INTERNATIONAL JOURNAL OF ADVANCED INNOVATIVE TECHNOLOGY IN ENGINEERING

Published by Global Advanced Research Publication House Journal

Home page: www.ijaite.co.in

Design and Development of Duct Cooler

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Article History

Received on: 15 April 2023

Revised on: 03 May 2023

Accepted on: 17 May 2023

Keywords: Duct Cooler, Cooling Air, Efficient Cooling System, Heat Transfer, Air Leakages in Duct

e-ISSN: 2455-6491

DOI:

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ABSTRACT

In an attempt to counter the problem of ill ventilation and discomfort due to heavy temperatures during summer in central India i.e., when the temperature in summer goes well above 45 degrees, it is necessary to have a cost-effective and efficient cooling system. The ideal cooling system should be effective as well as economical. It requires less maintenance Therefore; an effective air duct cooling system is designed forth places of gathering. In this attempt, ME02 has been chosen for the design. "ME02" can best replicate the situations under which people use to gather for practical and other activities. Thus, we can attempt to design for human comfort in a much more realistic way. To carry out certain loads and calculations, a mechanical cad lab has been chosen to represent the situation and for the availability of the prerequisite data. This design has been carried out as per the guidelines given by ISHRAE. Our concentration was mainly on the efficiency of the design while giving the highest priority to the uniform distribution of cooling air and minimizing the pipe friction loss. After a series of calculations and designing the outcome was a possible solution for an optimum ducting system for our classroom. This project report will study about velocity distribution of air in the duct at various sections, pressure difference at various outlets and distribution of air flow for different load conditions.

1. INTRODUCTION

Earlier the use of air-cooling duct for comfort purpose was considered a luxurious but now-a-day, it has been a necessity in extreme climatic conditions, such as extreme cold and hot in western countries. Window air cooling duct are preferred for office rooms while large centralized units are installed for cooling the auditorium, hospitals etc. The correct estimation of cooling load of large area is very complicated due to many factors such as outdoor temperature, humidity, air leakage into the conditioned space. The climate conditions at workplace like offices, hotels, workshops are also important factor while selecting the optimum design for cooling duct, which results in comfort condition.

A. What is Duct?

The conditioned air (cooled or heated) from the air conditioning equipment must be properly distributed to room or space to be conditioned in order to provide comfort conditions. When the conditioned air cannot be supplied from air conditioning equipment to the space to be conditioned, then the ducts are installed. Means the duct is a pipeline or system which is used to convey the cool air from the main source of cooling to the space to be cooled.

Ducts are conduits or passage used in heating, ventilation and air conditioning system. When the conditioned air cannot be supplied directly from the air conditioning equipment then ducts are to be installed. These ducts deliver or remove air. Duct commonly also deliver ventilation air as part of the supply air. It ensures acceptable indoor air quality. It also makes sure to provide thermal comfort. The duct system conveys the conditioned air from the air conditioning equipment to the proper air supply outlets in the room.

B. Duct sizing methods

Various methods of duct design are

- Equal friction method
- Constant velocity method, and
- Static regains method.

C. Duct Design Criteria

Many factors are considered when designing a duct system.

- Space availability
- Installation cost
- Air friction loss
- Noise level
- heat transfer and air leakages in duct.

2. Related Work

The design and development of duct coolers is an active area of research and development, with many studies and publications exploring various aspects of the technology. Some of the related work in this field includes:

Experimental and numerical investigation of a duct cooler with different flow rates and geometric configurations. This study explored the effect of different parameters such as the velocity and temperature of the air on the cooling performance of the duct cooler. [1]

Design optimization of a duct cooler using computational fluid dynamics (CFD) simulations and genetic algorithms. This study focused on optimizing the geometric design of the duct cooler to improve its cooling performance and reduce its energy consumption. [2]

A review of different cooling technologies for data centers, including duct coolers. This study examined the benefits and drawbacks of different cooling technologies and highlighted the potential of duct coolers as an efficient and cost-effective solution for data centers. [3]

Analysis of the performance of a solar-powered duct cooler in a residential building. This study evaluated the feasibility and effectiveness of using solar energy to power a duct cooler for cooling residential buildings in hot and humid climates. [4]

Experimental investigation of the thermal performance of a hybrid evaporative-heat exchanger air conditioning system with a duct cooler. This study explored the performance of a hybrid cooling system that combines the benefits of evaporative cooling and heat exchange to achieve high cooling efficiency with low energy consumption. [5].

