Free term paper about air conditioning

Technology, Development

Abstract

This paper discusses and examines thermodynamics concepts and systems, particularly air conditioners. The principles upon which these systems are built, namely the first and the second thermodynamics laws are analyzed. Air conditioner performance and efficiency is also examined under the two laws. The second law of thermodynamics helps in determining the effectiveness of thermodynamics-based systems and is used in this paper to determine the efficiency of air conditioners. This paper finally makes recommendations based on calculations that determine the levels of efficiency of air conditioners.

Introduction

Air Conditioning, which involves the processes of heating and cooling, is an essential part of thermodynamics engineering. Regulation of temperatures, while probably being an end by itself, is imperative in the building of other systems. Air conditioning uses several thermodynamics principles which form the basis of such systems. All space and matter that is external to a given system is termed as the “ surrounding”. Air conditioning is largely based on how a given system and its surroundings interact. Any given system interacts with the surroundings through transfer of heat from the surrounding to it and vice versa. A system is termed as isolated if there does not occur any exchange of energy between it and the surroundings . Because thermodynamics deals with energy interactions, something that happens all over the universe, the study of the processes of heating and cooling forms the basis of such systems. Air conditioning, like all other applications of thermodynamics, generally deals in systems in equilibrium. Equilibrium implies a state or condition of balance. Air conditioning, therefore, is based on the concept of thermal equilibrium. When a system lacks thermal gradient, no net heat transfer takes place inside the. There are two pillars around which the rules governing heat motion are based. These are the thermal quantities and work, also termed as mechanical quantities. Thermal quantities are Internal Energy U, Temperature T, and Entropy . Several mechanical processes take place when heating and cooling. When heating of a substance is taking place, the distance between its molecules increases. Additionally, heat energy is added and for the case of air, it loses its moisture component and the volume increases. When cooling, the distance between molecules decreases and its volume goes down as well. Also, kinetic energy is lost at the molecule level. The matter also gains density. Temperature of a substance or system is an intensive property. This is because of its mass-independent nature. If, for instance, we take a 2 kg mass with thirty degrees of temperature and split it into two, the temperature will still remain thirty degrees in each of the two resulting parts .

Air Conditioning (Heating and Cooling)

Why this Topic?

Air conditioners are some of the most widely used systems around the world today. Air conditioners enhance human comfort. The most imperative processes that are done by an air conditioner are heating and cooling. These two processes form the primary mechanisms through which most energy consumption takes place for the functioning of air conditioners. Therefore, analyzing the cooling and heating processes of air conditioners will form a good foundation where energy efficiency and functioning can be improved.

Importance of this Topic

Heating and cooling is one of the core principles of thermodynamics engineering. It forms the basis of engineering large scale engineering systems which range from nuclear power plants to air conditioners. Air conditioners simply operate by transferring or moving heat from a hot region to a cold region. Air Conditioners are all about energy use, transfer and its changes from one form to another. An Air Conditioner uses the principles that many other systems use in heating and cooling. A car engine, for instance, uses heat energy to carry out tasks or work, which is the process of heating. On the other hand, a refrigerator does work in order to transfer heat.

Besides being at the core of engineering, air conditioning processes, the principles of air conditioning through cooling and heating occur, are imperative in understanding how the universe is influenced by thermodynamics. This enables the achievement of important states in buildings and other mechanical applications. Buildings are maintained at the exact desired temperatures which are obviously dependent on the season. This topic is, therefore, important because through studying it and applying its principles, we improve the quality of engineering systems and that of life in general. Its principles ensure that there is efficient use of energy in these applications. For instance, in the process of regulating building temperatures, no excess energy is used or wasted on overcooling or overheating buildings. The set temperatures meet set standards and ensure comfort of those working in the buildings which, consequently, increases productivity . Additionally, air conditioners ought to be energy efficient. An examination of their workings and efficiency can determine their suitability and what needs to be done to enhance them.

