**Title:** VENTILATION HEAT EXCHANGER UNITS AND HOUSING FOR VENTILATION SYSTEMS

**Abstract:** A ventilation heat exchanger unit (10) has an outer enclosure and a heat exchanger (48) which may be hexagonal has a face thereof parallel to an outer wall (62, 66) of the enclosure; a ventilation housing (628) has multiple flat inlets (626) and an outlet (634), the inlets and outlet aligned at the same level; and a drive circuit (200, 6100) and calibrating method allow a commissioning step in which air flow is adjusted and fan motor speed set for a run mode.

**FIG. 10**

[Image of a diagram showing the ventilation heat exchanger unit and its components.]
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VENTILATION HEAT EXCHANGER UNITS
AND HOUSING FOR VENTILATION SYSTEMS

The present invention relates to ventilation heat exchanger units, such as but not limited to heat exchanger units having fans located therein for powering ventilation therethrough. The invention also relates to components for use in such units. The present invention also relates to a method of operating an electrically-driven ventilator and to a device for implementing that method. The present invention also relates to housings for ventilation systems, particularly but not exclusively to those for ventilation systems of habitable accommodation such as residential or commercial buildings including wet rooms such as kitchens and bathrooms. The invention is also concerned with housings for central ventilation extraction units of the type having multiple inlets and a single outlet, especially the type including a motorised fan wheel, in which due to the nature of a multiple inlet/single outlet configuration, airflow velocity at the outlet may be high.

A known mechanical heat recovery unit consists of a ventilation heat exchanger unit comprising an outer enclosure, the outer enclosure containing a heat exchanger and first and second pathways, each extending through the heat exchanger from a respective inlet port to a respective outlet port. The effectiveness of the heat recovery unit is not particularly high. Therefore, in a building where the heat recovery unit is used in order to exchange heat between outgoing warm air and incoming fresh cold air, a relatively large amount of heat is lost into the atmosphere.

It is current practice to install mechanical extract ventilation (MEV) devices and Mechanical Ventilation with Heat Recovery (MHVR) devices by ensuring that they will have sufficient flow rate under both continuous and boost operations to comply with statutory requirements, for example in the UK, Section F of the Building Regulations. To achieve this, it is current
practice to over-drive the devices to provide a capacity that is sufficiently in excess of the actual required capacity that the required flow rate is always likely to be achieved.

The present inventors have realised however that this way of installing such a device means that the device in use may have unnecessarily high power consumption.

Accordingly they have sought to provide a drive arrangement, embodiments of which enable better adaptation of the set-up or calibration of the device to the environment in which it operates, and a commissioning or calibrating routine that enable the device to be better adapted to its environment.

EP 1 541 933 discloses a known ventilation housing having an outlet, an inlet opening communicating with the room where the housing is located, and at least one other air inlet. The air outlet is circular providing the unit with considerable depth, which is not always convenient. Rectangular ducting is used for ventilation ducting due to the limited space available in ceiling voids and extract units such as this with round spigots require the use of adaptors. This increases the cost of installation, with additional components and fitting time. It also increases system flow resistance, reducing the ventilation system efficiency, and increasing specific fan power. It also adds to the number of joints in the system, increasing the potential for additional problems such as reduced system efficiency and leakage points. The distance between the mounting surface to which the rectangular ducting is fitted and the duct spigot on the housing varies in other prior art between 20mm and 160mm. With a distance of over 20mm and less than 50mm, the misalignment is made up by bending/curving the ducting away from the mounting surface, but this puts stress on the components and the joints, increasing the likelihood of leaks. Larger distances are accommodated with two rigid 90° bends or a short length of flexible ducting and a round-to-rectangular adaptors. The use of bends so
close to the fan wheel used in the unit has a significant adverse effect on efficiency, especially when used on the outlet. It also increases installation cost due to additional components and fitting time. It also increases system flow resistance, reducing ventilation system efficiency and increasing specific fan power. The additional number of joints also increases the potential for leaks and causes a reduction in system efficiency.

EP 0 499 813 discloses a hood extractor unit in which a fan housing has a single flat inlet aperture and a single flat outlet aperture. The fan wheel disclosed appears to be forwardly curved and rotates with its access aligned with a plane parallel to the elongate directions of the flat inlet and outlet apertures. Since there is only one inlet, flow speed at the outlet aperture is not particularly high such that this unit does not face the problems of units with multiple inlets and a single outlet. On the way from the inlet to the fan wheel, a complicated flow splitter is necessary resulting in at least two changes of direction of the flow before the fan wheel is encountered, one of which is a sharp 90° bend. Due to this complicated structure and the nature of the fan wheel which sucks air in from both ends, this type of structure is limited to the one shown, namely a hood extract with only one inlet into the fan housing.

The present invention aims to alleviate at least to a certain extent the problems of the prior art.

The present inventors have also sought to provide a drive arrangement, embodiments of which enable better adaptation of the set-up or calibration of the device to the environment in which it operates, and a commissioning or calibrating routine that enable the device to be better adapted to its environment.

According to a first aspect of the present invention there is provided a ventilation heat exchanger unit comprising an outer enclosure, the outer enclosure containing a heat exchanger and first and second ventilation pathways, each extending through the heat exchanger from a respective inlet
port to a respective outlet port, the heat exchanger having a generally polygonal cross-section having a first face thereof generally or substantially parallel to an outer wall of the outer enclosure. This arrangement is highly advantageous in that it allows a relatively large heat exchanger to be used inside a relatively small outer enclosure, thereby improving the heat recovery effectiveness of the ventilation heat exchanger unit.

The outer enclosure (or casing) may be substantially a rectangular parallelepiped. The outer enclosure may have a width of 600mm, making it compatible with standard kitchen units, e.g. for storing under worktops or in place of a 600mm wall cupboard in standard kitchen layouts. The heat exchanger may have, generally, a cross-section of a regular hexagon and may generally take the shape of a hexagonal prism such as a uniform hexagonal prism. This may allow for two faces of the heat exchanger to be located adjacent to and parallel (or at least generally or substantially parallel) to outer walls of the outer enclosure, thereby enabling a substantial portion of the internal volume of the outer enclosure to be filled by the heat exchanger. In some embodiments over 40% or over 30% of the internal volume of the outer enclosure may be filled by the heat exchanger, 25 to 50% being typical, over 30% being preferable and about 30 to 40% being more typical, e.g. 33%, although over 50% or over 55% or over 60% are envisaged, thereby allowing relatively good heat recovery effectiveness. This may especially be the case when the outer enclosure is a rectangular parallelepiped. This configuration may also allow two other ones of the hexagonal faces of a hexagonal heat exchanger to be used for airflow ingress into the heat exchanger and the remaining two faces of the heat exchanger to be used for airflow exit from the heat exchanger. Additionally, it has been established that a heat exchanger with a substantial counter-flow portion therein may be used in this configuration, thereby providing the ventilation heat exchanger unit with very
high heat recovery effectiveness, over 85% heat recovery effectiveness being achievable, close to or over 90% being envisaged.

Each of the first and second ventilation pathways may include a fan located inside the outer enclosure. A compact unit without the need for external fans may therefore be provided. Each fan may be located downstream of the heat exchanger in its respective ventilation pathway. This enables "sucking" through the heat exchanger and improves sealing of pathways upstream of the fan. Blowing through the heat exchanger may be similarly effective in other embodiments.

The outer enclosure may include a generally flat manifold face on which all of the inlet and outlet ports are located. This may enable easy connection of ventilation ducting to the unit. The manifold face may include two manifold plates, each manifold plate defining a said inlet and a said outlet. The manifold plates may be identical to one another.

A second face of the heat exchanger may be located adjacent and parallel (or generally or substantially parallel) to the manifold face of the outer enclosure, the second face being opposite and parallel to the first face of the heat exchanger. This may enable a heat exchanger of substantial size relative to the outer enclosure to be fitted inside the enclosure.

The outer enclosure may include a first duct housing unit located on one side of the heat exchanger and second duct housing unit located on an opposite side of the heat exchanger. Each duct housing unit may comprise an inner housing part and an outer housing part which is spaced from the heat exchanger by the inner housing part and at least partly defining outlet ducting which leads from the heat exchanger to a respect outlet port. The two duct housing units may be identical to one another. This may minimise tooling and manufacturing costs. The duct housing units may be oriented with the outlet ports thereof diametrically opposed to one another. Therefore, even though the duct housing units may be identical, by sitting them oriented at 180° to one another with the
outlets port diametrically opposed, a working arrangement may nevertheless be achieved in a highly novel manner.

A fan may be located between the inner and outer housing parts, the fan preferably being a centrifugal fan with forward or backward curved fan blades. The fan may be located off-centre in a fan scroll chamber defined in each duct housing unit. This arrangement has been found to provide effective airflow through the unit with minimal fan power consumption. Each duct housing unit may define a diffuser located between the scroll chamber and outlet port. The diffuser may thus be located downstream of the fan and heat exchanger and may therefore slow the airflow with minimal energy loss as the airflow approaches the outlet port. The scroll chamber may have a rectangular outlet into the diffuser. Accordingly, the flow within the scroll chamber may be two dimensional for maximum efficiency with a centrifugal fan with its axis generally perpendicular to a generally planar direction of the scroll chamber. However, the diffuser may have a transition from a rectangular cross-section at the scroll chamber exit to a circular cross-section at a location spaced there along. The transition may be smooth from rectangular to circular and may take up the whole length of the diffuser which may, despite the square to circular transition, have a generally conical shape, the smooth transition thereby allowing good smooth flow through the unit with minimum fan power consumption.

