

# *Energy Efficient Air Distribution Systems for Air Handling Unit*

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## **Abstract**

*An air handling unit (AHU) is a large piece of equipment that alters the temperature and pressure of air being distributed throughout a building. They are usually located in their own part of the building, often in the penthouse or basement.*

*Heating ventilation and air conditioning (HVAC) systems consumes nearly 50 to 60% of the total power consumption in any building and thus, offers huge potential and challenge to reduce the energy consumption by employing various innovative systems designs. No-cost measures for reducing the energy bills. For air conditioning systems, the measures include selecting the right temperature [no overcooling or overheating], minimizing the space for air conditioning and closing of dampers / grills for areas where air conditioning is not required.*

*Reducing wasted HVAC energy consumption is an important building block in the push for greater sustainability in the business world. It is also a great way to substantially reduce operating costs. And many of the steps that business owners and managers can take to improve sustainability and reduce costs require little to no expense. Many of those steps are also incredibly simple, and the more complex waste-reducing practices often offer excellent return on investment.*

*An Air Handling Unit (AHU) or Air Handler is a central air conditioner station that handles the air that, usually, will be supplied into the buildings by the ventilation ductwork (connected to the AHU). Handling the air means that the air will be delivered into the building spaces with thermo-hygrometric and IAQ (Indoor Air Quality) treatment.*

**Keywords:** HVAC, Air Handling Unit (AHU), air distribution system (ADS), energy conservation, office buildings.

## **I. INTRODUCTION**

Energy Conservation is unquestionably of great importance to all of us, since we rely on energy for everything we do every single day. Energy supplies are limited and, to maintain a good quality of life, we must find ways to use energy wisely. Reducing the amount of energy that we use is a good way to save money, and there are also other benefits to decreasing energy consumption. We depend on energy for almost everything in our lives. We wish to make our lives comfortable, productive and enjoyable. Hence even if the outside temperature rises a little, we immediately switch on the air conditioner to keep our house cool. This is again using up of energy. Unfortunately, what we do not realize is that we have started taking things for granted and we have started wasting energy unnecessarily. Most of us forget that energy is available in abundance but it is limited and hence to maintain the quality of life, it is important that we use our energy resources wisely. If we do not conserve energy, the energy will exhaust and we will have nothing to use. Also, energy conservation is also important when it comes to climate change. Currently, erratic climates and climatic changes are the greatest threats that we are facing today. Hence it is important to conserve energy. Heating, ventilation and air conditioning systems are among the most energy-intensive mechanism of any business. In fact, space cooling alone accounts for 15% of the electricity used in commercial buildings on average. According to the U.S. Department of Energy (DOE), much of the energy and cost that goes into powering HVAC is lost to waste – upwards of 30% in the average commercial building.

## **II. OBJECTIVE AND SCOPE**

The objectives of this paper are to:

- Introduce fan-law based airflow measurement methods and instrumentations for better air distribution and building pressure control.

- To optimize parameters and their influences on Air Handling Unit (AHU) performance.
  - To establish current state of energy efficiency practices in Air Handling Unit systems.
  - To analyze for energy efficiency management, design, operation, control, maintenance, installation and commissioning of Air Handling Unit systems installed in selected.
  - To identify possible optimization practices of Air Handling Unit systems for energy efficiency in selected buildings.
  - Develop a practical evaluation process for the performance of an Indoor Air Handling (IAHU) system.
- The scope of this paper is as follows:
- This paper basically describes Air Handling Unit (AHU). The presented model can be implemented in the Heating, Ventilating and Air Conditioning (HVAC) plant where AHU considered its main element.
  - To increase the efficiency of present AHU system.
  - To deliver better air quality in adequate amount with appropriate atmospheric condition.

