METHOD AND APPARATUS FOR SEALING BUILDING DUCTWORK DURING CHEMICAL OR BIOLOGICAL ATTACK

A system for sealing a building air duct in response to a chemical or biological attack to prevent the building HVAC system from delivering the chemical or biological agent throughout the building. The system can include an inflatable bladder for disposition within an air duct, a source of gas for expanding the bladder, an initiator for initiating the gas expansion, and a detector for detecting the agent. One bladder is formed of a resilient material suitable for extending into duct corners. Another bladder is larger than the duct to be sealed and is formed of a non-resilient material capable of inflating and bunching into duct corners. One source of gas is a gas canister while another source of gas is a chemical composition capable of reacting and forming the gas. One bladder includes a foaming agent which can expand and solidify within the bladder. One initiator utilizes an electronic signal to initiate the gas expansion. Another initiator includes use of an RF signal to initiate the gas expansion. One agent detector samples duct air while another detector includes a horizon detector for detecting agents in the air outside the building.
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METHOD AND APPARATUS FOR SEALING BUILDING DUCTWORK
DURING CHEMICAL OR BIOLOGICAL ATTACK

FIELD OF THE INVENTION

The present invention is generally related to building heating, ventilating, and air conditioning. Specifically, the present invention is related to inflatable bladders for tightly sealing ducts in response to chemical or biological attack. In particular, the present invention includes portable, rapidly expandable bags suitable for quick placement in large air ducts of public buildings.

BACKGROUND OF THE INVENTION

The recent demise of the cold war and decline in super-power tensions has been accompanied by an increase in concern over the viability of weapons of mass destruction such as chemical and biological (CB) weapons. CB weapons include chemical agents such as phosgene, nerve agents such as Sarin, and biological agents such as anthrax or small pox. CB weapons may be delivered to occupants within a building by releasing the agents external to the building but close to an air intake of the building. The air intake may be located near the ground or near the roof or somewhere in between, depending on the building architecture. Agents may also be released within a public area of a building, and be dispersed to other, private areas of the same building. Agents released in one area of a building may be further dispersed by the heating, ventilating, and air conditioning (HVAC) system of the building. It is possible that building air may be removed from the room of release and dispersed by the HVAC system itself through the building. If building air is recycled by mixing return air with intake air, as is sometimes the case, either intentionally or inadvertently, then the HVAC system may effectively deliver an agent from one room to the entire building.

Agents may be delivered in vehicles giving some warnings as to the delivery, such as missiles. Agents may be delivered in vehicles giving no warning, such as a pedestrian held putative asthma inhaler activated near an air intake.

Certain buildings, such as key military sites, can be equipped or designed well in advance to deal with the use of CB weapons. Other buildings, however, such as hotels that are hosting dignitaries or a head of state may be more susceptible to a CB weapons attack. What would be desirable therefore, is a system for sealing air ducts of a building that can be placed and activated on short notice.
SUMMARY OF THE INVENTION

The present invention includes a system for sealing an air duct of a building including an inflatable bladder coupled to means for initiating inflation. A harmful agent detector such as a chemical or biological detector (CBD) can be used in a manual mode to activate an alarm and rely on a human to initiate duct sealing or can be used in conjunction with a controller system in an automatic mode to automatically initiate duct sealing. In one embodiment, the bladder includes a rapidly reacting chemical composition that rapidly creates a volume of gas sufficient to inflate the gas bag.

One class of expandable bladders includes envelopes formed of non-resilient material that does not stretch an appreciable amount under pressure. The non-resilient bags are preferably oversized relative to the duct in which they are to be placed. The oversized bladders have sufficient surface area to extend into the duct corners and seal the ducts. Another class of expandable bladders includes envelopes formed of resilient material, which stretches under pressure. The resilient or elastic envelopes can stretch into the corners of, for example, rectangular air ducts to seal the corners.

Some expandable bladders are positioned along one internal wall of a duct. Other expandable bladders are pre-positioned between two corners of a rectangular duct and can be paired with another bladder or bladder portion disposed between two different corners of an opposing internal wall. Pre-positioned bladders can be held in place using mechanical, magnetic, or any other means. Pre-positioning bladders in duct internal corners can provide corner and wall sealing at the outset, leaving the duct interior to seal upon inflation.

