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- (71) **Applicant:** TYCO FIRE PRODUCTS LP [US/US]; 1400
Pennbrook Parkway, Lansdale, PA 19446 (US).
- (72) **Inventors:** AHMADZADEGAN, Arash; 7 North Avenue,
Apt 3, Providence, RI 02906 (US). LOUREIRO, Melissa
Ann Figueiredo; 63 Sweet Avenue, Pawtucket, RI 02861
(US). MULZER, Michael, David; 510 Wells Avenue,
Peshtigo, WI 54157 (US). SANDAHL, Derek, M.; W4595
Pinewood Loop No. 11, Wallace, MI 49893 (US).
- (74) **Agent:** KAKARLA, Bhaskar; Perkins Coie LLP, 700
Thirteenth Street, N.w., Suite 600, Washington, DC 20005
(US).

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(54) **Title:** LOW PRESSURE DROP ACOUSTIC SUPPRESSOR NOZZLE FOR INERT GAS DISCHARGE SYSTEM

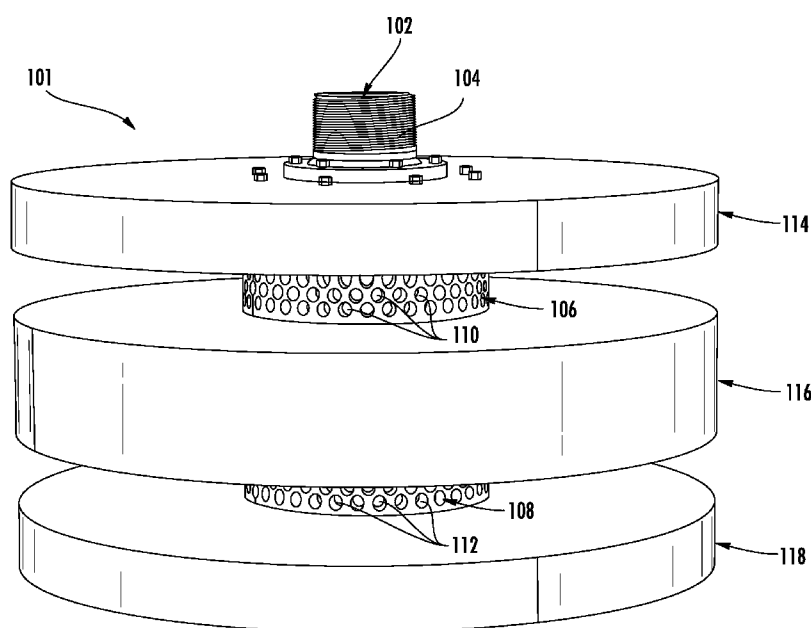


FIG. 2

(57) **Abstract:** A fire suppression system includes an inert gas source to supply inert gas to an enclosure via distribution piping. The system includes a fire suppression nozzle that is installed in the enclosure. The nozzle includes an inlet that connects to the distribution piping and includes a plurality of outlet holes. During discharge of the inert gas, the sound power level from the nozzle is no greater than 125 dB for a frequency range from 500 to 1,000 Hz for a coverage area up to 32 ft. x 32 ft. in compliance with UL 2127. The nozzles disclosed herein are configured such that gas exiting a plurality of outlet holes is balanced.

LOW PRESSURE DROP ACOUSTIC SUPPRESSOR NOZZLE FOR INERT GAS DISCHARGE SYSTEM

Priority Claim, Cross-reference & Incorporation By Reference

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[0001] This international application claims the benefit of U.S. Provisional Application Nos. 62/263,300, filed December 4, 2015 and 62/379,069, filed August 24, 2016, each of which is incorporated by reference in its entirety.

Technical Field

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[0002] This patent application is directed to fire protection systems and devices and, more specifically, to low pressure drop acoustic suppressor nozzles for inert gas discharge systems.

Background Of the Invention

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[0003] Inert gas fire suppression systems are often used to protect equipment that can get damaged by use of traditional suppression systems that use water, foams and powders. For example, inert gas fire suppression systems can be used to protect electronic equipment such as, e.g., personal computers, servers, equipment found in large data storage centers, and network switches to name just a few. A typical fire suppression system includes a high pressure inert gas source that is connected to one or more inert gas discharge nozzles via piping. A given fire suppression nozzle has an effective protection height and a maximum coverage area, i.e., the area in which the nozzle is effective in suppressing a fire. Depending on the area of coverage, one or more of the nozzles are installed in an enclosed space to protect the enclosure. In case of a fire, a detector triggers the system and a control valve is opened to send high pressure inert gas to the nozzles. Depending on the system, the high pressure source can be connected to more than one enclosure, through pipe network ending in multiple nozzles, and the flow to each enclosure is individually controlled via respective control valves.

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[0004] Industry regulations require that the fire suppression systems meet certain standards. For example, “NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems,” 2015 Edition (hereinafter “NFPA 2001”), which is incorporated herein by reference in its entirety as background, provides the requirements for clean agent fire extinguishing systems. Section 5.8 of NFPA 2001 generally states that the nozzle needs to be designed for the intended use and selected based on the limitations concerning size of the enclosure, the floor coverage and alignment. Section 5.4.2 of NFPA 2001 requires that the method for flame extinguishment and the suppression agent concentration conform to ANSI/UL 2127, “Standard for Inert Gas Clean Agent Extinguishing System Units,” Second Edition (hereinafter “UL 2127”), which is incorporated herein by reference in its entirety as background. UL 2127 states that the extinguishing system must suppress the fire within 30 seconds after completion of agent discharge and provides requirements on the construction of the test enclosure and the locations in the enclosure for measuring the agent concentration. According to UL 2127, the test enclosure to be constructed must have the maximum area coverage for the extinguishing system or nozzle and the minimum and maximum protected area height limitations. Thus, each fire suppression nozzle that is compliant with UL 2127 is rated for a maximum area coverage and a minimum/maximum protection height.

[0005] In order for the fire suppression nozzle to provide the coverage area and protection height and reduce the oxygen content in the enclosure in compliance with UL 2127, a large amount of inert gas is discharged into the enclosed area in a short period of time. To accomplish this, typically, the inert gas suppression systems often discharge the inert gas at supersonic velocities. The supersonic velocities create significant turbulence, resulting in a high power broadband spectrum of sound. That is, the high velocity gas flowing from the inert gas discharge nozzles can result in very high levels of sound. However, certain electronic components with sensitive mechanical parts (e.g., hard disc drives) are susceptible to adverse effects from high levels of

sound. The high sound levels can reduce the performance of these components, and in some cases, the components may stop functioning altogether. Although the computer equipment can be shut down to protect the sound sensitive components, in many cases, if the enclosure houses critical computer systems where downtime is unacceptable due to, e.g., economic or safety reasons, the computer equipment is kept operational even while the nozzle discharges the inert gas. Thus, while electronic equipment in an enclosure may be unaffected by the fire itself, the equipment can still experience damage and thus downtime due to the high sound levels from the inert gas discharge.

[0006] Previous attempts in the industry to reduce the high levels of sound associated with the high velocity/high pressure gas discharge have primarily dealt with restricting the flow rate of gas into the enclosed area. For example, previous designs have included blocking the flow inside the nozzle using sound absorbing materials. However, to effectively reduce the sound level of the gas to an acceptable range, e.g., to levels that prevent hard disk failures, the flow rate needs to be significantly reduced, which typically means a high pressure drop in the nozzle. The resulting reduction in the flow rate prevents the gas from being discharged fast enough to quickly reduce the oxygen level and meet current fire suppression standards. Thus, previous attempts to reduce the sound output of the fire suppression nozzles have resulted in a decreased effective coverage for the nozzle. That is, in an attempt to produce a reduced-sound nozzle, the related art nozzles have decreased the maximum coverage area and/or the maximum protection height. Accordingly, a greater number of the related art reduced-sound nozzles may be needed in order to have the same coverage area as existing fire suppression nozzles. In addition, because the coverage area is less, the related art reduced-sound nozzles cannot directly replace, i.e., retrofit, existing fire suppression nozzles that have already been installed in enclosures without substantial modifications to the system, e.g., by running new piping to install additional nozzles.

[0007] Accordingly, there is a need for fire suppression nozzles that can quickly discharge gases and reduce the sound generated during discharge to acceptable levels for electronic equipment. In addition, there is also a need to retrofit existing fire suppression nozzles with reduced-sound nozzles without substantial modifications to the existing systems. Further limitations and disadvantages of conventional approaches to inert gas nozzle configurations will become apparent to one skilled in the art through comparison of such approaches with embodiments of the present invention as set forth in the remainder of the present disclosure with reference to the drawings.

Summary of the Invention

[0008] Embodiments of the present invention are directed to low pressure drop acoustic suppressor nozzles for use in fire protection systems. The disclosed low pressure drop acoustic suppressor nozzles are particularly suitable for use in fire protection systems. For example, preferred embodiments of the low pressure drop acoustic suppressor nozzle are suitable for fire protection systems that protect sound sensitive equipment, such as, e.g., computers. The nozzles are directed to reducing sound associated with gas flow and have a sound power that is preferably no greater than 130 dB, more preferably no greater than 125 dB and even more preferably no greater than 108.6 dB. "Sound power" as used herein means the sound level generated by the nozzle. Typically, when the sound level is provided for fire suppression nozzles, it is sound level that has been measured at a known distance from the nozzle. However, such sound measurement readings can be misleading with respect to the actual sound level generated by the nozzle, because the measured sound level can be affected by the characteristics of the enclosure and for other reasons. For example, measurement of sound at a given one location can be inaccurate due to potential sound absorption impact from the enclosure construction, distance from the nozzle, and/or obstructions between the nozzle and the measurement location, which may not be disclosed or accounted for in the reported sound

measurement reading. Thus, the measured sound level may not accurately describe the actual sound level generated by the nozzle. The calculation of the sound power level of an object is routine for those skilled in the art and thus will not be discussed herein.

[0009] Preferred embodiments of the nozzles discussed herein include nozzles tested in

5 compliance with UL 2127. The sound power values, frequency values, pressure values, coverage values, flow values, and physical dimensions associated with various preferred embodiments are given in nominal values. These nominal values include a range of commercially acceptable values around the nominal. For example, sound power values can range $\pm 5\%$, frequency values can range $\pm 10\%$, pressure values can range $\pm 5\%$, coverage
10 values (e.g., area and height) can range $\pm 5\%$, flow values can range $\pm 10\%$, and the values for physical dimensions can range $\pm 10\%$ around the nominal value.

