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(54) **INDOOR VOLATILE ORGANIC COMPOUND QUANTITY CONTROL SYSTEMS**

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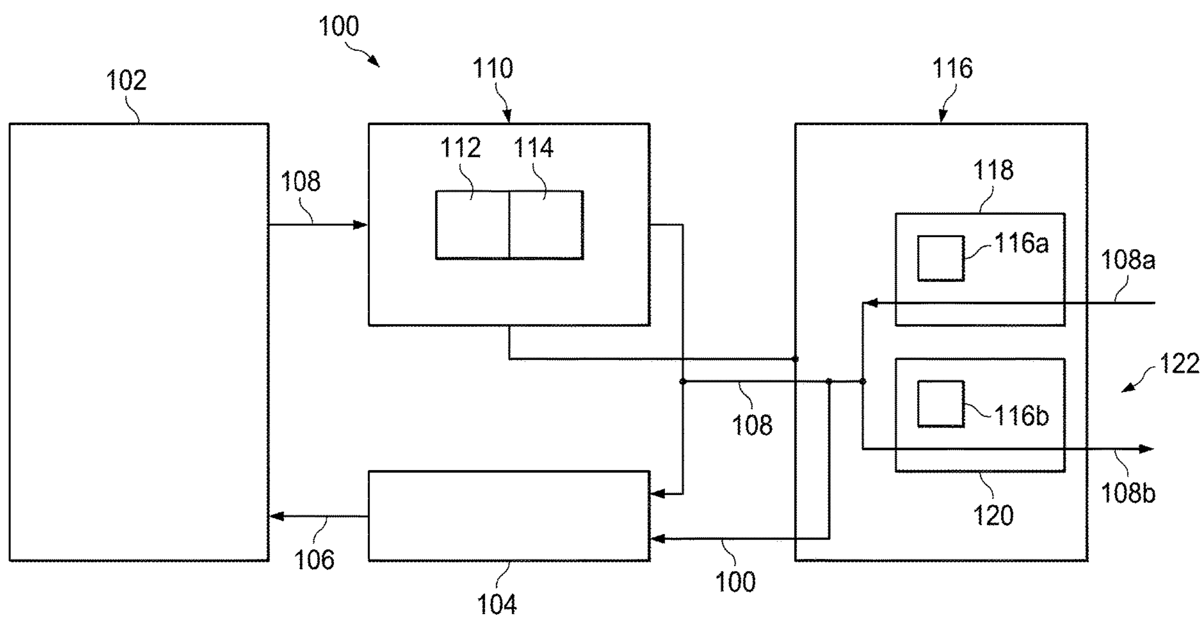
(57) **ABSTRACT**

A heating, ventilation and air conditioning (HVAC) unit can flow conditioned air into an indoor space through a first flow pathway, and receive returned air from the indoor space through a second flow pathway. A sensor module is positioned in the second flow pathway to receive the return air from the indoor space and determine that a quantity of volatile organic compounds (VOCs) in the return air exceeds a threshold VOC quantity. In response, the HVAC unit can flow a quantity of the return air out of the second flow pathway and into the atmosphere, and draw, into the second flow pathway, an equal quantity of air from the atmosphere. The HVAC unit can flow a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.



