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(54) **INTEGRATED COMPUTER EQUIPMENT CONTAINER AND COOLING UNIT**

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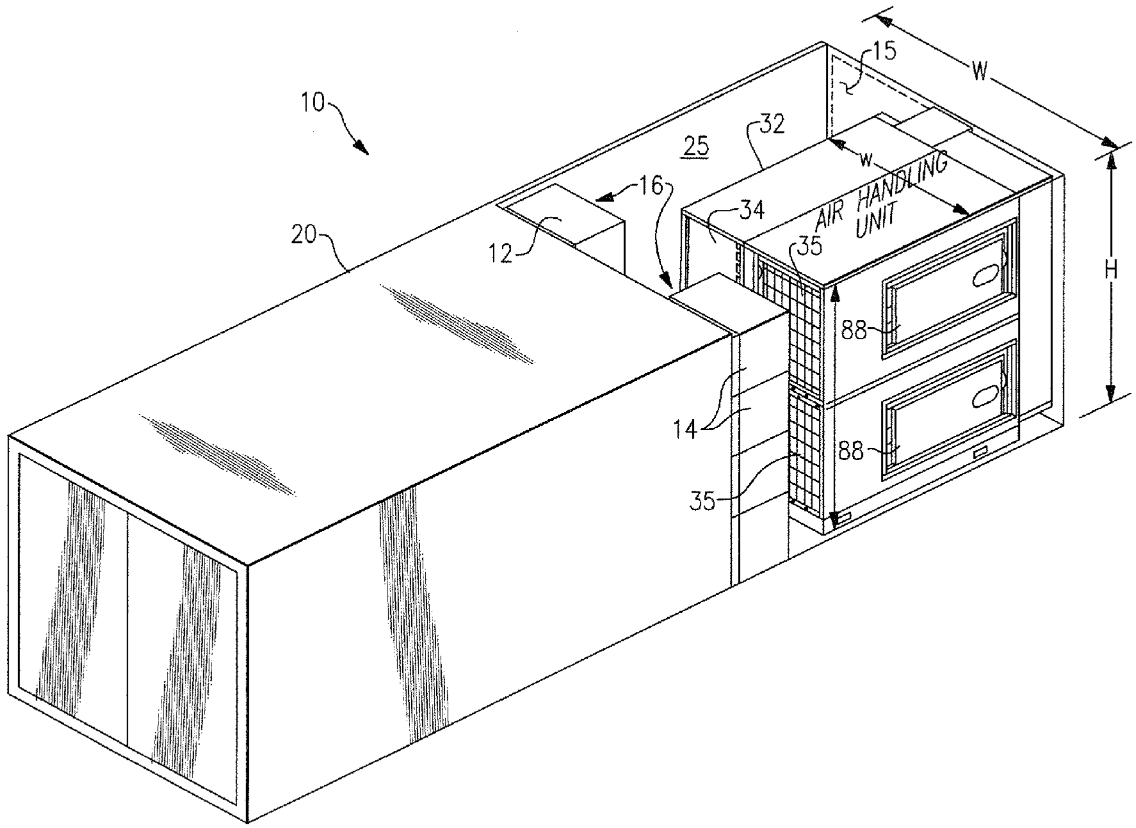
(57) **ABSTRACT**

A shipping container having an interior and a plurality of electronic equipment modules disposed within the interior of the container is cooled by an air conditioning unit adapted to be disposed within the interior of the container. The cooling can be assisted or assumed by use of an air side economizer cycle, or by use of a water side economizer cycle. The electronic equipment may include computing equipment and electronic data storage equipment.



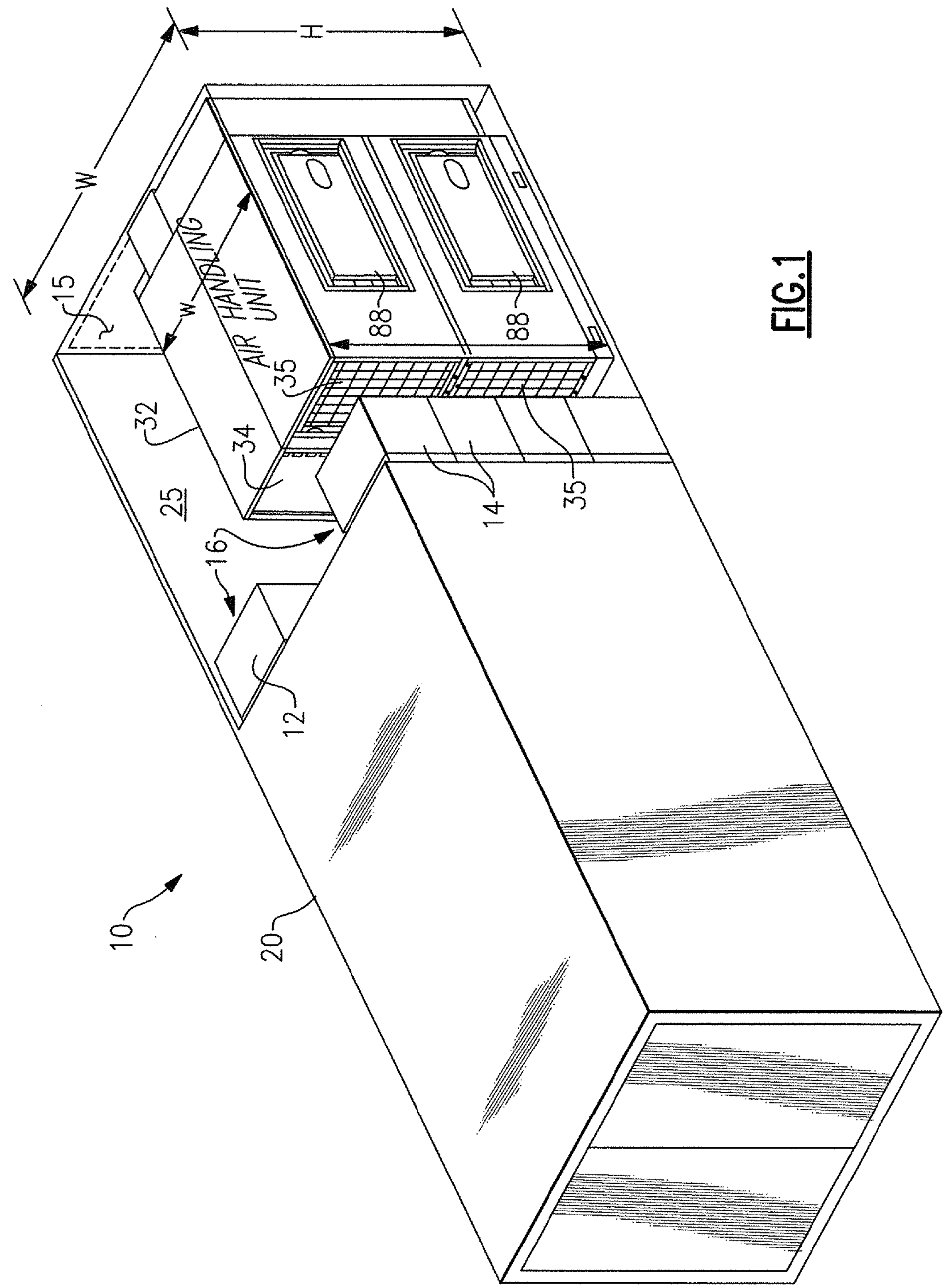
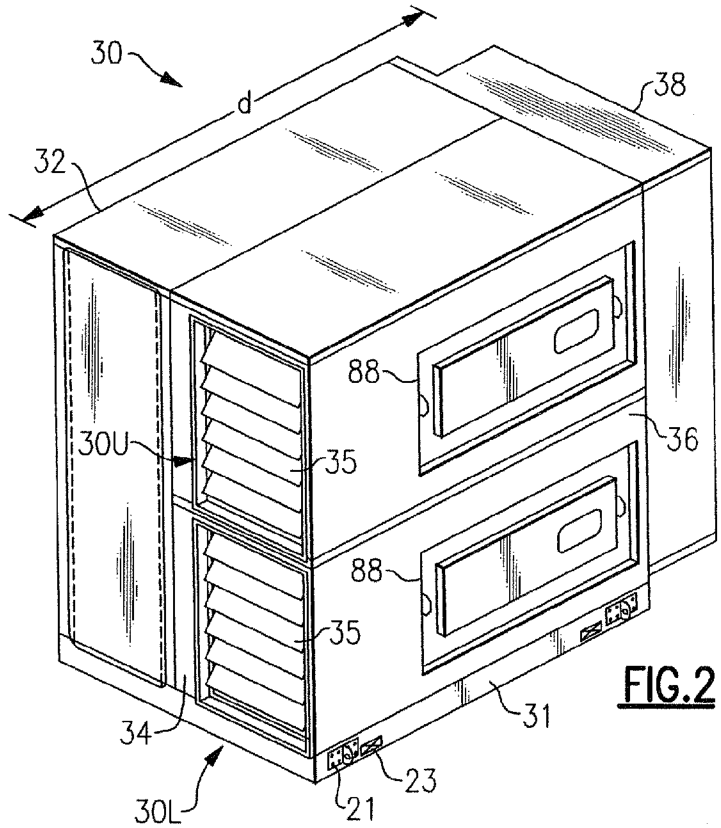


