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Smith et al.

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(54) **SYSTEMS AND METHODS FOR CONTROLLING SILICA DUST DURING HYDRAULIC FRACTURING OPERATIONS USING AN IMPROVED MANIFOLD**

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 This patent is subject to a terminal disclaimer.

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 B08B 15/00 (2006.01)
 B65G 67/24 (2006.01)
(52) **U.S. Cl.**
CPC **B08B 15/002** (2013.01); **B65G 67/24** (2013.01); **B65G 69/186** (2013.01)
(58) **Field of Classification Search**
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See application file for complete search history.

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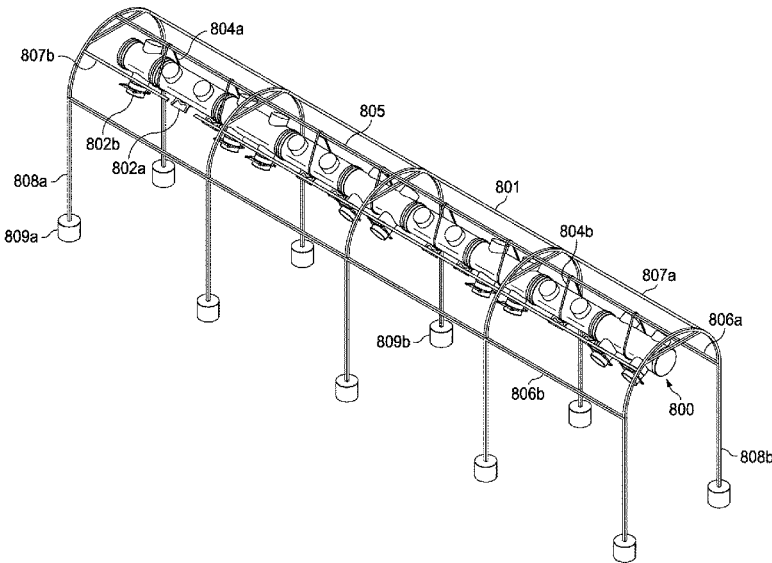
 Primary Examiner — Mikhail Kornakov
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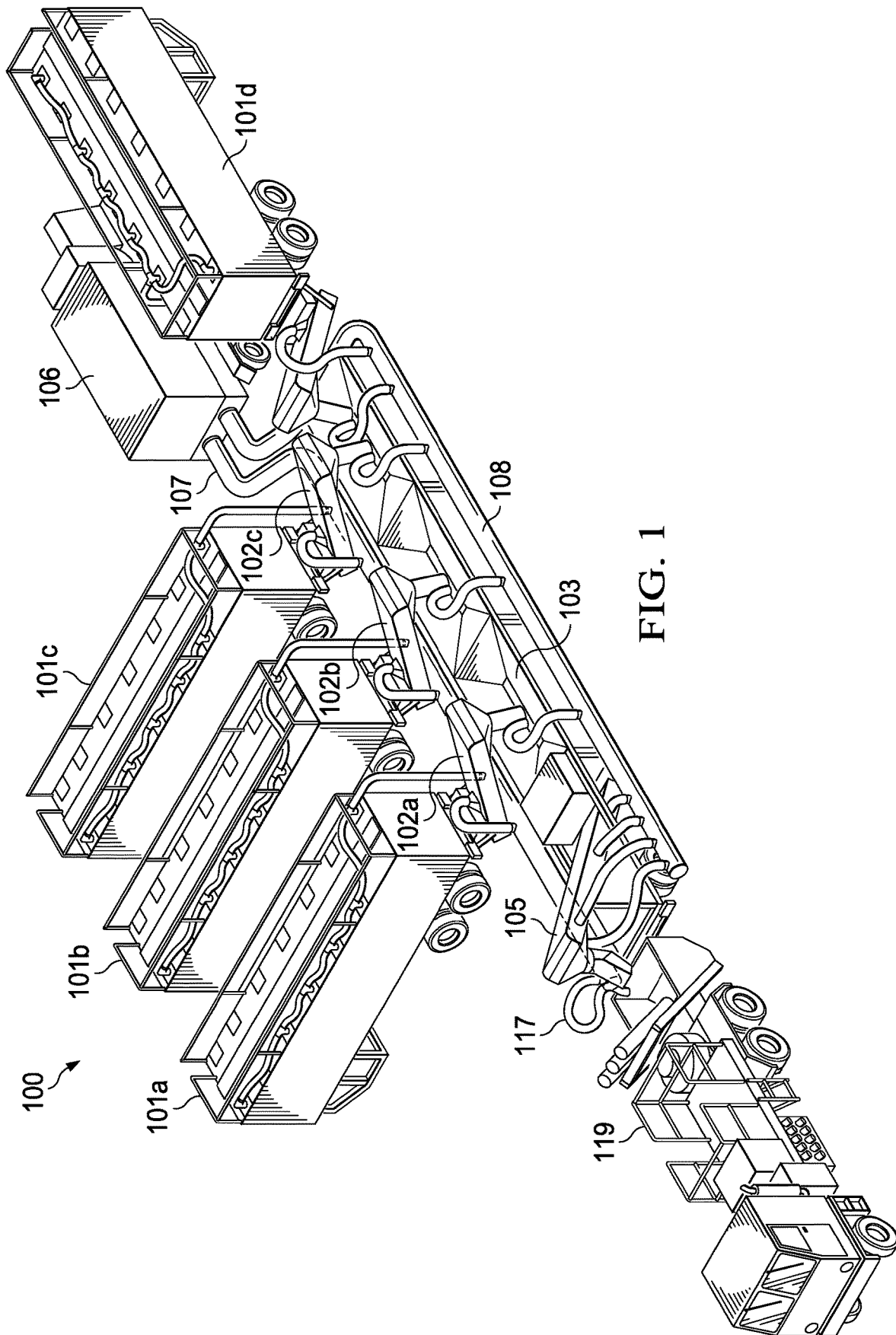
(57) **ABSTRACT**
A system for controlling dust during hydraulic fracturing operations includes a manifold having a plurality of ports for capturing dust when negative air pressure is applied to the manifold. A support frame positions the manifold above a piece of hydraulic fracturing equipment receiving sand from a sand source.

Related U.S. Application Data
(60) Continuation-in-part of application No. 14/862,354, filed on Sep. 23, 2015, now Pat. No. 9,630,233, which is a continuation of application No. 14/527,868, filed on Oct. 30, 2014, now Pat. No. 9,168,482, which is a division of application No. 14/178,782, filed on Feb. 12, 2014, now Pat. No. 8,881,749, which is a continuation of application No. 13/769,456, filed on Feb. 18, 2013, now Pat. No. 9,162,261.

(60) Provisional application No. 62/291,419, filed on Feb. 4, 2016.

28 Claims, 29 Drawing Sheets





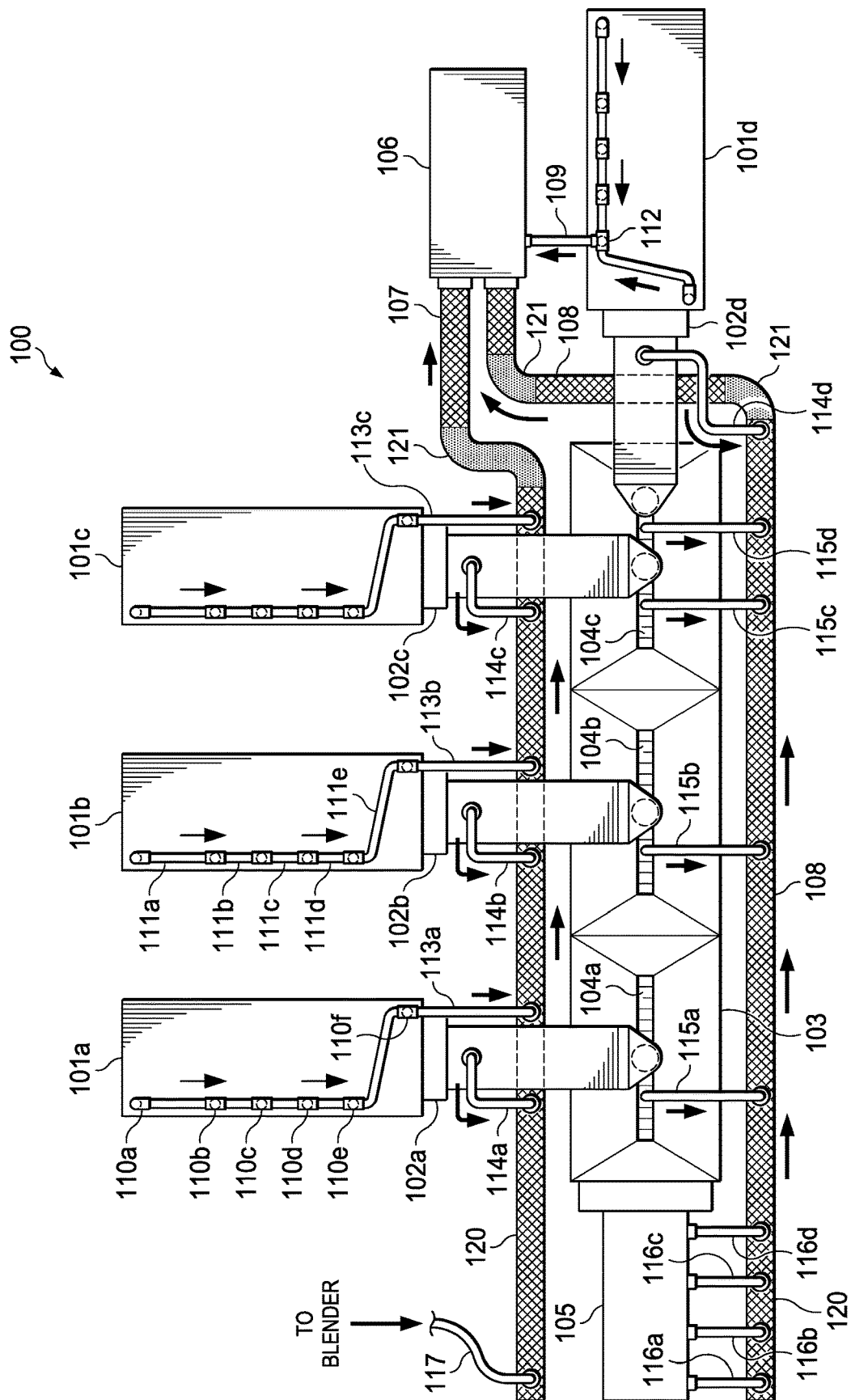


FIG. 2

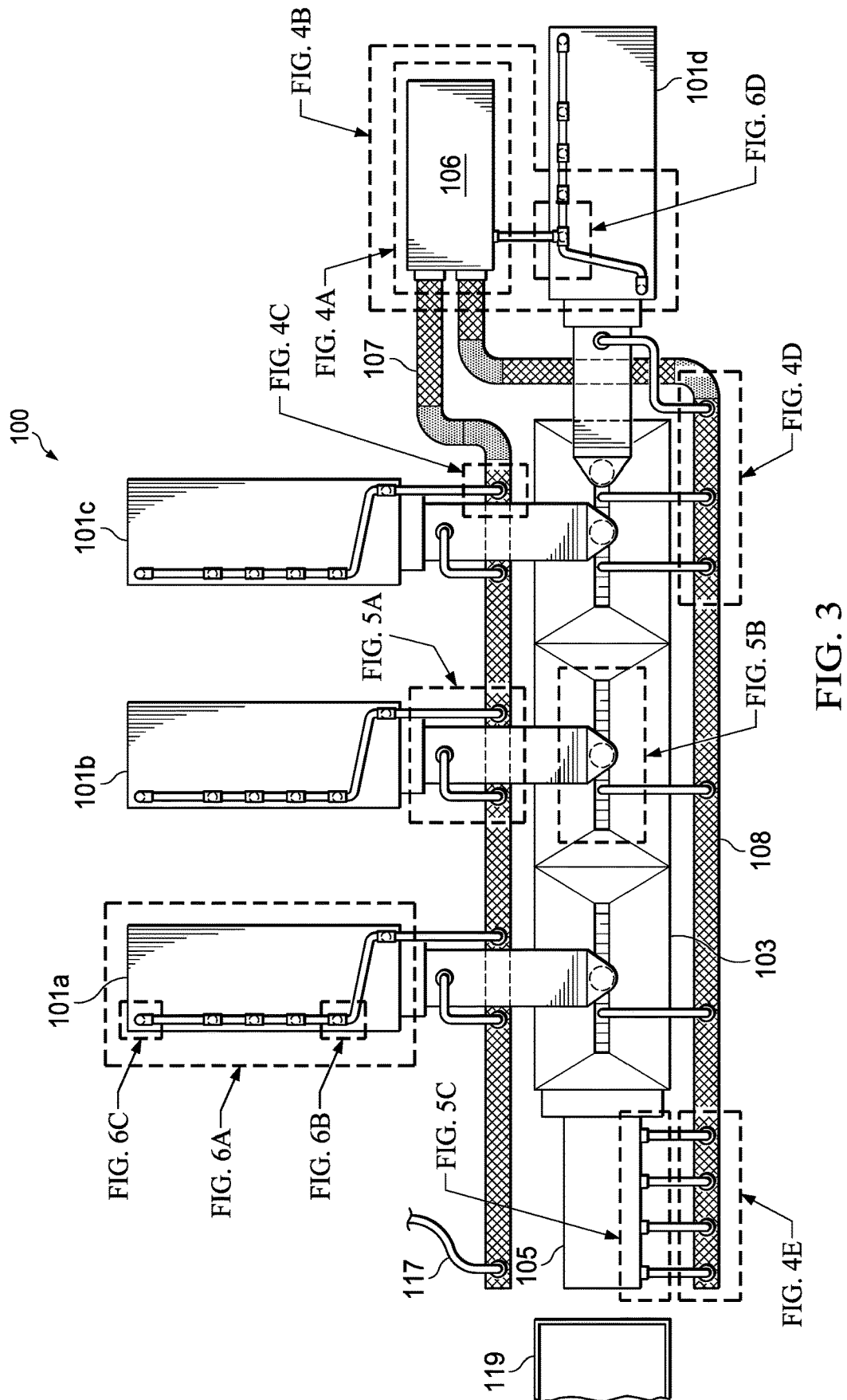
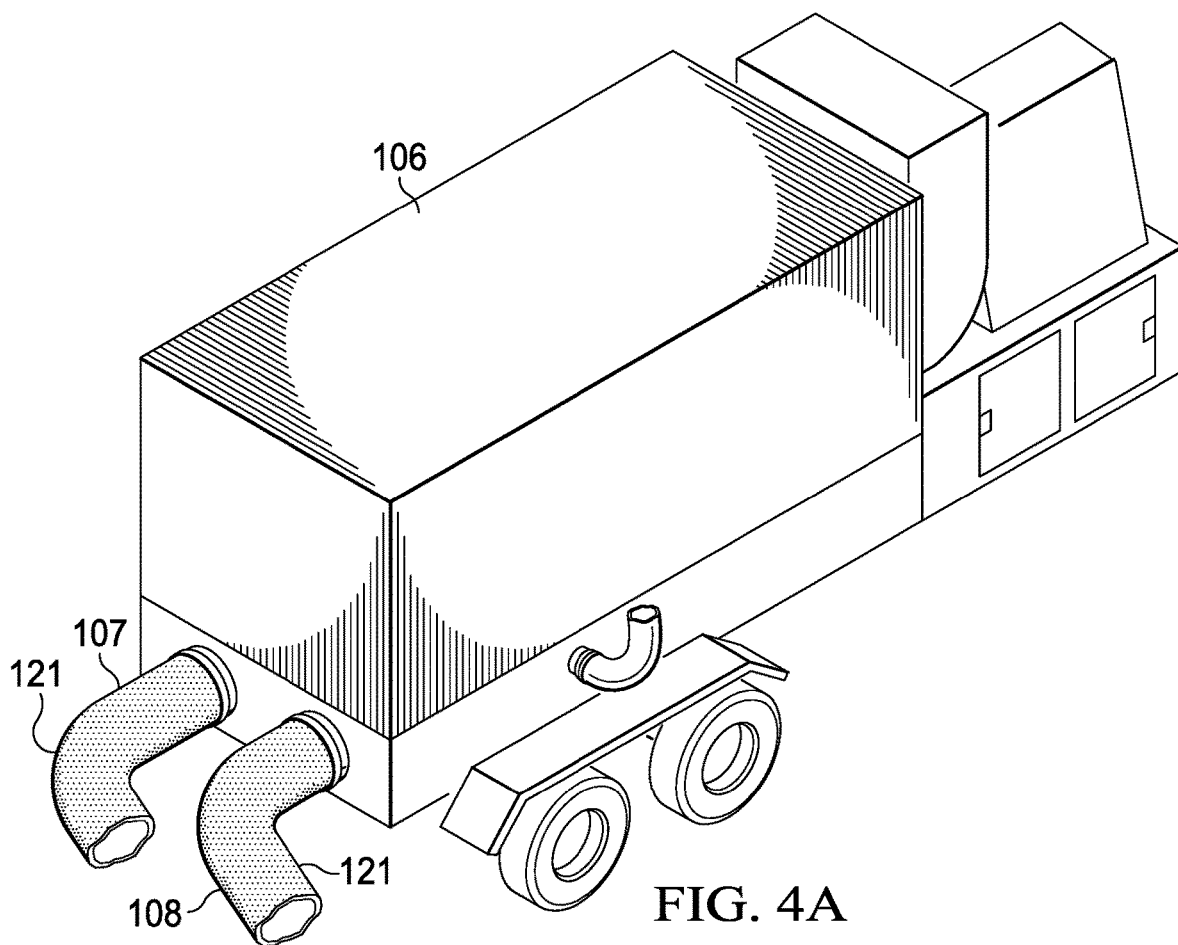