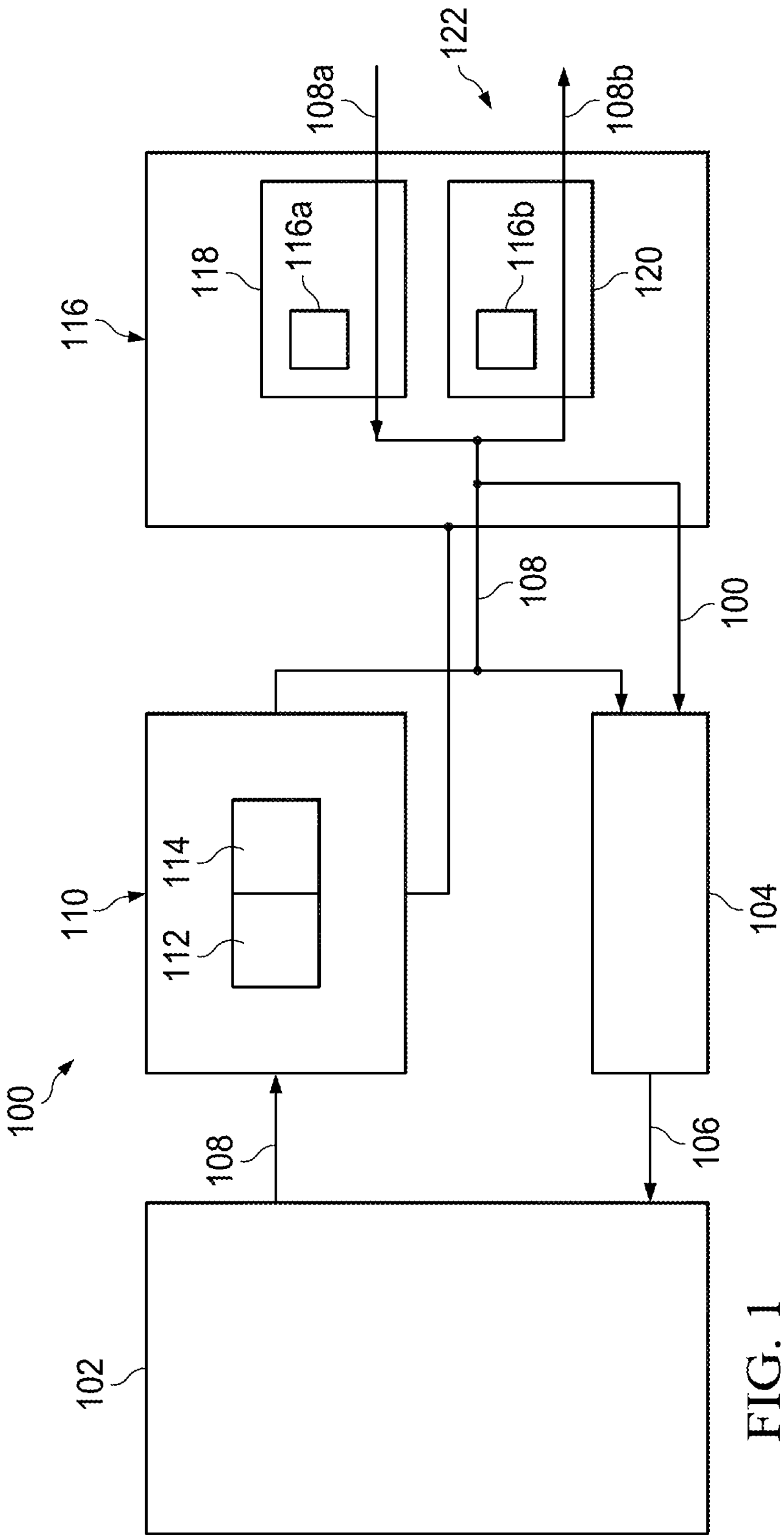

122
108a
108b
116
118
116a
116b
120
108
100
110
114
112
104
100
108
106
102

FIG. 1

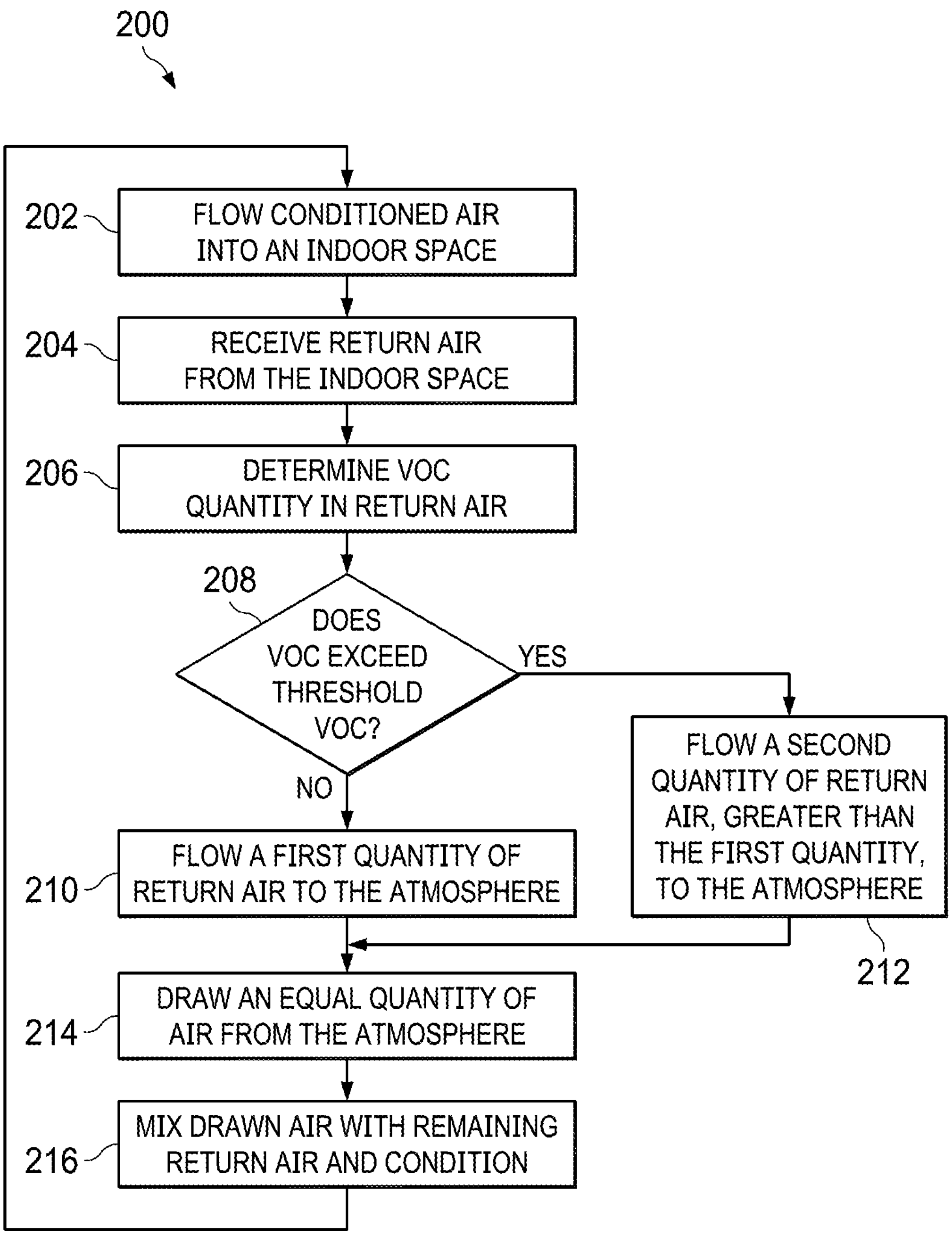

200
202
FLOW CONDITIONED AIR INTO AN INDOOR SPACE
204
RECEIVE RETURN AIR FROM THE INDOOR SPACE
206
DETERMINE VOC QUANTITY IN RETURN AIR
208
DOES VOC EXCEED THRESHOLD VOC?
YES
NO
FLOW A SECOND QUANTITY OF RETURN AIR, GREATER THAN THE FIRST QUANTITY, TO THE ATMOSPHERE
210
FLOW A FIRST QUANTITY OF RETURN AIR TO THE ATMOSPHERE
212
214
DRAW AN EQUAL QUANTITY OF AIR FROM THE ATMOSPHERE
216
MIX DRAWN AIR WITH REMAINING RETURN AIR AND CONDITION

FIG. 2

INDOOR VOLATILE ORGANIC COMPOUND QUANTITY CONTROL SYSTEMS

TECHNICAL FIELD

[0001] This disclosure relates to controlling content of chemicals in air flowed through an indoor space.

BACKGROUND

[0002] Laboratories and research and development facilities are usually operated in a controlled environment utilizing local exhaust ventilation (LEV) and chemical fume hoods (CFHs) to extract chemical releases from laboratory experiments/operations. However, volatile organic compounds (VOCs) can inevitably escape in low-level concentrations outside the designated CFHs and into the nearby indoor spaces in which the CFHs are installed. Although these low-levels of VOCs may not exceed occupational exposure levels (OELs), for example, threshold levels designated by government agencies, some of the VOCs are potentially toxic even at the low levels and are classified as carcinogens. In addition, the odor emitted by even the low-level VOCs can be strong and considered a nuisance to building occupants. Consequently, it is important to keep the levels of such VOCs in the indoor spaces outside of the CFHs to be as low as reasonably achievable.

SUMMARY

[0003] This specification describes technologies relating to indoor volatile organic compound (VOC) quantity control systems.