[0010] Preferred embodiments of the nozzles disclosed herein are configured such that gas exiting a plurality of outlet holes is balanced such that a ratio between a maximum flow value in the plurality of outlet holes and a minimum flow value in the plurality of outlet holes is less than

15 70:30, and more preferably 60:40 and even more preferably substantially equal. Preferably, the nozzle is configured such that the plurality of outlet holes are grouped into two or more sets of outlet holes having balanced flow between the sets, and a ratio between a maximum set flow value and a minimum set flow value in the two or more sets of outlet holes is less than 70:30, and more preferably 60:40 and even more preferably substantially equal. Preferably, the
20 plurality of outlet holes are disposed along a longitudinal axis of a chamber of the nozzle, and the nozzle is configured to provide the balanced flow regardless of the orientation and configuration of the plurality of outlet holes along the longitudinal axis. In some preferred embodiments, the nozzle directs inert gas flow in a passageway in a direction transverse to the inert gas flow in the passageway and then divide the transverse inert gas flow into two or more
25 balanced gas flow portions that each flow between opposed sound absorbing surfaces,

respectively. Preferably, a ratio between the maximum flow value and the minimum flow value in the two or more balanced gas flow portions is less than 70:30, and more preferably, less than 60:40, and even more preferably, the two balanced gas flow portions are substantially equal.

[0011] In an exemplary embodiment, a fire suppression system includes an inert gas source to

5 supply inert gas to an enclosure via distribution piping. The system includes a nozzle that is installed in the enclosure. The nozzle includes an inlet that connects to the distribution piping and includes a plurality of outlet holes. Preferably, during discharge of the inert gas, the sound power level from the nozzle is no greater than 125 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft. Preferably,

10 during the discharge, a pressure drop from the inlet of the nozzle to the plurality of outlet holes is no more than 80 psi higher than the enclosure gage pressure. In some embodiments, the sound power level from the nozzle is no greater than 120 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft. In some embodiments, the coverage area of the acoustic nozzle is at approximately 36 ft. x 36 ft., more preferably approximately 32 ft. x 32 ft. In addition, a maximum protection height of the acoustic nozzle is preferably up to 20 ft. Preferably, the sound power level is no greater than 130 dB for flow rates in a range of approximately 1,000 cubic feet per minute (CFM) to approximately 5,400 CFM, and more preferably at a flow rate of approximately 2,188 CFM. Preferably, the sound power from the nozzle is no greater than 125 dB for a frequency range from 500 to 10,000 Hz at a flow rate of approximately 2,188 CFM, and more preferably, no greater than 108.6 dB for a frequency range from 500 to 10,000 Hz at a flow rate of approximately 2,188 CFM.

[0012] In operation, in preferred embodiments, a flow of inert gas from the storage tanks is sent through an orifice plate that restricts the flow and pressure. In some embodiments, the orifice plate can be mounted remotely from the nozzle. In other embodiments, the orifice plate is
25 mounted at the inlet to the nozzle. The inert gas flow then enters an axially extending

passageway in the nozzle. The flow exits out of the passageway through a plurality of outlets that are disposed through a sidewall of the passageway and into an annular chamber. Preferably, the flow exits out of the plurality of outlets in a balanced manner such that the O₂ content in each corner of the enclosure is reduced at approximately the same rate. Preferably, the flow is
5 diverted through first and second sets of radially facing secondary outlets on an outer sidewall of the annual chamber. The disclosed low pressure drop acoustic suppressor nozzle reduces the sound associated with the gas discharge to acceptable levels within the operating frequency range while providing a low pressure drop that allows rapid inert gas discharge for fire suppression.

10 [0013] Although exemplary embodiments, as discussed below, are directed to a configuration having two flow portions exiting the nozzle through respective sets of outlet holes, nozzle configurations having one set of outlet holes or more than two flow portions can provide sound power that is preferably no greater than 130 dB, more preferably no greater than 125 dB and even more preferably no greater than 108.6 dB so long as the flows exiting the outlet holes are
15 balanced as discussed herein.

Brief Descriptions of the Drawings

[0014] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary embodiments of the invention, and, together with the general description given above and the detailed description given below, serve to explain the features of
20 the invention. It should be understood that the preferred embodiments are some examples of the invention as provided by the appended claims.

[0015] Embodiments of the low pressure drop acoustic suppressor nozzle introduced herein may be better understood by referring to the following Detailed Description in conjunction with the accompanying drawings, in which like reference numerals indicate identical or functionally
25 similar elements:

[0016] FIG. 1 shows a simplified diagram of a fire suppression system using an exemplary embodiment of a low pressure drop acoustic suppressor nozzle assembly.

[0017] FIG. 2 is a perspective view of the low pressure drop acoustic suppressor nozzle of FIG. 1.

5 [0018] FIG. 3 is an isometric view in cross-section of the nozzle shown in FIG. 2.

[0019] FIG. 4 is an isometric view in cross-section of the nozzle shown in FIGS. 2 and 3 illustrating fluid flow through the nozzle.

[0020] FIG. 5 is an isometric view in cross-section of another exemplary embodiment of a low pressure drop acoustic suppressor nozzle.

10 [0021] FIG. 6 is an isometric view in cross-section of another exemplary embodiment of a low pressure drop acoustic suppressor nozzle assembly.

[0022] FIG. 7 shows a chart illustrating failure and 50% degradation graphs for hard drives in terms of sound power level vs. frequency for various exemplary low pressure drop acoustic suppressor nozzles.

15 ***Detailed Description***

[0023] Exemplary embodiments of the present disclosure are directed to inert gas nozzles that suppress the sound from the nozzles to acceptable levels without the high pressure drop in the nozzle as found in prior art and related art systems. In the exemplary embodiments, the sound is reduced to acceptable levels by using only a minimal amount of sound dampening material in
20 the flow path of the nozzle and by strategically disposing the nozzle relative to a pressure reducing device disposed upstream of the nozzle. For example, in some exemplary embodiments, the sound power level from the nozzle is no greater than 125 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft. In some exemplary embodiments, the pressure reducing device is mounted

remotely from the main nozzle. In other embodiment, the pressure reducing device is mounted at the inlet of the nozzle.

[0024] Generally, when the fire suppression system is activated, the inert gas pressure in the piping upstream of the pressure reducing device, such as, e.g., an orifice, can be as high as 2,000
5 psi. Depending on the configuration of the enclosure being protected, the pressure reducing device reduces the pressure to achieve the required inert gas flow for the enclosure. Of course, the nozzle also introduces a pressure drop that must be accounted for. If the pressure drop in the nozzle is too high, the inert gas flow will be unable to meet design criteria for displacing the oxygen in the enclosure. In exemplary embodiments of the disclosure, the disclosed low
10 pressure drop nozzle has a pressure drop that is no more than 80 psi higher than the enclosure gage pressure. It is believed that there is no related art fire suppression nozzle that has such a low pressure drop (preferably no more than 80 psi higher than the enclosure gage pressure), low sound generation (preferably less than 125 dB and more preferably less than 108.6 dB) and high inert gas coverage area distribution (preferably up to 36 ft. x 36 ft., and more preferably up to 32
15 ft. x 32 ft.).

[0025] As shown in FIG. 1, a nozzle assembly 100 includes a low pressure drop acoustic suppressor nozzle 101 and a pressure reducing device. The pressure reduction device can be, e.g., orifice plate 120. The nozzle assembly 100 is mounted in an enclosure 50 to protect data storage equipment 52. The nozzle assembly 100 is connected to an inert gas fire suppression
20 system via piping 54. The configuration and operation of the fire suppression system is known in the art and thus, for brevity, will not be discussed further. The orifice plate 120 receives high pressure gas from a fire suppression system (not shown) and the downstream pressure in the piping connected to the nozzle 101 is reduced via the orifice opening 122. When mounted
remotely from the nozzle 101, the orifice plate 120 is preferably mounted in-line with the piping
25 54 using appropriate fitting and hardware. For example, the orifice plate 120 can be disposed in

the piping, e.g., welding, soldering, or attached to the piping using fittings or other appropriate means. The orifice opening 122 is sized based on the diameter of the piping 54 and the required flow in the system based on the application. Preferably, the orifice opening 122 is 5% to 70% of the diameter of the piping 54. As seen in FIG. 1, the orifice plate 120 is disposed a distance X from the inlet 102 from the main nozzle 101. The distance X is the length of the piping from the inlet 102 and the orifice 120, i.e., distance X is the distance the gas travels in the piping. In preferred embodiments of the present disclosure, the orifice plate 120 is disposed remotely from the nozzle 101. However, in other embodiments, the orifice plate 120 can be mounted directly at the inlet 102. In some embodiments, the distance X can be up to 6 feet depending on whether the configuration of fire system in the enclosure 50. Preferably, the distance X is in a range from 30 to 50 inches and more preferably between 35 to 45 inches. In some embodiments, the distance X is 41 inches. In some exemplary embodiments, the distance X is in a range of 0 to 12 inches from the inlet 102 and more preferably 3 to 9 inches. In some embodiments, the distance X is 6 inches. Preferably, the orifice plate 120 is mounted such that there are no bends in the piping 54 from the orifice plate 120 to the inlet 102, e.g., the orifice plate can be mounted in the vertical section of piping above the nozzle 101.

[0026] As seen in FIG. 2, nozzle 101 includes a fitting 104 configured to attach to the piping from the orifice plate 120. For example, fitting 104 can include male pipe threads that screw into a female coupling on the piping 54. When attaching to piping 54, appropriate adapters can be used to transition from the piping 54 and the fitting 104. Nozzle 101 includes a first set of secondary outlets 106 that includes a plurality of radially facing apertures 110. The first set of secondary outlets 106 is positioned between an inner annular disc 116 and a first outer annular disc 114. Nozzle 101 also includes a second set of secondary outlets 108 that includes a plurality of radially facing apertures 112. The second set of secondary outlets 108 is positioned between the inner annular disc 116 and a second outer annular disc 118. Broadly, the gas

received through inlet 102 is divided internally, as described more fully below, and exits through the first and second sets of secondary outlets 106 and 108 between sound absorbing annular discs 114, 116, and 118.

[0027] With reference to FIG. 3, nozzle 101 includes a longitudinally extending inner tube 126 having an inlet 102 and defining an axially extending passageway 128. Preferably, when the orifice plate 120 is mounted at the nozzle 101, it is mounted at the inlet 102 of the passageway 128 (see orifice plate 120 with dotted outline). Preferably the inner tube 126 is a cylindrical tube or pipe, but tube 126 can have other shapes. Preferably, diameter d_2 (see FIG. 4) of the inlet 102 is in a range of 1.25 to 1.75 inches, and more preferably 1.5 inches. The thickness of the inner tube 126 is in a range of 0.1 to 0.3 inches and most preferably 0.2 inches. The inner tube 126 is sized and configured to contain the supersonic gas flow moving through the orifice 122 and into passageway 128. Preferably, the inner tube 126 is composed of a metal such as aluminum, bronze, stainless steel or some other metal or material appropriate for the rated temperature of the application.

[0028] Inner tube 126 includes a set of primary outlets 130 that includes a plurality of radially facing primary apertures 132. In other words, the radially facing primary apertures 132 extend transversely through the sidewall of the inner tube 126. In general, smaller diameter and larger number of apertures provide better sound dissipating characteristics. Preferably, the apertures 132 of the primary outlets 130 are arranged in six rows with thirty apertures 132 in each row.

Each of the apertures 132 in the respective row can be on a same plane perpendicular to a longitudinal axis of the inner tube 126. The rows can be parallel to each other. Preferably, each row is offset from its adjacent row. In some embodiments, the offset is 6 degrees. However, in some embodiments, there is no offset. i.e., the apertures 132 are in-line as shown in FIG. 3.

