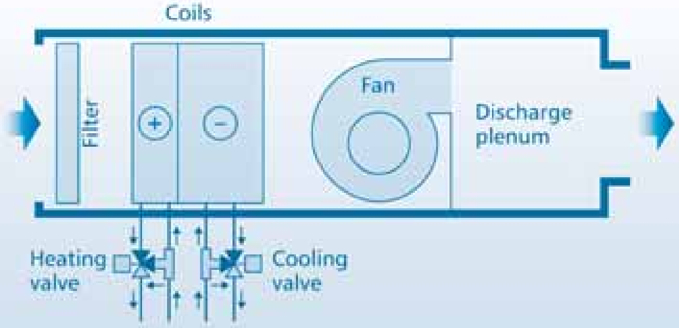
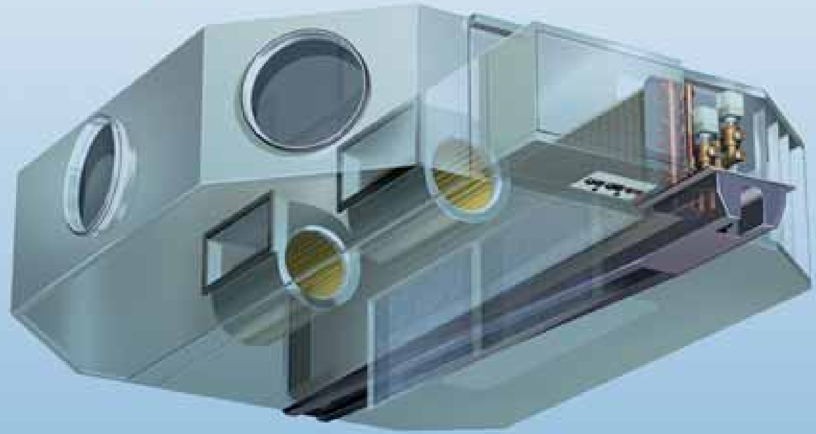
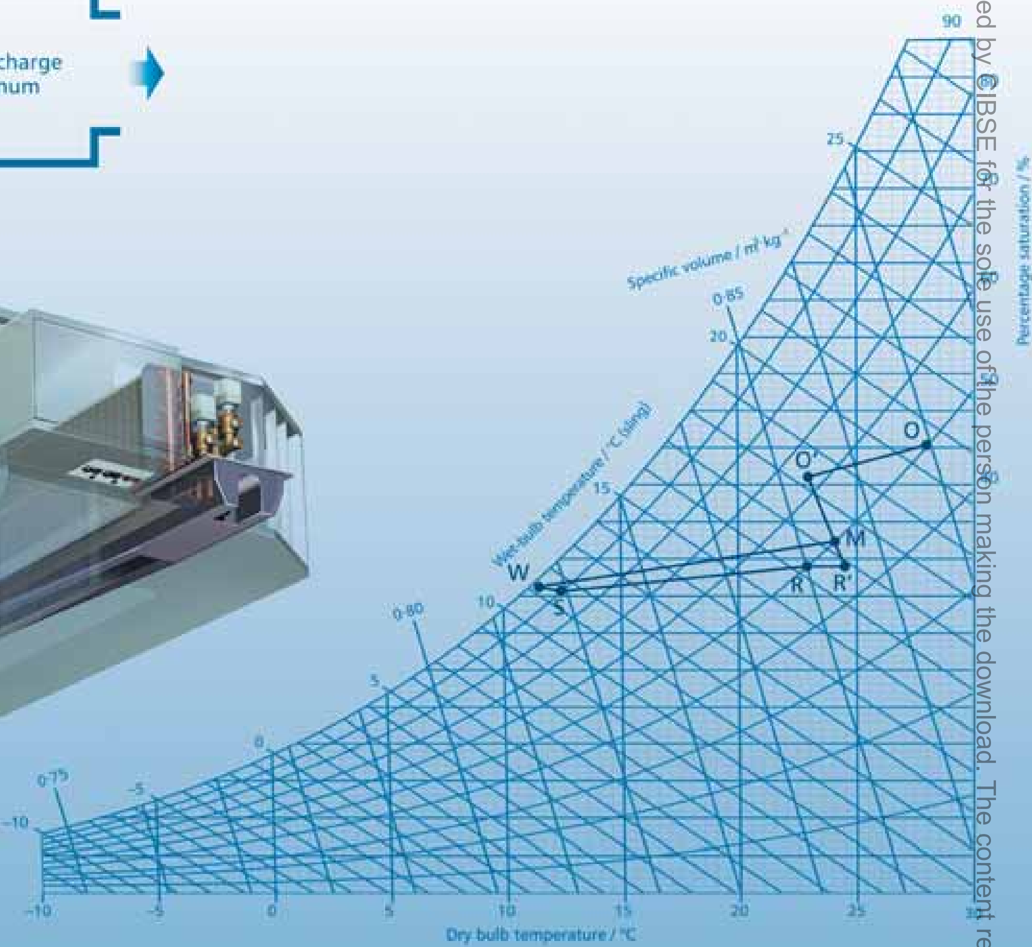
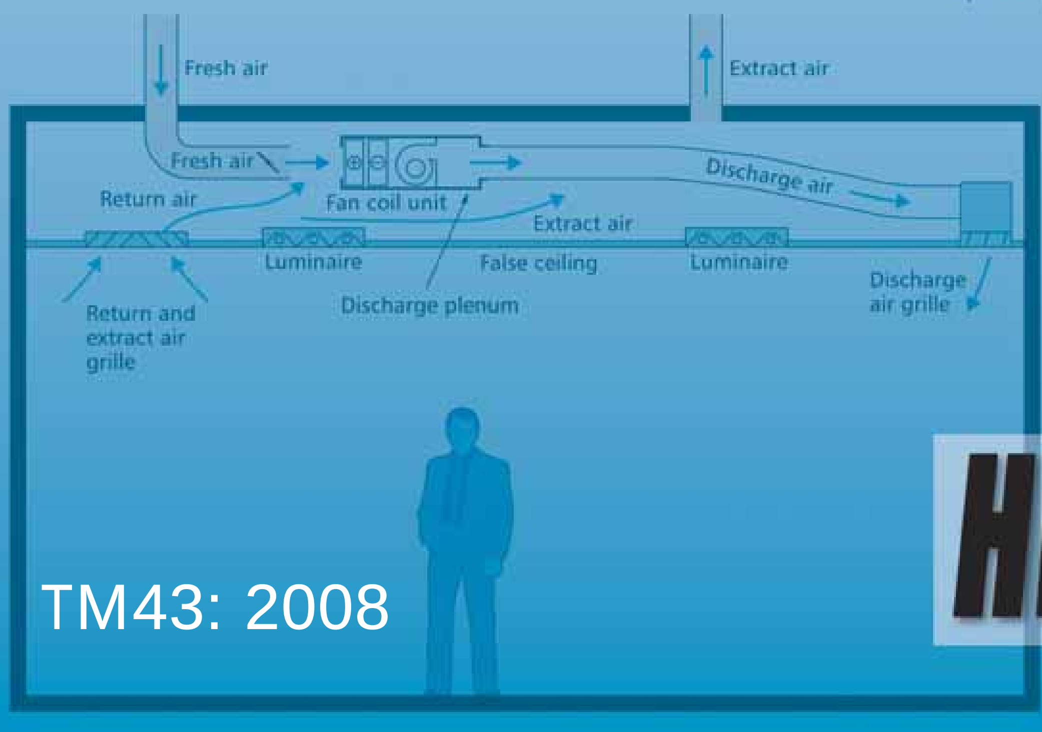
Fan coil units









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Fan coil units

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Note from the publisher

This publication is primarily intended to provide guidance to those responsible for the design, installation, commissioning, operation and maintenance of building services. It is not intended to be exhaustive or definitive and it will be necessary for users of the guidance given to exercise their own professional judgement when deciding whether to abide by or depart from it.

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Foreword

For a number of years, members of the HEVAC Fan Coil Group, within its umbrella organisation the Federation of Environmental Trade Associations (FETA), discussed the need for an industry guide to cover aspects of fan coil unit technology. A draft guide was developed by a working group as a HEVAC publication and this came to the attention of the Institution, under whose guidance it was developed into a more extensive document of interest to all parties involved in fan coil unit projects.

Fan coil unit equipment has evolved steadily over the past few decades into a highly developed and effective means of providing air conditioning for a building. As with any technology there is the potential for serious problems if products are applied or installed incorrectly, thus making professional guidance essential. Recent legislation concerning energy reduction and carbon emissions further highlights the importance of correct design, installation, commissioning and maintenance to achieve efficient air conditioning and avoid energy waste.

This Technical Memorandum sets out to describe all aspects of fan coil unit technology and provides manufacturers, designers, site personnel and operators a comprehensive guide.

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Contents

Fan coil units

1 Introduction to fan coil unit technology

This document is intended as a guide to designers of chilled water fan coil unit systems, the manufacturers who build them, the contractors who install and commission them, and end users. It does not include fan coil units operating on direct expansion/refrigerant systems.

In recent years fan coil unit installations have become one of the most popular types of air conditioning system in both new-build and refurbished commercial premises. The majority of these installations use ceiling void mounted units although a significant number of projects still specify cased or recessed units.

Chapter 2 of CIBSE Guide B[1] describes a fan coil unit as 'a packaged assembly comprising heating and cooling coil(s), condensate tray collection, circulating fan and filter, all contained in a single housing'. The fan recirculates air from the space continuously through the coil(s) either directly or via the void in which the fan coil unit is located. Ventilation is usually provided by a separate central air handling unit (AHU) or it can be drawn through an outside wall by the room unit itself. A fan coil system consists of a number of fan coil units linked together in control groups.

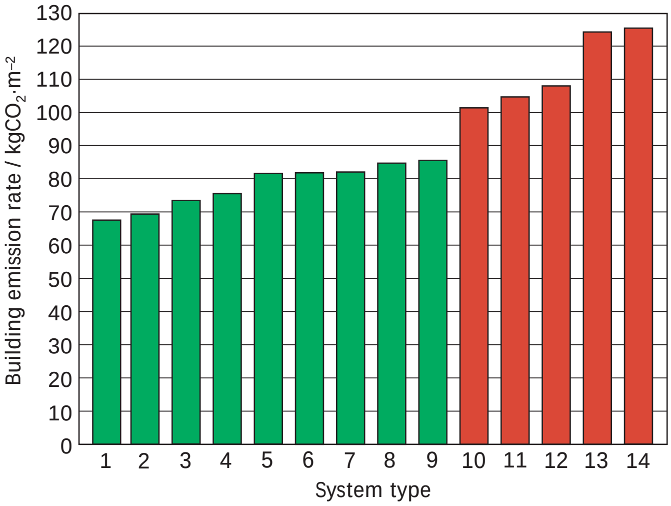
Fan coil units can be evaluated against other air conditioning systems such as constant volume all-air central plant, single/dual duct VAV, chilled beams/ceilings, water loop heat pump or split/multi-split systems. Using the SBEM[2] calculation tool, the CO_2 emissions for a fan coil unit system installed in the office type 'example building' compare favourably against most other HVAC systems, see Figure 1.1. If used with a well designed fresh air AHU a fan coil unit system will readily comply with current building regulations, surpassed only by more expensive and less flexible systems such as chilled beams/ceilings.

The benefits provided by fan coil unit systems include:

- significantly smaller ventilation plant and distribution ductwork than an all-air system
- high cooling capacity
- comparatively low capital equipment cost
- individual zone control of space temperature, if suitable controls fitted
- flexibility to accommodate future changes in load and space layouts (office 'churn').

Fan coil units are particularly suited to applications with intermittent medium to high sensible cooling loads and where close humidity control is not required, e.g. offices, hotels, restaurants etc. The designer should be aware that maintenance costs of fan coil units may be higher than some other systems and that there is potential for water leaks above the occupied space with fan coil units installed in the ceiling void.

The basic reason for installing fan coil systems is to provide 'comfort conditioning' at the specified environmental conditions within the space. Whilst not an inherently complicated system a number of problems can arise with fan coil unit installations, such as those related to noise, thermal output and draughts, and care needs to be taken in the manufacture, design, selection and installation of the equipment to avoid common pitfalls.



Key

1 Chilled ceiling or passive chilled beam with displacement ventilation
2 Active chilled ceiling
3 Fan coil system (well designed AHU)
4 Induction system
5 Fan coil system (conventional AHU)
6 Single duct VAV
7 Water loop heat pump
8 Dual-duct VAV
9 Split or multi-split system with natural ventilation
10 Multizone (hot deck/cold deck)
11 Constant volume system (variable fresh air rate)
12 Constant volume system (fixed fresh air rate)
13 Terminal reheat (constant volume)
14 Dual duct (constant volume)

Figure 1.1 Comparison of carbon dioxide emissions using the SBEM example building

An inadequate or badly performing HVAC system can have an adverse effect on the occupants. Studies have been carried out that show a link between sub-standard working environment and productivity in the work place(3). The correct design, selection and installation of fan coil units is important and this guide is intended to provide current best practice in this field.

2 Fan coil unit principles

2.1 Introduction

There are many types of fan coil unit as each manufacturer presents their own perspective on the basic design. There are some fundamental components, however, such as fans, casing and coils that are common to all types. This section describes how fan coil units are normally constructed for the UK market. It will assist the reader in writing fan coil unit specifications and to understand the engineering processes and their effect on the air conditioning system. It starts with descriptions of the two basic types of design: water-side and air-side.

2.2 Water-side fan coil units

2.2.1 Description

Water-side fan coil unit is the description given to a unit whereby the means of controlling the heating and cooling output is by adjusting the water flow rate passing through the heat exchanger (coil). As at 2006, water-side fan coil units account for approximately three-quarters of the UK market(4).

A water-side control system normally consists of a hot water control valve and a cooling water control valve with electric valve actuators to modulate the flow rate of water through the heating and cooling coils. It can also be in the form of open/closed control valves providing on/off control of the water.

Figure 2.1 shows a 'draw-through' water-side fan coil unit often used in ceiling mounted applications where the heating and cooling coils are on the suction side of the fan.

Refer also to section 3, Figure 3.6, which shows a 'blow-through' fan coil unit, normally used for wall mounted or perimeter cased vertical installations where the heating and cooling coils are on the discharge side of the fan.

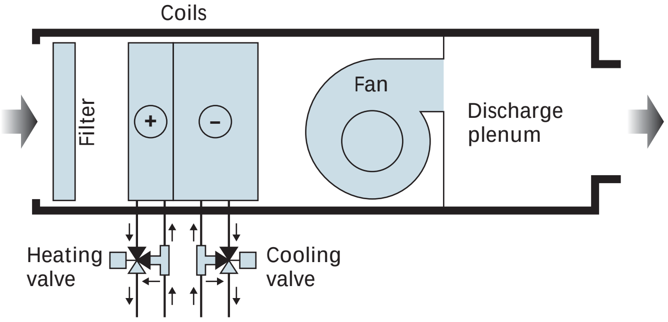


Figure 2.1 Water-side fan coil unit

2.2.2 Specific features

Water control valves are fitted to the coil connection pipes that protrude from the side of the unit. These can be fitted on site by the installation contractor but usually they are factory-fitted by the fan coil unit manufacturer, offering the advantage of off-site prefabrication with associated reduction of site installation problems and time. Other ancillary equipment, such as commissioning sets, hanging brackets, etc. can also be fitted during off-site pre-fabrication.

A condensate collection tray will extend out from the unit under the valves to collect condensation from exposed surfaces.

2.3 Air-side fan coil units

2.3.1 Description

Air-side fan coil unit is the description given to a unit whereby the means of controlling the heating and cooling output is by adjusting the flow rate of air passing through either the heating or cooling heat exchanger (coil) within the unit. Air-side fan coil units are fundamentally different in design from water-side fan coil units and there are distinct advantages and disadvantages with both forms (see sections 3.7.3 and 3.7.4).

Air-side control within the fan coil unit normally consists of air regulating dampers operated by linear electric actuators that control the flow rate of air passing through the heating and cooling coils, so modulating the heating and cooling output, see Figure 2.2.

2.3.2 Specific features

Hinged or pivoting air dampers are fitted inside the unit to open or shut-off the airways onto the heating and cooling coils. In some air-side fan coil units hinged

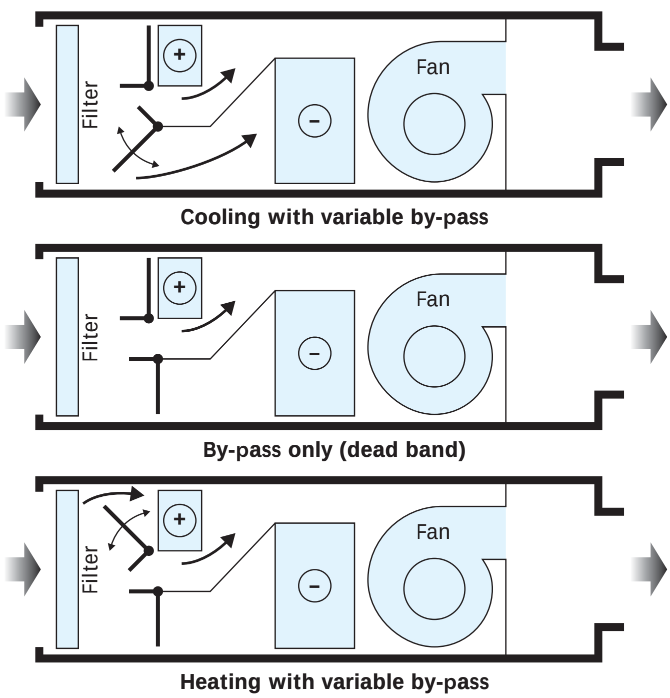


Figure 2.2 Air-side fan coil unit

dampers are replaced by rotating drums or pivoting plates operating on both the heating and cooling coils simultaneously.

Off-site factory prefabrication can be provided for ancillary equipment such as pipework components or hanging brackets.

2.4 Casing

Fan coil units are generally described as 'cased units' when they are visibly exposed to the occupants, i.e. floor, wall or ceiling mounted. They incorporate grilles within an attractive casing that is normally painted.

They are described as 'chassis units' when the whole assembly is concealed, such as is the case with ducted ceiling void mounted or vertical units enclosed in a proprietary perimeter casing. Chassis units are normally finished in galvanised steel and have a functional appearance.

2.4.1 Materials

The casing serves to contain all the components such as filters and coils, so the air can flow in the correct manner through and over these elements. The most common materials used are galvanised or painted sheet steel fixed together into an assembly with rivets, screws, spot welding or adhesives. The gauge of the sheet metal can vary between 20G (1.2 mm) and 16G (1.6 mm) depending on the application and specification.

Plastic materials are also used where a common casing component can be fitted throughout a range of units, although certain specifications may require a self extinguishing (flame retardant) plastic with a UL94V-0, UL94V-1 or UL94V-2 flammability rating(5).

2.4.2 Thermal insulation

The main reason for fitting thermal insulation inside a fan coil unit is to prevent moisture condensing out ('sweating') on the outside surface of the casing in parts of the unit where internal temperatures are low during cooling operation. If moisture were allowed to form, it would drip onto surfaces underneath the unit such as ceiling tiles or directly into the room such as with cased ceiling mounted units.

A variety of foam is used for thermal insulation. A typical specification is 3 mm thick, closed cell expanded polyethylene, with self extinguishing flammability properties to FMVSS302(6). The foam may be self adhesive and is fixed inside the case of the fan coil unit at the manufacturing stage.

A secondary function of thermal insulation is to reduce the transmission of heat either into or out of the fan coil unit. Sometimes the entire fan coil unit is wrapped in thermal insulation by the contractor on site, in the same manner that ducting is insulated, but this is not normal practice.

2.4.3 Noise attenuation

There is a range of acoustic foams available that can be used to line the inside of a fan coil unit to attenuate noise. They are most effective when placed as near to the fan noise source as possible. Generally they are used to combat noise at frequencies from 250 Hz and above. Noise from fan coil units tends to peak on the noise rating (NR) curve between 250 Hz and 1000 Hz, and noise absorption foams offer a relatively cost effective method of providing noise attenuation. They can be obtained in various thicknesses, starting at 10 mm, which can provide 3–4 NR of noise reduction, up to 20 mm thick, which gives greater attenuation. Common materials are high density polyester, polyether or polyurethane foams impregnated to offer flame retardancy capable of satisfying BS 476: Parts 6(7) and 7(8) and Building Regulations(9) Class 0. Low density open cell elastic melamine foams are also used, offering excellent fire and heat resistance to Class 0 without chemical treatments. Most manufacturers use self adhesive acoustic foams with bonding agents designed to operate in an HVAC environment.

Some specialist lead based composite materials are available that can attenuate noise at low frequencies if special low frequency noise criteria are specified, but at a much higher cost. Such frequencies are not generally an issue with fan coil units, however, where fan diameters are not normally greater than 200 mm. Acoustic insulation generally has acceptable thermal insulation properties and will double-up as thermal insulation.

2.5 Fans

Fans to produce an air flow rate through the unit are fitted in all fan coil units. They are forward curved centrifugal fans, usually double inlet double width (DIDW), although single inlet single width (SISW) can be used, see CIBSE TM42: *Fan application guide*(10). They are produced in the form of fan decks or external rotor motor fans ('pod fans'). Fan impellers and housings are normally manufactured from sheet aluminium or painted/galvanised sheet steel, although plastic fans with nylon impellers and polypropylene housings can also be used.

Fan motors can be 2-pole or 4-pole AC, single phase induction, capacitor start/run, up to approximately 200 W capacity with sealed-for-life ball or sleeve bearings. There is a move away from 2-pole AC fans as the specific fan power (SFP) of a fan coil unit fitted with these fans operating at its duty point can be higher than the limit set by current Building Regulations (see below). The specific fan power of fan coil units fitted with 4-pole AC fan motors is typically below 0.8 W/(l/s) with the unit operating at its duty point and can be as low as 0.5 W/(l/s) for well designed fans. Some fans are available fitted with electronically commutated (EC) DC motors and associated speed control equipment to further promote energy efficiency. The specific fan power for fan coil units fitted with these fans can be below 0.4 W/(l/s), although there are additional costs involved, noise levels may be higher and power factor could be an issue (see section 2.10.1). All motors fitted in fan coil units have a limited torque characteristic and any external air static pressure across the unit, such as created by ductwork and grilles, should be kept to a minimum.

The specific fan power of a fan coil unit (SFP_{fcu}) is defined as follows:

$$\text{SFP}_{fcu} = \frac{P_{mains}}{q_{fcu}}$$

where P_{mains} is the power supplied to the fan coil unit (W) and q_{fcu} is the airflow rate through the fan coil unit (l/s).

Tables 35 and 36 of the *Non-Domestic Heating, Cooling and Ventilation Compliance Guide*(11) (the second tier document referred to in Building Regulations Approved Documents L2A(12) and L2B(13)) limit specific fan power of fan coil units to a maximum of 0.8 W/(l/s), measured as the rating weighted average of the fan coil unit installation.

This is calculated by summing the product of the power supplied (P_{mains}) and the specific fan power (SFP_{fcu}) for each fan coil unit in the installation, divided by the sum of the power supplied (P_{mains}) for all the fan coil units in the installation. This can be expressed thus:

$$\frac{(P_{mains(1)} \times \text{SFP}_{fcu(1)}) + (P_{mains(2)} \times \text{SFP}_{fcu(2)}) + ...}{P_{mains(1)} + P_{mains(2)} + ...}$$

For example, for four fan coil units, the rating weighted average SFP_{fcu} could be:

$$\frac{(85\times0.7) + (175\times0.75) + (80\times0.9) + (115\times0.64)}{85 + 175 + 80 + 115}$$

$$= 0.74$$

Note that because the majority of fan coil units in this example installation have low specific fan powers the SFP (rating weighted average) of the installation is below 0.8 W/(l/s), despite the inclusion of a small fan coil unit with a high individual specific fan power.

