HVAC Design and Heat Recovery Options in an Office Building

Syed Abdul Gaffar, Raza Ahmed Khan, Md Sadiq Mohiuddin, Dr. Mohammed Yousuf Ali

Abstract— Heating, Ventilation, and Air Conditioning (HVAC) is the technology of indoor and automotive environmental comfort. HVAC system design is based on the principles of thermodynamics, fluid mechanics, and heat transfer. It is very important in the design of medium to large industrial and office buildings such as skyscrapers and in marine environments for safe and healthy building conditions are regulated with respect to temperature and humidity, using fresh air from outdoors. The basic purpose of an HVAC system is to provide interior thermal conditions that a majority of occupants will find acceptable. The heat and moisture control functions of HVAC systems provide the foundation for key system components. In specific building situations, supplemental functions, such as controlling smoke from fires or providing background noise for acoustic privacy, may be imposed on an HVAC system.

The primary purpose of this project is to design an HVAC System for a corporate office building to achieve human comfort conditions as per ASHRAE Standards. The project involves load calculations on a sample office building plan at New Delhi using Hourly Analysis Program (HAP). It further deals with routing each sub-system in coordination with other building services to prevent any collisions at site. The equipment machinery is selected based on the requirements and the designed load (tonnage) of the building. Efforts have been made to conserve energy by employing the Heat Recovery Wheel (HRW) in Air Handling Units.

Keywords—Central Plant System, HVAC Systems, Building Design, Heat Recovery, Design Software, Hourly Analysis Programme

1 INTRODUCTION

Heating, ventilation and air conditioning (HVAC) systems control the temperature, humidity and quality of air in buildings to a set of chosen conditions. To achieve this, the systems need to transfer heat and moisture into and out of the air as well as control the level of air pollutants, either by directly removing them or by diluting them to acceptable levels.

Heating systems increase the temperature in a space to compensate for heat losses between the internal space and outside. Ventilation systems supply air to the space and extract polluted air from it. Cooling is needed to bring the temperature down in spaces where heat gains have arisen from people, equipment or the sun and are causing discomfort. Heating, ventilation and air conditioning systems vary widely in terms of size and the functions they perform. Some systems are large and central to the building services – these were probably designed when the building was originally commissioned and use ventilation to deliver heating and cooling. Other systems may provide heating through boilers and radiators, with some limited ventilation to provide fresh air or cooling to certain parts of the building such as meeting rooms. In some cases, individual comfort cooling units have been added to a building to overcome a specific overheating problem that had not been thought of at the time of the original design.

So if heating, ventilation and air conditioning can be separate systems, why consider them holistically? The answer lies in the interaction of these services with each other and with the building. By considering HVAC systems as individual elements rather than as an interacting system, it would be easy to overlook a major area of energy wastage – that one component might impact on another. For example, it would be wasteful to increase heating inside a building while the cooling system is fighting to reduce temperatures. It is therefore useful to look at how the elements of an HVAC system interact with each other and fine tune each part to save energy and money.

The true definition of an air conditioning system is one which has the ability to control temperature, humidity and air quality within precise limits, yet the term is often applied to systems which simply cool the space. These cool air systems are more correctly referred to as 'comfort cooling'.

2 RESEARCH METHODOLOGY

Modern air conditioning is critical to almost every facet of advancing human activity. The Project report mainly intends to deliver the requirements and Procedures to implement HVAC Systems in a Commercial Building in terms of Heat Load Calculation, Air Distribution System and Chilled Water System. Understanding the building requirements and applying standards in designing a HVAC System using Tools like HAP (Hourly Analysis Program), etc. to define the capacity and routing of the system is the Scope of the Project.

The project also introduces the concept of Heat Recovery System in the HVAC segment to extract the energy being lost to the atmosphere through the exhaust air. Exhaust Air is the unwanted air being removed from the indoor space from

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areas like washrooms, toilets to maintain the indoor air quality. Such air will also contain the treated air of the indoors space, whose cooling is wasted to the atmosphere. By recirculating the building exhaust air and transferring its cooling to the fresh ambient air is a great alternative of Heat Recovery.

