Abstract:

Title: BIMETALLIC DAMPER DEVICE


Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(h))

— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(i))

[Continued on nextpage]

(57) Abstract: In some examples, a damper device includes a frame member defining an opening and at least one bimetallic damper member connected to the frame member. The at least one bimetallic damper member includes bimetallic material and is configured to substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature and bend when at a second temperature to reduce the obstruction of airflow through the opening by the at least one bimetallic damper member, the second temperature being higher than the first temperature.
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BIMETALLIC DAMPER DEVICE

[0001] This application claims the benefit of U.S. Application No. 14/934,609, filed November 6, 2015, which claims the benefit of U.S. Provisional Appl. No. 62/238,019, filed October 6, 2015, the entire contents of which are being incorporated herein by reference.

TECHNICAL FIELD

[0002] The invention relates to managing air temperatures within a data center.

BACKGROUND

[0003] A co-location facility provider (a "provider") may employ a co-location facility, such as a data center or warehouse, in which multiple customers of the provider locate network, server, and storage gear and interconnect to a variety of telecommunications, cloud, and other network service provider(s) with a minimum of cost and complexity. Such co-location facilities may be shared by the multiple customers. By using co-location facilities of the provider, customers of the provider including telecommunications providers, Internet Service Providers (ISPs), application service providers, service providers, content providers, and other providers, as well as enterprises, may interconnect their respective networks to reduce network latency and the freedom to focus on their core business. Additionally, customers may reduce their traffic back-haul costs and free up their internal networks for other uses.

[0004] A co-location facility may include a storage volume storing numerous electronic devices that produce heat, including network, server, and storage gear, as well as power distribution units for distributing power to devices within the facility. A cooling unit may be used to supply a cool air stream into the storage volume. Warm exhaust produced by electronic devices within the storage volume may be returned to the cooling unit as return air for cooling and recirculation within the storage volume. This return, cooling, and recirculation of air within the the facility may help to keep the air within the storage volume cool to maintain safety, performance, and reliability of the electronic devices within the storage volume.
SUMMARY

[0005] In general, techniques of the disclosure are directed to a passive damper device having bimetallic damper members. In some examples, the bimetallic damper members of the passive damper device may obstruct airflow through a duct when the temperature of air near the damper device is cool and may substantially reduce obstruction of airflow through the duct when the temperature of air near the passive damper device rises above a threshold temperature. The passive damper device may cost-effectively facilitate release of warm air, proximate to a power distribution unit (PDU), out of a storage volume storing the power distribution unit and other electronic devices and into an exhaust volume for return to a cooling unit while avoiding or reducing the mixing of the warm exhaust air with the cool supply air, as well as the release of cool air, proximate to the power distribution unit, from the co-location space into the return/exhaust volume to provide enhanced cooling efficiency.

[0006] In one example, a damper device includes a frame member defining an opening and at least one bimetallic damper member connected to the frame member. The at least one bimetallic damper member includes bimetallic material. The at least one bimetallic damper member is configured to substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature. The at least one bimetallic damper member is configured to bend when at a second temperature to reduce the obstruction of airflow through the opening by the at least one bimetallic damper member. The second temperature is higher than the first temperature. In some examples, the first temperature is in the range of about 80 degrees Fahrenheit and below and the second temperature is in the range of about 85 degrees Fahrenheit and above. The approximate ranges of the first and second temperatures may vary depending on the application and according to particular needs.

[0007] In another example, an assembly includes a damper device and a duct. The damper device includes a frame member defining an opening and at least one bimetallic damper member connected to the frame member. The at least one bimetallic damper member includes bimetallic material. The at least one bimetallic damper member is configured to substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature. The at least one bimetallic damper member is configured to bend when at a second temperature to reduce the obstruction of airflow through the opening by the at least one bimetallic damper member. The second
temperature is higher than the first temperature. The frame member is positioned substantially within the duct such that the substantial obstruction of airflow through the opening results in a substantial obstruction of airflow through the duct. In some examples, the first temperature is in the range of about 80 degrees Fahrenheit and below and the second temperature is in the range of about 85 degrees Fahrenheit and above. The approximate ranges of the first and second temperatures may vary depending on the application and according to particular needs.

[0008] In another example, a system includes a damper device, a power distribution unit, and a duct. The damper device includes a frame member defining an opening and at least one bimetallic damper member connected to the frame member. The at least one bimetallic damper member includes bimetallic material. The at least one bimetallic damper member is configured to substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature. The at least one bimetallic damper member is configured to bend when at a second temperature to reduce the obstruction of airflow through the opening by the bimetallic damper member. The second temperature is higher than the first temperature. The opening is positioned substantially proximate to the power distribution unit. The frame member is positioned substantially within the duct such that the substantial obstruction of airflow through the opening results in a substantial obstruction of airflow through the duct. The approximate ranges of the first and second temperatures may vary depending on the application and according to particular needs. In some examples, the first temperature is in the range of about 80 degrees Fahrenheit and below and the second temperature is in the range of about 85 degrees Fahrenheit and above. The approximate ranges of the first and second temperatures may vary depending on the application and according to particular needs.