Preferably, each aperture 132 is in a range of approximately 1/16 inch to 1/4 inch in diameter and more preferably 1/8 inch in diameter. In some embodiments, all the apertures 132 are the

same diameter. In some embodiments, the apertures 132 can have different diameters.

However, the diameter, number, offset and arrangement of the apertures 132 of the primary outlets 130 are not limiting and the inventive nozzle 100 can include a set of primary outlets 130 having other diameter, number, offset and arrangement configurations. For example, FIG. 5

5 shows a primary outlets 130 configuration where five rows of apertures 132 are used instead of six. In other embodiments, the apertures 132 are not arranged in parallel rows can be arranged using other patterns or even randomly arranged. In some embodiments, the set of primary outlets 130 have a combined flow area that is greater than a flow area of the orifice 122. The combined flow area of the primary outlets 130 is determined based on the quantity of gas flow
10 needed for a particular application. Preferably, the set of primary outlets 130 have a combined flow area in a range of approximately 7 to 11 in², and more preferably approximately 8.84 in².

[0029] A plug 138 encloses the inner tube 126 to create an inner chamber corresponding to passageway 128. In some embodiments, the plug 138 can be secured in the inner tube with suitable threads, by welding, or with a press fit, for example. In some embodiments, the inner

15 tube 126 is manufactured such that the end of the passageway 128 is already sealed and a plug 138 is not needed. For example, the tube 126 can be formed by starting with a cylindrical blank and drilling the passageway 128 to the correct depth, such that plug 138 is not needed.

The inner tube 126 includes a flange 124 that is attached to the first outer annular disc 114 an appropriate attachment means such as, snap rings, retaining rings or some other fastening means.

20 For example, as seen in FIG. 3, the flange 124 is attached to a support plate 154 of the first outer annular disc 114 by a plurality of fasteners 152.

[0030] In some embodiments, a sound absorbing body 136 (see FIG. 5) is disposed in the passageway 128 that reduces the interaction between the inert gas and the nozzle 101 and reduces the sound caused by vibration of the nozzle 101. In addition, where the sound absorbing

25 body 136 is used, the set of primary outlets 130 can be located above the sound absorbing body

136 to help balance the amount of gas flowing through the primary apertures 132 and create a uniform velocity of the inert gas. The sound absorbing body 136 can be comprised of any suitable sound absorbing material such as, e.g., high temperature, high-density rigid fiberglass insulation. An example of suitable fiberglass insulation is available from McMaster-Carr and
5 identified as part no. 9351K1. Of course, other sound absorbing materials, such as mineral wool or some other appropriate sound absorbing material can be used. However, in other embodiments, as shown in FIGs. 3 and 4, the sound absorbing body 136 is not needed.

[0031] Inner tube 126 is surrounded by an outer tube 134 defining an annular chamber 135 that surrounds the primary outlets 132. Preferably the outer tube 134 is a cylindrical tube or pipe, but
10 outer tube 134 can have other shapes. The outer tube 134 includes first and second sets of secondary outlets 106 and 108, respectively. Preferably, the inner diameter d_3 (see FIG. 4) of the outer tube 134 is in a range of 3.0 to 5.0 inches and more preferably 3.81 inches. Preferably the thickness of the inner tube 134 is in a range of 0.05 to 0.4 inches and more preferably 0.345 inches. The outer tube 134 can be composed of a metal such as aluminum, bronze, stainless
15 steel or some other metal or material appropriate for the rated temperature of the application.

[0032] In some embodiments, the apertures 110, 112 of the secondary outlets 106, 108, respectively, are arranged in four rows with thirty-six apertures 110, 112 in each row, respectively. Each of the apertures 110, 112 in the respective row can be on a same plane perpendicular to a longitudinal axis of the outer tube 134. The rows can be parallel to each
20 other. Preferably, each row is offset from its adjacent row. In some embodiments, the offset is 5 degrees. However, in other embodiments, the respective apertures 110, 112 are in-line with each other. Preferably, each aperture 110, 112 is in a range of approximately 1/8 inch to 1/2 inch in diameter and more preferably 1/4 inch in diameter. In some embodiments, all the apertures 110, 112 are the same diameter, respectively with each set of outlets 106, 108 or even between outlet
25 sets 106, 108. In some embodiments, the apertures 110, 112 can have different diameters,

respectively with each set of outlets 106, 108 and/or between outlet sets 106, 108. However, the diameter, number and arrangement of the apertures 110, 112 of the secondary outlets 106, 108, respectively, are not limiting and the inventive nozzle 100 can include a set of secondary outlets 106, 108 having other diameter, number, offset and arrangement configurations. For example, in
5 other embodiments, the apertures 110, 112 are not arranged in parallel rows and the apertures 110, 112 can be arranged using other patterns or even randomly arranged. In addition, in some embodiments, geometries other than holes can be used such as slots so long as the combined flow area of the secondary outlets 106, 108 is appropriate for the application.

[0033] In some embodiments, the first and second sets of secondary outlets 106 and 108 have a
10 combined flow area that is greater than the combined flow area of the primary outlet 130.

Preferably, the first and second sets of secondary outlets 106, 108 have a combined flow area in a range of approximately 45 to 68 in², and more preferably approximately 56.55 in². In some embodiments, the primary outlets 130 are disposed on the sidewall of the inner tube 126 such that the flow exits between the secondary outlets 106, 108. Preferably, the flow exits equidistant
15 between the secondary outlets 106, 108. In some embodiments, the flow path from the primary outlets 130 is split into two paths each directed to the respective secondary outlets 106, 108. In some embodiments, more than two secondary outlets are provided and the flow from the primary outlet is split into more than two paths.

[0034] Preferably, a sound absorbing device is disposed in the annular chamber 135. In some
20 embodiments, as shown in FIG. 3, the sound absorbing device includes baffle 140 and sound absorbing inserts 146 and 148 positioned at the upper and lower ends of the chamber 135. The baffle 140 is disposed inside the annular chamber 135 in the flow path of the inert gas.

Preferably, the baffle 140 is cylindrical in shape and an outer surface of the baffle 140 is disposed between the sidewall of the inner tube 126 and the sidewall of outer tube 134. In some
25 embodiments, the baffle 140 is disposed against the sidewall of the outer tube 134. Of course,

the shape of the baffle is not limiting and other shapes can be used so long as the flow is not adversely restricted. The baffle 140 surrounds the radially facing primary outlets 132 and covers the inlets of the first and second sets of secondary outlets 106 and 108. Preferably, the thickness of the baffle 140 is in a range of 1/8 inch to 1/2 inch and, more preferably 1/4 inch. Preferably, 5 baffle 140 is disposed on support plate 162 and the length of baffle 140 extends from support plate 162 to support plate 154. The baffle 140 is made of porous material that absorbs sound. Preferably, the baffle 140 is made of porous stainless steel wool sandwiched between wire mesh. The stainless steel wool can be, e.g., medium grade 1 or 0, fine grade 00, 000 or 0000. The wire mesh is used to hold the steel wool and can have, e.g., a mesh size of 40 x 200. Of course, 10 grades of steel wool and wire mesh sizes can be used as appropriate. In addition, other materials can be used for the baffle 140 such as, e.g., cloth screens, stainless steel wool between inner and outer wire cloth, perforated metals, metal foam having various geometries and pores per inch (PPI) densities, wire overlays, Scotch Brite and other screen mesh materials to name just a few. The porous material of baffle 140 helps in reducing the sound but unlike prior art nozzles, the 15 baffle 140 does not cause a significant pressure drop and thus does not adversely affect the quick discharge of the inert gas needed to rapidly drop the oxygen level for fire suppression. This is because the restricting geometry for controlling the flow is still the orifice plate 120 disposed upstream of the nozzle inlet 102. As discussed above, the sound absorbing device can also include inserts 146 and 148. Preferably, the sound absorbing inserts 146 and 148 are disposed at 20 a top end and a bottom end of the annular chamber 135, respectively. The sound absorbing inserts 146 and 148 help reduce the interaction between the gas flow and the nozzle 101. Preferably, the sound absorbing insert 148 is a disc with a diameter that extends to the sidewall of the baffle 140. The insert 148, along with insert 146, provides lateral support for the baffle 140. As seen in FIG. 3, the insert 148 acts as a base for the inner tube 126 and plug 138. 25 Preferably, the sound absorbing insert 146 is a donut shaped disc with an inner diameter that

circumscribes the inner tube 126. The outer diameter of the insert 146 extend to the sidewall of baffle 140 and provides lateral support to baffle 140. In some embodiments, the diameter of the sound absorbing insert 148 extends to the sidewall of the outer tube 134 (e.g., see insert 148' in FIG. 6 for comparison). In addition, the outer diameter of the insert 146 extends to the sidewall of the outer tube 134 (e.g., see insert 146' in FIG. 6 for comparison). In this case, the baffle 14 will be disposed between, e.g., sandwiched between the inserts 146 and 148. That is, the baffle 140 will be disposed on the insert 148 rather than the support plate 162 as discussed above and the top of baffle 140 will extend to insert 146 rather than to the support plate 154 as discussed above. Although described as a disc and donut shaped disc, the shape of the inserted will depend on the shape of the inner and outer tubes 126, 134. The sound absorbing inserts 146, 148 can be comprised of any suitable sound absorbing material such as, e.g., high temperature, high-density rigid fiberglass insulation.

[0035] As seen in FIG. 4, inner annular ring 116 is comprised of sound absorbing insert 172.

The annular ring 116 is secure to the outer tube 134 using known fastening means such as, e.g., clips or spiral retaining rings. The sound absorbing insert 172 further reduces the sound level of the inert gas as it flows from the first and second set of secondary outlets 106 and 108 and into the enclosure. Preferably, the thickness of sound absorbing insert 172 is in a range of 0.50 inch to 2.0 inch and more preferably, 1 inch. The sound absorbing insert 172 can be any appropriate sound absorbing material such as, e.g., fiberglass and mineral wool to name just a few.

[0036] The second outer annular ring 118 is comprised of a support plate 162 and a sound absorbing insert 164. The support plate 162 can be made of any appropriate material based on the temperature requirement of the application such as, e.g., metal, including aluminum, bronze and stainless steel, plastic, fiberglass and ceramic or composites thereof to name just a few. The sound absorbing insert 164 further reduces the sound level of the inert gas as it flows from the second set of secondary outlets 108 and into the enclosure. Preferably, the thickness of sound

absorbing insert 164 is in a range of 0.25 inch to 1.00 inch and more preferably, 0.50 inch. The sound absorbing insert 164 can be any appropriate sound absorbing material such as, e.g., fiberglass and mineral wool to name just a few. The second outer annular disc 118 is attached to one end of the outer tube 134 with, e.g., a plurality of fasteners 168 or by some other means.