### III. CURRENT TRENDS IN HEATING, VENTILATING AND AIR CONDITIONING

In commercial buildings the energy needs for building services systems often account for a substantial portion of total energy consumption. Within the commercial sector, office buildings are those with the largest consumption of energy and CO<sub>2</sub> emissions. In the United States, offices account for 17% of the total non-domestic building area and about 18% of the energy use in buildings (Luis et al. 2008). Across the US, the average annual energy intensity for office buildings is 79.8 kBtu per square foot and the average cost is \$1.65 per square foot. Of the total energy consumption, 66% is from electricity and 34% is from natural gas and other fuels. This consumption translates to 15.5 kWh per square foot of electricity and 0.27 therms (32 cubic feet) per square foot of natural gas (CBECS, 2003).

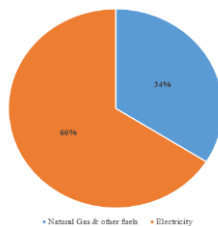


Figure 1. Energy consumption as per fuel

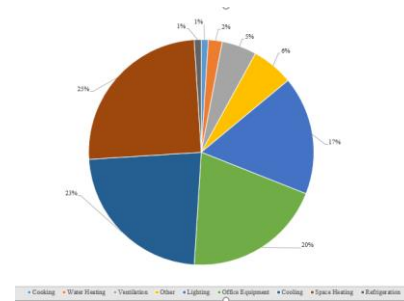


Figure 2. Energy consumption as per use

As shown in Figure 1 & 2, the energy consumption on space heating, ventilation, and air-conditioning (HVAC) represents about fifty-five percent of the total use in a typical office building. In another study, it is stated that energy represents about nineteen percent of total expenditures for a typical office building ("Managing Energy Costs in Office Buildings", 2006). As much as 30% of the energy consumed in office buildings was estimated to be wasted in daily operation ("Office Building Energy Use Profile", 2006).

Although the efficiency of heating/cooling energy use in office buildings has increased considerably in general because of better building insulation, component efficiency and automated control, etc., the amount of total thermal and mechanical energy demand for commercial buildings has not decreased. This increasing trend in building energy consumption will continue due to the expansion of office built areas and the associated energy needs.

### IV. THERMAL FEATURE OF OFFICE BUILDING

The office building is one of the great icons of our modern world. It differs from other commercial buildings due to its diversified building layout and corresponding occupancy and operation. An office building's layout can be a mixture of space divisions, private offices, open plans and auxiliary space, etc. The characteristics of an office building lead to the configuration complexity of HVAC systems. Furthermore, the control and operation of air conditioning systems are also difficult if a high energy performance is desired.

Compared to those of earlier times, modern office buildings have higher internal heat gains since more electricity-powered equipment is employed. The higher heat gains reflect from both the quantity and the density. Computers, copy machines, printers, even data servers are commonplace in office buildings. Although the efficiency and the convenience have been highly improved, a significant amount of heat exhausted by these equipment enters into the air conditioned spaces. If not properly

handled, the heat can turn into a thermal load that requires mechanical cooling year around.

In line with the prevailing architectural style, office buildings are built with large glass surfaces and becoming more air-tight with wall curtains and non-operable windows. The area along the perimeter of a typical office building and the area in the core possess very different load characteristics. Normally, seasons. In the context of this thesis, the definition of “zone” is extended to be the same as “region”, which includes multiple zones that possess the identical thermal characteristics.

Unless specially designed, natural ventilation is almost impossible for most existing and newly built office buildings. Because of the improved closeness, increasing occupancy density and longer residence time, the indoor air quality (IAQ) of modern office buildings is now a major concern. To acquire ventilation air for the occupants, either an individual system, or a system with a proper amount of OA should be installed. ASHRAE standard 62.1-2004 (ASHRAE 62.1, 2004), the code of Ventilation for Acceptable Indoor Air Quality, specifies the calculation of minimum ventilation rates for an acceptable IAQ in residential and commercial buildings. Office building spaces are normally open with continuous areas above the ceiling and no floor-to-floor partition walls or locked doors. To achieve the maximum use of area, work stations are created near windows and outer walls. In the center of the building, stair wells, elevators and hallways are located for passage convenience. Therefore, the exterior zones and interior zones do not have obvious

perimeter zones are mainly influenced by the outside air (OA) temperature and solar variation, while interior zones are dominated by the internal heat load density and occupancy schedules. The unique thermal feature of office buildings leads to a common practice that heating and cooling exist simultaneously under some circumstances in winter or swing

and rigid boundaries. The two zones influence each other in a way in which it is difficult to be clearly isolated. The terminals of the systems serving different zones also might be put in the same office room, which causes the ventilation air from different systems in the occupant space mix and network spontaneously.

