



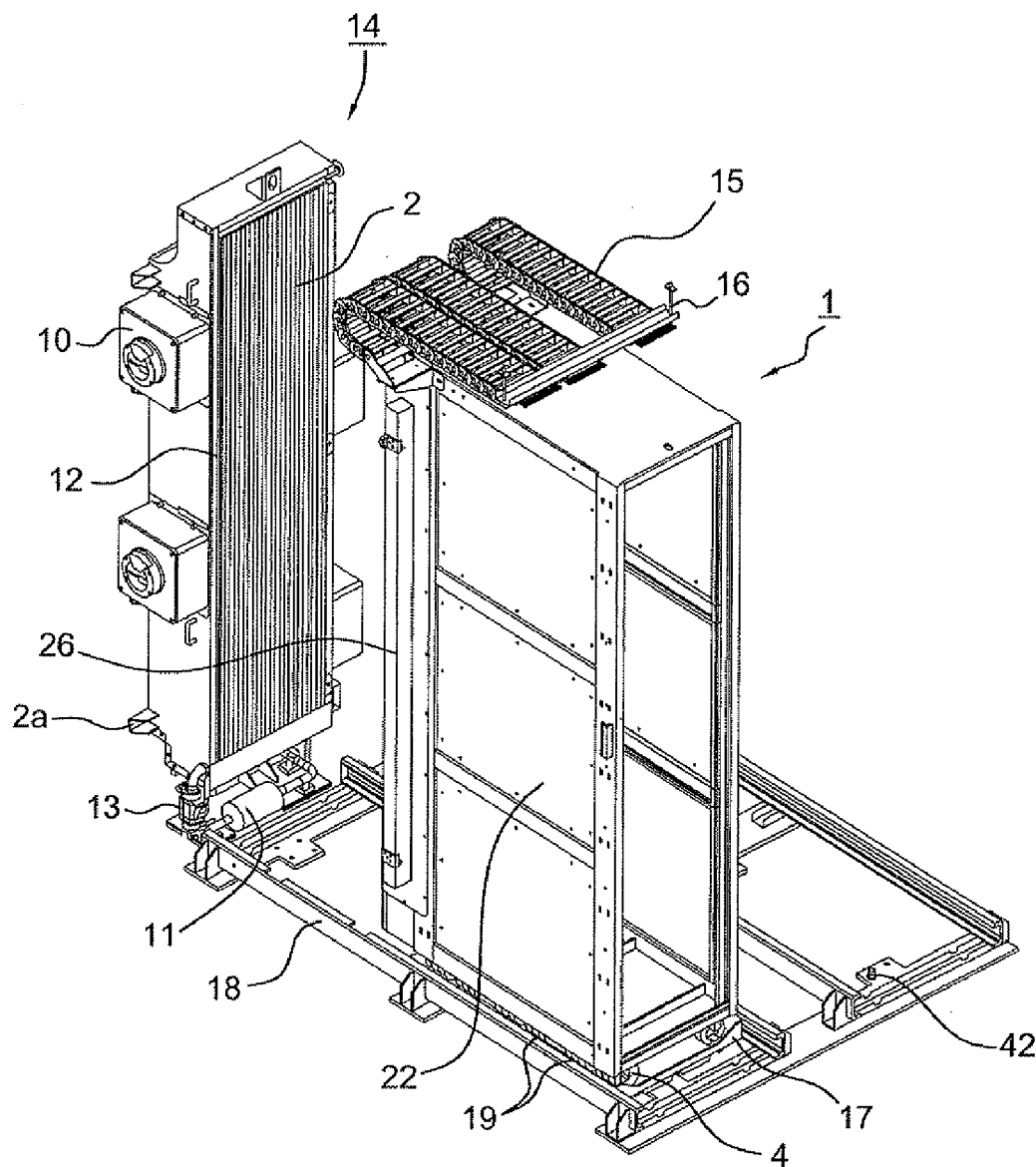
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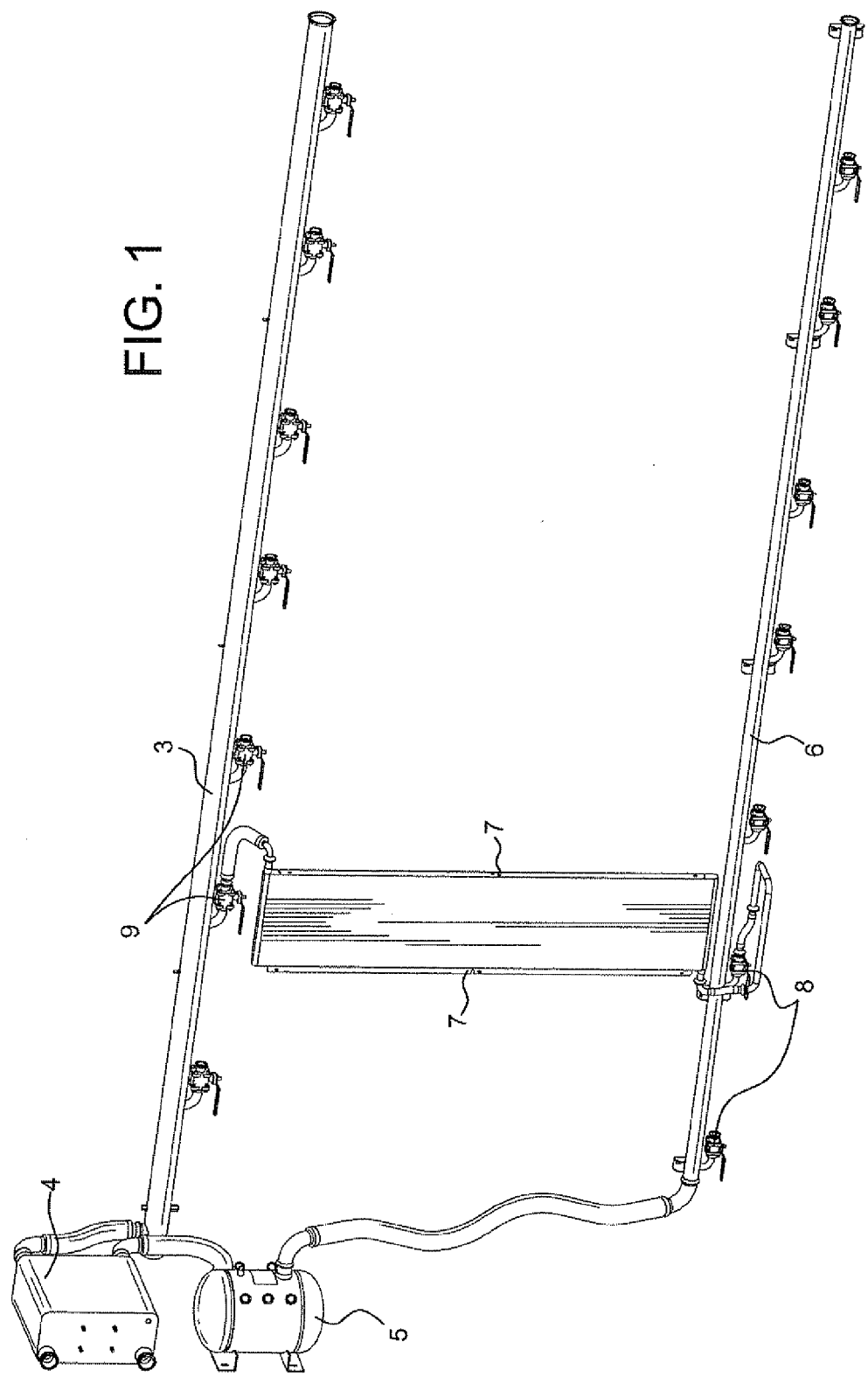
(19) **United States**(12) **Patent Application Publication****Jaena et al.**(10) **Pub. No.: US 2013/0032310 A1**(43) **Pub. Date: Feb. 7, 2013**(54) **TRANSPORTABLE,
ENVIRONMENTALLY-CONTROLLED
EQUIPMENT ENCLOSURE****Publication Classification**(51) **Int. Cl.**
F28D 15/02

(2006.01)

(52) **U.S. Cl.** **165/104.25; 165/138**(57) **ABSTRACT**

A transportable environmentally controlled equipment enclosure (TECEE), or other equipment enclosure of the type containing racks of heat-generating equipment, may include a pump-less heat pipe cooling system to carry heat away from the equipment, an improved equipment rack system that includes a suspended base supported by rails with multiple latching and/or locking positions, and various improvements related to power distribution, equipment access, internal and external communications, and safety.

(75) Inventors: **Mario L. Jaena**, Kent, WA (US);
Vladimir Gulkarov, San Diego, CA
(US); **Timothy Martin Cortes**,
Mechanicsville, VA (US); **Keith
Schmid**, Saint Charles, IL (US)(73) Assignee: **POWER DISTRIBUTION INC.**,
Richmond, VA (US)(21) Appl. No.: **13/196,101**(22) Filed: **Aug. 2, 2011**



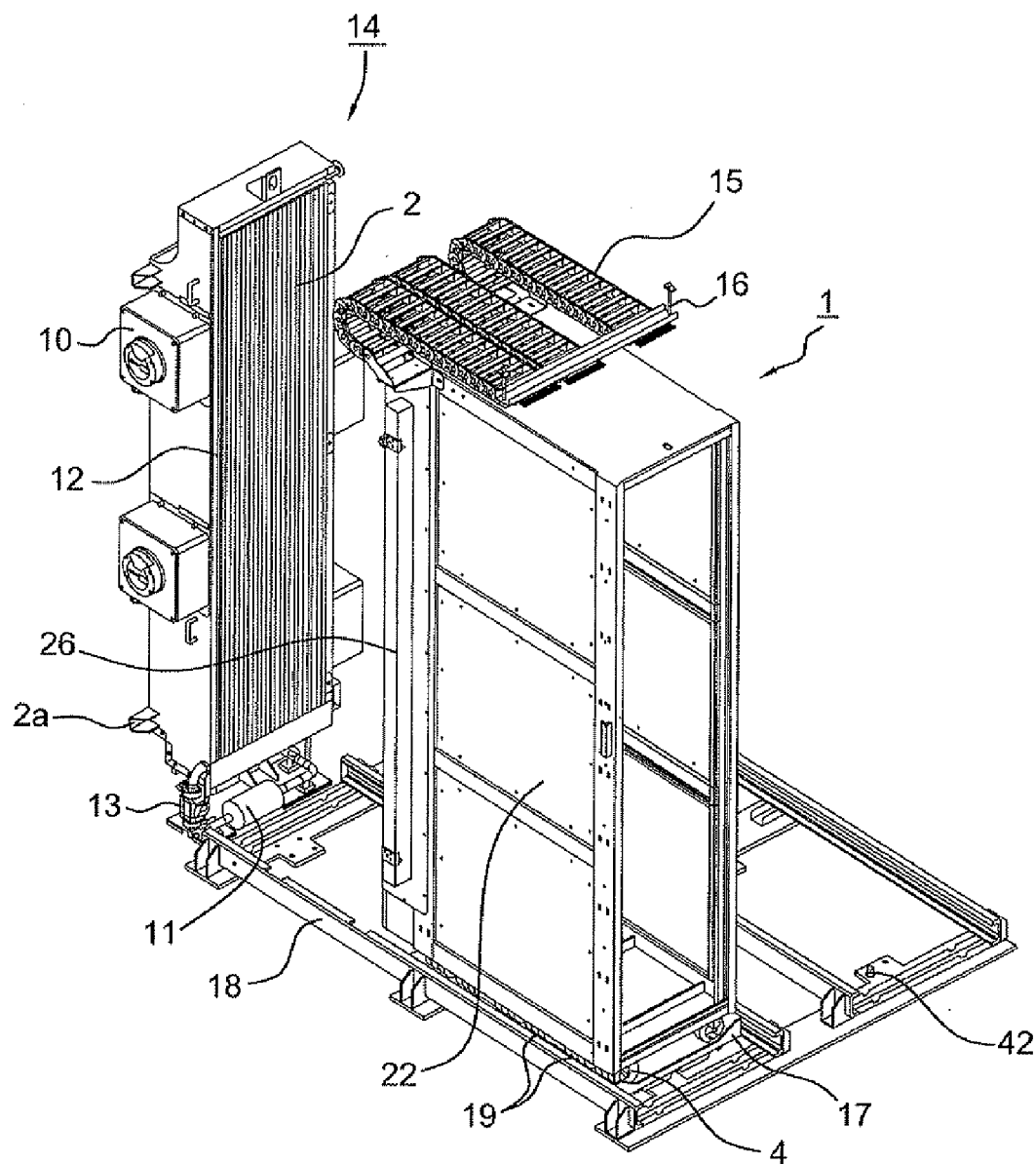
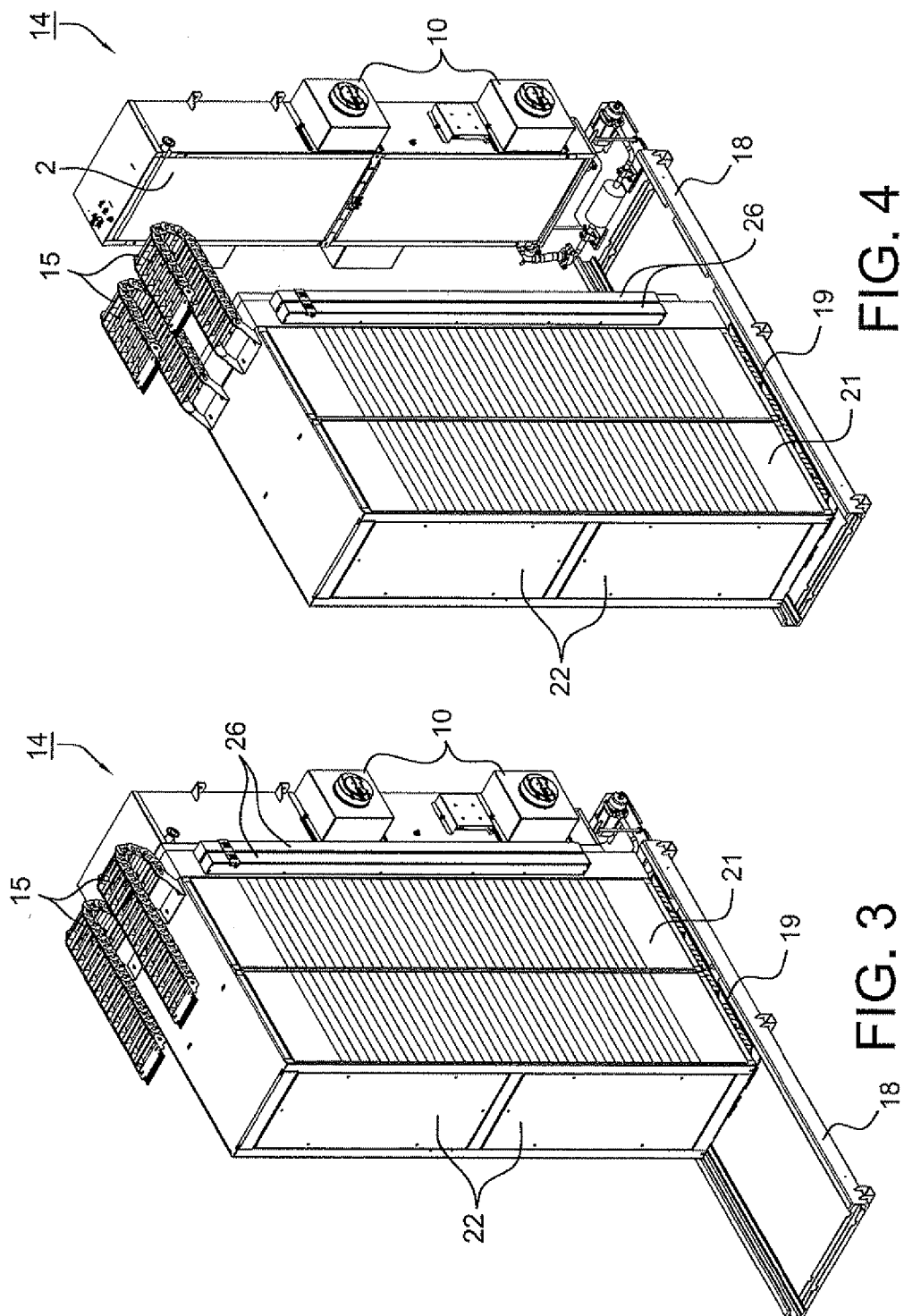
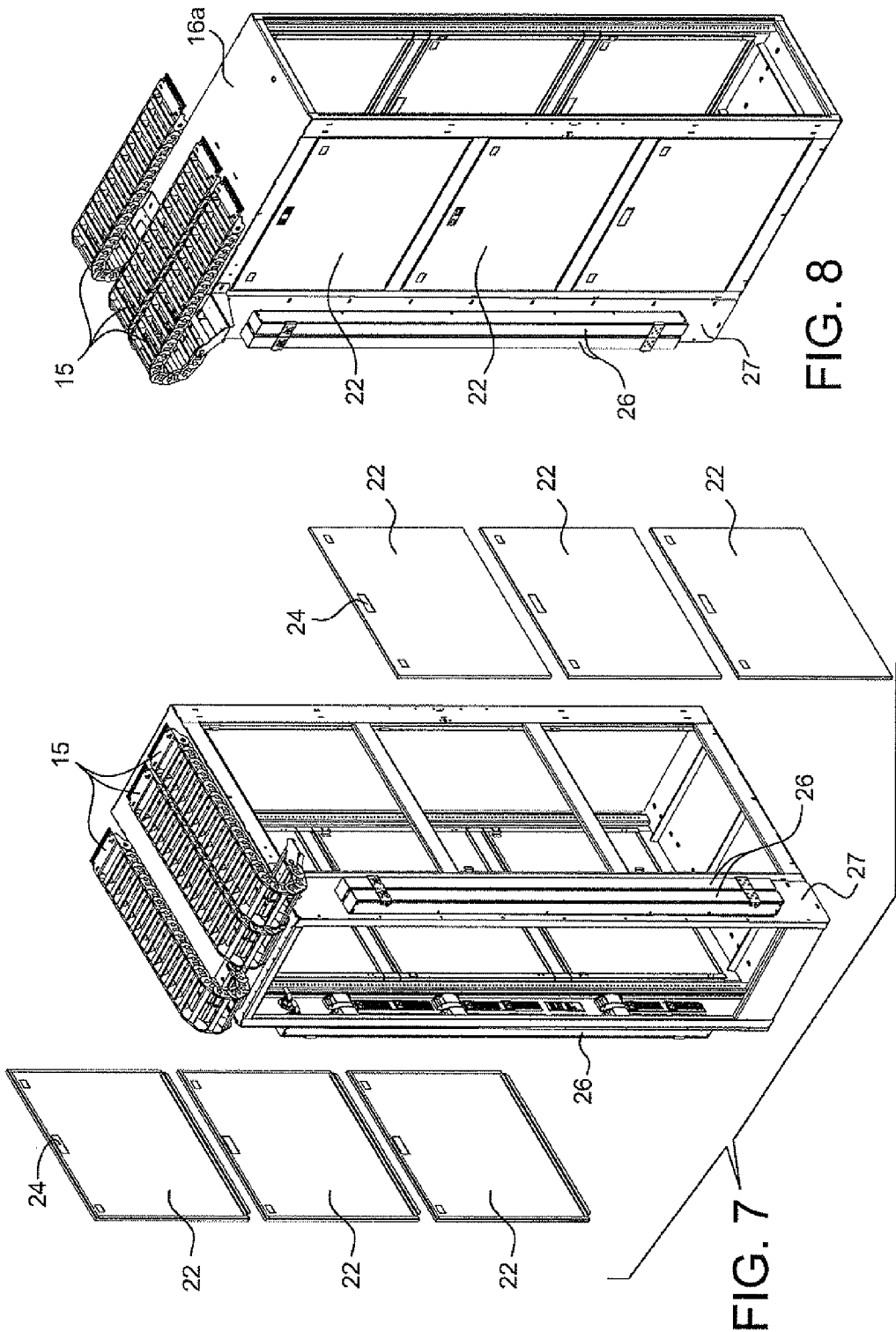
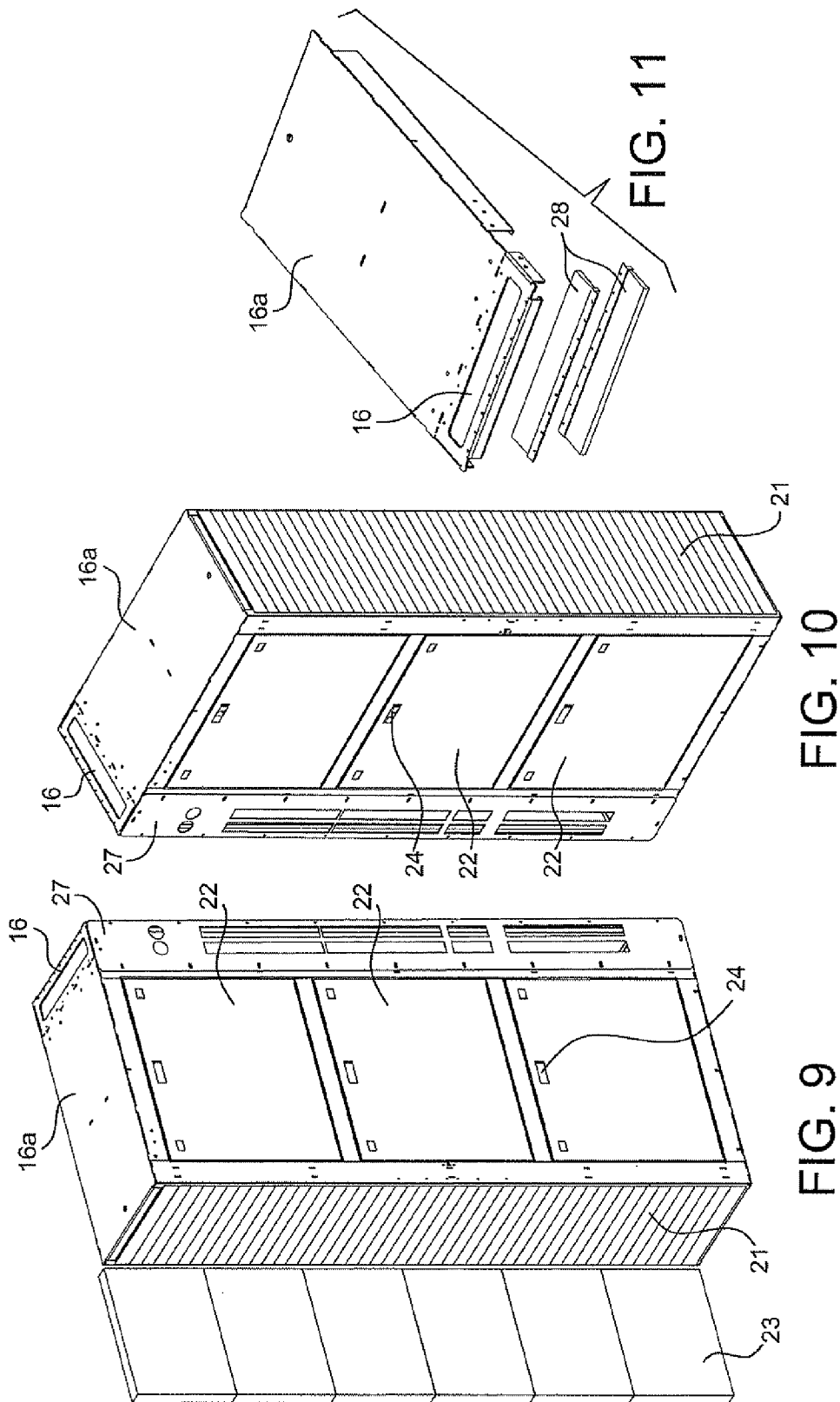