FIG.1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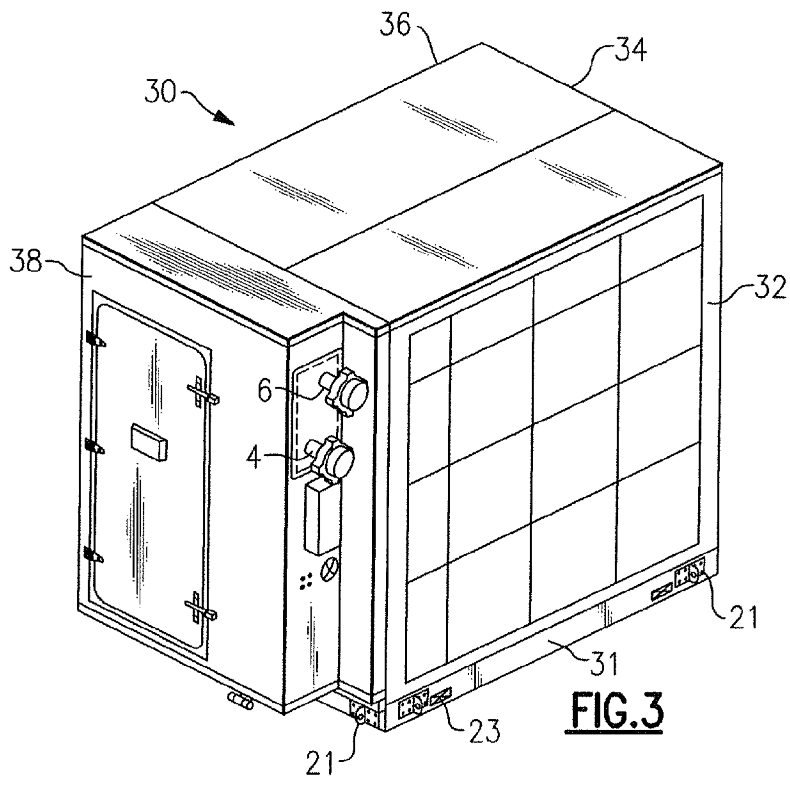
d
38
32
88
36
30U
35
88
35
34
31
21
23
30L

FIG.2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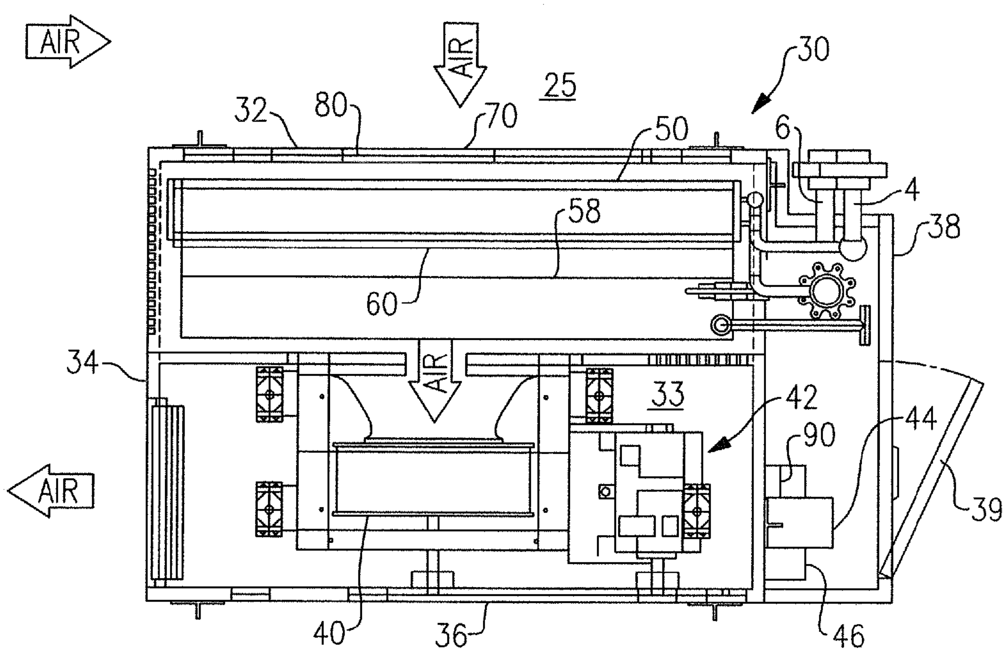
30
38
32
6
4
21
31
23
21

FIG.3


AIR
AIR
25
30
32
80
70
50
6
4
58
38
60
34
AIR
33
42
90
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39
40
36
46