[0009] The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

**BRIEF DESCRIPTION OF DRAWINGS**

[0010] FIG. 1 is a block diagram that illustrates a high-level view of a data center, in accordance with one or more techniques of the disclosure.

[0011] FIGS. 2A-2G are views of a damper device and components of the damper device at different temperatures, in accordance with one or more techniques of the disclosure.
Like reference characters denote like elements throughout the figures and text.

DETAILED DESCRIPTION

A co-location facility may store numerous electronic devices that produce heat, including the network, server, and storage gear, as well as power distribution units (PDUs) for distributing power to devices within the facility.

A co-location facility data center may employ a horizontal cooling air supply system for cooling electronic devices within the data center. Servers and other equipment may pull cool air from streams of cool air in cold aisles as needed and discharge warm server exhaust into contained hot aisles. The warm server exhaust may be returned to a cooling unit as return air for cooling and recirculation in cool air streams in the cold aisles. This design may be most efficient and effective when air velocities are low and mixing of the cool air and warm exhaust is minimized.

PDUs, used to distribute power to servers and/or other equipment, may be located at various locations within the storage volume of the data center independent of the aisle layout. A PDU located in a cold aisle may release warm PDU exhaust into a cool air stream in a cold aisle which results in a warm spot, known as "puddling," above the PDU under the ceiling of the storage volume, reducing the efficiency and effectiveness of the horizontal cooling air supply system.

One possible solution to this problem is creating an opening in the ceiling above the PDU to relieve the warm PDU exhaust air, which may prevent the warm PDU exhaust air from mixing with the cool air stream in the cold aisles. However, this solution may also result in leakage of a large volume of cool air from the cool air stream along with the warm PDU exhaust into the ceiling, which would be inefficient.

Another possible solution may include a thermostat and a control damper within a duct located proximate to the PDU and connected to the exhaust volume. This may release the warm PDU exhaust in a controlled fashion by allowing the release of air through the damper and into and exhaust volume when the thermostat indicates a predetermined air temperature indicating a collection or "puddling" of warm air above the PDU and obstructing the release of air through the damper when the thermostat indicates a lower air temperature indicative of cool air. For example, the control damper may be configured to open, allowing release of air through the damper and into the exhaust volume, when the thermostat measuring the temperature of air above the PDU indicates a
threshold temperature higher than the expected temperature of the cool air and may otherwise stay closed when the thermostat indicates a temperature below the threshold temperature. However, this control damper and thermostat system may be expensive to build, install, and/or maintain.

[0018] The damper device described herein may provide a cost-effective and efficient solution to release warm PDU exhaust while substantially inhibiting release of cool air from the storage volume.

[0019] FIG. 1 is a block diagram that illustrates a high-level view of data center 100, in accordance with one or more techniques of the disclosure. Data center 100 includes storage volume 102 that stores servers 104 and PDU 106. Cooling unit 108 cools and supplies cool air 110 to storage volume 102. Server exhaust 112 is released from servers 104. PDU exhaust 114 is released from PDU 106 into duct 116 located proximate to PDU 106. Warm air, including server exhaust 112 and PDU exhaust 114, in exhaust volume 118 is returned as return air 120 to be cooled and recirculated by cooling unit 108. Damper device 122 controls release of PDU exhaust 114 through duct 116 into exhaust volume 118.

[0020] Data center 100 may be a facility for storing one or more electronic devices such as servers 104, network and storage gear, as well as power distribution units (PDUs) 106, or any other suitable electronic or supporting devices according to particular needs. Data center 100 may be comprised in a stand-alone building used primarily or exclusively for data center 100 or may be a comprised in a portion of a larger building used for other uses including office space, residential space, retail space, or any other suitable use. Data center 100 may be located in an urban, suburban, or rural location or any other suitable location with any suitable climate. Data center 100 may provide an operating environment for co-location, interconnection, and/or other services. For example, data center 100 may provide an operating environment for any number of services that may be categorized according to service types, which may include, for example, applications/software, platforms, infrastructure, virtualization, and servers and data storage. The names of service types are often prepended to the phrase "as-a-Service" such that the delivery of applications/software and infrastructure, as examples, may be referred to as Software-as-a-Service (SaaS) and Infrastructure-as-a-Service (IaaS), respectively. In such examples, data center 100 may not provide interconnection services.