The inner housing part and outer housing part may be separate components which abut against one another at a surface lying in a plane perpendicular to an axis of the fan.

The inner housing part may be provided with a recess for accommodating a corner of the heat exchanger, the recess preferably having an internal angle of about 120° to 130° for accommodating an edge of a heat exchanger which has a cross-section or shape which, generally, is a regular polygon. This recess may space the heat exchanger closer into the arrangement
of the duct housing unit, thereby maximising heat exchanger volume inside the outer enclose. In larger units, a stretched hexagon may be used, having elongated opposite parallel faces which are preferably noticeably larger than the remaining four sides. This arrangement may increase the percentage of the volume of the unit taken up by the heat exchanger.

The inner housing part and the outer housing part may be made from EPP. Other materials could be used in other embodiments, e.g. other expanded plastics materials.

According to a further aspect of the invention there is provided a ventilation heat exchanger unit comprising an outer enclosure, the outer enclosure containing a heat exchanger and first and second ventilation pathways, each extending through the heat exchanger from a respective inlet port to a respective outlet port, the heat exchanger having a counter-flow section in which flow paths in adjacent portions of the first and second ventilation pathways are in opposite directions, a fan being provided inside the outer enclosure in at least one of the ventilation pathways for powering air therethrough. This enables a highly compact without the need for an external fan.

According to a further aspect of the invention there is provided a ducting housing unit for a ventilation heat exchanger unit, the ducting housing unit comprising an inner housing part arranged to be located adjacent to a heat exchanger having a cross-sectional shape which is generally a polygon, and an outer housing part arranged to be spaced from the heat exchanger by the inner housing part and at least partly defining outlet ducting leading to an outlet port. This arrangement may advantageously allow construction of the ducting housing unit with an internal fan chamber, so that an external fan is not needed. The inner housing part may be provided with a circular aperture in one wall thereof to provide for airflow into the fan chamber. A fan may therefore be located between the inner and outer housing parts, located in the fan chamber.
The fan chamber may comprise a fan scroll chamber and the fan may be located off-centre in the fan scroll chamber. The ducting housing unit may include a diffuser located between the scroll chamber and the outlet port. The scroll chamber may have a rectangular exit into the diffuser and the diffuser may have a transition from rectangular cross-section to circular cross-sectional shape there along. The diffuser may be generally cone-shaped in shape with the transition from rectangular to circular smoothly merging along the whole length of the generally conical diffuser. The scroll chamber may be provided with a centrifugal fan arranged to provide for generally two dimensional flow in the scroll chamber outside a fan wheel of the fan, leading to the rectangular exit and the smooth transition to circular is highly advantageous in that it minimises pressure loss compared to a rectangular duct and allows for airflow to a circular outlet port when the outlet port is circular, with minimal losses and minimal use of fan motor power.

The inner housing part may be provided with a recess for accommodating a corner of the heat exchanger. This recess may be provided in an otherwise generally flat wall of the inner housing part and is highly advantageous in that it allows the inner housing part to be positioned generally closer to the heat exchanger and therefore maximises the heat exchanger volume which may be used within a given space. The recess may define an internal angle of about 120° to 130° for accommodating a corner of a hexagonal heat exchanger. Other angles for the recess are envisaged particularly for use with heat exchangers having different cross-sections.

Another aspect of the invention provides a method of calibrating air flow in a ventilation system which includes a commissioning step in which a fan motor speed is adjusted to a set value to provide a desired air flow while measuring air flow; and a run step which includes selecting the set value.
In another aspect there is provided a method of operating a ventilator fan driven by an electric motor, the method comprising: a default operation step in which the electric motor is caused to operate the ventilator fan at at least one preset selectable speed; a commissioning step in which at least one stored value of motor rotation speed is adjusted to provide a desired airflow performance value of the fan; and a selectable run step in which the fan is caused to provide the desired airflow performance value.

There may be plural stored values of motor rotation speed, and a stored boost value, and the method may comprise selecting one of the stored values, adjusting that value in dependence on a measured parameter of the ventilator, selecting the boost value corresponding to the selected value, and adjusting the stored value corresponding to the boost value in dependence on said measured parameter of the ventilator.

The selecting steps may be performed via a wireless link.

The method may further comprise a step of selecting a commissioning mode to cause the commissioning step to be effected.

The step of selecting a commissioning mode may comprise making a switch connection to a control input of a controller.

The method may further comprise selecting a run mode by opening the switch connection.

In the run mode, the method may comprise switching between different motor speeds in accordance with sensed parameters.

The sensed parameters may include one or more of humidity, frost, CO₂ and temperature.

In another aspect there is provided a control system for a ventilator fan having means for performing one or more of the methods described in aspects above.

In a another aspect there is provided a drive circuit for a ventilator fan driven by an electric motor, the circuit having plural switches for selecting
motor rotation speeds, a speed control device connected to respond to the
switch settings for providing corresponding pulse widths in an output to the
motor, and commissioning circuitry, associated with the speed control device,
having a commissioning setting in which a selected motor rotation speed can be
adjusted to provide a desired airflow performance of the fan, and a run setting
in which the selected motor rotation speed cannot be adjusted, wherein before
actuating the commissioning circuitry, the plural switches are operative to
select between preset motor rotation speeds.

There may be a wireless remote control device operable to select
between different motor rotation speeds at least in said commissioning step.

The electric motor may be an electronically-commutated motor, having
an operating circuit responsive to a PWM input from the speed control device
for varying the speed of rotation of the electric motor.

There may be a microcontroller programmed to form the speed control
device

There may be one or more sensors so that in the run mode, different
motor speeds are selected in accordance with sensed parameters.

The sensors may comprise one or more of humidity, frost, CO₂ and
temperature.

Fans driven by electronically commutated motors typically include
motor operating circuitry as part of the fan device and can also be described as
brushless DC (BLDC). That is to say, the electronics necessary for correct
commutation of the motor to ensure that it operates smoothly and predictably
may be an integral component of the fan device.

According to another aspect of the present invention there is provided a
housing for a ventilation system, the housing having multiple flat inlet and an
outlet, the inlets and outlets being aligned at the same level.

Preferably, the flat inlets and outlet are elongate in form, for example
rectangular. The rectangular inlets/outlet may have webs or splitters providing
a series of subducts therein, three adjacent square subducts being used in one example. Corners of the rectangular inlets/outlet may be sharp or slightly radiused. Thus, the inlets/outlet may be essentially or substantially rectangular. This advantageously allows flat ducting, such as rectangular ducting, to be attached directly to the housing, with multiple inlet ducts attached thereto, with no adaptors, such as circular-to-round adaptors and without bending ducting. This allows a cost effective ventilation housing which is easy and quick to install, with good system flow resistance and with minimum possibilities of leakage at joints and minimum stressing of components. This also allows a highly efficient system which may produce required airflow with lower specific fan power than was previously the case, which is highly advantageous for environmental reasons.

The housing is preferably for a central ventilation extractor unit. Such a central ventilation extractor unit may house a fan wheel for drawing ventilation from the inlets and discharging through the outlet. Such a central ventilation extractor unit may have the housing mounted in one room of the building and may draw ventilation air from multiple other locations in the building, such as other rooms, through the ventilation ducting and may then discharge ventilation air through the outlet to atmosphere.

The housing may have a fan impeller wheel located in or adjacent an exit chamber thereof, such as for a centrifugal fan. The height of the fan wheel may be substantially the same height or slightly less than the height of the exit chamber. The exit chamber may communicate with an inlet plenum chamber of the housing through an aperture aligned with an inlet aperture of the fan wheel. Therefore substantively all of the flow entering the fan wheel may do so through this one aperture. A fan motor may be attached to the other end of the fan wheel.

Preferably, the outlet from the housing has an exit aperture which is wider in a plane perpendicular to the fan wheel axis than it is tall, for example
approximately two to four times wider, e.g. about 3.5 times wider. This advantageously provides a very wide outlet and enables the high speed flow downstream of the fan wheel to proceed without having to encounter sharp corners and is therefore highly efficient.

The exit chamber may be generally flat in form, e.g. having a generally planar form and the fan axis may be perpendicular to the plane of the exit chamber. This advantageously allows the fan wheel to sit in the exit chamber, allowing a wide and efficient exit of flow from the chamber. The exit aperture may comprise an elongate rectangular slot having a height substantially the same as the height of the chamber. The width of the slot may be greater than the diameter of the fan wheel, enabling a wide and efficient exit of flow from the housing.

A backwardly curved fan wheel may be used. This may advantageously minimise swirl in the flow immediately downstream of the fan wheel for high efficiency. The fan wheel may have a diameter greater than its axial length. When such a fan wheel is used, especially in the exit chamber, with its axis perpendicular to a generally flat planar form of the exit chamber, this may allow downstream of the fan wheel a two dimensional flow whose flow characteristics do not vary significantly along the axial direction of the fan wheel or in other words as one progresses up the height of the exit chamber. Therefore, velocity gradients and a swirling or turbulent flow immediately downstream of the fan wheel are avoided. Furthermore, any swirling is aligned with an elongate direction of the flat or elongate outlet, which as stated above may have a rectangular form, which can be advantageous for airflow efficiency reasons.