FIG.4

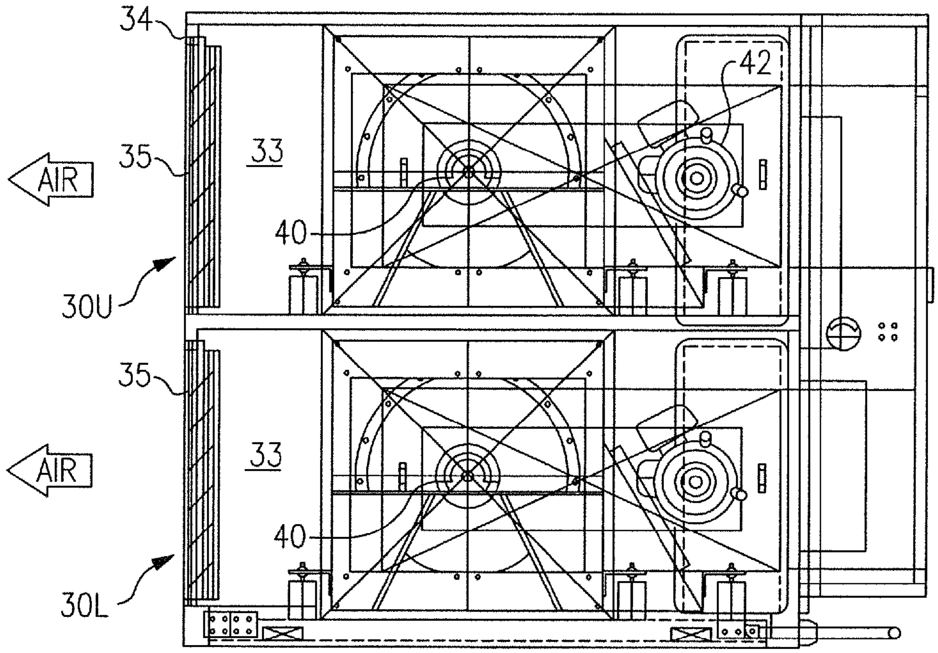
34
42
AIR
35
33
40
30U
35
AIR
33
40
30L

FIG.5

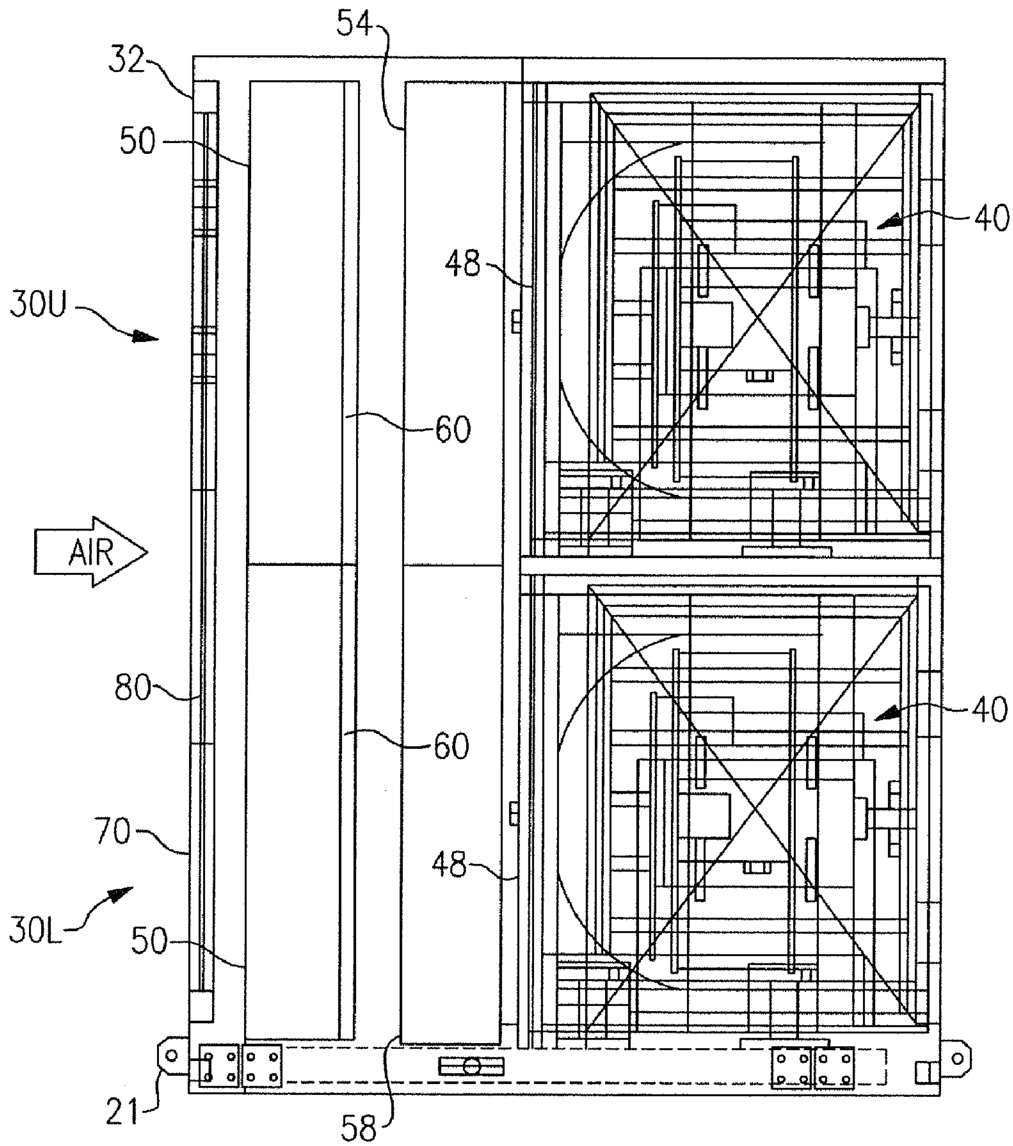

FIG.6

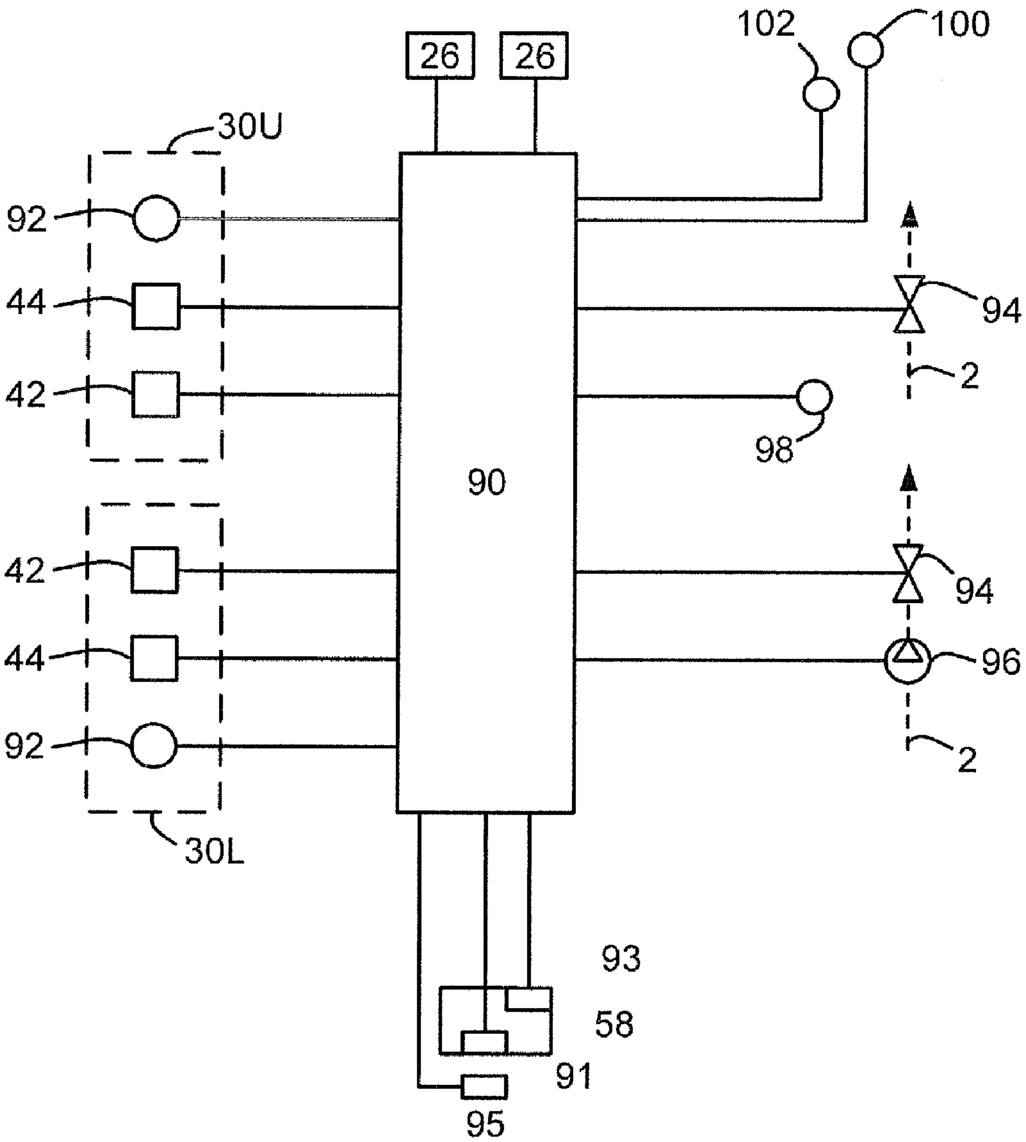

FIG. 7

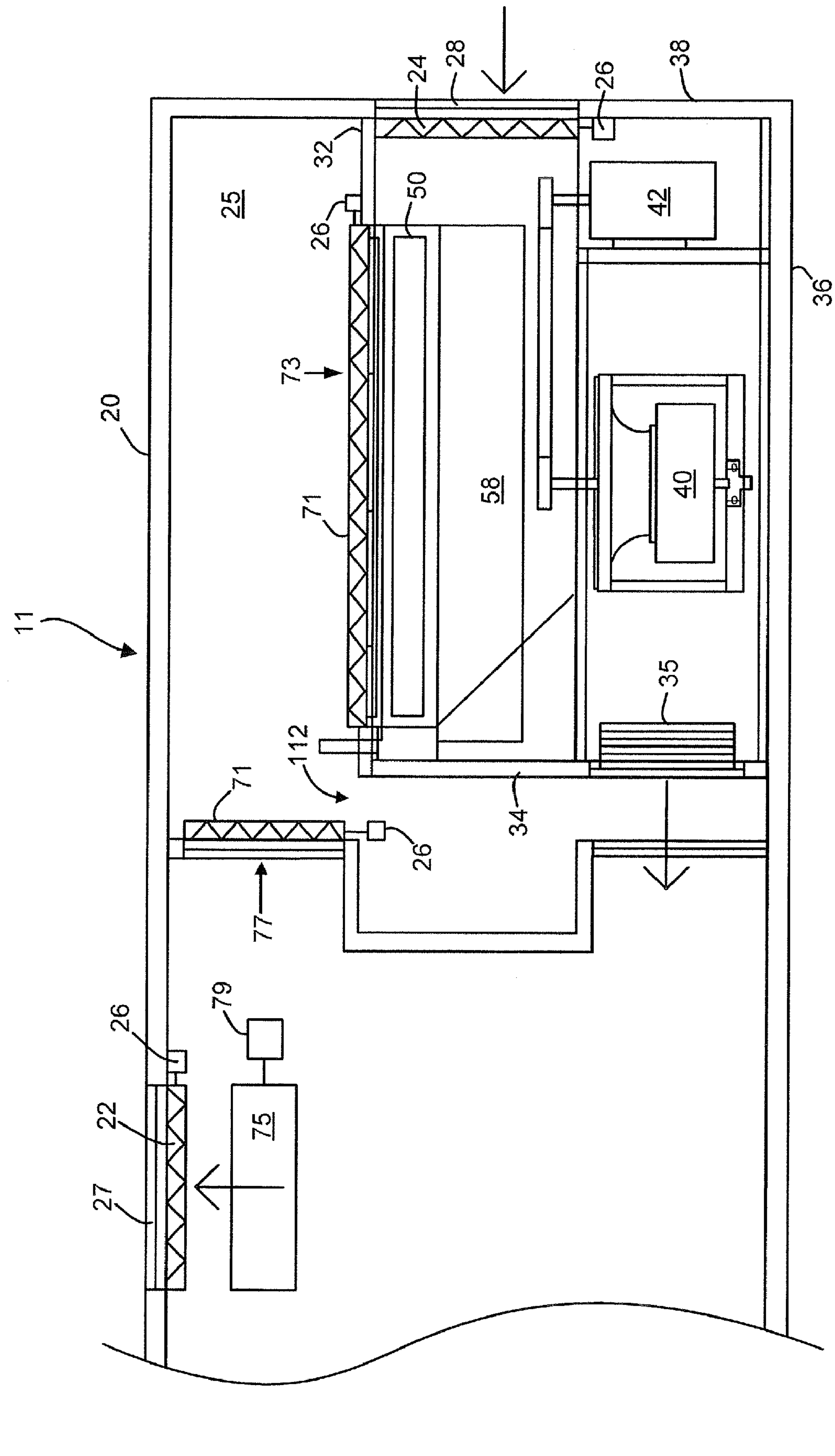

FIG. 8

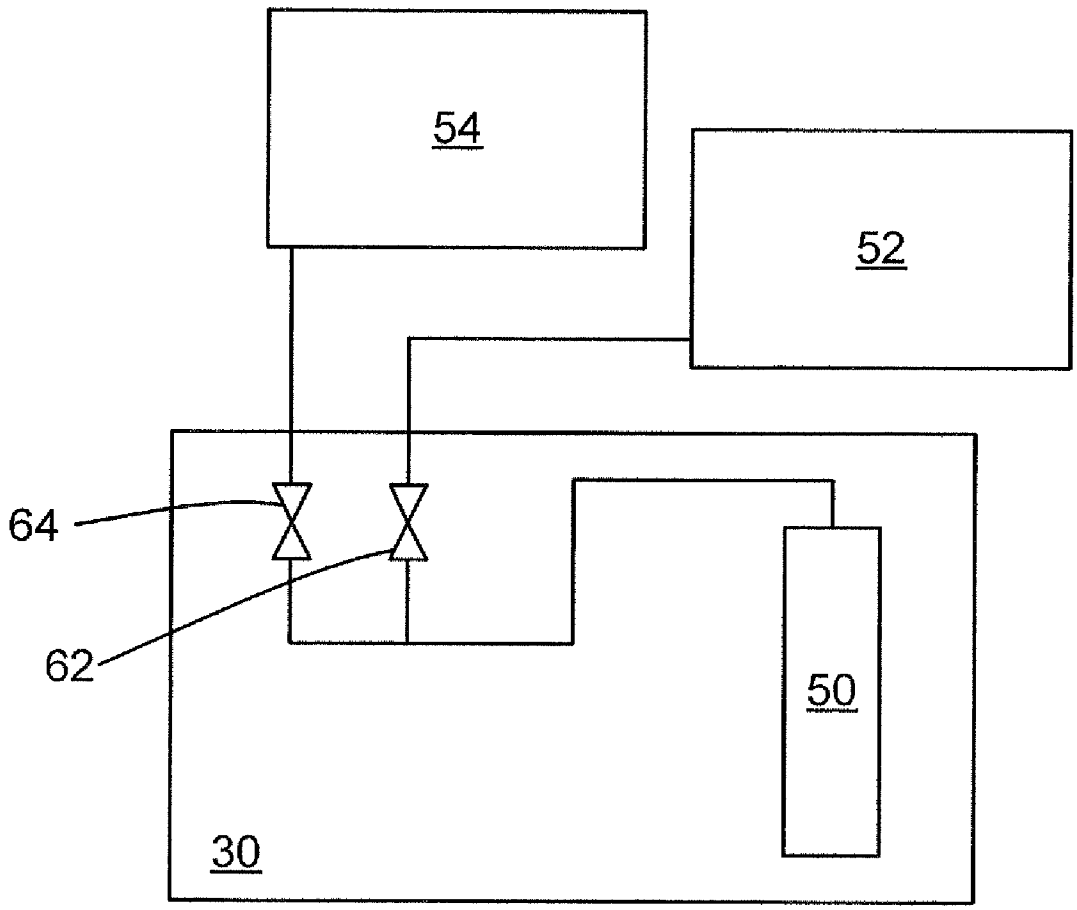

FIG. 9

INTEGRATED COMPUTER EQUIPMENT CONTAINER AND COOLING UNIT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation in part of International Patent Application No. PCT/US09/39873, filed Apr. 8, 2009, which claims the benefit of U.S. Provisional Application No. 61/050,502, filed May 5, 2008. International Patent Application No. PCT/US09/39873 is incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] This invention relates generally to transportable modular computer and information technology equipment centers, more particularly, to a transportable modular computer and information technology center having a cooling unit integrated therewith.

BACKGROUND OF THE INVENTION

[0003] Portable modular data centers are increasingly being used to provide additional computing and electronic storage data capability without the cost and time delay associated with the construction of a stationary data center. Such modular data centers typically house a plurality of electronic modules, either rack-mounted or shelf-mounted, within a transportable container. The electronic modules may be disposed on both sides of a central aisle extending the length of the container so that humans may access the equipment. Examples of the electronic modules include computer processors, storage modules such as random access memory, disc drives, compact discs, video disks and other computer equipment and electronic information storage devices. The transportable container may be an intermodal shipping container capable of being transported by truck, by rail car or by ship, or even by plane. To facilitate global portability, the container may conform to International Standard Organization (ISO) container manufacturing standards.

[0004] For example, U.S. Pat. No. 7,278,273 discloses a modular data center housed in an ISO compliant intermodal shipping container. The modular data center includes at least one computing module including a shipping container and a plurality of computing systems mounted on racks or shelves within the shipping container and configured to be shipped and operated within the shipping container. The modular data center also includes an additional shipping container housing a temperature control system for providing chilled air to one or more of the containers housing the computer modules.

