

# Indoor Air Quality Considerations for HVAC Systems Design in India

Raza Ahmed Khan, Dr. Kavita Daryani Rao, Dr. M. Manzoor Hussain, Dr. S. Kumar

**Abstract**— The performance and design of Heating, Ventilation, and Air-Conditioning (HVAC) Systems decides the soundness of Indoor Air Quality (IAQ) to a large extent. Almost all modern buildings are air-conditioned and a huge number of occupants spend considerable time inside these buildings. Hence, the goodness of indoor air is vital to their health and productivity. In this study, a research questionnaire survey is carried out for the HVAC designers to obtain information regarding their design practices in India. A large number of HVAC designers and offices were contacted and explained about the study. However, 52 HVAC designers / offices participated from across the country. Their responses were recorded and analyzed to build up a picture of the prevalent HVAC design practices in India.

**Index Terms**— Heating, Ventilation, & Air-Conditioning (HVAC); HVAC Designers; HVAC Systems; Indoor Air Quality (IAQ); Questionnaire Survey; Standards.

## 1 INTRODUCTION

THE economic liberalization policy and subsequent entry of multi-national companies in Indian market resulted in sprouting of many advanced air-tight glazed buildings throughout major cities of the country. All these modern buildings employ air-conditioners to control their indoor environments.

Now people spend most of their time indoors, where the concentration of pollutants are often much higher than those outside. Hundreds of chemical and biological pollutants are found indoors, many of which are known to have significant health impacts. Many research findings have highlighted the indoor environmental pollution as the greatest risks to human health [1].

The Heating, Ventilation, and Air-Conditioning (HVAC) design offices are the places where decisions on the performance of the buildings are first taken, either good or bad. It is therefore essential to know the design criteria that these designers take into account for Indoor Air Quality (IAQ) issues.

## 2 METHODOLOGY

The research methodology adopted for the investigation of IAQ problems that are related to HVAC systems is through gathering the required information from the feedback of HVAC designers. Self-administered questionnaire surveys (see Appendix) and personal interviews with the designers were carried out which provided useful information.

An extensive literature review was done to acquire the in-depth understanding of the issues related to IAQ and HVAC systems, which was helpful in formulating the questionnaire in particular.

The questionnaire is developed seeking information regarding the experience and design practices of HVAC design professionals in India. The designers were introduced to the objectives of the study, its scope and the usefulness of its results. Several aspects of design and compliance with guidelines and standards were also discussed during personal meetings. The architectural and engineering plans of some of the sample buildings were reviewed wherever possible, to have an insight into the design practices.

Various manufacturers and suppliers of HVAC systems were contacted, and information obtained about the range of HVAC products in the Indian market. Useful information and product information brochures were downloaded from the manufacturer's website

The information thus gathered from the HVAC designer's feedback, manufacturers and suppliers was useful in identifying the design criteria, standards followed, most common types of HVAC systems and products that are employed in commercial and office buildings.

It was encouraging to observe that many designers appreciated the objectives of the study and actively participated. However, some designers could not respond due to their job engagements. More than 100 designers were contacted personally and over e-mail throughout the country for the questionnaire survey. They were requested to either fill it on-line on "google forms" or on paper sheets [2]. A total of 58 HVAC designers responded by filling the questionnaire both on-line and on papers.

## 3 QUESTIONNAIRE ANALYSIS

The questionnaire for HVAC designers was developed and administered with the aim of obtaining information on the following aspects of design practice:

- General information like the years of experience, types of HVAC systems designed, their manufacturers, etc.
- The criteria for design and selection of HVAC products and their manufacturers
- The range of temperature and relative humidity for designing commercial and office buildings in India

