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ENERGY CONSERVATION BUILDING CODE TIP SHEET

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HVAC SYSTEM

Credits:
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Alliance to Save Energy

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Heating, Ventilation and Air Conditioning (HVAC) accounts for a significant portion of a commercial building's energy use and represents an opportunity for considerable energy savings. This Tip Sheet acts as a primer on energy efficient HVAC systems and proven technologies and design concepts which can be used to comply with the HVAC provisions in Energy Conservation Building Code.

Keeping buildings cool in hot climates has always been a human concern. For millennia, people ingeniously applied an astonishing array of design features to their shelters to avoid or reject unwanted heat. Windscoops, vents, cool towers, atria, shading, orientation, whitewash, night radiation – the whole panoply of modern passive techniques was invented at least three thousand to five thousand years ago and developed to an impressive level of maturity. However, the invention of refrigerative chiller by Willlis Haviland Carrier in 1902 changed the world and led to the abandoning of ancient and climate responsive building architecture, as it could cool any sort of boxy and sealed building space and technically take care of adverse hot climatic conditions. From 1945 onwards, refrigerative air-conditioning became the norm to maintain buildings in a narrow temperature range, irrespective of weather conditions.

As the Climate Map of India (ECBC, 2007) shows, most of India falls mainly under three climatic zones (hot-dry, warm-humid and composite) requiring cooling of buildings for almost 6-8 months to provide thermal comfort to the occupants. All of this comes with significant energy consumption and costs. Both need to be addressed while designing any building.

HVAC systems have a significant effect on the health, comfort, and productivity of occupants. Issues like user discomfort, improper ventilation, and poor indoor air quality are linked to HVAC system design and operation and can be improved significantly by better system design.

Thermodynamic processes take place between the human body and the surrounding thermal environment. Our perception of thermal comfort and acceptance of indoor thermal environment is a result of the heat generated by metabolic processes and the adjustments that the human body makes to achieve a thermal balance between itself and the environment. Six factors that influence the heat transfer between the human body and the surrounding environment are shown in Table 1.

Good HVAC design considers all the inter-related building systems while managing indoor air quality, energy consumption, and thermal comfort. Optimizing the design requires that the HVAC designer and the architect address these issues early in the schematic design phase and continually improve subsequent decisions throughout the design development process.

Table 1: Thermal Comfort Parameters

	Parameters	Significance
Environmental	Air Temperature	Most important parameter for determining thermal comfort
	Mean Radiant Temperature	Key factor in the perception of thermal discomfort resulting from radiant asymmetry
	Relative Humidity	Excessive dry or humid conditions are immediately perceived as uncomfortable
	Air Velocity	Key factor in the perception of draft due to elevated air velocity
Personal	Activity Level	Poses a problem to designers if an indoor space has to be designed for people with different activity levels
	Clothing Resistance	Important factor in the perception of thermal comfort; use of clothing to adjust to thermal environment is a good example of adaptive control.

Source: Fanger, 1970

At times issue comes why should building developers and financiers care for efficiency considerations, since they may sell the building to someone else or, if they retain ownership, pass along the operating costs to tenants. Reducing electricity consumption through a high quality and high efficiency design could enhance the value of the building and its rent. Whichever developer first captures the efficiency opportunity, therefore, can have a major competitive advantage.

This outlines an integrated strategy targeted for large buildings with a whole building approach.

Whole Building Approach

1. ***Reduce cooling load by controlling unwanted heat gain:*** As shown in Fig. 1, external heat gains can be avoided with architectural form, light-colored building surfaces, vegetation, high performance windows, etc. Internal heat gains can be reduced by using more efficient building equipment (such as lights, computers, printers, copiers, servers, etc.), and direct venting of spot heat sources. Load reduction not only saves energy, it allows HVAC equipment to be smaller, resulting in first-cost savings.

2. ***System interactions:*** Cooling load reduction should be approached in concert with whole-building load reduction measures for both cooling and heating systems. The objectives of saving cooling and heating energy may be in conflict or may support each other. For example, better insulation and efficient windows can reduce both loads while lighting load reductions may increase heating loads. High-performance windows may be the last step needed in eliminating part or all of the perimeter HVAC equipment, while providing superior radiant comfort in both summer and winter.

   To take advantage of load variations, it is critical that building HVAC systems be capable of reacting to the reduced loads. This requires variable capacity pumps and fans (or variable capacity compressor and condenser units in case of packaged or split-systems) and reliable sensors and controls to allow the equipment to power down when loads drop.

3. ***Expand the comfort envelope with reduced radiant heat load, increased air flow, less insulated furniture, more casual dress where appropriate:*** These opportunities are less understood and deployed but have the potential to save cooling loads. In an indoor environment with fixed air temperature, relative humidity, air speed, and activity, an office worker in cotton trousers and half shirt (with an insulating value of 0.5 clo) will be comfortable at almost 3°C warmer than the same person in a heavy two-piece business suit and accessories (with an insulating value of 1.0 clo). A 3°C increase in inside temperature can save significant amount of energy.

4. ***Apply non-vapor compression cooling techniques:*** They typically use 20-30% as much energy per unit of cooling as conventional cooling equipment and can serve much or all of the load that remains after the basic cooling load is reduced. These alternatives include natural ventilation with cool outside air, ground coupled cooling, night sky cooling, evaporative cooling, absorption cooling, and desiccant systems fueled by natural gas, waste heat, or solar energy (See Box 1).

5. ***Serve the remaining load with high-efficiency refrigerative cooling:*** More efficient chillers, pumps, and fans, multiplexed chillers (to minimize part-load operation penalties), large heat exchangers, low-friction duct layout and sizing, low pressure drops in air-handling and piping components, and overall optimization of the entire HVAC system can facilitate in making the system more efficient.

6. ***Optimize the delivery system:*** Huge savings are available from reducing the velocity, pressure, and friction losses in ducts and piping. These improvements can be captured with high-efficiency fans, diffusers, and other components.

7. ***Improve controls:*** Controls with better algorithms, sensors, signal delivery, user interface, simulators, and other measures can be applied to optimize HVAC operation.

8. ***Determining loads:*** Projected load for new buildings can be analyzed accurately by using Computer Simulation. Hourly simulation models designed for energy analysis, calculate hourly cooling loads from detailed building geometry, scheduling, and equipment data. Using actual weather data, it is possible to match a building's energy usage with actual utility billing data. Computer Simulation can provide the best understanding of how a building will operate under different scenarios from a combination of detailed end-use hourly simulation.