In some embodiments, the exit chamber is sloped relative to a plane containing the inlets. The inlets may consist of a plurality of inlet apertures into an entrance plenum, the plenum and exit chamber being located one on top of or next to the other. This advantageously allows a compact unit. The
entrance plenum may have a fan supply exit aperture, the fan supply exit aperture leading to the exit chamber where a fan wheel may be located. The fan supply exit aperture maybe substantially the same distance from each inlet aperture. This advantageously provides a system where the draw from each inlet aperture may be equal or substantially equal.

The exit chamber may, towards an exit aperture thereof, have an alignment region such as a curved region between a main planar portion thereof and the exit aperture. This may assist in providing efficient airflow exit from the chamber without providing a long and large housing. In some embodiments, the alignment portion may comprise a swan neck, e.g. a swan neck curve, having a first flow path change in one direction and a second flow path change in another direction - like the neck of a swan. This advantageously allows a very compact unit with efficient airflow characteristics, which does not have to be long in nature, especially when the exit chamber is sloped or at least partly at a different height from or misaligned with the inlet apertures to the housing.

The exit chamber may have an openable (e.g. removable or hingedly openable) lid which is arranged to be opened for fan inspection/removal. This advantageously allows fan inspection/servicing without entirely disassembling the housing and removing any attached ventilation ducts, as is necessary in prior art systems. The exit chamber may have an openable (e.g. removable or hingedly attached) base or intermediate portion which is connected to, or part of, an inlet plenum or manifolding section of the housing containing the inlets and outlet of the housing. This structure is highly advantageous since it allows the installation first of all of the ventilation ducting in a building or other accommodation and the connection thereto of the plenum portion of the housing containing the inlets and outlet. Then, as a later step, the exit chamber may be fitted, either as one installation component containing the fan wheel and motor, or in several installation stages if desired.
In some embodiments, a plane passing through the axis of the fan wheel and perpendicular to the exit aperture (or outlet) intersects the exit aperture at a point from 30% to 50% of the way along the exit aperture, 40% being the case in one example. This configuration allows the exit aperture/outlet to be relatively central on the housing which is useful for easy installation purposes. In some embodiments, the outlet may be aligned with the inlet, such that outlet ducting attached to the outlet is in effect a continuation of and coaxial with ducting at the inlet, thereby allowing very easy installation.

In some embodiments, a first plane may pass through an axis of the fan wheel and may be perpendicular to the exit aperture, and a second plane may be angled relative to the first plane at a compensation angle, a width to one internal side wall of the chamber wall from the fan wheel axis along a third plane perpendicular to the second plane being 35% to 45% higher than to an opposite internal side wall of the chamber, e.g. 40% higher. The compensation angle may, for example, be between 2° and 25°, e.g. between 5° and 15°, in one example being about 11°. The compensation angle may be positive such that a point on the fan wheel, in use, passes through the second plane the compensation angle, e.g. 11°, after it passes through the first plane. This configuration allows a highly efficient scroll shape downstream of the fan wheel while still enabling a relatively central or totally central ventilation outlet on the housing.

The opposite side wall may have a main portion parallel to the second plane. For example, where the compensation angle is 11°, the main portion of the opposite side wall may also be angled at 11° to the first plane which passes through an axis of the fan wheel and is perpendicular to the exit aperture.

Another aspect of the invention provides a housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber
generally downstream of the fan position, wherein the exit chamber is sloped relative to at least one selected one of the inlets and the outlet.

Another aspect of the invention provides a housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream of the fan position, wherein the exit chamber is sloped relative to a bottom surface of the housing.

Another aspect of the invention provides a housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream of the fan position, wherein the exit chamber is sloped relative to designed flow direction at the outlet or at least one of the inlets.

The slope angle may be between 10 and 40 degrees, for example, from 10 to 30 degrees. The slope angle is 15 degrees in one example.

Another aspect of the invention provides a housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream of the fan position, wherein the outlet is in a plane offset from the fan position.

The exit chamber may include a curved portion, such as a double-curved swan neck portion offsetting the outlet from the fan position. This allows a compact housing.

The inlets and outlet may be aligned with one another, e.g. in the same plane. The inlets and outlets may be flat, e.g. rectangular.

In another aspect there is provided a drive circuit for a fan driven by an electric motor, the circuit having plural switches for selecting motor rotation speeds, a speed control device connected to respond to the switch settings for providing corresponding pulse widths in an output to the motor, and commissioning circuitry, associated with the speed control device, having a
commissioning setting in which a selected motor rotation speed can be adjusted to provide a desired airflow performance of the fan, and a run setting in which the selected motor rotation speed cannot be adjusted.

The electric motor may be an electronically-commutated motor, having an operating circuit responsive to a pwm input from the speed control circuit for varying the speed of rotation of the electric motor.

A microcontroller may be pre-programmed to form the speed control device

In another aspect there is provided a method of operating a fan driven by an electric motor, the method comprising: a commissioning step in which plural motor rotation speeds are adjusted to provide desired airflow performance values of the fan; and a run step comprising selecting between the desired airflow performance values of the fan.

Fans driven by electronically commutated motors typically include motor operating circuitry as part of the fan device. That is to say, the electronics necessary for correct commutation of the motor to ensure that it operates smoothly and predictably may be an integral component of the fan device.

The present invention may be carried out in various ways and one embodiment of a ventilation heat exchanger unit and a number of preferred central mechanical extractor units and preferred drive circuits and calibrating methods in accordance with the various aspects of the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a heat exchanger or heat cell;

Figure 2 shows the heat exchanger with filters fitted on inlet faces thereof;

Figure 3 shows the heat exchanger with inner housing parts fitted;

Figure 4 shows a view similar to Figure 3 but with a fan motor assembly in position;
Figure 5 shows a similar view but with outer housing parts fitted;
Figure 6 shows a similar view but with inlet/exhaust manifolds fitted;
Figure 7 shows a view of the components of Figure 6 seen from a different angle;
Figure 8 is a view similar to Figure 7 but with the outer housing parts removed;
Figure 9 is a view similar to Figure 8 but with one of the outer housing parts and drainage pieces in place but with a fan motor and inner housing part removed;
Figure 10 is a view similar to Figure 6 but with drainage pieces shown;
Figure 11 is a view of the components of Figure 10, but from a different angle and with insulation plates fitted;
Figure 12 is a view similar to Figure 11 but also with metal casing components fitted;
Figure 13 is a view similar to Figure 12 but with a PCB controller access door in an open configuration;
Figure 14 is a view similar to Figure 12 but with the PCB controller access door shown closed and also showing wiring connectors;
Figure 15 is a view of the components of Figure 14, showing a wall mounting bracket;
Figure 16 shows the components of Figure 15, but from a different angle and showing a condensate drain plug;
Figure 17 is a partial view of the ventilation heat exchanger unit with the heat exchanger removed;
Figure 17a is an enlarged view of part of Figure 17;
Figures 18a, 18b and 18c are views of one of the inner housing units;
Figures 19a, 19b and 19c are different views of manifold plates of the ventilation heat exchanger unit.
Figure 20 shows the ventilation heat exchanger unit installed in a building:

Figures 21A and 21B show securement for fan motors.

Figure 22 shows a schematic diagram of an embodiment of a ventilator device;

Figure 23 shows a schematic diagram of a power supply suitable for the device of Fig 22; and

Figure 24 shows a schematic diagram of a remote control for the device of Figure 22;

Figure 25 shows a block diagram of a revised arrangement.

Figure 26A is a schematic view of a building containing a central mechanical extraction ventilator housing system in accordance with a preferred embodiment to the present invention;

Figure 26B is an enlarged view of part of the system;

Figures 27A to 27F are various views of a first embodiment of a ventilator housing in accordance with the invention;

Figures 28A and 28B are perspective and sectional views respectively of a second embodiment of a ventilator housing in accordance with the invention;

Figure 29A is a sectional view on the line A-A in Figure 29C of another embodiment of a housing in accordance with the invention;

Figure 29B is a side view of the housing of Figure 29A;

Figure 29C shows section C-C in Figure 29B;

Figure 29D is an exploded view corresponding to Figure 29A;

Figure 30A is a section on the line A-A in Figure 30C of a further preferred embodiment of a ventilator housing in accordance with the invention;

Figure 30B is a side view of the ventilator housing of Figure 30A;

Figure 30C is a section on the line C-C in Figure 30B;

Figure 30D is an exploded view corresponding to Figure 30A; and
Figure 31 shows a circuit for driving a fan in the housing of Figures 30A to 30D.

As shown in Figure 20, a ventilation heat exchanger unit (10) may be mounted in a room (12) in a building (14). The room (12) may be provided with a stale air outlet (16) connected to an exterior outlet (17) located on an outer wall (19) of the building (14) via a conduit (18) connecting the stale air outlet to the heat exchanger (10), internal heat exchanger pathway (20) and conduit (22) leading from the heat exchanger (10) to the exterior outlet (17). The room also has a fresh air delivery outlet (24) which is connected to a fresh air inlet (26) via a conduit (28) connecting the fresh air delivery outlet (24) to the heat exchanger (10), a second internal heat exchanger pathway (30) through the heat exchanger (10) and a conduit (32) connecting the heat exchanger to the fresh air inlet.

