PDHonline Course M149 (4 PDH)

HVAC Design Aspects: Choosing A Right System

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HVAC Design Aspects

Choosing A Right System "Central V/s Compact Systems"

Course Content

PART 1 AIR-CONDITIONING CONSIDERATIONS

Heating, Ventilating, and Air Conditioning (HVAC) systems play a vital role in the successful operation of a facility. They are responsible for maintaining comfort conditions day in and day out. HVAC systems are of great importance to architectural design efforts for *four main reasons*.

1. First, these systems often require substantial floor space and/or building volume for equipment and distribution elements that must be accommodated during the design process.
2. Second, HVAC systems constitute a major budget item for numerous common building types.
3. Third, the success or failure of thermal comfort efforts is usually directly related to the success or failure of a building's HVAC systems.
4. Last, but not least, maintaining appropriate thermal conditions through HVAC system operation is a major driver of building energy consumption.

HVAC System Evolution

The first step in selecting a HVAC system is to determine and document constraints dictated by performance, capacity, available space, budgets and any other factors important to the project. This usually starts with a formal meeting with an architect/owner and understanding his or her requirements.

Owner's Needs

If the architect is a creator, the customer is a king and his needs and requirements must be met. Depending on the customer goals, the building and its HVAC requirements have to be designed accordingly. For example take an example of multi-storey office building. The complete building may have either a single owner or multiple owners. A single owner normally has a preference for a central plant, as the quality of air conditioning is far superior and life expectancy is higher. The operation and maintenance costs are also lower than a floor-by-floor system. In addition the owners can opt for an intelligent building by incorporating a building management system (BMS). This will enable the owner to derive benefits of optimal utilization of the air conditioning plant.

A multiple owner facility requires a system, which provides individual ownership and energy billing for which a floor-by-floor air conditioning system using packaged units or split units is most suited subject to economics of space and aesthetics.

Another important requirement is the normal working hours of the user/users. Some users may have different working hours or different timings. Some areas such as computer rooms may need 24-hour air conditioning. Other areas may have special design requirements. Due to such multiple requirements many engineers prefer a “hybrid system” which is a combination of a central plant and packaged units/split units. For example, a hotel may use packaged unitary air conditioners (or fan coil units served with air-water central system) for the individual guest rooms, roof top units for meeting rooms/restaurants, and a central plant system for the lobby, corridors and other common spaces. Such systems offer high flexibility in meeting the requirement of different working hours and special design conditions.

While HVAC engineer manages the system design the architect retains control of the complete building product. The type of system selected is determined by HVAC designer's knowledge of systems. Architect must also understand the basics, system objectives, the role of key system components, the type of systems that are available and what such systems can and cannot accomplish.

Most customers may not understand HVAC design aspects; their benefits and limitations and it is the architect’s/HVAC engineer's responsibility to guide and advise the best option. For HVAC engineer the customer may be an architect whose customer may be the building owner.

What Influence HVAC design?

Investment in a building project entails significant capital investment and associated costs over the economic life of the project. It is a mistaken notion that the buildings costs have to be expensed once. The buildings like any other industry have running expenses in a way that they consume lot of energy and require water & disposal facilities that accounts for significant recurring costs. The HVAC systems often are very large and are responsible for a large portion of a building’s first cost and operating cost.

Every building is unique. For instance residential apartments, shopping complex, office complex, hospital, hotel, airport or industry; all have different functional requirements, occupancy pattern and usage criteria. The geographical location of the building, ambient conditions, indoor requirements, building materials, dimensional parameters, aesthetic requirements, noise and environment issues need careful evaluation. The HVAC design and selection must be customized to meet all these requirements.

Each solution begins with an assessment of the owner's business needs for HVAC, architect's vision, requirements of the facilities manager, combined with a review of the HVAC system itself, be it existing or planned.

Examples of few common restrictions are highlighted below that can change the course of design:

Constraints	Consequences
Space is at premium	Less mechanical room space is available to house the equipments. Small, sleek, ceiling or roof-mounted equipments may be desired in place of big air-handling units.
Water is scarce	Only air-cooled equipment is permitted
Aesthetics are prime importance	No equipment should be visible or should suitably blend with environment
Building heights are low	Inadequate spaces to run ducts, probably the system shall be best suited to air-water fan coil option
Electrical rates are high	Energy efficient design/equipments shall be primary goal
Noise control is important	Sufficient attenuation shall be required
Usage patterns are unique	Zone control or individual control is needed
Stringent codes & standards requirements	Say smoke removal systems, integration with fire systems, equipment location, Legion-alla disease etc…
Precise indoor environment	Equipment and control design must respond to close tolerances on temperature/humidity,

Constraints	Consequences
	cleanliness, indoor air quality etc.
Environmental constraints	Use of non-ozone depleting refrigerants, or may be the ambient is very corrosive/contaminated or no untreated exhaust from building is permitted
Schedules are tight	Desired/interface data may not be available or firmed up
Building retrofitting, expansion or refurbishment. Existing HVAC equipment/design must be utilized as far as possible while creating new plans	Requires sound knowledge of available technology that could be adaptable to existing equipment, ductwork and piping. Integrating is required to fit new equipment into existing spaces.

The above is just a random sample; there are many other factors that need to be coordinated.

Bringing all of these constraints to a common solution requires skillful evaluation of HVAC options, scrutinizing them and ultimately selecting the best alternatives for optimum results and maximizing the building's value.

PART 2 OVERVIEW OF CENTRAL & COMPACT SYSTEMS

The choice of an HVAC system, whether central or compact floor-by-floor is a critical decision required to be undertaken during preliminary or conceptual phase

HVAC systems are available in a wide variety such as:

- ✓ Chilled water central system (central systems)
- ✓ Direct expansion systems (which are also called compact units or local units or unitary units of floor by floor units such as heat pump, package, split or roof top units)

Selecting the best system or combination of systems for a particular building must be carefully considered and researched by the consulting engineer in close coordination with the architect, electrical and plumbing consultants and owners, before finalizing the basic HVAC system design and building layout.

Detailed engineering, duct and pipe layouts, shaft locations and sizes, plant room dimensions etc, can follow in a systematic manner before construction work begins.

HVAC system components may be grouped into three functional categories: source components, distribution components, and delivery components.

1. Source components provide or remove heat or moisture. This includes refrigeration chiller for cooling and boiler or hot water generator for heating.
2. Distribution components convey a heating or cooling medium from a source location to portions of a building that require conditioning. This includes air-handling units (AHU), fan coil units, radiators etc.
3. Delivery components serve as an interface between the distribution system and occupied spaces. This includes diffusers, grilles, registers etc.

Active HVAC systems may be designed to condition a single space (or portion of a space) from a location within or directly adjacent to the space. Such a system is known as a local system. Local systems (also known as compact systems or unitary systems) often incorporate all the above three functions in a single piece of equipment.

