Published in the Russian Federation
European Researcher
Has been issued since 2010.
ISSN 2219-8229
E-ISSN 2224-0136
Vol. 75, No. 5-2, pp. 932-939, 2014

DOI: 10.13187/issn.2219-8229
www.erjournal.ru

Engineering sciences

Технические науки

UDC 69

Evaluation of Active Cooling Systems for Non-Residential Buildings

M.A. Othuman Mydin

Universiti Sains, Malaysia
School of Housing, Building and Planning
11800, Penang

Abstract. Cooling systems are an essential element in many facets of modern society including cars, computers and buildings. Cooling systems are usually divided into two types: passive and active. Passive cooling transfers heat without using any additional energy while active cooling is a type of heat transfer that uses powered devices such as fans or pumps. This paper will focus on one particular type of passive cooling: air-conditioning systems. An air-conditioning system is defined as controlled air movement, temperature, humidity and cleanliness of a building area. Air conditioning consists of cooling and heating. Therefore, the air-conditioning system should be able to add and remove heat from the area. An air-conditioning system is defined as a control or treatment of air in a confined space. The process that occurs is the air-conditioning system absorbs heat and dust while, at the same time, cleaning the air breathed into a closed space. The purpose of air-conditioning is to maintain a comfortable atmosphere for human life and to meet user requirements. In this paper, air-conditioning systems for non-residential buildings will be presented and discussed.

Keywords: active cooling; air-conditioning; air movement; humidity; thermal comfort; split unit.

Introduction.

Heat always moves from a hot place to a cooler place (Figure 1). Because the heat energy moves from a warm to colder area, during this process the hotter area becomes cool and the cold place becomes warm. Heat is transferred into a mechanical air-conditioning system through the process of cooling water. A refrigerant vapour is passed through a coil and immersed in a container full of water. Heat is the transferred from the refrigerant to the water through the walls of the loop [1]. In the air cooling process, refrigerant vapour is passed through the loop and cooled by a fan. The fan blows air across the coil and brings the cold air from the refrigerant vapour into the air releasing heat through the walls of the loop. This process is referred to as heat transfer.

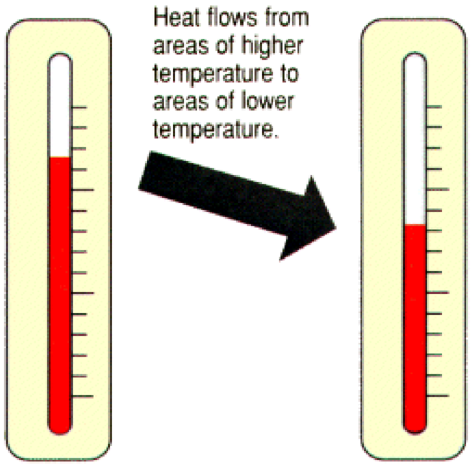

Figure 1. Heat Moves from Higher Temperatures to Lower Temperatures [1]