[0021] Storage volume 102 of data center 100 may be used to store servers 104 and PDU 106. In addition, storage volume 102 may be used to store network and/storage gear or
any other suitable electronic or supporting devices. Because servers 104 operate more efficiently and/or reliably within a temperature range exceeded by the temperature of heat exhaust produced by PDU 106, servers 104, and/or other devices stored in storage volume 102, it may be desirable to keep air in storage volume 102 relatively cool. While servers 104 and PDU 106 are shown to be arranged in storage volume 102 in a particular manner, servers 104 and PDU 106 may be arranged in any suitable manner within storage volume 102. Storage volume 102 may include one or more racks, cabinets, cages, or other storage devices storing servers 104, PDU 106, and/or any other suitable equipment. Storage devices for servers 104 may be arranged in rows within storage volume 102. Rows may be positioned between "cold aisles" for supplying cool air 110 to servers 104 and "hot aisles" for collecting server exhaust 112 and diverting server exhaust 112 to exhaust volume 118. In the view of FIG. 1, servers 104 are viewed as being located behind a cold aisle for supplying cool air 110 and servers 104 are viewed as being located in front of a hot aisle for collecting and diverting server exhaust 112 to exhaust volume 118.

[0022] Servers 104 may be systems that respond to requests across a computer network to provide, or help to provide, a network or data service. Each of servers 104 may include one or more processors that executes software that is capable of accepting requests from clients. Requests from clients may be to share data, information, or hardware and software resources. Servers 104 may include one or more of a database server, file server, mail server, print server, web server, gaming server, application server, communication server, compute server, media server, or any other suitable type of server that may be employed by a data center provider or tenant of the data center provider, according to particular needs. Servers 104 may be specialized or general-purpose devices. Servers 104 may represent x86 or other real or general-purpose servers configured to apply and/or offer services to customers. Servers 104 may also include special-purpose appliances or containers for providing interconnection services between customers of a co-location facility provided by data center 100 or for providing any other suitable services according to particular needs. Servers 104 may use any suitable operating system including Unix-like open source distributions, such as those based on Linux and FreeBSD, Windows Server, or any other suitable operating system.

[0023] PDU 106 may be a unit for distributing power to other devices in data center 100. For example, PDU 106 may distribute power to servers 104 or to any other suitable device in data center 100. PDU 106 may be fitted with multiple outlets designed to
distribute electric power. PDU 106 may be rack-mounted or floor mounted. PDU 106 may provide multiple functions including power filtering to improve power quality and power load balancing. PDU 106 may be remotely monitored and/or controlled using a remote management tool via, e.g., Simple Network Management Protocol (SNMP). PDU 106 may provide power metering at the inlet, outlet, and PDU branch circuit level and may provide support for environmental sensors. PDU 106 may provide power to multiple server cabinets. PDU 106 may include main breakers, individual circuit breakers, and/or power monitoring panels. PDU 106 may be substantially contained in a cabinet that provides internal bus bars for neutral and ground and/or that includes openings that allow for safe entry and exit of cables.

[0024] Cooling unit 108 may be a unit for cooling and circulating cool air 110 in storage volume 102. Any suitable number of cooling units 108 may be used to provide cool air 110 to storage volume 102. In certain examples, cooling unit 108 may cool air from return air 120 and recirculate it as cool air 110 in storage volume 102. In some cases, cooling unit 108 may draw air from another source, such as air outside data center 100 to supply as cool air 110 in storage volume 102. For example, in certain locations where the climate is relatively cool during at least part of the year, cooling unit 108 may draw air from outside data center 100 during those parts of the year and may supply that air as cool air 110 into storage volume 102. Cooling unit 108 may do this in addition to or alternatively to cooling return air 120 to supply as cool air 110. For example, cool air 110 may be supplied partly from cooling return air 120 and partly from air drawn from outside during times of cool climate in the location of data center 100. Cooling unit 108 may alternate from drawing air from outside during times of cool climate to cooling return air 120 during times of warmer climate. Alternatively or in addition, cooling unit 108 may, at the same time, use a combination of cooled return air 120 and air from outside to supply cool air 110 to storage volume 102. Drawing at least a portion of cool air 110 from outside may increase efficiency by limiting the energy needed to otherwise cool sufficient return air 120 to supply cool air 110 to storage volume 102. Alternatively or in addition, cooling unit 108 may cool air from a different source than return air 120. For example, cooling unit 108 may draw and cool air from outside that may be cooler than return air 120 but not cool enough to supply as cool air 110 without cooling by cooling unit 108. Cooling unit 108 may cool air using a refrigeration cycle, evaporation, free cooling, based on desiccants, or in any other suitable manner.

[0025] Cool air 110 may be air that is cooled and supplied to storage volume 102 to keep
air within storage volume 102 and surrounding servers 104 and PDU 106 relatively cool, such that servers 104 may be maintained at a temperature within a preferred operating temperature range for the servers 104. Although described herein as "air," cool air 110 may be any suitable composition of gas for cooling devices within storage volume 102. As described above, cool air 110 may be supplied by cooling return air 120 or any other suitable air source in cooling unit 108 or by drawing air from a source of air that is already cool such as, for example, outside air from a location with a cool climate. For example, for data center 100 in New York in the winter, cool air 110 may be supplied by drawing air in from outside data center 100.