It is contemplated that the duct may be reinforced when an expanding gas filled envelope might compromise duct integrity. Ducts may be reinforced internally with internal sleeves or externally with frame members disposed around the duct exterior. Ducts may also be reinforced by using external frame members held in place by internally disposed cross-members extending through the duct interior.

A preferred source of expansion gas includes chemical compositions that generate large amounts of gas when a reaction is initiated, often by an electrical spark or rapidly heated wire. Gas may be supplemented or even supplanted by use of an expanding foaming agent. The foaming agent can be used in part to force an envelope into duct corners to insure corner sealing. The foaming agent can be used to make the envelope’s expansion permanent, insuring that the duct will remain sealed even if the gas leaks from the envelope. The foam is preferably rapidly expanding and hardening,
and can be similar to foams used for in-place foam packing applications and home and building insulation applications.

In use, a building can be protected by selecting proper ducts and disposing expandable gas bladders within the ducts. Wiring can be extended to the outside of the duct, and may terminate locally through wires to a receiver which can be connected to an antenna. Chemical or biological detectors can be installed in select locations, including locations within ducts and within public areas of the building, and also can be located external to the building. Horizon detectors can be installed external to the building. The detectors can be either hardwired or linked with RF signals to a controller. The controller can either be run in manual mode, requiring a human to initiate envelope inflation, or can be run in automatic mode, using the controller to initiate envelope inflation.

**BRIEF DESCRIPTION OF THE DRAWING**

Figure 1 is a highly diagrammatic, perspective, cutaway view of a conventional building HVAC system shown delivering a harmful agent from a public area return air duct to private areas in the building interior;

Figure 2 is a highly diagrammatic, perspective, cutaway view of the building HVAC system of Figure 1 having local harmful agent detectors, a horizon detector, and duct isolation devices;

Figure 3 is a schematic view of a system for sealing an air duct including a harmful agent detector, a controller, an initiator and an inflatable bladder disposed inside a duct;

Figure 4 is a transverse, cross-sectional view of an un-inflated, oversized bladder disposed within an air duct;

Figure 5 is a transverse, cross-sectional view of the bladder of Figure 4 in an inflated state;

Figure 6 is a transverse, cross-sectional view of an un-inflated bladder having a first portion and a second portion, secured to the duct internal walls;

Figure 7 is a transverse, cross-sectional view of the bladder of Figure 6 in an inflated state;

Figure 8 is a transverse, cross-sectional view of a bladder device installed around all duct inner walls;
Figure 9 is a transverse, cross-sectional view of the bladder device of Figure 8 in an inflated state;

Figure 10 is a transverse, cross-sectional view of a bladder device having a first portion installed around all duct inner walls and a second portion disposed along one duct inner wall;

Figure 11 is a transverse, cross-sectional view of the bladder device of Figure 10 showing both bladder portions in an inflated state;

Figure 12 is a transverse, cross-sectional view of a bladder device installed in a circular air duct;

Figure 13 is a highly diagrammatic, transverse cross-sectional view of a foaming device installed external to an air duct;

Figure 14 is a transverse, cross-sectional view of an internal duct-reinforcing device;

Figure 15 is a transverse, cross-sectional view of an external duct-reinforcing device; and

Figure 16 is a transverse, cross-sectional view of an external duct-reinforcing device using internally disposed cross members.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a building 20 including a public atrium area 23 and having a conventional building heating, ventilating, and air conditioning (HVAC) system 22 not having any duct isolation equipment in place. HVAC system 22 includes an outside air intake 24 and an outside air exhaust 26. Air intake 24 and exhaust 26 are connected to a series of ducts including large, usually rectangular chambers or ducts such as chamber 28, and intermediate sized, usually rectangular, ducts 30. Intermediate ducts 30 split off into a series of smaller, often circular, ducts 32, which feed a series of room diffusers 38. Return air vents 36 and return air ducts 34 return air either to be expelled outside the building or be mixed with fresh air intake. Heating, cooling, humidification, and dehumidification functions are often performed in large chambers such as chamber 28, and in more local intermediate sized chambers 42. Mixing and/or recirculation can be performed by a return air duct 48.

