

(51) International Patent Classification:
F28F 7/00 (2006.01)

(21) International Application Number:

PCT/US2013/034171

(22) International Filing Date:

27 March 2013 (27.03.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/616,257	27 March 2012 (27.03.2012)	US
61/622,262	10 April 2012 (10.04.2012)	US
61/799,711	15 March 2013 (15.03.2013)	US

(71) Applicant: **LDM PRODUCTS, INC.** [US/US]; 228 West 12300 South, Denali Bldg. 108, 109, Draper, UT 84020 (US).(72) Inventors: **MAINERS, Larry, D.**; 11892 September Cove, Sandy, UT 84092 (US). **LAKE, Vincent, M.**; 127 Steep Mountain Dr., Draper, UT 84020 (US). **MCKENRICK, Charles, D.**; 1127 Denver Street, Salt Lake City, UT 84111 (US). **LAKE, Zachary, B.**; 14851 Ox Cart Ln., Draper, UT 84020 (US). **LAKE, Richard, W.**; 10928 S. Langford, Apt. 3093, South Jordan, UT 84095 (US). **SAVOLD, Nicholas, R.**; 44 Birch Hill Lane, Draper, UT 84020 (US).(74) Agents: **REED, Carl, T.** et al.; Workman Nydegger, 60 East South Temple, Suite 1000, Salt Lake City, UT 84111 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: MONITORING AND CONTROLLING DATA CENTER COMPONENTS

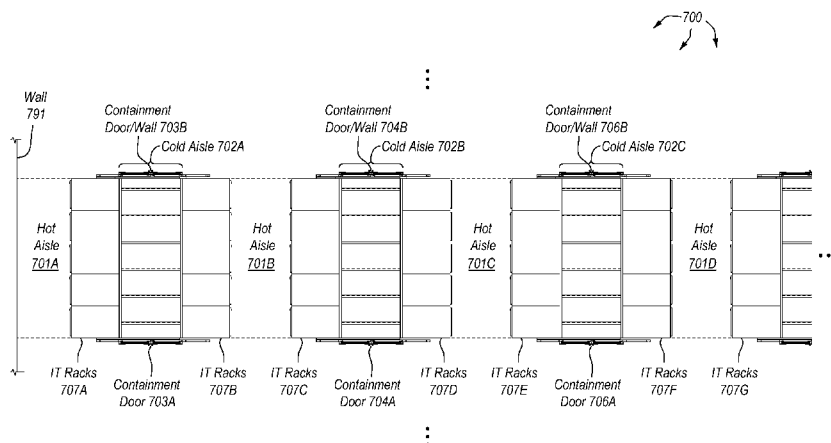


FIG. 7

(57) Abstract: A containment system is provided to access, monitor and control a containment area in a facility. A computing device can be associated with the containment system in order to control the containment area and/or devices inside the containment area without having to break the containment of the containment area. Hot areas can be kept separated from cold areas and efficiency of the facility is improved.

MONITORING AND CONTROLLING DATA CENTER COMPONENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/616,257 filed March 27, 2012, this application claims the benefit of U.S. Provisional Application Serial No. 61/622,262 filed April 10, 2012, and this application claims the benefit of U.S. Provisional Application Serial No. 61/799,711 filed March 15, 2013. The foregoing applications are incorporated by reference in their entirety.

BACKGROUND

1. Background and Relevant Art

10 [0002] Computer systems and related technology affect many aspects of society. Indeed, the computer system's ability to process information has transformed the way we live and work. Computer systems now commonly perform a host of tasks (e.g., word processing, scheduling, accounting, etc.) that prior to the advent of the computer system were performed manually. More recently, computer systems have been coupled to one another and to other electronic devices to form both wired and wireless computer networks over which the computer systems and other electronic devices can transfer electronic data. Accordingly, the performance of many computing tasks is distributed across a number of different computer systems and/or a number of different computing environments.

20 [0003] In some computing environments, a single facility, often referred to as a "data center", is used to house (a potentially large number of) computer systems and associated components, such as, for example, telecommunication and storage systems. A data center can also include redundant or backup power supplies, redundant data controls, environmental controls (e.g., air conditioning, fire suppression, etc.), and security devices. The various devices inside the data center can be referred to as computing devices, which may include various types of Information Technology (IT) devices and equipment. Use of reliable and controlled data center environments minimizes the chance for disruption and increases information security for entities that use the data center.

30 [0004] Some data centers include rows of cabinets (e.g., server racks) that are arranged in a manner that facilitates cooling. For example, the intake of each computer is aligned in a supply or "cold" aisle and the exhaust of each computer blowing out is aligned into a corresponding "hot" aisle. An arrangement that separates cold airflow and hot airflow provides at least two advantages. One provided advantage is consistent and safe supply temperatures to the computer intake. Another provided advantage is warmer

and drier air is returned to air conditioning (“AC”) units so as to increase cooling capacity (tonnage).

[0005] Within a data center, the mechanical “throw rate” of supply airflow limits what locations supply airflow can reach within a cold aisle. Other locations in the cold aisle are provided homogenized ambient airflow as intake airflow. The homogenized ambient airflow results, at least in part, from air stratification where a band of warmer air with similar temperature and relative humidity are formed.

[0006] As such, containment systems can be used to separate hot and cold air. More specifically, two types of containment, cold aisle containment and hot aisle containment, can be used. In general, containment systems result in energy savings and increase cooling capacity of corresponding AC units.

[0007] A cold aisle can be surrounded by end doors and a roof and potentially also side walls. Containing a cold aisle creates an environment with consistent temperature and relative humidity at the intake of the computing devices inside the aisle. Cold aisle containment provides consistent airflow by creating a “pool” of cold supply air as it enters the contained space with no outlet except through the computing devices. Consistent airflow substantially reduces (and potentially eliminates) air stratification. As such, cold aisle containment increases locations within a cold aisle that can be reached with intake airflow. In turn, the amount of computing devices in cabinets in a cold aisle can also be increased.

[0008] Accordingly, disrupting containment also disrupts the delivery of cooling airflow to the computing devices and reduces the benefits of using containment. For example, if an aisle end door is opened in a cold air containment, cold and thus denser air flows out the aisle end into the ambient room. Inside the containment area, cold air would be replaced with warmer air that would flow into the cold aisle above the “throw rate” band of air. Thus, for a period of time while the door is open, and after which the warmer air would require replacement with cold supply air, the cooling solution would be compromised.

[0009] Unfortunately, personnel have to enter a cold aisle from time to time to collect data and operate devices, such as, for example, to measure environmental conditions (temperature, humidity, airflow, inside containment, etc.), to measure power usage effectiveness (“PUE”), access electrical systems, inventory equipment, adjust lighting, respond to equipment malfunctions, etc. Every time containment is disrupted the cooling solution is compromised.

BRIEF SUMMARY

[0010] Embodiments of the present invention extend to methods, systems, and computer program products for monitoring and controlling data center components. Embodiments of the invention integrate a docking station into a data center containment system. The docking station can be configured to accept a computing device. The computing device may be configured to control and/or monitor aspects of the containment system and/or of the computing devices inside the containment system.

[0011] A containment system may be associated with a containment area. A facility or data center, however, may have multiple containment systems. The number of containment systems in a data center may depend on the configuration of the data center. Because the computing device is configured to control and/or monitor aspects of the containment system and/or of the computing devices inside the containment system, a user can visit a containment system and monitor or control the containment system without having to break the containment. This helps maintain the efficiency of the containment system by preventing or at least minimizing the impact of external air that may be allowed inside the containment system when the containment is broken.

[0012] The computing device can connect wirelessly and/or via a wired connection to the computing devices inside the containment system and/or to the containment system if necessary. In one example, a single computing device may be used for multiple containment systems (or for each contained area).

[0013] Because many data centers are arranged to have rows of computing devices, the containment systems are often configured to contain aisles of the rows. As a result, a hot aisle or a cold aisle is an example of a containment area that may be contained by a containment system. Although embodiments of the invention are discussed with reference to cold aisles and hot aisles, one of skill in the art can appreciate that embodiments of the invention apply to other containment areas and containment systems regardless of their specific configurations.

[0014] Each containment system may include a docking station configured to receive a computing device. The docking station can include mechanical connections for selectively securing and releasing the computing device from the docking station. Selectively securing the computing device in the docking station can communicatively couple the computing device to one or more sensors within a hot and/or cold aisle (and/or adjacent aisles) for monitoring components within the hot aisle and/or cold aisles (and/or adjacent aisles). Selectively securing the computing device in the docking station can

also communicatively couple the computing device to one or more controls for controlling components within a hot and/or cold aisle (and/or adjacent aisles). At the same time, securing the computing device in a docking station may physically connect the computing device to the containment system while any computer or network type communications occur using the wireless capabilities of the computing device.

[0015] When a computing device is selectively secured, input/output devices (e.g., a touch screen) of the computing device can be located outside of a cold aisle or hot aisle containment area. The computing device can be connected (wired or wirelessly) to monitoring equipment that monitors and/or collects monitoring data for one or more of: information technology ("IT") equipment (which includes computing devices inside the containment system), other related devices, and environmental conditions, within a cold aisle or hot aisle of a data center. The computing device can also be connected (wired or wirelessly) to controls for controlling or interacting with the IT equipment or computing devices, other related devices, and environmental conditions within the cold aisle and/or hot aisle.

[0016] The computing device can include a user interface for presenting monitoring data and receiving control commands. Users can interact with the containment system through with the user interface and the input/output devices (e.g., touch screen) of the computing device located outside the containment area. For example, the user interface can present monitoring data at a touch screen for one or more of: information technology ("IT") equipment, other related devices, and environmental conditions within a cold aisle or hot aisle. The user interface can also receive user-entered commands at a touch screen for controlling one or more of: information technology ("IT") equipment, other related devices, and environmental conditions within a cold aisle and/or hot aisle through the touch screen.

[0017] In response to user-entered commands, the computing device can control one or more of: IT equipment, other related devices, and environmental conditions within a cold aisle containment area and/or a hot aisle containment area via corresponding control connections. Accordingly, docking stations permit a data center operator to move between containment locations and monitor and control a number of containment areas with a single (mobile) computing device. Further, embodiments of the invention allow, by way of example, IT equipment, other related devices, and environmental conditions within a containment area or in a containment system without breaking the containment. As a result, the cooling system is not compromised as frequently and operating

efficiencies are improved.

[0018] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0019] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The features and advantages of the invention may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0020] Figure 1 illustrates an example data center.
- 15 [0021] Figure 2 further illustrates an example of the structure of a containment system.
- [0022] Figure 3 illustrates a hinged door.
- [0023] Figure 4 illustrates a computing device.
- [0024] Figure 5 illustrates a computing device integrated into a containment door.
- 20 [0025] Figure 6 illustrates example connections to a computing device.
- [0026] Figure 7 illustrates a portion of data center.
- [0027] Figure 8 illustrates a portion of data center.
- [0028] Figure 9 illustrates front view and rear view of a containment door.
- [0029] Figure 10 illustrates a mounting assembly.
- 25 [0030] Figures 11A and 11B illustrate different views of a containment door.
- [0031] Figures 12A and 12B illustrate different views of a containment door.

DETAILED DESCRIPTION

[0032] Embodiments of the present invention extend to methods, systems, and computer program products for accessing, monitoring and controlling data center components. Embodiments of the invention integrate a user interface computing device into a data center containment system. Examples of the computing device include, but are not limited to, laptop computers, smartphones, tablet devices, or the like or any combination thereof. The computing device may be able to connect to a docking station that may be located in a containment system. The docking station may be located in a

door of the containment system, in a wall of the containment system, or in another part of the containment system. In one example, the docking station may be exposed on an exterior of the data center aisle that is not inside the containment area.

[0033] The docking station can be configured to accept a computing device that is inserted into or attached to the docking station. The docking station can include mechanical connections for selectively securing and releasing the computing device from the docking station. Selectively securing the computing device in the docking station can communicatively couple the computing device to one or more sensors within a hot and/or cold aisle (and/or adjacent aisles) for monitoring components within the hot aisle and/or cold aisles (and/or adjacent aisles). Selectively securing the computing device in the docking station can also communicatively couple the computing device to one or more controls for controlling components (including the computing components or IT equipment) within a hot and/or cold aisle (and/or adjacent aisles). The docking station may also provide electrical connections including, but not limited to, power lines and data lines.

[0034] The docking station may be inset into the door, wall, or other portion of the containment system. In this example, the computing device, when removably secured, may be flush with the outer surface of the containment system. This allows the computing device to remain connected to the containment system without hindering certain operational aspects of the containment system. For example, if it becomes necessary to open a door, the computing device could remain connected while the door is opened. The docking station may also hold the computing device such that the user is not required to support the computing device while operating the computing device.