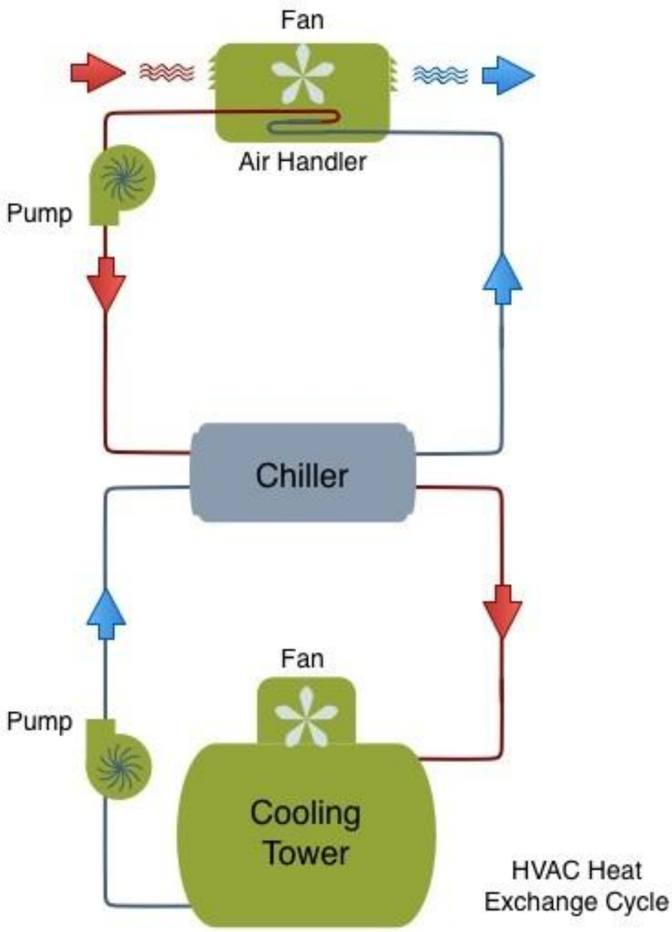

Figure 2. Heat Exchange Cycle [3]

Heat transfer can be done in three ways which are radiation, convection and evaporation. Radiation means heat is radiated through a space with no need for a medium of delivery. The movement of heat energy through electromagnetic waves means no medium is needed to move. Infrared radiation heat is greatly transferred in sunlight. Convection is actually the movement of a mass or volume of fluid or gas from a hot to a cold region [2]. Fluids or hot gases will lightly rise up, begin to cool, gain more weight, and then drop down. Various control cycles need to be done to create comfort conditions that fit the requirements of the user. The fields of refrigeration and air-conditioning are related to one another, but each one has its own purpose [3]. The main use is for cooling systems and cooling processes. This cooling process is used in the air-conditioning system to cool the air. However, air conditioning is not only for cooling, it also includes heating (Figure 2), cleaning, and air distribution to achieve a base from which reconditioning requirements are met.

Air-Conditioning Systems for Non-Residential Buildings.

Air-conditioning systems are installed in buildings depending on several factors. The system must be capable of cooling and generating enough heat to properly cool or heat the entirety of the enclosed area [4]. These main types of air-conditioning are separated into categories and usually depend on the system's capacity and design, as well as on the system's heat transfer mechanism. In general, for non-residential buildings, air-conditioning systems can be categorized in several ways as shown in Figure 3.

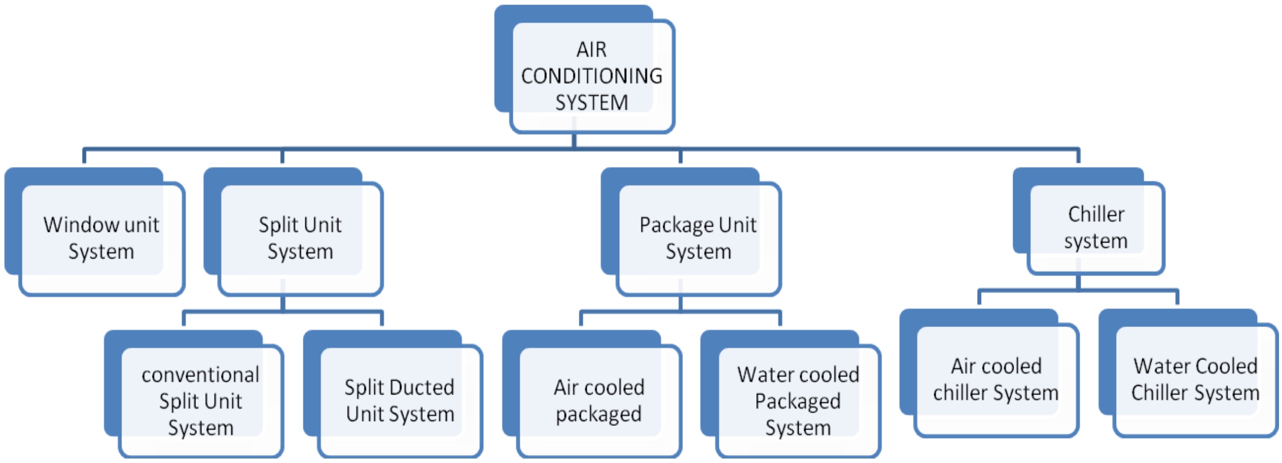

Figure 3. Categories of Air-Conditioning Systems Typically Installed in Office Buildings [4]

Split Ducted System.

A split ducted system is similar to a conventional split system unit but the indoor unit's fan will distribute the cold air into certain spaces. A fan coil unit blows conditioned air into spaces through ducting and diffusers and is usually installed in a small room in a building as a central cooling system. A split ducted system requires its own separate control system. Figure 4 shows a common split ducted system for a house.