FIG. 3



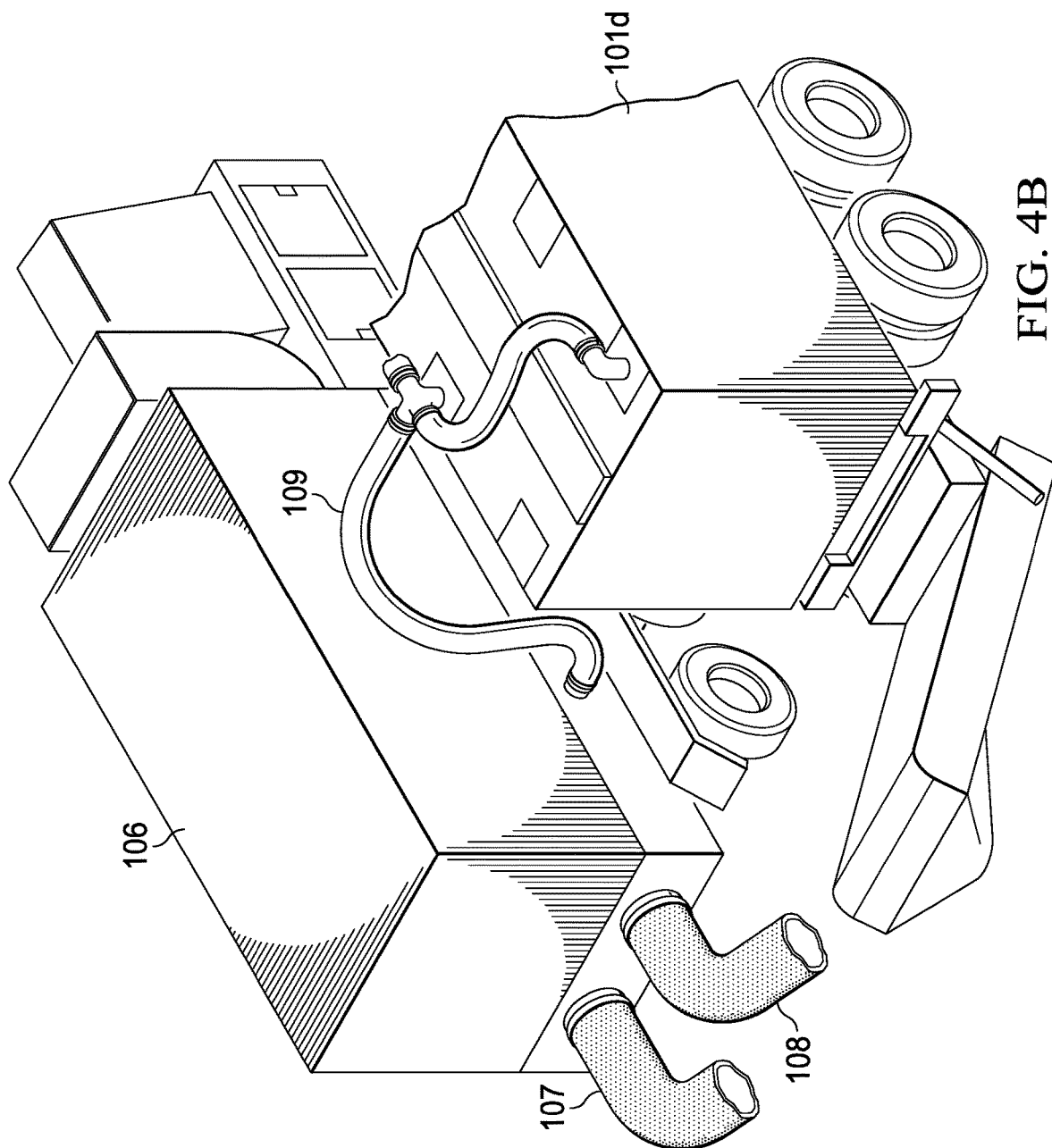
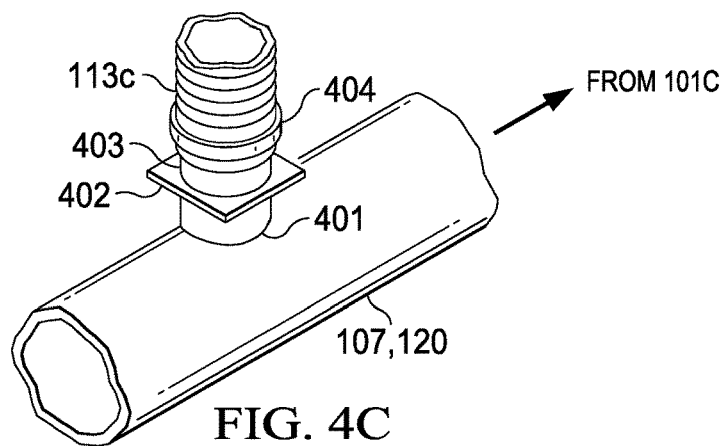
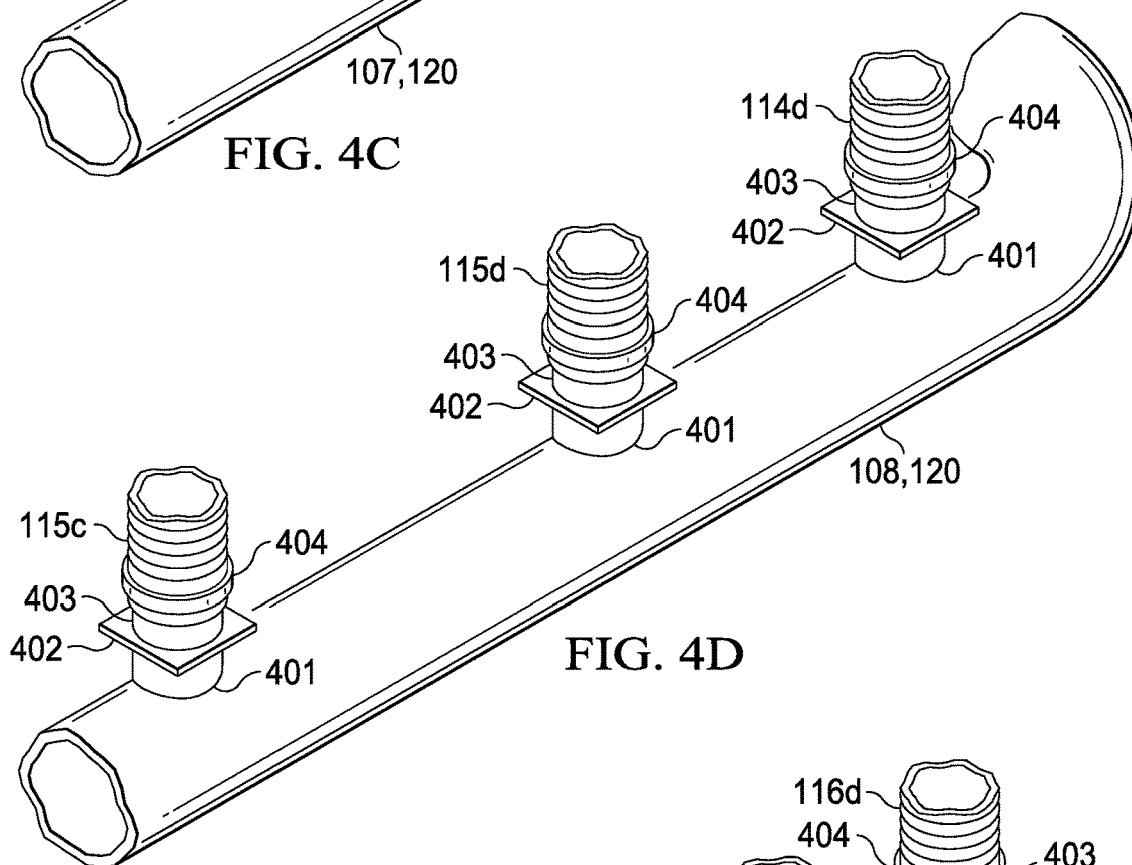
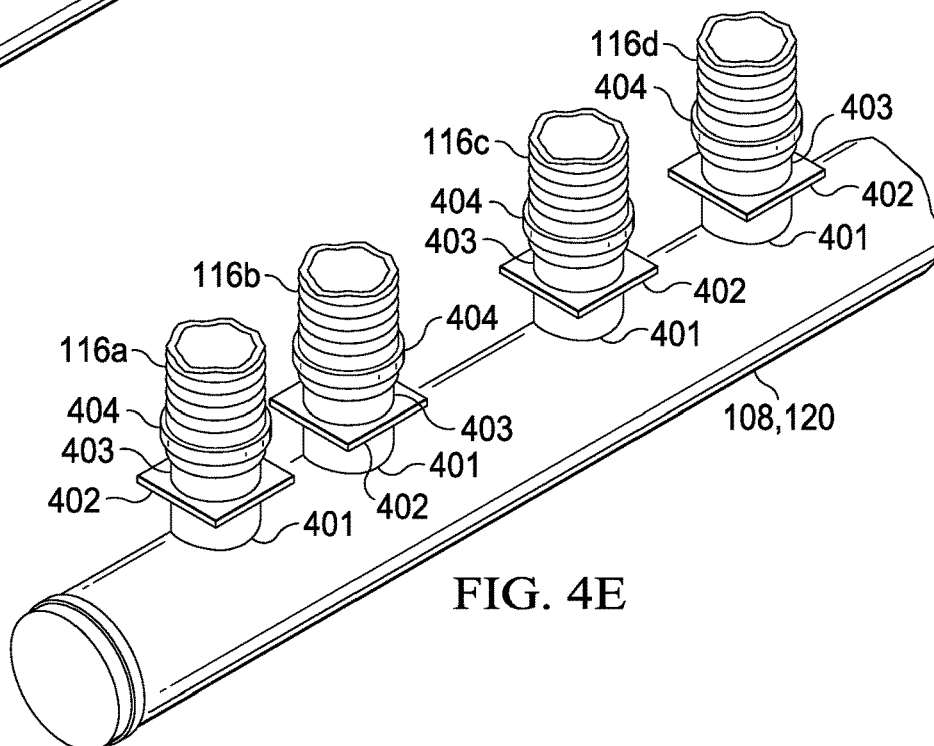
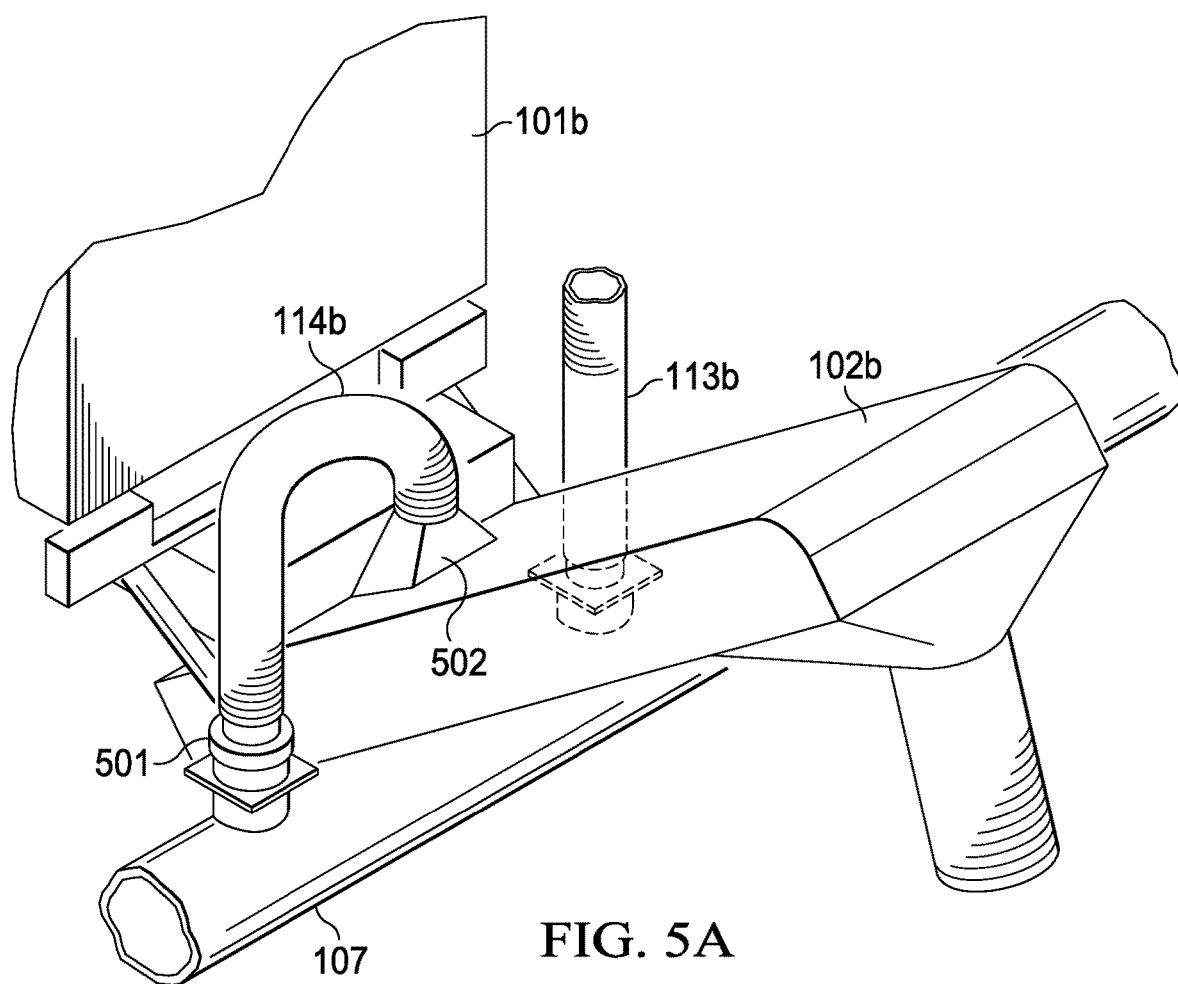
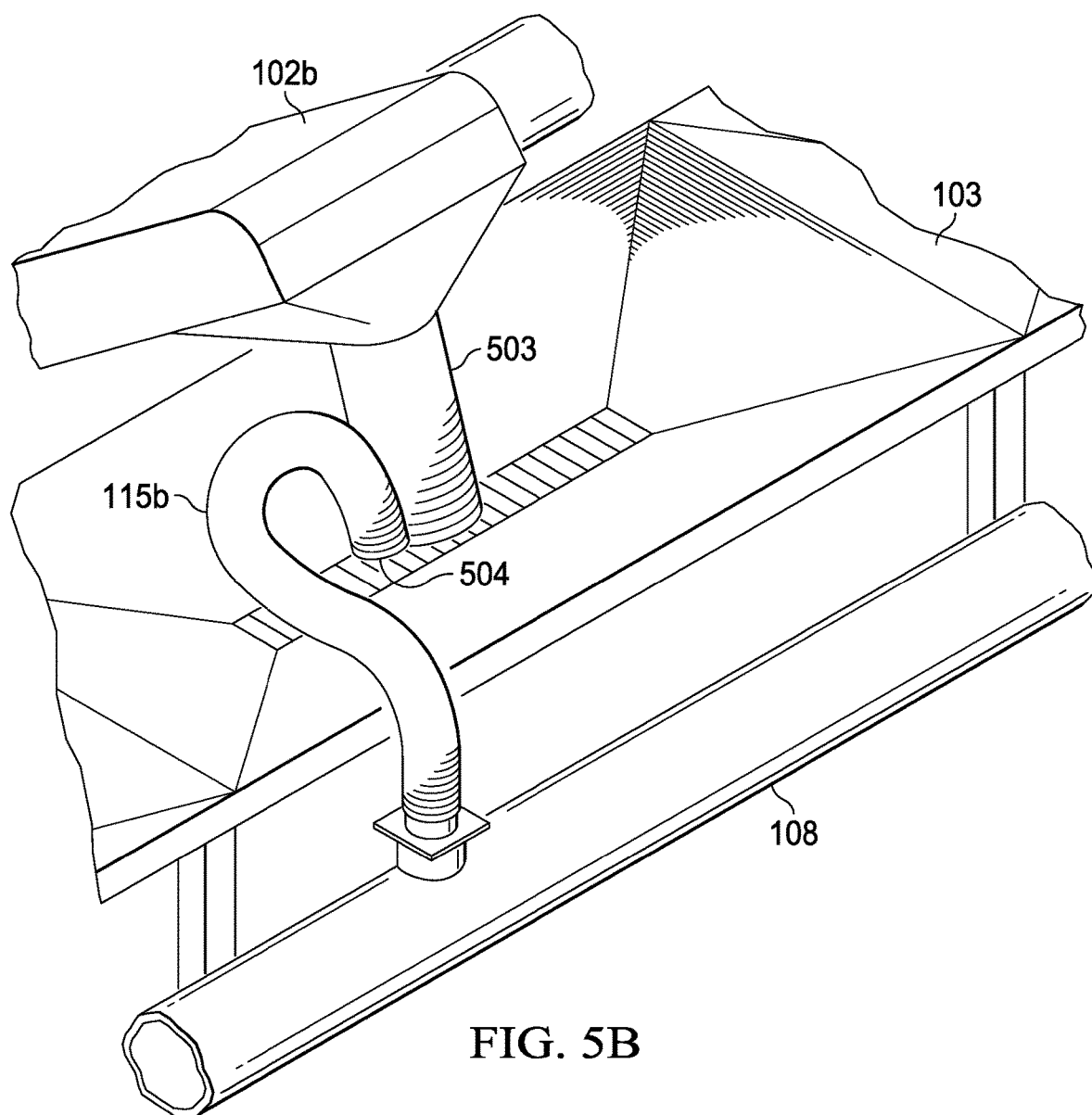
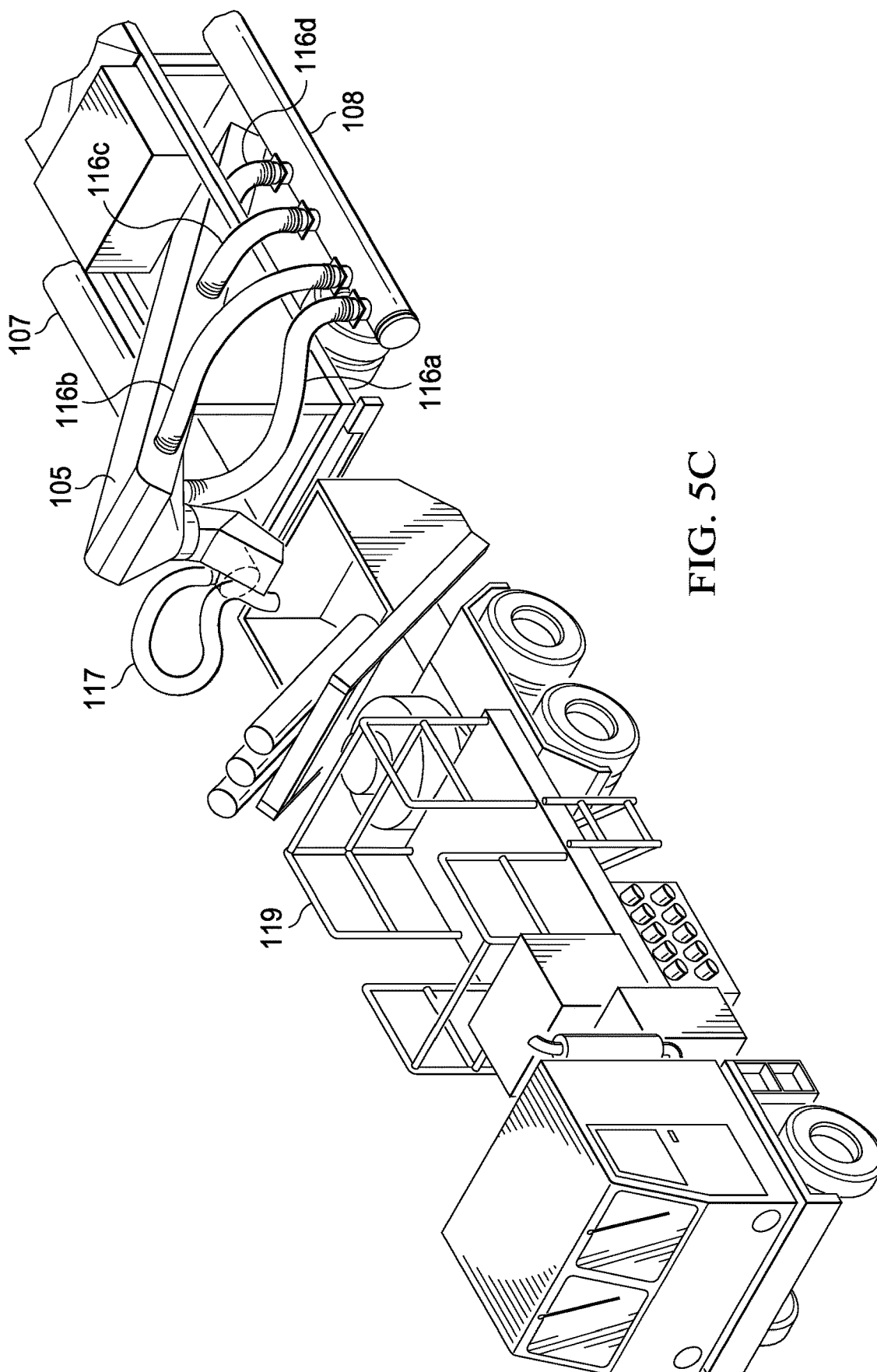