HVAC system provides adequate indoor air quality by: conditioning the air in the occupied space of a building in order to provide for the comfort of its occupants; diluting and removing contaminants from indoor air through ventilation; and providing proper building pressurization.

In many buildings, the air distribution system also includes a return air system so that conditioned supply air is returned to the AHU (return air) where it is mixed with supply air, re-filtered, re-conditioned, and re-circulated throughout the building.

This is usually accomplished by drawing air from the occupied space and returning it to the AHU by: (1) ducted returns, wherein air is collected from each room or zone using return air devices in the ceiling or walls that are directly connected by ductwork to the air-handling unit or (2) plenum returns, wherein air is collected from several rooms or zones through return air devices that empty into the negatively pressurized ceiling plenum (the space between the drop ceiling and the real ceiling). The air is then returned to the air-handling unit by ductwork or structural conduits. Finally, some portion of the air within is exhausted from the building. The air exhaust system might be directly connected to the AHU and/or may stand-alone.

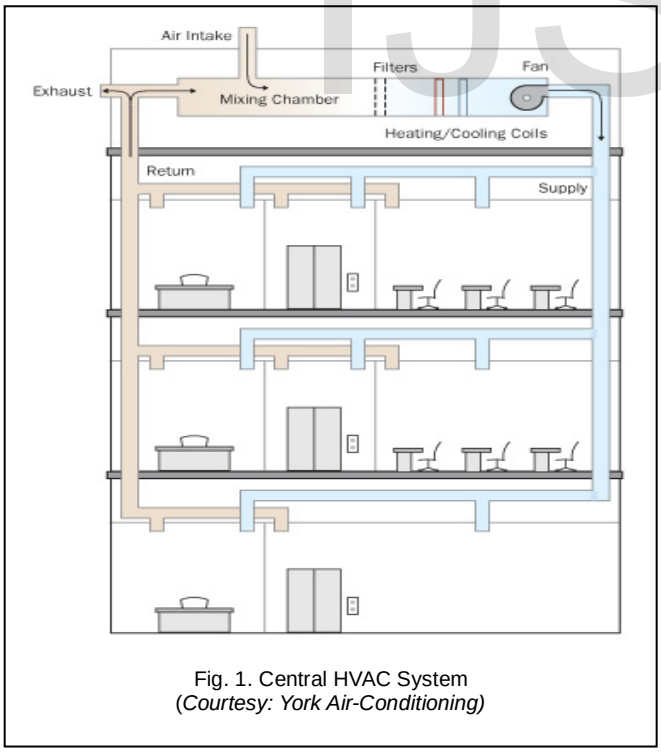

Fig. 1. Central HVAC System
(*Courtesy: York Air-Conditioning)*

The Calculation and selection of the Heat Recovery Wheel depends on the temperature conditions of the return air and the supply air through the heat exchanger. A rotary air-to-air heat exchanger has a revolving wheel filled with an air-permeable medium having a large internal surface area is selected. The wheel is mounted in a supporting structure, and the motor driven at up to approximately 20 revolutions per minute. Adjacent supply and exhaust air streams each flow through half of the wheel in a counter-flow pattern. The selection is done using an application software ECOFRESH for the desiccant wheel.