[0005] The multitude of electronic modules disposed on racks or shelves housed within a data center enclosure collectively generate a significant amount of heat, for example, between 50 kW and 400 kW of sensible (dry) heat, during operation. Release of this heat into, and subsequent accumulation of the heat in the environment within the enclosure results in temperatures that could adversely impact the performance, reliability and useful life of the electronic modules and components thereof. Therefore, it is desirable to remove the heat produced by the electronic modules from the environment within the data center enclosure. For example, U.S. Pat. No. 7,365,973 discloses a cooling system for a data center wherein chilled coolant from an external source, such as a chiller unit, is circulated through a plurality of cooling racks positioned at selected locations within the data center enclosure for cooling air within the enclosed environment by circulating that air via fans mounted in the cooling racks through heat exchangers, also mounted in the cooling racks, in heat exchange with the chilled coolant.

SUMMARY OF THE INVENTION

[0006] An air conditioning unit is adapted to be installed in a shipping container having an interior and a plurality of electronic equipment modules disposed within the interior of the container. The air conditioning unit includes a casing having dimensions sized to be disposed within the interior of the shipping container. The casing has a forward wall facing the plurality of electronic equipment modules and a first side wall extending perpendicularly to the forward wall, and defines an interior chamber. An air inlet is provided in the first side wall opening in flow communication to the interior chamber and an air outlet in the forward wall, which is perpendicular to the first side wall, opening in flow communication to the interior chamber. An air mover is disposed within the interior chamber. The air mover has an inlet in flow communication with the air inlet and an outlet in flow communication with the air outlet. A heat exchanger is disposed within the interior chamber upstream with respect to air flow of the air mover for cooling the air flow passing through the interior chamber. In an embodiment, a mist eliminator may be disposed within the interior chamber downstream with respect to air flow of the heat exchanger. The mist eliminator may include a steel mesh screen.

[0007] To facilitate the return of air flow from the interior of the container, the casing of the air conditioning unit has a width that is less than a corresponding width of the container whereby an air plenum is formed adjacent the first side wall of the casing of the air conditioning unit when the air conditioning unit is disposed within the container. In an embodiment, the air conditioning unit is disposed within an intermodal ISO container. In an embodiment, the ISO container has a width of about 8 feet and the casing of the air conditioning unit has a width of about 6 feet.

