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(54) **LIMITED LOSS LAMINAR FLOW DAMPERS FOR HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS**

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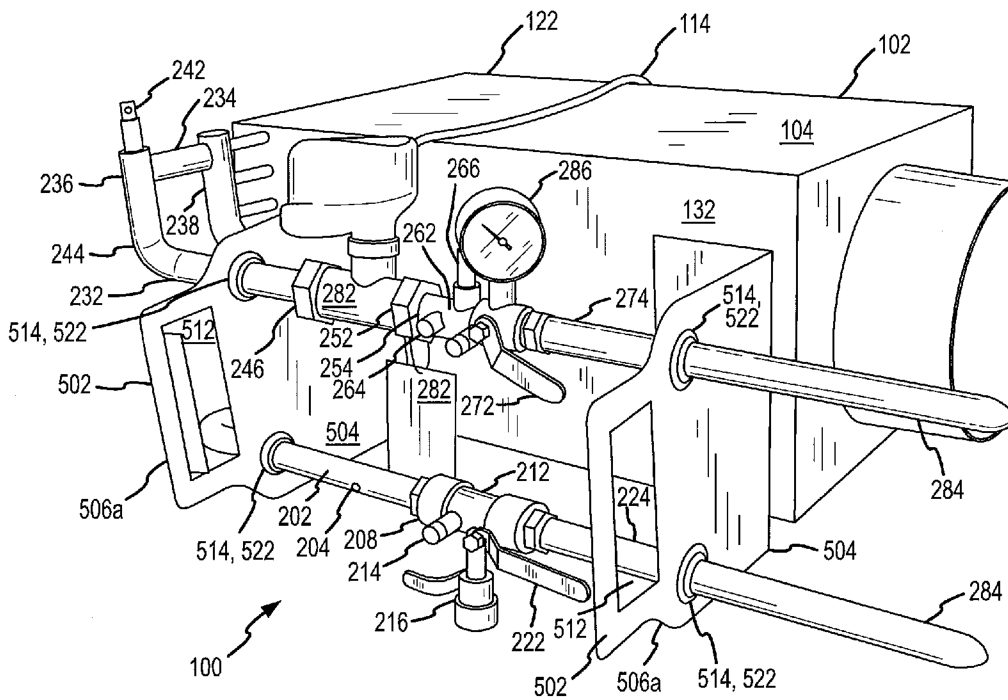
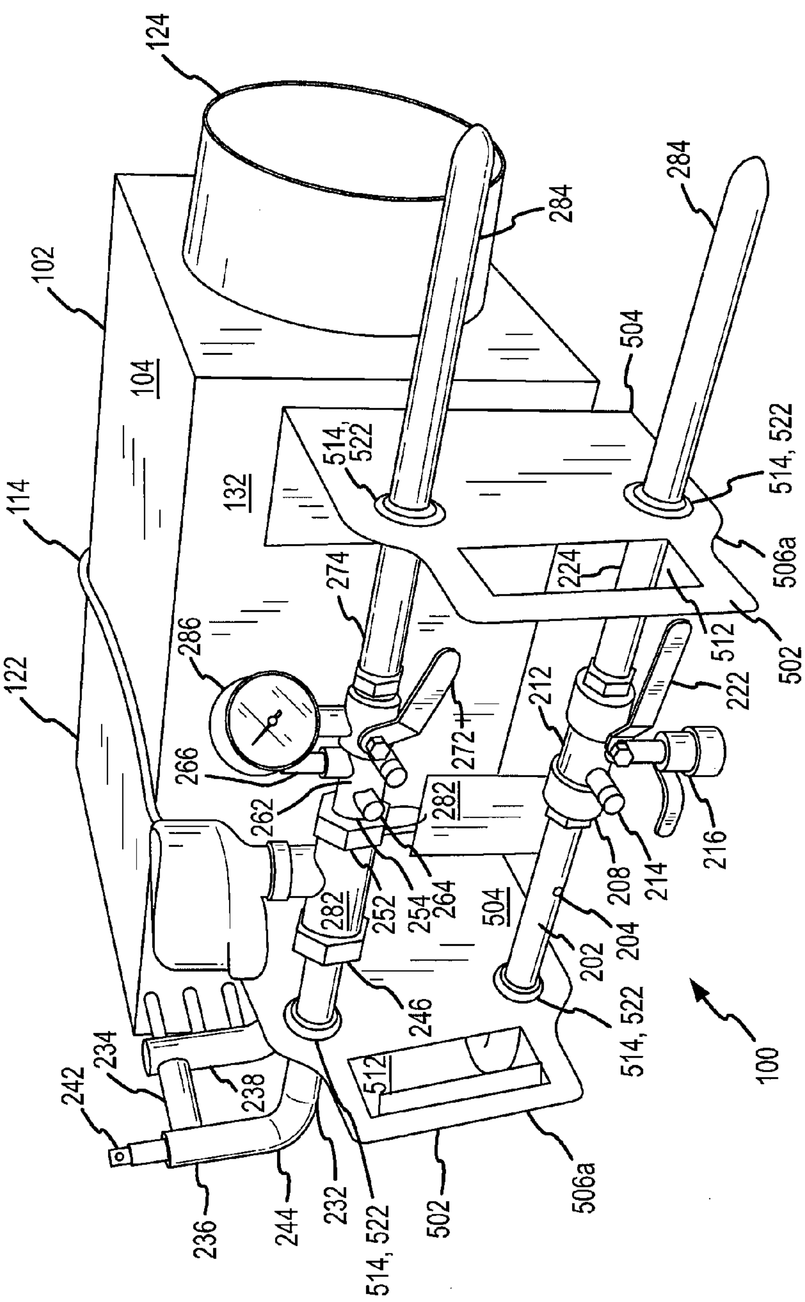
F24F 7/00 (2006.01)

(52) **U.S. Cl.** **236/49.3**

(57) **ABSTRACT**

HVAC devices, systems, and methods include dampers for controlling the flow of air or other gasses through an HVAC duct, often while inhibiting turbulence within the duct or pressure loss within the duct. Embodiments of such dampers may employ a two-part damper arrangement. In many embodiments, flow will travel through the middle of the damper uniformly and with a laminar flow. One or more small, relatively unobtrusive sensor (optionally being wireless) can be included for controlling operation of the damper, the sensor(s) optionally measuring the distance between damper elements, sound, air flow, or the like, with such sensor(s)/damper combination inhibiting inadvertent pressure drop and turbulence in flows through the damper. The damper elements may optionally comprise airfoil cross-sections, with alternative dampers having a resilient helical configuration that can choke down flow by inducing a vortex in the flow, allowing static pressure regain to occur within the duct system.

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264
208
214
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244
232
514, 522
502
506a

FIG.1

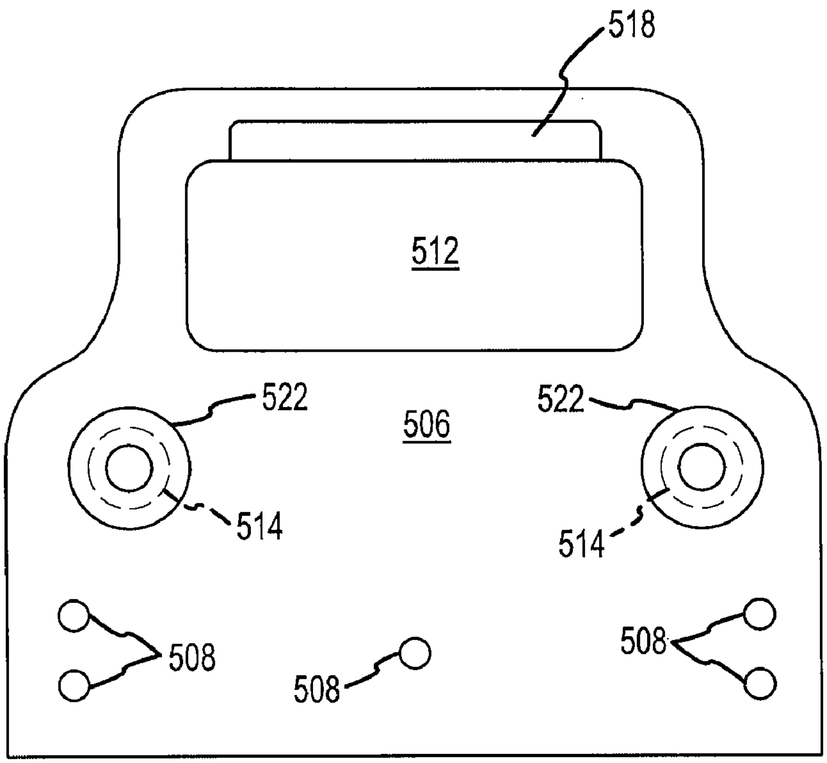
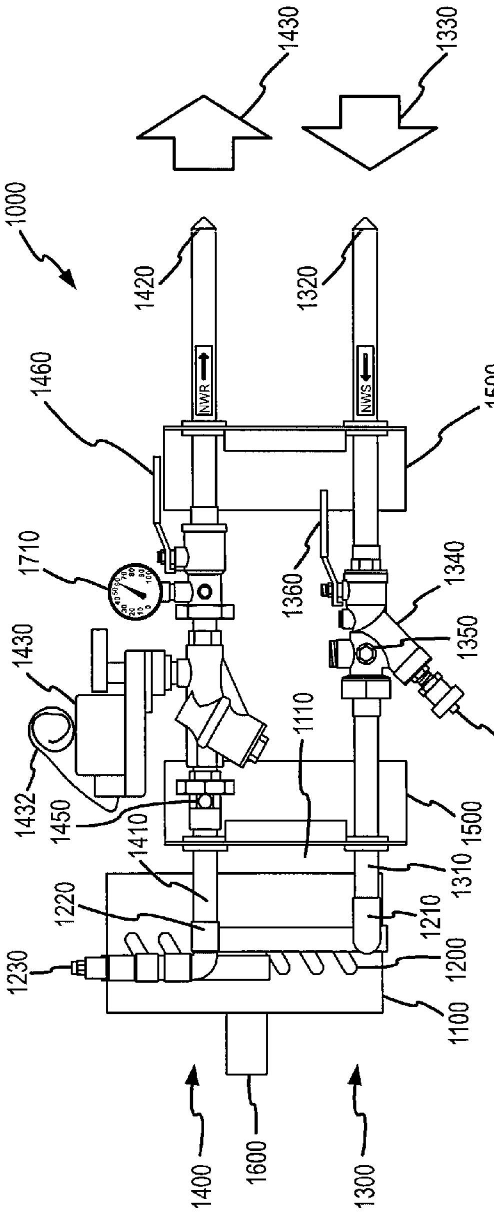


FIG.2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1430
1330
1420
1320
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1430
1432
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1310
1220
1210
1230
1200
1100
1400
1600
1300

FIG.2A

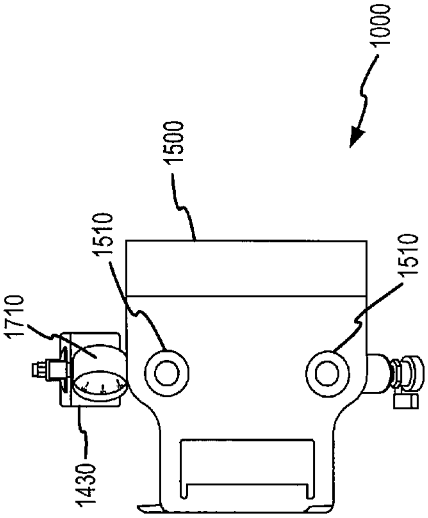
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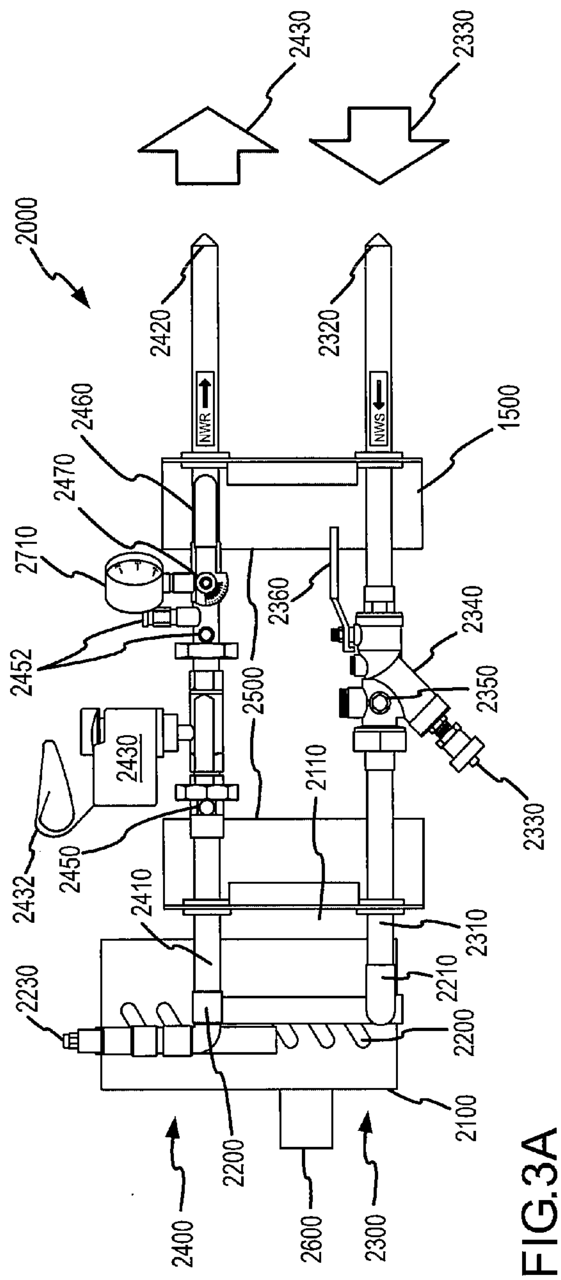
FIG.2B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2350
2430
2330
2432
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2110
2410
2310
2230
2210
2200
2200
2100
2400
2600
2300

FIG.3A

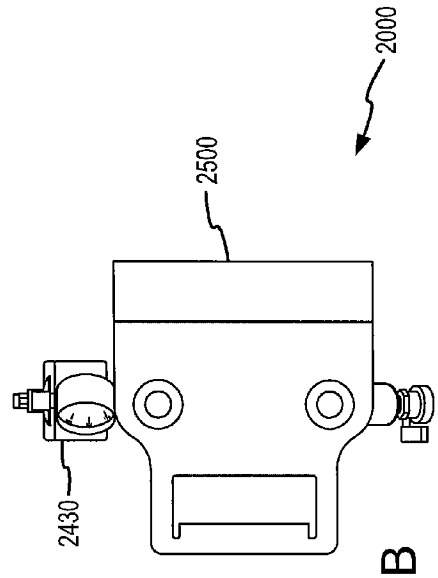
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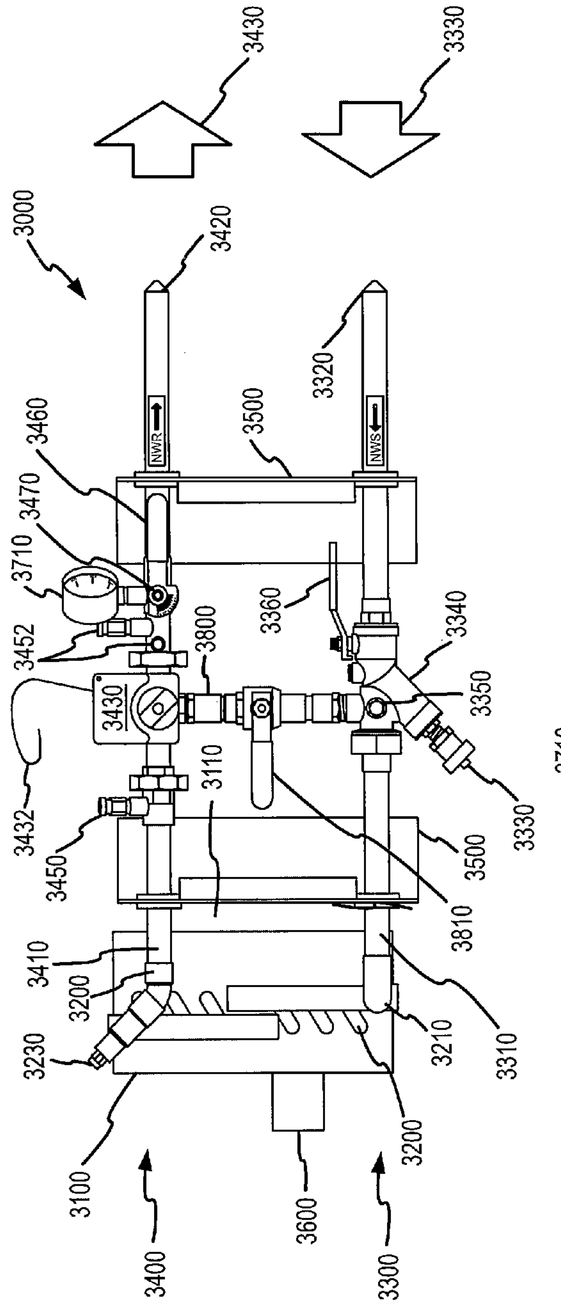
FIG.3B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NWS
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3432
3110
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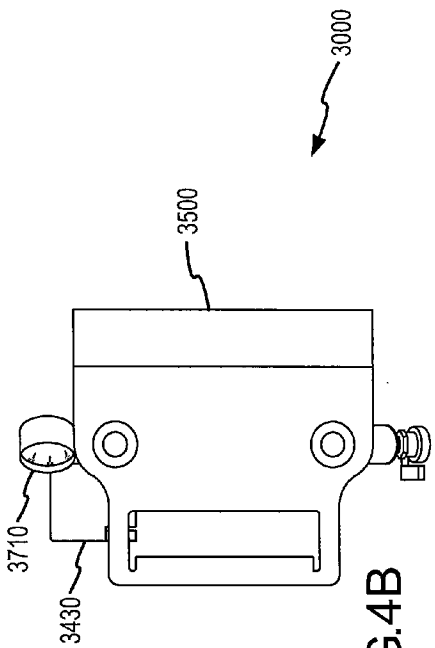
3400
3300