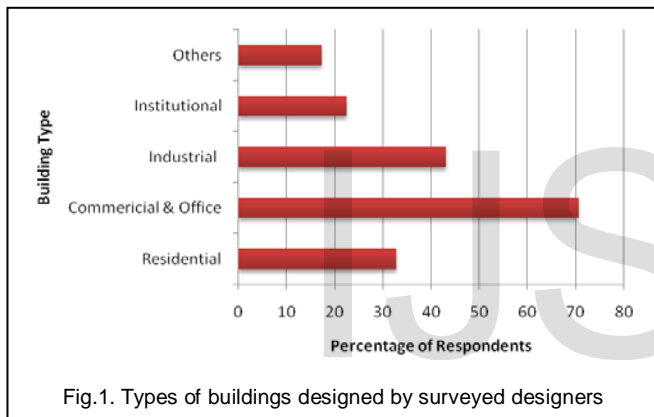
- Raza Ahmed Khan is currently pursuing Doctoral Research Program from Jawaharlal Nehru Architecture & Fine Arts University (JNAFAU), India, PH-09848058830. E-mail: [raza\\_a\\_khan@hotmail.com](mailto:raza_a_khan@hotmail.com)
- Dr. Kavita Daryani Rao is Professor in Architecture, JNAFAU, India.
- Dr. M. Manzoor Hussain is Professor in Mechanical Engineering, Jawaharlal Nehru Technological University Hyderabad (JNTUH), India.
- Dr. S. Kumar is Professor in Architecture, JNAFAU, India.

- (d) The rates of ventilation and fresh air intakes
- (e) Common choices of filters, location and types of duct insulation

The response to this questionnaire was used to build up a picture of the prevalent design practices in India. Data analysis and discussion of this questionnaire are discussed in the subsequent sections.

### 3.1 Background Information

Most of the HVAC designers, who were contacted, were senior professionals having sound experience in designing HVAC systems in different building types. Out of the 58 HVAC designers who responded, around 41% of respondents possess more than 10 years of experience, 19% possess between 5-10 years of experience, another 19% has 2-5 years of experience, and 21% are relatively freshers with less than 2 years of designing experience. It is interesting to note that 60% of respondents have more than 5 years of working experience and about 59% have less than 10 years of field experience. It indicates that the respondents are well experienced and that the HVAC field has emerged in the past 10 years in India.



As per the feedback received from the designers, about 71% of them deal with the design of HVAC systems in commercial and office buildings as shown in Fig.1. Other building types that they design include industrial buildings (about 43%), residential buildings (about 33%) and institutional buildings (about 22%). 17% of the designers also deal with the design of other buildings like hotels and hospitals.

### 3.2 HVAC Systems Design and Selection

A large variety of HVAC systems are available for commercial and office buildings in India. These systems differ according to the size of the building, occupant activities, building age, climatic conditions, geographic location and so on.

According to the Indian designers, the most frequently used HVAC system for commercial and office buildings is the chilled water system with Air Handling Units (AHUs) as shown in Fig.2. 77% of respondents prefer to use chilled water system with 74% using AHUs and 53% opting for Fan Coil Units (FCUs). It is however, interesting to note that about 60% of HVAC designers are utilizing the Variable Refrigerant Flow (VRF) systems. The split systems are used by 46% of respondents where as 44% employ rooftop packaged units, followed by Variable Air Volume (VAV) systems at 37%. The split systems are available in the variants of ducted and non-ducted.

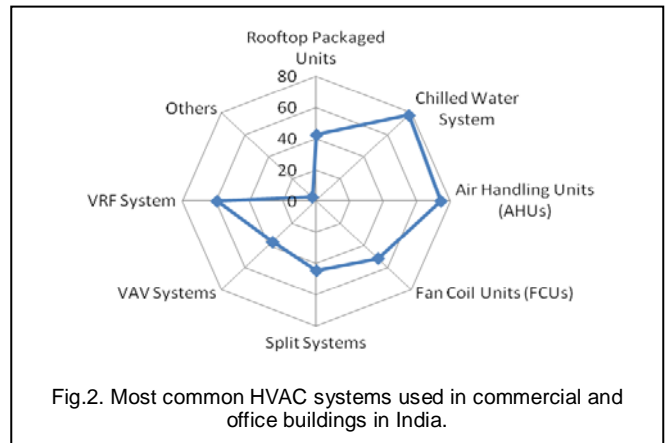


Fig.2. Most common HVAC systems used in commercial and office buildings in India.

There are more than a dozen HVAC system manufacturers available in the Indian market which caters to the commercial and office building sector. The popular manufacturers among the HVAC designers are Carrier (70%), Blue Star (52%), Daikin (44%), Voltas (39%) and Trane (30%) as shown in Fig.3. The other manufacturers like Kirloskar (17%) and LG (15%) are popular in other sectors like industrial and residential buildings. There are few other trade names that are recommended by about 11% of respondents.