Figure 1 illustrates an internally released harmful agent cloud 46 dispersed in public atrium 23 near return air vents 36. HVAC system 22 is illustrated transporting harmful agent 46 through return air ducts 34, through return air duct 48, into intake
chamber 28, and dispersing it as externally released cloud 44 and internally released harmful agent cloud 47 through diffusers 38. As illustrated, the harmful agent is delivered from a public portion of the building to the private areas of the building by the HVAC system and to the exterior near the building as well.

Referring now to Figure 2, building 20 and HVAC system 22 have been outfitted with harmful agent detectors or chemical-biological detectors (CBDs) and a ductwork isolation system. In the example illustrated, a CBD 60 is disposed in large chamber 28, a CBD 62 is disposed near air exhaust 26, a CBD 64 is disposed in intermediate chamber 40, and a room air CBD 66 is disposed in public atrium 23. A horizon CBD 70 can be disposed external to the building, such as on the roof. Horizon CBD 70 can detect more distant harmful agents using spectroscopic techniques including those incorporating LIDAR and laser technologies. Horizon CBDs can be useful for detecting harmful agents released a distance from the building, such as those delivered by missile. In the embodiment illustrated, the CBDs are in communication with an Isolation Control System (ICS) 72, preferably using wires (omitted to simplify the drawing).

Disposed within the ducts are a series of duct isolation devices such as inflatable bladders. A duct isolation device 50 is disposed within large duct 28, duct isolation devices 52 and 54 are disposed within the intermediate sized ducts, and another duct isolation device 56 is disposed within a small, local circular duct. Another duct isolation device 51 is disposed within return air duct 48. The duct isolation devices are preferably in communication with central Isolation Control System 72 using hard wiring. In some embodiments, radio frequency links are used to link detectors, controllers, and duct isolation devices. In other embodiments, the detector and controller are disposed in close proximity to the duct isolation device.

Referring now to Figure 3, a control system for duct isolation is further illustrated. A duct 80 is shown having a CBD 82 mounted external to the duct and a probe 83 extending into the duct. CBD 82 is linked to a transmitter 84, which is in communication with a receiver 86, which is coupled to the input of a controller 88. The output of controller 88 is coupled to a transmitter 90 which is in communication with a receiver 92 disposed near a duct isolation device 96. Duct isolation device 96 includes an inflator 94 coupled to receiver 92. In use, when CBD 82 detects a harmful agent, the system can be run in automatic mode, using controller 88 to trigger inflator 94 automatically. The system can also be run in manual mode, with controller 88 using an
annunciator to signal a human operator who is required to operate controller 88 to signal inflator 94.

Referring now to Figure 4, a duct 100 having corners 103 is illustrated having an un-inflated duct isolation device 101 including a communication wire 106, an inflator 104, and an inflatable bladder 102. Inflatable bladder 102 is shown disposed on the bottom of duct 100. In some embodiments, duct isolation device 101 can be totally disposed within an air duct, including the CBD for triggering the device. In other embodiments, only an antenna for receiving RF triggering signals extends external to the commonly metallic duct walls. In still other embodiments, a wire such as wire 106 runs to a receiver or controller external to the duct.

Referring now to Figure 5, duct isolation device 101 is illustrated in an inflated state. Duct isolation device 101 has an envelope 108 pressing against the internal duct wall surfaces. In the embodiment illustrated, envelope 108 is oversized relative to duct 100. This results in a plurality of small folds of material pressing against the internal duct walls. Taken over a short longitudinal distance, the small folds can allow air passage between the folds. Taken over a moderate or long distance, the folds terminate and other folds begin, at random, thus precluding air passage any appreciable distance. One reason for using over sized inflatable envelopes is to insure that corners 103 are filled with envelope material. In particular, the use of round envelopes may be undersized with respect to the corners. In some embodiments, the envelope includes external ribs at regular intervals, extending about partially or totally around the envelope’s circumference. The ribs can act to interrupt any airflow through the folds, where the folds are pressing against the flat duct sides away from the corners. In some embodiments, resilient envelope material is used to allow the envelope to expand elastically under pressure into corners 103. In still other embodiments, the envelope surfaces are coated with an extremely sticky material which can secure the envelope outer surface to the duct internal surface immediately after expansion of the envelope against the duct walls.