FIG.4A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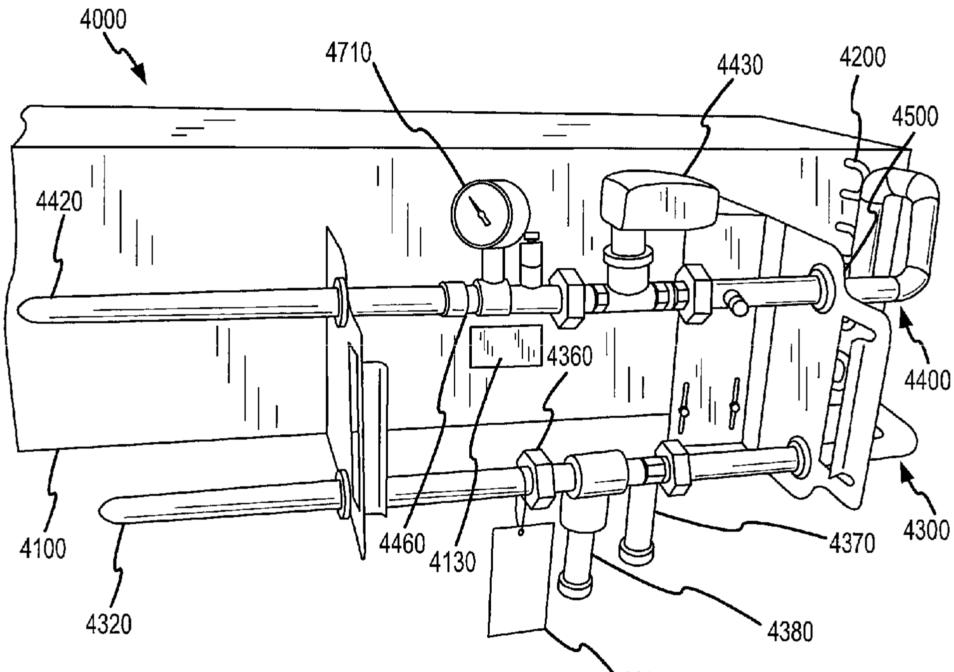
3500
3710
3430

FIG.4B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4710
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4300
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4460
4130
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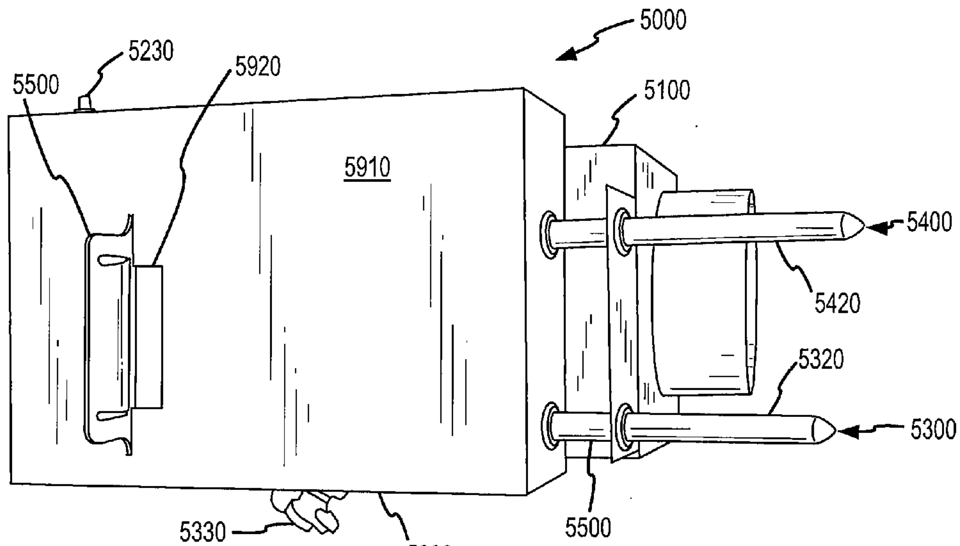
4380
4120

FIG.5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5300
5330
5900
5500

FIG.6

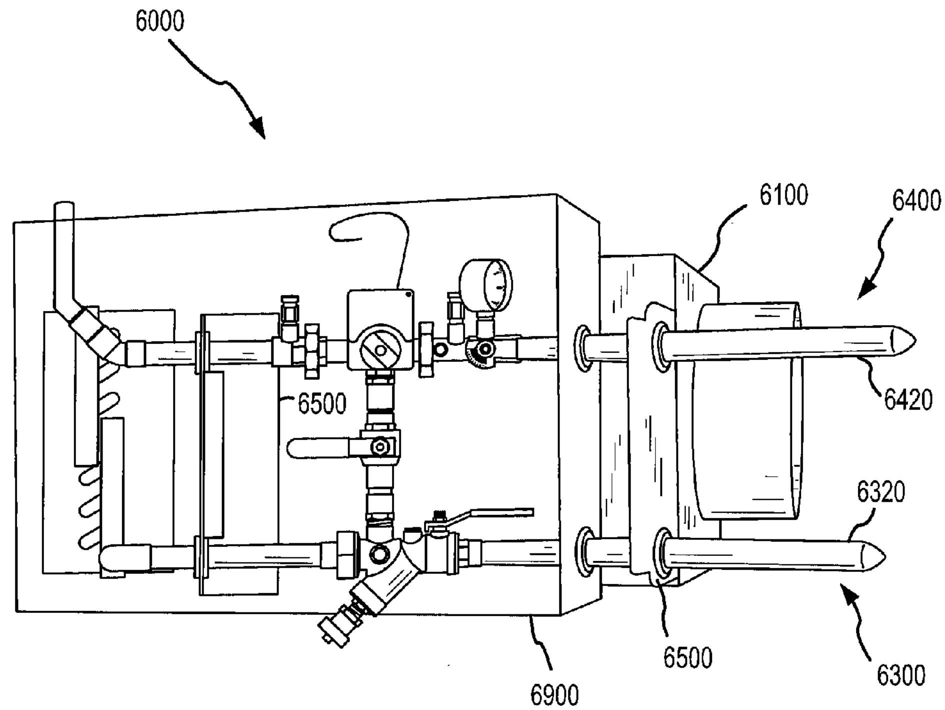

FIG.7

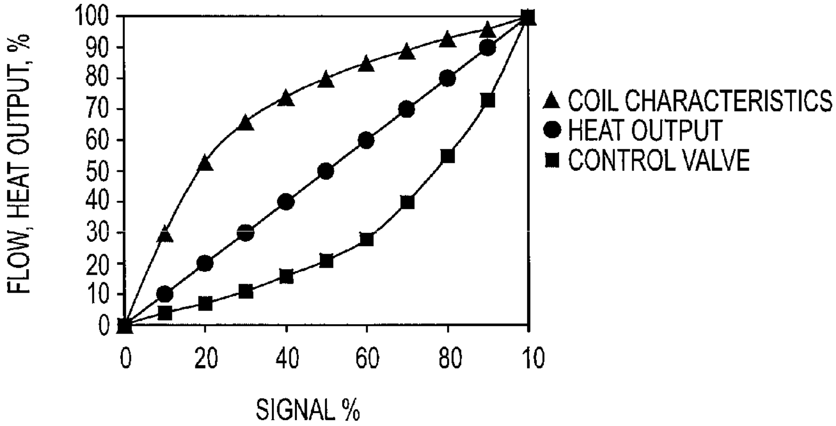
100
90
80
70
60
50
40
30
20
10
0
FLOW, HEAT OUTPUT, %
0
20
40
60
80
10
SIGNAL %
COIL CHARACTERISTICS
HEAT OUTPUT
CONTROL VALVE