[0035] The docking station may be configured with flexible tabs that flex when the computing device is inserted. The tabs may have an edge that overlaps with the edge of the computing device one the computing device is fully inserted. The computing device can be removed by flexing the tabs and removing the computing device. The docking station may alternatively have one or more bars or latches that when connected hold the computing device in place without interfering with the display or the input/output devices. The bars and latches may overlap edges of the computing device. Tabs and bars or latches can be include in the docking station and are examples of components that are configured to overlap an edge of the computing device and hold the computing device in place at least while in use.

[0036] When a computing device is selectively and/or removably secured,

input/output devices (e.g., a touch screen) for the computing device can be located outside of a cold aisle or hot aisle containment area. The computing device can be connected (wired or wirelessly) to monitoring equipment that monitors and/or collects monitoring data for one or more of: information technology ("IT") equipment, other related devices, and environmental conditions, within a cold aisle or hot aisle of a data center. The computing device can also be connected (wired or wirelessly) to controls for controlling the IT equipment, other related devices, and environmental conditions within the cold aisle and/or hot aisle.

[0037] In response to user-entered commands, the computing device can control one or more of: IT equipment, other related devices, and environmental conditions within a cold aisle containment area and/or a hot aisle containment area via corresponding control connections. Accordingly, docking stations permit a data center operator to move between containment locations and monitor and control a number of containment aisle locations with a single (mobile) computing device.

[0038] Embodiments of the invention provide an intelligent aisle containment system that is accessible via at least one aisle end doors or access. The containment area for an aisle containment system can correspond to a cold aisle or a hot aisle. As previously stated, a cold aisle or a hot aisle is an example of a containment area, which may have other configurations. The containment system, through an integrated computing device, can control IT components, other related devices, and environmental conditions within a cold aisle and/or hot aisle without having to disrupt the containment area. For example, a computing device integrated into a containment system (e.g., in a door of the containment system) can control security, equipment, inventory, lighting, and other similar aspects of a cold aisle or a hot aisle or other containment area. The computing device can be connected (wired or wirelessly) to other devices for controlling operation within the containment area. In some embodiments, the computing device is connected to existing cold aisle and/or hot aisle systems that would otherwise have to be monitored manually (resulting in containment area disruption).

[0039] The containment system contains a containment area by providing one or more of at least one door, a roof, a contained connection to an air conditioning system, one or more walls, or the like. Because a data center often includes rows or racks of computing equipment, the containment systems are configured such that the air is directed through the computing equipment from a cool side to a hot side. In effect, the rows or racks of equipment become a portion of the containment system. The other

portions of the containment system are arranged such that air flow primarily occurs through the computing equipment. As a result, the configuration of the containment system may depend on the arrangement of the rows or racks or, more generally, of the computing equipment in the data center.

5 [0040] In some examples, the containment system may be associated with a network operation center (NOC). However, the portability of the computing device and the ability to interface directly with a containment system can be advantageous. For example, some data centers such as high security centers often prohibit electronic devices such as phones, tablets, thumb drives, cameras, recording devices, or the like from entering the data
10 center. As a result, this may lead to the containment areas being breached or broken when it is necessary to monitor or control the computing equipment of the environment. Embodiments of the invention can provide the ability to prevent containment areas from being broken even in high security data centers since the computing devices may already be present inside the data center and are not removed from the data center. As a result,
15 the containment systems can be monitored/controlled without having to break the containment provided by the containment systems.

[0041] Embodiments of the invention provide portable control for containment systems and containment areas.

[0042] The following information, by way of example only, can be provided,
20 accessed, monitored, and or controlled using a computing device that is associated with a containment system:

- Environmental Conditions
 - Temperature
 - Readings by cabinet (Bottom U, Middle U, Top U)
 - 25 ▪ Readings of aisle average
 - Relative humidity
 - Readings by cabinet (Bottom U, Middle U, Top U)
 - Readings of aisle average
 - Readings of airflow volume (CFM)
 - 30 ○ Negative Air Pressure
 - Wireless sensors will read acquire data and send to a console (e.g., the display) attached to the computing device.
 - AC controls
 - Adjust temperature and relative humidity
 - 35 ▪ Adjust fan speed and volume
- PUE measurement and optimization
- Security
 - Video and still photography inside the aisle
 - Video and still photography at the outside door

- The three-axis gyroscope can be used to turn on and off the camera system if the door is moved or opened
 - Audio warnings can be played to inform people around the containment
 - Electronic Access Control Systems (ACS), which allow only authorized individuals to enter the containment. This could include biometric safeguards, such as palm readers, iris recognition, and fingerprint readers.
 - Aisle entry log
- IT equipment inventory
 - Location (cabinet/U)
 - Status
 - Serial number
 - Dates
 - Process
 - A computing device compass can be used to identify location
- Lighting
 - Control of aisle lighting so as to save energy
 - Lights off when the aisle is empty
 - Ambient light sensor
- Alarm
 - Red flashing alarm for quick identification of aisle where an immediate response is required
- IT equipment monitoring
 - Individual IT status
 - Server Administration
 - IT Dashboard
 - Desktop PC access (secured)
- Facility messenger
 - Instant messages can be sent from the computing device to key personnel for instant response such as cleanup, security, and safety.
- Fire suppression
 - Bypass switch
 - Monitor

35 **[0043]** In some embodiments, a containment system (e.g., the containment system door) may be integrated with a computing device. The portion of the containment system, such as the door, that is integrated or that may be removably connected with the computing device may include or be made of any suitable material (e.g., made from glass, acrylic, a polycarbonate material, or any other suitable material). The structures of the

40 containment system, such as doors, ceilings, walls, or the like may be transparent, solid, partially transparent, have windows, or the like. Each containment system may include a docking station configured to receive a computing device. The portion of the containment system may contain a computing device so that the computing device is accessible from outside the containment system. The computing device can be operated

by a touch interface in one example. The computing device can include cameras. One camera can record images within a corresponding containment area. The other camera can record images of users using the computing device. The computing device can include or interface with a motion sensor that activates a user facing camera when motion is detected at or near the touch interface. The height of the tablet computing device from the floor is configurable for convenient access by a user.

[0044] A containment door, or other portion of the containment system, can be configured with connectors, for example, a 30 pin dock connector or the like. The connectors can provide power (e.g., Universal Serial Bus (“USB”) power) for powering the computing device as well as connections to various sensors. A computing device can be connected to connectors of a containment door or other portion of the containment system. Many types of connectors may be used and the connections can be wireless in some examples.

[0045] The containment system may include a door having a width that extends between two rows or racks in a data center. The other end of the containment system opposing the door may also be a second door or may be an end wall. A roof is typically provided that is connected to the door and the end wall. The roof is also mounted to the two racks. The door and the opposing end wall (or second door) are also connected to the floor. The door of the containment system is configured to open as discussed in more detail below. When the door is a sliding door, the front end of the containment system may also include a front wall that includes a pocket.

[0046] The roof, doors, and walls are typically configured such that leakage (air entering or leaving) the containment area is minimal (e.g., 3% or less, or 2% or less, or 1% or less) when the containment system is closed. The bottoms of the walls and doors may be formed to press against the floor to close the containment area while still allowing movement necessary to open the door. For example, the bottom of the door may be a material that is configured to slide on the floor such as a thick brush or a flexible rubber piece.

[0047] The connections between the roof and the wall may be integral or sealed to prevent leakage into or out of the containment area. Any areas where movement of the containment system is expected (e.g., between a door and the floor, between the door and the door frame) may include a cover that allows movement while preventing leakage.

[0048] In addition, the various connections between the containment system and the computing device that may be removably mounted are configured to account for

movement. For example, the electrical connections provided in the docking station may be configured to account for movement of the door.

5 [0049] The containment system may also include a conduit to a vent or other air ingress/egress (access) point. The roof, for example, may be connected to the air access point such that the connection can be sealed. The connection may be sealed with any suitable material or may be configured to account for relative movement and maintenance access. For example, the edges of the roof (or other portion of the containment system) that connects to the air access may have a flexible rubber plate mounted thereon that presses against a surface of the air access. The flexible plate can press against the surface
10 of the air access point to prevent leakage while still allowing for movement.

[0050] A data center may include both hot containment areas and cold containment areas. The containment systems are often configured to contain either the cold areas or the hot areas, although the containment systems could contain both (in separate containment pods).

15 [0051] The containment systems often provide a path for air flow. For a containment system for a hot containment area, the hot air exiting the IT devices is contained by the containment system and directed via a return path to the AC system in one example. In a containment system for a cold containment area, the output of the ac system is contained and directed to the air intake portions of the IT devices in the data system or of the
20 containment area.

[0052] In both cases, mixing of the hot air and the cold air is minimized. This prevents reductions in efficiencies and helps maintain adequate temperatures, humidity, etc., inside of the containment areas.

[0053] In some embodiments, a data center contains a plurality of cold aisles. As
25 such, a computing device can be integrated into a containment door (or other portion of the containment system) at each of the plurality of cold aisles. When a plurality of integrated computing devices are used, data acquired at each of the plurality of integrated computing devices can be combined. Data can be synched between integrated computing devices to compile data for consolidated reporting or other functions.

30 [0054] Figure 1 illustrates an example data center 100. As depicted data center 100 includes a number of racks of Information Technology components (e.g., servers). Racks of IT components are grouped together with cold aisles separating different groups of racks. Groups of racks also have external hot aisles. In generally, cooler air (e.g., in the range of 18-22 degrees Celsius) is released into cold aisles, such as, for example, through

a raised floor. The intake side of rack components accepts air from a corresponding cold aisle. The exhaust side of rack components outputs warmer air into external hot aisles.

[0055] The following discussion discusses containment systems and containment areas in the context of racks and aisles. One of skill in the art can appreciate, with the benefit of the present invention, that embodiments of the invention can be applied to other containment area configurations and to different sizes of containment areas. The hot and cold aisles are examples of potential containment areas.

[0056] For example, cold aisle 102 separates racks 103A-103E and racks 103F-103J. Cooler air is released into cold aisle 102. The intake side of components in racks 103A-103J accepts air from cold aisle 102. The exhaust side of components in racks 103A-103E output warmer air into hot aisle 104B. Similarly, the exhaust side of components in racks 103F-103J output warmer air into hot aisle 104A.

[0057] Likewise, cold aisle 112 separates racks 113A-113E and racks 113F-113I. Cooler air is released into cold aisle 112. The intake side of components in racks 113A-113I accepts air from cold aisle 112. The exhaust side of components in racks 113A-113E output warmer air into hot aisle 114B. Similarly, the exhaust side of components in racks 113F-113I output warmer air into hot aisle 114A.

[0058] Along the same lines, cold aisle 122 separates racks 123A-123E and racks 123F-123J. Cooler air is released into cold aisle 122. The intake side of components in racks 123A-123J accepts air from cold aisle 122. The exhaust side of components in racks 123A-123E output warmer air into hot aisle 124B. Similarly, the exhaust side of components in racks 123F-123J output warmer air into hot aisle 124A.

[0059] Portions of each cold aisle can be contained within one or more containment doors and one or more containment walls. For example, cold aisle 102 is contained by containment door 101 and containment door/wall 106 (which in different embodiments can be either another containment door or a containment wall). Cold aisle 112 is cold aisle 102 is contained by containment door 111, containment wall 117 (since the number of racks on each side of cold aisle 112 differ), and containment door/wall 116 (which in different embodiments can be either another containment door or a containment wall). Cold aisle 122 is contained by containment door 121 and containment door/wall 126 (which in different embodiments can be either another containment door or a containment wall).

[0060] In some embodiments, cold aisles also include a top portion that reduces cooler air leakage out of the top of the cold aisles. Raised floor portions at or around cold

aisles can also be sufficiently sealed to reduce cooler air leakage out of the raised floor portions.

[0061] Computing devices can be mounted to and/or integrated into any of the containment doors or other portions of the containments systems depicted in Figure 1. The computing devices can collect data monitored within corresponding cold aisles and can send commands (e.g., in response to used input) to adjust settings, conditions, devices, etc, within the corresponding cold or hot aisles. The computing devices can also be connected (wirelessly or wired) with one another and with other computing devices, systems, and modules (e.g., an aggregation module that synchronizes data for consolidated reports). The computing devices can also be used to perform operations such as check email, install updates, or the like using the IT equipment inside the containment area without breaking the containment (e.g., without entering the containment area).