[0004] Certain aspects of the subject matter described here can be implemented as a method. Conditioned air is flowed into an indoor space through a first flow pathway. Return air from the indoor space is received through a second flow pathway fluidically coupled to and separate from the first flow pathway. The return air is flowed through a sensor module positioned in the second flow pathway. The return air is flowed through a sensor module positioned in the second flow pathway. The sensor module determines that a quantity of VOCs in the return air exceeds a threshold VOC quantity. In response, a quantity of the return air is flowed out of the second flow pathway and into the atmosphere. A quantity of air equal to the quantity of return air that was flowed into the atmosphere is drawn into the second flow pathway. A remainder of the return air and the drawn quantity of air from the atmosphere are flowed into the first flow pathway to be conditioned and flowed into the indoor space.

[0005] An aspect combinable with any other aspect includes the following features. To flow a quantity of the return air out of the second flow pathway and into the atmosphere, a first damper is opened. The first damper is positioned in the second flow pathway upstream of a first outlet to the atmosphere.

[0006] An aspect combinable with any other aspect includes the following features. To open the first damper, the sensor module transmits a signal to a first damper controller operatively coupled to the first damper in response to determining that the quantity of the VOCs in the return air exceeds the threshold quantity.

[0007] An aspect combinable with any other aspect includes the following features. The sensor module includes a VOC sensor and a damper actuator operatively coupled to the VOC sensor. The damper actuator transmits the instruction to the first damper controller.

[0008] An aspect combinable with any other aspect includes the following features. To draw a quantity of air from the atmosphere equal to the quantity of the return air that flowed into the atmosphere into the second flow pathway, a second damper positioned in the second flow pathway upstream of a second outlet to the atmosphere is opened.

[0009] An aspect combinable with any other aspect includes the following features. To open the second damper, the sensor module transmits, to a second damper controller operatively coupled to the second damper, a signal to open the second damper in response to determining that the quantity of VOCs in the return air exceeds the threshold quantity.

[0010] An aspect combinable with any other aspect includes the following features. The sensor module includes a VOC sensor and a damper actuator operatively coupled to the VOC sensor. The damper actuator transmits the instruction to the second damper controller.

[0011] An aspect combinable with any other aspect includes the following features. The quantity of the return air flowed into the atmosphere in response to determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity is a first quantity of the return air. The sensor module determines that the quantity of the VOCs in the return air does not exceed the threshold VOC quantity. In response, the a second quantity of the return air less than the first quantity of the return air is flowed out of the second flow pathway and into the atmosphere. A quantity of air equal to the quantity of the second quantity of the return air is drawn into the second flow pathway. A remainder of the return air and the drawn quantity of air from the atmosphere are flowed into the first flow pathway to be conditioned and flowed into the indoor space.

[0012] Certain aspects of the subject matter described here can be implemented as a system. The system includes a heating, ventilation and air conditioning (HVAC) unit. The HVAC unit can flow conditioned air into an indoor space through a first flow pathway, and receive returned air from the indoor space through a second flow pathway fluidically coupled to and separate from the first flow pathway. The system includes a sensor module positioned in and fluidically coupled to the second flow pathway. The sensor module can receive the return air from the indoor space and determine that a quantity of VOCs in the return air exceeds a threshold VOC quantity. In response to the sensor module determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity, the HVAC unit can flow a quantity of the return air out of the second flow pathway and into the atmosphere, and draw, into the second flow pathway, a quantity of air from the atmosphere equal to the quantity of the return air that was flowed into the atmosphere. The HVAC unit can flow a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

[0013] An aspect combinable with any other aspect includes the following features. The system includes a first damper positioned in the second flow pathway upstream of a first outlet to the atmosphere. The first damper can open to permit the quantity of the return air to flow out of the second flow pathway and into the atmosphere.

[0014] An aspect combinable with any other aspect includes the following features. The system includes a first damper controller operatively coupled to the sensor module. The sensor module can transmit a signal to the first damper controller to open the first damper. The first damper controller can open the first damper in response to receiving the signal from the sensor module.

[0015] An aspect combinable with any other aspect includes the following features. The sensor module includes a VOC sensor and a damper actuator operatively coupled to the VOC sensor. The damper actuator transmits the instruction to the first damper controller.

[0016] An aspect combinable with any other aspect includes the following features. The system includes a second damper positioned in the second flow pathway upstream of a second outlet of the atmosphere. The second damper can open to draw the quantity of the air equal to the quantity of the return air that was flowed into the atmosphere.

[0017] An aspect combinable with any other aspect includes the following features. The system includes a second damper controller operatively coupled to the sensor module. The sensor module can transmit a signal to the second damper controller to open the second damper. The second damper controller can open the second damper in response to receiving the signal from the sensor module.

[0018] An aspect combinable with any other aspect includes the following features. The sensor module includes a VOC sensor and a damper actuator operatively coupled to the VOC sensor. The damper actuator transmits the instruction to the second damper controller.

[0019] An aspect combinable with any other aspect includes the following features. The quantity of the return air flowed into the atmosphere in response to determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity is a first quantity of the return air. The sensor module can determine that the quantity of VOCs in the return air does not exceed the threshold VOC quantity. In response to the sensor module determining that the quantity of VOCs in the return air does not exceed the threshold VOC quantity, the HVAC unit can flow, out of the second flow pathway and into the atmosphere, a second quantity of the return air less than the first quantity of the return air. The HVAC unit can draw, into the second flow pathway, a quantity of air from the atmosphere equal to the second quantity of the return air. The HVAC unit can flow a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

[0020] Certain aspects of the subject matter described here can be implemented as a non-transitory computer-readable medium storing instructions executable by one or more computer systems to perform operations. The operations include the following. A first signal is received. The first signal represents a first quantity of VOCs in return air received from an indoor space into which conditioned air was flowed. It is determined that the first quantity of VOCs in the return does not exceed a threshold VOC quantity. In response, instructions to open a first damper to flow a first quantity of the return air into the atmosphere are transmitted. Instructions to open a second damper to draw a first quantity of air from the atmosphere equal to the first quantity of the return air flowed into the atmosphere are transmitted. The first quantity of the air from the atmosphere mixes with a remainder of the return air received from the indoor space, is conditioned and is flowed back into the indoor space. After receiving the first signal, a second signal is received. The second signal represents a second quantity of the VOCs in the return air received from the indoor space. It is determined that the second quantity of VOCs in the return air exceeds the threshold VOC quantity. In response, instructions to open a first damper to flow a second quantity of the return air into the atmosphere are transmitted. The second quantity of the return air is greater than the first quantity of the return air flowed into the atmosphere in response to receiving the first signal. Instructions to open a second damper to draw a second quantity of air from the atmosphere equal to the second quantity of the return air flowed into the atmosphere are transmitted. The second quantity of the air from the atmosphere mixes with the remainder of the return air received from the indoor space, is conditioned and is flowed back into the indoor space.