Systems that are intended to condition multiple spaces from one base location are called central systems. Such systems usually have distinctly different equipment elements for each function.

CENTRAL SYSTEMS

Central systems are defined as those in which the 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.

Heating in these systems is often generated in a boiler and is distributed in hot water or steam piping.

Central heating, ventilation, and air conditioning (HVAC) systems regulate temperature, ventilation, and humidity levels to ensure the physical comfort of occupants in most commercial and industrial buildings. Central HVAC systems come in a variety of different types such as all-air systems, constant volume, variable volume, dual duct, air-water and all-water systems. All-air systems are the most commonly used central HVAC systems because of its simplicity and effective control. Escalating concerns for acceptable indoor air quality may suggest the increasing use of all-air systems.

Unfortunately, air is not an efficient heat transfer medium, thus, all-air systems may require extensive building volume for ductwork distribution. In situations where ductwork cannot be reasonably accommodated in the building design, air-water or all-water approaches may be considered.

Brief Overview

A central or built-up HVAC system is custom-designed for a building. The components of a central system fall into two broad categories: "primary components" and "secondary components."

Primary Components

Primary components, often called "central plant" equipment, convert energy from fuel or electricity into heating and cooling energy in the form of hot water, steam, chilled water or refrigerant:

- Refrigeration equipment options include water chillers and direct-expansion (DX) equipment.

  Chilled water chillers use a refrigeration cycle to cool water to 42 to 45º F for pumping to chilled water-cooling coils. Air is then blown over the chilled water-cooling coils to provide cool air to the conditioned space. DX systems also use a refrigeration cycle, but distribute refrigerant directly to DX cooling coils. High-efficiency chillers can produce chilled water using less than 0.60 kW per ton of cooling capacity.

  A refrigeration system must also reject the heat that it removes using a water cooling or air-cooling. Water-cooled chillers require condenser water (CW) pumps and cooling towers to reject heat. Air-cooled chillers reject heat in air-cooled condensers, which use significant fan power.

  Chillers could be reciprocating compressors (up to 200 tons), screw compressors (100 to 750 tons) and centrifugal compressors (200 to 2000 tons).

Centrifugal chillers	150-2000 TR
Water cooled screw chillers	100-750 TR
Air cooled screw chillers	100-750 TR
Water cooled reciprocating chillers	30-200 TR
Air cooled reciprocating chillers	10-200 TR
Steam fired absorption chillers	150-2000 TR
Direct fired absorption chillers	300-2500 TR

The centrifugal compressors offer the best peak load efficiency while screw chillers give better part load and the off-design performance.
They also offer turn down ratios up to about 20% by employing capacity control methods like VSD for centrifugal chillers and modulating/stepped slide valve control for screw chillers. Semi hermetic and open type reciprocating chillers have stepped capacity controls, however, the part load efficiency of a reciprocating machine is lower than its full load efficiency.

- Boilers produce hot water or steam to distribute to heating coils. Though hot water is the most common fluid, steam is sometimes used because of its high heat per unit volume. Both types of boiler are typically 80-85 percent efficient. Gas is the most common fuel.
- Pumps circulate chilled water, hot water, and cooling tower water. Centrifugal pumps, driven by electric motors, are most common. When water flow varies with changing loads, pumps can be efficiently controlled with variable speed (frequency) drives (VFDs).

Secondary Components

Secondary components, sometimes called "system" equipment, deliver heating and cooling to occupied spaces:

- Air handling equipment may be centrally located or several air handlers may be distributed throughout a facility. Most facilities use modular air handlers, but built-up air handlers may be found in larger facilities. All air handlers adjust air temperature and humidity and remove dust and other particles from air before distributing it to occupied spaces. This is accomplished through a series of coils, filters, humidifiers, fans, and dampers.

Ducts, plenums and shafts distribute air. Plenums above suspended ceilings are frequently used for return air. Large multi-story facilities often use shafts built into the structure for supply air return air and outside air.

- Terminal units are devices at the end of a duct or pipe that transfer desired heating or cooling to the conditioned space. Some types commonly used with central HVAC systems include fan-coil units, induction units, and convectors.
- Controls are used to make components work together efficiently. They turn equipment on/off, adjust energy outputs (chillers, boilers), adjust flow rates (fans, pumps, coils), adjust temperatures (air, water, thermostats in conditioned spaces), and adjust pressures (ducts, pipes, conditioned space).

Refrigerants in chiller systems are generally chlorofluorocarbons (HFCs and HCFCs). CFCs can no longer be used due to environmental concerns of ozone depletion under Montreal & Kyoto protocol. HCFC 22 shall be phased out by the year 2020 and majority of new central installations are with refrigerant HFC-134a. The table below provides a brief compilation of current and future refrigerants for various types of air-conditioner packages.

Equipment Type	Traditional Refrigerant	Replacement Refrigerants
Rotary Screw- Chiller	HCFC-22	R407C, HFC-134a
Scroll Chiller	HCFC-22	R407C, R-410A
Reciprocating Chiller	HCFC-22	R-407C, R-410A
Absorption Chiller	R-718 (water)	R-718
Centrifugal Chiller	CFC-11, CFC-12	HFC-134a, HCFC-123
Packaged Air Conditioners	HCFC-22	R-407C, R-410A
Heat Pump	HCFC-22	R407C, R-410A
PTAC, PTHP	HCFC-22	R-407C, R-410A
Room Air Conditioning	HCFC-22	R-407C, R-410A

System Types

Most facilities use variations and combinations of a few basic approaches, and their HVAC systems are frequently described according to how they use air, water or both to distribute heating and cooling energy to the space; i.e., all-air, all-water or air-water systems. Common system types are discussed below. (Note: constant volume and dual-duct systems are inefficient.

- Constant Volume (CV) and CV Terminal Reheat systems accomplish cooling and heating by varying the supply air temperature and keeping the air volume constant. Air gets heated or cooled and humidified to the desired level, and the constant-volume supply fan moves this conditioned air to the zone*. The system works well and maintains comfortable conditions in spaces with uniform heating and cooling requirements.

If heating and cooling requirements are not uniform dividing the space into several zones and using several single-zone systems, or a dual-duct/ multi-zone system can achieve better temperature control. Systems serving multiple zones must meet differing requirements. One way to do so is with a constant-volume terminal reheat system. To meet differing heating or cooling loads in each zone, an electric reheat or a hot water heating coil reheats the constant volume cool supply air just before it enters the room. The reheat system is energy inefficient and is not recommended.

- Variable Air Volume (VAV) and VAV with Terminal Reheat system changes the quantity of air supplied to a zone rather than the temperature of cool air in response to changes in loads. As a zone's cooling load decreases, a damper in its VAV control box starts to close, reducing the supply of cool air. A VAV system saves fan energy as a result of this reduced airflow. Maximum savings are achieved using variable frequency drive (VFD) to control the fan speed/output.

