Designing of Optimum Cooling Load and Airflow System for a Four-Story Building

Stephano Ian Yanga[1], and Aristotle Ubando[1,2]
[1] *Department of Mechanical Engineering, De La Salle University, 2401 Taft Avenue, 0922 Manila, Philippines*
[2] *Center for Engineering and Sustainable Development Research, De La Salle University, 2401 Taft Avenue, 0922 Manila*
* *stephano_yanga@dlsu.edu.ph*, *aristotle.ubando@dlsu.edu.ph*

Abstract: Effective HVAC design is paramount for creating comfortable and energy-efficient indoor spaces. This abstract explores three pivotal aspects: cooling load calculations, ventilation considerations, and duct pressure loss analysis. Cooling load calculations establish the foundation for sizing HVAC systems, optimizing thermal comfort through accurate estimates of factors like outdoor conditions and heat gains. Ventilation, essential for air quality and health, balances fresh air exchange and energy efficiency, considering occupancy and pollutants. Duct pressure loss calculations ensure efficient airflow distribution, reducing energy consumption. Proficiency in these principles empowers HVAC professionals to design systems that enhance comfort, air quality, and sustainability. The study designed cooling load, duct sizing and external static pressure (ESP) calculation using Cooling Load Temperature Difference (CLTD) method, equal friction method and ASHRAE manual calculation for duct pressure loss, respectively.

Key Words: Cooling Load; Ventilation; Duct Design

1. INTRODUCTION

In the Philippines, a nation characterized by its vibrant culture and stunning landscapes, the pursuit of thermal comfort through meticulous HVAC design takes on a significance that extends beyond mere engineering. With its tropical climate bestowing scorching heat upon bustling cities and the occasional embrace of monsoon rains, the art of HVAC design becomes a vital component of modern living. The challenge lies not only in the technical aspects of system efficiency but also in the cultural understanding of comfort and the integration of sustainable practices.

HVAC systems in this region must transcend their utilitarian role, becoming envoys of well-being that harmonize with the cultural and social fabric of Filipino society. It is a delicate balance of engineering precision and adaptive solutions that cater to the diverse needs of occupants, be it in towering skyscrapers or traditional dwellings. Beyond mere cooling, these systems must be adept at mitigating humidity, managing air quality, and even preserving the architectural heritage of the country.

As urban centers like Metro Manila continue to evolve, the symbiotic dance between sustainable design principles and cutting-edge technologies emerges as a defining characteristic of HVAC innovation. The quest for thermal comfort now converges with ecological consciousness, resulting in the integration of energy-efficient practices, renewable energy sources, and smart controls. This marriage of environmental stewardship and technological progress strives to create indoor environments that enhance the well-being and productivity of occupants, while simultaneously reducing the carbon footprint.

In this dynamic landscape, the pursuit of thermal comfort is an ever-evolving journey, involving an intricate web of considerations. The role of HVAC design goes beyond the pragmatic implementation of mechanical systems; it embodies an ethos of adaptability, responding to the Philippines' distinct climatic nuances and cultural nuances. The art and science of thermal comfort intertwine, shaping spaces where architectural aesthetics seamlessly coexist with the subtle hum of state-of-the-art ventilation.

2. METHODOLOGY

Below outlines the procedures employed in the creation of an HVAC system design:

2.1 Design Consideration

When conducting cooling load computations for the office structure, a critical architectural consideration involves tailoring cooling systems to the distinct needs of diverse spaces, encompassing even the bathroom exhaust requisites. The design parameters of the office building under peak heat load conditions are presented in Figure 2. Strategic choice was made to implement a centralized air conditioning (AC) system for workspaces, while alternative split type or window type AC units were designated for other areas, aligning with thermal comfort and ventilation prerequisites. This approach is poised to maximize energy efficiency and operational adaptability within the building's framework.

Workspaces, being the central zones of occupants' activities, necessitate meticulous temperature regulation and harmonized airflow. Hence, a centralized AC framework is poised to adeptly govern temperature and ventilation in these sectors. In contrast, meeting rooms, offices, and break areas can ensure optimal thermal comfort by leveraging decentralized cooling systems. The strategic installation of split type or window type AC units in these locales adeptly caters to localized cooling demands, thus ensuring occupants' well-being.

Further, bathrooms, being single-occupancy spaces, can sufficiently fulfill exhaust mandates through household-style exhaust fans. This pragmatic approach expeditiously eliminates odors and humidity from the air, fostering a refreshing and healthful ambiance devoid of elaborate or costly ventilation infrastructures.