The user guide for the Simplified Building Energy Model (SBEM)* calculation tool(2), for calculating annual energy use, makes reference to an SFP_{fcu} of 0.8 W/(l/s) for fan coil unit systems. Notwithstanding this, designers may specify SFP_{fcu} values lower than 0.8 W/(l/s) in order to realise their required building services design. (This can be achieved indirectly within SBEM by clicking on the 'Building Services' form menu in iSBEM, then the 'HVAC systems' tab and then the 'System adjustments' sub-tab and adjusting the SFP for the fresh air AHU from its actual value as appropriate.)

Speed control of AC fan motors can be achieved by auto-transformer voltage tappings or tap wound motor winding steps. Speed control for EC/DC motors is done via a 0–10 V DC potentiometer, selector switch or BMS signal control.

* The SBEM has been developed by the Building Research Establishment (BRE) for the UK Department for Communities and Local Government (DCLG) from the National Calculation Method (NCM)(14) for energy performance of buildings. The NCM is the annual energy use calculation for demonstrating compliance with Building Regulations Approved Documents L2A(12) and L2B(13) and in turn the Energy Performance of Buildings Directive (EPBD)(15). The EPBD requires that the energy performance of new buildings be evaluated with a calculation methodology that complies with the Directive.

2.5.1 Fan decks

DIDW fans and motors are mounted in-line on a single fan plate designed specifically for a manufacturer's range of fan coil units, see Figure 2.3. A typical fan deck assembly may have two or three fans driven by one motor with the fans linked by a common shaft. It is also possible to have more than one motor on a fan deck, e.g. a duplex fan (two fans, one motor) and a simplex fan (one fan, one motor) on the same fan plate.

Figure 2.3 Duplex and triplex fan decks (courtesy of ELCO Fans)

2.5.2 External rotor motor fans (pod fans)

Normally available as DIDW fans (although SISW is possible), the spinning rotor of the motor is integrated with the fan impeller producing a compact fan that lends itself to modular designed fan coil units, see Figure 2.4. The majority of manufacturers use these fans. Identical pod fans can be used throughout a fan coil unit range, with increasing number in the bigger units. This can benefit the facilities manager, where a stock of spare fans is kept on site.

Fan decks are the most cost effective way of providing DIDW fans and many manufacturers now produce good quality assemblies. Some designers prefer the style of the external rotor motor fan, however, although the motor situated in the fan inlet can affect performance (i.e. air flow and noise) and needs careful selection by the manufacturer. Having a motor incorporated with each fan provides a degree of redundancy if one motor were to fail, albeit at reduced air flow, however this may not be noticed by the occupants.

Figure 2.4 External rotor motor fan (pod fan) (courtesy of ebm-papst UK Ltd.)

2.5.3 Fan life cycle

The life of a fan and motor is largely dependent on the life of the motor bearings. Bearings are normally sealed-for-life lubricated and rated L10 for, say, 20 000 hours. Statistically this means that the bearing manufacturer will warranty that no more than 10% of the bearings will fail within 20 000 hours when operated at their design loading. Bearings in fan coil units are rarely loaded to this extent so far fewer actually fail in service.

Manufacturers will provide the L10 rated hours for their equipment on request to enable the fan coil units to be included in a life cycle costing exercise for the building services.

2.6 Coils

Coils within a fan coil unit refer to an air-to-fluid heat exchanger used to heat or cool air that is then discharged to the air conditioned space, see Figure 2.5. It can also mean electrically heated elements arranged in an array for heating applications. Water coils are normally manufactured from copper tubing with aluminium fins bonded to them by expanding the tubes. A typical (Cu/Al) coil would have 3/8″ copper tubing with 0.1 mm thick aluminium fins at a pitch of approximately 2.1 mm (12 fins per inch). For special applications fins can be coated aluminium, copper, or tinned copper. For water coils in a water-side fan coil unit it is normal to have the separate heating and cooling coil elements combined into one 'fin block' having separate hot water and chilled water connections. Water coils in an air-side fan coil unit are normally separate heating and cooling coils to suit the arrangement of dampers. Pipe connections should be fitted with end caps or plugs when the unit is delivered to site.

Figure 2.5 Heating and cooling water coil with water valves fitted

2.6.1 Water heating

In the UK, low pressure hot water (LPHW) heated coils (sometimes known as low temperature hot water (LTHW)) are normally designed for water flow and return temperatures of 82/71 °C with flow temperatures generally no higher than 85 °C. Other temperatures can be specified such as 80/60 °C for lower water flow rates or 55/35 °C for condensing boiler applications.

Medium pressure hot water (MPHW) 100–120 °C, high pressure hot water (HPHW) above 120 °C or saturated steam up to 8 bar can also be used, often where it is available for another process. Specially designed coils and fan coils are used for these higher temperature applications because of the hazard of flash steam and overheating of components.

With the advent of 'tighter' build specifications, heating loads in new buildings have reduced (see CIBSE TM29: *HVAC strategies for well insulated airtight buildings*[16]) and heating coils are normally only a single row of a few tubes high. Most fan coil applications involve recirculated air passing through the unit. However, if fan coils are used to handle full fresh air the heating coil should be positioned before the cooling coil (at the on-air face of the cooling coil) to avoid the possibility of frost damage to water in the cooling coil.

2.6.2 Water cooling

Water cooling coils are often designed to operate with 6/12 °C chilled water but other temperatures such as 7/13 °C or 8/14 °C can also be used. In some applications the psychrometry is arranged so the cooling coil operates 'dry', i.e. there is no condensate produced and water temperatures such as 12/16 °C can used. Fan coil manufacturers will generally have only one range of cooling coils to fit into their units, normally designed for 6/12 °C operation, and use these coils for all other water temperature combinations.

As the temperature difference between the air to be cooled and the chilled water in the coil is relatively small in a cooling application (defined by the log mean temperature difference), a water cooling coil is generally three or more rows deep. Provision is made for condensate removal and air velocities within a fan coil unit are kept below about 2 m/s to avoid carry over of water condensate within the unit as this could leak out and damage the building fabric. By default, the coil cannot be used horizontally (i.e. flat), so cooling coils are generally vertical or pitched at an angle up to 45° from the vertical.

2.6.3 Electric heating

Various types of electric resistance element can be used for heating, from black heat tubular (with or without fins) to aluminium ladder type or bare wire. Heat outputs of up to about 3 kW are used on single phase, with higher outputs normally requiring a 3-phase supply. If not carefully controlled, electric heating in fan coil units can use significant amounts of energy. Some manufacturers offer the control package with electric heated fan coil units, whilst others just provide the electric heater battery in the fan coil unit, the contractor being required to wire on site and install the controls.

Unlike water heated coils that can only get as warm as the flow temperature of the hot water, electric elements can become dangerously hot if air flow is reduced to below a safe level, e.g. due to blocked filters, or if air flow stops completely, e.g. due to fan failure. To avoid this, electric heating elements have an overheat cut-out (high limit thermostat) that switches off the power if temperatures become dangerously high. This should be of the 'manual reset' type so access is required to the unit to reset it. Nuisance trip can occur in some fan coil units if there is no fan over-run after switching the unit off, such as could occur upon isolation of mains electrical power with a 'last-out' or fireman's switch.

2.6.4 Associated equipment

2.6.4.1 Drain tray

A drain tray should be provided for the collection and disposal of water condensate from the cooling coil of a fan coil unit. It also has the secondary function of catching water due to any small leaks from valves and joints. To reduce the possibility of *legionella* bacteria the tray design should minimise 'pooling' of water by the positioning of the spout or by incorporating a small sump. Some drain trays incorporate a positive fall towards the outlet spout so that water can drain from the unit. Alternatively, the fan coil unit itself can be installed at a slight angle.

As cold water will be in contact with the inside of the drain tray it will need to be externally insulated to prevent moisture condensing on its outside surface ('sweating'). Alternatively it can be manufactured from a suitable material such as plastic. Either way the tray should comply with spread of flame requirements of BS 476: Part 7[8].

The drain tray will have a spout for connecting to a condensate drain system or to a condensate pump. It is not normally necessary to incorporate a trap on the drain tray, as is the case with air handling units, as negative pressures within a fan coil unit are comparatively low.

2.6.4.2 Condensate pump

In some situations where water condensate cannot drain by gravity into the condensate drainage system, e.g. in basement installations, it is necessary to pump it away to a drain. There are many types of condensate pump, the most common being reciprocating, peristaltic and low head 'lift' pumps. Condensate pumps normally operate only when condensate water is detected and switch-off when the drain tray is emptied below a certain level. Some incorporate a safety device if the pump finds it is unable to pump away water after a certain time. This device will incorporate an electrical contact that can be used to stop the flow of condensate, either by switching off fans or closing the cooling valve via the building management system (BMS). It may also activate an alarm to alert the facilities manager.

2.6.4.3 Air vents/drains

Water coils will have air vents to enable the commissioning technician to bleed air from the coil when filling with water. Sometimes a drain point with a plug is also provided. Air vents should not be fitted if the coil is intended for use with MTHW, HTHW or steam because of the hazard of flash steam.

2.7 Filters

The primary function of a filter in a fan coil unit is to protect the fan and coil from the build-up of dust and dirt which may then be difficult to remove and would reduce the airflow through the unit. It should be understood that they will provide only the minimum level of air filtration for the occupants of the room that the fan coil is serving. Fresh air to the space would normally be filtered by central plant air handling units fitted with higher specification filters for this purpose.

2.7.1 Types and grades

The normal grade of filter for a fan coil unit is usually G2 (EU2) (65–80% average arrestance to BS EN 779[17]), with G3 (EU3) (80–90% average arrestance) sometimes specified for larger units with more powerful fans. Filters range from 6 mm thick synthetic filter media in a metal frame to cardboard framed disposable panel filters, see Figure 2.6. It should be possible to remove and vacuum clean the filter several times before replacement is necessary.

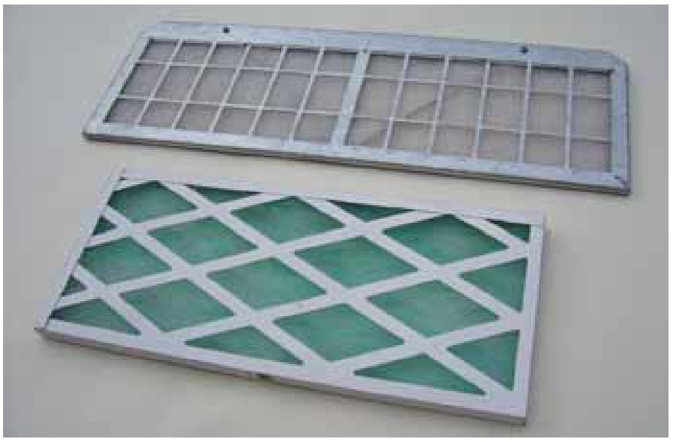


Figure 2.6 Filter medium in a metal frame (top) and a cardboard framed filter (bottom)

2.7.2 Filter resistance

Because of the modest airflow/pressure characteristic of the fans and motors used in fan coil units, the initial clean resistance of filters is designed to be low at 10–15 Pa and dirty resistances will only be as high as 40–50 Pa.

It is good practice to clean or change the filters in a fan coil unit after commissioning and at handover as they are often in a dirty condition. Fan coil units may be operated during building construction works to dry out the building fabric and will pick up a great deal of builders' dust. The fan coil unit contract should ideally include for a complete set of replacement filters.

2.8 Fan coil unit plenums

2.8.1 Discharge plenum

Discharge plenums direct the air flowing through the fan coil unit into circular ducts to supply air to grille diffusers as required, see Figure 2.7. All manufacturers provide standard discharge plenums with a number of circular spigots, not all of which are used in an installation. Projects will often require plenums to be designed specifically to suit the ducting arrangement on site.

Plenums introduce airflow losses and manufacturer's performance figures should account for the effect of the discharge plenum in their catalogue information, including the reduction in performance if one or more of the outlet spigots is capped on site.

Figure 2.7 Fan coil unit discharge plenum

Figure 2.8 4-port, 3-way valve with actuator (courtesy of Siemens Building Technologies)

2.8.2 Inlet plenum

Inlet plenums are sometimes used to provide spigot entry points into the fan coil unit for return air ducting from the room or for fresh air ducting from the central plant air handling unit (see Figure 3.2). The use of inlet plenums will incur additional installation costs compared to using the ceiling void as a path for the return air and locating the fresh air duct near the inlet of the fan coil unit (see Figure 3.1). Some designers still favour them, however, as they potentially provide a more hygienic solution for the return air path and a more accurate mix of fresh air and return air.

Care needs to be taken during the design and commissioning of an installation with ducted inlet plenums as the fan coil unit could see high external resistances. If the fresh air supply is not balanced carefully, some fan coil units will see a high negative resistance at the inlet, thereby compromising performance.

2.8.3 Acoustic plenum

Acoustic plenums can be either on the discharge or the inlet of the fan coil unit and provide a suitable method of reducing noise levels from the unit. Plenums are lined with acoustic insulation as described above in section 2.4.3 and can incorporate additional baffle plates, also lined with foam to enhance attenuation.

For example, a 600 mm long acoustic inlet plenum can provide the equivalent of approximately 3 dB attenuation of inlet noise levels, although the additional length of the fan coil unit must be accommodated.

2.9 Controls

2.9.1 Water-side controls

2.9.1.1 Control valves and actuators

In the UK, 4-port, 3-way valves, see Figure 2.8, are generally fitted to fan coil units although 2-port valves are now also being specified. It is important that a valve having the correct K_{vs} value is fitted to the coil otherwise control of the heating or cooling output will be compromised.

The K_{vs} value of a 4-port, 3-way valve is calculated from the water flow rate and the hydraulic pressure drop of the coil in the fan coil unit. A 2-port valve calculation not only requires information about the coil in the fan coil unit, but also that of the installation pipework up to the fan coil unit and this needs to be carried out by the design consultant (see section 3.7.3.2). K_{vs} and valve authority are also explained in sections 3.7.3.2 and 3.7.3.4.

There is a variety of control valve actuators used to modulate the opening of the valve. 0–10 V DC actuators can provide very fine control if required by the application. Raise/lower motorised valve actuators offer a compromise between cost and controllability. Thermic actuators offer a cheaper solution with acceptable control for most applications provided that the controller compensates for the action of the device.

2.9.1.2 Test points

Binder temperature and pressure test points can be fitted to the fan coil unit pipework to assist in site commissioning procedures.

2.9.2 Air-side controls

2.9.2.1 Dampers and actuators

Dampers for controlling the flow of air over the heating and cooling coil and therefore the output from the fan coil unit can be in the form of a hinged flap, rotating drum or pivoting plates. To minimise energy crossover, particularly from the heating to the cooling air path, dampers and the fan coil unit casing must be rigidly constructed so there is a good air seal over the face of the coil when the damper is closed.

Actuators to modulate the dampers can be linear push/pull rod type, connected via a linkage to the damper, or rotating type linked via a gearbox.

2.9.2.2 Variable speed fans

Air-side control can also be achieved by changing the speed/airflow of the fan and therefore the output of the coil. For a fan coil unit with heating and cooling coils this would involve operating only one coil at a time such as with a 2-pipe changeover system.

2.9.3 Controllers

Controllers are fitted to fan coil units to adjust the heating and cooling output of a unit in accordance with the control requirements. Generally this would be to control the air temperature of the room, or the return air temperature to the fan coil unit, against a set point temperature. They are sometimes included with valves and actuators and supplied direct to the fan coil manufacturer for factory fitting. It is important that controls supplied direct to the fan coil manufacturer are of the correct type and are supplied on time, otherwise this will delay delivery of the fan coil units. All mounting accessories and pipe fittings must also be supplied and it is recommended that at least one spare set of controls is included as there may be a problem with defective controls hardware in the factory.

2.9.3.1 Standalone controls

Standalone controllers have an independent control function sometimes with local wall mounted manual controls adjusted by the occupant of the room whilst in use. This can be for a single fan coil unit or for several units wired together as a master/slave system with one user control interface.

2.9.3.2 Programmable controller/building management system (BMS)

With a programmable controller/BMS, the basic control algorithm is carried out within the controller on the fan coil unit but global functions, such as time schedules and optimum start and stop are carried out by the central BMS. It can be beneficial to provide the occupant with some degree of set point temperature control as an adaptive technique to ensure user satisfaction.

2.10 Energy considerations

2.10.1 DC/EC motor fans

Direct current (DC) or electronically commutated (EC) motors have lower energy consumption than conventional AC motors for the same air volume flow rate. This is particularly so at reduced fan speeds and when comparing against 2-pole AC fan motors, when the energy savings are significant, see section 2.5. DC/EC fan motors require a controller to convert mains AC power to DC and to adjust the speed of the fan in response to some control signal or a speed control potentiometer. This controller can be in the form of a separate control box (DC motors) or with the electronics integrated within the fan motor (EC motors). Capital costs of DC/EC fans are high, being approximately double that of AC fans, but costs should fall as they become more widely available and energy reduction legislation takes effect.

Power factor may be an issue with EC fans in a fan coil unit installation and active power factor correction would be necessary to raise the power factor of the installation to about 0.9. In addition, mains harmonics may be present that can lead to tariff penalties with the electrical supply undertaking. The EC fan manufacturer can advise on an appropriate course of action.

2.10.2 Variable air volume

Theoretically, fan impeller power varies as the cube of the fan speed or the air volume flow rate. Basically this means that if the air volume flow rate is halved, energy consumption is reduced to one eighth. In practice, the gain is not this high but is still significant, particularly if there is a large number of fan coil units in an installation, and controls to reduce the air volume flow rate when it is not required can yield good energy savings. This can be achieved in speed steps using suitable controls, or by variable speed control using DC/EC motor fans, see section 2.10.1.

2.10.3 2-port valves/variable water volume

As described above for variable air volume, similar energy savings may be made by reducing the water flow rate of system pumps below their ‘design day’ performance level during part load conditions. When combined with 2-port control valves, the water flow can be diverted around control zones (system diversity) and there is the potential for using smaller pumps and smaller diameter pipework.

2.10.4 Environmental considerations

The amount of embodied energy and embodied carbon used in the manufacture and supply of building services equipment is becoming an increasingly important issue with designers. An example of high embodied energy and carbon is the use of aluminium components, which need large amounts of energy to produce resulting in a significant carbon footprint, see Table 2.1[18].

Table 2.1 Values of embodied energy and carbon[18]

Material	Embodied energy / (MJ/kg)	Embodied carbon / (kg CO_2/kg)
Aluminium	154.30	8.53
Copper	40–55	3.18–4.38
Galvanised sheet steel	35.8	2.82
Plastics	80.5	2.53

Delivery of fan coil units over long distances also contributes to a high carbon footprint, especially with air, sea and road transport across international borders.

Many fan coil unit manufacturers and installation contractors are now registered in accordance with BS EN ISO 14001[19] and certification is available upon request if this is an important issue with the building services designer.

Higher chilled water supply temperatures can be used, i.e. 8/14 °C, and this can promote more efficient operation of the central plant chillers, although it will require larger fan coil units for the same duty. The chilled water supply temperature can also be increased for part-load free cooling conditions, see BSRIA BG8/2004: *Free cooling systems*[20].

Some fan coil units are available with oversize or counterflow cooling coils for use with lower grade chilled water temperatures, e.g. 14/18 °C, such as supplied by free cooling systems and ground source heat pump chillers.

See also section 1 and section 2.5 for information relating to the Simplified Building Energy Model (SBEM) calculation tool[2] for calculating energy performance and CO_2 emissions of fan coil unit systems.

3 Design of fan coil unit installations

3.1 Introduction

There are many variations in the design of a fan coil unit installation. This section describes some of the more common designs encountered and indicates areas of good practice. It is primarily aimed at the design engineer (consultant).

The starting point for the design of the fan coil installation is calculating the cooling and heating loads for the space. Several rules of thumb exist for calculating these loads including BSRIA BG 14/03: *Rules of thumb*[(21)]. However, it is often necessary to carry out a more detailed load assessment of the external and internal heat gains and heat losses. This can be done manually, see Jones[(22)], or using one of the proprietary software packages available to assess the various gains and losses.

At this stage it is necessary to consider the location of the fan coil units to be used. Two main categories are described here. They are:

(*a*) located within a ceiling void (these being ducted chassis type fan coil units, mounted horizontally within a ceiling void, see section 3.2)

(*b*) located within the occupied space (these being vertical chassis fan coil units in floor mounted perimeter casing or a purpose built compartment, also cased fan coil units, either floor mounted or suspended beneath a ceiling, see section 3.3).

These two categories are distinguished by the location of the services to the fan coil units (fresh air, extract air, water, electricity, etc.), either within a ceiling void or the room that the units serve.

3.2 Ceiling mounted, ducted chassis fan coil units

3.2.1 Design layout

The layout of fan coil units within a ceiling void installation is largely determined by the other services within the void. The following is an order of priority for designing ceiling void services and therefore where the fan coil units can be located within the void:

(1) lighting array in ceiling grid to achieve design levels of illuminance

(2) fresh air and extract ductwork system

(3) condensate drainage pipework

(4) discharge grille layout considering building perimeter and core loads

(5) chilled water and heating pipework

(6) fan coil units

(7) electrical supply.

Design layout is an acquired skill but there are computer design aids now available using case-based reasoning and constraint programming techniques that provide standard solutions for complex layouts. Such a design aid has been developed by the University of Nottingham[(23)].

3.2.2 Discharge air

3.2.2.1 Ductwork routing

Discharge air is transferred to ceiling diffuser grilles via supply ducting. Fan coil units are normally supplied with a discharge plenum having a number of outlet spigots for the connection of discharge ductwork. It is important not to impose unnecessary air resistance across the fan coil unit as this will often lead to increased noise and energy consumption, and a reduction in heating/cooling output. The following rules should be observed:

— Minimise the length of ductwork and the number of ductwork bends.

— Wherever possible use solid ducting; flexible ducting should be used carefully as it can impose significant air resistance, especially if formed into tight bends.

— Use flexible ducting only for final connections and not to compensate for poorly installed or misaligned ductwork.

— Use as many of the available outlet spigots on the fan coil unit as possible to minimise the static resistance across the unit.

— Use ducting of the same size as the outlet spigot on the fan coil unit; never reduce the diameter.

— Avoid using volume control dampers (VCDs) in supply ducting if possible as these will increase air pressure drops.

— Use discharge diffuser plenum boxes wherever possible to minimise air resistance, either top or side entry.

— For noise levels of NR35 aim for a maximum duct air velocity of 3 m/s or lower for noise levels below NR35.

Note: extract air needs to be balanced to ensure that correct volumes are extracted from individual spaces.

Refer also to HEVAC's *Guide to air distribution technology for the internal environment*[(24)].

3.2.2.2 Ductwork insulation

All ductwork should be well insulated and vapour sealed to avoid energy losses in cooling and heating mode and to stop condensation forming on the ducting ('sweating') in cooling mode.

3.2.3 Return air

3.2.3.1 Using the ceiling void as a plenum

A mechanism is required for introducing fresh air into the room and for taking some extract air out from the room. Fan coil units predominantly recirculate return air from the room but fresh air can also be introduced via the fan

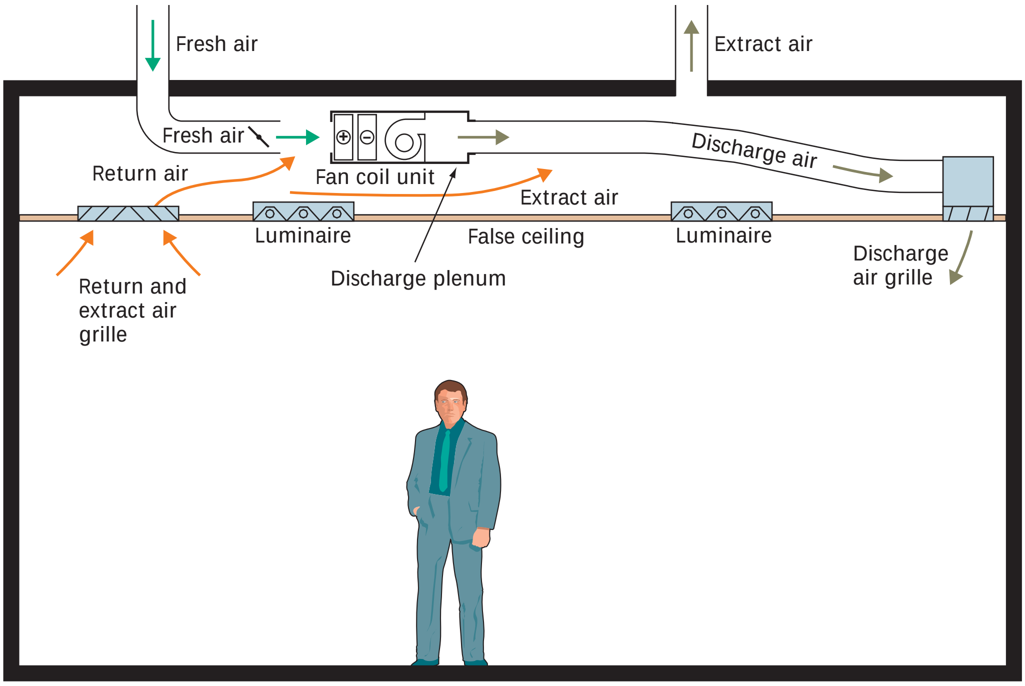


Figure 3.1 Fan coil unit in a ceiling void installation (not to scale)

coil unit. Figure 3.1 shows how the fan coil unit and other ventilation services are positioned within the ceiling void. The ceiling void is used as a plenum for the return air from the room to be re-conditioned and for the introduction of ventilation fresh air from a central plant air handling unit (AHU). These two air flows are introduced into the vicinity of the fan coil unit air inlet and then drawn into the unit for conditioning.