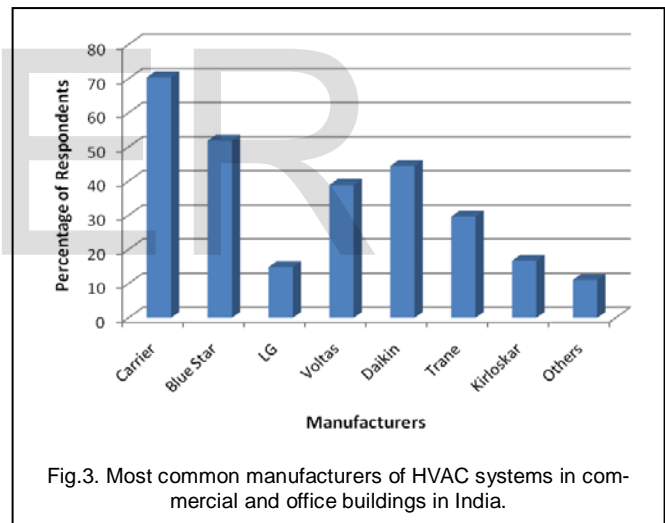


Fig.3. Most common manufacturers of HVAC systems in commercial and office buildings in India.

According to the HVAC designers, the most important criteria for the selection of these manufacturers is their good experience with the product, with about 72% of the respondents indicating this aspect. 40% of the designers have pointed out that the manufacturers are usually specified by the building owners. About 28% respondents have expressed that local weather conditions dictate the choice of manufacturers, where as 19% designers say that availability of product in the market is crucial to this decision.

The main criterion for designing and selecting the HVAC system in commercial and office building is to provide good IAQ to building occupants. This was indicated by about 78% of respondents. 72% designers also expressed that the next important criterion is the energy conservation, and 67% have marked that providing the thermal comfort in office spaces is crucial to productivity.

### 3.3 Indoor Conditions and Ventilation Design

ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy specifies the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space [3]. The standard addresses the four primary environmental factors (temperature, thermal radiation, humidity, and air speed) and two personal factors (activity and clothing) that affect thermal comfort.

The HVAC designer anticipates based on owner's feedback, the occupant activity and equipment, which may reject heat into the space prior to calculating the heating loads.

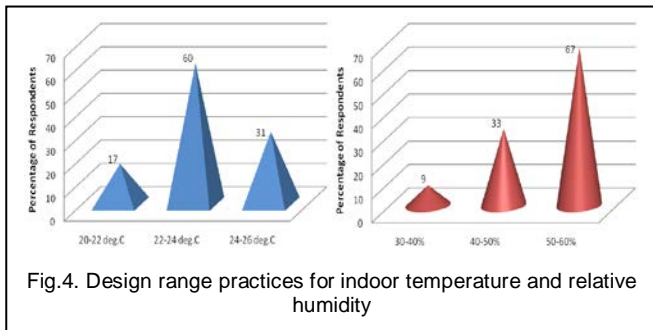


Fig.4. Design range practices for indoor temperature and relative humidity

The most common range of indoor temperature that the HVAC designers normally design for commercial and office buildings in India is 22°C to 24°C as shown in Fig.4. About 60% of designers normally design in this range, whereas 31% design in the range of 24°C to 26°C and 17% in the range of 20°C to 22°C. These values are within the acceptable range as ASHRAE Standard 55 recommends that the temperature in occupied spaces be maintained between 21°C to 26°C (70°F to 78°F).

Most designers (about 67%) specify relative humidity in the range of 50 to 60% as shown in Fig.4. 33% of respondents design in the range of 40 to 50% and only 9% design between 30 to 40% relative humidity. These values too are within the acceptable range as ASHRAE Standard 55 recommends that the relative humidity in occupied spaces be maintained between 30 to 60 percent.

ASHRAE Standard 62.1-2013: Ventilation for Acceptable Indoor Air Quality specifies that any one of the Ventilation Rate Procedure, the IAQ Procedure, and the Natural Ventilation Procedure can be used to meet the requirements of ventilation [4].