As will be described below, the heat exchanger (10) includes fan motors (34) for powering air through the first and second heat exchanger pathways (20, 30). The fan motors are powered by a supply cable (36) leading from a power storage/control unit (38) which is adapted to provide power to the heat exchanger (10) originating from a mains power supply source (40), solar panel (42) and/or wind turbine (44). The purpose of the heat exchanger (10) is to provide fresh air ventilation to the room (12) with small power consumption and small energy loss from the building by virtue of the energy in the air exiting through the exterior outlet (17). As shown in Figure 15, the ventilation heat exchanger unit (10) is 600mm wide for compatibility with standard kitchen equipment.

As shown in Figure 10, the ventilation heat exchanger unit (10) includes in addition to the two fan motors (34) both of which drive centrifugal fans (36) with forwardly curved vanes (not shown), the ventilation heat exchanger unit includes a hexagonal heat exchanger (48), identical inner housings (50) identical outer housings (52), identical manifold plates (54) and air inlet filters.
(56). Identical drain pieces (58) are also provided. These are arranged to drain condensation through a drain plug (60). The identical nature of the inner housings (50) outer housings (52), manifold plates (54) and drain pieces (58) greatly reduces manufacturing costs. As shown in Figures 21A and 21B, motor retaining ring (500), screws (504) are used to hold fan motors (34) securely in position.

The heat exchanger or heat cell (48) as shown in Figure 1 is a hexagonal counter flow heat exchanger, which in one embodiment is as is available from Recair BV of Waalwijk, Netherlands under the name Recair Sensitive RS160 (Trade Mark). This heat exchanger (48) (Figure 1) has inlet faces (62) leading via a counter flow section (64) to outlet faces (66). The ducts (not shown) in the heat exchanger’s counter flow section (64) are triangular such that each duct is surrounded by ducts in which the air flows in the opposite direction. Therefore, there is maximum heat transfer between the exiting stale air from the building (14) and the entering fresh air. The heat exchanger (48) volume is about 33% of the volume of the unit (10), which is substantially higher than in the prior art unit which is about 12.5%. Accordingly, there is minimum feeling of cold drafts in the building and minimum energy loss while maintaining a fresh inside atmosphere. The overall heat exchange effectiveness of the heat exchanger (48) is generally over 92% in many conditions, depending upon humidity, mass flow rate and temperature. As shown in Figure 2, the replaceable filters are placed on the inlet faces (62) of the heat exchanger (48). The filters are G3 grade and protect the heat exchanger (48) from dirt build-up. It is also envisaged that the unit (10) may include additional or optional filters (not shown) design to remove specific air borne contaminants such as pollen.

In Figure 3, it can be seen that the inner housings (50) may be fitted to the heat exchanger adjacent to outlet faces (66) of the heat exchanger (48). The inner housings (50) are non-handed such that exhaust ports (68) thereon are diametrically opposed. The inner housings (50) each include a generally planar
wall (70) whose inner face (700) engages along an edge (720) of the heat exchanger (48) defining a boundary between an inlet face (62) and outlet face (66) of the heat exchanger (48). Together with the outer housings (52), the inner housings (50) define a scroll chamber (72) in which the fans (46) are located, the scroll chamber having a rectangular outlet (74) which leads via a diffuser (76) to the exhaust port (68). Each exhaust port (68) is circular and there is a smooth transitional all of the way along the diffuser (76) from the rectangular section at the exhaust rectangular outlet (74) all of the way to the exhaust port (68) to the circular section at the port (68). This smooth transition enables flow with minimal pressure loss and inefficiencies. This is highly advantageous. The outer housings (52) interlock with the inner housings (50) by way of conical pegs (78) which engage with corresponding recesses (not shown) in the outer housings. As shown in Figure 17, the outer housings (52) define inlet ducting (79) which provides for a smooth flow leading from inlet ports (80) of the manifold plates (54) to the inlet faces (62) of the heat exchanger (48). The circular exhaust ports (68) defined by the inner (50) and outer housings (52) are located next to the outlet ports (82) which, like the inlet ports (80) of the manifold plates (54), are circular. These ports will accept 100mm diameter round ducting for the conduits (17, 32, 18, 28) internally or 125mm diameter ducting externally. In larger embodiments, other sizes may be employed, such as ports capable of using 125 mm diameter internally and 150mm externally. The manifolds plates (54) are made of a material resilient enough to accept the ducts as a push fit without the need for clamps such as jubilee clips, and the material has good insulating properties to prevent heat losses.

As shown in Figure 7, cool internal stale air exiting from the building (14) is pushed by the fan motor (34) through the left hand exhaust port (82) out of the building. Cool external fresh air is sucked into the heat exchanger unit (10) through the left hand inlet port (80) by the other fan motor which is not
shown in Figure 7. Warm internal stale air from the building (14) is sucked into the ventilation heat exchange unit (10) by the fan (34). Warm external fresh air for the building (14) is pushed out of the right hand exhaust port (82) shown in Figure 7 by the other fan (not shown). Figure 8 shows the outer housings (52) removed in order to illustrate the flow path of air within the units (10) in greater detail. As shown in Figure 9, the drainage pieces (58) are fitted. Again, these are non-handed and are shaped to guide condensate out of the unit (10). These parts are made of the same material as the fan housings (EPP) and manifolds to prevent heat losses. Figure 7 shows wiring channels (34a, 34b) for communication and power supply to fans and frost or other sensors (not shown).

Figure 10 shows the drainage pieces (58) from the back. Although they are identical, only one side will ever collect condensate, due to their novel inclined structure. Figure 11 shows insulation pieces (90) added to the top and bottom of the unit (10). These are made from Lamapro (Trade Mark) Lamacell (Trade Mark) thermal insulation of a foamed nitrile rubber type and available from Siderise (Special Products) Limited of Hadleigh, Suffolk, England. These insulation pieces prevent heat losses. In Figure 12, outer enclosure – defining components (92) of metal are shown on different sides of the heat exchanger unit (10). Figure 13 shows an access door (94) to a PCB controller (96) open for allowing commissioning of the unit. Figure 14 shows the access door (94) shut and wiring connections (98) for connecting the ventilation heat exchanger unit to the power storage/control unit (38) via the supply cable (36). As shown in Figure 15, the ventilation heat exchanger unit (10) may be provided near a top edge (99) thereof with a longitudinally extending wall mounting bracket (100), and spacer (101) may be positioned nearer a lower edge (102) of the unit (10). As shown in Figure 16, a lower face (110) of the ventilation heat exchanger unit (10) may be provided with the drain plug (60). The drain plug (60) may be compatible with domestic plumbing sizes and permanently
connected to the nearest waste pipe. The figures from 1 to 16 do not reflect the necessary sequence in which the mechanical ventilation heat recovery unit (10) will be assembled. Instead, the assembled sequence may start with a metal casing and the other components may be fitted into it. Figure 17 shows location grooves (58a) for filters (56).

The use of the identical parts, notably the inner housing (50) outer housings (52) and inlet/exhaust manifold plate (54) which are oriented differently to achieve the final assembly is considered to be highly novel and are advantageous. The unit (10) also has a very large heat exchanger (48) inside a relatively small compact casing compared to the prior art. This is enabled at least partly in that at least one generally flat face of the heat exchanger (48) is located adjacent and generally parallel to a face of the outer enclosure of the ventilation heat exchanger unit. In particular, the lower face (120) and upper face (122) of the heat exchanger (48) are abutted against and parallel to the drainage pieces (58) and the manifold plates (54) are abutted against and parallel to the respective faces of the metal outer casing of the unit (10). This configuration enables a very large heat exchanger to be used in a small rectangular parallelepiped outer housing suitable for use in domestic applications. This allows the unit overall to achieve greater efficiency and this is also by virtue of the way in which the internal parts, namely the inner housing (50) may be positioned close to the heat exchanger (48) thereby minimising leakage paths. This close positioning is enabled by the provision of the location grooves (125) extending there along and having internal faces (126, 127) angled relative to one another at approximately 120° to 130° for accepting the respective edge of the hexagonal heat exchanger (48) with a snug and excellent sealing fit, the grooves (125) also placing the inner housing (50) the outer housings (52) and diffusers (76) and inlet ducts (79) closer to the heat exchanger mass than would otherwise be the case, thereby enabling a larger heat exchanger to be accommodated in a smaller space. This highly inventive
groove also minimises leakage since the groove (125) may engage two adjacent faces of the heat exchanger (near the common edge thereof). The overall effect is that the unit may have a maximum nominal size of 600mm and may be compatible with modular kitchen units, yet may have excellent heat exchanger effectiveness and small fan power consumption.

The PCB 96 allows for remote commissioning of the unit. The unit may be fitted with an LCD display (not shown) to ease commissioning. A blocked filter alarm, such as visual warning or audible warning may also be provided. This may be implemented via a time function, e.g. after a year of operation, or through monitoring fan speeds and monitoring load/filter resistance via the PCB 96, in order to ascertain when the filters (56) must be changed. The fan motors (34) may be AC or EC (DC) and either direct mains voltage from the supply (40) or transformed mains voltage, i.e. transformed in the power storage/control unit (38). The solar panel (42) may use photovoltaic cells (43) and the wind turbine may be used independently or in combination with the solar power (42) to form a charging system with the power storage/control unit (38) to allow stored energy to be used so as to provide continuous power. Accordingly, a very environmentally-friendly and energy efficient system for ventilating a building may be provided.

Control of the fan motor (34) (or both motors of the Figure 1 embodiment or multiple motors in other embodiments, which may be shown collectively as only one motor in Figure 22) will now be described with reference to Figures 22 and 23. Control of fan motor(s) and calibration thereof may alternatively be as described with reference to Figure 31.