FIG. 2









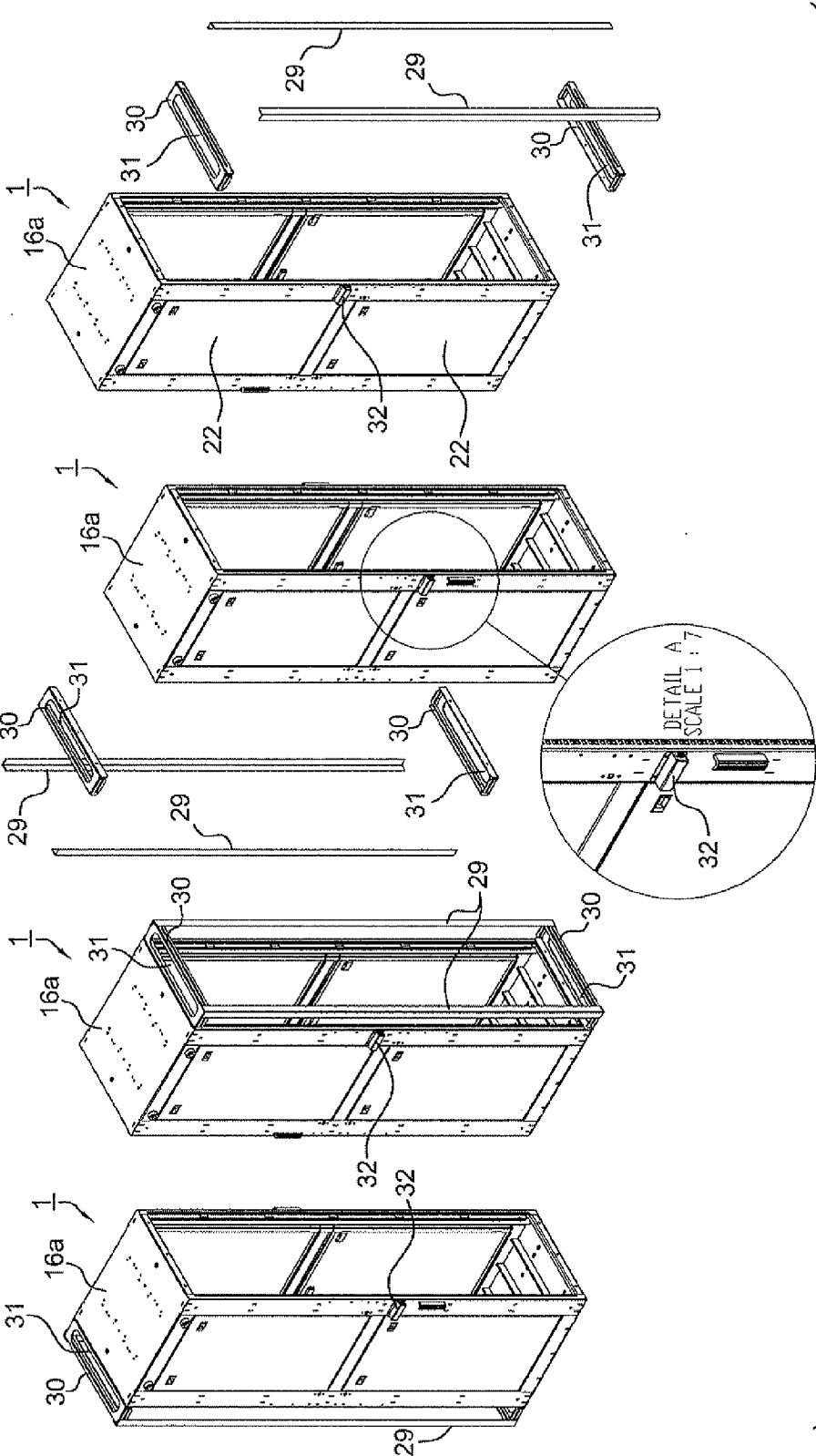
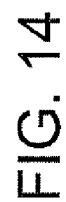
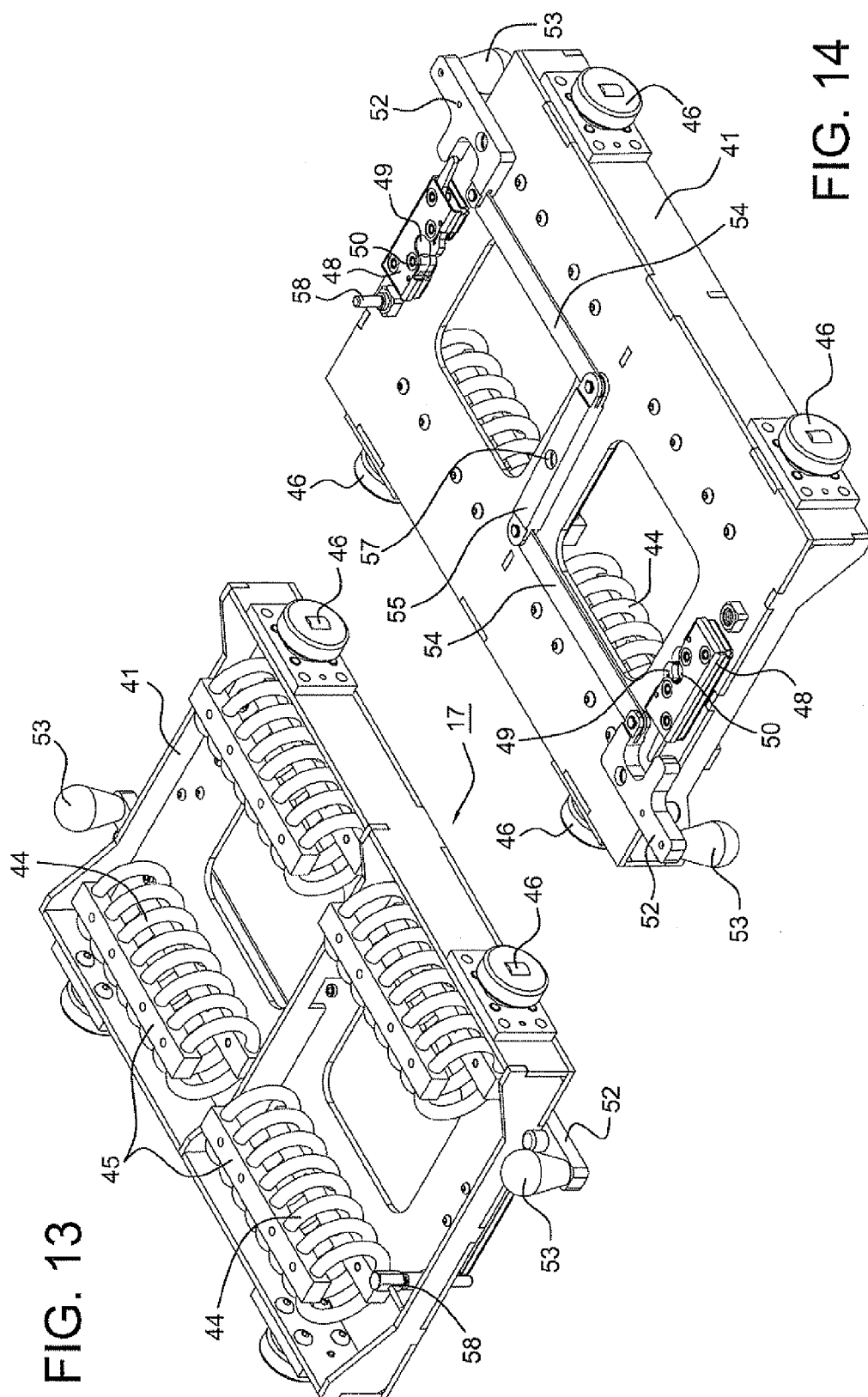
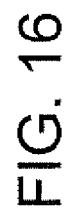
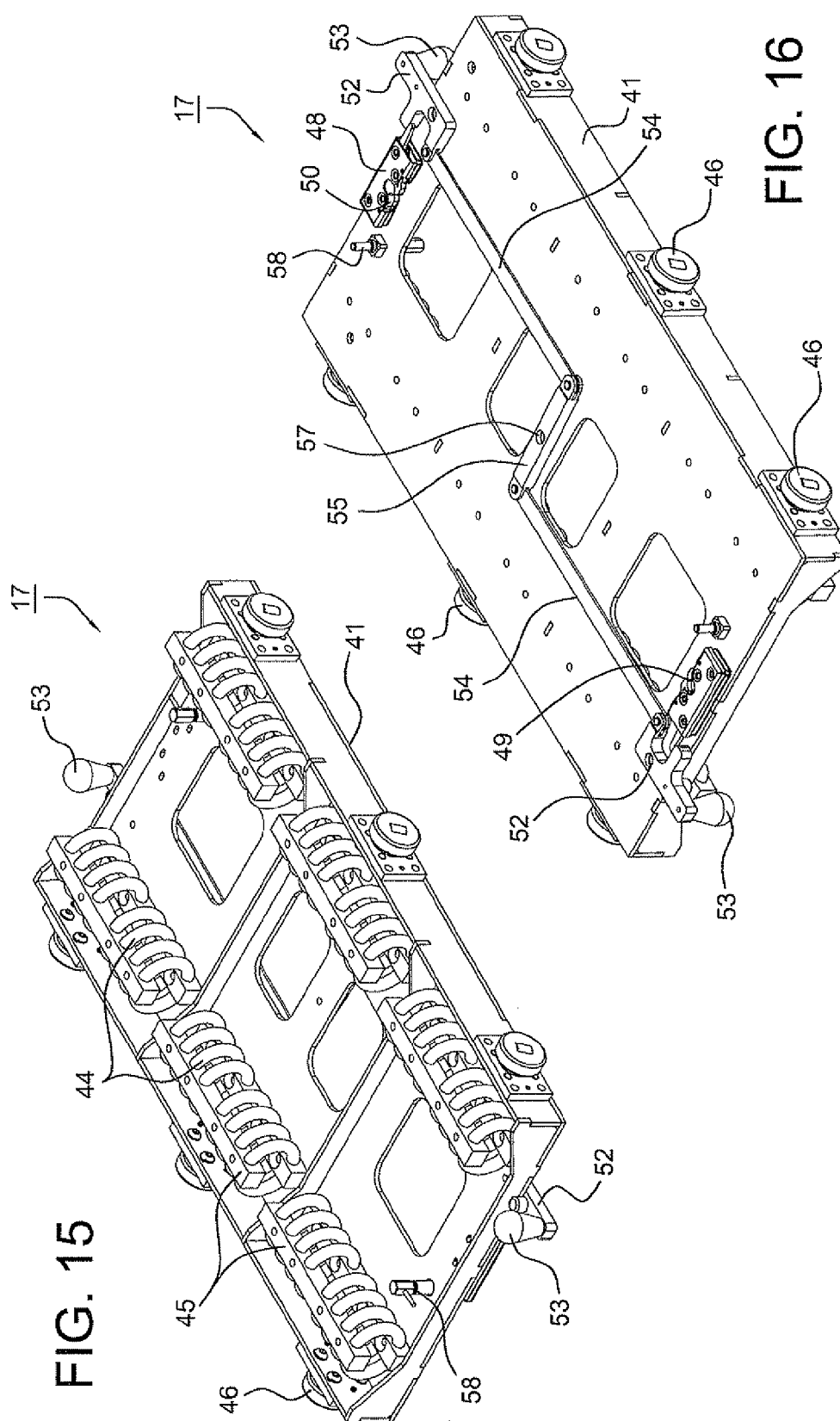
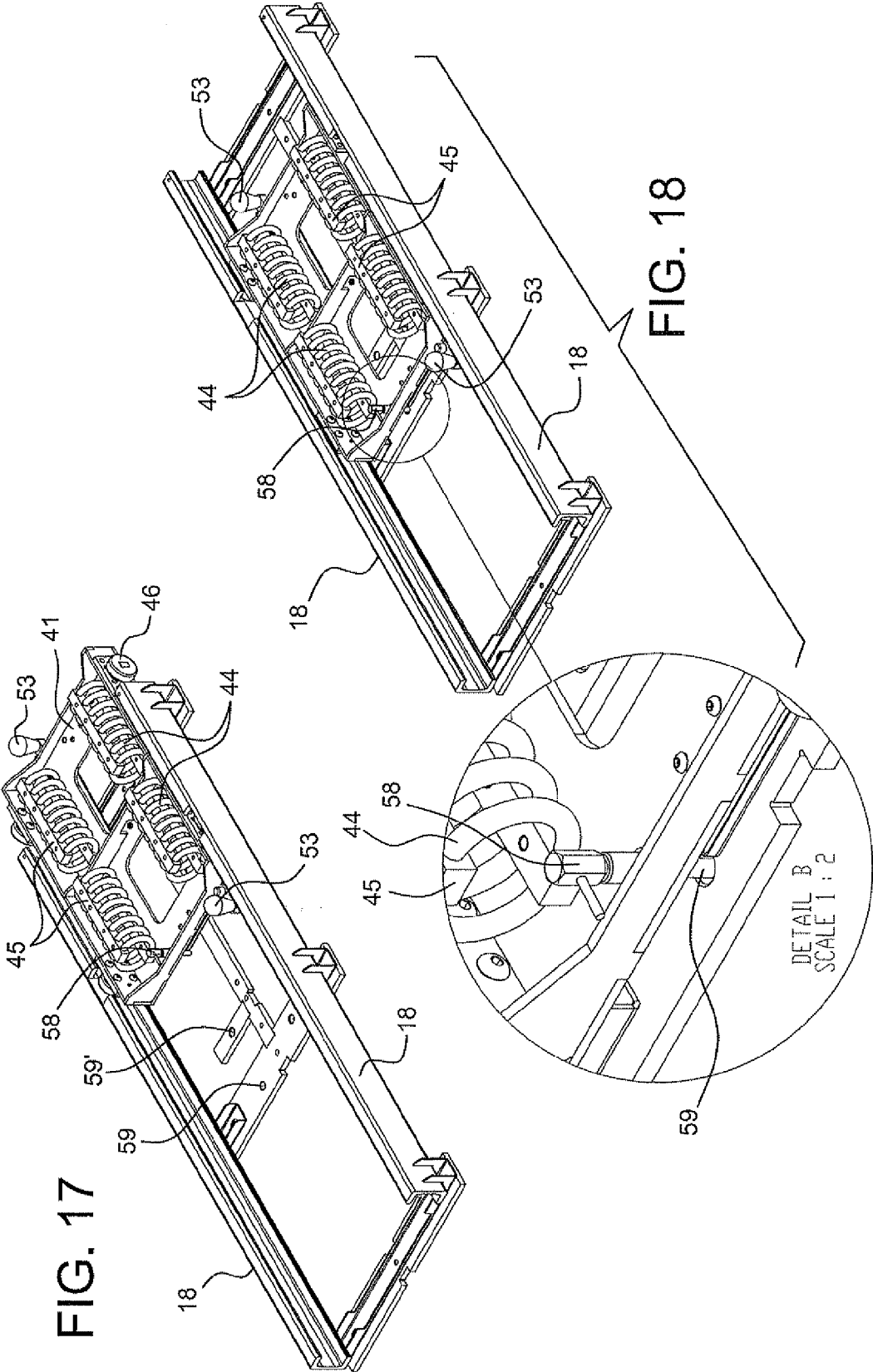
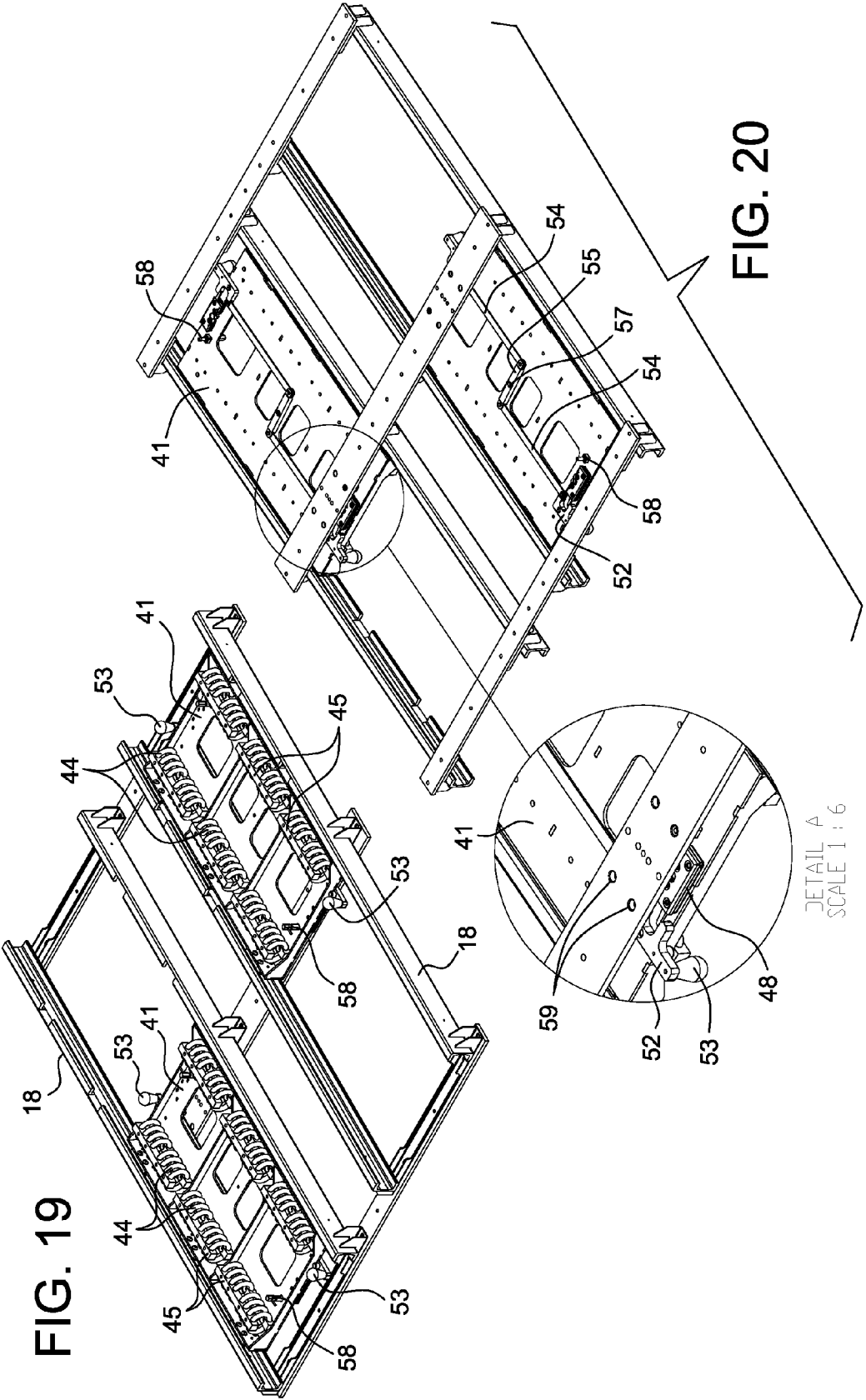