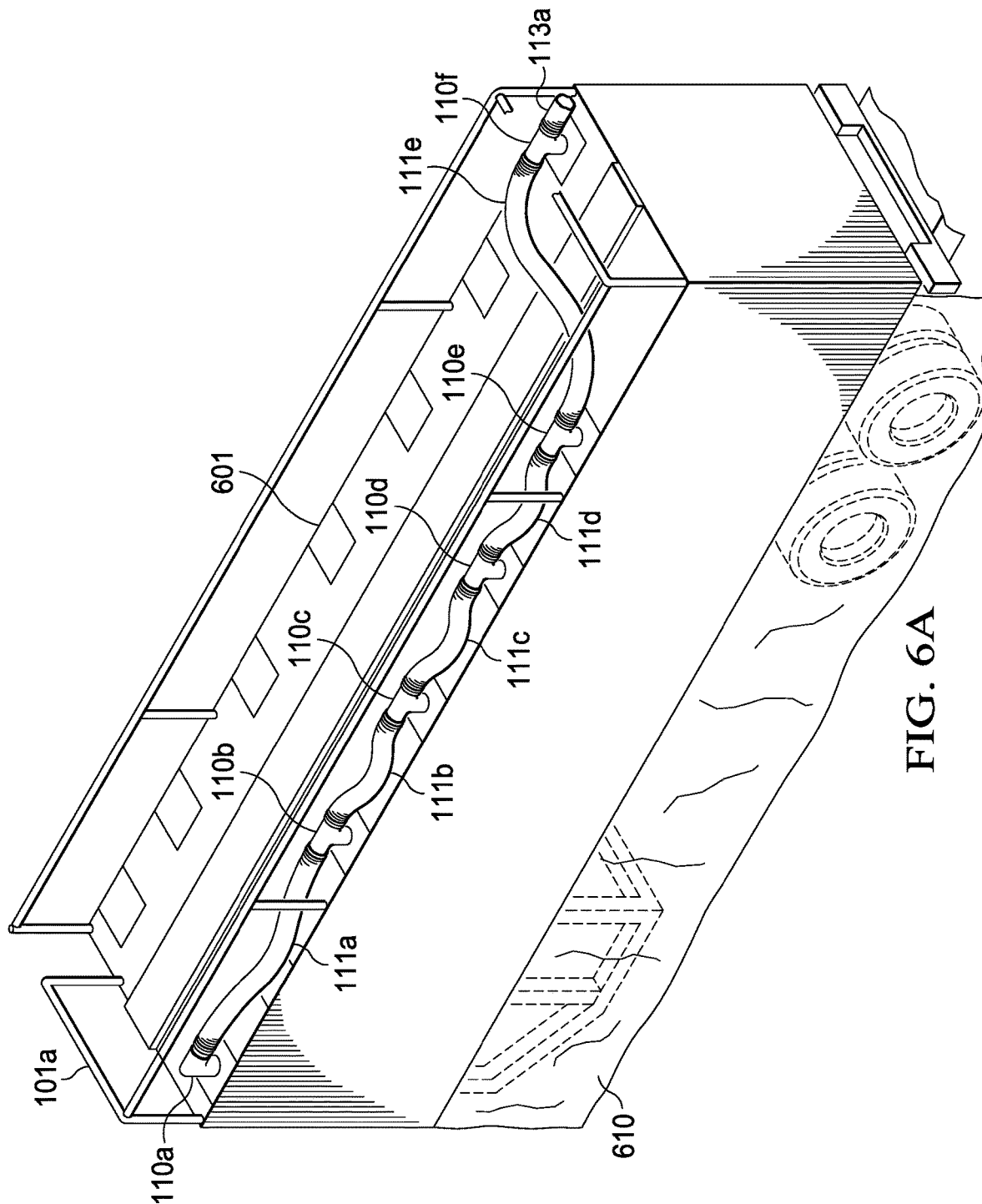
FIG. 4B











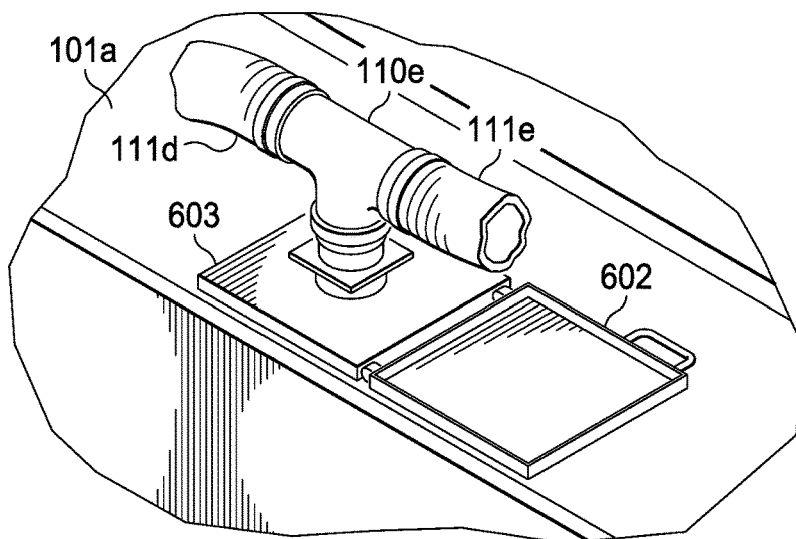


FIG. 6B

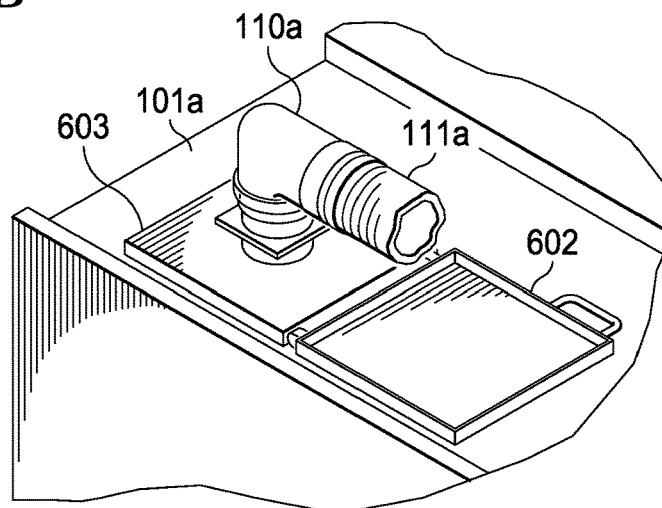


FIG. 6C

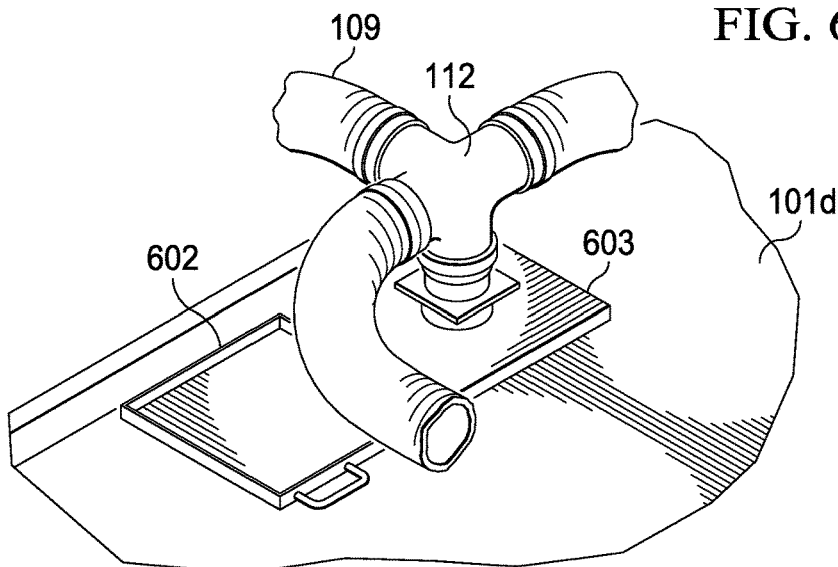
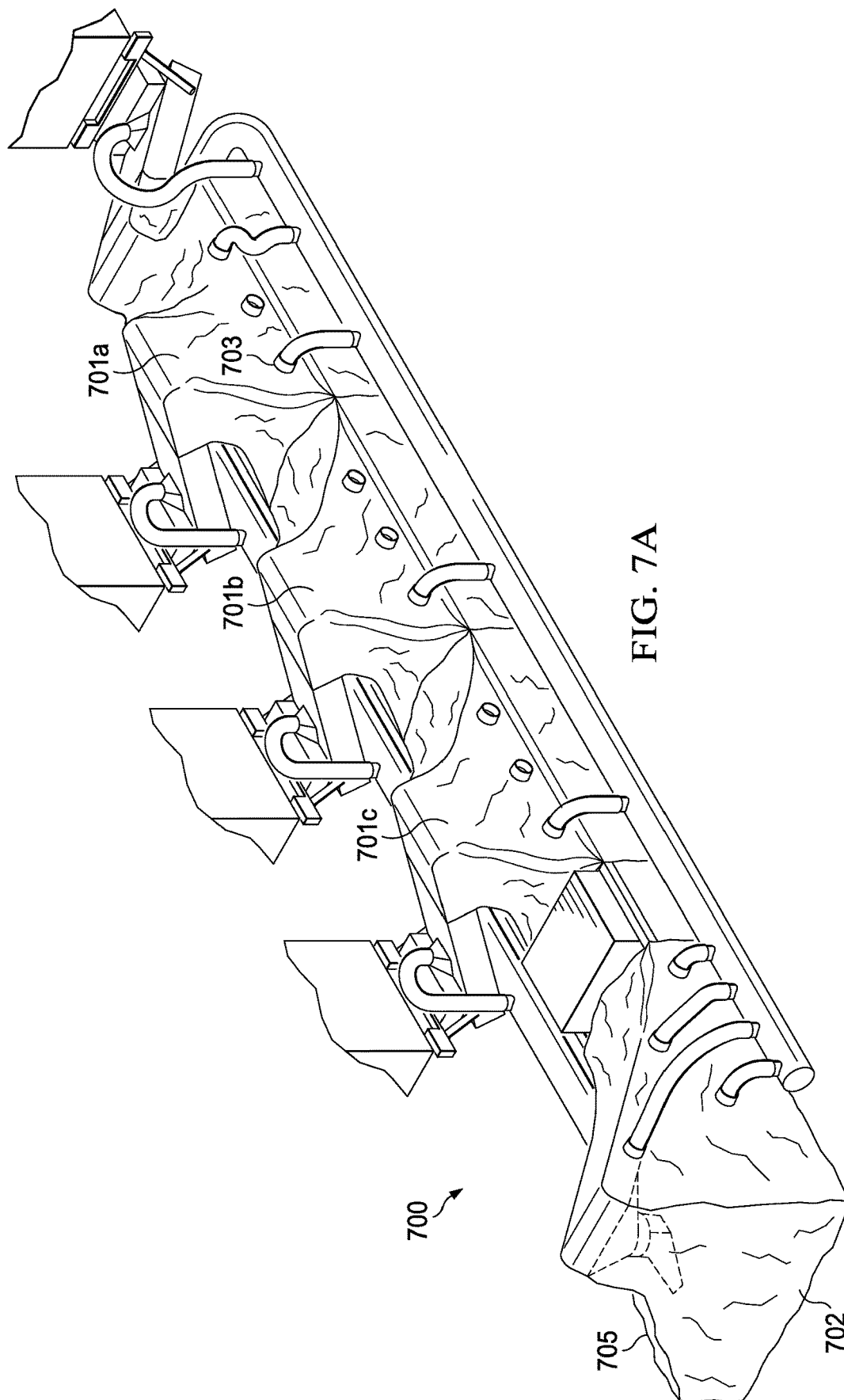