Referring to Figure 22 the ventilator device 10 includes an electronically-commutated motor 210 whose shaft 212 drives a fan 214, i.e. fan 34 (or both fans 34 of the Figure 1 embodiment or multiple fans in others, shown collectively as only one fan in Figure 22). Commutation of the motor
and general operation is performed by integral operating circuitry 216 having speed control inputs 218, 219.

A control circuit 200 has a microcontroller 220 (PCB 96 in Figure 13), here a PIC16F690, which operates as a PWM controller having PWM ratios that are varied to provide different speeds of motor operation. Different motor speeds may be provided in different ways, such as by selecting voltage signals from a 0 to 10 V DC range. The controller 220 has an output 221 to the bases of both of a pair of bipolar transistor 224a, 224b, whose collectors are connected via respective pull-up resistors 225a, 225b to a power supply voltage Vcc. The collectors are also connected to the speed control input 218, 219 of the motor 210. The emitters of the transistor 224a, 224b are connected to a ground reference. The arrangement is such that when the output 221a, 221b go high, the transistors 224a, 224b turn on, providing a logic 0 to the speed control input 219a, 219b. When the output 221 goes low, the transistors 224a, 224b turn off, supplying a 10v “logic 1” to the speed control input of the motor.

The microcontroller 220 has a second output terminal 226 used in selecting PWM values and hence motor speed in the run mode, a mode terminal 227 used to set a commissioning mode and a run mode, a trim terminal 228 used to input correction values, and plural (in this embodiment, four) control inputs 232-5.

Connected to mode terminal 227 are a first pull-down resistor 282 connected to the earth reference, and a jumper 283, shown as a switch, selectively connecting mode terminal 232 to a power voltage Vdd.

The system has first – fourth switches 242-245, connected to respective control/setting inputs 232-235 of the microcontroller 220. Each input 232-235 has a respective associated pull-down resistor 236-239, connected at the remote end to ground. The switches 242-245 have a common terminal connected to a second output terminal 231 of the microcontroller.
The second output terminal 226 is connected via the switches 242-245 to the respective inputs 232-235.

A humidity sensor 254 is connected via a bridge rectifier 255 to a further input 256 of the microcontroller 220. The humidity sensor acts like a variable resistor (depending on the humidity) to provide a voltage that varies in dependence on the humidity. When the humidity rises above a threshold programmed into the microcontroller 220, the ventilator is caused to run at a higher speed than the current speed. When the humidity drops –by virtue of the action of the ventilator, or due to some other non-related effect, the microcontroller 220 causes the ventilator speed to revert to its normal speed.

In this embodiment a frost sensor 260 is also provided, which is connected to the microcontroller 220 between a sixth terminal 257 and a seventh terminal 258 of the microcontroller 220. Also in this embodiment a carbon-dioxide sensor 262 is connected to an eighth terminal 259 of the microcontroller 220. The carbon dioxide sensor 262 receives a power voltage Vdd, and provides a logic 1 to the eighth terminal 259 when a received carbon dioxide level exceeds a threshold. This is turn causes the ventilator to switch to a boost speed.

The trim terminal 228 is connected to the wiper 249a of a preset potentiometer 249 via a fourth resistor 250. The preset has one end connected to Vdd and the other to the earth reference.

The microcontroller 220 operates as a pulse width modulator to provide a voltage to the speed setting terminals 218, 219 that lies between an average of 0 volts and an average of 10 volts. The PWM ratio is determined by the first switch 243, which when closed causes a boost mode to apply, in which the speed of rotation of the fan 214 is increased to a boost speed. It is also determined by the second switch, which when open or respectively closed causes the fan to rotate at a first or second “normal” speed. The actual speeds
associated with each switch setting are determined in a commissioning mode by values of voltage at trim terminal 228.

When the jumper 242 is connected, and a logic “1” applied to the mode terminal 232, the microcontroller 220 is placed into the commissioning mode. In this mode, when a voltage at trim terminal 228 is varied, the value at the end of the variation is stored in the microcontroller 220 for the associated speed setting.

Referring to Fig 23, in this embodiment the microcontroller 220 is powered by a voltage of Vdd [=5 volts] and to this end there is provided a power supply 300 having a mains [230 volts ac] input 301 and providing Vdd, as well as a voltage Vcc [=10 volts] for the PWM control signal and a pulsed voltage Vs= 2.7 volts for a humidity sensor. The skilled person will be aware of many circuit arrangements for such a supply. In the embodiment the supply is provided by a 12v-0v-12v centre tapped transformer 302 with one tap to a resistor 303, and 2.7-volt zener diode 304, the other to a bridge rectifier 305, whose output 306 goes via a first shunt smoothing capacitor 307, series resistor 308 and 10-volt zener 309 to the Vdd output 310, then via a second series resistor 311, 5-volt zener 312 and smoothing capacitors 313, 314 to the Vcc output 315.

Upon initial power up, the microcontroller 220 is in a so-called “default” mode. In this mode, the microcontroller has pre-stored values of motor speed that correspond to the speeds of the switches 242-4. In one embodiment, the switches 242, 243, 244 can be used in combination to select eight different speeds in 10% increments. The fourth switch 245 can be used to select between a boost period of 5 or 10 minutes, depending upon whether the switch is made or not. In a typical embodiment, the boost speed is a 15% increase on the speed selected by the first-third switches 242-244. The stored values of speed cannot be varied in the default mode.
The microcontroller can be switched to a commissioning mode by connecting jumper 246. In the commissioning mode settings may be input to the microcontroller 220, and stored for use in a subsequent “run” mode that is entered when the jumper 246 is opened.

To commission the microcontroller and associated motor and ventilator, the jumper 246 is made and the unit switched on. The desired speed range is then set using first- third switches 242-244. Using an air cone air flow meter set the kitchen and wet room terminals to the minimum high flow rates requirement of Part F of the UK Building Regulations. If the flow rate is more or less than the requirement, the preset 249 is adjusted to fine tune the system. Then the flow rates are rechecked for each speed setting. A similar process is used for the boost setting. The activity of adjusting the preset 249 causes variation in the values of motor rotation speed that are stored in the microcontroller 220.

Removing the jumper 246 prevents any changes in the stored values of motor rotation speed, and thus ensures that the air flow setting cannot be tampered with. Removal of the jumper, which causes pull down of the mode input 227 to ground, also places the microcontroller into its run mode. In the run mode, no adjustment of speed values corresponding to any switch setting can be made. However switching into and out of boost mode, switching between the stored values of speed remains possible.

Referring to Fig 24, in this embodiment, the system has an RF-type remote control device 270 for setting the speed of the ventilator. This remote control device may be used during normal operation to control the speed. During commissioning it may be used to cause the speed vary. The remote control device 270 of the presently described embodiment has an RF transmitter 272 coupled to a transmitting antenna 271, and operated by an encoder 273, having pushbutton switches shown figuratively as 273a. The RF transmitter here operates in the 433 MHz region, and communicates to an RF
receiver device 274, having a receiving antenna 275. The receiver 274 is connected to a decoder 276, which in this embodiment may accept signals from up to 7 different encoders. The decoder has a learn switch 277 and status LED 278, and has four digital outputs 280-3. The four digital outputs are connected to respective control inputs 284-7 of the microcontroller 220- see Fig. 1.

In operation, each of the remote control inputs 284-7 of the microcontroller is connected to have like functionality to the first-fourth inputs 232-235. Hence, the speed setting can also be performed remotely using the remote controller, so enabling remote commissioning if that is more convenient, and also remote control during the run mode. Specifically, the remote controller has “up/down” controls, and also a “boost” switch. The speed control is effected by using the “up/down” control to cycle through the speed settings.

With the jumper 242 connected, the person who is commissioning the device can switch between the different speed settings while checking the flow meter and without having to return to the controller itself to change speeds. Once the jumper 242 is disconnected, the commissioning mode is left and the run mode entered.

In the run mode the switches 242-245, and in the same way, the remote control settings have different functions to those in the commission and default modes. Specifically, third and fourth switches in the run modes are used to set different boost periods- since there are two boost switches, four periods may be selected by the combined switches – in this example 5, 10, 15 and 20 minutes.

Figure 25 shows a block diagram for a modified PCB controller arrangement 96, also for use with the mechanical heat recovery unit 10 shown in Figures 1 to 21A. For commissioning (or installation) of the ventilation heat recovery unit 10, the revised microcontroller 220' has input 401 from a boost delay setting system 402, input 403 from a CO2 set point system 404, input 405 from a humidity set point system 406, and input 406' from a speed setting
system 407 controlled by an RF input speed selection system 408 and/or a local controller speed selection system 409.