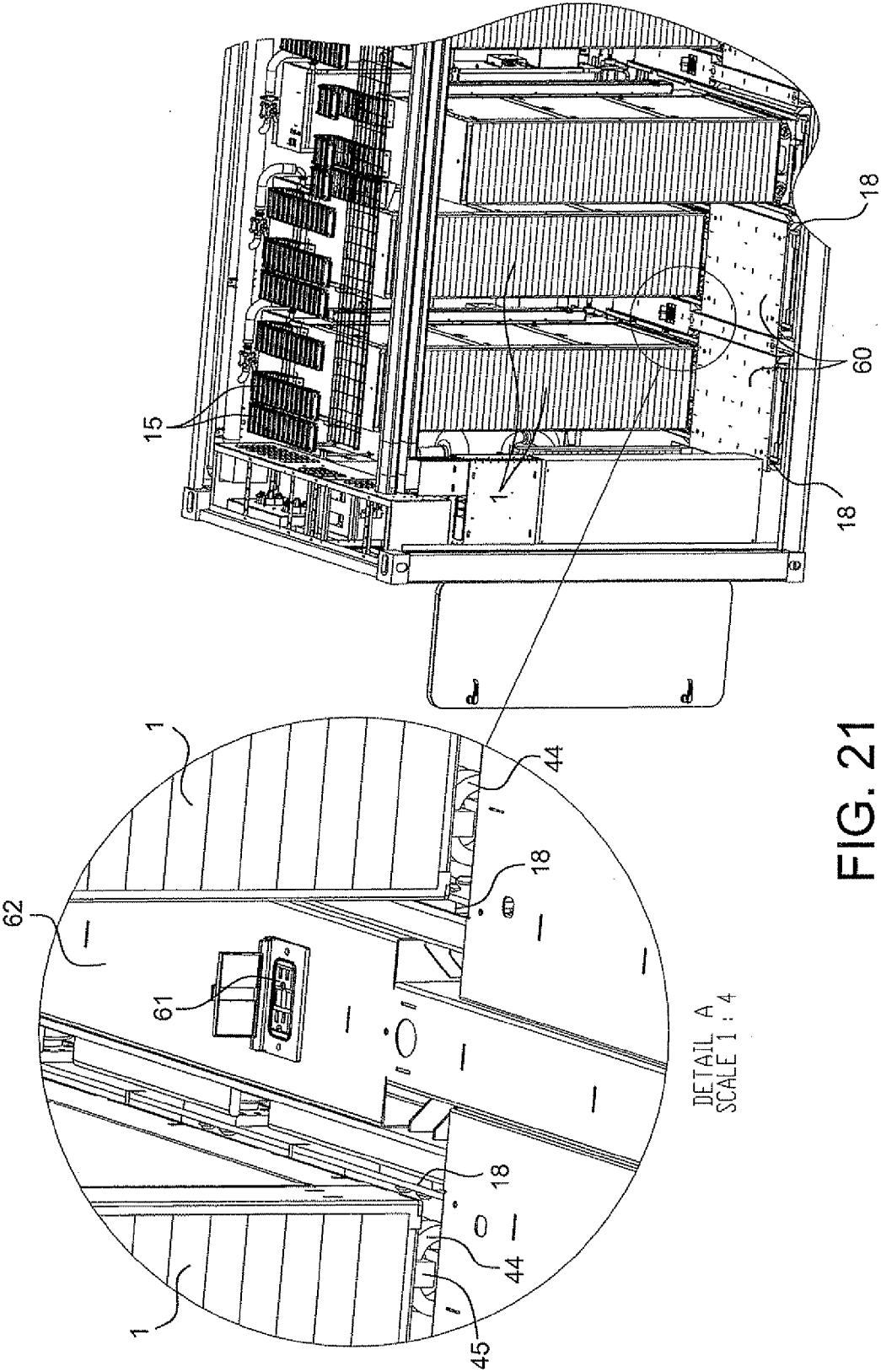
FIG. 12

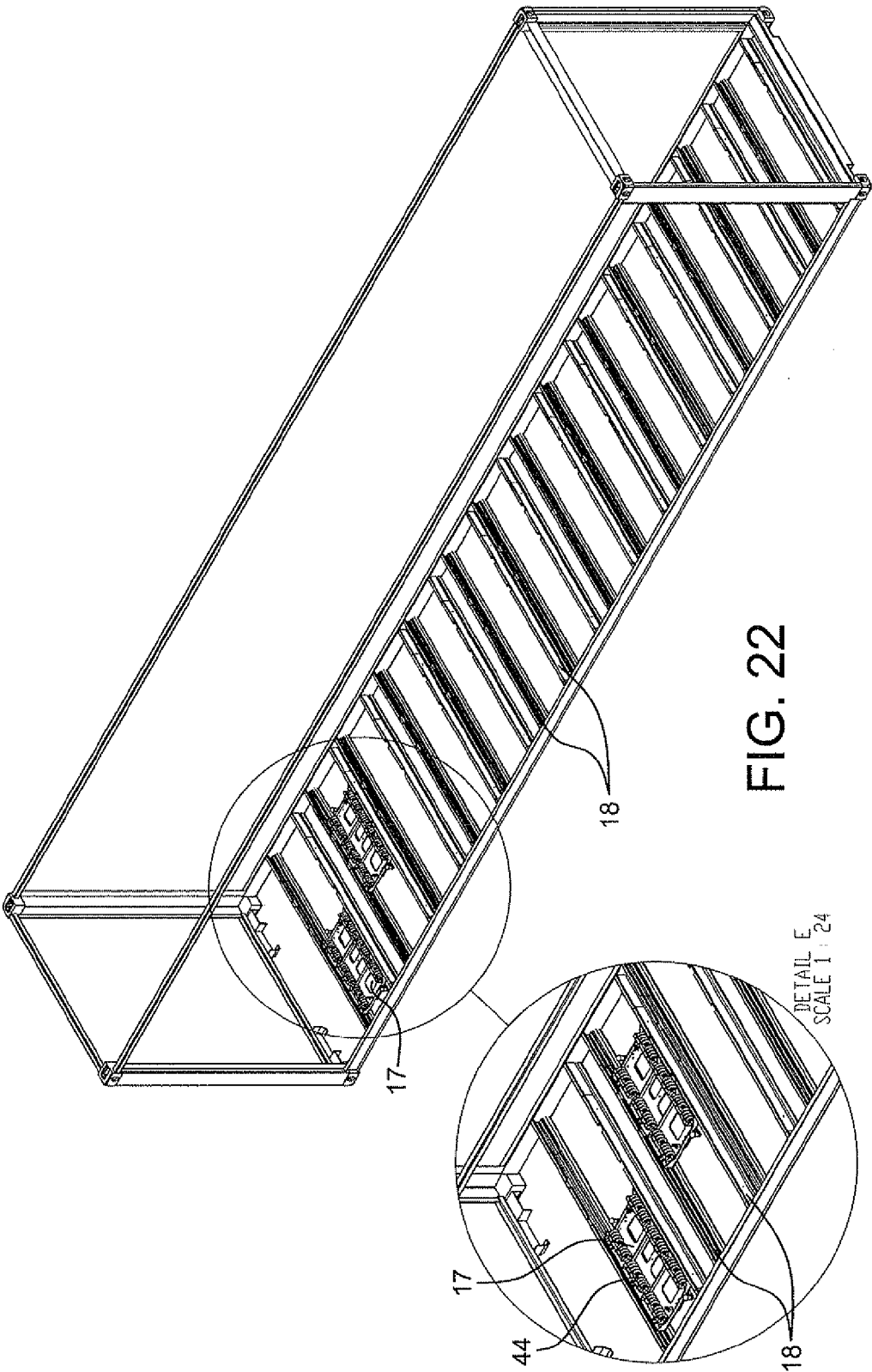












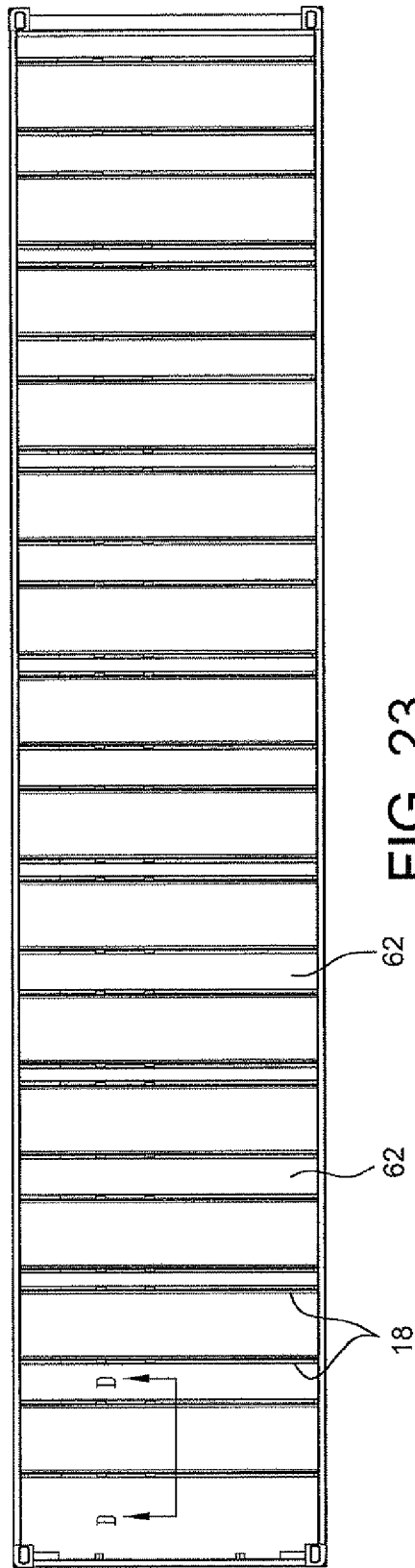


FIG. 23

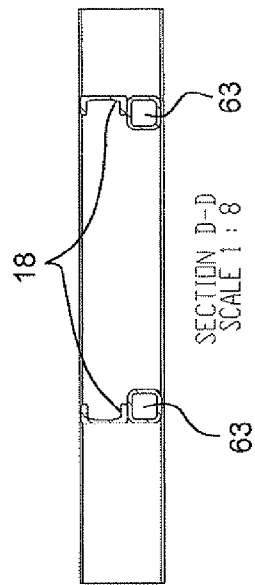