FIG. 6D



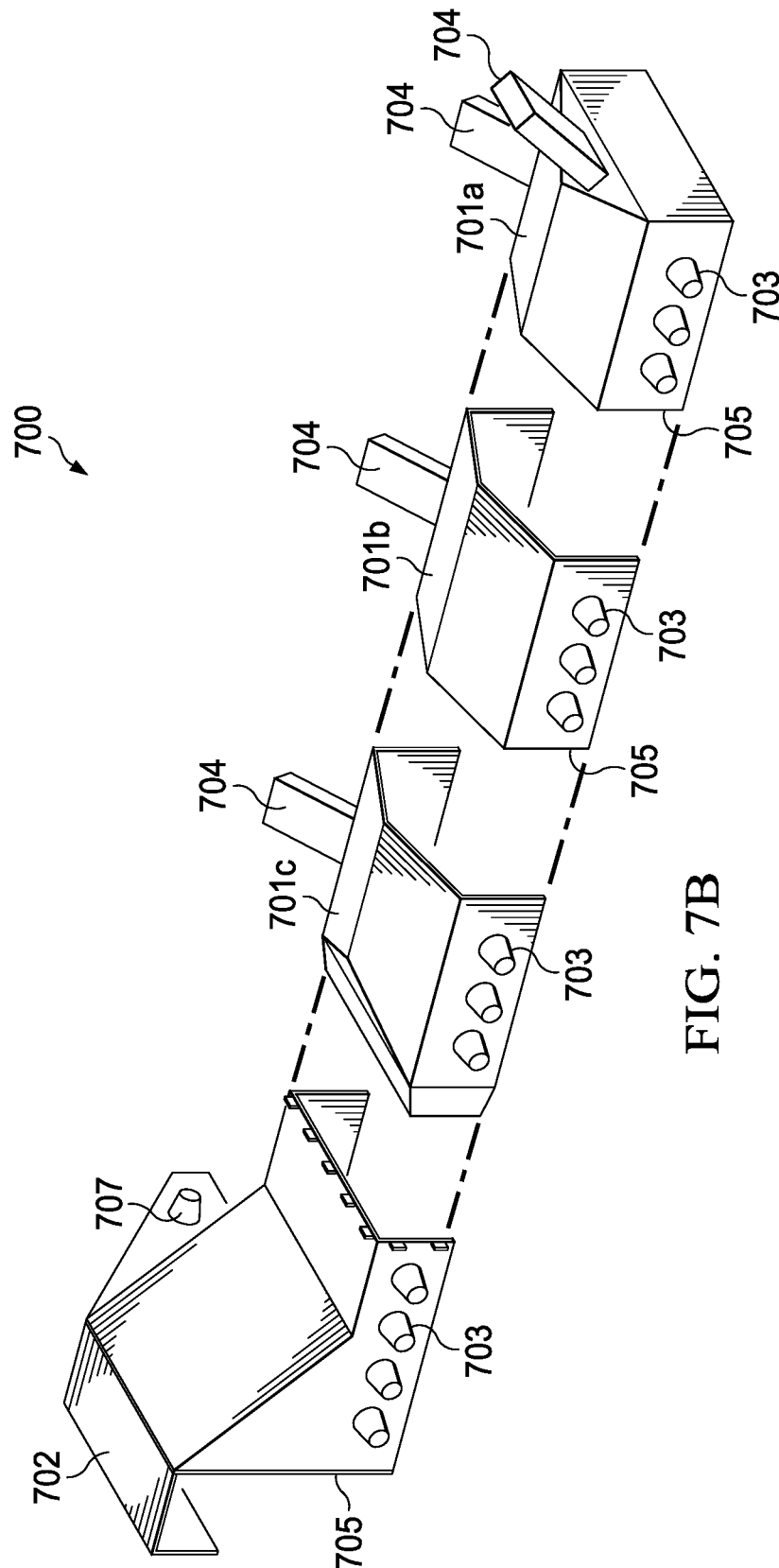


FIG. 7B

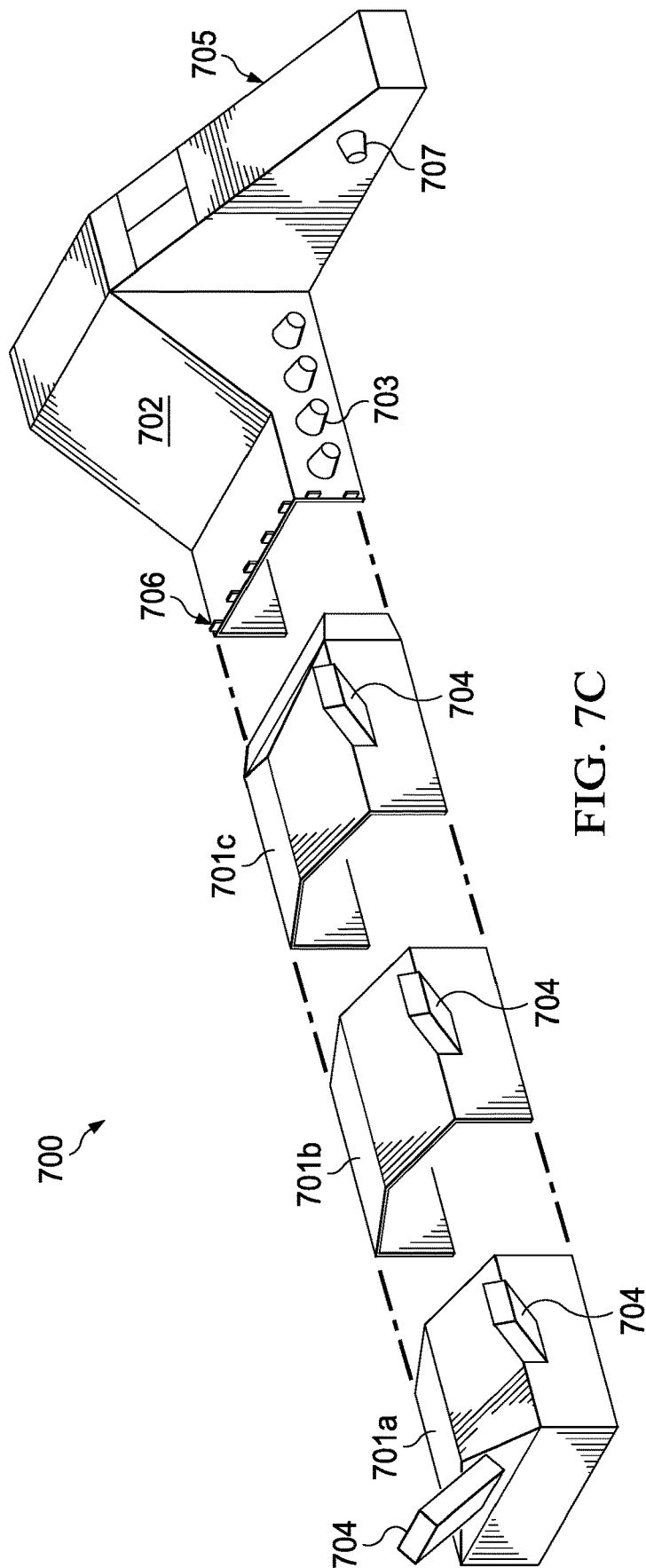


FIG. 7C

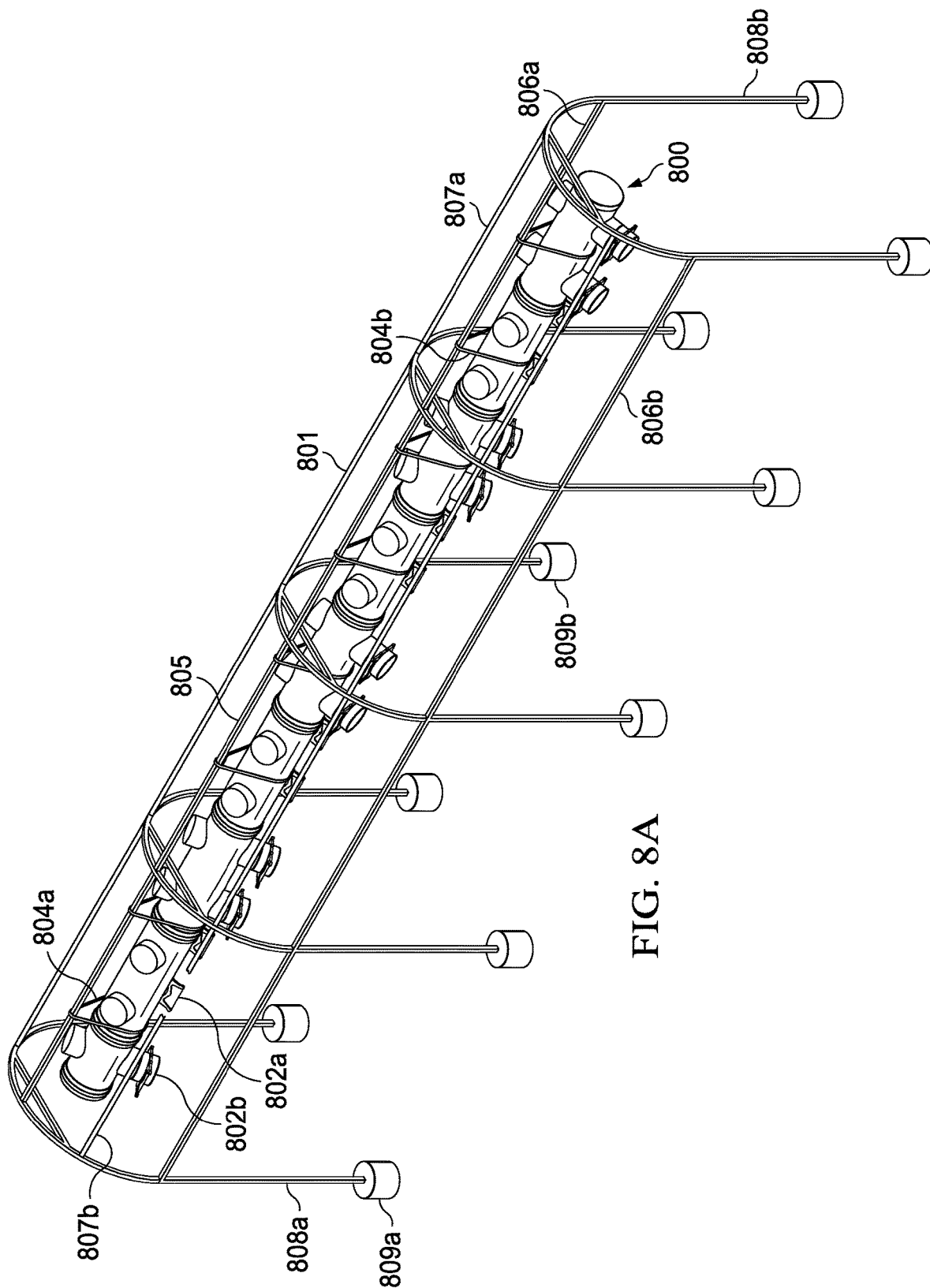


FIG. 8A

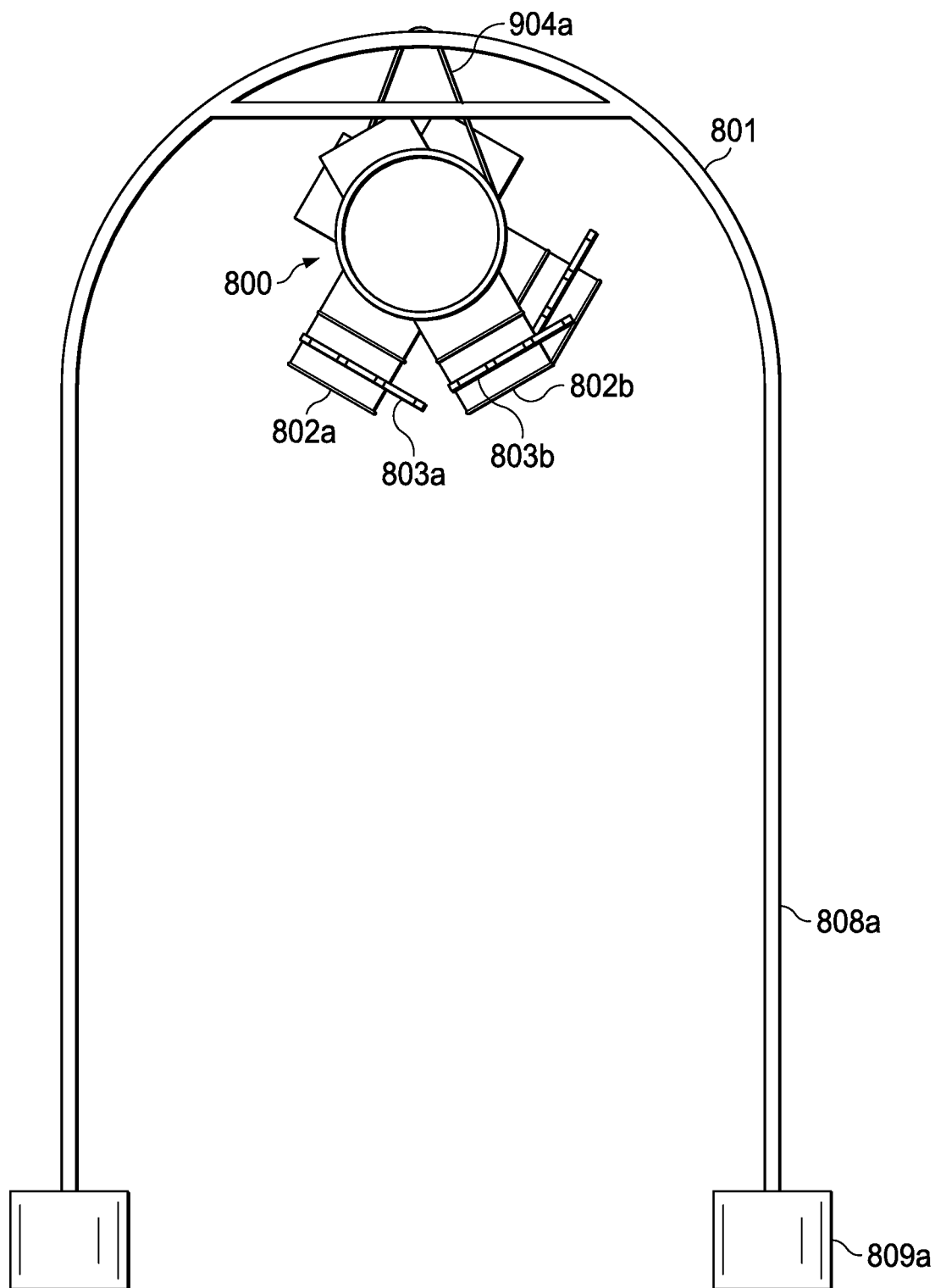


FIG. 8B

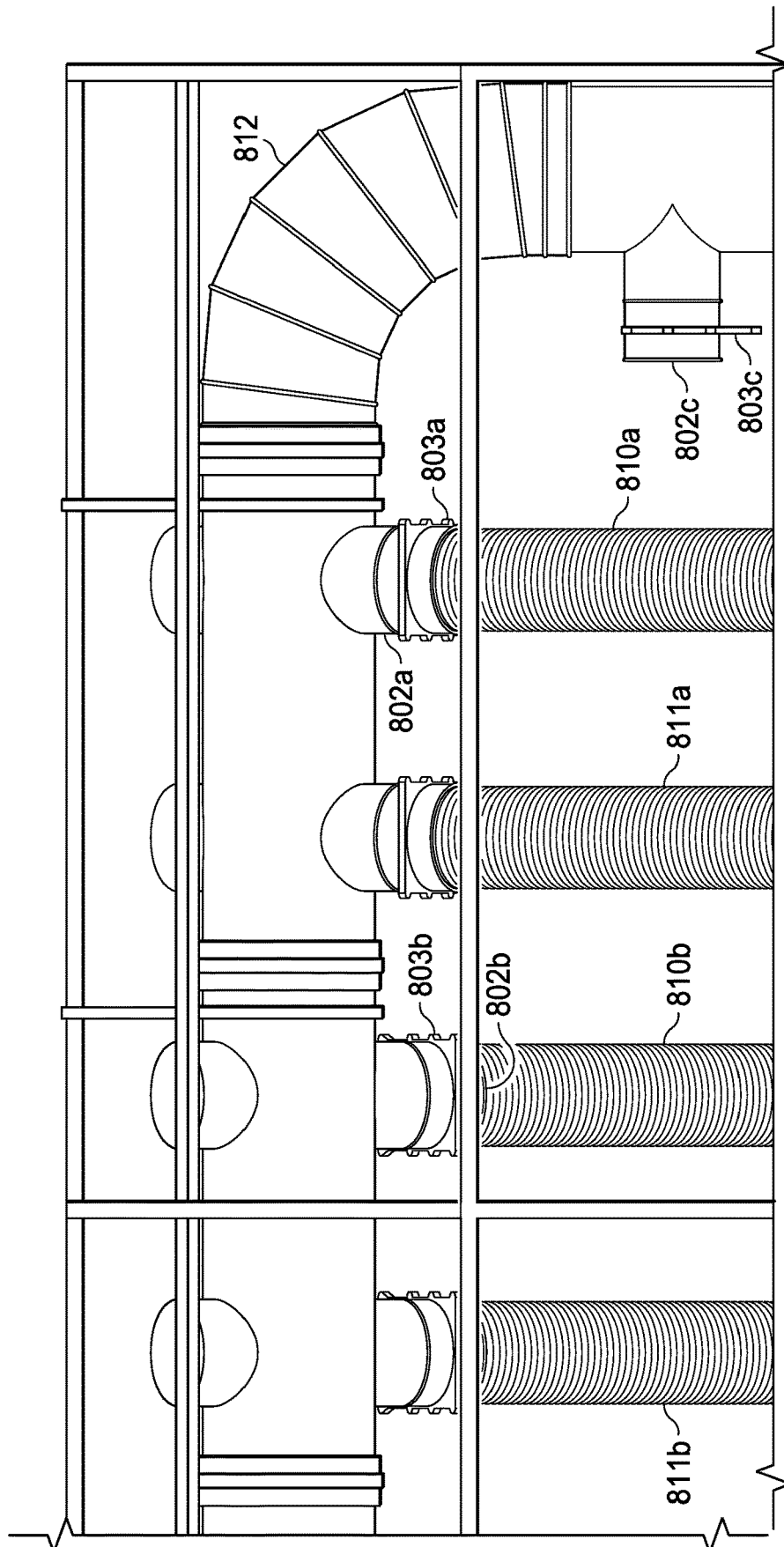


FIG. 8C

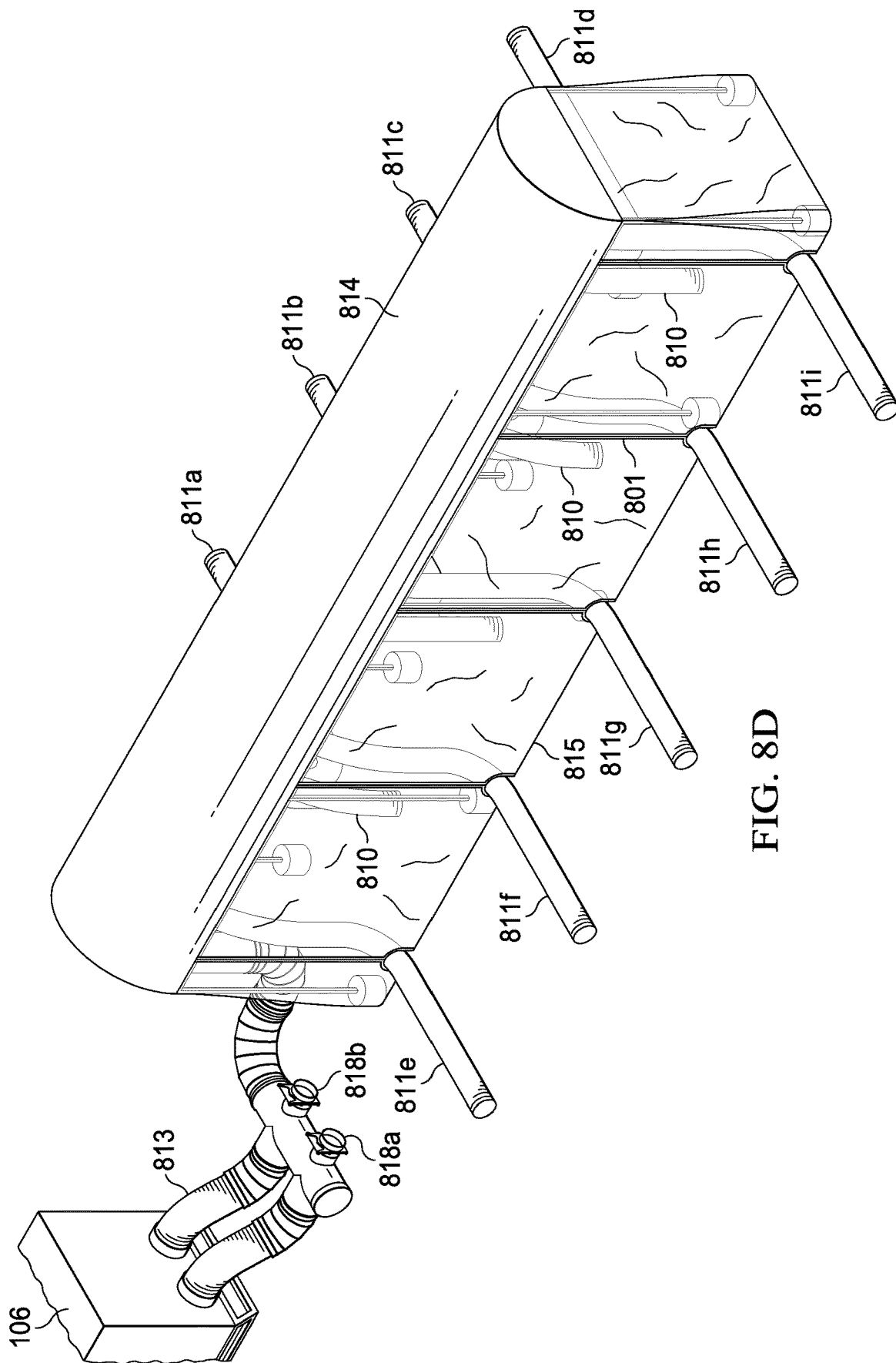


FIG. 8D

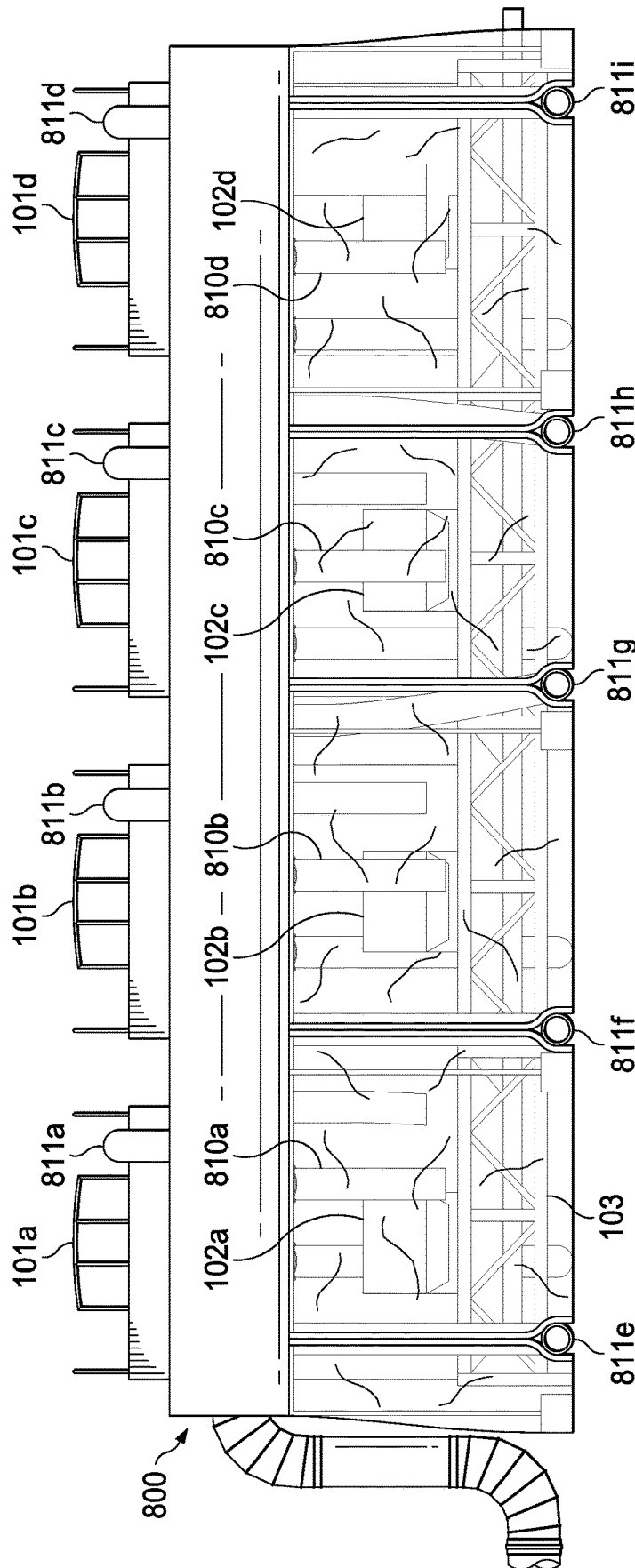


FIG. 8E

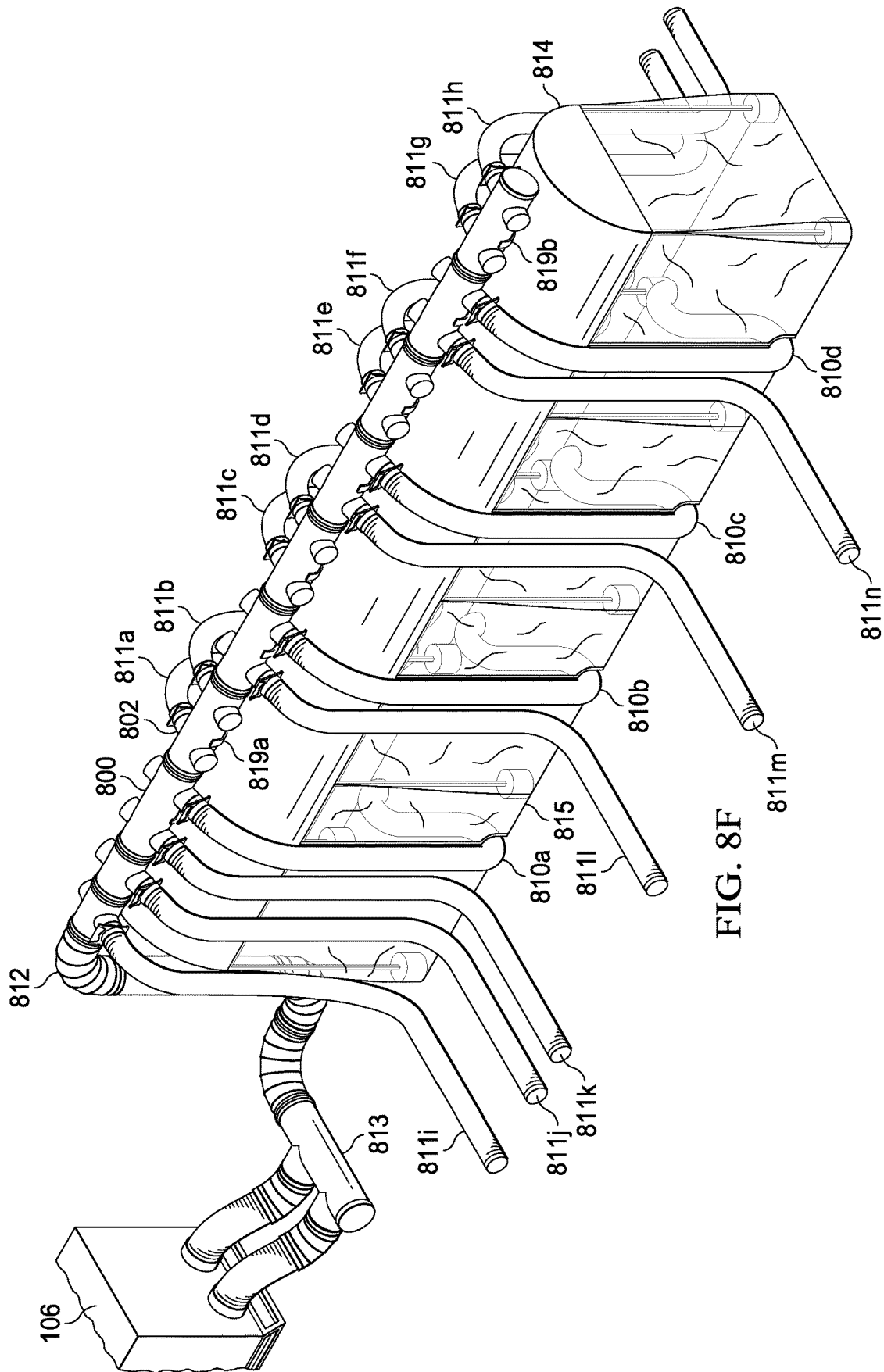
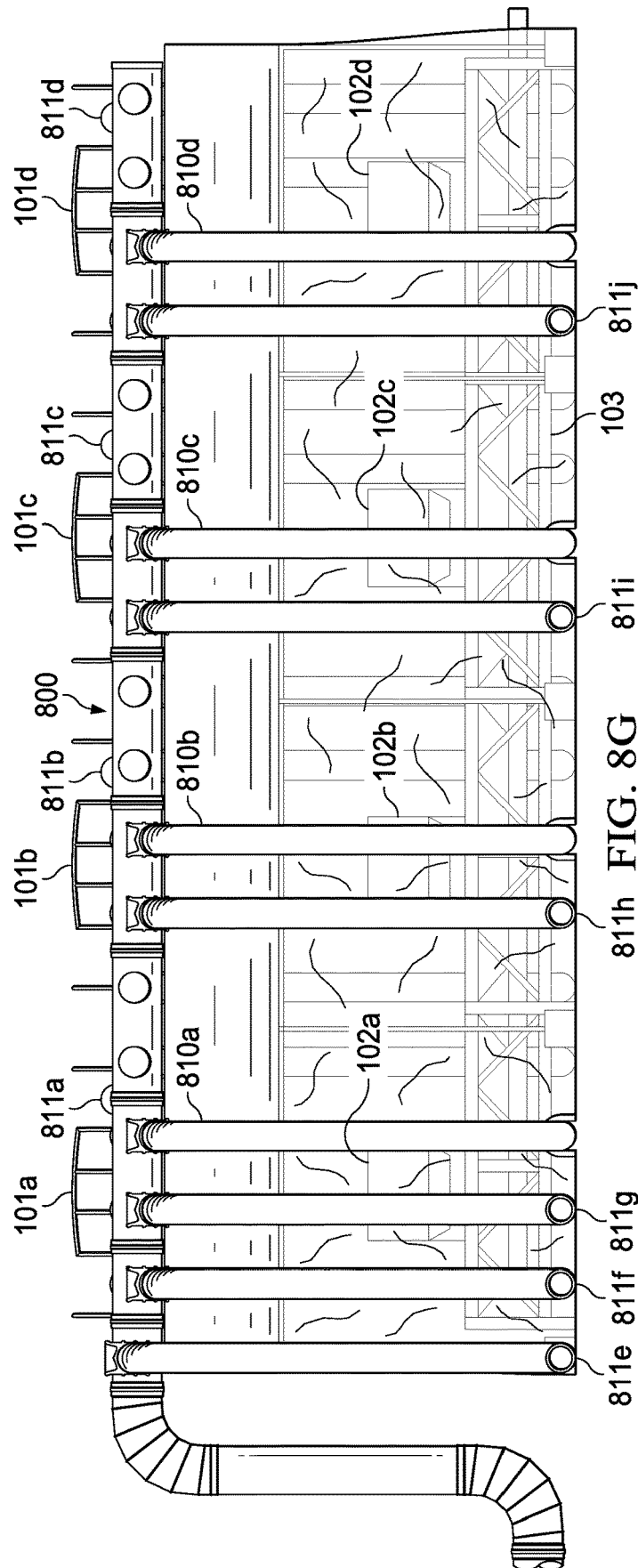