Server exhaust 112 may be warm air heated by servers 104. As electricity passes across circuits and through wires within servers 104, it may meet a natural degree of resistance. This resistance may create heat. Vents in a chassis of servers 104 and/or server cabinets may allow for the escape of heat from servers 104 resulting in warm server exhaust 112. Vents may be strategically placed to release heat and, therefore, server exhaust 112 in the "hot aisles" described above and to allow for server exhaust 112 to enter exhaust volume 118 for return to cooling unit 108 for cooling and recirculation. Alternatively or in addition, server exhaust 112 may be diverted outside data center 100 or to any other suitable location instead of being cooled and recirculated. For example, as described above, data center 100 located in a geographic region with a relatively cool climate may draw cool air 110 from outside instead of cooling and recirculating return air 120 such that server exhaust 112 is not needed for return air 120 but is instead otherwise diverted away from storage space 102 as return air 120 to cool storage volume 102 and servers 104 in an alternative manner. The amount of heat generated by servers 104, and therefore the amount of server exhaust 112 generated by servers 104, may vary depending on the number, composition, and functions of servers 104. For example, different functions performed by different components within servers 104 may result in different amounts of heat generation.

PDU exhaust 114 may be warm air heated by PDU 106. As with servers 104, as electricity passes across circuits and through wires within PDU 106, it may meet a natural degree of resistance and this resistance may create heat. Vents in a chassis of PDU 106 and/or PDU cabinets may allow for the escape of heat from PDU 106 resulting in warm PDU exhaust 114 near PDU 106. As previously described, PDU 106 may be positioned within a "cold aisle" of storage volume 102 such that warm PDU exhaust 114 may be released in a cold aisle. Because the warm PDU exhaust 114 is at a higher temperature
than cool air 110, it has a lower density than cool air 110 and may therefore rise above cool air 110, resulting in PDU exhaust 114 rising above PDU 106 when PDU 106 is located in a cold aisle. As described in more detail below, PDU exhaust 114 may be released through damper device 122 and duct 116 into exhaust volume 118 for return to cooling unit 108 as return air 120 for cooling and recirculation in storage volume 102. Alternatively or in addition, PDU exhaust 114 may be diverted outside data center 100 or to any other suitable location instead of being cooled and recirculated. For example, as described above, data center 100 located in a geographic region with a relatively cool climate may draw cool air 110 from outside instead of cooling and recirculating return air 120 such that PDU exhaust 114 is not needed for return air 120 but is instead otherwise diverted away from storage volume 102 as cool air 110 is drawn from outside to cool storage volume 102, servers 104, PDU 106, and any other devices in an alternative manner. The amount of heat generated by PDU 106, and therefore the amount of PDU exhaust 114 generated by PDU 106, may vary depending on the functions of PDU 106. For example, PDU 106 may distribute more power at certain times than at others or may not distribute any power at certain times, which may result in varying amounts of heat generation.

[0028] Duct 116 may be a portion of a duct system located above or otherwise proximate to PDU 106 to collect PDU exhaust 114. Duct 116 may be composed of galvanized steel, aluminum, Polyurethane and phenolic insulation panels, fiberglass duct board, flexible plastic, metal wire coil, aluminium/zinc alloy, multilayer laminate, fibre reinforced polymer, or any other suitable material or combination of materials. Duct 116 may include a return grille or bell mouth positioned above PDU 106 for collection of PDU exhaust 114. Duct 116, positioned above PDU 106, may be positioned to substantially trap PDU exhaust 114 within duct 116 such that PDU exhaust 114 is concentrated within duct 116 and does not substantially spread within storage volume 102. Duct 116 may be positioned at a distance above PDU 106 to allow space for maintenance of PDU 106 but may be close enough to PDU 106 to allow for collection of most or all of PDU exhaust 114 within duct 116.

[0029] Exhaust volume 118 may be a volume within data center 100 for collecting and returning warm air to the cooling system for cooling and recirculation. For example, server exhaust 112 may be collected in exhaust volume 118. As another example, PDU exhaust 114, once collected within duct 116 and allowed passage by damper device 122, may be collected in exhaust volume 118. Exhaust volume 118 may be a volume within a
duct system including a volume within a plenum for collecting server exhaust 112, PDU exhaust 114, and any other suitable warm air, according to particular needs, and returning it to cooling unit 108 as return air 120, releasing it outside data center 100, or otherwise diverting it in any other suitable manner according to particular needs. All or a portion of exhaust volume 118, including a plenum in exhaust volume 118, may be depressurized to help divert server exhaust 112 and PDU exhaust 114 into exhaust volume 118 according to particular needs.