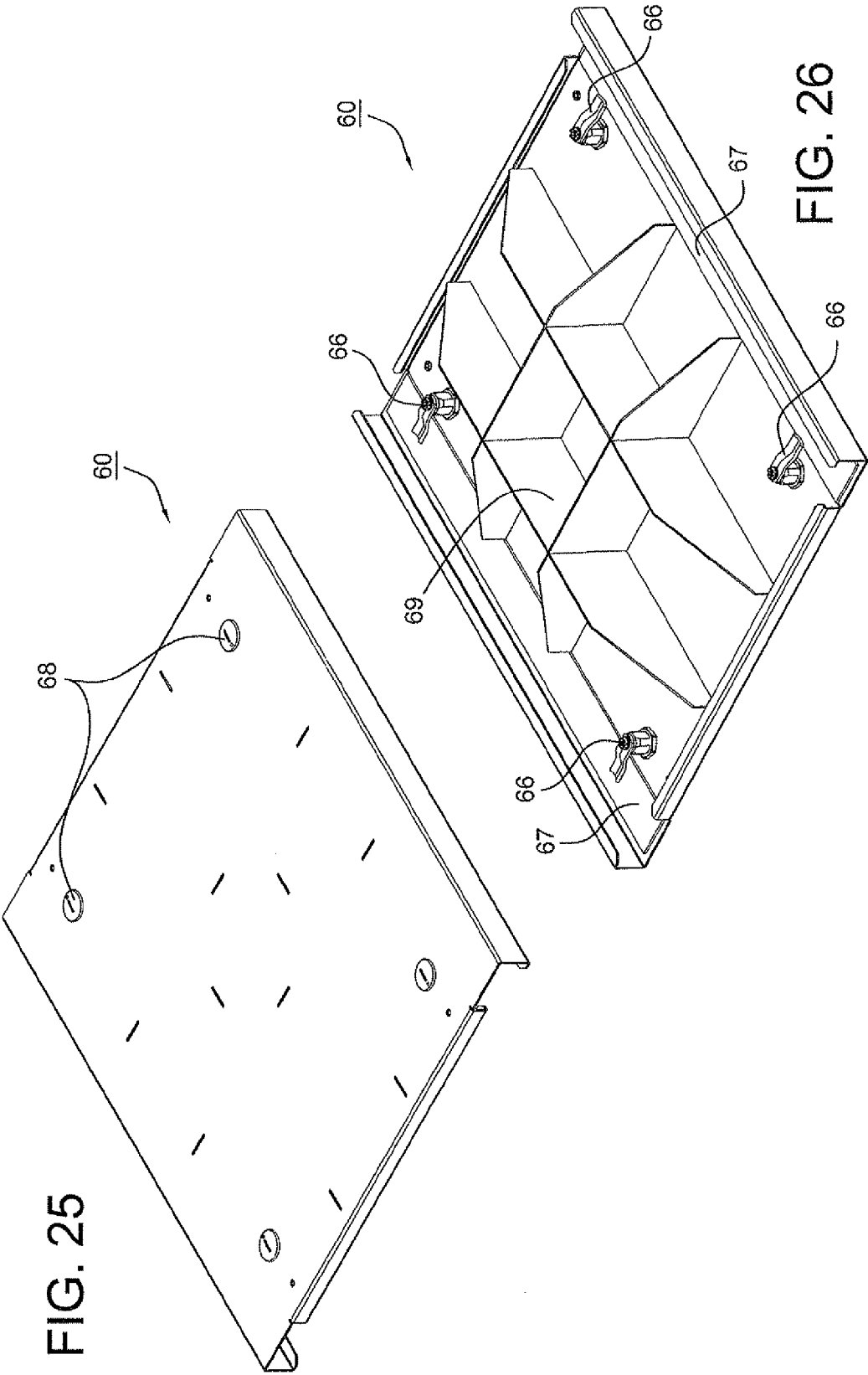


FIG. 24



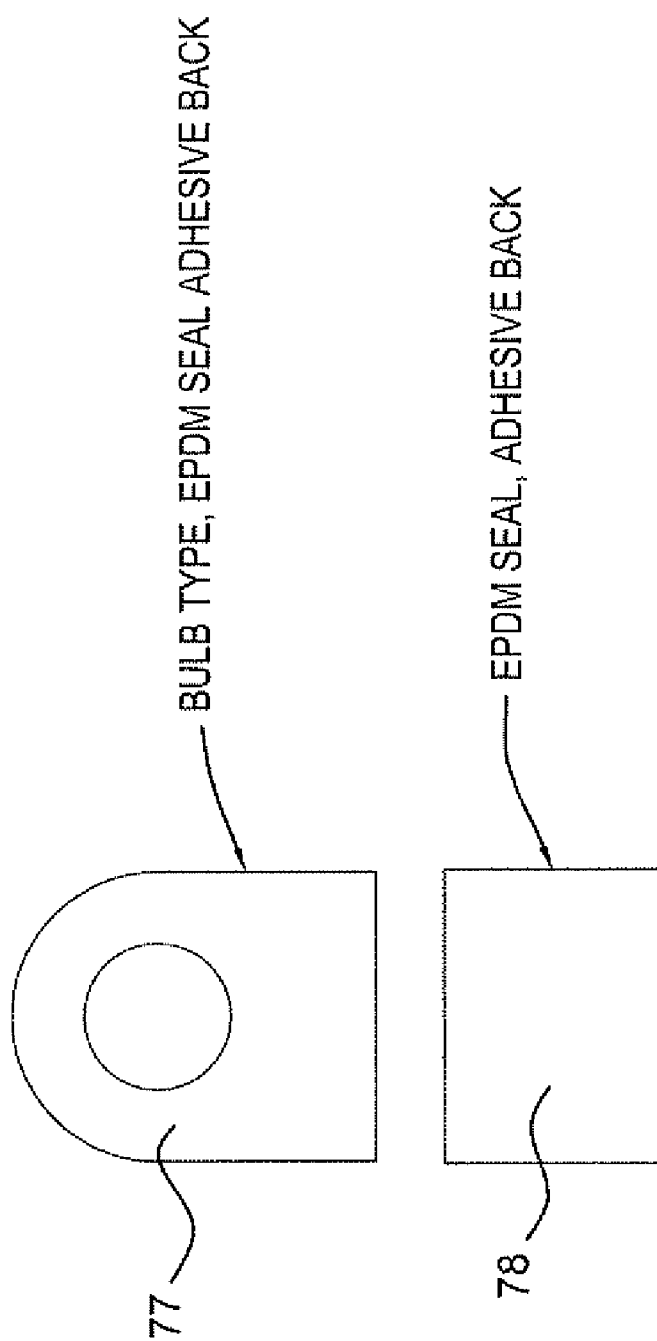
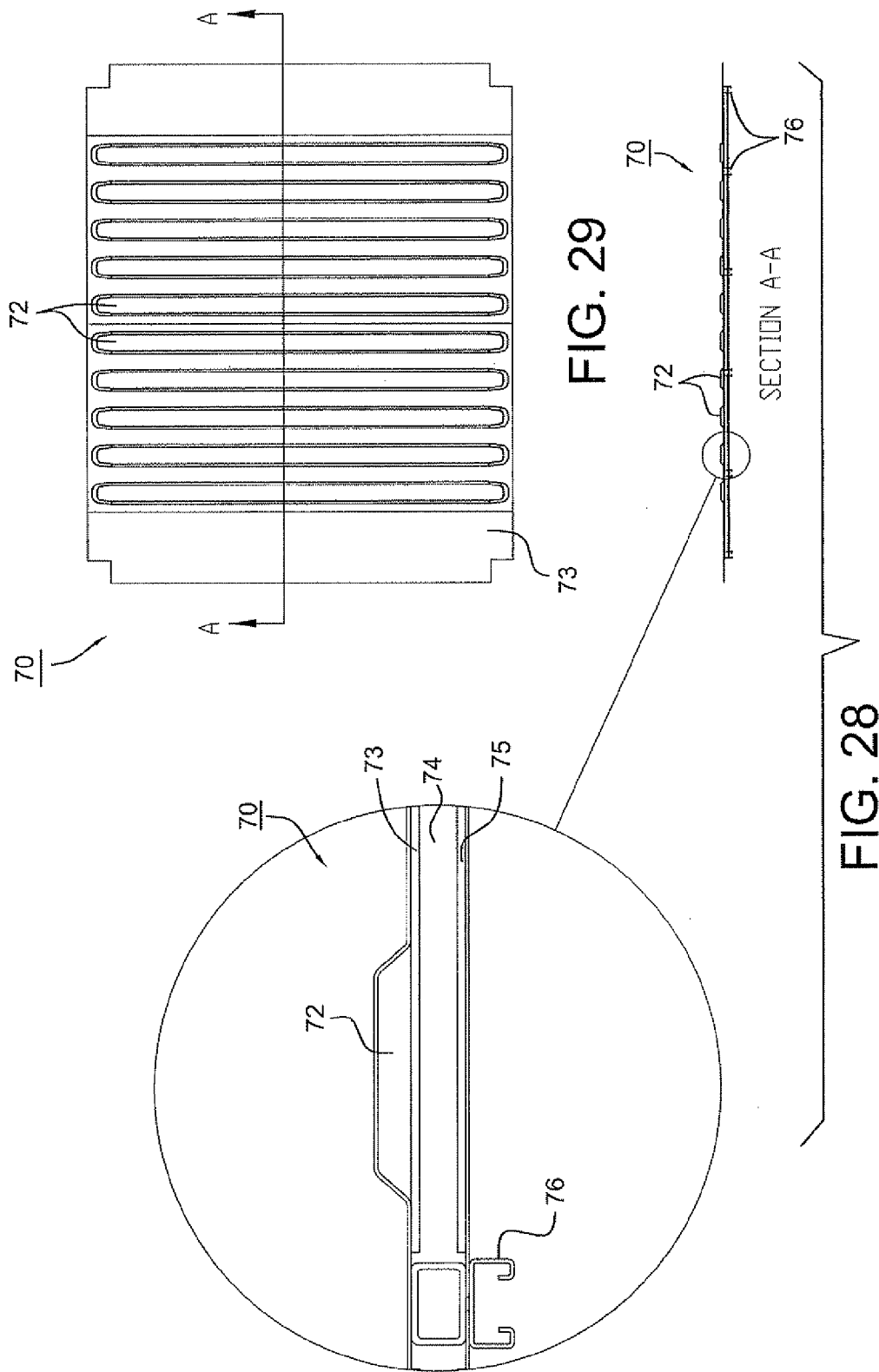
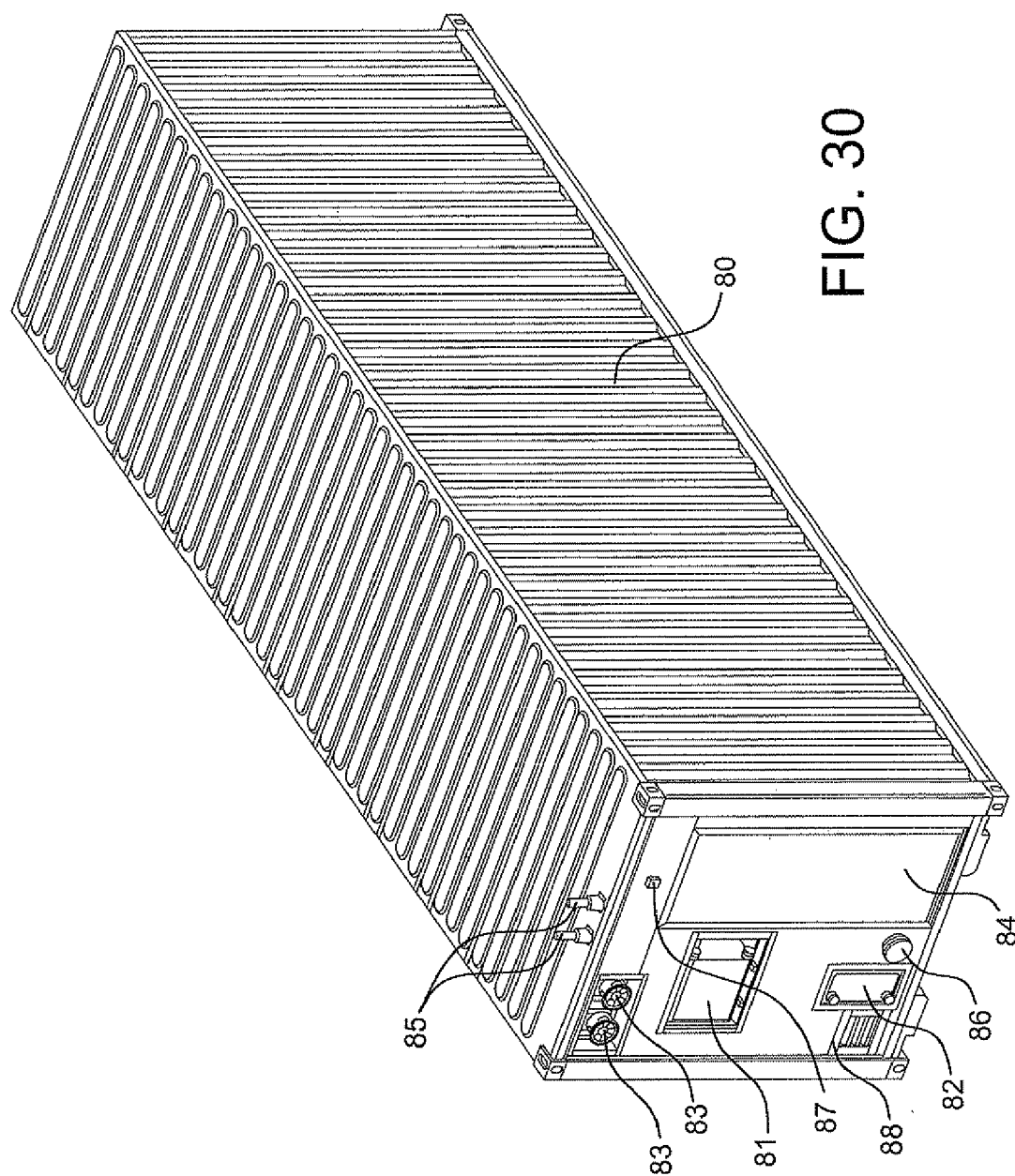


