



# Fan Coil Units - Inside Out

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## Introduction

The scope of this article is restricted to Fan Coil Units for chilled and hot water application.

A Fan Coil Unit, or FCU in short, is a mini-air handling unit, commonly used to maintain comfort conditions in individual hotel guest rooms, hospital wards, office rooms, etc. with fan speed and on/off control switches. Chilled/ hot water from a central plant room with chillers and heat pumps/ boilers is pumped into the cooling and heating coils of the FCU. Standard FCU capacities range from 0.5TR (1500 Kcal/hr) to 4TR (12,000 Kcal/hr).

Basically, an FCU comprises of a cooling and/or heating coil, direct driven DIDW blower and single or three phase motor,

a treated steel casing with a plenum box and air filter, and a control system – like On/Off type control valves, modulating and Pressure Independent Balancing Control Valves (PIBCV). Many other sophisticated features add to the design of an acceptable unit. Over years of development, several new designs have been introduced to suit different customer requirements. See *Figure 1 to 4* for a few types of FCUs.

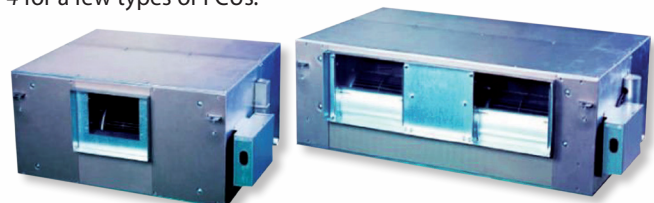


Figure 2: High static ductable FCUs

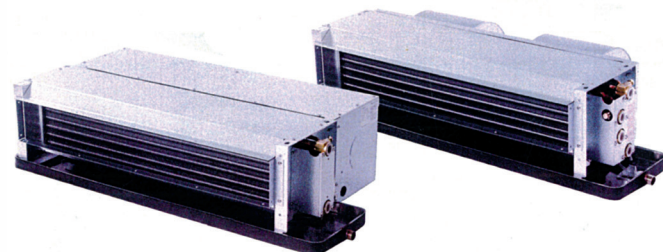


Figure 1: Ceiling suspended hide-away two-pipe (cooling only) and four-pipe (cooling and heating) FCUs

## About the Author

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Figure 3: Ceiling mounted cassette FCU with decorative grille and condensate pump



Figure 4: Vertical FCU, used in areas without false ceiling

Various features of different types of FCUs are explained in this article, including an important feature – that of noise control, which is of utmost importance in hotel and office rooms as the FCU is generally installed within a few feet of the occupant's ears.

### Cooling/Heating Coils

Standard FCUs are available with 3 row and 4 row configurations. However, manufacturers today offer 2 rows to up to 6 rows (for treating fresh air or applications with high outside air requirement).

Areas with changing ambient conditions, like most parts of Northern India with low temperatures in winter months and high temperatures in summer, require FCUs with combined heating and cooling application (four-pipe system). Chilled water from the chiller is circulated in the coils (generally three rows deep) in summer, and one row or two rows for heating during winter months, for which the hot water comes from a boiler.

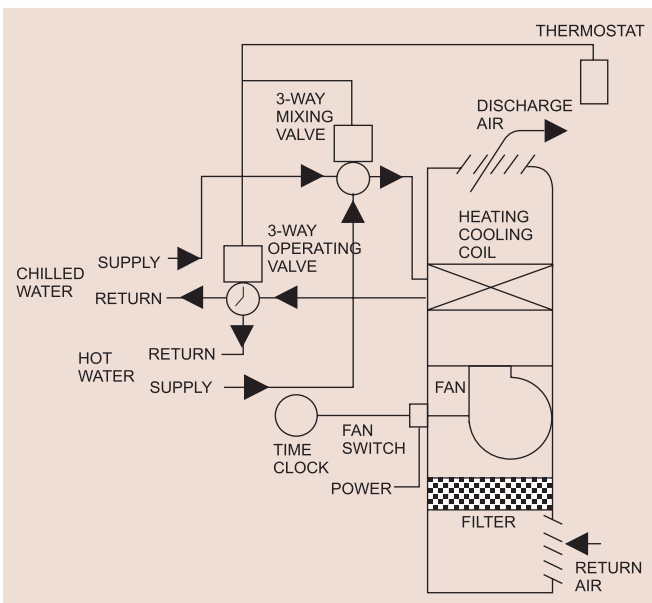


Figure 5: Typical chilled and hot water piping for an FCU

Sometimes, the FCUs are equipped with combined cooling and heating coils for reheating applications to maintain closer temperature and relative humidity control in the conditioned areas. Some of the new 5 Star international hotel chains specify such FCUs with cooling and re-heating coils, even in areas like Bengaluru and Hyderabad; the heating coil caters to humidity

