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Robots to Replace Manual Application in Air Ducts

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Antimicrobials play an important role in public health and safety. While providing health benefits of pathogen removal as well as duct liner preservation, the same antimicrobials involve risks of potential efficacy failure and exposure hazards. This is why the effectiveness and proper use of these products are of widespread concern.

To ensure proper application of antimicrobial products, contractors should be in compliance with any safety and regulatory requirements. Therefore, it is important to make sure that the antimicrobial action has been approved and registered by the U.S. Environmental Protection Agency or is covered by an exemption from registration for use in HVAC ducts. In this regard, note that any pesticide originally registered before November 1984 has to be reregistered, thus older EPA-issued documents may no longer be valid.

Duct systems are designed with materials that do not support microbial growth as manifested in the Underwriters Laboratories 181 standard. However, as dirt and organic matter accumulates in the ducts over time, the situation dramatically changes. Such buildups are perfect food sources for microbial growth when combined with high moisture levels. Fiberglass lined duct is usually more prone to dirt buildup than galvanized just because of the holding capacity of the fiberglass blanket. However, even galvanized duct will support microbial growth if enough organic matter is available.

With more than 100,000 mold species in the world, it is no wonder molds can be found everywhere. In nature, mold plays a key role in the decomposition of leaves, wood and other plant debris. Without mold, everybody would be wading neck-deep in dead plant matter. Due to the wide diversity of mold types, there are molds

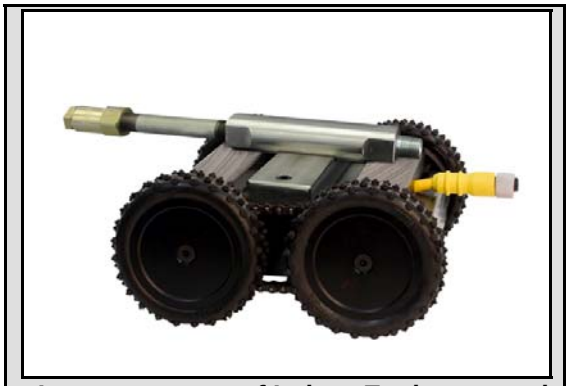

Image courtesy of Indoor Environmental Consultants

In any industry, the use of robotics such as this antimicrobial sprayer has primarily been driven by considerations of productivity, quality and safety.

that can grow on wood, ceiling tiles, wallpaper, paints, carpet, gypsum wallboard and insulation, to mention a few.

A microbial problem first arises when more than one mold species starts digesting organic materials indoors and they release toxins when attempting the fight off competing mold species. Realistically, there is no way to rid all mold and mold spores from a building. The best defense is proper maintenance that includes a combination of changing filters, moisture control, source removal of any potential food sources and antimicrobial treatment. If a proper maintenance plan is followed, the probability that microbial growth will occur even in environments with permanent high moisture content, is very low.

Productivity

Productivity can be dramatically improved by working smarter and not harder. Today's robots allow cleaning and antimicrobial application in sections up to 200 feet, or about 60 meters, between access openings such as preexisting fire-damper doors or other access holes such as those required for manual cleaning and spraying of turning veins. This range significantly reduces the labor need of cutting and patching approximately 50 access holes that is required for manual cleaning and antimicrobial application of a duct 400 feet long.

A quick work-study of such duct system comprised of 15×30 inch insulated duct shows that proper preparation, cutting and patching of each access hole takes approximately 30 minutes. Furthermore, manual cleaning and application take approximately 200 minutes each for the same 400-foot section. Thus, the manual approach requires a total of 32 man-hours to complete the job.

In contrast, newer design robotic systems may provide 20 feet cleaning per minute and 40 feet spraying per minute. With a total setup time of less than one hour, the same job takes approximately three man-hours from start to finish, reducing the total labor by at least a factor of 10.

If the cost per man-hour is $20, then the manual procedure is $640 compared to $60 when using robotics.

In order to reap these benefits, it is very important to assess what robot to use, as some of the older robotic technology can be quite inefficient. One-pass application robots are superior in performance and are the ones used in the above cost study.

As EPA-approved antimicrobials with additional material preservation benefits cost $30–40 per gallon, significant cost savings can also be achieved by using the same one-pass application robotics. For example, several studies have shown chemical savings of approximately 30 percent when applied robotically versus manually. Using these numbers with the previous cost study for the 400-foot duct section, manual application would require approximately 21 gallons versus 16 when applied robotically.

Considering a popular antimicrobial coating for HVAC ducts, the savings for this small duct would be $200. Comparing the cost of the two approaches, the difference of $780 translates into a total savings of $1.95 per linear foot for 15"×30" ducts. Cleaning and spraying only 5,100 linear feet of ductwork can therefore realize the return of investment of a robot costing $10,000.

Ergonomics studies have verified that muscle fatigue is significant when individuals work overhead during manual cleaning and antimicrobial application in HVAC ducts. Fatigued muscles make it impossible to keep arms raised overhead for even short periods of time. This makes reliable performance calculations more challenging, making each job susceptible for cost overruns. Contractors using manual cleaning and spraying methods should allocate an additional quality-control person responsible to verify that all cleaning and application have been properly completed. The

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rationale behind this is that persons who experience muscle fatigue have reduced motivation to complete the task properly. Furthermore, fatigued muscles increase the risk of labor-related injuries as addressed under safety.