Referring now to Figure 6, duct 100 is illustrated having a duct isolation device or bladder including a first part 112 installed along one internal wall of duct 100. First part 112 is substantially rectangular in the embodiment illustrated, and extends to two corners of the duct. In some embodiments, the un-inflated bladder is secured to the duct interior wall using mechanical fasteners inserted through the duct walls. In other embodiments, the un-inflated bladder is secured using magnetic material, preferably
covering a large amount of duct internal surface area. By using a pre-installed inflatable
portion extending from one corner to a second corner, two corners can be covered prior
to inflation. Upon inflation, the inflatable device can inflate across the rectangular duct
and seal the opposite two corners as well, along with blocking the intervening duct
interior. In one embodiment, the corner-to-corner inflatable envelope is sized to match
the dimension of the duct wall upon which it will be installed. In another embodiment,
more suitable for quick installation, the corner-to-corner inflatable envelope is sized
larger than the wall upon which it is installed, with the excess material allowed to bulge
out either in the middle of the wall, or to wrap around the corners onto the adjacent
perpendicular walls. In the embodiment illustrated in Figure 6, a second inflatable
device 114 is secured to the internal duct wall opposite first inflatable device 112.
Device 114 illustrates one device for sealing the other two corners of a rectangular duct.
Inflators 104 and wires 106 are illustrated being coupled to devices 112 and 114.

Referring now to Figure 7, inflatable devices 112 and 114 are illustrated in an
inflated state, meeting along a common boundary 116. Figure 7 further illustrates a
method for sealing the difficult to seal corners using two opposed inflatable devices,
which may more easily seal along common boundary 116.

Referring now to Figure 8, another inflatable device 118 is illustrated, installed
so as to cover all interior surfaces of the duct, while presenting only a small profile to
obstruct airflow. Inflatable device 118 can be used in one of two ways. Device 118 can
be fully inflated to totally occlude duct 100. Fully inflated device 118 is illustrated in
Figure 9. The inflatable bladder comes together at the center to totally occlude duct
100. Device 118 can be used in a second way, illustrated by Figures 10 and 11, as a
corner sealing aid used in conjunction with second inflatable device 102 illustrated in
Figure 4. Used in this way, device 118 can be inflated as illustrated in Figure 11, to
present a non-perpendicular corner to be sealed by second device 102. Used in this
way, device 118 need only be partially inflated, as illustrated by Figure 11. Device 102
can be inflated in conjunction with device 118 to totally occlude duct 100. Device 118
can be precisely sized to fit the duct or can be oversized, with ends overlapping within
the duct. In some embodiments, device 118 has one edge cut to length and sealed or
crimped at the point of installation.

Referring now to Figure 12, a circular duct 120 is illustrated having an
expandable device 122 including inflator 104 and wires 106. Figure 12 illustrates a
device suitable for installation in circular ducts, which present no corner-sealing
problem to be dealt with. Device 122 can be used for sealing circular, local ducts feeding a small number of rooms.

Referring now to Figure 13, another device for sealing ducts is illustrated in foaming device 124, including a foam generator 126 and nipple 128 extending into duct 100. Foaming device 124 uses a rapidly-expanding and rapidly-hardening foam to seal duct 100. Rapidly expanding and hardening foams are well known to those skilled in the art. Polyurethane or phenolic foams are believed suitable for the present invention. Foaming device 124 presents another device used to seal duct corners and to seal the center of the duct as well. In a preferred embodiment, air-handling equipment such as fans are turned off prior to triggering foam generator 128. Foam generators can also be used in conjunction with inflatable envelopes, discussed below.

The use of rapidly expandable envelopes, in particular those using variants of automobile air bag technology, may cause some deformation or damage to ducts, especially if not sized properly. To lessen or eliminate this problem, ducts may be reinforced close to where the inflatable devices are deployed. In particular, the duct wall may be reinforced either internally or externally, to maintain the integrity of the duct walls.