[0008] At least one flow balancing plate may be disposed at the air inlet to the air conditioning unit upstream with respect to air flow of the heat exchanger for selectively distributing the air flow pass into the heat exchanger. In an embodiment, the perforated plate has a plurality of selectively sized and selectively arrayed openings therein. An air filter rack may be disposed at the air inlet to the air conditioning unit upstream with respect to air flow of the heat exchanger.

[0009] Economizer cycles can reduce the cooling burden of the air conditioning unit by using passive cooling sources. In one embodiment, an air side economizer circuit circulates external air through the container **20**. In another embodiment, a water side economizer circuit is utilized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a further understanding of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawing, where:

[0011] FIG. **1** is a perspective view, partly in section, of a modular data center and air conditioning unit housed in a shipping container;

[0012] FIG. **2** is a first perspective view of an exemplary embodiment of the air conditioning unit shown in FIG. **1**;

[0013] FIG. **3** is a second perspective view of an exemplary embodiment of the air conditioning unit shown in FIG. **1**;

[0014] FIG. **4** is a plan view looking down upon the air conditioning unit of FIG. **2**;

[0015] FIG. **5** is a side elevation view taken along line **4-4** of FIG. **4**;

[0016] FIG. **6** is a side elevation view taken along line **5-5** of FIG. **5**; and

[0017] FIG. **7** is a schematic diagram of an exemplary control system associated with the air conditioning unit.

[0018] FIG. **8** is a plan view looking down upon an alternate embodiment of the modular data center and air conditioning unit housed in a shipping container, illustrating apparatus associated with an air cooling economizer cycle.

[0019] FIG. **9** is a simplified schematic diagram illustrating apparatus associated with a water cooling economizer cycle, according to an alternate embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to FIGS. **1** and **2**, there is depicted an exemplary embodiment of a modular data center **10** including a plurality of electronic equipment **12** disposed on shelves or racks housed in a shipping container **20** and an air conditioning unit (ACU) **30** housed in an aft portion of the shipping container **20**. The electronic equipment may, for example include, but is not limited to, computer servers, computer processors, storage modules such as random access memory, disc drives, compact discs, video discs and other computer equipment and electronic information storage devices. The electronic equipment may be organized in electronic modules **14** that may be arranged in rows **16** disposed on both sides of a central aisle extending the length of the container or in any other desired arrangement permitting human access to the equipment. A container access door **15** may be provided in the aft wall of the container **20**. Additional container access doors may be provided in other walls of the container if desired.

[0021] The shipping container **20** may be an intermodal shipping container capable of being transported by truck trailer, rail car or ship. In an embodiment, the container **20** may conform to International Standardization Organization (ISO) container manufacturing standards. Typically, ISO containers have a width of 8 feet, a height of 8½ feet, and a length of 40 feet, although other lengths, shorter and longer, are common. However, containers of various other combinations of height, width and length may be used.

[0022] The ACU **30** has a casing having a first side wall **32** on the air inlet side of the ACU **30**, a forward wall **34**, a second side wall **36** opposite the first side wall, and an aft wall **38** opposite the forward wall **34**, and defines an interior chamber **33** therein. The ACU casing has a height, h, compatible with the height, H, of the container **20** and a depth, d, substantially less than the length of the container **20**. However, the ACU casing has a width, w, that is less than the width, W, of the container **20**, such that when the ACU **30** is positioned within the interior of the container **20**, a return air plenum **25** is formed between the air inlet side wall **32** of the ACU **30**. As will be explained in further detail hereafter, to remove heat from the environment within the interior of the container **20**, air from within the interior of the container **20** is drawn by air movers within the ACU **30** through the air plenum **25** into and through the ACU **30** and discharged therefrom through the louvered air outlets **35** in the forward wall **34** of the ACU **30**. In passing through the ACU **30**, the air passes in heat exchange relationship with a chilled coolant provided from a source (not shown) external of the container **20**, whereby the air is cooled, typically to a temperature in the range of about 55° F. (about 12.8° C.) to about 75° F. (about 23.9° C.), and the heat removed from the air is transferred to the coolant and discharged externally of the environment within the interior of the container **20**.

[0023] Referring now to FIGS. **2-6**, in particular, the air conditioning unit **30** includes an upper ACU module **30**U and a lower ACU module **30**L disposed in a stacked array. Each ACU module includes at least one air mover **40**, a heat exchanger **50** and a mist eliminator **60**. The ACU module may also include an air filter **70**. The stacked array of ACU modules **30**U and **30**L is, as noted previously, disposed in the aft portion of the container **20** with the air inlet side wall **32** of the ACU **30** facing the inlet air plenum **25** defined between the air inlet side **30** and the opposed inside surface of the container **20**.

[0024] The air movers **40** of the upper and lower ACU modules **30**U, **30**L are disposed in the chamber **33** extending along the side **36** of the ACU **30** opposite the air inlet side wall **32** of the ACU **30**. Each of the air movers **40** may include at least one plenum blower, such as, for example, a centrifugal fan, having its inlet in flow communication with the air inlet plenum **25** and its outlet in flow communication with a respective one of the air outlets **35** in the forward wall **34** of the ACU **30**. Each plenum blower **40** may be driven by an electric motor **42** operatively associated therewith, either through a belt drive or a direct mechanical connection. Each electric motor **42** is driven via a motor drive **44**, which may be fixed frequency drive or a variable frequency drive **44** associated with an electric service/supply panel **46** adapted to be connected to an external electric power source.

[0025] If driven by a variable frequency drive, each motor **42** may be a variable speed motor whereby the speed of the motor **42** may be selectively varied to vary the air flow capacity of its associated blower **40** to match the cooling demand. In this case, each plenum blower **40** may be sized to provide 100 percent of the required cooling capacity at maximum design demand. By over sizing each blower **40** and providing variable speed capability, air mover redundancy is provided. In the event that one (or more) blower(s) is out of operation, maximum design cooling operation may still be met by the remaining active blowers. A shutoff damper assembly **48** may be provided in operative association with each of the plenum blowers **40** to permit a failed blower **40** to be isolated by closing the dampers of the shutoff damper assembly **48** to prevent air flow into the failed blower.

[0026] Each heat exchanger **50** is disposed within the ACU **30** so as to extend along the air inlet side **32** of the ACU **30**, downstream with respect to air flow of the air inlet opening in the air inlet side wall **32** of the ACU **30** and upstream with respect to air flow of the plenum blower **40**. Each heat exchanger **50** may include one or more heat exchanger tube banks arranged in parallel with respect to coolant flow through the tubes thereof and in series with respect to the flow of air over the tubes thereof. Each tube bank is connected in a conventional manner to an external supply of chilled coolant (not shown), such as, for example, but not limited to, chilled water from a chiller, or chilled refrigerant from a refrigerant condensing unit disposed external of the container **20**, or chilled refrigerant cooled in an external water tower condenser. In operation, chilled coolant is pumped through the tubes of the heat exchanger **50** to cool and remove heat from air drawn by means of the plenum blowers **40** from within the compartment of the container **20** housing the electronic equipment **12**, through the air plenum **25**, over the tubes of the heat exchanger **50**, and through the blowers **40** to be discharged therefrom through the louvered air outlets **35** back into the compartment of the container **20** housing the electronic equipment **12**. In this manner, heat produced within the container **20** due to operation of the electronic equipment is removed from the closed environment within the interior of the container **20** and transferred to the coolant passing through the tubes of the heat exchanger **50**. The warmed coolant having traversed the tubes of the heat exchanger **50** is returned to the external source of chilled coolant whereby the heat produced due to the operation of the electronic equipment is effectively rejected from the environment within the container **20**.

[0027] In an alternative embodiment, the modular data center **10** includes an air side economizer circuit. The air side economizer circuit, during operation, eases or ceases the burden on the external supply of chilled coolant (not shown) to cool the air in the container **20**. Referring to FIG. **8**, the apparatus for the air side economizer circuit **11** includes an exhaust air vent **27** and an associated exhaust air damper **22**, and an intake air vent **28** and an associated intake air damper **24**. The exhaust air vent **27** and intake air vent **28** are each openings in a wall of the container **20** for allowing air to exit the interior of the container or flow into the container, respectively. A grill might also be attached at the vents, for instance, to keep out intruders, such as persons or non-human animals.

[0028] Each respective damper **22** and **24** is positioned in flow communication, through the air vents **27** and **28**, between the air internal to the container **20** and the air external to the container **20**. This position can be achieved by placing the dampers **22**, **24** directly in the respective vent **27**, **28**, thereby aligning the dampers **22**, **24** with the wall. This position can also be achieved by attaching the dampers **22**, **24** directly to the respective vent **27**, **28**. Also, this position can be achieved by attaching each of the dampers **22**, **24** to the respective vent **27**, **28** indirectly, such as by using a duct to connect between them.