[0030] Return air 120 may be a stream of air returned to cooling unit 108 for cooling and recirculation. For example, server exhaust 112 and PDU exhaust 114, as described above, may be collected in exhaust volume 118 and returned to cooling unit 108 as return air 120. Once returned to cooling unit 108, warm return air 120 may be cooled and recirculated in storage volume 102 as cool air 110 by cooling unit 108. Return air 120 may be steered to cooling unit 108 by controlling pressure within all or a portion of exhaust volume 118 or by any other suitable manner according to particular needs.

[0031] In accordance with techniques described herein, a damper device 122 is employed within duct 116 to facilitate release of warm PDU exhaust 114 from storage volume 102 into exhaust volume 118 while inhibiting release of cool air 110. Damper device 122 may be configured to substantially allow passage of PDU exhaust 114 through damper device 122 and duct 116 and into exhaust volume 118 and to substantially obstruct passage of cool air 110 through damper device 122 and duct 116 and into exhaust volume 118. Damper device 122 may be configured to substantially obstruct airflow through damper device 122 or reduce the obstruction of airflow through damper device 122 based on the temperature of air proximate to damper device 122. For example, damper device 122 may be configured to substantially obstruct airflow through damper device 122 when at temperatures about at or below the expected temperature of cool air 110 and to reduce the obstruction of airflow through damper device 122 at temperatures above a threshold temperature above the expected temperature of cool air 110. When a substantial amount of PDU exhaust 114 collects within duct 116 and next to damper device 122, the temperature of PDU exhaust 114 next to damper device 122 may result in damper device 122 allowing passage of airflow through damper device 122 such that PDU exhaust 114 may flow through damper device 122 and duct 116 into exhaust volume 118. When substantially little or no PDU exhaust 114 is collected within duct 116, cool air 110 may be within duct 116 next to damper device 122, the temperature of which may cause damper device 122 to substantially obstruct airflow through damper device 122. Thus,
cool air 110 may be substantially contained within storage volume 102. Additional
details concerning the operation of damper device 122 are described below with
references to FIGS. 2A-2G.

In operation, storage volume 102 of data center 100 may include servers 104,
PDU 106, and any other suitable devices. Servers 104 may be arranged in a row between
a "cold aisle" and a "hot aisle" and PDU 106 may be positioned within the "cold aisle."
Cool air 110 may enter the "cold aisle" of storage volume 102 to help cool servers 104
and PDU 106. Servers 104 may release server exhaust 112 in the "hot aisle," which may enter exhaust volume 118 and may then be directed to cooling unit 108 as at least a
portion of return air 120. PDU 106 may at times release heat resulting in warm PDU
exhaust 114. Duct 116 may be positioned above PDU 106 and may be connected to a
duct system defining exhaust volume 118. Damper device 122 may be positioned within
duct 116. At times when PDU 106 distributes little or no power, PDU 106 may release no
or substantially little PDU exhaust 114. Thus, the air above PDU 106 and proximate to
damper device 122 may substantially comprise cool air 110 and may be at or about the
expected temperature of cool air 110. Based on the temperature proximate to damper
device 122 being at or at about the expected temperature of cool air 110, damper device
122 may obstruct passage of air through damper device 122 and duct 116 into exhaust
volume 118. At times when PDU 106 distributes a substantial amount of power, it may
produce a substantial amount of PDU exhaust 114. PDU exhaust 114 may collect within
duct 116 proximate to damper device 122. Thus, the temperature proximate to damper
device 122 may rise to be at or above a threshold temperature above the expected
temperature of cool air 110. Based on the temperature proximate to damper device 122
being at or above a threshold temperature above the expected temperature of cool air 110,
damper device 122 may substantially reduce the obstruction of airflow through damper
device and thus substantially allow passage of PDU exhaust 114 through damper device
122 and duct 116 into exhaust volume 118. PDU exhaust 114 may then be directed to
cooling unit 108 as return air 120. This obstruction of airflow and reduction in
obstruction of airflow by damper device 122 based on the temperature of air proximate to
damper device 122 may allow for the release of PDU exhaust 114 while inhibiting the
release of cool air 110 from storage volume 102, allowing for improved efficiency over
systems that do not allow for substantial release of PDU exhaust 114 and resulting in
"pooling," and systems including static openings that allow for substantial passage of
both PDU exhaust 114 and cool air 110 into exhaust volume 118.
FIGS. 2A-2G are views of a damper device 122 and components of damper device 122 at different temperatures, in accordance with one or more techniques of the disclosure. Damper device 122 may comprise frame member 202, defining at least one opening 204, and at least one bimetallic damper member 206 connected to frame member 202 by at least one fastener 208. As described above, damper device 122 may be configured to substantially obstruct airflow through damper device 122, as illustrated in FIGS. 2A and 2F, when at a temperature at or about at the expected temperature of cool air 110. Damper device 122 may be further configured to substantially reduce the obstruction of airflow through the at least one opening 204, as illustrated in FIGS. 2E and 2G, when at a temperature that is at or above a threshold temperature higher than the expected temperature of cool air 110. Damper device 122 may be configured to reduce the obstruction of airflow through damper device 122 at any suitable range of temperatures for which it may be desirable to reduce the obstruction of airflow through damper device 122. Damper device 122 may be configured to reduce the obstruction of airflow through damper device 122 when at a temperature at, or about at, a few degrees Fahrenheit above the expected temperature of cool air 110. For example, damper device 122 may be configured to be in a configuration that reduces obstruction of airflow through damper device 122 when at a temperature in a range of about 85 degrees Fahrenheit and above. Damper device 122 may be configured to be in a configuration that substantially obstructs airflow through damper device at any suitable range of temperatures for which it may be desirable to obstruct airflow through openings 204. For example, damper device 122 may be configured to be in an airflow-obstructing configuration when at a temperature in a range of about 80 degrees Fahrenheit and below.