FIG. 8F



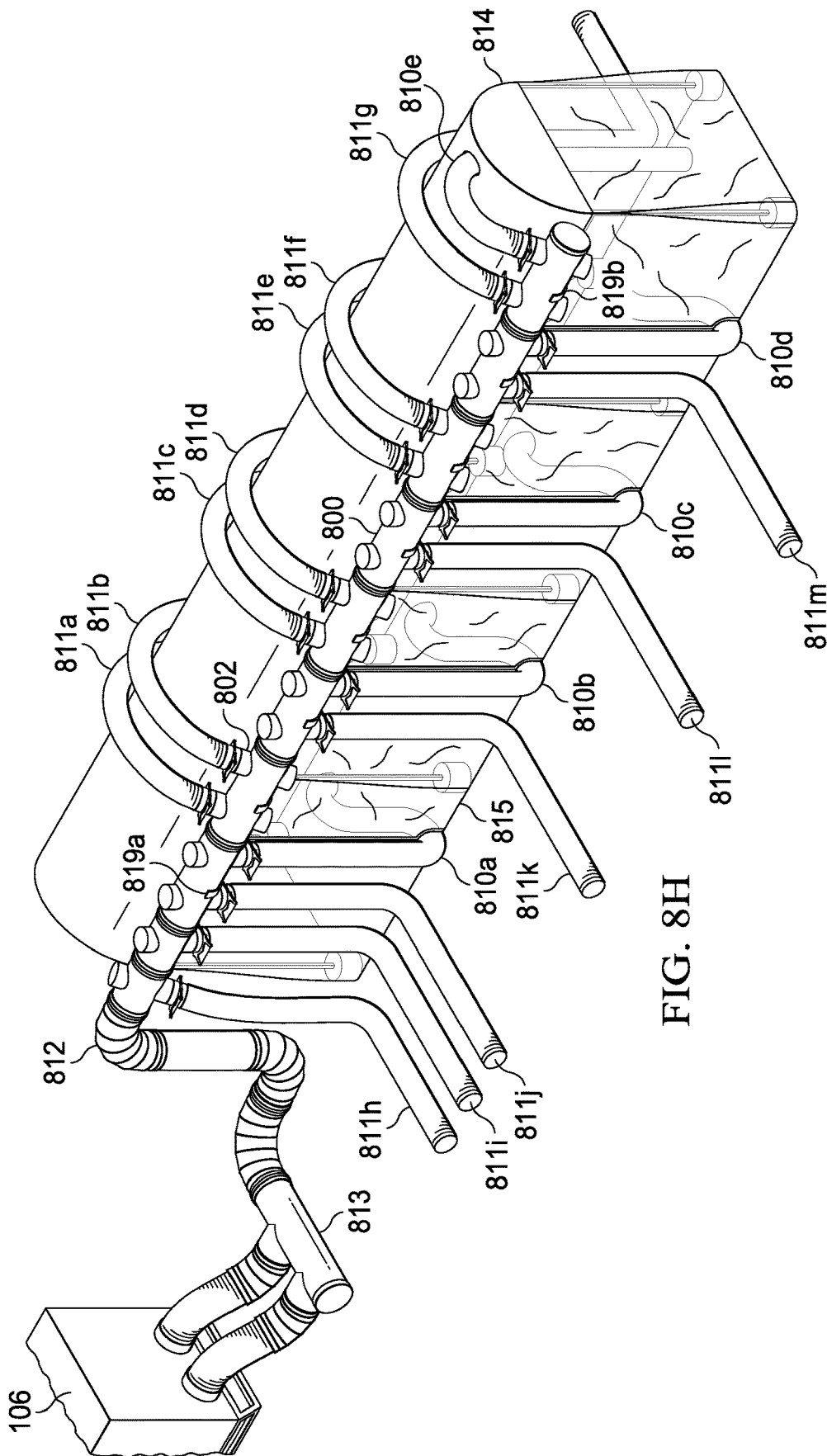
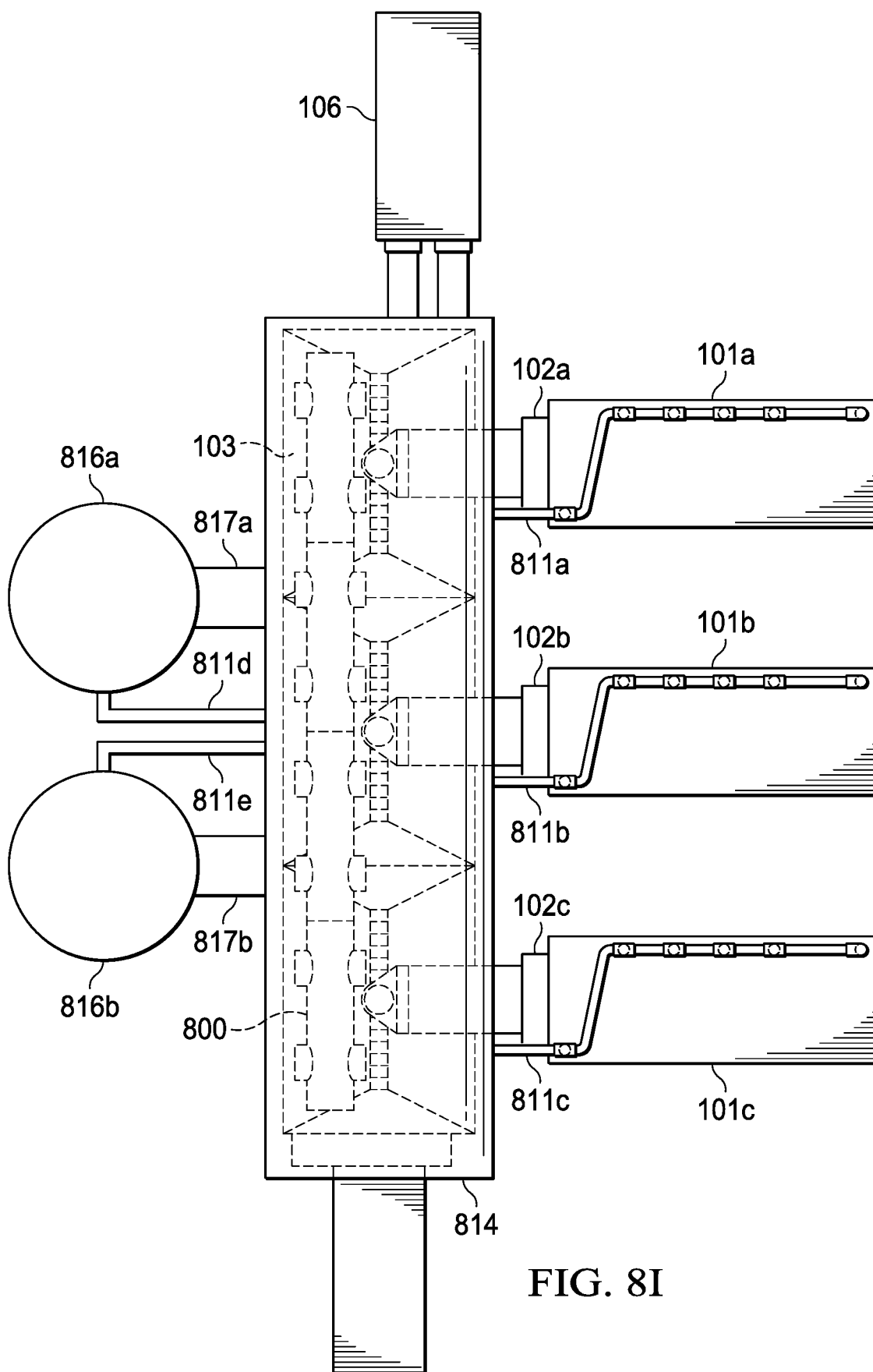
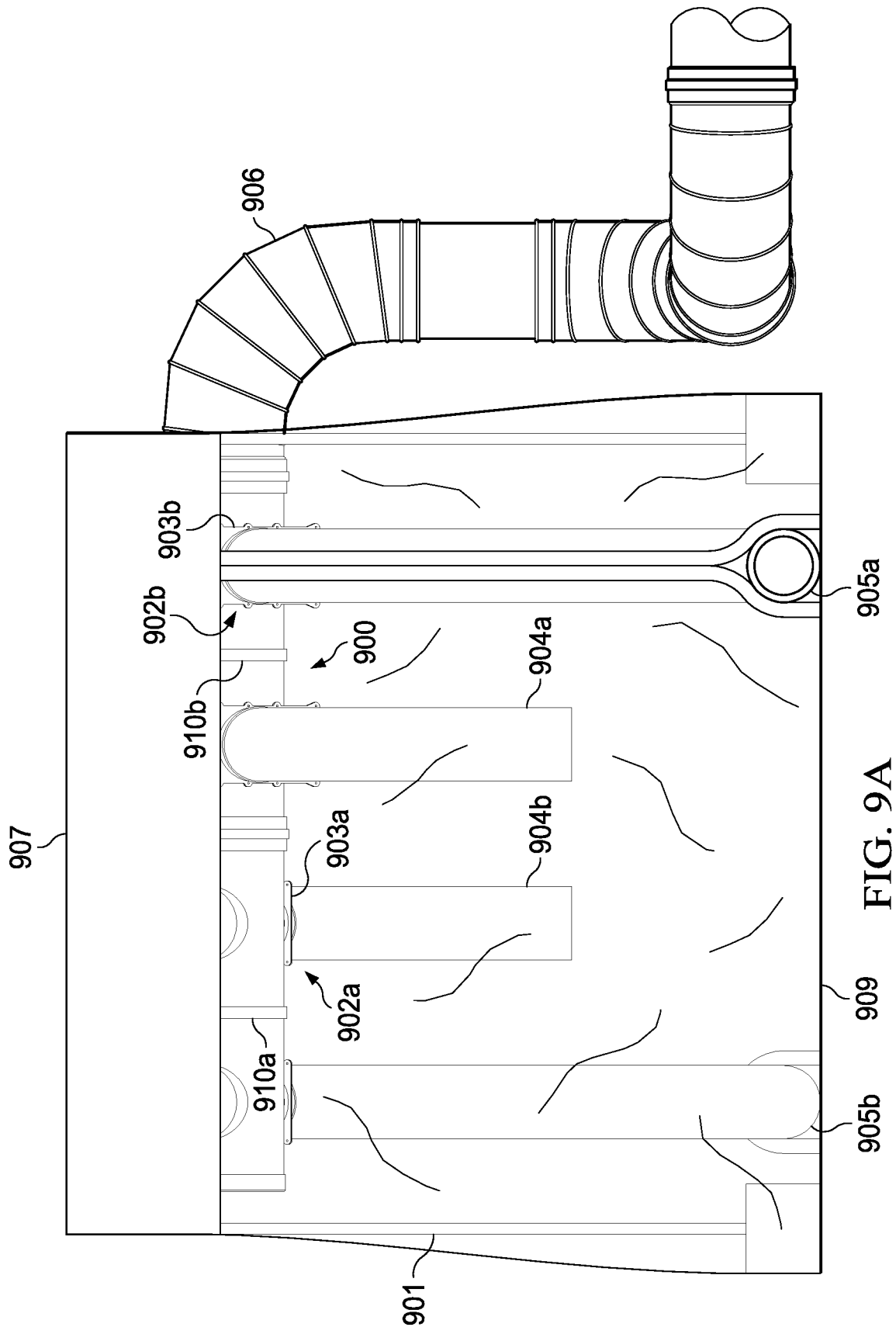
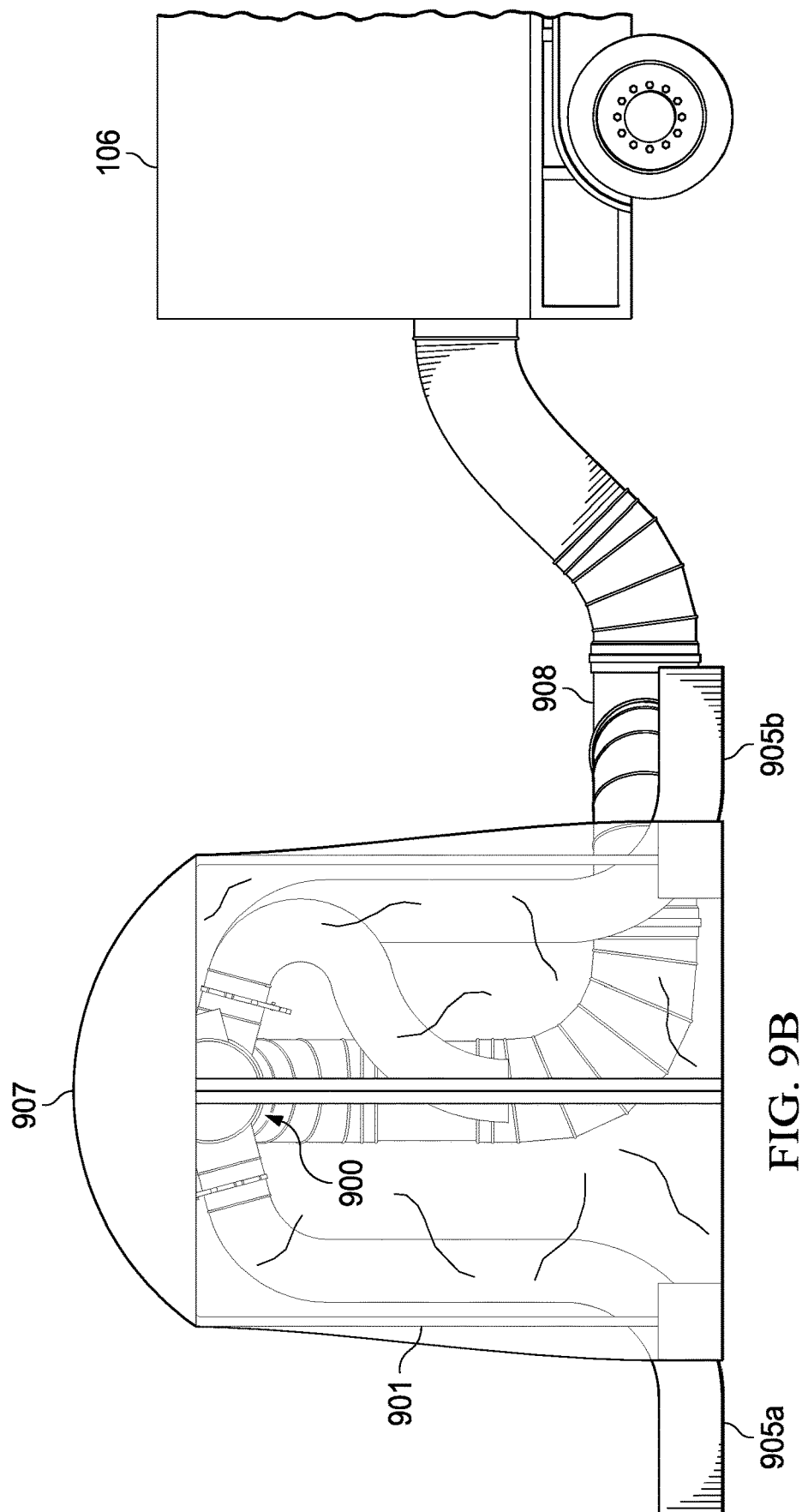


