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Creating an Effective CONTAINMENT

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Containment is a well-recognized, widely applied concept in building restoration and involves the creation of temporary structures and linings to separate work areas from unaffected ones. It provides the means to prevent or control emission of contaminants from the work area to uninvolved ones.

The principle underlying the concept of containment is the controlled and deliberate inward flow of air from the uncontaminated zone into the contaminated area through known and unknown leakage paths. This provides protection to occupants in the uncontaminated zone so that they can proceed with their business in a seamless manner while remedial work occurs.

Treatment of large items works well in contained structures. This work can occur on site or in a facility. Control of airborne contaminants occurs through the use of negative airmovers or vacuum cleaners to create a negative differential pressure in the contained area. The negative pressure forces the inward flow of air from outside the structure through known and unknown openings or penetrations. High Efficiency Particulate Air (HEPA)

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Figure 1 (Oppsite page): A HEPA-filtered vacuum cleaner serves as both negative airmover and vacuum cleaner. Note the location of the vacuum cleaning machine and its discharge outside the containment.

Figure 2: An airmover was used to create inflow into the small containment. Note the inward movement of the flaps.

filtration or sorbents in the negative airmover removes contaminants from the air prior to discharge. The negative airmover can also incorporate other filtering media, such as activated charcoal and other sorbents, for removal of vapors and gases from the air prior to discharge or recycle. The latter is important when odorants are present or generated during work activity.

Work activity performed inside contained structures provides no benefit to workers, since it generates considerable contamination once disruptive work begins. As a result, conditions in the contaminated zone can require a high level of respiratory protection and personal protective equipment (PPE) such as protective clothing, gloves and boots. Requirements for respiratory protection can range up to a full facepiece air-line respirator and escape bottle, the equivalent of a self-contained breathing apparatus. Careful attention to work practices may be able to reduce this requirement to a more manageable full facepiece, Powered Air-Purifying Respirator (PAPR) or a full facepiece cartridge respirator.

It is more desirable for workers to clean from outside the contained structure, but this is often possible only for small items and is best suited to repetitive tasks performed in an assembly line manner. Work from outside the enclosure offers, at the very least, the benefit of not having to wear a high level of PPE. This reduces the burden on the individual from:

- heat stress brought on by hot suits
- slippage from booties that provide poor traction
- respiratory burden from resistance imposed by air filtering respirators
- loss of peripheral vision from the full facepiece or chemical goggles
- hand discomfort from sweating inside tight-fitting gloves that cannot be removed
- general discomfort from wearing burdensome equipment that fits tightly against body surfaces

Containment or enclosure can occur in several ways. One possibility involves construction of temporary enclosures and the use of negative airmovers to create both volumetric flow and negative differential pressure, as required by the IICRC S520. The other involves the use of a hood structure to channel airflow to a duct and the airmover. Examples of these include laboratory fume hoods and spray booths.

Directional flow of air between rooms in laboratories is the subject of Section 5.1.1 (Differential Airflow and Pressure Between Rooms) in ANSI/AIHA Z9.5-2003 (Laboratory Ventilation). The clarification and explanation column provides guidance on how to achieve and maintain directional airflow in these circumstances. The document describes how the difference in pressure is the driving force that causes air to flow through openings from one space to another, but specifies that quantitative pressure differential is a poor basis for design. What is needed is differential volumetric flow, meaning a difference between supply and exhaust. This approach is fine where exhaust capacity and supply capacity are quantities to be manipulated in design; however, this approach will not work in situations where the containment has only exhaust capacity and obtains supply air by passive entry through the access door and other openings. Section 5.1.1 also indicates that many designers routinely use a differential of 10 percent between supply and exhaust capacity.

An extremely important concept in exhaust ventilation is capture velocity, the velocity across the opening into which air flows. The recommended capture velocity in many industrial systems containing exhaust hoods is 100 ft/min or higher. Hoods used in exhaust ventilation systems rely on velocity at the face opening to capture or maintain contaminants within the structure enclosed by the hood. There is no mention of differential pressure between the room and the interior of the hood in design of exhaust systems, meaning the walls of the hood are not under negative static pressure.

The clarification and explanatory column in Section 5.1.1 recommends setting air flows through any opening, including open doorways, at a minimum velocity of 50 ft/min (0.25

Figure 3 a, b, c: Construction of the unit for treating mold-contaminated paper documents. Note the use of readily available materials and equipment in the construction.

m/s) and preferably 100 ft/min (0.5 m/s) in the desired direction even when differential pressure is used as the basis for design. The entrance to a containment and the unknown openings between the contained area and the surroundings essentially are the same as the openings of an exhaust hood.

