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Reflections on the Usage of Air - Conditioning Systems in Nigeria

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Abstract: - Air conditioning systems are usually designed to meet the indoor environmental requirements of occupants, process or products in a conditioned space. Three types of air-conditioning systems are mainly used in Nigeria, namely, room or window air-conditioners, split air–conditioning systems and central air–conditioning systems. The increasing utilization of the split air-conditioning systems has led to a decline in the usage of room air-conditioners and central air- conditioning systems in Nigerian buildings. The split air conditioning systems have even been wrongly applied to condition buildings with unit large floor spaces. For such spaces, the specified indoor environmental conditions are not met with the usage of split air conditioning systems because their air distribution performance index is low. This paper strongly advocates the usage of central air conditioning systems for these types of buildings and recommends the adoption of good thorough procedures regarding the design, procurement, installation, commissioning, operation and maintenance of innovative and energy-efficient air conditioning systems in buildings. For this to be actualized, the paper also recommends the generation of air conditioning system design data to address the dearth of such data in the country.

Keywords: - *Air conditioning systems, design, installation, operation, maintenance, reflection,*

I. INTRODUCTION

The American Society of Heating, Refrigeration and Air – Conditioning Engineers (ASHRAE) has defined air – conditioning as the process of treating air to control simultaneously its temperature, humidity, cleanliness, quality and distribution to meet the requirements of the occupants, process or product in the conditioned space [1]. Depending on the application, the sound level and pressure differential between the conditioned space and adjacent spaces are also controlled within prescribed limits.

An air – conditioning system consists of components and equipment arranged in sequential order to heat or cool, humidify or dehumidify, clean and purify, attenuate objectionable equipment noise, convey the conditioned outdoor air and return air to the conditioned space, and control and maintain an indoor or enclosed environment at optimum energy use [2]. The types of building served by air – conditioning systems include institutional, commercial, residential, and manufacturing buildings. In institutional, commercial and residential buildings, air – conditioning systems are designed principally to meet the health and comfort of the occupants. In manufacturing buildings, air – conditioning systems are provided to meet requirements for product processing or storage, or for the health and comfort of workers as well as processing in enclosed spaces.

Historically two types of air – conditioning systems have been observed to be used in Nigeria [3]. These are the room or window air conditioners and the central air conditioning systems. The room air conditioner is a factory – made encased assembly designed for delivery of conditioned air to an enclosed space without making use of ducts. It is usually installed through a wall enclosing the conditioned space. The central air conditioning system is a system in which the air is treated in a central plant and carried to and from the conditioned space(s) by one or more fans and a system of ducts.

The advent of the split air – conditioning systems has brought a new dimension to the usage of air – conditioning systems in Nigeria. A split air – conditioning system consists of two main parts, namely, the outdoor unit and the indoor unit. The outdoor unit houses the compressor, condenser and associated fan, as well as the expansion valve or capillary tubing while the indoor unit contains the cooling coil, blower and an air filter. A recent study has shown preference by many building owners and clients in Nigeria for the utilization of

split air – conditioning systems to control the indoor environment in their buildings [3]. This has led to a considerable reduction in the usage of room air-conditioners and central air – conditioning systems in buildings. The use of split air – conditioning systems to control the indoor environment in rooms or spaces with small floor areas can adequately satisfy the comfort requirements of the occupants of such buildings. However, this requirement cannot be satisfactorily met when such systems are used to condition buildings with very large floor spaces like large church halls, auditoriums, large boardrooms, banquet halls, theatres, conference centres, operating suites of hospitals, clean spaces, etc.. This is so because the supply air leaving the indoor units of split air – conditioning systems cannot be properly distributed within the entire conditioned space resulting in localized cooling of the spaces close to the indoor units of such systems. On a very hot day, complaints are often heard from the occupants or owners of these buildings about the poor performance of the installed split air – conditioning systems.

The authors have observed the increasing utilization of split air - conditioning systems to condition the indoor environment of a good number of commercial and institutional buildings with large floor spaces as well as churches with big auditoriums. Preliminary inquires made by the authors concerning the selection of such systems for installation by the air - conditioning contractors reveal that no proper design of the indoor environmental conditioning system was carried out.

The solution to this problem and therefore the provision of an acceptable indoor environment is proper design, specification, procurement, installation, commissioning, operation and maintenance of an efficient central air – conditioning system for these types of buildings. This paper discusses the various practices or measures to be undertaken in the provision of a healthy and comfortable indoor environment with acceptable indoor air quality in buildings starting from the design of an appropriate air conditioning system to its proper operation and maintenance. The adoption of these measures by all professionals associated with the building industry will enhance engineering practice relating to the provision of acceptable indoor environment in Nigeria buildings.

