

# ENERGY EFFICIENT HVAC DESIGN FOR WARM-HUMID CLIMATE

## Overview of Design Conditions:

Air conditioning system consumes most of the energy that a building needs in its operation. In order to reduce energy consumption in air conditioning effort should be made as per the following steps:

1. Reduce dependence on air conditioning system in the building while designing.
2. Recognise spaces inside the building which do not require air conditioning, as reduction in air conditioned spaces will reduce AC consumption load and energy needed for the same.
3. Optimise cooling load by selecting inside design conditions and outdoor design conditions specified in National Building Code of India 2005.

## Indoor design conditions

Inside design conditions for air conditioned spaces for various types of spaces:

S. No.	Category	Inside Design Conditions	
(I)	Restaurants	DB 23 to 26 °C	RH 55 to 60%
(ii)	Office Buildings	DB 23 to 26 °C	RH 55 to 60%
(iii)	Radio and Television Studios	DB 23 to 26 °C	RH 45 to 55%
(iv)	Departmental Stores	DB 23 to 26 °C	RH 50 to 60%
(v)	Hotel Guest Rooms	DB 23 to 26 °C	RH 50 to 60%
(vi)	Class Room	DB 23 to 26 °C	RH 50 to 60%
(vii)	Auditoriums	DB 23 to 26 °C	RH 50 to 60%
(viii)	Recovery Rooms	DB 24 to 26 °C	RH 45 to 55 %
(ix)	Patient Rooms	DB 24 to 26 °C	RH 45 to 55 %
(x)	Operation Theatres	DB 17 to 27 °C	RH 45 to 55 %
(xi)	Museums and libraries	DB 20 to 22 °C	RH 40 to 55 %
(xii)	Telephone Terminal Rooms	DB 22 to 26 °C	RH 40 to 50 %

\* DB: Dry bulb temperature, RH: Relative humidity

### Outdoor design conditions:

As per part 8 section 3 of National Building Code 2005, Outdoor Design Condition for Warm-Humid Climate of Chennai is as follows:

Cooling DB/MCWB						Cooling WB/MCDB					
0.4 %		1.0%		2.0%		0.4 %		1.0%		2.0%	
DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB
38.4	26.2	37.3	26.7	36.3	26.4	29.1	33.8	28.6	33.2	28.1	31.9

Cooling load can also be optimised, by implementing required ventilation rate and pre-cooling of fresh air required to maintain good indoor air quality through heat/energy recovery from cool exhaust air.

### Minimum Ventilation rate and outside fresh air:

Outside fresh air is required for the space to achieve acceptable air change in the space to maintain non odorous ambience arising out of body odour and tobacco smoke and dilute carbon dioxide level. The amount of fresh air required depends upon the number of occupants in the air conditioned space. Minimum ventilation rate to be maintained in the air conditioned spaces shall conform to the ASHRAE Standard 62.1.2007- Ventilation for Acceptable Indoor Air Quality.

**Table 5.3: Minimum ventilation rates in breathing zone**

Occupancy category	People outdoor air rate Rp		Area outdoor air rate Ra		Occupant density (see note 4)	Combined outdoor air rate(see note 5)		Air class
	Cfm / person	l/s.person	Cfm/ft <sup>2</sup>	l/sm <sup>2</sup>		Cfm / person	l/s.person	
Office buildings					#/1000ft <sup>2</sup> or #/100m <sup>2</sup>			
Office space	5	2.5	0.06	0.3	5	17	8.5	1
Reception areas	5	2.5	0.06	0.3	30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3	60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3	10	11	5.5	1

## **Air Handling Units (AHU) and its specifications to achieve Energy Efficiency:**

### ***Air Handling Units:***

An air handler, or air handling unit (often abbreviated to AHU), is a device used to condition and circulate air as part of a heating, ventilating, and air-conditioning (HVAC) system.

Components: An air handler is a large metal box containing a blower, heating and/or cooling elements filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to ductwork that distributes the conditioned air through the building, and returns it to the AHU.

AHU are used to cool larger areas and their cooling capacity varies from 5-30 tons. The chilled water from central plant is passed through the cooling coil present in the AHU. Air from the room returns to the AHUs either through the ceiling or return ducts and passes through the filters where dust particles are arrested and removed. Then it is passed over the coil where it loses its heat and the cool air is then supplied to the room through a duct by a draw through fan kept in the AHU. Two types of air handling units are available:

#### **1. Constant air volume**

In the constant air volume, the circulating air volume remains constant or the blower fan is of constant speed and fluctuations in the cooling demand are controlled by variation in the flow of chilled water in the cooling coil.

#### **2. Variable air volume**

In the variable air volume type, the airflow can be varied using controls to meet the cooling demand of different rooms.