[0021] An aspect combinable with any other aspect includes the following features. In response to determining that the first quantity of VOCs in the return air exceeds the threshold VOC quantity, to transmit instructions to open the first damper to flow the second quantity of the return air into the atmosphere, a flow rate of the return air received from the indoor space is determined. Based on the flow rate of the return air, a duration for which the first damper is to remain open to allow the second quantity of the return air to flow into the atmosphere is determined. To transmit the instructions to open the first damper to flow the second quantity of the return air into the atmosphere, the first damper is opened for the determined duration and closed after the determined duration.

[0022] An aspect combinable with any other aspect includes the following features. In response to determining that the first quantity of VOCs in the return air exceeds the threshold VOC quantity, to transmit instructions to open the second damper to draw the second quantity of the air from the atmosphere, a flow rate of the return air received from the indoor space is determined. Based on the flow rate of the return air, a flow rate at which the second quantity of air is to be drawn from the atmosphere is determined. A duration for which the second damper is to remain open to allow the second quantity of air to be drawn from the atmosphere is determined. To transmit the instructions to open the second damper to draw the second quantity of air from the atmosphere, the second damper is opened for the determined duration. Air is drawn from the atmosphere at the determined flow rate at which the second air is to be drawn from the atmosphere. The second damper is closed after the determined duration.

[0023] An aspect combinable with any other aspect includes the following features. The instructions to open the first damper to flow the second quantity of the return air into the atmosphere and the instructions to open the second damper to draw the second quantity of air from the atmosphere equal to the second quantity of the return air flowed into the atmosphere are transmitted simultaneously. Doing so allows both dampers to operate simultaneously.

[0024] The details of one or more implementations of the subject matter described in this specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1** is a schematic diagram of a heating, ventilating and air-conditioning (HVAC) unit.

[0026] FIG. **2** is a flowchart of an example of a process of operating the HVAC unit of FIG. **1**.

[0027] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0028] This disclosure describes monitoring the presence of VOCs in indoor spaces, for example, in laboratories and research and development facilities. Upon determining that the quantity of VOCs in the indoor space exceeds a threshold VOCs quantity, action is taken to decrease the quantity of VOCs in the indoor space below the threshold.

[0029] In some implementations, a HVAC unit that circulates air through an indoor space includes a VOC sensor module in the path of return air from the indoor space. For example, the indoor space is a room in which a CFH is installed and in which the potential exists for the VOC to escape the CFH and leak into the rest of the indoor space. The VOC sensor senses a quantity of VOC in the return air. If the quantity of VOC exceeds a threshold quantity, then the sensor module actuates a first damper exhaust more exhaust air and actuates a second damper to intake more outside, fresh air. The HVAC unit mixes and conditions the reduced return air and the increased outside, fresh air, and flows that air into the indoor space. The resulting mixture dilutes the VOC in the indoor space.

[0030] Implementations of the subject matter described here can have one or more of the following advantages. The system and techniques described here act as a safeguard and complement existing control measures in indoor spaces such as laboratories and research and development facilities. The system and techniques described here can optimize and improve efficiency of HVAC energy consumption. Instead of continuous fresh air supply to dilute data contaminants, fresh air will only be introduced based on concentrations determined by the sensor module.

[0031] This disclosure describes implementations using VOC as an example. The subject matter described here can be implemented to sense other compounds, elements, contaminants or material that can be found in indoor spaces. For example, by using a sensor or sensors that can sense quantities of other compounds, elements, contaminants or material in the air returned from the indoor space, the subject matter described here can be implemented beyond the control of just VOC quantity in indoor spaces. In addition, this disclosure describes systems and techniques that can be used in combination with LEVs to minimize concentrations of harmful material from the air in indoor spaces.

[0032] FIG. **1** is a schematic diagram of a heating, ventilating and air-conditioning (HVAC) unit **100**. The HVAC unit **100** is configured to flow conditioned air into an indoor space **102**, for example, a laboratory or a research and development facility that has a separate LEV within a CFH (not shown). In some implementations, the HVAC unit **100** includes an air handling unit (AHU) **104** that receives, conditions, filters and then flows air into the indoor space **102** through an airflow pathway **106**, for example, airflow ducts or pipes. The HVAC unit **100** is configured to receive the return air from the indoor space **102** through a second flow pathway **108**. As shown in FIG. **1**, the first flow pathway **106** and the second flow pathway **108** are separate, yet fluidically coupled to the indoor space **102**.

[0033] A sensor module **110** is positioned in an fluidically coupled to the second flow pathway **108**. The return air from the indoor space **102** flows through the sensor module **110**. Thus, the sensor module **110** is configured to receive the return air from the indoor space **102**. The sensor module **110** is configured to determine if a quantity of VOCs in the return air exceeds or does not exceed a threshold VOC quantity.

[0034] In some implementations, the sensor module **110** includes a VOC sensor **112** and an integrated motorized damper actuator (IMDA) **114**. The VOC sensor **112** can be any sensor that is configured to sense a quantity of VOCs in air. The VOC sensor **112** can have a sensitivity that allows the sensor to read at least 0.01 parts per million (ppm) total VOCs in air. The VOC sensor **112** can also be of a type that can have connectivity/compatibility with the IMDA **114** and can exchange signals/instructions with the IMDA **114**. Such sensors are known in the art.

[0035] In some implementations, the IMDA **114** can be implemented as a controller that is operatively coupled to the VOC sensor **112**. For example, the IMDA **114** can be implemented as a computer system that includes one or more processors (or data processing apparatuses) and a computer-readable medium (for example, non-transitory computer-readable medium) storing computer instructions executable by the one or more processors to perform some or all of the operations described here. Alternatively, or in addition, the IMDA **114** can be implemented as processing circuitry, firmware, software, hardware or any combination of them.

[0036] In some implementations, the VOC sensor **112** generates a signal that is representative of the quantity of VOCs in the return air received through the second flow pathway **108**. If the quantity of VOCs in the return air is less than a lowest VOC quantity that the VOC sensor **112** can sense, then the VOC sensor **112** does not generate the signal.