  A cooling-only VAV system works well in areas where cooling load is quite fluctuating say for conference room (load fluctuate due to occupancy) or exterior zone of the building (load fluctuate due to solar orientation). If a VAV system is used to serve zones at the perimeter, which require winter heating, hot water coils or electric heater in the VAV box reheat the air. The reheat is only applied in situations where the box has already reduced the cool supply air to the minimum position required for ventilation.

- All-water Systems and Air-Water Systems: In a typical hydronic (all-water) system, heated and/or cooled water is pumped from the central plant through pipes to a terminal unit in each zone where room air passes through is heated or cooled by a coil. There are two common piping arrangements: two-pipe and four-pipe systems. Combining a hydronic system with an air system provides clean, comfortably humidified outside air from a central air system that has been heated or cooled by hydronic terminal units in each zone.

* *A zone is defined as a region of a building that requires separate control. For example, it may not be possible to successfully condition an interior space of the building and perimeter spaces covered with glazing or below ground office area and glass enclosed atrium from a single control point. The dynamics of the thermal loads in the two spaces are not compatible. To provide comfort, each space must be provided with its own control -- the climate control system must be designed to accommodate separate thermal zones. Thermal zones must be established very early in the HVAC system design process.*

Typical Applications

Commercial buildings commonly choose several types of systems based on the space conditioning needs of different systems. A constant-volume system might cool the interior, which has relatively uniform cooling requirements while a VAV system conditions perimeter areas, which have variable requirements. Where precision control is required (e.g., laboratories, precision electronic industry or hospital operating rooms), custom single-zone air handlers may be used. In large facilities, which have widely varying requirements, flexibility is extremely important. Table below shows some typical applications for various types of systems.

Typical Applications of Central HVAC System

Building Type	Type of System
Office Buildings (low rise)	VAV; or CV in the core, and hydronic at perimeter
Office Buildings (high-rise)	Central CV system for core and VAV or hydronic at perimeter
Department Stores	Multiple CV or VAV air handlers
Universities	CV, VAV or combined air-water systems at each building
Schools	CV or VAV air handlers serving individual common areas, and hydronic or combined air-water systems in classrooms
Hospitals	Separate CV systems for critical areas; CV or VAV for common areas; hydronic and combined air-water in patient rooms
Hotels	VAV for common areas like lobbies, restaurants, ball rooms & banquets; fan-coil units in guest rooms for individual temperature and humidity control
Assembly, Theatres	Multiple VAV air handlers
Libraries, Museums	Multiple CV air handlers, with precise humidity and temperature control

LOCAL COMPACT SYSTEMS

Local compact systems are known by various names viz. unitary systems, packaged systems or individual system. These systems do not use chilled water as an intermediate cooling medium. The cooling is delivered directly to the supply air in a refrigerant evaporator coil. These units are sometimes also referred as “Direct Expansion,” or DX, units.

These typically consist of pre-assembled, off-the-shelf equipment combining heating, cooling, and fan sections. Local systems include rooftop units or split systems, which have direct-expansion cooling coils, and are generally have air-cooled heat rejection remote from the cooled space.

These systems are used in most classes of buildings, particularly where low initial cost and simplified installation are important, and performance requirements are less demanding. Packaged and unitary air-conditioning systems however consume a large portion of the energy used in these buildings.

Brief Overview

Local air-conditioning systems are self contained factory made assemblies consisting of a heat and/or cool source (depending on climate and occupancy demands), a fan, a filter, and control devices. The most common local air-conditioning system is a small window air-conditioning unit or large rooftop system. Usually these systems are air-cooled type. The most common types of unitary HVAC equipment are described below:

Window Units

A window unit is an encased assembly designed primarily for mounting in a framed or unframed opening in a vertical building enclosure element and takes their name from the face that they are often installed in window openings. These units are designed for comfort cooling and to provide delivery of conditioned air to a room without ducts.

As the unit contains both an exterior heat exchange element (condenser) and an interior heat exchange element (evaporator) it must be located partly inside and partly outside of the building. This location can lead to several architectural concerns including aesthetics, noise, space utilization, and leakage (infiltration and water). Heating may be provided by electric resistance coils or by a reversible refrigeration cycle.

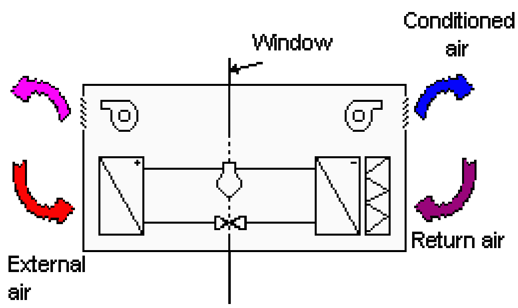

Figure: Typical Window Unit

Split Units

In a split system, the two sides of the unit shown in the figure (typical window unit above) are separated, with refrigerant piped between them (hence the name “split”).. A condensing unit, consisting of the refrigerant compressor, the condensing coil, and the condensing fan, is located externally. The indoor unit, consisting of the evaporator and indoor blower, is located near or in the conditioned space.

The close coupling of evaporator and condenser components in small-scale single-zone systems using window, unitary or packaged equipment is often too restrictive for many architectural applications.

- Window units for example, must penetrate vertical elements of the building envelope -- with substantial impact on aesthetics and envelope integrity. Having all system components in a single location also limits installation flexibility.
- A through-wall air-conditioner, for example, can only be installed where there is a wall available; interior spaces cannot be reasonably conditioned with such equipment.

The split system provides a solution to these potential problems. For example, the evaporator unit might be located in a basement; interior closet or attic while the compressor/ condenser unit might be located on the side, rear or roof of a building.

Such an arrangement provides enhanced architectural and thermal opportunities -- HVAC equipment may be easily concealed and interior spaces easily conditioned. Split indoor units blend well into interior spaces and you don't have to sacrifice a window as window type air conditioning units.

Separation distance between exterior and interior elements is usually limited to around 100 feet.

Split-systems are popular in small, single-story buildings.

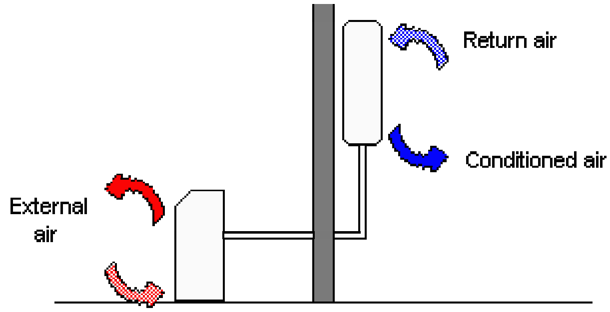

Figure: Typical Split Unit Arrangement

Packaged Air Conditioners:

A package air-conditioner system is a variant of large split systems. This equipment differs from small individual air conditioning or heating equipment in that air ducts are used to move the conditioned air to and from the unit.