### ***Energy Efficiency through AHU:***

Energy saving potential can be maximised in air conditioning system by employing following features in the air handling units:

1. Air system design shall be equipped to operate in 100% fresh air mode.
2. Free cooling mode
3. AHU minimum fan efficiency
4. Energy saving through efficient motors

#### **1. Air system design shall be equipped to operate in 100% fresh air mode.**

Heat usually builds up in building when air conditioning system is not working during non-working hours, weekends and holidays. This heat build-up affects the following day

operation of air conditioning system by increasing the cooling demand; thus energy consumption goes high. IN order to remove this heat everyday night, flushing out air is needed. In this regard, the outdoor fresh air intake is important as its cooler in comparison to the zone air. Thus the AHUs supply this outdoor fresh air and helps in flushing out this heat build up. In order to maximise the effectiveness of the air flushing; all AHUs should be designed so that it operates at 100% fresh air mode to remove the heat.

## **2. Air-side economizers**

Energy can be saved in buildings by using cool outside air as a means of cooling the indoor space. When the enthalpy of the outside air is less than the enthalpy of the re-circulated air, conditioning the outside air is more energy efficient than conditioning re-circulated air. When the outside air is sufficiently cool, it doesn't require additional conditioning; this portion of the air-side economizer control scheme is called free cooling. Air-side economizers can reduce HVAC energy costs and should be designed in accordance with **ASHRAE 90.1.2007**.

### **Design capacity**

Air economizer systems shall be capable of modulating outdoor air and return air dampers to provide up to 100% of the design supply air quantity as outdoor air for cooling

### **Control signal**

Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature. However, the use of mixed air temperature limit control shall be permitted for the systems controlled from space temperature e.g., single-zone systems

### **High-limit shutoff**

All air economizers shall be capable of automatically reducing outdoor air intake to the design minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage. The high-limit shutoff control types and settings for those controls shall be as recommended in ASHRAE standard 90.1.2007.

## **3. AHUs should be equipped to vary the supply air capacity**

All AHUs are designed for peak load condition but mostly operates at part load conditions. This operating capacity of the AHUs when un-synchronized with the cooling demand, lead to over cooling of space which ends with discomfort and energy wastage. In comfort cooling, AHUs supply air at constant air volume; hence fan operates as constant speed.

In order to control the part load capacity two methods are employed:

- Increasing the supply air temperature by varying the chilled water flow in coil with same air quantity or
- Varying the air quantity but keeping the supply air temperature same.

However, it has been observed that the best comfort conditions can be provided if AHUs have provision for both.

### **Recommendations:**

It is recommended that AHUs shall have provision to vary supply air quantity in response to the varying cooling demand with a minimum supply air capacity up to 50% of the design supply air capacity. This can be achieved by installing variable frequency drives on constant speed fans fitted in AHUs.

### **Variable frequency drives:**

These are devices used for varying the speed of fans to exactly match the supply air quantity needed to provide required cooling in the conditioned space. A VFD consists of an input rectifier (which converts AC to DC) followed by an inverter (that inverts DC to AC) connected through a DC intermediate voltage link and operates in response to the return air temperature.

#### **4. AHU minimum fan efficiency**

The energy consuming component in AHUs is fan and fan efficiency plays an important role in enhancing overall efficiency of the air conditioning systems. Forward curved, backward curved or radial types of centrifugal fans are generally used in AHUs. For fans less than 6 bhp (break horse power) the fan efficiency shall not be less than 65% and fans 6bhp and larger the fan efficiency shall not be less than 80%.

#### **5. Pre-cooling of fresh air required for maintaining good indoor air quality:**

Outdoor fresh air requirement is required to maintain an acceptable indoor air quality. In general, the temperature of outdoor air is at higher temperature in compared to the return air from the space, which increases the cooling load of the space. Therefore, pre cooling of outdoor fresh air is needed before it mixes with return air, thereby reducing its impact on

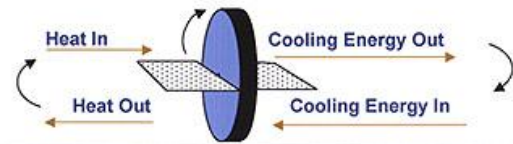
cooling load and energy consumption of air conditioned space. This pre-cooling of the fresh air can be done with the help of *Energy Recovery Wheel (ERV)*

## Energy Recovery Wheel

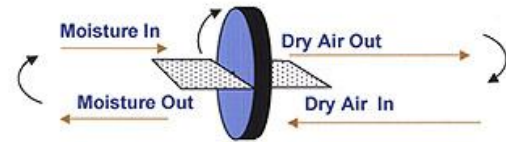
When a unit is equipped with an optional enthalpy wheel, energy recovery is provided by drawing outside air across half of the enthalpy wheel and drawing exhaust air across the other half. Latent heat and sensible heat are transferred from the hotter and moist exhaust air to the colder and dry outside air during winter conditions. Latent heat and sensible heat are transferred from the hotter and moist outside air to the cooler and dry exhaust air during summer conditions. Energy recovery control consists of starting and stopping an exhaust fan, modulating the speed of the exhaust fan, starting and stopping an enthalpy wheel, optionally controlling the speed of the enthalpy wheel and opening and closing a set of bypass dampers. The outdoor dampers are controlled in the normal manner.