The central plant AHU is typically a full fresh air system with off-coil control of heating and cooling coils, including humidification if required. The ventilation air will normally be supplied at a neutral temperature to minimise loads on the fan coil units. This temperature may be scheduled down against outside air to provide an element of 'free' cooling in warmer weather and this can reduce fan coil unit sizes. The central plant AHU and distribution ductwork are normally sized to meet only the fresh air requirements of the occupants and so are much smaller than those for an all-air system.

The fresh air duct spigot will have a volume control damper (VCD) to set the volume of fresh air that each fan coil unit will receive. It is important that the fresh air duct terminates short of the fan coil unit inlet (approx. 150 mm) so that both return air and fresh air are offered to the unit at effectively atmospheric pressure. This avoids the possibility of negative pressures imposing additional static air resistance across the fan coil unit and possibly creating noise problems.

With the air being returned via the ceiling void, heat pick-up from light fittings may result in temperatures onto the fan coil unit being somewhat higher than the room temperature. This should be taken into account in fan coil unit sizing, see section 4.3.2.

3.2.3.2 Ducted return air

Another method of getting the return air from the room back into the fan coil unit for re-conditioning is to duct it directly to the inlet plenum of the unit, see Figure 3.2.

Whilst this is a more direct solution there are additional costs involved with ductwork and grille plenum boxes and the system can impose a higher static air resistance across the fan coil unit (see section 3.2.4.2). There are advantages, however, where air cleanliness is critical, e.g. public health engineering, if it is felt that return air passing through a common ceiling void (see Figure 3.1) is an issue. See CIBSE Guide G: *Public health engineering*[25] and HTM03-01: *Heating and ventilation systems — Specialised ventilation for healthcare premises*[26] for further information. Acoustic 'cross-talk' via the ceiling void will also be reduced with this system.

3.2.4 Primary fresh air

3.2.4.1 Rationale

From a building services perspective a supply of fresh air is required for the dissipation of odours from a space, for control of moisture that could damage the building fabric and to prevent the build-up of CO_2 from respiration of occupants. Air for the supply of oxygen to breathe is small in comparison with what is needed for the above, so it can be assumed to be adequate if odours, moisture and CO_2 are tackled. CIBSE Guide A[27] and chapter 2 of CIBSE Guide B[1] should be consulted for detailed information on fresh air supply quantities and design considerations.

3.2.4.2 Fresh air supply for fan coil units

Fresh air can be ducted to the fan coil unit from a central plant air handling unit in the manner indicated in Figure 3.1 or Figure 3.2. Considerable care must be taken if fresh air is ducted directly to the inlet plenum of the fan coil unit as in Figure 3.2. If the central plant ductwork volume control dampers are not set precisely some fan coil units will see significant positive or negative static pressures that could markedly affect performance and increase fan noise.

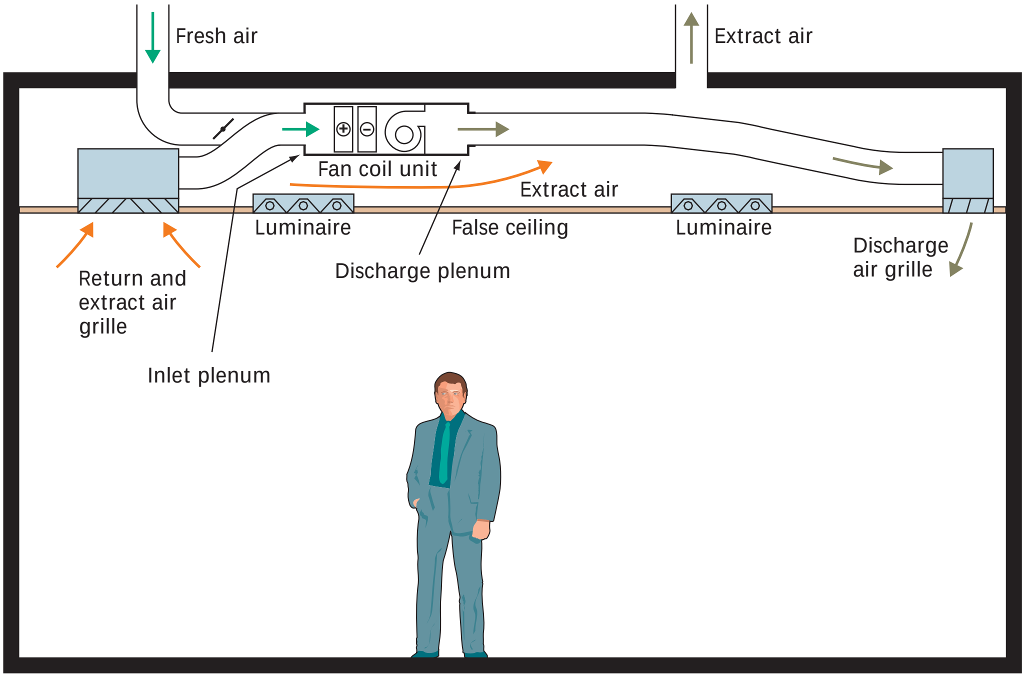


Figure 3.2 Fan coil unit in ceiling void, ducted fresh air and return air (not to scale)

In certain applications fan coil units can be operated on 100% fresh air by connecting an inlet duct direct to the outside air and using the fans within the unit to induce fresh air, see Figure 3.3. This arrangement is useful when central plant fresh air duct systems are impractical, although external static air resistance across the fan coil unit will be increased.

The inclusion of a built-in fresh air damper system connected to outside air provides a fan coil unit that operates both in recirculation and fresh air modes, see Figure 3.4.

In most fan coil unit installations the ducted fresh air supply from a central plant air handling unit will be less than the total air volume flow rate through the fan coil unit. However, in densely occupied rooms the fresh air supply could be equal to, or even higher than this flow rate. In the latter case return air grilles and extract air grilles may then only be required to:

— allow fan coil unit operation without central plant fresh air during pre-heat warm-up periods

— minimise external pressure drop across the fan coil unit.

In either case return/extract air grilles can be easily retrofitted.

Where larger quantities of fresh air are introduced it should be introduced directly into the room as shown in Figure 3.6.

3.2.5 Condensate

3.2.5.1 Wet-coil systems

Fan coil units typically operate using chilled water temperatures of 6 °C flow and 12 °C return although other temperatures such as 7/13 °C or 8/14 °C are also

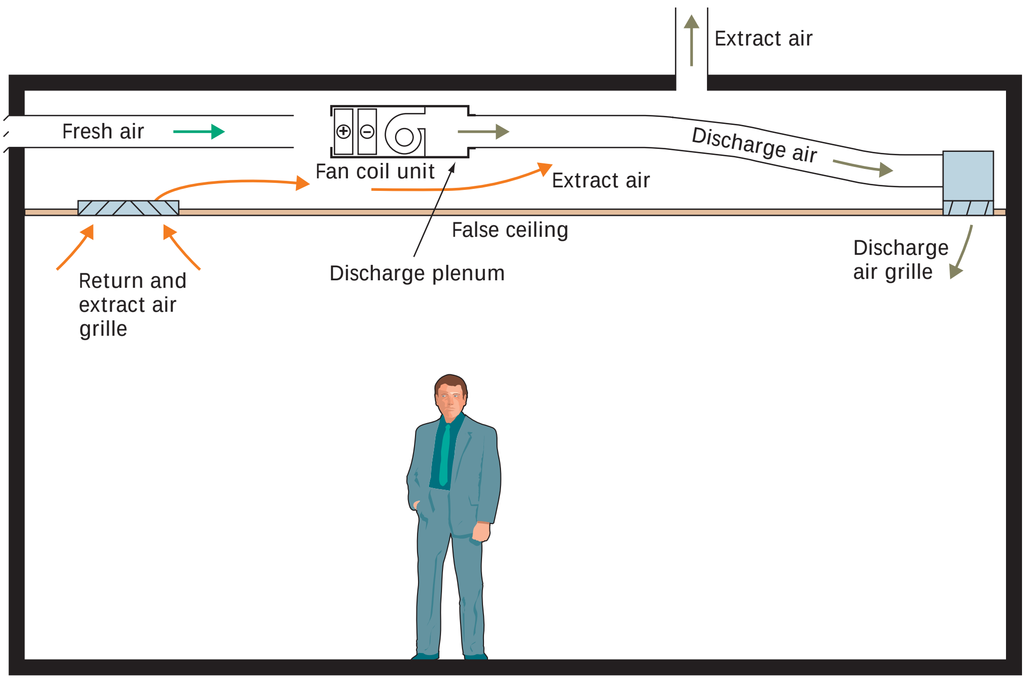


Figure 3.3 Fan coil unit in ceiling void, 100% ducted fresh air (not to scale)

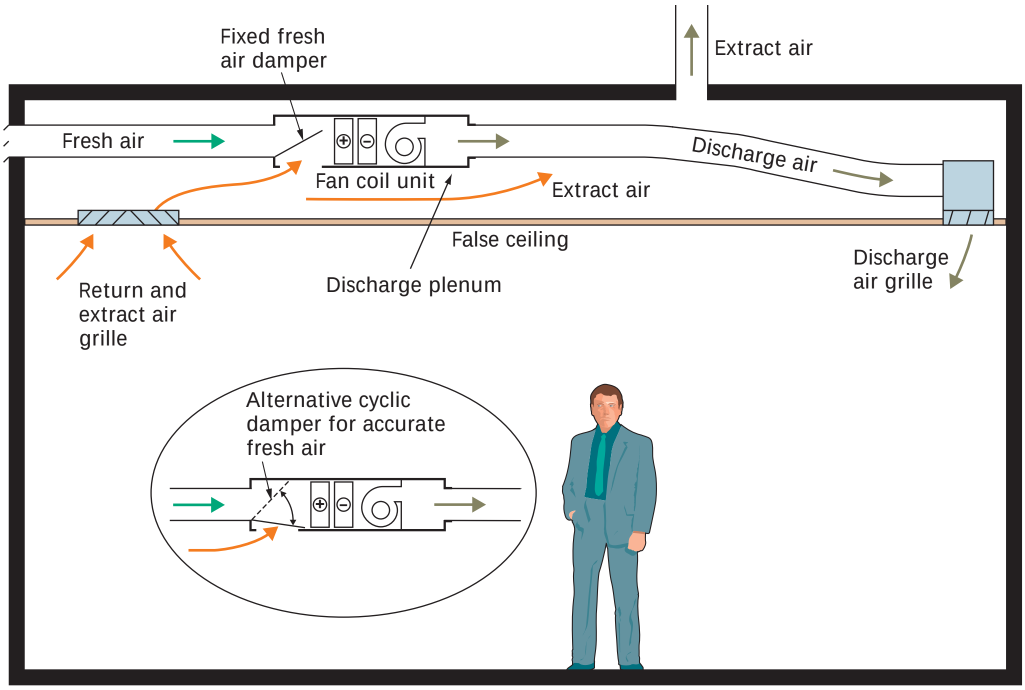


Figure 3.4 Fan coil unit in ceiling void, ducted fresh air with damper (not to scale)

encountered. All these chilled water temperatures will result in condensation forming on the chilled water coil when used in UK environments. In a typical UK office building a fan coil unit will produce approximately 0.4 litre/h condensate per kW of sensible cooling output which will increase markedly during levels of high humidity. Provision needs to be made for the collection and proper disposal of this water condensate or ceilings, furniture, computers etc. will become water damaged.

A formula for calculating the rate at which condensate is produced is:

$$q_{cond} = q_{air} \times \rho_{air} \times (g_{air\,(on)} - g_{air\,(off)}) \times 3600$$

where q_{cond} is the rate of condensate production (litre/h), q_{air} is the volume flow rate of air through the FCU (m^3/s), ρ_{air} is the density of air at the mean air temperature condition (kg/m^3), $g_{air\,(on)}$ is the moisture content of air going onto the FCU coil (kg/kg dry air) and $g_{air\,(off)}$ is the moisture content of air coming off the FCU coil (kg/kg dry air).

As an example, Figure 3.5 shows a psychrometric chart with a fan coil unit summer cooling line (M–W) superimposed, where:

M is the ‘air on’ condition into the FCU chilled water cooling coil ($g_{air\,(on)} = 0.0096$ kg/kg dry air)

W is the ‘air off’ condition from the FCU chilled water cooling coil ($g_{air\,(off)} = 0.0082$ kg/kg dry air)

$q_{air} = 0.3\ m^3/s$

$\rho_{air} = 1.20\ kg/m^3$ (air at 18 °C dry-bulb/14.6 °C wet-bulb).

For this fan coil unit with a sensible cooling output of about 4.3 kW, the condensate produced would be 1.81 litre/h.

There is also a small risk of *legionella* bacteria occurring if condensate is not properly removed. BRE document IPS/85[28] should be referred to for the design of the condensate disposal system.

See also CIBSE TM13: *Minimising the risk of Legionnaires’ disease*[29] and chapter 4 of CIBSE Guide B[30] for more information on the control of Legionnaires’ disease.

3.2.5.2 Gravity drain system

If the depth of ceiling void allows, a gravity assisted condensate drainage system can be used. The drain tray from each fan coil unit is connected to the drainage system within the ceiling void and extends throughout the void with a gradient of about 1:50 (20 mm/m). It serves all fan coil units and drains the condensate to the nearest riser where it enters the building drainage system. In this

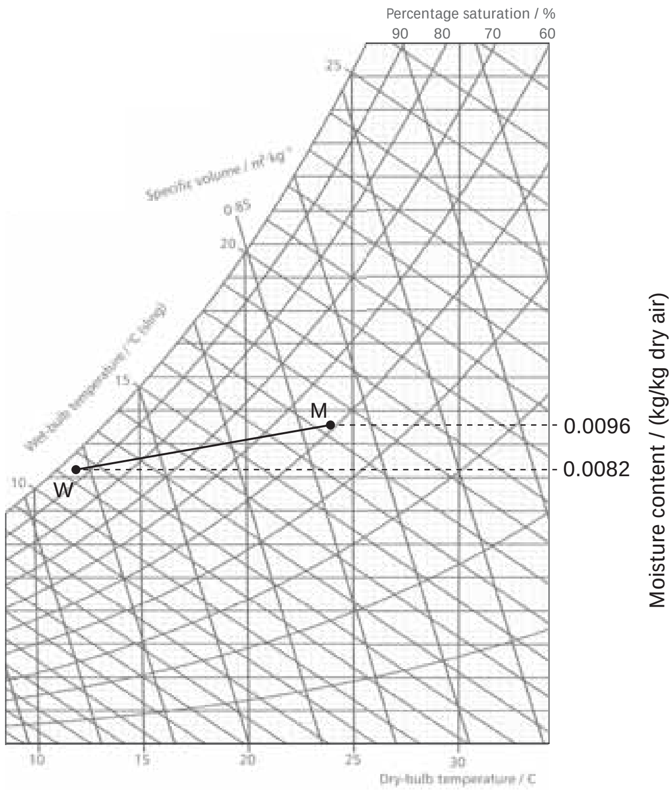


Figure 3.5 Extract from psychrometric chart showing calculation of condensate

way the condensate from the fan coil units in a floor zone can be disposed of in a safe and reliable manner. Whilst not often fitted, consideration should be given to condensate traps where the drain tray spout connects to the condensate drainage system. These are useful when back pressure from the drainage system could prevent condensate draining away from the fan coil unit drain tray.

Where it is not possible to achieve gravity drainage, a pumped system must be used, see below.

3.2.5.3 Pumped drainage system

If it is not possible to drain condensate from the fan coil unit into the building drainage system by gravity, e.g. in a basement room or shallow ceiling void, a condensate pump can be used. There are several types available, such as reciprocating or peristaltic, and careful selection is required as problems here can result in water damage to the building. To minimise noise and prolong working life, condensate pumps should have a liquid sensing mechanism so they operate only when there is condensate to pump away. They should also have an alarm system such that the cooling valve on the fan coil unit cooling coil is closed in the event of condensate not being pumped away. This can be done via the control valve input or a BMS interface. Other options, although less favourable, are to wire the alarm so as to disable the fan (some condensate may still be produced in this situation) or to a remote annunciation system as a warning.

3.3 Vertically mounted and cased fan coil units

3.3.1 Application design

3.3.1.1 Layout

Vertically mounted fan coil units provide air conditioning at building perimeter locations, such as under windows where cooling loads can be higher, see Figure 3.6. They can also be suitable for compartment enclosures within the building core. Unlike ceiling mounted installations the various services such as pipework, electrical supply, controls, condensate disposal, ductwork and fresh air can be difficult to route to the fan coil unit and this can limit its location. Early design collaboration with other site disciplines is important to avoid these problems.

3.3.1.2 Types of enclosure

Vertically mounted fan coil units can be supplied in basic chassis style for fitting inside a decorative perimeter casing supplied by others, or to be installed within a builder's cabinet. Cased fan coil units are also available where the casing is intended to be on view to the room occupants; these units incorporate integral discharge and return air grilles.

3.3.2 Discharge and return air

Vertically mounted chassis fan coil units require ductwork and grilles to be connected to the discharge and, with some installations, also to the return air inlet. Discharge grilles in perimeter casings should be designed to discourage occupants from leaving papers and objects on the unit that could disrupt air flow. For cased fan coil units the discharge and return air paths are incorporated into the unit and additional ductwork is not required. Cased fan coil units can also be mounted on the ceiling if the condensate drainage system allows.

3.3.3 Primary fresh air

Unless it is possible to duct fresh air into the casing or the compartment that the fan coil unit is installed in, fresh air will need to be supplied separately into the room via a central plant ductwork system, see Figure 3.6. The same rationale and design considerations apply as for ceiling mounted fan coil units, see section 3.2.4.

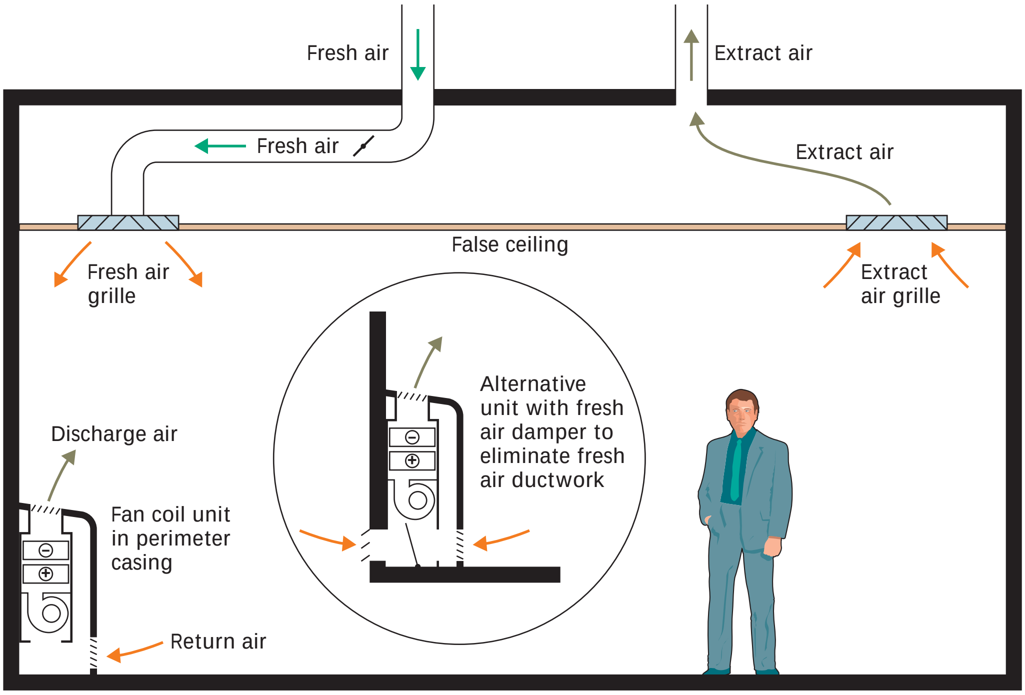


Figure 3.6 Wall mounted vertical fan coil unit in perimeter casing (not to scale)

3.3.4 Condensate

Because of their location, vertically mounted fan coil units will often require a condensate pump system able to deliver condensate to a drain that is many metres away and sometimes at a higher level. Condensate pumps should be sized to cope with the static pressure, bearing in mind that installers may leave pipe partially kinked.

3.4 Sizing of fan coil units

Cost considerations promote the use of a smaller number of larger size fan coil units to serve large areas such as open plan offices. Smaller units are used for cellular offices and smaller spaces. Key design constraints governing unit size are cooling output, noise levels, entering air temperature and cooling temperature differential (8–12 K)[1] (which determines the temperature of the air leaving the coil). Most fan coil unit manufacturers have sophisticated selection programs that will choose the most appropriate units against a specification, see section 4.

3.5 Air terminal devices

Air terminal devices such as discharge diffusers and return air grilles are used extensively in fan coil unit installations to supply and remove conditioned air from the treated space. The correct design and commissioning of these devices is important for the fan coil unit air conditioning system to work effectively. Refer to HEVAC's *Guide to air distribution technology for the internal environment*[24] for the detailed design of these elements.

3.6 Pipework systems

3.6.1 2-pipe changeover

The fan coil unit is equipped with only one water coil which is supplied with either hot water or chilled water from a common water circuit connected to the boiler or chiller plant via changeover valves. This system is only suitable when the summer/winter transition is well-defined, which is not normally the case in the UK.

3.6.2 2-pipe non-changeover

The fan coil unit is equipped with one water coil which is supplied only with chilled water from a chiller circuit. Heating is normally provided either by a separate room perimeter system or possibly by electric heaters within the fan coil units. The use of electric heaters with fan coil units is not usually recommended, however, because of the high energy costs and associated CO_2 emissions. Section 3.7.6 details where electric heating can be considered.

3.6.3 4-pipe systems

The majority of fan coil units in the UK are equipped with two coils, one for heating and one for cooling. The coils may be separate or they may be within the same coil block. These are fed by separate heating and chilled water circuits which may function concurrently to satisfy the requirements of different building control zones. In some circumstances heating is only required for warm-up periods and the whole heating circuit zone can be 'valved-off' during the day, such as with air-side fan coil unit installations to minimise energy crossover.

3.7 Controls

See also CIBSE Guide H: *Building control systems*[31].

3.7.1 Standalone/non-programmable controls

The simplest form of fan coil unit control consists of a controller with water control valves (or damper actuators for air-side units) and a return air sensor (see section 3.7.5.1), all of which are fitted to the unit. The room set point is adjusted at commissioning to the required setting via some control means on the controller (e.g. potentiometer, dip-switch etc.) and the controller will then select cooling, heating or dead band (i.e. neither cooling nor heating) as appropriate.