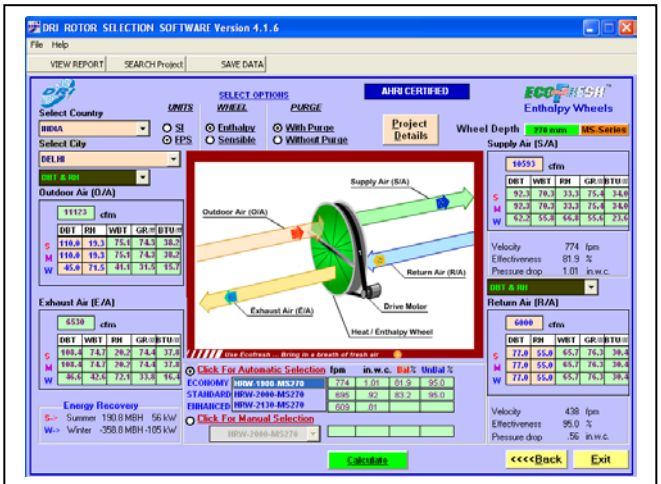

Fig. 2. Selection of Desiccant Wheel by Eco-Fresh Software

The actual use of the words "air conditioning" varies considerably, so it is always advisable to check what is really meant. Consider, for example, "window air conditioners." The vast majority provide cooling, some dehumidification, some filtering, and some ventilation when the outside temperature is well above freezing. They have no ability to heat or to humidify the conditioned space and do not cool if it is cold outside. In colder climates, heating is often provided by a separate, perimeter heating system that is located within the outside walls. The other functions: cooling, humidification, dehumidification, cleaning, ventilating and air movement, are all provided by a separate air system, often referred to as the "air-conditioning system." It is important to remember that both the heating and the air system together form the "air-conditioning" system for the space.

Finally, by keeping the Heat Recovery Wheel in the Air Handling Unit tried to make heat transfer from the exhaust air to the fresh air. Heat Recovery Wheel plays a vital role to save the energy consumption and recommendations are made at the end to save the energy consumption.

3 Designing Software

Computer-aided design and sizing programs are widely used for more precise calculation and optimum sizing of large and more complicated systems.

Heat Load Calculation – Hourly Analysis Program (HAP)
Duct Designing – McQuay Software
Heat Recovery – Eco Fresh Software

4 Building Survey

The Civil Construction details for the Commercial Corporate Project (G+3F) are as per the specifications provided from the civil consultant. The Civil specifications form the consultants

include the complete civil plan with a given North direction and all the material specifications of all those kinds of materials to be used in the project.

The material specifications were inserted into the HAP software and are as given below.

U 8" wall = 0.222 BTU/hr/ft²/F
U 6" roof = 0.091 BTU/hr/ft²/F
U glass = 0.590 BTU/hr/ft²/F

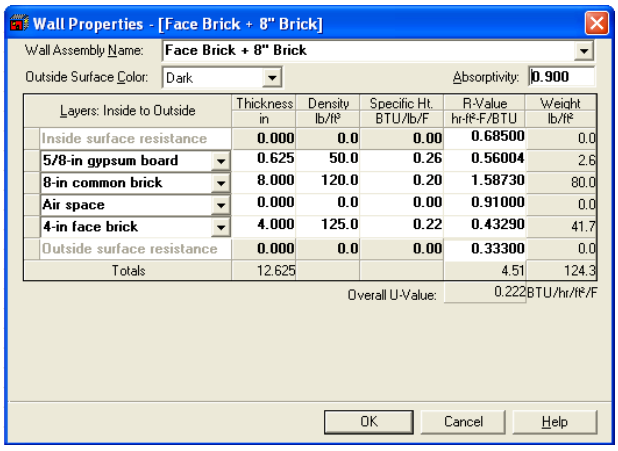

Fig. 3. External Wall Properties

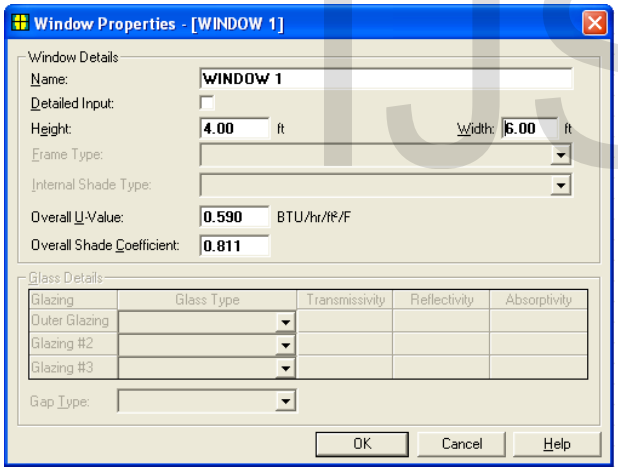

Fig. 4. Glass Properties

5 Discussion of Design

While there are many different HVAC system designs and operational approaches to achieving proper system functionality, and every building is unique in its design and operation, HVAC systems generally share a few basic design elements like outside air intake, air handling unit, air distribution system, and air exhaust system.