Figure 4. Common Split Ducted System for a House [4]

Conventional Split Unit System.

Conventional split unit systems have two parts: an outdoor unit and an indoor unit. The outdoor unit houses components like a compressor, condenser and expansion valve. The indoor unit is comprised of an evaporator or cooling coil and a cooling fan (Figure 5). These systems are sometimes known as multi-split systems and there can be more than one indoor unit per system. Normally, they are installed in a small space and require individual control of the air-conditioning system.

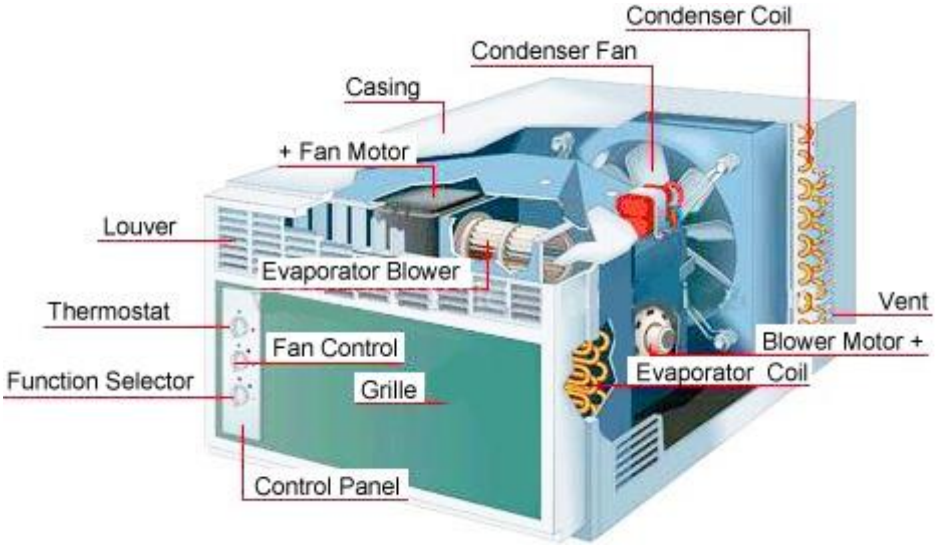

Figure 5. Conventional Split Unit System [4]

Air-Cooled Packaged System.

In a packaged air-conditioning system, all the important components of the system are enclosed in a single casing, like a window unit. Thus, the compressor, cooling coil, air handling unit and air filter are all housed in a single casing and assembled at the factory. The condenser of the refrigeration system is cooled by atmospheric air. This system is also installed as a centralized air-conditioning system in small buildings with the cooling unit comprised of an expansion valve, evaporator, an air handling blower and filters are located together with the compressor outside the building (Figure 6). From outside, the conditioned air is blown through ducting to the various spaces that are to be cooled [5].