3. Problem Identification

An efficient DUCT system can you save you loads of money in the long run and keep your home nice and comfortable throughout the year. Problems in the ductwork, however, can quickly consume your energy budget and make it hard to heat and cool certain areas of the home.

A. Abnormal Electric Bill

A sudden spike in your energy bill is a good sign that your home's DUCT system is compromised. Leaky connectors and poor designs lead to air flow loss, which makes the system work harder to heat and cool the home. This in turn expends more energy and runs up the electricity bill.

B. Noisy Ductwork

Another good indication of a bad DUCT system is noisy ductwork. In rectangular ducting, these noises are usually the result of the metal expanding and contracting. It should be noted that noises are typical when the system first turns on or off. You should be concerned, however, if the noises continue while the system is running. If you hear a whistling sound, for example, you are likely dealing with vent covers that are too small for the system.

C. Uneven Temperature

If you have areas of the home that are hard to heat and cool or get overly stuffy, your DUCT system probably has a leak or two. Uneven temperatures are caused by poor air flow because the system is simply losing too much air to properly do its job. In extreme cases, you will not be able to heat or cool certain areas of the home even if the thermostat is turned to its highest setting.

D. Sheet Metal Ductwork

Sheet metal ducts are the most popular form of rigid ductwork. These ducts are usually made from either galvanized aluminum or steel. The aluminum variety is great because it's lightweight and relatively easy to install. Aluminum also does not tend to grow mold or bacteria due to its non-porous surface. When selecting the right kind of sheet metal ductwork, look for the kind that comes equipped with insulation wrap, which helps prevent air leakage over time.

4. Material and Methodology

A. Component Used

1. Vibration Insulator
2. Stack Boots and heads
3. Volume control dampers
4. Smoke and fire dampers.

A. Vibration Insulator

A duct system often begins at an air handler. The blowers in the air handler can create substantial vibration and the large area of the duct system would transmit this noise and vibration to inhabitants of the building. To avoid this, vibration isolators (flexible sections) are normally inserted into the duct immediately before and after the air handler.

B. Stack Boots and heads

\Ducts especially in homes, must often allow air to travel vertically within relatively thin walls. These vertical ducts are called stacks and it is either very wide and relatively thin rectangular sections or oval sections. At the bottom of the stack, a stack boot provides a transition from an ordinary large round or rectangular duct to the thin wall-mounted duct. At the top, a stack head can provide a transition back to ordinary ducting while a register head allows the transition to a wall-mounted air register.

C. Volume Control Dampers

Ducting systems are providing a method of adjusting the volume of airflow to various parts of the system. Volume controls dampers (VCD) are not to be confused with smoke/fire dampers that provide this function. Besides the regulation provided at the registers or diffusers that spread air into individual rooms, the damper can be fitted within the ducts themselves. These dampers may be manual or automatic.

D. Smoke And Fire Dampers

Smoke and fire dampers are found in ductwork where the duct passes through a firewall. Smoke dampers are driven by a motor, referred to as an actuator. A probe connected to the motor is installed in the run of the duct and detects smoke, either in the air which has been extracted from or is being supplied to a room, or elsewhere within the run of the duct. Once smoke is detected, the actuator will automatically close the smoke damper until it is manually re-opened.

B. Air Cooler

An air cooler is an equipment used for air cooling. It is one type of heat exchanger used to cool the air. A desert cooler is a device that cools air through the evaporation of water. Evaporative cooling is differing from typical air conditioning systems which use vapors compression or absorption refrigeration cycles.

An air cooler is a unit for cooling the air supplied to a building or dissipating the heat from machinery and furnaces and other types of heat-producing equipment. Air coolers are used in ventilation and air conditioning systems for industrial, public, and residential buildings as well as in cooling systems for electric generators, computers, radio, and chemical equipment.

Components of Air Cooler

a) Body: The body is made up of Galvanized Iron (G.I) sheet with 24 gauge (.57mm). The other component of the cooler is enclosed within the body.
b) Fan: It is necessary to choose a fan with the required capacity otherwise the cooling effect will decrease.
c) Pump: A pump is used to pump the water from the water reservoir to the wood wool.
d) Wood Wool: Wood wool absorbs water pumped up from the reservoir.
e) Reservoir: Reservoir stores the excess water and through this reservoir, the pump draws the water.