During installation, the revised microcontroller 220' is set in a commissioning mode, for example by a jumper like the jumper 246. In the commissioning mode, settings may be input to the microcontroller 220' through the inputs 401, 403, 405, 406'. To commission the microcontroller 220' and associated motor/fan 34, the jumper is made and the unit is switched on. The desired speed range is then set using the speed setting system 407 (remotely when RF input 408 is used). Using an airflow meter, kitchen, wet room or other terminals can be set to the minimum high flow rates required by building regulations. If the flow rate is more or less than the requirement, the controller system 409 or RF input system 408 may be used to adjust the system for minimum power use at the fan motor 34 while still meeting the regulatory airflow requirement. The installer can do this remotely from the unit 10 using RF input while measuring airflow simultaneously at a remote location in the building at a remote air inlet or outlet, thereby meaning only one member of installation staff is needed. The flow rates are checked for each speed setting and a similar process may be used for a boost setting. Humidity set point, CO₂ set point and boost delay setting may be set using the humidity set point system 406, CO₂ set point system 404 and boost delay setting system 402. The inputted data causes variation in the values of the motor rotation speed and humidity, CO₂ and boost delay setting which are stored in the microcontroller 220'. The boost delay setting can, for example, set a time period of boosted fan speed to be used when boost is later requested by the user or, for example, in response to light switch operation or motion sensor output (e.g. in a bathroom or kitchen or toilet). Likewise, CO₂ set point and humidity set point can be chosen in order to initiate operation of the motor 34 or increase speed of the motor 34 during later running mode when the preset humidity and/or CO₂ set points are reached at sensors in the building.
Once the commissioning is completed, the jumper may be removed to prevent change in the stored values and places the microcontroller 220' into its run mode. In the run mode, no adjustment of speed values corresponding to any switch settings can be made. However, switching into and out of boost mode and switching between the stored values of speed remains possible. RF boost control 410 and/or fixed local boost control 411 may be used by a user in the building to provide operating inputs to the microcontroller 220' to change speed of the fan motor 34 by virtue of signal 412 to the motor 34 via motor speed control signal path 413. Inputs 414 and 415 to the microcontroller 220' from CO₂ sensor 416 and humidity sensor 417, which are located suitably in the building, may also during the run mode initiate operation of a motor 34 or increase or decrease motor speed as appropriate, such as to maintain humidity and CO₂ levels in the building below predetermined values (set during calibration mode).

Microcontroller 220' may optionally be provided with display outputs 420 leading to display 422 located on a visible position of the PCB 96/microcontroller 220' on the outer enclosure of the mechanical heat recovery ventilation unit 10.

Figure 25 also shows power supply system 424 for the microcontroller 220' and motor 34 (or motors 34). In addition to the mains supply 40 shown in Figure 20, a SELV supply 426 may be provided alongside the wind turbine 44 and solar 42 sources, the storage device and supply controller 38 may comprise two separate logical units as shown in Figure 25 and separate power supply lines 428, 429, 430 may be provided to the microcontroller 220' and fan motor/motors 34 from the mains 40/SELV 426 supplies and the supply controller 38 as shown in Figure 25.

With reference to an embodiment shown with reference to Figure 26A, a building 610 includes a kitchen 612, bathroom/wetroom 614 and living room 616 separated by walls 618 and having trickle ventilator inlets 620. Each of
these rooms 612, 614, 616 has a ventilation outlet 622 connected by rectangular ducting 624 to a respective inlet 626 of a central mechanical extract unit housing 628 as shown in Figures 30A to 30E. The housing 628 contains a backwardly curved centrifugal fan 630 powered by a motor 632 and an outlet 634 which communicates via outlet rectangular ducting 636 to the atmosphere. As shown in Figure 26B, the housing 628 has the three inlets 626 and an outlet 634 formed as short spigots 638 with an internal rectangular shape as shown in Figure 30B, matching the external cross-sectional shape of the ducts 624, 636, whose width to height ratio is approximately 3.5 to 1. The housing as shown in Figure 26B, has four mounting apertures 640 enabling it to be mounted conveniently, for example to the ceiling or within a suspended ceiling or roof space.

As shown in Figure 30A, all of the spigots 638 and the inlets 626 and outlet 634 are aligned with another. They are the same distance above a bottom face 642 of the housing as shown in Figure 30A and are close to the bottom face, with the closest edge 644 of each of the inlets 626 and outlet 634 being approximately 20mm above the bottom face 642. Although the word “bottom” has been used here, the housing 628 may in fact usually be mounted in the building 610 in a configuration inverted from that shown in Figure 30A, with the ducting 626, 636 close to the ceiling or top of a roof space and with the “bottom” face 642 mounted thereto. The way in which the housing inlets 626, 634 and outlet are aligned is highly advantageous in that rectangular ducting with relatively large width and small height can be connected to the central housing 628 without the use of any adaptors and without bending the ducting. This means that additional components are not needed and fitting time is minimised. Additionally, there are no sharp bends necessary close to the housing, minimising system flow resistance and optimizing ventilation system efficiency, allowing a lower specific fan power and therefore more environmentally friendly system. The number of joints in the system is also
minimised, resulting in an efficient system with minimum leaks. The components and joints do not need to be stressed, also minimising the likelihood of leaks.

As seen in Figure 30A, the housing 628 has an inlet plenum chamber 46 into which each of the inlets 626 emerges. The inlet plenum chamber has a bottom wall 48 and four side walls 650 and is generally trapezium shaped in cross-section when viewed from the side as in Figure 30D. The bottom wall 648 and side walls 650 of the inlet plenum chamber 646 are formed unitarily as part of a manifold component 652 of the housing 628 which includes all of the inlets 626 and outlet 634. A top wall 654 of the chamber 646 is formed as part of a separate intermediate component 656 of the housing 628 and includes a circular exit aperture 658 on sloped top wall 654 which leads to a circular inlet 660 to the fan wheel 630. Together with a top cover 662, the intermediate component 656 forms an exit chamber 664 of the housing 628. As shown in Figure 30A, the exit chamber is generally planar, and is wholly planar in the region of the fan wheel 630, being of constant height slightly higher than the height of the fan wheel 630. In a planar portion 666 of the exit chamber 664, lower 668 and upper 670 walls of the exit chamber are parallel to one another and the top wall 654 of the inlet plenum chamber 646. A side wall 672 of the exit chamber 664 is curved as a scroll. The planar portion 666 of the exit chamber 664 is joined by a swan neck portion 672 of the exit chamber 664 to the outlet 634. The swan neck portion is highly advantageous in that it minimises the size of the housing 628 and enables the outlet 634 to be aligned at the same level as the inlets 626 without a long outlet section for the exit chamber 664. The swan neck portion 672 comprises a first section 674 which curves in one direction away from the plane of the planar portion 666 and a second oppositely curved portion 676, which merges into the outlet 634 in a highly efficient manner. The way in which the exit aperture 658 is not aligned with the outlet 634 and inlets 626 and the exit chamber 664 is of small height.
and located above the inlet plenum chamber 646 allows a very compact housing 628. The sloping of the exit chamber 664, whose planar portion 666 is oriented at an angle of 15° to a plane parallel to the flow directions at the outlet 634 and inlets 626 and the bottom wall 642 allows the outlet 634 to be aligned with the inlets 626, without having any sharp corners in the flow path through the housing 628, especially downstream of the fan wheel 630 and through the exit chamber 664 and outlet 634 where the airflow velocity, when the fan 630 is being driven by the motor 632, is substantially higher than the airflow velocity at the multiple inlets 626, due to mass flow rate conservation, i.e. mass flow rate at the outlet equals the sum of inlet mass flow rates.

The outer diameter of the blades of the fan wheel is approximately 190mm and the height of the blades of the fan wheel is about 45mm. The outer diameter of the rotor blades of the fan wheel 630 is approximately four times the height of the blades of the rotor fan wheel. The width of the outlet 634 is 200mm, which is greater than the outer diameter of the blades of the fan wheel 630. The height of the outlet 626 is about 3.5 times smaller than the width thereof.

A plane X (see Figure 30C) is perpendicular to a plane Y which is angularly spaced at a compensation angle of 11° from a plane Z which is parallel to a longitudinal axis of the housing 628 and parallel to flow direction at the outlet 634 and to the outlet rectangular ducting 636. An outlet guide wall part 678 of the side wall 672 is parallel to the plane Y, starts where the plane X intersects the side wall 672 on one side of the housing 628 and merges smoothly into the outlet 634.

Along the line of the plane X, the outer diameter of the blades 680 of the fan wheel 630 is about 70% of the distance along the plane X between the two points at which it intersects with the side wall 672. It has been found that this ratio in combination with the compensation angle of 11° provides efficient flow characteristics. Additionally, the way in which the outlet guide wall portion
678 is angled relative to the plane Z is highly advantageous in that it allows the outlet 634 to be aligned with the opposite inlet 638 such that the connected ducting may be aligned and co-axial, allowing easy installation. Likewise, the other two inlets 626 are opposite one another and perpendicular to the outlet 634 and opposite inlet 626, allowing easy installation.

The top cover 662 is removably attached to the intermediate component 656. This is advantageous in that it allows installation of the housing without the fan wheel 630, motor 632 and top cover 662, if desired, and these components may be fitted later. Likewise, the intermediate component 656 may be fitted after the manifolding component 652, if desired.

Figure 31 shows an example embodiment of a ventilator device 6200 (i.e. the housing 628 of one of the embodiments of Figures 26A to 30D) including electronically-commutated motor 632 whose shaft 6212 drives the fan 630. Alternatively the ventilator device may be any of those described in other embodiments e.g. Figures 1 to 21 or 26 to 29D, or control/drive of the Figure 26A to 30D embodiments can be as described above with reference to Figures 22 to 25. Commutation of the motor and general operation is performed by integral control circuitry 6216 having a speed control input 6219. The motor is powered from a mains connection 6217; the control circuitry 6216 provides a dc output Vcc, here 10 v, at a terminal 6215. The ventilator device in this embodiment is the housing 628 of Figures 30A to 30D.