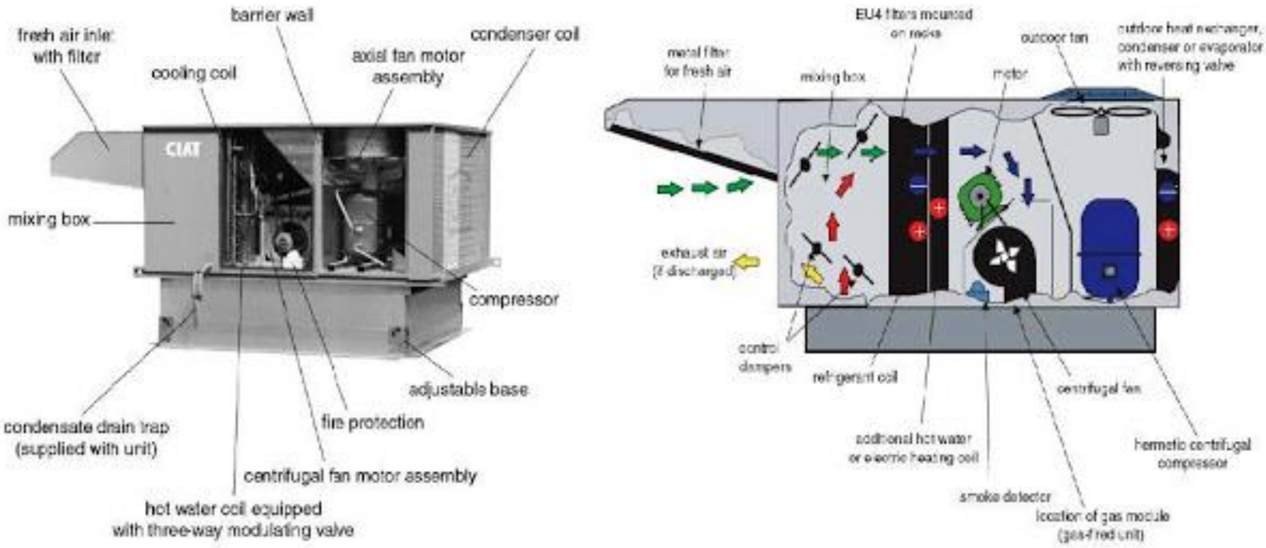

Figure 6: Air-Cooled Packaged System [5]

Water-Cooled Packaged System.

The shell and tube type of condenser is compact in shape and is enclosed in a single casing along with the compressor, expansion valve, and air handling unit including a cooling coil. This whole packaged air-conditioning unit looks like a box with the control panel located on the outside [5]. The air handling unit is made up of a centrifugal blower and air filter which is located above the cooling coil (Figure 7). The centrifugal blower has the capacity to handle large volumes of air required for cooling a number of spaces.

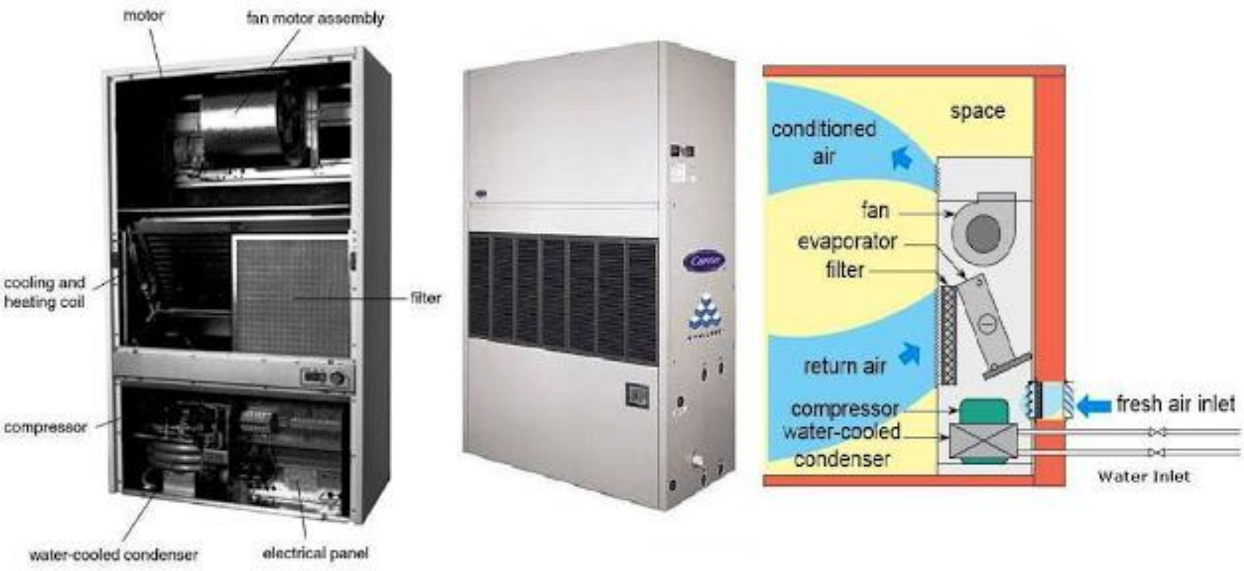

Figure 7: Water-Cooled Packaged System [5]

Water-Cooled Chiller System.

The main feature of this system is the use of cooling water from the cooling cycle to chill the surrounding air. It has four separate rounds to conduct heat from the cooled space to indoor air. This system operates with cold water which is processed into the chiller system and distributed to several air handling units. Similar to an air-cooled chiller system, this system is generally used for large capacity applications. Figure 8 shows the schematic cycle of a portable water-cooled chiller system.