control by reheat process through a humidistat. The average system design for a hotel has two aspects to cover – the room load and the outside air load. While the room load is taken care of by the FCU located in the vestibule, the outside air is mostly tackled by a Treated Fresh Air (TFA) unit. TFA can be provided with a cooling coil and a re-heating coil, so that the entry condition of the outside air remains uniform throughout the year

irrespective of seasonal weather change. The room FCU then has to handle only the room load. Since TFA feeds treated air, the rooms remain fresh. TFA is normally a once-through system, as the air supplied in the form of outside air gets exhausted through the toilet exhaust system to be passed through a heat recovery system to recover energy. Treated outside air, besides removing staleness from the room, helps maintain a positive pressure to prevent entry of air from outside, such as open corridors.

The coils are generally manufactured on automatic coil making machines with mechanical expansion. They are generally made from copper tubes of 3/8" diameter expanded into aluminum corrugated or split fins to get a higher contact factor for heat transfer, and pressure tested to 21-25 kg/m<sup>2</sup> pressure. For FCUs of higher capacities, 1/2" diameter tubes are used. Various independent certifications like AHRI, Eurovent, UL, etc. are available for coils. ARI- 440 standards apply to FCUs.

### Motors

Conventional FCUs employed a Permanent Split Capacitor (PSC) motor with permanently lubricated ball bearings. Newer developments have introduced the energy efficient Electronically Commutated Motor (ECM), which is a Brushless DC (BLDC) motor using a permanent magnet rotor. Manufacturers have shown the power consumption benefits of these motors: approximately 75% higher efficiency at all speeds. PSC motors have lower efficiency, especially at lower speeds. The use of ECMs has also resulted in lower noise generation, which is a critical consideration. Fan speed control is achieved by a microprocessor based variable controller in the DC motor. Figure 6 shows an FCU with a BLDC motor, and Figure 7 shows the benefits of EC motors with regard to lower power input, closer temperature and humidity control and lower sound power levels. The initial capital cost is substantially higher than the conventional FCUs, and therefore ECMs have not caught on much, despite the overall benefits outweighing the initial cost difference.

The DC motor allows the speed of the fan within a Fan Coil Unit to be controlled by means of a 0-10 volt input signal to the motor; the transformers and speed switches associated with AC Fan Coil Units are not required. The fan generally stops if the signal voltage goes below 2.5V. The fan will be in the off condition but as the signal voltage increases, the fan speed will increase. FCUs generally operate best between a 4 volt and 7.5 volt signal because below 4 volts, air volumes are too low to achieve the

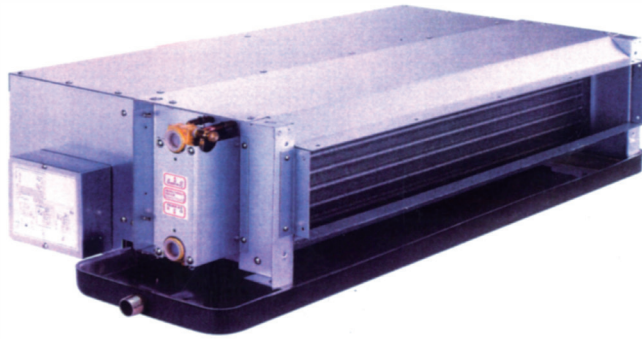


Figure 6: FCU with brushless DC motor

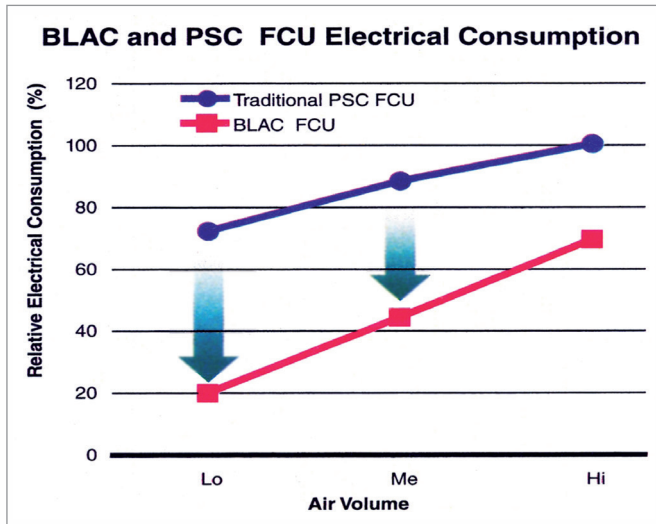


Figure 7: Power consumption of FCUs with BLDC and PSC motors

necessary throw. Similarly, with higher voltage at 8 or above, the fan may deliver excess air, leading to undesirable draft and noise.