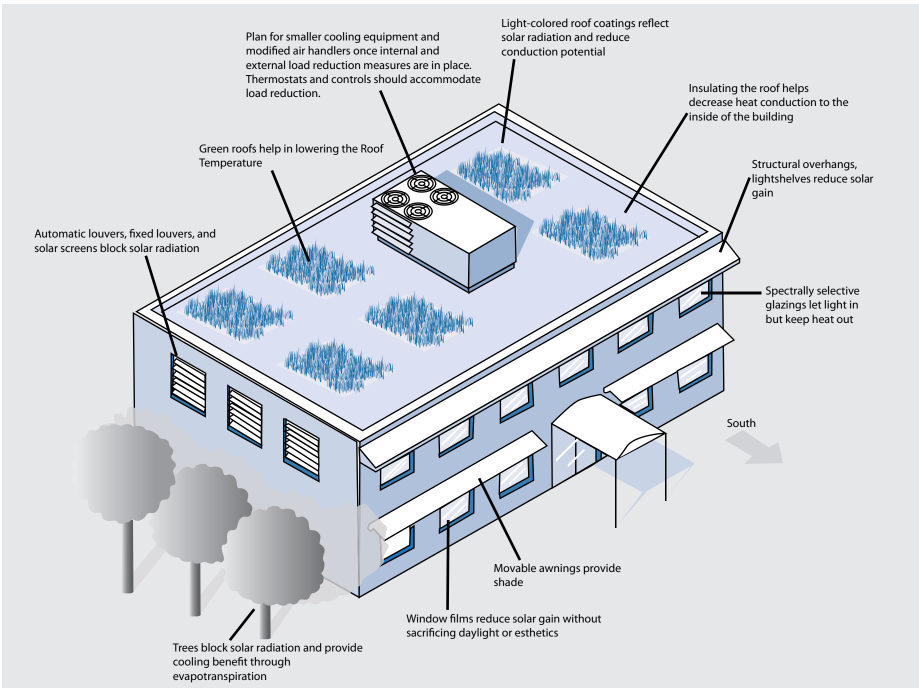

Fig. 1: Cooling Load Reduction Measures
(Source: E Source Cooling Atlas)

Non Refrigerative Technological Options in HVAC System

Box 1

Evaporative Cooling

Evaporative cooling is an ancient air conditioning technique that is growing in popularity due to increased interest in energy efficiency, reduced peak demand, improved indoor air quality, and non-CFC cooling. Evaporative cooling typically uses less than one-fourth the energy of vapor-compression air-conditioning systems, while using no more water than a power plant uses to produce the electricity needed for the same amount of vapor-compression cooling. The cost of an evaporative cooling system may be higher than a vapor compression chiller system, but payback is typically 1-5 years depending on climate.

The most common type of direct evaporative cooler uses a cellulose fiber pad, permeable to both water and air, which has water pumped into its top edge. As the air passes through the wetted pad, water evaporates, taking heat from the air, and the air cools adiabatically to balance the heat it has lost to evaporation.

Indirect evaporative coolers (See Fig. 2) eliminate the problem of increasing the moisture content of the air that enters the conditioned space by using a heat exchanger. In an air-to-air heat exchanger system, secondary (exhaust) air flows through one side of the heat exchanger where it is sprayed with water and cooled by evaporation. The building supply air flows through the other side of the heat exchanger where it is sensibly cooled by the evaporative cooled secondary air. Because of the heat exchanger, the effectiveness of indirect evaporative cooling is reduced to about 65-75 %, but it has wider applicability to climates where increased air humidity is unwelcome.

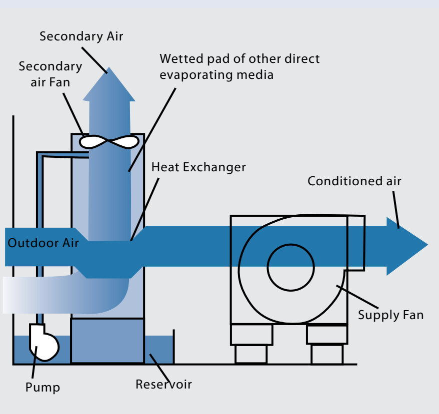

Fig. 2: Indirect Evaporative Cooler
(Source: E Source Cooling Atlas)

Desiccant Heat Recovery

Properties of desiccants materials to readily attract water and thus dehumidify air can be used in HVAC applications to reduce cooling loads, improve chiller efficiency, and widen the applicability of evaporative cooling, while providing improved indoor air quality and eliminating the use of CFC refrigerants. In combination with evaporative cooling, desiccant cooling can eliminate refrigerative air conditioning in many climates.

A conventional cooling system dehumidifies bypassing the supply air across a cooling coil that is cold enough to condense water vapor. This dehumidification requires a colder coil than would be required for sensible cooling alone, often doubling energy requirements at typical low-load conditions where it is necessary to dehumidify but not cool. Often in these conditions, the air is cooled for dehumidification and then must be reheated for comfortable supply. With desiccants, dehumidification takes place independently of sensible cooling. In large buildings, desiccants can reduce HVAC electricity use by 30-60 %. Fig. 3 shows how the desiccant wheel alternately passes through two separate airstreams; one to be dehumidified and used in the building, and one to regenerate the desiccant with warm, dry air.

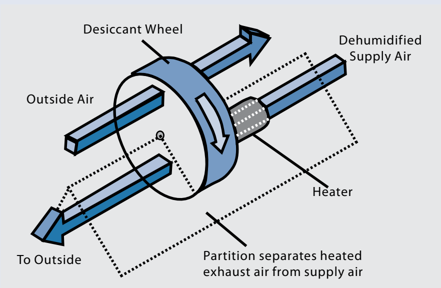

Fig. 3: Solid Desiccant Wheels
(Source: E Source Cooling Atlas)

Ground Source Heat Pump:

Water-loop heat pump (WLHP) systems have captured a small (3 to 4%) but slowly growing percentage of the U.S. commercial cooling market and have good potential in India as well.

Ground coupled systems provide passive heating and cooling by using the ground as a heat source or a heat sink. There are two basic varieties.

- ***Groundwater-source heat pumps (GWHPs)*** draw water from wells, lakes, or other reservoirs of groundwater, pass the water through an open loop, and discharge it back to the environment.
- ***Ground-source closed-loop heat pumps (GSHPs)*** system use a pump and ground-coupled heat exchanger to provide a heat source and heat sink for multiple GSHPs within the building.

Absorption Cooling

On the surface, the idea of using an open flame or steam to generate cooling might appear contradictory, but the idea is actually very elegant. Instead of mechanically compressing a gas (as occurs with a vapor-compression refrigeration cycle), absorption cooling relies on a thermochemical "compressor." Absorption cooling is more common today than most people realize. Large, high-efficiency, double-effect absorption chillers using water as the refrigerant dominate the Japanese commercial air-conditioning market. While less common in India, interest in absorption cooling is growing, largely as a result of high electricity tariffs and growing availability of natural gas on a commercial basis.

Absorption cooling is most frequently used to air-condition large commercial buildings. Absorption cooling equipment on the market ranges in capacity from less than 10 tons to over 1,500 tons (35 to 5,300 kW). Coefficients of performance range from about 0.7 to 1.2, and electricity use ranges from 0.004 to 0.04 kW/ton of cooling. Absorption chillers may make sense in the following situations:

- Electric demand charges are high
- Electricity use rates are high
- Natural gas prices are favorable
- Utility and manufacturer rebates exist

The potential of absorption cooling systems to use waste heat can greatly improve their economics. Indirect-fired chillers use steam or hot water as their primary energy source, and they lend themselves to integration with on-site power generation or heat recovery from incinerators, industrial furnaces, or manufacturing equipment. Indirect-fired, double-effect absorption chillers require steam at around 190°C and 900 kPa, while the less efficient (but also less expensive) single-effect chillers require hot water or steam at only 75-132 °C. High-efficiency, double-effect absorption chillers are more expensive than electric-driven chillers. They require larger heat exchangers because of higher heat rejection loads; this translates directly into higher costs.