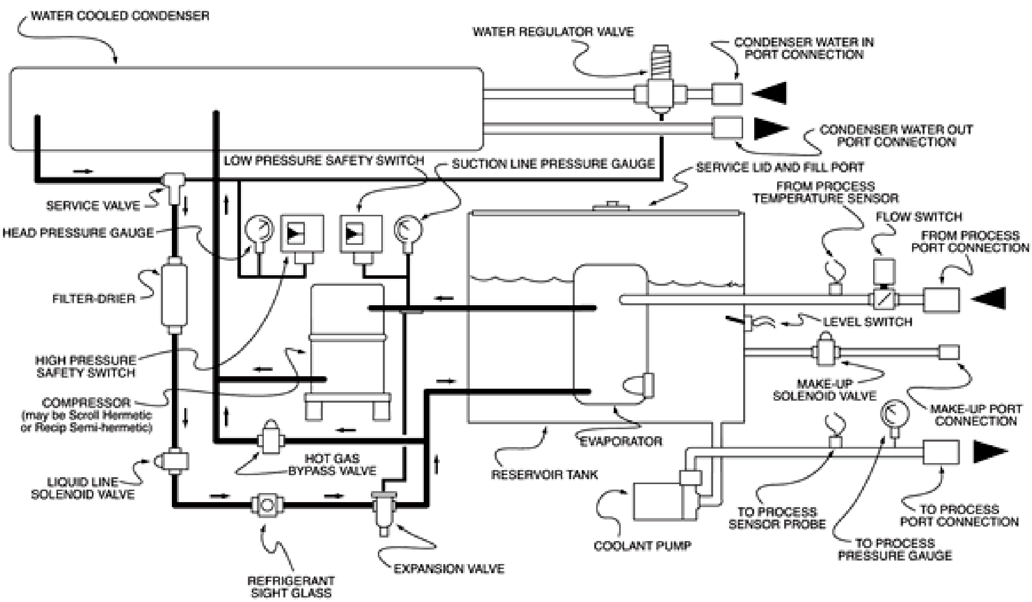

Figure 8. Portable Water-Cooled Chiller System [5]

This type of system is more suited to areas with good sources of water and where the client requires optimum power consumption [6]. The chiller is a system that absorbs heat from one process and then transfers it to a separate water source such as a cooling tower. This system consists of six major parts: chillers, chilled water pumps, condenser water pumps, a cooling tower, an air handling unit and a control panel [7]. Figure 9 is an example of an industrial water-cooled chiller system.

Figure 9. Industrial Water-Cooled Chiller System [6]

Air-Cooled Chiller System.

Air-cooled chiller systems are usually installed in large buildings for the comfort of the buildings' occupants. Moreover, this system requires less maintenance and can increase management efficiency. The air handling unit supplies conditioned air to spaces through ducts and diffusers while warm air in these areas is then drawn back into the air handling unit through return air grills and ducts [7]. Figure 10 demonstrates a common air-cooled chiller system loop.

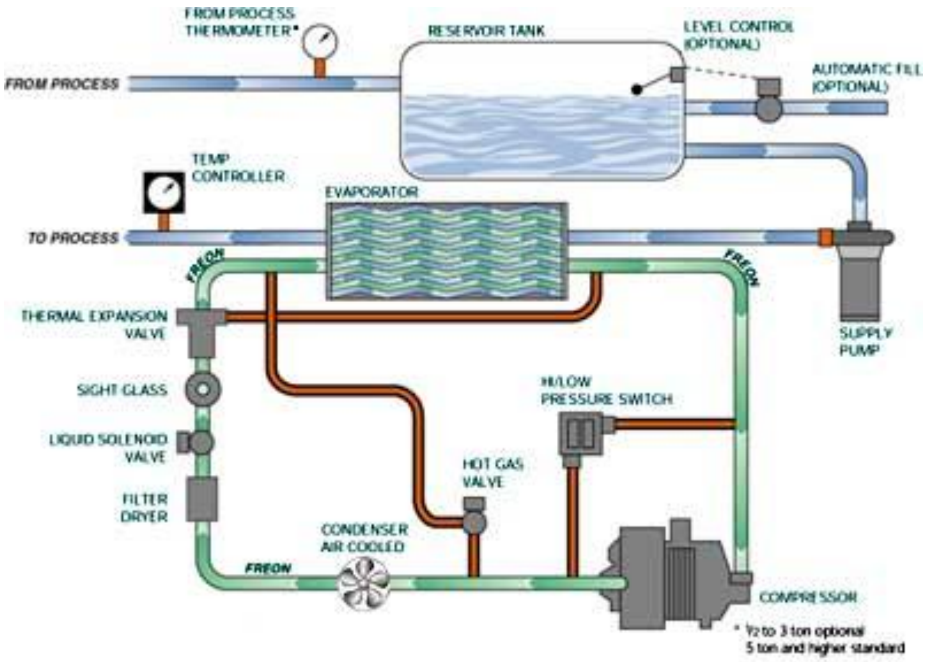

Figure 10. Common Air-Cooled Chiller System Loop [7]