## V. OFFICE BUILDING HVAC SYSTEMS

The comfort of occupants in office spaces is fundamentally influenced by the thermal and air quality. HVAC systems are designed to provide workers in office buildings with a suitable air temperature, humidity and quality. HVAC systems can vary greatly in complexity, from stand-alone units that serve individual rooms to large, centralized systems serving multiple zones in a building. In project EPA 402-C-06-002 for building assessment survey and evaluation study, the EPA randomly selected 100 public and commercial office buildings, which were built from before 1900 to 2000, in 37 cities and 25 states (“BASE Study”). The majority of existing office buildings has centralized cooling and heating systems, as shown in Fig 3.

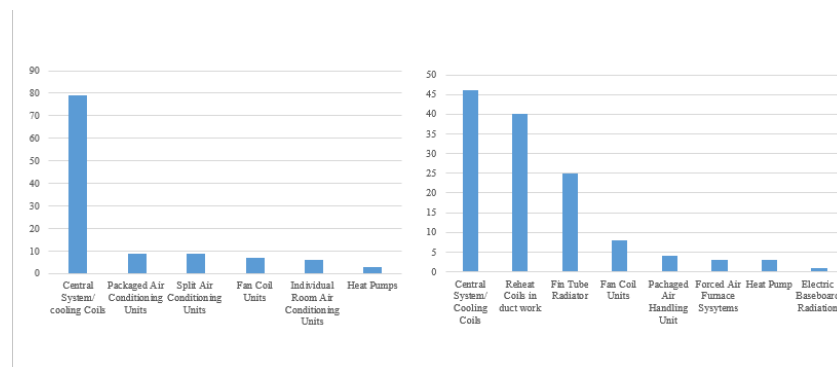


Figure 3. Office building cooling&Heating system type

Among them, 98% use mechanical ventilation; 50 out of 141 air handlers are constant air volume (CAV), while the others are variable air volume (VAV). Air based centralized HVAC systems with different terminals and layouts still dominate office buildings for air conditioning because of the associated advantages. A DOE report about energy consumption

characteristics of commercial buildings shows that central systems with VAV air handling units (AHUs) are more efficient than packaged systems (Roth et al, 2002). The other reason of the dominance is that a central HVAC system is more flexible in providing air distribution with duct work throughout the entire building.

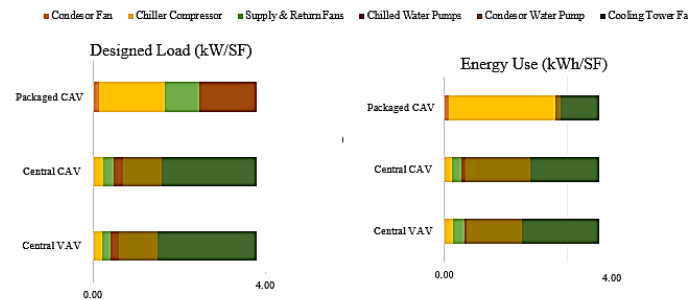


Figure 4. Design load and energy use comparison across systems

There are many different types of air based HVAC systems, as shown in Fig.4 which have evolved gradually for better control, energy savings or thermal comfort considerations. A CAV system has the features of simplicity, low cost and reliability. It does not change air delivery rates when building load changes. To accommodate the varying building load for thermal comfort, it either mixes cold air with warm air or use terminal reheats to offset the excessive cooling. The air distribution in the conditioned space can be easily ensured with this type of system.

In many applications, pure CAVs are not energy conservative and are becoming rare in newer construction. Some changes in the system operation and configuration have been adopted to preserve the original simplicity while achieving better energy conservation. Resetting the supply air temperature, supply water temperature or water flow rate can be utilized in a CAV and induction terminal system for building perimeter air conditioning.