Key Technical Terms

Air System Balancing: Adjusting airflow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc., or by using automatic control devices, such as constant air volume or variable air volume boxes.

Boiler: A self-contained low-pressure appliance for supplying steam or hot water. A packaged boiler includes factory-built boilers manufactured as a unit or system, disassembled for shipment, and reassembled at the site.

Coefficient Of Performance (COP) – Cooling: the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions

Coefficient Of Performance (COP) – Heating: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions

Constant Volume System: A space-conditioning system that delivers a fixed amount of air to each space. The volume of air is set during the system commissioning.

Economizer, Water-side: A system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment with the use of mechanical cooling.

Economizer, Air-side: A duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce the need for mechanical cooling during mild or cold weather.

Energy Efficiency Ratio (EER): Performance of room ACs smaller chillers and rooftop units is frequently measured in EER rather than kW/ton. EER is calculated by dividing a chiller's cooling capacity (in Btu/h) by its power input (in watts) at full-load conditions. The higher the EER, the more efficient the unit.

Heat Pump: A heat pump consists of one or more factory-made assemblies that normally include indoor conditioning coil, compressor, and outdoor coil, including means to provide a heating function. Heat pumps provide the function of air heating with controlled temperature, and may include the functions of air cooling, air circulation, air cleaning, dehumidifying, or humidifying.

Hydronic System Balancing: Adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position of valves, or by using automatic control devices, such as flow control valves.

kW/ton Rating: Commonly referred to as efficiency, but actually power input to compressor motor divided by tons of cooling produced, or kilowatts per ton (kW/ton). Lower kW/ton indicates higher efficiency.

Integrated Part-Load Value (IPLV): This metric attempts to capture a more representative "average" chiller efficiency over a representative operating range. It is the efficiency of the chiller, measured in kW/ton, averaged over four operating points, according to a standard formula.

Outdoor Air : Air taken from outdoors and not previously circulated in the building. For the purposes of ventilation, outdoor air is used to flush out pollutants produced by the building materials, occupants and processes.

Part-Load Performance: For Water chilling packages covered by this standard, the IPLV shall be calculated as follows:

Determine the part-load points. Use the following equation to calculate the IPLV.

$$IPLV = 0.01A + 0.42B + 0.45C + 0.12D$$

For COP and EER:

Where: A=COP or EER at 100%

B=COP or EER at 75%
C=COP or EER at 50%
D=COP or EER at 25%

For kW/ton:

$$IPLV: \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}}$$

Where:

A=kW/ton at 100%
B=kW/ton at 75%
C=kW/ton at 50%
D=kW/ton at 25%

The weighting factors have been based on the weighted average of the most common building types and operation using average weather in 29 U.S. cities, with and without air side economizers.

Return Air: Air from the conditioned area that is returned to the conditioning equipment for reconditioning. The air may return to the system through a series of ducts, plenums, and airshafts.

Seasonal Energy Efficiency Ratio (SEER): SEER is a measure of equipment energy efficiency over the cooling season. It represents the total cooling of a central air-conditioner or heat pump (in kWh) during the normal cooling season as compared to the total electric energy input consumed during the same period.

Supply Air: Air being conveyed to a conditioned area through ducts or plenums from a heat exchanger of a heating, cooling, absorption, or evaporative cooling system. Supply air is commonly considered air delivered to a space by a space-conditioning system. Depending on space requirements, the supply may be either heated, cooled or neutral.

Tons: One ton of cooling is the amount of heat absorbed by one ton of ice melting in one day, which is equivalent to 12,000 Btu/h or 3.516 thermal kW.

Variable Air Volume (VAV) System: A space conditioning system that maintains comfort levels by varying the volume of conditioned air. This system delivers conditioned air to one or more zones. The duct serving each zone is provided with a motorized damper that is modulated by a signal from the zone thermostat.

Zone: A space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

Air-Conditioner Basics

Basic components of the system include an evaporator, compressor, condenser (air-cooled or water cooled), and an expansion device, similar to that of a domestic refrigerator. A refrigerant circulates in these components (Fig. 4). It vaporizes in the evaporator absorbing the heat from the warm room air drawn across the evaporator coil. This cools and dehumidifies the air. The compressor raises the pressure and temperature of the refrigerant vapors. The condenser condenses the refrigerant and transforms the high pressure vapor into high pressure liquid. Heat is rejected via outside air drawn across the condenser. The expansion device transforms the high pressure high temperature liquid refrigerant to low pressure low temperature mixture of refrigerant liquid and vapor. The refrigerant goes to the evaporator, and the cooling cycle continues.

Types of Air-Conditioners

The most common types of air-conditioners are room air-conditioners, packaged air-conditioners, and central air-conditioners. Fig. 5 shows market share of different types of vapor compression HVAC systems (residential and commercial) in India.

Unitary and split air-conditioners: These air-conditioners cool rooms rather than the building. They provide cooling only when needed. These air-conditioners are less expensive to operate than central units, even though their efficiency is generally lower than that of central air-conditioners.

In a split-system air-conditioner, an outdoor metal cabinet contains the condenser and compressor, and an indoor cabinet contains the evaporator. In many split-system air-conditioners, this indoor cabinet also contains an electric heater or the indoor part of a heat pump.

Packaged air-conditioners: In a packaged air-conditioner, the evaporator, condenser, and compressor are all located in one cabinet, which usually is placed on a roof or on a concrete slab adjacent to the building. This type of air-conditioner is typical in small commercial buildings and also in residential buildings. Air supply and return ducts come from indoors through the building's exterior wall or roof to connect with the packaged air-conditioner, which is usually located outdoors. Packaged air-conditioners often include electric heating coils or a natural gas furnace. This combination of air-conditioner and central heater eliminates the need for a separate furnace indoors.

Central air-conditioners: In central air-conditioning systems, cooling is generated in a chiller and distributed to air-handling units or fan-coil units with a chilled water system. This category includes systems with air-cooled chillers as well as systems with cooling towers for heat rejection (See Box 2).