Unlike small individual small split units, the compressor is installed together with the indoor unit rather than the outdoor unit. This makes this unit noisier compared to the small splits but shall allow a larger cooling capacity for the indoor unit.

Take a note on terminology; when we say condensing unit while explaining split air-conditioning system, it implies both the condenser and the compressor. Also sometimes word ‘packaged terminal air-conditioner’ is used which in technical parlance is described as a unit which does not require any thermal distribution ductwork or piping. These are packaged units are intended for through-the-wall installation. Simple controls are located on the unit.

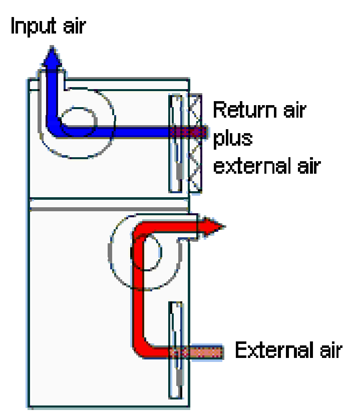

Figure: Typical Vertical Package Unit

Roof top Units

A rooftop unit typically consists of vapor compression refrigeration cycle and a heat source (electric resistance, heat pump, or on-site combustion), an air handler (fan, filter, dampers), and control devices. A packaged rooftop air-conditioner may function as a local air-conditioning system if it is not connected to substantial distribution ductwork. Packaged rooftop units are also commonly used with distribution ductwork in central systems.

The typical capacity for a rooftop-packaged unit is 5 to 100 tons. Rooftop units work well for single-story buildings, but don't fit into multi-storey schemes. Unitary Systems have all components on the roof. Split Systems have the compressor and condenser on the roof and the evaporator coil and air handling components in separate packages located inside the building.

These systems are commonly applied to low-rise buildings and have the bulk of the equipment on the roof, either as a factory package or in a built-up penthouse. They usually use reciprocating or screw compressors with air-cooled condensers.

These units are popular for general air-conditioning of stores, residences, schools, offices, etc. particularly suitable for single flat building with extensive floor areas

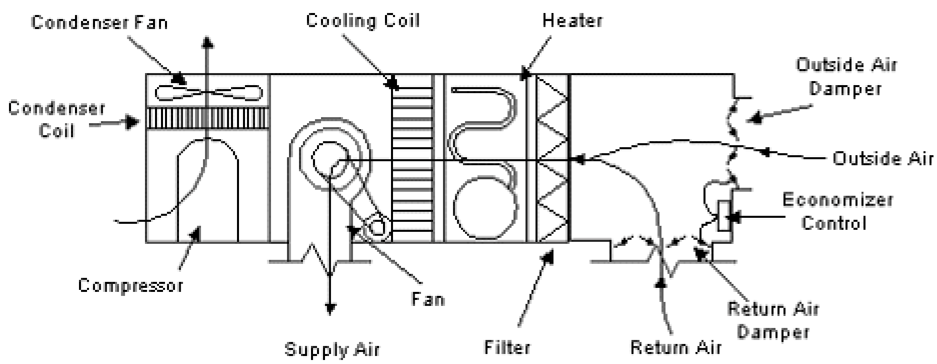

Figure: Typical Single-Package Rooftop System

Heat Pumps

Heat pumps are similar to cooling only systems with one exception. A special valve in the refrigeration piping allows the refrigeration cycle to be operated in reverse; it can heat or cool the space. For cooling, it operates as a conventional air conditioner. For heating, it reverses the refrigeration process, removing heat from the outside air and blowing it indoors for space heating.

Heating capacity drops off as the outdoor temperature gets colder; a supplementary electric resistance heater may also be used to assist the heat pump for colder days.

Heat pumps are configured as single-package units, split-systems, and as packaged terminal heat pumps (PTHP), similar to the equipment types mentioned above.

The air-to-air heat pump is the most common type of heat pump. Water source heat pumps (WSHP) are also available that use water as the heat source in the heating mode and reject heat to water in the cooling mode. In commercial buildings they are typically connected to a central water loop. A cooling tower and boiler maintain the temperature of the loop within the proper range.

Compact units including gas heaters are sometimes called "gas-packs." Units mounted on an exterior wall are commonly called "wall-packs."

Typical Applications of Compact Systems

Building Type	Type of System
Residences, Dormitories	Window or Split Units, Heat Pumps or Package Units
Office Buildings (low rise)	Split Units, Package Units, Roof top Units
Department Stores	Rooftop Units, Package Units
Restaurants	Package Units
Motels	Package Units, Split Units, Heat Pumps, Roof top Units
Small commercial complexes	Package Units, Rooftop Units
Cinema Halls, Theatre	Rooftop Units, Package Units, Custom built DX Units
Library	Rooftop Units, Package Units, Custom built DX Units
Medical centers, clinics	Rooftop Units, Package Units, Custom built DX Units

PART 3 CENTRAL SYSTEMS V/s LOCAL SYSTEMS

Below, the reader will find the most comprehensive information on central and local systems:

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
1	Central air-conditioning systems are categorized by field assembly of components viz. 1. Source component comprising of chiller/boiler, 2. Distribution components (air-handling units, ducting, piping, terminal units and auxiliaries) and 3. Delivery units (diffusers, grilles, register etc). All these components are field assembled along with control instruments to form a wider system.	A local system will consist of one or more self-contained equipment units containing cooling/heat source, distribution, and delivery functions in a single package. The most common local air-conditioning system comprises one or more window, split or heat pump air-conditioning units. The available capacity of these units ranges from 0.5 ton to 5 tons. Large compact units are called package and rooftop direct expansion units that are available from 5 tons to 100 tons capacity.
2	Central systems are procured from multiple vendors for instance chiller, boilers, pumps, cooling tower, expansion vessel, air handling units, acoustic silencers, piping, ducting & auxiliaries etc. System designer has to produce schematic, layout, control philosophy and general arrangement drawings to assist installation.	One manufacturer is responsible for the final unit. Manufacturer-matched components have certified ratings and performance data. Factory assembly allows improved quality control and reliability. The local units are easy to install, which means less mess, or disruption or downtime.

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
3	Central HVAC system may serve one or more thermal zones and has its major components located outside of the zone/s being served -- usually in some convenient central location.	A local HVAC system essentially serves a single thermal zone and has its major components located within the zone itself or directly adjacent to the zone. Multiple units are required for multiple zones.
4	Central HVAC systems will have as many points of control thermostats) as there are multiple zones. The controls are field wired and are integrated to central control panel.	Serving only a single zone, local HVAC systems will have only one point of control -- typically a thermostat for active systems. Local units are off shelf items complete with integrated controls.
5	Since the central system may serve multiple zones the controls are complex and depend on the type of system. Constant air volume (CAV) systems alter the temperature while keeping the constant air delivery. CAV systems serving multiple zones rely on reheat coils to control the delivered cooling. This incurs lot of energy wastage due to simultaneous cooling and heating. Space temperature control can also be achieved by applying a variable air volume (VAV) system, which primarily alters the air delivery rates. The VAV system	Local Air-Conditioning Systems offer room-by-room or "zone" control, which minimizes over-cooling typical of central air-conditioning systems. With the zone-control ability of the compact systems, only occupied spaces are maintained at a comfort level, and conditioning for the rest of the building is turned down or shut off.