3.7.2 Programmable controls/BMS

Building management system (BMS) outstation controllers can be fitted to fan coil units in the same way as a standalone controller. They will provide the same basic control function as a standalone controller but with the capabilities of BMS control, e.g. remote operation of unit on/off, set point adjustment, monitoring and trend logging of air temperatures, filter and fault conditions etc. Some BMS controllers have a pre-programmed suite of standard fan coil unit strategies to choose from, to suit the installation. Freely programmable BMS controllers are also available so a dedicated control strategy can be written to incorporate any special site requirements. This is normally done by a controls specialist software engineer.

BMS systems now utilise a number of common communications protocol such as LonWorks and BacNet, enabling controls equipment from different manufacturers to work with each other. Some control features may be lost so mixing of different manufacturers' controls should be assessed carefully before deciding to implement such a proposal.

3.7.3 Water-side control

3.7.3.1 Considerations

Section 2.2 provides information and describes water-side control for fan coil units. Table 3.1 lists some advantages and disadvantages of fan coil units using water-side control as the means of control.

Section 2.9.1.1 provides a description of water-side control valves used with water-side control fan coil units. Tables 3.2 and 3.3 list some advantages and disadvantages of using 2-port and 4-port valves.

There is no discernable difference between 2- and 4-port valves with regards to the control function of the fan coil unit. All considerations are with respect to the pipework installation. Both 2- and 4-port valve systems need balancing valves for each branch leg.

Table 3.1 Evaluation of water-side control of fan coil units

Advantages	Disadvantages
Can make significant energy savings if used with 2-port valves and variable speed pumps	Slightly higher commissioning costs as water valves and systems generally need more commissioning time
For the same output water-side fan coil units are typically smaller than air-side fan coil units as energy loss between the coils in air-side fan coil units reduces their output	Water valves need maintenance as they can stick or block-up, some controllers have valve exercising features to prevent sticking during periods of inactivity
Water-side control is more familiar to designers and contractors than air-side (approx. 75% of UK market	Cleanliness of hydronic systems is more critical for water-side than for air-side units; filters/strainers needed

Table 3.2 Evaluation of 2-port valves with water-side control of fan coil units

Advantages	Disadvantages
Variable flow rate, so can use variable speed pumps to make significant energy reductions	Balancing of 2-port systems potentially more difficult as it is a dynamic system with more than one variable
In systems with several zones, water flow rate can vary around the whole system as some valves shut down. This 'diversity' has the potential for using smaller pumps and pipe sizes in main pipework	Needs more complicated differential pressure control valves to adjust water pressures as some zones shut down
Potential for lower return water temperatures on part load, good for condensing boilers	Fan coil units at the end of a branch leg cannot always react quickly to a sudden load

Table 3.3 Evaluation of 4-port valves with water-side control of fan coil units

Advantages	Disadvantages
Has a by-pass built into the valve so whatever the valve does the pump sees the same pressure so easy to design circuits	Constant volume circuit so always needs 100% of pump design power
Perceived easier to commission and demonstrate whether installation is to design performance	Uses more pump energy with significant additional life cycle costs for the operator
Normal practice in UK, where there is more familiarity with 4-port than 2-port design	

3.7.3.2 2-port control valves

A 2-port control valve controls by directly throttling the flow of water through the fan coil unit branch circuit. This is known as a variable volume circuit, see Figure 3.7. A regulating valve can also be fitted in the circuit to set the correct flow of water at commissioning.

For a cooling coil the 2-port control valve can be placed either in the flow or the return. For a heating coil it is preferable to position the 2-port control valve in the return from the coil as shown in Figure 3.7. This is because the higher vapour pressure, due to the lower LPHW temperatures in this part of the circuit, provides less risk of cavitation within the valve when the valve seat opening is small.

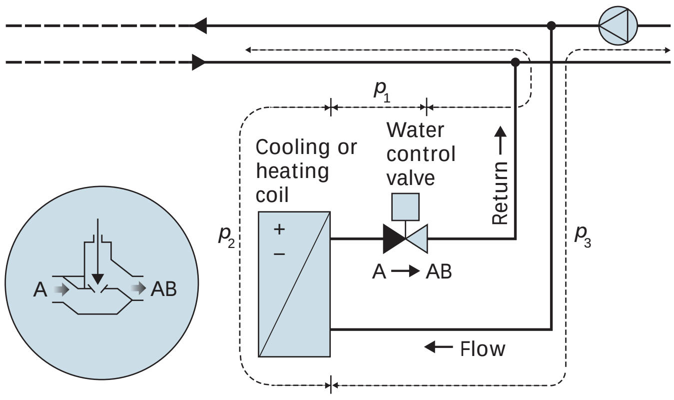


Figure 3.7 2-port water control valve

When a number of fan coil units are fitted with 2-port valves the setting of the associated regulating valves provides a system that runs perfectly at full design load only. Most of the time, however, there are different loads acting on the building and some 2-port valves will be opening while others will be closing at the same time. The system will then struggle to maintain stable control. A way of reducing the problems caused by the continually changing pressures is to install a differential pressure control valve (DPCV) across subcircuits serving groups of fan coil units. In recent years automatic balancing valves (ABVs) with pressure tappings for flow measurement have become available as an alternative to the regulating valve. These allow the 2-port control valve to maintain a high authority over a wide range of main system pressures and simplify the selection process and commissioning[32].

To size a 2-port valve properly it is necessary to know both the coil pressure drop in the fan coil unit and the pressure drop in the remainder of the branch circuit. A valve authority of between 0.23 and 0.3 is acceptable[33] and assuming DPVCs are fitted the valve authority can be described by the following formula:

$$\text{VA} = \frac{p_1}{p_1 + p_2 + p_3}$$

where VA is the valve authority, p_1 is the pressure drop across the fully open valve for a particular K_{vs} value (Pa), p_2 is the pressure drop across the coil within the fan coil unit (Pa) and p_3 is the pressure drop in the remainder of the branch circuit with the valve open (Pa).

Note: p_1, p_2 and p_3 must be in the same pressure units, i.e. either kPa or bar.

K_{vs} is defined as the flow at 20 °C in m^3/h to produce a pressure drop of 1 bar when the valve is fully open. Also:

$$K_{vs} = C_{vs} \times 0.865$$

where C_{vs} is the flow at 60 °F in US gallons per minute to produce a pressure drop of 1 lbf/in^2.

Clearly it is necessary to have information about the branch circuit components, and the correct procedure for 2-port valve sizing is for the fan coil unit manufacturer to supply the system designer with the FCU coil pressure drops at the design water flow rates. The system designer, who will know the pressure drop in the remainder of the branch circuit, then calculates the control valve K_{vs} from the above formula and supplies this to the fan coil unit manufacturer. This is not something the fan coil unit manufacturer can do in isolation, as in the case with 3- or 4-port valves.

Further design information for 2-port control valve systems and variable speed pumping is available in CIBSE Guide H: *Building control systems*[31], BSRIA AG16/02: *Variable-flow water systems*[33], BSRIA AG14/99: *Variable speed pumping in heating and cooling circuits*[34] and CIBSE KS7: *Variable flow pipework systems*[35].

3.7.3.3 3-port control valve with DRV

3-port valves with a double regulating valve (DRV) in the bypass, such as used on air handling units or duct mounted coils, are rarely used with fan coil units and they have largely been superseded by 4-port valves.

3.7.3.4 4-port control valves

4-port, 3-way, mixing control valves are used on the majority of fan coil units in the UK with separate control valves on the cooling and heating coils. Strictly speaking the diverter valve is being used in a mixing application and Figure 3.8 shows the arrangement known as a constant volume circuit. The control valve opens to allow mixing as passes through the coil and less through the by-pass (B) until maximum coil output is reached with all the flow then diverted through the coil. The opposite action will reduce output until all the flow is diverted through the by-pass and the coil output is zero.

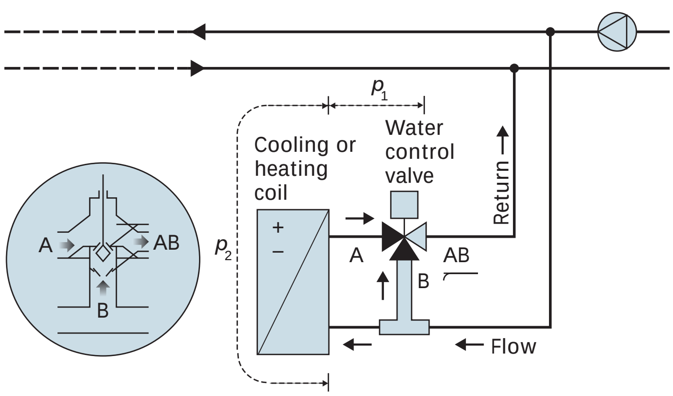


Figure 3.8 4-port, 3-way water control valve

Either the fan coil unit manufacturer or the system designer can calculate the K_{vs} (see section 3.7.3.2) of the control valve using the coil pressure drop, at the design water flow rate, and referring to the following formula:

$$\text{VA} = \frac{p_1}{p_1 + p_2}$$

where VA is the valve authority (to be between 0.4 and 0.6), p_1 is the pressure drop across the fully open valve for a particular K_{vs} value (Pa), p_2 is the pressure drop across the coil within the fan coil unit (Pa).

Note: p_1 and p_2 must be in the same pressure units, i.e. either kPa or bar.

3.7.4 Air-side control

3.7.4.1 Considerations

Section 2.3 provides information and describes air-side control for fan coil units. Table 3.4 lists some advantages and disadvantages of fan coil units using air-side control.

Table 3.4 Evaluation of air-side control of fan coil units

Advantages	Disadvantages
Slightly lower commissioning costs as damper actuators are quicker to commission than water valves	Energy wasted within unit by the inevitable pick-up, or crossover, of heating and cooling between coils both operating at full duty.
Potentially smaller pumps with reduced capital costs and pump energy as fan coil unit hydraulic pressure drops are lower without water control valves	Difficult damper-seal design problem for FCU manufacturers to overcome in order to minimise this crossover.
No awkward drain tray extensions outside of the casing with some types	Typically higher capital cost than an equivalent water-side unit because of sophistication of damper system and larger size
Output control more responsive to changeover between heating and cooling	Air-side control less familiar to designers and contractors than water-side
	Air resistance can vary as dampers open and close and can lead to noise variation problems

3.7.4.2 Pipework system

The design of the branch pipework system is simplified for an air-side fan coil unit installation as there are no water control valves and the heating and cooling coils simply operate at full flow rate. Fewer commissioning sets are needed, especially if identical fan coil units are on the same pipework branch. Pump pressures will remain constant as control of the heating and cooling output is achieved via dampers opening or closing air paths within the fan coil unit, rather than by controlling water flow.

Zone valves may be required in control zone heating circuits serving several units to turn off water flow to the heating coils of these units as a means of avoiding energy pick-up, or crossover, when the space no longer requires heating.

3.7.5 Control considerations

See also CIBSE Guide H: *Building control systems*[31].

3.7.5.1 Air sensor location

If a return air sensor is fitted to the inlet of the fan coil unit it needs to be sensing air that is representative of the room air temperature or it will not control the room to the required temperature. A return air sensor on a ceiling void mounted fan coil unit may pick up temperatures in the void that are unrelated to the room air temperature if care is not taken with the location of return air ceiling grilles and fresh air ducts placed near to the FCU inlet. An alternative would be have the return air sensor in the return air ceiling grille which can then be positioned further from the fan coil unit to improve the acoustic design of the installation (see section 3.8.3). The control system could be further enhanced by having a remote temperature sensor within the room (e.g. on a wall), together with a set point adjuster and fan speed control for operation by the end user.

Room temperature sensing is preferred where automatic fan speed control is used as return air sensors will not give a reliable measure of room temperature when the fans are turned off. Room temperature sensing also allows the fans to be turned off if the room temperature is near to the set point, thereby saving fan energy.

3.7.5.2 Simultaneous heating and cooling

Consideration should be given to avoiding conflict between heating and cooling to avoid unnecessary energy loss, particularly where a separate perimeter heating system is provided. One possible approach is to control the heating and cooling in sequence from a common temperature sensor, while ensuring that there is an adequate dead band (i.e. no control valve overlap) between heating and cooling. Most controllers have the facility to adjust the dead band from 1 K (‘tight’ control but less energy efficient) to, say, 4 K (‘coarse’ control but more energy efficient).

3.7.5.3 Fresh air AHU

The fresh air AHU is sized to meet the fresh air requirements of the occupants. It will have ‘off-coil’ control of its heating and cooling coils and can include humidification, if required. The ventilation air will normally be supplied at a neutral temperature to minimise loads on the fan coil units. This temperature may be scheduled down against outside air temperatures to provide an element of free cooling. The fresh air AHU can be held off during unoccupied early morning preheat while the fan coil units are operating on full recirculation.

3.7.5.4 Master/slave control

Care should be taken to avoid conflict between fan coil units located within the same space but with separate control systems. This can be overcome by operating several fan coil units under a master/slave system from a master controller with air sensor.

3.7.5.5 Dehumidification effects

In winter it may be necessary to increase the humidification of the fresh air supplied to the fan coil units when relative humidity levels become low in the room. Fan coil units dehumidify air and energy that is put into the AHU for humidification of the fresh air could be wasted. These losses can be reduced by running the chilled water system at elevated temperatures, which also improves the efficiency of the chiller plant and provides increased opportunities for ‘free’ cooling.

3.7.6 Electric heating

Unless carefully controlled, electric heating in fan coil units can use significant amounts of energy and is therefore not the favoured choice as a heating medium. There is a clear disadvantage in terms of the CO_2 conversion factor in comparison to other heat sources, but electricity may be considered for heating provided that the Building Energy Rating (BER) remains below the Target Energy Rating (TER) in the Simplified Building Energy Model (SBEM)[2] calculation.

It may be appropriate when heating load requirements are low, or if used only during warm-up periods, or with very tight building specifications (see CIBSE TM29: *HVAC strategies for well insulated airtight buildings*[16]). Control of the electric heater battery can be on/off (if heat output is low), step control or proportional control. Low inertia elements can avoid the delay associated with rod type elements.

Air-side fan coil units with cooling only water coils can incorporate electric heating as the heat source. This could avoid the problem of heat pick-up (crossover) between the heating and cooling coil associated with this type of fan coil unit design, but should only be used if the BER remains below the TER, as above.

3.8 Acoustics

This section provides acoustic design information specific to a fan coil unit installation. Further information on acoustics can be found in chapter 5 of CIBSE Guide B[36].

3.8.1 Noise criteria

The ASHRAE recommended RCII noise criterion[37] is derived from actual measurements in air conditioned offices with good acoustics. There is an emphasis on noise quality with a low frequency bias. It is cumbersome for quick site calculations however.

As an acoustic criterion, noise rating (NR) has been used in the UK for many years. It is not as stringent as RCII at low frequencies but fan coil units are generally not a problem at these frequencies, having noise levels predominantly between 250 Hz and 1000 Hz.

As an alternative noise criterion, dBA is very simple and has the advantage of being a direct reading on most sound meters. It can provide the same reading for a wide range of noise spectra, however, and a reduction in dBA level will not necessarily lead to more acceptable acoustics.

All three of the above noise criteria give very similar results at octave band centre frequencies between 125 Hz and 1000 Hz, so NR could remain the preferred criteria for fan coil unit installations. CIBSE Guide B[36] chapter 5 makes reference to NR being phased out, but this suggestion is aimed at larger building services installations with dominant low frequency noise and plantroom breakout.

Chapter 1 of CIBSE Guide A: *Environmental design*[27] lists recommended NR levels in various spaces, e.g. NR35 for open plan offices and NR30 for cellular offices as design noise levels. Notwithstanding this, a significant number of fan coil unit installation noise specifications state NR38 for open plan offices and NR35 for cellular offices.

3.8.2 Room effects

NR levels can be calculated for any particular space from the sound power levels (L_w) of the fan coil unit(s) at the octave band centre frequencies from 63 Hz to 8000 Hz. For ceiling void installations it is necessary to have both the 'discharge' and the 'combined inlet/casing' sound power levels of the fan coil unit(s) operating at various fan speeds and against a range of static air resistances across the unit. For cased units the 'total' sound power level is required with the unit operating at various fan speeds.

A common method used for calculating NR levels in ceiling void installations is the room correction approach, see Figure 3.9.

For the noise from the discharge of the fan coil unit a room correction factor (RCF) is applied for each of the 'discharge' octave band sound power levels. For the combined inlet/casing noise a RCF plus a 'ceiling sound reduction index' (SRI) is applied for each of the 'combined inlet/casing' octave band sound power levels. The two sound pressure levels so derived for discharge and combined inlet/casing noise are then added logarithmically to give sound pressure levels in the room for each octave band and these are plotted on a nest of NR curves. Room size and acoustic characteristics are implicit in the room correction factors and ceiling performance is included in the ceiling SRI. The room correction approach is moderately accurate albeit it calculates noise levels only for a specific size of room and makes many assumptions.

A more accurate approach for ceiling void installations is the advanced methodology as illustrated in Figure 3.10.

This method looks at all the possible sound paths in a fan coil unit ceiling void installation for both the direct and reverberant sound fields and calculates their total effect from first principles. The sound pressure levels so derived are then plotted on a nest of NR curves to produce a single figure NR level. The method distinguishes between the separate sound power levels from the discharge and the combined inlet/casing of the fan coil unit. It allows for the

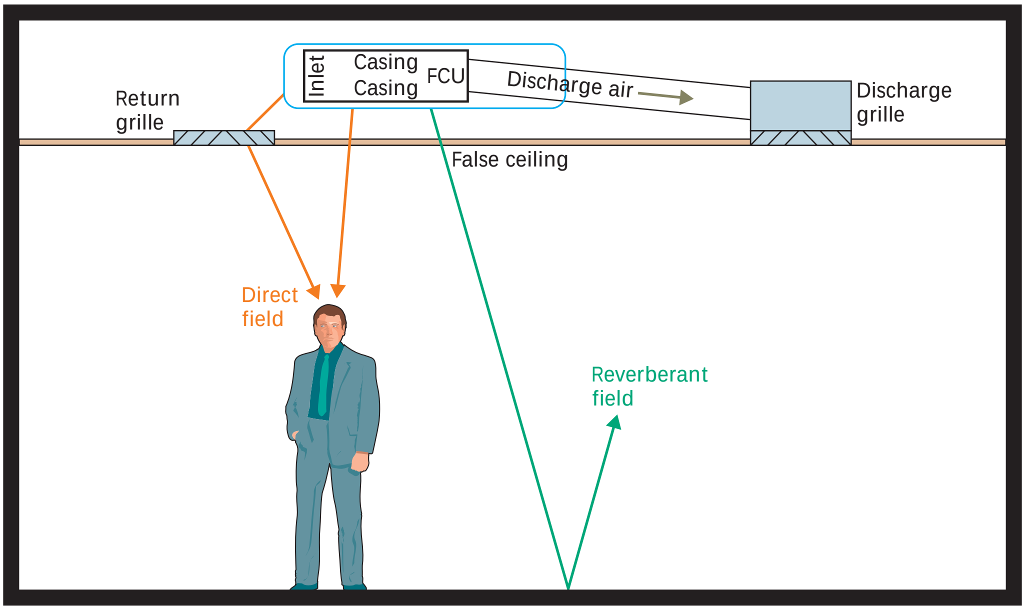


Figure 3.9 Room correction approach for ceiling void installations (not to scale)

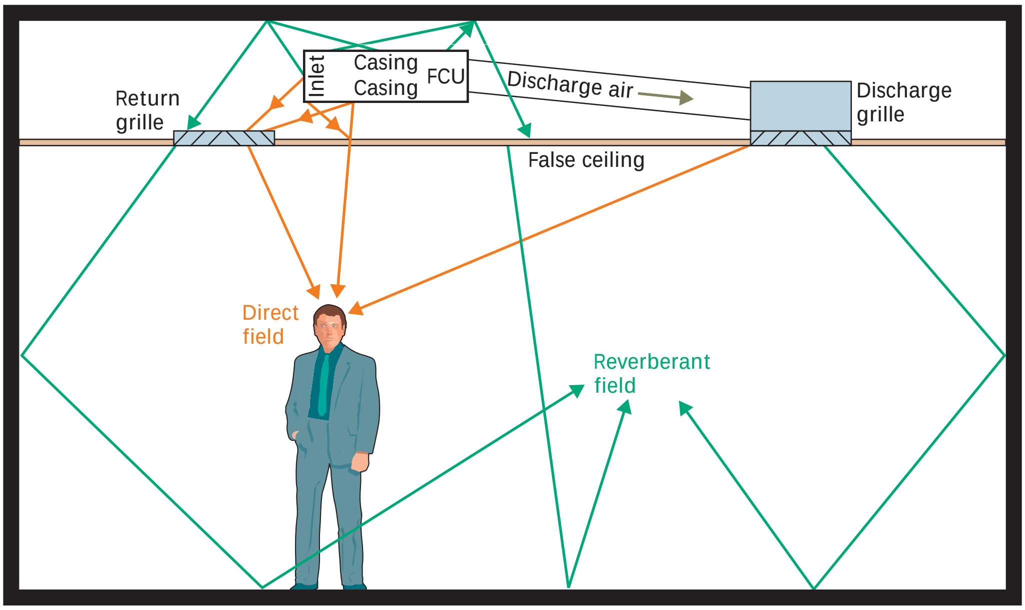


Figure 3.10 Advanced method for assessing noise in ceiling void installations (not to scale)

size and position of ceiling grilles, different room sizes, different numbers of fan coil units, and the attenuation of the discharge ducting, discharge grill plenum boxes and false ceiling. It is a complicated method with a higher degree of accuracy than the room correction approach and calculation spreadsheets are produced by acoustic consultants and some manufacturers.

Chapter 5 of CIBSE Guide B[36] refers to the empirical Schultz formula to derive sound pressure levels from sound power levels and this has been found to give good results for office type environments:

$$L_p = L_w - 5 \log V - 3 \log f - 10 \log r + 12$$

where L_p is the room sound pressure level (dB re. 20 μPa), L_w is the sound power of the source (dB re. 10^{-12} W), V is the room volume (m^3), f is the octave band centre frequency (Hz) and r is the distance from the source to listener's location (m).

A classical formula, derived from first principles, can also be used for this purpose but is more suited for higher spaces:

$$L_p = L_w + 10 \log \left(\frac{Q}{4 \pi r^2} + \frac{4}{R} \right)$$

where L_p is the room sound pressure level (dB re. 20 μPa), L_w is the sound power of the source (dB re. 10^{-12} W), Q is the directivity factor (2 for ceiling, 4 for two boundaries, 8 for a corner), r is the distance from the source to listener's location (m) and R is the room constant (high value for a 'dead' room, low value for a 'live' room).

3.8.3 Design principles

Generally, the higher the air resistance, the higher the noise level generated by the fans. There are several acoustic design principles that should be taken into account when designing a fan coil unit installation:

— do not expect very low NR levels from a fan coil unit installation; levels lower than NR30 are generally unrealistic unless special measures are taken

— noise from the inlet of a fan coil unit is normally more of an issue for ceiling void units, so these units are generally of the 'draw-through' type, see Figure 2.1

— noise from the discharge of a fan coil unit is normally more of an issue for cased, floor standing units so these units are generally of the 'blow-through' type, see Figure 3.6

— use the maximum number of discharge outlets possible to reduce air resistance over the unit and thereby reduce fan noise

— specify a good acoustic grade for the false ceiling, see section 5.8

— with a ceiling void installation beware of the poorly placed return grille, positioned directly under or near the fan coil unit inlet and therefore close to occupants, see Figure 3.11, as this can increase overall noise levels by 3–4 dB, see Figure 3.12.