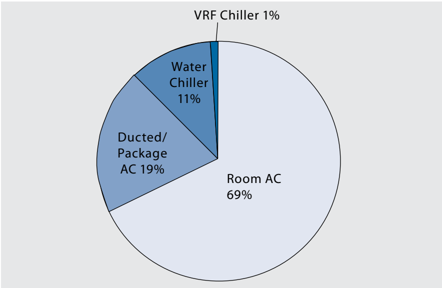

Fig. 5: Market Share of Different Types of AC Units in India

(Source: 2007 Sales Data from Emerson Climate Technology)

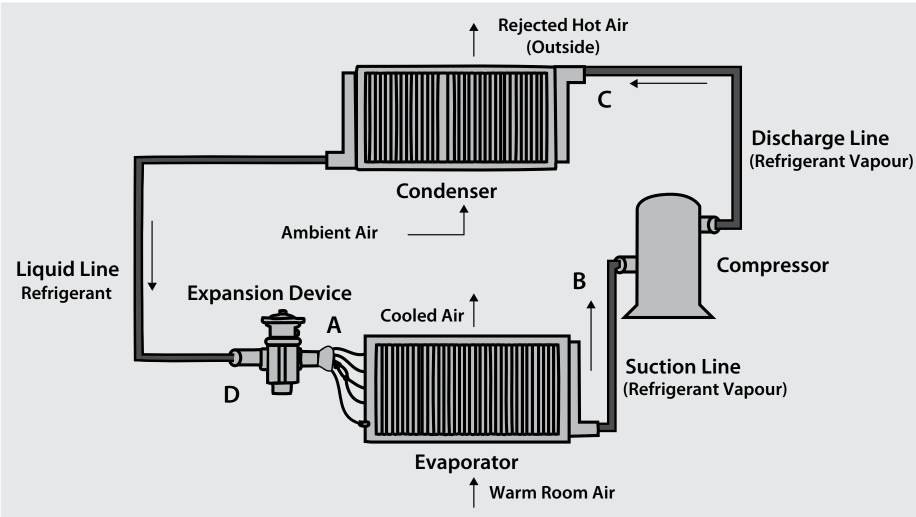

Fig. 4: Air Conditioner Basics

Heating Systems Types

Heating systems can be classified fairly well by the heating equipment type. The heating equipment used in commercial buildings include boilers (oil and gas), furnaces (oil, gas, and electric), heat pumps, and space heaters.

Boiler-based heating systems have steam and/or water piping to distribute heat. The heated water may serve preheat coils in air handling units, reheat coils, and local radiators. Systems that circulate water or a fluid are called hydronic systems. Additional uses are for heating of service water and other process needs, depending on the building type. Some central systems have steam boilers rather than hot water boilers because of the need for steam for conditioning needs (humidifiers in air-handling units) or process needs (sterilizers in hospitals, direct-injection heating in laundries and dishwashers, etc.).

The remaining heating systems heat the space directly and require little or no distribution. These include heat pumps and space heaters.

ECBC Requirements

The Energy Conservation Building Code (ECBC) covers several prescriptive requirements for HVAC systems including requirements for economizer, duct and pipe insulation, controls optimization, and system balancing.

Equipment Efficiency

HVAC equipment are required to meet or exceed minimum efficiency requirements mentioned in ECBC 5.2.2. Power consumption ratings for unitary air conditioners, split systems and packaged air conditioners are referred to BIS codes (See Table 2, 3 and 4). Cooling systems not included are referred to ASHRAE 90.1 – 2004. Single zone unitary systems are covered as well as multiple zone air and water systems. The more complex the system, the more requirements apply to that system: a single-zone unitary system has fewer requirements than a complex system made up of chillers, boilers, and fan coil units.

For natural ventilation requirements, buildings are required to follow the design guidelines provided for natural ventilation in the National Building Code of India, 2005 [ECBC 5.2.1].

Chiller Basics

Box 2

Overview

A chiller is essentially a packaged vapor compression cooling machine. The chiller rejects heat either to condenser water (in the case of a water-cooled chiller) or to ambient air (in the case of an air-cooled chiller). Fig. 6 shows the different loops of heat transfer in a chilled water system. A typical chiller is rated between 15 to 1000 tons (53 to 3,500 kW) in cooling power.

Water-cooled chillers incorporate the use of cooling towers which improve heat rejection more efficiently at the condenser than air-cooled chillers. For a water-cooled chiller, the cooling tower rejects heat to the environment through direct heat exchange between the condenser water and cooling air. For an air-cooled chiller, condenser fans move air through a condenser coil. As heat loads increase, water-cooled chillers are more energy efficient than air-cooled chillers.

Type of Chillers

Chillers are classified according to compressor type. Electric chillers for commercial comfort cooling have centrifugal, screw, scroll, or reciprocating compressors. Centrifugal and screw chillers have one or two compressors. Scroll and reciprocating chillers are built with multiple, smaller compressors.

- Centrifugal chillers are the quiet, efficient, and reliable workhorses of comfort cooling. Although centrifugal chillers are available as small as 70 tons, most are 300 tons or larger.
- Screw chillers are up to 40% smaller and lighter than centrifugal chillers, so are becoming popular as replacement chillers.
- Scroll compressors are rotary positive-displacement machines, also fairly new to the comfort cooling market. These small compressors are efficient, quiet, and reliable. Scroll compressors are made in sizes of 1.5 to 15 tons.

Chiller Efficiency

Chiller efficiency is rated in kW/ton (or COP) for larger machines and EER or COP for smaller machines (See Fig. 7). Efficiencies are measured at peak load and at IPLVs. The concept of the "most efficient chiller" makes sense only in context of the facility to be cooled. If a chiller operates 90% of the time at 60% load and very rarely at 90-100 % load, then the most efficient chiller for that application is the one with the lowest kW/ton at 60% load, regardless of peak load kW/ton.

In this figure, thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through five loops of heat transfer:

- Indoor air loop. In the left most loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- Chilled water loop. Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.
- Refrigerant loop. Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.
- Condenser water loop. Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.
- Cooling tower loop. The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

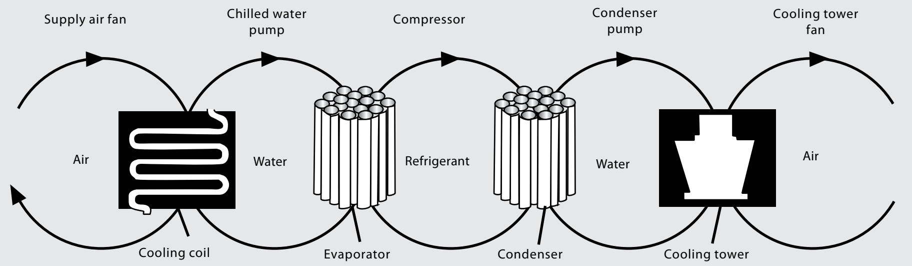

Fig. 6: Process Diagram of a Chilled Water Air-Conditioning System
(Source: E Source Cooling Atlas)

Chillers are getting more efficient
Thanks to design advances, new chillers are far more efficient than their predecessors, even though CFC -free refrigerants are less efficient than CFC refrigerants.

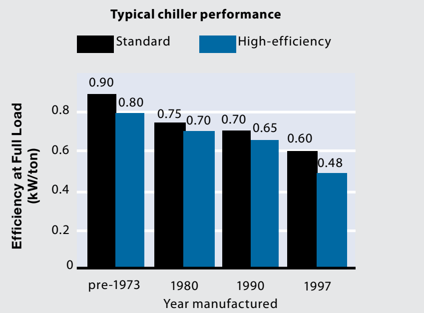

Fig. 7: Trend in Chillers Efficiency
(Source: E Source Cooling Atlas)

Top Issues to Consider When Buying a Chiller

Box 3

1. ***Plan ahead:*** It makes sense to start planning early to allow sufficient time to evaluate various scenarios and to identify a comprehensive system approach which best meets budgetary and facility needs.

2. ***Buy only as much chiller as you need:*** Reduce building loads and improve air-side distribution before sizing the chiller. Buying more cooling than you need not only costs money for equipment, it also increases monthly utility bills.