The Workings of an Air Conditioner

Air conditioners and refrigerators share common principles of how they work. A compressed gas system for refrigeration is used to cool air before passing it to the room for cooling. The refrigerant is then cooled to maintain low temperatures. The Figure below shows the different parts and the flow of air.

Figure 1: Air Conditioner Workings.

As shown above, ACs work by using chemicals responsible for converting liquid to gas and vice versa. Through this chemical, heat is taken from inside the house for cooling and vice versa for heating. An AC is comprised of three main or key components which dictate the working process of an AC: An evaporator, a condenser and a compressor .

The three parts have distinct functionalities. The compressor compresses the refrigerating substance from low temperature and pressure to high temperature and pressure. That conversion makes the boiling point to rise, enabling heat elimination caused by the outside air. The condenser receives gas at high temperature and pressure directly from the compressor. Its metallic surfaces do gas cooling to make it liquid. For condensers using water for cooling, the water circulation results in a similar effect. The evaporator functions by evaporating the refrigerating substance which absorbs heat from its surrounding air to produce a cooling effect .

There are auxiliary parts of a compressor. A capillary tube sits between the evaporator and the condenser and is a narrowing tube whose diameter is in the region of 1 and 2 mm, and length between 1 to 2 m. The tube enables the amount of gas into the evaporator to be adjusted. The electrical components allow electricity to be fed into the AC. A fan provides the AC’s cooling mechanism .

First Law of Thermodynamics

This first law or principle that is used in thermodynamics is at the core of air conditioning processes- cooling and heating. The principle can be expressed in several ways one of which is that energy can neither be destroyed nor created. The other is that nature does energy conservation. This principle is extensively applied in air conditioning systems, especially when expressed as a balance of energy thus: the change in energy in a given system equals the energy added to it minus the energy taken from it .

“ System”, in this context refers to a closed body or a set of bodies where we determine and examine the flow of energy. A system could be the air inside a room, or a boiler, or even a complete air conditioning setup. This balance in energy is expressed as an equation thus:

Ech = Ein - Eout (1)

Where

Ech = change in the energy within the system

Ein = the energy entering into the system

Eout = the energy leaving the system

The solution here is to apply equation (1) above to determine heat losses and gains inside the room system.

Ech = Ein - Eout

Ech = 3000BTUhr- 4500BTUhr

Ech = -1500BTUhr

This shows that heat energy is being lost from the system and therefore Mr. James would need to use a mechanism to compensate for the enthalpy loss since it will cause a drop in room temperature, making it too cold for his comfort. The solution would be to use a heater, which the demonstrated converter lacks, of 1500 BTU/hr. This will ensure a net heat loss of zero from the room and maintain the room temperature. Since a heater's electric power is measured in watts (W), as opposed to BTU/hr, the heater's capacity should, therefore, be:

3410BTUhr= 1000 W

1500BTUhr×1000 W3410BTUhr= 439. 88 W

There are three states, also termed as " phases", in which substances can exist. These are liquid, vapor (gas), or solid. The temperature and pressure of a substance determine its phase.

The pressure, as well as the temperature which triggers boiling, is known as the saturated condition. In technical terms, the boiling point is termed as the saturation pressure and saturation temperature. At saturation, vapor is termed as saturated vapor while liquid is termed as saturated liquid. Saturated liquid is exactly at its boiling temperature while saturated vapor is at its boiling temperature. A sub-cooled liquid is one at a temperature point that is below its saturation temperature. Sensible heat change is change in temperature that occurs on a substance such that its temperature gets reduced yet the element does not change its state. The enthalpy change for such a substance is termed as latent heat change. As a substance changes from liquid to vapor, the enthalpy increase is known as latent heat of vaporization. The opposite is known as latent heat of condensation. It is normally equal to latent heat of vaporization for any given substance .

The sensible heat equation is represented as shown below.

Qs= m ×c ×TC= mc t2-t1..(2)

Where

Qs = the rate that the sensible heat is removed or added to a substance given in BTU/hr.

m = rate of weight flow in the substance

c = the substance's specific heat given in BTU/lb-F

TC = the temperature change of the substance, also arrived at by using (t2-t1).