FIG.8A

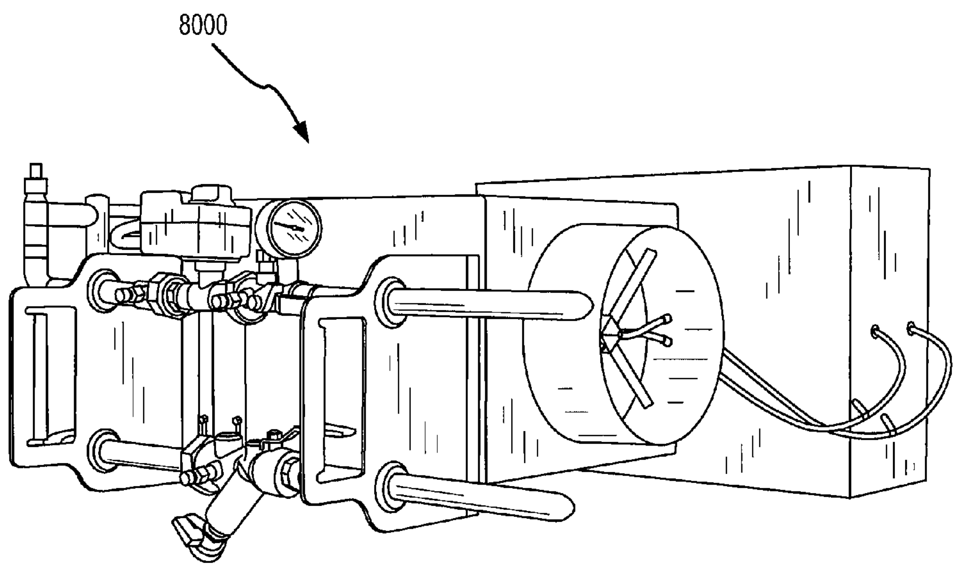
8000

FIG.8B

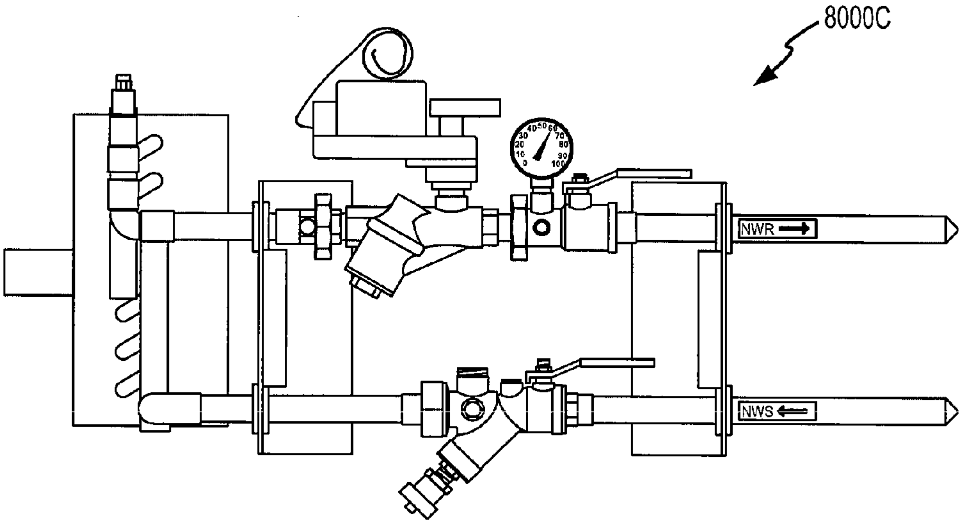

FIG.8C

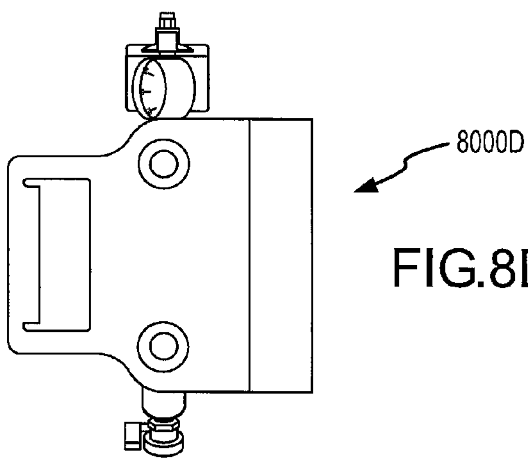

FIG.8D

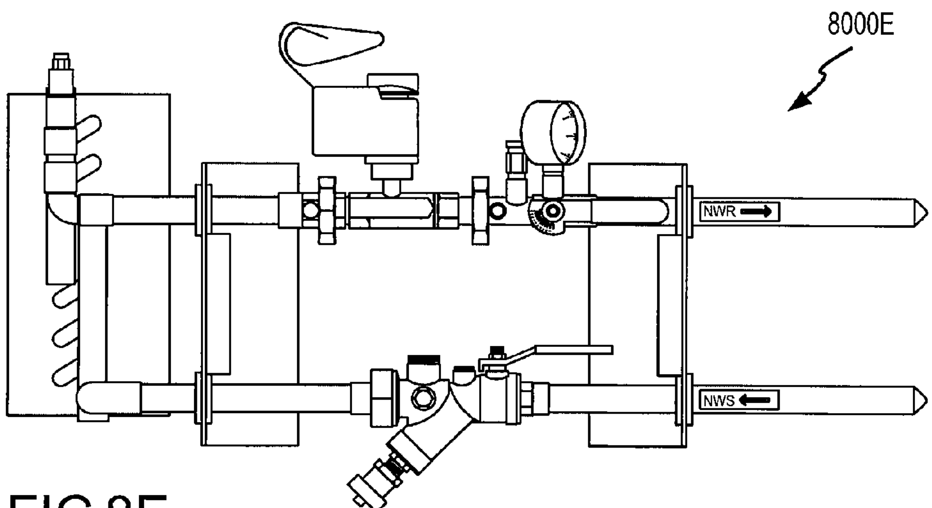

FIG.8E

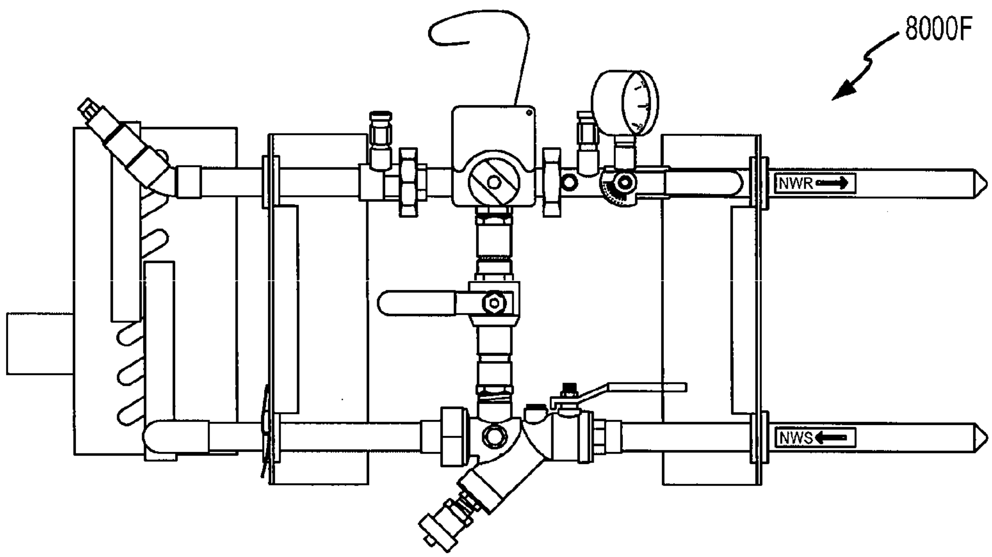

FIG.8F

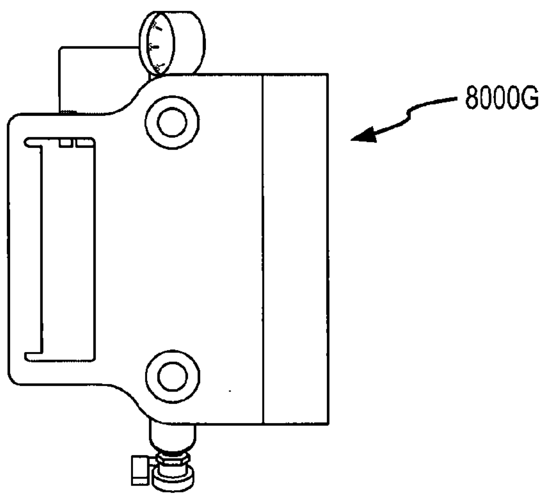

FIG.8G

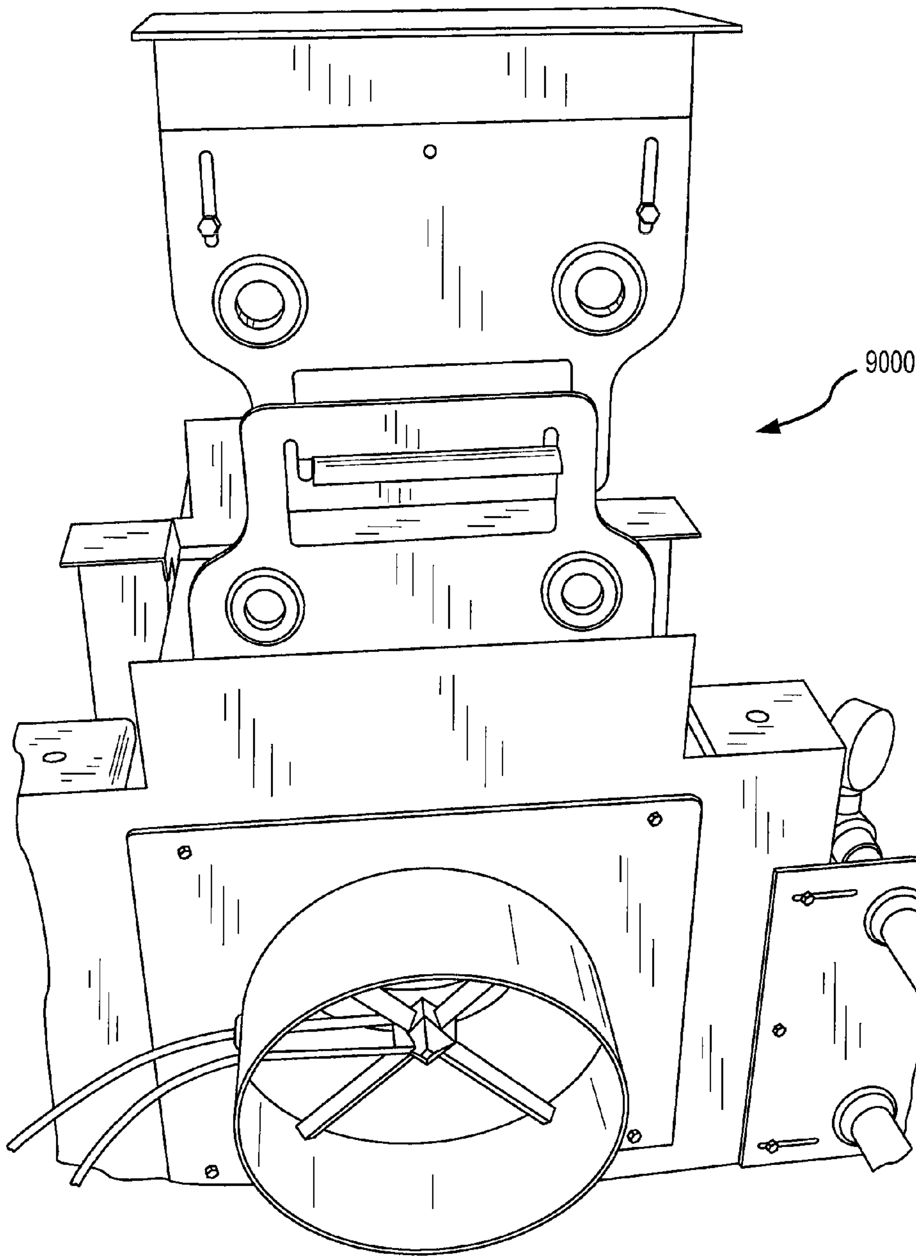

FIG.9

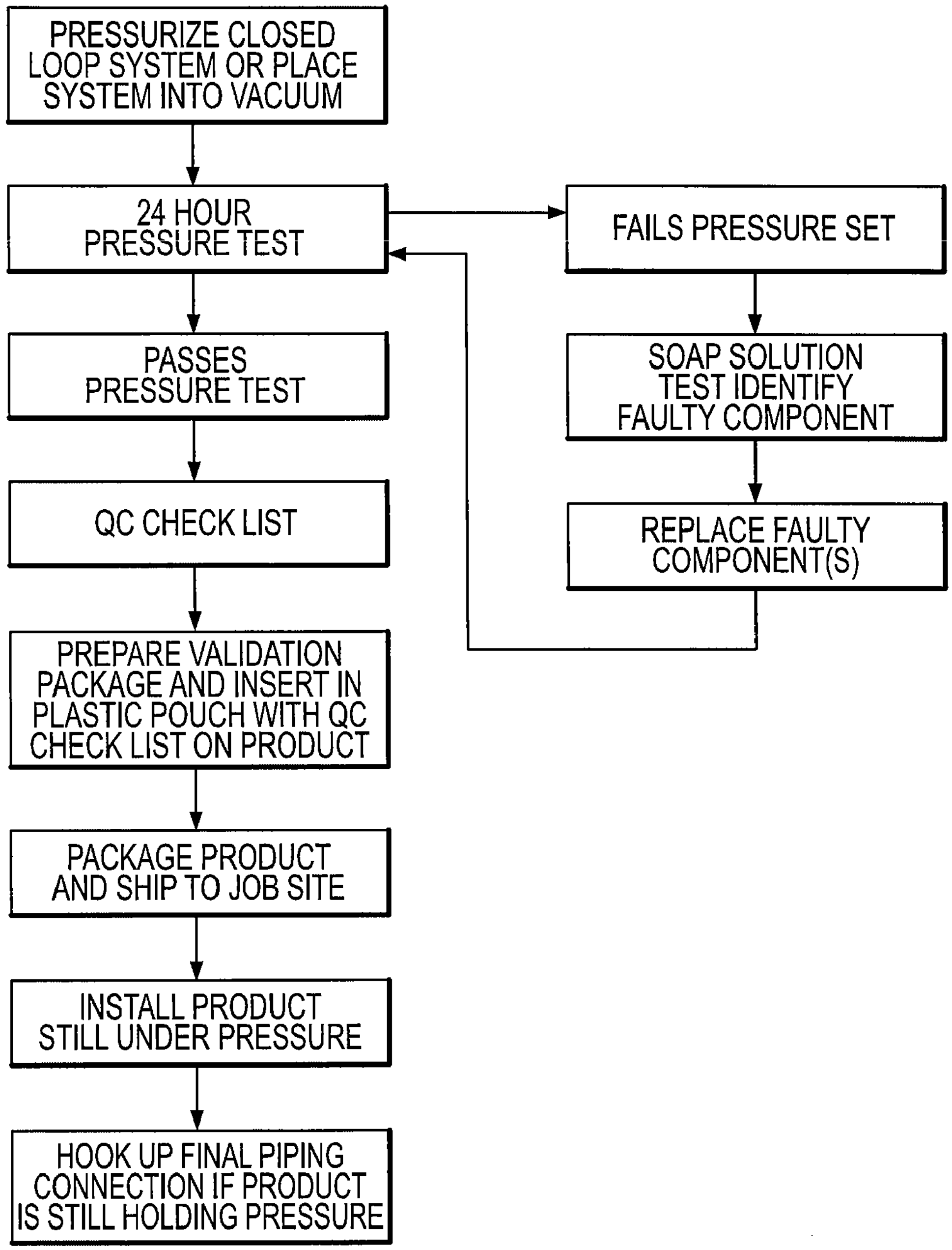
PRESSURIZE CLOSED LOOP SYSTEM OR PLACE SYSTEM INTO VACUUM
24 HOUR PRESSURE TEST
FAILS PRESSURE SET
SOAP SOLUTION TEST IDENTIFY FAULTY COMPONENT
REPLACE FAULTY COMPONENT(S)
PASSES PRESSURE TEST
QC CHECK LIST
PREPARE VALIDATION PACKAGE AND INSERT IN PLASTIC POUCH WITH QC CHECK LIST ON PRODUCT
PACKAGE PRODUCT AND SHIP TO JOB SITE
INSTALL PRODUCT STILL UNDER PRESSURE
HOOK UP FINAL PIPING CONNECTION IF PRODUCT IS STILL HOLDING PRESSURE

FIG.10A

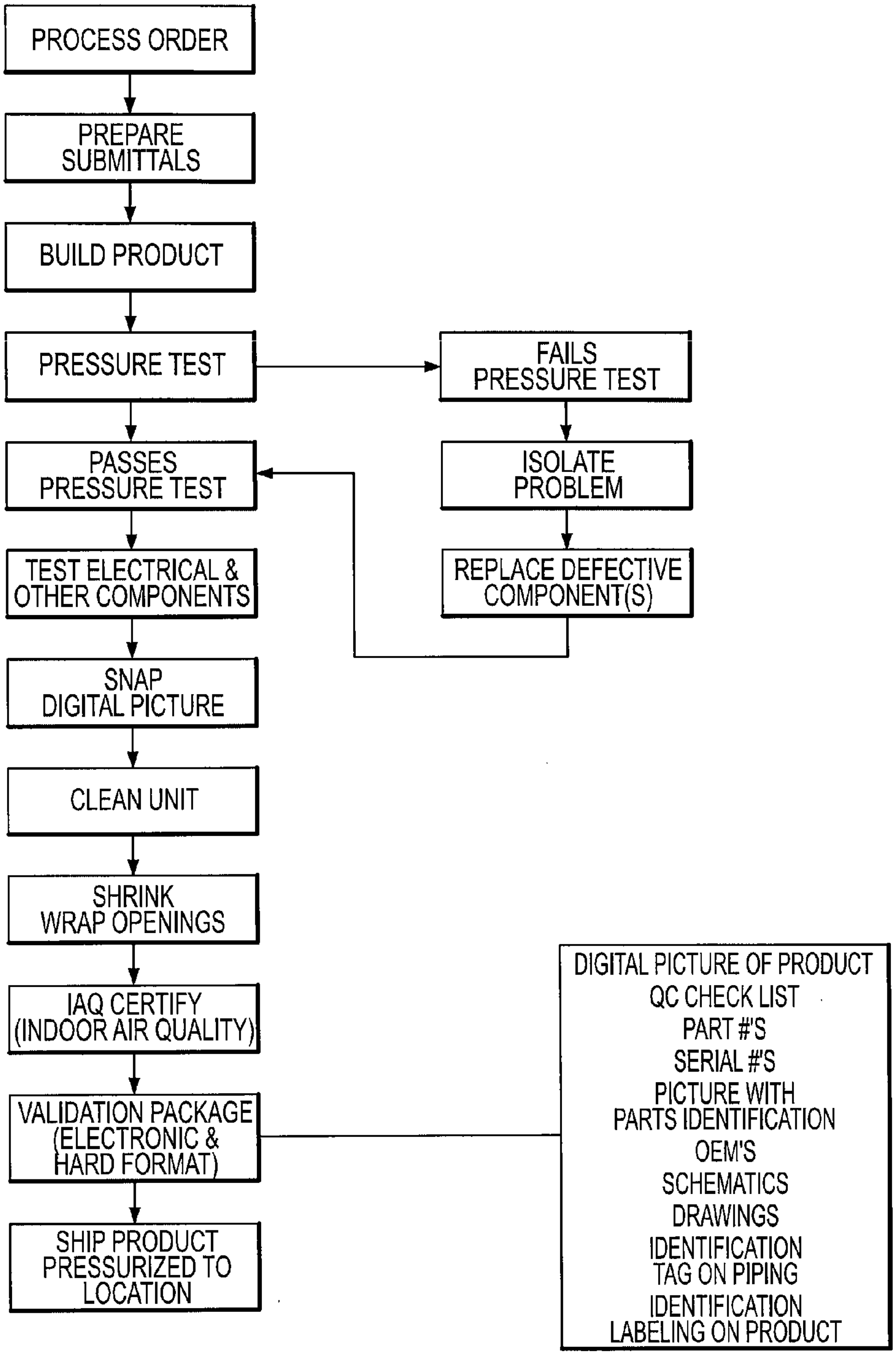
PROCESS ORDER
PREPARE SUBMITTALS
BUILD PRODUCT
PRESSURE TEST
FAILS PRESSURE TEST
ISOLATE PROBLEM
REPLACE DEFECTIVE COMPONENT(S)
PASSES PRESSURE TEST
TEST ELECTRICAL & OTHER COMPONENTS
SNAP DIGITAL PICTURE
CLEAN UNIT
SHRINK WRAP OPENINGS
IAQ CERTIFY (INDOOR AIR QUALITY)
VALIDATION PACKAGE (ELECTRONIC & HARD FORMAT)
SHIP PRODUCT PRESSURIZED TO LOCATION
DIGITAL PICTURE OF PRODUCT
QC CHECK LIST
PART #'S
SERIAL #'S
PICTURE WITH PARTS IDENTIFICATION
OEM'S
SCHEMATICS
DRAWINGS
IDENTIFICATION TAG ON PIPING
IDENTIFICATION LABELING ON PRODUCT

FIG.10B

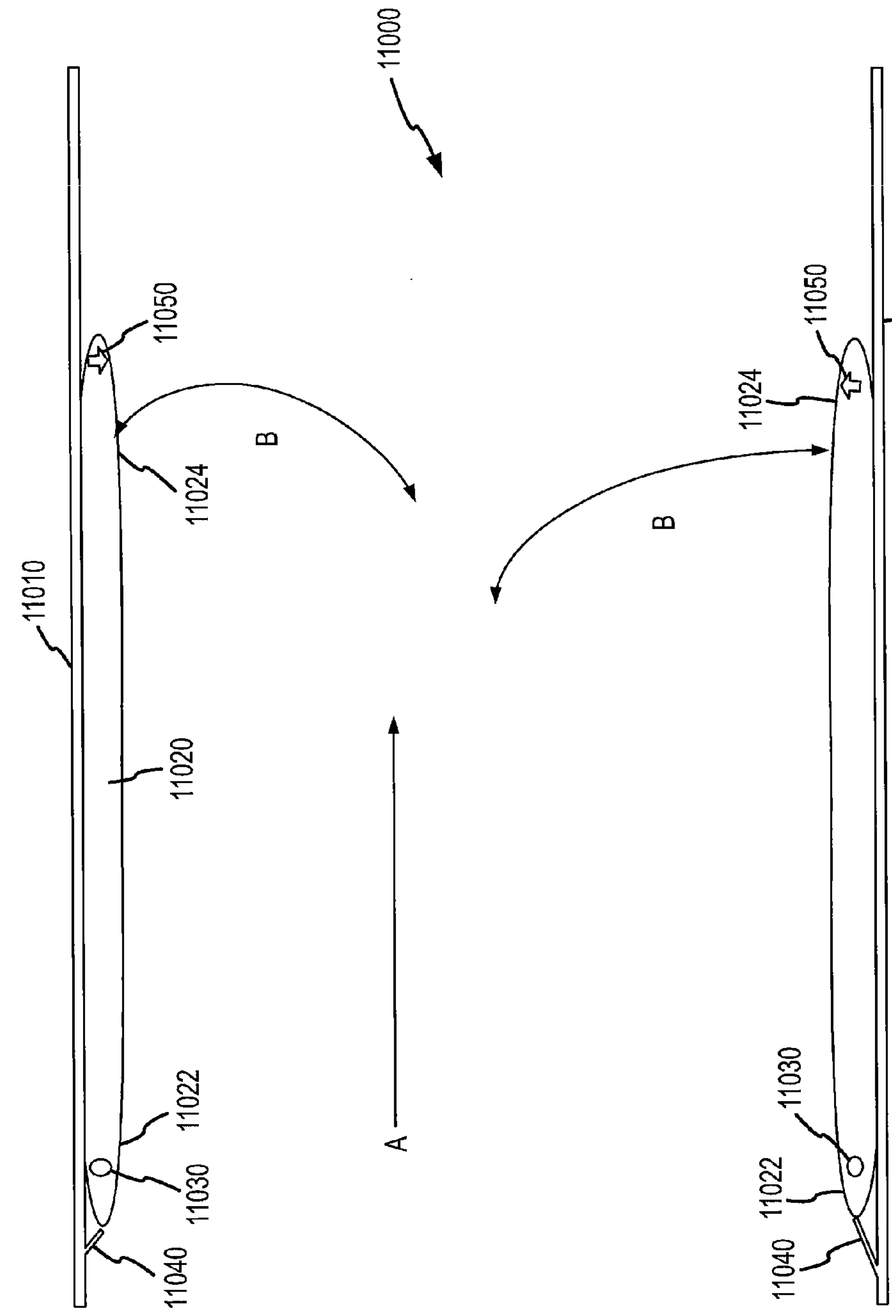
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FIG.11