Frame member 202 may be a member defining at least one opening 204. Frame member 202 may include holes, shown in FIG. 2B for allowing passage of fasteners 208. Frame member 202 may include an outer member as well as any number of inner vane members separating openings 204. Alternatively, frame member 202 may include no inner vane members and may define only one opening 204 defined by an outer member. Although frame member 202 is illustrated as being rectangular in shape, frame member 202 may be of any suitable shape according to particular needs. Frame member 202 may be configured to be positioned within duct 116. Frame member 202 may comprise metal, plastic, or any suitable material according to particular needs.

Frame member 202 may define openings 204. Openings 204 may allow air to pass through damper device 122, as shown in FIGS. 2E and 2G. Openings 204 may be
substantially occluded to obstruct airflow through damper device 122, as shown in FIGS. 2A and 2F. Openings 204 may be formed by welding members of frame member 202 together including portions defining an outer member and, in some cases, one or more inner vane members; by cutting portions of metal away from frame member 202; or by any other suitable method. Although openings 204 are illustrated as being rectangular in shape, openings 204 may be of any suitable shape according to particular needs. Although three openings 204 are illustrated, frame member 202 may define any suitable number of openings 204 according to particular needs. If frame member 202 includes multiple openings 204, they may be of similar or different size and/or shape according to particular needs.

[0036] Bimetallic damper members 206 may be attached to frame member 202. Bimetallic damper members 206 may be configured to substantially straighten to form a substantial obstruction of airflow through openings 204 when at a temperature proximate to an expected temperature of cool air 110, as shown in FIGS. 2A and 2E. Bimetallic damper members 206 may be configured to bend when at a temperature above a threshold temperature to reduce the obstruction of airflow through openings 204 by bimetallic damper members 206, as shown in FIGS. 2E and 2G. Bimetallic damper members 206 may comprise bimetallic material. For example, as shown in FIG. 2D, bimetallic damper member 206a may comprise metallic strips 210a-b that are bonded together to form bimetallic damper member 206a. Metallic strip 210a may comprise a different type of metallic material than metallic strip 210b. For example, metallic strip 210a may comprise approximately 36% nickel and metallic strip 210b may comprise approximately 72% manganese, 10% copper, and 10% nickel. Because of the different compositions of metallic strips 210a-b, metallic strip 210b may have a higher thermal expansion coefficient than metallic strip 210a such that heating metallic strips 210a-b may result in deflection of bimetallic damper member 206a. For example, heating bimetallic damper member 206a may result in bimetallic damper member 206a bending as shown in FIGS. 2E and 2G. In certain examples, bimetallic damper members 206 may have a flexivity of about 217x10^-7 (in/in)/°F to 211x10^-7 (in/in)/°F from about 50°F to 300°F. Metallic strips 210a-b may be bonded together by riveting, brazing, welding, or in any other suitable manner. Metallic strips 210a-b may comprise materials with thermal expansion coefficients such that bimetallic damper member 206a is configured to substantially straighten when at a temperature proximate to the expected temperature of cool air 110 or below, such that bimetallic damper members 206 may substantially obstruct passage of
air though openings 204, and to substantially bend when at or above a threshold
temperature to substantially remove the obstruction of air through openings 204.

[0037] Fasteners 208 may be used to fasten bimetallic damper members 206 to frame
member 202. Fasteners 208 may include any suitable type including bolts, brass
fasteners, captive fasteners, nails, rivets, staples, screws, or any other suitable type and
may comprise metal alloy, plastic, or any other suitable material.