[0029] Intake air vent **28** is shown in FIG. **8**, with its associated intake air damper **24**, situated in the aft wall of the container **20** and/or the aft wall **38** of the air inlet side of the ACU **30**, in order to provide a closeable path to take air external to the container **20** into the air conditioning unit. Through air vent **28** and air damper **24**, blowers **40** can draw air into the ACU **30** and discharge it therefrom through the louvered air outlets **35** in the forward wall of the ACU **30**. Air circulates through the portion of the container **20** housing the plurality of electronic equipment **12**. Air is discharged from the container **20** through air vent **27** and its associated air damper **22**, which provide a closeable path from the container **20** to the outside. The air vent **27** and air damper **22** are situated at a wall of the container **20** in order to promote air circulation over the electronic equipment from the ACU **30**. In FIG. **8**, the placement is at a side wall shared by the plenum **25**, except in the portion of the container **20** housing the plurality of electronic equipment **12**.

[0030] Positioning the intake air vent **28** and its associated damper **24** in this close proximity to blower(s) **40** increases the draw of outside air into the air conditioning unit **30** and blower **40**. When the damper **24** opens, negative pressure in the plenum **25** is relieved, causing the air pressure at the exhaust air damper **22** to change from negative to positive, which creates the pressure gradient required to exhaust the heated airflow. In this embodiment, the supply fan(s) (i.e. blowers **40**), which supply air in the air conditioning unit **30** to the rest of the container **20**, are sufficient to circulate external air into the container, around the container, and out through the exhaust air damper **22** without the use of any additional return fan, such as one positioned to assist blowing air out of the container **20**.

[0031] A recirculation air damper **71** can optionally be used to further prevent air recirculation. Preventing air recirculation using the recirculation air damper **71** also reduces a need to use a return fan. The recirculation air damper **71** can be positioned at an ACU inlet vent **73** in order to close the pathway for air flow from the plenum **25**, through the ACU inlet vent **73**, into the air conditioning unit **30**. Closing the ACU inlet vent **73** reduces or prevents air circulated from the air conditioning unit **30** through the container **20** from being recirculated through the air conditioning unit **30**. In this embodiment, the more air tight the plenum **25** is, the more efficient is the circuit. For instance, closing the gap **112** shown in FIG. **8** seals air exiting the air conditioning unit **30** through the louvered ducts **35** from being back drawn through a plenum inlet vent **77** and out of the container **20** through the exhaust air damper **22**.

[0032] Alternatively, the recirculation air damper **71** can be positioned to close a pathway through a plenum inlet vent **77** for air flow from the portion of the container **20** housing the plurality of electronic equipment **12** to the plenum **25**. In this latter position, the recirculation air damper prevents air from exiting into the plenum **25**, thereby eliminating extra area for air to flow and possibly leak back into a path of recirculation. Closing the recirculation air damper **71** at either ACU inlet vent **73** or plenum inlet vent **77** increases the draw of air through the intake air damper **24** and forces air to exit through the exhaust air vent **27**. Again, however, closing gap **112** will help prevent air exiting the air conditioning unit **30** through the louvered ducts **35** from short circuiting its way back to the air intake side of the air conditioning unit **30** by way of plenum **25**. Coordinating the use of the recirculation damper **71** at both vents **73** and **77** can also prevent leaking to assure air recirculation is 100% prevented.

[0033] Intake air vent **28** and intake air damper **24** can be positioned alternatively on a wall of the container to provide flow communication between the air external to the container **20** and the plenum **25**. In this case, the recirculation air damper **71** can be positioned to close the air pathway through the plenum inlet vent **77**. Closing air flow through the ACU inlet vent **77** increases the draw of air through the intake air damper **24** and the exhaust of air through the exhaust air damper **22**. Furthermore, this positioning of the intake air vent **28** and its associated air damper **22** can be useful when using the air side economizer cycle **11** simultaneously with the heat exchanger **50**. External air that is cooler than the air exiting the container **20** through the exhaust air vent **27** can be further cooled as it enters the air conditioning unit **30** at ACU inlet vent **73** and passes thoroughly over the heat exchanger **50**.

[0034] Air dampers **22**, **24** and their associated air vents **27**, **28** can be positioned in alternative locations or on alternative walls within the portion of the container **20** housing the plurality of electronic equipment **12**. For instance, the exhaust air damper **22** and the air vent **27** can alternatively be situated in the forward wall of the container **20**, or in the side wall opposite the one shown holding the air damper **22** in FIG. **8**. In each of these cases, closing the recirculation damper **71**

positioned at either the vent **73** or the vent **77** promotes the flow of air to exit the container **20** through the exhaust air damper **27** and the exhaust air vent **22**.

[0035] When the intake air vent **28** and its associated damper **24** intake air directly, or through a duct, to the air conditioning unit **30**, closing the recirculation air damper **71** at either the vent **77** or the vent **73** promotes the flow of air to exit the container **20** through the exhaust air vent **27** and its associated damper **22**. Closing recirculation damper **71** at the vent **73** eliminates the risk of the blower(s) drawing air from a leak or unsealed path from the plenum **25** to heated air. Also, in this case, the exhaust air vent **27** and its associated damper **22** can be located in a wall of the container **20** at the plenum **25** to exhaust air from the plenum **25** rather than the portion of the container **20** housing the plurality of electronic equipment **12**.

[0036] To further help promote air flow exiting the container through exhaust air vent **27** and exhaust air damper **22**, for instance, when complete recirculation is not achieved, an optional return fan **75**, such as a centrifugal fan, can be used. The return fan **75** is positioned in flow communication with the exhaust air damper **22**. The return fan **75** may be driven by an electric motor **79** operatively associated therewith, either through a belt drive or a direct mechanical connection. The electric motor **79** may be driven by a fixed frequency drive or a variable frequency drive (not shown) associated with an electric service/supply panel (e.g. the electric service/supply panel **46** illustrated in FIG. **4**) adapted to be connected to an external electric power source.

[0037] If driven by a variable frequency drive, the motor **79** may be a variable speed motor whereby the speed of the motor **79** may be selectively varied to vary the air flow capacity of the return fan **75** to match the cooling demand.

[0038] Each air damper **22**, **24**, **71** is opened or closed by an actuator **26** operatively associated therewith. Each actuator **26** is connected to an external electric power source (not shown), possibly through an electric service/supply panel (e.g. the electric service/supply panel **46** illustrated in FIG. **4**) adapted to be connected to the external electric power source.

[0039] In operation, when the air temperature external to the container **20** is below a predetermined external air temperature set point, the air dampers **22**, **24** open. Air movers **40** draw air into the ACU **30** through air damper **24**, circulate the drawn air amongst the electronic equipment **12** in the container **20**, and expel the drawn air through the air damper **22**. When a return fan **79** is used, it further blows air out of the container **20** through the exhaust air damper **22**. When a recirculation air damper **71** is used, it operates in coordination to achieve the desired air flow and the resultant desired cooling. Generally, damper **71** closes when dampers **22** and **24** are open.

[0040] The set point can be adjusted as necessary, depending on the amount of heat required to be removed. A typical application might require cooling approximately 300 kW of dry heat, while any amount in the range from 50 kW to 400 kW might be required. The operating speed of the air movers **40** is also adjusted as required depending on the air temperature internal and external to the container **20** and the required amount of heat to be removed from the container **20**. As an example, if 300 kW of heat is required to be removed from the container **20**, and the external air temperature is approximately 60 degrees Fahrenheit, then the air cooling economizer cycle must intake and expel 30,000 CFM of air in order to deliver air at 87 degrees Fahrenheit and avoid using the external supply of chilled coolant (not shown).

[0041] Referring to FIG. **9**, a further embodiment includes a water cooling economizer cycle, that, during operation, transfers in part or in whole, the cooling burden from an active coolant chiller **52** to a passive fluid cooler **54**. An active chiller synthetically chills. A refrigerant condensing unit is an example. A passive fluid cooler allows heat to be removed from the coolant using natural resources which may be available. Examples of passive fluid coolers include, but are not limited to, water towers, rivers, lakes, and reservoirs.

[0042] The active chiller **52** and the passive fluid cooler **54** are located external to the container **20**. The active chiller **52** is connected to the tube banks of the heat exchanger **50** in each ACU module **30**U, **30**L. An active chiller valve **62** exists either inside the ACU **300**, or between the ACU **300** and the passive fluid cooler **54**. The passive fluid cooler **54** is also connected to the tube banks of the heat exchanger **50** in each ACU module **30**U, **30**L. A passive fluid cooler valve **64** exists either inside the ACU **300**, or between the ACU **300** and the passive fluid cooler **54**. Alternatively, valves **62**, **64** can be a series of valves to appropriately achieve the same function.