The airflow to a conditioned space could be adjusted to the needed rate with a VAV system. The system supplies cold air to the space via terminal damper boxes. Depending on the system layout, the terminal boxes may or may not be equipped with a reheat coil. Additional heat is provided by a reheat coil if the space needs less cooling than that delivered by the supply air at the box's minimum airflow rate setting. Since the air can be adjusted at the terminal side with both rate and temperature, VAV is considered more energy conservative under most circumstances. It has been used in many applications where the space cooling/heating loads have a wide range variation with occupancy activities and external air conditions. In a large or multi-story office building, more than one AHU is needed to accommodate the load variances across zones. As stated in the previous section, the office building load can be characterized as interior and exterior. Since the central interior area is less influenced by outside conditions, the space is mainly cooling dominant. The variance of load within the interior zone seldom changes the cooling

dominancy throughout the seasons. A constant supply air temperature at 55°F is commonly used so that the building humidity and temperature can be maintained with relatively low fan power consumption. The system's minimum airflow rate varies from 30% to 50%, or higher, which depends on factors including minimum OA intake, mechanical fan features and air circulation requirements.

Circumferential perimeter zones in an office building can also be conditioned by one or more AHUs. Since perimeter zones have strong correlations between building envelopes, outside conditions and orientations, the load across the zones could have significantly different features. The extreme situation is that cooling and heating coexists in the zones. A CAV with induction units and a VAV with terminal reheats are two common types of air-based systems that are applied in perimeter zones for flexibility. The AHUs are controlled to adjust the supply air temperature, or along with the flow rate.

## VI. A CASE STUDY OF AIR HANDLING UNIT

The accuracy of the treatment will depend from the specificity of each project (offices, schools, swimming-pools, laboratories, factories with industrial processes, etc.). This means, the Air Handling Unit treat the air by filtering, cooling and/or heating, humidifying and/or dehumidifying.

There are several types of Air Handling Units: Compact, Modular, Residential, DX integrated, Low Profile (ceiling), Packaged, Rooftop mounted (typically on the roofs of buildings, with special weather protection), etc.

## VII. CONSTRUCTION

Usually the Air Handling Units have a casing (also known box) constructed by a framing system and double skin insulated panels (also known as insulated sandwich panel). The most common framing materials are galvanized steel, AluZinc or aluminium.

Regarding the panels skin, the most common materials are galvanized steel and AluZinc. In hygienic AHU's the inner skin usually is made from stainless steel or AluZinc with a special painting finishing. The materials used to insulate the panels are 99% of the times mineral wool (also known as stone wool or mineral fiber) or PU (Polyurethane). Some manufacturers choose the mineral wool and some the PU, it all depends the compromise between thermal characteristics, acoustic attenuation, mechanical strength and production costs that each one is looking for the final product. All the components will be installed inside the casing. The casing is installed on top of a base (or chassis).

#### A. Components of Air Handling Unit

Here are some of the air handling unit components that may be contained in the equipment.

1) *Housing*: The housing that contains all the other components of an AHU is usually made of metal, some are painted to prevent corrosion. In sections where the fans and the coil are located, 1-2 inches of polyurethane foam or PU is used to insulate them to prevent the condensation on the panel. Drain pan is also used as a precaution in the event of condensation of water.

2) *Fan*: Centrifugal fan is used to circulate the air to the various parts of the sections in the building. The typical types of fan available are Backward Inclined, Backward Curved, Forward Curved and Airfoil. The selection of the fan will depend on the air volume and the static pressure required of the system. Usually, the designer of the system will use specialized software to do this selection. In order to reduce the effect of vibration on the panel, the motor and the fan are usually installed on the vibration isolator except when the drive assembly is external to the fan casing.

In recent years, the use of variable air volume (VAV) system is becoming more popular as the volume of the air being discharged can be varied depending on the load condition. If the load is high, the fan speed will be higher and if the load is lower, the speed of the fan will be lower.

The speed of the fan is varied by using frequency inverter instead of conventional motor. Frequency inverter provides better control of the fan speed as a whole range of fan speed from super low to

super high can now be utilized based on the load conditions required.