3. ***Use computer simulations to model the building throughout the year:*** Designs should include chillers that operate most efficiently under part-load conditions that most chillers spend most of their time satisfying (typically 40 to 70% load).

4. ***Maximize system efficiency:*** Cooling tower fans and condenser and chilled water pumps should be considered along with chiller energy consumption. Chiller efficiency increases with higher-temperature chilled water and lower-temperature condenser water (called lower "lift").

5. ***Select unequally sized machines for multiple chiller installations:*** Select one machine small enough to meet light loads efficiently and the others to meet larger loads efficiently. Start additional chillers only when the chillers that already are running are near full capacity.

6. ***Obtain competitive bids:*** There are often good reasons to stay with the same brand of chiller—maintenance, other equipment in the facility, existing service relationships, etc. However, for such a major purchase it makes sense to obtain bids from more than one manufacturer. All manufacturers have "sweet spots"—sizes at which their equipment is most efficient.

7. ***Monitor the system on an ongoing basis:*** Monitor compressor power and cooling load to determine whether or when attention will be needed, and to allow optimal system operation.

Table 2: Power Consumption Rating for Packaged Air Conditioners-Under Test Conditions

Cooling Capacity		Maximum Power Consumption in Watts	
Watts	Tons of Refrigeration	Water Cooled	Air Cooled
10,000	3	3,750	4,750
17,500	5	6,000	7,000
26,250	7.5	9,000	10,000
35,000	10	11,500	13,500
52,000	15	17,000	20,000

Source: Code No.: IS 8148: 2003

Table 3: Power Consumption Ratings for Unitary Air Conditioners – Under Test Conditions

Rated Cooling Capacity		Maximum Power
(kcal/h)	kW	Consumption (kW)
1,500	1.7	1.1
2,250	2.6	1.4
3,000	3.5	1.6
3,750	4.4	2.0
4,500	5.2	2.4
6,000	7.0	3.2
7,500	8.7	4.25
9,000	10.5	5.2

Source: Code No.: IS 1391 (Part-1): 1992 (amendment No. 2 Dec.2006)

Table 4: Power Consumption Ratings for Split Air Conditioners – Under Test Conditions

Rated Cooling Capacity		Maximum Power
(kcal/h)	kW	Consumption (kW)
3 000	3.5	1.7
4 500	5.2	2.6
6 000	7.0	3.4
7 500	8.7	4.5
9 000	10.5	5.4

Source: Code No.: IS 1319 (Part-2): 1992 (amendment No. 2 Dec.2006)

Controls

Controls determine how HVAC systems operate to meet the design goals of comfort, efficiency, and cost-effective operation. The ECBC requires that all HVAC equipment (>28 kW cooling and/or >7 kW heating capacity) be controlled with a timeclock capable of retaining programming for at least 10 hours, controlling varying schedules. [ECBC 5.2.3]

All heating and cooling systems are required to be temperature controlled [ECBC 5.2.3]. Each zone must be controlled by an individual temperature controller.

A temperature of dead band of 3°C (5°F) is required for equipment that supplies both heating and cooling. Thermostats must also prevent simultaneous heating and cooling. [ECBC 5.2.3.2].

Distribution System

Distribution systems carry a heating or cooling medium to condition the space. The two most common mediums are air and water. Air-based systems are often "forced air" because they use a fan to push the air from the furnace or air-conditioner through the duct work to the conditioned space. Water-based systems are often called hydronic, and steam-based systems are called steam systems, both of which use a piping system to circulate water or steam.

Forced hot air systems are more common than hydronic or steam heating systems because they cost much less to install. However, hydronic systems perform better than forced hot air because they leak less heat, are easier to insulate, make almost no noise, can be easily zoned and can provide more even temperatures. Hydronic systems also do a much better job of serving a radiant heating system.

The energy efficiency of a distribution system depends largely on the design and installation quality. Duct distribution systems are prone to the most significant losses—especially if the ducts are poorly sealed and/or installed outside the "thermal envelope" of the building (in an unconditioned attic, for example). Hydronic systems are typically installed within conditioned or "buffered" spaces like an unconditioned basement. In either case, it is important to insulate ducts/hot water pipes that are in unconditioned spaces.

Small commercial buildings typically use constant volume rooftop HVAC units, and a simple duct layout for circulating conditioned air. They are generally "un-engineered" systems and it is acknowledged by the construction industry that first-cost dominates construction practices. This leads to short cuts in construction practices and/or the use of lower-grade materials. In the case of duct work this shows up as sloppy connections, inexpensive leaky diffusers, and low-grade duct tapes. With respect to the HVAC equipment this leads to installations and service techniques that produce degraded equipment performance.

The ECBC requires insulating ducts and pipelines to reduce energy losses in heating and cooling distribution systems. Insulation exposed to weather is required to be protected by aluminum sheet metal, painted canvas, or plastic cover. Cellular foam insulation needs to be protected as described above, or be painted with water retardant paint.

Duct sealing: Duct sealing applies to supply and return duct work and to plenums that are formed by part of the building envelope. Proper duct sealing ensures that correct quantities of heated or cooled air is delivered to the space, and not be lost to unconditioned spaces or the outdoors through leaks in the ducts. This may be one of the most important conservation features to check. A properly sealed duct system will increase the comfort and lower the energy use of the building. Some areas to be sealed include:

- Longitudinal seams are joints oriented in the direction of air flow.
- Transverse joints are connections of two duct sections orientated perpendicular to airflow.
- Duct wall penetrations are openings made by any screw or fastener.
- Spiral lock joints in round and flat oval duct need not be sealed.

Pipe insulation: To minimize heat losses, the Code requires that piping of heating and cooling systems, (including the storage tanks,) must be insulated. The Code specifies required R-values of insulation for heating and cooling systems based on the operating temperature of the system. These are as shown in Table 5 and Table 6.

Air System Balancing

Air balancing is a small part of the building commissioning process. Commissioning involves the functional testing of all components of an HVAC system to insure proper operation. Commissioning

Table 5: Insulation of Heating Systems

Heating System	
Designed Operating Temperature of Piping	Insulation with Minimun R-value ($m^2 \cdot K/W$)
60°C and above	0.74
Above 40°C and below 60°C	0.35

Table 6: Insulation of Cooling Systems

Cooling System	
Designed Operating Temperature of Piping	Insulation with Minimun R-value ($m^2 \cdot K/W$)
Below 15°C	0.35
Refrigerant Suction Piping	
Split System	0.35

is a systematic process of verification and documentation—from the design phase to a minimum of one year after the construction—that all systems perform in accordance with design documentation and intent, and in accordance with the operational needs. The air-balancing portion of the commissioning process is usually done at the completion of a new construction project.

Air balancing should verify damper operation and adjust settings to deliver the designed airflow to each zone. It is important that some balancing be done prior to occupancy for several reasons. Some equipment has minimum airflow requirements across the coils to avoid compressor damage. Generally before project acceptance the building owner would like to know that comfort conditions could be maintained in the building before occupancy, particularly in the warmer and cooler months. This does not necessarily need to be a detailed room-by-room investigation. The total supply, return, and outside airflow quantities should be measured for each air handling system. A detailed balance is often done before occupancy because it is much easier to do measurements when the building is unoccupied.