A control or drive circuit 6100 has a microcontroller 6120, here a PIC16F684, which operates as a pwm controller having pwm ratios that are varied to provide different speeds of motor operation. The controller 6120 has an output 6121 to the base of a bipolar transistor 6124, whose collector is connected via a pull-up resistor 6125 to Vcc. The collector is also connected to the speed control input 6219 of the motor 6210. The emitter of the transistor 6124 is connected to a ground reference. The arrangement is such that when the output 6121 goes high, the transistor 6124 turns on, providing a logic 0 to the
speed control input 6219. When the output 6121 goes low, the transistor 6124 turns off, supplying a 10v “logic 1” to the speed control input of the motor.

The microcontroller 6120 is powered by a voltage Vdd lower than Vcc, and to this end the control circuit 6100 includes a power supply 6130 providing, in this embodiment, 5 v. The skilled person will be aware of many circuit arrangements for such a supply, for example a resistor, zener diode and smoothing capacitor.

The microcontroller 6120 has a second output terminal 6132 used in setting pwm values and hence motor speed, a mode terminal 6139 used to select a programming mode or a run mode, a trim terminal 6133 used to input correction values, and plural (in this embodiment, three) speed terminals 6134, 6135, 6136 for selecting fan speed. The first speed terminal 6134 is referred to hereinafter as a boost terminal.

Connected to mode terminal 6139 are a first pull-down resistor 6141 connected to the earth reference, and a jumper 6142, shown as a switch, selectively connecting mode terminal 6132 to power voltage Vdd.

Second output terminal 6132 is connected to the wiper 6143a, of a boost switch 6143 and to the wipers 6144a, 6145a of a first and a second speed switch 6144, 6145. Each switch is an on/off switch. The other terminal 6143b of the boost switch 6143 is connected to the boost terminal 6134, which is also connected via a second pull-down resistor 6146 to ground reference. The other terminal 6144b of the second switch 6144 is connected to the second speed terminal 6135, which is also connected via a third pull-down resistor 6147 to ground reference. The other terminal 6144b of the third switch 6145 is connected to the third speed terminal 6136, which is also connected via a fourth pull-down resistor 6148 to ground reference. In use, the first and second speed switches 6143, 6144, 6145 can be set to provide any of four continuous speed settings; the boost switch 6143 provides a boost value to the selected continuous setting; each setting corresponds to a different pwm ratio.
The trim terminal 6133 is connected to the wiper 6149a of a preset potentiometer 6149 via a fourth resistor 6150. The preset has one end connected to Vdd and the other to the earth reference.

The microcontroller 6120 operates as a pulse width modulator to provide a voltage to the speed setting terminal 6129 that lies between an average of 0 volts and an average of 10 volts. The pwm ratio is determined by the first switch 6143, which when closed causes a boost mode to apply, in which the speed of rotation of the fan 6214 is increased to a boost speed. It is also determined by the second switch, which when open or respectively closed causes the fan 6214 to rotate at a first or second “normal” speed. The actual speeds associated with each switch setting are determined in a commissioning mode by values of voltage at trim terminal 6133. When the jumper 6142 is connected, and a logic “1” applied to the mode terminal 6132, the microcontroller 6120 is placed into the program mode. In this mode, when a voltage at trim terminal 6133 is varied, the value at the end of the variation is stored in the microcontroller 6120 for the associated speed setting.

In an example of commissioning the unit for the UK, ensure jumper 6142 is connected. This sets the microcontroller 6120 into a “program” mode, in which settings may be input to the microcontroller 6120. The boost switch 6143 is then made, i.e. placed into the connected state. Switch unit on. Select appropriate speed range setting using second switch 6144 and/or third switch 6145. Using an air cone air flow meter (not shown) set the kitchen and wet room 622 terminals to the minimum high flow rates requirement of Part F of the UK Building Regulations. If the flow rates are more or less than the requirement adjust preset 6149 to fine tune the system and recheck the flow rates.

Once the boost rate is set the continuous speed setting is configured. While the unit is running, switch boost switch 6143 to the “open” state, representing continuous mode. Then select appropriate speed range setting
using second and third switch 6144, 6145. Using the air cone air flowmeter check the total air from kitchen and wet room terminals 622 ensure the total meets the minimum low flow rate requirement of Part F of UK Building Regulations. If the flow rates are more or less than the requirement, adjust preset 6149 to fine tune the system and recheck the flow rates. Fine tuning the air flow rate not only ensures the correct flow rates are achieved but also ensures that the system is running at its most efficient. This calibration is highly advantageous since the system can then run at minimum power specific to the particular installation.

Removing the jumper 6142 ensures that the air flow setting cannot be tampered with and places the unit into its run mode. In the run mode, no adjustment of speed values corresponding to any switch setting can be made. However switching into and out of boost mode remains possible.

Figures 29A to 29D are views equivalent to those in Figures 30A to 30D of a modified form of the housing 628 in which all similar components have like reference numerals. However, in the embodiment of Figures 29A to 29D, the outlet guide wall portion 678 is parallel to the plane Z, such that the outlet 634 is offset from the opposite inlet 626.

Figures 28A and 28B show a modification in which the exit chamber 664 smoothly curves into the outlet 634, without a swan neck. The distance between the outlet and opposite inlet 626 is therefore greater than in the embodiment of Figures 30A to 30B. Instead of having a slope angle of 15°, the slope angle in the embodiment of Figure 28B is approximately 26.75°.

In the embodiment of Figures 27A to 27G, the housing 628 is generally circular. In this embodiment, the same reference numerals are used for components equivalent to those in the embodiment of Figures 30A to 30B. In this embodiment, the diameter of the generally circular housing 628 is approximately 415mm. Each inlet 626 has a swan neck-shaped entrance passage into domed inlet plenum chamber 646 for efficient flow into the
chamber 646. The exit chamber 664 is located under the inlet plenum chamber 646 and is at least partly located between the outlet 634 and all of the inlets 626. The outlet chamber 664 is not sloped but includes a swan neck portion 6100 leading to the outlet 634. The exit chamber 664 is raised relative to the inlets 626 and outlets 634 to provide room for the motor 632 above the bottom surface 642 of the housing 628.

Various modifications to the invention which do not extend beyond the scope of the claims as interpreted under Patent Law are envisaged.
CLAIMS:

1. A ventilation heat exchanger unit comprising an outer enclosure, the outer enclosure containing a heat exchanger and first and second ventilation pathways, each extending through the heat exchanger from a respective inlet port to a respective outlet port, the heat exchanger having a cross-section having a first face thereof generally parallel to an outer wall of the outer enclosure.

2. A ventilation heat exchanger unit as claimed in Claim 1 in which the cross-section is generally polygonal and in which the outer enclosure preferably is a rectangular parallelepiped.

3. A unit as claimed in Claim 1 or Claim 2 in which the heat exchanger has, generally, a regular hexagonal cross-section, or a stretched hexagonal cross-section having three pairs of opposite generally parallel sides with the sides of one pair being longer than the others.

4. A unit as claimed in any preceding claim in which each of the first and second ventilation pathways includes a fan located inside the outer enclosure.

5. A unit as claimed in Claim 4 in which each fan is located downstream of the heat exchanger in its respective ventilation pathway.

6. A unit as claimed in any preceding claim in which the outer enclosure includes a generally flat manifold face on which all of the inlet and outlet ports are located; the manifold face preferably including two manifold plates, each manifold plate defining a said inlet and a said outlet, the manifold plates preferably being identical to one another.
7. A unit as claimed in Claim 6 when dependent upon Claim 3 in which a second face of the heat exchanger is located adjacent and generally parallel to the manifold face of the outer enclosure, the second face being opposite and parallel to the first face.

8. A unit as claimed in Claim 6 or Claim 7 in which the outer enclosure includes a first duct housing unit located on one side of the heat exchanger and a second duct housing unit located on an opposite side of the heat exchanger, each duct housing unit comprising an inner housing part, and an outer housing part which is spaced from the heat exchanger by the inner housing part and at least partially defines outlet ducting leading from the heat exchanger to a respective outlet port.

9. A unit as claimed in Claim 8 in which the two duct housing units are identical to one another, the duct housing units preferably being oriented with the outlet ports diametrically opposed to one another.

10. A unit as claimed in Claim 8 or Claim 9 in which a fan is located between the inner and outer housing parts, the fan preferably being a centrifugal fan with forwardly curved fan blades.

11. A unit as claimed in Claim 10 in which each fan is located off-centre in a fan scroll chamber defined in each duct housing unit.

12. A unit as claimed in Claim 11 in which each duct housing unit defines a diffuser located between the scroll chamber and outlet port, the scroll chamber having a rectangular outlet into the diffuser, the diffuser having a transition from rectangular to circular therealong.
13. A unit as claimed in any one of Claims 10 to 12 in which the inner housing part and outer housing part are separate components which abut against one another at a surface lying in a plane perpendicular to an axis of the fan.

14. A unit as claimed in any one of Claims 8 to 13 in which each inner housing part is provided with a recess for accommodating an edge of the heat exchanger, the recess preferably having an internal angle of about 120° to 130° for accommodating an edge of a rectangular polygonal heat exchanger.

15. A unit as claimed in any one of Claims 8 to 14 in which the inner housing part and outer housing part are made from EPP.

16. A ventilation heat exchanger unit comprising an outer enclosure, the outer enclosure containing a heat exchanger and first and second ventilation pathways, each extending through the heat exchanger from a respective inlet port to a respective outlet port, the heat exchanger having a counter flow section in which flow paths in adjacent portions of the first and second ventilation pathways are in opposite directions, at least one of the ventilation pathways including a fan for powering air therethrough.