— to reduce air resistance over the fan coil unit, specify that filters be cleaned or replaced before air volume flow rate and acoustic checks are carried

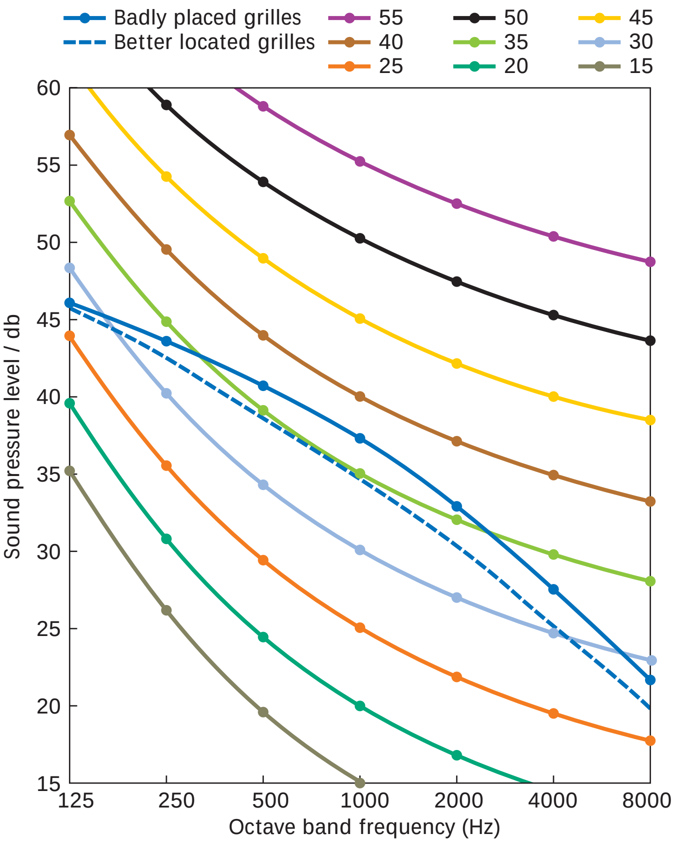


Figure 3.12 NR curves showing the effect of better located return grilles

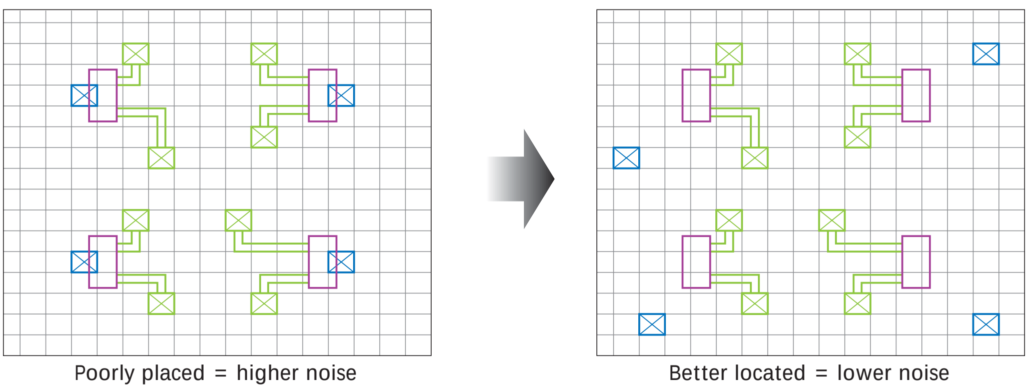


Figure 3.11 Poorly and better located return grilles

out on site (filters often get dirty with builders' dust during a fit-out, especially if the FCUs are used for drying-out the building)

— for ceiling void mounted units all rooms that the units serve should have an adequate return air path back to the units to minimise resistance across them

— beware of fresh air ducted directly to the inlet of a fan coil unit with no air break as this can impose a significant resistance across some units

— beware of tight duct bends, flexible corrugated ducting and reducing duct diameters all of which increase resistance across the fan coil unit

— minimise duct leakage, see HVCA DW144: *Specification for sheet metal ductwork*(38), as air leaks will require higher fan speeds to produce the specified duty

— avoid locating return air grilles in adjacent rooms too close to one another as they may provide a path for 'cross-talk' via the ceiling void*.

4 Selection of fan coil units

4.1 Introduction

This chapter details the way in which fan coil units are selected to meet the criteria required for the customer's enquiry or specification.

Catalogue selections with tabular data and graphical nomograms can be used but this is a slow process and the number of variables is limited. The selection of fan coil units is usually done by the supplier/manufacturer using proprietary, or in-house developed, computer software and the results are then presented to the prospective customer in the form of a quotation with technical schedule. Typically the software will contain a database covering all of the units available from a particular supplier and a selection program using sophisticated rule based algorithms. The database will contain the air volume, acoustic, thermal, hydraulic and electrical performance for each unit, based on laboratory tests, see section 8.

To carry out a selection the customer's performance specification for noise, thermal performance, off-coil temperatures etc. is entered into the selection software, and the computer compares this against the performance of the range of units being considered. From the database, all units meeting and or exceeding the specified performance criteria will be displayed as valid selections. The estimator or person undertaking the selection process will choose the most appropriate unit from the list of valid selections. Often this is the smallest or most economical fan coil unit but this is not always the case.

* Using full height walls between cellular rooms is often impractical due to penetrations required for services. One solution is to ensure adequate separation, e.g. 4 m between return air grilles serving different cellular spaces, to allow speech from one room to be absorbed in the ceiling void before it can enter the adjacent room. If this is not possible it may be necessary to use cross-talk silencers with a low air resistance, e.g. 5 Pa maximum, on the return air grilles.

The selection software will generate a technical schedule, which provides important information for the designer. The technical schedule will include:

— air volume flow rate for the specified air pressure drop across the fan coil unit

— guidance NR noise levels for the manufacturer's quoted room

— total and sensible cooling outputs

— heating output

— dry bulb and wet bulb temperatures for the entering air stream and leaving air stream

— water flow and return temperatures

— water volume flow rates for both cooling and heating coils

— water hydraulic pressure drops across heating and cooling coils

— condensate water flow rate

— electrical supply, power consumption and current loading

— fan speed settings (with selection generally made on a medium speed)

Figure 4.1 shows a typical technical schedule for a fan coil unit quotation, generated using fan coil unit selection software(39).

4.2 Type of unit

The fan coil unit estimator will need the following basic information from the specifier/customer regarding the type of unit, before they can start the selection:

(*a*) The basic form of the unit, which may be:

 — concealed horizontal chassis unit for ceiling void or under floor installations

 — visible cased horizontal unit for mounting on an exposed ceiling

 — concealed vertical chassis unit for fitting in a compartment or behind perimeter casing

 — visible cased vertical unit for floor standing against a wall or mounting up on a wall

 — cassette type fan coil unit.

(*b*) The basic form of output control:

 — water-side control, where the heating or cooling output is regulated by water valves

 — air-side control, where the heating or cooling output is controlled by the opening or closing of air dampers across the coils within the fan coil unit.

Few manufacturers can offer all of the above variants; many specialise in particular forms.

4.3 Performance parameters

The primary performance criterion for a fan coil unit is to provide the maximum possible cooling or heating output

Cooling Selection Data						Heating Selection Data				
Air on db °C	**Air on wb °C**	**Medium**		**Liquid flow °C**	**Liquid return °C**	**Air on db °C**	**Medium**		**Liquid flow °C**	**Liquid return °C**
23.0	16.4	Chilled Water	N/A	6.0	12.0	21.0	Hot Water	N/A	82.0	71.0

Unit Data		Air Data			Cooling Data						Heating Data				Extra Data	
Unit reference	**Description code**	**Noise rating NR**	**Air details l/s**	**Pa**	**Sens duty kW**	**Total duty kW**	**Air off db °C**	**Air off wb °C**	**Liquid flow rate l/s**	**Hyd res kPa**	**Heat duty kW**	**Air off db °C**	**Liquid flow rate l/s**	**Hyd res kPa**	**Speed setting**	**Hnd.**
FCU-B1-1	K3H1(H3) - 140v	34	203	30	2.52	3.00	12.5	11.6	0.119	2.51	1.50	27.2	0.018	0.20	Low	Right
FCU-B1-2	K3H1(H3) - 140v	34	203	30	2.52	3.00	12.5	11.6	0.119	2.51	1.50	27.2	0.018	0.20	Low	Right
FCU-B1-3	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Right
FCU-B1-4	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Left
FCU-B1-5	K3H1(H3) - 160v	34	312	30	4.10	5.00	11.9	11.1	0.198	5.37	0.50	22.3	0.006	0.03	Medium	Left
FCU-B1-6	K3H0(H3) - 140v	35	158	30	2.05	2.50	12.0	11.2	0.099	1.39	-	-	-	-	Low	Left
FCU-B1-7	K3H1(H3) - 160v	34	312	30	4.10	5.00	11.9	11.1	0.198	5.37	1.50	25.0	0.018	0.21	Medium	Left
FCU-B1-8	K3H1(H3) - 140v	35	158	30	2.05	2.50	12.0	11.2	0.099	1.39	0.50	23.6	0.006	0.03	Low	Left
FCU-B1-9	K3H0(H3) - 170v	36	478	30	6.48	8.00	11.6	10.9	0.317	11.12	-	-	-	-	High	Right
FCU-B1-10	K3H0(H3) - 160v	35	423	30	5.39	6.50	12.2	11.3	0.258	7.60	-	-	-	-	Medium	Left
FCU-B1-11	K3H0(H3) - 160v	35	423	30	5.39	6.50	12.2	11.3	0.258	7.60	-	-	-	-	Medium	Right
FCU-B1-12	K3H1(H3) - 160v	34	312	30	3.83	4.50	12.7	11.7	0.179	4.43	1.50	25.0	0.018	0.21	Medium	Left
FCU-B1-13	K3H1(H3) - 160v	34	312	30	3.83	4.50	12.7	11.7	0.179	4.43	1.50	25.0	0.018	0.21	Medium	Left
FCU-B1-14	K3H1(H3) - 160v	34	312	30	3.83	4.50	12.7	11.7	0.179	4.43	1.50	25.0	0.018	0.21	Medium	Left
FCU-B1-15	K3H1(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	1.50	26.4	0.018	0.20	Medium	Right
FCU-B1-16	K3H1(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	1.50	26.4	0.018	0.20	Medium	Right
FCU-B1-17	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Right
FCU-B1-18	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Right
FCU-B1-19	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Right
FCU-B1-20	K3H0(H3) - 150v	35	233	30	2.94	3.50	12.4	11.5	0.139	4.33	-	-	-	-	Medium	Right

Figure 4.1 Typical technical schedule for a fan coil unit quotation, generated using fan coil unit selection software[36]

whilst operating at or below the specified noise level. Secondary performance criteria include air volume flow rate for providing sufficient 'throw' from the diffusers.

The performance parameters required to carry out a selection to achieve these criteria are:

— thermal performance*
— entering air temperature*
— water flow and return temperatures*
— noise requirements*
— external air resistance*
— hydraulic coil resistance
— leaving air temperature

Note: asterisks denote the minimum required from the specifier/customer

4.3.1 Thermal performance

Thermal performance outputs are determined from the air conditioning design load calculations, see section 3. The cooling output, or cooling duty, should be expressed in kilowatts or watts as 'total' cooling output or more usually 'sensible' cooling output. Heating output, or heating duty, should be expressed in kilowatts or watts. Fan coil unit selection is usually prescribed by the cooling requirement as this is often the more difficult to fulfil. Most selections look to achieve the sensible cooling requirement and the heating output is then generally satisfied.

During the selection the heat 'pick-up' from the fan motor should be taken into account and selection software will calculate this as a loss in cooling mode or a gain in heating mode. A more subtle effect is whether the motor heat gain is at the on-air face of the cooling coil, as it would be with a 'blow-through' unit, or at the off-air face, as it would be with a 'draw-through' unit, and the effect this has on psychrometric gains.

Heating can also be achieved using electric heating elements. This is usually when heating loads are low and normally only to provide heating at start-up before internal loads take over when the space is occupied; see also section 3.7.6.

The air volume flow rate of the fan coil unit is generally determined by the thermal performance although the flow rate may be specified.

4.3.2 Entering air temperature

This is the temperature of the air when it comes into contact with either the cooling or heating coil within the fan coil unit. For cooling this needs to be expressed in °C dry-bulb (db) and °C wet-bulb (wb) (or %RH). For heating it needs only to be expressed in °C dry-bulb (db) as there is no moisture phase change. Choosing the correct 'air on' temperature can have a significant effect on the thermal output of the unit. For a typical UK fan coil installation a change of entering air conditions from 23 °C db/50%RH to 24 °C db/50%RH can increase the sensible cooling by approximately 10% with no additional capital outlay.

For many selections a predetermined 'air on' dry bulb and wet bulb temperature is used and 23 °C db/16.4 °C wb (50%RH) is often chosen for UK installations, although there are indications that 24 °C db is more realistic. A rule of thumb for ceiling void installations is to add 1.5 °C to the design room air temperature. For exactness, however, the dry bulb and wet bulb temperatures of the air entering the fan coil unit should be calculated(22).

For a ceiling void installation in cooling mode the following air temperatures need to be considered:

— the return air from the room, say 23 °C
— heat pick up from high level lighting and within the ceiling void, say 1.5 °C
— the primary fresh air from the central station AHU controlled at a particular air-off temperature.

The volume ratio of return air from the room to primary fresh air is decided by the cooling load and the fresh air requirements of the occupants respectively. A mass ratio calculation of these two air streams will give the entering air temperature to the fan coil unit, i.e. the coil air-on temperature. The moisture content of the mixed air stream also needs to be calculated to determine the wet bulb temperature. Most selection software will have the capability to calculate the 'mixed' condition, providing that the volume proportions, temperatures and psychrometrics of the two air stream components are known. On the psychrometric chart a typical 'wet-coil' ceiling void fan coil unit installation might appear as shown in Figure 4.2 for the summer cooling cycle.

Explanation of Figure 4.2:

— O = outdoor air temperature (design day: 28 °C db at 50%RH)
— O′ = fresh air supply from AHU to inlet of FCU (the AHU could do more or less cooling than indicated in this example)
— R = return air from room (23 °C db at 50%RH)
— R′ = return air entering inlet of FCU (dew-point = 12.2 °C)
— M = mixed air condition (return air plus fresh air) (dew-point = 13.2 °C)
— W = FCU off-coil condition (dew-point = 11.2 °C)
— S = supply air diffuser condition (including heat pick-up from duct).

For cased or vertical fan coil units drawing all of their air from the conditioned space, the entering air condition will more closely reflect that of the room itself and this condition can be calculated and used for the selection. Fresh air in these situations is fed into the room elsewhere and is mixed with the room air before entering the fan coil unit, see Figure 3.6.

For ceiling void and cased fan coil units in heating mode the same logic applies as for cooling except in reverse and the calculation is simpler as latent effects and moisture content is not considered. A rule of thumb is to subtract 1.5 °C from the design room air temperature and a dry bulb temperature of 21 °C is often chosen for UK installations.

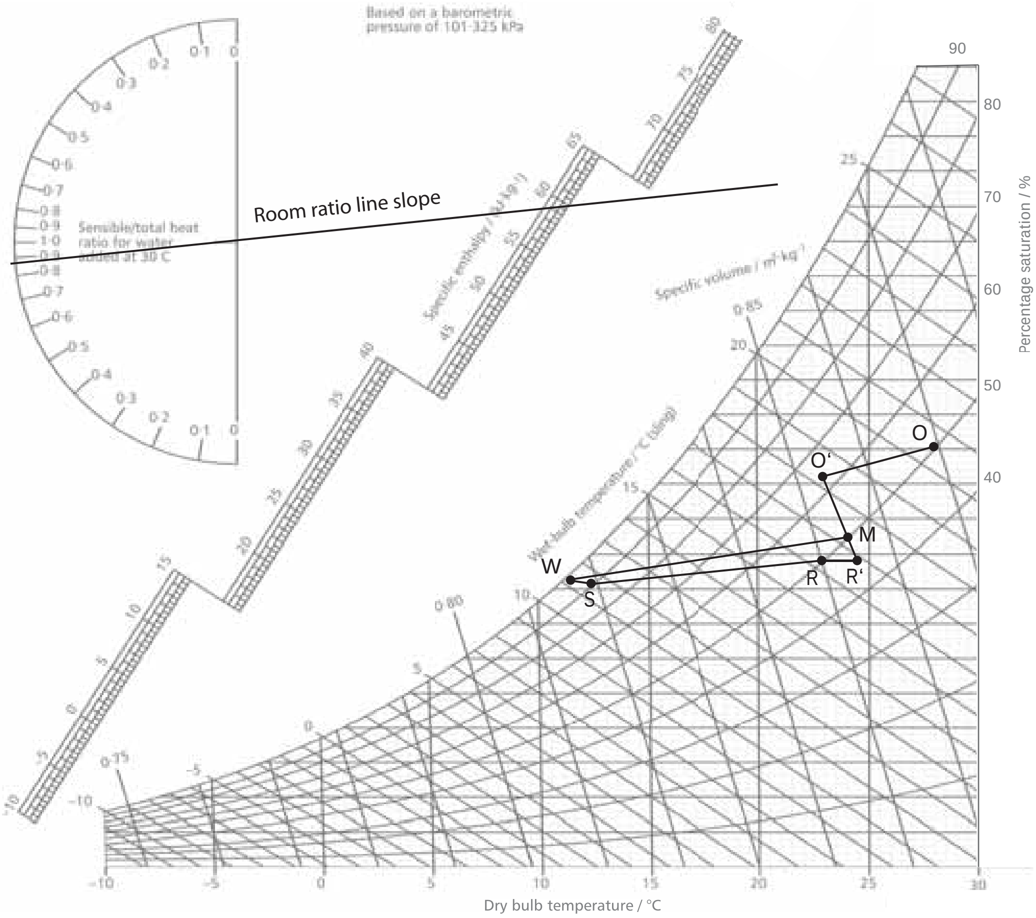


Figure 4.2 Extract from psychrometric chart for fan coil unit; summer cooling cycle

4.3.3 Water flow and return temperatures

The majority of fan coil unit installations use a constant flow temperature for cooling and heating with a specified design return temperature for the design day load condition.

4.3.3.1 Chilled water

Flow temperatures for chilled water are a function of the chiller system design, and may be influenced by the requirement of other building services plant on the same site. Common 'wet-coil' chilled water temperatures are 6 °C flow with 12 °C return, although flow/return temperatures of 5 °C/11 °C and 7 °C/13 °C are also encountered. Certain designs will use secondary chiller circuitry with higher flow/return temperatures of, say, 12 °C/16 °C and this generally results in a 'dry-coil' when used in UK environments*. Using these higher water temperatures may create savings elsewhere in the system, such as smaller chillers, but larger fan coil units will be required for the same thermal output, which will increase the cost of the fan coil unit installation.

4.3.3.2 Low pressure hot water

Flow temperatures for LPHW are a function of the boiler plant and heating system. Common flow and return water temperatures for non-condensing boilers are 82 °C/71 °C and 80 °C/70 °C. Condensing boilers function more efficiently at lower return temperatures and temperature differentials are greater to ensure heat emitter outputs, i.e. 60 °C/40 °C or 55 °C/35 °C.

Compensating control circuits with non-condensing boilers can also produce lower flow temperatures although the design day flow water flow temperatures will still be high.

4.3.3.3 Medium/high pressure hot water and steam

Occasionally there may be a requirement for medium pressure hot water (100–120 °C), high pressure hot water (above 120 °C) or steam as the heating medium, see also section 2.6.1.

4.3.3.4 Glycol content

If antifreeze additives are to be included the glycol type and percentage by weight need to be supplied as this will affect the thermal performance.

4.3.4 Noise requirements

Noise is a particularly sensitive issue in the performance of fan coil units and should be specified in one of the following ways:

— *Sound pressure level*: it is usual to specify a single figure sound pressure noise criterion, such as the NR level in the UK. Maximum sound pressure

* Theoretically for a 'dry-coil' system the water flow temperature should be no lower than about 1 °C below the on-coil dew point temperature. In Figure 4.2 the mixed air condition onto the coil (M) has a dew-point of 13.2 °C so a water flow temperature of, say, 12 °C could be used. To operate a 'dry-coil' system during cooling the fresh air AHU will have an off-coil temperature in the order of 12 °C, or sufficiently low to handle all the latent gains, both fresh air and internal.

levels can also be specified for a number of octave band centre frequencies, say, 63 Hz to 8000 Hz within the room. Section 3.8.1 provides information on noise criteria and sound levels used with fan coil unit installations.

— *Sound power level*: an alternative to specifying the resulting sound pressure level in the space is to specify the maximum sound power level (L_w) of the fan coil unit at a number of octave band centre frequencies, i.e. 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz. These will have been calculated by the designer to achieve an acceptable overall sound pressure level in the space. Two sets of sound power levels should be supplied, one for the fan coil unit discharge and the other for the combined inlet and casing radiated sound. Reputable suppliers will have these sound power levels for their equipment at all fan speeds, measured against a range of external resistances.

4.3.5 External air resistance

External air resistance is measured across the fan coil unit as a static pressure drop and the higher this is the more it will affect the air volume flow rate of the fans and create possible additional noise. Ceiling mounted fan coil units and some vertical chassis units will have ductwork attached to them.

To allow for ductwork resistance and for the filter getting dirty 30 Pa external air resistance is often specified, although air resistance across large fan coil units can be higher than this. In practice it is common to find that the external air resistance across a fan coil unit is significantly different from 30 Pa therefore ductwork resistances should be carefully calculated by the designer before being specified.

Cased units do not have additional ductwork and external resistance is normally considered to be 0 Pa.

4.3.6 Hydraulic coil resistance

Limits for the hydraulic pressure drop across water coils are generally given to ensure pump pressures do not become too high. A rule of thumb is approximately 2kPa per kW of sensible cooling output.

4.3.7 Leaving air temperature

This is the temperature of the air as it leaves the fan coil unit. For cooling and heating it is expressed in °C dry bulb (db). For UK installations a leaving air temperature of 12 °C db from the fan coil unit is often chosen but other temperatures can be specified. Ideally heat pick-up from the supply ductwork system should also be considered. As guidance a lower leaving air temperature is generally associated with an increase in thermal output of the unit and a higher leaving air temperature with a decrease in thermal output.

For a cooling application with ceiling void mounted fan coil units, chapter 2 of CIBSE Guide B[1] recommends that the cooling temperature differential between the room air temperature and the discharge air temperature from the discharge ceiling diffuser be in the range 8–12 K. This helps promote Coanda effect across the ceiling, minimising ‘dumping’ of cold air from the supply diffusers.

Another consideration is that with air supply temperatures much below 11 °C there is the distinct possibility of moisture condensing in the supply duct and on the discharge diffuser, with resultant damage to the building and fittings.

For heating mode the temperature differential between the room air temperature and the discharge air temperature should be 10 to 15K to avoid warm air collecting at the ceiling and not diffusing into the room.

4.4 Commercial considerations

4.4.1 Capital costs

Capital cost plays an important part in the supply of building services equipment and fan coil unit projects are no exception. There is a wide range of products within the fan coil unit market, from the large volume budget sector, where profit margins are usually low, to the high quality niche market for specialised projects. British fan coil unit manufacturers are known for their flexible approach, designing bespoke units for the UK building services industry, which tends to adopt a more customised design approach than that practiced by its European neighbours.

4.4.2 Life cycle costing

Life cycle costs should be used to show that procuring more expensive, but higher quality equipment, costs less over the lifetime of the installation than purchasing cheaper utility plant. Life cycle costing looks at the balance between initial and future expenditures of, say, a fan coil unit installation. The concept is that spending a little extra initially may reduce expenditure in the future. Additional benefits flow from increased initial expenditure in terms of improved quality, less disruption due to breakdowns, etc. Flanagan[40] states that:

> Clients are seeking appraisal techniques which can show the balance between future revenue expenditure and initial capital investment. The thrust is coming mainly from public-sector clients and owner occupiers, but speculative developers are also showing an increasing interest in achieving an efficient balance between current and future expenditures.

A frequent criticism of life cycle costing is that developers will not be interested because running costs are the responsibility of the tenants. This idea is beginning to lose credence, however, although the relevance of life cycle costs is still more important to the owner-occupier because they have to pay for the total lifetime costs. See also CIBSE TM30: *Improved life cycle performance of mechanical ventilation systems*[41].

4.4.3 Caveats

Caveats are included in fan coil unit suppliers’ quotations to protect the interests of the supplier, although the purchaser should beware of misleading information that may hide the true performance of equipment. Examples of such caveats are:

— it is the responsibility of the designer to check that the cooling temperature differential between the room air temperature and the discharge air temperature is correct

— similarly, that the relative humidity of the supply air is acceptable

— certain water conditions and additives could have a detrimental effect on copper and brass components of a fan coil unit, i.e. stress corrosion cracking in brass, as a result of small levels of ammoniacal compounds, or brass dezincification through dissolved chlorides, low pH or other similar water conditions.