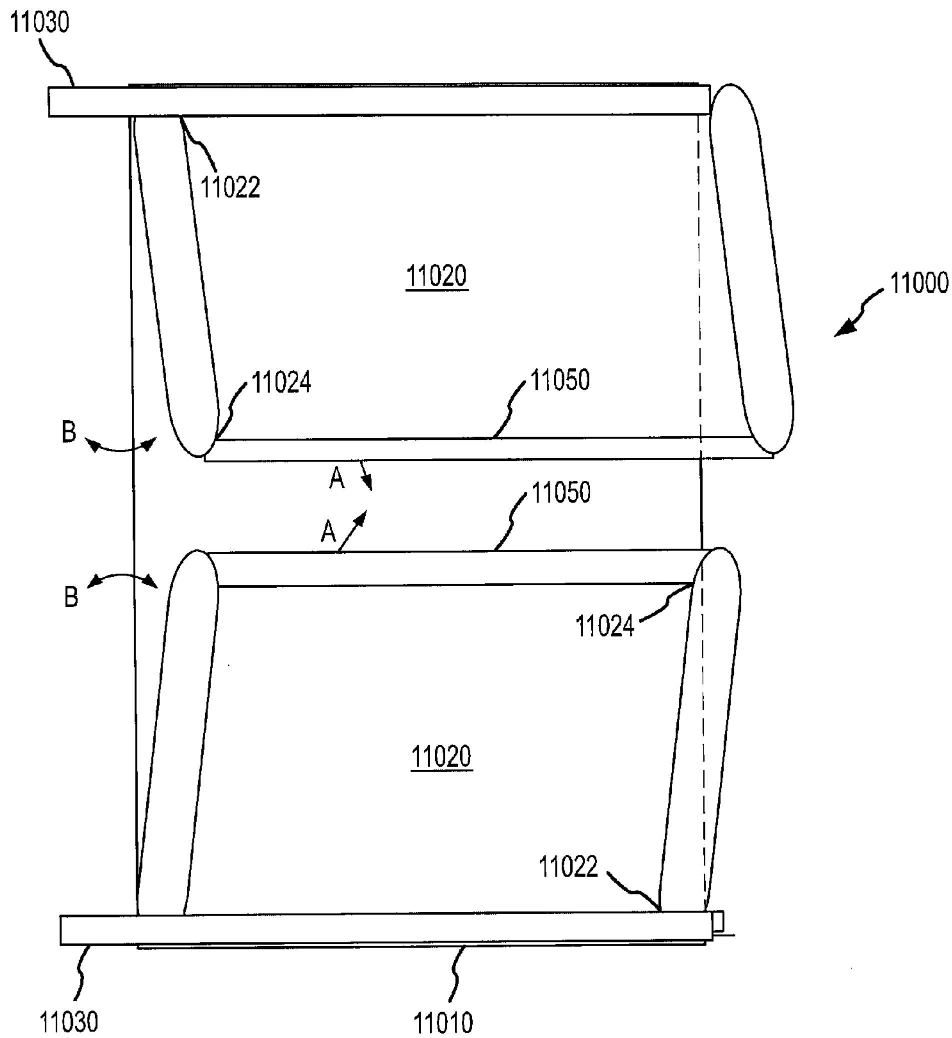
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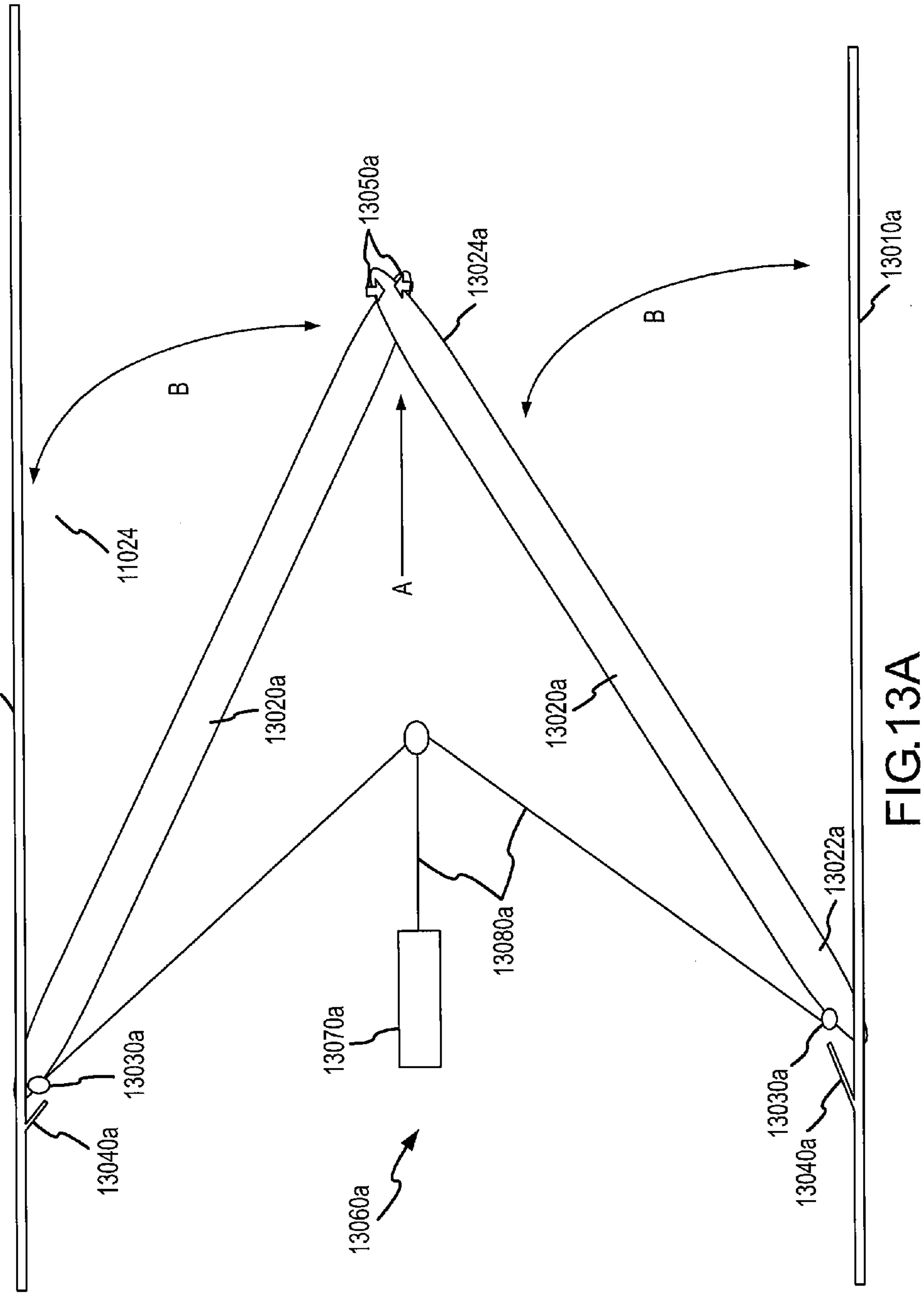
FIG.12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13010a
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B
A
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13040a
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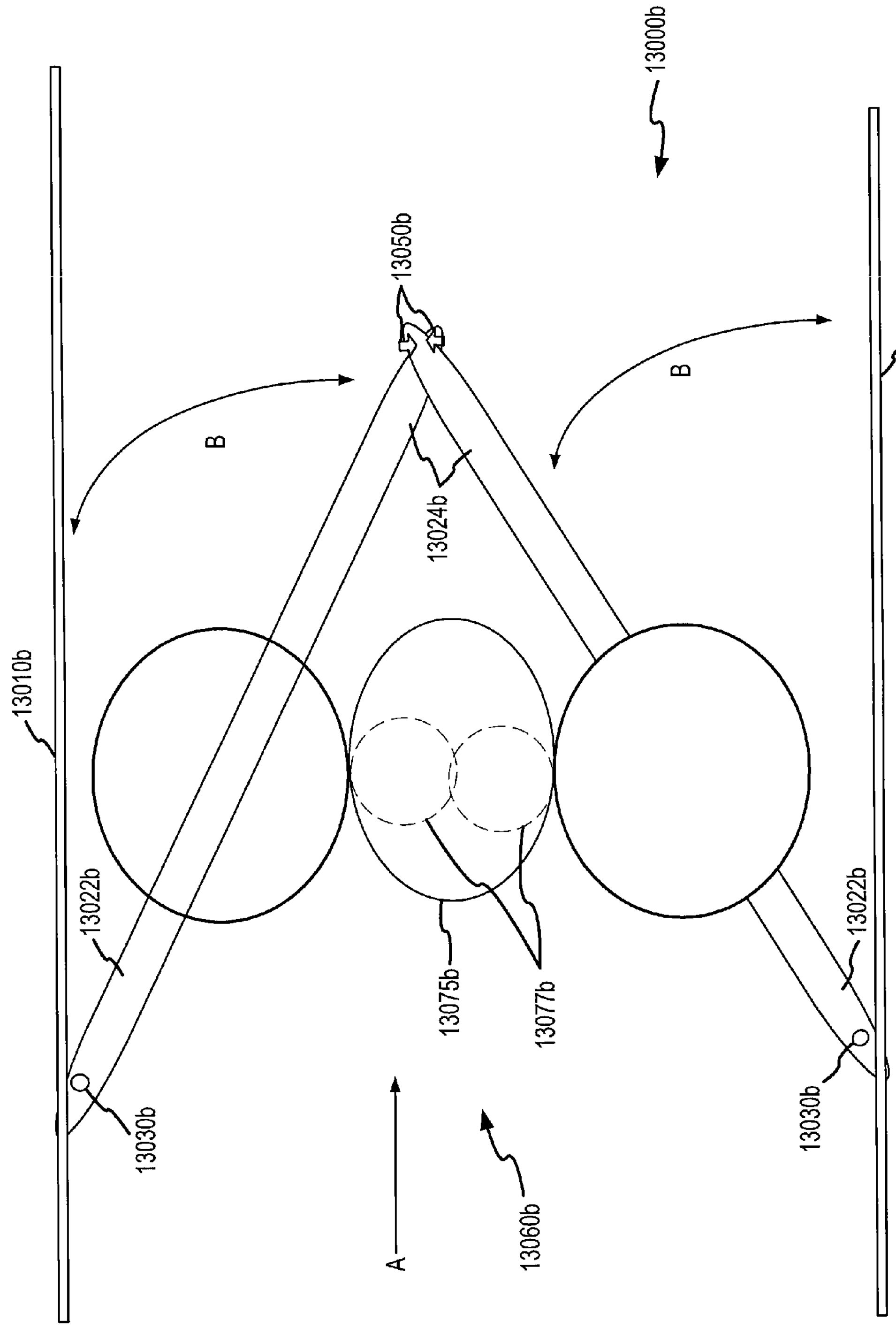
FIG.13A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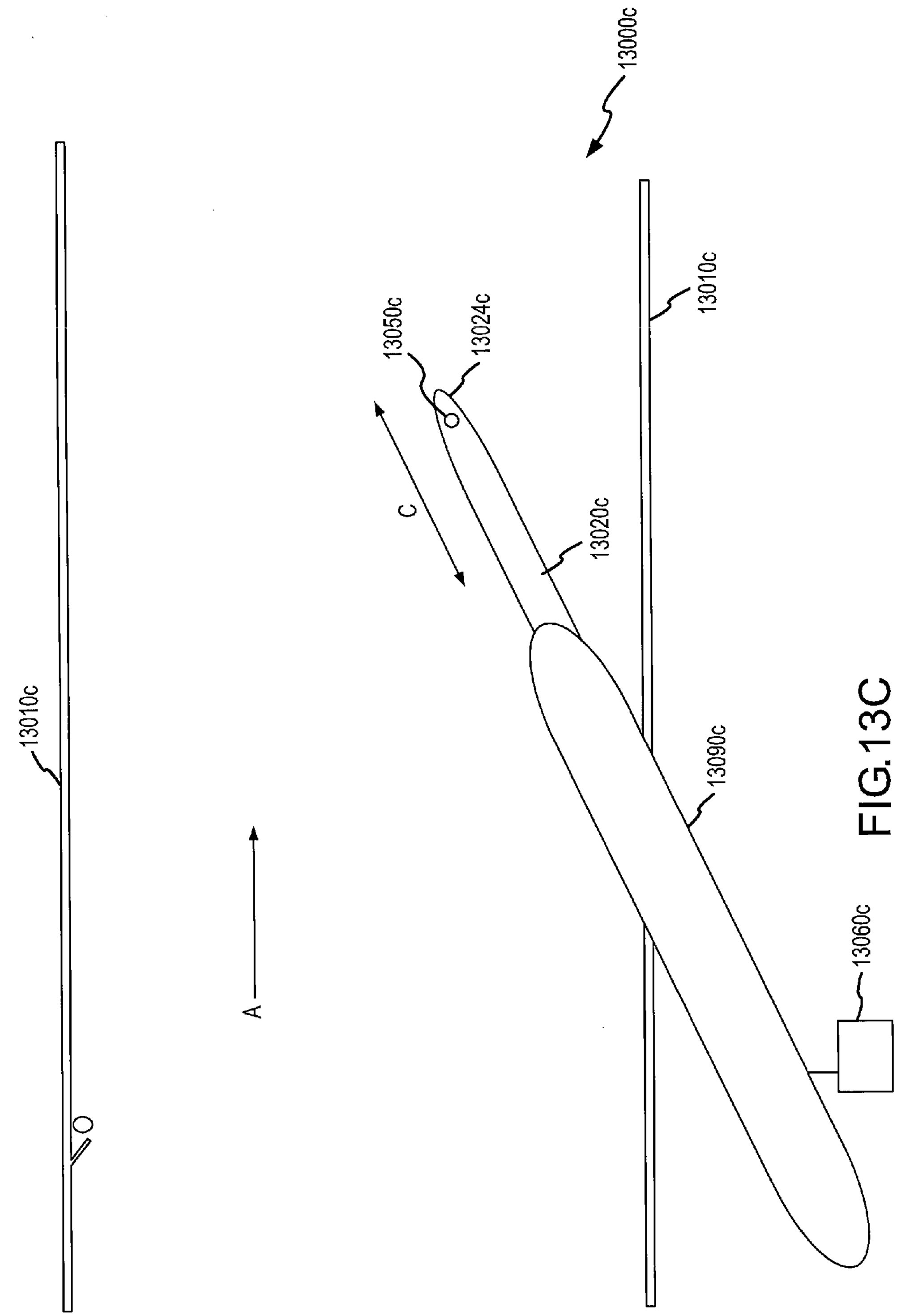
13030b
A
13060b

FIG.13B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C
13020c
13090c
13060c
A
13010c

FIG.13C

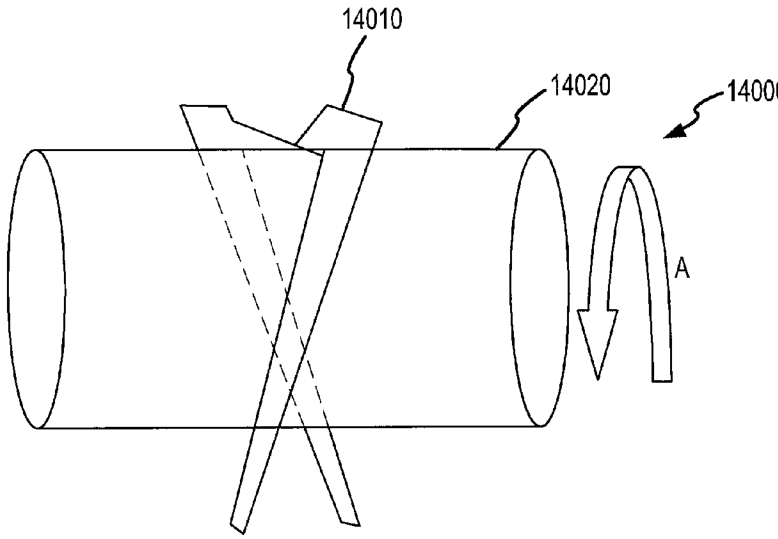

FIG.14A

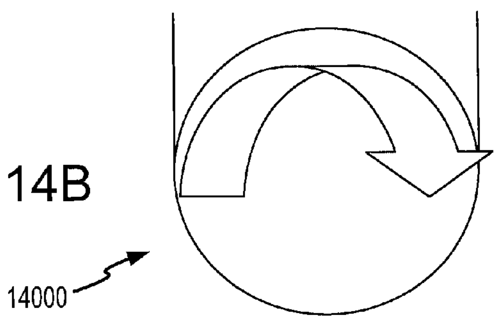

FIG.14B

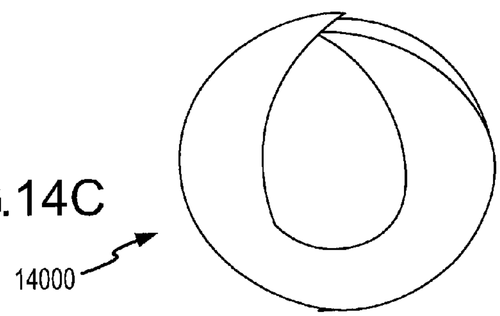

FIG.14C

LIMITED LOSS LAMINAR FLOW DAMPERS FOR HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority from U.S. Provisional Patent Application No. 60/756,037 filed Jan. 3, 2006 (Attorney Docket No. 025920-000500US). This application is related to U.S. patent application Ser. No. 11/429,418 filed May 5, 2006 (Attorney Docket No. 025920-000120US), which claims the benefit of U.S. Patent Application No. 60/678,695 filed May 6, 2005 (Attorney Docket No. 025920-000100US) and U.S. Patent Application No. 60/755,976 filed Jan. 3, 2006 (Attorney Docket No. 025920-00011US); and to U.S. patent application Ser. No. 11/180,310 filed Jul. 12, 2005 (Attorney Docket No. 025920-000210US), which is a continuation of U.S. Pat. No. 6,951,324 (Attorney Docket No. 025920-000200US); and to U.S. patent application Ser. No. 10/857,211 filed May 24, 2004 (Attorney Docket No. 025920-000300US); and to U.S. patent application Ser. No. 10/860,573 filed Jun. 2, 2004 (Attorney Docket No. 025920-000400US). This application is also related to U.S. Patent Publication No. 2003/0171092. The entire contents of each of these applications and their priority filings is incorporated herein by reference for all purposes.