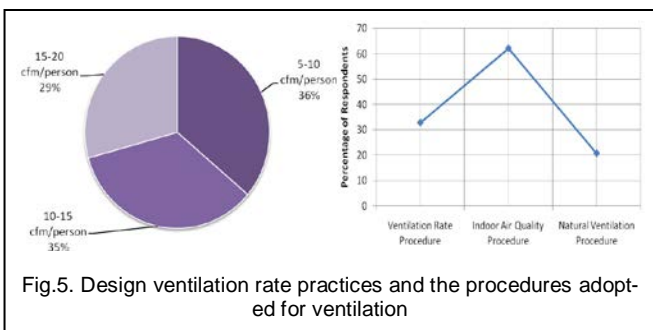


Fig.5. Design ventilation rate practices and the procedures adopted for ventilation

Ventilation air or the fresh outdoor air is a crucial aspect of HVAC designs as it controls the indoor air contamination

through dilution [5]. The ventilation rates that are incorporated by different designers are as follows: 5-10 cfm/person by 36%, 10-15 cfm/person by 34%, and 15-20 cfm/person by 29% as shown in Fig.5.

All the three procedures specified by ASHRAE are practised by the Indian designers. IAQ procedure is used by about 62% of respondents, 33% refer to the Ventilation Rate procedure, and about 21% opt for the Natural Ventilation procedure as shown in Fig.5. It has to be noted that the intake airflow determined using each of these approaches may differ significantly because of assumptions about the design, any of these approaches is a valid basis for design.

### 3.4 HVAC System's Components Design

Proper filter selection plays an important role in the control of IAQ issues. Efficiency, resistance to air flow, and dust holding capacity are the main characteristics that distinguish different types of air filters [6]. As shown in Fig.6, about 53% of designers generally recommend bag filters for commercial and office buildings in India. About 45% specify the High Efficiency Particulate Air (HEPA) filters, 29% respondents recommend rigid aluminum filters, 28% suggest media filters, and only 7% opt for Electrostatic Air Cleaners (EAC).

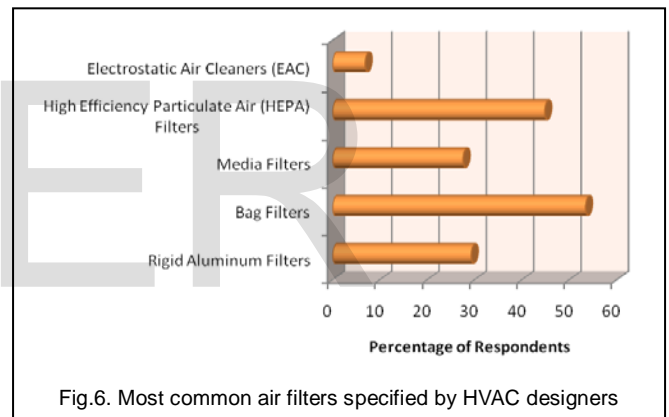


Fig.6. Most common air filters specified by HVAC designers

It is important for the HVAC designers to know the types of contaminants that are or could be present in the building environment so as to prescribe proper filter efficiency. The air filtration efficiency normally specified by designers is as follows: 48% respondents prescribe more than 90% filtration efficiency, 43% specify between 70 to 90% filtration efficiency, 12% designers recommend 60 to 70% filtration efficiency, and only 5% design for 50 to 60% filtration efficiency. It is a healthy trend to recommend high efficiency filters as they provide cleaner air and cleaner HVAC system coils, duct works, and diffusers.

In order to have better control over IAQ issues, HVAC designers must take into account the minimum maintenance requirements, equipment access and serviceability, and overall equipment reliability [7].

In response to the question on the design of coil condensation pan to ensure complete condensate drain and prevent blockage, about 93% designers indicated that they recommend U-trap connections and 17% specify P-trap connections to the condensate drain lines.

The ductwork system is one of the most important compo-

ment of the HVAC system that affects the air quality. It becomes pathway for pollutants and transports it from one place to areas throughout the building [8].

The ductworks made of Galvanized Iron (GI) sheets are popular among surveyed designers with about 93% recommending it. 14% respondents also specify aluminum duct and a minor 3% even recommends PVC ducts.

Regarding the duct insulation, fiberglass is very popular among designers with about 53% recommending it as shown in Fig.7. About 36% respondents specify EPS / styrofoam / thermocol insulation, 19% respondents recommend rockwool insulation, 17% designers specify cellulose fiber insulation, and 17% designers recommend nitrile rubber insulation.