To illustrate the situation, the ANSI document explains that volumetric flow through an ordinary door measuring three feet by seven feet (0.9 m x 2.1 m) at a velocity of 100 ft/min (0.5 m/s) would require 2100 ft^3/min (991 L/s) with differential pressure about 0.0006 in. wg (0.15 Pa). A differential pressure of only 0.01 in. wg (2.5Pa) when the door is open would generate air velocity and airflow of 400 ft/min (2.0 m/s) and 8400 ft^3/min (3964 L/s) respectively, quantities that are impractical in building operation, but not unheard of with temporary enclosures.

An airlock containing zippered flaps provides the means to control volumetric flow even more precisely. The outer door minimizes flow from the surroundings into the airlock, and the inner door minimizes flow from the airlock into the work zone. This configuration allows the use of small airmovers in containments, provided that one door of the airlock is opened at a time and that the inner door is always closed when the outer is opened. Defined flow paths of small surface areas containing self-closing dampers for air entry from the surroundings can maintain inward flow at high velocity into an otherwise sealed enclosure.

Example 1: Mini Containment

This example concerns a temporary structure erected adjacent to a storage container holding mold-contaminated household effects located in the warehouse. This structure provided access to the interior of a storage container for removing and cleaning mold-contaminated household effects. Exposing the contents of the container to the air of the warehouse posed the risk of needless worker exposure to spores, as well as the potential for contamination and recontamination of other stored articles.

A large HEPA-filtered vacuum cleaner served as both the airmover to create and maintain negative pressure in the structure and the vacuum cleaner to remove and collect contamination from surfaces (Figure 1).

A low volume, high velocity system can produce the desired results of containment and remove surface contaminants; however, this application requires considerable attention to detail. A small bag-type canister machine operates around 70 ft^3/min maximum when the bag is fresh. Volumetric flow decreases as the bag loads with dirt. Larger machines operate around 85 ft^3/min maximum. A small unit would provide the flow-through of four air changes per hour specified in the IICRC S520 in a chamber having a maximum open volume of 1000 ft^3. To maintain velocity exceeding 100 ft/min would require the controlled opening admitting air from the surroundings to be around 0.5 ft^2 to allow for inefficiencies in operation of the airmover. This unit likely would be unable to maintain the containment simultaneously under the negative pressure requirement of -0.02 in wg specified in the IICRC S520 because of the flexibility of the sheet poly used in its construction.

Tight sealing of potential leakage paths, an airlock containing zippered flaps, and dedicated inflow paths to control entry of air from the surroundings provide the means to achieve control in small enclosures using small airmovers, such as vacuum cleaners. Zippered flaps can almost completely seal the structure. Small, self-closing flapped openings that will produce inflow at high velocity into the work chamber will prevent any outward migration of spores.

The location of inflow openings must ensure maximum residence of air in the work chamber so that short circuiting to the intake of the vacuum cleaner does not occur. At the same time, the openings must be large enough to avoid aggressive bowing in of the sheet poly due to overly high resistance to air entry from the surroundings. This ensures optimum removal of contaminated air from the airspace of the structure, as well as from the surfaces being vacuum cleaned.

To restate, the preceding approach requires considerable care, as the geometry described is potentially confined space. Short-circuiting of air entering the structure could lead to local depression of oxygen concentration, especially since the occupant is the consumer of the oxygen. Checking oxygen concentration during work in such a chamber is advised as a precautionary measure.

A variation on this theme is to use a negative airmover to ventilate the space while vacuum cleaning is occurring (Figure 2). The negative airmover creates considerably more volumetric flow than a vacuum cleaner and is more tolerant of the use of conventional flaps at the entry point. The location of the negative airmover should be as far as possible from the entry point to optimize inward flow. Discharge of HEPA-filtered air from the vacuum cleaner inside the enclosure will create considerably greater turbulence than advisable.

Work flow and work practices are also critical to achieving success when using small enclosures. Exposing the minimum number of contaminated items to the air of the containment at any time and repackaging vacuum-cleaned items immediately in a second container that remains closed except during transfer minimizes generation of spores and the potential for recontamination. The clean container is removed to the isolated chamber when full. The zippered door between the two chambers remains closed except during transfer of closed cleaned containers and personnel.