FIG. 27





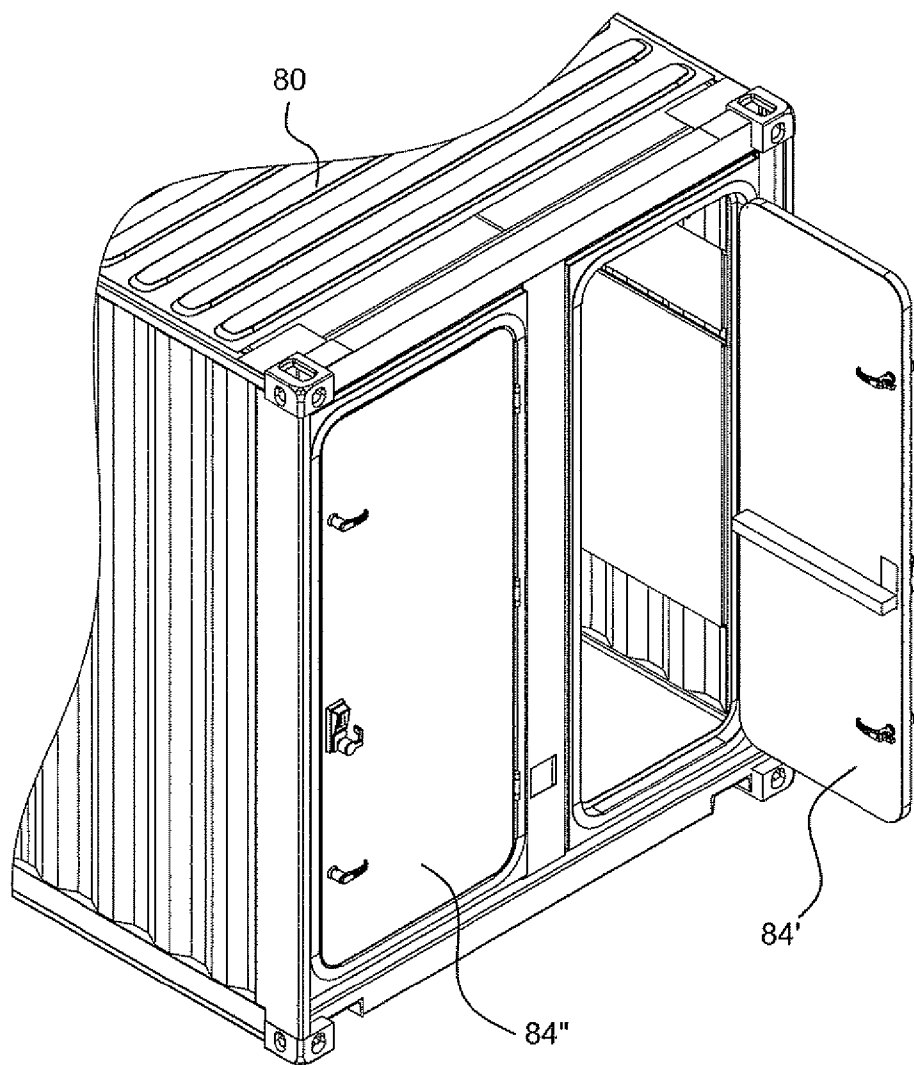


FIG. 31

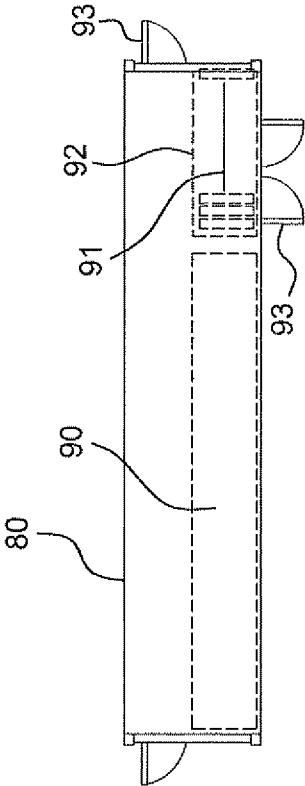


FIG. 32

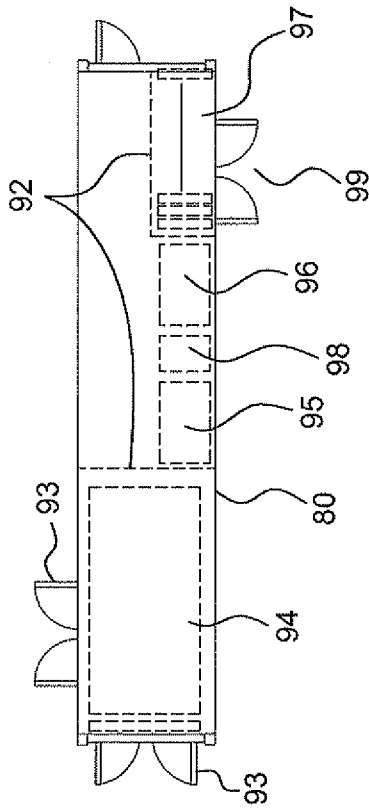


FIG. 33

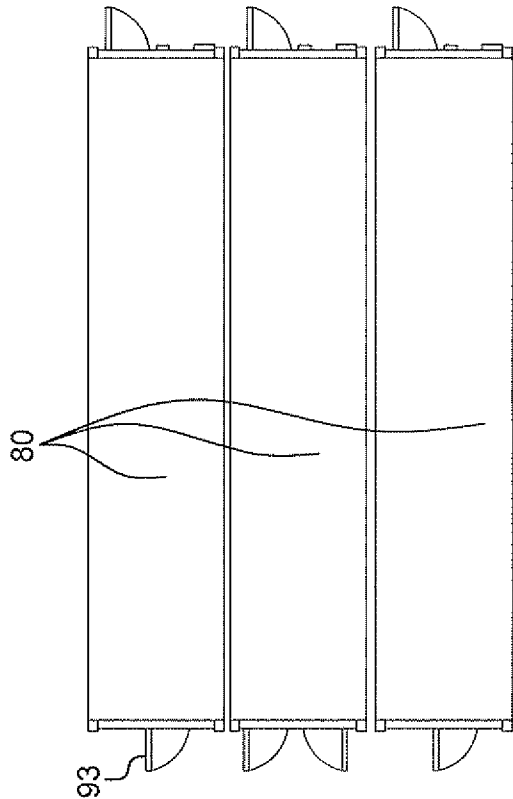


FIG. 34

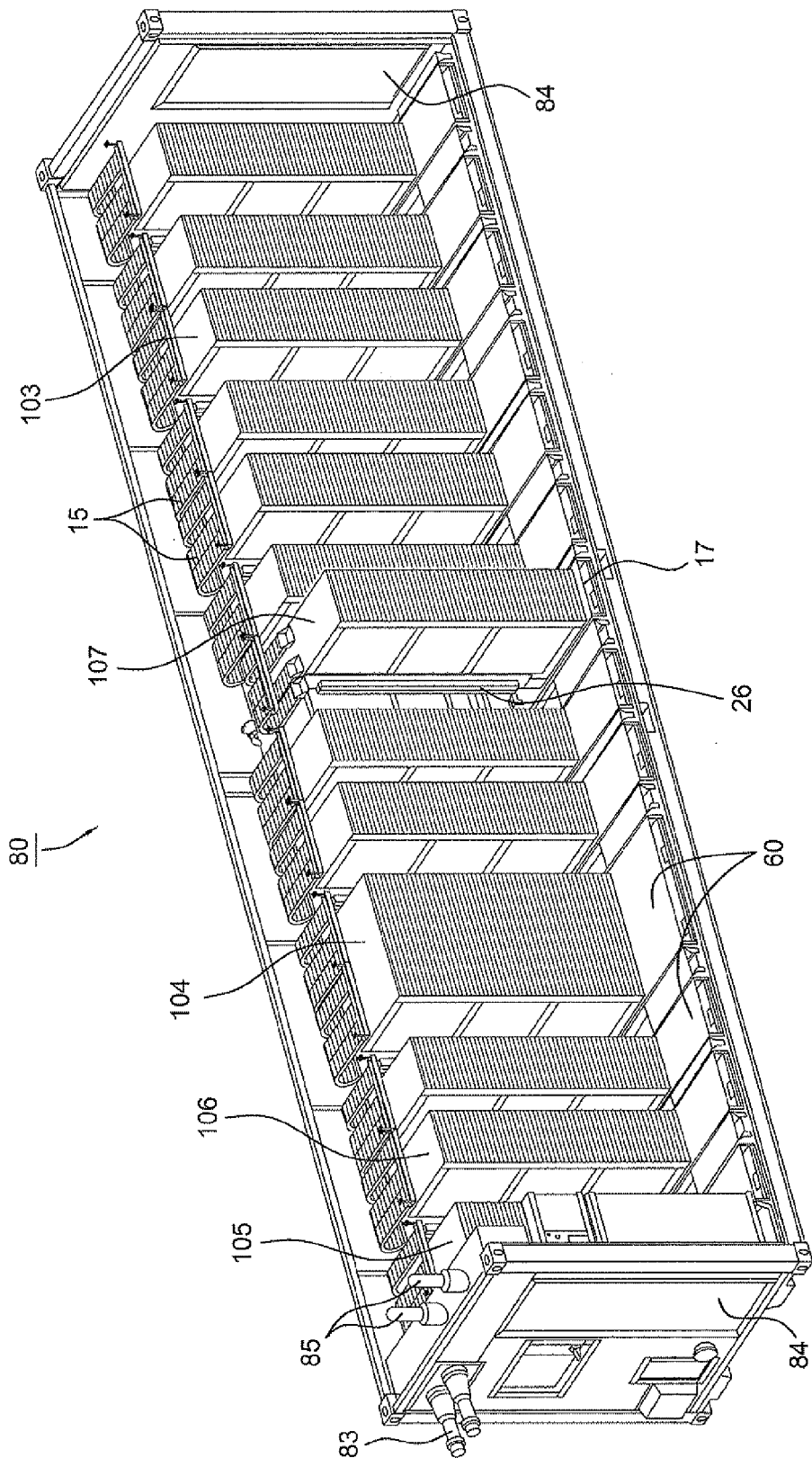


FIG. 35

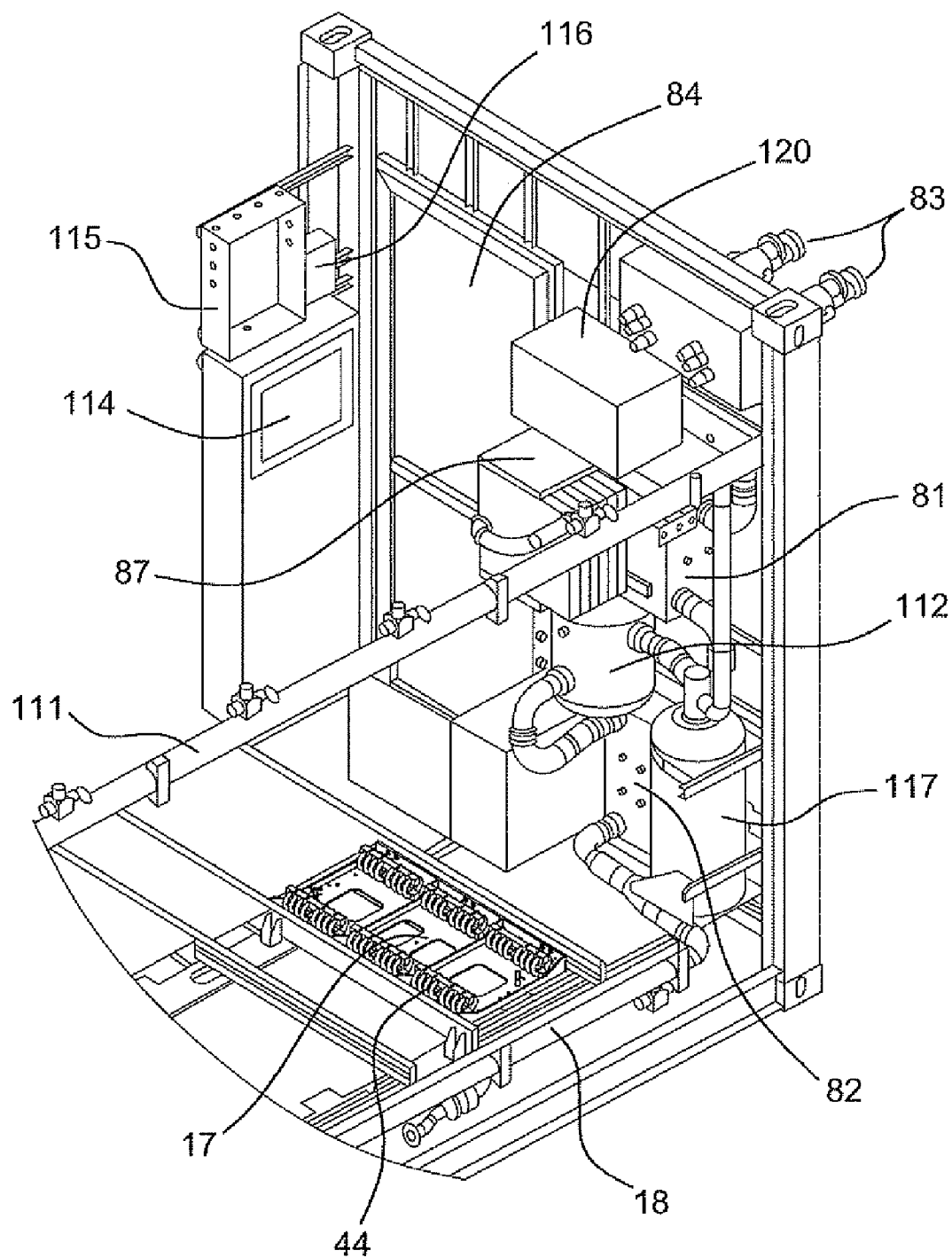


FIG. 36

TRANSPORTABLE, ENVIRONMENTALLY-CONTROLLED EQUIPMENT ENCLOSURE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to improvements to a Transportable Environmentally Controlled Equipment Enclosure (TECEE) or other equipment enclosure of the type containing racks of heat-generating equipment. By way of example and not limitation, the equipment may be computing equipment and the equipment enclosure may be part of a modular and/or containerized “data center.” Alternatively, the equipment may be ground support, tracking, or communications equipment, or any other equipment requiring a transportable, environmentally controlled enclosure.

[0003] The improvements include use of a pump-less heat pipe cooling system to carry heat away from the equipment, an improved equipment rack system that includes a suspended base supported by rails with multiple latching and/or locking positions, and various improvements related to power distribution, equipment access, internal and external communications, and safety.

[0004] 2. Description of Related Art

[0005] Historically, site planners and designers for equipment sites, including ground support sites, tracking sites, server sites and/or communication sites, have worked to balance personnel needs, equipment density, and power efficiency while keeping environmental control and serviceability. Traditional “brick and mortar” equipment sites are still built, but the new equipment center form factor is the Transportable, Environmentally Controlled Equipment Enclosure (TECEE).

[0006] The TECEE can be customized but can contain all the key attributes of a standard “brick and mortar” equipment center. This approach is incredibly rapid to manufacture, position, and install, is significantly more cost effective, and balances the need for density, power efficiency, environment control, total efficiency, redundancy and maintainability.

[0007] Universities and governments are interested in TECEEs because of the ability of multiple TECEEs to address the often competing needs of different departments. Healthcare’s interest is in the small size and the fact that they generally have limited talent and experience with technical equipment structures so the TECEE becomes a product solution. Financial officers are interested in the rapid depreciation and built in technology refresh rates of a TECEE, and all markets are interested in the rapid deployment that a TECEE provides. As a result of the importance and interest in TECEE technology, the prior art includes a number of patents and patent publications directed to TECEE-type enclosures or portable data centers and related technologies, including U.S. Pat. Nos. 7,050,299, 7,187,550, 7,724,513, 7,551,971, and 7,660,121, and U.S. Patent Publication Nos. 2005/0244280, 2009/0229194, 2010/0165565, 2010/0236772, 2010/0251629, 2010/0263855, and 2010/0277863.

[0008] A current issue at equipment sites is power consumption. Most existing “brick and mortar” sites run out of power capacity long before they reach maximum equipment density. In the TECEE, however, equipment density is very high. The TECEE is basically an equipment-only space, the only personnel space required being for maintenance, and therefore the TECEE can be highly efficient since ambient temperature and humidity can be much higher in equipment-

only spaces. Maintenance switches can decrease the temperature when service personnel are present.

[0009] Even though TECEEs can be maintained at a higher temperature than conventional fixed equipment housing structures, power consumption by the cooling system is still a significant issue, and thus much of the prior art has focused on cooling system improvements. The most common cooling arrangements for TECEEs are those in which coolant pressure is maintained by a central pump (such as the Liebert pump), and by individual flow-control valves for each rack. Another known cooling arrangement involves providing individual pumps at each equipment rack, i.e., “distributed” pumps, as disclosed for example in U.S. Patent Publication No. 2010/0236772. In either of the known pump-based cooling arrangements, however, the pumps are significant source of power consumption and add to the installation and maintenance costs of the TECEE.

[0010] Additional problems of conventional TECEEs include problems related to equipment mounting, such as the problem of allowing access to the equipment and/or securing the equipment for transport without complicating connection/disconnection of equipment to the power supply and cooling system, the problem of providing a power back-up or redundancy to ensure an adequate power supply, and safety issues.

[0011] With respect to equipment mounting, U.S. Pat. No. 7,551,971 is of interest for its general disclosures of shock absorbing rack mounts and restraint of the racks during transport, while U.S. Pat. No. 7,660,121 is of interest for its disclosure of pull-out, rail-mounted equipment racks (see, especially, FIGS. 12A-12D). The present invention also uses rail-mounted equipment racks, but with a number of improvements that facilitate both equipment access and restraint during operation or transport.

SUMMARY OF THE INVENTION

[0012] The invention provides improvements to a transportable, environmentally controlled equipment enclosure (TECEE) of the type that can be factory designed and manufactured, factory tested with installed equipment, transported and position quickly to another location, connected to power sources, and quickly put into operation. The improvements relate to, by way of example and not limitation, equipment cooling and environmental control, power consumption, power distribution, equipment mounting and access, internal and external communications, and safety.

[0013] Although the improvements provided by the invention are especially applicable to TECEE structures, at least some of the improvements, such as the cooling system and equipment rack design, may also be applied to non-transportable equipment enclosures or data centers. Thus, the invention not only provides an improved TECEE structure, but also improved equipment cooling systems, improved equipment rack mounting structures, and such varied improvements as an improved floor tile arrangement, improved insulation panels, improved equipment enclosure management, and so forth.

[0014] For example, the preferred embodiments of the invention include a gravity-fed cooling arrangement that does not require a main loop pump or expansion valves, and an equipment rack mounting mechanism that provides improved access to the equipment while permitting the equipment to be securely latched or locked in multiple operation and/or transport positions.

[0015] The preferred high efficiency cooling system uses a low boiling point liquid/vapor and the following main loop components:

[0016] a main loop condenser used to transfer heat from the coolant to an externally supplied cooling fluid;

[0017] a return manifold that channels coolant vapor coming out of each equipment heat exchanger module to the main loop condenser, to transfer heat to externally supplied fluid, and which is preferably slanted to facilitate gravity flow to the main loop heat exchanger;

[0018] a supply manifold that supplies coolant to pumps located in each equipment cooling module, the supply manifold also being slanted for gravity flow to the pumps; and

[0019] a coolant reservoir mounted close to the ceiling of the container where coolant from the main condenser is pooled to supply sufficient coolant to the supply manifold and rack evaporators to keep them flooded with refrigerant, thereby eliminating the need for pumps at each rack.

[0020] In the preferred cooling system, each rack is associated with a cooling module that includes an individual heat exchanger. The cooling module is preferably mounted to the enclosure wall via brackets **2a** and mates with the rear of a movable equipment rack module. The movable equipment rack module is in the form of a rack suspended on a sled aligned with the cooling module and movable from an operating position, in which the sled is mated with the cooling module, and positions in which the rack is separated from the cooling module for transport or storage. Instead of mating with the rear of the equipment, it is also possible for the exchanger to be mounted so as to mate with the top of the equipment or to mate with sides of the equipment module, depending on the design of the equipment and in particular on the direction in which hot air is exhausted. Preferably, the cooling module also includes fans/blowers arranged to pull hot air exhausted from the equipment through the heat exchanger and then exhaust the cooler air away from the equipment rack.

[0021] The return manifold preferably has a slant or inclination toward the main loop heat exchanger and the supply manifold preferably has a slant or inclination toward the equipment heat exchanger, so as to provide a gravity assist to coolant circulation. Both the supply and return manifold have multiple ball valves along the manifold length, and the equipment racks are mounted on rails placed so the equipment heat exchanger lines up with the valves.

[0022] In operation, the coolant used in the cooling system of the preferred embodiment flows from the reservoir through the supply manifold towards the equipment heat exchanger modules. In the liquid/vapor system the coolant fluid entering the equipment heat exchanger is changed into vapor as the heat is removed from the equipment hot exhaust. The vapor is collected by the slanted return manifold and returned to the main loop condenser unit. The vapor is cooled in the main loop condenser unit, returning the vapor to the liquid state. External fluid flow from an external source is the heat removal agent.

[0023] In the preferred embodiment, a shock and vibration isolation system is situated between the sled and the equipment to protect the equipment from seismic shock and/or vibration during shipping. A post lock allows the internal equipment sled to be locked in a normal operating position or locked in an extended position for service using another post

lock. In addition, a plunger mechanism is provided to latch the sled in intermediate positions on the rails in order to adjust the center of gravity of the enclosure during transport. Any rails that are exposed due to positioning of the sleds are, in a preferred embodiment of the invention, covered by floor tiles that are suspended from the rails or beams associated with the rails.

[0024] Additional features of the preferred embodiment include redundant power runs across the entire container length, tap-off boxes with built-in transformers for 120V power, more than one voltage input into the container, power strip mounting on the rack, removable rack side access panels, grounding features for servicing personnel, rack extensions to increase rack depth, improved equipment enclosure insulation panels, and dual container entry doors.