[0038] In operation, damper device 122 may allow release of warm PDU exhaust 114
from storage volume 102 while inhibiting release of cool air 110. Damper device 122
may be positioned within duct 116, as shown in FIG. 1. When air within duct 116
proximate to damper device 122 substantially comprises cool air 110, the temperature of
bimetallic damper members 206 may be proximate to the temperature of cool air 110.
For example, the temperature of bimetallic damper members 206, and thus metallic strips
210a-b, may be in a range of approximately 80 degrees Fahrenheit and below. At
temperatures within this range, bimetallic damper members 206 may be substantially
straight and form a substantial obstruction of airflow through openings 204. When a
substantial amount of PDU exhaust 114 collects within duct 116 proximate to damper
device 122, the temperature of at least some bimetallic damper members 206, and thus
the corresponding metallic strips 210, may rise to be in a range of approximately 85 degrees
Fahrenheit and above. Because of the different thermal expansion coefficients of metallic
strips 210, heated bimetallic damper members 206 may bend, reducing the obstruction of
airflow through opening 204 by bimetallic damper members 206, thus allowing passage
of PDU exhaust 114 through duct 116, out of storage volume 102, and into exhaust
volume 118 for return to cooling unit 108 as return air 120.

[0039] Although FIGS. 2E and 2G show similar deflection of bimetallic damper members
206a-n, bimetallic damper members 206a-n may be at different temperatures and thus
bend at different rates. For example, if damper device 122 is centered over an output of
PDU exhaust 114 on PDU 106, bimetallic damper members 206 positioned closer to the
center of damper device 122 may experience a greater and/or faster rise in temperature
than those bimetallic damper members 206 positioned farther from the middle of damper
device 122 due to PDU exhaust 114 collecting proximate to the center of damper device
122 faster than proximate to other portions of damper device 122. Thus, bimetallic
damper members 206 proximate to the center of damper device 122 may bend more
and/or at a faster pace than those further from the center of damper device 122. In certain
examples, each set of bimetallic damper members 206 that occlude a corresponding one
of openings 204 may be connected together to allow for a more even deflection across each of openings 204. However, this may result in less deflection of bimetallic damper members 206 located proximate to the center of damper device 122.

[0040] Any suitable number and widths of bimetallic damper members 206 may be used to allow for desirable obstruction of airflow and reduction in the obstruction of airflow according to particular needs. For example, a greater number of thinner bimetallic damper members 206 may be used to obstruct openings 204 and may experience a greater deflection than the illustrated example. Alternatively, fewer, thicker bimetallic members 206 may be used and may experience less deflection that those illustrated. Alternatively or in addition, longer or shorter bimetallic damper members 206 may be used with corresponding wider or narrower openings 204, which may result in greater or less deflection respectively. Alternatively or in addition, any combination of bimetallic members 206 and openings 204 having any variety of dimensions may be used according to particular needs.

[0041] The foregoing examples have several advantages including release of PDU exhaust from a data center storage volume, thus reducing or eliminating "puddling" of warm air above PDUs and resulting in more efficient cooling of the data center storage volume. The foregoing examples, unlike systems with static openings in the ceiling above PDUs, also limit release of cool air from the data center storage volume, also resulting in more efficient cooling of the data center storage volume. The foregoing examples are also more economical than systems using a thermostat and control damper to release warm PDU exhaust while inhibiting release of cool air.

[0042] Although the foregoing examples have been illustrated as being used to allow release of PDU exhaust while inhibiting the release of cool air, damper device 122 can be used in a variety of different applications requiring release of a relatively warm fluid and containment of a relatively cool fluid. For example, damper device 122 can be used to release server exhaust or exhaust from any other suitable device within a data center storage volume while inhibiting release of cool air within the data center storage volume. As an additional example, damper device 122 may be used in a building's chimney to automatically allow airflow through damper device 122 to release fire exhaust when a fire is started and to automatically obstruct airflow through damper device 122 to contain cool air within the building when the fire is extinguished.

[0043] Various examples have been described. These and other examples are within the scope of the following claims.
WHAT IS CLAIMED IS:

1. A damper device comprising:
   a frame member defining an opening; and
   at least one bimetallic damper member connected to the frame member, the at least one bimetallic damper member comprising bimetallic material and configured to:
   substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature; and
   bend when at a second temperature to reduce the obstruction of airflow through the opening by the at least one bimetallic damper member, the second temperature being higher than the first temperature.

2. The damper device of claim 1, wherein the opening is a first opening, and wherein:
   the frame member defines a second opening; and
   the damper device comprises a second at least one bimetallic damper member configured to form a substantial obstruction of airflow through the second opening when at the first temperature.

3. The damper device of claim 2, wherein the frame member comprises:
   an outer member being substantially rectangular and comprising a first, second, third, and fourth side member;
   at least one vane member, each of the at least one vane member:
   being substantially perpendicular to the first and third side members of the outer member and substantially parallel to the second and fourth side members of the outer member; and
   having a first end and a second end, the first end being attached to the first side member of the outer member and the second end being attached to the third side member of the outer member.

4. The damper device of claim 1, wherein the frame member is positioned substantially within a duct such that the substantial obstruction of airflow through the opening results in a substantial obstruction of airflow through the duct.
5. The damper device of claim 1, wherein the opening is positioned between a first volume defining a storage volume and a second volume defining an exhaust volume.

6. The damper device of claim 5, wherein:
   the storage volume comprises a power distribution unit; and
   the opening is positioned substantially proximate to the power distribution unit.