Here, chillers transfer heat from processed water (*return chilled water*) to the surroundings. An air-cooled chiller consists of a compressor, evaporator, blower fan, chilled water pumps, control panel and condenser. These are all housed together as a package that supplies chilled water to the air handling units located in various floors or locations [7].

Thermal Comfort for Office Buildings.

Thermal comfort is best defined as a subjective condition of mind which expresses satisfaction with the surrounding thermal environment [3]. The environmental conditions required for comfort are not the same for each person. Because of this, when a space is occupied by a group of people, it is not feasible to satisfy everyone's thermal comforts due to differences in their physiological and psychological needs [8]. Thermal comfort is heavily influenced by the level of comfort that is considered suitable for humans and it is also influenced by environmental factors. Therefore, thermal comfort is actually too abstract because it depends on each individual. Figure 3 demonstrates how our bodies exchange heat with the thermal environment.

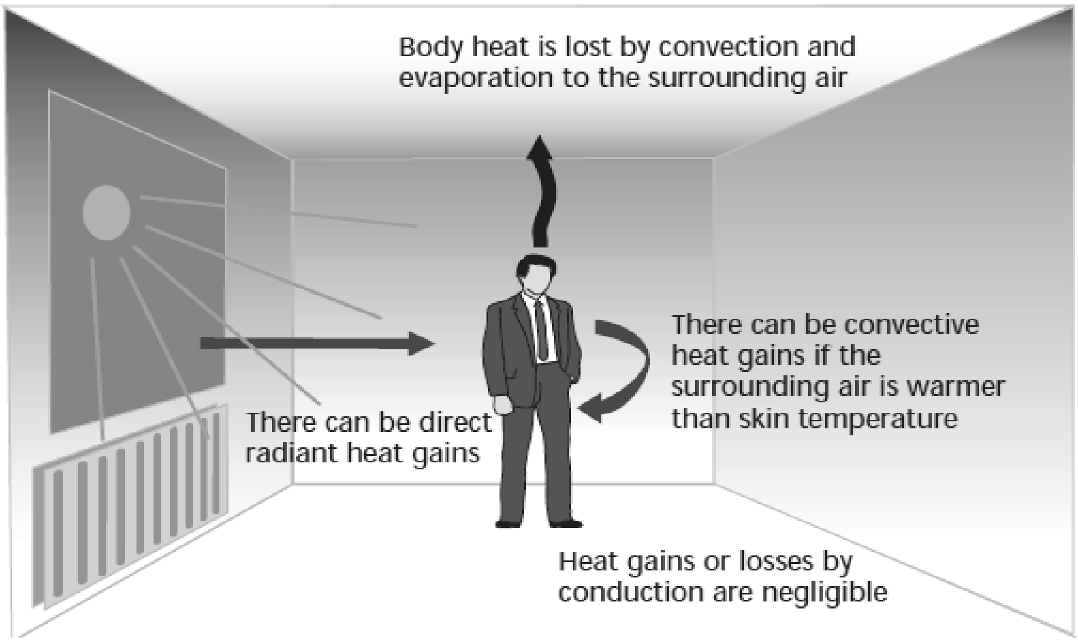

Figure 3. Exchange of Body Heat with the Thermal Environment [8]

While every individual has different levels of comfort, air-conditioning systems are becoming more and more common in buildings. The energy consumed by air-conditioning systems is a matter of key concern for those involved in the design and operation of buildings. Energy consumption, building sustainability and occupant comfort are interrelated and highly dependent on the provision of good indoor environmental comfort. As a result, an adaptive approach to thermal comfort based on the natural tendency of humans to adapt to the changing conditions of their environment, has been proposed [9].

Air Temperature.

While there are a number of thermal comfort variables, one which is equally important is air temperature. It is defined as the average temperature of the air surrounding an occupant. In this research, the value of air temperature is measured in Celsius. It is also often referred to as dry and wet bulb temperature.