**Filter**

All FCUs are provided with some type of filter to entrap floating particles. Filters are generally mounted on the rear or bottom panel. New applications call for filters with MERV ratings. One has to study pressure drops across such filters to ensure that the FCU fan has the capacity to meet the additional pressure drop involved. Generally, for comfort applications, filters of 80-85% efficiency down to 20 microns particle size are used.

**Return Air Plenum**

FCUs are generally provided with a return air plenum/ chamber to facilitate mounting of filters and, sometimes, to provide acoustic lining to reduce noise levels of FCUs with high static pressure. Plenums are used for filter mounting at the rear or the bottom.

**Standard Noise Levels**

Noise levels are identified as sound pressure levels or NC levels. The room construction and features offer different sound absorbing characteristics, and the Noise Criteria (NC level) is arrived at by subtracting the room absorption effect from the sound power levels (dB) at different octave bands. Sound power levels for an FCU over 63 to 8000 octave band frequencies are given in Table 1. From the table of room absorption effects (Table 2),

depending upon the room interiors and finishes that affect sound absorption, a factor has to be selected and applied to plot an NC level curve at different octave band frequencies, to derive the NC curve at different External Static Pressures (ESPs). For example, if the measured sound power level at, say, 2000 Hz is 45 dB and the room absorption effect is found to be 11 (in a room with high level of upholstery, curtaining, etc. typical of a 5 Star hotel guest room), the NC level is arrived at by subtracting the room absorption effect of 11, as an NC level of 34. Less than 35 is generally an accepted norm in the hotel industry with a high speed FCU.

Table 1: Sound power levels for an FCU, measured at 30 Pa ESP (dB)

Fan Speed	Unit Size	Octave Band Center Frequency, Hz							
		63	125	250	500	1000	2000	4000	8000
H	300 SW	34	45	43	45	43	38	32	??
	400 SW	33	43	42	43	41	37	27	---
	600 SW	36	46	45	47	45	40	28	---
	800 SW	37	53	48	50	48	45	38	31
	1000 SW	39	51	47	49	47	43	35	27
	1200 SW	41	53	48	51	49	44	37	29
	1400 SW	43	56	51	53	51	47	40	30
M	300 SW	30	42	38	39	37	31	21	---
	400 SW	29	36	36	37	34	28	20	---
	600 SW	33	41	40	42	38	32	22	---
	800 SW	35	46	43	45	41	37	28	21
	1000 SW	34	46	42	44	40	35	26	20
	1200 SW	34	46	43	45	42	36	28	20
	1400 SW	38	49	46	47	44	39	31	23

Table 2: Room absorption effect

Room Type	Octave Band							
	2	3	4	5	6	7	8	
	Center Frequency, Hz							
	125	250	500	1000	2000	4000	8000	
Soft (executive office)	4	8	11	11	11	11	11	
Medium (apartments and motels)	3	7	8	9	9	9	9	
Hard (hospital)	0	1	3	4	4	5	6	

**Fans**

FCU fans are generally forward curved Double Inlet-Double Width (DIDW) type, directly shaft mounted with multiple impellers. The fan plays the critical role of delivering the required air at the right velocity to get the required throw, pick up the return air from the rooms, push it through the filter and the cooling coil at a permissible noise level and overcome the basic system pressure loss. Some ducted FCUs require fans to generate higher ESP and are termed as high static fans. (The maximum ESP for a conventional unit is 10mm or less, but for ducted units the ESP may be higher.)

**FCU Casing**

While most manufacturers use a single skin galvanized sheet of 1.0 or 1.2mm thickness cross broken for structural strength, there are new trends of FCUs in double skin construction with

*continued on page 56*

*continued from page 54*

sandwiched insulation. The panels are generally of 15 or 19mm thickness. Such FCUs are now being specified for some large projects by consultants. These are suitable for applications with high ambient temperature/humidity and TFAs. In addition, double skin helps in reducing noise levels of FCUs and makes them sturdier.

