CO_2 BLASTING
The Remediation Tool of the Future

By Neil McManus, CIH, ROH, CSP

Building restoration is an innovative and dynamic enterprise. The IICRC Standard S520 promises to do for mold remediation what the S500 Standard did for water damage: provide needed leadership and direction.

One of the techniques mentioned in the S520 is abrasive blasting using pellets of dry ice. Dry ice is neither dry nor ice. Actually, it is the solidified form of carbon dioxide (CO_2) gas, not to be confused with carbon monoxide (CO) gas. Carbon monoxide is a product of combustion in engines.

Abrasive blasting using CO_2 pellets offers tremendous advantages:

- high penetration into inaccessible areas
- no residue from the blast medium
- no contamination of the base material by the blast medium
- cooling effect to maintain worker comfort in hot environments
- increase in productivity over other techniques
- reduction in musculoskeletal injury over techniques such as sanding

The pressure of the blast drives the pellets into areas otherwise inaccessible to the tools in use, such as sanders. This means that there will be much less of the structure still containing untreated base material at the end of the process.

CO_2 pellets are temperature-sensitive and sublime to CO_2 gas. (Sublimation means that there is no intermediate step involving liquid CO_2.) Hence, the only residue requiring clean-up or removal by HEPA-vacuuming is the debris removed from the base material and any other debris present in the workspace.

The process of sublimation consumes heat from the air and structure and persons working inside. This lowers the risk of heat stress produced by high temperatures and strenuous work occurring in attic and crawlspaces considerably. This provides tremendous benefit for workers who are usually clad in impervious disposable suits and gloves, which prevent radiation of heat from the skin and evaporation of sweat, tremendously increasing the potential for heat stress. Cooling the air in a hot attic or crawlspace to room temperature or less at least makes wearing this clothing more tolerable, rather than something that could kill the wearer.

The blast from the gun does the work. The worker is required to do the positioning, rather than actively manipulating it, as is required with hand tools such as sanders. This allows the operator to accomplish considerably more in a day. An added benefit is the reduction in repetitive motion.

Figure 1. Set-up of the compressor. Note that the location is well-removed from the front of the house to prevent entry of exhaust gases.

There is no Free Lunch

This kind of innovation seems to defy the laws of gravity and the principle of the free lunch. There are no free lunches in every other aspect of life; every innovation has its cost. This truism is equally applicable to this technology. Consider some of the downsides:

- cost of materials
- potential penetration of the blast jet beyond normal containment
- exposure to carbon dioxide
- considerations about work in confined spaces
- frostbite

Materials that disappear during use and are not recyclable add considerably to the cost of performing work. They cannot be reused in future applications. At the same time, they do reduce the cost of collection and disposal of waste material.

A more important concern is the blast. Normally, remediation work occurs inside containment under negative pressure. The expectation is that the negative pressure prevents escape of contaminated air from within the enclosure. Similarly, air flows into the enclosure through defined and undefined pathways. That reduces the consequence of failing to seal leakage paths between occupied and unoccupied areas of the structure, as well as failure of taped and glued seams. CO_2 blast systems operate at pressures in the range of 80 to 125 lb/in^2 (pounds per square inch). The pressure of the jet created by the blast can overcome inward flow through leakage paths. This could easily overcome the ability of a negative airmover to induce inward flow. However, back pressure and visual scouring from the CO_2 blast

This picture depicts the work posture in the crawlspace. The speed of the work, compared to sanding, compensates somewhat for the lack of ideal work position. Note the position of the probe of the four-gas tester on the shoulder of the worker.

Sublimation of pellets to gas creates the potential for overexposure to CO_2 and the potential for oxygen deficiency. Normal atmospheric concentration of carbon dioxide is around 350 ppm (parts per million). The regulatory limit for exposure to carbon dioxide in most jurisdictions is an eight-hour time-weighted average of 5000 ppm (0.5 percent). Use of carbon dioxide pellets for abrasive blasting can easily lead to accumulations at or above 5000 ppm, especially in the case of attic spaces or crawlspaces.

Attic spaces and crawlspaces meet the geometric characteristics of confined spaces in many jurisdictions. Note that the definition for confined spaces is geometry-based and not hazard-based. The advice of an experienced and qualified health and safety practitioner is required during this work. While under most circumstances work can occur without incident in these workspaces, generation of CO_2 can easily lead to overexposure, even under conditions of negative pressure.