[0062] Any of a variety of different containment door configurations can be used including but not limited to aisle end dual sliding containment doors, dual sliding doors, dual sliding containment doors, single sliding containment doors, and hinged doors. Figure 2 illustrates an example of a containment system 200 that includes a dual sliding door with sliding door portion 201A and sliding door portion 201B. Figure 3 illustrates a hinged door 301 that may also be included in a containment system such as illustrated in Figure 3. Figures 2 and 3 further illustrate that the containment system may have various configurations that can account for the computing equipment or racks or that account for the environment.

[0063] Figure 2 further illustrates an example of the structure of a containment system 200. The containment system 200 includes a door 201C that includes a door portion 201A and 201B. The door 201C is a sliding door and includes a door frame 202 in which the door 201C is mounted. The frame 202 extends past the aisle and is mounted to the racks 224 and 226. A connection or an interface 204 between the frame 202 and the rack 224 may be sealed. Similarly, an interface 206 between the door portion 201A and the frame 202 may also be sealed to prevent or reduce air leakage while still enabling the door to be opened. As discussed herein, the interface 206 may be a flexible rubber plate or a thick brush that is mounted to the frame 202 and that presses against the door portion 201A. The frame 202 may be similarly configured for the door portion 201B. The interface 218 between the door 201C and the floor may also be configured to prevent or reduce air leakage.

[0064] The containment system 200 may also include a roof 226 that is mounted to the racks 224 and 210 and to the frame 202. The door 201C may be mounted to a front of the frame 202, which may facilitate sealing a connection between the roof 226 and the frame 202. In this example, the roof 226 includes a connection or interface 214 to the tops of the racks 224 and 210. Sides 222 of the roof 226 may extend to the ceiling and are connected by a connection or interface 216. The side 220 of the roof 226 may connect to the ceiling and the frame 202.

[0065] The connection or interface 208 between the frame 202 and the floor may be more permanent. Alternatively and depending on leakage tolerances, the containment system 200 may rest on the floor and may not require any sealing. The space between the frame 202 and the floor (or between the roof 226 and the racks 224 and 210) may be sufficiently small such that leakage is not a concern. The back end of the containment system 200 may be a wall that extends to contain the containment area or may be configured as a second door. The computing device may be mounted in the frame 202, the door 201C, the opposing end wall 228, or the like. Figure 3 illustrates another example of a roof and a different configuration for the door frame.

[0066] Figure 4 illustrates a computing device 401, which may be a tablet device, a laptop computer, a smartphone, or the like or combination thereof. Computing device 401 can be integrated into a containment door, such as, for example, an aisle end dual sliding containment door, a dual sliding door, a dual sliding containment door, a single sliding containment doors, and hinged door. For dual sliding doors, a tablet or other computing device can be integrated into one portion of the door. The computing device could be integrated into other structure of the containment system such as the walls. The location where the computing may be integrated may depend on the configuration of the containment area and the arrangement of computing or IT devices inside the containment area. For example, in Figure 2, a computing device can be integrated into door portion 201B. Alternatively, the door portion 201B may be configured to removably receive the computing device.

[0067] Figure 5 illustrates a computing device integrated into a containment door. As depicted, containment door 501 includes door handle 502. Containment door 501 can be made of a clear material (e.g., glass, acrylic, a polycarbonate material, etc.) that permits a user to see through containment door 501. Containment door 501 may also be made of any other material than may not be clear. The containment door 501 may alternatively have windows or the like. Computing device 503 can be removably or permanently

mounted into containment door 501. Computing device 503 can include a touch screen 504. Monitored data related to a cold aisle environment or a hot aisle environment, IT resources mounted in a rack, and auxiliary devices can be displayed at touch screen 504. Touch screen 504 can present a virtual keyboard 506. A user can use virtual keyboard 506 to enter data and comments into computing device 503. Computing device 503 can use (wireless and/or wired) connections to various controls within a cold aisle or a hot aisle to effectuate changes within the cold aisle or the hot aisle. The computing device 503 may also be configured to make adjustments to a remotely located air conditioning controller so as to control air flow, air temperature, or the like. As such, a cold aisle and/or a hot aisle can be changed without disrupting the containment of the cold aisle and/or the hot aisle.

[0068] Figure 6 illustrates example connections to a computing device. As depicted, computing device 601 can communicate with sensors and/or controls through connections 602.

[0069] Racks of IT equipment can have a variety of different arrangements within a data center. In some embodiments, rows of IT racks are arranged together with alternating cold aisles and hot aisles between rows. The intake for IT equipment in the IT racks can draw air from a cold aisle. The exhaust for IT equipment in the IT racks output air into a hot aisle. In these embodiments, cold aisles, hot aisles, or both cold aisles and hot aisles can be contained.

[0070] Figure 7 illustrates a portion of data center 700. As depicted, IT racks 707A-707G are arranged around hot aisles 701A-701D and cold aisles 702A-702C. In Figure 7, cold aisles are contained. Containment door 703A and containment door/wall 703B contain cold aisle 702A. Containment door 704A and containment door/wall 704B contain cold aisle 702B. Containment door 706A and containment door/wall 706B contain cold aisle 702C. As such, a computing device can be mounted on each of containment doors 703A, 704A, and 706A to monitor and, when appropriate, adjust environmental conditions of cold aisles 702A, 702B, 702C and equipment in corresponding IT racks respectively. Of course, the computing device can be mounted elsewhere on the containment system. Often, the door is selected because the rows or racks essentially form the walls of the computing system. As a result, the computing device may be mounted at the aisle ends or in the door at at least one of the aisle ends.

[0071] In some embodiments, a computing device on a cold aisle containment door also monitors one or more aspects of a corresponding hot aisle or vice versa. For

example, a computing device on containment door 703A can also monitor aspects of hot aisle 701A. The horizontal ellipsis in Figure 7 indicates that further cold aisles, IT racks, and hot aisles can continue in a similar pattern. The vertical ellipses indicate that other rows of IT racks, cold aisles, and hot aisles can be included in data center 700.

5 **[0072]** Figure 8 illustrates a portion of data center 800. As depicted, IT racks 807A-807G are arranged around cold aisles 801A-801D and hot aisles 802A-802C. In Figure 8, hot aisles are contained. Containment door 803A and containment door/wall 803B contain hot aisle 802A. Containment door 804A and containment door/wall 804B contain hot aisle 802B. Containment door 806A and containment door/wall 806B contain host
10 aisle 802C. As such, a computing device can be mounted on each of containment doors 803A, 804A, and 806A to monitor environmental conditions of hot aisles 802A, 802B, and 802C respectively. Based on monitored environmental conditions in a hot aisle, a computing device on a hot aisle containment door can adjust the environment of a corresponding cold aisle and/or equipment in corresponding IT racks.

15 **[0073]** Further, computing devices on hot aisle containment doors can also monitor environmental conditions of corresponding cold aisles, such as, for example, 801A, 801B, 801C, 801D, etc., and equipment in IT racks. The computing devices can consider information for cold aisle and IT rack equipment when adjusting the environment of a cold aisle and/or equipment in IT racks

20 **[0074]** In further embodiments (not shown), containment doors and/or containment walls are used to contain both cold aisles and hot aisles within a data center. Computing devices can be included on hot aisle containment doors, cold aisle containment doors, or some combination of both hot aisle and cold aisle containment doors.

[0075] Figure 9 illustrates front view and rear view of a containment door 901
25 respectively. As depicted, tablet device 902 is mounted on the side of containment door 901 visible in the front view. The side of containment door 901 visible in the view is the side that is external to containment and thus can be accessed by a user without disrupting a containment area.

[0076] Figure 10 illustrates a mounting assembly 1004 that can be mounted in a
30 containment door. Computing device 1001, face plate 1002, and mounting plate 1003 can be combined into mounting assembly 1004. Other mounting assemblies may also be considered. The mounting assembly 1004 may be configured such that when mounted, the computing device is flush with the containment door (or other portion of the containment system). The mounting system may hold the computing device. The

mounting assembly may hold the computing device with sufficient force so that a user can operate the computing device easily and such that the computing device could be removed. In some embodiments, the computing device may be a permanent part of the containment system. Alternatively, the computing device may be removable and may be associated with multiple containment systems or areas in a facility or data center, for example. When inserted into a mounting assembly, the computing device may be able to automatically identify which containment system or containment area is being connected to.

[0077] The mounting assembly 1004 may be integrated with a containment door or be mounted on a surface of the containment door. Connectors, including mechanical and/or electrical and/or data connections may be run through an interior of the face plate 1002 or other portion of the mounting assembly 1004. These connectors may also be run through an interior of the door and to an interior of the containment system, where they may be connected with various sensors or other equipment. The connectors are configured to account for movement of the door if necessary.

[0078] The connectors may enter the docking area 1005 through a bottom of the face plate 1002. The connectors, such as the connector 1006 may be sufficient to hold the computing device 1001 in place during operation. The docking area 1005 may also be sufficiently large such that the computing device 1001 can be mounted on the connector 1006 or to allow a user's fingers to grasp the computing device 1001 when removing the device 1001. Alternatively, an eject device may be provided that can be pressed by a user to eject the device with a lever, for example. This may enable the size of the docking area 1005 to be reduced and fit tightly with the computing device 1001.

[0079] An exterior of the docking area 1005 may be provided with flexible tabs that can grasp an edge of the computing device 1001 and securely hold the computing device 1001 in place.

[0080] The mounting assembly 1004 may be placed on a door or other portion of the containment system such that the operation of the containment system is not impaired by the mounting assembly 1004. For example, the mounting assembly 1004 may be placed on a sliding door. If the door is attached to the frame as illustrated in Figure 11A, for example, the mounting assembly 1004 does not interfere with door movement.

[0081] Figures 11A and 11B illustrate different views of a containment door 1101. Containment door 1101 includes mounting assembly 1104, which can contain a tablet device for monitoring and/or adjusting environmental conditions within an aisle and/or IT

equipment.

[0082] Figures 12A and 12B illustrate different views of a containment door 1201. Containment door 1201 includes mounting assembly 1204, which can contain a computing device for monitoring and/or adjusting environmental conditions within an aisle and/or IT equipment.

[0083] In some embodiments, different components of a computing device are in different locations. Thus, a display device can be mounted on a containment door and other components of a computing device, such as, for example, a processor and system memory are in another location. For example, a touch screen can be mounted on a containment door and a processor and system memory connected to the touch screen can be included in an adjacent IT rack. A user can still interact with the computing device to monitor and/or adjust environmental conditions and/or IT equipment without disrupting containment.

[0084] In some embodiments, a mounting assembly, such as, for example, similar to mounting assembly 1004, 1104, 1204, etc. is configured as a docking station. The docking station can be integrated into a door panel. The docking station can be configured to accept a computing device, such as, for example, a tablet computing device, a smartphone computing device, or the like, inserted into the docking station. The docking station can include mechanical connections for selectively securing and releasing the computing device from the docking station. Selectively securing the computing device in the docking station can communicatively couple the computing device to one or more sensors within a hot and/or cold aisle (and/or adjacent aisles) for monitoring components within the hot aisle and/or cold aisles (and/or adjacent aisles). Selectively securing the computing device in the docking station can also communicatively couple the computing device to one or more controls for controlling components within a hot and/or cold aisle (and/or adjacent aisles).

[0085] Accordingly, a computing device can be inserted into and secured within the docking station. When secured, the tablet computing device can monitor and/or control hot aisles and/or cold aisles as appropriate. When monitoring and/or controlling are completed, the computing device can be removed from the docking station. The use of docking stations can reduce hardware costs since computing devices can be moved between different containment doors/walls, etc.

[0086] For example, a data center operator can bring a tablet computing device with them and dock the tablet computing device into a containment door of a specific hot or

cold aisle location within a data center. After docking, the data center operator can establish a connection with components in that specific hot or cold aisle containment location for monitoring and system control. Accordingly, the data center operator is able to view available information associated with that containment location from outside the
5 containment. After completing work at the containment location, the data center operator can un-dock the tablet computing device and move on to another location within the data center.

[0087] Accordingly, embodiments of the invention preserve containment airflow by maintaining a consistent static pressure differential. Embodiments also maintain cooling
10 temperature and relative humidity in the cold aisle. Warmer and potentially contaminated outside air is preventing from entering a containment area. An integrated computing device can provide information for both IT and facility personnel in one location.

[0088] Embodiments of the present invention may comprise or utilize a special purpose or general-purpose computer including computer hardware, such as, for example,
15 one or more processors and system memory, as discussed in greater detail below. Embodiments within the scope of the present invention also include physical and other computer-readable media for carrying or storing computer-executable instructions and/or data structures. Such computer-readable media can be any available media that can be accessed by a general purpose or special purpose computer system. Computer-readable
20 media that store computer-executable instructions are computer storage media (devices). Computer-readable media that carry computer-executable instructions are transmission media. Thus, by way of example, and not limitation, embodiments of the invention can comprise at least two distinctly different kinds of computer-readable media: computer storage media (devices) and transmission media.