— descriptive detail as to how quoted NR levels have been calculated.

4.5 Specifications

4.5.1 Specification Expert

Specification Expert[42] (formerly known as the *National Engineering Specification* (NES)) is a specification writing tool based around the *Common Arrangement of Work Sections*[43] (CAWS). Each technical work section contains project description, workmanship and materials, and specific equipment clauses. The user selects from a substantial library of clauses. Specification formats can be arranged to suit the user.

Fan coil units are covered in work section U41 (Fan Coil Air Conditioning). Within this section are clauses for specifying the project, particular requirements for design, system description and controls, as well as standards for design and manufacture and component materials and construction. Schedules are included to assist the user with multiple units.

The work section also provides references for workmanship and materials elements associated with the fan coil unit installation, such as pipework, fittings, ductwork etc.

4.5.2 National Building Specification (NBS)

Within the *National Building Specification*[44] there are engineering services work sections dealing with all aspects of engineering services for the building industry. Of particular relevance for fan coil units is core work section U41 (Fan Coil Air Conditioning). This details a range of specification features such as design parameters, system description, control requirements, FCU construction, internal components, ductwork, etc.

Standards of compliance are included within the specification, e.g. FCU performance to BS 4856[45,46] or filters to BS EN 779[17]. Also included are cross references to other NBS work sections, such as copper pipes (Y10) and site commissioning (Y51).

4.5.3 Consultants' specifications

Whilst useful as a foundation document many designers will adapt one of the U41 specifications to their own requirements making it specific to their particular project. These specifications often contain more detail about fan coil unit construction, performance, controls, accessories, etc. They often include the design engineer's preferred supplier(s) of fan coil unit equipment, although the phrase 'or equivalent' can be inserted to give the contractor greater choice for procurement.

4.5.4 Manufacturers' catalogue specifications

Manufacturers will often include within their catalogue literature detailed specifications of their fan coil unit range. Whilst primarily a marketing tool to promote their own equipment, these catalogue specifications can be a useful source of information to the design engineer formulating his/her own fan coil unit specification.

5 Installation

5.1 Health and safety

Site health and safety is of vital importance and this section deals with the hazards that could be encountered during the installation of fan coil units.

All persons performing installation, maintenance or repair work on fan coil units must be fully trained and competent to carry out the necessary tasks. They must be familiar with the current legislation, including the Manual Handling Operations Regulations[47,478], and the Approved Codes of Practice published by the Health and Safety Commission. They must also carry an appropriate Construction Skills Certification Scheme (CSCS) card. If ceiling void mounted units are to be installed they should be trained for working at height in accordance with the Work at Height Regulations[49–52] and for using lifting equipment in accordance with the Lifting Operations and Lifting Equipment Regulations[53,54]. Designers and managers must be conversant with the Construction (Design and Management) Regulations[55,56] (CDM), relevant to the work in hand.

Reference should also be made to:

— CIBSE Commissioning Code A: *Air distribution systems*[57] (Appendix AA4: Health and safety arrangements)

— Construction (Health, Safety and Welfare) Regulations[58,59]

— Construction (Head Protection) Regulations[60,61]

— Construction (Lifting Operations) Regulations[62]

Before commencement of work, a risk assessment in accordance with the Management of Health and Safety at Work Regulations[63–65] must be carried out for the site work involved and any necessary training carried out in line with the Health and Safety (Training for Employment) Regulations[66,67].

Before installation the fan coil unit should be checked to ensure that it is suitable for:

— the electrical supply

— the environment in which it is to be used

— the water temperatures and hydraulic pressures for which it is to be used.

For a correct installation ensure that the fan coil unit:

— is site wired and electrically earthed in accordance with BS 7671[68] (the 'IEE Wiring Regulations'*) and any other local electrical regulations

— can be manually isolated from the mains electrical supply via a local isolator

— can be manually isolated from the water supply.

On completion of the work the interior of the fan coil unit should be left clean and free of debris, the filters should be left in a clean condition and all access panels correctly re-fastened.

5.2 Delivery and storage

5.2.1 Delivery

Fan coil units should be delivered suitably packaged and protected from building rubble, dust, dampness and extremes of cold and heat.

All deliveries should be signed for and upon receipt of the equipment a visual inspection should be made and any damage noted on the delivery form and the supplier informed. All claims for damage, or short delivery, should be advised to the supplier as soon as possible and confirmed in writing.

Equipment on pallets should be off-loaded from the delivery vehicle using a fork-lift vehicle or similar lifting plant. Loose units should be unloaded by hand. Take care when handling fan coil units to ensure that damage to coil pipe work connections, spigots, drain trays, etc. is avoided.

5.2.2 Storage

Should it be necessary to store fan coil units on site for any period of time prior to installation, they should be stored in a clean, dry, secure area. Inlet and discharge openings, pipe connections and filters should be sealed if not already. They should be inspected on a regular basis and packaging repaired if damaged. If access panels are removed for inspection purposes or to carry out work on site they should be refitted and made secure. Fan coil units should not be stored in areas where there is excessive vibration as this could damage fan motor bearings.

5.3 Fitting of units

Fan coil units should be installed in accordance with the manufacturer's instructions and with due care and attention to avoid damage. Before installing the units in position ensure that there is suitable access for connecting all services. There must also be adequate access to the units once they are installed for routine maintenance and the removal of access panels and internal components such as fans, filters, coils and drain trays. Establish the weight of each unit and, if the unit is to be suspended, make sure that ceilings, walls, floors and fixings will be adequate to support up to four times the weight of the unit.

Ceiling mounted fan coil units are often suspended from the soffit with M8 or M10 threaded rod although wire rope suspension systems can also be used or the unit attached directly to the soffit via its hanging brackets. Depending on the type of building structure there can be a number of ways of attaching the suspension system, such as drilled-in fixings, clamps and clips, wedge nuts, powder actuated fixings, wire rope loop etc.

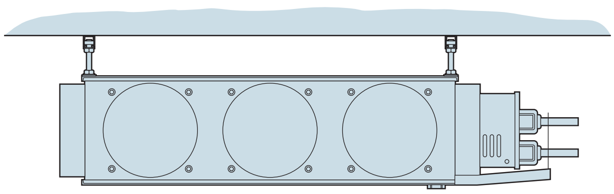
Suspension systems are described in detail in the following:

— BSRIA IEP 4/2004: *Supporting services from structure. Guidance for a defect-free interface*[69]

— BSRIA COP 22/2002: *Wire rope suspension systems*[70].

An example of a horizontal chassis fan coil unit mounted in the ceiling void is shown in Figure 5.1. Suspension is by means of M8 or M10 threaded hanging rods with attachment to the fan coil unit using 25 mm diameter form 'C' washers and 28 mm diameter by 3 mm thick rubber washers for vibration isolation.

Vertical cased fan coil units should be mounted using the fixing points provided on the unit, onto a flat, solid surface, such as a concrete or brick wall in such a way that they cannot be pulled off and impose a hazard.



Fan coil installation must ensure level positioning to facilitate correct operation and condense removal

Figure 5.1 Typical suspension of a fan coil unit mounted in a ceiling void

5.4 Ductwork connections

Ductwork should be connected between the discharge plenum spigots on the fan coil unit and the grille/diffuser plenums, normally external (male) fittings. All connecting ductwork should be independently supported from the fan coil unit and grille/diffuser plenums in accordance with HVCA DW144: *Specification for sheet metal ductwork*[38].

Insulated rigid ductwork with swept bends should be used for main duct runs with connections to the fan coil unit and grille/diffuser plenum boxes in flexible ductwork (minimum 600 mm long) of acoustic grade if necessary. Connections should be made using suitable clamps or clips ensuring that an airtight joint is made and the ductwork then insulated and taped down. Ducting or connections smaller than the fan coil unit spigots should not be used. Flexible corrugated ducting can impose high resistances if formed into tight bends and should therefore be extended so that it is internally as smooth as possible.

If possible, multiple ducts from the fan coil unit should be routed to provide resistances proportional to the air

* It should be noted that the electrical safety design of a fan coil unit is subject to product standards rather than BS 7671, which details requirements for the electrical installation up to the unit; see section 8.6.

volume flow rate through each duct; this avoids the need for volume control dampers (VCDs) to balance air flows. If VCDs are used they should not impose more than the specified external resistance. Fresh air ducting for ceiling void fan coil unit installations should normally stop short of the inlet of the fan coil unit by approximately 150 mm. Vertical fan coil units fitted into builder's work cabinets or perimeter casings should be connected to discharge ducting and discharge grilles, and the joints made airtight.

The ductwork system should then be tested for leakage according to HVCA DW143: *A practical guide to ductwork leakage*(71) and a static completion certificate issued.

5.5 Pipework connections

Figure 3.8 shows the correct connections to the flow and return ports of a 4-port, 3-way water control valve. Most water-side fan coil units are now supplied to site with water control valves factory fitted to the heating and cooling coils. Pipework connections are then made on site to the valve inlet/outlet ports using 15 mm/22 mm compression fittings, or G $^1/_2$ in./G $^3/_4$ in. face-to-face short body brass adapters. Air-side fan coil units will come with 15 mm or 22 mm copper pipe connections ready for suitable copper pipe fittings on site.

To avoid strain on pipe joints from movement or vibrations, pipework should be connected to the fan coil unit inlet and outlet connections using suitable flexible hoses of the same size as the installation pipework, see BSRIA COP 11/2002: *Flexible hoses — a code of practice for services installers*(72), and BSRIA BG4/2004: *Flexible hoses standard — a standard for manufacturers*(73). Installation pipework should be supported independently from the fan coil unit.

All pipework and connections that are not directly over the drain tray of the fan coil unit must be insulated to prevent thermal losses and condensation dripping from chilled surfaces. Insulation must not cover over air vents, drain cocks or ports on commissioning sets. Commissioning sets must be placed so ports are easily accessible for measuring purposes.

Provision should be made, e.g. binder test points, for measuring pressure at flow and return connections, or at common test points where a number of identical units are connected to self balancing pipework. Access must be provided to all test points and across orifice/venturi measuring devices.

Flow measuring devices, e.g. commissioning set with orifice plate and double regulating valve, should be selected to give a measured pressure of no less than 1 kPa. It may be necessary to use a device less than line size for a small fan coil unit. There should be a minimum of ten diameters of straight pipe length upstream and five diameters downstream of the measuring device.

5.6 Condensate removal

Ensure the fan coil unit is level or angled slightly towards the condensate tray outlet spout to facilitate correct condensate removal from the unit. Most fan coil units will come with a suitable outlet spout fitted to the end or bottom of the condensate drain tray to which a proprietary pipe or waste fitting can be attached for gravity disposal systems. Copper or plastic pipework can be used for the condensate disposal system which should run at a gradient of about 1:50 (20 mm/m). There should also be access and provision for inspection, rodding and maintenance. If the outlet spout is fitted to the drain tray on site a parallel threaded, thin shouldered fitting can be used. Make sure that the condensate will drain away from the tray in operation. Figure 5.2 shows the condensate disposal pipework from a fan coil unit drain tray.

Figure 5.2 Condensate disposal pipework from drain tray

If condensate pumps are fitted these should be properly mounted so pipes and hoses will not kink or become detached in operation. Pipe clips should always be used. Remember that a failure in the condensate disposal system can result in damage to the building fabric and its contents. If dirt can fall into the condensate tray a filter should be fitted between the outlet of the drain tray and the inlet to the condensate pump.

By providing a positive displacement, a condensate pump can help to keep discharge water tubing clean, helping to flush away algae and dirt deposits that may build up with slow moving water in gravity drainage systems, particularly if tubing is transparent and exposed to daylight.

5.7 Electrical and controls wiring

Wiring for electrical power to the fan coil units should be via a local switch isolator fitted no more than 1.5 m away from the unit electrical/controls enclosure. The isolator switch should have 3 mm contact separation on both poles ('live' and 'neutral') and the fan coil unit must be earthed. All wiring must be in accordance with BS 7671(68). Wiring on site can be carried out using a proprietary bus-bar system with the connection end pre-fitted by the manufacturer into the electrical/controls enclosure mounted on the side of the fan coil unit, thereby saving time on site during the installation.

Controls wiring is connected into the electrical/controls enclosure via hard wired cables and/or communications bus connections for BMS controls.

5.8 False ceilings

For ceiling mounted fan coil unit installations the integrity of the false ceiling is vital to the acoustic design and should be installed with care. Laser sights are effective in ensuring that ceiling grids are level and square so that ceiling tiles will all fit snugly. Any gaps between the edges of ceiling tiles will compromise the attenuation properties of the ceiling. The design of the ceiling must provide for access to the fan coil units for commissioning and maintenance.

Discharge diffusers and plenum boxes should be supported independently from the ceiling. Return air grilles should not be positioned directly under the inlet of the fan coil units but located some distance away, see section 3.8.3. They should ensure good air distribution throughout the room and that air at room temperature passes over return air temperature sensors (if fitted), see section 3.7.5.1.

6 Site commissioning

6.1 Pre-commissioning

A number of tests and measurements need to be carried out on site to determine whether a fan coil unit installation is operating in accordance with the client's specification, the contract requirements of the project and the manufacturer's quotation.

Persons working on fan coil unit equipment and at height on ceiling void mounted units should refer to section 5.1 for codes of practice and regulations pertaining to such work.

Before operating each fan coil unit, ensure that all electrical testing including earth bonding has been completed and the electrical installation complies with BS 7671[68]. All requirements of the Electricity at Work Regulations 1989[74,75] and the Health and Safety at Work etc. Act[76] regarding safety must be strictly observed and if required a 'permit to work' must be obtained.

CIBSE Commissioning Code M: *Commissioning management*[77] should be referred to and the following pre-commissioning checks should be carried out before any measurements are taken.

6.1.1 General pre-commissioning checks

Check that:

- a commissioning method statement is available
- fan coil unit and control electrical circuits are locally isolated
- fan coil units and surrounding areas are clean and dry
- transit packing has been removed from fan coil unit and equipment
- fan coil units and associated components are properly secured
- all electrical connections are tight
- all power and control wiring has been completed in detail in accordance with the circuit diagram(s)
- all fuse ratings and cable sizes are correct
- the declared voltage is available on supply phase(s)
- any static completion records are provided and necessary warning notices are posted.

6.1.2 Air distribution pre-commissioning checks

Check that:

- the central plant fresh air supply system is commissioned, balanced and fully operational
- any separate extract system is commissioned, balanced and fully operational
- ductwork joints are properly sealed
- sections of flexible duct are not formed into tight bends
- the installation of the false ceiling is complete
- the room has adequate return air grilles
- all fan coil units are switched to their design fan speed (manual or BMS switching)
- volume control dampers (VCD) in diffusers or ducting are set to fully open
- adjustable cones on diffusers are all in the fully up or fully down position
- filters and fans are clean (*Note*: filters generally need to be cleaned before commissioning)
- cooling coil damper is fully open on air-side fan coil units
- ambient air temperature is between 10 °C and 25 °C.

6.1.3 Water distribution pre-commissioning checks

Check that:

- strainers with specified mesh from CIBSE Commissioning Code W[78] are fitted
- the water system has been flushed, cleaned (see BSRIA AG 1/2001.1[79]) filled and dosed
- primary and secondary circuits have been previously balanced
- control valves are kept held fully open (for water-side units)
- air has been bled from heating and cooling coils
- all pipework and pipe joints are sound
- flow and return pipes are connected the correct way around (see Figures 3.7 and 3.8)
- measuring flow rate devices are fitted the correct way around

6.2 Commissioning the air distribution system

See also CIBSE Commissioning Code A[57], and BSRIA AG 3/89.3[80].

6.2.1 Measurements

Air volume flow rate measurements should be taken of the air discharging from ceiling discharge diffusers for ceiling void units, or the discharge grilles on casing/vertical units.

This will normally be done at the design fan speed as given in the fan coil unit manufacturer's quotation.

Switch on the fan coil unit air distribution system including any central plant air handling units and/or any separate extract system(s). After the system has been operating for at least 20 minutes, air flow measurements are taken at each discharge diffuser/grille using a suitable instrument such as balometer measuring hood (see Figure 6.1) or custom-made hood with vane anemometer. All instruments must have current calibration certification traceable to a national calibration standards body.

If there is more than one supply duct from a fan coil unit, such as with ceiling void installations, volume control dampers, if fitted, are adjusted to produce a balanced air flow from the separate diffusers in the proportion as required by the design. Accurate measurements of air volume flow rates are then taken at each diffuser. Settings on dampers should be marked.

For air-side control fan coil units the air volume flow rates are checked with the cooling damper in the open position.

A long, slim balometer hood should be used for continuous slot diffusers measuring at the active sections only. Beware of placing the measuring hood over segments of slot diffusers that have return air sections adjacent to discharge sections.

Figure 6.1 Balometer airflow measuring hood

6.2.2 Results, adjustments and problems

It is the responsibility of the designer to specify flow rate tolerances and to ensure that these are appropriate to the particular design, installation and application. From BS 848-1: *Fans for general purposes*[81], the allowable tolerance for air volume flow rate from each fan coil unit should be +10%/–5%. CIBSE Commissioning Code A[57] specifies +10%/–0%. It should be understood that a 5% drop in air volume flow rate from a fan coil unit is equivalent to a drop of approximately 3% in the design day cooling output and that commissioning measurements are to verify design day performance that may only occur a few days each year.

If results are outside of the stated tolerance band it is likely that duct static resistances are excessive or the fans in the fan coil unit are under performing.

Duct static resistances should be checked using the static tapping from a pitot static tube inserted into the ducting from the fan coil unit. Great care must be taken to find tapping positions that are representative of the static pressure that the ductwork system is imposing across the fan coil unit. The static pressure reading taken will be for the air volume flow rate as measured, not necessarily the design air volume flow rate required.

If air volume flow rate measurements are different from the design air volume flow rate required it will be necessary to refer to the airflow performance curves for each fan coil unit. These give the relationship between air volume flow rate and external static pressure for the particular fan coil unit. From these laboratory derived curves it is possible to 'normalise' the measured air volume flow rate to what it would be at the specified external static pressure, i.e. 30 Pa.

For example, in Figure 6.2 the air volume flow rate for a fan coil unit operating on speed 4 is measured as 265 l/s (solid lines) but the specification calls for 325 l/s at 30 Pa external static resistance (dotted lines). Measurements of duct static resistance at 265 l/s air volume flow rate, indicate the fan coil unit is operating against 50 Pa external static pressure. From the air flow performance curves shown in Figure 6.2, if the external static pressure of the

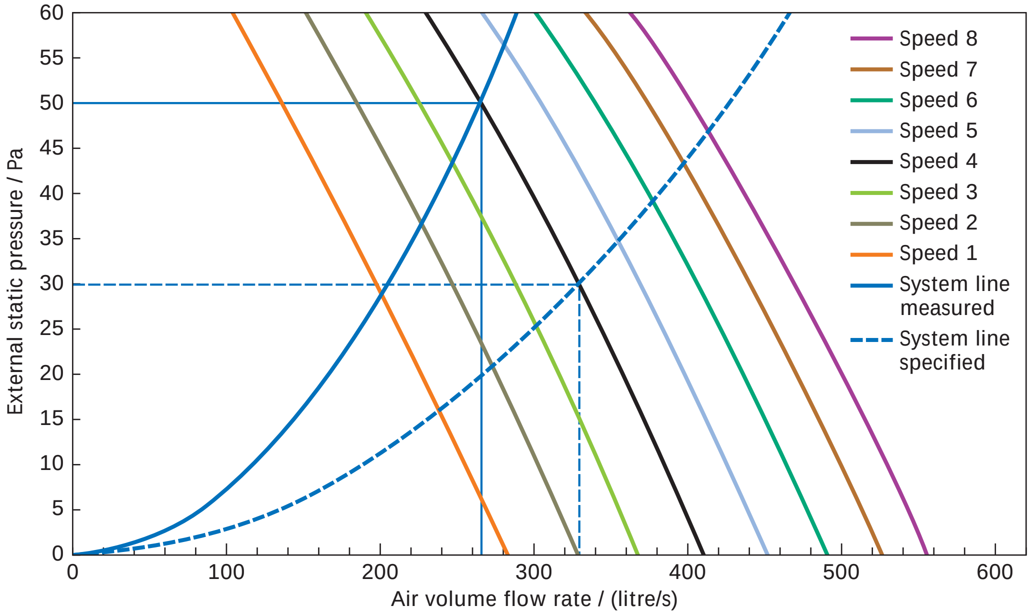


Figure 6.2 Fan coil unit airflow performance curves

system (the system line) were reduced from 'system line measured' (red dotted line) to 'system line specified' (green dotted line) it can be seen that the fan coil unit can now provide just over the specified air volume flow rate.

What is happening in this example is that the actual system resistance is higher than that specified and it is this high system resistance that pulls the air volume flow rate down below the design air volume flow rate.

However, if after checking duct resistances it is suspected that the fans in the fan coil units are under-performing the manufacturer should be invited to attend to this problem and rectify it if necessary.

6.3 Commissioning the water system

See also CIBSE Commissioning Code W[78], CIBSE KS9[82], BSRIA AG 2/89.3[83] and BSRIA AG 1/2001.1[79].

6.3.1 Measurements

With pumps operating at their design speed, carry out proportional balancing and final regulation of the fan coil units and associated branches, risers and headers in accordance with CIBSE Commissioning Code W[78]. Suitable instruments should be used such as a mercury manometer gauge or electronic differential pressure meter. All instruments must have current calibration certification traceable to a national calibration standards body.

Measurements are taken with water control valves fully open. For water-side fan coil units fitted with 4-port, 3-way valves, measurements should also be taken with the valves fully closed in the coil bypass condition. For water-side fan coils fitted with 2-port valves, measurements should also taken with the valves fully closed to check for correct system water flow conditions in the closed valve state.

6.3.2 Results, adjustments and problems

It is the responsibility of the designer to specify flow rate tolerances and to ensure that these are appropriate to the particular design, installation and application. From CIBSE Commissioning Code W[78] the recommended tolerance for water volume flow rate through the cooling coil of a fan coil unit is +10%/–5% and +10%/–10% through the heating coil. For a fan coil unit the heat transfer performance effect is 'medium' for the cooling coil and 'low' for the heating coil.

It should be understood that these measurements are to verify performance for the design day, which may only occur a few days each year. A 5% drop in water flow rate to a fan coil unit in its design day cooling mode is equivalent to a drop in cooling output of approximately 2%. In heating mode a 10% drop in water flow rate is equivalent to a drop in heating output of approximately 3%.

Allowances need to be made for:

— pipe other than medium grade steel to BS 1387[84], as this affects the beta ratio for flow rate data
— anti-freeze (if present), as this affects specific gravity, viscosity and surface tension
— air and detritus still in the system
— very low water flow rates.

Where water flow rates to fan coil units are very low and likely to generate correspondingly low pressure differentials the scope for accurate and reproducible measurements will be severely limited. Measurement accuracy will be affected and it may be necessary to make tolerance allowances in excess of the ranges given above.

If results are outside of the specified tolerance band it is likely that there is a problem with the water circuit system. Occasionally the problem may be as a result of a partial or total blockage within the coil of the fan coil unit. This would manifest itself as an abnormally high resistance if one or more coil circuits are blocked and would probably only occur on one or two fan coil units on a project.

6.4 Condensate drainage system

The following checks should be carried out before testing is commenced:

— Ensure fan coil units are level or, if required by the manufacturer, angled slightly towards the condensate drain spigot.
— Clean out the condensate drain tray and use clean water to flush any residual dirt into a separate container before connecting to the drainage system.
— Ensure all joints in the condensate drainage system are tight and the drain is ready to accept water.
— If condensate traps are fitted these should be filled with clean water.

Slowly fill the condensate drain tray with water as far inside the fan coil unit as possible and check that the water drains away quickly leaving only a minimal quantity, e.g. what remains in the drain tray sump.

If condensate pumps are fitted check that these pump water away quietly when it collects and that they stop operating when the sump is almost empty. Some condensate pumps may not work as well with tap water as they would with condensate and distilled water may have to be used to test their operation. Ensure the alarm circuit, if fitted, is operating to provide warning and/or to turn off fans or close valves in the event of pump failure.