This equation can be applied where there is temperature change through heat removal or addition and no change in state. Both refrigeration (cooling) and heating undergo this process of heat change to achieve the desired temperatures.

Figure 2: A sketch of an electric heater for the heating process

Figure 3: A sketch of the refrigeration (cooling) process

Enthalpy Equation

The heat removed or added in air conditioning systems through these processes can be calculated using a different equation known as the enthalpy equation, which uses enthalpy change as opposed to temperature change.

Q= mh2-h1(3)

Where

Q = the rate of removal or addition of heat from a substance in question, expressed as BTU/hr

m = the substrate's weight flow rate, expressed in lb/hr

h2-h1 = the specific change in enthalpy for the substance, expressed in BTU/lb.

Equation 3 can be used instead of equation 2 where the enthalpy for the substance is known.

Latent Heat Equation

A change in enthalpy occurs where a substance condenses or evaporates and that change can be determined by applying the latent heat equation, which in turn is found using equation 3 for enthalpy change.

Q= m hg-hf= m ×hfg(4)

Where

Q = The heat removed or added from the substance, expressed in BTU/hr

m= The rate at which the weight flows.

hf= The enthalpy of a saturated liquid, expressed in BTU/lb

hg= The enthalpy of a saturated vapor, expressed in BTU/lb

hfg= The latent heat for vaporization, expressed in BTU/lb

Since both cooling and heating involve latent heat as well as sensible heat change on the substrate, adding both equations can give the right result. Also, the perfect (ideal) gas laws fall under this first principle of thermodynamics. Air under pressures and temperatures as applied in air conditioning environments work following this equation.

pV= mRT(5)

Where

p = the absolute pressure, expressed in lb/ft2.

V= The air volume, expressed in ft3

m = the weight of the gas, in lb

R = the gas constant

T= the absolute temperature, in R degrees

If two conditions of the same gas substance are considered, the following equation is obtained by rearranging equation 5 above.

p2V2T2 = p1V1T1(6)

This perfect gas law is imperative when finding changes in V, p, and T for changed situations or conditions. If one variable remains unchanged, leaving two of them to change, the equation simplifies further if temperature, T remains unchanged.

p2p1 = V1V2(7)

If the volume is the one that does not change,

p2p1 = T2T1 . (8)

And, lastly, if the pressure is the one that is constant,

V2V1 = T2T1 . (9)

Example:

Compressed air used for operating pneumatic controls for an air conditioner is stored at 15 pisg in a 9 ft3 tank. The air used at the controls is at 15 psig. The volume of air available for the controls can be determined as below.

With absolute pressure pabs= pg+ patm, if the assumption that temperature does not vary is made,

V1= P2P1V2= 164. 7 psia29. 7 psia ×9 ft3= 49. 9 ft3

Entropy

The second principle additionally deals with entropy, which measures disorder. In regard to entropy, the second principle in thermodynamics states that the universe has ever increasing entropy. Entropy is represented as: S= H/T

Where:

S = entropy, represented in kJ/kg K

H = enthalpy, represented as (kJ/kg)

T = the absolute temperature, represented in K

A system’s change in entropy is determined by heat content changes inside of it. Air conditioners apply this principle in the cooling and heating processes. An example of entropy equations is the heating of steam. Assuming a 1 kg of steam at 423 K pressure, and enthalpy at 373 K is 2675 kJ/kg (obtaining from steam tables). The enthalpy of steam, also obtained through steam tables look up, is 423 K. The entropy changes are obtained as follows:

dS = dH/Ta

2777 – 2675 = 102 kJ/kg and 423+373 = 796 K

= 102kJkg796 K= 0. 256 kJ/kgK

The Second Law of Thermodynamics

The first principle discussed above, mostly in the form of energy equations, is useful in determining problems in heating and cooling processes. That principle simply tells us the amount of energy that has been used to accomplish a certain task, such as the capacity of a heater or cooler in an air conditioner. However, it gives no information on questions such as whether it is possible to user tinier air conditioner. It does not provide a way for determining how good and efficient a design is, something that will minimize energy consumption while still doing what it was meant to .