5 First outer annular disc 114 includes a support plate 154 and a sound absorbing insert 156. The support plate 154 can be made of any appropriate material based on the temperature requirement of the application such as, e.g., metal, including aluminum, bronze and stainless steel, plastic, fiberglass and ceramic or composites thereof to name just a few. The sound absorbing insert 156 further reduces the sound level of the inert gas as it flows from the first set of secondary outlets
10 106 and into the enclosure. Preferably, the thickness of sound absorbing insert 156 is in a range of 0.25 inch to 1.0 inch and more preferably, 0.5 inch. The sound absorbing insert 156 can be any appropriate sound absorbing material such as, e.g., fiberglass and mineral wool to name just a few. The first outer annular disc 114 is attached to another end portion of the outer tube 134 with, e.g., a plurality of fasteners 160 or by some other means.

15 **[0037]** In another exemplary embodiment, as seen in FIG. 5, the inner annular disc 116' includes a support plate 170 that attaches to a flange 178. Flange 178 is secured to the outer tube 134, e.g., by welding or by some other means that secures the flange 178 to outer tube 134. Support plate 170 can be made of any appropriate material based on the temperature requirement of the application such as, e.g., metal, including aluminum, bronze and stainless steel, plastic,
20 fiberglass and ceramic or composites thereof to name just a few. Support plate 170 is attached to flange 178 with a plurality of fasteners 180. Inner annular disc 116' also includes a hoop 176 attached to the support plate 170. A pair of sound absorbing inserts 172' and 174' are placed against the support plate 170. The sound absorbing inserts 172' and 174' further reduce the sound level of the inert gas as it flows from the first and second set of secondary outlets 106 and
25 108 and into the enclosure. Inserts 172' and 174' may be tightly fit within the hoop 176 and/or

retained within the hoop by a suitable adhesive. Clearance is provided for fasteners 180 and flange 178 by clearance cavities 182 and 184 formed in the inserts 172' and 174', respectively.

Preferably, the thickness of each of sound absorbing inserts 172', 174' is in a range of 0.25 inch to 1.0 inch and more preferably, 0.5 inch. The sound absorbing inserts 172', 174' can be any

5 appropriate sound absorbing material such as, e.g., fiberglass and mineral wool to name just a few. The second outer annular ring 118' is comprised of a support plate 162, a hoop 166, and a sound absorbing insert 164. Insert 162 may be tightly fit within the hoop 166 and/or retained within the hoop by a suitable adhesive. The remaining structure of annular ring 118' is similar to annular ring 118 discussed above and thus, for brevity, will be omitted. First outer annular

10 disc 114' includes a support plate 154, a surrounding hoop 158 and a sound absorbing insert 156. Insert 156 may be tightly fit within the hoop 158 and/or retained within the hoop by a suitable adhesive. The remaining structure of annular ring 114' is similar to annular ring 114 discussed above and thus, for brevity, will be omitted.

[0038] When the fire suppression system is operated, as seen in, e.g., the exemplary embodiment

15 of FIG. 4, a high velocity fluid flow F passes through orifice 122 and is received into passageway 128. The fluid flow F is then redirected in a direction transverse to the longitudinal passage 128 by plug 138 (and/or the sound absorbing body 136 in some embodiments) such that the fluid flow F passes through the radially facing primary outlets 132. As fluid flow F flows through the primary outlets 132, it is divided in chamber 135 into first and second fluid flow

20 portions F1 and F2, respectively. In some embodiments, first fluid flow portion F1 and second fluid flow portion F2 are balanced. Preferably, the fluid flow portions F1 and F2 are balanced regardless of the orientation and configuration of the outlets along the longitudinal axis of the chamber 135. Preferably, a ratio between the maximum flow value and the minimum flow value between the two balanced fluid flow portions F1 and F2 is less than 70:30, and more preferably,

25 less than 60:40, and even more preferably, the two balanced gas flow portions F1 and F2 are

substantially equal. In some embodiments, the fluid flows F1 and F2 are balanced by the location of the first and second set of secondary outlets 106 and 108 with respect to the primary outlets 132. In embodiments that use inner ring 200 (see FIG. 6), the inner ring 200 can be adjusted up or down to adjust the flow. In still other embodiments, the balancing is affected by adjusting the size of the fluid flow area for each of the secondary outlets 106, 108. Turning to the embodiment of FIG. 4, before flowing through the first and second secondary outlets 106, 108, however, the first and second fluid flow portions F1 and F2 pass through the sound absorbing baffle 140. The sound absorbing baffle 140 reduces the sound in the fluid flow portions F1 and F2, but unlike prior art nozzles, the baffle 140 does not significantly reduce the flow of fluid flow portions F1 and F2. Preferably, a pressure from the inlet 102 of the nozzle (after the orifice plate 120) is no more than 80 psi higher than the gage pressure of enclosure 50. After flowing through the baffle 140, the fluid flow portions F1 and F2 flow through the first and second secondary outlets 106, 108, respectively. As it exits the first secondary outlets 106, the first fluid flow portion F1 is directed between sound absorbing surfaces 190 and 192 of inserts 156 and 172, respectively, which further reduce the sound. Similarly, as it exits the second secondary outlets 108, the second fluid flow portion F2 is directed between sound absorbing surfaces 194 and 196 of inserts 172 and 164, respectively, which further reduce the sound.

[0039] As shown in FIG. 4, nozzle 101 has an overall height H and an overall diameter d_4 . The inlet passageway 128 has an inlet 102 with a diameter d_2 and the outer tube 134 has an inner diameter d_3 . Annular discs 114, 118 have a sound absorbing insert thickness T and annular disc 116 has a sound absorbing insert thickness of 2T and each sound absorbing surface 192 - 196 is spaced apart by a distance Z. In some embodiments, both the thickness T and spacing Z are in a range of approximately 0.25 inch to 1.0 inch, and preferably 0.50 inch. In at least one embodiment, the height H is in a range of approximately 4 inches to 9 inches, and preferably 5.5 inches. The diameter d_4 is in a range of approximately 6 inches to 13 inches and preferably 5.5

inches. The inner tube diameter d_2 is in a range of approximately 1.25 inches to 1.75 inches and preferably 1.5 inches. The outer tube diameter d_3 is in a range of approximately 3 inches to 4 inches and preferably 3.81 inches. In some embodiments, the following ratios can apply to the dimensions of the nozzle: d_4/d_1 , relates the diameter of the nozzle to the inert gas flow is greater than 15 and preferably in a range of approximately 15 to 30; d_3/d_2 , which ensures the chamber 135 is sufficiently large enough for the inert gas flow is in a range of approximately 2 to 3; and d_4/T , which ensures a sufficient sound absorbing capacity at the outlet of the nozzle is less than 20.

[0040] Although the low pressure drop acoustic suppressor nozzle 100 is shown and described in the above exemplary embodiments as having cylindrical components, other suitable shapes can be used to construct the nozzle components. In addition, although the above exemplary embodiments were described with a sound absorbing device having a porous baffle 140, some embodiments of the sound absorbing device do not use a porous baffle. For example, in some embodiments, the sound absorbing device in the annular chamber 135 can include a non-porous material can be used to divert the flow of gas from primary outlets 130 to secondary outlets 106, 108. For example, FIG. 6 illustrates an embodiment in which the sound absorbing device includes a non-porous sound absorbing ring (or rings). Because many of the structures and features of the nozzle of FIG. 6 is similar to the structures and features discussed above with respect to FIGS. 2-5, for brevity, a detailed description of the common features discussed above is omitted. As shown in FIG. 6, a sound absorbing body 136 is disposed in the passageway 128 to reduce the interaction between the entering gas and the nozzle and to reduce the sound caused by the vibration of the nozzle. The set of primary outlets 130 can be located above the sound absorbing body 136 to help balance the amount of gas flowing through the primary apertures 132 and reduce the velocity of the gas flow. When the gas exits the passageway 128 through primary outlets 130, a pair of sound absorbing rings 200 are positioned inside the annular

chamber 135 between the first and second sets of secondary outlets 106 and 108. Accordingly, the sound absorbing rings 200 surround the radially facing primary outlets 132. The sound absorbing rings 200 reduce the interaction between the gas flow and the outer tube 134. In some embodiments, the sound absorbing rings 200 can be adjusted in size and position to help balance the gas flow through the first and second sets of secondary outlets 106 and 108. The fluid flows may be balanced by moving the rings 200 up and down with respect to the primary outlets 132. In some embodiments, the fluid flows are balanced by the location of the first and second set of secondary outlets 106 and 108 with respect to the primary outlets 132. In still other embodiments, the balancing is affected by the size of the secondary outlets. Preferably, the nozzle provides the balanced flow regardless of the orientation and configuration of the secondary outlets 106 and 108 along the longitudinal axis of the chamber 135. Preferably, a ratio between the maximum flow value and the minimum flow value between the two balanced fluid flow portions is less than 70:30, and more preferably, less than 60:40, and even more preferably, the two balanced gas flow portions are substantially equal. The sound absorbing rings 200 can be retained in the outer tube 134 with washers 202 and snap rings 204, for example. Although the rings 200 are described as two separate rings, in some embodiments the pair of sound absorbing rings can be combined into a single unitary body. Annular chamber 135 includes sound absorbing inserts 146' and 148' positioned at the ends of the chamber to help reduce the interaction between the gas flow and the nozzle. The configurations of the inserts 146' and 148' in the chamber 135 can be similar to the configuration of inserts 146 and 148 and thus for brevity will not be discussed further. The sound absorbing body 136 and rings 200 can be comprised of any suitable sound absorbing material such as, e.g., fiberglass or mineral wool to name just a few. In some embodiments, depending on the application, the inventive nozzle does not include the baffle 140, the sound absorbing body 136 or the sound absorbing rings 200. Although described separately in the above exemplary embodiments, some embodiments can

include both the baffle 140 and ring 200. In addition, some embodiments do not include either the baffle 140 or the ring 200.

[0041] The exemplary embodiments discussed above are directed to a configuration having two flow portions exiting the nozzle through respective sets of outlet holes. However, exemplary
5 embodiments of the nozzle are not limited to this configuration. In some embodiments, the nozzle can be configured with more than two sets of secondary outlet holes similar to outlets 106 and 108. In still other embodiments, the chamber 135 has one set of secondary outlet holes which are disposed along a longitudinal axis of chamber 135. Preferably, the exemplary nozzles are configured to provide balanced flow regardless of the orientation and configuration of the
10 plurality of outlet holes along the longitudinal axis. For example, the nozzles are configured such that gas exiting a plurality of outlet holes is balanced such that a ratio between a maximum flow value in the plurality of outlet holes and a minimum flow value in the plurality of outlet holes is less than 70:30, and more preferably 60:40 and even more preferably substantially equal.