II. DESIGN OF APPROPRIATE AIRCONDITIONING SYSTEMS FOR BUILDINGS IN NIGERIA

A building is a structure that has a roof and walls and primarily designed to provide shelter and ensure comfort for its occupants. Heerwagen [4] has outlined the basic requirements of a building to include controlling its internal environment well enough to satisfy the occupants physical and physiological needs, supporting the psychological state and social activities of each occupant, and resisting the natural forces that act against it (e.g. weather and climate, gravity and seismic loads etc). The aforementioned requirements should be provided at a reasonable cost and efficient use of resources.

The design of an air conditioning system to meet the requirements of an indoor environment begins with a study of architectural drawings of the building with a view to determining the following data [5]:

i) The functional use of the building, namely, residential, commercial, industrial, institutional or other facility.
ii) The geographical site location and means of accessing the building.
iii) The building area, height, number of stories, internal transportation, materials used for the walls and roof as well as type and amount of fenestration.
iv) The number, distribution and occupancy patterns of the building. Other data required include the following:
v) The weather and climatic design data for the geographical location of the building (outdoor dry and wet bulb temperatures, solar radiation data, wind velocity and direction data etc).
vi) Indoor environmental data (indoor dry and wet bulb temperatures, (or relative humidity)), air quality and ventilation requirements.
vii) Data about internal loads such as lights, equipment and special conditions concerning noise and vibration.

In Nigeria, efforts have been made by various researchers to determine climatic design data and thermal properties of building materials which are required to estimate the space cooling load [6,7,8,9 and 10]. The researchers must be commended for carrying out studies relevant to the determination of data used in air conditioning system design. However, the fact that these studies did not cover the entire scope of materials used for constructing buildings in Nigeria and the non – availability of recent climatic design data have led to the usage by local building services engineers of air conditioning system design data produced by foreign organizations such as the American Society of Heating, Refrigerating and Air – Conditioning Engineers (ASHRAE) [11], Inc. and the Chartered Institution of Building Services Engineers (CIBSE) [12]. The usage of such data, more often than not, results in the incorrect estimation of space cooling loads and this ultimately affects the design of air-conditioning systems for buildings.

In order to produce comprehensive air-conditioning system design data for Nigeria, relevant government ministries, departments and agencies, research institutes, professional organizations, universities,

etc should execute collaborative programmes to address the issue of the determination of the thermal properties of building materials and detailed climatic design data. The availability of these data and their proper usage by building services engineers will bring about the design of appropriate and energy efficient air-conditioning systems in Nigeria.

With the correct estimation of the building sensible and latent cooling loads, the next step in the design process is the selection of an air-conditioning system that can compensate for the loads and produce the desired indoor environment in a sustainable way with the minimum consumption of energy. The selection procedure will entail a consideration of various competing air-conditioning systems. All such systems must be capable of maintaining the indoor environmental condition required in each area. The ability to provide adequate thermal zoning is also mandatory [5]. For each system considered, the following items should be evaluated: (i) the relative space requirements for equipment, ducts and piping, (ii) the fuel and /or electrical use and thermal storage requirements, (iii) the initial and operating costs, (iv) the acoustical requirements, (v) the compatibility with the building plan and structural system, and (vi) the effect of indoor air quality, illumination, noise and vibration [5]. The results of this rigorous study will lead to the selection of an appropriate air conditioning system.

The selected air-conditioning system must maintain the indoor environmental condition by transferring the sensible and latent cooling loads from the building and rejecting them to a sink. A detailed psychrometric analysis is used to determine the sizes or capacities of components of the air-conditioning system. The space air-conditioning design process requires the determination of the quantity of air to be supplied and the supply air condition necessary to remove the sensible and latent loads from the space.

For buildings with large floor areas, the selection of adequately sized fans and the design of a ducting system that will convey the supply air to the conditioned spaces and ensure proper air circulation within them must be carried out. The ducting system must incorporate appropriate terminals (for regulating the quantity of air entering the space or conditioning it), diffusers (for admitting air to the space), grilles (for gathering the air from the space). Diffusers, registers or grilles selected must exhibit the correct throw, drop, spread, noise level and pressure drop performance to ensure proper circulation of supply air within the conditioned space thereby producing an indoor environment comfortable for the occupants.