The second law provides an understanding of these questions that enable the application and investigation capabilities for better energy utilization. This is especially imperative due to the increasing need for efficient energy use and the advocacy for green energy consumption. The second law states that a thermally isolated system comprised of various systems has entropy that never reduces. The implication of this is quite simple and direct as exemplified below.

After a while, there occurs natural movement of heat from hot to cold area, and that can be exemplified by this diagram.

Figure 4: An illustration of natural heat movement from hot to cold area

However, there are several other key implications of this principle, which are considered in improving the efficiency of thermodynamic system. One of the caveats of this principle is that whenever heat is used to perform work, not all of it is utilized well, as some of it is lost hence becomes unavailable to perform the task it was meant to do. However, the maximum amount available for the actual work can be calculated. That way, the best efficiency can be determined .

An air conditioner can also be termed as a heat pump in the warming process. The second law gives us the ability to determine the coefficient of performance. This is just the ratio of the total heat energy moved to the outside QH to the total work, W, needed to accomplish that.

COP= QHW..(10)

For instance if an air conditioner needs 2, 400 joules of energy for pumping 7, 600 joules from outside to the inside of a room, we can determine the coefficient of performance as follows:

COP= QHW= 76002400= 3. 17

Air conditioning during summers relies on cooling techniques mostly. These chillers in air conditioners are either thermal or electric. These two types of chillers have different coefficients of performance (COP).

COPel= QPel.(11) And

COPth= QQg .(12)

Where

Q = the cooling power or simply the useful effect, and

Pel = the amount of electricity needed for driving the chiller, and

Qg = the thermal power made available for the chiller

The actual values for the COP are in the range of COPth = 0. 6 ÷ 1. 2.; COPel = 2 ÷ 4.

This is not to say that thermal chillers are worse than electric ones by this measure. A better metric is PE or Primary Energy Ratio. PER= QPE. PE is defined as energy that is yet to be subjected to transformation processes or conversions. The previous equations are combined to assess PER as follows:

PERth= COPthηg And

PERel= COPelηel

Where

ηg = the boiler's efficiency, this boiler is responsible for driving the sorption chiller, and

ηel= Pel /EP which is the electric system's efficiency nationwide.

Using the formulas,

ζth=-Q1-ToTaQg1-ToTg= COPthToTa-11- ToTg = 0. 7 306299-11-3061500= 2%

ζel=-Q1-ToTaPel= COPelToTa-1= 3306299-1= 7%

Therefore, using the second principle, one is able to determine efficiency precisely as done above.

Recommendations

The operation of air conditioners in maintaining the desired room temperatures varies vastly on a number of things and trade-offs one of such being the energy necessary to maintain the room temperatures around the desired levels. During winter, for instance, a lot more energy and effort is required to maintain room temperatures. It is all-important therefore to find mechanisms to ensure the best possible efficiency of operation for the cooling and heating processes of air conditioners. Global warming is contributed by inefficient use of various energy resources, especially non-renewable ones. Therefore, renewable energy alternative and improving efficiency while maintaining best effectiveness is imperative.

Conclusions

Thermodynamics and its principles are applied in a varied number of engineering applications from large systems to small household units such as air conditioners. These systems have undergone many innovations in the course of multiple decades in order to significantly improve the quality of life. Since most individuals spend a lot of daily productive hours indoors, it is all-important to ensure the best possible stay in terms of comfort. Air conditioners provide that comfort through humidifying, cooling and heating rooms.

The first law of thermodynamics does not reveal much in terms of performance of systems built based on it. The second principle, however, reveals very important details on the performance of systems built on the thermodynamics principles such as air conditioners. There is a need to come up with mechanisms to improve the energy utilization of thermodynamic systems such as air conditioners. Some options to be considered are the development of solar-powered systems and also systems that emit little or no heat when operating.

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Abbreviations

BTU - British thermal unit

AC – Air Conditioner