Quality

Quality guarantees for the customer should be the main objective for professional contractors. In this aspect, the main objective should first be to ensure proper source removal before properly executing the antimicrobial application. A robotic system enables a contractor to view and digitally record both the cleaning and application sequences for real-time quality assurance and customer documentation. Spraying or coating lined duct manually requires many new access openings, and each opening creates a new frayed edge in the fiberglass liner. So, even though the microbial problem has been successfully addressed, a new hazard has been created where fiberglass particles are now continuously released into the indoor air. Various countries have recommended exposure limits that typically range from 1.0 to less than 0.5 fibers per cubic centimeters based on an eight-hour workday.

Furthermore, an increased number of access holes will create more turbulent airflow and, therefore, become new areas that will accumulate dirt and debris. All of these new openings, especially if improperly sealed, will cause increased air leakage from the duct system over time. These factors could significantly affect the energy efficiency of a building. When more scientific studies become available, it is possible that building owners will file civil lawsuits against contractors who have severely damaged the duct system's integrity in a building.

According to UL 181, fibrous glass duct systems, when installed according to manufacturer's recommendations, are virtually leak-free before the access holes are cut. Building owners may sue to recover energy losses and maybe even for the entire duct replacement cost if the damage is severe enough.

Robotic cleaning and coating, on the other hand, offers a secondary benefit to building owners. Coating tends to smooth the surface and seal air leakage, providing a more energy-efficient duct system. This provides an additional financial benefit to building owners in that energy savings may pay for an aggressive maintenance program. Tests are underway that will quantify the energy savings related to general duct-maintenance procedures.

Robotics allow access to ducts over inaccessible areas such as gypsum wallboard, plaster ceilings or those ceilings high over atriums. In these cases, robotic is the only method that can accomplish the objective with guaranteed quality assurance. Furthermore, using robotics, the contractor avoids uneven application. This translates not only into wasted chemicals as described earlier, but also into longer drying time and increased release for volatile organic compounds.

Robots exist that enable proper cleaning, spraying, coating and/or sealing of square, rectangular and circular ducts from 6×8 inches to 48×48 inches. Duct that is larger than 4×4 feet can be cleaned and coated manually if no confined space issue exists and the system is properly structurally supported. For ducts smaller than 6×8 inches, the most effective method for cleaning and application of antimicrobials is still manual.

Safety

Safety issues are and will be even more prevalent in the future as better scientific knowledge becomes widespread. It will be easier for employees to prove that their employer acted with intent, exposing them to unacceptable hazard levels. This, in conjunction with the government's increasing enforcement of machine safety, falls from elevations, and chemical exposure standards will continually increase employer liabilities. This applies to all occupational areas concerning contactors providing cleaning and antimicrobials application to HVAC ducts.

Reducing the excessive access hole cutting required by manual cleaning and application can minimize machine safety liabilities. There are three main methods of cutting sheet metal:

1. Shears are efficient, but they leave a dangerously sharp edge, which is a significant safety hazard.
2. Circular access cutters operate as a drill bit of varied diameters and make a more smoothly cut edge compared to shears, but the hot dangerous metal chips created are extreme eye hazards.
3. Nibblers are the fastest cutting device and leave the smoothest edge, but these also

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produce small crescent shaped metal chips that are extreme eye hazards too.

Many eye and cut injuries are reported yearly due to the exposure during sheet metal cutting. Therefore, robotic techniques that eliminate the need for many access holes provides the best worker compensation insurance.

Any unprotected side or edge that is six feet or more above a lower level should be protected from falling by the use of a guardrail system, safety net system, or personal fall arrest system. These hazardous exposures exist in many forms. From changing a light bulb with a step ladder to something as high-risk as connecting bolts on steel beams 200 feet in the air. These requirements make it challenging if the ductwork is more than 12 feet above the floor. The cost of a duct cleaning and antimicrobial spraying job increases exponentially with widespread secure scaffold or ladder entry points. To reduce these risks and costs, robotics can get the job done with only a few elevated scaffold or ladder entry points, and the robot operator can work from the floor.

Recommended or mandatory occupational exposure limits have been developed in many countries for airborne exposure to gases, vapors and particulates. The most widely used, threshold limit values, are issued by the American Conference of Governmental Industrial Hygienists. The purpose of such limits for antimicrobial application is to avoid harmful aerosol particle exposure when using paint sprayers for manual application. To stay safely under the limits, respiratory protection should be used in conjunction with capturing those particles that would otherwise escape into the building space. Robotics solve this occupational exposure limit hazard as the duct is under negative pressure from HEPA-filtered negative-air machines. Also, there are very few access holes where exposure may happen. Furthermore, a significant distance between the robot's spray nozzle and the operator ensures no direct exposure.

Conclusion

Trends in indoor environmental robotics show a dramatic change as small handheld digital video displays with standard SD card recording systems rapidly replace the previous generation of bulky systems. Many of the previous generation's systems have large TV monitors and VCRs that require two people to set up and operate, whereas newer systems provide a dynamic capability whereby one system may be used for inspection, cleaning and application of antimicrobials operated by one person.

Furthermore, increasing focus has been on autonomous operation that significantly simplifies the operator interactions with the robotics and minimizes operator error. Autonomous operation allows the robot to automatically self center in the duct, adjust travel speed and raise or lower the spray head to ensure even application of antimicrobial coating.

Robotic cleaning and antimicrobial application can now be executed in ducts from 6×8 inches up to 4×4 feet providing a powerful video guided platform that document the work process and expose any internal issues of the HVAC system. Some vendors have already announced similar solutions for smaller ducts and for vertical chases. The availability of complete suites of video guided HVAC maintenance procedures will significantly improve delivered quality to the building owners thus provide better indoor quality for its occupants.

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