[0089] Computer storage media (devices) includes RAM, ROM, EEPROM, CD-ROM, solid state drives (“SSDs”) (e.g., based on RAM), Flash memory, phase-change
25 memory (“PCM”), other types of memory, other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store desired program code means in the form of computer-executable instructions or data
30 structures and which can be accessed by a general purpose or special purpose computer.

[0090] A “network” is defined as one or more data links that enable the transport of electronic data/communication between computer systems and/or modules and/or other electronic devices. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of

hardwired or wireless) to a computer, the computer properly views the connection as a transmission medium. Transmissions media can include a network and/or data links which can be used to carry desired program code means in the form of computer-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer. Combinations of the above should also be included within the scope of computer-readable media.

[0091] Further, upon reaching various computer system components, program code means in the form of computer-executable instructions or data structures can be transferred automatically from transmission media to computer storage media (devices) (or vice versa). For example, computer-executable instructions or data structures received over a network or data link can be buffered in RAM within a network interface module (e.g., a "NIC"), and then eventually transferred to computer system RAM and/or to less volatile computer storage media (devices) at a computer system. Thus, it should be understood that computer storage media (devices) can be included in computer system components that also (or even primarily) utilize transmission media.

[0092] Computer-executable instructions comprise, for example, instructions and data which, when executed at a processor, cause a general purpose computer, special purpose computer, or special purpose processing device to perform a certain function or group of functions. The computer executable instructions may be, for example, binaries, intermediate format instructions such as assembly language, or even source code. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the described features or acts described above. Rather, the described features and acts are disclosed as example forms of implementing the claims.

[0093] Those skilled in the art will appreciate that the invention may be practiced in network computing environments with many types of computer system configurations, including, personal computers, desktop computers, laptop computers, message processors, hand-held devices, multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, mobile telephones, PDAs, tablets, pagers, routers, switches, and the like. The invention may also be practiced in distributed system environments where local and remote computer systems, which are linked (either by hardwired data links, wireless data links, or by a combination of hardwired and wireless data links) through a network, both

perform tasks. In a distributed system environment, program modules may be located in both local and remote memory storage devices.

[0094] Accordingly, in some embodiments, different types of computing devices may be used. The devices may have the same or different operating systems. And the software may be configured to interface with sensors, computers, or the like using appropriate protocols and interfaces.

[0095] Embodiments of the invention include components that are connected to one another over (or is part of) a network, such as, for example, a Local Area Network ("LAN"), a Wide Area Network ("WAN"), and even the Internet. Accordingly, each of the components as well as any other connected computer systems and their components, can create message related data and exchange message related data (e.g., Internet Protocol ("IP") datagrams and other higher layer protocols that utilize IP datagrams, such as, Transmission Control Protocol ("TCP"), Hypertext Transfer Protocol ("HTTP"), Simple Mail Transfer Protocol ("SMTP"), etc.) over the network.

[0096] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

What is claimed:

1. A containment door for containing an aisle within a data center, the containment door comprising:

5 a door panel constructed of a material, wherein the door panel is configured to open and close, wherein a containment of the aisle is disrupted when the door panel is opened; and

a docking station configured to accept a computing device inserted into the docking station, the docking station including:

10 communication connections to one or more sensors within the aisle and/or at least one adjacent aisle, the one or more sensors collecting sensor data for one or more of: rack mounted information technology ("IT") components that either intake air from or exhaust air into the aisle, auxiliary devices related to operation of the aisle and/or the at least one adjacent aisle, and environmental conditions within the aisle and/or the at least one adjacent aisle;

15 communications connections to one or more controls for controlling one or more of: the rack mounted information technology ("IT") components, the auxiliary devices, and the environment conditions within the aisle and/or the at least one adjacent aisle; and

20 mechanical connections for selectively securing and releasing the computing device from the docking station, selectively securing the computing device in the docking station, communicatively coupling the computing device to the communication connections to one or more sensors and to the communications connections to one or more controls.

2. The containment door of claim 1, wherein the docking station comprises a mounting assembly configured to accept a tablet computing device.

3. The containment door of claim 1, further comprising a motion sensor, the motion sensor for sensing motion at or near the docking station.

30 4. The containment door of claim 1, wherein the door panel comprises a door panel of one of: an aisle end dual sliding containment door, a dual sliding containment door, a single sliding containment door, and a hinged door.

5. The containment door of claim 1, wherein communication connections to one or more sensors within the cold aisle comprise wired and/or wireless connections to

one or more sensors that monitor temperature and relative humidity of air within the cold aisle.

6. The containment door of claim 1, wherein the aisle comprises a cold aisle.

7. The containment door of claim 1, wherein the aisle comprises a hot aisle
5 and the at least one adjacent aisle includes a cold aisle.

8. A containment system for containing at least one aisle within a data center, the containment system including a data aggregation module and a plurality of containment doors,

each of the plurality of containment doors comprising:

10 a door panel constructed of a material, wherein an aisle corresponding to the door panel is disrupted when the door panel is opened; and

a docking station integrated into the door panel, the docking station configured to accepting a computing device inserted into the docking station, the docking station including:

15 connections to one or more sensors within the aisle, the one or more sensors collecting sensor data for one or more of: rack mounted information technology ("IT") components that intake air from or exhaust air into the aisle, auxiliary devices related to operation of the aisle and/or at least one adjacent aisle, and environmental conditions within the aisle
20 and/or the at least one adjacent aisle;

connections to one or more controls for controlling one or more of: the rack mounted information technology ("IT") components, the auxiliary devices, and the environment conditions within the aisle and/or the at least one adjacent aisle;

25 mechanical connections for selectively securing and releasing the computing device from the docking station, selectively securing the computing device in the docking station communicatively coupling the computing device to the communication connections to one or more sensors and to communications connections to one or more controls; and

30 a data aggregation module including connections to each of the docking stations so as to receive collected sensor data from computing devices that are selectively secured into the docking stations, the aggregation module configured to synchronize collected sensor data from the selectively secured computing devices with one another to compile the collected sensor data into a consolidated report.

9. The containment system of claim 8, wherein the docking station comprises a mounting assembly configured to accept a tablet computing device.

10. The containment system of claim 8, further comprising a motion sensor, the motion sensor for sensing motion at or near the docking station.

5 11. The containment system of claim 8, wherein the door panel comprises a door panel of one of: an aisle end dual sliding containment door, a dual sliding containment door, a single sliding containment door, and a hinged door.

12. The containment system of claim 8, wherein communication connections to one or more sensors within the cold aisle comprise wired and/or wireless connections to one or more sensors that monitor temperature and relative humidity of air within the cold aisle.

13. The containment system of claim 8, wherein the aisle comprises a cold aisle.

14. The containment system of claim 8, wherein the aisle comprises a hot aisle and the at least one adjacent aisle includes a cold aisle.

15 15. The containment system of claim 8, wherein the computing device is configured to record at least one of video data and audio data when inserted into the docking station.

16. The containment system of claim 15, wherein the video data includes video data inside the at least one aisle and outside the at least one aisle.

17. The containment system of claim 8, wherein the docking station includes components configured to overlap an edge of the computing device when the computing device is inserted into the docking station and hold the computing device in place at least while in use.

25 18. The containment system of claim 8, wherein the computing device is configured to be mounted in multiple containment doors.

19. The containment system of claim 8, further comprising a roof and an end portion opposing the door panel, and a door frame in which the door panel is mounted, wherein the roof, the end portion, the door frame, and the door panel are connected in a manner to contain the aisle such that air flow is directed through the rack mounted information technology components, wherein the roof, the end portion, the door frame, and the door panel are connected such that a leakage of air into or out of the containment system is within a tolerance level.

20. The containment system of claim 19, wherein electrical connections to the computing device run through an interior of the door panel.

21. A containment system for containing a containment area in a data center, the containment system comprising:

5 a structure including:

at least one wall;

a door frame;

a door mounted in the door frame;

10 a roof, wherein the at least one wall, the door, the door frame, and the roof are arranged to define a containment area with respect to computing equipment; and

a computing device, wherein the structure is configured to removably receive the computing device and the computing device is configured to control environmental conditions within the containment area without disrupting the containment area.

15 22. The containment system of claim 21, wherein the door is configured to removable receive the computing device.

23. The containment system of claim 21, wherein the containment area includes either a hot aisle that receives air that has passed through the computing equipment or a cold aisle that contains air to be passed through the computing equipment.

20 24. The containment system of claim 21, wherein the computing device is configured to control the computing equipment without having to disrupt the containment area.

25 25. The containment system of claim 21, wherein the structure includes interfaces that are configured such that a leakage of air into or out of the containment area is within a tolerance level.

26. The containment system of claim 25, wherein the interfaces include an interface between the door and the door frame, an interface between the structure and the floor, and an interface between the structure and the computing equipment.

30 27. The containment system of claim 21, wherein the computing device is configured to control the environmental conditions of multiple structures, each structure defining a separate containment area.

28. The containment system of claim 21, wherein the door includes a mounting assembly having a docking area, wherein the computing device is mounted the docking area.

29. The containment system of claim 28, the mounting assembly further including components configured to overlap the computing device when inserted in the mounting assembly such that the computing device is removably retained in the docking area.

5 30. A method for monitoring environmental conditions in a data center, the method comprising:

 mounting a computing device in a first structure, wherein the first structure defines a first containment area that controls air flow related to computing equipment, wherein the computing device is mounted outside of the first containment area;

10 controlling environmental conditions of the first containment area with the computing device without disrupting the first containment area;

 mounting the computing device in a second structure that defines a second containment area; and

 controlling environmental conditions of the second containment area without
15 disrupting the second containment area.

31. The method of claim 30, further comprising removably mounting the computing device in a door of the first structure, wherein the door includes a mounting assembly configured to removably receive the computing device.

32. The method of claim 31, further comprising controlling the computing
20 equipment inside the first containment area and inside the second containment area using the computing device without disrupting the first containment area or the second containment area.