[0043] In operation, valves **62**, **64** open and close, inversely, to route the chilled coolant to/from the passive fluid cooler **54** or the active chiller **52**, depending on the temperature of the air, the temperature of the passively chilled coolant external to the container **20**, the temperature of the coolant in the ACU **300**, the humidity external to the container, and/or the amount of heat required to be removed from the container **20**. By "open and close inversely", it is meant that when the valve **62** is selectively opened, the valve **64** is closed, and conversely, when the valve **64** is selectively opened, the valve **62** is closed. When cooling is not required, both valves **62**, **64** may be closed. For example, if the air temperature external to the container **20** is 58 degrees Fahrenheit, and the ACU **300** requires an inlet coolant temperature of 65 degrees Fahrenheit, then it is economical for the valves **62**, **64** to route the coolant exiting the ACU **300** to the passive fluid cooler (e.g., a cooling tower) to be naturally cooled before returning to the container **20**. The valves **62**, **64** can be self-actuated. Alternatively, separate actuators (not shown) operatively connected to the valves **62**, **64** can be controlled separately. If necessary, the self-actuated valves, or each actuator (not shown) can be connected to an external electric power source (not shown), possibly through an electric service/supply panel (e.g. the electric service/supply panel **46** illustrated in FIG. **4**) adapted to be connected to the external electric power source. Further, separate heat exchangers may be coupled to the active and passive fluid coolers.

[0044] A mist eliminator **60** may be disposed in the path of the air flow passing through the ACU **30**. Moisture may enter the closed environment within the container **20** from the outside when humans make entry into the container **20** to access the electronic equipment housed therein. Additionally, moisture may condense out of the air within the closed environment when the air temperature therein drops, such as when the electronic equipment is shut-down, and therefore not generating heat, or the outside temperature drops significantly. Upon start-up of the ACU **30**, this condense moisture will be re-entrained into the sir flow and will be removed therefrom before the electronic equipment is booted up. In the exemplary embodiment depicted in the drawing, a mist eliminator **60** is disposed downstream heat exchanger **50** with respect to air flow. Although most of the moisture in the air flow entering the heat exchanger **50** will condense on the outside of the tubes and drain into a condensate pan disposed beneath the heat exchanger **50**, the mist eliminator **60** will collect those moisture droplets that may be carried over in the air flow passing from the heat exchanger **50**. The mist eliminator **60** will also function to help balance airflow across the heat exchanger **50**. The mist eliminator **60** may of conventional design. In an embodiment, the mist eliminator **60** comprises a steel mesh screen.

[0045] An air filter rack **70** having a framework supporting one or more air filters may be disposed at the air inlet in the air inlet side wall **32** of the casing of the ACU **30** upstream with respect to air flow of the heat exchanger **50**. The air filters function to remove dust, dirt and other debris that may be entrained in the air flow from the compartment of the container **20** housing the electric equipment. Dirt, dust and other debris may be brought into the closed environment within the container **20** when humans enter therein to service, maintain or replace the electronic equipment **12** housed therein. The air filter rack **70** may be of conventional design.

[0046] Additionally, one or a plurality of flow balancing plates **80** may be disposed in the ACU **30** upstream of the heat exchanger **50** either in the filter rack **70** or external to the air inlet to the ACU **30**. The flow balancing plates **80** may comprise perforated sheets having a plurality of opening therein arrayed in a desired pattern or non-perforated, solid sheets. Those skilled in the art will recognize that the distribution of air flow from the air plenum **25** into the heat exchanger **50** may be selectively adjusted to provide a uniform flow distribution across the face of the air inlet to the ACU **30** by selective sizing and arrangement of the openings in the perforated flow balancing plates **80**. If desired, the flow balancing plates **80** may be disposed and supported in the supporting framework of air filter rack.

[0047] The ACU **30** may also include a controller **90** for controlling the operation of each of the air conditioning modules **30**U and **30**L. The controller **90** may be located within the electrical panel for ready access via the container doors **15** at the end of the container **20**. Referring now to FIG. **7**, in particular, the controller **90** monitors each of the respective discharge air temperature sensors **92** associated with the blowers **40**. Each discharge air temperature sensor **92** may be located in the discharge duct of its associated blower **40**. The controller **90** also monitors the temperature of the coolant entering and the temperature of the coolant leaving each of the heat exchangers **50** associated with the air conditioning modules **30**U and **30**L via coolant temperature sensors **98**. The controller **90** also controls the variable frequency drives **44** to vary the speed of the fan motors **42** to vary the air flow delivered by each of the blowers **40**. The controller **90** also controls the flow of coolant through the respective heat exchangers **50**, for example by opening, closing or modulating a coolant flow control valve **94** disposed in the coolant supply line **2** to the respective heat exchangers **50** if the ACU **30** is associated with an external water chiller, or starting and stopping a compressor **96** in conjunction with modulating a refrigerant flow control valve **94** if the ACU **30** is associated with an external refrigerant condensing unit (in which case the compressor may be located off-board the container) or a water tower condensing unit (in which case the compressor may be located on-board). The controller **90** processes the discharge air and the coolant temperature measurement signals received and in response thereto varies the air flow and/or water flow as appropriate to maintain a desired discharge air temperature, typically in the range of about 55° F. (about 12.8° C.) to about 75° F. (about 23.9° C.), as well as to optimize the efficiency of the cooling system, including the external coolant supply device, for example a water chiller or a refrigerant condensing unit. It is to be understood that the controller **90** may vary the air flow delivered by the blower **40** and water flow through the heat exchanger of one of the modules **30**U and **30**L independently of the other of the modules **30**U and **30**L.

[0048] In conjunction with the optional air cooling economizer cycle, the controller **90** can also monitor the air temperature external to the container **20** via sensor **100**. The controller **90** can control the selective opening and selective closing of the air dampers **22**, **24**, and adjust the speed of each blower **40** to regulate the air temperature inside the container **20** when the external air temperature is below. Furthermore, the controller **90** can control the selective opening and selective closing of recirculation damper **71**, as well as the operation of return fan **75**, in coordination with the operation of air dampers **22**, **24** and blowers **40**.

[0049] In conjunction with the optional water cooling economizer cycle, the controller **90** can monitor the external air temperature, or alternatively, the coolant in the passive fluid cooler **54** (e.g., water in a lake or river) via sensor **100**. The controller **90** can also monitor external humidity via sensor **102** in order to determine the outdoor air enthalpy. The controller **90** processes the external air temperature, the external humidity, the discharge air temperature, and/or the coolant temperature measurement signals received and in response thereto routes the water flow as appropriate between the active chiller **52** and the passive fluid cooler **54** via active chiller valve **62** and passive fluid cooler valve **64**. Valves **62**, **64** of FIG. **9** are represented in FIG. **7** by flow control valves **94**. However, additional valves can be used to increase the source of coolant and the method of cooling the coolant. In an example, when the outside temperature drops below a predetermined external air temperature set point, then the controller **90** closes the active chiller valve **62** and opens the passive fluid cooler valve **64**. The controller **90** may modulate the passive fluid cooler valve **64** to maintain the air temperature desired inside the container **20**. If the passive fluid cooler valve **64** is fully open, and the controller **90** receives temperature data indicating the coolant exiting the ACU **300** exceeds a predetermined exiting coolant temperature set point, then the controller **90** will gradually close the passive fluid cooler valve **64** while gradually opening the active chiller valve **62**, as necessary to maintain the air temperature desired inside the container **20**. If the outside temperature is above the external air temperature set point, or the air temperature desired inside the container **20** cannot be maintained, then the controller **90** will turn off the water cooling economizer cycle by closing the passive fluid cooler valve **64** and opening the active chiller valve **62**.

[0050] The controller **90** may have functional capability to shut down a blower **40** by deactivating its associated fan motor **42** in the event of a sudden drop or complete loss of static pressure, detected by a static pressure sensor (not shown) disposed in association with each blower, such as may occur as a result of a fan belt break or other component failure. The controller **90** may have functional capability to detect condensate build-up in a condensate drain pan **58** beneath each of the heat exchanger **50** and the capability to detect a water leak, either from the heat exchanger itself or from an overflowing condensate drain pan. To do so, the controller **90**

may be programmed to monitor a plurality of sensors **91**, **93**, **95** for example electrical resistance sensor tapes, associated with a condensate drain pan disposed beneath each of the heat exchangers **50** and with the floor beneath the condensate drain pan. If an electrical resistance sensor tape becomes wet, the sensor transmits a signal to the controller **90** indicating the presence of water. For example, a first sensor tape **91** may be disposed in the bottom of drain pan **58** to detect if condensate is present in the drain pan, a second sensor **93** may be disposed near the top rim of the drain pan **58** to detect if the drain pan is filled with condensate, and a third sensor tape **95** may be disposed beneath the drain pan **58** to detect if the condensate has over flowed the drain pan or the heat exchanger has developed a coolant leak.