[0042] In the above exemplary embodiments, the sound power of nozzle 101 is no greater than
15 130 dB for a frequency range from 500 to 10,000 Hz for inert gas flow rates in a range of approximately 1,000 CFM to approximately 5,400 CFM while conforming to the standards in UL 2127. In some exemplary embodiments, the peak value of the sound power level of nozzle 101 is no greater than 130 dB, preferably no greater than 120 dB, and more preferably no greater than 111 dB, for a frequency range from 500 to 10,000 Hz for inert gas flow rates in a range of
20 approximately 950 CFM to approximately 5,400 CFM while conforming to the standards in UL 2127. In some exemplary embodiments, the peak sound power level of nozzle 101 is in a range between 111 dB to 130 dB, for a frequency range from 500 to 10,000 Hz for inert gas flow rates in a range of approximately 950 CFM to approximately 5,400 CFM while conforming to the standards in UL 2127. For example, FIG. 7 shows a chart illustrating sound power level in dB
25 vs. frequency in Hz for various embodiments with and without baffle 140 and with and without

an offset for the orifice plate 120. For the embodiments shown in FIG. 7, INERGEN gas at a flow rate of 2,188 CFM and an orifice of 0.368 was used. The line A represents a graph of a sound level vs. frequency at which failure of a hard drive is believed to occur. Line B represents a graph of the sound level vs. frequency at which a 50% degradation of the performance of the hard drive is believed to occur. As seen in FIG. 7, exemplary embodiments of the present disclosure reduce the sound power levels such that they are at 130 dB or below, i.e., below the level at which failure of the HDD is believed to occur, for frequencies from 500 to 10,000 Hz. For example, Line C represents a nozzle which does not include either a remotely disposed orifice plate or a baffle with sound absorbing material. The sound power level for this embodiment never reaches the believed failure point of Line A. Some exemplary embodiments provide even better results with sound power levels they are below 125 dB. For example, Line D represents a nozzle in which an orifice plate is disposed 41 inches upstream from the inlet to the nozzle but does not have a baffle with sound absorbing material. The sound power level for Line D is generally better than Line C, especially from 500 to approximately 5,000 Hz, and Line D has a peak value at 1000 Hz that is less than 125 dB. The sound power level of the exemplary embodiment represented by Line D is also at or below the 50% degradation Line B for frequencies in a range of approximately 500 to 800Hz and approximately 2000 to 10,000 Hz. Line E represents a nozzle that includes a baffle with sound absorbing material but the orifice plate is not remotely disposed. The sound power level for Line E is better than Line D for frequencies ranging from approximately 800 to 10,000 Hz, and the peak value of Line E at 500 Hz is also below 125 dB. In addition, the sound level for Line E is below the 50% degradation Line B from approximately 1,600 to 10,000 Hz and significantly below Line B from approximately 2,000 to 10,000 Hz. Further exemplary embodiments provide even sound power levels that are at 108.6 dB or below. For example, Line F embodies a nozzle that is disposed 41 inches upstream from the inlet to the nozzle and includes a baffle with sound absorbing material

in the nozzle. As seen in FIG. 7, except for a short peak of approximately 108.6 dB at approximately 1,000 Hz where Line F just touches the 50% degradation Line B, Line F is significantly below the 50% degradation Line B for all other frequencies.

[0043] As discussed above, hard disk drives are susceptible to sound, and a high sound level can lead to degradation or, in some cases, failure. The exemplary embodiments disclosed above reduce or minimize the probability of degradation or failure of the hard disk drives while conforming to the standards in UL 2127. For example, in some embodiments, the sound power from the acoustic nozzle 101 is no greater than 125 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft., and more preferably, no greater than 120 dB. It is believed that there is no related art fire suppression nozzle meeting the UL 2127 standard generates a sound power level that is at 125 dB or less at any coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft. In some exemplary embodiments, the acoustic nozzle 101 is no greater than 130 dB, and more preferably, no greater than 108.6 dB, for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft., and more preferably up to 32 ft. x 32 ft.. In the above exemplary embodiments, the maximum protection height of the acoustic nozzle 101 is up to 20 ft.

[0043] While the present invention has been disclosed with reference to certain embodiments, numerous modifications, alterations, and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present invention not be limited to the described embodiments, but that it has the full scope defined by the language of the following claims, and equivalents thereof.

What Is Claimed Is:

1. A fire suppression system, comprising:
an enclosure;
5 an inert gas source for supplying inert gas to the enclosure via distribution piping;
a nozzle disposed in the enclosure, the nozzle having an inlet connected to the
distribution piping and having a plurality of outlet holes,
wherein, during a discharge of the inert gas, a sound power level from the nozzle is no
greater than 125 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft.
10 x 36 ft. in compliance with UL 2127, Second Edition.
2. The system of claim 1, wherein the nozzle is configured such that gas exiting the
plurality of outlet holes is balanced.
3. The system of claim 2, wherein the nozzle is configured such that the plurality of holes
are grouped into two or more sets of outlet holes having balanced flow between the sets, and
15 wherein a ratio between a maximum set flow value and a minimum set flow value in the
two or more sets of outlet holes is less than 60:40.
4. The system of any one of claims 1 to 3, wherein the sound power level from the nozzle is
no greater than 108.6 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to
36 ft. x 36 ft. in compliance with UL 2127, Second Edition.
- 20 5. The system of any one of claims 1 to 3, wherein the sound power level from the nozzle is
no greater than 120 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36
ft. x 36 ft. in compliance with UL 2127, Second Edition.
6. The system of any one of claims 1 to 5, wherein a protection height of the nozzle is up to
20 ft. in compliance with UL 2127, Second Edition.
- 25 7. The system of any one of claims 1 to 6, wherein, during the discharge, a pressure drop

from the inlet of the nozzle to the plurality of outlet holes is no more than 80 psi higher than a gage pressure of the enclosure.

8. The system of any one of claims 1 to 7, wherein the nozzle comprises,

a first tube having an inner surface and an outer surface, the inner surface of the first tube defining an axially extending passageway, the passageway including an inlet at an axial end of the passageway, a plurality of primary outlets disposed through a sidewall of the first tube, the primary outlets having a combined first flow area;

a second tube circumscribing the first tube, an inner surface of the second tube and the outer surface of the first tube defining a chamber, the plurality of primary outlets providing fluid communication between the passageway and the chamber, a sidewall of the second tube having a first set of radially facing secondary outlets axially offset from the primary outlets in a first direction and a second set of radially facing secondary outlets axially offset from the primary outlets in a second direction opposite the first direction, the first and second sets of radially facing secondary outlets having a combined second flow area greater than the combined first flow area;

an inner annular disc circumscribing the second tube between the first and second sets of radially facing secondary outlets and having sound absorbing material facing the first and second sets of radially facing secondary outlets;

a first outer annular disc disposed on an opposite side of the first set of radially facing secondary outlets than the inner annular disc, the first outer annular disc having sound absorbing material disposed on a side facing the first set of radially facing secondary outlets; and

a second outer annular disc disposed on an opposite side of the second set of radially facing secondary outlets than the inner annular disc, the second outer annular disc having sound absorbing material disposed on a side facing the second set of radially facing secondary outlets.

9. The system of claim 8, wherein the nozzle further comprises,
a sound absorbing device disposed in the chamber.

10. The system of claim 9, wherein the sound absorbing device includes a baffle comprising
porous sound absorbing material and at least one sound absorbing insert.

5 11. The system of claim 9, wherein the sound absorbing device includes at least one ring
comprising non-porous sound absorbing material disposed between the first and second sets of
primary outlets and at least one sound absorbing insert.

12. The system of any one of claims 8-11, further comprising:
an orifice plate to provide flow to the first tube.

10 13. A fire suppression nozzle assembly, comprising:
a nozzle to be disposed in an enclosure, the nozzle having an inlet for connection to
distribution piping and having a plurality of outlet holes,

wherein, during a discharge of inert gas into an enclosure, a sound power level from the
nozzle is no greater than 125 dB for a frequency range from 500 to 10,000 Hz for a coverage
15 area up to 36 ft. x 36 ft. in compliance with UL 2127.

14. The assembly of claim 13, wherein the nozzle is configured such that gas exiting the
plurality of outlet holes is balanced.

15. The assembly of claim 14, wherein the nozzle is configured such that the plurality of
holes are grouped into two or more sets of outlet holes having balanced flow between the sets,
20 and

wherein a ratio between a maximum set flow value and a minimum set flow value in the
two or more sets of outlet holes is less than 60:40.

16. The assembly of any one of claims 13-15, wherein the sound power level from the nozzle
is no greater than 108.6 dB for a frequency range from 500 to 10,000 Hz for a coverage area up
25 to 36 ft. x 36 ft. in compliance with UL 2127, Second Edition.

17. The assembly of any one of claims 13-15, wherein the sound power level from the nozzle is no greater than 120 dB for a frequency range from 500 to 10,000 Hz for a coverage area up to 36 ft. x 36 ft. in compliance with UL 2127, Second Edition.

18. The assembly of any one of claims 13 to 17, wherein a protection height of the nozzle is up to 20 ft. in compliance with UL 2127, second edition.

19. The assembly of any one of claims 13 to 18, wherein, during the discharge, a pressure drop from the inlet of the nozzle to the plurality of outlet holes is no more than 80 psi higher than a gage pressure of the enclosure.

20. The assembly of any one of claims 13 to 19, wherein the nozzle comprises,

10 a first tube having an inner surface and an outer surface, the inner surface of the first tube defining an axially extending passageway, the passageway including an inlet at an axial end of the passageway, a plurality of primary outlets disposed through a sidewall of the first tube, the primary outlets having a combined first flow area;

a second tube circumscribing the first tube, an inner surface of the second tube and the outer surface of the first tube defining a chamber, the plurality of primary outlets providing fluid communication between the passageway and the chamber, a sidewall of the second tube having a first set of radially facing secondary outlets axially offset from the primary outlets in a first direction and a second set of radially facing secondary outlets axially offset from the primary outlets in a second direction opposite the first direction, the first and second sets of radially facing secondary outlets having a combined second flow area greater than the combined first flow area;

an inner annular disc circumscribing the second tube between the first and second sets of radially facing secondary outlets and having sound absorbing material facing the first and second sets of radially facing secondary outlets;

25 a first outer annular disc disposed on an opposite side of the first set of radially facing

secondary outlets than the inner annular disc, the first outer annular disc having sound absorbing material disposed on a side facing the first set of radially facing secondary outlets; and

a second outer annular disc disposed on an opposite side of the second set of radially facing secondary outlets than the inner annular disc, the second outer annular disc having sound absorbing material disposed on a side facing the second set of radially facing secondary outlets.

21. The assembly of claim 20, wherein the nozzle further comprises,
a sound absorbing device disposed in the chamber.

22. The assembly of claim 21, wherein the sound absorbing device includes a baffle comprising porous sound absorbing material and at least one sound absorbing insert.

23. The assembly of claim 21, wherein the sound absorbing device includes at least one ring comprising non-porous sound absorbing material disposed between the first and second sets of primary outlets and at least one sound absorbing insert.

24. The assembly of any one of claims 20-23, further comprising:
an orifice plate to provide flow to the first tube.

25. A fire suppression system, comprising:
an enclosure;
an inert gas source to supply inert gas to the enclosure via distribution piping.;
a nozzle disposed in the enclosure, the nozzle having an inlet connected to the distribution piping and having a plurality of outlet holes,

wherein, during a discharge of the inert gas, a sound power level from the nozzle is no greater than 130 dB for a frequency range from 500 to 10,000 Hz at a coverage area of 36 ft. x 36 ft. in compliance with UL 2127, Second Edition.