[0037] The IMDA **114** is operatively coupled to the VOC sensor **112** and can receive the signal from the VOC sensor **112**. The IMDA **114** can store a value that represents a threshold VOC quantity. The threshold VOC quantity can be defined by an operator of the HVAC unit **100** based, in part, a volume of the indoor space **102** and a flow rate of air circulated through the**102**. If the IMDA **114** does not receive a signal from the VOC sensor **112**, then the IMDA **114** determines that the quantity of VOCs in the return air does not exceed the threshold VOC quantity. Alternatively, if the IMDA **114** does receive a signal from the VOC sensor **112**, then the IMDA **114** compares a VOC quantity represented by the received signal with the stored value that represents the threshold VOC quantity. Based on the comparison, if the IMDA **114** determines that the quantity of VOCs in the return air does not exceed the threshold VOC quantity, the IMDA **114** does not trigger action to reduce the quantity of VOCs in the return air. Conversely, based on the comparison, if the IMDA **114** determines that the quantity of VOCs in the return air exceeds the threshold VOC quantity, the IMDA **114** triggers action to reduce the quantity of VOCs in the return air, as described below.

[0038] The second flow pathway **108** extends downstream of the sensor module **110** allowing the return air from the indoor space **102** to flow past the sensor module **110** toward outlets **108***a* and **108***b*. A damper controller module **116** is installed upstream of the two outlets **108***a* and **108***b*. The damper controller module **116** includes a first damper **118** and a second damper **120** that are upstream of the first outlet **108***a* and the second outlet **108***b*, respectively. The HVAC unit **100** can draw air from the atmosphere **122** through the first outlet **108***a* and can exhaust the return air to the atmosphere **122** through the second outlet **108***b*. In addition, the damper controller module **116** can include a controller similar to the one included in the IMDA **114**. In some implementations, the damper controller module can include a first damper controller **116***a* to control the first damper **118** and a second damper controller **116***b* to control the second damper **120**.

[0039] The damper controller module **116** can include actuators (not shown) that can independently or simultaneously open or close the damper is **118** and **120** between respective fully open positions and fully closed positions as well as intermediate positions in between. In some implementations, the damper controller module **116** can operate independently of the sensor module **110** to open or close the first damper **118** or the second damper **120** (or both). In addition, the damper controller module **116** can be operatively coupled to the sensor module **110**, specifically to the IMDA **114**, and control the first damper **118** and the second damper **120** responsive to instructions from the sensor module **110**, specifically from the IMDA **114**.

[0040] In some implementations, the HVAC unit **100** can include a pump or a fan (not shown) fluidically coupled to the first outlet **108***a* to draw air from the atmosphere **122** through the first outlet **108***a*. The pump or the fan can operate at a constant speed, and the damper controller module **116** can control a quantity of air drawn from the atmosphere **122** through the first outlet **108***a* by adjusting an amount by which the first damper **118** is open or closed. Alternatively, the pump or the fan can operate at variable speeds, and the damper controller module **116** can control the quantity of air drawn from the atmosphere **122** by adjusting a speed of the pump or the fan, or the amount by which the first damper **118** is open or closed, or both.

[0041] As described earlier, if the IMDA **114** does not receive a signal from the VOC sensor one **112** or receives a signal from the VOC sensor **112** indicating that the quantity of VOCs in the return air does not exceed the threshold VOC quantity, the IMDA **114** does not trigger action to reduce the quantity of VOCs in the return air. Specifically, the IMDA **114** does not transmit any instructions to the damper controller module **116** to trigger action to reduce the quantity of VOCs in the return air. The second damper controller **116***b* maintains the second damper **120** at an open position that is sufficient for the HVAC unit **100** to flow a quantity of the return air out of the second outlet **108***b* and into the atmosphere **122**. The first damper controller **116***a* maintains the first damper **118** at an open position that is sufficient for the HVAC unit **100** to draw, through the second outlet **108***b*, a quantity of air from the atmosphere **122** that is equal to the quantity of the return air that was flowed into the atmosphere **122** through the first outlet **108***a*. After the first damper controller **116***a* and the second damper controller **116***b* determine that sufficient air has been respectively drawn into and exhausted to the atmosphere **122**, the first damper controller **116***a* and the second damper controller **116***b* close the first damper **118** and the second damper **120**, respectively.

[0042] On the other hand, if the IMDA **114** receives a signal from the VOC sensor **112** indicating that the quantity of VOCs in the air exceeds the threshold VOC quantity, the IMDA **114** triggers action to reduce the quantity of VOCs in the return air. Specifically, the IMDA **114** transmits instructions to the damper controller module **1162** trigger action to reduce the quantity of VOCs in the return air. Here too, the second damper controller **116***b* maintains the second damper **120** at an open position that is sufficient for the HVAC unit **100** to flow a quantity of the return air out of the second outlet **108***b* and into the atmosphere **122**. However, based on instructions received from the IMDA **114**, the second damper controller **116***b* opens the second damper **120** to a greater level compared to when the damper controller module **116** did not receive instructions from the IMDA **114**. Alternatively, or in addition, the second damper **120** opens the second damper **120** for a longer duration compared to when the damper controller module **116** did not receive instructions from the IMDA **114**. Consequently, the HVAC unit **100** exhausts more of the return air to the atmosphere **122**. Similarly, the first damper controller **116***a* maintains the first damper **118** at an open position that is sufficient for the HVAC unit to draw, through the second outlet **108***b*, a quantity of air from the atmosphere **122** that is equal to the quantity of the return air that was flowed into the atmosphere **122** through the first outlet **108***a*. After the first damper controller **116***a* and the second damper controller **116***b* determined that sufficient air has been respectively drawn into and exhausted to the atmosphere **122**, the first damper controller **116***a* and the second damper controller **116***b* close the first damper **118** and the second damper **120**, respectively. In this manner, the HVAC unit **100** has exhausted more of the return air that has the low-level concentration of VOCs to the atmosphere **122**, replacing that air with an equal quantity of fresh air drawn from the atmosphere **122**. Consequently, the quantity of the VOCs in the air flow to the indoor space **102** is diluted.