[0025] Still further improvements related to power distribution, equipment access, internal and external communications, and safety are also included in the preferred embodiments described below and in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1 is an isometric view showing a main loop of a preferred cooling system for a transportable, environmentally controlled equipment enclosure constructed in accordance with the principles of a preferred embodiment of the invention.

[0027] FIG. 2 is an isometric view showing a cooling module and a mating equipment rack constructed in accordance with principles of a preferred embodiment of the invention.

[0028] FIGS. 3 and 4 are isometric views showing variations of the cooling module and equipment rack of FIG. 2.

[0029] FIGS. 5-12 are isometric views showing various sub-assemblies and parts of the equipment racks of FIGS. 2 and 3.

[0030] FIGS. 13-16 are isometric views showing various embodiments of a sled assembly arranged to support the equipment racks of FIGS. 2-12.

[0031] FIGS. 17-20 are isometric views of the sled assemblies of FIGS. 13-16, mounted on rails in accordance with the principles of the preferred embodiment.

[0032] FIG. 21 is an isometric view showing an installed version of the rail/sled arrangement of FIGS. 2-20, with the addition of removable floor tiles and 120 VAC outlets in accordance with the principles of a preferred embodiment of the invention.

[0033] FIG. 22 is an isometric view showing a layout for the rails **18** corresponding to the arrangement shown in FIG. 21.

[0034] FIG. 23 is a plan view of the rail layout shown in FIG. 22.

[0035] FIG. 24 is a cross-sectional front view of the layout of FIGS. 22 and 23.

[0036] FIGS. 25 and 26 are isometric view of preferred floor tiles for use in a transportable environmentally controlled equipment enclosure.

[0037] FIG. 27 is a cross-sectional side view of a preferred panel or tile for insulating a transportable environmentally controlled equipment enclosure.

[0038] FIG. 28 is a plan view of the panel tile of FIG. 27.

[0039] FIG. 29 shows front elevations of adhesive arrangements for the preferred cooling module and equipment rack.

[0040] FIG. 30 is an isometric view showing an equipment enclosure of a preferred embodiment of the invention with an alternative cooling system, viewed from the front.

[0041] FIG. 31 is an isometric view of the exterior of an equipment enclosure with dual access doors.

[0042] FIGS. 32-34 are plan views showing various alternative layouts for the interior of the equipment enclosure of FIG. 30.

[0043] FIG. 35 is an isometric view showing an interior of the enclosure of FIG. 31, with both large and small rack modules.

[0044] FIG. 36 is an isometric view of a portion of the interior of the enclosure of FIG. 30, showing details of the alternative cooling arrangement and a controller panel.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0045] The preferred embodiments of the invention may be implemented in any transportable, environmentally controlled equipment enclosure, as well as in static or non-transportable equipment enclosures. While specific features of the enclosure exterior and layout are preferred, these features should in general be taken as exemplary and not limiting. In particular, the cooling system and rack mounting arrangements may be separately applicable to a wide variety of different equipment enclosure types, as may various safety and other improvements described below and depicted in the accompanying drawings.

[0046] a. Pump-Less Cooling System

[0047] The cooling system of this preferred embodiment of the invention differs from conventional equipment enclosure cooling systems in that it does not require either a central coolant pump or distributed pumps for the respective enclosures, thereby achieving both power savings and reduced equipment/maintenance costs.

[0048] As illustrated in FIG. 1, the pump-less cooling system of embodiment supplies coolant to individual equipment racks 1 via individual heat exchangers 2, illustrated in FIG. 2, that are part of cooling modules 14 for transferring heat from equipment in the rack (not shown) to the coolant, causing the coolant to vaporize. The coolant passes from the respective heat exchangers 2 associated with the individual racks 1 through, as illustrated in FIG. 1, a common return manifold 3 to a main loop condenser 4, which transfers heat from the vapor to an external cooling loop or to the environment outside the equipment enclosure, thereby causing the vapor to condense and flow to a main loop reservoir 5. The reservoir 5 prevents cavitation in the system and supplies liquid coolant to a supply manifold 6, which is connected to individual coolant ducts or passages 7 that transport the coolant through the respective equipment rack heat exchangers 2.

[0049] In operation, the coolant flows from the main loop reservoir 5 through supply manifold 6 towards the equipment heat exchanger modules 2. In the liquid/vapor system, the coolant fluid entering the equipment heat exchanger is changed into vapor as the heat is removed from the equipment hot exhaust. The vapor is collected by the slanted return manifold 3 and returned to the main loop condenser 4. The vapor is cooled in the main loop condenser 4, returning the vapor to the liquid state. The heat removal agent for the condenser preferably involves external fluid flow from an external source. The external fluid cooling source can be user supplied, from a supplemental cooling enclosure, or from geothermal slinky or coil techniques or geothermal standing well techniques. Alternatively, if the condenser is situated

outside the enclosure, heat may be removed from the condenser by radiation to the ambient air surrounding the enclosure.

[0050] Connections between the equipment rack coolant ducts or passages 7, which may include pipes, hoses, combinations of pipes and hoses, or any other suitable fluid carrying passages, is preferably through supply manifold couplers 8 and return manifold couplers 9, each containing suitable valves, such as ball valves, that permit the equipment racks to be easily connected to and disconnected from the return manifold 3 and supply manifold 6. As illustrated in FIG. 1, the return manifold couplers 9 are installed at the bottom of the return manifold 3 to enable liquid refrigerant run-off back into a respective evaporator.

[0051] In order to maintain circulation of the coolant, the main loop condenser 4 may be mounted above the ceiling of the enclosure, on top of the container. If not on top of the container and/or above the ceiling of the equipment enclosure, the position of the condenser, as well as that of the reservoir 5, should at least be high enough to provide a gravity-assist for circulation of the coolant through the coolant loop, and ensure that the supply manifold 3 and coolant passages 7 through the rack evaporators 2 are sufficiently flooded with coolant to maintain circulation and ensure transfer of heat away from equipment in the racks. The invention is not limited to a particular coolant or refrigerant, although it is preferred that it has a boiling and condensation points that enable vaporization in the individual evaporators 2, and condensation in the main loop condenser 4.

[0052] As noted above, the preferred cooling system shown in FIGS. 1 and 2 is unique since there is no main loop pump and no expansion valves required. This is preferably achieved not only by appropriate positioning of the main loop condenser 4 and reservoir 5 relatively high in or on the equipment enclosure, by flooding the supply manifold 3 and individual rack heat exchangers 2, and by providing a coolant that vaporizes in the heat exchangers 2, but also by optionally inclining the return and supply manifolds 8, 9 to provide an additional gravity-assist. The return manifold 3 has up to a thirteen degree slant toward the main loop condenser and the supply has an up to a thirteen degree slant toward the equipment heat exchanger 9. The up to a thirteen degree manifold slant, together with the arrangement of the main condenser 4 and reservoir 5 as described above form a gravity assisted coolant flow design, requiring no main loop pump or pumps for the individual equipment racks 1.

[0053] As shown in FIG. 2, excess heat transferred to the coolant from the equipment may be removed at the heat exchanger 2 by forced air, using fans or blowers 10 mounted in a cooling module 14 that also includes heat exchanger 2 to assist the flow of air through the equipment. Because of the way the racks are mounted at the front of the heat exchanger 2, the forced air cooled equipment has a rear exhaust, although the forced air cooled equipment could alternatively have a side or top exhaust of hot air. The equipment cooling air intake is generally in the front of the equipment. The equipment hot exhaust air is cooled by the heat exchanger and then the air is exhausted into the equipment enclosure. The equipment cooling air intake uses the ambient air in the enclosure.

[0054] As indicated above, reservoir 4 functions as a coolant reservoir in which coolant from main condenser 5 is pooled. A level transducer (not shown) may optionally be mounted in the reservoir and connected to a main or central

controller/processor for the enclosure or connected to a dedicated cooling controller/processor. The central or cooling controller/processor can issue alarms based on preset level and/or can inform other controller/processors of detected coolant levels.

[0055] In addition, a pressure transducer (not shown) may be mounted in the return manifold. The output of this transducer indicates the vapor pressure which in turn indicates the average heat that is being removed from all connected equipment. The transducer can be connected to a central TEECE controller/processor or connected to a cooling controller/processor. The controller/processor connected to the transducer can control electrically variable fluid valves to vary the flow of external fluid to the main loop condenser 4. In addition, the flow control can be direct flow control or bypass some of the individual equipment rack heat exchangers 2. This function can be part of an algorithm that controls the average internal temperature of the environmentally controlled equipment enclosure. The internal equipment enclosure temperature has a large effect on operating efficiency.

[0056] As shown in FIG. 2, the coolant may be arranged to flow through the ball valves of supply manifold couplers 9 to a filter/drier 11, which filters the coolant to prevent the heat exchanger and/or pump from clogging.

[0057] The heat exchanger-to-equipment interface 12 shown in FIG. 2 is not required to have a tight seal, but the heat exchanger module fan/blowers 10 should have a higher flow rate than the equipment exhaust flow rate. The fan/blowers can be variable speed, within limits, to increase efficiency by enabling the cooling controller/processor to control the fan speed based on an output signal from an air pressure transducer output signal mounted in front of the heat exchanger. The controller/processor should preferably maintain the pressure at zero or slightly negative so there will be no back pressure on the equipment internal cooling system.

[0058] For maximum efficiency the overall internal ambient air temperature of the equipment enclosure should be as high as possible that will not affect the performance or life of the equipment. Most industrial equipment is designed for operation in 40 degree centigrade ambient temperature. To accomplish this, the exhaust or internal temperature of the equipment may be monitored and the speed of each individual fan/blower 10 varied to keep the equipment temperature as high as possible but generally 10 degrees centigrade lower than the equipment rated operating temperature. If some equipment is not rated for the higher ambient temperature, special provision can be made for that piece of equipment, for example by providing a shroud/duct assembly (not shown) to route the exhaust air from the heat exchanger module fan/blowers to the front equipment air intake. By controlling the amount of heat removed by the exchanger, and the fan/blower speed, the recirculation of air through the shroud/duct assembly to the equipment cooling air intake can be made cooler than the ambient temperature of the equipment enclosure.

[0059] The internal temperature of the equipment enclosure may be too high for service personnel to comfortably work. To remedy this situation a human-machine interface (HMI) of the equipment enclosure may have a control to change the ambient temperature within the enclosure for a fixed length of time to allow for human comfort.

[0060] A Schrader valve 13, shown in FIG. 2, may be used in the installation or replacement of the heat exchanger to reclaim the coolant charge for reclamation in accordance with HVAC best practices.

[0061] b. Equipment Rack

[0062] As shown in FIG. 2, the cooling module 14 is arranged to mate with rack 1 at an interface 12 when the rack is moved from an extended position, shown in FIGS. 2 and 4, to an operating position shown in FIG. 3, in which the rack is mated with the cooling module. In the arrangement of FIG. 2, a single rack 1 and cooling module 14 are provided while in the arrangement of FIGS. 3 and 4, the cooling module 14 is divided into individually controllable units that may be stacked to provide increased flexibility in accommodating different equipment configuration within the racks. For example, the arrangement illustrated in FIGS. 3 and 4 may be configured to support 24 inch deep equipment mounted on the side of the rack. The number of cooling modules and internal arrangements of the racks may be varied in a number of ways without departing from the scope of the invention.

[0063] Electrical connections to the equipment in the racks are preferably provided by flexible harnesses 15 that permit movement of the racks. FIG. 2 shows three such harnesses, while FIGS. 3 and 4 show two harnesses. One or two of the harnesses may be used to supply power to the rack (different equipment might require different current types or voltages), while the additional harness or harnesses may be used for data connections to equipment in the rack and/or connections to temperature or environmental control elements in the rack. Of course, power connections may be distributed between harnesses, or arranged to share one or more harnesses with data/control/communications connections, depending on the requirements of the equipment to be included in the racks. The harnesses are connected to fixed power, data, or communications busway structure or structures extending along a length of the enclosure, which may, by way of example and not limitation, take the form of the busway disclosed in U.S. Pat. No. 7,819,676.

[0064] As shown in FIGS. 2-4, the rack 1 is mounted on a sled 17 to form an equipment rack module that is arranged to slide in and out on rails 18, which can be mounted anywhere on the enclosure floor along one side of the enclosure to allow for any size internal equipment module to be installed internally, without the need for cantilevering the module. A shock and vibration isolation system 19 (described in more detail below in connection with FIGS. 14-21) is situated between the sled 17 and the equipment to protect the equipment from seismic shock and/or vibration during shipping. A post lock mechanism 20 shown in FIGS. 14-21 allows the internal equipment sled to be locked in a normal operating position, as shown in FIG. 3, or locked in the extended position shown in FIGS. 2 and 4 for service. Being able to lock the equipment in the extended position also allows the center of gravity of the entire enclosure to be adjusted for transit. All of the components that make up a rail/sled system and the self-contained equipment cooling module 14 can be installed or replaced in the field on an as needed basis.

[0065] Each rack 1 may include shelves of any number and spacing, the ventilation grill or end panel 21 on an open end or side of the rack as shown in FIGS. 9 and 13, equipment access panels 22 that may be removably secured to the rack by screws or other fasteners, as shown in FIGS. 2-4, or by a squeezable latch arrangement 24 as shown in FIG. 5, and doors 23 on any number of configuration for closing off sections of the open end of the rack when not in use.

[0066] As shown in FIGS. 5-8, each rack may include power strips 26 mounted on brackets 27 that are secured to rear sides of the racks and connected to the wiring harnesses

at **15** at the top of the rack for distributing power and/or data/communications signals to individual shelves within the rack. Individual wires are passed from the harnesses **15** to the power strips **26** through an opening **16** in the rack top panel **16a** to which strips or slats **28** are secured, as shown in FIG. **11**, to form louvers of a “horse hair” slot and provide isolation for the interior of the panel by limiting airflow into the rack.

[0067] As shown in FIG. **12**, the horsehair cable entry structure may take the form of two vertical posts **29** and a separate panel **30** that includes the horsehair-type opening **31**, so that it may be provided on either the front or back of the rack to form an extender for the rack.

[0068] In addition, FIG. **12** shows a ground structure **32** that may be used to attach an electrostatic discharge strap worn by service personnel to ensure that the service personnel are grounded to prevent damage to equipment from static discharge.

[0069] Next, the shock absorption/sled locking structure will be described in connection with FIGS. **13-21**.

[0070] c. Rail/Sled Mounting Arrangement

[0071] FIGS. **13** and **14** are isometric views, respectively taken from the top and bottom, of a preferred embodiment of a sled **17** for movably supporting the equipment racks of FIGS. **2-12**. Sled **17** includes a chassis **41** connected to a corresponding rack by spring assemblies **43**. Each spring assembly includes upper and lower connection bars **44,45**, respectively fixed to the chassis and the rack so that the rack is isolated from the chassis **41** by the spring assemblies **43**. Each chassis includes wheels **46** for movably engaging rails **18** shown in FIG. **2** to permit movement of the sled **17** and rack **1** relative to the rails **18**.

[0072] As best seen in the bottom view of FIG. **14**, the chassis includes a bottom plate **45** that supports a locking mechanism made up of notched locking plates **48** at the front and rear of the chassis, each plate include a notch or recess **49**. Extending across the openings of notches or recess **49** are post locks in the form of pivotal latching members or jaws **50**, which are movable from a locking position in which they capture a locking post **42** that extends from the rail assembly, as shown in FIG. **2**, and a release position, in which they release the post **42** to permit movement of the sled. Jaws **50** are connected to a lever/cam arm **51**, which in turn is moved by a release/locking mechanism that includes slidable member **52** arranged to move forwards and backwards with respect to lever **51** to alternately engage opposites sides of the lever **51** to cause it to move jaws **50** between a capture and release position. An identical lock/release mechanism is preferably provided on the opposite end of the sled so that the sled can be release from either side, by pushing or pulling on a handle **53** extending from the slidable member **52**. It is noted that the jaws may be spring biased to a closed position so that latching can occur simply by pushing the rack into the operating and/or transport position. Slidable members **52** may be attached to mutually pivotal arms **54-56** secured to the plate **47** by a central pivot **57** so that movement of one of the handles **53** causes corresponding movement of both of the slidable members **52** to latch or release the sled.

[0073] The sled arrangement shown in FIGS. **15** and **16** is identical to that of FIGS. **13** and **14** except that three isolation springs and sets of wheels are provided rather than 2, in order to support the larger rack of FIGS. **3** and **4**. FIGS. **17-20** illustrate the manner in which sleds **17** cooperate with rails **18**. In addition to the front and rear latch positions, the carriage may be latched at an intermediate position by a pin **58**

that can be inserted into any or a plurality of openings **59, 59'** to secure the carriage at different intermediate positions to adjust the center of gravity of the equipment enclosure for transport, as shown in FIGS. **18-20**.

[0074] As shown in FIG. **21**, when the racks **1** are in an operating position, the rails in front of the racks are preferably covered by removable insulated floor tiles **60** to enable personnel to walk over the rails **18** and also to provide sound/vibration insulation during operation of the equipment. Also as shown in FIG. **21**, 120 VAC outlets **61** may be provided in the floor of the equipment enclosure in the aisles or spaces between the racks. These outlets are in addition to the electrical connections provided by the power distribution system discussed above, and enable additional equipment to be plugged-in, for example tools used by service or maintenance personnel.

[0075] The rails **18** may be arranged in a variety of ways. FIGS. **22** and **23** shows an exemplary arrangement in which the rails **18** are arranged so that pairs of sled/rack assemblies are separated by aisles **62** that permit access to the sides of the racks, and in which the above-mentioned 120 VAC outlets **61** are situated. As shown in FIG. **24**, the rails **18** are themselves shock absorbing mounts **63** to provide further isolation from external shocks/vibrations, particularly during transport.

[0076] FIGS. **25** and **26** show the top and bottom of the removable floor tiles **60** shown in FIG. **21**. The tiles **60** are secured by rotatable fasteners **66** extending from the underside of the floor tiles, which engage beams **67** of the rails **18** when rotated via slotted heads **68** accessible from the tops of the tiles **65**. As shown, the floor tiles **65** include reinforcing ribs **69**, although ribs **69** may of course be omitted or arranged in any desired fashion to provide sufficient strength/rigidity for the tiles.