BACKGROUND OF THE INVENTION

[0002] The present disclosure relates to methods, systems and apparatuses for heating, ventilation, and air conditioning ("HVAC") systems and, more particularly to limited loss and/or laminar flow dampers for such systems.

[0003] In general, HVAC systems control the temperature and humidity of indoor air. In most HVAC systems, air is drawn in, filtered, cooled and dehumidified or heated and humidified, and then delivered to an air conditioned space. The greatest portion of incoming air is drawn from the air conditioned space for recirculation through the HVAC system. HVAC system includes fans and ductwork for moving conditioned air to where it is needed while passing it through cooling and/or a heating sections of the ductwork.

[0004] One risk which must be addressed in designing and operating HVAC systems is that of biological contamination by bacteria, molds, and viruses. In recent years, biological problems in indoor environments have received considerable attention. Most frequently, molds, bacteria and/or virus grow wherever water collects in a HVAC systems ductwork, such as at its cooling sections.

[0005] Poor indoor air quality ("IAQ") and the spread of infectious disease through a HVAC system, at a minimum, can reduce worker productivity and increase absenteeism. Even more alarming is the potential liability for illnesses suffered by workers due to poor IAQ. The Legionnaires' disease outbreak in Philadelphia in 1976, is probably the most publicized instance of illness caused by poor IAQ. Even if contamination by molds and bacteria doesn't affect workers, their growth within HVAC system equipment creates maintenance problems which are very costly to correct. Left uncorrected, these problems exacerbate and, at a minimum, eventually reduce system's heat transfer efficiency.

[0006] HVAC systems in residential, commercial, education and research buildings usually include metallic pipes, hollow composite materials such as tubes, and the like. The systems are typically supported from and between floor or ceiling joists. The HVAC system typically includes a primary or main duct. A series of smaller branch ducts which extend from the main duct are mounted between adjacent floor or ceiling joists. Such main and branch ducts are normally supported by metal hangers located between the joists. Often the branch ducts include pipes and conduit lines for transporting liquid or gas which are suspended from ceiling joists or an adjacent wall typically with Unistrut®, threaded rod, couplings, and various hanger brackets.

[0007] Piping and conduits that supply gas and/or liquids within buildings require careful preparation. Builders or contractors typically use ladders or scaffolding to reach areas where piping is routed so installation may be cumbersome. Occasionally the pipe or conduits are prepared on the ground and installed by ladder as more complete assemblies. Pipe and conduit assemblies prepared on the ground or a floor of a building under construction are more unwieldy than the unassembled components, but pre-assembly is often more practical. Furthermore, conditions existing at construction sites and the number of differing types of components used in assembling a HVAC system render cataloging those components impractical if not impossible.

[0008] Generically, a terminal unit, also sometimes referred to as an air handling unit, is a HVAC system component that is located near an air conditioned space that regulates the temperature and/or volume of air supplied to the space. When providing air to a more critical environment such as a laboratory, an almost identical ductwork section is frequently referred to as a lab valve damper rather than as a terminal unit. One difference between a terminal unit and a lab valve damper is the precision with which the unit controls the temperature and humidity of conditioned air. As used throughout this document, the phrase terminal unit may identify either a terminal unit or a lab valve damper.

[0009] A HVAC system may be assembled using any one of several different types of terminal units. Generally, the mechanical portion of a terminal unit includes a casing through which air flows during operation of a HVAC system. Accordingly, a casing includes an inlet for receiving air from ductwork of a HVAC system, and an outlet for supplying air to a space in a building. Casings are usually fabricated from 22 gauge galvanized sheet steel. Due to the use of such light material, casings are easily damaged during shipping to a building site and during installation into the HVAC system. Those familiar with such damage to terminal unit casings frequently refer to it as "oil canning" because it resembles how a light gauge oil can collapses as the liquid flows out.

[0010] In a typical hydronic (all-water) HVAC system, the mechanical portion of a terminal unit includes a heat exchanging coil. Heated and/or cooled water is pumped from a central plant through pipes to the coil. Air from the HVAC system's ductwork passes through the coil after entering and before leaving the casing. Usually, a single terminal unit is dedicated for heating and/or cooling each air conditioned space. Air from the duct connected to the terminal unit passes through the coil to be heated and/or cooled by water flowing through the coil before the air enters the air conditioned space.

[0011] A Variable Air Volume ("VAV") HVAC system, in response to a control signal from a thermostat or room sensor, supplies only that volume of hot and/or cold air to an air conditioned space needed to satisfy the space's thermal load. A VAV HVAC system meets changing cooling and/or heating requirements by adjusting the amount, rather than the temperature, of air that flows to a space. For most buildings, a VAV HVAC system yields the best combination of comfort, first cost, and life cycle cost.

[0012] A VAV terminal unit is a relatively complex assembly which includes sheet metal, plumbing, electrical and pneumatic components. For example, a VAV terminal unit includes an airflow sensor that senses the velocity of air entering the terminal unit. To adjust the volume of cold air, a VAV terminal unit frequently includes a damper which automatically opens and closes as needed.

[0013] As a space's thermal load decreases, the damper starts closing thereby reducing the amount of heated or cooled air supplied to the space. Alternatively, the volume of air entering a space may be controlled by varying the speed of a fan included in the terminal unit. For either type of VAV terminal unit, VAV HVAC systems save energy consumed by fans in comparison with alternative HVAC systems by continually adjusting airflow to the heating and/or cooling required.

[0014] To be operable and fully-functional, terminal units for a hydronic HVAC system often include a coil, ductwork for supplying air to the coil and receiving air from the coil, plumbing for supplying water into and receiving water from the coil, and a control valve for regulating the amount of water flowing through the coil.

[0015] To match the flow of air through the terminal unit's ductwork to the profile of the coil, the terminal unit's ductwork may include transition sections both for air entering the coil and for air leaving the coil. In addition, a terminal unit may also include a re-heat coil, and/or a sound attenuator. In a terminal unit adapted for use in a VAV HVAC system, the terminal unit's ductwork may also include a damper and a damper actuator or variable speed fan for controlling the volume of air supplied by the terminal unit, and an airflow sensor for sensing the volume of air passing through the terminal unit.

[0016] Usually, all of the various parts needed to assemble a fully-functional VAV HVAC system's terminal unit arrive at building construction sites as separate components. Generally, these components are then assembled into a fully functional terminal unit at the construction site. Due to cluttered working conditions usually existing at a construction site where workers skilled in different crafts, e.g. plumbing, electrical, structural, etc., must concurrently collaborate to complete the building project, assembling the various components into a fully functional terminal unit may occupy the better part of a day. Furthermore, present practices and equipment are poorly adapted for swiftly constructing a high quality HVAC system that is easily commissioned.

[0017] For example, because it is less expensive to wire a HVAC system's terminal units with 24 volt low voltage electrical power rather than 220 or 110 volt power, presently sections of buildings include transformer trees which an electrician generally assembles by installing multiple step down transformers on an electrical panel. This technique permits wiring 220 or 110 volt electrical power to the transformer tree on each panel, with the 24 volt low voltage electrical power then being wired individually from a transformer on the panel over distances of five (5) to one hundred (100) feet to a terminal units for energizing its Direct Digital Control ("DDC") controller, and 2 way or 3 way automatic temperature control ("ATC") control valve.

[0018] Usually, terminal units are supported from a building using angle brackets, straps, or thread rod. Usually these support devices are attached directly to the terminal unit. Terminal unit casings are usually made using 22 gauge sheet metal. Due to the use of this light material, casings are easily dented or bent during installation.

[0019] With current construction site labor costing up to $80.00/hour, assembling a terminal unit at a construction site may cost $500.00 to $1,000.00 for labor alone. Furthermore, terminal units assembled at a construction site generally differ from one another due to assembly by different craftsmen, and insufficient use of identical components in assembling each terminal unit. Due to conditions existing at construction sites and the number of differing types of components used in assembling a HVAC system, cataloging the components used in assembling the system is impractical. Lastly, construction sites generally lack any facilities for individually pre-testing building components, such as terminal units, assembled on-site.

[0020] After assembling a HVAC system, it must be activated, tested and commissioned to ensure IAQ. Testing a HVAC system only after it is completely assembled inevitably results in many hours of problem-solving and leak-hunting. Usually, there are leaky joints, broken valves, damaged pipes, leaky coils and improperly assembled components that must be tracked down which further increases building costs. After finding a faulty component, it must be identified, ordered and replaced which takes time and delays completion of the building project. Furthermore, years after a building project is complete to maintain IAQ a building manager responsible for the HVAC system's maintenance will surely have to identify and replace broken components.

[0021] The preceding considerations arising from construction site assembly of fully functional terminal units slows construction, increase building costs, requires rework when a terminal unit experiences an initial failure, and ultimately makes more difficult and expensive maintaining a building's HVAC system years after those responsible for its assembly are no longer available.

[0022] A variety of dampers are used in the HVAC industry. Many of these dampers, when installed in an HVAC system, have an associated air flow monitoring device to sense the pressure drop or otherwise measure the air moving across the damper, and to adjust the position of the damper so as to control airflow therethrough. The sensors are often located in the inlet or outlet of the damper. Unfortunately, many dampers and/or sensors induce turbulence, and in some cases rely on sensing pressures or the like at large numbers of locations distributed across the duct, increasing pressure drops, noise, and energy use.

[0023] In light of the above, it would generally be desirable to provide improved HVAC devices, systems, and methods. It would be particularly desirable to provide improved techniques and devices for controlling flow of air and other gasses within the ductwork of an HVAC system.

BRIEF SUMMARY OF THE INVENTION

[0024] Improved HVAC devices, systems, and/or methods include dampers for controlling the flow of air or other gasses through an HVAC duct, often while inhibiting turbulence within the duct and/or pressure loss within the duct at least when the damper is in an open flow configuration. By limiting flow turbulence, these embodiments may facilitate relatively simple flow measurement techniques, allowing sufficiently accurate flow measurements without, for example, having to resort to a multi-axis flow sensor. Embodiments of such dampers may employ a two-part damper arrangement. In many embodiments, flow will travel through the middle of the damper uniformly and with a laminar flow. One or more small, relatively unobtrusive sensors (optionally being wireless) can be included for controlling operation of the damper, the sensor(s) optionally measuring the distance between damper elements, sound, air flow, or the like, with such sensor(s)/damper combination inhibiting inadvertent pressure drop and turbulence in flows through the damper. The damper elements may optionally comprise airfoil cross-sections, with alternative dampers having a resilient helical configuration that can choke down flow by inducing a vortex in the flow, allowing static pressure regain to occur within the duct system. Such dampers may have control advantages, enhance energy efficiency, limit noise, and/or provide enhanced performance characteristics.

[0025] In a first aspect, embodiments of the present invention provide a damper assembly or system for use in a heating, ventilation, and air conditioning (HVAC) system. The damper assembly or system includes a casing having an inlet and an outflow with a flow direction extending therebetween, a first damper member movably disposed within the casing, and a second damper member movably disposed within the casing. The damper members each have a cross-sections and are movable between an open flow configuration and a restricted flow configuration such that laminar flow is maintained as the flow is restricted. The assembly may also include a damper assembly controller coupled to the damper members. In some cases, the assembly includes a flow sensor coupled to the damper members. Optionally, the flow sensor may measure pressure at less than 5 locations across the dampers. In some cases, the assembly includes a first sensor coupled with the first damper member. The first sensor can detect an orientation of the first damper member relative to the casing. In some cases, the first sensor is disposed at or near a trailing end of the first damper member. A first sensor may detect an orientation of the first damper member relative to the second damper member. The assembly may also include one or more air stops. In some aspects, the assembly includes a first damper member having a trailing end and a second damper member having a trailing end, and the first damper member trailing end and the second damper member trailing end are configured to be moved toward each other when the assembly is moved toward a restricted flow configuration.

[0026] In another aspect, embodiments of the present invention provide a damper assembly or system for use in a heating, ventilation, and air conditioning (HVAC) system. The damper assembly or system includes a casing having an inlet and an outflow with a flow direction extending therebetween, and a damper member disposed within the casing, the damper member comprising a helical body deformable between an open flow configuration and a restricted flow configuration. The damper in at least one configuration may have a shape suitable for inducing a vortex in a flow within the casing.

[0027] In yet another aspect, embodiments of the present invention provide a method of controlling a fluid flow in a heating, ventilation, and air conditioning (HVAC) system. The method includes flowing a fluid through a casing inlet toward a casing outlet, flowing the fluid across a plurality of damper members disposed within the casing, restricting an amount of the fluid passing through the casing by actuating a first damper member, and maintaining a laminar flow within the fluid during the actuation of the first damper member. The method may also include sensing an orientation of the first damper member. In some cases, the method includes sensing a pressure within the casing. The step of restricting the amount of fluid passing through the casing may include actuating a second damper member. Relatedly, the method may also include maintaining the laminar flow during actuation of the second damper member. Optionally, the method may include sensing an orientation of the second damper member. For example, the method may include sensing an orientation of the second damper member relative to the first damper member. In some cases, the method includes sensing an orientation of the second damper member relative to the casing. A cross section of the first damper member can include an aerodynamic profile and a cross section of the second damper member can include an aerodynamic profile. In some cases, the method includes sensing a distance between the first damper member and the second damper member.

[0028] These and other features, objects and advantages will be understood or apparent to those of ordinary skill in the art from the following detailed description of the preferred embodiment as illustrated in the various drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] FIG. **1** is a perspective view of an fully-functional zone-control unit ready for installation in a HVAC system which includes a zone-control unit having a casing from which a pair of handles project for supporting inlet and outlet piping assemblies included in the fully-functional zone-control unit, according to one embodiment of the present invention.

[0030] FIG. **2** is an elevational view of a plate that is included in the handles illustrated in FIG. **1** which project from the zone-control unit's casing and support the piping assemblies, according to one embodiment of the present invention.

[0031] FIGS. **2**A and B illustrate a zone-control unit according to one embodiment of the present invention.

[0032] FIGS. **3**A and B illustrate a zone-control unit according to one embodiment of the present invention.

[0033] FIGS. **4**A and B illustrate a zone-control unit according to one embodiment of the present invention.

[0034] FIG. **5** illustrates a zone-control unit according to one embodiment of the present invention.

[0035] FIG. **6** illustrates a zone-control unit according to one embodiment of the present invention.

[0036] FIG. **7** illustrates a zone-control unit according to one embodiment of the present invention.

[0037] FIGS. **8**A-**8**G illustrate differing HVAC units having standardized components, along with aspects of those components.

[0038] FIG. **9** illustrates interfacing of HVAC unit support structures, showing that the support structures can be used to suspend and support the HVAC unit for use in an HVAC system.

[0039] FIGS. **10**A and **10**B illustrate a quality control process and method for providing HVAC units and assembling and HVAC system.

[0040] FIG. **11** schematically illustrates a cross-sectional view of a two part damper having two airfoil-shaped dampers to inhibit turbulence.

[0041] FIG. **12** schematically illustrates a rear view of the damper of FIG. **11**.

[0042] FIGS. **13**A-**13**C schematically illustrate differing alternative actuation mechanisms for dampers similar to those of FIG. **11**.

[0043] FIG. **14**A-C illustrate an alternative damper configuration having a deformable helical damper body for inducing a vortex in flow through an associated duct.

DETAILED DESCRIPTION OF THE INVENTION

[0044] The perspective view of FIG. **1** illustrates a fully-functional HVAC terminal unit referred to by the general reference character **100**. The fully-functional zone-control unit **100** depicted in FIG. **1**, which illustrates one embodiment of the present invention, preferably includes a mechanical terminal unit **102** having a casing **104** visible in FIG. **1**. The casing **104**, which can be made from various materials of differing thicknesses, is frequently made from galvanized sheet steel material. Frequently, the casing **104** is lined with a thermal insulation material, not visible in FIG. **1**, which may be chosen from various different types such as fiberglass insulation, rigid duct board fiber insulation, polyolefin, closed cell, foam insulation, etc. In some embodiments, insulation contained in zone-control unit **100** complies with an industry standard, such as a standard set by the Office of Statewide Health and Planning Department (OSHPOD).

