Passivhaus Trust
The UK Passive House Organisation

Good Practice Guide
MVHR for single dwellings

September 2018
Rev 1.2

Contents

Acknowledgements 1

Introduction 2

The process 2

Outline design and specification of ventilation system 2

The specification 4

Design and procurement 4

Installation 7

Commissioning 8

The design 8

MVHR choice and PHI data 8

Duct systems 9

Noise 9

Commissioning 10

The installation 10

The commissioning process 11

Introduction 11

The aims of the commissioning process 11

Commissioning the internal air flows 13

The method of demonstrating overall air flow balance 13

Appendix A: Commissioning instruments – Details and discussion 14

Airflow measurement 14

Essential equipment required for commissioning: 15

Optional items: 15

In-duct air flow rate measurement devices: 15

Appendix B – Trouble-shooting, a basic guide 16

Potential problems & causes 16

Acknowledgements

This paper was written by Dr Mich Swainson, Sally Godber & Andrew Farr, and peer reviewed by Kym Mead, Rupert Kazlauciunas, Nick Grant, Alan Clarke, Alex Baines, Jon Bootland and Mark Siddall.

Sponsors

Introduction

Brief explanation of why the following document is thought to be useful

Within the Passivhaus documentation and guidelines there has been no explicit requirement to embed at the 'design and procurement stage' specification of MVHR that will lead to appropriate delivery, or indeed support about what MVHR specification should look like. That is not to say that most of the Passivhaus (PH) fraternity is not aware of the 'comfort' requirements associated with PH MVHR, namely low sound emission and lack of perceivable drafts, just that this has sometimes been poorly facilitated. The result of this has been that the actual specification of PH MVHR might be carried out by the sales people of the delivery companies. Most importantly unless there is some testable technical requirement given to the design and delivery companies, any dispute over the performance of an MVHR system once installed is largely subjective.

The building process and the design team can take many forms and the roles of the key players differ in each variation, this document has therefore been set out in terms of the tasks that need to be covered, with an indication of the key players that may be responsible for each.

This document is to work alongside the ventilation protocol worksheet, specifically relating to the design and commissioning of ventilation systems serving single dwellings.

It is expected that all parties are experienced and qualified to undertake their various tasks, and it is recommended that the Passivhaus consultant and ventilation designer have undergone training such as the Certified Passivhaus consultant training, or similar, to ensure all the specific requirements of the system are achieved.

This guidance should be read as an addendum to the 'How to build a Passivhaus: Rules of thumb' document. It provides specific design guidance that is not readily available anywhere else.

The process

The key to the handover of a high-quality ventilation system is governed to a large extent by responsibility being taken by the appropriate people for each of the key elements of the process; the specification, the design, the installation and the commissioning.

Figure 1 sets out very basically these key elements and the input required from members of the design and construction team.

The first and therefore probably the most important element of the process is the development of the specification, only with a well-defined set of requirements for the system can the output of the designer and the installer be assessed and the performance verified.

Outline design and specification of ventilation system

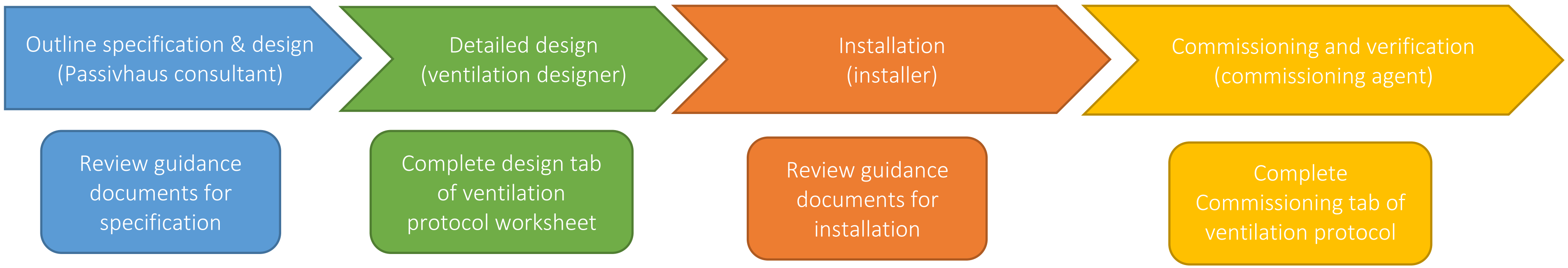
To allow a building design to move forward and to incorporate appropriate provision for the ventilation system (space for installation of MVHR, run ducts, etc.) an early assessment of the needs of the ventilation system must be made. This must be undertaken prior to planning and would typically include:

1. Ventilation rates for entry into PHPP; see sizing below but typically 30m3/hr.bedspace or 1 m3/h.m2 of ventilated floor area, whichever is greater, are sensible starting point at early design.
2. Selection of a suitable MVHR for entry into PHPP and correct spatial allowance (this may change as the design progresses).
3. Location of the key parts of the ventilation equipment to ensure there is adequate space, to include:
   a. MVHR
   b. primary silencers
   c. typical duct routes and location of terminals
   d. maintenance space