[0077] Finally, FIG. **27** shows various sealing members **77,78** that may be situated between the rack and the coolant module in the preferred embodiments. These sealing members are secured by an adhesive to the cooling module or rack and maintain a loose seal between the cooling module and rack during operation of the rack to prevent excess loss of heat to the interior of the enclosure. It will be appreciated that these seals are exemplary in nature, and that any other suitable sealing arrangement, or no sealing arrangement at all, may be used in appropriate circumstances.

[0078] d. Insulating Panels

[0079] In order to maintain a desired temperature within the enclosure, it is necessary to provide appropriate insulation for the walls, floor, and ceiling of the enclosure. FIGS. **28** and **29** show insulating panels **70** that may be used for this purpose. These panels feature a unique double wall construction that combines insulated sections **73** and **75** for providing a radiant energy barrier and an air gap **74** extending between insulated sections **73** and **75** for providing a thermal barrier, so as to reduce weight and costs will providing both thermal and radiant insulation. As shown in FIG. **28**, panels **70** also include corrugations **72** and mounting features **76** for internal devices, which are conventional wall panel features that may be varied or omitted.

[0080] e. Additional Exterior Features

[0081] FIG. **30** is an isometric view showing the exterior of a transportable, environmentally controlled equipment enclosure (TECEE) **80** having various additional improvements relating to safety and efficiency.

[0082] Enclosure **80** is illustrated as having a cooling system that differs from that shown in FIG. **1**, in that includes a

primary heat exchanger **81** and a secondary heat exchanger **82** rather than a single condenser and a reservoir corresponding to those shown in FIG. **1**, but it will be appreciated that the cooling system of FIG. **1** may also be used in the enclosure of this embodiment, if necessary by moving the power connectors **83** to accommodate the higher location of the condenser, and that additional features shown in FIG. **30** are not limited by the nature of the cooling system illustrated in FIG. **30**. However, if a cooling arrangement including a primary and secondary heat exchanger of the type illustrated in FIG. **30** is used, then distributed pumps (not shown) may be added to assist in circulating the coolant through the individual racks, although the inclined manifolds may still be used to eliminate the need for a central pump and expansion valves. Further details of this type of alternative cooling system are also shown in FIG. **35**.

[0083] It will be noted by those skilled in the art that, while the heat exchangers **81,82** shown in FIG. **30** are shown as being exposed to the exterior of the enclosure, the heat exchangers (and/or other condenser(s) if the cooling arrangement of FIG. **1** is used) do not necessarily require opening directly to the exterior of the enclosure, but instead may exchange heat exclusively with fluid connections (not shown) to external coolant sources. Whichever cooling arrangement is used, the cooling system elements, as well as power connectors and other features, will generally be provided on only one end of the enclosure, while sensors, alarms, and the like may be provided at both ends.

[0084] Generally, an enclosure **80** of the type shown in FIG. **30** will be less than 12 feet wide and 90 feet long in order to enable transport over public highways, although those skilled in the art will appreciate that the enclosure can be manufactured to any size that can be transported and that in certain circumstances larger enclosures may be possible. Enclosure **80** is illustrated as having a rectangular foot print and rectangular vertical cross section, but the enclosure can be manufactured to have any shape required.

[0085] As illustrated in FIG. **30**, enclosure **80** includes one entry/exit access or door **84**, although two doors may be substituted as illustrated in FIG. **31** in order to provide separate access to the racks when the racks are respectively in the operating position (door **84'**) and in the withdrawn position (door **84''**). In either case, the doors **84, 84', 84''** are preferably associated with an air barrier system to prevent entry of outside contaminants and maintain internal environmental conditions within the container while permitting entry and exit of service or operating personnel as necessary. The air barrier system may take the form of an air blower (not shown) mounted above the entry access that directs air downward to act as an air barrier to reduce the amount of humidity, dust, and other contaminants that might enter the enclosure when the entry access is opened. Each entry/exit access door is preferably double sealed with high thermal insulation qualities.

[0086] Also, as illustrated in FIG. **30**, enclosure **80** further includes wireless communications antennas **85** that connect to one or more transceivers within the enclosure, and a wire/fiber communications access port **86** that provides a sealed passage for communications cables. Redundant antennas **85** are used for RF communications and are contained in tamper proof fiber glass or similar material.

[0087] Preferably, any wire, fiber, and/or wireless communications include redundant communication links that enable verification of proper operation. For example, during opera-

tion of equipment in the enclosure, the RF communication antennas **85** may issue communication integrity signals at specified time intervals, which can be compared to verify redundancy and ensure that the communication links are intact.

[0088] The wire/fiber communication access port **86** provides a connection point for wire cabling or fiber for network communication or other forms of wire/fiber communications. The wire connection can be used to relay contacts or solid state switches that can be programmed to activate based on user preset alarms. Like the RF antennas, the wire/fiber communications links can issue communication integrity signals at specified time intervals to ensure the communication links are intact.

[0089] An emergency horn and strobe **87** is provided to alert personnel outside the container of system failures or hazardous conditions within the container, and to indicate whether it is unsafe for humans to go inside. Detectors include, but are not limited to, smoke, cooling leak, and fire detectors (including incipient detectors), as well as oxygen deficiency and other life support detectors, any of which will cause the emergency horn and light to operate when the internal enclosure environment is unsafe for humans.

[0090] The exterior of enclosure **80** also may include a ventilation system opening **88**, and the above-mentioned input power terminals or connectors **89**. Ventilation system opening **88** may be part of an energy recovery ventilation (ERV) system and/or a heat recovery ventilator (HRV) in the enclosure front, which provide an energy recovery process of exchanging the energy contained in normally exhausted enclosure or space air and using it to treat the incoming outdoor ventilation air. The benefit of using a recovery system is the ability to improve indoor air quality and assist in the enclosure cooling capacity. The ERV system can be a honeycomb type device or total enthalpy device such as a rotary enthalpy wheel system or fixed plate system. An ERV system is a type of air-to-air heat exchanger that can transfer sensible heat and latent heat. The make-up air system uses a negative pressure louver system with a standard AC or DC current fans/blowers to pull in fresh air via a filter that can be via simple low-MERV pleated media, a HEPA filter, an electrostatic filter, a cyclonic separator or a combination of techniques. The ERV/HRV/filter system along with a bypass system can increase the efficiency of enclosure cooling when the outside air temperature is cooler than the inside temperature of the enclosure since the infusion of cool outside air requires less cool air output from the equipment module heat exchanger. A differential temperature sensor with motorized valves may be used to control this function.

[0091] In addition to or instead of the above-described double-walled insulating panels shown in FIGS. **27** and **28**, the enclosure **80** can be bulletproofed by using Kevlar plated enclosure walls for military applications or high security installations, and/or provided with an exterior polyurea coating to prevent rusting, vibration, and noise etc. The polyurea coating can block up to 95% of heat transfer and up to 80% of sound transfer, and can increase resistance to moisture, mold and mildew. If used, it should have a class "A" fire rating with zero flame spread and smoke production.

[0092] Solar load can be a significant source of heat, so mounting surfaces (not shown) for sun shade canopies or solar shields may be provided.

[0093] In addition to or instead of the shock and vibration isolation provided by the preferred rack supporting structure

described above, the enclosure **80** may include outside locations (not shown) for seismic tie downs and mounting surfaces (also not shown) for seismic isolation pads if required.

[0094] In the illustrated embodiment, the limited outside openings prevent EMI leaks. In addition, the entry access panels have EMI gaskets to prevent EMI leakage when closed. Furthermore, the entire enclosure **80** can have electromagnetic shielding to lower magnetic fields by at least 1.25 u Tesla. To this end, the interior and exterior skin must be grounded for EMI protection, for example by providing four bolts, one in each corner, for connection to ground rods and/or other grounding points. The bolts may extend from the inside metal skin of the enclosure **80**, though the enclosure body, with a threaded section extending through the bottom and the outside skin, the bolt head being welded to the inside skin, and the shaft being welded to the outside skin. Preferably, all four points of the enclosure should be grounded for electric shock safety and for EMI shielding.

[0095] f. Security Features

[0096] A transportable, environmentally controlled equipment enclosure of the type illustrated herein may include the following additional security features:

[0097] Indoor and outdoor video surveillance;

[0098] Internal panoramic motion detectors;

[0099] External motion detection, for example utilizing cameras;

[0100] Entry/egress open alarms

[0101] Entry/egress controlling biometric security scanners, for eye/face or fingerprint recognition/identification, and the like;

[0102] Entry/egress card readers.

[0103] The enclosure may thus include mounting surfaces for cameras and/or motion detectors to monitor the entry/exit access points. If connected to the data collection and management system, the motion detectors can generate alarms when movement is "seen".

[0104] The entry access points may have magnetic triggers connected to the data collection system to alarm and time/date a detected entry/exit event and reference the location of entry point accessed. In addition, the data collection and management system can trigger any associated cameras to start recording upon detecting an entry/exit event.

[0105] g. Equipment Layouts/Floor Plans

[0106] FIGS. **32-34** are top views of the equipment enclosure **80** of FIG. **30**, showing site views. The enclosure **80** can be used as a single unit as shown in FIGS. **32** and **33**, or two or more units can be used in an array of units, as shown in FIG. **34**. Because no side access is necessary for installation or maintenance, access to the normal enclosure **1** can be limited to ends of the enclosure, which allows enclosures to be stacked side by side, as shown in FIG. **34**, as well as in other site configurations such as on top of each other, allowing total equipment density per square foot to be improved. On the other hand, it is also possible to include side access to any of the enclosures.

[0107] When using multiple enclosure units, the cooling and power systems in each unit may be entirely independent of each other, and communication between the units may be provided by any of a wire/fiber or wireless communication link, and by single ended or redundant connections. This independence allows the units to be placed on different site elevations. Each of the illustrated enclosures can be a "module" in a redundant system i.e., the equipment in each unit is performing to same function. If there is a general problem,

like a fire or disaster in one redundant module, the complete enclosure can be "hot swapped" with another similar enclosure.

[0108] The normal internal configuration of enclosure **80** contains only equipment modules or equipment racks, and associated components, but the equipment modules or racks can be arranged in numerous different ways, including the following examples:

[0109] As shown in FIG. **32**, enclosure **80** houses equipment **90**, and a battery room **91** for a plurality of battery cells. The battery room is sealed from the equipment area by walls **92** for the safety of the maintenance personnel and for the protection of the equipment. The battery in this configuration may be serviced via external access points **93**. In addition, the battery room requires filtered ventilation, and must meet the temperature and humidity requirements of the battery specification. The battery can supply central back-up power for equipment operating on DC power, and the room can also contain a charger.

[0110] FIG. **33** shows an example of an enclosure **80** which has been modified to serve as a supplemental power enclosure. The supplemental enclosure can contain, by way of example and not limitation, an electric set **94**; an automatic transfer switch (ATS) **95**; a UPS **96** and battery **97**; and an AC to DC converter **98** for DC power requirements. The electric set **94** can be, for example, a diesel electric set (DES) fitted with a generator/alternator, a turbine electric set (TES) fitted with a generator/alternator, or some other type of electric set. Vent doors **99** automatically open when the electric set starts or requires outside air, while service openings **93** are preferably closed in normal operation.

[0111] A secondary radiator (not shown) can be mounted in front of the electric set **94** so that the cooling air for the electric set will also flow through the secondary radiator. The secondary radiator and a pump can supply coolant to heat exchangers located in the equipment-containing enclosures. This is necessary because when power is lost, the water to the heat exchanger will probably be lost also.

[0112] Preferably, a UPS is used to bridge the power gap between the occurrence of a power outage and the time it takes for a graceful shutdown of the equipment and/or the time it takes for the electric set to start supplying power. The internally sealed room **97** can contain a battery for the UPS. The battery, a flywheel, super capacitors or other energy storage component can be used with the UPS to supply energy for the power gap.

[0113] Alternatively, it might be possible to reduce the need for the UPS and associated batteries if lightning detectors are included to warn of possible power outages. The lightning detectors would be coupled to a controller and/or automatic transfer switch **95**, which in turn would be used to start the electric set **94**, parallel the electric set with a utility, and then drop utility power, thereby transferring the load to electric set power without a power interruption before a possible power outage caused by lightning or a lightning storm. Lightning detectors can detect lightning or storms that have accompanying lightning up to 15 miles away. Depending on the mission of the equipment enclosures, the UPS and associated batteries may not be needed if lightning detectors, an auto-start, and auto cycle-on-line system are implemented, since it is believed that 50% to 92% of power outages are the direct or indirect effect of lighting or storms that have accompanying lightning.

[0114] FIG. 35 shows a normal arrangement of equipment models and racks within an equipment enclosure 80 of the type shown in FIG. 30. The number of equipment modules or equipment racks contained in the enclosure 1 is determined by the size of the equipment modules/racks and the size of the enclosure. A typical enclosure will contain small equipment modules 103 and/or larger equipment modules 104, the cooling system (not shown in FIG. 33), a power system (not shown), environmental systems (not shown), and a data collection and human-machine interface (HMI) system. The normal operating position of the equipment modules is illustrated by items 103 and 104. The equipment module 107 is shown in the extended position for service or for changing the equipment enclosure center of gravity for transport.

[0115] FIG. 35 shows the two power terminals or connectors 83 of FIG. 30, but up to six or more can be provided. One or more transformers or transformer modules can be mounted in the enclosure 1 to transform the input voltage to the voltages or voltage configurations used by the equipment, for example at a location 105 close to the input power terminals or connectors 83. A static switch module may optionally be located at location 106, close to the input power terminals or connectors 83, or the transformer modules. Power strips 26, if required, would be mounted on the outside of the equipment module or equipment racks as illustrated above, staying in the "cold aisle" for improved life performance, as opposed to being mounted in hot plenums.

[0116] Power from the input power terminals or connectors 83, and/or power from output(s) of the transformer module(s) and/or the static switch, is distributed to the equipment modules via wire cabling or by busways with drop boxes or tap-off boxes to supply power the equipment. A suitable busway is described in U.S. Pat. No. 7,819,676, although other busway systems may be substituted. If a busway is used it must allow the power drops to be mounted anywhere along its length since the equipment can be located anywhere along a length of the equipment enclosure. The continuous power distribution system described in U.S. Pat. No. 7,819,676, for example, installs an overhead or wall-mounted busway with a continuous slot to plug in the power drop. Since the equipment density is high, a cable management system may be used to allow each piece of equipment, rack, or module to be moved to the service position for maintenance.

[0117] FIG. 36 shows the main externally cooled heat exchanger 81; a receiver 110; the secondary-heat exchanger 82; a return manifold 111 a supply manifold 112; and a coolant reservoir 113 of the alternative cooling system shown in FIG. 30. In addition, FIG. 34 shows a panel 114 that contains a management system controller/processor(s).

[0118] The management system included in controller panel 114 controls all system and functions of the equipment enclosure. The management system can be one central controller/processor or distributed controller/processes supervised by a smaller central controller/processor or a combination of both arrangements. For mission critical applications, the controller/processes may be dual redundant or tri-redundant with voting.

[0119] A human-machine interface (HMI) included in a panel 115 of the illustrated enclosure displays all collected data and allows manual control of certain management functions within the enclosure, as explained in more detail below. A three-axis (XYZ) cable management system allows equipment modules to remain connected while being extended and rotated while extended, if necessary, for service. The XYZ

arrangement gives the cable management system the ability to route cables in all three axes.

[0120] Also shown in FIG. 35 is a fire package that includes the human-machine interface panel 115, distributed detectors 116 (including incipient detectors), a suppression system including a tank 117 for storing a fire suppression agent, and alarm functions. Each equipment module can have internal fire detectors. The fire suppressant system can be activated automatically or manually via the human-machine interface panel 115. Preferably, flame and smoke detectors are distributed throughout the equipment modules. The detectors are preferably parallel connected by wire/fiber or wireless methods to the controller in the panel 114 for redundancy.

[0121] Upon detection of flame or smoke the controller issues an alarm internally and externally and releases the stored fire control suppressant from tank 117. An alarm signal can also be issued over the communications links to the outside world including the local fire departments. The suppressant agent can be any type of wet, dry or gaseous agents, but a gaseous agent such as carbon dioxide, Halon, Novec, or FE-13 is preferred for electrical equipment.

[0122] Since systems using certain agents in enclosed spaces present a risk of suffocation to humans, a warning alarm precedes the agent release. The warning is an audible and a visible alert, advising the immediate evacuation of the enclosed space. After a preset time, the agent is discharged.

[0123] In addition, the fire detection/suppression system preferably has a battery back-up since the fire can cause power shut down, and the controller can also be programmed to remove power as necessary. Finally, the controller/processes for the fire detection/suppression system can be redundant and independent of other functions.

[0124] Although not shown, the human-machine interface panel 115 may include its own rechargeable power supply and mounted on wheels or slides so that the panel can be moved across the length of the enclosure 80 and used as a trouble shooting device for the equipment electronics.

[0125] During transit, the enclosure can be equipped with GPS, and in particular a battery-operated GPS logger that logs the position of the enclosure at regular intervals in its internal memory during transit. This allows downloading of the track log data when requested or the data can be automatically downloaded at preset intervals. The transmit/receive function can be by mobile phone, cell phone or satellite phone techniques or any satellite messenger.

[0126] h. Power Distribution System

[0127] As described above, power from a utility or from a supplemental power enclosure of the type shown in FIG. 32 enters the equipment enclosure via input power terminals or connectors 83. The equipment contained in the enclosure may require several voltage levels and/or several voltage configurations including several DC voltage levels. Each input power terminal or connector 83 can be configured for a single phase with ground, two phases with or without neutral and with ground, or three phases, wye or delta, with ground. The terminals 83 are connected, by way of example and not limitation, to a Continuous Bus Power Distribution System (CBusPDS) of the type disclosed in U.S. Pat. No. 7,819,676, incorporated herein by reference, which can provide power at any point along its length to the load equipment via a plug-in power tap. The CBusPDS consists of two main components: a power track housing assembly with current carrying and a plug-in power tap. The CBusPDS power track housing assembly has a continuous slot so that the plug-in power taps

can be placed anywhere along the housing length. There can be one or more power track housing assemblies placed along the length of the enclosure to supply one or more voltages to the equipment. The voltages can be AC or DC, single ended or redundant.