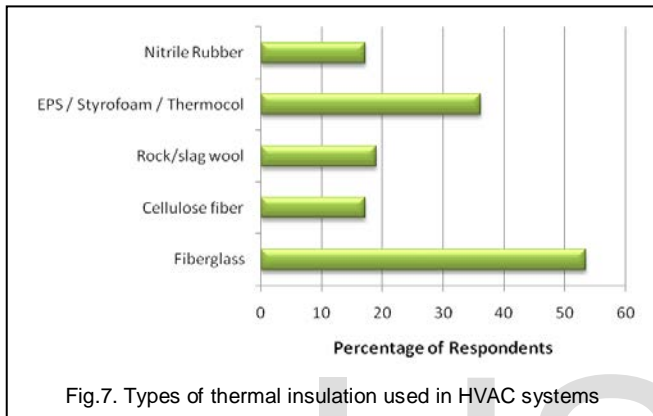


Fig.7. Types of thermal insulation used in HVAC systems

Almost 93% of designers highly recommend external insulation to duct. However, about 24% respondents specify internal insulation as acoustical lining for sound absorption. However care must be exercised for internal insulation as there is a potential for biological and mold growth in it when subjected to humid air [9].

### 3.5 IAQ Strategies in HVAC Design

In response to a question on separate smoking zones inside commercial and office buildings, about 60% respondents agreed that they provide such tobacco smoking zones in buildings with local exhaust. 29% designers provide such zones as per the requirements, and about 12% designers have never provided such zones in their buildings. ASHRAE recommends that 100% air in smoking lounges should be exhausted [4].

About 78% of the designers allocate local exhaust with localized contaminant generation like toilets, kitchen, labs, printers, etc. Almost 19% indicated that they design it based on the requirements or specifications of the building owners.

To compensate for the exhausted air from the building, fresh outside air is introduced into the building. It also acts as a dilution strategy for the building contaminants [10]. The surveyed HVAC designers emphasized that various considerations have to be taken into account while designing the fresh air intakes. 69% designers feel that the location of air intake is crucial, about 64% respondents are of the opinion that outdoor air quality is important, and 41% specifies proper bird screen and mesh to prevent the unwanted entry.

The HVAC designers were asked about the special components that they normally use in their designs. About 64% designers use energy recovery wheels, 36% use dehumidifiers

and electric heater, 33% use humidifiers, and 9% use under-floor ducting as shown in Fig.8.

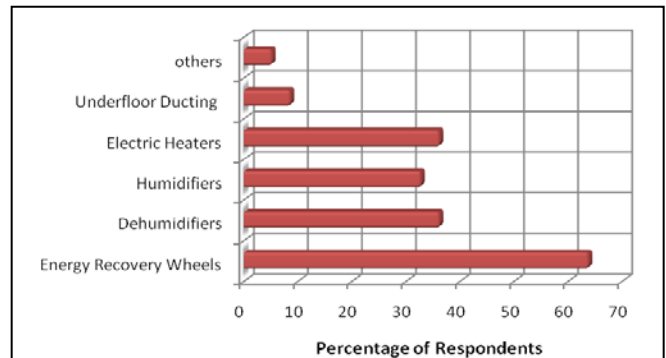


Fig.8. Special components used in HVAC designs

In response to a question on the standards that are referred while designing the HVAC systems, the designers listed out some of them. About 60% refer to the ASHRAE Standard 62 for IAQ and ISHRAE Standards, 53% refer to SMACNA Standards for ductworks, 45% refer to ASHRAE Standard 90 for Energy Conservation, 36% refer to ASHRAE Standard 55 for Thermal Comfort, 40% refer to IGBC / LEED-NC Standards for Green Buildings, and 33% refer the NFPA Standards for Fire Safety.

The HVAC designers were asked about the strategy they employ for better IAQ in commercial and office buildings. 59% designers suggested that fresh air intake is a sound strategy to improve IAQ. About 53% respondents feel that Fresh Air Handling Units (FAHUs) is a better idea for good IAQ. 34% participants opined that using high efficiency filters can enhance IAQ, while 17% believe that providing local exhaust at the source of pollutant generation is the best solution.