[0043] For example, assume that the HVAC unit **100** flowed 3000 cubic feet per minute (CFM) of air into the indoor space **102** and that the entire 3000 CFM flowed into the second flow pathway as return air. If the sensor module **110** did not determine that the quantity of VOCs in the return air exceeded the threshold VOC quantity, then the damper controller module **116** can operate the second damper **120** to exhaust about 500 CFM of the return air to the atmosphere **122** and can operate the first damper **118** to draw about 500 CFM of fresh air from the atmosphere **122** to compensate for the exhausted quantity of air. On the other hand, if the sensor module **110** did determine that the quantity of VOCs in the return air exceeded the threshold VOC quantity, then the damper controller module can operate the second damper **120** to exhaust about 1000 CFM of the return air to the atmosphere **122** and can operate the first damper **118** to draw about 1000 CFM of fresh air from the atmosphere **122** to compensate for the exhausted quantity of air. In other words, the HVAC unit **100** can dilute the return air with twice as much fresh air from the atmosphere **122** if the sensor module **110** determines that the quantity of VOCs in the return air exceeds the threshold VOC quantity.

[0044] The remainder of the airflow process implemented by the HVAC unit **100** is common to the situation in which the sensor module **110** did not determine that the quantity of the VOCs in the return air exceeded the threshold VOC quantity and to the situation in which the sensor module did. Specifically, the HVAC unit **100** flows a remainder of the return air and the quantity of air drawn through the first outlet **108***a* towards the AHU **104**. The AHU **104** receives, conditions, filters and then flows air into the indoor space **102** through the airflow pathway **106**. The airflow cycle through the indoor space **102** continues as described above with the sensor module **110** continuously determining if the quantity of the VOCs in the returning air exceeds the threshold VOC quantity and, in response to determining that the quantity of the VOCs in the returning air does exceed the threshold VOC quantity, triggering return air dilution by implementing the techniques described above.

[0045] FIG. **2** is a flowchart of an example of a process **200** of operating the HVAC unit of FIG. **1**. At **202**, conditioned air is flowed into an indoor space through a first flow pathway. For example, the HVAC unit **100** flows air conditioned by the AHU **104** into the indoor space **102** through the first flow pathway **106**. At **204**, return air is received from the indoor space. For example, the HVAC unit **100** receives return air from the indoor space **102** into the first fluid pathway **104**.

[0046] At **206**, a quantity of VOCs in the return air is determined. For example, the HVAC unit **100** flows the return air through the sensor module **110** positioned in the second flow pathway **104**. The VOC sensor **112** in the sensor module **110** compares the sensed VOC quantity in the return air with a threshold VOC quantity stored by the IMDA **114**. At **208**, a determination is made whether the quantity of VOCs in the return air exceeds the threshold VOC quantity. For example, based on comparing the sensed VOC quantity in the return air with the stored threshold VOC quantity, the sensor module **110** determines whether the quantity of VOCs in the return air exceeds or does not exceed the threshold VOC quantity.

[0047] If it is determined that the quantity of VOCs in the return air does not exceed the threshold VOC quantity (decision branch "NO"), then, at **210**, a first quantity of the return air is flowed to the atmosphere. For example, the IMDA **114** does not transmit any instructions to the damper controller module **116**. The second damper controller module **116***b* operates the second damper **120** to exhaust a quantity of return air to the atmosphere **122**. On the other hand, if it is determined that the quantity of VOCs in the return air exceeds the threshold VOC quantity (decision branch "YES"), then, at **212**, a second quantity of the return air is flowed to the atmosphere. The second quantity is greater than the first quantity flowed at step **10**. For example, the IMDA **114** transmits a signal to the second damper controller **116***b* to open the second damper **120** to a greater level or for a longer duration (or both) compared to a corresponding level or duration at step **210**.

[0048] In some implementations, the second damper controller **116***b* determines a duration for which the second damper **120** should remain open to exhaust a quantity of the return air to the atmosphere **122**. To do so, the HVAC unit **100** can include flow meters (not shown) disposed in the second flow pathway **108** that determine a flow rate of the return air received from the indoor space. Alternatively, or in addition, a flow rate of the return air can be set to a pre-determined value based on pumps or fans or other flow devices implemented by the HVAC unit **100**. The damper controller module **116** can store a pre-determined quantity of return air to be exhausted to the atmosphere **122** upon not receiving a signal from the IMDA **114** indicating that the quantity of VOCs in the return air exceeds the threshold VOC quantity. Based on the flow rate of the return air and based on the pre-determined quantity of return air to be exhausted to the atmosphere **122**, the damper controller module **116** can determine a duration for which the second damper **120** is to remain open to allow the quantity of return air to flow into the atmosphere **122**. The second damper controller **116***b* can open the second damper **120** for the determined duration and close the second damper **120** after the determined duration. The damper controller module **116** can store another pre-determined quantity of return air to be exhausted to the atmosphere **122** upon receiving a signal from the IMDA **114** indicating that the quantity of VOCs in the return air exceeds the threshold VOC quantity. Alternatively, the damper controller module **116** can be configured to multiply, by a factor (for example, a value greater than 1 and up to a factor that results in at most 50% of the total quantity of air circulated by the HVAC unit **100**), the pre-determined quantity of return air to be exhausted to the atmosphere if the quantity of the VOCs in the return air does not exceed the threshold VOC quantity.

[0049] In either situation, at **214**, an equal quantity of air is drawn from the atmosphere. For example, if the quantity of VOCs in the return air does not exceed the threshold VOC quantity, and the IMDA **114** does not transmit any instructions to the damper controller module **116**, the first damper controller module **116***a* operates the first damper **118** to draw a quantity of air from the atmosphere **122** that is equal to the quantity of return air exhausted to the atmosphere **122**. Similarly, if the quantity of VOCs in the return air is determined to exceed the threshold VOC quantity, and the IMDA **114** does transmit instructions to the damper controller module **116**, the first damper controller module **116***a* operates the first damper **118** to draw a quantity of air from the atmosphere **122** that is equal to the quantity of return air exhausted to the atmosphere **122**. In this latter situation, the quantity of air drawn from the atmosphere **122** is greater compared to the quantity of air drawn from the atmosphere **122** when the quantity of VOCs in the return air was determined to not exceed the threshold VOC quantity. Thus, regardless of whether the quantity of VOCs in the return air is determined to exceed or not exceed the threshold VOC quantity, a total quantity of air circulated by the HVAC unit **100** remains the same. When the quantity of VOCs in the return air is determined to exceed the threshold VOC quantity, the HVAC unit **100** exhausts more of the return air and draws correspondingly more of fresh air, thereby diluting the quantity of VOCs in the total quantity of air circulated by the HVAC unit **100**.