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
	may or may not have a reheat coil, which provides additional heat when the space does not need to be cooled or needs less cooling than would be delivered by supply air at the terminal box's minimum air quantity setting.	
6	All the components of the central system are integrated and function in unison for a large setup.	A local system is truly an *isolated system* but the multiple independent units may be used to cover the entire building. Each local system generally does its own thing, without regard to the performance or operation of other local systems.
7	Central systems are categorized as *non-distributed systems*. Failure of any key equipment component (such as a pump or chiller) may affect an entire building. For critical facilities, a standby-cooling machine is generally provided to ensure that air conditioning is always available.	Local systems tend to be *distributed systems* having multiple units; Only one zone is affected if a unit malfunctions. A building conditioned using local system may have a dozen (or a hundred) individual and independent units located throughout the building. Distributed systems tend to provide greater collective reliability than do centralized systems. The failure of one of many units may cause discomfort in one room of a building but the remaining units can still

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
		operate for rest of the building.
8	In the central plant system it is easy to provide for redundancy by installing a standby chiller and pump in the same plant room. These units are connected to common condenser water/chilled water headers thus minimizing the requirement of additional space. A multiple chiller plant arranged in N*+1 configuration provides more than 100% redundancy because of the fact that most of the chiller plant operates at *off-design conditions* 99% of the time. Air handling units are normally not provided as standby, as the breakdown rates are insignificant. A few standby motors can be kept as spares in the premises for such units. (*N is number of chiller units with an aggregate capacity of peak load requirements)	In a floor-by-floor air conditioning system using packaged units and splits it is not always possible to provide a non-working standby unit. Normally such units are installed in multiple and are distributed over the air-conditioned space. Therefore whenever a unit suffers a breakdown, air conditioning is inadequate causing user complaints. Local rooftop units or package units if applied to critical facilities like control rooms/laboratories are often provided with standby.
9	The quality of air conditioning is much superior in central air-conditioning system. Central systems provide better control over temperature, relative humidity, indoor air quality and air distribution. The central systems are best	The quality of air conditioning is OK but not comparable to central systems. Local systems for instance do not provide close humidity control. The compact systems being standard factory items

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
	suited for applications demanding close control of temperature, humidity and cleanliness.	cannot be modified to suit the required design conditions all the times. Close humidity control, if needed, in computer room applications or the like, can be accomplished through special purpose packaged units.
10	Central systems allow for proportional control of temperature and eliminate hot spots if the systems is properly tested and balanced.	Individual room control (on/off and temperature) is simple and inexpensive. However, because temperature control is usually two-position, there can be swings in room temperature.
11	Central system provides good dust and particulate air filtration. These systems can incorporate high efficiency particulate filters (HEPA), which offer 99.99% efficiency down to 0.3 micron.	Local systems cannot be modified to include high efficiency filtration as the fan pressure is factory fixed and is inadequate to overcome the filter resistance.
12	Central systems provide better indoor air quality. Multi stage filtration can be employed to improve the quality of supply air and the fan static pressure can be selected to suit the pressure drop. Central systems provide good control over ventilation air. It is possible to control indoor air quality in a central plant by designing the main air handling	In floor-by-floor systems, it is not possible to provide a high level of filtration or increase the fresh air quantity. Special filtrations need however shall be carefully evaluated against the unit's fan static pressure.

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
	system for fixed or varying quantities of fresh air.	
13	Prestigious owners prefer central systems. Most landmark buildings with a single corporate or government owner prefer to install central plants as the quality of air conditioning is superior and life expectancy is higher. The operation and maintenance cost is lower than a floor-by-floor system.	Local systems provide individual ownership. Each tenant can own his air conditioning plant, operate it at his convenience and pay the individual power bills. Therefore, when a building complex has a multiple owner profile a floor-by-floor system is preferred. For applications such as leased office space, energy use can be metered directly to each tenant. Units can be installed to condition just one space at a time as a building is completed; remodeled, or as individual areas are leased and occupied.
14	Central HVAC systems offer opportunities for economies of scale. Larger capacity refrigeration equipment is usually more efficient than smaller capacity equipment. Larger systems can utilize cooling towers, which can improve system efficiencies in many climates.	Local systems cannot benefit from economies of scale. The coefficient of performance (COP) of a refrigeration system generally increases with capacity; as each local unit is normally of low capacity, local system COPs are relatively low. Local systems are generally air-cooled but the water-cooled options are available

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		to packaged units above 10tons of refrigeration.
15	Central systems permit building-wide load sharing; this may result in reduced equipment sizes (and costs) and the ability to shift conditioning energy from one part of a building to another. Several central HVAC systems deliver improved efficiency and lower first cost by sharing load capacity across an entire building.	Lack of interconnection between multiple compact units' means that loads cannot be shared on a building-wide basis. A peak load capacity shall be provided for each zone. The capacity of local unit equipment shall be designed for peak load of the zone without any diversity. The local equipment energy use may also be greater because fixed unit size increments require over sizing for some applications.
16	The supply air quantities of central system can be designed to any value by ordering custom build fans. The cooling coils in a central plant can be specially designed to handle higher latent loads and thus provide better control over moisture. The cooling coils can be selected for high rows deep (enhanced surface area) for effective condensate removal. The condenser sizing can also be varied based on the refrigeration capacity.	The local system provides fixed supply air quantity, which is usually 400CFM per ton of refrigeration. The size of the cooling and condenser coils is standard. No choice is available for coil selection, which is generally fixed by the unit nameplate rating.
17	Generally trained and skilled operators are required due to complexity of controls and	These systems are easy to operate. Trained operators are usually not required.