Possible players	Ventilation task	Detailed design tasks	PHPP input	Ventilation protocol
Architect/Client		Building form Internal layout		
PH consultant	Outline ventilation concept Outline specification	Overall ventilation plan – room to room air movement Outline ventilation air flow rates – total, per room, etc.	x	
		Detailed layout of rooms – space for ducts, space for MVHR, location of intakes, location of valves	x	
	Detailed specification	Full specification of system	x	
	Tender for design/supply/etc.	Review tenders		
Vent system designer	Detailed design	Detailed design of system components Review against specification Ensure system can be commissioned	x	Design tab
Installer	Installation	Installation following design 'Slightest' variation required – refer back to designer		
Commissioning engineer	Commissioning	Review of specification Review of design Measurement of performance Sign-off performance	x	Commission tab
	Handover	Documentation		

Figure 1: The process and players

Or alternatively:



The specification

The specification is a document that sets out the overall operational performance requirements of the ventilation system. It should provide a set of criteria that can be verified by assessment and/or measurement throughout the design, installation and commissioning processes.

Upon completion of the build process a commissioning engineer will measure the performance of the installed system and verify if the performance requirements set out in the design have been met. It is therefore vital that the specification sets out the performance criteria in sufficient detail to allow verification.

An example of a poor specification would be: "Install an MVHR and duct system to ventilate the dwellings to meet the requirements of the Passivhaus standard". This leaves the design and the performance of the system to be set be the ventilation designer. In some cases this could be sufficient but relies upon the skill of the designer to adequately understand the client's needs as well as those of the Passivhaus standard. The commissioning engineer can verify that the system meets the design, but with no detailed specification this may not be what the client wanted or compliant with Certification.

By setting out verifiable criteria, the specification is providing a means by which the responsibility for delivering a functioning ventilation system can be defined in terms of the design, the installation and the commissioning. Each of these stages must follow the requirements of the specification, with the cause of any deviations being identifiable to a stage in this overall process.

The role of the PH consultant and the ventilation system designer will vary between projects, where for example, at one end a client or PH consultant may have experience of a given MVHR manufacturer and model and require that this is included in the system, to the other extreme, the client passes all responsibility for the means of ventilation onto the design team. In this latter case the specification must set out all the criteria that must be met by the system to ensure that the most appropriate components are used.

The following list includes a wide range of performance and other criteria that should be considered for inclusion within the specification.

Design and procurement

Item	Performance criteria and discussion
Number of fan speeds available.	For dwellings the minimum is 3; fan speed 1, Base, fan speed 2, Standard and fan speed 3, Peak. The fan speeds should be configured such that fan speed 1 and fan speed 3 are typically 30% below and above fan speed 2 respectively. (Throughout this document and others speed 2 may also be referred to as standard/normal/medium rate, speed 3 is boost/peak/high/maximum rate and speed 1 is the minimum/base/low rate.)
Overall fresh air flow rate.	Fresh air demand is determined by the number of occupants. Typically, 25-30m^3/h.bedspace or 1 m^3/h.m^2 of ventilated floor area, whichever is greater should be used. This is the minimum ventilation rate that is required under normal operation, i.e. fan speed 2. There are of course scenarios where other criteria are used to size the ventilation. However, if it varies significantly from this the building certifier should be consulted.
Air flow rate per room.	Each space should have mechanical ventilation; either supply, transfer or extract. Supply –consideration should be given to the planned/likely use of spaces A good starting point for bedrooms is ~20m^3/h for single rooms and ~30m^3/hr for double rooms.

	Extract air flow rates are sized based on moisture generation rates and thus are based on periods of moisture generation, i.e. air flow rates required for *peak* ventilation (fan speed 3) typical figures used for Passivhaus design are below, note that certification does not require compliance with these: Kitchen 60 m^3/h Bathroom, utility room 40 m^3/h WC 20 m^3/h
Total static pressure on each side of the MVHR (determined at the spigots).	It is very important that a practically achievable upper limit is set for the system static pressure at the normal running speed (fan speed 2). This will ensure that the duct design is aerodynamically efficient, limit the energy use of the fans and also the noise generated both within the MVHR and the ducts. PHI suggest a practical upper limit should be a 100 Pa for a single house. This should be the total of the fresh air and supply duct side of the system and also on the extract and exhaust air side of the system. Small systems should be able to achieve values less than 100 Pa and suggested values are given in Table 1. Normally this limit would be assumed to be at fan speed 2. However, if the dwelling requires the ventilation system to run at fan speed 3 or above over the summer period, especially at night, then the design should aim to meet the pressure limit at this higher air flow rate to minimise energy use and the potential for noise nuisance.
Noise - Living Rooms - Bedrooms - Technical room - Wet rooms - Cross talk - External	The ventilations system designer must demonstrate that the system being installed will, at fan speed 2, supply the correct air volume to each room and meet the following sound pressure levels: • living and sleeping rooms ≤ 25 dB(A), and; • kitchen, bathroom, WC's, utility rooms, etc. ≤30 dB(A); and • plant room or service cupboard contain the MVHR ≤35 dB(A); and • appropriate cross talk attenuation has been installed. To demonstrate this has been achieved it is recommended the designer must produce evidence that sound calculations have been carried out on the whole system.
Type of user control – local, remote, Wi-Fi, App, etc.	A very wide range of control options are becoming widely available, including but not limited to: • local on machine with only fan speed control and alarms fed to a remote display; or • full LCD screen with total control remotely – hard wired, Wi-Fi, etc.; or • app based control.
Type of air flow regulation.	There are two basic types of fan control – fixed fan speed and automatically controlled fan speed. Fixed fan speed – This is the typical and simplest form of fan speed control. The fan is provided with a fixed control signal and the speed does not vary unless a different speed is chosen. The draw-back of this approach is that as pressures in a system change, for example, filters become dirty, the air flow rate reduces. The impact of this may not be noticed by the residents and may, if left uncorrected, result in poor IAQ. Controlled fan speed – The most common control function for MVHR fans is constant volume. This control function monitors the required air flow rate set by the user and then maintains it regardless of changes in overall system pressure. The advantage of this is that the air flow rate, and the balance between supply and extract air flows remains constant, thereby reducing the risk of poor IAQ and loss of heat recovery efficiency due to a reduction in ventilation levels as, for example, filters become soiled.
Filters installed and location, special requirements.	The minimum filter grade requirements are F7 on the fresh air intake from outside, and G4 on the extract air from the 'wet' rooms. (Filter classification is changing; the new EN ISO 16890-2016 is likely to be implemented summer 2018. At time of writing the Passivhaus Institut hasn't confirmed what is required under the new standard.)