In general, outside (supply) air is drawn into a building's HVAC system through the air intake by the air handling unit (AHU). Once in the system, supply air is filtered to remove particulate matter (mold, allergens, and dust), heated or cooled, and then circulated throughout the building via the air distribution system, which is typically a system of supply ducts and registers.

Hourly Analysis Program (HAP):

The Heat Load Calculation for the project was performed with the industry oriented software called as HAP, Hourly Analysis Program. The Heat Load Calculation sheets for the project building as per each room/space are as given below. The values required herein for further calculations are the Tonnage and CFM flow of air of each room/space. These values are formulated through HAP Software and printed in form of word formats as Project reports.

HAP is designed for consulting engineers, design/build contractors, HVAC contractors, facility engineers and other professionals involved in the design and analysis of commercial building HVAC systems. The program is a powerful tool for designing systems and sizing system components.

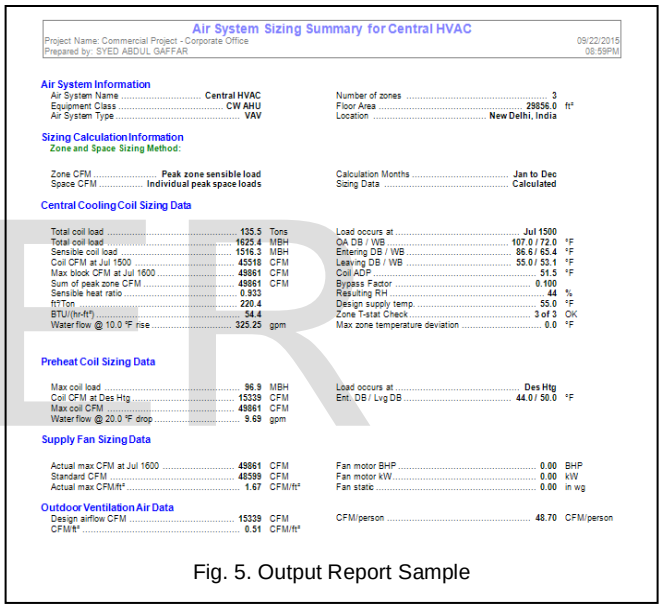

Fig. 5. Output Report Sample

6 Discussion of Results

The centralized Air Conditioning System for the Commercial Corporate project were designed for New Delhi region under the specification of the civil part to achieve the indoor conditions of the project with considerable options of efficient design such as heat recovery. The design and drafting of the project is as submitted, below are the results and their discussion which can be further carried out to evaluate the outcomes of the project.

The design of the complete project was done as per the requirements to maintain the given human comfort conditions for all the occupants with the climatic condition at New Delhi.

The design load calculations for the project were performed on Hourly Analysis Program Software which estimates the heat transfer as per hourly basis to provide efficient way of selecting the machines. The complete shop drawings for the project were prepared along with the

schedules of all equipment for further procurement an installation at site. The air calculations were performed to determine the air inflow and outflow requirement for the heat recovery option of desiccant wheel.

The implementation of the FAHUs along with Heat Recovery option as per the requirement will provide its savings in the life of project. The desiccant wheel selected for the FAHU to extract cooling from the exhaust air to pass it to the fresh air as supplied to the building as per human comfort requirement.

Usually these Heat Recovery systems do provide and reduction on 1-2˚F which in turn provide significant savings in the lifetime of project. The building's energy performance will be continuously monitored with further fine tuning and improvements to control strategies.

There is a need to conducting site-wide energy efficiency assessments to identify the opportunities to reduce energy intensity and identify waste heat recovery and reuse opportunities. The Savings for the same will be more in terms of energy consumption like Electricity and also the cooling thus given can be more appropriately reused for further saving requirement. In addition to the energy savings, building reliability has increased together with an improvement in occupant comfort due to enhanced zoning arrangements and better control.