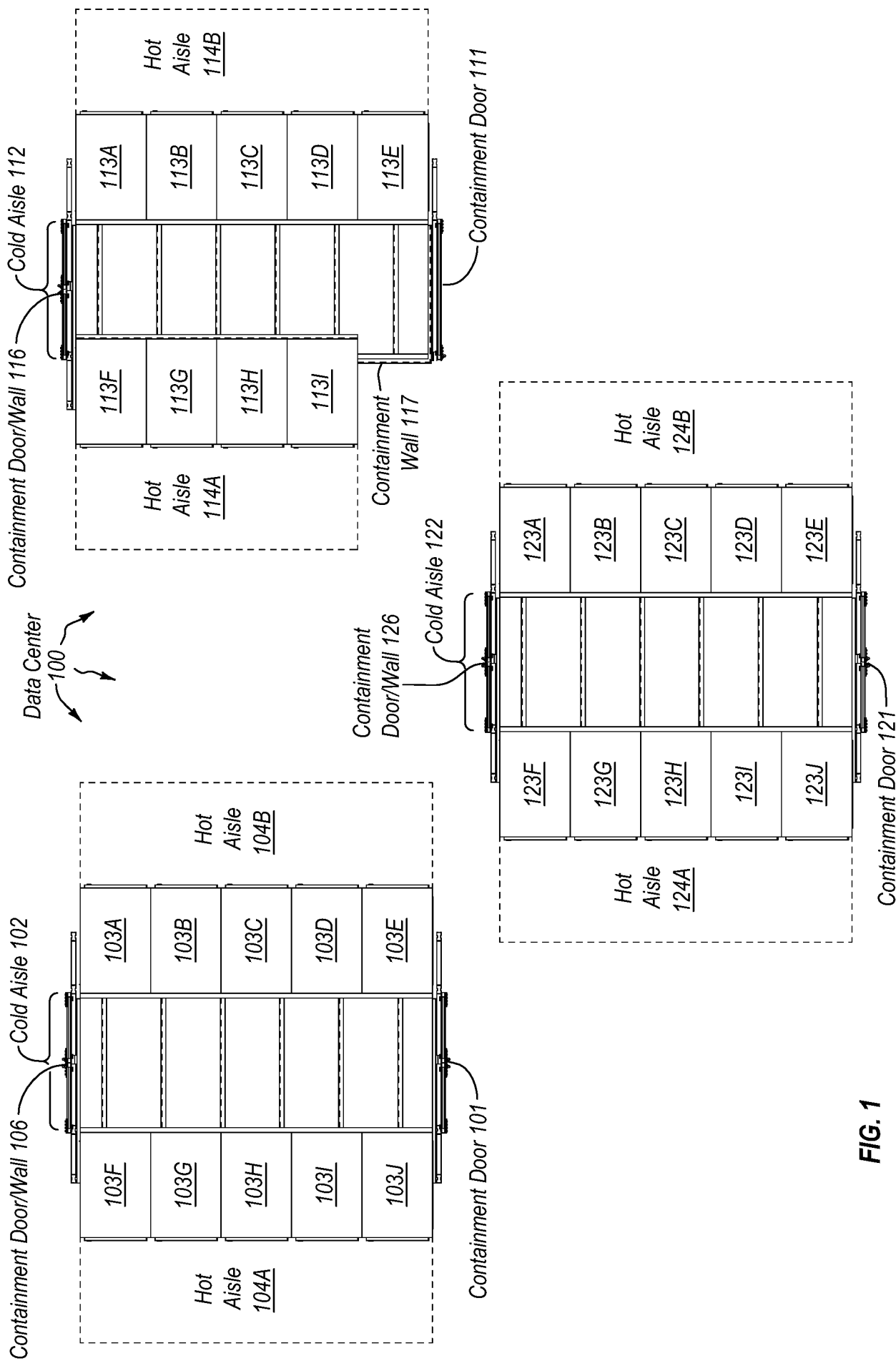


FIG. 1

2 / 14

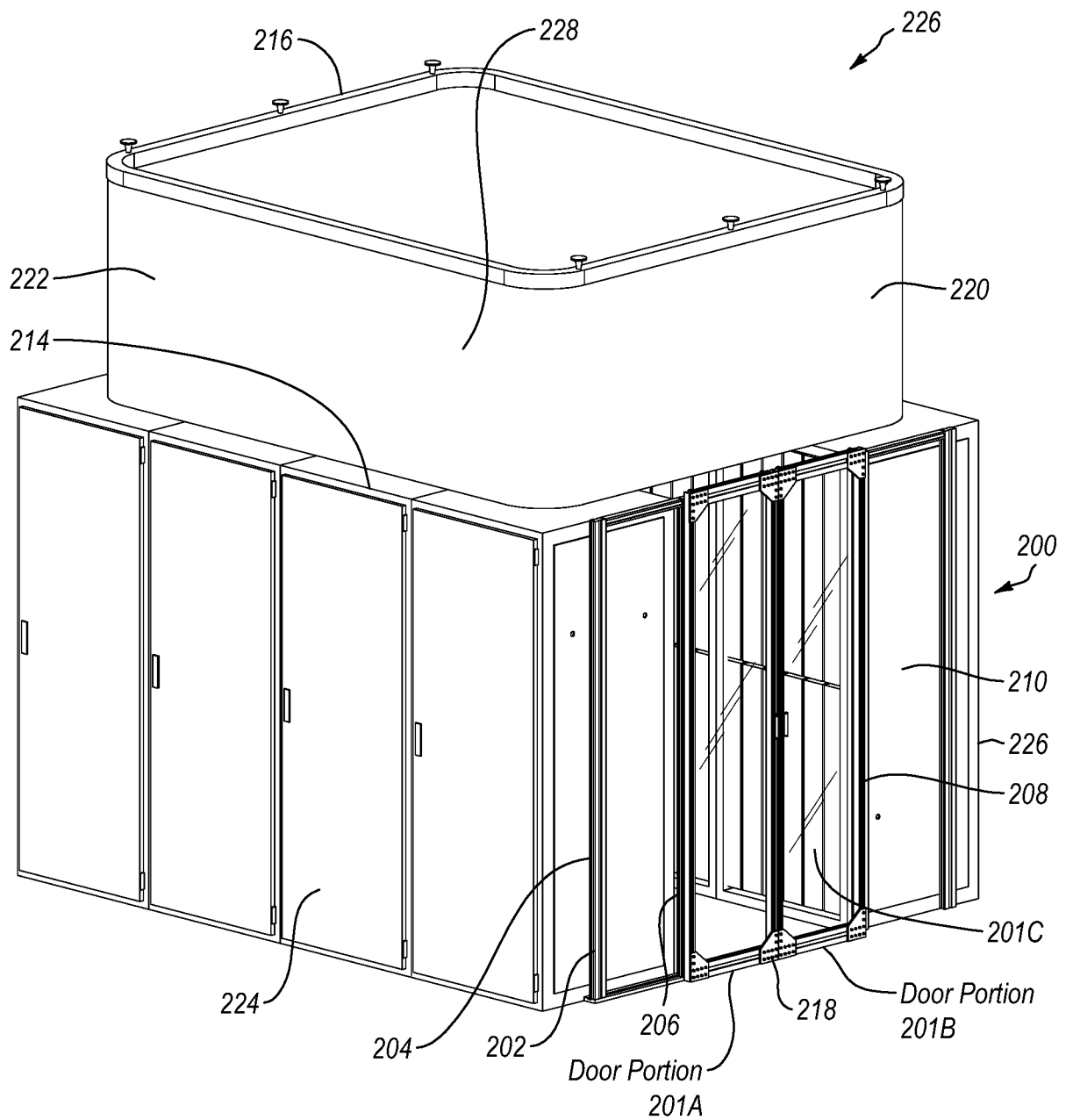


FIG. 2

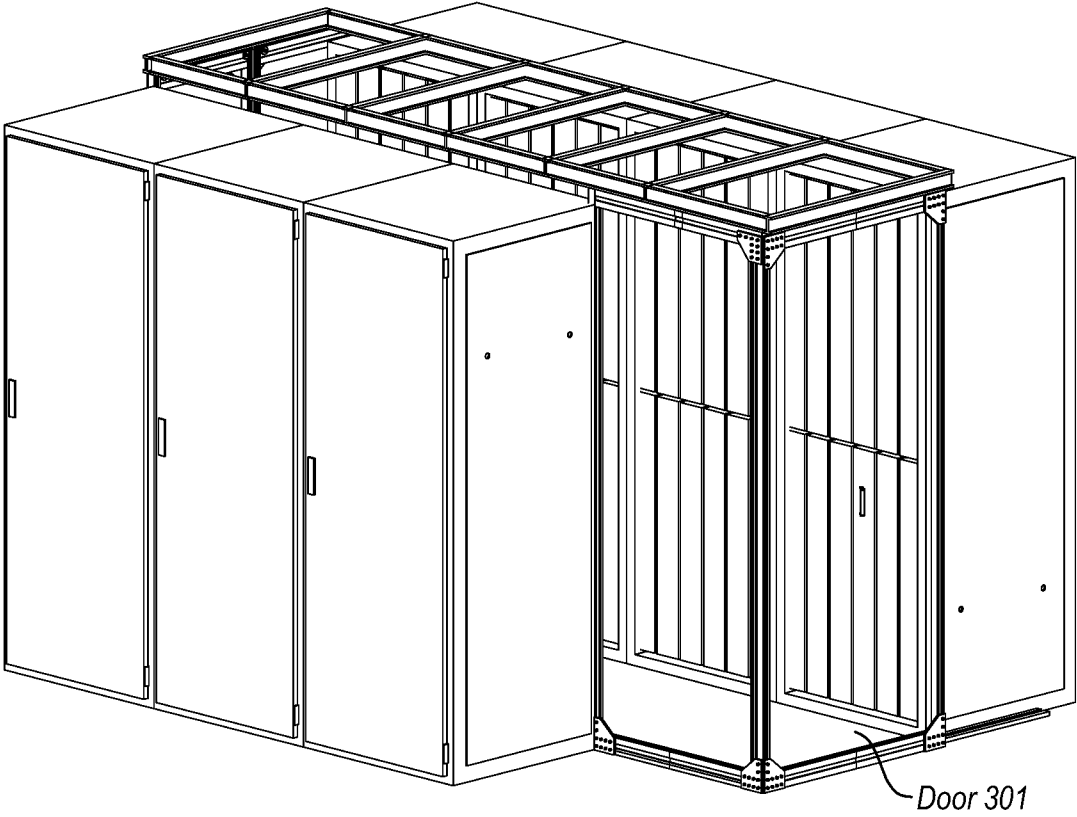


FIG. 3

4 / 14

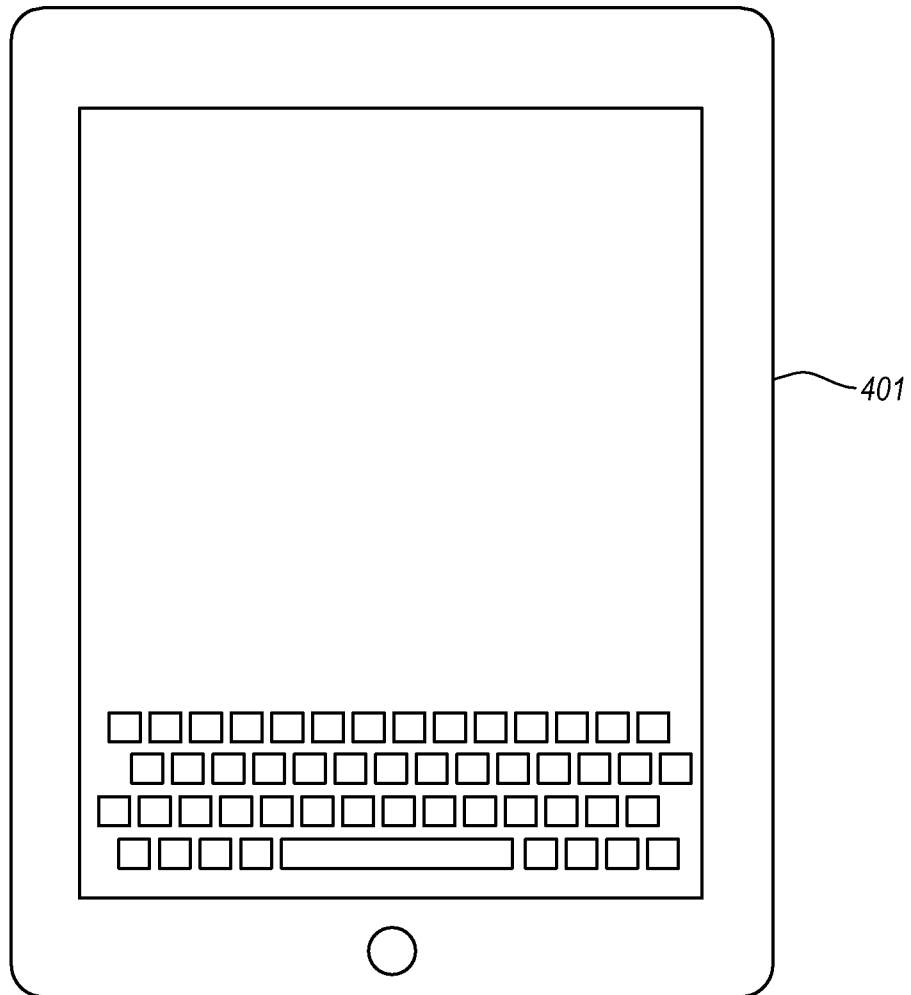