[0050] In some implementations, the first damper controller **116***a* determines a duration for which the first damper **118** should remain open to draw a quantity of the air from the atmosphere **122**. To do so, the HVAC unit **100** can include flow meters (not shown) disposed in the second flow pathway **108** that determine a flow rate of the return air received from the indoor space. Alternatively, or in addition, a flow rate of the return air can be set to a pre-determined value based on pumps or fans or other flow devices implemented by the HVAC unit **100**. The damper controller module **116** can store a pre-determined quantity of air to be drawn from the atmosphere **122** upon not receiving a signal from the IMDA **114** indicating that the quantity of VOCs in the return air exceeds the threshold VOC quantity. Based on the flow rate of the return air and based on the pre-determined quantity of return air to be drawn from the atmosphere **122**, the damper controller module **116** can determine a flow rate at which the quantity of air is to be drawn from the atmosphere **122** and a duration for which the first damper **118** is to remain open to allow the quantity of air to be drawn from the atmosphere **122**. The first damper controller **116*a*** can open the first damper **118** for the determined duration and close the second damper **118** after the determined duration. The damper controller module **116** can be configured to draw, from the atmosphere **122**, an amount of air equal to the amount that was exhausted to the atmosphere **122**.

[0051] At **216**, the drawn air is mixed with remaining return air and conditioned. For example, the HVAC unit **100** flows the remaining return air and the drawn fresh air through the same flow pathway, for example, the second flow pathway **108** and into the AHU **104**. As described earlier, the AHU **104** filters and conditions the air, and flows the conditioned air to the indoor space **102**.

[0052] Although not expressly shown, flow control devices such as valves of different types can be implemented at one or more locations in any flow pathway to control the flow of air through the HVAC unit **100**. The valves can be opened or closed, partially or fully, responsive to signals from any of the controllers described in this disclosure. The valves can also be operated responsive to the signals from any of the controllers to split airflow into multiple streams. Also, the quantity of air that this exhausted to or drawn from the atmosphere can be controlled by controlling a flow rate of the air through the flow pathways.

[0053] Implementations of the subject matter and the operations described in this specification can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Implementations of the subject matter described in this specification can be implemented as one or more computer programs, i.e., one or more modules of computer program instructions, encoded on computer storage medium for execution by, or to control the operation of, data processing apparatus. Alternatively or in addition, the program instructions can be encoded on an artificially-generated propagated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal, that is generated to encode information for transmission to suitable receiver apparatus for execution by a data processing apparatus. A computer storage medium can be, or be included in, a computer-readable storage device, a computer-readable storage substrate, a random or serial access memory array or device, or a combination of one or more of them. Moreover, while a computer storage medium is not a propagated signal, a computer storage medium can be a source or destination of computer program instructions encoded in an artificially-generated propagated signal. The computer storage medium can also be, or be included in, one or more separate physical components or media (e.g., multiple CDs, disks, or other storage devices).

[0054] The operations described in this specification can be implemented as operations performed by a data processing apparatus on data stored on one or more computer-readable storage devices or received from other sources.

[0055] The term "data processing apparatus" encompasses all kinds of apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, a system on a chip, or multiple ones, or combinations, of the foregoing The apparatus can include special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit). The apparatus can also include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, a cross-platform runtime environment, a virtual machine, or a combination of one or more of them. The apparatus and execution environment can realize various different computing model infrastructures, such as web services, distributed computing and grid computing infrastructures.

[0056] A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, declarative or procedural languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, object, or other unit suitable for use in a computing environment. A computer program may, but need not, correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub-programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

[0057] The processes and logic flows described in this specification can be performed by one or more programmable processors executing one or more computer programs to perform actions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

[0058] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for performing actions in accordance with instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. However, a computer need not have such devices. Moreover, a computer can be embedded in another device, e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio or video player, a game console, a Global Positioning System (GPS) receiver, or a portable storage device (e.g., a universal serial bus (USB) flash drive), to name just a few. Devices suitable for storing computer program instructions and data include all forms of non-volatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and

DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

[0059] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any inventions or of what may be claimed, but rather as descriptions of features specific to particular implementations of particular inventions. Certain features that are described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub combination or variation of a subcombination.

[0060] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0061] Thus, particular implementations of the subject matter have been described. Other implementations are within the scope of the following claims.

1. A method comprising:

flowing conditioned air into an indoor space through a first flow pathway;

receiving return air from the indoor space through a second flow pathway fluidically coupled to and separate from the first flow pathway;

flowing the return air through a sensor module positioned in the second flow pathway;

determining, by the sensor module, that a quantity of volatile organic compounds (VOCs) in the return air exceeds a threshold VOC quantity; and

in response to determining, by the sensor module, that the quantity of VOCs in the return air exceeds the threshold VOC quantity:

flowing, out of the second flow pathway and into the atmosphere, a quantity of the return air,

drawing, into the second flow pathway, a quantity of air from the atmosphere equal to the quantity of the return air that was flowed into the atmosphere, and

flowing a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

2. The method of claim **1**, wherein, flowing, out of the second flow pathway and into the atmosphere, a quantity of the return air, comprises opening a first damper positioned in the second flow pathway upstream of a first outlet to the atmosphere.

3. The method of claim **2**, wherein opening the first damper comprises transmitting, by the sensor module and to a first damper controller operatively coupled to the first damper, a signal to open the first damper in response to determining, by the sensor module, that the quantity of VOCs in the return air exceeds the threshold quantity.

4. The method of claim **3**, wherein the sensor module comprises a VOC sensor and a damper actuator operatively coupled to the VOC sensor, wherein transmitting, by the sensor module and to the first damper controller, the instruction to open the first damper comprises transmitting, by the damper actuator, the instruction to the first damper controller.

5. The method of claim **1**, wherein, drawing, into the second flow pathway, a quantity of air from the atmosphere equal to the quantity of the return air that was flowed into the atmosphere comprises opening a second damper positioned in the second flow pathway upstream of a second outlet to the atmosphere.

6. The method of claim **5**, wherein opening the second damper comprises transmitting, by the sensor module and to a second damper controller operatively coupled to the second damper, a signal to open the second damper in response to determining, by the sensor module, that the quantity of VOCs in the return air exceeds the threshold quantity.

7. The method of claim **6**, wherein the sensor module comprises a VOC sensor and a damper actuator operatively coupled to the VOC sensor, wherein transmitting, by the sensor module and to the second damper controller, the instruction to open the second damper comprises transmitting, by the damper actuator, the instruction to the second damper controller.