Access requirements for maintenance.	Filters should be accessible without the need for tools and the manufacturer's recommendations for space around the MVHR when installed must be followed to allow routine maintenance to be undertaken. Ultimately the fans and heat exchangers will need replacing within the MVHR casing, ducting, valves and terminals will all eventually need access for cleaning and replacement and this need is to be considered at the design state to minimise the need for massive disruption to the building fabric. For social housing provision it may be required that the MVHR is accessible from outside the dwelling to allow the filters to be changed and routing maintenance performance on the MVHR without access to the dwelling.
Pre-heater requirements.	Set out the type of pre-heater and the location of the heater, i.e. internally within the MVHR or externally mounted in the fresh air duct, plus any pre-filtering required upstream of the heater.
If known – MVHR to be used.	Manufacturer, model, controls options, etc.
MVHR installation location.	A dedicated location may be defined. The specification should emphasise the anticipated duct lengths and sizes, as well as the need to minimise the duct runs from the MVHR to outside. Specifying this will have an impact on the location of the space required for the MVHR unit and therefore needs to be considered by the architect.
Ductwork – type and layout.	Rigid or semi rigid. Trunk and branch or radial. Recommended – pre-insulated from the MVHR to the outside terminals Method of sealing ductwork, and method of supporting.
Ductwork insulation.	If pre-insulated ducting is not to be installed on the intake and exhaust then the insulation of these ducts requires care with cutting and fitting and should be considered a dedicated process in the construction programme. It may be appropriate to consider a subcontract package for the insulation installation. This will ensure that the required skills and tooling is used for this task.
Summer by-pass, need for, type.	Although summer bypass isn't a direct requirement of Passivhaus Certification it is useful mechanism for helping to maintain summer comfort. Not all summer bypass systems work the same with some providing 100% by-pass and others only partial bypass. The type should be specified with 100% by-pass being recommended. Modulating by-pass control allows the degree of by-passing to be varied which can be controlled to maintain a supply air temperature set point. Summer by-pass is sometimes used with a higher than normal flowrate (e.g. set to boost for long periods) to remove heat build-up. In this case it is important that the system can operate at high fan speeds quietly and efficiently in terms of electrical power consumption.
Type of heat exchanger – sensible or total.	Sensible or total (sometimes referred to as enthalpy) Not considered as required for dwellings in the UK – thermal efficiency is usually lower with these heat exchangers and the recovery of moisture cannot be controlled and therefore if a dwelling becomes damp, this type of heat exchanger will tend to maintain the moisture level rather than provide drying, potentially exacerbating the problem.
Need to measure combined air flow rates.	Consideration must be given to the method of determining the outside air flow rates. Installed in-duct measurement devices require the manufacturer's recommendations for installation, straight duct lengths before and after the device, to be followed to ensure accuracy. If wall mounted terminals are to be installed, they must be accessible to allow measurement with hand held instruments.

Intake and exhaust terminals.	Restrictions on location – local air quality considerations, external noise levels and/or sensitivity to noise in the outside environment to noise from the exhaust terminal. Minimising the length of the insulated intake/exhaust ducts can help minimise fan power and maintain overall system thermal performance, however it may result in the outside terminals being close to each other. To minimise the potential for recirculation of exhaust air there are various solutions: • proprietary combined terminals; or • exhaust louvres that throw the air away from the intake – typically louvred exhausts throw the air downwards if they have a relatively high velocity, say 2m/s, so locating the intake above or to the side on an unobstructed wall can be sufficient; or • terminals separated at greater than 1 m horizontally. It is not recommended to put intakes & exhausts on different sides of a building as the wind pressure on each will vary significantly, which may affect overall system balance.
Duct pressure measurement.	Duct tapings should be provided in each of the four legs of the MVHR. Ideally this should be a minimum of 4 duct diameters downstream of a bend or the MVHR spigot. Pressure pipe should be installed and brought back to the MVHR and labelled.
Procurement route.	Suppliers will sometimes offer a design service which can be useful as they will use this to develop a parts list and they often use specialist 3D software to ensure the system will fit. This offers huge benefits to the installer but be careful to ensure they understand the specification and the ventilation protocol sheet prior to developing the design. It is also vital that if this route is taken, the supplier has access to all architectural drawings to ensure that every potential clash of space can be resolved at the design stage.
Air transfer paths within dwelling.	Specify the type of transfer path; under-door cuts, transfer grilles, etc. If under-door cuts are to be used the gap should ensure that the air speed under the door is around 1 m/s maximum. This may require significantly more than the 10 mm undercut required by the UK Building Regulations. Details of undercuts or vent size is to be provided for each transfer path by the ventilation system designer.