[0045] For VAV zone-control units **100**, the mechanical terminal unit **102** preferably includes a damper assembly, not visible in FIG. **1**. The damper assembly is supported for rotation within the casing **104** by a shaft which extends through and beyond the casing **104**. The mechanical terminal unit **102** of a zone-control unit **100** that includes the damper assembly also includes a DDC controller **112** depicted in FIG. **3**. The DDC controller **112** is coupled to a damper motor, not visible in any of the FIGS., which rotates the damper assembly. The DDC controller **112** receives a signal from a thermostat or room sensor and responsive thereto controls operation of the damper assembly to regulate the amount of heating or cooling provided by air leaving the zone-control unit **100**. The DDC controller **112** may be selected from various different types such as pneumatic, analog electronic or direct digital electronic. The mechanical terminal unit **102** also includes an airflow sensor, also not visible in FIG. **1**, which is usually located near an air inlet to the casing **104** and may be selected from various types for sensing the velocity of air entering the casing **104**.

[0046] To heat or cool air flowing through the mechanical terminal unit **102**, the casing **104** includes a coil **122** that is located near the air inlet thereto, and which adapts the mechanical terminal unit **102** for inclusion in a hydronic HVAC system. The casing **104** includes both an inlet collar, not visible in FIG. **1**, and an outlet connection **124** each of which is adapted to mate with a building's HVAC ductwork. If a zone-control unit **100** were to be assembled at a construction site, the mechanical terminal unit **102** would arrive there with the various components listed above mostly assembled, other than the DDC controller **112** and the damper motor, by the terminal unit's manufacturer.

[0047] The mechanical terminal unit **102** is preferably selected from among various different types and styles sold by Krueger based in Richardson, Tex. Krueger is a division of Air Systems Components (ASC) which is part of the Dayton, Ohio Air System Components Division of Tomkins Industries, Inc. of London, England.

[0048] To fashion the mechanical terminal unit **102** into a zone-control unit **100** ready for installation into a building's HVAC system, various plumbing components must be added for circulating either hot or cold water through the coil **122**. For supplying water to the coil **122** the zone-control unit **100** includes an inlet piping assembly **202**. The piping assembly **202** includes an L-shaped section of pipe **204** which connects at one end to a lower header of the coil **122**, not visible in FIG. **1**. At its other end, the pipe **204** ends at a union **208**. The other half of the union **208** connects to a tailpiece **212** which receives both a pressure/temperature ("P/T") port **214** and a drain **216**. The drain **216** includes a ball valve integrated ¾" male garden hose end connection to facilitate draining the coil **122** when maintenance or repairs become necessary. A ball valve **222**, which includes a strainer, connects to a side of the tailpiece **212** away from the union **208** to permit stopping hot or cold water from circulating through the coil **122**. An opposite side of the valve **222** from the tailpiece **212** receives a length of pipe **224** which adapts the piping assembly **202** for connecting to a building's plumbing.

[0049] The zone-control unit **100** also includes an outlet piping assembly **232** for receiving water from the coil **122**. A short length of pipe **234** which ends in a tee **236** connects to an header **238** of the coil **122**. A manual air vent **242** is connected to and projects upward above the tee **236** to facilitate eliminating air from the piping assemblies **202**, **232** following first assembling the HVAC system, or reassembly of the zone-control unit **100** when maintenance or repairs become necessary. An L-shaped section of pipe **244** is connected to and depends below the tee **236**. Similar to the pipe **204**, an end of the pipe **244** furthest from the tee **236** ends at a union **246**. The other half of the union **246** connects to a 2 way or 3 way ATC control valve **252**. The ATC control valve **252** may either be of a type depicted in FIG. **1** that provides only on-off control, or be of a type that provides proportional control, not illustrated in any of the FIGS. An electrical signal supplied to the ATC control valve **252** from the DDC controller **112** via a control signal cable **114** energize operation of the ATC control valve **252**.

[0050] A side of the ATC control valve **252** furthest from the union **246** connects to a union **254**. Connecting the ATC control valve **252** into the piping assembly **232** on both sides with unions **246**, **254** facilitates its replacement when maintenance or repairs become necessary. A tailpiece **262**, connected to the other side of the union **254** furthest from the ATC control valve **252**, receives both a P/T port **264** and a manual air vent **266**. The P/T ports **214** and **264** facilitate measuring pressure and/or temperature of water circulating through the coil **122**. The vent **266** facilitates eliminating air from the piping assembly **232** following first assembling the HVAC system, or reassembly of the zone-control unit **100** when maintenance or repairs become necessary. A manual balancing valve **272** connects to the other side of the tailpiece **262** from the furthest from the union **254**. An opposite side of the valve **272** from the tailpiece **262** receives a length of pipe **274** which, similar to the pipe **224**, adapts the piping assembly **232** for connecting to a building's plumbing. The valves **222**, **216**, **272** and other plumbing fittings included in the piping assemblies **202**, **232** are preferably manufactured by HCI of Madison Heights, Mich. The valves **222**, **272** permit isolating from the building's plumbing, when maintenance or repairs become necessary, the coil **122** and those portions of the piping assemblies **202**, **232** which connect to the valves **222**, **272**.

[0051] As described thus far, the zone-control unit **100** including the piping assemblies **202**, **232** are substantially the same as those which a skilled sheet metal worker, controls contractor, electrician, and pipe fitter might collectively assemble at a building site. However, in assembling zone-control units **100** in accordance with the present invention for a particular building project or significant portion thereof, all of the lengths of pipe, plumbing fittings, valves, vents, P/T ports, etc. are the same. Consequently, when a repair become necessary a building manager or the manager's personnel responsible for maintaining the HVAC system may confidently order a replacement part knowing that it will surely fit because the plumbing of each zone-control unit **100** is not unique. Rather, in accordance with the present invention the plumbing of zone-control units **100** is uniform throughout the building or significant portion thereof. Furthermore, because plumbing of zone-control units **100** is uniform throughout the building or significant portion thereof, acting either from prudence or caution a building manager may confidently maintain an inventory of plumbing components for the zone-control units **100** to have on hand when they need repair thereby significantly reducing downtime while also maintaining IAQ.

[0052] In addition to being assembled with uniform plumbing, in accordance with the present invention tags **282** are attached to each valve **252**, **272** or other component that are likely to eventually require replacement. After the HVAC system has been commissioned, when a failure occurs and is located, the presence of an identifying tag **282** attached to a failed component simplifies its replacement and reduces the time required therefor. The tags **282** are particularly helpful if components from different manufacturers and/or different catalogs have been incorporated into the HVAC system. The tags **282** are preferably engraved plastic, but may also be made from metal, paper, or any other appropriate material. The tags **282** may carry barcodes or plain language, for example, and may be customized to provide information in the manner most useful for a particular project. In accordance with the present invention, performance requirements for each zone-control unit **100** such as GPM, CFM, CV and so on are marked thereon in an accessible and well defined location.

[0053] Also in accordance with the present invention, each pipe **224**, **274** is sealed by a spun copper cap **284** which is five (5) times thicker than the pipe **224**, **274**, and the assembled piping assemblies **202**, **232** include a pressure gauge **286**. Following fabrication and sealing of the piping assemblies **202**, **232**, they are pressure tested with, for example, a gas such as air. Other gasses or a liquid may be used as appropriate for materials used in the piping assemblies **202**, **232**. A typical pressure range used in testing assembled piping assemblies **202**, **232** and coil **122** is 20-400 psi, and in one embodiment is preferably 140 psi. While pressurized, the piping assemblies **202**, **232** and the coil **122** are checked for leaks, e.g. with a soap solution. Any defects in assembly found during pressure testing are repaired and/or defective components replaced. For example, experience in assembling zone-control units **100** in accordance with the present invention indicates that about 3 to 7% of new coils **122** are defective and must be replaced.

[0054] When inspection and pressure testing indicates that no leaks appear to exist in the piping assemblies **202**, **232** and the coil **122**, they are then sealed and re-pressurized to at least 100 psi, preferably 140 psi. After pressurization, the piping assemblies **202**, **232** and the coil **122** remain sealed for 24 hours throughout which they must hold the pressurization to confirm that the zone-control unit **100** is undergoing installation into a HVAC system. After the piping assemblies **202**, **232** and the coil **122** pass this 24 hour quality assurance test, zone-control units **100** can be ready for shipping to a construction site. In accordance with one embodiment of the present invention, the piping assemblies **202**, **232** and coil **122** of zone-control units **100** ready for installation remain pressurized continuously after their 24 hour quality assurance test at a pressure of at least 60 psi until they are about to be installed into a building's HVAC system. In some cases, the shipping pressure can be 40 psi, or any other desired pressure.

[0055] Immediately before installing a zone-control unit **100** at a construction site, their readiness for installation can be confirmed by checking the pressure gauge **286**. If the pressure gauge **286** fails to indicate a specified pressure, then the zone-control unit **100** may need further testing and/or repair, and should not be installed into the HVAC system. Instead an identically assembled zone-control unit **100** having a pressure gauge **286** which indicates the specified pressure may be immediately substituted for a defective one, and the defective zone-control unit **100** may either be repaired and re-tested at the construction site, or it may be returned to its vendor for repair.

[0056] Identifying and replacing faulty piping assemblies **202**, **232** and/or coil **122** in this way prior to installing the zone-control unit **100** saves time and money. The present invention can eliminate an inability to test the piping assemblies **202**, **232** and coil **122** of each zone-control unit **100** assembled at a construction site until the entire HVAC system is completely assembled and ready for commissioning. Off-site assembly and testing of zone-control units **100**, rather than assembling the components at the construction site, improves quality control by individually assuring that each zone-control unit **100** is ready for installation in a HVAC system. In this way the present invention saves time and money that would otherwise be spent tracking down leaks that occur using traditional on-site assembly of zone-control units **100**. Furthermore, by preventing pinhole leaks in the zone-control unit **100**, which inevitably result in mold, biochemical hazards, etc., the present invention significantly improves IAQ both initially and throughout the HVAC system's service life.

[**0057**] One problem which arises with assembling zone-control units **100** at a location remote from a construction site is that during their transportation to the site and during installation into a building's ductwork zone-control units **100** may be manipulated by the piping assemblies **202**, **232** and/or the coil **122** of the mechanical terminal unit **102**. Such handling of zone-control units **100** during installation may damage seals between the components as well as the components themselves. Furthermore, such damage may not be noticed until the HVAC system is pressurized for commissioning or at a later date. At that time, locating a leak or malfunctioning part may be time-consuming, virtually impossible and cost prohibitive. To reduce any possibility that a zone-control unit **100** might be damaged while being transported from its assembly, test and qualification location to a construction site and to facilitate handling the zone-control unit **100** during its installation into the HVAC system, in accordance with the embodiment of the present invention illustrated in FIG. **1** each zone-control unit **100** also includes a pair of handles **502** that are preferably secured to the casing **104** of the mechanical terminal unit **102** near opposite ends thereof.

[**0058**] Each of the handles **502** includes an L-shaped handle mounting bracket **504** which is rigidly secured to a wall **132** of the mechanical terminal unit **102** which is nearest to the piping assemblies **202**, **232**. As depicted in FIG. **1**, the handle mounting brackets **504** are secured near opposite ends of the wall **132** of the zone-control unit's casing **104**. Each of the handles **502**, for example illustrated in FIG. **2**, is formed by a plate **506*a*** of sheet metal. Each plate **506*a*** include a plurality of holes **508** through which fasteners pass for securing the plate **506*a*** to a portion of the handle mounting bracket **504** that projects outward from the wall **132**. The handle mounting brackets **504** and the plates **506*a*** can be made from 12 gauge sheet steel. The handle mounting brackets **504** can be galvanized and the plates **506*a*** can be powder coated, and can be made from various materials and gauge sizes.

[**0059**] For use with the zone-control unit **100**, each plate **506*a*** is also pierced by a rectangularly-shaped hole **512**, and by a pair of circularly-shaped holes **514** illustrated with dashed lines in FIG. **2**. The holes **512** are large enough to accept many lifting devices including human hands, forklift, Unistrut, pipe or other lifting device. Each hole **512** has a curved edge **518** to prevent hand injuries, and may lack any sharp edges or non-rolled edges. The holes **514** each receive a grommet **522** that fits snugly around the piping assemblies **202**, **232** where they pass through plates **506*a***.

[**0060**] Arranged in this way, the handle mounting brackets **504** and plates **506*a*** provide a structure for mechanically coupling the mechanical terminal unit **102** and the piping assemblies **202**, **232** together thereby reducing any possibility that the zone-control unit **100** might be damaged while being transported from its assembly, test and qualification location to a construction site. Furthermore, the handles **502** protect zone-control units **100** during shipping, and facilitate their handling during installation into the HVAC system such as maneuvering zone-control units **100** into position in a building's ductwork. During installation, the handle mounting brackets **504** and plates **506*a*** maintain positional relation-ships between the mechanical terminal unit **102** including the coil **122** and the piping assemblies **202**, **232** because the handle mounting brackets **504** and plates **506*a*** mechanically bind the entire zone-control unit **100** together into a single unit.

[**0061**] DDC controllers include a communication capability that permits a central computer to monitor a building's HVAC system's operating status, and to coordinate operation of the various portions of the system including all of its terminal units. DDC controllers are equipped with Local Area Network ("LAN") communications capability. To facilitate installing the zone-control unit the electrical components enclosure is optionally equipped with a 100 ft. length of LAN cable connected to the DDC controller Establishing the LAN that interconnects groups of zone-control units may involve the LAN cables of all but one of the zone-control units in the group be connected to another one of the group's zone-control units.

[**0062**] FIG. **2**A illustrates a side view of a zone-control unit **1000** for use in an HVAC system, according to one embodiment of the present invention, and FIG. **2**B illustrates the corresponding end view. Zone-control unit **1000** includes a duct or casing **1100**, a thermal transfer unit **1200**, an inlet piping assembly **1300**, an outlet piping assembly **1400**, and at least one bracket **1500**. In some embodiments, bracket **1500** can be a powder-coated handle shipping bracket. Inclusion of bracket **1500** can allow zone-control unit **1000** to be pre-engineered, sealed, pressure-tested, and shipped to job-site in working condition, free of defects. Zone-control unit **1000** may include military rubber Nitrile grommets **1510** for isolation between bracket **1500** and piping assemblies **1300** and **1400**. Grommets **1510** can help secure and protect zone-control unit **1000**, and can help reduce or eliminate the possibility of galvanic corrosion at the interface between bracket **1500** and piping assemblies **1300** and **1400**. Grommets **1510** can be manufactured to withstand heat, and in some cases can withstand a direct flame of 220 degrees F., or higher. Bracket **1500** may include openings that are designed to fit the fork of a forklift, a steel pole, or a human hand. Bracket **1500** is well suited for reducing or preventing field damage. For example, with known systems and methods, field personnel typically lift or move HVAC components simply by grasping various piping or probe elements, which often results in destruction or serious damage to the component. Bracket **1500** confers the ability to ship and maneuver zone-control unit **1000** in a standardized and safe manner. Often, thermal transfer unit **1200**, which may include a coil, is at least partially disposed within casing **1100**. Inlet piping assembly **1300** is coupled with thermal transfer unit **1200** for supplying liquid or gas to coil **1200**, and outlet piping assembly **1400** is coupled with coil **1200** for receiving liquid or gas from coil **1200**. This can be accomplished by coupling a first passage **1310** of inlet piping assembly **1300** with a supply port **1210** of thermal transfer unit **1200**, and coupling a first passage **1410** of the outlet piping assembly **1400** with a return port **1220** of thermal transfer unit **1200**. A second passage **1320** of inlet piping assembly **1300** can be coupled with an upstream fluid source **1330**, and a second passage **1420** of outlet piping assembly **1400** can be coupled with a downstream fluid destination **1430**.

[**0063**] It is appreciated that inlet piping assembly second passage **1320** and outlet piping assembly second passage **1420** each can be sealed, inlet piping assembly first passage **1310** can be in sealed communication with thermal transfer assembly supply port **1210**, and outlet piping assembly first passage **1410** can be in sealed communication with the thermal transfer assembly return port **1220**. When sealed in this fashion, thermal transfer unit **1200** can contain a vacuum, a non-pressurized fluid, or a pressurized fluid. Inlet piping assembly second passage **1320** and outlet piping assembly second passage **1420** can be manufactured from, for example, ¾ inch type L copper water pipe. They can be sealed according to a heating and spinning procedure that introduces no annealing or distortion of the pipe. After zone-control unit **1000** is placed in the desired location relative to the HVAC system, distal tips of inlet piping assembly second passage **1320** and outlet piping assembly second passage **1420** can be cut, and connected with other HVAC piping or hose elements, such as a hot water piping building loop. Relatedly, zone-control unit **1000** includes a pressure gauge **1710** coupled with inlet piping assembly **1400**. In some embodiments, pressure gauge **1710** may be coupled with thermal transfer unit **1200** or outlet piping assembly **1300**. Inlet piping assembly **1300** may be coupled with a drain valve **1330**, a Y-strainer **1340**, a pressure/temperature port **1350**, or a supply shutoff valve **1360**, or any combination thereof. Outlet piping assembly **1400** may be coupled with control valve **1430**, a balancing valve (not shown), a vent (not shown), a pressure/temperature port **1450**, or a return shutoff valve **1460**, or any combination thereof. Control valve **1430** may be an automatic temperature control (ATC) valve having a compensated ball valve including an integral pressure limiting and flow setting apparatus. Valve **1430** can assure consistent flow response regardless of the head pressure. In some cases, there is no CV setting on the valve. Relatedly, zone-control unit **1000** may include a field set manual or factory programmable maximum flow setting. In some embodiments, valve balancing may be accomplished in less than 30 seconds. Valve **1430** may have a shutoff pressure of 200 psi. Conveniently, valve **1430** may have a pressure sufficient to counteract a heating loop dead head pressure, which can be 50 psi or more. In related embodiments, valve **1430** can be a ½ inch, a ¾ inch, or 1 inch valve. Control valve **1430** may be a modulating Siemens ATC.