FIG. 4

5 / 14

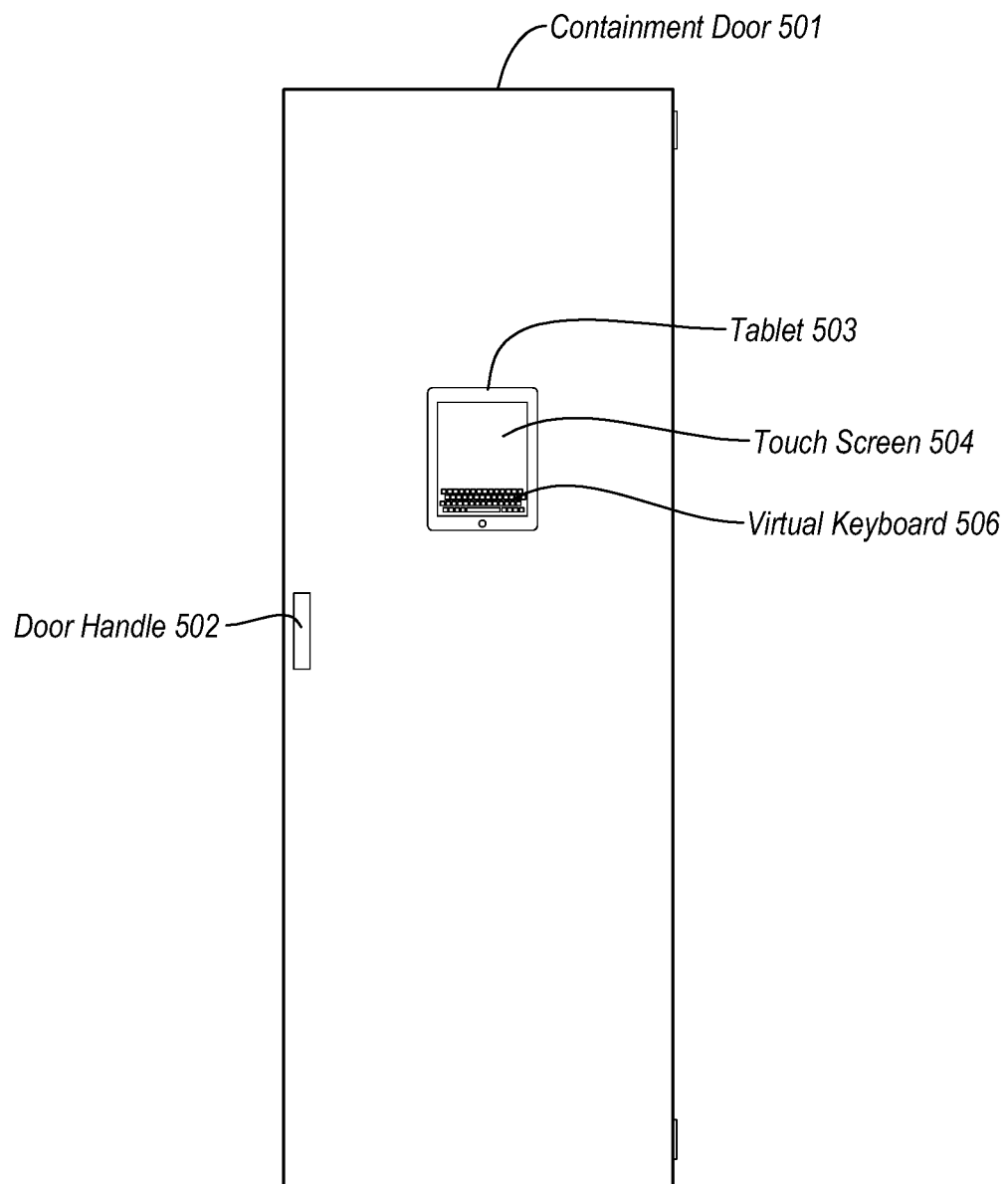


FIG. 5

6 / 14

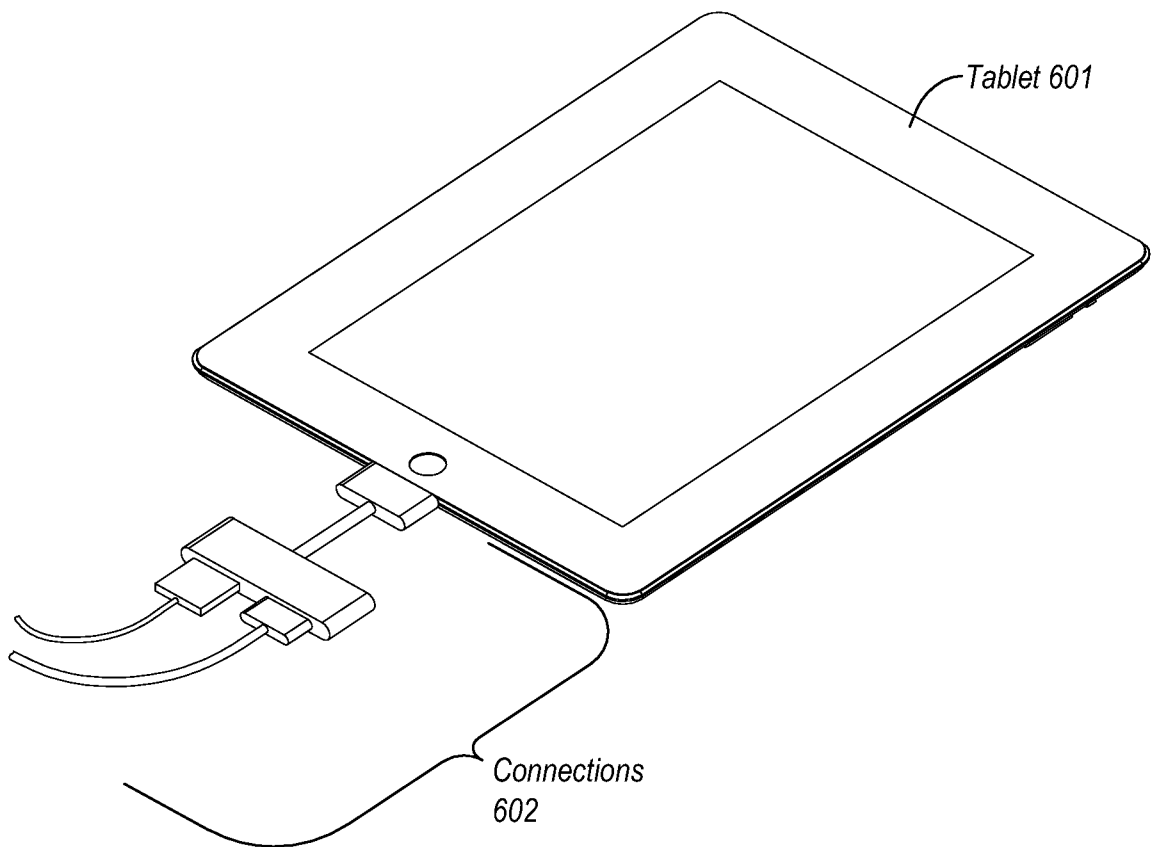


FIG. 6

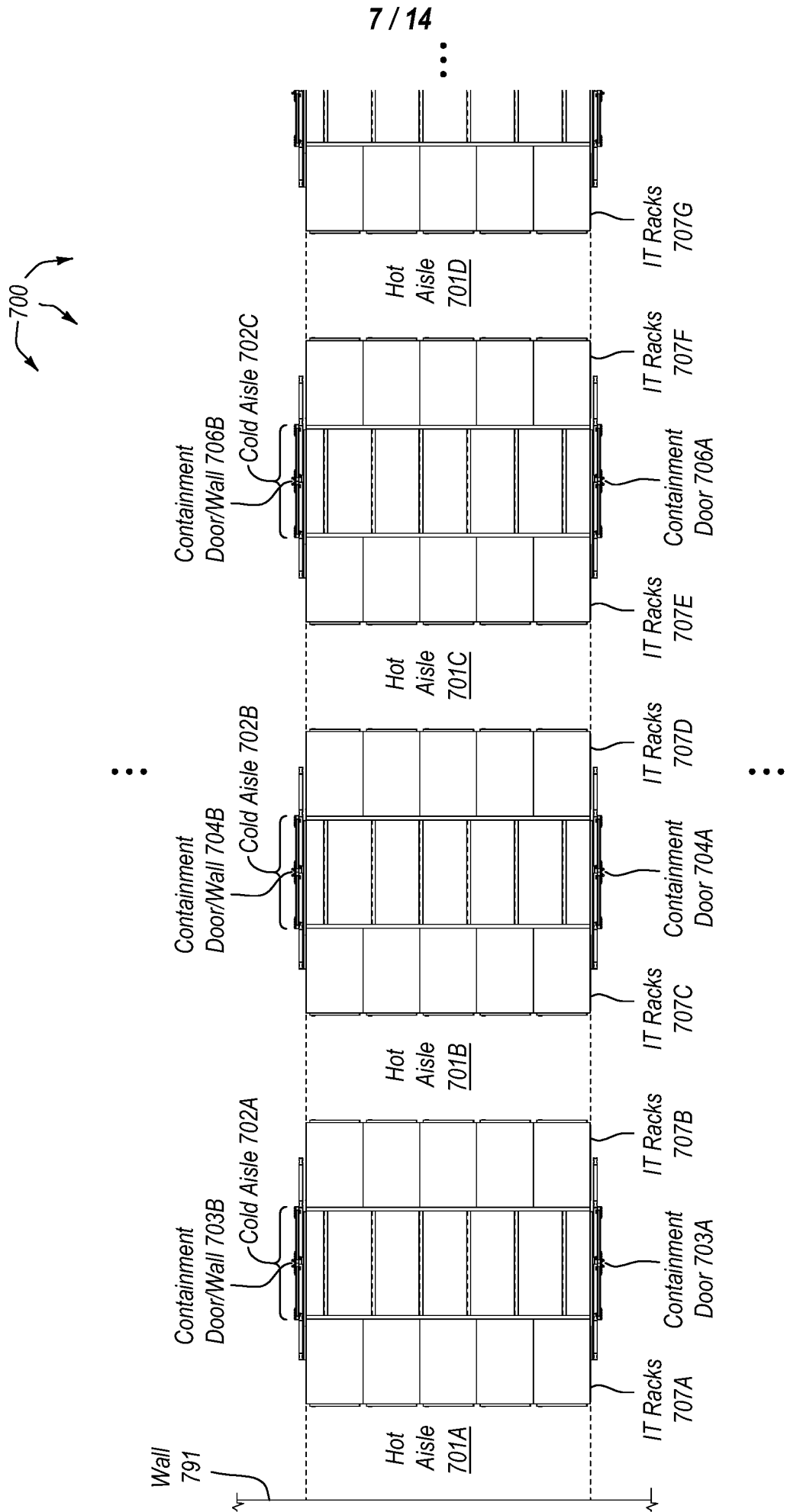
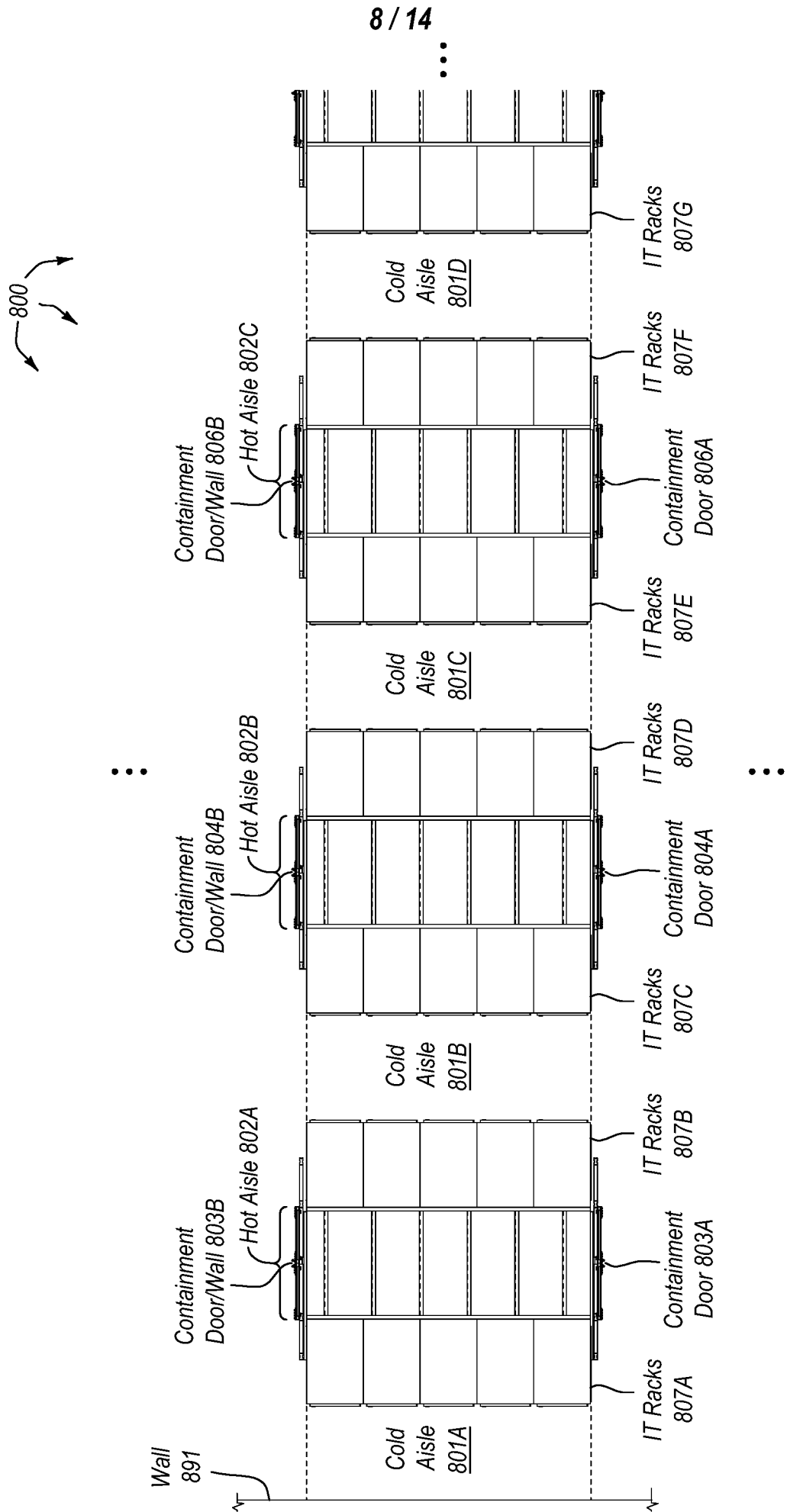