### **Drain Pan**

FCUs need to have a drain pan to collect the condensate from the coil and ensure its smooth and uninterrupted flow to the common drain connection. The drain pan can be of single skin made of stainless steel, or galvanized iron sheet with painted finish. Some FCUs have sandwich type double skin drain pans. Drainage connections are generally of 3/4" size.

### **Recent Design Trends**

#### **Chilled Water Pumps**

The basic HVAC system design has undergone several changes in recent times. In the conventional design, chilled water was generated in the chiller in the plant room and thereafter pumped to terminal heat exchange equipment like AHUs and FCUs through chilled water pumps located in the plant room, generally in the basement or service areas. A single stage pump was used to pump the water. After picking up heat rejected in the terminal units, the chilled water in circulation returned to the chiller.

In the current system design, in order to reduce the cost of power, dual pumps (primary and secondary) are used. The building is divided into various zones, depending upon the utility factor. While primary pumps are used to circulate water across chillers, secondary pumps cater to the circulation needs in the zones. Depending upon the load pattern, secondary pumps are made to change speed through Variable Frequency Drives (VFDs), which help to supply the exact quantity of chilled/hot water to meet the cooling/heating load pattern in the zones, thus bringing about substantial power saving.

#### **Control Valves**

##### *On/Off Type Control Valve*

The most commonly used valve continues to be the On/Off type, purely due to price considerations and easy availability. This type of valve requires 230V AC supply, which is easily available. The On/Off type generally satisfies the room conditions within  $\pm 1^\circ\text{C}$ . However the economics needs to be understood along with other considerations such as reverse return piping for pressure balancing in the system. Selection needs to be made based on Kv value (maximum allowable flow rate) and shut off pressure design. The body is generally designed to work up to 16-20 bar. Manufacturers furnish these details if asked for, and they are also available in Technical Data Sheets.

*Modulating Control Valve (without balancing)*

These valves regulate water flow as per the requirement of a proportional type thermostat, which sends out a signal of 0-10V to the control valve actuator. The actuators work on 24V supply, achieved by using a 230-to-24V transformer. Hence, 24V supply becomes unavoidable. Besides being more expensive than the On/Off type, the additional requirement of 24V supply adds to the cost, albeit to get a better control on room temperature.

##### *Pressure Independent Balancing-cum-Modulating Control Valve (PIBCV)*

These are presently the most precise and expensive control valves, used for pressure/flow balancing and temperature control. Where the other types of control valves may require flow balancing to be carried out by other means like using a balancing valve in the risers, PIBCV balances the exact flow through the control valve depending upon the load factor. These valves do not require a reverse return piping system, saving considerable cost of a third insulated piping for pressure loss balancing between the supply and return lines in the risers. The valve actuator works on 24V supply, similar to the modulating control valve. Here again the flow is controlled through the 0-10V signal received from the proportional thermostat. *The saving in other items like piping costs and space more than offsets its additional cost, if it is consistently used 60-70% of the year or more.*

All the valves have individual design characteristics and need good and diligent consideration before selection, especially in a price sensitive market like India.

#### **EC Motors**

Conventional FCUs with PSC motors running on 220-230V AC supply are still very popular with hoteliers due to the cost factor. Many areas in India have seasonal business, where the occupancy varies drastically. Motor speeds for such applications are typically restricted to less than 1100 RPM to prevent excessive noise. These motors have lower efficiency and consume substantially higher power. But economic balancing justifies their selection in several installations.

*The most significant feature of new design FCUs is EC motors.* They work uniformly at 75% efficiency, unlike PSC motors which have a lower efficiency that gets worse at slow speeds. EC motors help reduce power consumption to the extent of 70%. Having no rotor induced current, unlike fixed speed AC motor driven fans, means a significant reduction in power consumption and consequently lower CO<sub>2</sub> emissions.

The use of EC motors combined with PIBCV will have control on both sides – air and water, and can bring about larger savings than EC motors alone. However, higher capital cost may deter the owners. The number of actual operating hours of FCUs will determine the choice after the payback period is calculated.

#### **System Design Aspects**

- While standard FCUs work with a chilled water temperature difference of 8 to 10°F, the trend has changed to higher temperature difference ( $\Delta T$ ) in applications such as high rise buildings and district cooling. Selection of FCUs with higher  $\Delta T$  (as much as 12 to 16°F) results in lower water circulation rate through pipes, thus bringing down the cost of installation with smaller pumps and pipe sizes, which also need less space in shafts for the risers.
- The hotel industry is the largest consumer of FCUs for maintaining room conditions. As soon as the hotel guest enters the room, the expectation of freshness is achieved through the release of outside treated air through TFA. A new trend in

*continued on page 58*

continued from page 56

hotels is to keep the FCU running at a low speed at all times, so that the guest entering the room is greeted with a pleasant room condition. Many hotels use occupancy sensors in rooms, generally integrated with the Building Management System (BMS). Individual FCUs have small fractional HP motors, but in a 5 Star hotel typically with 300 or more rooms, FCU power consumption adds up to a large amount.