### 4 CONCLUSION

The responses to questionnaire represent the general HVAC design practice for commercial and office buildings in India. The chilled water system, AHUs and VRFs are the most popular HVAC systems. Providing good IAQ is the main criterion for designing and selecting these systems. All design professionals design the indoor conditions and ventilation rates as per the relevant standards. Bag filters and HEPA filters are most commonly used filters. More than 80% designers recommend use of more than 70% filtration efficiency. 93% of respondents use GI sheets for ductworks with external insulation. Fiberglass and thermocol are popular thermal insulations. 78% participants design local exhaust for local pollution sources. Fresh outside air is introduced to compensate for the exhaust air. Energy recovery wheels are being recommended by many professionals. Standards are being referred by designers, including the green building codes. The HVAC industry is expanding in India, new products are being introduced and young professionals are choosing HVAC as their careers.

## APPENDIX – HVAC DESIGNER’S QUESTIONNAIRE

11. What kind of **air filters** do you generally recommend for HVAC systems (C&O Bldgs)?  
 Rigid Aluminum Filters  High Efficiency Particulate Air Filters (HEPA)  
 Bag Filters  Electrostatic Air Cleaners (EAC)  
 Media Filters  Others (specify) \_\_\_\_\_
12. What is the **air filtration efficiency** that you normally specify?  
 >90%  70-80%  60-70%  50-60%  Others (specify) \_\_\_\_\_
13. Do you take any measure during the design of **coil condensation/drain pan** to ensure complete condensate drain and prevent blockage?  
 P-trap  U-trap  T-trap  Others (specify) \_\_\_\_\_
14. What is the **ducting material** that you generally prescribe for air distribution system?  
 PVC Duct  GI Duct  Aluminum Duct  Others (specify) \_\_\_\_\_
15. What kind of **thermal insulation** you specify for the ducting system?  
 Fiberglass  EPS / Styrofoam / Thermocol  
 Cellulose fiber  Others (specify) \_\_\_\_\_  
 Rock/slag wool
16. Which type of **insulation** you generally specify for ducts?  
 Internal to the duct  External to the duct
17. Do you normally allocate **separate areas for smoking** with local exhaust (C&O Bldgs)?  
 Always  Sometimes  Never
18. Do you provide **local exhaust system** for spaces with localized contaminant generation (like kitchen, laboratories, copy machines, etc.) in C&O Bldgs?  
 Always  Sometimes  Never
19. What are the considerations you take into account while designing for **fresh air intake**?  
 Outdoor air quality  Bird screens and mesh  
 Location of air intake  Others (specify) \_\_\_\_\_
20. What are the **special components** that you normally use in HVAC designs?  
 Energy Recovery Wheels  Electric Heaters  
 Dehumidifiers  Underfloor Ducting  
 Humidifiers  Others (specify) \_\_\_\_\_
21. Which **standards** you refer to while designing the HVAC Systems for C&O Bldgs?  
 ASHRAE Standard 55 version \_\_\_\_\_  SMACNA  
 ASHRAE Standard 62 version \_\_\_\_\_  NFPA  
 ASHRAE Standard 90 version \_\_\_\_\_  USGBC / IGBC / LEED-NC  
 ISHRAE Standards  Others (specify) \_\_\_\_\_
22. What **strategies** do you employ for **better Indoor Air Quality** (C&O Bldgs)?  
 Fresh Air Intake  Fresh Air Handling Units (FAHU)  
 Local Exhaust at Source of Generation  Others (specify) \_\_\_\_\_  
 High Efficiency Filters

Additional Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Thank you for participating in this study. We appreciate your efforts and time spent to make this research more meaningful. We strongly encourage you to kindly provide the following details (optional):

HVAC Designer's Name: \_\_\_\_\_ Designation: \_\_\_\_\_  
Design Office (Name & Address): \_\_\_\_\_  
E-mail: \_\_\_\_\_ Phone (Mobile): \_\_\_\_\_

### Research Questionnaire for HVAC Design Professionals

Dear HVAC Designer,

The following information is required for an academic research project to study the existing Heating, Ventilating and Air-Conditioning (HVAC) design practices in Commercial & Office buildings in India.

We request you to kindly participate in this study by providing valuable information in this questionnaire. We assure you that the confidentiality of your inputs will be maintained and used for research purpose only. Should you have any queries regarding this study, please feel free to contact the undersigned.