[0051] The controller **90** may also control a reaction to other events, such as unauthorized or accidental access, smoke, high or low temperatures and humidities, failure of any moving part, dirty filters, failure of a part to respond properly to the controller **90**, and power failure. Additional sensors, not shown, may be used. Sensors to collect data to be sent to the controller **90** include, but are not limited to, smoke detectors, temperature sensors, water detectors, pressure sensors and mechanical interlock switches. Reaction events vary depending on the event. Some examples include, but are not limited to, the following. In the event of a fan failure, an alert causes other forms of cooling to increase, such as coolant flow opening to maximum. If a belt breaks, the fan motor shuts off while operational fans and coolant flow increase speed. If condensate is detected, it is logged. If excess condensate is detected or a catastrophic leak is detected, an alert is sent, and the ACU **30** is shut down. Air dampers **22**, **24** can be opened. If a door is open, the event is logged and cooling increases. A dirty filter causes an alarm. High air humidity causes a reaction to promote condensation, including increasing coolant flow and minimizing fan speeds.

[0052] As noted previously, the air conditioning unit **30** is designed with a width, w, that is less than the width, W, of the container **20**, such that when the ACU **30** is positioned within the interior of the container **20**, a return air plenum **25** is formed between the air inlet side **32** of the ACU **30**. Additionally, the air inlet side **32** of the ACU **30** and the air outlet side **34** of the ACU **30** are perpendicular to each other. Thus, as best seen in FIG. **4**, air flow through the ACU **30** is therefore in a general U-shaped pattern. The ACU **30** draws in air flow at a high velocity, up to about 600 feet per minute, into the compartment housing the electronic equipment **12** along one side of the interior of the container **20**, referred to as the "cold side", and receives return air at a high velocity, up to about 600 feet per minute, from the compartment housing the electronic equipment **12** along the other side of the interior of the container **20**, referred to as the "warm side". In this manner, adequate cooling air is provided to all of the electronic equipment supported of racks or shelves within the interior of the container **20**.

[0053] The air conditioning unit **30** is capable of delivering an amount of cooled air flow sufficient to meet maximum cooling demand for a modular data center disposed within a standard ISO shipping container while still fitting entirely within the interior of a standard ISO shipping container. The casing of the ACU **30** may have cutouts and offsets to recess coolant inlet and outlet connections **4** and **6**. All protuberances from the ACU **30**, such as door handles, door hinges, power connections and the like are within the footprint defined by the width and depth of the ACU **30**. For example, the casing of the ACU **30** may have a height, h, of about 8¼ feet, a depth of about 9½ feet and an overall width of about 6 feet. When installed in a standard ISO container, due to the limited width of the ACU **30**, the air plenum **25** formed between the air inlet side wall **32** of the casing of the ACU **30** and the facing wall of the container **20** will have a width of about **20** inches, which is large enough to also provide access with the air plenum **25** to service and replace the rack of air filters **70** and flow balancing plates **80**.

[0054] Additionally, the ACU **30** may be equipped with lifting lugs **21** mounted to the base frame **31** of the ACU **30** for providing members to which a crane or other hoisting device may be attached to permit the ACU **30** to be lifted. The lifting lugs may be removable to facilitate final installation of the ACU **30** into the container **20**. The ACU **30** may also be equipped with strap holes **23** and forklift points (not shown) in the base frame **31** of the ACU **30** to facilitate securing the ACU **30** to a forklift truck and maneuvering the ACU **30** during final installation of the ACU **30** into the container **20**. The ACU **30** may also include an access door **39** in the aft side wall **38** of the casing of the ACU **30**, accessible via opening the container door **15**, to provide human access to the plenum blowers **40** and associated fan motors **42**, motor drives **44** and the electric supply panel **46**. Additionally a pair of removable access panels **88** may be provided in the side wall **36** of the casing of the ACU **30** to permit access to the bearings, gearing and drive system of the plenum blowers **40** and associated fan motors **42**. A corresponding access door **18** may be provided in the side of the container to permit access to the access panels **88**.

[0055] The terminology used herein is for the purpose of description, not limitation. Specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as basis for teaching one skilled in the art to employ the present invention. While the present invention has been particularly shown and described with reference to the exemplary embodiments as illustrated in the drawing, it will be recognized by those skilled in the art that various modifications may be made without departing from the spirit and scope of the invention. Those skilled in the art will also recognize the equivalents that may be substituted for elements described with reference to the exemplary embodiments disclosed herein without departing from the scope of the present invention.

[0056] Therefore, it is intended that the present disclosure not be limited to the particular embodiment(s) disclosed, but that the disclosure will include all embodiments falling within the scope of the appended claims.

We claim:

1. A modular computer equipment center comprising:

a shipping container having an interior;

a plurality of electronic equipment modules disposed within the interior of said container;

an air conditioning unit disposed in the interior of said container, said air conditioning unit having a casing having a forward wall facing said plurality of electronic equipment modules, a first side wall extending perpendicularly to the forward wall, and an aft wall opposite the forward wall, said air conditioning unit having a width that is less than a corresponding width of said container whereby an air plenum is formed between the first side wall of said casing and a side wall of said container; and an air side economizer circuit associated with said container and coupled to said air conditioning unit for cooling said interior of said container in part using air from external said container.

2. The modular computer equipment center as recited in claim **1**, wherein said air side economizer circuit comprises:

an exhaust air vent disposed in a wall of said container;

an intake air vent disposed in a wall of said container;

a closeable exhaust air damper in flow communication between the atmosphere external said container and the atmosphere internal said container, said flow communication being through said air exhaust vent; and

a closeable intake air damper in flow communication between the atmosphere external said container and said air conditioning unit, said flow communication being through said air intake vent.

3. The modular computer equipment center as recited in claim **2**, wherein said air side economizer circuit further comprises a recirculation air damper in flow communication with an inlet vent of said air conditioning unit for restricting airflow from interior said container to said air conditioning unit.

4. The modular computer equipment center as recited in claim **1**, wherein said container comprises an intermodal container.

5. The modular computer equipment center as recited in claim **2**, wherein said exhaust air damper is in flow communication with a portion of said container housing said plurality of electronic equipment modules.

6. The modular computer equipment center as recited in claim **1**, wherein said air side economizer circuit is controlled in part using data collected by an external temperature sensor positioned outside said container.

7. The modular computer equipment center as recited in claim **2**, wherein said air side economizer circuit is operable using a supply fan of said air conditioning unit and does not include a return fan.

8. The modular computer equipment center as recited in claim **2**, wherein at least one of the exhaust air damper and the intake air damper is actuated by control of a controller.

9. A modular computer equipment center comprising:

a shipping container having an interior;

a plurality of electronic equipment modules disposed within the interior of said container;

an air conditioning unit disposed in the interior of said container, said air conditioning unit having a casing having a forward wall facing the plurality of electronic equipment modules and a first side wall extending perpendicularly to the forward wall, said air conditioning unit having a width that is less than a corresponding width of said container whereby an air plenum is formed between the first side wall of said casing and a side wall of said container; and

a water side economizer circuit coupled to said air conditioning unit for providing cooling fluid thereto.

10. The modular computer equipment center as recited in claim **9** wherein said water side economizer circuit comprises:

a heat exchanger coupled to said air conditioning unit;

a passive fluid cooler coupled in flow communication with said heat exchanger for providing cooling fluid to said air conditioning unit;

one or more valves configured to divert an amount of flow between said passive fluid cooler and said heat exchanger.

11. The modular computer equipment center as recited in claim **9** wherein said container comprises an intermodal container.

12. The modular computer equipment center as recited in claim **9**, wherein said water side economizer circuit is controlled in part using data collected by an external air temperature sensor.

13. The modular computer equipment center as recited in claim **9**, wherein said water side economizer circuit is controlled in part using data collected by a passive fluid cooler temperature sensor.

14. The modular computer equipment center as recited in claim **9**, wherein said water side economizer circuit is controlled in part using data collected by an external humidity sensor.

15. The modular computer equipment center as recited in claim **9**, wherein said passive cooler includes one of a water tower, a river, a lake, and a reservoir.

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