Table 1a: Design and procurement

Installation

Typical considerations are shown below but this list is not exhaustive:

Item	**Performance criteria and *discussion***
Certification evidence.	Set out who is responsible for doing this. The evidence should be confirmed with the building certifier, but will typically comprise of: • insulation continuity in intake/exhaust: photos plus signed declaration that site manager has run hands over complete ductwork and free from gaps or defects, including correctly adhered to airtightness line on external wall and MVHR; and • identification of any parts of the installation that are different from the design (drawing sketch and photographs); and • delivery notes and photographs of products used on site; and • proof that all components have been kept clean, from delivery, to storage, throughout installation and up to commissioning; and • proof all duct joints are effectively sealed as specified; and • confirmation that MVHR hasn't been run prior to commissioning.
Ductwork installation.	Explicit statement that where the installation deviates from the design, the process of sign-off for this is defined clearly, e.g. must be logged with supporting photographs and checked with the designers prior to closing up.

Keeping components clean.	State that all components must be capped off during storage and install to prevent dust and dirt entering the system.
Need for MVHR to be not run until commissioning.	State the MVHR fans must not be operated until the final clean-up has been undertaken and the system is to be commissioned. The MVHR must be protected against ingress of dirt during the construction and should preferably be stored off site until second fix.

Table 1b: Installation

Commissioning

Complete the tab "Commission spec" in addition to the items below

Item	Performance criteria and discussion
Requirement for comm. engineer to be trained in use of controls of MVHR.	Trained level required; by manufacturer of the MVHR to be installed, NICEIC, other.
Commissioning of air flow rates in rooms.	Instruments to be used to commission the system to achieve the design air flow rates into and out of each space.
Demonstrating overall balance of the system.	Set out the means of assessing the design performance has been met, i.e. in terms of; air flow rate, total static pressures in supply and extract sides of the system, noise within rooms and electrical power consumption.
What performance variables should be measured and values with tolerances of acceptability.	Detailed list of variables is provided in Table 2.
Need for pressure (leakage) testing of duct system.	The total fresh air supplied to the house and the overall balance between the fresh air intake and the exhaust air must be demonstrated. This requires air flow measurement of the combined flows.

Table 1c: Commissioning

The design

If after reviewing the specification and the design drawings made available, or at any time during the design process, the ventilation designer finds that the requirements of the specification cannot be met, or for example meeting them would be excessively expensive, require significant increases of space to accommodate components, etc. then he must report this back to the PH consultant immediately.

MVHR choice and PHI data

If the MVHR manufacturer and model to be installed has not been fixed, then it is vital that a review of the overall requirements of the system is undertaken. A range of MVHRs may be identified as meeting the requirements of the specification. However, a comparison of the performance of products can only really be undertaken if the performance data for each is produced at the same operating point. This should ideally also be at the operating point required for the installed system. Data produced through testing MVHRs is based on the performance characteristics of the MVHR and therefore the data for each product is at a different operating point (the system pressure for all testing is set at 100 Pa, but the air flow rate is a function of the capability of the MVHR).

The PHI certificates therefore provide electrical power and noise data that may be at a very different air flow rate and system pressure to that of the installed system. If detailed manufacturer's data for other operating points is not available, then it is recommended that the PHI data is used for the design. However, for certification the heat recovery efficiency and specific fan power should be taken from the certificate.

The PHI certificates provide a range of flow over which an MVHR is able to operate and therefore a designer may have a choice between an MVHR where the speed 3 air flow rate is equal to the upper limit of the MVHR operating range and a second product where the air flow rates are well within the operating range of the MVHR. When an MVHR runs at the upper limit of the certification range the electrical power and the acoustic data presented on the PH certificate may be significantly exceeded.

If, in order to meet the requirements for thermal comfort over the summer period, it is required to operate the MVHR at fan speed 3 or above, the above pressure requirements should be applied to this fan speed. In this way the noise and electrical power calculations used for Certification will be based on the operating speed that will be used over much of the summer period.

Duct systems

The layout of the ductwork may be very well defined due to the physical layout of the structure of the building, in which case the pressure losses will be governed by duct sizing. If however the duct layout and system have not been fixed then the alternatives of semi-rigid and rigid should be assessed, balancing the trade-off of installation time and cost against cost of materials.

The pressure in each of the duct distribution legs is, for a given air flow rate, primarily a function of the duct size, length and the number of bends and fittings in the duct. The larger the duct, the lower the changes in direction of the air, the lower the air velocity and therefore the lower the overall pressure drop. There is however an economic and space requirement balance and this results in ducts not being over-sized. Another limiting factor of air velocity in ducts is noise. High velocity air generates noise, and therefore air speed limits are recognised for ducts in different locations to minimise noise problems. Within a single dwelling the air speed in the primary ducts should not exceed 2~3 m/s and in the final runs to room valves the speed should be limited to 1~2 m/s.