FIG. 8H







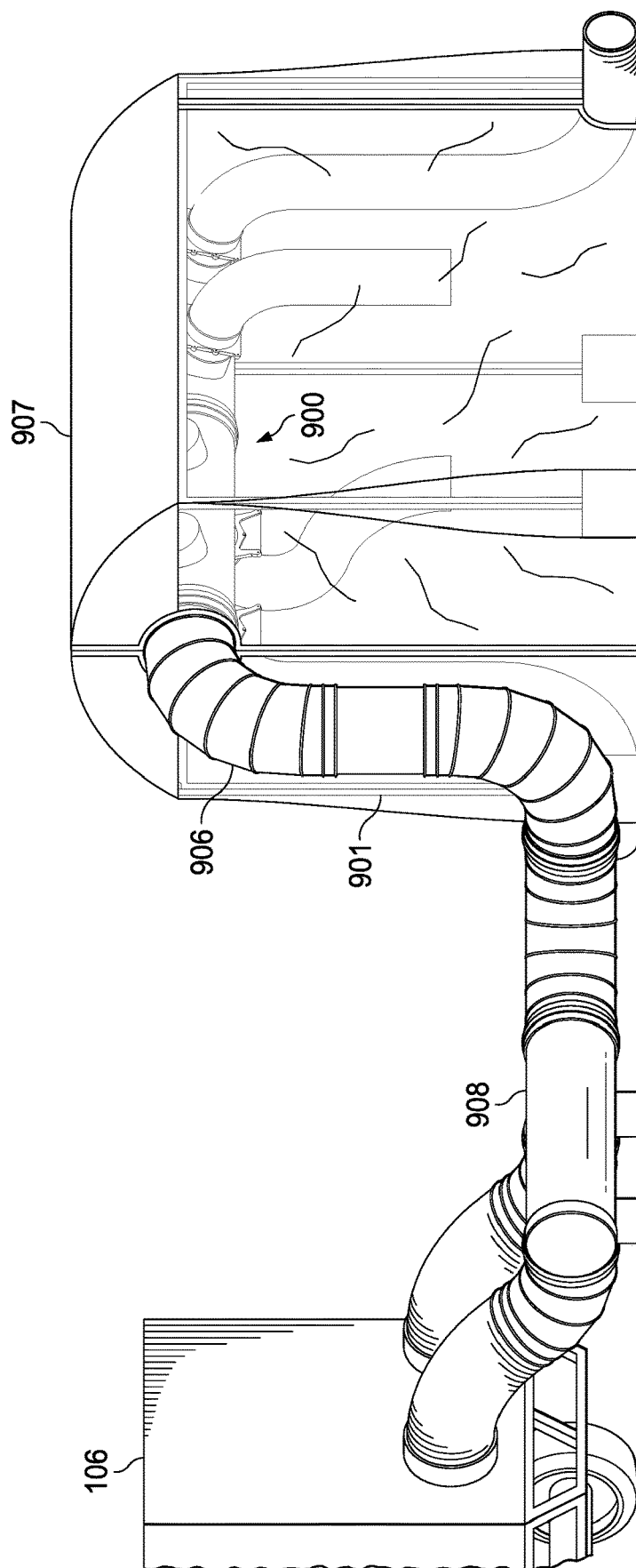


FIG. 9C

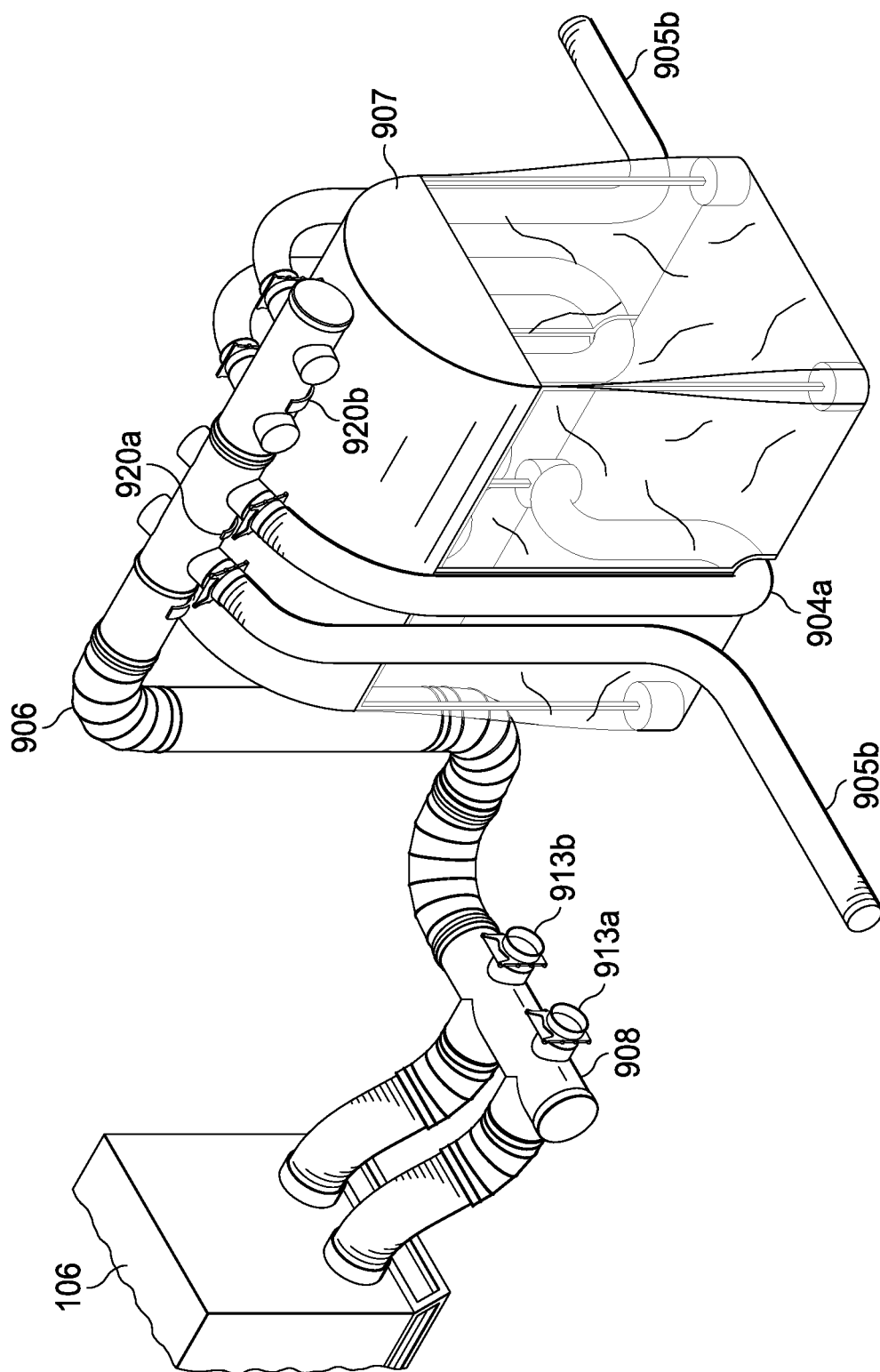


FIG. 9D

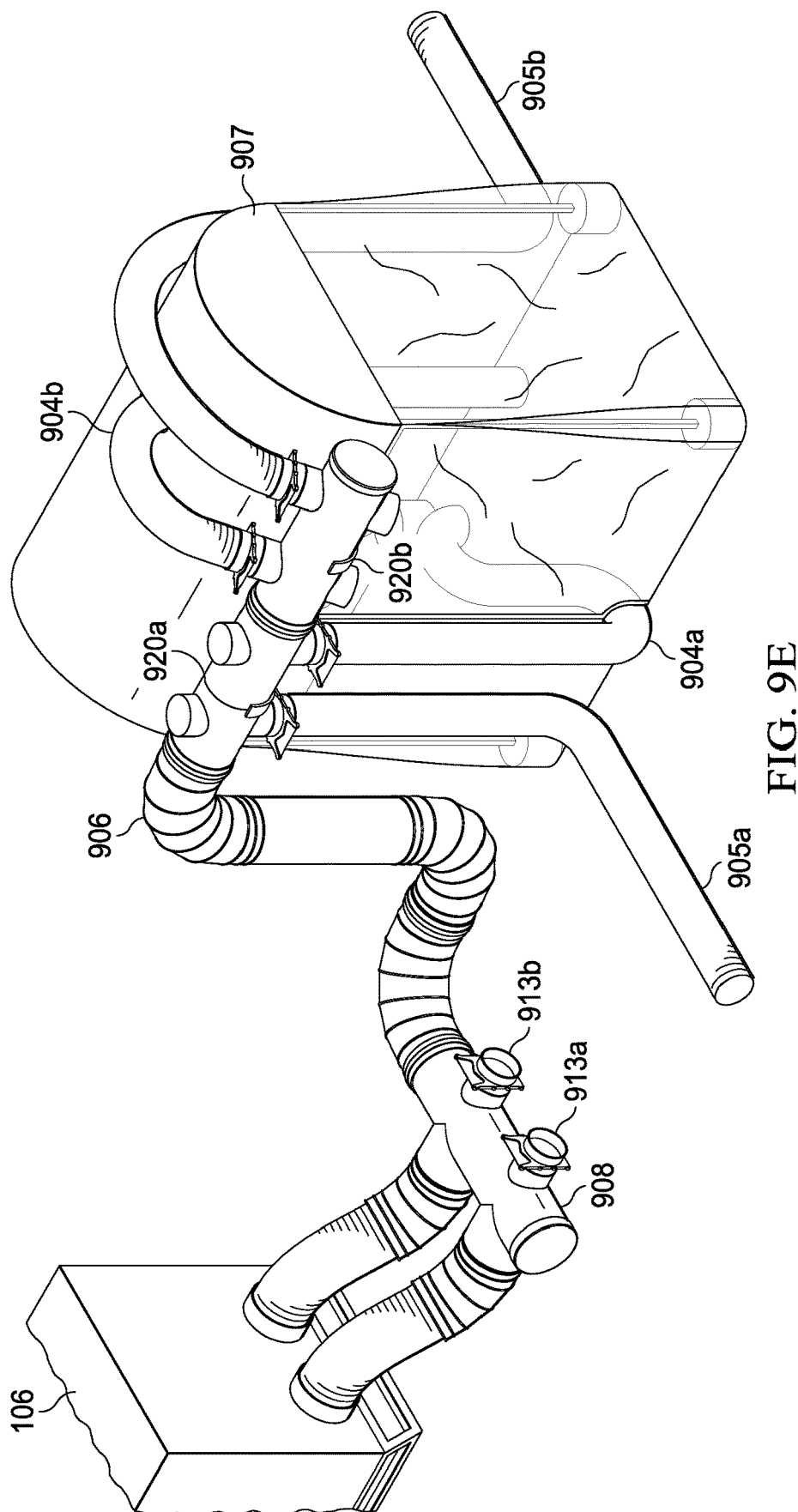


FIG. 9E

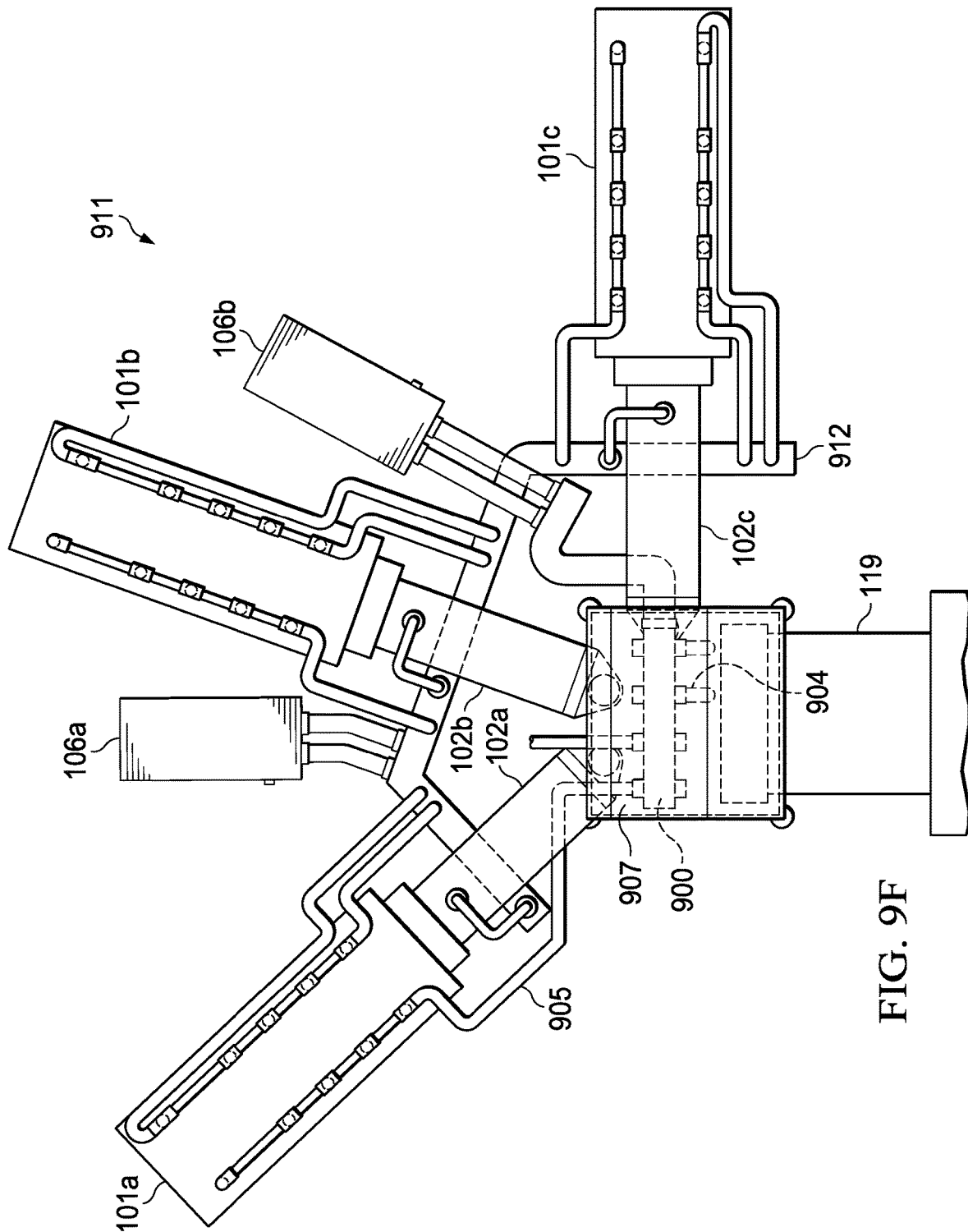


FIG. 9F

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SYSTEMS AND METHODS FOR CONTROLLING SILICA DUST DURING HYDRAULIC FRACTURING OPERATIONS USING AN IMPROVED MANIFOLD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. patent Ser. No. 14/862,354, filed Sep. 23, 2015, which is a continuation of application Ser. No. 14/527,868, filed Oct. 30, 2014, which is a divisional of U.S. patent application Ser. No. 14/178,782, filed Feb. 12, 2014, which is a continuation of U.S. patent application Ser. No. 13/769,456, filed Feb. 18, 2013, all of which are incorporated herein by reference for all purposes.

The present application also claims the benefit of U.S. Provisional Patent Application No. 62/291,419, filed Feb. 4, 2016, which is incorporated herein by reference for all purposes.

FIELD OF INVENTION

The present invention relates in general to hydraulic fracturing, and in particular to systems and methods for controlling silica dust during the handling of frac sand.

BACKGROUND OF INVENTION

Hydraulic fracturing ("fracing") is a well known technique for releasing oil and natural gas from underground reservoirs within rock formations having a limited permeability. For example, fracing is often used to release oil and natural gas, such as natural gas or oil, from shale formations.

Fracing is a well completion technique performed after the drilling of the wellbore, which in the case of releasing natural gas from shale, is commonly a horizontal wellbore, although occasionally the wellbore is vertical. Fracing fluid, which is primarily water and chemicals that form a viscous gel, is pumped into the well to create fractures within the surrounding rock. The viscous gel carries a "proppant" into the fractures, such that when the pumping stops, the fractures remain substantially open and allow the oil and natural gas to escape into the wellbore.

One typical proppant is "frac sand." Frac sand is normally high purity silica sand with grains having a size and shape capable of resisting the crushing forces applied during the closing of the fractures when the hydraulic force provided by the pumping is removed. However, given that frac sand contains a high proportion of silica, the loading, transportation, and unloading of frac sand presents significant safety challenges.

The United States Occupational Safety and Health Administration ("OSHA") lists silica as a carcinogen. In particular, the exposure and inhalation of silica dust has been linked to silicosis, which is an irreversible lung disorder characterized by inflammation and scarring of the upper lobes of the lungs. The best, and perhaps only way, to reduce or eliminate the threat of silicosis is to carefully control worker exposure to silica dust.

OSHA lists a number of different ways to limit worker exposure to silica dust, including limiting worker time at a worksite, limiting the number of workers at a worksite, watering roads and other worksite areas, enclosing points where silica dust is released, and requiring workers to wear respirators. These techniques do not, at least on their own, provide a complete solution to the problem of controlling

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silica dust. Furthermore, these existing techniques, while commendable, are nonetheless burdensome, time-consuming, inefficient, and impractical.

SUMMARY OF INVENTION

One representative embodiment of the principles of the present invention is a system for controlling dust during hydraulic fracturing operations, which includes a manifold having a plurality of ports for capturing dust when negative air pressure is applied to the manifold. A support structure positions the manifold above a piece of hydraulic fracturing equipment receiving sand from a frac sand source.

Another representative embodiment is a system for controlling dust during hydraulic fracturing operations, which includes a support structure and a manifold positioned by the support structure above a piece of frac sand handling equipment receiving frac sand from a frac sand source. An enclosure supported by the support structure encloses at least a portion of the piece of frac sand handling equipment. At least one conduit in fluid communication with the manifold has an inlet for capturing dust contained within the enclosure when negative air pressure is applied to the manifold.

A further exemplary embodiment of the present principles is a frac sand handling system including frac sand handling equipment, and a support structure. An enclosure is supported by the support structure and encloses at least a portion of the frac sand handling equipment including a point at which frac sand is received by the frac sand handling equipment. A manifold is positioned by the support structure above the frac sand handling equipment. The manifold includes a plurality of ports for capturing dust when negative air pressure is applied to the manifold, with at least one of the ports adapted to capture dust generated around the point at which frac sand is received by the frac sand handling equipment.

The present inventive principles advantageously provide for efficient and flexible systems and methods for collecting the silica dust generated during the offload of frac sand from a frac sand source, such as a sand transport and storage trailer, a vertical sand mover, or one or more containers positioned directly above the lateral conveyor. Among other things, by positioning the manifold above the lateral handling equipment (e.g., blender bin and/or tub, t-belt, or dragon tail) the overall profile of the enclosure and manifold system becomes more compact. As a result, the amount of dust control system equipment on or near the ground can be reduced, which reduces tripping hazards, reduces clutter, and increases accessibility to both the dust control system and the associated frac sand handling equipment.

The manifold, support structure, and enclosure can be configured to control dust generated in and around various pieces of frac sand handling equipment such as lateral conveyors (t-belts), angled lifting conveyors (dragon tails), and blenders, as well as different combinations of those pieces of equipment.

The support structure allows the manifold to either be suspended from the support structure using a cable or strap or supported at a point on the support structure itself. The support structure may be free-standing such that other equipment within the frac sand handling and dust control system can be moved or reconfigured without the need to move or reconfigure the manifold, support structure, and/or enclosure.

The support structure also allows the manifold to be positioned inside or outside of the enclosure that contains

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dust generated during operation of the frac sand handling equipment. In embodiments in which the manifold is positioned inside the enclosure, air flow into the manifold can be achieved through a simple aperture through the manifold wall, through a fitting adapted to connect with a flexible conduit, with or without the flexible conduit attached, or through an extended fitting or rigid conduit.

The application of these principles improves the efficiency and flexibility of the frac sand offloading process by allowing increased worker time at the worksite and/or for more workers to be present at the worksite at one time, reducing the need for watering of worksite areas and the enclosure of points where silica dust is released, reducing the need for respirator wear, and decreasing the amount of silica dust intake by the engines of nearby vehicles and equipment.

BRIEF DESCRIPTION OF DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective diagram of a representative frac sand transportation and unloading system including a frac sand silica dust control system according to a preferred embodiment of the principles of the present invention;

FIG. 2 is a plan view diagram of the frac sand transportation and unloading system of FIG. 1, which emphasizes the airflow paths through the frac sand silica dust control system;

FIG. 3 is a plan view diagram of the frac sand transportation and unloading system of FIG. 1, which generally indicates the locations of particular structures of the frac sand silica dust control subsystem shown in more detail in FIGS. 4-6;

FIG. 4A is a diagram showing in further detail the pneumatic connections between the inlets of the silica dust control unit and the manifolds of FIG. 1;

FIG. 4B is a diagram showing in further detail the direct airflow path between the silica dust control unit and the silica dust control conduit subsystem servicing one selected trailer of FIG. 1;

FIG. 4C is a diagram showing in further detail the pneumatic connection between a selected manifold and the silica dust control conduit subsystem serving another selected trailer of FIG. 1;

FIG. 4D is a diagram showing in further detail the pneumatic connections between a selected manifold and the silica dust capture hose controlling silica dust generated during the operation of a corresponding trailer discharge conveyor shown in FIG. 1;

FIG. 4E is a diagram showing in further detail the pneumatic connections between a selected manifold and the silica dust capture hoses controlling silica dust generated by the system discharge conveyor of FIG. 1;

FIG. 5A is a diagram showing in further detail a selected silica dust capture hose controlling silica dust generated by the discharge of frac sand from the tank of representative trailer to the base of the corresponding trailer discharge conveyor shown in FIG. 1;

FIG. 5B is a diagram showing in further detail a selected silica dust capture hose controlling silica dust generated by the discharge of frac sand from the outlet of a corresponding representative trailer conveyor to the lateral transfer conveyor section of FIG. 1;

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FIG. 5C is a diagram showing the hoses controlling silica dust generated during the movement of sand by the upwardly angled conveyor section of FIG. 1 to a point above the bin of the blender of FIG. 1, along with the silica dust capture hose controlling silica dust generated during the discharge of sand into the blender bin from the conveyor section spout;

FIG. 6A is a diagram showing in further detail the pneumatic connections of the silica dust control conduit subsystem of a representative one of the trailers of FIG. 1;

FIG. 6B is a diagram showing in further detail one of the T-fittings interconnecting the air conduits of the silica dust control conduit subsystem shown in FIG. 6A;

FIG. 6C is a diagram showing one of the end fittings terminating the air conduits of the silica dust control conduit subsystem shown in FIG. 6A;

FIG. 6D is a diagram showing the four-way fitting interconnecting the air conduits of the silica dust control subsystem of one particular trailer with the silica dust control unit, as shown in FIG. 4B;

FIG. 7A is a diagram showing an alternative embodiment of the principles of the present invention in which a cover is provided over portions of the representative frac sand transportation and unloading system of FIG. 1 for containing silica dust generated during movement of sand through the system;

FIG. 7B is a conceptual diagram providing a first detailed view of a representative embodiment of the cover shown in FIG. 7A;

FIG. 7C is a conceptual diagram providing a second detailed view of the representative embodiment of the cover shown in FIG. 7A;

FIG. 8A is a perspective view diagram of a representative raised manifold system according to the principles of the present invention, which is suitable for use in a frac sand silica dust control system, such as that shown in FIG. 1;

FIG. 8B is an end elevational view diagram of the raised manifold system of FIG. 8A;

FIG. 8C is a diagram providing a more detailed side elevational view of a portion of the raised manifold system of FIG. 8A along with a representative number of attached dust collection conduits;

FIG. 8D is a perspective view diagram of the raised manifold system of FIG. 8A shown connected to an associated air movement system and disposed within an enclosure suitable for containing dust generated along the lateral conveyor and/or lifting conveyor of FIG. 1;

FIG. 8E is a side elevational view diagram showing a representative use of the raised manifold and enclosure system of FIGS. 8A-8D in the system of FIG. 1, wherein the lateral conveyor is enclosed and flexible conduits attached to the raised manifold collect dust generated at points along the lateral conveyor and from within the sand transportation and storage containers;

FIG. 8F is a perspective view diagram of an alternative raised manifold and enclosure system according to the principles of the present invention, which is suitable for use in a frac sand silica dust control system such as that shown in FIG. 1;

FIG. 8G is a side elevational view diagram showing a representative use of the raised manifold and enclosure system of FIG. 8F in the system of FIG. 1, wherein the lateral conveyor is enclosed and flexible conduits collect dust generated along the lateral conveyor and from within the transportation and storage containers;

FIG. 8H is a perspective view diagram of another alternative raised manifold and enclosure system according to

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the principles of the present invention, which is suitable for use in a frac sand silica dust control system such as that shown in FIG. 1;

FIG. 8I is a top plan view diagram of an alternative sand transportation and unloading system including a frac sand silica dust control system using the raised manifold and enclosure system of FIGS. 8A-8D;

FIG. 9A is a side elevational view diagram of another alternative raised manifold and enclosure system according to the inventive principles and suitable for containing dust generated in and around a blender bin, blender tub, or both, in a dust control system such as that shown in FIG. 1;

FIG. 9B is an end elevational view diagram of the raised manifold and enclosure system shown in FIG. 9A, as connected to an air system such as that shown in FIG. 1;

FIG. 9C is a perspective view diagram of the raised manifold and enclosure system of FIGS. 9A-9B, shown connected to an air system such as that shown in FIG. 1;

FIG. 9D is a perspective view diagram of a further alternative raised manifold and enclosure system according to the inventive principles, as connected to an air system such as that shown in FIG. 1; and

FIG. 9E is a perspective view diagram of an additional alternative raised manifold and enclosure system according to the inventive principles, as connected to an air system such as that shown in FIG. 1;

FIG. 9F is a top plan view diagram of an alternative sand transportation and unloading system including a frac sand silica dust control system using the raised manifold and enclosure system of FIGS. 9A-9C.

DETAILED DESCRIPTION OF THE INVENTION

The principles of the present invention and their advantages are best understood by referring to the illustrated embodiment depicted in FIGS. 1-9 of the drawings, in which like numbers designate like parts.

FIG. 1 is a diagram of an exemplary frac sand transportation, storage, and unloading system **100** including a frac sand silica dust control system according to a preferred embodiment of the principles of the present invention. System **100** is also shown in the plan views of FIGS. 2 and 3, with FIG. 2 emphasizing the air flow paths of the silica dust control system and FIG. 3 generally showing the locations of particular features of the silica dust control system shown in further detail in FIGS. 4-6.

Generally, system **100** is assembled at a hydraulic fracturing worksite and is used to offload frac sand transported to the worksite from a frac sand supplier via trailers and offloaded into a blender. The blender mixes the sand with the water and chemicals to form the fracturing fluid. Given the significantly large amounts of frac sand that are typically required during typical hydraulic fracturing operations, a substantial amount of potentially hazardous silica dust is commonly generated during conventional trailer offloading operations. The principles of the present invention advantageously provide for the control of frac sand produced silica dust, which consequently improves personnel safety, helps reduce the need for respirators and other burdensome safety equipment, and allows personnel to work longer and more efficiently at the worksite.

In the illustrated embodiment of system **100** shown in FIGS. 1, 2, and 3, four (4) conventional sand storage trailers **101a-101d** are shown at a fracturing worksite. While four (4) trailers **101** are shown as an example, the actual number of sand storage trailers **101** utilized in any particular embodi-

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ment or configuration of system **100** may vary based on the needs and restrictions at the worksite. The size and configuration of system **100** in any given worksite application will depend on such factors as the amount of sand that must be offloaded, the speed at which sand must be offloaded, and the size and capabilities of the offloading conveyor system. In the illustrated embodiment of system **100**, each trailer **101** includes a retractable trailer discharge conveyor (transfer belt) **102a-102d**, which receives sand from the compartments of the trailer internal tank via a lateral transfer belt running underneath the trailer tank (not shown). Trailers **101** are, for example, Sand King 3000/4000 frac sand trailers from Convey-All Industries, Inc., although there are a number of other commercially available sand storage trailers known in the art. It should also be recognized that the principles of the present invention are also applicable to embodiments of system **100** in which sand is stored and discharged from other types of fixed and transportable storage systems, such as tanks, silos, compartmented vehicles, and so on.

Each trailer discharge conveyor **102a-102d** discharges sand to a conventional transportable conveyor system, for example, Unibelt conveyor system from Convey-All Industries, Inc., which includes a continuous transfer belt running through a lateral conveyor section **103** and a upwardly angled discharge conveyor section **105**. During typical offloading operations, one or more randomly selected trailers **101** discharge sand to the lateral conveyor section **103** at a given time.

Sand being discharged by each trailer discharge conveyor **102a-102d** falls through slots **104** and onto lateral conveyor section **103**. Lateral conveyor section **103** then carries the sand to upwardly angled discharge conveyor section **105**, which discharges the sand to a bin of a blender truck **119** (FIGS. 3 and 5C), which mixes the sand with water and chemicals in quantities needed for the formulation of the particular fracturing fluid being used.

The amount of sand being transferred at any one time in system **100** can be substantial. For example, a Convey-All Unibelt conveyor can nominally transfer and discharge 22,000 pounds per minute of sand from trailers **101a-101d**. The generation of a corresponding substantial amount of fine silica dust is a natural consequence of this transfer and discharge process.

According to the principles of the present invention, silica dust generated during the offloading of trailers **101a-101d** is collected by suction at selected points around system **100** most susceptible to the generation and discharge of silica dust. In the preferred embodiment, silica dust is collected: (1) within the compartments of the tanks of trailers **101a-101d**; (2) at the base of each trailer discharge conveyor **102a-102d**, near the point at which sand is received from the trailer lateral conveyor and the trailer tanks; (3) at the point sand is discharged from trailer discharge conveyors **102a-102d** through slots **104** and onto lateral conveyor section **103**; (4) at multiple points along upwardly-angled discharge conveyor section **105**; and (5) near the point sand is discharged from the spout of discharge conveyor **105** in to the bin of blender **119**. It should be noted that in alternative embodiments, silica dust may be collected at additional points, or even fewer points, within system **100**, as required.

The silica dust control function of system **100** is driven by a silica dust control unit **106**, which draws silica dust-bearing air collected at points across the system through a pair of large manifolds **107** and **108**. In the illustrated embodiment of system **100**, silica dust control unit **106** also draws silica dust-bearing air directly from trailer **101d**

through flexible hosing **109**, although this is not a strict requirement of the principles of the present invention. Silica dust control unit **106**, which may include a baghouse and/or cyclone, separates the silica dust from the air and discharges substantially silica dust-free air into the surrounding environment. One exemplary silica dust control unit, suitable for use as silica dust control unit **106** of system **100**, is an ETI Cyclone 20 DC system, available from Entech Industries, which includes multiple twenty-inch (20") inlets and produces a nominal airflow of 20000 cubic feet per minute (cfm).

Silica dust control unit **106** establishes airflow in the direction shown by arrows in FIG. 2. In the preferred embodiment, two intake ports of silica dust control unit **106** are pneumatically connected with manifolds **107** and **108**, which run along corresponding sides of lateral conveyor section **103**, and one intake port of silica dust control unit **106** is directly pneumatically connected to trailer **101d** through flexible hosing **109**.

Silica dust generated in each of the compartments of trailers **101a-101d** is collected through a corresponding set of fittings **110a-110f** and hoses **111a-111e**. In the illustrated embodiment of system **100**, the compartments of trailers **101a-101c** are pneumatically coupled to manifold **107** through flexible hosing **113a-113c**. For trailer **101d**, one fitting **110** is replaced with a four-way fitting **112**, which directly pneumatically couples the compartments of trailer **101d** with silica dust control unit **106**.