6.5 Control system commissioning

See also CIBSE Guide H: *Building control systems*[31] and CIBSE Commissioning Code C: *Automatic controls*[85].

The designer should provide the commissioning specialist with a full description of the intended operation of the fan coil unit control system, explaining the control strategy and logic. If controls software is necessary to carry out commissioning this should be downloaded at this stage of commissioning.

6.5.1 Water-side fan coil units

Ensure that any devices used to hold water control valves open (to vent air from water coils) have been removed. With power on to the units operate the controls to give:

- full cooling
- dead band conditions (i.e. no cooling or heating)
- full heating.

Ensure that control valves operate as appropriate, i.e. cooling valves open when cooling load is applied. It may well be necessary to inspect each valve to observe whether the valve position indicator is moving as expected. If valves do not have such an indicator it will be necessary to have chiller and boiler systems in operation to ensure that the fan coil units provide cooled or heated air at the appropriate time.

6.5.2 Air-side fan coil units

Appropriate damper movement from the control system needs to be verified for each fan coil unit. It is normally possible to observe the movement of the cooling coil and heating coil dampers with access panels and filters removed from the underside of the fan coil units. If this is done for all the units in the room at the same time it is a relatively quick job to observe that the cooling coil dampers open and the heating coil dampers close when a cooling load is applied from the control circuit, and vice versa for a heating load. It may still be necessary, however, to inspect each damper as it shuts to ensure it seals properly to minimise heating/cooling pick-up from these units.

6.5.3 Functional control checks

Once chiller and boiler systems are operational, functional checks of the control elements can be carried out. Commissioning of the BMS, if fitted, should be carried out as per the guidelines in CIBSE Guide H: *Building control systems*[31].

Often the first time that controls can be checked on a fan coil unit is on site once essential operating software has been downloaded; responsibility must then rest with the site commissioning specialist.

6.6 Acoustic performance

Like air, water or control functions, acoustic performance is an important factor for determining whether a fan coil unit installation is acceptable or not.

6.6.1 Noise measurement

The following checks should be carried out before measurements are taken.

Check that:

- for ceiling void installations the installation of the false ceiling is complete
- air volume flow rates have been commissioned and any volume control dampers in diffusers or supply ducting are set as per air-side commissioning
- for ceiling void installations the room has sufficient return air grilles
- the AHU central plant fresh air supply and extract system is balanced and commissioned
- all fan coil units are switched to their design fan speed (manual or BMS switching)
- filters and fans are clean
- cooling coil damper is fully open for air-side fan coil units
- for ceiling void installations return air grilles are not placed directly under the inlet of fan coil units, if at all possible
- ambient noise conditions are quiet enough to be 10 dB below the lowest level of FCU or plant noise for all of the octave bands examined.

Moving from room to room and lifting ceiling tiles for ceiling void installations, a general aural check (i.e. assessing by ear) should be carried out to gauge whether there are any abnormal noises, such as mechanical rattles or pure tones emanating from the system. If possible these should be corrected before any further noise testing is carried out.

A precision sound level meter having octave band and dBA filter sets should be used. The meter and its calibrator must have current calibration certification traceable to a national calibration standards body. After calibrating the sound level meter at 1000 Hz with the calibrator, the meter should be set to dBA and an initial assessment of the space carried out. From this initial assessment a few representative locations can be chosen to check the octave band sound pressure spectrum of the space. For ceiling void fan coil unit installations do not measure directly under a return air ceiling grille if the grille has been placed right under the inlet of a unit.

The sound level meter should be fixed on a tripod approximately 1.5 m high and set to the 'LZ_{eq}' (i.e. linear, equivalent continuous level) measurement function. Sound pressure readings are taken at each of the chosen measurement locations at octave band centre frequencies 63 Hz to 8000 Hz for:

- background level ambient conditions (fan coil units and AHU central plant fresh air and extract systems all off)
- AHU central plant fresh air and extract systems only on
- fan coil units only on
- fan coil units and AHU central plant fresh air and extract systems all on.

The sound level meter should be located at least 1.5 m away from the discharge grille of cased and vertical fan coil units or from discharge and return air ceiling grilles on ceiling void installations.

For reference purposes sound pressure readings can also be taken for the fan coil units operating at other fan speeds than the design speed, i.e. higher or lower.

6.6.2 Analysing noise levels

For each set of readings the eight octave band centre frequency sound pressure levels are plotted on a nest of NR curves. The NR level is judged to be where the curve of the measured values peaks, relative to the NR curves. For example, Figure 6.3 and Table 6.1 show the results of plotting sound pressure levels for background noise, AHU noise and combined fan coil unit/AHU noise. It shows that with the FCUS and AHU operating together the noise level in this space is NR37.

The NR curve for background ambient noise levels should be superimposed to check that environmental conditions are favourable for the tests (see section 6.6.1). The NR curve with only the central plant fresh air/extract AHU operating (i.e. without the FCUS running) should also be superimposed to gauge the significance of this sound source.

If NR levels are above specification and the central plant AHU noise levels are significant the fan coil installation should be assessed with the central plant turned off.

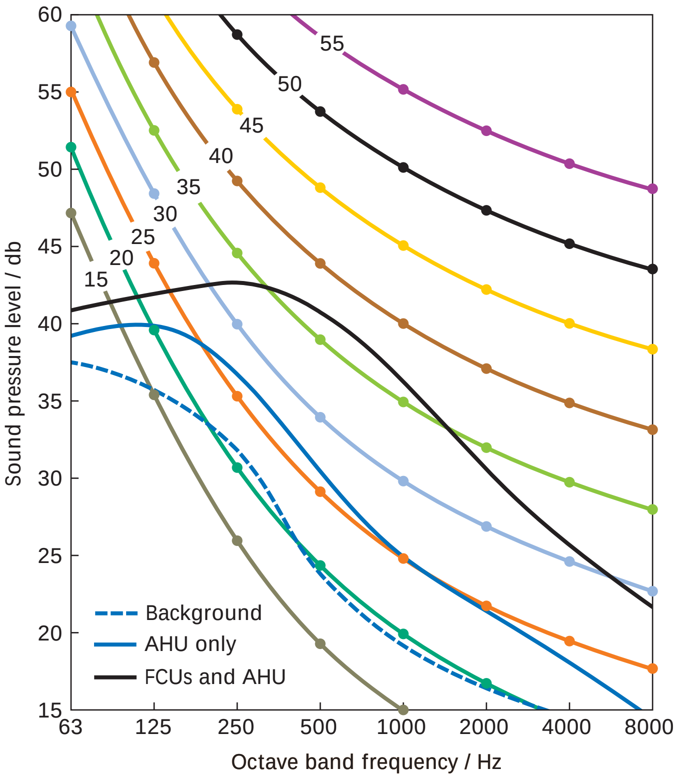


Figure 6.3 Example sound pressure levels for background, air handling units (AHU) and fan coil units (FCUS) plotted on NR curves

Table 6.1 Noise data for Figure 6.3

Test	Sound pressure level, LZ_{eq} (/ dB re. 2×10^{-5} Pa) at stated octave band centre frequency / Hz								NR
	63	125	250	500	1000	2000	4000	8000	
FCUS and AHU	40.9	42.0	42.7	40.7	36.3	30.5	25.8	21.9	37
AHU only	39.4	40.0	36.8	30.4	25.0	21.5	18.1	14.5	27
Background	37.6	35.8	31.8	23.8	19.4	16.5	14.8	13.2	22

6.6.3 Noise problems

It is rare that measuring conditions are ideal and it may well be necessary to be take into account one or more of the following:

— *Whether carpets or furnishings have yet been fitted*: noise levels can be up to 2 or 3 dB higher if floor still has metal decking or hard surface.

— *Room size*: if room volume does not concur with the manufacturer's quotation, apply a dB correction factor of 5 log (V_1/V_2), where V_1 is the measured room size and V_2 is the quoted room size.

— *Ceiling attenuation*: for ceiling mounted fan coil unit installations, a section of the false ceiling can be removed and measurements made again to assess the degree of attenuation of the false ceiling.

If a noise problem cannot be rectified it is likely that the acoustic consultant will need to liaise on site with the designer, installer and equipment manufacturer(s) and resolve the situation as necessary.

6.7 Thermal output

Measurements of heating and cooling outputs are rarely attempted on site as the conditions to simulate the design day specification are virtually impossible to achieve. It is generally agreed that if fan coil units are certified for their performance by a third party test house, and if the air volume flow rates on site are correct, then the correct heating and cooling outputs will follow.

6.8 Witnessing

For most projects, the specification requires the commissioning results to be approved as a condition of system acceptance. The most common form of acceptance procedure is to undergo a process of witnessing as a means of ensuring that the fan coil unit system has been commissioned to meet the specified requirements. Normally only a proportion of the commissioning checks are witnessed in the presence of the designer, or an agent acting on behalf of the designer.

When carrying out spot checks on recorded data, the witnessing authority should recognise that, because of site conditions and measurements, identical results are unlikely to be achieved. It may be sensible therefore to expect a deviation (of, say, ±5%), provided that this does not increase overall the tolerances specified or suggested above.

6.9 Documentation and handover

Documentation should be prepared recording all the relevant details of the fan coil unit installation subjected to the commissioning procedures as set out in the specification and/or described in any method statement. See also CIBSE Commissioning Code M: *Commissioning management*(77) and BSRIA AG5/2002: *Commissioning management guide*(86).

Commissioning documentation will be included in the operation and maintenance (O&M) instructions for handover to the end user or building facilities manager and therefore should be logical and unambiguous. Documentation should also include the fan coil unit manufacturer's installation, service and maintenance instructions.

Whilst filters should have been clean for the commissioning of the air distribution system, they will nearly always be dirty at the end of building construction works and handover. The end user or building facilities manager who will take on the building services should be aware of this and insist on clean filters at handover.

7 Servicing and maintenance

7.1 Introduction

The service and maintenance of fan coil unit installations is normally carried out by the end user or a facilities management company, unless attendance is required by the manufacturer during the warranty period. Fan coil units are reliable items of equipment and generally require only routine servicing to avoid repair work at a later date. Service frequencies for fan coil units are given below so that a service and maintenance programme can be formulated for the building.

Persons working on fan coil unit equipment and at height on ceiling void mounted units should refer to section 5.1 for codes of practice and regulations pertaining to such work.

The operational effectiveness of fan coil units may be impaired by the build-up of dust, dirt and related deposits. In a dirty environment it may be necessary to increase the frequency of service and maintenance above that recommended in this section.

The HVCA's *Standard Maintenance Specification for Mechanical Services in Buildings*(87) should be referred to, particularly the sections dealing with terminal units (fan coils), fans, filters, heat emitters and heat exchangers (coils). See also HVCA TR/19: *Internal cleanliness of ventilation systems*(88).

Before working on any fan coil unit or associated equipment, the electrical supply must be isolated in accordance with Health and Safety legislation. Service and maintenance should be carried out by a competent technician and a risk assessment carried out and method statement produced before the work commences. Personal protective equipment (PPE) may be required and occupants of the building and their equipment may need to be moved out of affected areas, particularly if there is a risk of water damage or if filters are dirty and a nuisance dust hazard could exist.

7.2 Servicing

Where fan coil units are ceiling mounted, it may be necessary to cover any office machinery/equipment situated below the unit being serviced. Seek permission before switching off any equipment that needs to be covered. Take care not to damage, stain or mark ceiling tiles. Clean gloves are beneficial.

Fan coil units should be serviced every six months in accordance with the HVCA's *Standard Maintenance Specification for Mechanical Services in Buildings*(87). In very dusty environments or where contaminants are present more frequent servicing may be necessary.

After removing access panels the condition of fans, motors and coils should be checked and, if necessary, these components should be cleaned, particularly if filters have previously failed through lack of service or maintenance. Dust build-up on motors can cause them to overheat so these need to be cleaned, including any ventilation slots in the motor casing. Check for any evidence of overheating on the motor and its associated wiring and that any electrical connections to the motor are sound.

Fan impellers should be carefully cleaned by brushing and vacuuming and the fan spun by hand to check if the impeller is in balance and is not rubbing or touching the fan housing. If an impeller is tight to turn or stops spinning much sooner than other identical fans there may be a problem with the motor/fan bearings. If there is the facility to relubricate bearings this should be carried out, although the small fans fitted in fan coil units normally have sealed-for-life bearings.

Filters are fitted primarily to stop the build-up of dirt and dust on fans, motors and coils that could be difficult to clean and which would ultimately have a significant effect on the performance and life of these components. Permanent filters require cleaning by vacuuming on both faces and disposable filters need to be replaced. The six-monthly service interval referred to above is for average air conditions. In a dirty environment filters will need more frequent cleaning or replacement. When replacing filters the same grade of filter should be used and filter replacements should comply with Eurovent 4/5(89), and/or BS EN 779(17), normally grade G2 or G3.

In normal use air filters do not present a health and safety hazard. However, dirty filters contain quantities of dust and dirt which, unless precautions are taken, may expose service personnel and room occupants to a 'nuisance dust hazard', as defined by the Control of Substances Hazardous to Health Regulations(90–92) (COSHH). If this is the case special precautions need to be taken, such as personal protective equipment (PPE), cordoned-off areas, vacuuming regimes and sealed refuse sacks to remove and contain dust and particles that could become airborne.

Because of the potential hazard, dirty filters need to be disposed of in an environmentally friendly manner in accordance with national and local regulations. Contractors carrying out this work should ideally be registered under BS EN ISO 14001: *Environmental Management Systems*(19).

Heating and cooling coil surfaces should be cleaned using an industrial vacuum cleaner drawing air through the heat exchanger in the opposite direction to the normal air flow, if access permits. Coil faces, fins, pipe headers, return bends, brazed joints and sheet metal end plates should be inspected for any damage, corrosion or leaks. These should be repaired as necessary. The coil block should be vented to remove any air and, where access permits, damaged areas of fins should be combed out straight. If the heating and cooling water systems on site are being cleaned, fan coil unit heat exchangers should also be flushed out to remove sediment, in accordance with CIBSE Commissioning Code W[78].

Water control valves, valve actuators and damper actuators should be inspected for damage and signs of wear. Check for leakage of water from valves and fittings on water-side units. Damper actuators on air-side fan coil units should be inspected and if necessary adjusted to minimise the leakage of bypass air around dampers.

Control systems need to be checked for correct function including operation of the dead band between heating and cooling modes. This is detailed in section 6.5. Check that air sensors and wall mounted room controllers have not been damaged and set-point adjusters, if fitted, can be operated. If set-point adjusters are on unsuitable settings these should be turned to the appropriate value. If necessary air temperature sensors should be calibrated against an accurate master.

Electrical wiring should be inspected for damage including evidence of burning or overheating. The condition of earthed equipotential bonding (i.e. earth studs, earth wiring and connections) and the automatic disconnection of the electrical supply (i.e. correct MCB or fuse rating) should be checked. Electrical connections should be examined and re-tightened if necessary, especially on electrically heated fan coil units which will carry high currents and can cause burning if terminals are loose. The operation of the local electrical isolator should be checked and the earth fault loop impedance path checked in accordance with BS 7671[68].

The condensate drainage system should be flushed clean of dirt and debris and condensate pumps cleaned and inspected. Condensate drain trays should be cleaned to minimise any build up of bacteria; if necessary, remove the drain tray from the fan coil unit for cleaning if the design of the unit provides this feature. When cleaning the coil and/or the condensate tray, remove the condensate drain connection to prevent debris from entering drain lines or the condensate pump. If chemical cleaners are used, ensure that both the coil and drain tray are flushed with clean water before re-connecting the drain connection. Re-test the condensate system as explained in section 6.4.

Grilles and ceiling diffusers should be brushed and vacuumed clean of dust and debris taking care not to damage the diffuser, ceiling or ceiling light fittings. Check the condition of grilles and diffusers and that the settings of adjustable ceiling grilles have not altered or been tampered with.

Carefully check the condition of discharge and inlet ductwork and grille plenum boxes. Check that there is no damage to flexible couplings, ductwork insulation, insulation protective covering and ductwork support systems; repair if necessary.

Fan coil unit casings should be inspected for damage and repaired if necessary. Exposed decorative casings should be cleaned using warm water and a mild detergent. Abrasive cleaning materials should not be used. For cased units ensure that all fixed panels, access panels, grilles and covers are secure and fixings and fasteners are tight to protect against electrical and mechanical hazards.

After servicing, fan coil units should be tested for correct operation if this has not already been done during the service.

7.3 Maintenance and repair

Where fan coil units are ceiling mounted, it will be necessary to cover or move any office machinery or equipment situated below the unit being repaired. It may be necessary to move occupants out of the immediate working area but this should only be done after gaining prior permission. Seek authorisation before switching off or moving any occupant's equipment. Take care not to damage, stain or mark ceiling tiles. Clean gloves are beneficial.

Coils do not normally need repair or replacement during the lifetime of a fan coil unit although if this becomes necessary, adjacent pipework should be isolated and the coil drained of water before removal from the unit. Following repairs, re-filling with water and re-commissioning should be carried out in accordance with CIBSE Commissioning Code W[78].

Fan motors may need to be repaired or replaced. This can occur if they have been allowed to run hot following a build-up of dirt or dust if filters have not been serviced. Generally the whole fan or fan deck will need to be removed to repair or replace a motor. With large fan coil units this equipment is heavy and will require two persons to avoid a handling hazard, see Figure 7.1. It is sensible to have a replacement fan or fan deck ready to fit into the fan coil unit straight after removal of the defective part.

Water control valves have undergone a great deal of development over the years and are now very reliable. In the event of a problem, however, replacement will entail draining down of a section of branch pipework to one or more units before the valve can be removed and replaced. If controls become defective they should be replaced and

Figure 7.1 Replacing a fan deck in a large fan coil unit

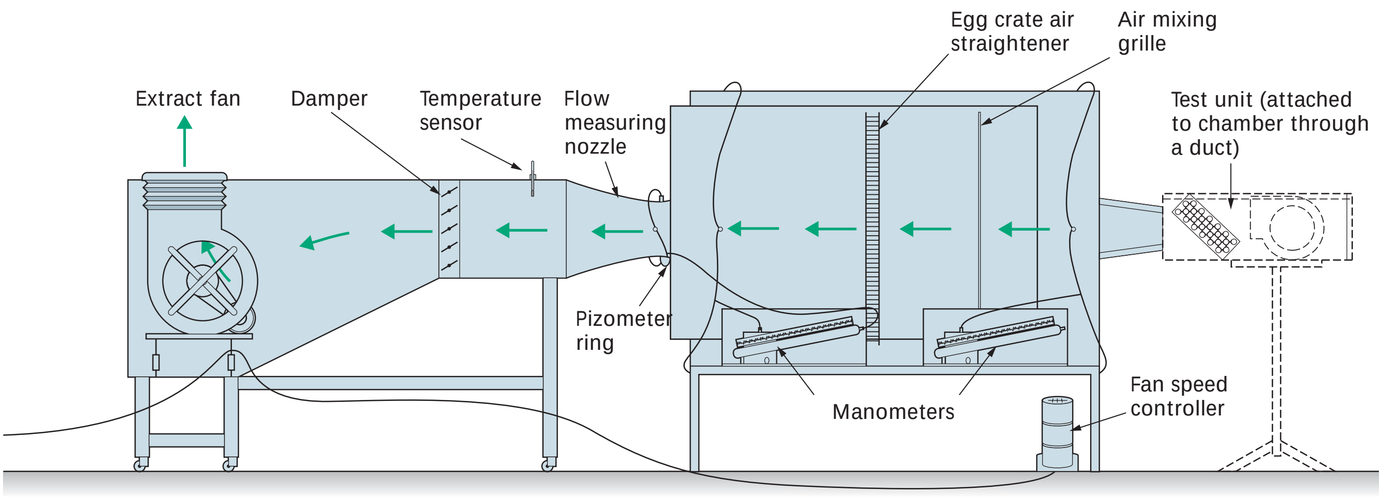


Figure 8.1 Fan coil unit being tested on a AMCA test rig

commissioned. Normally the controls supplier can provide an exchange unit or an alternative control if the original unit has become obsolete.

7.4 Energy performance inspections

Legislation to implement the Energy Performance of Buildings Directive[15] (EPBD) was laid before the UK Parliament in March 2007 and comes/came into force in a phased manner:

— New systems put into service on or after 1 January 2008 will be required to have an inspection within 5 years of their first being put into service.

— The first inspection of all existing air conditioning systems over 250 kW will have occurred by 4 January 2009.

— The first inspection of all remaining, existing, air conditioning systems over 12 kW will have occurred by 4 January 2011.

It is intended by the EPBD that air conditioning systems be carefully maintained and managed in order that they do not consume too much energy and inspections will be carried out by accredited energy assessors.

As an integral component of an air conditioning system, fan coil units will require examination as part of the air conditioning inspection. The inspection will include an assessment of efficiency, a review of sizing and advice on improvements or replacements and alternative solutions. CIBSE TM44: *Inspection of air conditioning systems*[93] provides guidance on carrying out the required inspections. Various guidance documents are also available from the Department for Communities and Local Government (DCLG) (http://www.communities.gov.uk/epbd).

8 Laboratory testing

8.1 Introduction

Like many other items of building services equipment, fan coil units are laboratory tested to validate their performance parameters. This confirms to the end user and specifier that units will perform to project requirements and allows accurate selection by manufacturers, suppliers and purchasers. Testing procedures and testing rationale for air, water, acoustics, electrical and control performance parameters are explained.

8.2 Air-side criteria

8.2.1 Air volume flowrate

An accepted industry standard for testing fan coil units is described in ANSI/AMCA Standard 210-99: *Laboratory methods of testing fans for aerodynamic performance rating*[94], where a test rig fitted with a calibrated nozzle is used to measure air volume flow rate against static pressure drop across the fan coil unit. The static pressure is varied using a variable speed auxiliary fan on the test rig and in this way curves of air volume flowrate against external static pressure can be generated. An AMCA test rig suitable for testing fan coil units is shown in Figure 8.1.

Air volume flowrate can also be checked by a variety of other methods such as anemometer/pitot-static traverse or duct mounted orifice plate. Various test methods are described in BS 848-1: *Fans for general purposes. Performance testing using standardized airways*[81].

8.2.2 Air pressure drop

The static pressure drop across the whole fan coil unit or across individual components, such as fans, filters or coils, can be measured using a suitable pressure gauge, such as the static tapping of a pitot-static tube. It can also be done using the AMCA test rig as described in section 8.2.1 whilst measuring the air volume flow rate.

8.3 Water-side criteria

8.3.1 Heating and cooling duties

The measurement of heating and cooling duties from fan coil units is a specialised and lengthy procedure and is normally only performed by specialised test houses such as BRE or BSRIA or by a few manufacturers who have the dedicated facilities. For UK projects, testing is usually carried out to the requirements of BS 4856-3[45]. For these tests an entering air condition of 23 °C db, 50% RH is normally adopted*. Manufacturers generally have a few sizes in a range of fan coil units tested by an independent test house and then tune their sales selection software to match the results for the whole range. Eurovent 6/3: *Thermal test method for fan coil units*[95] can be used for performance testing of fan coil units intended for European markets. The air entering conditions of 27 °C db and 19 °C wb (46% RH) used by Eurovent are suited to fan coil units operating in southern European climates but would give falsely high cooling outputs for UK projects.

8.3.2 Water pressure drop

It is important to know the water pressure drop across heating and cooling coils at various water volume flow rates so that the designer can properly size pumps and pipework to suit the installation. This can be checked using a dedicated test rig or during the measurement of heating and cooling duties with a suitable pressure gauge. The unit of measurement is the kilopascal (kPa) and values from 1 kPa for a small coil up to 25 kPa for a very large unit can be expected. Manufacturers and their coil suppliers will check a few products at specific flow rates and then tune their sales selection computer software to match the results for the whole range of units.

8.4 Acoustic performance

8.4.1 Sound power level testing

To calculate the sound pressure levels within a particular room it is necessary to know the sound power level (L_w) of the fan coil unit at the octave band centre frequencies 63 Hz to 8 kHz for the fan speeds and range of external air static pressure drops at which the fan coil unit will operate. A few specialised independent test houses and some manufacturers have reverberation chambers for this purpose and tests are carried out to BS 4856-4[46].