7. The damper device of claim 1, wherein:
   each of the at least one bimetallic damper member is elongate and comprises a first end and a second end; and
   each of the at least one bimetallic damper member is connected to the frame member proximate to the first end of each of the at least one bimetallic damper member.

8. The damper device of claim 1, wherein:
   the first temperature is in the range of about 80 degrees Fahrenheit and below; and
   the second temperature is in the range of about 85 degrees Fahrenheit and above.

9. The damper device of claim 1, wherein the bimetallic material comprises:
   a first portion comprising approximately 36% nickel; and
   a second portion comprising approximately 72% manganese, 10% copper, and 10% nickel.
10. An assembly comprising:
   a damper device comprising:
      a frame member defining an opening; and
   at least one bimetallic damper member connected to the frame member,
   the at least one bimetallic damper member comprising bimetallic material and configured
to:
      substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature; and
      bend when at a second temperature to reduce the obstruction of airflow through the opening by the bimetallic damper member, the second temperature being higher than the first temperature; and
   a duct,
      wherein the frame member is positioned substantially within the duct such that the substantial obstruction of airflow through the opening results in a substantial obstruction of airflow through the duct.

11. The assembly of claim 10, further comprising a cooling system comprising:
   a cooling unit; and
   the duct.

12. The assembly of claim 10, wherein:
   the opening is positioned between a first volume defining a storage volume and a second volume defining an exhaust volume;
   the storage volume comprises a power distribution unit; and
   the opening is positioned substantially proximate to the power distribution unit.

13. The assembly of claim 10, wherein:
   the first temperature is in the range of about 80 degrees Fahrenheit and below; and
   the second temperature is in the range of about 85 degrees Fahrenheit and above.
14. The assembly of claim 10, wherein the bimetallic material comprises:
   a first portion comprising approximately 36% nickel; and
   a second portion comprising approximately 72% manganese, 10% copper, and
   10% nickel.

15. The assembly of claim 10, wherein the opening is a first opening, and wherein:
   the frame member defines a second opening; and
   the damper device comprises a second at least one bimetallic damper member
   configured to form a substantial obstruction of airflow through the second opening when
   at the first temperature.
16. A system comprising:
   a damper device comprising:
   a frame member defining an opening; and
   at least one bimetallic damper member connected to the frame member,
   the at least one bimetallic damper member comprising bimetallic material and configured to:
   substantially straighten to form a substantial obstruction of airflow through the opening when at a first temperature; and
   bend when at a second temperature to reduce the obstruction of airflow through the opening by the bimetallic damper member, the second temperature being higher than the first temperature;
   a power distribution unit, wherein the opening is positioned substantially proximate to the power distribution unit; and
   a duct, wherein the frame member is positioned substantially within the duct such that the substantial obstruction of airflow through the opening results in a substantial obstruction of airflow through the duct.

17. The system of claim 16, wherein the opening is positioned between a first volume defining a storage volume and a second volume defining an exhaust volume.

18. The system of claim 17, further comprising:
   at least one server, wherein the storage volume comprises the at least one server and the power distribution unit;
   a cooling unit for providing a cool air stream to the storage volume.

19. The system of claim 16, wherein:
   the first temperature is in the range of about 80 degrees Fahrenheit and below; and
   the second temperature is in the range of about 85 degrees Fahrenheit and above.

20. The system of claim 16, wherein the bimetallic material comprises:
   a first portion comprising approximately 36% nickel; and
   a second portion comprising approximately 72% manganese, 10% copper, and 10% nickel.
FIG. 2A
INTERNATIONAL SEARCH REPORT

International application No. PCT/US 16/55519

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) ... Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-8300
Form PCT/ISA/2 0 (second sheet) (January 2015)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): F23N 3/04, F23L 11/00, 13/00; F24F 13/10 (2016.01 )
CPC: F23N 3/04, F23L 11/00, 13/00; F24F 13/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google; Google Scholar; Science Direct

Keywords: bimetal, damper, Fahrenheit, Celsius, percent, nickel, manganese, copper, server, air condition, power, distribution

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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</thead>
<tbody>
<tr>
<td>X</td>
<td>US 4,245,778 A (DIERMAYER, W.) 20 January 1981: figures 2-5, column 1, lines 15-20, column 2, lines 35-50, column 3, lines 10-15</td>
<td>1-2, 4-7, 10-12, 15-17</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,465,014 A (AWISATI, CG) 07 November 1995: column 1, lines 30-40, column 6, lines 25-30</td>
<td>8, 13, 19</td>
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<td>Y</td>
<td>US 2014/0371924 (Fujitsu Limited) 18 December 2014: figures 3, 6, paragraphs [0033], [0052], [0053], [0055]</td>
<td>16-18</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search

06 December 2016 (06.12.2016)

Date of mailing of the international search report

29 DEC 2016

Name and mailing address of the ISA/US

Authorized officer

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