Dry Ice

The only raw material used in the manufacture of dry ice is carbon dioxide. Carbon dioxide was discovered in the early 17th century by the Flemish scientist Jan Baptista van Helmont. He was the first scientist to acknowledge there are different sorts of gases. In early 1770 Torbern Bergman discovered that an equal volume of CO_2 gas was almost entirely soluble in water at a temperature of 10°C and observed that the solubility of this gas decreases as the temperature rises. By means of taste experiments and litmus paper he found out that the solution was slightly acidulous, which inspired him to use it in the production of artificial mineral waters. In 1854 Faraday also succeeded in producing dry ice on a lab level. It would only be in 1925, however, that dry ice was produced commercially for the first time from out of the United States (http://inventors.about.com/library/inventors/bldryice.htm).

Carbon dioxide occurs in three forms: as a solid (also called dry ice), a liquid and a gas (Fig. 1). Gaseous CO_2 is found in low concentrations in the atmosphere as a greenhouse gas. Atmospheric carbon dioxide is produced from volcanic activity, the combustion of organic materials and the respiration process of all aerobic organisms.

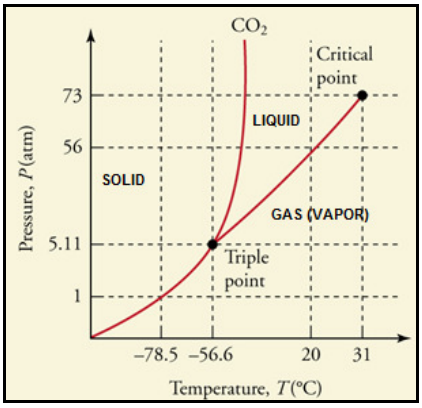

Fig. 1 − The phase diagram for carbon dioxide. Carbon dioxide occurs in three forms: as a solid (also called dry ice), a liquid and a gas. The axes are nonlinear, and the graph is not to scale. Dry ice is solid carbon dioxide and has a sublimation temperature of −78.5ºC.

Carbon dioxide is an odorless, colorless gas and has a limited solubility in water. When CO_2 gas is solved in water it forms a weak acid: acid carbonate also known as carbonic acid.

This mineral acid and the base components in the water react with each other. On top of that carbon dioxide is a non-toxic and non-corrosive gas, making it a recommendable solution to treat (waste) waters, in stark contrast with strong acids such as sulfuric acid and chloric acid. Using CO_2 to neutralize the pH level in water is therefore an ecologically sound process, as a CO_2 injection does not bring about excessive acidification of the water nor does it introduce any pollutants to it (http://www.dryiceinfo.com).

This raw material (CO_2) is extract manly from ground or byproduct of the refinement of gases emitted during the manufacture or refinement of other products. Most carbon dioxide used in the manufacture of dry ice in the world is derived from refinement of gases given off during the refinement of petroleum and ammonia. The carbon dioxide emitted during these processes is sucked off and "scrubbed" to remove impurities for food grade carbon dioxide that will eventually become dry ice.

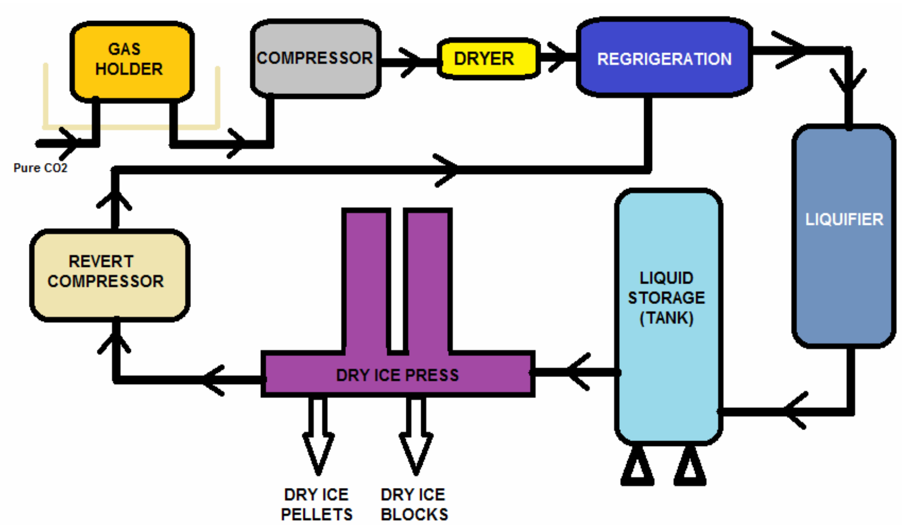

Fig. 2 − Process for dry ice production.