Metabolic Rate.

Metabolic rate refers to the transformation rate of chemical energy into heat and mechanical work by metabolic activities within an organism. It is usually expressed per unit area of the total body surface such as Btu/h.ft2W/m2 [10]. Metabolic rate varies according to human activity and not to the physical environment. It is the key variable in thermal comfort research and it has been considered safe to assume that constant values for all occupants in one space are the same as their work activity.

Clothing Insulation.

Another variable that greatly contributes to thermal comfort is clothing insulation. As defined by ASHRAE Standards, clothing insulation is an ensemble of clothing that acts to create resistance to sensible heat transfer of the whole body including the uncovered parts such as face, head and hands. The guidelines are provided for thermal comfort related calculations which are based on insulation values of typical clothing ensembles [10].

Humidity.

Humidity, the moisture content of the air, is yet another variable of thermal comfort. In this research, humidity is measured as relative humidity. Relative humidity below 30 % can result in shocks from static electricity. Ratings below about 25 % can cause eyes and skin to feel dry. Levels above 80 % lead to a sticky and uncomfortable feeling. Such high levels of humidity can also lead to condensation and mould growth on building surfaces. The air can feel very stale and stuffy at high relative humidity.

Air speed

In thermal comfort, air speed is the variable which refers to an average air speed exposed to the occupant's body.

Conclusion.

At present, the majority of office buildings are equipped with adequate air-conditioning systems. It is necessary to maintain the temperature and humidity in the building. Furthermore, in warm and humid climates, worker productivity throughout the year can be indirectly impacted by the effect of the temperature on the indoor environment. Using air-conditioning systems in buildings is one way to maintain the temperature and moisture to ensure the thermal comfort of employees. Therefore, it is important to conduct proper investigations to understand employee reactions to the differences in temperature and humidity their places of employment. Doing such research can greatly improve the performance and design of air-conditioning systems in office buildings.

References:

1. Sekhar, S.C., Tham, K.W., Cheong, D., Ventilation Characteristics of an Air-Conditioned Office Building In Singapore, *Building and Environment Journal*, Volume 37, pp. 241-255, 2002.
2. Nicol, J.F. and Humphreys, M.A., Adaptive Thermal Comfort and Sustainable Thermal Standards for Buildings, *Energy and Buildings Journal*, Volume 34, pp. 563-572, 2002.
3. Bhatt, M.S. Energy Audit Case Studies Ii - Air Conditioning (Cooling) Systems, *Applied Thermal Engineering Journal*, Volume 20, pp. 297-307, 2000.
4. Barry P.H, The Impact of Office Comfort On Productivity, *Journal of Facilities Management*, Volume 6, pp. 37-51, 2008.
5. Reinikainen, L.M., Jaakkola, J.K., Effects of temperature and humidification in the office environment, *Archives of Environmental Health Journal*, Volume 56, pp. 365-371, 2001.
6. Gay L.R., *Comfort CIBSE Knowledge Series*: KS6, the Chartered Institution of Building Services Engineers, pp. 43-55, 2006.
7. Markham, S.F, *Climate and the energy of nationals*, Oxford Univ. Press. London, pp. 68-73, 1947.
8. Hundy, G.F., A.R. Trott, and T.C. Welch, *Packaged Units, in Refrigeration and Air-Conditioning*, (Fourth Edition), pp. 168-176, 2008.
9. Hussey, J., Hussey, R., A Practical Guide for Undergraduate and Postgraduate Students, *Business Research*, 1997.
10. Cheong, K.W., Chong, K.Y., Development and application of an indoor airquality audit to an air-conditioned building in Singapore, *Building and Environment Journal*, 2001.
11. Yu, F.W. and Chan, K.T., Experimental determination of the energy efficiency of an air-cooled chiller under part load conditions, *Energy Journal*, Volume 30, 2005, pp. 1747-1758.
12. Seppanen, O., Fisk, W.J., Lei, Q.H., *Effect of temperature on task performance in office environment Laboratory*, Lawrence Berkeley National, pp. 134-139, 2006.
13. Wargocki P., Wyon D.P., Sundell J., Clausen G., Fanger P.O., *The effects of outdoor air supply rate in an office on perceived air quality*, Sick building syndrome (SBS) symptoms and productivity, pp. 2-4, 2000.