Referring now to Figure 14, duct 100 is illustrated having an internal, rectangular duct reinforcement liner 130 installed within duct 100. Liner 130 is preferably formed of metal such as heavy gauge sheet metal and can be sized to fit a particular duct. Liner 130 is preferably at least as long as the expected length of the inflated envelope, nominally at least two feet long. A liner such as liner 130 may require too much time to install for some applications.

Referring now to Figure 15, an external reinforcing frame 132 is illustrated, having frame members 134 joined externally at corners 136. Reinforcing frame 132 can be rapidly installed. Frame members 134 need not be sized exactly to the size of duct 100, as they can be oversized, extending past corners 136. Multiple external frames 132 can be installed over the length of the duct near the location of the duct-sealing device. In some locations however, the duct may not be accessible around all four sides and four corners.

Referring now to Figure 16, an external reinforcing frame 138 is illustrated, having external frame members 140 held to duct 100 by internal cross members 142 extending through duct 100 and held to frame members 140 by nuts 144 threaded onto a threaded portion of cross members 142. Figure 14 illustrates two pairs of external
frame members, which need not be located exactly opposite each other. External reinforcing frame 138 may be suitable where the entire duct cannot be enclosed, but where opposing duct surfaces can be accessed. Other methods and devices for reinforcing ducts are presented in U.S. Patent No. 4,315,361 to Brooks, U.S. Patent No. 4,519,177 to Russell, U.S. Patent No. 5,253,901 to Hunter, and U.S. Patent No. 5,660,212 to Elder, hereby incorporated by reference.

Various methods for expanding inflatable devices are suitable for use with the present invention. One class of inflators includes compressed gas sources such as air cylinders. The compressed gas sources may be relatively bulky and too slow to respond for some applications. Another class of inflators includes chemical compositions that react to generate gas, such as those used in automobile air bags. Such inflators are rapid, relatively compact, and relatively stable when properly handled. Gas generating compositions and devices are well known to those skilled in the art. See, for example, U.S. Patent No. 3,715,131 to Hurley et al., U.S. Patent No. 3,741,585 to Hendrickson et al., U.S. Patent No. 3,904,221 to Shiki et al, and U.S. Patent No. 4,005,876 to Jorgensen et al., hereby incorporated by reference.

While inflators using gas can be rapidly acting, it may sometimes be desirable to seal an inflatable envelope and duct with something even longer lasting. In such cases, the use of expandable, hardening foam may be desirable, as discussed above. In general, the foam may be less rapidly expanding than an inflator such as those used in automobile air bag technology. If the slower speed is acceptable, then foam, itself, may be used as the expansion media. If the slower speed is not acceptable, then a rapidly expanding gas may be used to expand the envelope against the duct walls, followed by an expanding foam material within the envelope. The rapidly expanding gas filled envelope will occlude the duct and the hardening foam will make the occlusion more permanent. Foamed plastics and foaming or foam blowing agents, well known to those skilled in the polymer art, are often used in foam-in-place packing applications. Polyurethane foams and phenolic foams are believed suitable for duct sealing applications.

In use, the duct isolation devices can be installed with varying degrees of speed, coverage, and permanence. Ducts of all sizes can be rapidly protected using the devices previously described. Devices as illustrated in Figure 4, for example, can be set within a duct and a wire or antenna may be extended inside or outside of the duct. The device can be bolted to existing structure within the duct or bolted to newly formed holes.
through the duct wall. The wire or antenna can be extended through a newly drilled hole in the duct wall or through existing conduit commonly found in large ducts. A CBD can be installed where desired in the building. An RF triggering device can be installed where desired. For example, if an important meeting is to be held in a public building, an inflatable device can be disposed in a duct with an antenna extending from the duct. An RF triggering device can be manually or automatically tripped when a harmful agent is detected by any means.

The various duct isolation devices can likewise be rapidly installed in a variety of duct sizes and shapes. Some duct reinforcing structures, in particular those of Figures 15 and 16, can be quickly installed to preserve the integrity of the duct, if the nature of the duct and duct isolation device makes maintaining duct integrity an issue.