17. A ducting housing unit for a ventilation heat exchanger unit, the ducting housing unit comprising an inner housing part arranged to be located adjacent to a generally polygonal heat exchanger and an outer housing part arranged to be spaced from a heat exchanger by the inner housing part and at least partly defining outlet ducting leading to an outlet port.
18. A unit as claimed in Claim 17 in which the fan is located between the inner and outer housing parts.

19. A ducting housing unit as claimed in Claim 18 in which the fan is located off-centre in a fan scroll chamber defined in the ducting housing unit.

20. A unit as claimed in Claim 19 which includes a diffuser located between the scroll chamber and the outlet port, the scroll chamber having a rectangular exit into the diffuser, the diffuser having a transition from rectangular to circular there along.

21. A unit as claimed in any one of Claims 17 to 20 in which the inner housing unit part is provided with a recess for accommodating an edge of a polygonal heat exchanger.

22. A ducting housing unit as claimed in Claim 21 in which the recess defines an internal angle of about 120° to 130° for accommodating an edge of a hexagonal heat exchanger.

23. A ventilation heat exchanger unit which comprises an outer enclosure containing a heat exchanger and two ducting housing units as claimed in any one of Claims 17 to 22, the ducting housing units being located on opposite sides of the heat exchanger and identical to one another.

24. A unit as claimed in Claim 23 in which the outer enclosure has a manifold face, the manifold face including two manifold portions, each manifold portion having an inlet and outlet, the manifold portions being identical to one another.
25. A method of calibrating air flow in a ventilation system which includes a commissioning step in which a fan motor speed is adjusted to a set value to provide a desired air flow while measuring air flow; and a run step which includes selecting the set value.

26. A method of operating a fan driven by an electric motor, the method comprising:

   a commissioning step in which at least one motor rotation speed is adjusted to provide desired airflow performance value of the fan; and

   a run step comprising selecting at least one said desired airflow performance value of the fan.

27. A method of calibrating air flow in a ventilation system comprising operating a fan as set out in Claim 26 and which includes measuring air flow while adjusting motor rotation speed in the commissioning step prior to performing the run step.

28. A method as claimed in Claim 25 or Claim 26 or Claim 27 which includes calibrating plural motor speeds in the commissioning step.

29. A method as claimed in any one of Claims 25 to 28 in which the run step is set by removing a jumper.

30. A drive circuit for a fan driven by an electric motor, the circuit having at least one switch for selecting a motor rotation speed, a speed control device connected to respond to the switch settings for providing corresponding pulse widths in an output to the motor, and commissioning circuitry, associated with the speed control device, having a commissioning setting in which a selected motor rotation speed can be adjusted to provide a desired airflow performance
of the fan, and a run setting in which the selected motor rotation speed cannot be adjusted.

31. A drive circuit as claimed in Claim 30 having plural switches for selecting between plural motor rotation speeds, the commissioning circuitry being adapted to provide independent setting of said speeds while the commissioning setting is set.

32. A drive circuit according to Claim 30 and Claim 31, in which the electric motor is an electronically-commutated motor, having an operating circuit responsive to a PWM input from the speed control circuit for varying the speed of rotation of the electric motor.

33. A drive circuit according to Claim 30 or Claim 31 of Claim 32 or Claim 33, having a microcontroller programmed to form the speed control device.

34. A drive circuit as claimed in Claim 30 or Claim 31 or Claim 32 or claim 33 having a jumper which is removable for setting the run setting.

35. A method of operating a ventilator fan driven by an electric motor, the method comprising: a default operation step in which the electric motor is caused to operate the ventilator fan at preset selectable speeds; a commissioning step in which at least one stored value of motor rotation speed is adjusted to provide a desired airflow performance value of the fan; and a selectable run step in which the fan is caused to provide the desired airflow performance value.

36. A method according to Claim 35, in which there are plural stored values of motor rotation speed, and a stored boost value, the method comprising
selecting one of the stored values, adjusting that value in dependence on a measured parameter of the ventilator, selecting the boost value corresponding to the selected value, and adjusting the stored value corresponding to the boost value in dependence on said measured parameter of the ventilator.

37. A method according to Claim 36, in which the selecting steps are performed via a wireless link.

38. A method according to any one of Claims 35 to 37 further comprising a step of selecting a commissioning mode to cause the commissioning step to be effected.

39. A method according to Claim 38, wherein the step of selecting a commissioning mode comprises making a switch connection to a control input of a controller.

40. A method according to Claim 39, further comprising selecting a run mode by opening the switch connection.

41. A method according to Claim 40, wherein in the run mode, the method comprises switching between different motor speeds in accordance with sensed parameters.

42. A method according to Claim 41, wherein the sensed parameters include one or more of humidity, frost, CO₂ and temperature.

43. A method as claimed in any one of Claims 35 to 42 in which the fan is a fan of a ventilation heat exchanger unit, preferably a unit as claimed in any one
of Claims 1 to 16; or in which the fan is a fan of a housing as claimed in any one of Claims 52 to 68.

44. A control system for a ventilator fan having means for performing the method of any one of Claims 35 to 43.

45. A drive circuit for a ventilator fan driven by an electric motor, the circuit having plural switches for selecting motor rotation speeds, a speed control device connected to respond to the switch settings for providing corresponding pulse widths in an output to the motor, and commissioning circuitry, associated with the speed control device, having a commissioning setting in which a selected motor rotation speed can be adjusted to provide a desired airflow performance of the fan, and a run setting in which the selected motor rotation speed cannot be adjusted, wherein before actuating the commissioning circuitry, the plural switches are operative to select between preset motor rotation speeds.

46. A drive circuit according to Claim 45, having a wireless remote control device operable to select between different motor rotation speeds at least in said commissioning step.

47. A drive circuit according to Claim 45 or 46, in which the electric motor is an electronically-commutated motor, having an operating circuit responsive to a PWM input from the speed control device, or to a variable voltage range signal such as from a 0 to 10 V DC signal range, for varying the speed of rotation of the electric motor.

48. A drive circuit according to any of Claims 45 to 47, having a microcontroller programmed to form the speed control device.
49. A drive circuit according to any of Claim 45 to 48, having one or more sensors so that in the run mode, different motor speeds are selected in accordance with sensed parameters.

50. A drive circuit according to Claim 49, wherein the sensor comprises one or more of humidity, frost, CO₂ and temperature.

51. A drive circuit according to any one of Claims 45 to 52 in which the ventilator fan is a fan of a ventilation heat recovery unit, preferably a unit as claimed in any one of Claims 1 to 16; or in which the fan is a fan of a housing as claimed in any one of Claims 52 to 68.

52. A housing for a ventilation system, the housing having multiple flat inlets and an outlet, the inlets and outlet being aligned at the same level.

53. A housing as claimed in Claim 52 in which the inlets and outlet are essentially rectangular.

54. A housing claimed in Claim 52 or Claim 53 which houses a fan wheel.

55. A housing as claimed in Claim 54 which includes an exit chamber, and in which the fan wheel is located in the exit chamber.

56. A housing as claimed in Claim 54 or Claim 55 in which the exit chamber is generally flat, having a generally planar form and in which a fan axis is perpendicular to the plane of the exit chamber.
57. A housing as claimed in Claim 55 or Claim 56 in which the outlet comprises an elongate rectangular slot having a height substantially the same as the height of the chamber.

58. A housing as claimed in any one of Claims 55 to 57 in which plane of the exit chamber is sloped relative to a plane containing the inlets.

59. A housing as claimed in any one of Claims 52 or 58 in which the inlets comprise a plurality of inlet apertures into an entrance plenum.

60. A housing as claimed in any one of Claims 55 to 58 in which the exit chamber, towards the outlet, has an alignment region between a main planar portion of the chamber and the outlet, e.g. a curved alignment region.

61. A housing as claimed in Claim 60 in which the alignment region comprises a swan neck, e.g. a swan neck curve.

62. A housing as claimed in any one of Claims 55 to 58 or Claim 60 or Claim 61 in which the exit chamber has an openable lid which is openable for fan inspection/removal.

63. A housing as claimed in any one of Claims 55 to 58 or Claims 60 to 62 in which the exit chamber has an openable base portion which is attached to (or part of) a manifolding portion of the housing which contains the inlets and the outlet.

64. A housing as claimed in any one of Claims 55 to 58 and 60 to 63 in which a first plane passes through an axis of the fan wheel and is perpendicular to the outlet, and a second plane is angled relative to the first plane at a
compensation angle, a width to one internal side wall of the chamber from the fan wheel axis along a third plane perpendicular to the second plane being between 35 and 45 percent higher than to an opposite internal side wall of the chamber.

65. A housing as claimed in Claim 64, which the compensation angle is between 2° and 25°.

66. A housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream of the fan position, wherein the exit chamber is sloped relative to at least one selected one of the inlets and the outlet.

67. A housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream of the fan position, wherein the exit chamber is sloped relative to a bottom surface of the housing.

68. A housing for a central ventilation extractor system, the housing having multiple inlets and an outlet, an inlet chamber generally upstream of a fan position and an exit chamber generally downstream wherein the exit chamber is sloped relative to designed flow direction at the outlet or at least one of the inlets.

69. A ventilation system including a ventilation housing as claimed in any one of Claims 52 to 68, and ventilation ducts attached to the inlets and outlets.
FIG. 27A
FIG. 30A

FIG. 30B