26. The system of claim 25, wherein the nozzle is configured such that gas exiting the plurality of outlet holes is balanced.

27. The system of claim 26, wherein the nozzle is configured such that the plurality of holes

are grouped into two or more sets of outlet holes having balanced flow between the sets, and

wherein a ratio between a maximum set flow value and a minimum set flow value in the two or more sets of outlet holes is less than 60:40.

28. The system of any one of claims 25 and 27, wherein the sound power level from the nozzle is no greater than 108.6 dB.

29. The system of any one of claims 25 and 27, wherein the sound power level from the nozzle is no greater than 125 dB.

30. The system of any one of claims 25 to 29, wherein a protection height of the nozzle is up to 20 ft. in compliance with UL 2127, Second Edition.

31. The system of any one of claims 25 to 29, wherein, during the discharge, a pressure drop from the inlet of the nozzle to the plurality of outlet holes is no more than 80 psi higher than a gage pressure of the enclosure.

32. The system of any one of claims 25 to 29, wherein the nozzle comprises,

33. The system of claim 32, wherein the nozzle further comprises,
a sound absorbing device disposed in the chamber.

34. The system of claim 33, wherein the sound absorbing device includes a baffle comprising porous sound absorbing material and at least one sound absorbing insert.

35. The system of claim 33, wherein the sound absorbing device includes at least one ring comprising non-porous sound absorbing material disposed between the first and second sets of primary outlets and at least one sound absorbing insert.

36. The system of any one of claims 32-35, further comprising:
an orifice plate to provide flow to the first tube.

37. A fire suppression nozzle assembly, comprising:
a nozzle to be disposed in an enclosure, the nozzle having an inlet for connection to distribution piping and having a plurality of outlet holes,

wherein, during a discharge of inert gas into an enclosure, a sound power level from the nozzle is no greater than 130 dB for a frequency range from 500 to 10,000 Hz at a coverage area of 36 ft. x 36 ft. in compliance with UL 2127, Second Edition.

38. The assembly of claim 37, wherein the nozzle is configured such that gas exiting the plurality of outlet holes is balanced.

39. The assembly of claim 38, wherein the nozzle is configured such that the plurality of holes are grouped into two or more sets of outlet holes having balanced flow between the sets, and

wherein a ratio between a maximum set flow value and a minimum set flow value in the two or more sets of outlet holes is less than 60:40.

40. The assembly of any one of claims 37 and 39, wherein the sound power level from the nozzle is no greater than 108.6 dB.

41. The assembly of any one of claims 37 and 39, wherein the sound power level from the nozzle is no greater than 125 dB.

42. The assembly of any one of claims 37 to 41, wherein a protection height of the nozzle is up to 20 ft. in compliance with UL 2127, Second Edition.

43. The assembly of any one of claims 37 to 42, wherein, during the discharge, a pressure drop from the inlet of the nozzle to the plurality of outlet holes is no more than 80 psi higher than a gage pressure of the enclosure.

44. The assembly of any one of claims 37 to 43, wherein the nozzle comprises

a first tube having an inner surface and an outer surface, the inner surface of the first tube defining an axially extending passageway, the passageway including an inlet at an axial end of the passageway, a plurality of primary outlets disposed through a sidewall of the first tube, the primary outlets having a combined first flow area;

a second tube circumscribing the first tube, an inner surface of the second tube and the

outer surface of the first tube defining a chamber, the plurality of primary outlets providing fluid communication between the passageway and the chamber, a sidewall of the second tube having a first set of radially facing secondary outlets axially offset from the primary outlets in a first direction and a second set of radially facing secondary outlets axially offset from the primary outlets in a second direction opposite the first direction, the first and second sets of radially facing secondary outlets having a combined second flow area greater than the combined first flow area;

an inner annular disc circumscribing the second tube between the first and second sets of radially facing secondary outlets and having sound absorbing material facing the first and second sets of radially facing secondary outlets;

a first outer annular disc disposed on an opposite side of the first set of radially facing secondary outlets than the inner annular disc, the first outer annular disc having sound absorbing material disposed on a side facing the first set of radially facing secondary outlets; and

a second outer annular disc disposed on an opposite side of the second set of radially facing secondary outlets than the inner annular disc, the second outer annular disc having sound absorbing material disposed on a side facing the second set of radially facing secondary outlets.

45. The assembly of claim 44, wherein the nozzle further comprises,

a sound absorbing device disposed in the chamber.

46. The assembly of claim 45, wherein the sound absorbing device includes a baffle comprising porous sound absorbing material and at least one sound absorbing insert.

47. The assembly of claim 45, wherein the sound absorbing device includes at least one ring comprising non-porous sound absorbing material disposed between the first and second sets of primary outlets and at least one sound absorbing insert.

48. The assembly of any one of claims 44-47, further comprising:

an orifice plate to provide flow to the first tube.

49. The system of any one of claims 1-12 and 25-36, wherein a sound power level of the nozzle is no greater than 130 dB for inert gas flow rates in a range of approximately 950 CFM to approximately 5,400 CFM.

50. The system of claim 49, wherein the sound power level is no greater than 120 dB.

5 51. The system of claim 49, wherein the sound power level is no greater than 111 dB.

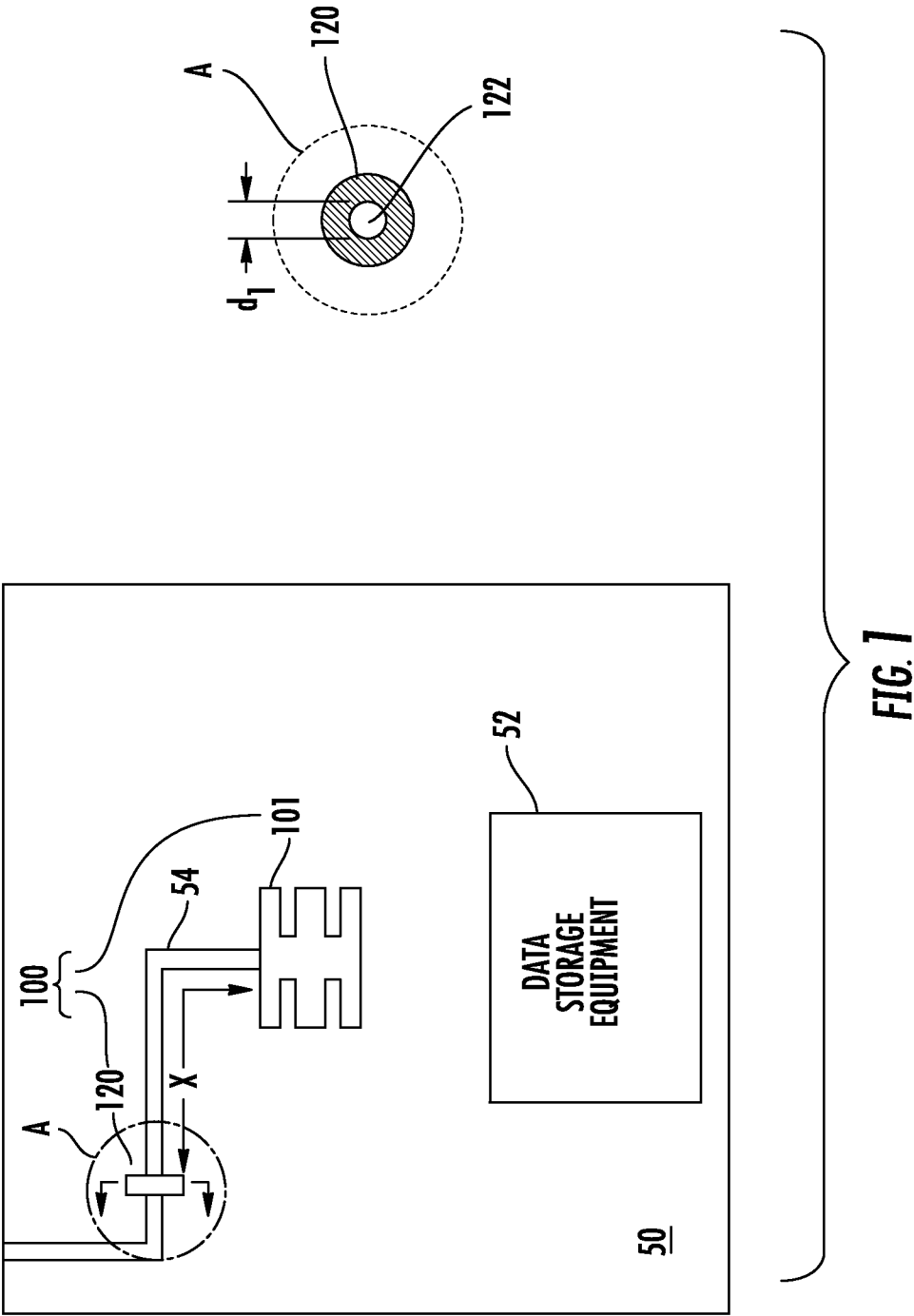
52. The system of any one of claims 1-12 and 25-36, wherein a sound power level of the nozzle is in a range between 111 dB to 130 dB for inert gas flow rates in a range of approximately 950 CFM to approximately 5,400 CFM.

53. The nozzle assembly of any one of claims 13-24 and 37-48, wherein a sound power level
10 of the nozzle is no greater than 130 dB for a frequency range from 500 to 10,000 Hz for inert gas flow rates for inert gas flow rates in a range of approximately 950 CFM to approximately 5,400 CFM.

54. The nozzle assembly of claim 53, wherein the sound power level is no greater than 120 dB.

15 55. The nozzle assembly of claim 53, wherein the sound power level is no greater than 111 dB.

56. The nozzle assembly of any one of claims 13-24 and 37-48, wherein a sound power level of the nozzle is in a range between 111 dB to 130 dB for a frequency range from 500 to 10,000 Hz for inert gas flow rates in a range of approximately 950 CFM to approximately 5,400 CFM.