[**0064**] Thermal transfer unit **1200** may be coupled with a vent **1230** such as an air vent. In some instances, vent **1230** is a manual air vent disposed at or toward the highest point of thermal transfer unit **1200**. Vent **1230** can help ensure proper drainage of air or other unwanted fluids or gasses that enter the system, which can have deleterious effects on an HVAC system. For example, unwanted air in a hot water system can cause cavitation in a hot water pump, which may cause malfunction or destruction of the pump or other system components. Vents can also help ensure optimum flow characteristics when draining thermal transfer unit **1200** or other zone-control unit **1000** components. Full drainage of such components can facilitate the removal of unwanted particles such as rust or other chemical buildup. In some embodiments, vent **1230** is constructed of a non-corrosive military grade brass. In the embodiment shown here, zone-control unit **1000** includes a duct interface **1110** which is coupleable with duct or casing **1100**, which may be attached with or integral to a duct or ductwork of an HVAC system. Bracket **1500**, which may include a handle, supports duct interface **1100**, inlet piping assembly **1300**, and outlet piping assembly **1400** with relative positions appropriate for use in an HVAC system or other climate control system. In some cases, bracket **1500** may be a handle configured to maintain duct or casing **1100**, inlet piping assembly **1300**, and outlet piping assembly **1400** in positional relationship.

[**0065**] As shown in FIG. **2**A, zone-control unit **1000** can include a damper assembly controller **1600**, which may be coupled with casing **1100**. Damper assembly controller **1600** may be configured to receive a signal from a thermostat or a room sensor (not shown). In some embodiments, damper assembly controller **1600** can include, for example, an analog electronic controller, or a direct digital control (DDC) controller equipped with Local Area Network (LAN) communication capability. In some cases, controller **1600** can be a pneumatic DDC. Controller **1600** can also be configured to operatively associate with or have connectivity with a LonWorks or BACnet system. Unit **1000** can also include an automatic temperature control (ATC) valve **1430**, which is typically coupled with or part of outlet piping assembly **1400**, and configured to receive a signal from damper assembly controller **1600**, for example, by connection with plenum rated actuator wires **1432**. Other embodiments may employ wireless signal transmission technologies. In certain embodiments, ATC valve **1430** is a Nema 1 24V Belimo proportional actuator. Accordingly, in some embodiments the present invention provides a proportional hot water valve package (PICCV). Often, zone-control unit **1000** will be configured to have one piping interface, one electrical interface, and one sheet metal interface, so as to provide a "plug and play" unit for ease of shipping and installation.

[**0066**] FIG. **3**A illustrates a side view of a zone-control unit **2000** for use in an HVAC system, according to one embodiment of the present invention, and FIG. **3**B illustrates the corresponding end view. Zone-control unit **2000** includes a duct or casing **2100**, a thermal transfer unit **2200**, an inlet piping assembly **2300**, an outlet piping assembly **2400**, and at least one bracket **2500**. Often, thermal transfer unit **2200**, which may include a coil, is at least partially disposed within casing **2100**. Inlet piping assembly **2300** is coupled with thermal transfer unit **2200** for supplying liquid or gas to coil **2200**, and outlet piping assembly **2400** is coupled with coil **2200** for receiving liquid or gas from coil **2200**. This can be accomplished by coupling a first passage **2310** of inlet piping assembly **2300** with a supply port **2210** of thermal transfer unit **2200**, and coupling a first passage **2410** of the outlet piping assembly **2400** with a return port **2220** of thermal transfer unit **2200**. A second passage **2320** of inlet piping assembly **2300** can be coupled with an upstream fluid source **2330**, and a second passage **2420** of outlet piping assembly **2400** can be coupled with a downstream fluid destination **2430**.

[**0067**] It is appreciated that inlet piping assembly second passage **2320** and outlet piping assembly second passage **2420** each can be sealed, inlet piping assembly first passage

2310 can be in sealed communication with thermal transfer assembly supply port **2210**, and outlet piping assembly first passage **2410** can be in sealed communication with the thermal transfer assembly return port **2220**. When sealed in this fashion, thermal transfer unit **2200** can contain a vacuum, a non-pressurized fluid, or a pressurized fluid. Relatedly, zone-control unit **2000** includes a pressure gauge **2710** coupled with inlet piping assembly **2400**. In some embodiments, pressure gauge **2710** may be coupled with thermal transfer unit **2200** or inlet piping assembly **2300**. Inlet piping assembly **2300** may be coupled with a drain valve **2330**, a Y-strainer **2340**, a pressure/temperature port **2350**, or a supply shutoff valve **2360**, or any combination thereof. Outlet piping assembly **2400** may be coupled with control valve **2430**, a manual balancing valve **2470**, a vent (not shown), a pressure/temperature port **2450** disposed upstream of control valve **2430**, a pressure/temperature port **2452** disposed downstream of control valve **2430**, or a return shutoff valve **2460**, or any combination thereof. In some cases, balancing valve **2470** may be a Griswold pressure independent balancing valve. Thermal transfer unit **2200** may be coupled with a vent **2230** such as an air vent. In the embodiment shown here, zone-control unit **2000** includes a duct interface **2110** which is coupleable with duct or casing **2100**, which may be attached with or integral to a duct or ductwork of an HVAC system. Bracket **2500**, which may include a handle, supports duct interface **2110**, inlet piping assembly **2300**, and outlet piping assembly **2400** with relative positions appropriate for use in an HVAC system or other climate control system. In some cases, bracket **2500** may be a handle configured to maintain duct or casing **2100**, inlet piping assembly **2300**, and outlet piping assembly **2400** in positional relationship.

[0068] As shown in FIG. **3**A, zone-control unit **2000** can include a damper assembly controller **2600**, which may be coupled with casing **2100**. Damper assembly controller **1600** may be configured to receive a signal from a thermostat or a room sensor (not shown). In some embodiments, damper assembly controller **2600** includes a direct digital control (DDC) controller equipped with Local Area Network (LAN) communication capability. Unit **2000** can also include an automatic temperature control (ATC) valve **2430**, which is typically coupled with or part of outlet piping assembly **2400**, and configured to receive a signal from damper assembly controller **2600**, in some embodiments by connection with plenum rated actuator wires **2432**, via wireless signal transmission systems, or the like. In certain embodiments, ATC valve **2430** is a Nema 1 24V Belimo on/off actuator. Accordingly, in some embodiments the present invention provides a two way water valve package (CCV).

[0069] FIG. **4**A illustrates a side view of a zone-control unit **3000** for use in an HVAC system, according to one embodiment of the present invention, and FIG. **4**B illustrates the corresponding end view. Zone-control unit **3000** includes a duct or casing **3100**, a thermal transfer unit **3200**, an inlet piping assembly **3300**, an outlet piping assembly **3400**, a bypass piping assembly **3800**, and at least one bracket **3500**. Often, thermal transfer unit **3200**, which may include a coil, is at least partially disposed within casing **3100**. Inlet piping assembly **3300** is coupled with thermal transfer unit **3200** for supplying liquid or gas to coil **3200**, and outlet piping assembly **3400** is coupled with coil **3200** for receiving liquid or gas from coil **3200**. This can be accomplished by coupling a first passage **3310** of inlet piping assembly **3300** with a supply port **3210** of thermal transfer unit **3200**, and coupling a first passage **3410** of the outlet piping assembly **3400** with a return port **3220** of thermal transfer unit **3200**. A second passage **3320** of inlet piping assembly **3300** can be coupled with an upstream fluid source **3330**, and a second passage **3420** of outlet piping assembly **3400** can be coupled with a downstream fluid destination **3430**.

[0070] It is appreciated that inlet piping assembly second passage **3320** and outlet piping assembly second passage **3420** each can be sealed, inlet piping assembly first passage **3310** can be in sealed communication with thermal transfer assembly supply port **3210**, and outlet piping assembly first passage **3410** can be in sealed communication with the thermal transfer assembly return port **3220**. Similarly, bypass piping assembly **3800** can be in sealed communication with inlet piping assembly **3300** and outlet piping assembly **3400** so as to provide a fluid passage therebetween, whereby the passage can be open and closed via operation of bypass shutoff valve **3810**. When sealed in this fashion, thermal transfer unit **3200** can contain a vacuum, a non-pressurized fluid, or a pressurized fluid. Relatedly, zone-control unit **3000** includes a pressure gauge **3710** coupled with outlet piping assembly **3400**. In some embodiments, pressure gauge **3710** may be coupled with thermal transfer unit **3200** or inlet piping assembly **3300**. When bypass shutoff valve **3810** is in the open position, fluid can flow directly from inlet piping assembly **3300** to outlet piping assembly **3400** without flowing through thermal transfer unit **3200**. When bypass shutoff valve **3810** is in the closed position, fluid can flow from inlet piping assembly **3300** to outlet piping assembly **3400** through thermal transfer unit **3200**, without flowing through bypass piping assembly **3800**. Inlet piping assembly **3300** may be coupled with a drain valve **3330**, a Y-strainer **3340**, a pressure/temperature port **3350**, or a supply shutoff valve **3360**, or any combination thereof. Outlet piping assembly **3400** may be coupled with control valve **3430**, a manual balancing valve **3470**, a vent (not shown), a pressure/temperature port **3450** disposed upstream of control valve **3430**, a pressure/temperature port **3452** disposed downstream of control valve **3430**, or a return shutoff valve **3460**, or any combination thereof. Thermal transfer unit **3200** may be coupled with a vent **3230** such as an air vent. In the embodiment shown here, zone-control unit **3000** includes a duct interface **3110** which is coupleable with duct or casing **3100**, which may be attached with or integral to a duct or ductwork of an HVAC system. Bracket **3500**, which may include a handle, supports duct interface **3110**, inlet piping assembly **3300**, and outlet piping assembly **3400** with relative positions appropriate for use in an HVAC system or other climate control system. In some cases, bracket **3500** may be a handle configured to maintain duct or casing **3100**, inlet piping assembly **3300**, and outlet piping assembly **3400** in positional relationship.

[0071] As shown in FIG. **4**A, zone-control unit **3000** can include a damper assembly controller **3600**, which may be coupled with casing **3100**. Damper assembly controller **3600** may be configured to receive a signal from a thermostat or a room sensor (not shown). In some embodiments, damper assembly controller **3600** includes a direct digital control (DDC) controller equipped with Local Area Network (LAN) communication capability. Unit **3000** can also include an automatic temperature control (ATC) valve **3430**, which is typically coupled with or part of outlet piping assembly

3400, and configured to receive a signal from damper assembly controller **3600** by connection with plenum rated actuator wires **3432**, wireless transmission systems, or the like. In certain embodiments, ATC valve **3430** is a Nema 1 24V Belimo three way actuator. Accordingly, in some embodiments the present invention provides a three way water valve package (CCV).

[0072] FIG. **5** illustrates a side view of a zone-control unit **4000** for use in an HVAC system, according to one embodiment of the present invention. Zone-control unit **4000** includes a duct or casing **4100**, a thermal transfer unit **4200**, an inlet piping assembly **4300**, an outlet piping assembly **4400**, and at least one bracket **4500**. Often, thermal transfer unit **4200**, which may include a coil, is at least partially disposed within casing **4100**. Inlet piping assembly **4300** is coupled with thermal transfer unit **4200** for supplying liquid or gas to coil **4200**, and outlet piping assembly **4400** is coupled with coil **4200** for receiving liquid or gas from coil **4200**. Zone-control unit **4000** includes a pressure gauge **4710** coupled with outlet piping assembly **4400**. In some embodiments, pressure gauge **4710** may be coupled with thermal transfer unit **4200** or inlet piping assembly **4300**. Inlet piping assembly **4300** may be coupled with a basket strainer **4380**. Zone-control unit **4000** can be cleaned by fluid or water pressure without removing basket strainer **4380**. Inlet piping assembly may also be coupled with a blow down drain **4370** for basket strainer **4380**. Outlet piping assembly **4400** may be coupled with a control valve **4430**. In the embodiment shown here, zone-control unit **4000** includes a casing **4100** which may be attached with a duct or ductwork of an HVAC system. Bracket **4500**, which may include a handle, supports casing **4100**, inlet piping assembly **4300**, and outlet piping assembly **4400** with relative positions appropriate for use in an HVAC system or other climate control system.

[0073] FIG. **6** illustrates a side view of a zone-control unit **5000** for use in an HVAC system, according to one embodiment of the present invention. Zone-control unit **5000** includes a duct or casing **5100**, a thermal transfer unit (not shown), an inlet piping assembly **5300**, an outlet piping assembly **5400**, and at least one bracket **5500**. Zone-control unit **5000** also includes a housing **5900** coupled with casing **5100**, such that housing **5900** encompasses ATC valve (not shown) and other components of zone-control unit **5000** as described elsewhere herein. For comparative reference with other figures of the present disclosure, zone-control unit **5000** is depicted here showing a vent **5230**, a drain valve **5330**, an inlet piping assembly second passage **5320** and an outlet piping assembly second passage **5420**. A housing cover **5910** of housing **5900** may have an aperture **5920** through which bracket **5500** may extend, or through which bracket **5500** may be otherwise accessible via an operator's hands, a forklift, or other maneuvering apparatus used during transportation, shipping, or installation. Zone-control unit **5000** may also have a validation package **4120**, which may include a digital picture of the zone-control unit **5000** or components thereof, a quality control sheet, an operations and maintenance document, a parts list with model and serial numbers, an Indoor Air Quality (IAQ) certification, or a piping, electrical, and controls schematic, or any combination thereof. These components of validation package **4120** may be stored in a plastic pouch and attached with unit **6000**. It is appreciated therefore that the present invention can be conveniently tested, validated, standardized, cataloged, and certified prior to shipping or installation.

[0074] FIG. **7** illustrates a side view of a zone-control unit **6000** for use in an HVAC system, according to one embodiment of the present invention. In many ways, the embodiment shown in FIG. **7** is similar to that shown in FIG. **6**. Zone-control unit **6000** includes a duct or casing **6100**, an inlet piping assembly **6300**, an outlet piping assembly **6400**, and at least one bracket **6500**. Zone-control unit **6000** also includes a housing **6900** coupled with casing **6100**, such that housing **6900** encompasses various components of zone-control unit **6000** as described elsewhere herein, and to avoid prolixity are not described in detail here. The zone-control unit **6000** embodiment shown in FIG. **7** differs from the zone-control unit **5000** shown in FIG. **6**, however, in a housing cover (not shown) of zone-control unit **6000** is removed, thereby exposing various elements contained in housing **6900**. In some embodiments, the zone-control unit complies with a standard such as a Leadership in Energy and Environmental Design (LEED) standard, an American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standard, an Air-Conditioning and Refrigeration Institute (ARI) standard, or a building code standard, or any combination thereof. Zone-control unit **6000** may be a capital piece of equipment, depreciable, and can be stocked by local distributors anywhere in the world as an "off the shelf" product. Zone-control unit **6000** is well suited for installation in a new HVAC system, or for retrofit in an existing HVAC system. It is also appreciated that the present invention also provides for the manufacture and installation of the zone-control units discussed herein. Such manufacture will often occur remotely from a job installation site, and may be performed by a union member selected from the group consisting of the United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry of the United States and Canada, the construction sheet metal union, and the electrical union. In other embodiments, such union(s) may certify the fabrication site and/or supplier as being in compliance with the applicable union rules, that use of certain catalogued HVAC units complies with applicable union requirements and/or does not constitute a customized product so as violate work preservation rules. Relatedly, zone-control units or components thereof may be constructed by a manufacturing facility that is a signatory to any of these unions. Such manufacturing facilities may also have an Underwriter's Laboratory certification. Accordingly, zone-control units may include or be affixed with certain union, standards, or certification compliance labels.

[0075] FIGS. **8A-8G** generally illustrate standardization of components in differing HVAC units. Rather than attempting to minimize the costs of individual components of the many HVAC units in an HVAC system (which can lead to extensive on-site work, delays, and large installation labor costs), overall system installation efficiencies can be enhanced through the use of more standardized components, even if those components have capacities that exceed the requirements of some units.