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	numerous field assembled items interfacing with each other.	usually not required. Generally for small units the control features are available on hand held wireless remote.
18	Large central systems have life expectancies of 20 to 25 years.	Local systems have life expectancies of usually 10 to 15 years.
19	Central systems are selected for big projects having large areas where excellent quality of air-conditioning is of paramount importance.	Compact systems are selected when it is decided that a central HVAC system is too large or too expensive for a particular project.
20	Central systems that serve the interior building spaces can be used along with compact units for parametric zones. Alternatively, a central plant with a VAV system can very well handle the variations in peripheral load.	Compact systems are good for parametric areas or where spot cooling is required for example, in large retail stores, the pharmaceutical products can be maintained at lower temperatures than the surroundings.
21	Central systems allow major equipment components to be isolated in a mechanical room. Grouping and isolating key operating components allows maintenance to occur with limited disruption to building functions.	Local systems maintenance may often be relatively simple but such maintenance may have to occur directly in occupied spaces. Outdoor units are designed for easy access unless the units are mounted on the steel overhang platforms.
22	As system size and sophistication increase, servicing/replacement	Because local systems are likely to be of small capacity

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	may become more difficult and may be available from specialist providers.	and are not complicated by interconnections with other units, servicing of local systems tends to be simple and available through numerous service providers.
23	In a building where a large number of spaces may be unoccupied at any given time, the central system shall run on part load, which shall consume higher specific energy. During design phase it is necessary to select optimum configuration of chiller machines for instance a peak load of 225 tons could be served through 3 x 75 ton machine so that one machine can be switched off at low loads. Also it may be wise to consider adding local units for the few rooms that are required operation during off hours.	In a building where a large number of spaces may be unoccupied at any given time, such as a dormitory or a motel, local systems may be totally shut off in the unused spaces, thus providing potential energy savings.
24	In a central system, the individual control option is not always available. If individual control is desired, the system shall be designed as variable air volume system (VAV) with localized thermostats.	As a self-contained system, a local HVAC system may provide greater occupant comfort through totally individualized control options -- if one room needs heating while an adjacent one needs cooling, two local systems can respond without conflict. Heating and cooling capability can be provided at all times, independent of other spaces in

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
		the building.
25	Central systems designed for VAV system is based on block load calculations, as the VAV units allow the system to borrow air from areas with low load. By incorporating VAVs with variable speed drive on air handling units, it is possible to achieve excellent savings in power, which can be as high as 30 - 50% Even though the initial cost of the plant increases by 7% - 10% due to VAVs and variable speed drives, the pay back is normally less than 2 years.	The compact systems being small are designed for full peak load. No diversity is taken on design. The standard rooftop or package units are not available with variable speed option till now.
26	The conditioning effect from a central HVAC system is conveyed throughout a building. The need to transfer conditioned air or water imposes space and volume demands on a building. Large duct sizes, for example, may require an increase in floor-to-floor height and, consequently, building cost. If this size is too large to permit a reasonable false ceiling height it may be desirable to consider two smaller AHUs on each floor. Sometime this also requires an additional shaft in the floor space.	Many of the compact systems are essentially ductless systems. For package or roof top units if the duct is used these are usually small and run very short. This requires a little plenum space or can be accommodated in limited floor-to-floor height of the building. Larger floor areas can use multiple units, which can further help in reducing duct sizes.

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27	A central plant will require plant room space to house chilling machines, chilled water pumps; condenser water pumps electric and control panels. In addition space is required outdoors for condensing unit for air-cooled machines and cooling tower for water-cooled machines. The plant room size will depend on the size of the plant. The plant room requires an adequate height of 4.3 to 4.9 meters. For air-cooled condenser options, a space at one central location is required outdoors at grade or at terrace.	No separate plant room space is required as the refrigeration package is integral to the package unit/condensing unit which is generally located outdoors. Evaporator units are generally located indoors. Multiple condensing units are to be located outdoors for the package units or split units. There is a limitation that the condensing unit should not be located more than 100 ft horizontally from the indoor unit and vertically not more than 30 ft higher than the indoor unit. This distance limitation for multiple units may require condensing units to be mounted on the overhanging sunshades or on steel platforms bolted to the outside building walls-making maintenance extremely risky and difficult. Buildings also start looking shabby and disfigured.
28	The water-cooled systems are more compact in size. A space for cooling tower shall be required outdoors or at the terrace. The centrifugal machines require water-cooled condenser while the reciprocating and screw machines	While package/rooftop units are available with water-cooled condensers options, the major share of small capacity installations use air-cooled equipment. Even though the power requirements for air-

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
	are available with both air-cooled and water cooled options.	cooled equipment may exceed the total power requirement per ton for water-cooled equipment at rated conditions, actual operating circumstances may result in a lower total power cost for air-cooled equipment on a year round basis in some applications. Poor water quality, regular chemical dosage requirements etc. is also a factor in favor of air-cooled equipment
29	Central systems do not provide flexibility of individual energy metering very easily. A complex metering system generally based on BTU/hr (measured from flow and temperature differential) of chilled water energy is first measured to convert to equivalent power units in kWH.	The energy utilization of local compact units can be simply measured by installing a local energy meter with each unit.
30	Accessible space above false ceiling is needed for locating the volume control dampers and other duct auxiliaries. Accessible space above false ceiling is needed if ceiling mounted fan coil units are considered for instance all-water or air-water central systems.	Accessible space above false ceiling is needed for split unit coolers. Accessible space above false ceiling is also needed for ducted packaged or rooftop systems.
31	For central systems, the building structure should be designed to take the weight of equipment. Suitable vibration control must	The local systems are smaller in size and are less bulky.

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	be considered. Adequate load bearing beams and columns must be available for lifting and shifting of such equipment.	
32	A shaft is needed to house chilled water piping, condenser water piping, supply, return & fresh air ducts and power/control distribution cables.	Does not require chilled water pipes as the units are DX (direct expansion refrigerant) type. Separate shafts are not required until the package unit is water-cooled type. The air-cooled package unit shall require refrigerant piping routing to connect the indoor evaporator unit with the condenser unit, which is normally not routed through shafts.
33	Central systems require plumbing and drainage arrangement in the central plant room where chiller/pumps are located and also where AHU/FCU cooling coils are provided.	Moisture condensate removal can be a problem if proper removal is not provided. Since majority of time the evaporator unit is located with in the zone or at the zone boundary, the plumbing need to be carried out in the indoor spaces.
34	Consideration must be given to the noise of the chillers and whether this will affect adjacent buildings particularly if the equipment is located outdoors. If the equipment is located	Local system unit compressors are totally sealed (hermetic or semi-open) and are located outdoors. Operating sound levels of the indoor equipment could be high

Sno	CENTRAL SYSTEMS	LOCAL SYSTEMS
	indoors, the plant room walls and the AHU room walls must be acoustically treated.	though tolerable. Outdoor units are generally quiet enough to be installed under a window or near a patio so sleeping or the entertaining of guests is not disrupted.
35	Thought must be given to the access path to plant rooms and AHU rooms. The equipment may be quite bulky and voluminous. In case of a breakdown, the machine may have to be shifted to a service shop for repair. The building design must provide this space.	The local systems are usually compact. Replacement is quite simple and easy.
36	It is possible to design central system to include active smoke control. This is best accomplished by “all-air” HVAC system.	The local systems are standard items and it may not suit modifications in system design other than interlocking the fan motors with fire detectors/panel.
37	Central systems are also amenable to centralized energy management control schemes and the building management systems (BMS).	Local system units cannot be easily connected together to permit centralized energy management operations. Local systems can be integrated to BMS with respect to on-off functions through electric circuit control, but more sophisticated central control (such as night-setback or economizer operation) is not possible.