Flexible hoses **114a-114c**, which tap manifold **107**, and the flexible hose **114d**, which taps manifold **108**, collect silica dust at the bases of each trailer discharge conveyor **102a-102d**. Flexible hoses **115a-115d**, which tap manifold **108**, collect silica dust at the discharge points of trailer discharge conveyor **102a-102d** into slots **104a-104c** of lateral conveyor section **103**. Flexible hoses **116a-116d**, which tap manifold **108**, collect silica dust moving up upwardly angled discharge conveyor section **105**. It should be noted that the pneumatic paths between silica dust collection hoses **113**, **114**, **115**, and **116** and silica dust control unit **106** may vary between embodiments of system **100**. In the preferred embodiment of system **100** shown in FIG. 1, the tapping point, as well as the manifold **107** or **108** being tapped, minimizes the lengths of manifolds **107** and **108** and silica dust collection hoses **113**, **114**, **115**, and **116**. Generally, so long as sufficient suction is available at a given silica dust collection point, the manifold **107** or **108** tapped, the point on the manifold **107** or **108** tapped the corresponding flexible hose, or both, may be varied.

A flexible hose **117**, which taps manifold **107**, captures silica dust generated by the discharge of sand from upwardly angled discharge conveyor **105** into the bin of blender **119**. (While flexible hose **117** taps manifold **107**, in alternative embodiments flexible hose **117** may tap manifold **108**).

Manifolds **107** and **108** include a number of straight sections **120** and bent or curved sections **121** and are preferably constructed as tubes or pipes of rigid metal, such as aluminum. Rigid metal embodiments provide durability, particularly when manifolds **107** and **108** sit on or close to the ground and/or are exposed to contact by personnel or to other structures within system **100**. However, in alternative embodiments, manifolds **107** and **108** may be constructed, either in whole or in part, from sections of semi-rigid conduit or flexible (corrugated) hose. For example, semi-rigid conduit or flexible hose may be used in sections **121** of manifolds **107** and **108** that must be bent to provide a path around, over, or under, other structures in system **100**.

Preferably, manifolds **107** and **108** are each constructed in multiple straight sections **120** and multiple bent or curved sections **121**, which are clamped together using conventional clamps. This preferred construction allows manifolds **107** and **108** to be efficiently assembled and disassembled at the worksite, allows the most direct paths to be taken to silica dust control unit **106**, and allows the overall system of conduits to be adapted to different configurations of system **100** (e.g., different types and number of trailers **101**, different transportable conveyor systems, different surface conditions).

Additionally, the diameters of the various sections of manifolds **107** and **108** may increase or decrease, depending on the airflow provided by the given silica dust control unit **106**. The diameters of manifolds **107** and **108** are determined by a number of factors, including the intake diameters of silica dust control unit **106**, the airflow produced by silica dust control unit **106**, and the amount of suction needed at the silica dust collection points. Similarly, the diameters of silica dust collection hoses **113**, **114**, **115**, and **116** will depend on factors such as the airflow available from silica dust control unit **106**, the diameters of manifolds **107** and **108**, and the amount of suction required at a given hose inlet. In one typical embodiment of system **100**, manifolds **107** and **108** have a nominal diameter of twenty inches (20") and silica dust collection hoses **113**, **114**, **115**, and **116** are nominally within the range of six to sixteen inches (6"-16") in diameter. In other words, the principals of the present invention advantageously allow for variations in the components and configuration of system **100**.

It should be recognized that the transportable conveyor system, including lateral conveyor section **103** and discharge conveyor section **105**, is not always required. In this case, one or more trailer discharge conveyors **102** discharge sand directly from the corresponding trailers **101** into the bin of blender **119**. In embodiments of system **100** that do not utilize the transportable conveyor system, only a corresponding number of flexible hoses **114** and **115** are required for collecting silica dust at the base and outlet of each trailer discharge conveyor **102** discharging to blender **119**. (Along with the desired connections for removing dust within the trailers **101** themselves.) Advantageously, only single manifold **107** or **108** may be required in these embodiments.

FIG. 4A is a more detailed diagram showing the pneumatic connections between manifolds **107** and **108** and silica dust control unit **106**. FIG. 4B shows the direct pneumatic connection between trailer **101d** and silica dust control unit **106** through flexible hose **109** in further detail.

FIGS. 4C-4E illustrate representative tapping points between the heavier rigid sections **120** of manifolds **107** and **108** and selected flexible hoses utilized in system **100**. In particular, FIG. 4C shows a representative pneumatic connection between manifold **107** and hose **113c** collecting silica dust from the tank compartments of trailer **101c**. FIG. 4D shows representative pneumatic connections between manifold **108** and hose **114d**, which collects silica dust generated at the base of trailer discharge conveyor **102d**, and hoses **115c** and **115d**, which collect silica dust generated at corresponding outlets of trailer discharge conveyors **102c** and **102d**. FIG. 4E shows representative pneumatic connections between manifold **108** and hoses **116a-116d** collecting silica dust generated by discharge conveyor section **105**.

As well known in the art, numerous techniques are commonly utilized for connecting flexible hose with a rigid conduit or pipe, many of which are suitable for use in system **100**. In the illustrated embodiment shown in FIGS. 4C-4D, an aperture is tapped through the wall of the given manifold

107 or 108 and the lower periphery of a fitting (e.g., aluminum or steel pipe) 401 is attached, for example, by welding or brazing. The lower section of a coupling 402 is attached to the upper periphery of fitting 401, for example by welding or brazing. The tubular upper section 403 of coupling 402 is received with the periphery of the corresponding hose, which is then clamped in place by one or more conventional clamps 404. When necessary, an extension or elbow (not shown) may be provided between upper section 403 of coupling 402 and the corresponding hose. Similarly, a reduction coupling (see FIG. 5A, designator 501) may be provided between upper section 403 and coupling 402, as required to transition to the selected hose diameter.

In the preferred embodiment shown in FIGS. 4C-4E, each coupling 402 includes a slide gate, which provides for air flow control between the given silica dust capture hose 113, 114, 115, and 116 and the corresponding manifold 107 or 108. In addition to allowing control of the amount of suction produced at the capture hose inlet, these slide gates also allow any unused taps to manifolds 107 and 108 to be completely shut off, particularly when a hose is not connected to coupling 402.

FIG. 5A depicts in further detail representative silica dust collection hose 114b collecting silica dust generated at the base of trailer discharge conveyor 102b. Hose 114b pneumatically couples with manifold 107 through a reduction coupling 501. The inlet end of hose 114b, which includes an optional nozzle or shroud 502, is disposed proximate the point where the lateral conveyor of trailer 101b discharges sand to the base of trailer discharge conveyor 102b. Silica dust generated during sand transfer is captured by the suction created by silica dust control unit 106 at the discharge end of hose 114b and carried through manifold 107 to silica dust control unit 106 to be filtered from the air. Silica dust collection hoses 114a, 114b, 114c, and 114d, which respectively collect silica dust generated at the bases of trailer discharge conveyors 102a, 102b, 102c and 102d, are similar in configuration and operation.

FIG. 5B depicts in further detail representative silica dust collection hose 115b collecting silica dust generated during the discharge of sand from trailer discharge conveyor 102b into lateral conveyor section 103. In the illustrated embodiment, trailer discharge conveyor 102b discharges through a section of flexible hose (conduit) 503 into the corresponding slot 104 of lateral conveyor section 103. The inlet 504 of silica dust collection hose 115b is disposed proximate the outlet of flexible hose 503. The suction produced by silica dust control unit 106 gathers silica dust generated during the transfer of sand, which in turns moves to silica dust control unit 106 for filtering through manifold 108. The configuration and operation of silica dust collection hoses 115a, 115b, 115c, and 115d, which respectively collect silica dust from the discharge points of trailer conveyors 102a, 102b, 102c, and 102d into lateral conveyor section 103 are similar.

Silica dust collection hoses 116a-116d, and the suction generated by silica dust control unit 106, collect silica dust generated by the lifting and discharge of sand by discharge conveyor section 105. As shown in FIG. 5C, silica dust collection hoses 116a-116d extend from apertures through the body of discharge conveyor section 105 at selected spaced-apart points. During operation, silica dust generated as sand moves upwards towards the outlet spout is removed through silica dust collection hoses 116a-116d and manifold 108 for filtering by silica dust control unit 106.

FIG. 5C also one possible configuration for flexible 117 with respect to the spout of upwardly angled conveyor 105. Generally, the intake end of flexible hose 117 is located near

the discharge point of the spout of conveyor 105 and creates an updraft, which captures silica dust generated as sand falls into the bin of blender 119. The actual attachment point of flexible hose 117 to the spout of conveyor 105, as well as the proximity of the intake end of hose 117 to the blender bin, may vary in actual practice of system 100.

As discussed above, silica dust generated in the compartments of the tanks of trailers 101a-101d is collected by a set of fittings 110 and hoses 111. FIGS. 6A-6C depict this subsystem in further detail, using trailer 101a as an example.

Each trailer 101 includes a set of inspection hatches 601 through the trailer roof. In the illustrated embodiment, trailers 101 include two rows of hatches 601 that run along opposing sides of the trailer roof. (In other embodiments of trailers 101, the number and location of inspection hatches 601 may differ. For example, some commercially available sand storage trailers utilize a single row of inspection hatches that run along the centerline of the trailer roof.)

In addition, FIG. 6A shows optional skirts 610, which run along each side of the depicted trailer 101. Skirts 610, which are preferably constructed from a durable flexible material, such as heavy plastic or canvas, contain silica dust generated by the movement of sand through the lateral conveyor that runs underneath the trailer tank.

In the preferred embodiment of system 100, silica dust collection is performed using the hatches 601 running along one side of the trailer tank, although in alternative embodiments silica dust collection could be performed using the hatches running down both sides of the trailer tank. For a given compartment, the regular hatch 602 is pulled back and replaced with corresponding cover 603 attached an associated fitting 110 (FIGS. 6B-6D).

FIG. 6B shows in further detail an example of a T-shaped (three-way) fitting 110e interfacing with corresponding hoses 111d and 111e. FIG. 6C shows an example of an elbow (two-way) fitting 110a and the final section of hose 111a in the trailer silica dust subsystem. The remaining connections between the given trailer 101 and fittings 110 and 111 are similar. The four-way fitting 112 used to connect trailer 101d and silica dust control unit 106 through hose 109 is shown in detail in FIG. 6D. In each case, fittings 110 include well-known transitions and clamps to connect to hoses 111. Similar to the taps shown in FIGS. 4C-4E, each fitting, such as T-shaped (three-way) fitting 110e, elbow fitting 110a, and four-way fitting 112, includes a slide gate for controlling airflow between the space within the given trailer 101 and manifold 107.

FIGS. 7A-7C illustrate an enhancement to system 100, which includes a flexible cover system 700 for containing the silica dust generated during the movement of sand through the system. Preferably, flexible cover system 700 extends over the discharge ends of trailer discharge conveyors 102a-102d, the length of lateral conveyor section 103, and the length of upwardly angled discharge conveyor section 105. (In alternative embodiments, flexible cover system 700 may only cover portions of system 100, as necessary to effectively control silica dust.)

In the preferred embodiment, flexible cover system 700 is constructed as separate sections 701a-701c and 702, as shown in FIGS. 7B and 7C. Sections 701a-701c cover corresponding portions of lateral conveyor section 103 and section 702 covers upwardly angled discharge conveyor section 105. Boots 703 are provided to allow insertion of corresponding flexible capture hoses 115 and 116 into the underlying silica dust containment spaces when cover system 700 is deployed. Boots 704 extend over the ends of trailer discharge conveyors 102a-102d.

Section 702 also includes a lateral extension 705 for covering the spout of upwardly angled discharge conveyor section 105. A boot 707 provides for the insertion of flexible hose 117 into extension 702 for fastening on or near the outlet of the discharge spout of conveyor 105.

Flexible cover system 700 is preferably constructed of canvas, heavy plastic, or other flexible material that is durable, relatively easy to deploy and remove, and transportable. Preferably, the surfaces of the selected material are impervious to frac sand, as well as able to withstand the normal wear and tear expected at a fracing worksite. When deployed, sections 701 and 702 are attached to each other with areas of Velcro 706 or similar attachment system, which minimizes the escape of silica dust at the seams between the sections.

FIGS. 8A and 8B are respectively perspective and end view diagrams of a raised manifold system 800 suitable for use in frac sand dust control systems, such as that described above in conjunction with FIG. 1. Depending on the configuration of the dust control system, raised manifold 800 may be used to replace either or both of manifolds 107 and 108 of FIG. 1 or be used in addition to manifolds 107 and 108.

As discussed further below, when in use in a dust collection system such as system 100 of FIG. 1, raised manifold 800 is located generally above lateral conveyor section 103, angled lifting conveyor section 105, the bin and/or the tub of blender 119, or a combination thereof. In the embodiment of FIG. 8A, raised manifold 800 is suspended from a support structure 801, which may also be used to support a cover or enclosure for enclosing lateral conveyor section 103, lifting conveyor section 105, and/or the bin and tub of blender 119.

As shown in FIGS. 8A and 8B, fluid communication with the interior passage of raised manifold 800 is through a set of rigid cylindrical fittings 802 coupled to taps or apertures through the manifold wall. In other words, fittings 802 provide a plurality of ports into raised manifold 800 for capturing dust when negative air pressure (i.e., suction) is applied to manifold 800, for example, by air unit 106 in embodiments of system 100. In some instances, fittings 802 are not required. For example, within a dust control enclosure, such as those discussed further below, a port into the interior of manifold 800 can be a simple aperture through the manifold wall, which can be capped when not in use.

Two representative fittings are shown at 802a and 802b in FIG. 8B for reference. The actual number of fittings 802 may vary between embodiments, depending on such factors as the length of raised manifold 800, the number of fittings 802 needed to support a range of different dust control system configurations and dust control operations, and the diameters of the flexible conduits discussed below, among other things. In the illustrated embodiment, each fitting 802 includes a sliding gate 803, two of which (802a and 803b) are shown in FIG. 8B for reference. The amount of air flowing through a given fitting 802 is set by the corresponding sliding gate 803, which includes completely shutting-off air flow through an unused or unnecessary fitting 802 (with or without a rigid extension or attached flexible conduit.)

Preferably, raised manifold 800 and fittings 802 are constructed from aluminum for lightness and durability, with fittings 802 coupled to raised manifold 800 by welding or brazing. However, in alternative embodiments, raised manifold 800, fittings 802, or both, may be fabricated from other materials, such as steel or plastic, and fastened together using other fastening techniques. For example, threads may be provided on fittings 802 for mating with corresponding threads in the taps through the manifold wall.

Moreover, while raised manifold 800 is shown as a rigid conduit having a cylindrical shape, the principles of the present invention may be embodied in raised manifolds of other shapes or having different degrees of rigidity. For example, raised manifold 800 could be a flexible conduit or have a rectangular cross-section. Generally, raised manifold 800 can be any conduit or chamber having a size, shape, and rigidity suitable to provide sufficient air flow through a sufficient number of branches (i.e., fittings or ports 802) as required to achieve the desired amount of dust capture in a given dust control system having a given configuration and a given air system rated cubic feet per minute (cfm). (In the illustrated embodiment, rigid, cylindrical raised manifold 800 is nominally 20 inches in diameter and fittings 802 are nominally 10 inches in diameter, based on 40000 cfm of air flow, which could be provided by a single air system 106 or two air systems 106 providing 20000 cubic feet cfm of air flow each.)

In the illustrated embodiment of FIGS. 8A and 8B, raised manifold 800 is suspended from frame 801 by a series of periodically spaced straps 804, two of which are shown for reference at 804a and 804b. In alternative embodiment, other techniques may be used to suspend raised manifold 800, such as cables, cradles, direct bolting to support frame 801, tubing or bars, among others. The particular suspension system configuration may vary depending on such factors as the weight of raised manifold 800 and fittings 802, the number and size of fittings 802, the length and diameter of raised manifold 800, and the ability to quickly couple and uncouple raised manifold 800 and support frame 801.

Support frame 801 can be based on any one of a number of different configurations and constructions. In the embodiment illustrated in FIGS. 8A and 8B, support frame 801 includes a central upper longitudinal reinforcing member 805, lower lateral longitudinal reinforcing members 806a-806b, upper lateral longitudinal reinforcing members 807a-807b, and U-shaped support members 808, two of which are shown at 808a and 808b for reference. Generally, each U-shaped support member 808 includes a pair of opposing substantially straight vertical support members (legs) and a curved upper section. While support frame 801 is shown as having a generally inverted U-shape horizontal cross-section, other shapes are possible, such as rectangular, triangular, or ovoid, for example. When used in a dust control system such as system 100 of FIG. 1, the width between the vertical support member of U-shaped support members 808 is adapted to straddle the sides of lateral conveyor section 103, the sides of lifting conveyor section 105, the bin and/or tub of blender 119, the chutes from a vertical sand mover, or a combination thereof.

Longitudinal reinforcing members 805, 806, and 807 and U-shaped support members 808 are preferably fabricated and fastened together to maximize durability and stability while still allowing support frame 801 to be assembled and disassembled quickly at the job site. For example, longitudinal reinforcing members 805, 806, and 807 and U-shaped support members 808 may be fabricated as aluminum or steel tubing and fastened together using pins or bolts. Alternatively, longitudinal reinforcing members 805, 806, and 807 and U-shaped support members 808 could be solid aluminum or steel bars or U-shaped beams. Support frame 801 could also be constructed as sections in which some components are permanently fastened together, for example by welding or brazing.

While raised manifold 800 is shown in FIGS. 8A and 8B as being positioned along the longitudinal centerline of the upper portion of support frame 801, generally referencing

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central upper longitudinal reinforcing member **805**, the lateral and vertical position of raised manifold **800** may vary in alternative embodiments. More specifically, raised manifold **800** may be laterally and/or vertically displaced with respect to central upper longitudinal reinforcing member **805**. The actual location of raised manifold **800** may be varied as needed, for example, to accommodate different underlying structures, such as the discharge ends of trailer conveyors **102** and angled lifting conveyor **105**, or variations in the length of the flexible conduits discussed below.

In the illustrated embodiment, U-shaped frame members **808** are directly supported by the ground through bases **809**, two of which are shown at **809a** and **809b** for reference. In alternative embodiments, U-shaped frame members **808** may be supported or attached, either in whole or in part, by another structure within the dust control system, such as lateral conveyor section **103**, blender **119**, or angled lifting conveyor section **105**. For example, U-shaped frame members **808** may be attached or supported by the top or fastened to a lateral surface of lateral conveyor section **103**.

A given fitting **802** may be used unmodified (i.e., not connected to a flexible conduit or rigid extension), connected to a flexible conduit that extends towards the upper surface of lateral conveyor section **103**, to a point along angled lifting conveyor section **105**, or the bin and tub of blender **119**, or may be extended lengthwise to form a longer rigid conduit for drawing in air and dust from a selected dust collection point, such as a point along lateral conveyor section **103** or within the bin of blender **119**. Not all fittings **802** need be used, with those not being used closed by the associated sliding gate **803** or capped.

FIG. **8C** is a more detailed view of a portion of raised manifold **800** and support frame **801**. Representative fittings **802**, including fittings **802a** and **802b** of FIGS. **8A** and **8B**, are shown connected to flexible conduits. Generally, local flexible conduits **810** are used to collect air and dust at selected points along lateral conveyor section **103**, along angled lifting conveyor **105**, or within the bin and/or tub of blender **119**. Remote flexible conduits **811** are used to collect air and dust from within sand storage containers, such as trailers **101** of FIG. **1**.

FIG. **8C** also shows an elbow conduit **812** for coupling raised manifold **800** to a source of negative air pressure, such as air system **106** of FIG. **1**. Elbow conduit **812** is constructed, either in whole or in part, by a rigid or semi-rigid material such as aluminum, or a flexible material, such as rubber or polyurethane. An additional fitting **802c** and associated sliding gate **803c** tap into elbow conduit **812**.

In FIG. **8D**, raised manifold **800** is shown in combination with an enclosure **814**, which is configured to enclose lateral conveyor section **103**, angled lifting conveyor section **105**, the bin and tub of blender **119**, or any combination of the three. Elbow conduit **812** couples with air unit **106** through a manifold system **813**, which includes sections of rigid and flexible conduit, although other configurations may be used in alternative embodiments. For example, air system **106** could be connected either to elbow conduit **812** or directly to raised manifold **800** by a flexible conduit (i.e., eliminating elbow conduit **812**, conduit system **813**, or both). FIG. **8D** also includes optional fitting/air flow control assemblies **818a-818b**, which allow for additional local or remote flexible conduits to be connected directly to conduit system **813**.

The inlets of local flexible conduits **810** remain within enclosure **814**, while remote flexible conduits **811** run under bottom edge **815** of enclosure **814** or through an aperture through the sidewall of enclosure **814** near bottom edge **815**.

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In alternative embodiments, remote flexible conduits **811** could exit enclosure **814** at different points, including points higher up on the sidewalls of enclosure **814** or through the enclosure **814** roof.

Enclosure **814** is not required for using raised manifold **800**, although use of enclosure **814** increases the efficiency of dust capture through manifold **800** and flexible conduits **810**, as well as generally minimizes the escape of dust into the surrounding environment. Moreover, when enclosure **814** is used, one or more unmodified fittings **802** can be used for capturing dust within the confined space. Furthermore, while enclosure **814** is shown as having substantially clear sidewalls and an opaque roof, these are not requirements for practicing the inventive principles. For example, the sidewalls may be opaque and the roof may be substantially clear, both the roof and the sidewalls may be opaque, or both the roof and the sidewalls may be substantially clear.

In FIG. **8E**, raised manifold **800** and enclosure **814** of FIG. **8D** are shown in use with an embodiment of frac sand transportation, storage, and unloading system **100** of FIG. **1** including four (4) transportation and storage containers **101a-101d** coupled to four (4) corresponding remote flexible conduits **811a-811d** extending from the bottom edge **815** of the opposing side of enclosure **814**. Remote conduits **811e-811i** extending from the bottom edge **815** of the facing side of enclosure **814** may be used for collecting dust at other points within system **100**, such as along lifting conveyor section **105** or from within additional sand storage and transportation containers (see FIG. **8H**).