### Installation Tips

I am giving these tips based on my exposure to installations in various hotels, to bring into focus the lacunae of job execution where most of the power saving sometimes gets frittered away due to poor selection and installation of control valves, piping, fittings, etc.

1. Provide a slope towards the drain line of FCU.
2. Use suspender rods for vibration isolation. Rubber grommets are important, and should never be dispensed with.
3. Use full bore fittings to get minimum pressure drop.
4. With high rise buildings of 30 to 100 floors coming up, use forged fittings designed for 20 bar.
5. Avoid sharp bends, kinks and twists in the pipeline, especially copper.
6. Use flushing line, available readymade from many suppliers, to ensure that at the commissioning stage no foreign particles enter the control valve or cooling coil. Please see *Figure 8*.
7. Give the FCU a free run before lifting in position to ascertain that there is no transit damage or misalignment.
8. Location of trap door for easy access to valves, etc., is important.
9. Select correct size SA grilles to avoid high velocity discharge creating air cutting noise and unpleasant drafts in the form of air jets.
10. Locate return air grille to minimize air travel route, saving on FCU air resistance for better performance.
11. Acoustic baffles may need to be provided near RA openings to help reduce noise in applications where the FCU is close to the occupied sensitive areas.
12. Select FCU with low static or high static, depending on ESP encountered. High static FCUs are available for ducted application and should be selected depending on application. The selection of FCU with appropriate static is important, since a wrong FCU selection at higher ESP will deliver more air, consuming power and creating extra noise. Similarly, improper selection of low static FCU may fall short on air capacity and throw to meet the room requirements.
13. As mentioned earlier, FCUs with EC motors may not deliver the required air quantity or throw at less than 30% of motor speed. They work best at between 40-75% speed.



Figure 8: Flushing line

14. Many installations have high noise levels due to improper outlet collars, acoustic treatment and grille velocities designed for the throw required to avoid hot/cold pockets. In one particular installation, the author was called for a noise complaint only to find that the grille size selected was too small, creating a cutting noise. This would also be consuming more power. Normal velocities at grille outlets are maintained at less than 500 fpm across the free area of the SA grille. RA grilles, if provided, should be selected for around 350 fpm.

### Industry Scenario

The following information is relevant to the FCU segment of the industry:

- a. Many multinational HVAC companies like Trane, York, Carrier and Daikin have set up factories to produce their equipment range in India, with global quality products conforming to ARI/Eurovent/JIS and other international standards. They are now striving towards IGBC norms.
- b. Imports of FCUs are currently permitted for hotels and SEZs at concessional rate of Customs Duty. With the indigenous production of global quality FCUs that can satisfy domestic demand as well as export requirements, this policy may not last.
- c. IGBC standards for use of material need to be followed to reduce carbon footprint.
- d. Fire safety regulations need to be met by using material compliant to the regulations.
- e. Certain independent laboratories and facilities are available for testing of FCUs, like VIPAC Laboratories in Melbourne. Similarly, a facility exists for testing the performance of PICBVs.

### Conclusion

There is a steady progress in developing newer versions of FCUs, as seen in the changes pertaining to size, power consumption and noise, all of which address the needs of hotels. However we need not fall overboard, and the capital, space, running and maintenance costs of newer developments like ECM, sophisticated controls, etc., must be weighed against the needs of each individual project. Consultants have a large role to play, and more focus on installation methods needs to be built in their specifications, especially on power savings through lower pressure drops in piping and fittings.

The range of products also needs to be expanded, as there is a steady growth of 3 and 4 Star hotels with smaller rooms requiring only 0.75TR units. The manufacturers should focus on sizing of the FCUs with a wider range. Many manufacturers can extend their product range with minimal extra expense, by optimizing the coil and motor selection. Certain manufacturers use more than one motor for 2.5 and 3TR sizes, which if converted to one motor may lead to a large cost saving and make the unit more compact; space above the corridors is always at a premium.

More and more players are offering new products claiming new benefits, and the consultant's expert opinion goes a long way towards shaping the purchase decision. ❖