The ECBC requires that air systems be balanced in a manner to first minimize throttling losses; then for fans > 0.75 kW (1.0 HP) the fan speed needs to be adjusted to meet design flow conditions. [ECBC 5.2.5.1.1]. Refer Box 4 for more information on air handling units.

Air Handling Unit Concepts

Box 4

Overview

On an annual basis, continuously operating air distribution fans can consume more electricity than chillers or boilers, which run only intermittently. High-efficiency air distribution systems can substantially reduce fan power required by an HVAC system, resulting in dramatic energy savings. Because fan power increases at the square of air speed, delivering a large mass of air at low velocity is a far more efficient design strategy than pushing air through small ducts at high velocity. Supplying only as much air as is needed to condition or ventilate a space through the use of variable-air-volume systems is more efficient than supplying a constant volume of air at all times.

The largest gains in efficiency for air distribution systems are realized in the system design phase during new construction or major retrofits. Modifications to air distribution systems are difficult to make in existing buildings, except during a major renovation.

Most of the air in commercial buildings is recirculated (returned) through the space. Only about 10 percent is exhausted and replaced with outside air.

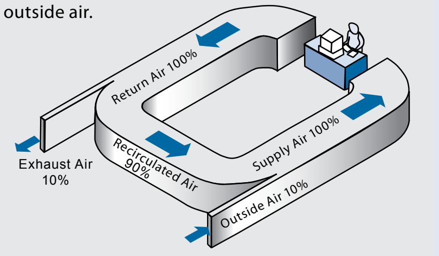

Fig. 8: Air Flow and its Make Up
(Source: E Source Cooling Atlas)

Design options for improving air distribution efficiency include:

- Variable-air-volume (VAV) systems
- VAV diffusers
- Low-pressure-drop duct design
- Low-face-velocity air handlers
- Fan sizing and variable-frequency-drive (VFD) motors
- Displacement ventilation systems.

Air-handling systems deliver fresh outside air to disperse contaminants and provide free cooling, transport heat generated or removed by space-conditioning equipment, and create air movement in the space also being served, deliver heated or cooled air to conditioned air to conditioned spaces (See Fig. 8). Passive or natural air transport systems have the highest efficiency, and successful, modern examples of this approach are steadily accumulating. For buildings that require mechanical ventilation, innovative design approaches and a methodical examination of the entire air system can greatly improve efficiency and effectiveness.

Air-handling efficiency: The energy required to move air is:

$$\text{Energy} = \frac{\text{Flow x Pressure x Duty Factor}}{\text{Efficiency}}$$

All four of these factors can be manipulated to reduce the energy consumption of the system.

Flow: Air flow has a dominant effect on energy consumption because it shows up twice in the energy equation: as the first term and as a squared function in the second term (pressure).

The energy required to move air through a ducted system increases with the cube of the flow rate. This important relationship, known as the "cube law," points to a meticulous and comprehensive examination of required flow as the start of designing an efficient air-handling system.

Pressure: The pressure a fan must work against depends on two primary factors: the flow and duct design features such as diameter, length, surface treatment, and impediments such as elbows, filters, and coils. Typical pressure losses are on the order of 2 to 6 inches water gauge (wg); an efficient system operates at less than 1.5" wg.

Duty factor: A fan's duty factor is the number of hours per year that it operates, sometimes presented as a percentage. Many large fans spin at full speed continuously (8,760 hours per year). Using simple or complex controls, duty factors can often be reduced to about 3,000 hours per year or less by limiting fan operation to occupied periods.

Efficiency: The mechanical efficiency of the fan and its drive system, can typically be raised from the 40 to 60% range to the mid - 80 % range.

Building Commissioning and System Balancing

Box 5

Overview (US DOE, 2008)

Building commissioning is a systematic process of ensuring that a building performs in accordance with the design intent, contract documents, and the owner's operational needs. Due to the sophistication of building designs and the complexity of building systems constructed today, commissioning is necessary, but not automatically included as part of the typical design and construction process. Commissioning is critical for ensuring that the design developed through the whole-building design process is successfully constructed and operated.

Building commissioning includes the following:

- Systematically evaluating all pieces of equipment to ensure that they are working according to specifications. This includes measuring temperatures and flow rates from all HVAC devices and calibrating all sensors to a known standard.
- Reviewing the sequence of operations to verify that the controls are providing the correct interaction between equipment.

In particular, building commissioning activities include:

- Engaging a commissioning authority and team
- Documentation
- Verification procedures, functional performance tests, and validation
- Training.

Commissioning HVAC systems is even more important in energy-efficient buildings because equipment is less likely to be oversized and must therefore run as intended to maintain comfort. Also, HVAC equipment in better performing buildings may require advanced control strategies. Commissioning goes beyond the traditional HVAC elements. More and more buildings rely on parts of the envelope to ensure comfort.

Commissioning includes evaluating the building elements to ensure that shade management devices are in place, glazing is installed as specified, air-leakage standards have been met—these are the static elements of the building. Commissioning can also evaluate other claims about the construction materials such as Volatile Organic Compounds (VOCs) emission content and durability.

Continuous commissioning ensures that the building operates as efficiently as possible while meeting the occupants' comfort and functional needs throughout the life of the building. It is worth noting that Continuous commissioning is different from building operation and maintenance.

Benefits of building commissioning include:

- Energy savings and persistence of savings
- Improved thermal comfort with proper environmental control
- Improved indoor air quality
- Improved operation and maintenance with documentation
- Improved system function that eases building turn-over from contractor to owner.

Commissioning Cost

Building owners are finding that the energy, water, productivity, and operational savings resulting from commissioning offset the cost of implementing a building commissioning process. Recent studies in the U.S. indicate that on average the operating costs of a commissioned building range from 8 to 20% below that of a non-commissioned building. The one-time investment in commissioning at the beginning of a project may result in reduced operating costs that will last the life of the building.

The cost of commissioning is dependent upon many factors including a building's size and complexity, and whether the project consists of new construction or building renovation. In general, the cost of commissioning a new building ranges from 0.5% to 1.5% of the total construction cost. For an existing building, never before commissioned, the cost of retro-commissioning can range from 3% to 5% of the total operating cost. For HVAC and Control Systems, cost of commissioning ranges from 1.5 to 2.5% of mechanical system cost.

Testing, Adjusting, and Balancing (Nolfo, 2001)

Testing, Adjusting, and Balancing (TAB) refers to the process whereby a system or a component must first be tested to determine its operating state, then adjusted, and finally balanced to produce the desired results and performance in accordance with the design documents. The primary objective of carrying out the TAB function is to help the system to work properly by balancing the fluid flows to their correct proportion and in the process identify design and installation errors, if they exist, to ensure the performance of the HVAC system. Some key issues that a firm undertaking TAB functions must address are listed below:

1. ***Identification of a Traverse Location:*** To ensure that accurate measurements of airflows inside ducts can be obtained. This information is then used by HVAC control system to regulate the flow of air and optimize system operation.