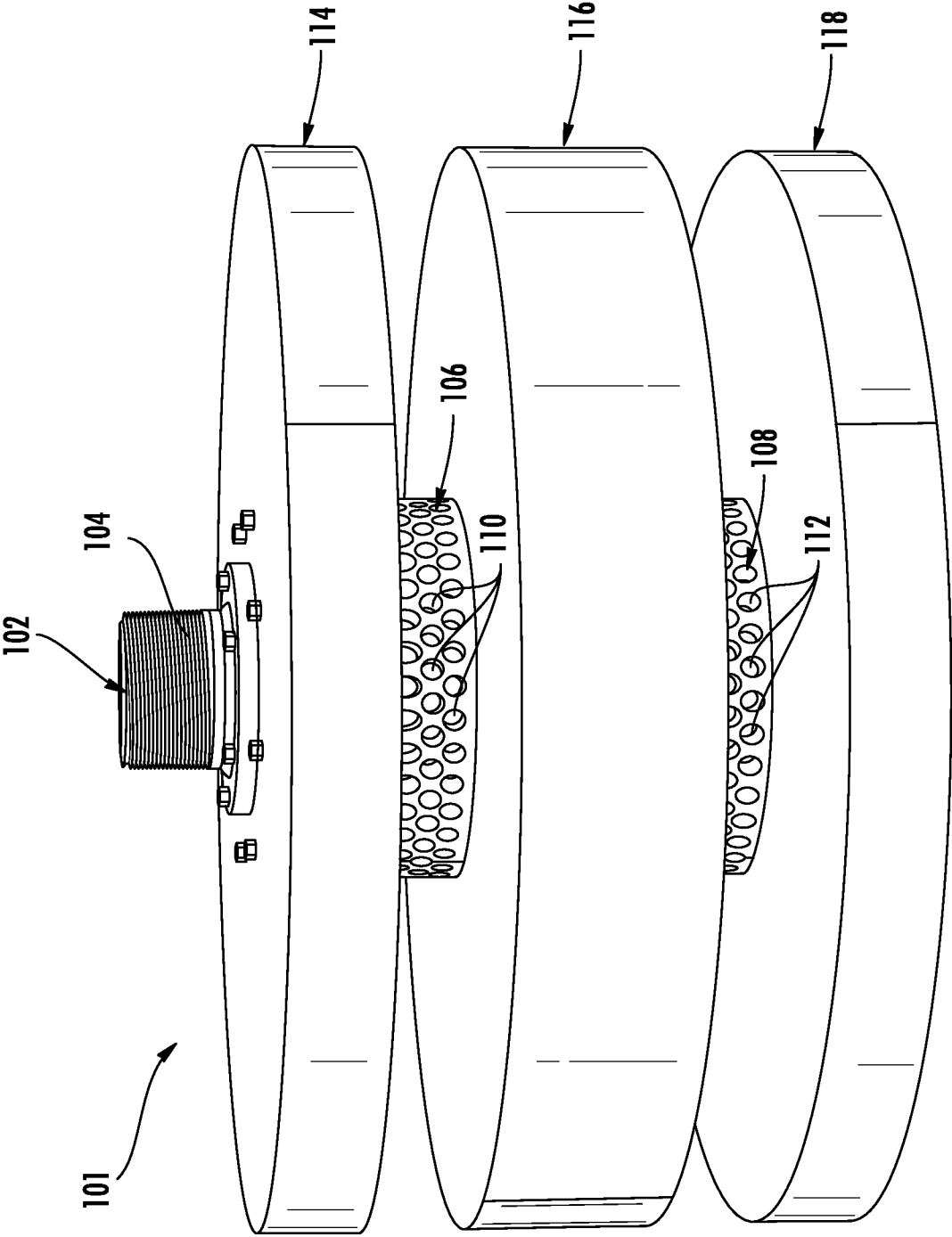


FIG. 2

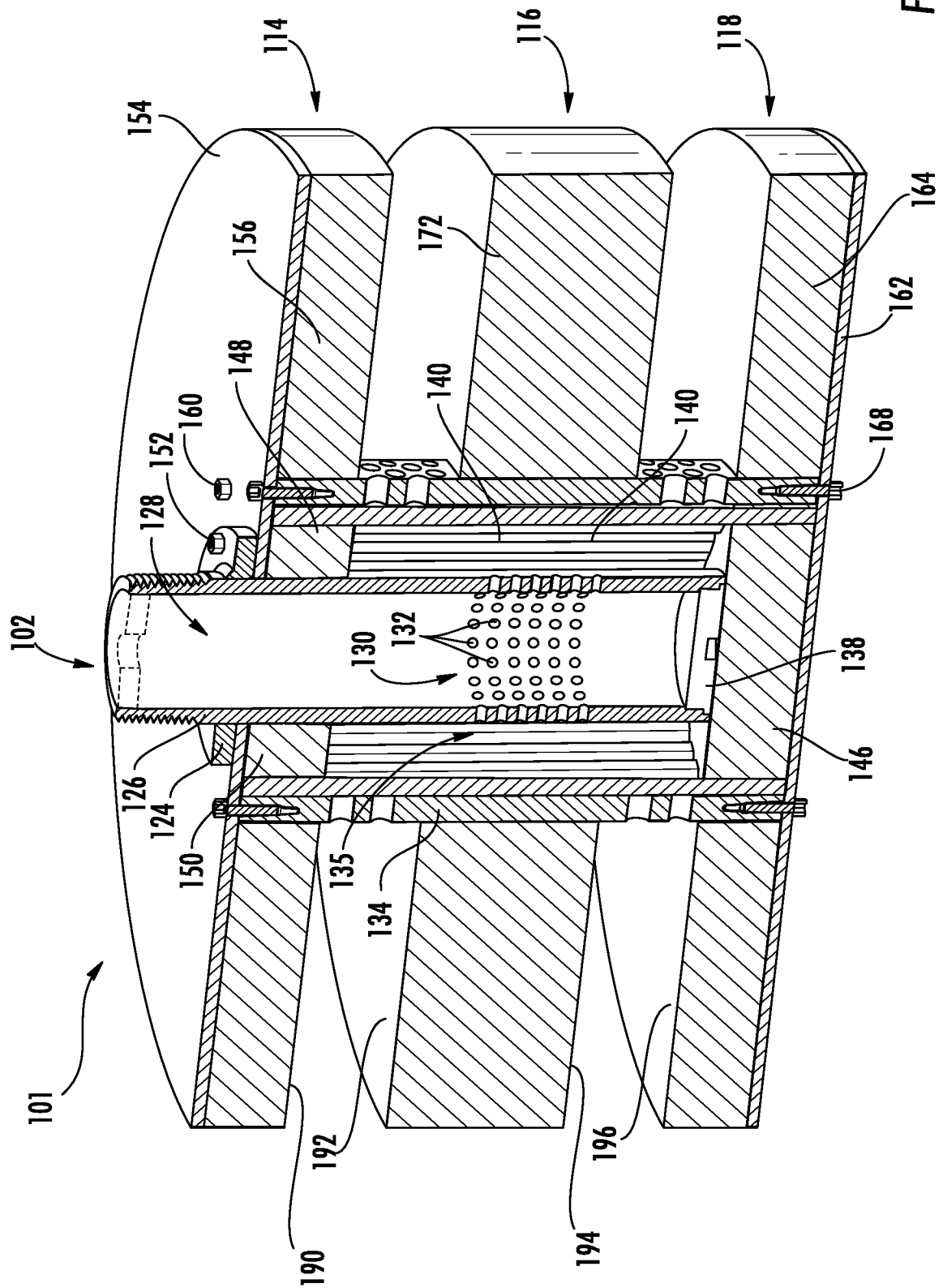
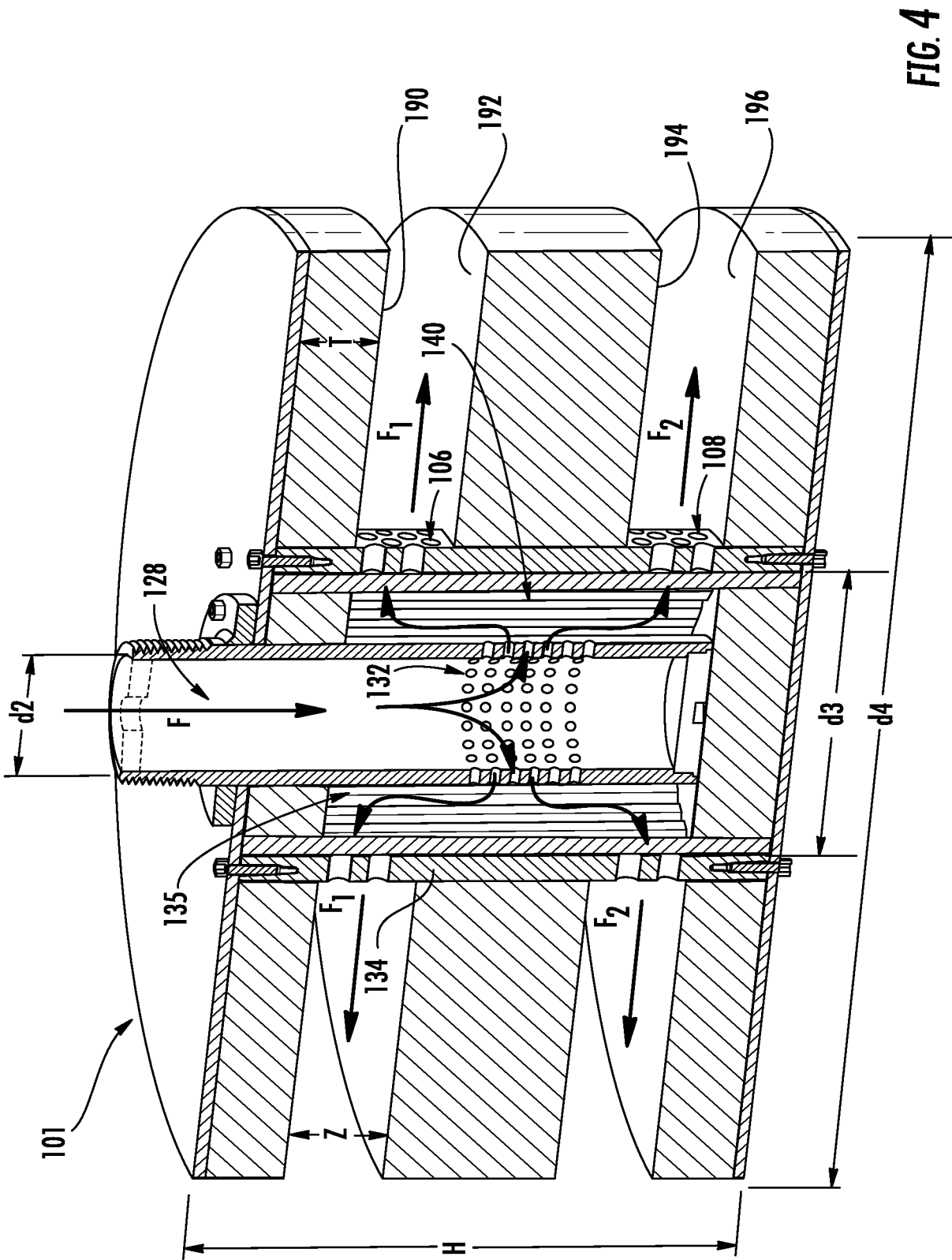
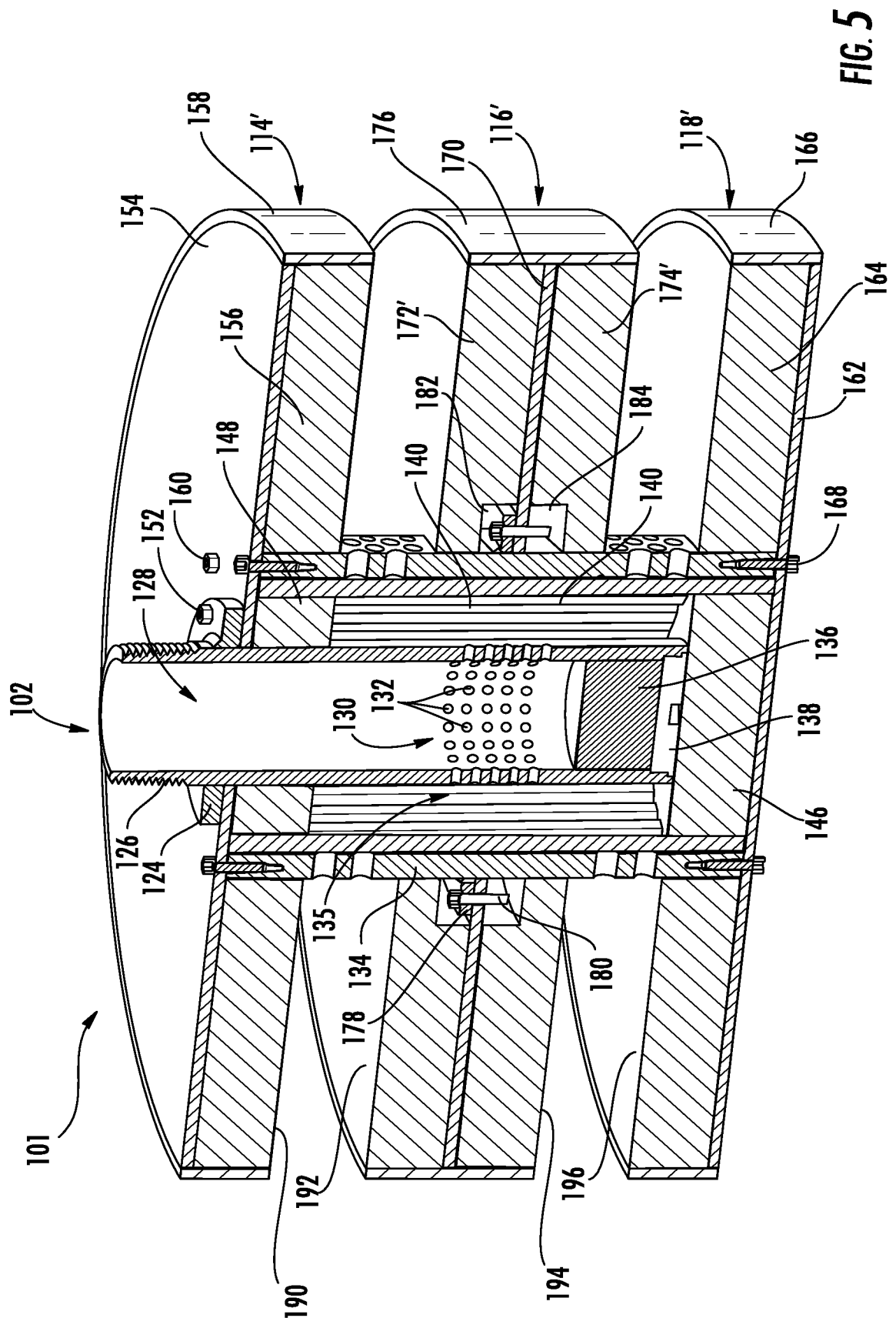
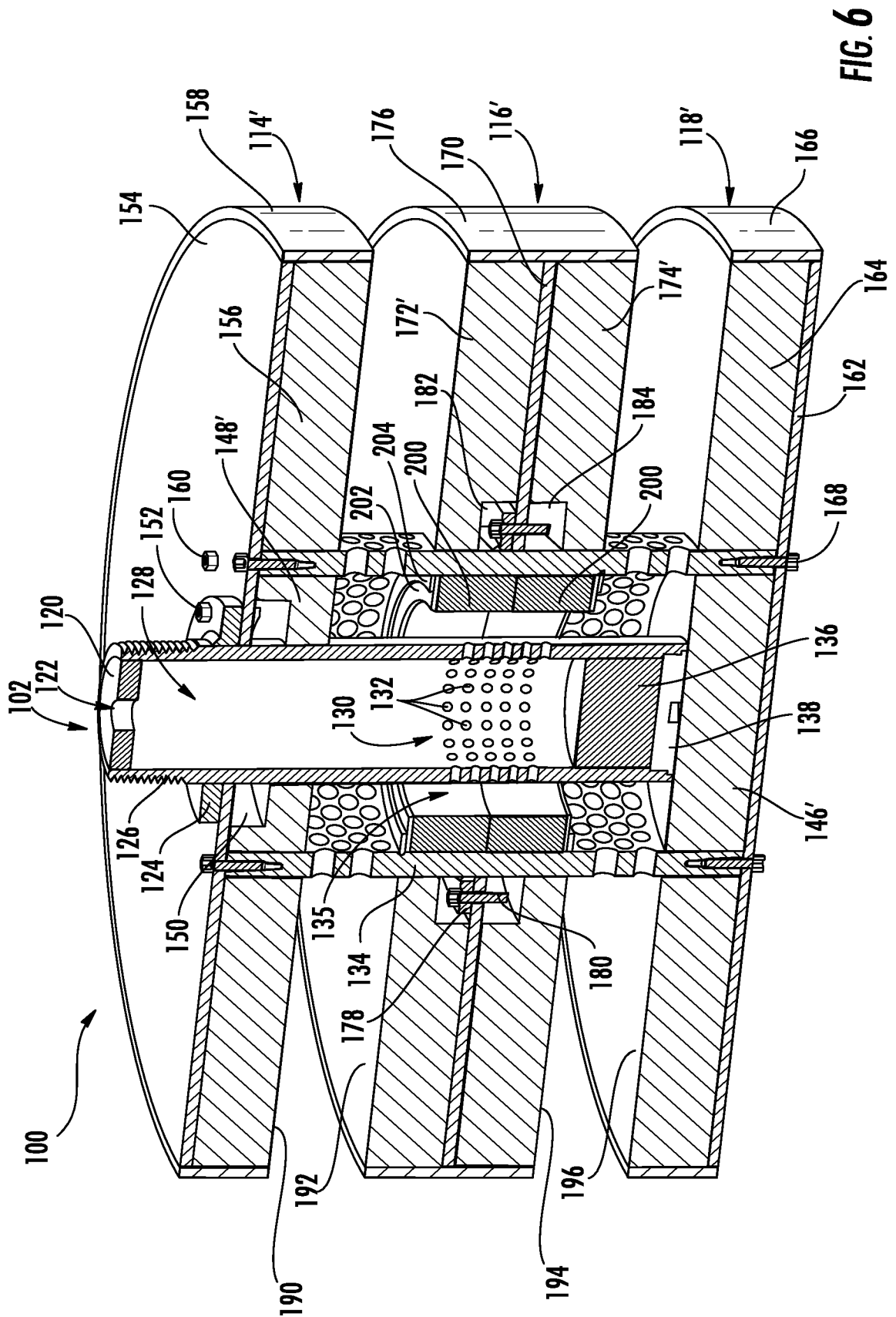