Design of Duct Layout

On the basis of a particular airflow and velocity obtained from the selected AHU, the area of the duct is determined using the equal friction method by using McQuay software, as we are dealing with a moderate velocity system. The above process culminates with the establishment of a feasible duct network, and the estimation of the type, number and location of outlets & inlets. i.e. Diffusers, grills are required in the cooling space to accomplish the goal of uniform cooling; keeping in mind the numerous principles guiding room air distribution for adequate comfort.

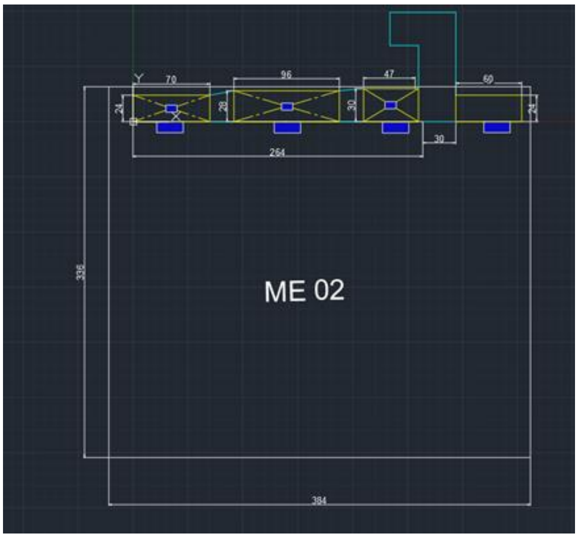

Figure 1: Design of Duct Model

Heat Load Calculations

a) Gross Wall Area (Wall Material includes in windows)

b) Net Wall Area (Wall Area-Window Area)

Q=U*A*ΔT

Where,

U = Overall Heat transfer Coefficient

U=1/ΣR (R=Resistance of material)

A (Area)= 25*50=1250 sq ft

ΔT=Temp difference

ΔT=106-76=30 ˚ F

Gross wall area

Q= U*A* ΔT

A = 352 sq ft

ΔT= 30 ˚ F

U= O/A+1/2*(C.P)+ 8 Inch brick + ½ *(C.P)+ Internal Area

ISHRAE Standard Values

ΣR=0.25 + ½ * (0.12) + 8* (0.2) + ½ * (0.12) + 0.25

ΣR=2.2

U=1/ΣR =1/2.2=0.45 BTU/hr ˚ F ft

Q=UA ΔT

Q=0.45*352*30

Q=6750BTU/hr (1w=3.41BTU/hr)

Q=1.39 kw

Roof Area

Q=U*A*ΔT

U=1/ΣR

ΣR=O/A + 1 * (C.P) + 8 Inch concreate + ½ (C.P) + I/A

ΣR=0.25+0.12+8*(0.08) + ½ * 0.12 + 0.65

ΣR=1.72

Standards Values Of ISHRAE

U=1/1.72=0.58 BTU/hr ˚ F ft

A=32*28=896 sq ft

ΔT=106-76 =30 ˚ F

Q=U*A*ΔT

Q=15590 BTU/hr

Q=4.5 kw (1w=3.41BTU/hr)

Internal Heat Load

Level of Activity	Typical	Heat Grain/Person btuh	
	application	SHG (qs)	LHG (ql)
Seated at rest	Theater	245	105
Seated, light work	Office	245	155
Moderate office work	Office	250	200
Standing, walking slowly	Retail Sales	250	250
Light beach work	Factory	275	475
Dancing	Nightclub	305	545
Heavy work	Factory	580	870

1) People heat load

2) Lighting heat load

3) Electrical heat load

1) People heat load

Qs= Sensible heat / people * no of people

Ql= latent heat / people * no of people

Ex. Class Room =896 sq ft (65 peoples)

Sensible heat (from chart of ishrae)=245

Latent heat = 155

Qs=245*65 = 15,925 BTU/hr = 4.6kw

Ql=155*65 = 10.075 BTU/hr = 2.9 kw

Lighting heat load

Q= watts / sq ft * area in sq ft * 3.4

For office = 1.1 watt/sq ft

Q=1.1 * 896 * 3.4

Q=3351 BTU/hr

Q=0.98 kW

Design Tools Duct Sizer Version 6.4 McQuac

M° = Q/(CP X ΔT)

where,

M° = mass flow rate kg/s

Q = (kW) heat load

Cp = Specific heat capacity (kJ/kgK)