Air-conditioning systems are usually sized to satisfy a set of design conditions which are selected to generate a near – maximum load. These design conditions occur for only a few hours of the year and therefore the air-conditioning equipment operates most of the time at less than rated capacity. Thus a control system is necessary and its function is to adjust the equipment capacity to match the load. A properly designed, operated and maintained automatic control system is of utmost importance and will provide economy in the operation of the air-conditioning systems [13].

The design process is concluded by providing a detailed specification of all components of the air handling and associated control systems, cooling equipment, heating equipment, heat transfer equipment, pumps, valves, piping and ducting systems. Design documents include drawings and specifications. These documents are the means by which the designer can convey the design requirements to the contractor. The drawings and specifications must define the work to be done by the contractor in a clear, complete and unambiguous manner.

III. PROCUREMENT, INSTALLATION AND COMMISSIONING OF AIR CONDITIONING SYSTEMS

With the completion of the preparation of design documents, the next step is the selection of a competent and responsible contractor that will be awarded the contract to execute the installation of the air-conditioning system. The selection of the contractor is done after a competitive bidding process by various contractors for the project and subsequent evaluation of the bids have taken place. The chosen contractor should be one having a good track record in the execution of similar projects.

Good procurement practice requires that the selected contractor purchases all components of the air conditioning system as specified in the design documents. The air-conditioning system design team of engineers should verify that the purchased items conform to the specification and are of right quantity and quality. The contractor proceeds with the installation of the procured components and this activity should be monitored, supervised and inspected by the team of engineers who designed the air-conditioning system.

After the installation of the air-conditioning system, the commissioning exercise is the next in the series of activities concerning project execution. The commissioning of an installed air-conditioning system is the implementation of a quality – oriented process for achieving, verifying and documenting that the performance of the system is in accordance with the design intent and the building owner's operational needs [14].

The commissioning process includes all the elements of Testing, Adjusting and Balancing (TAB) as well as training of Operations and Maintenance (O &M) personnel. The process should preferably be carried out

by air-conditioning system commissioning specialists consisting of competent and experienced engineers and technicians working in conjunction with the design team and building owner.

The TAB process consists of all operational tests and measurements carried out on the installed air-conditioning system to show compliance with the design requirement. The process includes adjustments to fluid (air, water, steam) flows rates and temperatures to satisfy those requirements. Load tests should also be performed on cooling and heating equipment.

IV. PROPER OPERATION AND MAINTENANCE OF AIRCONDITIONING SYSTEMS

The design team of air-conditioning systems can greatly facilitate their proper operation and maintenance by doing a good job of turning over the systems to those who will operate them. A proper commissioning process is the first step towards achieving the task.

4.1 Designing for Operation and Maintenance

The air-conditioning system designers should observe the following basic criteria [13]:

i) Adequate space and accessibility should be provided for equipment. This includes ease of access, space for maintenance and repair and access for removal and replacement of large items of equipment.

ii) Well – written operational and maintenance procedures for the air-conditioning system which are simple, straightforward and easy for operations and maintenance personnel to understand should be prepared. The schematic flow and control diagrams from the contract drawings constitute reference materials for these procedures. A collection of components manufacturer's descriptive and maintenance bulletins is useful as a reference but is not a procedure.

iii) The contractor should provide comprehensive training for all operations and maintenance personnel to cover all items and procedures. In this connection, the air-conditioning system designer should request the building owner or manager to embark on continuous training or retraining of all new or old operating and maintenance personnel. It is important to stress here that inadequate maintenance will result in higher operating costs.

4.2 Maintenance Management

Section 4.1 has stressed the importance of the availability of well – written operation and maintenance documentation as well as the continuous training and retraining of operating and maintenance personnel. Maintenance management entails the planning, implementation and review of maintenance activities. ASHRAE [13] has stated three maintenance strategies as follows: run – to - failure, preventive maintenance and condition – based maintenance. In run – to – failure strategy, minimal resources are invested in maintenance until equipment or systems break down or fail. The preventative maintenance strategy schedules the maintenance of equipment, either by run time or by the calendar. The condition –based maintenance is based on equipment monitoring to establish the current condition of equipment and on condition and performance indices to optimize repair intervals.

The success of maintenance management depends on dedicated, trained and accountable personnel, clearly defined goals and objectives, measurable benefits, management support, constant examination and re - examination. To be effective and efficient, operations and maintenance programs require staff with the right combination of technical and managerial skill. Technical skills range from hands–on correct application of methods and procedures to the analytical problem-solving skill of the plant engineer. Managerial skills include overseeing the stewardship of the facility on a day – to – day basis and in life – cycle terms.