Numerous advantages of the invention covered by this document have been set forth in the foregoing description. It will be understood, however, that this disclosure is, in many respects, only illustrative. Changes may be made in details, particularly in matters of shape, size, and arrangement of parts without exceeding the scope of the invention. The invention's scope is, of course, defined in the language in which the appended claims are expressed.
What is claimed is:

1. A system for preventing airborne transmission of agents harmful to human life through an air duct comprising:
   an inflatable gas bladder;
   means for detecting said airborne agents harmful to human life;
   means for initiating inflation of said inflatable bladder; and
   means for inflating said inflatable gas bladder responsive to said means for initiating inflation.

2. A system as recited in claim 1, wherein said air duct has internal walls and said means for inflating said gas bladder includes a chemical composition capable of generating sufficient quantities of gas to inflate said gas bladder against said internal walls.

3. A system as recited in claim 1, wherein said inflatable bladder includes an envelope formed of a substantially non-compliant material and said envelope has an external surface area substantially larger than a corresponding area of said duct internal walls.

4. A system as recited in claim 3, wherein said bladder has an interior further comprising an expandable foaming agent disposed proximate said bladder and in communication with said bladder interior, means for initiating foaming, wherein said foaming agent hardens after expansion, wherein said means for initiating foaming is responsive to said means for initiating inflation.

5. A system as recited in claim 4, wherein said means for detecting said agent includes an optical horizon sensor.

6. A system as recited in claim 4, wherein said means for detecting said agent includes a sensor disposed near said duct for sampling air in said duct.

7. A system as recited in claim 1, wherein said means for initiating inflation includes a human activated switch.
8. A system as recited in claim 1, wherein said inflatable bladder includes means for securing said bladder to said duct internal walls prior to said inflation.

9. A system as recited in claim 8, wherein said inflatable bladder includes a first part for securing to a duct first internal wall and a second part for securing to a duct second internal wall.

10. A system as recited in claim 9, wherein means for securing said bladder includes magnetic material.

11. A method for sealing a building air duct in response to the presence of an airborne agent harmful to human life comprising the steps of:
   providing a duct isolation system including a harmful agent detector, an inflatable bladder adapted to occlude said duct when inflated, an inflator for inflating said inflatable bladder, and an initiator for initiating inflation of said inflator;
   installing said bladder in said building air duct;
   detecting said agent with said detector;
   initiating said inflation of said bladder with said initiator; and
   allowing said bladder to inflate and seal said air duct.

12. A method for sealing a building air duct as recited in claim 11, wherein said duct is in communication with an air mover further comprising turning said air mover off in response to detecting said agent.

13. A method for sealing a building air duct as recited in claim 11, wherein said initiating is performed automatically in response to said detecting.

14. A method for sealing a building air duct as recited in claim 11, wherein said initiating is performed manually in response to said detecting.

15. A method for sealing a building air duct as recited in claim 11, further comprising reinforcing said duct prior to said initiating step.
16. An inflatable bladder for sealing an air duct having internal walls comprising:
an envelope having an interior;
a chemical composition capable of reacting and generating a gas of sufficient
quantity to force said envelope against said duct internal walls, said chemical
composition disposed such that said generated gas is in fluid communication with said
bladder interior after reaction; and
an initiator for initiating said reaction in said chemical composition.

17. An inflatable bladder as recited in claim 16, wherein said initiator is
responsive to an electronic signal.

18. An inflatable bladder as recited in claim 16, including means for
generating foam into said envelope interior, wherein said generated foam expands and
hardens.

19. An inflatable bladder as recited in claim 16, wherein said envelope
includes means for securing said envelope to said duct walls prior to initiation.

20. An inflatable bladder as recited in claim 19, wherein said means for
securing said envelope to said duct walls includes magnetic material.

21. An inflatable bladder as recited in claim 16, wherein said bladder
includes at least two parts, each of said two parts being suitable for securing to a duct
wall.

22. An inflatable bladder as recited in claim 16, wherein said envelope is
formed of a resilient material.