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38	It is possible to maintain positive pressure with central systems. The clean room applications, pharmaceutical units, electronic rooms etc require high degree of positive pressurization.	Package or rooftop units provide limited positive pressurization. The smaller split units mounted indoors are generally 100% re-circulation type and can not ensure pressurization.
39	Different AHU units shall be required for critical areas where cross contamination is a concern such as pharmaceutical plants. Also in food court areas ideally different restaurants shall be fed with independent units to avoid cross zoning of smells.	It is easy to provide independent package units where cross-contamination is a concern.
40	With central systems it is possible to incorporate strategies which are desirable with increased ventilation rates: ✓ Increased re-circulation with high efficiency filters ✓ Heat recovery devices can be provided ✓ Economizer: An economizer allows outside air to be used for cooling when its temperature is lower than the temperature inside the building. The economizer function is part of the control package on many single-packaged units. ✓ Automatic carbon dioxide monitoring can be	Increased ventilation rate is normally not used with standard compact units. Sometimes to maintain acceptable indoor air quality it is often recommended to install a separate dedicated fresh air unit. Outdoor air economizers are not always available to provide low cost cooling with standard units. Economizers are available as an option for rooftop units. California energy efficiency standards require economizers on large units to avail benefits of 'free cooling' during low ambient temperatures.

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	incorporated.	The package and rooftop units can be provided with CO_2 sensors and heat recovery devices.
41	Central systems are generally designed as concealed systems and the visible distribution grilles etc can be easily blended with the aesthetics.	The appearance of local units can be unappealing and may not necessarily blend well with the aesthetics.
42	**Initial Cost** The initial cost of a central air conditioning system is much higher than a local system. Depending on the type of equipment selected the cost can vary to a great extent. For example, a reciprocating packaged chiller is much cheaper than a screw-packaged chiller and the screw-packaged chiller is cheaper than a centrifugal chiller. Air-cooled machines are costlier than water-cooled machines. Therefore, the budget available with the owner at the time of building the facility play a major role in selecting the type air conditioning system. When it comes to air handling units, the single skin air-handling unit is much cheaper than a double skin air handler.	Packaged and split units have much lower first cost than a central system. These units are standard and the cost of these systems is proportional to the capacity. However, the life expectancy of floor-by-floor system is much lower at about 12 to 15 years only as compared to 20 to 25 years for central systems. Also the operating costs tend to be higher on peak load comparisons.

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	However, the system cleanliness and aesthetics achieved by using double skin air handling units is far superior. The life expectancy of these units is also higher. VAVs and a building management system if added will increase the capital cost by 10%-15%. However there will be a saving in power cost and so it is important to work out the payback period to determine the techno-commercial liabilities of the final selected system.	
43	**Engineering Cost** Whenever a major facility like a multi-storey building project is designed, it is imperative that an HVAC engineer be involved from the initial stage itself. Such a design and build approach will lead to a well co-coordinated effort between the architect, HVAC engineer, builder and client. Such involvement will also provide expertise to evaluate and analyze the techno-economic aspects of each system. • The system selection must precede the final architectural design of the building. Even though such engineering inputs seem to add to the cost and time of the project.	Engineering cost, time and risk factors for designing a unitary floor-by-floor system are usually lower than those for a central system for the following reasons: • Load calculations and corresponding equipment selections are less critical with packaged floor-by-floor systems. The multiple numbers of modular units will provide built in safety cum flexibility into the design. • Unitary or packaged systems are factory built standard equipment. The quantum of work to be carried

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	• A central plant design envisages equipment layouts, ducting layouts, piping layouts, which are much more complex. • Layout finalization is also time consuming, as these designs are required to be well integrated with structural, interior layouts and other utilities.	out at site is much less as compared to central plant system as the amount of ducting piping and insulation work is much less. • Engineering skill, cost and time required to install a floor-by-floor packaged system is much less as compared to a central plant. • Floor-by-floor system layouts are much simpler and repeated multiple times.
44	**Installation Cost** The mechanical installation cost of a central plant is much higher than a floor-by-floor system due to the following reasons. • Main air conditioning equipment is heavy and voluminous requiring strong foundations and proper material handling facility at site. • Air handling units/cooling towers/fans must be lifted to upper floors or terrace. • Some equipment requires extra care during installation to ensure minimum vibrations and smooth operation.	Local system provides simple and faster installation. These are easy to install and less time consuming since standard size units are readily available. Replacements can be carried out very fast.

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	• Larger quantities of ducting, piping and insulation are required and their installation cost is higher.	
45	**Operating Costs** The modern centrifugal machine is capable of operating at a power consumption of 0.50 - 0.60 kW per ton. In addition to the above, centrifugal machines are now available with variable speed drives (VSD), which enables machines to operate at *off design conditions* at 0.40, 0.30 and even at 0.20 kW/ton. This leads to an unprecedented energy saving. On the low side of the central AC system, air-handling units are the biggest consumer of power next to the chillers. If constant volume air handling units are provided, these consume the same energy day in and day out irrespective of variation in load. By incorporating VAV terminal boxes with variable speed drive on air handling units it is possible to achieve excellent savings in power. Saving in power could be as high as 30% -50%. For all air-conditioning systems a vast majority of operating	The power consumption of local compact units can vary from 1.0 kW per ton to 1.3 kW per ton. The type of compressors used in these machines is either hermetic reciprocating type or scroll. The part load efficiency of such units is lower than their full load efficiency. Cooling efficiency for air conditioners, splits, package units and heat pumps is indicated by a SEER (Seasonal Energy Efficiency Ratio) rating. Heat pumps also have heating efficiency ratings, indicated as an HSPF (Heating Seasonal Performance Factor). In general, the higher the SEER or HSPF rating, the less electricity the unit will use to cool (or heat) your home. The government-mandated minimum efficiency standards for units installed in new homes at 10.0 SEER and 6.8

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	hours are spent at *off design conditions*. Therefore it is important select machines which the best *off design performance*.	HSPF. Air conditioners and heat pumps manufactured today have SEER ratings that range from 10.0 to about 17. Heat pumps are available with HSPF ratings from about 6.8 to 10.0.
46	**Maintenance Cost** The breakdown, repair, replacement and maintenance cost of central plants can be expensive and time consuming. However, the frequency of such breakdown is quite low. These systems require routine inspection and planned checks. Daily operation also adds to the running cost, as trained operators are required. Maintenance costs are difficult to predict since they can vary widely depending on the type of system, the owner's perception of what is needed, the proximity of skilled labor and the labor rates in the area. A recent survey of office buildings indicated a median cost of $0.24 per sq. ft per year. The Building Owners and Managers Association (BOMA) may provide more locally specific information.	The floor-by-floor system repair cost per breakdown is normally low. With the emergence of reliable hermetic and scroll compressors, their maintenance expenditure has shown remarkable improvements and is less time consuming and simple. Roof mounted packaged units typically have maintenance costs of 11% or higher than a central plant system serving the same building.