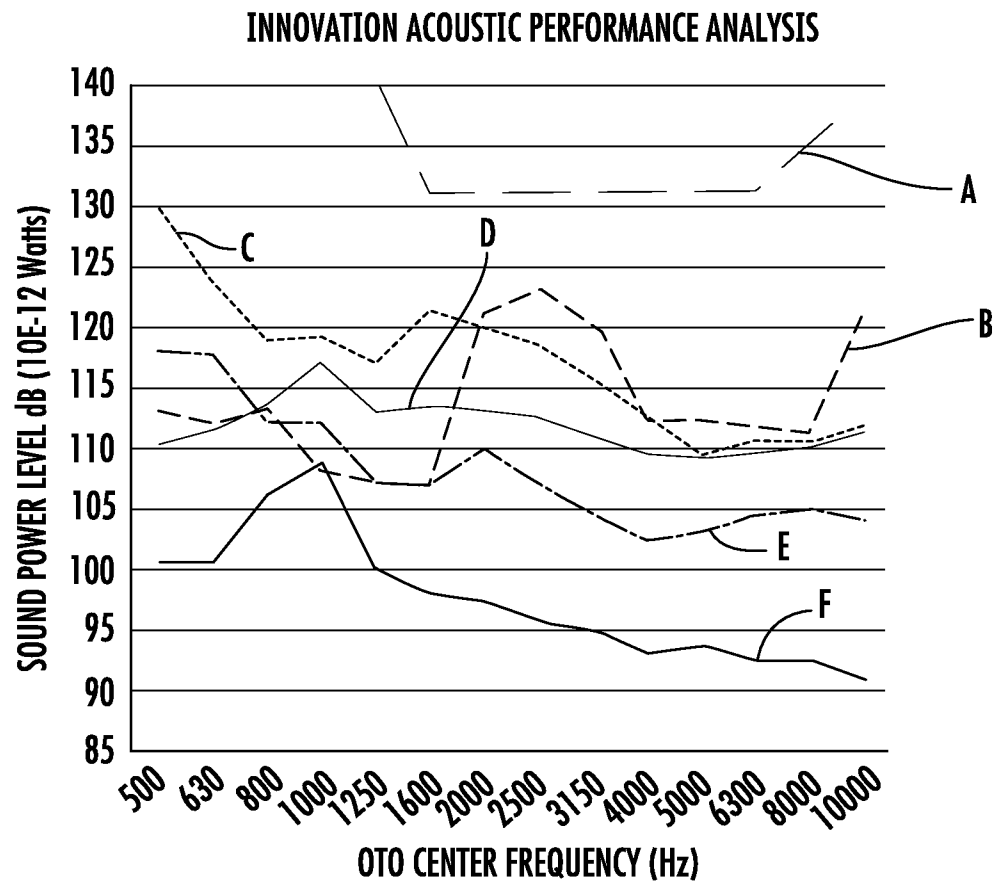
FIG. 3







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**FIG. 7**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/064768

A. CLASSIFICATION OF SUBJECT MATTER
INV. A62C31/05 A62C99/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A62C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/154652 A1 (FIKE CORP [US]; HILL GENE [US]; PATEL DEVANG [GB]) 15 November 2012 (2012-11-15)	1-7, 13-19, 25-31, 37-43, 49-56
A	page 2, line 12 - page 3, line 17 page 4, line 6 - page 8, line 2 figures 1-9 ----- -/--	8-12, 20-24, 32-36, 44-48



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

14 February 2017

Date of mailing of the international search report

23/02/2017

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Zupancic, Gregor

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/064768

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	paragraphs [0008] - [0038] paragraphs [0048] - [0102] figures 1-16	8-12, 20-24, 32-36, 44-48
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A	paragraphs [0008] - [0012] paragraphs [0028] - [0097] figures 1-9	8-12, 20-24, 32-36, 44-48
X	----- EP 1 151 800 A2 (VESTA SRL [IT]) 7 November 2001 (2001-11-07)	1-7, 13-19, 25-31, 37-43, 49-56
A	paragraph [0013] paragraphs [0022] - [0049] figures 1-4, 6-8 -----	8-12, 20-24, 32-36, 44-48

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/064768

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