To ensure that the MVHR is operating at a low fan speed, minimising noise generation and electrical power consumed, the PHI suggests a practical target for all residential Passivhaus duct distribution systems should be a maximum pressure across the MVHR of 100 Pa. In small systems, i.e. with low air flow rates this should be easily met and ideally the target system pressures should be as outlined below.

Air flow rate (m^3/h)	Suggested upper system pressure drops (Pa)
<60	50
<100	60
<200	80
<300	100

Table 2: Recommended design targets for total pressure in supply and extract duct legs (i.e. the sum of the fresh air intake and supply leg, and the sum of the extract and exhaust air leg, each of these should be less than the values indicated).

To allow the pressure to be measured in each of the legs of the distribution system duct tapings should be provided in each of the four legs of the MVHR. Ideally this should be as close to the MVHR as practical and a minimum of 4 duct diameters downstream of a bend or the MVHR spigot. The intake and exhaust legs of duct will be insulated and therefore it is vital that pressure pipe should be installed and brought taken back to the MVHR and labelled to remove the need to disturb the insulation on these ducts.

The designer must liaise closely with the architect and other designers to ensure that duct routes remain clear of obstructions, which may if they go unnoticed, require the installer to deviate from the design and ultimately the requirements of the performance specification to be missed.

Noise

It is the ventilation designer's responsibility to ensure that the design meets the noise requirements.
If the ventilation designer is sufficiently competent at acoustic calculations and the manufacturer's data exists, then the sound power levels at the normal operating point, fan speed 2, can be determined. If this data is not available from the manufacturer then the PH published data must be used.

The level of attenuation installed must be demonstrated to be sufficient to ensure that all rooms are below the required levels. This may be achieved by installing a set of primary and secondary attenuators and room valves that can be shown to ensure that all rooms are below the acoustic requirements. This provides a safe, if probably oversized solution. Alternatively, calculations should be undertaken to demonstrate that each room is below the required level with the attenuation installed in the leg of the system serving that room. The latter approach allows attenuator sizing to be tuned and therefore minimised the risk of over-sizing, however, it requires considerable experience and design effort.

Note – The data that is measured and presented in the PHI list and cert is at the upper end of the operational range of the MVHR. The normal operating point for the MVHR when installed may be very significantly below this point and thus designing sound attenuation around this data will, as noted above, be very safe for operation at fan speed 2.

Note – If the system is designed to run at fan speed 3 or higher across the summer (at night), then the fan speed may be higher than that used during the PHI acoustic testing of the product. This will require manufacturer's data to be sought and used for attenuator sizing.

Commissioning

Part of the design must be a consideration of how the system is to be commissioned. The most critical issue for the designer is the method of determining the air flow rate in the intake and exhaust legs of the system, i.e. the fresh air intake and the exhaust. If the designer has the space and can meet the requirements for straight duct lengths before a measuring section, then the installation of an in-duct measuring device removes the need to measure air flow rates on the outside of the building. If this cannot be accommodated, then wall mounted terminals that are easily accessible should be considered. If neither of these approaches are possible, then the testing of the leakage of the internal duct system will need to be undertaken.

MVHRs that control the air flow rate automatically, controlled fan speed units, usually provide a readout in flow rate. Although not universally available, manufacturers may offer calibration data on the flow measurement accuracy, its long-term stability and the overall level of uncertainty. The uncertainty may arise from manufacturing tolerances in components, etc. but also differences in the installation compared to the ideal, i.e. different pressures in the duct legs to that during calibration.

The installation

The installer must review the design, the specification and the 'list of components' (products supplied for install). If there are any questions regarding the installation, if it is felt that the design cannot be met without modification, then the installer must alert the ventilation designer and the PH consultant prior to starting the installation.

If the ventilation designer has integrated the duct runs with all the other services and structural elements of the building, then there should not be any clashes of space. If however, the design is 'indicative' and only shows a duct routed within a ceiling void with no details of bends, etc. required, then the installer must seek clarification before starting the installation. If this is not undertaken there is a risk of higher than acceptable system pressure at commissioning, with the responsibility being placed on the installer.

It is vital that the installer follows the design to the letter. Any need to deviate must be referred back to the designer who will 'make a decision' as to the impact of each proposed change.

The need to record the installation of all components of the installation is vital, as first fix items are very quickly covered and if there is uncertainty as to the quality of the installation, for example that ducts have been jointed correctly or too many bends have been installed, then photographs will allow these questions to be immediately answered. The responsibility as to who takes records of the installation should be set out in the specification, but if it is not then the installer should undertake this role as proof of the works he has undertaken.

It is very important that the cleanliness of the system is maintained throughout the build process – all open ends of ducts must be sealed during storage and throughout installation. MVHR spigots should be sealed before installation and the MVHR must not be run until post construction cleaning has been completed and commissioning of the system is to be undertaken.