2. ***Determining Outside Air Quantity:*** If supply and return airflow are measured accurately, outside airflow could easily be determined from the following Equation:

   $$Q_{supply} = Q_{return} + Q_{outside}$$

3. ***Duct Leakage:*** A good duct traverse can also be used to determine duct leakage.

4. ***Determining Pump Flow:*** Like measuring airflow on a fan, pump flow measurements can sometimes be suspect. Most TAB technicians will determine flow by measuring the differential pressure between pump discharge and pump suction. By using the manufacturer's pump curve and the pressure measurements, the technician can estimate total flow.

5. ***Sizing Balancing Valves:*** A balancing device is similar to a control device and should be sized accordingly. Balancing devices should be sized based on the design pressure difference at that part of the system.

6. ***Fan and Pump Curves:*** Manufacturers' performance curves are graphic representations of measured performance under laboratory conditions. The combination of field measurements and associated calculations can be plotted on the fan curve. If accurate, careful, thoughtful measurements can be taken, the measured data usually matches the published data within the normal tolerances of the performance tests.

Indoor Environment Quality

Role of Temperature and Humidity

The influence of the indoor thermal environment on thermal comfort is widely recognized. Even in laboratory settings with uniform clothing and activity levels, it is not possible to satisfy more than 95% of occupants by providing a single uniform thermal environment (Fanger 1970) because thermal preferences vary among people. Despite the significant attention placed on thermal comfort by building professionals, dissatisfaction with indoor thermal conditions is the most common source of occupant complaints in office buildings (Federspiel 1998).

Air temperature and humidity also influence perceptions of the quality of indoor air and the level of complaints about non-specific building-related health symptoms (often called sick building syndrome symptoms). Relative humidities below approximately 25% have been associated with complaints of dry skin, nose, throat, and eyes. At high humidities, discomfort will increase due substantially to an increase of skin moisture. The upper humidity limits of ASHRAE's thermal comfort zone vary with temperature from approximately 60% RH at 26°C to 80% RH at 20°C.

Sick Building Syndrome

The most common health symptoms attributed by building occupants to their indoor environments are non-specific health symptoms that do not indicate a specific disease, such as irritation of eyes, nose, and skin, headache, fatigue, chest tightness, and difficulty breathing. These symptoms are commonly called sick building syndrome symptoms. In some buildings, the symptoms coincide with periods of occupancy in the building. Buildings within which occupants experience unusually high levels of these symptoms are sometimes called "sick" buildings. On average, occupants of sealed air-conditioned buildings report more symptoms than occupants of naturally ventilated buildings. Most studies have found that lower indoor air temperatures are associated with fewer non-specific health symptoms. Symptoms have been reduced through practical measures such as increased ventilation, decreased temperature, and improved cleaning of floors and chairs (Mendell 1993).

Impact of IEQ on Health and Productivity

Some characteristics of the indoor environment, such as temperatures and lighting quality, may also influence worker performance without impacting health. In many businesses, such as office work, worker salaries plus benefits dominate total costs; therefore, very small percentage increases in productivity, even a fraction of one percent, are often sufficient to justify expenditures for improvements that increase productivity.

In a critical review and analysis of existing scientific information, Fisk and Rosenfeld (1997) have developed estimates of the potential to improve productivity in the U.S. through changes in indoor environments. The review indicates that building and HVAC characteristics are associated with prevalences of acute respiratory infections and with allergy and asthma symptoms and non-specific health symptoms. From analyses of existing scientific literature and calculations using statistical data, the estimated potential annual nationwide (for the US) benefits of improvements in IEQ include the following:

- A 10% to 30% reduction in acute respiratory infections and allergy and asthma symptoms.
- A 20% to 50% reduction in acute non-specific health symptoms (commonly referred to as Sick Building Syndrome)
- A 0.5% to 5% increase in the performance of office work.
- Associated annual cost savings and productivity gains of $30 billion to $170 billion.

Tips to Ensure Good IEQ While Designing and Commissioning HVAC systems

Assure Quality of Intake Air

Assuring adequate quality of intake air is essential. Outside air intakes should not be located near strong sources of pollutants such as combustion stacks, sanitary vents, busy streets, loading docks, parking garages, standing water, cooling towers, and vegetation. The outside air intake must be separated sufficiently from locations where ventilation air is exhausted to prevent significant re-entrainment of the exhaust air. Incoming air should be filtered to remove particles. The recommended minimum particle filtration efficiencies vary among IAQ and ventilation standards and guidelines.

Maintain Min. Ventilation Rates

The minimum ventilation rates specified in the applicable code requirements should be maintained or exceeded. The HVAC system should be designed so that rates of outside air intake can be measured using practical measurement techniques. In buildings with variable air volume (VAV) ventilation systems, special controls may be needed to ensure minimum outside air intake into the AHU is maintained during operation.

Recirculation of Indoor Air

Recirculation of indoor air is standard practice in some countries, such as India, and discouraged in other countries such as those of Scandinavia. When air is recirculated, it should be filtered to remove particles. However, filters are often used only to prevent soiling and fouling of the HVAC equipment. These filters have a very low efficiency for respirable-size particles (smaller than 2.5 micrometers). Use of filters that exceed minimum requirements is an option to improve IAQ, often with a small or negligible incremental cost.

Maintenance of the HVAC System

Regular preventative maintenance of the HVAC system is necessary to assure proper delivery of outside air throughout the building and to limit growth of microorganisms in the system. Elements of periodic maintenance that are important for maintaining good IEQ include changing of filters, cleaning of drain pans and cooling coils, checks of fan operation, and checks of operation of dampers that influence air flow rates.

Integrated Approach to IEQ

The IEQ performance of a building also depends on the interactions among building design, building materials, and building operation, control, and maintenance. Therefore, an integrated or whole building approach is recommended to maximize IEQ. Such an integrated approach may focus on the following:

- IEQ targets or objectives;
- Occupancy and indoor pollutant sources and pollutant sinks and their variation over time;
- Building and HVAC design.

Hydronic System Balancing

A balanced hydronic system is one that delivers even flow to all the devices on that piping system. Each component has an effective equal length of pipe on the supply and return. And when a system is balanced, all of the pressure drops are correct for the devices. When that happens, the highest efficiencies are possible in the system, which translates into reduced pumping costs.

ECBC requires hydronic systems to be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller must be trimmed or pump speed adjusted to meet the design flow conditions. [ECBC 5.2.5.1.2] The ECBC allows the following exceptions to the hydronic system balancing requirement:

- Pump motors of 7.5 kW (10 HP) or less, and
- When throttling results in no greater than 5% of the nameplate HP draw, or 2.2 kW (3 HP), whichever is greater.

Technical Tips for Efficient HVAC System

Box 7

Reduce cooling load

- About half of the cooling load in an inefficient building comes from solar gain and lighting, so careful treatment of these two sources of heat gain can yield impressive savings.
- Well-designed building form and orientation can maximize daylighting and natural ventilation, while minimizing unwanted solar gain and the need for electric lighting.
- Appropriate envelope materials, including advanced solar control glazing, insulation, venting, and light-colored façades and roofs can significantly reduce cooling loads and enhance comfort.
- Landscaping and vegetation can cost effectively reduce heat gain and provide evapotranspiration cooling while enhancing esthetics.
- Well-designed load reduction measures may allow cooling or heating equipment to be downsized or even eliminated, thus reducing capital cost as well as operating cost.