8. The method of claim **1**, wherein the quantity of the return air flowed into the atmosphere in response to determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity is a first quantity of the return air, wherein the method further comprises:

determining, by the sensor module, that the quantity of VOCs in the return air does not exceed the threshold VOC quantity;

in response to determining, by the sensor module, that the quantity of VOCs in the return air does not exceed the threshold VOC quantity:

flowing, out of the second flow pathway and into the atmosphere, a second quantity of the return air less than the first quantity of the return air,

drawing, into the second flow pathway, a quantity of air from the atmosphere equal to the second quantity of the return air, and

flowing a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

9. A system comprising:

a heating, ventilation and air conditioning (HVAC) unit configured to:

flow conditioned air into an indoor space through a first flow pathway; and

receiving return air from the indoor space through a second flow pathway fluidically coupled to and separate from the first flow pathway; and

a sensor module positioned in and fluidically coupled to the second flow pathway, the sensor module configured to:

receive the return air from the indoor space; and

determine that a quantity of volatile organic compounds (VOCs) in the return air exceeds a threshold VOC quantity,

wherein, in response to the sensor module determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity, the HVAC unit is configured to

flow, out of the second flow pathway and into the atmosphere, a quantity of the return air,

draw, into the second flow pathway, a quantity of air from the atmosphere equal to the quantity of the return air that was flowed into the atmosphere, and

flow a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

10. The system of claim **9**, wherein the system comprises a first damper positioned in the second flow pathway upstream of a first outlet to the atmosphere, wherein the first damper is configured to open to permit the quantity of the return air to flow out of the second flow pathway and into the atmosphere.

11. The system of claim **10**, wherein the system comprises a first damper controller operatively coupled to the sensor module, wherein the sensor module is configured to transmit a signal to the first damper controller to open the first damper, and wherein the first damper controller is configured to open the first damper in response to receiving the signal from the sensor module.

12. The system of claim **11**, wherein the sensor module comprises a VOC sensor and a damper actuator operatively coupled to the VOC sensor, wherein the damper actuator transmits the instruction to the first damper controller.

13. The system of claim **9**, wherein the system comprises a second damper positioned in the second flow pathway upstream of a second outlet to the atmosphere, wherein the second damper is configured to open to draw the quantity of the air equal to the quantity of the return air that was flowed into the atmosphere.

14. The system of claim **13**, wherein the system comprises a second damper controller operatively coupled to the sensor module, wherein the sensor module is configured to transmit a signal to the second damper controller to open the second damper, and wherein the second damper controller is configured to open the second damper in response to receiving the signal from the sensor module.

15. The system of claim **14**, wherein the sensor module comprises a VOC sensor and a damper actuator operatively coupled to the VOC sensor, wherein the damper actuator transmits the instruction to the second damper controller.

16. The system of claim **9**, wherein the quantity of the return air flowed into the atmosphere in response to determining that the quantity of VOCs in the return air exceeds the threshold VOC quantity is a first quantity of the return air, wherein the sensor module is configured to determine that the quantity of VOCs in the return air does not exceed the threshold VOC quantity,

wherein, in response to the sensor module determining that the quantity of VOCs in the return air does not exceed the threshold VOC quantity, the HVAC unit is configured to:

flow, out of the second flow pathway and into the atmosphere, a second quantity of the return air less than the first quantity of the return air,

draw, into the second flow pathway, a quantity of air from the atmosphere equal to the second quantity of the return air, and

flow a remainder of the return air and the drawn quantity of air from the atmosphere into the first flow pathway to be conditioned and flowed into the indoor space.

17. A non-transitory computer-readable medium storing instructions executable by one or more computer systems to perform operations comprising:

receiving a first signal representing a first quantity of volatile organic compounds (VOCs) in return air received from an indoor space into which conditioned air was flowed;

determining that the first quantity of VOCs in the return air does not exceed a threshold VOC quantity;

in response to determining that the first quantity of VOCs in the return air does not exceed the threshold VOC quantity:

transmitting instructions to open a first damper to flow a first quantity of the return air into the atmosphere, and

transmitting instructions to open a second damper to draw a first quantity of air from the atmosphere equal to the first quantity of the return air flowed into the atmosphere, wherein the first quantity of the air from the atmosphere mixes with a remainder of the return air received from the indoor space, is conditioned and is flowed back into the indoor space;

after receiving the first signal, receiving a second signal representing a second quantity of the VOCs in the return air received from the indoor space;

determining that the second quantity of VOCs in the return air exceeds the threshold VOC quantity; and

in response to determining that the second quantity of VOCs in the return air exceeds the threshold VOC quantity:

transmitting instructions to open a first damper to flow a second quantity of the return air into the atmosphere, wherein the second quantity of the return air is greater than the first quantity of the return air flowed into the atmosphere in response to receiving the first signal, and

transmitting instructions to open a second damper to draw a second quantity of air from the atmosphere equal to the second quantity of the return air flowed into the atmosphere, wherein the second quantity of the air from the atmosphere mixes with the remainder of the return air received from the indoor space, is conditioned and is flowed back into the indoor space.

18. The medium of claim **17**, wherein in response to determining that the first quantity of VOCs in the return air exceeds the threshold VOC quantity, transmitting instructions to open the first damper to flow the second quantity of the return air into the atmosphere comprises:

determining a flow rate of the return air received from the indoor space; and determining, based on the flow rate of the return air, a duration for which the first damper is to remain open to allow the second quantity of the return air to flow into the atmosphere,

wherein transmitting the instructions to open the first damper to flow the second quantity of the return air into the atmosphere comprises:

opening the first damper for the determined duration, and

closing the first damper after the determined duration.

19. The medium of claim **17**, wherein in response to determining that the first quantity of VOCs in the return air exceeds the threshold VOC quantity, transmitting instructions to open the second damper to draw the second quantity of the air from the atmosphere comprises:

determining a flow rate of the return air received from the indoor space; and

determining, based on the flow rate of the return air:

a flow rate at which the second quantity of air is to be drawn from the atmosphere, and

a duration for which the second damper is to remain open to allow the second quantity of air to be drawn from the atmosphere,

wherein transmitting the instructions to open the second damper to draw the second quantity of air from the atmosphere comprises:

opening the second damper for the determined duration,

drawing air from the atmosphere for the determined duration and at the determined flow rate at which the second quantity of air is to be drawn from the atmosphere, and

closing the second damper after the determined duration.

20. The medium of claim **17**, wherein the instructions to open the first damper to flow the second quantity of the return air into the atmosphere and the instructions to open the second damper to draw the second quantity of air from the atmosphere equal to the second quantity of the return air flowed into the atmosphere are transmitted simultaneously.

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