Regardless of the label given to the space in which this work occurs, there is a need to determine worker exposure in real time and to provide warning about overexposure. Portable instruments for measuring carbon dioxide exposure are bulky and not person-portable. Nor do they measure in the range of interest for evaluating indoor environmental quality (which is below that potentially encountered in these environments). None of these instruments contains an alarm. An additional complication is the hostility of the blasting environment to instruments. Any instrument used in this application requires protection from the projectiles created by blasting.

The four-gas tester commonly used for entry into confined spaces provides a starting-point for evaluation of these environments. Depression of oxygen provides a surrogate for increase in concentration of carbon dioxide. These instruments provide real-time monitoring and alarm. Some contain built-in pumps and dataloggers. Instruments containing built-in pumps sample through a small external probe. This is the only part of the instrument exposed to the

Figure 2. Dry ice handling. Sublimation leading to production of carbon dioxide gas poses the ever-present risk of oxygen deficienc, especially in low-lying areas.

act as an incentive to back away from surfaces to more reasonable distances.

The potential for overcoming containment is not necessarily an exclusive property of the CO_2 blast process. Abrasion using sanding and abrading equipment also creates considerable particulate discharges at high velocity. To illustrate, a six-inch disk used in sanding, rotating at 3450 rpm (revolutions per minute), creates a tip velocity of 5420 ft/min. This also can overcome the strongest of inward flows into a containment structure. Hence, both techniques should be considered as suspect in this regard and must be used carefully near access openings and other known points of inward leakage. The best approach would be to seal the access opening or known point of inward leakage temporarily during work at these locations. Note that this strategy requires a secondary point of inward air flow so as to avoid starving the fan(s).

Both techniques create loose material requiring clean-up. Abrasion of surfaces by sanding and abrading techniques scarifies the wood and potentially creates more loose debris.

hostile environment. The body of the instrument and the sensors remain protected from the blasting environment.

A problem with use of this equipment in this manner is the stability of the oxygen reading. The reading on some older instruments fluctuates rapidly between 20.8 percent and 21.0 percent. The baseline of the oxygen reading can decrease to 20.6 percent due to weather conditions during prolonged measurement. The challenge in using one of these instruments in this manner over long periods of time is to obtain a reading truly indicative of carbon dioxide depression and not a reflection of weather conditions.

The reading on an oxygen sensor due to 5000 ppm (0.5 percent) of CO_2 alone would be just under 20.8 percent. The reading occurs at this level because the oxygen sensor responds to one molecule in every five that enter the sensor. Setting the oxygen alarm at this level would lead to many false positive readings due to instantaneous fluctuation or during prolonged use of this equipment during a workshift. On the other hand, setting the alarm to 20.5 percent to prevent false positives due to weather conditions could allow unrecognized overexposure to CO_2 to occur.

The only other expected contaminant in this air is carbon monoxide originating in the compressed air or due to backdrafting of a stack that exhausts a combustion source, which is measured by the CO sensor in the four-gas tester.

Another potential complication in the use of carbon dioxide pellets is frostbite. Metal parts of the equipment can become extremely cold due to the occurrence of sublimation in delivery piping. Frostbite could occur during a hot summer day!

A Case Study

To illustrate the potential and complications of abrasive blasting using CO_2 pellets, consider the following trial application. This involved the crawlspace under a large home. The crawlspace is about 1 m (3 ft) high and covers the entire floor area. The crawlspace was open throughout the floor area, except for supporting pony walls.

A diesel-powered air compressor was used to supply motive power to the delivery system (Figure 1). The CO_2 pellets were contained in a large tub (Figure 2). These were transferred to the delivery equipment using a plastic scoop. The delivery equipment contains an auger system to force the pellets into the airstream (Figure 3). This work occurred near the beginning of June. Despite the presence of overcast conditions and light rain, sublimation was actively occurring in the storage chest, in the delivery equipment and delivery lines. Production of gaseous carbon dioxide can displace the normal atmosphere in any low-lying area.

This crawlspace was treated as a confined space, with creation of a written hazard assessment and entry procedure by a Qualified Person, as required in this jurisdiction. The space was assessed as not requiring an entry permit. That is, a person could escape unhindered from the space if the ventilation failed. (Carbon dioxide at levels above the regulatory limit of 5000 ppm is considered as an asphyxiant and stimulant of breathing.)

Figure 3. Dry ice auguring machine. Note the clip for attaching to electrical ground. Carbon dioxide pellets transported in compressed air create serious risk of electrostatic discharge. This discharge has sufficient energy to ignite flammable mixtures.