ΔT = temperature difference

Cp = 1.026 (kJ/kgK) (standard value from ISHRAE)

ΔT = should be less than 10 °C

= 17.07 kW Total Heat Transfer

M° = 2.07 kg/s

M° = kW/(kJ/kgK.8K)

Density of Air = 1.2 kg/m^3

Specific volume = Density^{-1}

= 1.2^{-1} = 0.833 m^3/kg

Formula,

v° = m° X v

v° = volume flow rate (m^3/s)

m° = mass flow rate (kg/s)

V = specific volume (m^3/kg)

V = 2.07 X 0.833

V = 1.73 m^3/s (1cubic metre/second = 2118.8 cfm)

So,

v = 1.73*2118

= 3665 cfm

5. Result and Discussion

All the problems associated with the cooling of the room have been solved. All the losses while delivering the air are calculated and the design is selected by checking all the parameters and CFM has been calculated according to the requirement. Furthermore, the design and development process considered factors such as compactness, ease of installation, and maintenance requirements. The resulting duct cooler was designed to be easily integrated into existing ductwork systems, ensuring minimal disruptions during installation. Additionally, its modular design facilitated easy maintenance and servicing, further enhancing its usability and longevity.

6. Recommendation

1) Cleaning of honeycomb pad every season or changing it if required.
2) Cleaning the water pump.
3) Providing proper ventilation in the room.
4) Checking water blockages.

Conclusion

As with all case study techniques, knowledge of components and their function in a system is vitally important. Duct air coolers are simple in design but there are chances of poor air delivery if the air cooler is not maintained properly. Overall, the design and development of the duct cooler yielded a highly efficient and reliable cooling solution. Its superior performance, energy efficiency, and user-friendly features make it a valuable asset in various applications, including commercial buildings, industrial facilities, and residential spaces, where effective temperature regulation and comfort are paramount.

Conflict Of Interest

The authors declare that they have no conflict of interest.

Funding Support

The author declares that they have no funding support for this study.

References

[1] Cui, Z., Li, J., & Wang, L. (2018). Experimental and numerical investigation of a duct cooler. Energy Procedia, 152, 771-776.

[2] Karakurt, O., & Oztop, H. F. (2017). Design optimization of a duct cooler using genetic algorithm and computational

fluid dynamics. Journal of Thermal Analysis and Calorimetry, 128(1), 193-205.

[3] Belady, C. (2015). Cooling technologies for data centers. ASHRAE Journal, 57(1), 22-28.

[4] Asgari, A., & Farzaneh-Gord, M. (2019). Performance analysis of a solar-powered duct cooler in a residential building. Energy and Buildings, 188, 12-21.

[5] Zhu, Y., Yang, X., Wang, L., Wang, C., & Lu, L. (2021). Experimental investigation of the thermal performance of a hybrid evaporative-heat exchanger air conditioning system with a duct cooler. Applied Thermal Engineering, 194, 116928.

[6] Refrigeration and Air Conditioning by R.S. Khurmi and J.K. Gupta

[7] Refrigeration and Air Conditioning by C.P. Arora

[8] Refrigeration and Air Conditioning by R.K. Rajput

[9] Md. Almostasim Mahmud International Journal of Emerging Technology and Advanced Engineering. Design Optimization and Installation of the Evaporative Cooler, Volume 2, Issue 11, November 2012

[10] Dave Janquart, Design of an air distribution system for a multi-story office building

[11] Design of Air cooling Duct, Version 1 MF, IIT Kharagpur [5] Midwest Research Institute National Renewable Energy Laboratory Division, An Emerging Solution for Homes in Hot and Dry Climates with Modest Cooling Loads

[12] Indian Society of Heating Refrigeration and Air conditioning engineers, Hand Book, Industrial Ventilation Application. [7] American society of Heating, Refrigeration and Air Conditioning Engineers, HVAC Chapter 7

[13] Y.S. Abubakar, ARPN Journal of Engineering and Applied Science, Design and Construction of an Evaporative Cooler

[14] T. Pavan, National Conference of Recent Trend and Innovations in Mechanical Engineering, Duct Design of seminar Hall, April 2016

[15] M. Hafeez shaik, Tech supporter “National refrigeration Pvt. Ltd. services” Anantapuram for Heat load calculation and duct design.