Raza A. Khan  
Research Scholar, JNAFAU  
Ph: 9849058830

Dr. Kavita Daryani Rao  
Research Supervisor  
JNAFA University, Hyderabad

1. How long have you been involved in designing the HVAC systems in buildings?  
 <2 years  2-5 years  5-10 years  10-15 years  \_\_\_\_\_
2. What **kind of buildings** have you designed the HVAC systems so far?  
 Residential  
 Commercial & Office  
 Industrial  
 Institutional  
 Others (specify) \_\_\_\_\_

The following questions refer to HVAC design in Commercial & Office Buildings (C&O Bldgs). You may choose more than one options, wherever required. Write your comments in blank spaces.

3. What **type of HVAC system** is mostly used in commercial & office buildings in India?  
 Rooftop Packaged Units  Split Systems  
 Chilled Water System  VAV Systems  
 Air Handling Units (AHUs)  VRF System  
 Fan Coil Units (FCUs)  Others (specify) \_\_\_\_\_
4. Which **manufacturer / brand name** of HVAC systems do you normally use in your projects?  
 Carrier  Daikin  
 Blue Star  Trane  
 LG  Kirloskar  
 Voltas  Others (specify) \_\_\_\_\_
5. What is the **criteria for selection** of a particular manufacturer?  
 Specified by the building owner  
 Suitable for local weather conditions  
 Availability in the market  
 Good experience with the product  
 Others (specify) \_\_\_\_\_
6. What is your **main criterion** for designing and selecting the HVAC system? (You may give ranking)  
 Energy conservation  
 Thermal comfort  
 Indoor air quality  
 Others (specify) \_\_\_\_\_
7. What is the range of **indoor temperature** that you normally design (C&O Bldgs)?  
 20°-22°C  22°-24°C  24°-26°C  Others (specify) \_\_\_\_\_
8. What is the range of **indoor relative humidity** that you normally design (C&O Bldgs)?  
 30-40%  40-50%  50-60%  Others (specify) \_\_\_\_\_
9. What is the **ventilation rate** (outside fresh air) that you incorporate to design the HVAC system?  
 5-10 cfm/person  10-15 cfm/person  15-20 cfm/person  Others (specify) \_\_\_\_\_
10. Which procedure is followed to determine the required **ventilation rate**?  
 Ventilation Rate Procedure  Natural Ventilation Procedure  
 Indoor Air Quality Procedure  Others (specify) \_\_\_\_\_

## ACKNOWLEDGMENT

The authors wish to thank Jawaharlal Nehru Architecture & Fine Arts University and NSAK College of Engineering & Technology of JNTUH for facilitating this research work. The authors also wish to thank the HVAC designers who participated in this study. Thanks is also due to the Indian Society for Refrigerating and Air-Conditioning Engineers (ISHRAE) for encouragement.

## REFERENCES

- [1] EPA, "Healthy Buildings, Healthy People: A Vision for the 21<sup>st</sup> Century", United States Environment Protection Agency, EPA 402-K-01-003, October 2001.
- [2] Google Forms: <http://www.google.com/forms/>
- [3] ASHRAE (2013). "Thermal Environmental Conditions for Human Occupancy", ANSI/ASHRAE Standard 55-2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
- [4] ASHRAE (2016). "Ventilation for Acceptable Indoor Air Quality", ANSI/ASHRAE Standard 62.1-2016, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
- [5] F.C. McQuiston and J.D. Parker, "Heating, Ventilating, and Air Conditioning: Analysis and Design", John Wiley & Sons, 2004.
- [6] H.E. Burroughs, "Filtration: An Investment in IAQ", HPAC Journal, August, Vol.69, No.8, pp.55-65, 1997.
- [7] S.M. Hays, R.V. Gobbell, and N.R. Ganick, "Indoor Air Quality: Solutions and Strategies", McGraw-Hill Inc., New York, 1995.
- [8] L. Zhijian, Z. Zunqiang, Z. Yexuan, X. Wei, L. Hao, "Investigation of dust loading and culturable microorganisms of HVAC systems in 24 office buildings in Beijing", Energy and Buildings, Vol.103, pp.166-174, September 2015.
- [9] M. Meckler, "Improving Indoor Air Quality through Design, Operation and Maintenance", The Fairmont Press, Inc., Lilburn, 1996.
- [10] I.M. Budaiwi, "Impact of Combined Dilution and Pressurisation Effects of Ventilation Air on Indoor Contaminant Concentration", Indoor Built Environment, Vol.7, No.5-6, pp.289-299, 1998.