1. Heating/Cooling Energy (e.g. 80%) Is Always Returned To Where It Came From



2. Moisture and Dry Air (e.g. 80%) Is Always Returned To Where It Came From



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## 6. Energy saving through efficient motors

2 poles & 4 poles, 3 phase squirrel cage induction motors are generally used in air conditioning systems. The minimum efficiency of motors shall be in compliance with nominal efficiency of eff-1 type mentioned in Table 1 & Table 2 for 2 poles & 4 poles motors in Indian standard IS 12615: 2004 – Energy efficiency induction motors – Three phase squirrel cage (First Revision).

**Values of performance characteristic of 2 pole & 4 pole energy efficient induction motors**

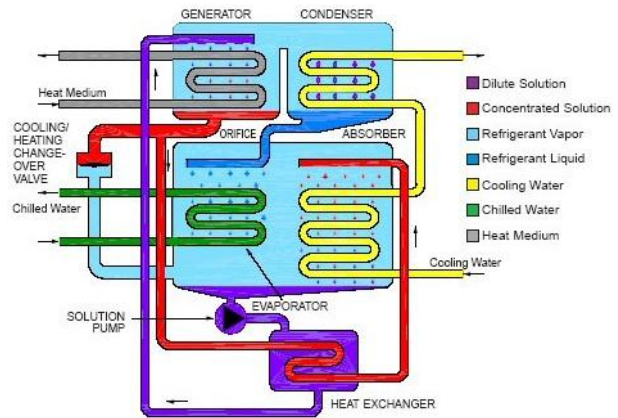
<b>Rated output (kW)</b>	<b>2-pole Motor Nominal Efficiency For eff. 1 (%)</b>	<b>4-pole Motor Nominal Efficiency For eff. 1 (%)</b>
0.37	70.2	73
0.55	74	78
0.75	77	82.5
1.1	82.8	83.8
1.5	84.1	85
2.2	85.6	86.4
3.7	87.5	88.3
5.5	88.6	89.2
7.5	89.5	90.1
9.3	90	90.5
11	90.5	91
15	91.3	91.8
18.5	91.8	92.2
22	92.2	92.6
30	92.9	93.2
37	93.3	93.6
45	93.7	93.9
55	94	94.2
75	94.6	94.7
90	95	95
110	95	95.2
125	95.3	95.5
132	95.3	95.5
160	95.5	95.8

## Chillers and guidelines for energy efficiency:

### Chiller

It's a device that removes heat from a liquid via a vapour-compression or absorption refrigeration cycle. This cooled liquid flows through pipes in a building and passes through coils in air handlers, fan-coil units, or other systems, cooling and usually dehumidifying the air in the building. Chillers are of two types; an air-cooled or water-cooled.

Air-cooled chillers are usually outside and consist of condenser coils cooled by fan-driven air.



Water-cooled chillers are usually inside a building, and heat from these chillers is carried by re-circulating water to outdoor cooling towers. A vapour-compression water chiller comprises the four major components of the vapour-compression refrigeration cycle - compressor, evaporator, condenser, and some form of metering device.

Sources: <http://www.treehugger.com>

### Energy Efficiency:

Energy efficiency in air conditioning system can be achieved by employing the following measures for chiller efficiency:

1. Chiller efficiency as per ECBC recommendations
2. Chilled water supply temperature
3. Chilled water flow rate.
4. BEE Star rated Unitary systems

#### 1. Chiller Efficiency as per ECBC Recommendations:

In the process of designing the air conditioning system, the chiller selected should follow the efficiency recommended in Energy Conservation Building Code 2007. It must be noted that, foot note of ASHRAE 90.1.2007 to be included.

All cooling equipment shall meet or exceed the minimum efficiency requirements presented in tables below:



Sl	Equipment class	Min. COP	Min. IPLV	Test Standards
1	Air cooled chillers <530 kW(<150 tons)	2.9	3.16	ARI 550/590-1998
2	Air cooled chillers ≥530 kW(≥150 tons)	3.05	3.32	ARI 550/590-1998
3	*Centrifugal water cooled chiller <530 kW(<150 tons)	5.80	6.09	ARI 550/590-1998
4	*Centrifugal water cooled chiller ≥530 and < 1050 kW (≥150 and < 300 tons)	5.80	6.17	ARI 550/590-1998
5	*Centrifugal water cooled chiller ≥1050 kW (≥ 300 tons)	6.30	6.61	ARI 550/590-1998
6	Reciprocating compressor, water cooled chiller all sizes	4.20	5.05	ARI 550/590-1998
7	Rotary screw and scroll compressor , water cooled chiller < 530 kW (<150 tons)	4.70	5.49	ARI 550/590-1998
8	Rotary screw and scroll compressor , water cooled chiller ≥530 and < 1050 kW (≥150 and < 300 tons)	5.40	6.17	ARI 550/590-1998
9	Rotary screw and scroll compressor , water cooled chiller ≥1050 kW (≥ 300 tons)	5.75	6.43	ARI 550/590-1998
10	Unitary Air Cooled Air Conditioner R19 and <40 kW ( R5.4 and <11 tons )	3.08		ARI 210/240
11	Unitary Air Cooled Air Conditioner R40 to <70 kW (R11 to	3.08		ARI 340/360
12	Unitary Air Cooled Air Conditioner R70 kW (R20 tons)	2.93	2.99	ARI 340/360
13	Unitary Water Cooled Air Conditioner <19 kW (<5.4 tons)	4.1		ARI 210/240
14	Unitary Water Cooled Air Conditioner R19 and <40 kW	4.1		ARI 210/240
15	Unitary Water Cooled Air Conditioner R<40 kW (R11 tons )	3.22	3.02	ARI 210/240

## 2. Supply chilled water temperature shall not be lower than 44 o F

ARI conditions specify a supply chilled water temperature of 44 °F and return at 54 °F or in chilled water line and a temperature drop of 10 °F is recommended. For comfort applications where a 75 °F temperature and 60 % RH is recommended to maintain in spaces, the cooled air is generally supplied at 55 °F and in order to get the supply air at design condition the chilled water temperature in coil is maintained around 44 °F. Recently a new trend has started to design chilled water loop water higher delta T which is more than 10 °F (generally 12 to 14 °F) to save energy in pumping. This trend is also introducing a lower chilled water supply design temperature than 44 °F. The lowering of chilled water adversely affects the efficiency of chiller and whatever advantage is gained in saving pumping energy ay be lost in increased chiller energy. Bangalore climate also does not demand a lower chilled water temperature for humidity control. Therefore it is recommended that for water chillers in comfort applications the supply chilled water temperature shall not be lower than 44 o F.

## 3. Chilled water flow rate shall not exceed 2 gpm/TR

The chilled water flow/TR is defined by  $24/\Delta T$  where  $\Delta T$  is the difference of supply chilled water and return chilled water temperature. In chilled water line the design  $\Delta T$  is 10 °F as per ARI specifications that means chilled water line should be designed for 2.4 gpm

(US gallon per minute). High chilled water flow leads to high pumping energy and in order to reduce pumping energy chilled water lines are being designed for high delta T which is more than 10 °F.

It is recommended that chilled water line shall be designed for a flow rate of 2 gpm/TR or lower that means the design delta T in chilled water line shall be 12 °F or higher.

## **4. Cooling Tower and Guidelines for energy efficiency**

### **Cooling Towers**

Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems. Cooling is achieved by evaporating a small proportion of recirculating water into outdoor air stream. Cooling towers should be installed at a place where free flow of atmospheric air is available. Range of cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the entering air wet bulb temperature.

### **5. BEE Star rated Unitary systems**

The Standards & Labelling Program aims at providing the consumer about the energy saving through appropriate equipment selection. In this process, the cost saving potential of the marketed household and other equipment is provided to the consumer. The above procedure has the potential for energy savings during the period of usage. Adding to this, it provides the domestic industry to compete with markets with mandatory norms for energy efficiency.

Started, way back in May 2006, the scheme is currently applicable for equipments/appliances (Frost Free(No-Frost) refrigerator, Tubular Fluorescent Lamps, Room Air Conditioners, Direct Cool Refrigerator, Distribution Transformer, Induction Motors, Pump Sets, Ceiling Fans, LPG, Electric Geysers and Color TV).

### **6. Room air conditioners labelling**

BEE energy labelling is applicable for single-phase split and unitary air conditioners of the vapour compression type to a rated cooling capacity of **11 kW**.

#### *Star rating*

The available star ranges from one to five star increasing as one star interval. The star rating is calculated from the star rating band given in table below. The star rating band is a range of

energy efficiency ratio (EER) expressed in W/W and that is nothing but the ratio of cooling capacity in watts to energy consumption also in watts.

**Table5.5: Star rating band valid from 01 January to 31 December 2012**

Star Rating	EER (W/W)	
	Min	Max
1 Star *	2.7	2.89
2 Star **	2.9	3.09
3 Star ***	3.1	3.29
4 Star ****	3.3	3.49
5 Star *****	3.5	-

It is recommended that only a BEE five star rated room air conditioners shall be used for air-conditioning of spaces.