System sizing

- Operating cost for an HVAC system of a given size will not fall linearly with cooling load, because most of the cooling systems are less efficient at low loads than they are in upper range of their capacity. To fully capture operating cost savings as well as the capital cost savings from the load reduction, a smaller HVAC system matched carefully to the load profile should be installed or retrofitted. At the very least, this should mean fewer tons of cooling plant. In some cases it may mean smaller ducts, pipes, pumps, fans, and other auxiliaries.
- In addition to reducing energy consumption and costs, right sizing of HVAC Systm:
  - Reduces noise.
  - Lowers first costs for both equipment and installation.
  - Reduces equipment footprint.
  - Controls moisture and improve indoor air quality.

Chillers

- Chiller efficiencies have improved in recent years because of better heat transfer (more surface area through more and/or enhanced tubes). Keep these surfaces clean to maintain high efficiency, either through automatic or annual cleaning. A control system can monitor heat exchanger approach temperatures and sound an alarm when increasing temperatures indicate fouling.
- Select the chiller and cooling systems which minimize energy consumption of the building throughout the year. Most chillers spend most hours at 40 to 70 percent load, not at design conditions.

Air handing units

- An efficient air system works from the end-user upstream. Reducing flow requirements by minimizing internal and external heat gains offers potentially deep cube-law savings.
- Matching air supply continuously to cooling and ventilation loads using a Variable Air Volume (VAV) system provides the best system efficiency.
- Arranging air zones logically is key to making VAV systems efficient and effective. VAV boxes should be grouped to serve areas with similar cooling and ventilation loads (for example, combine core offices for one zone, south perimeter offices for another, and so on).
- Measuring fan power is critical to ensure energy savings with VAV systems.
- Displacement air distribution can efficiently provide excellent air quality and heat removal by moving a large mass of air slowly, instead of conventional turbulent induction systems that move less air at higher speed.
- Exhaust air fans are a viable alternative to return air fans. They have lower power requirements, move less air, avoid redundancy, and expel their fan heat from the building.

Duct layout

- HVAC duct layout must have a good design that is planned early in the construction process and understood by the designer and HVAC contractor.
- The duct system must be properly installed with the correct amount of airflow. Every joint and bend in the duct system affects the efficiency of the system.
- The duct system must be air sealed, insulated and appropriately sized.

Operation and maintenance

- Maintain chilled water systems with DT up to 9°C to increase the overall energy efficiency of chilled water production and distribution.
- Incorporate variable speed drives for pumps and fans to efficiently meet partial load requirements.
- Use of thermal energy storage systems in places where cooling plays a major role in peak electricity demand and off peak grid energy rate is considerably lower than the peak time rate.
- Have demand control ventilation for high occupancy spaces. Use of CO_2 sensors in spaces that have varying people density loads.
- Plug leakages in ducts and plenums by sealing of all the joints. Ensure good duct work quality, workmanship, duct sealing, functionality of dampers, duct cleanliness and testing.
- Use building management system (BMS) to improve energy efficiency. It helps in optimizing the run time of equipment at desired levels of efficiency to maintain building inside temp, humidity, air quality etc within set limits.
- Reduce face velocities at coils to increase heat transfer efficiency and reduce condensate entrainment
- Deploy indoor air quality monitoring and controls system to monitor CO_2 and volatile organic compound levels.

Environmental Tips *(Source: USGBC, 2004)* **Box 8**

The lack of a direct relationship between the Global Warming Potential (GWP) and the Ozone Depletion Potential (ODP) creates a challenge in developing a rating system that allows the two environmental factors to be considered together, as they should be in evaluating the environmental impact of an HVAC system. In the absence of perfect or ideal refrigerant we should follow a 'trade-off' approach to identify a better combination of HVAC equipment and its refrigerants to facilitate optimum environmental impact in terms of GWP and ODP per unit of cooling capacity.

Refrigerant	ODP	GWP	Application
CFC-11	1	4600	Centrifugal chillers
CFC-12	0.82	10600	Freezers, chillers, air conditioners
HFC-410A	0	2000	Air conditioning
HCF-134a	0	1600	CFC-12 replacement
HCFC-123	0.012	120	CFC-11 replacement

Energy savings can be achieved by controlling the fluid flow rate in hydronic systems. Very often demand on these systems is not 100% of the design flow rate. Controls capable of reducing pump rates cut energy costs by modulating the flow to meet demand. The ECBC addresses Variable Flow Hydronic Systems [ECBC 5.3.2] in several ways. First, by requiring that pump flow rates be controllable to either 50% of the design or the minimum required by the equipment manufacturer for proper operation of the chillers or boilers. Second, the ECBC requires that circulation pumps ≥ 3.7 kW (5 HP) in water-cooled air-conditioning units or heat pumps contain a two-way automatic isolation valve to shut off the condenser water flow when the compressor is not operating [ECBC 5.3.2.2].

Thirdly, the ECBC requires pump motors in all hydronic systems ≥ 3.7 kW (5 HP) shall be controlled with variable speed drives [ECBC 5.3.2.3]. While throttling reduces the flow, the motor is still running at full speed and works even harder as it has to work against a restriction. By reducing the speed of the motor, the variable speed drive ensures reduction in energy consumption while maintaining the required flow.

Scale Control in Water Circuit

In a water-cooled air-conditioning system, heat is rejected from the refrigerant to the cooling water in the condenser. The impurities in the cooling water circuit get accumulated, and thus the scales and deposits are built up in the condenser tubes, creating scaling problems on the condenser heat transfer surfaces. This reduces the heat transfer efficiency of the condenser and thus increases chiller energy consumption. The ECBC requires [ECBC 5.2.6.2] use of soft water for condensers and chilled water systems to reduce scale formation.

Economizers

An economizer is a collection of dampers, sensors, actuators, and logic devices that together decide how much outside air to bring into a building (See Fig. 9). When the outdoor temperature and humidity are mild, economizers save energy by cooling buildings with outside air instead of by using refrigeration equipment to cool recirculated air.

A properly operating economizer can cut energy costs by as much as 10 percent of a building's total energy consumption, depending mostly on local climate and internal cooling loads. ECBC requires an economizer for cooling systems over 1,200 liters/sec (2,500 cfm) fan capacity and with a cooling capacity > 22 kW [ECBC 5.3.1.1].

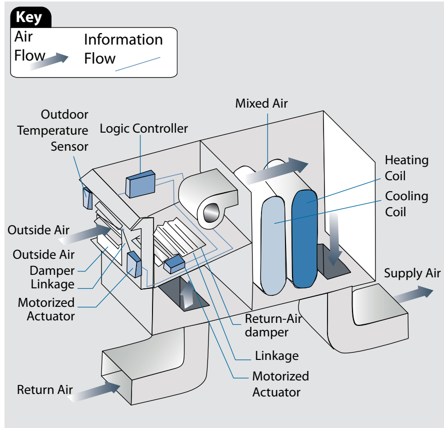

Fig. 9: The Components of an Economizer
(Source: E Source Cooling Atlas)

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