FIG. 7



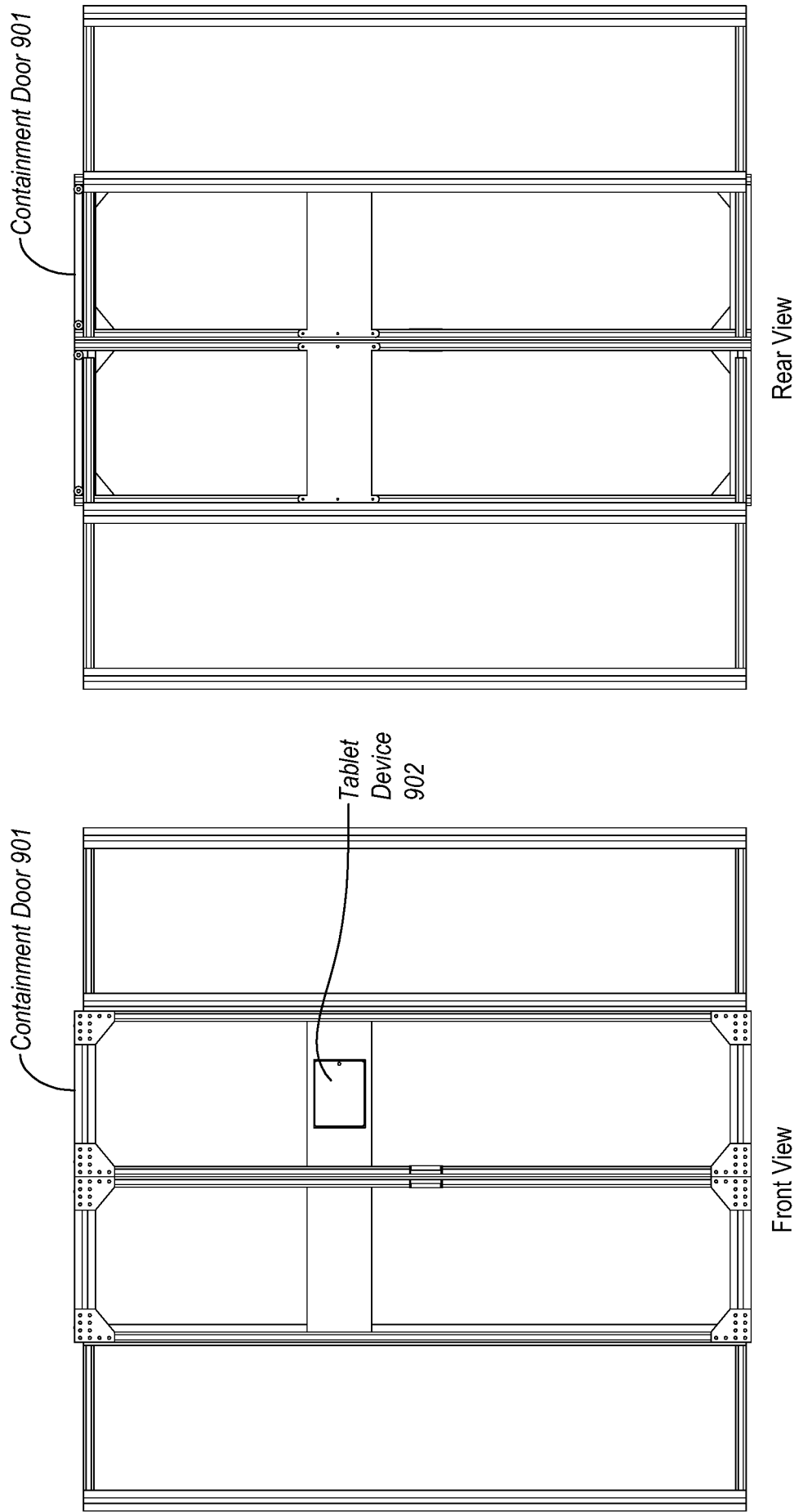


FIG. 9

10 / 14

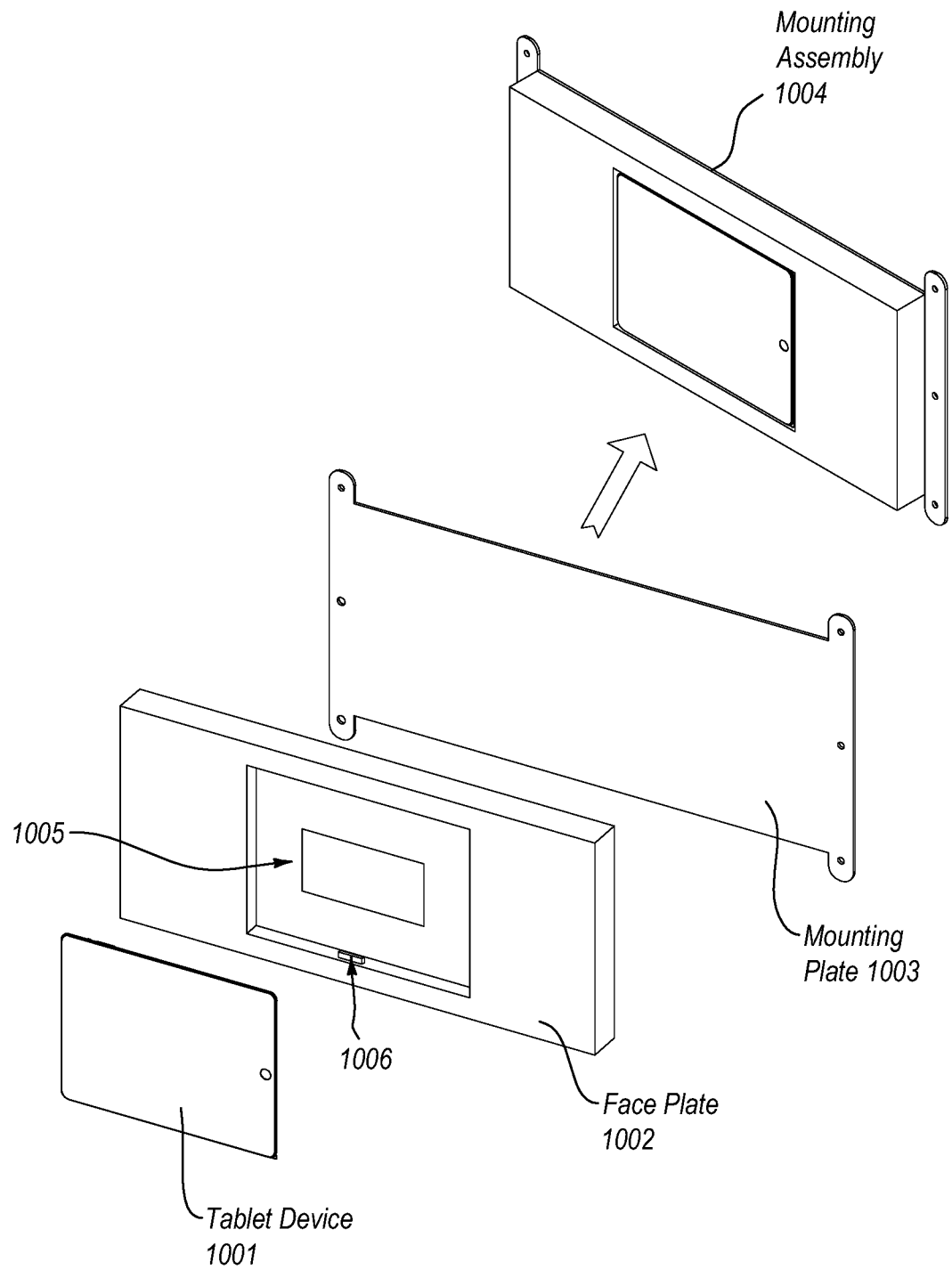


FIG. 10

11 / 14

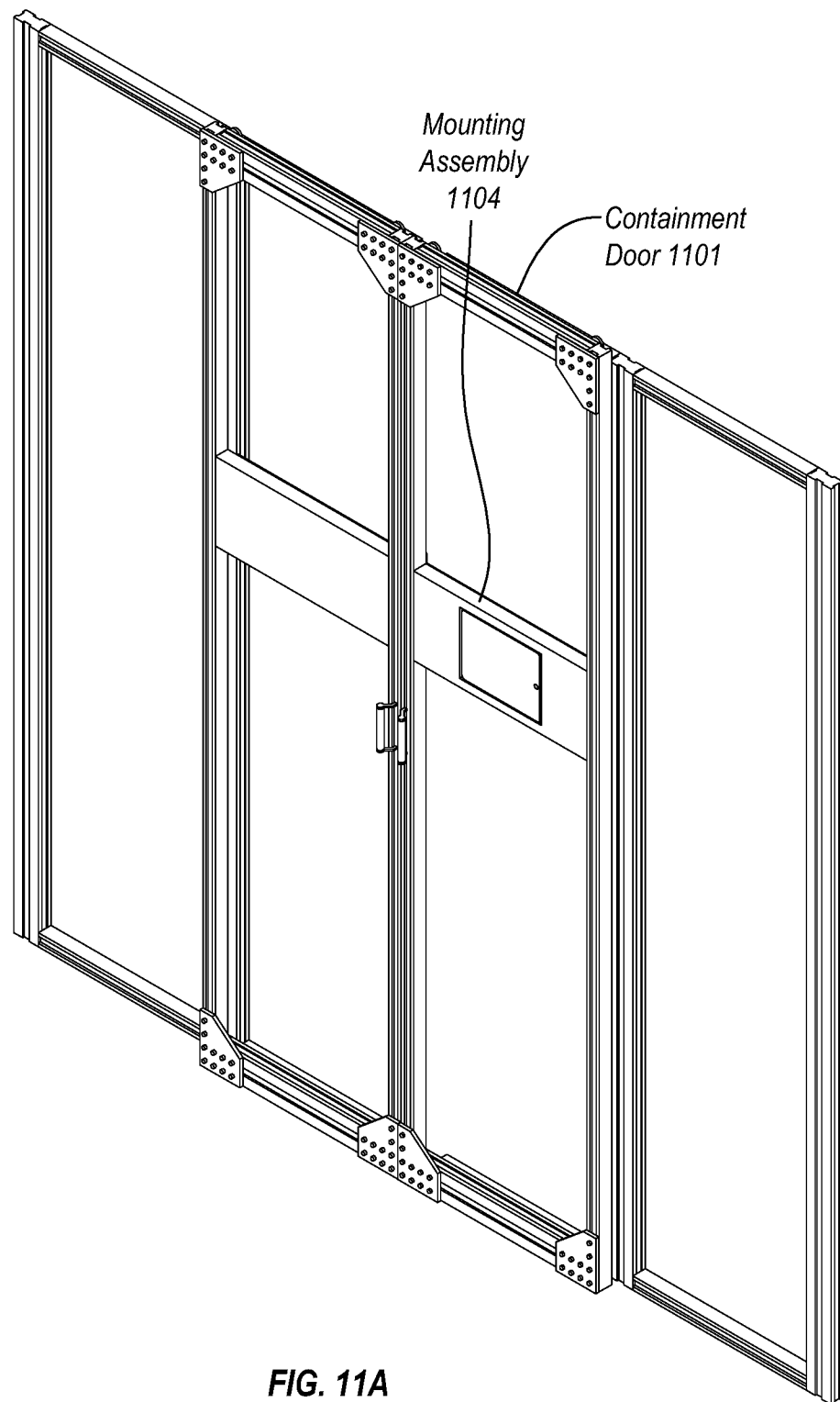


FIG. 11A

12 / 14

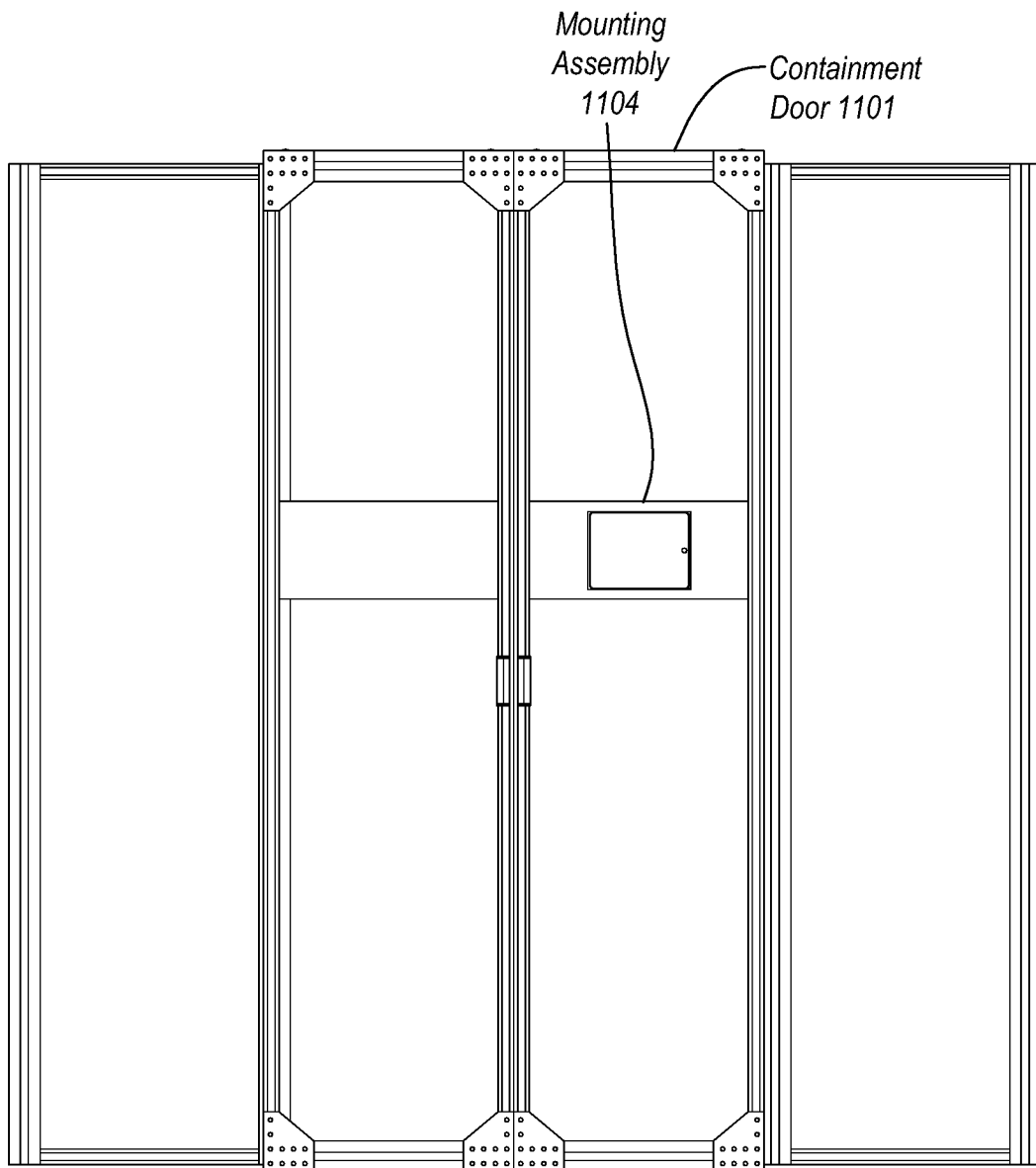


FIG. 11B

13 / 14

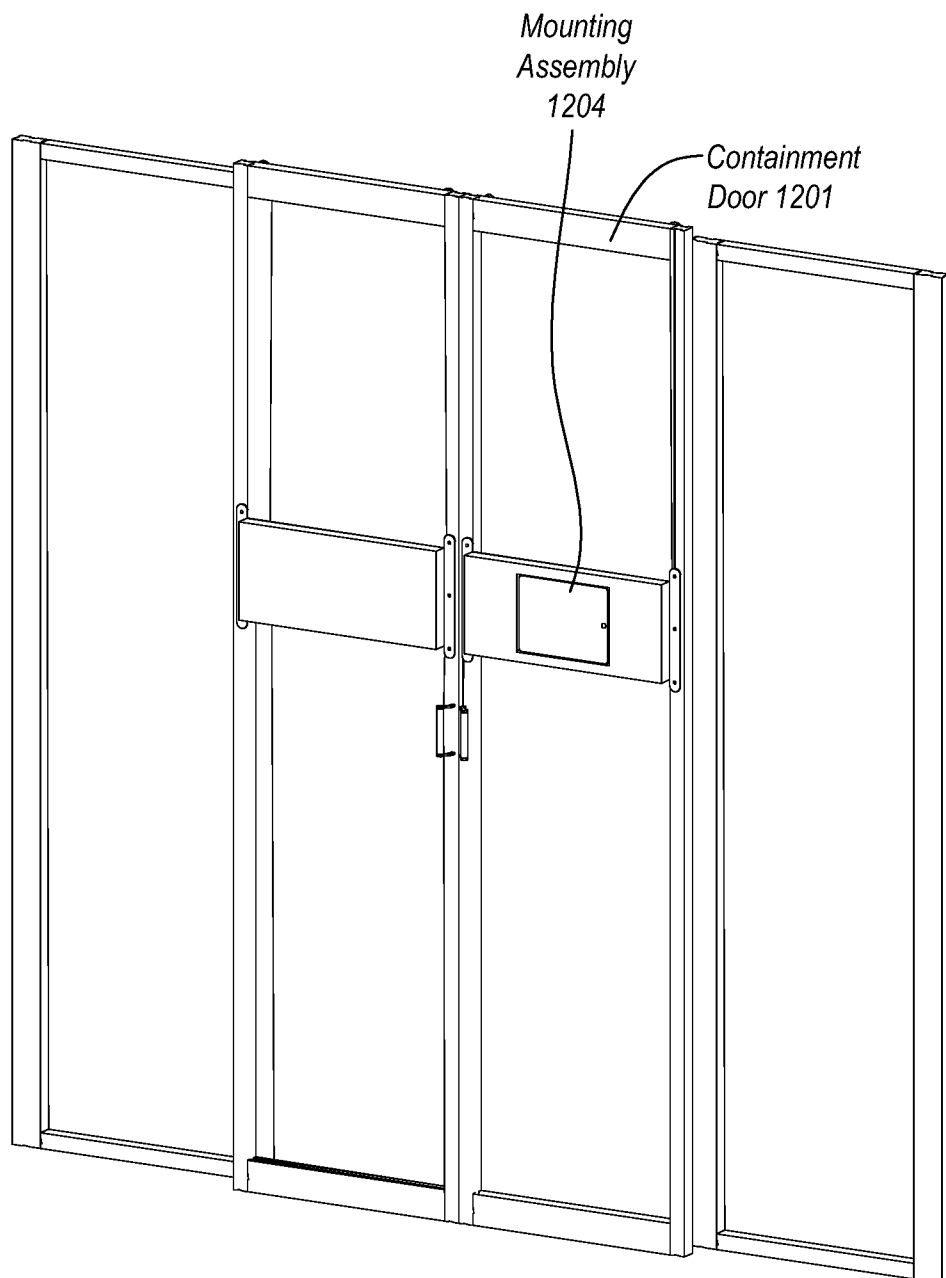


FIG. 12A

14 / 14

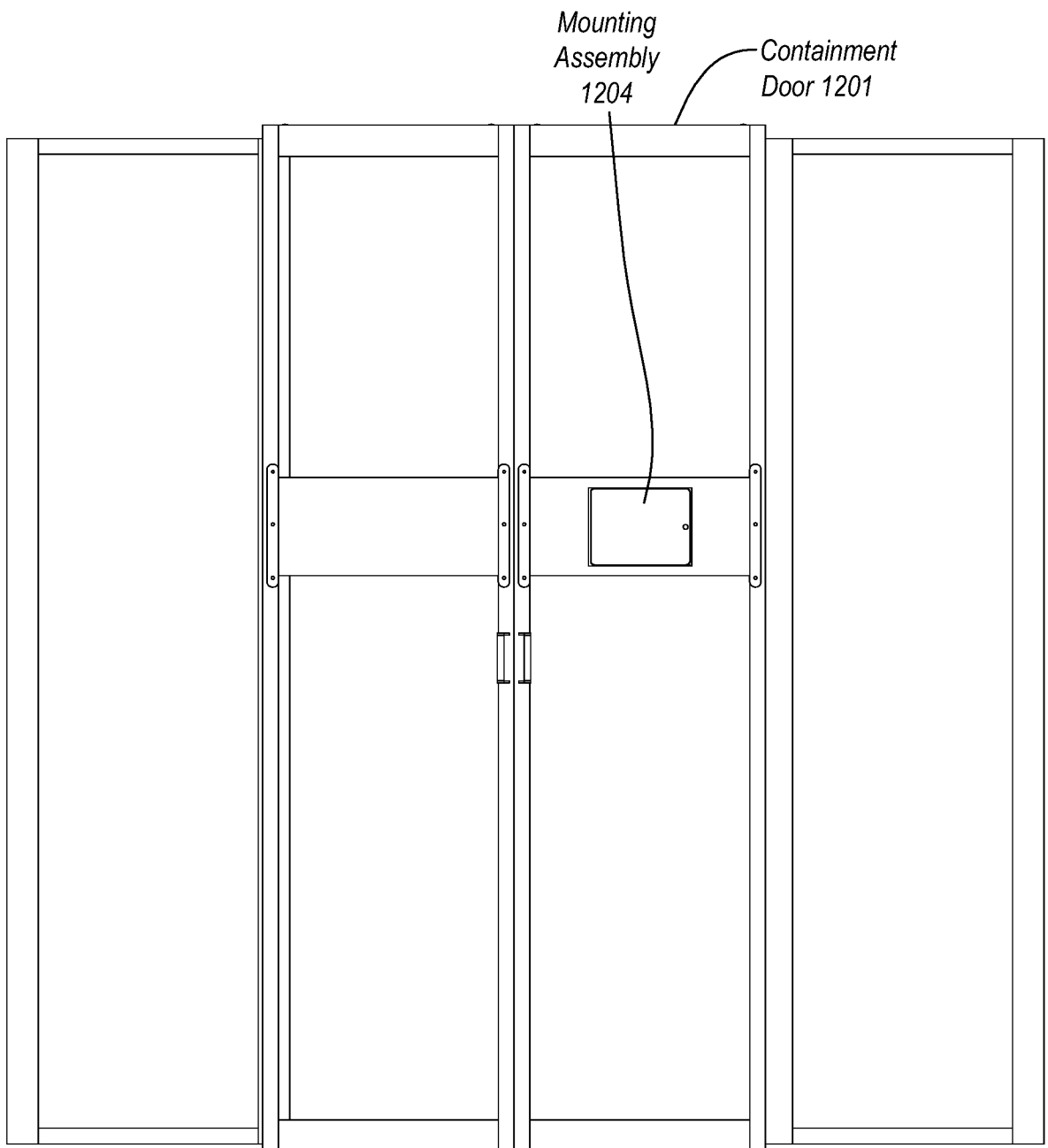


FIG. 12B

INTERNATIONAL SEARCH REPORT

international application no.

PCT/US2013/034171

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - F28F 7/00 (2013.01) USPC - 165/80.2 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC(8) - F24F 3/14; F25D 3/12, 17/06; F28F 7/00; H02B 1/00 (2013.01) USPC - 165/67, 77, 80.1, 80.2, 110, 111, 112, 114; Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched CPC: A23L 3/20; A63B 2220/40; F24F 3/1405; F25B 39/04; F25D 3/122, 17/02; F28B 1/02, 9/10; F28F 9/002; G06F 1/20, 1/181, 1/1601, 1/1616; G01N 9/12; G04D 7/1214; H023 1/056; H01L 23/467, 23/473; H05K 7/142, 7/20009, 7/20745 (2013.01) Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Orbit, Google Advanced Patents, Google		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0139887 A1 (SLESSMAN) 10 June 2010 (10.06.2010), see entire document.	1-32
Y	US 2009/0064705 A1 (MAGLINGER) 12 March 2009 (12.03.2009), see entire document.	1-32
Y	US 2009/0059523 A1 (MALLIA et al) 05 March 2009 (05.03.2009), see entire document.	16
A	US 7,800,900 B1 (NOTEBOOM et al) 21 September 2010 (21.09.2010), see entire document.	1-32
A	US 2009/0107652 A1 (VANGILDER et al) 30 April 2009 (30.04.2009), see entire document.	1-32
☐ Further documents are listed in the continuation of Box C. ☐		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 14 June 2013		Date of mailing of the international search report 01 JUL 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201		Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774