This technology has enabled better use of energy and is in tandem with the move to go for greener energy.

3) *Cooling Coil*: Cooling Coil is used to cool and dehumidify the air. Both DX (direct expansion) cooling and CW (chilled water) cooling coils are available for use depending on the system design. These coils are arranged in rows with different fin spacing. Aluminium fins and copper tubes are used in the design of the coils. The corrosion resistance hydrophilic fins are also used due to its lower cost and lower resistance to the air velocity.

4) *Filters*: Filters are to remove particles and contaminants of various sizes from the air. The type of air filter being used will very much depend on the application of the system.

a) *Prefilters*: Prefilters are used to accumulate dust through its 5 $\mu$  media paper

b) *High Efficiency Particulate Filter (HEPA) Filter*: HEPA Filter is very efficient and is able to achieve efficiencies up to 99.97%, removing minute particles and airborne bacteria from the air. It is usually used in clean room applications such as semiconductor production floor, operating theatres and critical processes.

5) *Mixing Box*: This box has air inlets that is attached to the dampers. This is the place where the outside air and the return air are mixed to provide the correct proportion of air to be distributed to the space that is to be conditioned.

#### B) System Operation

The Air Handling Unit which will draw fresh air from the ambient through 10-micron fresh air filters and mixed with return air from room and will pass through cooling coil and 5 micron filters and will get treated and temperature reduced. The treated air then enters through the final filters of 3 Micron and further cleaned through the 0.3 microns HEPA filters at terminals and enter into the Clean rooms. The filtered air entering controlled environment gives a dilution effect to the particles' concentration inside the room. Return air is picked up at 10" (approx.) away from floor level through return air risers installed at strategic locations in the modular wall panels and sent back to AHU for recirculation and filtration. The air entering into the return air risers is filtered through 10 micron filters



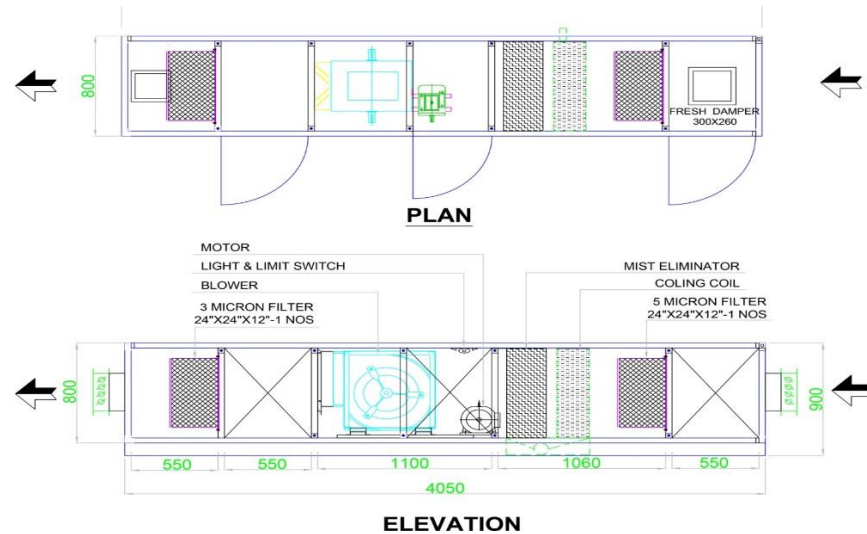


Figure 5. Air Handling Unit

## VIII. CONCLUSION

It is concluded that the public building studied were largely inefficient need efforts to minimally achieve base efficiency. The need to increase energy recovery and decreased operating cost of air handling units is predicted to play a significant role in propelling the global air handling units market.

The expected outcomes will be:

- 1) Identification of the key parameters of AHU performance that impact a building's energy consumption; and
- 2) Modelling the energy consumption process and develop a control algorithm strategy for energy improvement. The result will be the air handling unit with identification of dominates parameters.

The system will have continuous data collection for further evaluation. An optimized control strategy can be developed during second phase of completion of this project.

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