By embracing this architectural blueprint, the allocation of cooling loads is judiciously spread across distinct zones, obviating unnecessary cooling in non-essential areas. Cooling load estimations were accomplished using the Cooling Load Temperature Difference (CLTD) method, assuring precision. In tandem, the Equal Friction method guided duct sizing and design to meet ventilation criteria within workspaces.

This all-encompassing design strategy not only guarantees effective cooling, energy efficiency, and occupants' contentment but also streamlines maintenance and scalability endeavors. It establishes a meticulously controlled indoor milieu across the entire edifice, striking an equilibrium between cooling load demands, operational malleability, and occupants' aspirations.

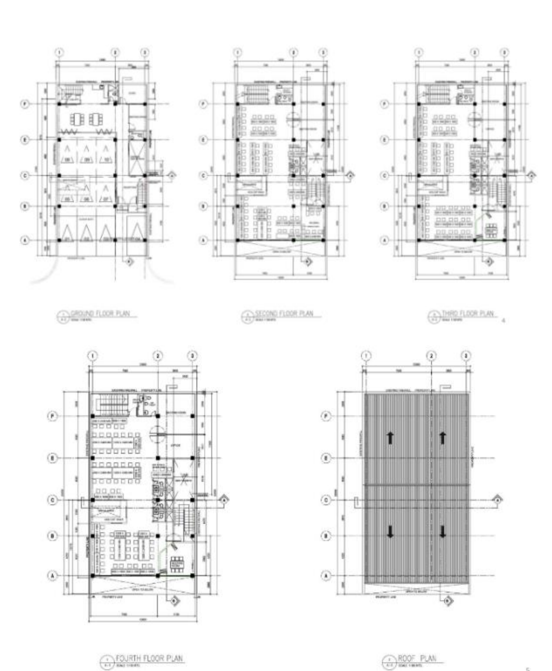

Fig. 1. Building Floor Plan.

2.2 Computation of Cooling Load and Ventilation

Internal Heat Sources: Equations 1-4 encompass heat gains stemming from various sources as extracted from [2], incorporating parameters such as lighting power density (LPD), area (A), sensible heat (SH), latent heat (LH), and cooling load factor (CLF).

$$qs,_{lights} = \text{LPD} \times \text{A} \times \text{CLF} \quad (1)$$

$$qs,_{computers} = \text{Load Factor} \times \text{A} \times \text{CLF} \quad (2)$$

$$qs,_{people} = \text{no. of people} \times \text{SHperson} \times \text{CLF} \quad (3)$$

$$qL,_{people} = \text{no. of people} \times \text{LHperson} \times \text{CLF} \quad (4)$$

External Heat Sources: Calculations for external heat gains are presented in Equations 5 and 6. Parameters U and CLTD are extracted from [6] and [7] respectively, with $qs,_{roof}$ representing heat gain through the roof and $qs,_{glazing}$ indicating heat gain through windows.

$$qs,_{roof} = (\text{U} \times \text{A} \times \text{CLTD}) \quad (5)$$

$$qs,_{glazing} = (\text{U} \times \text{A} \times \text{CLTD}) \quad (6)$$

3. RESULTS AND DISCUSSION

3.1 Cooling Load Calculation

The information presented in the table provides a synopsis of the cooling load assessments for the individual rooms within the 4-story building. On the first floor, there is a heat load of 10203 Watts. The second and third floors have heat loads of 35208 Watts and 32459 Watts, respectively. The final floor registers the most substantial heat load due to its higher occupancy and roof heat, amounting to 37272 Watts. As a result, the overall cooling load for the building sums up to 212314 Watts or 60.37 Ton of Refrigeration (TOR), factoring in a 10% safety margin.