Figure 8.2 shows a ceiling void fan coil unit being noise tested in a twin room acoustic suite. Such a facility is necessary to determine the separate/discharge' and 'combined inlet and casing radiated' sound power levels for such a fan coil unit.

For floor mounted, wall mounted and ceiling mounted units, intended to be fitted within the room, it is necessary to know the total sound power levels in order to then determine the resultant sound pressure levels and single figure NR† from room calculations.

For ceiling void mounted fan coil units it is necessary to know the separate 'discharge' and 'combined inlet and casing radiated' sound power levels to then determine the resultant sound pressure levels and single figure NR† from room calculations.

* Entering air conditions in the ceiling void of a typical UK office can be in excess of 23 °C, 50% RH. Using 24 °C, 50% RH can increase cooling output by as much as 10% with no additional capital outlay. See also section 4.3.2.

† Section 3.8.2 describes methods for determining NR levels from the sound power levels of equipment.

8.4.2 Real room testing

Some projects require a sample of the fan coil unit to be installed in a mock-up of the actual room, as would be built on site, and sound pressure noise levels measured with the fan coil unit(s) operating. This could provide a better 'feel' for what the likely noise levels will be and can avoid potential problems that may be missed if relying on acoustic calculations. These real room tests can be involved and expensive to perform, and any differences between the mock-up room and the actual room(s) needs to be carefully assessed as to what effect this would have on noise levels.

HEVAC's *Real room acoustic test procedure*[96] describes a method for measuring sound pressure levels of fan coil units within a practical standard real room set-up, and is useful for comparative measurements of different fan coil units in the same room.

Real room testing should not be confused with deriving sound power levels from measurements taken of sound pressure levels in a real room environment. Data derived in this way is sometimes given in manufacturers' catalogue information and at best can only be approximate.

8.5 Electrical and control systems

8.5.1 Water-side and air-side control

This is usually confined to checking the correct operation of valve or damper actuators against a control signal from the controller. Manufacturers should check for the correct operation of controls during their 'end of line' testing procedures. Sometimes this is not possible as essential operating software is not downloaded into free issue controls until the units are installed on site and the responsibility is then on the site commissioning engineer/technician.

8.5.2 Fan motor ratings

As well as the maximum watts and amps required by the installer for sizing the electrical installation, the watts consumed per unit air volume flowrate, i.e. the specific fan power (W/(litre/s)), should also be measured by the manufacturer for the fan speeds and external air static pressure drops at which the fan coil unit will be operated. This should be done using a wattmeter measuring the 'true' electrical power consumed by the fan coil unit, including any transformer or controls losses. Building Regulations Approved Documents L2A[12] and L2B[13] require that the specific fan power of a fan coil unit installation, measured as the rating weighted average, be no higher than 0.8 W/(litre/s). (See section 2.5 for details of how to calculate specific fan power.)

8.6 Product safety testing

Legislation requires that products sold within the European Union bear the CE-mark to demonstrate that they have been tested and certified to conform with relevant European Directives relating to their safe use. For a fan coil unit the relevant Directives are:

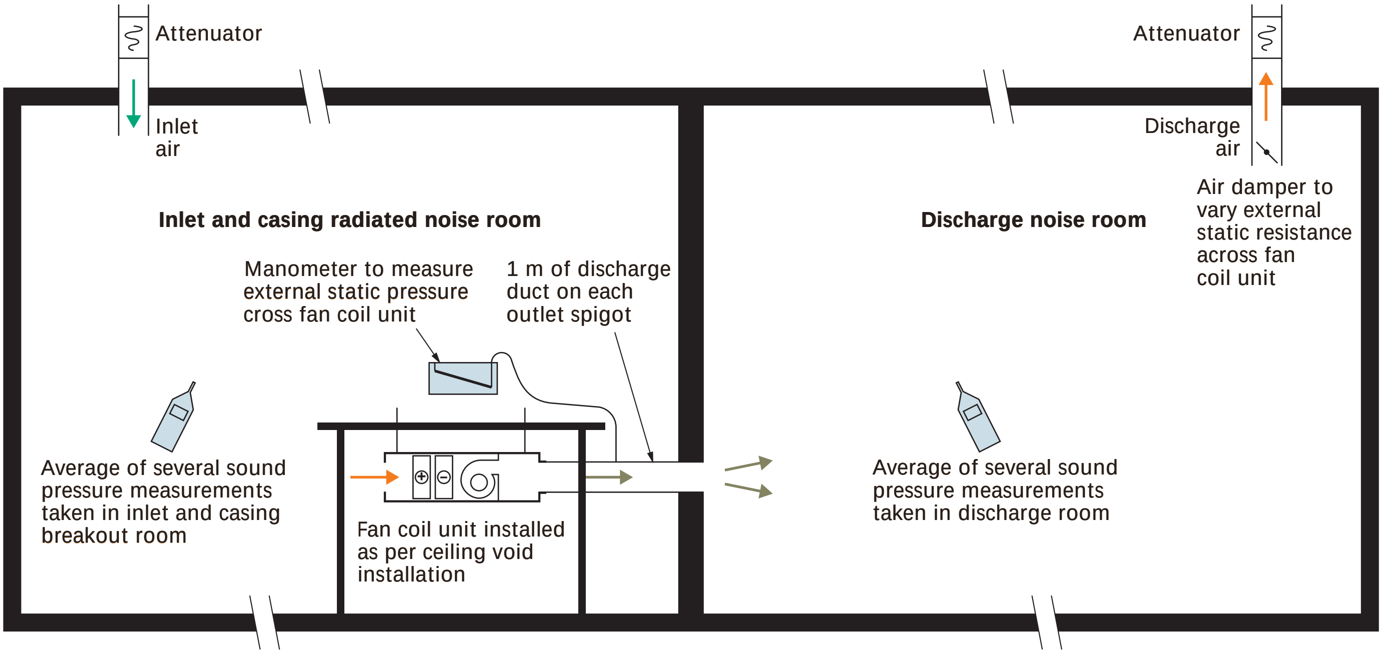


Figure 8.2 Acoustic testing of a fan coil unit in a twin room suite

— Machinery Directive, 89/392/EEC[97]

— Low Voltage Directive (LVD), 73/23/EEC[98]

— Electromagnetic Compatibility Directive (EMC) 89/336/EEC[99]

— Pressure Equipment Directive (PED) 97/23/EC[100], where applicable.

Fan coil unit manufacturers will test their products against various European harmonised safety standards (EN Standards) as the means to check compliance with the above European Directives through UK Regulations. This testing can be carried out by DTI appointed, competent body test houses, or through in-house self assessment where the manufacturer's test facilities and personnel competence permit.

Technical Construction Files for each product range are then produced. These detail the results of test work carried out, risk assessments of the equipment and components and other technical rationale and information to demonstrate compliance with the standards.

Compliance is demonstrated to the purchaser by the CE-mark affixed to equipment when manufactured and supported by a Declaration of Conformity signed by a senior representative of the manufacturer. CE-marking is also a permit to freely export products within the member states of the European Community.

It should be noted that the electrical safety design of a fan coil unit under the Low Voltage Directive is subject to product safety standards, such as BS EN 60335-1[101]. It is not subject to BS 7671[68], which detail requirements for the electrical installation up to, but not including, the unit.

8.7 Test facilities

8.7.1 Independent test houses

Wherever possible fan coil unit manufacturers should have sample testing carried out by an independent test house with UKAS accreditation, or a Eurovent accredited test house for non-UK applications. Engineers who specify equipment should understand, however, that because of the high cost of external test house time manufacturers will only have some of the units in a range tested and then interpolate results over the whole range.

8.7.2 Manufacturers test facilities

Fan coil unit manufacturers will generally have a range of test facilities at their disposal. The acceptable minimum should be access to an air volume flowrate test rig with external air static pressure measuring facilities, as it is unlikely that the required testing for catalogue data could all be done at an external test house and air volume flowrate cannot be interpolated over all ranges. Some manufacturers will have acoustic test facilities including a twin room acoustic suite and environmental test rooms. But, as with an independent external test house, such facilities are only as good as the resources the company puts into them and the personnel that operate and maintain them.

8.8 Testing rationale

8.8.1 Catalogue data tests

It is imperative that catalogue data (hard copy or web based) is accurate, as specifiers will rely on it for the success of their project. For fan coil unit projects this data is normally seen in the form of the manufacturer's sales quotation which is often generated from computer based sales selection software. The database of catalogue performance information should normally be obtained from test results at an independent test house or a manufacturer's in-house facilities if these are comparable.

8.8.2 Witness tests

As an assurance to the contract a specifier can include a requirement for carrying out witnessed tests at the manufacturer's premises or at an independent test house. This can be in the form of a standards based test (e.g. to AMCA Standard 210-99[94], BS 4856-3[45] etc.) or a purpose built mock-up room test such as with an acoustic measurement of a complicated site situation. Mock-up tests should be seen as guidance to what can be expected from the final site installation not as a guarantee of performance.

References

1 *Ventilation and air conditioning* ch.2 in *Heating, ventilating, air conditioning and refrigeration* CIBSE Guide B (London: Chartered Institution of Building Services Engineers) (2001–2)

2 *Simplified Building Energy Model (SBEM): Calculation tool for non-domestic buildings to demonstrate compliance with the National Calculation Methodology* (Garston: Building Research Establishment) (2005) (available from http://www.ncm.bre.co.uk) (accessed 11/12/07)

3 Clements-Croome D and Kaluarachchi Y *An assessment of the influence of the indoor environment on the productivity of occupants in offices* in Clements-Croome D (ed.) *Creating the Productive Workplace* (1st. edn.) (London: E & FN Spon) (2000)

4 HEVAC Fan Coil Unit Group *Statistical survey 2006* (Reading: Federation of Environmental Trade Associations) (2006)

5 *Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances* UL94 (Northbrook, IL: Underwriters Laboratories Inc.) (1996)

6 *Flammability of Interior Materials — Passenger Cars, Multipurpose Passenger Vehicles, Trucks, and Buses* Federal Motor Vehicle Safety Standard 302 (Washington, DC: US Department of Transportation, Office of Vehicle Safety Compliance) (1972)

7 BS 476-6: 1989: *Fire tests on building materials and structures. Method of test for fire propagation for products* (London: British Standards Institution) (1989)

8 BS 476-7: 1997: *Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products* (London: British Standards Institution) (1997)

9 *Fire safety* The Building Regulations 2000 Approved Document B (London: NBS/Department for Communities and Local Government) (2006) (available from http://www.planningportal.gov.uk/england/professionals/en/4000000000084.html) (accessed 11/12/07)

10 *Fan application guide* CIBSE TM42 (London: Chartered Institution of Building Services Engineers) (2006)

11 *Non-domestic heating, cooling and ventilation compliance guide: Compliance with Approved Document L2A: New buildings other than dwellings and L2B: Existing buildings other than dwellings* (London: NBS/Department for Communities and Local Government) (2006) (available from http://www.planningportal.gov.uk/uploads/br/BR_PDF_PTL_NONDOMHEAT.pdf) (accessed 11/12/07)

12 *Conservation of fuel and power* The Building Regulations 2000 Approved Document L2A: *New buildings other than dwellings* (London: NBS/Department for Communities and Local Government) (2006) (available from http: http://www.planningportal.gov.uk/england/professionals/en/111531423180.html) (accessed 11/12/07)

13 *Conservation of fuel and power* The Building Regulations 2000 Approved Document L2B: *Existing buildings other than dwellings* (London: NBS/Department for Communities and Local Government) (2006) (available from http://www.planningportal.gov.uk/england/professionals/en/1115314231813.html)

14 *National Calculation Method* (webpage) (Garston: Building Research Establishment) (2005) (http://www.ncm.bre.co.uk/)

15 Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings *Official J. of the European Communities* **L1** 65–71 (4.1.2003)

16 *HVAC strategies for well-insulated airtight buildings* CIBSE TM29 (London: Chartered Institution of Building Services Engineers) (2002)

17 BS EN 779: 2002: *Particulate air filters for general ventilation. Determination of the filtration performance* (London: British Standards Institution) (2002)

18 Hammond G and Jones C *Inventory of carbon and energy (ICE)* (database) (Bath: University of Bath) (2006) (available from http://www.bath.ac.uk/mech-eng/sert/embodied/) (accessed 11/12/07)

19 BS EN ISO 14001: 2004: *Environmental management systems. Requirements with guidance for use* (London: British Standards Institution) (2004)

20 *Free cooling systems* BSRIA BG8/2004 (Bracknell: Building Services Research and Information Association) (2004)

21 *Rules of thumb* (4th edn.) BSRIA BG14/03 (Bracknell: Building Services Research and Information Association) (2003)

22 Jones WP *Air conditioning engineering* (5th edn.) (Oxford: Butterworth-Heinemann) (2000)

23 Bi G and Medjdoub B *Building services standard solutions implemented in CAD: Design of ceiling void solutions* EPSRC reference GR/R69983/01 (Nottingham: University of Nottingham, School of the Built Environment) (2005)

24 *Guide to air distribution technology for the internal environment* (Reading: HEVAC Association) (2000)

25 *Public health engineering* CIBSE Guide G (London: Chartered Institution of Building Services Engineers) (2004)

26 *Heating and ventilation systems — Specialised ventilation for healthcare premises* Health Technical Memorandum HTM 03-01 (London: Department of Health) (2007)

27 *Environmental design* CIBSE Guide A (London: Chartered Institution of Building Services Engineers) (2006)

28 *Legionnaires disease — the implications for design and use of hot water systems* BRE IPS/85 (Garston: Building Research Establishment) (1985)

29 *Minimising the risk of Legionnaires' disease* CIBSE TM13 (London: Chartered Institution of Building Services Engineers) (2002)

30 *Refrigeration and heat rejection* ch. 4 in *Heating, ventilating, air conditioning and refrigeration* CIBSE Guide B (London: Chartered Institution of Building Services Engineers) (2001–2)

31 *Building control systems* CIBSE Guide H (London: Chartered Institution of Building Services Engineers) (2000)

32 Dwyer T 'Application of pressure independent control valves' *Building Serv. J.* **29**(1) 71–74 (January 2007)

33 *Variable flow water systems — Design, installation and commissioning guidance* BSRIA AG16/02 (Bracknell: Building Services Research and Information Association) (2002)

34 *Variable speed pumping in heating and cooling circuits* BSRIA AG14/99 (Bracknell: Building Services Research and Information Association) (1999)

35 Parsloe C *Variable flow pipework systems* CIBSE KS7 (London: Chartered Institution of Building Services Engineers) (2006)

36 *Noise and vibration control for HVAC* ch. 5 in *Heating, ventilating, air conditioning and refrigeration* CIBSE Guide B (London: Chartered Institution of Building Services Engineers) (2001–2)

37 *HVAC Applications* ASHRAE Handbook (Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers) (2007)

38 *Specification for sheet metal ductwork — low, medium and high pressure/velocity air systems* HVCA DW/144 (London: Heating and Ventilating Contractors Association) (1998, Appendix 2005)

39 *WinFCUExpress (*fan coil unit selection software) (Toddington: Computaire Ltd.) (2001)

40 Flanagan R and Jewell C *Whole life appraisal for construction* (Oxford: Blackwell Science) (2005)

41 *Improved life cycle performance of mechanical ventilation systems* CIBSE TM30 (London: Chartered Institution of Building Services Engineers) (2003)

42 *Specification Expert* (electronic database) (Ascot: Barbour/CMP Information Ltd.)

43 Common Arrangement of Work Section for Building Works (CAWS) (London: Construction Project Information Committee) (1998)

44 *National Building Specification* (electronic database) (Newcastle Upon Tyne: NBS)

45 BS 4856-3: 1975: *Methods for testing and rating fan coil units, unit heaters and unit coolers. Thermal and volumetric performance for heating and cooling duties; with additional ducting* (London: British Standards Institution) (1975)

46 BS 4856-4: 1997: *Methods for testing and rating fan coil units, unit heaters and unit coolers. Determination of sound power levels of fan coil units, unit heaters and unit coolers using reverberating rooms* (London: British Standards Institution) (1997)

47 The Manual Handling Operations Regulations 1992 Statutory Instruments 1992 No. 2793 (London: Her Majesty's Stationery Office) (1992)

48 Manual Handling Operations Regulations (Northern Ireland) 1992 Statutory Rule 1992 No. 535 (London: Her Majesty's Stationery Office) (1992)

49 The Work at Height Regulations 2005 Statutory Instruments 2005 No. 735 (London: Her Majesty's Stationery Office) (2005)

50 The Work at Height (Amendment) Regulations 2007 Statutory Instruments 2007 No. 114 (London: The Stationery Office) (2007)

51 The Work at Height Regulations (Northern Ireland) 2005 Statutory Rules of Northern Ireland 2005 No. 279 (London: The Stationery Office) (2005)

52 The Work at Height (Amendment) Regulations (Northern Ireland) 2007 Statutory Rules of Northern Ireland 2007 No. 135 (London: The Stationery Office) (2007)

53 The Lifting Operations and Lifting Equipment Regulations 1998 Statutory Instruments 1998 No. 2307 (London: The Stationery Office) (1998)

54 Lifting Operations and Lifting Equipment Regulations (Northern Ireland) 1999 Statutory Rule 1999 No. 304 (London: The Stationery Office) (1999)

55 The Construction (Design and Management) Regulations 2007 Reprinted March 2007 Statutory Instruments 2007 No. 320 (London: The Stationery Office) (2007)

56 The Construction (Design and Management) Regulations (Northern Ireland) 2007 Statutory Rules of Northern Ireland 2007 No. 291 (London: The Stationery Office) (2007)

57 *Air distribution systems* CIBSE Commissioning Code A (London: Chartered Institution of Building Services Engineers) (1996/2004)

58 The Construction (Health, Safety and Welfare) Regulations 1996 Statutory Instruments 1996 No. 1592 (London: Her Majesty's Stationery Office) (1996)

59 Construction (Health, Safety and Welfare) Regulations (Northern Ireland) 1996 Statutory Rule 1996 No. 510 (London: The Stationery Office) (1996)

60 The Construction (Head Protection) Regulations 1989 Statutory Instrument 1989 No. 2209 (London: Her Majesty's Stationery Office) (1989)

61 Construction (Head Protection) Regulations (Northern Ireland) 1990 Statutory Rule 1990 No. 424 (London: Her Majesty's Stationery Office) (1990)

62 The Construction (Lifting Operations) Regulations 1961 Statutory Instruments 1961 No. 1581 (London: Her Majesty's Stationery Office) (1961)

63 The Management of Health and Safety at Work Regulations 1999 Statutory Instruments 1999 No. 3242 (London: The Stationery Office) (1999)

64 The Management of Health and Safety at Work (Amendment) Regulations 2006 Reprinted January 2007 Statutory Instruments 2006 No. 438 (London: The Stationery Office) (2007)

65 Management of Health and Safety at Work Regulations (Northern Ireland) 2000 Statutory Rule 2000 No. 388 (London: The Stationery Office) (2000)

66 The Health and Safety (Training for Employment) Regulations 1990 Statutory Instruments 1990 No. 1380 (London: Her Majesty's Stationery Office) (1990)

67 Health and Safety (Training for Employment) Regulations (Northern Ireland) 1994 Statutory Rule 1994 No. 1 (London: Her Majesty's Stationery Office) (1994)

68 BS 7671: 2001: *Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition* (London: British Standards Institution) (2001)

69 Bunn R and Heywood M *Supporting services from structure. Guidance for a defect-free interface* BSRIA IEP 4/2004 (Bracknell: Building Services Research and Information Association/Co-Construct) (2004)

70 Roper M, Brown R and Salmon M *Wire rope suspension systems: A code of practice for services installers* BSRIA COP 22/2002 (Bracknell: Building Services Research and Information Association) (2002)

71 *A practical guide to ductwork leakage testing* HVCA DW/143 (London: Heating and Ventilating Contractors Association) (2000)

72 Gomez S *Flexible hoses. A code of practice for service installers* BSRIA COP 11/2002 (Bracknell: Building Services Research and Information Association) (2002)

73 Brown R *Flexible hoses standard: A standard for manufacturers* BSRIA: BG4/2004 (Bracknell: Building Services Research and Information Association) (2004)

74 The Electricity at Work Regulations 1989 Statutory Instrument 1989 No. 635 (London: Her Majesty's Stationery Office) (1989)

75 Electricity at Work Regulations (Northern Ireland) 1991 Statutory Rule 1991 No. 13 (London: Her Majesty's Stationery Office) (1991)

76 Health and Safety at Work, etc. Act 1974 Elizabeth II. Chapter 37 (London: Her Majesty's Stationery Office) (1974)

77 *Commissioning management* CIBSE Commissioning Code M (London: Chartered Institution of Building Services Engineers) (2003)

78 *Water distribution systems* CIBSE Commissioning Code W (London: Chartered Institution of Building Services Engineers) (2003)

79 Parsloe C *Pre-commission cleaning of pipework systems* (2nd edn.) BSRIA AG1/2001.1 (Bracknell: Building Services Research and Information Association) (2001)

80 Parsloe C *Commissioning air systems. Application procedures for buildings* BSRIA AG3/89.3 (Bracknell: Building Services Research and Information Association) (2002)

81 BS 848-1: 1997 (ISO 5801: 1997): *Fans for general purposes. Performance testing using standardized airways* (London: British Standards Institution) (1997)

82 Parsloe C *Commissioning variable flow pipework systems* CIBSE KS9 (London: Chartered Institution of Building Services Engineers) (2007)

83 Commissioning water systems. Application principles BSRIA AG2/89.3 (Bracknell: Building Services Research and Information Association) (2002)

84 BS 1387: 1985: *Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads* (London: British Standards Institution) (1985)

85 *Automatic controls* CIBSE Commissioning Code C (London: Chartered Institution of Building Services Engineers) (2001)

86 Dicks M *Commissioning management: How to achieve a fully functioning building* BSRIA AG5/2002 (Bracknell: Building Services Research and Information Association) (2002)

87 *Standard Maintenance Specification for Mechanical Services in Buildings* (electronic database) HVCA SFG20 (London: Heating and Ventilating Contractors Association) (2004)

88 *Internal cleanliness of ventilation systems* HVCA TR/19 (London: Heating and Ventilating Contractors Association) (2005)

89 *Method of testing air filters used in general ventilation* Eurovent 4/5 (Brussels: Eurovent) (1992) (available from http://www.eurovent-cecomaf.org/web/eurovent/web/documents.asp) (accessed 12/12/07)

90 The Control of Substances Hazardous to Health Regulations 2002 (Reprinted April 2004 and March 2007) Statutory Instruments 2002 No. 2677 (London: The Stationery Office) (2007)

91 Control of Substances Hazardous to Health Regulations (Northern Ireland) 2003 Statutory Rules of Northern Ireland 2003 No. 34 (London: The Stationery Office) (2003)

92 The Control of Substances Hazardous to Health (Amendment) Regulations (Northern Ireland) 2005 Statutory Rules of Northern Ireland 2005 No. 165 (London: The Stationery Office) (2005)

93 *Inspection of air conditioning systems* CIBSE TM44 (London: Chartered Institution of Building Services Engineers) (2007)

94 ANSI/AMCA Standard 210-99: *Laboratory Methods of Testing Fans for Aerodynamic Performance Rating* (Arlington Heights, IL: Air Movement and Control Association) (1999)

95 *Thermal test method for fan coil units* Eurovent 6/3 (Brussels: Eurovent) (1996) (available from http://www.eurovent-cecomaf.org/web/eurovent/web/documents.asp) (accessed 12/12/07)

96 *Real room acoustic test procedure* (Reading: HEVAC Association) (1987)

97 Council Directive 89/392/EEC of 14 June 1989 on the approximation of the laws of the Member States relating to machinery *Official J. of the European Communities* **L183** 9–32 (29.6.1989) (as amended by 98/37/EEC)

98 Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to Electrical Equipment designed for use within certain voltage limits *Official J. of the European Communities* **L374** 10–19 (27.12.2006)

99 Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC *Official J. of the European Communities* **L390** 24–37 (31.12.2004)

100 Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment *Official J. of the European Communities* **L181** 1–55 (9.07.1997)

101 BS EN 60335-1: 2002: *Household and similar electrical appliances. Safety. General requirements* (London: British Standards Institution) (2002)