[0076] Proportional valves (including those having characteristics similar to those graphically illustrated in FIG. **8A**, such as the Belimo™ PICCV pressure independent proportional ball valve) and the like can facilitate integration of a single type of HVAC unit in multiple locations having differing specifications, tailoring the functioning of the unit by though appropriate use of the electronic controller software. FIG. **8**B illustrates an HVAC hot water coil piping package unit **8000**, while FIGS. **8**C and **8**E illustrate an HVAC proportional hot water valve package unit **8000**C and a 2 way water valve package unit **8000**E, respectively. FIG. **8**D illustrates a support structure or handle **8000**D which may be used in both, and FIG. **8**F illustrates a 3 way water valve package unit **8000**F. FIG. **8**G illustrates a support structure or handle **8000**G that can be used with any of the units described herein. Despite the significant differences between these units, many, most, or all of the components (including piping components) may be common, with the aspect ratio of the piping optionally being identical.

[0077] FIG. **9** illustrates engagement between the support structure or handle **9000** mounted to an HVAC unit and another similar corresponding support structure, allowing the support structures to be used as mounting fasteners. A plurality of different configurations of support structures can be provided with different sizes, different numbers, sizes, and configurations of holes and grommets for receiving piping, and the like. One or more supports may be secured to a joist, beam, or other building structure where the HVAC unit is to be installed. The unit support structure or handle is then lifted into engagement with the secured support(s), and the engaging surface at least temporarily "hanging" or maintaining the position of the HVAC unit. Fasteners may then affix the corresponding engaged support structures together to provide a secure and/or permanent installation. Deformable damping materials such as rubber, neoprene, resilient polymers, or the like along one or both of the engaging support surfaces can provide vibration and/or sound isolation. The support structures or handles may comprise carbon fiber, stainless steel, aluminum, plastic, or the like, and the engaging support structures may have similar shapes (as shown) or different shapes.

[0078] FIGS. **10**A and **10**B illustrate methods for testing and validation of HVAC units. HVAC units. Unit ordering and fabrication can be automated, and testing of piping by pressurizing piping assemblies, sealing, and verifying an acceptable pressure is maintained after a test period (for example, 24 hours) ensures leak-free fabrication. Any rework can be identified and completed prior to shipping to a constructions site, and quality control documentation (optionally comprising a magnetic media such as a floppy disk, an optical media such as a mini CD, a memory such as a flash memory stick, or some other tangible media embodying machine readable computer data, a print-out, a digital photograph, and/or the like) can be associated with each unit to validate the components and testing. In some embodiments, such quality control may be integrated into the HVAC signal transmission system so as to facilitate remote validation via LAN conductors or a wireless network system, and/or radiofrequency identification or RFID techniques and structures may be employed.

[0079] FIGS. **11** and **12** schematically illustrate a two part damper having two airfoil-shaped damper members. Automatic dampers are used in HVAC to control air flow. They may be used for modulating air flow to maintain a desired control variable, such as mixed air temperature, supply air duct static pressure, or the like. They can also be used for two-position control to initiate or halt operating flow, for example, when opening minimum outside air dampers when a fan is started. Inadvertent damper leakage can be undesirable, as tight shut-off of flows can reduce energy consumption significantly. Also, outdoor air dampers should close tightly to inhibit freezing of coils and pipes in cold climates.

[0080] The two-part damper design of FIGS. **11** and **12** may provide little or no pressure drop in one, some, or all damper configurations, with the air always traveling through the middle of the damper casing being uniform and laminar. The exemplary damper members may have an airfoil-shaped cross-section, and may pivot within the casing, slide within the casing, or the like. A small wireless sensor or sensors can be used for controlling damper actuation. Such sensors, may, for example, measure the distance between the two damper members, sound, air flow, or the like. By avoiding cross flow measurement devices having numerous (often over 5) sensor locations, pressure drop and turbulence of the damper system may be further inhibited. Characteristics of known dampers are described and illustrated in a 1997 ASHRAE Fundamentals Handbook, and known damper assemblies and features thereof are described and illustrated in pages 6-13 of a 2001 Model SDR Calalog from Environmental Technologies, Inc., the contents of each of which are incorporated herein by reference. FIG. **11** shows a side view of a damper system **11000** according to embodiments of the present invention. The damper system is shown in a 100% open configuration, with air or fluid flowing through the system as indicated by arrow A. Damper system **11000** includes a damper casing **11010**, and one or more damper members **11020** disposed within the damper casing. As shown here, damper members **11020** are attached with damper shafts **11030** toward a leading end **11022** of the damper members, and can pivot about damper shafts **11030** as indicated by arrow B. The damper system also includes one or more air stops **11040**, optionally disposed toward leading end **11022** of damper members **11020**, that assist in maintaining laminar air flow and reducing or avoiding turbulence, particularly when the damper system is in the 100% open configuration. In the embodiment shown here, damper members **11020** are coupled with one or more sensors **11050**. The sensors are disposed on the trailing end **11024** of the damper members **11020**. Sensors may also or alternatively be disposed at any location along the damper member, at or near the damper casing, and the like. Sensors may detect any of a variety of spatial, positional, or angular orientations of a damper member. For example, a sensor may detect a distance between damper members, a distance between a damper member and the damper casing, a position or an orientation of a damper member relative to the damper casing, a position or an orientation of a damper member relative to another damper member, and the like. A sensor may also detect sound or pressure that is present in the damper system. Often, the sensor will be configured so as to present minimal or no disruption to air or fluid passing through the damper system. For example, the sensor may be embedded beneath the surface of the damper member, or may be contiguous with the smooth or aerodynamic surface of the damper member. As shown here, the side profile or end view of damper members **11020** present an aerodynamic design or cross section, similar to an airfoil or wing. The leading end **11022** in combination with the air stop **11040** can present a smooth surface or profile that introduces minimal or no disruption to laminar fluid flowing through the damper system. The air stop may be coupled with the damper casing, the damper element, or both. In some cases, the air stop is flexible. In some cases, the air stop is rigid. The air stops, damper members, and sensors operate to minimize unwanted or inadvertent pressure drop across the damper system, particularly when the damper system is in an open configuration. Thus laminar flow of fluid passing through the damper system is maximized, particularly the fluid passing through a central area or zone disposed between the two damper members.

[0081] FIG. 12 shows an end view of damper system **11000** according to embodiments of the present invention. The damper system is shown in a 10% open configuration, with air or fluid flowing through the system toward the viewer as indicated by arrow A. Damper system **11000** includes a damper casing **11010**, and one or more damper members **11020** disposed within the damper casing. As shown here, damper members **11020** are attached with damper shafts **11030** toward a leading end **11022** of the damper members, and can pivot about damper shafts **11030** as indicated by arrow B. In the embodiment shown here, damper members **11020** are coupled with one or more sensors **11050**. A trailing end **11024** of damper member **11020** can be shaped, profiled, or contoured so as to allow for a 100% shutoff of fluid passing through the damper system. This shutoff may be accomplished by a cooperative association between trailing edges or ends **11024** of two opposing damper members, or between a trailing end **11024** and a damper casing **11030**. In related embodiments, the shutoff can be accomplished by a cooperative association between sensors that are disposed at or near the trailing ends of the damper members.

[0082] FIGS. **13**A, **13**B and **13**C schematically illustrate drive systems for pivoting or sliding of the damper members. FIG. **13**A shows a side view of a damper system **13000***a* according to embodiments of the present invention. The damper system is shown in a 100% closed configuration, with air or fluid flowing through the system as indicated by arrow A being prevented from passing across the trailing ends **13024***a* of damper members **13020***a*. Damper system **13000***a* includes a damper casing **13010***a*, and one or more damper members **13020***a* disposed within the damper casing. As shown here, damper members **13020***a* are attached with damper shafts **13030***a* toward a leading end **13022***a* of the damper members, and can pivot or rotate about damper shafts **13030***a* as indicated by arrow B. The damper system also includes one or more air stops **13040***a*, optionally disposed toward leading end **13022***a* of damper members **13020***a*, that assist in maintaining laminar air flow and reducing or avoiding turbulence. In the embodiment shown here, damper members **13020***a* are coupled with one or more sensors **13050***a*. The sensors are disposed on the trailing end **13024***a* of the damper members **13020***a*. Sensors may also or alternatively be disposed at any location along the damper member, at or near the damper casing, and the like. Sensors may detect any of a variety of spatial, positional, or angular orientations of a damper member. For example, a sensor may detect a distance between damper members, a distance between a damper member and the damper casing, a position or an orientation of a damper member relative to the damper casing, a position or an orientation of a damper member relative to another damper member, and the like. A sensor may also detect sound or pressure that is present in the damper system. Often, the sensor will be configured so as to present minimal or no disruption to air or fluid passing through the damper system. For example, the sensor may be embedded beneath the surface of the damper member, or may be contiguous with the smooth or aerodynamic surface of the damper member. Damper system **13000***a* may also include a control mechanism **13060***a* that controls operation of the damper members. In some embodiments, the control mechanism includes an input for receiving signals or information generated by the sensors, or an input for receiving signals, instructions, information, and the like from various components of an HVAC system. Control mechanism **13060***a* may include an actuator **13070***a* and a linkage arrangement **13080***a*. Typically, all or part of the control mechanism is located on the exterior of the damper casing, or does not otherwise affect the flow of fluid passing through the damper casing and across the damper members.

[0083] FIG. **13**B shows a side view of a damper system **13000***b* according to embodiments of the present invention. The damper system is shown in a 100% closed configuration, with air or fluid flowing through the system as indicated by arrow A being prevented from passing across the trailing ends **13024***b* of damper members **13020***a*. Damper system **13000***b* includes a damper casing **13010***b*, and one or more damper members **13020***b* disposed within the damper casing. As shown here, damper members **13020***b* are attached with damper shafts **13030***b* toward a leading end **13022***b* of the damper members, and can pivot or rotate about damper shafts **13030***b* as indicated by arrow B. In the embodiment shown here, damper members **13020***b* are coupled with one or more sensors **13050***b*. The sensors are disposed on the trailing end **13024***b* of the damper members **13020***b*. Sensors may also or alternatively be disposed at any location along the damper member, at or near the damper casing, and the like. Sensors may detect any of a variety of spatial, positional, or angular orientations of a damper member. For example, a sensor may detect a distance between damper members, a distance between a damper member and the damper casing, a position or an orientation of a damper member relative to the damper casing, a position or an orientation of a damper member relative to another damper member, and the like. A sensor may also detect sound or pressure that is present in the damper system. Often, the sensor will be configured so as to present minimal or no disruption to air or fluid passing through the damper system. For example, the sensor may be embedded beneath the surface of the damper member, or may be contiguous with the smooth or aerodynamic surface of the damper member. Damper system **13000***b* may also include a control mechanism **13060***b* that controls operation of the damper members. In some embodiments, the control mechanism includes an input for receiving signals or information generated by the sensors, or an input for receiving signals, instructions, information, and the like from various components of an HVAC system. Control mechanism **13060***b* may include a gear assembly **13075***b* that includes one or more gears **13077***b*. Typically, all or part of the control mechanism is located on the exterior of the damper casing, or does not otherwise affect the flow of fluid passing through the damper casing and across the damper members.

[0084] FIG. **13**C shows a side view of a damper system **13000***c* according to embodiments of the present invention. In this figure, one of two damper members **13020***c* is shown. Air or fluid flows through the system as indicated by arrow A. Damper system **13000***c* includes a damper casing **13010***c*, and one or more damper members **13020***c* disposed within the damper casing. As shown here, damper members

13020*c* are coupled with a damper housing or track **13090***c*, such that the damper member can slide within or along the track as indicated by arrow C. Damper members **13020***c* can be coupled with one or more sensors **13050***c*. The sensors are disposed on the trailing end **13024***c* of the damper members **13020***c*. Sensors may also or alternatively be disposed at any location along the damper member, at or near the damper casing, and the like. Sensors may detect any of a variety of spatial, positional, or angular orientations of a damper member. For example, a sensor may detect a distance between damper members, a distance between a damper member and the damper casing, a position or an orientation of a damper member relative to the damper casing, a position or an orientation of a damper member relative to another damper member, and the like. A sensor may also detect sound or pressure that is present in the damper system. Often, the sensor will be configured so as to present minimal or no disruption to air or fluid passing through the damper system. For example, the sensor may be embedded beneath the surface of the damper member, or may be contiguous with the smooth or aerodynamic surface of the damper member. Damper system **13000***c* may also include a control mechanism **13060***c* that controls operation of the damper members. In some embodiments, the control mechanism includes an input for receiving signals or information generated by the sensors, or an input for receiving signals, instructions, information, and the like from various components of an HVAC system. Control mechanism **13060***c* may operate to slide or move the damper member along or within the track. Typically, all or part of the control mechanism is located on the exterior of the damper casing, or does not otherwise affect the flow of fluid passing through the damper casing and across the damper members.

[0085] FIGS. **14**A-**14**C schematically illustrate an alternative damper assembly having a deformable helical damper member. When in a restricted flow configuration, such a damper member may induce a vortex within the duct and/or casing. Static pressure may result from such a vortex within the duct system, helping to make the system more energy efficient, quieter, and may provide better overall HVAC performance characteristics. FIG. **14**A shows a side view of a damper system **14000** according to embodiments of the present invention. FIGS. **14**B and **14**C present end views of the damper system. Damper system **14000** includes a control member **14010**, which optionally includes a metal or a composite, and a deformable helical damper member **14020**. When control member **14010** is rotated or turned as indicated by arrow A, the damper member **14020** may also turn or otherwise form to provide or create a vortex in fluid that passes through the damper system. In some embodiments, the amount or degree to which the control member is turned or activated determines the amount of air or fluid being turned down or otherwise regulated. For example, if the control member is turned a greater amount, the damper member may prevent a greater amount of fluid from passing therethrough. Conversely, if the control member is turned or activated a lesser amount, the damper member may prevent a lesser amount of fluid from passing therethrough. The damper system may be operated to any desired configuration, within a range from 0% open to 100% open.

[0086] Although the present invention has been described in terms of the presently preferred embodiment, it is to be understood that such disclosure is purely illustrative and is not to be interpreted as limiting. Consequently, without departing from the spirit and scope of the invention, various alterations, modifications, and/or alternative applications of the invention will, no doubt, be suggested to those skilled in the art after having read the preceding disclosure. Accordingly, it is intended that the following claims be interpreted as encompassing all alterations, modifications, or alternative applications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A damper assembly for use in a heating, ventilation, and air conditioning (HVAC) system, the assembly comprising:

a casing having an inlet and an outflow with a flow direction extending therebetween;

a first damper member movably disposed within the casing; and

a second damper member movably disposed within the casing;

the damper members having cross-sections and movable between an open flow configuration and a restricted flow configuration such that laminar flow is maintained as the flow is restricted.

2. The assembly of claim 1, further comprising a damper assembly controller coupled to the damper members.

3. The assembly of claim 1, further comprising a flow sensor coupled to the damper members, wherein the flow sensor measures pressure at less than 5 locations across the dampers.

4. The assembly of claim 1, further comprising a first sensor coupled with the first damper member, wherein the first sensor detects an orientation of the first damper member relative to the casing.

5. The assembly of claim 4, wherein the first sensor is disposed near a trailing end of the first damper member.

6. The assembly of claim 1, further comprising a first sensor coupled with the first damper member, wherein the first sensor detects an orientation of the first damper member relative to the second damper member.

7. The assembly of claim 1, further comprising an air stop.

8. The assembly of claim 1, wherein the first damper member comprises a trailing end and the second damper member comprises a trailing end, and the first damper member trailing end and the second damper member trailing end are configured to be moved toward each other when the assembly is moved toward the restricted flow configuration.

9. A damper assembly for use in a heating, ventilation, and air conditioning (HVAC) system, the assembly comprising:

a casing having an inlet and an outflow with a flow direction extending therebetween; and

a damper member disposed within the casing, the damper member comprising a helical body deformable between an open flow configuration and a restricted flow configuration.

10. The assembly of claim 9, wherein the damper in at least one configuration has a shape suitable for inducing a vortex in a flow within the casing.

11. A method of controlling a fluid flow in a heating, ventilation, and air conditioning (HVAC) system, comprising:

flowing a fluid through a casing inlet toward a casing outlet;

flowing the fluid across a plurality of damper members disposed within the casing;

restricting an amount of the fluid passing through the casing by actuating a first damper member; and

maintaining a laminar flow within the fluid during the actuation of the first damper member.

12. The method of claim 11, further comprising sensing an orientation of the first damper member.

13. The method of claim 11, further comprising sensing a pressure within the casing.

14. The method of claim 11, wherein restricting the amount of fluid passing through the casing comprises actuating a second damper member.

15. The method of claim 14, further comprising maintaining the laminar flow during actuation of the second damper member.

16. The method of claim 14, further comprising sensing an orientation of the second damper member.

17. The method of claim 14, further comprising sensing an orientation of the second damper member relative to the first damper member.

18. The method of claim 14, further comprising sensing an orientation of the second damper member relative to the casing.

19. The method of claim 14, wherein a cross section of the first damper member comprises an aerodynamic profile and a cross section of the second damper member comprises an aerodynamic profile.

20. The method of claim 14, further comprising sensing a distance between the first damper member and the second damper member.

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