Room Name	Manual Calcs			SQ.m/TR	W/M2
	Cooling		CHECK VALUES		
	Sensible. Load (watts	Total Cooling Load (watt	watts/ sq.m.		
GF					
L1-Reception/Lobby	6593	6760	87.4	40.2	87.4
L1-Meeting Room	1272	1289	161.3	21.8	161.3
L1-Clinic	1026	1045	117.4	29.9	117.4
L1-Utility Room	248	253	111.1	31.7	111.1
L1-Toilet	377	382	167.6	21.0	167.6
L1-Powder Room	468	474	164.7	21.4	164.7
		10203			
LEVEL 2					
L2-Office	28567	28872	186.5	18.9	186.5
L2-Meeting Room 1	1795	1832	97.8	36.0	97.8
L2-Meeting Room 2	1257	1278	120.8	29.1	120.8
L2-HR Area	1456	1483	108.9	32.3	108.9
L2-Utility Room	349	355	108.6	32.4	108.6
L2-VIP Toilet	362	367	143.5	24.5	143.5
L2-Women's Toilet	437	443	156.0	22.5	156.0
L2-Men's Toilet	567	577	114.5	30.7	114.5
		35208			
LEVEL 3					
L3-Office	25984	26256	190.3	18.5	190.3
L3-Meeting Room 1	1768	1802	103.8	33.9	103.8
L3-Meeting Room 2	1619	1646	119.7	29.4	119.7
L3-Small Office	1125	1146	108.3	32.5	108.3
L2-Utility Room	349	355	108.6	32.4	108.6
L2-VIP Toilet	362	367	143.5	24.5	143.5
L2-Women's Toilet	437	443	156.0	22.5	156.0
L2-Men's Toilet	437	443	156.0	22.5	156.0
		32459			
LEVEL 4					
L4-Office	30780	31053	225.1	15.6	225.1
L4-Meeting Room 1	1763	1797	103.5	34.0	103.5
L4-Meeting Room 2	1599	1624	129.5	27.2	129.5
L4-Small Office	1122	1142	114.8	30.6	114.8
L4-Utility Room	249	253	133.8	26.3	133.8
L2-VIP Toilet	366	371	145.0	24.3	145.0
L2-Women's Toilet	442	447	157.5	22.3	157.5
L2-Men's Toilet	575	585	116.0	30.3	116.0
		193013		819.1	4057.2
		212314		**901.1**	**4463.0**

Fig. 2. Manual Calculation of Cooling Load.

3.2 Duct Design

The information presented in the table provides an overview of the duct configuration, encompassing dimensions, lengths, fittings, and pressure differentials. During the design stage, rectangular ducts were selected for both the supply and exhaust systems. To determine the duct size, the equal friction method was employed, with a specific consideration of 0.8 Pa/m. The sizing of the ducts was facilitated through the utilization of McQuay software. Additionally, the calculation of total pressure loss in both the supply and exhaust ducts was based on the employment of External Static Pressure (ESP) measurements. This approach enhances the accuracy of the duct system's performance evaluation and ensures efficient air movement throughout the system.

Furthermore, the incorporation of rectangular ducts offers advantages in terms of fitting into diverse architectural spaces while maintaining optimal airflow. The application of the equal friction method, coupled with McQuay software, enables a meticulous design that considers factors such as pressure gradients and air velocity, leading to a balanced and effective ventilation system. The utilization of External Static Pressure as a metric for assessing pressure loss ensures a comprehensive analysis of the system's capacity to overcome resistance and deliver the desired airflow. This holistic approach results in a well-engineered duct system that aligns with both functional and efficiency requirements.

Section	Flow Rate	Duct Type	Duct Width	Duct Height	Duct Material	Duct Length
	lps		mm	mm		m
SUPPLY DUCT:						
GF	84	Rectangular	200	150	Galvanized Steel Sheet	12.66
Level 2	261	Rectangular	300	300	Galvanized Steel Sheet	15.68
Level 3	240	Rectangular	400	350	Galvanized Steel Sheet	15.68
Level 4	270	Rectangular	400	400	Galvanized Steel Sheet	15.68
EXHAUST DUCT:						
GF	165	Rectangular	250	200	Galvanized Steel Sheet	8.04
Level 2	240	Rectangular	350	300	Galvanized Steel Sheet	9.02
Level 3	225	Rectangular	400	350	Galvanized Steel Sheet	9.02
Level 4	270	Rectangular	450	400	Galvanized Steel Sheet	9.02

Fig. 3. Manual Duct Size Calculation.

4. CONCLUSIONS

Determining the cooling load plays a pivotal role in HVAC design, acting as a guide for selecting the right cooling equipment and ensuring optimal energy usage while keeping occupants comfortable. By thoroughly analyzing both internal and external heat factors, as well as ventilation needs, designers can create HVAC systems that perfectly fit the space's unique requirements. A thorough cooling load calculation is essential, leading to indoor spaces that are not just efficient and practical, but also incredibly cozy. In our recent study, we found the cooling load to be 212,314 Watts, along with a well-thought-out ventilation plan customized to the building's needs.

6. REFERENCES

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