Ducts should be sealed and airtight at joints – innovations are continually coming onto the market and there is a move to mechanical joints that do not require additional sealing. Mechanical joints must be capable of withstanding movement of ducts as other fittings are installed. This is especially the case for some semi rigid duct systems where joints are good in terms of airtightness but some systems are relatively weak when subject to rotation and tension movements- which may occur during installation of this type of duct. Use of duct tape and silicone sealant are not considered to be airtight over the lifetime of the installation and should not be used to seal duct without mechanical seals. Duct joint sealants are available from duct manufacturers/retailers.

The commissioning process

Introduction

Commissioning is taking an installation from a set of connected components, installed following a design and bringing them to life as a functioning system. The commissioning engineer configures the various components to operating settings that allow the performance, as set out in the design, to be demonstrated and recorded.

The specification provides the performance criteria against which the final measured performance must be assessed. However, the system design must be based around these values and the design will contain additional information such as the design duct pressures at normal air flow rates, anticipated fan speed settings, etc. It is the responsibility of the PH consultant to check that the design meets the requirements of the specification and the commissioning engineers' responsibility to assess the system performance against the design.

The ventilation designer will provide the commissioning engineer with a (PHPP) Final Protocol Sheet with the design tab completed. This Final Protocol Sheet provides details of the design air flow rates, supply and extract and total fresh air and exhaust, the static pressures at the MVHR spigots, the calculated noise in each room. It is recommended that an electronic version on a laptop is used during commissioning to allow calculation during the process. In addition to this the designer must provide any other performance data that has been determined during the design process, for example, the electrical power use predicted at the fan set points.

The commissioning engineer has the responsibility of the final sign-off to say that a system does or does not meet the design performance figures. The commissioning engineer is therefore independent of the designer, installer and PH consultant.

The aims of the commissioning process

Prior to commissioning a ventilation system, the commissioning engineer must make himself fully familiar with the MVHR installed, the controls architecture of the MVHR including any installer or engineering level access codes and the design intent of the system installation.

Commissioning is an engineering process and as such there are levels of uncertainty and tolerances within which the measured data should be expected to fit. Commissioning a ventilation system is an iterative process of setting the fan speed and moving from room to room setting valves to achieve the required overall air flow rate and balance this between individual rooms.

To minimise the level of uncertainty in the final measured values the commissioning must be undertaken with appropriate and calibrated instruments. Details of appropriate instruments are given in Appendix A

The primary aim of commissioning the ventilation system is to meet the design air flow rates and this is assessed in several ways. Initially the internal air flow rates must be achieved at each of the valves in line with the design values. This must be achieved at the lowest practical system pressure which is achieved through good design and installation of the duct system. In addition to measurement of the air flow rate at each valve, the static pressure in each leg of the system should be measured along with the total electrical power being drawn by the MVHR. These values should be compared with the deign values.

In addition to meeting the internal air flow rates at each valve, the overall measurement of the system air flow rates in the intake and exhaust legs of the system are used to determine overall balance of the system. Three measurements are used for this with tolerances allowed for each, as set out below.

Number	Criteria
1	The total fresh air drawn from outside meets the requirement of the design within ± 5% at all fan speeds. This ensures that the dwelling as a whole meets the design fresh air flow rate to provide a healthy internal environment.
2	The balance between the overall fresh air supply into and the exhaust air out of the dwelling must be within 10% at all fan speeds This measurement ensures that there is no over or under pressure of the house resulting in infiltration or exfiltration at any fan speed.
3	The volume of fresh air drawn into the house and that delivered to the rooms, and the extract air drawn from the rooms and that exhausted to outside should aim to be within 10% of each other. This measurement will identify if there are any major leaks in the ductwork system which will result in a difference between the internal and external air flow measurements.

Table 3: System air flow rates

The approach to commissioning should be to ensure that the system is set up to operate at the design condition, fan speed 2. Once this has been achieved, the overall flows are set-up for fan speeds 1 and 3. The order of approaching the commissioning should be as set out in Table 4.

Number	Criteria	Tolerance
1	Individual room supply or extract air flow rates and valve settings to be in line with design figures.	Record – but no tolerance given.
2	Total fresh air supply to dwelling at fan speed 2.	Within 5 % of design.
3	Balance between fresh air intake and exhaust air flow rate, at speed 2.	To be within ± 10% of design.
4	Balance between fresh air intake and sum of room supplies, and sum of extract from rooms and exhaust, at speed 2.	To not significantly exceed ± 10% of design.
5	Total static pressure across the MVHR on supply and extract sides at fan speed 2.	Not more than 10% greater than the design figure.
6	Total electricity drawn at fan speed 2.	Not more than 20% greater than the design figure.
7	Measure the noise levels in bedrooms and living rooms. (COMMENT – measurements to be undertaken only if calculations have not been undertaken and noise noted as a potential problem in these rooms).	To be 25 dB(A) or below @1.5m, i.e. generally inaudible. Tolerance +1 dB(A).
8	Measure the noise levels in functional rooms (kitchens, bathrooms, etc.).	To be 30 dB(A) or below @1.5m. Tolerance +1 dB(A).
9	Total fresh air supply to dwelling at fan speeds 1 and 3.	Within 5 % of design.
10	Balance between fresh air intake and exhaust air flow rate, at speeds 1 & 3.	To be within ± 10% of design.
11	Check all air transfer paths meet the design size requirements. If this is in doubt, the air speed through transfer grilles or door undercuts should be measured at fan speed 2.	Less than 1 m/s. Tolerance ± 0.5 m/s.
12	Measure the noise levels in room with MVHR at fan speed 2.	To be 35 dB(A) or below. Tolerance +1 dB(A).