The results thus discussed are the outcomes of the project Central HVAC for Commercial Corporate Building, will be further developed and to be utilized for a proper implementation for the future scenario of the MEP Industry requirements.

S.No.	DESCRIPTION OF RESULT	RESULT
1	Total Tonnage TR	135.5 TR
2	Total Air Supply CFM	49861 CFM
3	Fresh Air CFM	10500 CFM
4	Exhaust Air CFM	6000 CFM

Result Analysis:

By the design analysis it has been identified that, by using Heat Recovery Wheel there was power consumption of 10-15% on the total load.

In general, the comfort levels as per the ASHRAE standards are:

Temperature range: 22oC - 26oC

Relative Humidity range: 30% - 60%

CO2 level: <1000ppm

The abnormal distribution of cool air in the space by the HVAC system, hence it needs proper rotation and distribution of air in the space.

More over from the Research Questionnaire analysis, it seems that the quality of air is better. Further to improve the air quality levels in the space and healthy environment of the occupants, it is necessary to allow the fresh air continually in the floors which is rectified to be done in the office in walk through inspection. Maintenance and Operation person of the HVAC system need to monitor the proper working of the system from time to time. Cleaning of the carpets is to be done to remove dust formation and accumulation of the pollutants. Also noted that the locations are free from wet or moist with which there are chances of growing fungi which also lowers the quality of air.

7 Conclusion

HVAC systems are the mostly required in now-a-day corporate offices for maintaining the Human Comfort at international & large scale level. The report describes the importance of proper design of a Centralized Air-Conditioning System for the Corporate Office building as per the standards of ASHRAE & SMACNA, will be submitted for approval from the sponsored authority.

The Heat Load Estimated provides the requirement of Cooling for the project, provides a guideline for the Selection of Machines.

HAP is designed for consulting engineers, design/build contractors, HVAC contractors, facility engineers and other professionals involved in the design and analysis of commercial building HVAC systems. The program is a powerful tool for designing systems and sizing system components.

All the Equipment are installed as per the manufacturer's recommendations to achieve its best efficient performance. The Duct designing is done as per SMACNA Standards, providing the most economical and effective routing to deliver the cool air with least losses. There is a need to conducting more such site-wide energy efficiency assessments to identify the opportunities to reduce energy intensity and identify waste heat recovery and reuse opportunities, thus the Project Report clearly identifies the requirements of the project and provides an effective way of Air-Conditioning to achieve Human comfort for the occupants. The design and drawings as approved will be sent to the site installation process. Therefore, the project defines the requirement and process of achieving the Human Comfort and Environment.

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References

[1] Annual Energy Outlook 1998, DOE Energy Information Administration, December 1997, DOE/EIA – 0383 (98)
[2] "A/C Equipment Efficiency", Heating, Ventilation, Air-Conditioning and Refrigeration News, November 10, 1997, p.3. Re-Print from October Tech Update, ARI, October 1997
[3] 1995 Commercial Buildings Energy Consumption Survey, DOE/EIA, October 1998, DOE/EIA-0625 (95)
[4] Fouche, Ed and Heck, Greg. 2006. "Industrial Waste Heat Recovery and Reuse." Paper presented at the Global Energy Partners 2006 Summit Meeting, Nashville, TN., September 13-14.
[5] American Society of Heating Refrigeration & Air conditioning Engineer's Fundamentals Hand Books 2003
[6] Carrier Design Manual
[7] Trane Air Conditioning System Design Manual
[8] Sheet Metal & Air Conditioning Contractors National Association Standard

[9] 1992 Commercial Buildings Energy Consumption Survey, DOE/EIA Characteristics, April 1994, DOE/EIA-0246 (92); Consumption and expenditures, April 1995, DOE/EIA-0318 (92).
[10] Analysis and Categorization of the Office Building Stock, Briggs et al, PNL for GRI, 1987.
[11] Energy Requirements for Office Buildings, PNNL for GRI, February 1992, GRI- 90/0236.1.