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47	Central systems can be applied with large thermal energy storage systems to take benefits of reduced cooling demand during expensive peak load periods.	With local systems, switching off few of the multiple units can control the peak load energy demand. Thermal energy storage is not possible with compact systems.

In nutshell central systems provides better quality of indoor parameters and energy efficiency. From energy efficiency point of view it is highly recommended to evaluate your selection thoroughly if any of the conditions below are true.

1. If the building square feet floor area exceeds 10000 sqft
2. Ratio of occupancy hours to operative hours of less that 0.6 indicates that rescheduling equipment operation can save energy.
3. Annual energy consumption in excess of 50,000 BTU/sqft. (Of the building)
4. Total capacity of heating and cooling equipment combined capacity exceeding 100 BTUH/sqft

PART 4 HVAC DESIGN DEVELOPMENT CHECKLISTS

HVAC systems consume an important part of the building construction budget, account for a major portion of a typical building's annual energy consumption, often require substantial space allocations and contribute to interior environment that is critically evaluated by the building occupants and visitors.

Everyone cares about cost! But the wise customer lays down a list of minimum requirements and then negotiates. The "penny-wise pound-foolish" customer goes for price only and skimps on equipment and design specifications.

The design of HVAC systems is intimately related to various parameters, including but not limited to the factors listed below.

Details of architecture:

- ✓ Structure, orientation, geographical location, altitude, shape, modules- size & height
- ✓ Purpose of the building, area classification, occupancy and usage patterns
- ✓ Ratio of internal to external zones, glazing, plant room sitting, space for service distribution
- ✓ Climate and shading, thermal insulation, passive climate control, relationship with adjacent buildings
- ✓ New or existing building, renovation or extension project, retrofitting or new equipment,
- ✓ Plant and system design to match the characteristic of the building and the need to meet the needs (known and unknown) of the ultimate occupants.

Details of Space allocation:

- ✓ Floor space and clear heights to accommodate HVAC plant, equipment, distribution and room elements
- ✓ Shaft spaces available for routing ducts/pipes etc
- ✓ Location and size of structural columns and beams, clearance through steelwork, position of reinforcing rods, etc;
- ✓ Ceiling height, clearance between suspended ceilings and beams;
- ✓ Foundation and supports requirement, permissible loadings;
- ✓ Location of obstructions that may be in the route of air-conditioning services, particularly ductwork;

Details of building construction:

- ✓ Materials and thickness of walls, roof, ceilings, floors and partitions and their relative positions in the structure, thermal and vapor transmittance coefficients, areas and types of *glazing*, external building *finishes* and color as they affect solar radiation, *shading devices* at windows, overhangs, etc., as they reduce solar radiation and light transmission, building mass, particularly as it affects thermal capacity;
- ✓ Sound and vibration control requirement, relation of air-conditioning equipment to critical areas;
- ✓ Co-ordination with other services (e.g. electrical and plumbing work), use of service shafts, ducts and equipment rooms to best mutual advantage;

Building regulations

- ✓ Government and local regulation on occupancy & safety classification
- ✓ Regulations of Public utilities on electrical wiring, power usage, water supply and drainage
- ✓ Health and Safety regulations on indoor air quality, ventilation air quantities, noise control, electrical, fuel, insulation and other hazardous materials
- ✓ Local fire authority regulations and smoke removal systems
- ✓ Insurance company regulations

Miscellaneous Requirements

- ✓ Accessibility for installation of equipment, space for maintenance;
- ✓ Location of fresh air intakes and exhausts (to avoid short-circuiting and contamination);
- ✓ Location of fire zones and fire walls (position of fire dampers);
- ✓ Acceptable noise level: space available to house equipment and its location relative to the conditioned space
- ✓ Indoor & outdoor equipment preferences
- ✓ Acceptability of components obtruding into the conditioned space
- ✓ Plumbing arrangements, drains – location, capacity, restriction on discharge;

Building Aesthetics

- ✓ Architectural characteristics of space,
- ✓ Reflected ceiling plans: Integration of air distribution devices in ceiling to harmonize with lighting layout, fire sprinklers, detectors, communication systems and ceiling design
- ✓ Size and appearance of terminal devices

System considerations:

- ✓ Thermal influence – Solar gain, ambient conditions (dry bulb/wet bulb temperatures), indoor condition (dry bulb/relative humidity) requirements, heat gain from people, artificial lighting, equipment and machinery, ventilation air load
- ✓ System behavior – Thermal comfort, indoor air quality, cooling /heating peak loads, partial loads, average load conditions and pattern of variation, capacity of the system
- ✓ *Load behavior – Sensible/latent heat balance, Load diversity, and system response related to thermal capacity storage effects*
- ✓ Psychrometric processes – engineer prefer to carry out their calculations on a psychrometric chart of the aspects include *actual vapor pressure; relative humidity; moisture content; specific enthalpy; specific volume (or humid volume) and dewpoint.*
- ✓ *Operation Philosophy- Hours of system operation;*
- ✓ *Control Systems- Zone or individual control, system response and lags, permissible tolerances and time system, direct digital controls, sequence of operations and control logic*
- ✓ Energy Efficiency- Energy availability, level & pattern of energy use, type of system, peak load and part load energy performance, Variable speed drive, energy efficient equipment, building management systems, economizer controls, zoning requirements
- ✓ Control and operational requirements – supervision, records, type of adjustment and regulation, hours of operation, summer/winter changeover, day/night and weekend operation, high/low limit protection, frost protection, fire protection, special control areas (e.g. computer rooms, executive offices);
- ✓ Redundancy- Spare & standby requirements, equipment configuration
- ✓ Technology features – Humidification/dehumidification requirements, Air purity, Special acoustic treatment, fire protection & smoke management; Water service – capacity, pressure, maximum temperature, chemical analysis (choice of materials), water treatment;

- ✓ Commissioning and testing of the completed plant and the adjustment to ensure that it operate as designed in all respect. It is a matter of increasing importance, as components become more sophisticated, more packaged and thus less susceptible to any level of repair.

Financial Constraints

- ✓ Capital cost
- ✓ Operating cost (fuel, power & water)
- ✓ Maintenance & consumables cost
- ✓ Replacement costs
- ✓ Upgrading costs
- ✓ Equipment failure costs
- ✓ Labor costs
- ✓ Insurance costs
- ✓ Interest on capital and depreciation
- ✓ Return of investment (ROI)/Life cycle analysis

Costs can often be influenced by the owner's/company's insurers and risk managers.

Successful HVAC systems are the key to successful buildings. Proper selection of air-conditioning services and choice of the most effective system is the foremost application consideration. This includes primary influence from the architect.

It is important to understand the characteristics of the building envelope, functional requirements and desired environmental conditions. Each solution begins with an assessment of the owner's business needs, architect's vision and the requirements of the end user, combined with a review of the HVAC system itself, be it existing or planned.