The operations and maintenance manual of the air-conditioning system should contain in detail the maintenance practices to be undertaken by personnel assigned to perform such duties. Let us briefly consider here some maintenance tips. The filters of the air-handling unit (AHU) must be cleaned monthly and replaced if found to be defective. Dirty filters restrict the flow of air thereby affecting the performance of the air-conditioning system. The cooling coils of the AHU should be cleaned at least once a year. Dirty coils are inefficient. The fan blades of the AHU should be cleaned regularly because clean blades move more air. All condensate lines must also be cleaned.

It is important to ensure that the shut down switches of the air-conditioning system are working. The tubes and cooling fins of air cooled condensers should be cleaned at least once a year since accumulated dirt around the primary and secondary heat transfer surfaces will impede their ability to dissipate heat. The ducting system must be accessible for inspection and necessary periodic cleaning. Dirty ducts are first and foremost unhealthy and they must be cleaned every 3 – 5 years. All ducts must be insulated, sealed, and checked for air leakage.

V. USAGE OF CENTRAL AIRCONDITIONING SYSTEMS IN NIGERIA

Sanni [3] has conducted a preliminary study to examine the functional state of the central air-conditioning systems installed in various buildings and had worked for a minimum of ten years. The findings of the study can be categorized as follows:

Category A: The central air-conditioning systems are functioning in an efficient and effective manner.

Category B: The central air-conditioning systems are operating in an epileptic manner.

Category C: The central air-conditioning systems are no more working and have since been replaced by split air-conditioning units or room window units.

A pertinent question to be asked here is what is responsible for this state of affairs? The causative factors are as follows:

i) Poor maintenance culture/inadequate maintenance strategy employed by the building owners or management staff of establishments utilizing the buildings.
ii) Epileptic power supply by Power Holding Company of Nigeria (PHCN) PLC.
iii) Incompetent technicians or maintenance personnel and the dwindling number of competent technicians. This can be mainly attributed to the neglect of technical and vocational education by the federal and state governments in Nigeria.
iv) High cost of maintenance and purchase of spare parts.

However, the management staff of establishments or building owners whose functional state of central air-conditioning systems was classified into Category A utilized a preventive maintenance strategy to ensure that the desired environmental conditions were maintained in their buildings while those in Categories B and C fell far short of this. A good maintenance policy must adopt the following practices:

a) It must be welled funded.
b) All operating and maintenance personnel must possess the relevant skills and be properly motivated.
c) Sufficient personnel must be employed to carry out operations and maintenance duties. In the absence of this, competent contractors can be hired to carry out maintenance operations on the air-conditioning system.
d) All spare parts required to keep the air-conditioning system functioning must be properly stocked.

The practice of using split air-conditioning system in buildings whose spaces have large floor areas is not recommended. This is because the conditioned supply air emanating from the indoor units of the split air-conditioning system is not distributed properly within such spaces. The designed temperature and relative humidity are not maintained within the space because of poor throw, spread and drop performance of the supply air from the indoor units serving it. For such spaces, a central air-conditioning system having a properly designed ducting network employing diffuser, registers or grilles produces the requisite air distribution performance of supply air and ensures thermal comfort of the occupants. As a rule of thumb, the authors recommend that if the floor area of a building space exceeds $150m^2$, a split air-conditioning system should not be used to condition the space. Therefore, split air conditioning systems should not be used to condition the indoor environment of large church halls, auditoriums, large boardrooms, banquet halls, theatres, conference centres, operating suite of hospitals, clean spaces etc.

VI. CONCLUSION AND RECOMMENDATION

This paper has focused on the use of air-conditioning systems to produce desired indoor environment in buildings in Nigeria. It noted that the types of air-conditioning system utilized in these buildings are room or window air conditioners, split and central air-conditioning systems. The split air-conditioning systems are increasingly being applied to condition the air in various buildings including residential buildings, commercial and public buildings, hotels, motels and hostels, educational and health care facilities, church halls and auditoriums, theatres, conference centres etc. This practice has led to a decline in the usage of room air-conditioners and central air-conditioning systems in Nigerian buildings.

The increasing utilization of split air-conditioning systems has led to their being used in some types of buildings not suited for their application. These buildings are those with spaces having floor areas exceeding $150m^{2.}$ .In order to do the right thing and utilize central air-conditioning systems to produce desired indoor environmental conditions in these types of buildings, this paper recommends the adoption of good practices that entail proper design, procurement, installation, commissioning, operation and maintenance of such systems. To facilitate the design of innovative and energy efficient air-conditioning systems, the authors also recommend a comprehensive research work to be undertaken to determine the thermal properties of local building materials and relevant climatic data.

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