[0128] Each plug-in power tap assembly can contain circuit breakers or other protective devices, and/or other sub-modules such as, but not limited to, power monitoring circuits, DC power supplies, transformers, voltage inverters/converters or frequency inverters/converters. One or more plug-in power taps can be placed close to the equipment requiring power. Input power to the equipment may utilize single ended or redundant feeds. Redundant feeds can be available from the input power terminals or connectors or can be generated by an internal transformers or static transfer switches.

[0129] i. Operation of Site Management System

[0130] The preferred site management system can be used to control the overall efficiency of the enclosure by calculating a variable known as Power Usage Effectiveness (PUE) and varying certain parameters to maximize PUE. PUE is a measure of how efficiently an equipment site uses power; specifically, how much of the power is actually used by the equipment in contrast to cooling and other overhead. For an equipment enclosure, PUE is the ratio of the total amount of input power to the enclosure divided by the power used by the equipment. The management system determines the total input power and the power used by each piece of equipment for local and remote data display and logging, and uses the data to calculate the PUE.

[0131] The management system can maximize the PUE by varying the following parameters:

[0132] the amount of outside air flow, if the outside air temperature is less than the internal ambient temperature of the equipment enclosure;

[0133] the internal ambient temperature of the enclosure;

[0134] equipment cooling module adjustable pump speed and/or adjustable pump displacement, if a pump is provided (the preferred cooling of FIG. 1 does not include any pumps); and/or

[0135] the equipment cooling module adjustable fan/blower.

[0136] PUE optimization by the controller/processor allows the enclosure to run at maximum efficiency even as the equipment load and outside solar and ambient temperature varies.

[0137] The controller/processor may also control operation of the ventilation system, make up air and humidifying systems and other environmental parameters. Two or more detectors may be used to monitor the environmental parameters distributed throughout the enclosure, and are connected by wire/fiber or wireless methods to the controller located in controller panel 114. The wire/fiber connected detectors are preferably parallel connected to the panel for redundancy.

[0138] The average ambient air temperature within the enclosure is determined by the volume and temperature of the air exhausted from the heat exchangers on each piece of the equipment. Normally the equipment temperature controller regulates the coolant pump flow and the heat exchanger fan air flow in each piece of equipment to run the equipment as hot as possible for high cooling efficiency but within safe operating temperatures. Since the average internal operating temperature is not regulated, it may be too hot for human comfort levels. There is a provision to lower the internal

temperature to a preset level when service is to be performed. This is accomplished via a communications link to the equipment temperature controller.

[0139] Relative humidity and dew point are preferably also monitored and decisions to turn on the humidifier or the dehumidifier performed by the environmental parameters controller located in panel 114. The humidifier can be any type such as vapor type or a dry fog type. The preferred type is a compressed air, dry fog humidifier that is externally mounted with the nozzle pointing into the container. No air input is necessary to the unit, only a potable water connection. A dehumidifier 120 shown in FIG. 36 is controlled by the environmental parameter controller to control the humidity thus managing the equipment cooler condensate.

[0140] In general, the controller(s) included in panel 114 acquires data through an enclosure Data Collection System (DCS) that can continuously monitor/meter all properties of the enclosure and equipment in the enclosure. The monitoring or metering will include, for example, environmental parameters (temperature, humidity, oxygen, etc) and/or power parameters (voltage, current, power factor, frequency, KW, KVA etc) and/or power quality parameters (harmonic and/or waveform distortion, harmonic signature, peak power, tending etc) and/or physical parameters (heat exchanger parameters; fluid/air flow; fluid levels; fluid temperature, etc) and/or system (safety systems; fire system; security, ventilation systems). The DCS system collects data, conditions the data, displays the data, and/or transmits the data to other controller/processors or to other remote locations.

[0141] The modular data collection system of the preferred equipment enclosure may contain modules made up of some or all of the following analog and/or digital circuit elements:

[0142] sensors and other stand-alone components for continuous detection of monitored systems such as video from a camera, outputs from biometric components such as finger prints, scanners, card readers, ventilation system parameters;

[0143] signal conditioning circuits for sensor outputs that continuously detect power parameters such as voltage, current, frequency, etc.;

[0144] signal conditioning circuits for sensor outputs continuously detect environmental parameters such as temperature, humidity, oxygen level sensor and/or other such sensor outputs;

[0145] signal conditioning circuits for Sensor outputs that continuously detect parameters such as fluid/air flow; fluid levels, etc.;

[0146] circuits for generating power quality, parameter analysis such as harmonic and/or waveform distortion, harmonic signature, peak power, KW, KVA, power factor, tending, etc.;

[0147] non-volatile memory containing correction tables/equations for components and modules to correct/compensate for bandwidth, linearity, slew rate, phase shift, signal/noise ratio, temperature, altitude, etc. for each sensor/circuit;

[0148] non-volatile memory containing parameter tables (serial number, ID, scale factor, model etc) for sensor/modules;

[0149] analog-to-digital converter if the sensor output is analog and digital processing is required;

[0150] analog circuits if analog processing is used;

[0151] majority voting circuits if N-redundancy is used;

[0152] combining circuits for redundancy;

- [0153] data accumulator or collection circuits;
- [0154] data processing, analog or digital, and associated circuits;
- [0155] communication circuits and/or network drivers;
- [0156] display drivers if required;
- [0157] time-coherent signal generators, receivers and/or repeaters and/or bus(s);
- [0158] data storage;
- [0159] application drivers for spreadsheets and/or other applications;
- [0160] data logging; and/or
- [0161] other circuits as required.

[0162] Having thus described a preferred embodiment of the invention and variations of the preferred embodiment in sufficient detail to enable those skilled in the art to make and use the invention, it will nevertheless be appreciated that numerous variations and modifications of the illustrated embodiment may be made without departing from the spirit of the invention. Accordingly, it is intended that the invention not be limited by the above description or accompanying drawings, but that it be defined solely in accordance with the appended claims.

What is claimed is:

1. A high efficiency cooling system for an environmentally controlled equipment enclosure, using a low boiling point liquid/vapor coolant that does not require a main loop pump, distributed rack pumps, or expansion valves, comprising:

- a main loop condenser used to transfer heat from the coolant and cause said coolant to change from a coolant vapor to a coolant liquid;
- a return manifold that channels said coolant vapor from respective equipment rack heat exchangers to the main loop condenser;
- a supply manifold that supplies said coolant liquid to said equipment rack heat exchangers; and
- a coolant reservoir where said coolant liquid from the main condenser is pooled to supply sufficient coolant to the supply manifold to flood the supply manifold and said equipment rack heat exchangers, thereby eliminating the need for distributed pumps.

2. A cooling system as claimed in claim 1, wherein the equipment enclosure is a transportable environmentally controlled equipment enclosure (TECEE).

3. A cooling system as claimed in claim 1, wherein the main loop condenser transfers heat to a fluid supplied by a source outside said equipment enclosure.

4. A cooling system as claimed in claim 3, further comprising ball valves that allow the equipment heat exchangers to be disconnected or reconnected to the manifolds for service or installation.

5. A cooling system as claimed in claim 1, wherein the return manifold is slanted toward the main loop heat exchanger and the supply manifold is slanted toward the equipment heat exchanger, whereby slanting of the return and supply manifolds provides a gravity assisted coolant flow design, requiring no main loop pump.

6. A cooling system as claimed in claim 1, wherein both the supply and return manifold have multiple ball valves along the manifold length, wherein said equipment rack heat exchangers are fixed with respect to said supply and return manifolds, and wherein the equipment to be cooled is mounted in equipment racks movable on rails placed so the equipment racks line up with the equipment heat exchangers when the equipment racks are moved along said rails from a

transport/service position away from said equipment heat exchangers to an operating position adjacent said equipment heat exchangers.

7. A cooling system as claimed in claim 1, wherein the respective heat exchangers for each equipment rack are mounted in the rear of the equipment, and fans/blowers are provided to pull hot air exhausted from the equipment through the heat exchangers so as to transfer heat from the hot air to the coolant in the heat exchangers and then exhaust the cooler air into the inside of the equipment enclosure.

8. A cooling system as claimed in claim 7, wherein the heat exchanger module fan/blowers have a higher flow rate than the equipment exhaust flow rate, and wherein a cooling controller or processor controls the fan speed based on an air pressure transducer output signal.

9. An equipment enclosure, comprising:

- a plurality of equipment cooling modules;
- a plurality of equipment racks mounted on sleds for movement between an operating position adjacent respective said cooling modules and a transport/service position away from said cooling modules;
- a main loop condenser used to transfer heat from a coolant and cause said coolant to change from a coolant vapor to a coolant liquid;
- a return manifold that channels said coolant vapor from respective equipment cooling modules to the main loop condenser, the return manifold being slanted for gravity flow to the main loop condenser;
- a supply manifold that supplies said coolant liquid to said equipment cooling modules, the supply manifold also being slanted for gravity flow to the equipment heat exchangers; and
- a coolant reservoir where said coolant liquid from the main condenser is pooled to supply sufficient coolant to the supply manifold to flood the supply manifold and said equipment cooling modules, thereby eliminating the need for distributed pumps.

10. An equipment enclosure as claimed in claim 9, wherein the main loop condenser transfers heat to a fluid supplied by a source outside said equipment enclosure.

11. An equipment enclosure as claimed in claim 9, further comprising ball valves that allow the equipment heat exchangers to be disconnected or reconnected to the manifolds for service or installation.

12. An equipment enclosure as claimed in claim 9, wherein the return manifold is slanted toward the main loop heat exchanger and the supply manifold is slanted toward the equipment heat exchanger, whereby slanting of the return and supply manifolds provides a gravity assisted coolant flow design, requiring no main loop pump.

13. An equipment enclosure as claimed in claim 1, wherein the respective heat exchangers for each equipment rack are mounted in the rear of the equipment, and fans/blowers are provided to pull hot air exhausted from the equipment through the heat exchangers so as to transfer heat from the hot air to the coolant in the heat exchangers and then exhaust the cooler air into the inside of the equipment enclosure.

14. An equipment enclosure as claimed in claim 13, wherein the heat exchanger module fan/blowers have a higher flow rate than the equipment exhaust flow rate, and wherein a cooling controller or processor controls the fan speed based on an air pressure transducer output signal.

15. A transportable environmentally controlled equipment enclosure (TECEE), comprising:

a plurality of equipment cooling modules;
a plurality of sets of rails fixed in said equipment enclosure;
and

a plurality of equipment racks mounted on sleds for movement along respective said rails between an operating position adjacent respective said cooling modules and at least two different transport/service positions away from said cooling modules, thereby enabling a center of gravity of said equipment enclosure to be adjusted by securing said racks at different positions during transport.

16. An equipment enclosure as claimed in claim **15**, further comprising multiple position-establishing openings for each said equipment rack, said multiple position-establishing openings being included in one or more members fixed to said equipment enclosure, and plungers mounted to said sleds and engageable in said openings to latch said sleds in said different transport/service positions.

17. An equipment enclosure as claimed in claim **16**, further comprising a post-capture arrangement at each end of respective said sleds, said post-capture arrangement including jaws that are movable to capture posts extending from a floor of said equipment enclosure to lock said sled in said operating position and a service position away from both said operating position and said different service/transport positions.

18. An equipment enclosure as claimed in claim **17**, wherein said jaws at each end of respective said sleds are moved by a slidable member operated by a handle to release a captured post.

19. An equipment enclosure as claimed in claim **18**, wherein slidable members at each end of a respective one of said sleds are linked by a plurality of first pivot arms and a central pivot arm pivotally attached to the respective sled.

20. An equipment enclosure as claimed in claim **15**, wherein said equipment racks are mounted to said sleds by isolation springs having ends fixed to said sleds, said springs also being fixed to rack attachment members movable relative to said sleds such that said racks are isolated from said sleds by said spring.

21. An equipment enclosure as claimed in claim **15**, wherein said rails are mounted on shock absorbing members.

22. An equipment enclosure as claimed in claim **15**, wherein when a respective said equipment rack is in said operating position, a floor tile is positioned in a space that is not occupied by said equipment rack to cover said rails and provide a path for service personnel.

23. An equipment enclosure as claimed in claim **22**, wherein said floor tile is suspended from and secured to said rails.

24. An equipment enclosure as claimed in claim **23**, wherein said floor tiles include latches operated from above said tiles for releasably securing said floor tiles to said rails.

25. An equipment enclosure as claimed in claim **15**, wherein said equipment racks are arranged in pairs, said pairs being spaced to form aisles between said pairs.

26. An equipment enclosure as claimed in claim **25**, wherein auxiliary power outlets are situated in said aisles.

27. An equipment enclosure as claimed in claim **15**, wherein equipment in said equipment racks is supplied with power through at least one busway extending along said equipment enclosure.

28. An equipment enclosure as claimed in claim **27**, wherein respective said equipment is connected to said busway by at least one flexible harness containing wires or

cables that extend into a respective said rack through a horsehair opening and at least one power strip extending along a side of said rack.

29. An equipment enclosure as claimed in claim **28**, wherein said horsehair opening is included in a rack extension panel that extends from a front or rear of said rack to form an add-on module that increases a size of said rack.

30. An equipment enclosure as claimed in claim **15**, wherein each said rack includes at least one grounding structure electrically connected to ground and arranged to receive a static discharge strap worn by a service person.

31. An equipment enclosure as claimed in claim **15**, wherein each said rack includes removable side panels for accessing equipment from a side of the rack.

32. An equipment enclosure as claimed in claim **31**, wherein each said rack further includes doors on an end of said rack opposite an end that faces a respective said cooling module.

33. An equipment enclosure as claimed in claim **15**, wherein said equipment enclosure is insulated by panels having a double wall construction with an air gap between walls of the panels.

34. An equipment enclosure as claimed in claim **15**, wherein said equipment enclosure includes two doors at one end, including a first door permitting access to a cool aisle away from said cooling modules, and a second door permitting access to a hot aisle adjacent said cooling modules.

35. An equipment enclosure as claimed in claim **15**, further comprising an air barrier system for preventing entry of outside contaminants through at least one access door of said enclosure.

36. An equipment enclosure as claimed in claim **15**, further comprising a ventilation system for maintaining a predetermined temperature within said enclosure.

37. An equipment enclosure as claimed in claim **15**, further comprising detectors for detecting hazardous conditions within said enclosure, and for warning personnel not to enter.

38. An equipment enclosure as claimed in claim **37**, wherein said detectors include a lighting detector arranged to shut down power and/or provide warnings when lighting is detected.

39. An equipment enclosure as claimed in claim **38**, wherein said lighting detector is connected to an automatic transfer switch used to start an electric set, parallel the electric set with a utility, and drop utility power, thereby transferring power to the electric set in case lighting, and therefore potential power outages, is detected.

40. An equipment enclosure as claimed in claim **15**, further comprising redundant communications links to outside said enclosure, said redundant communications links including a pair of wireless antennas extending from said enclosure and at least one cable input port.

41. An equipment enclosure, comprising:

a plurality of equipment cooling modules;

a plurality of equipment racks mounted on sleds for movement between an operating position adjacent respective said cooling modules and a transport/service position away from said cooling modules;

a plurality of position-establishing openings for each said equipment rack, said multiple position-establishing

openings being included in one or more members fixed to said equipment enclosure, and

plungers mounted to said sleds and engageable in said openings to latch said sleds in said different positions.

42. An equipment enclosure as claimed in claim **41**, further comprising a post-capture arrangement at each end of respective said sleds, said post-capture arrangement including jaws that are movable to capture posts extending from a floor of said equipment enclosure to lock said sled in said operating position and a service position away from both said operating position and said different service/transport positions.

43. An equipment enclosure as claimed in claim **42**, wherein said jaws at each of end of respective said sleds are moved by a slidable member operated by a handle to release a captured post.

44. An equipment enclosure as claimed in claim **41**, wherein slidable members at each end of a respective one of said sleds are linked by a plurality of first pivot arms and a central pivot arm pivotally attached to the respective sled.

45. An equipment enclosure, comprising:
a plurality of equipment cooling modules; and
a plurality of equipment racks mounted on sleds for movement between an operating position adjacent respective said cooling modules and a transport/service position away from said cooling modules,

wherein said equipment racks are mounted to said sleds by isolation springs having ends fixed to said sleds, said springs also being fixed to rack attachment members movable relative to said sleds such that said racks are isolated from said sleds by said spring.

46. An equipment enclosure, comprising:
a plurality of equipment cooling modules; and
a plurality of equipment racks mounted on sleds for movement along rails between an operating position adjacent respective said cooling modules and a transport/service position away from said cooling modules,

wherein when a respective said equipment rack is in said operating position, a floor tile is positioned in a space that is not occupied by said equipment rack to cover said rails and provide a path for service personnel.

47. An equipment enclosure as claimed in claim **46**, wherein said floor tile is suspended from and secured to said rails.

48. An equipment enclosure as claimed in claim **47**, wherein said floor tile includes latches operated from above said tiles for releasably securing said floor tile to said rails.

49. Panels for walls of an environmentally controlled equipment enclosure, comprising a pair of insulated walls that each serves as a radiant energy barrier separated by an air gap between said insulated walls to serve as a thermal barrier.

50. An environmentally controlled equipment enclosure, comprising:

a plurality of equipment racks; and
a lighting detector arranged to shut down power and/or provide warnings when lighting is detected,

wherein said lighting detector is connected to an automatic transfer switch used to start an electric set, parallel the electric set with a utility, and drop utility power, thereby transferring power to the electric set in case lighting, and therefore potential power outages, is detected.

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