Carbon dioxide is liquefied by compressing and cooling, liquefying at a pressure of approximately 400 kg/cm^2 at room temperature. Liquid carbon dioxide is pumped, via piping, into huge holding tanks so that dry ice manufacturers can remove the liquid required. The liquid carbon dioxide is shipped in huge quantities, sometimes weighing many tons. Thus, most dry ice manufacturers choose to locate their factories close to the petroleum or ammonia refineries to keep transportation costs affordable. The pressurized, refrigerated liquid carbon dioxide is piped directly into a pressurized tank or rail car owned by the dry ice manufacturer and heads for the plant. The tank trunk pulls up to the factory and dumps the liquid carbon dioxide into tanks on the premises. These tanks hold the liquid under pressure, keeping it refrigerated so that it remains in liquid state. These tanks are situated adjacent to the factory wall and, through piping; the liquid is brought directly inside when required for manufacturing (Fig. 2).

The liquid carbon dioxide is released, again via piping, from the adjacent tanks through the factory wall and into the dry ice press. When the liquid moves from a highly-pressurized environment to atmospheric pressure, it expands and evaporates at high speeds, causing the liquid to cool to its freezing point which is −78.5°C. A nozzle puts the liquid into the top block of a dry ice press. This press includes a large block at the top that can exert extreme pressure on the product that is brought into it. When the liquid carbon dioxide hits the block of the dry ice press, it immediately solidifies since it is now at room temperature. The carbon dioxide now resembles snow (Fig. 3).

This snow, now in the upper portion of the press, must be compressed into pallets of dry ice or directly in blocks. This pallets or blocks of opaque white dry ice are pushed out of the press and onto a roller. A pneumatic saw cuts the blocks. The dry ice pallets are put into containers that keep cold so sublimation is kept to a minimum.

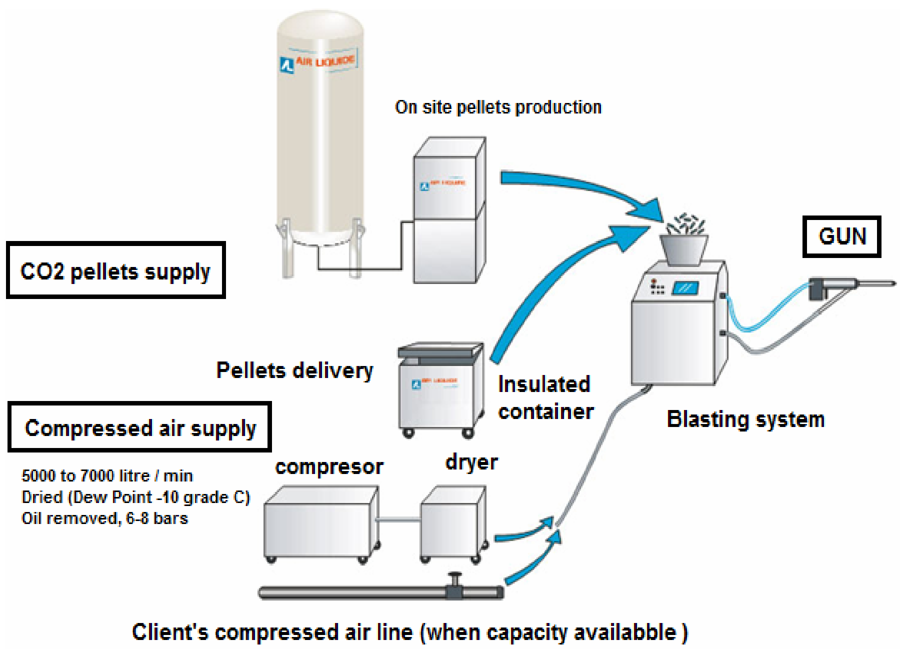

Fig. 3 − Possibility to use dry ice blasting.

The most common variant for dry ice blasting use in industry is like in Fig. 4.

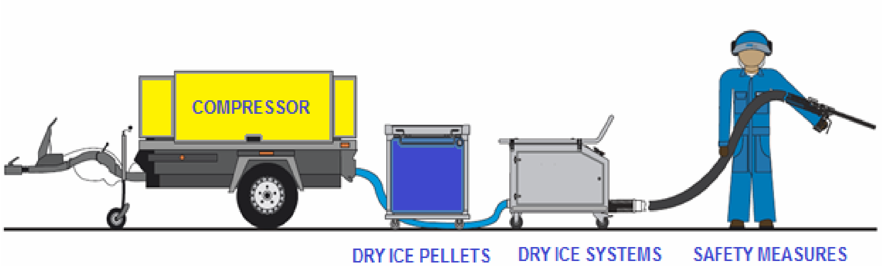

Fig. 4 − The most common variant for dry ice blasting use.

Cleaning with dry ice is used in most cases pellets with a diameter of 3 mm who look like in Fig. 5. Dry ice pallets are pushed with some pressure adjusted in advance in dry ice systems (blasting machines) and process start.

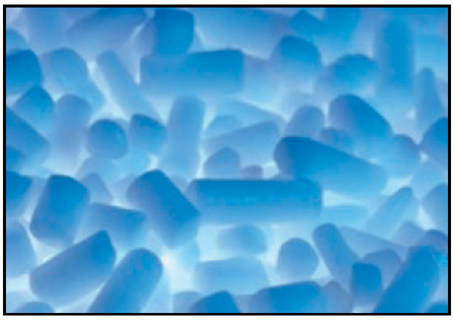

Fig. 5 − Dry ice pellets – 3 mm.