Table 4: Suggested sequence of commissioning measurements and measurement tolerances

Commissioning the internal air flows

As noted previously, there are 2 basic types of fan control, fixed fan speeds and controlled fan speeds. The latter is most commonly based on constant volume flow rate, i.e. the MVHR maintains a constant air flow rate into and out of the dwelling regardless of changes to the valve settings, changes in filter soiling, etc. The approach to commissioning each of these systems differs slightly in that a constant volume controlled MVHR will continually adjust the fan speeds as the room valves are adjusted to achieve the desired air flow rate in each room, thereby maintaining the overall air flow rate and the balance between supply and extract. Systems with fixed speed fan controls require a much more iterative approach whereby the supply and extract fans are adjusted individually after each change to the setting of the room valves, in order that the total supply and extract air flow rates are maintained along with the balance between the two.

A system that maintains fixed overall air flow rates is much simpler and quicker to commission than a system that requires repeated iterations between the room valves and the fan speeds in order to maintain the total air flow rate.

The method of demonstrating overall air flow balance

The method of demonstrating the criteria set out in Table 2 have been met is primarily governed by the ability to measure the flow rate in the fresh air and exhaust air legs of the system. There are two means of achieving this, either by using an in-duct measurement device, or by measurement of the air flow rate on the outside of the building, i.e. at the fresh air intake and exhaust air terminals. This latter option is only practical if the terminals are wall mounted and are accessible, which limits this option for high rise developments or where the design is based around roof terminals.

A further restriction on the use of air flow measuring devices on the outside terminals is that the wind speed should be low to minimise interference with the measurements taken. High winds or gusty conditions may make the readings of most instruments unstable and thus the uncertainty in the measured air flow through the terminal will increase significantly.

Installing permanent air flow measuring devices in the intake and exhaust legs of the system removes many of the limitations of attempting to make measurements on the outside of the building, however there is a capital cost to their installation. If such devices have been installed, then the conversion factors should be taken from the manufacturer's certificate for the device and used to convert pressure difference to air flow rate.

If physical measurement of the air flow rate is not appropriate, then undertaking a leakage test of the ductwork on the internal side of the MVHR should be undertaken. The result of this testing can be used to demonstrate that the inside legs of ductwork do not contain any significant levels of leakage and thus the fresh and exhaust air flow rates should match the sum of the supply and extract air flow rates.

Note: Overall the use of the MVHR controller and the assessment of the leakage of the internal legs of ductwork provide an indication of the overall external flows. Leakage within the MVHR or in the intake and exhaust legs of the system may not be revealed by these measurements which places an increased level of responsibility on the installer to ensure that these parts of the system are airtight.

Appendix A: Commissioning instruments – Details and discussion

Airflow measurement

A capture hood with some form of anemometer should be used to measure the flow at terminals. Typical systems and their suitability are described below:

Type	Inside measurements	Outside measurements
Pitot tube	Not suitable $^{\phi}$	Not suitable $^{\phi}$
Thermal anemometer, hood mounted	Not suitable	Not suitable
Vane anemometer	Not recommended*	Not suitable
Differential pressure anemometer	Not recommended*	Not suitable
Thermal air capture hood	Good	Good
Balometer air capture hood	Good	Good
Powered flow hood	Very good	Very good

All hoods noted as good/very good can be hired.

The equipment should have the following properties:

When measuring internal terminals:

- Must be capable of measuring in steps of 1m3/hr.
- Air capture hood must be at least 300mm long, esp on supply terminals and should not be circular*. Identify hood types used on the commissioning sheet. E.g. Swema is 350 x 350 x 600 long, Acin is 600+ x 600+ x 600 long.
- Operational range accurate down to 10m3/hr, preferably to 5m3/hr, with a measurement accuracy of +/-5%**

When measuring external terminals:

- Must be capable of measuring the combined air flow rate, i.e. not a vane/differential pressure anemometer*
- Record the weather conditions with special reference to the wind conditions at the measurement location (may differ significantly from the conditions away from a building façade).

$^{\varphi}$CIBSE commissioning guide A which covers the commissioning of all ventilation systems suggests that pitot tube measurement can be used to calibrate air capture hoods, but it should be noted that these do not necessarily work well with small scale domestic systems as experience has shown that in small scale duct (≤160mm) the inaccuracies in traverse position outweigh the absolute readings obtained.