Personnel should vacuum their disposable suits in the contaminated chamber prior to moving to the isolation chamber. Prolonged cleanup prior to vacating the work chamber enables purging of the air to occur. The nozzle of a second vacuum cleaner operating in the isolation chamber or the nozzle of the first passed by an assistant through the wall or a second self-closing flap in the isolation chamber provides a means to ensure the inward flow of air from the surroundings and an opportunity to clean items to be removed prior to opening the outer flap.

Example 2: Containment Hood

The processing of mold-contaminated documents is a major line of business for some building restoration companies. Mold-contaminated documents include books from libraries, records bound into books, sheet music, loose paper files in folders, and so on. Objects of commercial and intellectual value are not considered disposable or sacrificial and sometimes receive heroic efforts at restoration.

Treatment can include exposure to high concentrations of ozone and biocides in an attempt to kill vegetative fungal and bacterial growth. Killing vegetative growth does nothing to spores, which can still provoke adverse respiratory response in sensitized individuals.

Work that occurs in large chambers on small items needlessly exposes workers to the conditions in the chamber. Small items suit an assembly line approach in small ventilated enclosures that allow the worker to remain outside. This approach minimizes exposure to spores and chemical treatments, and it also provides greater control over emissions into the airspace of the enclosure from which removal is required. Removal from a small enclosure occurs more easily than from a large one.

Figure 4: Compressed air gun used to remove spores from paper documents.

Figure 5: Concept of a system for hanging and transporting items requiring air spraying.

Figure 6: Inflow of air into the containment structure.

To investigate possible designs, a proof-of-concept structure for treating mold-contaminated papers was constructed (Figure 3). This device consists of a T-shaped chamber. The middle arm of the "T" was connected to a HEPA-filtered negative air machine. The cross-arm of the "T" was opened and a panel of sheet poly and sleeves from a disposable suit attached. This design results in construction of an open-ended glovebag. The sleeves provide access to the item to be cleaned using a compressed air blow-off gun (Figure 4).

The cross-arm of the "T" provides a route for entry and exit for the items to be cleaned. For high volume work, these could be suspended from a hanger in a tracked conveying system, created here using a pole and coat hangers (Figure 5). The cross-arm of the "T" also provides enclosure and control of air flow. Enclosure prevents the escape of spores carried in the jet from the air gun into the work area, thus minimizing exposure of the worker and the potential for contaminating the work area. Enclosure by the cross-arm of the "T" also enables the exhaust fan to overcome the sudden pressurization of the middle area by expansion of air to normal pressure and potential reversal of flow from the ends of the structure into the work area. The enclosed space along the cross-arm of the "T" provides a potential location for another workstation for application of the anti-fungal agent.

Capture velocity at the open ends of the cross-arm of the "T" depends on surface area of the opening, amount of air provided by the compressor during spray cleaning, capacity of the airmover and configuration of duct connecting to it. Note that negative differential pressure is not an issue in this type of design. The issue is capture velocity.

The system, as configured, provided considerable inflow of air, although this was not measured quantitatively (Figure 6). The surface area of the openings is controllable through the use of vertical baffles constructed from strips of heavy gauge vinyl plastic. These would reduce surface area and increase velocity, and at the same time permit outward movement of treated items. The best location for such restriction to surface area is the clean (outlet) side of the system. Installation on the dirty (inlet) side could lead to needless emission of spores into the external surroundings due to disturbance of items to be treated.

This type of system should maintain a capture velocity across the open ends exceeding 100 ft/min at all times. The volumetric flow must account for emission of compressed air from the blow-off gun. Small industrial compressors produce 5 ft^3/min of air at pressure (around 80 lb/in^2). Given atmospheric pressure of 14.7 lb/in^2, the delivery rate of this air at normal pressure is around 27 ft^3/min. The operating position aims the jet from the blow-off gun along the perpendicular arm of the "T" toward the intake to the airmover. This minimizes the impact of the sudden disruption of flow inward from the openings on the cross-arm of the "T" caused by injection of air in the jet. The injection of 27 ft^3/min should

Figure 7: Connection to the negative air mover.

cause negative impact on performance of this system when connected to a negative airmover of the capacity used in this example (nominally 1000 ft^3/min) less losses created in the geometry of hook-up to the hood (Figure 7).

Each containment must be constructed according to the conditions and areas affected. Effective units can require some ingenuity to satisfy the unique demands of the situation.

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