In the example of FIG. **8E**, at least four (4) local conduits **810a-810d** extend downward within enclosure **814** from raised manifold **800** to collect dust generated from the discharge of sand from four (4) container conveyors (stingers) **102a-102d** to lateral conveyor section **103**. Preferably, in configurations where manifold **800** is generally located above lateral conveyor section **103**, such as those shown in FIGS. **8E** and **8G**, manifold **800** is also located above the discharge end of trailer discharge conveyors **102**, as well.

FIG. **8F** illustrates an alternative system configuration in which raised manifold **800** is supported above support frame **801** and outside of enclosure **814**. In this configuration, local conduits **810** run generally down the sidewalls of enclosure **814**, extend underneath enclosure edge **815** or through apertures near enclosure edge **815**, and then extend further within enclosure **814** to the corresponding dust collection points. Alternatively, local conduits **810** could enter the interior of enclosure **814** at different points, such as through one or both of the enclosure sidewalls or through the enclosure roof.

In the supported configuration of FIG. **8F**, raised manifold **800** is supported by periodically spaced u-shaped cradles **819**, two of which are shown at **819a** and **819b** for reference. Cradles **819** are fastened to central upper longitudinal reinforcing member **805** of support frame **801**, for example, by bolts or pins. Alternatively, raised manifold **800** could be directly fastened to upper longitudinal reinforcing member **805** or fastened to support structure **801** using another technique. Furthermore, while raised manifold **800** is shown positioned along the centerline generally defined by central upper longitudinal reinforcing member **805**, it could be laterally and/or vertically displaced from the centerline in alternative embodiments.

In FIG. **8G**, the supported configuration of raised manifold **800** and enclosure **814** are shown in use with an embodiment frac sand transportation, storage, and unloading system **100** of FIG. **1** including four (4) transportation and storage containers **101a-101d** coupled to four (4) corre-

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sponding remote flexible conduits **811a-811d** coupled to corresponding fittings **802** on the opposing side of raised manifold **800**. Remote conduits **811e-811j** extending from fittings **802** on the facing side of enclosure **814** may be used for collecting dust at other points within system **100**, such as along lifting conveyor section **105** or from within additional sand storage and transportation containers.

In the example of FIG. 8G, at least four (4) local conduits **810a-810d** extend downward outside of the sidewall of enclosure **814**, extend underneath enclosure edge **815** or through apertures near enclosure edge **815**, and then extend upward within cover **814** to collect dust generated from the discharge of sand from four (4) container conveyors (stingers) **102a-102d** to lateral conveyor section **103**.

An alternative configuration is shown in FIG. 8H, where manifold **800** remains outside of enclosure **814** and is supported by support structure **801**, but is now located lower down the side of the support structure **801**. While manifold **800** is shown generally at the point where U-shaped support members **808** transition from a curve to vertical support members, manifold **800** can be placed at any point between the very top of support structure **801** (FIGS. 8F and 8G) and the ground. In addition, manifold **800** can be positioned on either side of support structure **801**, as need for a particular worksite or dust control system configuration.

In the embodiment of FIG. 8H, manifold **800** is preferably secured directly to support frame **801** by bolts, pins, or a similar fastening technique. Remote flexible conduits **811** then extend over the upper curved portion of support structure **801** and enclosure **814**. In some embodiments, flexible conduits **810** could extend through the top portion (roof) of enclosure **814** to capture dust within the enclosure interior. Local flexible conduit **810e** is an example of a flexible conduit extending through the top portion of enclosure **814**.

FIG. 8I illustrates an example in which remote conduits **811** extend from both sides of raised manifold **800**. In this example, raised manifold **800** is shown in the configuration of FIGS. 8A-8E, although the same principles apply to the configuration shown in FIGS. 8F-8G. Here, three (3) remote conduits **811a-811c** service three (3) sand transportation and storage containers **101a-101c** and two (2) remote conduits **811d-811e** service two (2) portable silos or vertical sand movers **816a-816b**. (The number of sand sources, such as transportation and storage containers **101** and portable silos/vertical sand movers **816** may vary in actual practice.) Within enclosure **814**, at least one local flexible conduit **810** or extended fitting **802** collects dust generated around each of the sand discharge points from trailer conveyors **102a-102b** and the sand discharge points from portable silo chutes **817a-817b**.

The principles of the present invention are also embodied in a raised manifold and enclosure system more specifically adapted for containing and collecting dust generated in and around the bin and tub of blender **119**. One such system is shown in FIG. 9A, which includes a raised manifold **900** suspended below a support structure **901** by a set of straps or cables, two of which are shown at **910a** and **910b** for reference. Preferably, the construction of support structure **901** and straps/cables **910** are similar to those of support structure **801** and straps/cables **804** discussed above, although that is not a strict requirement of practicing the inventive principles. Support structure **901** also supports an enclosure **907**, which is preferably similar in construction to enclosure **814** discussed above.

In the embodiment shown in FIG. 9A, raised manifold **900** includes a set of fittings, such as fittings **902a** and **902b**, which are in fluid communication with the interior passage

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through raised manifold **900**. Similar to fittings **802** discussed above, fittings **902** provide a plurality of ports into raised manifold **900** for capturing dust when negative air pressure (i.e., suction) is applied to manifold **900**, for example, by air unit **106** in embodiments of system **100**. Each fitting **902** is associated with an air flow control device, which could be a gate, butterfly valve, ball valve, or similar device, controls air flow control through the corresponding fitting **902**. (Air flow control preferably extends from a complete airflow shut-off to a maximum allowable flow through the given fitting **902** under the given system operating conditions.) In the illustrated embodiment, sliding gates **903a** and **903b** are shown as an example. While four (4) fittings **902** are shown in the exemplary embodiment of FIG. 9A, the number of fittings **902** may vary in actual applications, depending on the dust-capture requirements.

Fittings **902** can be used unmodified (e.g., without a flexible conduit or rigid extension), with a rigid extension, or in conjunction with a flexible conduit or rigid extension. Unmodified or extended fittings **902** are particularly suitable for capturing dust contained within enclosure **907**. Fittings **902** connected to flexible conduits are suitable for capturing dust at one or more points within enclosure **907**, as well as one or more points outside of enclosure **907**. Not all fittings **902** need be used and unused fittings **902** can be shut-off using the corresponding sliding gates **903**.

The construction of raised manifold **900** is preferably similar to that of raised manifold **800** discussed above. As with raised manifold **800**, characteristics such as shape, fabrication material, degree of rigidity, and so on, may vary from embodiment to embodiment of the present inventive principles.

As shown in FIG. 9A, all four (4) exemplary fittings **902** are coupled to a corresponding set of four (4) flexible conduits. Two (2) fittings **902** are connected to local flexible conduits **904a** and **904b**, which extend downward within cover **907** for capturing dust in the areas around the bin and tub of blender **119** (see FIG. 9E). In addition, two other fittings **902** are coupled to remove flexible conduits **905a-905b**, which extend under the bottom edge **909** or through an aperture close to bottom edge **909** of enclosure **900**. Remote flexible conduits **905** may be used to capture dust at other points around a frac sand storage and movement system, for example, dust within a trailer **101**, dust generated along lateral conveyor system **103**, or dust generated along angled lifting conveyor **105** of an embodiment of system **100** of FIG. 1. In alternative embodiments, remote flexible conduits **905** could exit enclosure **907** at different points, including points higher up on the sidewalls of enclosure **907** or through the enclosure **907** roof.

An elbow-shaped conduit **906** couples raised manifold **900** to an air system **106**, which is similar to those discussed above. In one particular configuration shown in FIGS. 9B and 9C, rigid elbow-shaped conduit **906** communicates with an air system **106** through a manifold system **908** formed of both rigid and flexible sections of conduits, although other configurations may be used in alternative embodiments. For example, air system **106** could be connected either to elbow-shaped conduit **906** or directly to raised manifold **900** through a flexible conduit or conduit.

FIG. 9D shows an alternative configuration where raised manifold **900** is supported above the roof of enclosure **907** by frame **901** and u-shaped cradles **920a-920b**. In this configuration, local conduits **904** run generally down the sidewalls of enclosure **907**, extend underneath enclosure edge **909** or through apertures near enclosure edge **909**, and then extend further within enclosure **907** to the correspond-

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ing dust collection points. Alternatively, local conduits **904** could enter the interior of enclosure **907** through one or both of the enclosure sidewalls or through the roof. In addition, while cradles **920** are shown as u-shaped in the illustrated embodiment, different cradle shapes may be used in alternate embodiments.

A further alternative configuration is shown in FIG. 9E, where manifold **900** remains outside of enclosure **907** and is supported by support structure **901**, but is now located lower down the side of the support structure **901**. While manifold **900** is shown generally at the point where support structure **901** transitions from a curve to vertical support members, manifold **900** can be placed at any point between the very top of support structure **901** (FIG. 9D) and the ground. In addition, manifold **900** can be positioned on either side of support structure **901**, as need for a particular worksite or dust control system configuration. FIG. 9D also shows optional fittings/air flow control assemblies **913a-913b**, which allow additional local or remote flexible conduits to be connected directly with manifold system **908**.

In the embodiment of FIG. 9D, manifold **900** is shown supported by a set of cradles **920a-920b** extending outwardly from support frame **901**, although manifold **900** could also be secured directly to support frame **901** by bolts, pins, or a similar fastening technique. Remote flexible conduits, such as remote flexible conduit **905b**, can then extend over the upper curved portion of support structure **901** and enclosure **907**. In some embodiments, one or more local flexible conduits **904**, such as local flexible conduit **904b**, could extend through the top portion of enclosure **907** to capture dust within the enclosure interior.

FIG. 9F illustrates an alternative frac sand transportation, storage, and unloading system **911** including a frac sand silica dust control system suitable for use with either of the configurations of raised manifold **900** shown in FIGS. 9A and 9D. Preferably, enclosure **907** encloses the bin, the tub, or both the bin and tub of blender **119**. In FIG. 9F, enclosure **907** encloses both the blender bin and the blender tub, as generally shown in broken lines. At least one fitting **902**, which may be unmodified, extended, or connected to a local flexible conduit **904**, as shown in FIG. 9F, collects dust contained by enclosure **907**.

In the system of FIG. 9F, the container conveyors (stingers) **102a-102c** associated with trailers **101a-101b** extend through apertures in the sidewalls of enclosure **907** and discharge sand directly into the bin of blender **119**. Preferably, manifold **900** is located above the discharge end of container conveyors **102a-102c** (or in embodiment using one or more silo chutes, above the discharge ends of the silo chutes). In addition, FIG. 9E provides an example where two (2) manifolds and two (2) air systems are used to collect dust at various points around the system.

Specifically, air system **106a** and manifold **912** are used to collect dust within the compartments of trailers **101a-101b**. Air system **106b** and raised manifold **900** capture dust within enclosure **907**, as well as provide a remote flexible conduit **905** for collecting dust within some of the compartments of trailer **101a**. Raised manifold **900** and manifold **912** may also be coupled together to create a unified conduit system serviced by either or both of air systems **106a-106b**.

FIG. 9F only shows one possible use of raised manifold **900**. Raised manifold **900** can be used alone to collect dust around the bin and tub of a fracing blender, provide negative air pressure to one or more local flexible conduits **905** for collecting dust along a lateral conveyor, lifting conveyor, a container conveyor, or silo chute, and/or provide negative air pressure through one or more remote flexible conduits **905**

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for collecting dust within a sand trailer or portable sand silo. Raised manifold **900** may also be use in conjunction with raised manifold **800** and enclosure **814**. Advantageously, when raised manifolds **800** are **900** are used in combination, a wide range of options are available for collecting dust around a given frac sand transportation, storage, and handling system.

In sum, the principles of the present invention provide for the efficient capture and removal of silica dust generated during the offloading of frac sand at a worksite. Silica dust removal is performed near, but not limited to, substantial sources of hazardous silica dust, including at trailer to trailer conveyor sand transfer point, each point of transfer from the trailer discharge conveyors and the lateral site conveyor, and points along the lifting/discharge conveyor. The embodiments of the inventive principles are scalable, and can be applied to any discharging system serving single or multiple frac sand storage trailers and can be implemented with various commercially available cyclone/baghouse silica dust removal systems. Moreover, the configuration and construction of these embodiments are also variable, allowing silica dust control to be effectively implemented under widely varying worksite conditions.

Although the invention has been described with reference to specific embodiments, these descriptions are not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed might be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

It is therefore contemplated that the claims will cover any such modifications or embodiments that fall within the true scope of the invention.

What is claimed is:

1. A system for controlling dust during hydraulic fracturing operations comprising:

a manifold having a plurality of longitudinally spaced-apart ports for capturing dust when negative air pressure is applied to the manifold;

a support frame including a plurality of spaced-apart support frame members positioning the manifold above and at least partially along piece of frac sand handling equipment that is configured to receive frac sand from an external frac sand source, the manifold displaced relative to a centerline of the support frame to accommodate the piece of frac sand handling equipment, wherein the support frame is adapted for transport to a hydraulic fracturing site, and wherein the piece of frac sand handling equipment comprises one of a conveyor, a bin of a hydraulic fracturing blender, or a tub of a hydraulic fracturing blender;

wherein each support frame member of the support frame includes an upper section connected between a pair of spaced-apart vertical portions, the pair of vertical portions being adapted to straddle the piece of frac sand handling equipment, and wherein a lower end of each respective vertical portion is connected to, and supported by, a respective individual base configured as a cylinder with an enlarged cross-sectional area relative to the respective vertical portion to rest on the ground,

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wherein each respective individual base is directly connected to the lower end of the respective vertical portion and is not directly connected to any other individual base, any other vertical portion, or any other support frame member of the support frame, wherein each respective vertical portion is directly connected to the respective individual base and the respective upper section, and is not directly connected to any other individual base, any other vertical portion or any other support frame member of the support frame; and wherein the individual bases, vertical portions and upper section are unconnected to the piece of frac sand handling equipment;

wherein the support frame further comprises a plurality of spaced-apart longitudinal reinforcing members directly connected between the upper sections of adjacent support frame members and unconnected to the piece of frac sand handling equipment, the plurality of spaced-apart longitudinal members being the only portions of the support frame longitudinally connecting adjacent support frame members;

a cover supported by the support frame for enclosing the piece of frac sand handling equipment, the cover including at least one aperture for receiving sand from the external frac sand source; and

a plurality of flexible conduits coupled to corresponding ones of the plurality of spaced-apart ports of the manifold and extending from the manifold through a space within the cover for capturing dust in areas local to spaced-apart points along the piece of frac sand handling equipment when negative air pressure is applied to the manifold.

2. The system of claim 1, wherein the manifold is suspended from the support frame.

3. The system of claim 1, wherein the manifold is attached to at least some of the spaced-apart frame members of the support frame.

4. The system of claim 1, wherein the piece of frac sand handling equipment comprises a conveyor.

5. The system of claim 4, wherein the conveyor comprises a lateral conveyor laterally moving frac sand received from the external frac sand source through a transfer mechanism, the manifold disposed above a discharge end of the transfer mechanism.

6. The system of claim 5, wherein the transfer mechanism comprises a selected one of a container conveyor and a silo chute.

7. The system of claim 1, wherein the piece of frac sand handling equipment comprises at least one of a bin of a hydraulic fracturing blender and a tub of a hydraulic fracturing blender.

8. The system of claim 1, wherein at least one of the plurality of ports comprises a fitting extending outwardly from an outer wall of the manifold.

9. The system of claim 1, wherein at least one of the plurality of ports comprises an air flow control mechanism for controlling air flow through the port.

10. A system for controlling dust during hydraulic fracturing operations comprising:

- a support structure including a plurality of spaced-apart support frame members adapted for transport to a hydraulic fracturing site;
- a manifold having a plurality of longitudinally spaced-apart ports positioned by the support structure above and at least partially along a piece of frac sand handling equipment receiving frac sand from a frac sand source, the manifold selectively displaced relative to a center-

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line of the support structure to accommodate the piece of frac sand handling equipment, wherein the piece of frac sand handling equipment comprises one of a conveyor, a bin of a hydraulic fracturing blender, or a tub of a hydraulic fracturing blender;

wherein each support frame member of the support structure includes an upper section connected between a pair of spaced-apart vertical portions, the pair of vertical portions being adapted to straddle the piece of frac sand handling equipment, and wherein a lower end of each respective vertical portion is connected to, and supported by, a respective individual base configured as a cylinder with an enlarged cross-sectional area relative to the respective vertical portion to rest on the ground, wherein each respective individual base is directly connected to the lower end of the respective vertical portion and is not directly connected to any other individual base, any other vertical portion, or any other support frame member of the support structure, wherein each respective vertical portion is directly connected to the respective individual base and the respective upper section, and is not directly connected to any other individual base, any other vertical portion or any other support frame member of the support structure, and wherein the individual bases, vertical portions and upper section are unconnected to the piece of frac sand handling equipment;

wherein the support structure further comprises a plurality of spaced-apart longitudinal reinforcing members directly connected between the upper sections of adjacent support frame members and unconnected to the piece of frac sand handling equipment, the plurality of spaced-apart longitudinal members being the only portions of the support structure longitudinally connecting adjacent support frame members; and

an enclosure supported by the support structure and enclosing at least a portion of the piece of frac sand handling equipment, wherein each port of then manifold is coupled to a flexible conduit extending through a space within the enclosure towards the piece of frac sand handling equipment and having an inlet for capturing dust contained within the enclosure and adjacent to a corresponding one of a plurality of spaced-apart points along the piece of frac sand handling equipment when negative air pressure is applied to the manifold, wherein the enclosure includes a sidewall with at least one aperture therethrough for receiving sand from an external source such that discharge of the sand within the enclosure generates the dust.

11. The system of claim 10, wherein the manifold is disposed within the enclosure.

12. The system of claim 10, wherein the manifold is suspended from the support structure.

13. The system of claim 10, wherein the manifold is disposed outside of the enclosure and at least one of the plurality of conduits extends through a wall of the enclosure such that the inlet of the at least one of the plurality of conduits is disposed within the enclosure.

14. The system of claim 10, wherein the piece of frac sand handling equipment comprises a conveyor and the enclosure encloses a length of the conveyor.

15. The system of claim 10, wherein the enclosure encloses at least one of a bin of a hydraulic fracturing blender and a tub of a hydraulic fracturing blender.

16. The system of claim 10, wherein the manifold is positioned at a point along a top portion of the support structure.

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17. The system of claim 10, wherein the manifold is positioned at a point along a side portion of the support structure.

18. A frac sand handling system comprising:

frac sand handling equipment, wherein the frac sand handling equipment comprises one of a conveyor, a bin of a hydraulic fracturing blender, or a tub of a hydraulic fracturing blender;

a support structure including a plurality of spaced-apart support frame members adapted for transport to a hydraulic fracturing site;

wherein each support frame member of the support structure includes an upper section connected between a pair of spaced-apart vertical portions, the pair of vertical portions being adapted to straddle the frac sand handling equipment, and wherein a lower end of each respective vertical portion is connected to, and supported by, a respective individual base configured as a cylinder with an enlarged cross-sectional area relative to the respective vertical portion to rest on the ground, wherein each respective individual base is directly connected to the lower end of the respective vertical portion and is not directly connected to any other individual base, any other vertical portion, or any other support frame member of the support structure, wherein each respective vertical portion is directly connected to the respective individual base and the respective upper section and is not directly connected to any other individual base, any other vertical portion or any other support frame member of the support structure;

wherein the support structure further comprises a plurality of spaced-apart longitudinal reinforcing members directly connected between the upper sections of adjacent support frame members and unconnected to the piece of frac sand handling equipment, the plurality of spaced-apart longitudinal members being the only portions of the support structure longitudinally connecting adjacent support frame members;

an enclosure supported by the support structure and enclosing at least a portion of the frac sand handling equipment including a point at which frac sand is received by the frac sand handling equipment from an external frac sand source, the enclosure including an aperture for receiving frac sand from the external frac sand source; and

a manifold positioned by the support structure above and at least partially along the frac sand handling equipment, the manifold selectively displaced relative to a

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centerline of the support structure to accommodate the frac sand handling equipment and having a plurality of ports for capturing dust when negative air pressure is applied to the manifold, at least some of the plurality of ports coupled to a corresponding flexible conduit extending through a space within the enclosure and adapted to capture dust generated at points along the frac sand handling equipment, wherein the dust is generated by discharge of the sand received from the external frac sand source.

19. The system of claim 18, wherein the external frac sand source comprises a trailer having a trailer conveyor, an end of the trailer conveyor extending through a wall of the enclosure to discharge frac sand to the frac sand handling equipment.

20. The system of claim 18, wherein the external frac sand source comprises a silo having a chute, an end of the chute extending through a wall of the enclosure to discharge frac sand to the frac sand handling equipment.

21. The system of claim 18, wherein the frac sand handling equipment comprises a conveyor system at least partially enclosed by the enclosure.

22. The system of claim 18, wherein the enclosure encloses at least one of a bin of a hydraulic fracturing blender and a tub of a hydraulic fracturing blender.

23. The system of claim 18, further comprising a first flexible conduit coupled to a corresponding one of the plurality of ports and having an inlet for capturing dust in an area around a point at which frac sand is received by the frac sand handling equipment from the external frac sand source.

24. The system of claim 23, wherein the manifold is positioned by the support structure within the enclosure and the first flexible conduit extends within the enclosure from the corresponding port to the area around the point at which frac sand is received by the frac sand handling equipment from the external frac sand source.

25. The system of claim 23, wherein the manifold is suspended within the enclosure from the support structure.

26. The system of claim 23, wherein the manifold is positioned by the support structure outside of the enclosure and the first flexible conduit extends through a wall of the enclosure from the corresponding port to the area around the point at which frac sand is received by the frac sand handling equipment from the external frac sand source.

27. The system of claim 18, wherein the external frac sand source comprises a frac sand tank.

28. The system of claim 18, wherein the external frac sand source comprises a frac sand storage trailer.

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