In this process of cleaning with dry ice can say that three effects occur in the same time: thermal shock effect, pellet kinetic energy and thermal-kinetic effect (http://encyclopedia.airliquide.com/encyclopedia.asp) (Fig. 6).

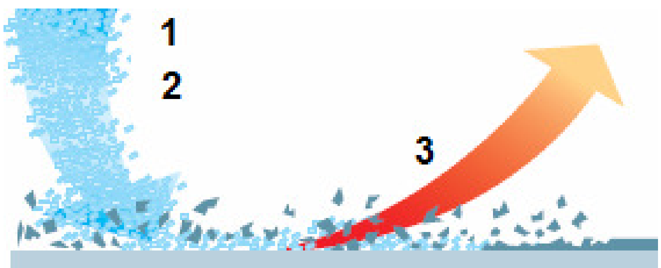

Fig. 6 − Effects in dry ice blasting.
1 − Thermal Shock Effect; **2** − Pellet Kinetic Effect; **3** − Thermal-Kinetic Effect.

• *Thermal Shock Effect.* Instantaneous sublimation (phase change from solid to gas) of CO_2 pellet upon impact absorbs maximum heat from the very thin top layer of surface coating or contaminant. Maximum heat is absorbed due to latent heat of sublimation. The very rapid transfer of heat into the pellet from the coating top layer creates an extremely large temperature differential between successive micro-layers within the coating. This sharp thermal gradient produces localized high shear stresses between the micro-layers. The shear stresses produced are also dependent upon the coating thermal conductivity and thermal coefficient of expansion/contraction, as well as the thermal mass of the underlying substrate. The high shear produced over a very brief expanse of time causes rapid micro-crack propagation between the layers leading to contamination and/or coating final bond failure at the surface of the substrate.

• *Pellet Kinetic Energy.* The process incorporates high velocity (supersonic) nozzles for surface preparation and coating removal applications. Since kinetic impact force is a product of the pellet mass and velocity over time, the delivery system achieves the greatest impact force possible from a solid CO_2 pellet by propelling the pellets to the highest velocities attainable in the blasting industry. Even at high impact velocities and direct head-on impact angles, the kinetic effect of solid CO_2 pellets is minimal when compared to other media (grit, sand, PMB). This is due to the relative softness of a solid CO_2, which is not as dense and hard, as other projectile media. Also, the pellet changes phase from a solid to a gas almost instantaneously upon impact, which effectively provides an almost nonexistent coefficient of restitution in the impact equation. Very little impact energy is transferred into the coating or substrate, so the blasting process is considered to be nonabrasive.

• *Thermal-Kinetic Effect.* The combined impact energy dissipation and extremely rapid heat transfer between the pellet and the surface cause instantaneous sublimation of the solid CO_2 into gas. The gas expands to nearly 700 times the volume of the pellet in a few milliseconds in what is effectively a "Micro-explosion" at the point of impact. The "Micro-explosion", as the pellet changes to gas, is further enhanced for lifting thermally-fractured coating particles from the substrate. This is because of the pellet's lack of rebound energy, which tends to distribute its mass along the surface during the impact. The CO_2 gas expands outward along the surface and its resulting "explosion shock front" effectively provides an area of high pressure focused between the surface and the thermally fractured coating particles. This results in a very efficient lifting force to carry the particles away from the surface. Advantage of Dry Ice Blasting is concentrated in Table 1.

Table 1

Cleaning Method	Secondary Waste	Electrically Conductive	Abrasive	Toxic	Effectiveness
Dry Ice	**No**	**No**	**No**	**No**	**Excellent**
Sand Blasting	Yes	No	Yes	*	Good
Soda Blasting	Yes	No	Yes	*	Good
Water Blasting	Yes	Yes	No	*	OK
Solvents/Chemicals	Yes	N/A	No	Yes	Limited
Power Tools	No	N/A	Yes	N/A	Limited
Hand Tools	No	N/A	Yes	N/A	Limited

*These blasting materials are also then classified as toxic waste and require appropriate safe disposal. Upon contact, traditional blasting materials become contaminated when used to clean hazardous substances and objects.

3. Conclusions

The blasting machines must optimize blast performance for each application by combining of three forces and adjusting the compressed air pressure, blast nozzle type (velocity distribution), CO_2 pellet size and density and pellet mass rate and flux density (particles per unit area per second).

Dry ice blasting is an environmentally-, employee- and equipment-friendly alternative to most conventional surface preparation and cleaning methods.

Dry ice Blasting is not abrasive.

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CURĂȚAREA CU GHEAȚĂ CARBONICĂ

Noua tehnologie în industria constructoare de maşini

(Rezumat)

Articolul prezintă descrierea procesului de obținere a gheții carbonice, materiei prime care se foloseşte pentru acest procedeu de curățare, particularitățile şi efectele care apar în timpul lucrului. De asemenea se face şi o paralelă cu celelate tipuri clasice cunoscute de curățare şi pregătire a suprafețelor.