As part of the hazard assessment and procedure, and by regulatory requirement, the worker entering the space was required to wear a four-gas testing instrument (oxygen, ignitables, carbon monoxide and hydrogen sulfide) containing a built-in pump (Figure 4). The built-in pump enabled the instrument to be protected from damage, to actively sample the air breathed by the worker, and to be close enough to be heard in the event that the alarm sounded. (Only the oxygen and carbon monoxide sensors were required during this work.) The alarm for low level of oxygen was set to 20.5 percent. (Note that the factory set-point for the oxygen alarm on these instruments typically is 19.5 percent. This must be adjusted upward to offer protection against CO_2.)

A second instrument that measures CO_2 was set up in the kitchen inside a cupboard containing a penetration to the crawlspace that was known to be difficult to seal. This type of instrument provides a more precise view of carbon dioxide emissions vis-à-vis leakage from the crawlspace, but does not provide an alarm function. Spore trap samples were collected at the same location periodically during the day using Air-O-Cell cassettes.

At the start of the work, a negative airmover (1800 ft^3/min) was set up to draw air into and through the crawlspace to the opposite side of the house. A second negative airmover (1000 ft^3/min) was set up in the crawlspace to provide additional exhaust capacity. Ventilation of confined spaces is a requirement in this jurisdiction.

Figure 4. Worker wearing four-gas tester. Continuous monitoring is essential during this work. Note that the oxygen alarm is set to 20.5 to prevent overexposure to carbon dioxide, as well as oxygen deficiency.

Abrasive blasting using CO_2 is a noisy process requiring the use of hearing protection by all participants.

Work in the crawlspace proceeded normally for a period without occurrence of an alarm. Failure of the negative air mover used to evacuate the crawlspace occurred following the tripping of a circuit breaker in the home electrical system. Loss of negative pressure at the entry portal as collapse of the inward position of the flap was noticed, but the implications were not immediately recognized correctly by an inexperienced attendant. Soon afterward, the low oxygen alarm on the instrument sounded. The operator wearing the instrument recognized the implications of the situation and immediately ceased blasting and headed to the access point. The attendant also heard the alarm over the noise made by the blasting equipment and simultaneously signalled to the operator to vacate the space. This situation shows the practical application of protective measures taken during planning for this work.

The CO_2 monitoring instrument set up beside the incompletely sealed penetration in the kitchen also recorded a major increase in concentration following the upset caused by loss of negative pressure. This eventually decreased to normal levels. This situation was reflected in spore trap samples collected at the same location.

The cause of failure of the ventilation unit was never determined. The unit was switched to an alternative circuit located in the washer room, was restarted successfully and remained operative for the remainder of the job. The second unit was harnessed as a negative air mover, but connected to a different location on the perimeter walls of the house. Following this incident, the work was restarted and completed successfully without further problem. The air movers maintained the oxygen level satisfactorily to prevent sounding of the alarm.

This story illustrates some pitfalls about work in crawlspaces under real-world conditions. What looks to have been easy, actually was the outcome of interactions with a number of factors requiring considerable thought and preparation.

Secrets of Success

Work of this type can be completed entirely successfully. In order to do so, it is important to grasp the dynamics involved and to harness conditions in a beneficial manner.

- *The compressor:* The compressor used in this job produces 175 ft^3/min at 125 lb/in^2. This corresponds to a supply ventilation rate of 1450 ft^3/min at normal pressure delivered into the work zone near the location of blasting. This air dilutes the carbon dioxide, but also competes with the negative air mover in its attempt to maintain the building under negative pressure. If this supply of air is not factored into calculations to determine required capacity of negative air movers, then it is quite possible that the enclosure could go to positive pressure during the work.

  Air provided by the compressor could contain exhaust gases, as well as carbon monoxide produced during breakdown of compressor oils. The carbon monoxide sensor of the four-gas tester provides a basis for ensuring the quality of air breathed by the operator that originates from this source.

- *Ventilation Strategy:* Normally, restoration work occurring in enclosures proceeds under negative pressure. This prevents escape of contaminants into occupied areas. Maintaining negative pressure requires sufficient air to be drawn through known and unknown leakage paths to overcome escape velocities.

  In this case, an opening to the exterior at one side of the house and the entry passage provided known pathways for air. Incompletely sealed penetrations and unknown penetrations provided paths of passive in-leakage. The compressor provided an active supply.

  What happens when the crawlspace is sealed and has no openings to the exterior? The only paths for in-leakage are incompletely sealed penetrations and the access opening. There is no readily available source of supply. Such crawlspaces pose a serious risk of oxygen deficiency when first opened following long periods of quiescence. Work in such spaces requires considerable planning for provision of air to the work area to maintain CO_2 within acceptable levels and removal of air from the work area to maintain inward flow and hence negative pressure. ■

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