**Small size anemometers (>100mm diameter such as vane or differential pressure) not preferred but if they are used a large square hood (eg 300 x 300mm square) should be used and the flow must be kept below around 60 m^3/h [BSRIA 57015/2]. On supply, small hoods and high air velocities can give higher readings (+20%) due to the air swirling and producing extra momentum on to the anemometer fan blades. Thus, if space is confined then rather than use a small hood on supply terminals, a large hood and a transfer piece should be made up to allow the full airflow to be captured, avoiding this error. If this is the case photograph the transfer piece used for the commissioning report. When taking measurements ensure that calibration value is correct, and sufficient time is given for anemometer to settle down before a measurement is taken (be careful of averaging setting).*

*** The domestic Ventilation Compliance Guide suggests calibration annually at UKAS accredited laboratory, with an accuracy of +/-5%.*

Essential equipment required for commissioning:

- Lo-tack tape and cardboard to extend hood as necessary (photograph and identify where used)
- Noise meter – down to 25dB(A), IEC 61672 Class 2 minimum, Class 1 recommended.
- Digital differential manometer – at least 1Pa resolution over measurement scale. E.g. Furness FCO520, Model 1, 0-600 Pa range, or Airflow PVM610 micromanometer.
- 13A plug in watt meter with power factor measurement – e.g. Maplin L61AQ (±3%)
- Basic tools such as drill, screwdrivers and sharp knife, airtightness tape for repairs & duct-tape for temporary sealing
- Loctite or similar to secure terminals
- Plans, schematics and laptop with commissioning sheet and completed design sheet
- Instructions for the ventilation unit and the controls unit

Optional items:

- Duct pressure testing kit: suitable for pressure testing ductwork >100Pa, and to measure airflow to the same accuracy as the main anemometer at this rate. In some cased the ventilation unit can be used to do this, or a secondary fan rigged up. Otherwise specialist equipment can be hired from BSRIA or similar.
- Hot wire anemometer probe for duct/transfer grille air speed check & under door velocity – e.g. Testo 405 Anemometer

In-duct air flow rate measurement devices:

Inserting a device in the fresh air intake and exhaust air duct legs may be an option if measuring the total air flow rate on the outside of the building is not practically possible, for example, multi-storey dwellings, roof cowls, etc.
Most devices are based on the measurement of pressure difference across a device inserted into the duct, however new non-invasive devices are coming on to the market and reduce the need to measure pressure differential accurately and then convert this into a flow rate.

Devices based on measuring pressure difference:

Venturi type: Lindab FMU

Flow grid type: Trox – VMR
Sensing Precision – Eco Radial Flowgrid and Wilson Flowgrid
Woods - MR

With all of the above products, an accurate pressure difference meter will be required. The pressure differences at low air flow rates will often be below 50 Pa and therefore a meter with a maximum range of ideally 1000 Pa is required.

Devices that allow direct readout of flow rate:

Lindab – FTSU + readout FTD.

All of the devices listed above will be influenced by the proximity to bends and other obstructions / disturbances of the flow. The manufacturers provide detailed installation instructions regarding distances from bends, etc. and the impact of this on accuracy. However, many of the devices can offer accuracies of within ± 5% when installed following the manufacturers' instructions.

Appendix B – Trouble-shooting, a basic guide

Basic fault finding is required if the commissioning figures cannot be obtained. It is expected that the commissioning engineer is experienced and diagnostics, basic advice only is provided below. The most common problem is low flow at some or all terminals, or flow is only possible with the fans running at very high speeds potentially resulting in unacceptable levels of noise.

Most commonly low flow or high fan power is caused by leakage in ductwork: suggest turn fans to maximum and listen to try and identify location. Smoke pellets are an option, but care needs to be taken that smoke is not passed through filters or heat exchanger. A pressure test may then be useful.

If the problem cannot be found and rectified, the system should be declared "Un-commissionable" and the Passivhaus consultant, and the ventilation designer notified.

Potential problems & causes

Problem	Cause
Fan is running higher than predicted but the duct pressures are as designed.	• Check the filters are in place correctly and not blocked/soiled • Check there are no blockages within the MVHR – transportation packaging, etc.
Duct pressure is higher than predicted, often coupled with high fan settings and noise. For the leg with high pressure.	• Confirm with contractor that it was installed as per the drawings. Follow the duct route and check against drawing as far as possible • Check that the dampers in the terminals are not too closed, particularly for the index run. • As far as possible check for leaks • As far as possible check for blockages. • The duct distribution system may contain sharp changes direction/size; ask the contractor to confirm it is installed as per the design. • The air speed in ducts may be too great – review design and check air speed is within appropriate limits • If the difference in pressure drop between legs is too great it may not be possible to balance without creating terminal noise on the shorter run. In this case a damper can sometimes be added to the ductwork (NOT FOR EXTRACT)
Noisy but all other tests acceptable.	• Attenuation is incorrectly sized or not installed. Check that all the components match the design, and they have been installed correctly. • The ventilation unit is operating at a higher flowrate than intended – see sections above about duct leaks/blockages. • Mechanical separation between MVHR and structure is not sufficient – see manufacturers guidance on installation and availability of isolating mounting brackets/feet. *Note this is not commonly a problem for domestic MVHR's unless they are operating at their peak flow* • Mechanical separation of MVHR to ducts is not sufficient – use gaiter or similar to reduce the mechanical connection between spigot and duct. *Again, not commonly a problem for domestic MVHR's unless they are operating at their peak flow*
Intake/supply or extract/exhaust terminal flowrates cannot be achieved within 10%.	• It may be too windy to take accurate external measurements; if this is the case then using a >1m long section of ductwork between the anemometer and the open air can steady the flow. Ensure the ductwork is of sufficient size not to increase the resistance. • If this is not the case it is likely there is a leak in the system. A pressure test of the ductwork will confirm

The Foundry, 5 Baldwin Terrace, London, N1 7RU I 020 7740 3520 I www.passivhaustrust.org.uk I info@passivhaustrust.org.uk