Topic 4
Air-Conditioning Systems

Introduction

Definitions

- Air conditioning is the process of conditioning enclosed spaces and places. Air is conditioned by varying its air temperature, humidity, air-change, air purity and distribution in order to achieve specific requirements for the space in which the air-conditioning functions.
- Heating and cooling is achieved by controlling the room temperature, humidity by the process of humidification and dehumidification. Filters are used to ensure air purity. The distribution process occurs where treated air is distributed to various parts of the building. Distribution requires the mechanical ventilation equipment (eg AHU) which ensures proper air flow.

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In summary:

Temperature heating and cooling

Humidity midification and dehumidification

Air Purity ration, purification and the absorption of

Distribution ventilation and flow mechanisms

Required air condition

- Note: the heating process does not normally take place in tropical countries.

Reasons for Air-conditioning

Comfort

- Changing climatic conditions results in internal environments that are not balanced in terms of providing comfort.
- Air-conditioning systems ensure a stable comfort level and contributes towards optimal satisfaction levels for carrying out activities.
- The current socio-economic conditions results in people and activities being concentrated in relatively compact spaces. Normal ventilation is not suitable under such circumstances in providing appropriate comfort levels – eg. in cinemas and theatres and halls.
- Small spaces are concentrated within limited spaces, like offices in a building. Buildings are concentrated within a small and compact area. This limits the available breathing space especially within urban areas.

Reasons for Air-conditioning

Performance

- Air-conditioning systems improves the comfort of workers, thereby improving productivity.
- Many types of occupations require comfortable and controlled environments.
- This is relevant not just for workers but also some types of production processes in factories and industries.
- They require controlled air supplies and environment, eg chocolate factories that require refrigeration to avoid chocolate from melting.

Reasons for Air-conditioning

Health

- Deteriorating environmental quality due to pollution and rapid urbanization and industrialization, congestion, noise pollution and raised air temperatures.
- Indoor spaces are isolated from these outdoor conditions and the interior spaces are air-conditioned.
- Micro-organisms, need environments that are free from contaminants and noise and the spaces they occupy need to be air-conditioned.

Reasons for Air-conditioning

Sensitive equipment

- Some equipment sensitive to the environment such as computers, electronic equipment, lenses, equipment that are used in the production of micro-chips and photonics components

Status symbol

- Air conditioned homes reflects the status of the owner.

importance of air-conditioning

In general the importance of air-conditioning is summarized as follows:

- prevent noise pollution
- environmental control
- remove excess heat
- provide sufficient ventilation
- humidity control
- prevent unwanted smells
- air distribution to achieve comfort
- achieving the above without negative impacts on the physiology and psychology of the users.

- Mechanical ventilation systems are not inevitable.
- Passive systems should be used where appropriate.
- Air conditioning systems are costly, whether they are initial installation, running costs and maintenance.
- Extensive use of air-conditioning systems on congested urban areas will give rise to heat islands that are difficult to rectify.
- Outdoor areas here becomes unsuitable in terms of human comfort.

Design Factors

- Before determiing the concept and type of air-conditioning that is to be used, we need to know the capacity for handling air within any given space. The capacity is based on the cooling load i.e. the ability to remove heat.

- There are several factors that affect heat gain within a space:
- Building Orientation
- Orientation of the building, size of openings, and the building enclosure relative to the sun-path determines the amount of heat that is gained through radiation and induction.

Design Factors

Building Envelope

- The mass of the building enclosure will determine the rate of heat flow and its storage factor. Walls that absorb and retain heat will retain more heat if it is larger. Thicker walls with faster heat flow rates are better in removing heat through air absorption.

Design Factors

Infiltration

- Openings and ventilation holes will affect the amount of air that infiltrates into the air-conditioned space and reduce the effectiveness of the system.

Surroundings and Climate

- Reflected radiation from surfaces such as ponds, shiny surfaces on buildings etc will increase cooling loads.

Activities and Equipment in the space

- People produce heat as do office equipment such as lighting, computers, photocopiers and printers. The amount of heat depends on the wattage of the equipment.

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Load Units

- Units used for Air-conditioning reflects its capacities, loading and efficiency.

Cooling Load

- A concept used to calculate the capacity of the ac system to cool the air during the process of refrigeration. It depends on the heat gain in the space. Units used for calculating heat is Btuh (British thermal unit per hour) and kilojoule. where 1w = 3.142Btuh
- Roughly 60 to 100 Btuh is needed to cool I square foot (0.093 square meters) of space.

Table 4.1 A
Units used for Cooling Systems

Unit used for quantity of energy		Unit used for capacity of energy	
1. F.P.S.	2. S.I.	3. F.P.S.	4. S.I.
Btu (british thermal unit) kCal (kilocalorie) 1 kCal=3968 Btuh	Kj (kilojoule) ikCal=4.187 Kj	Btuh (British Thermal Unit per Hour) 1 MBH=1000 Btuh TR (tons of refrigerant) 1TR = 12000 Btuh Kcal.h (Kilocalorie Hour) 1 Kcal.h=3.96 Btuh	Wh (Watt hour) 1w = 3.412 Btuh

Table 4.1 B
Units used for Air Handling Loads

Unit used for capacity		Unit used for requirement	
1. F.P.S.	2. S.I.	3. F.P.S.	4. S.I.
CFM (cubic foot per minute)	M^3/s (meter cube per second) 1 M^3/s = 35.3CFM	Air changes per hour Foot cube per minute	Air changes per hour Meter cube per second

Unit used for capacity		Unit used for usage	
1. F.P.S.	2. S.I.	3. F.P.S.	4. S.I.
hp (horse power) 1hp=7457watt	Kw (kilowatt)	Hp/hr	KwH (kilowatt hour)

Mechanical Power
Motor power, pump power and other similar equipment. In Table 4.1C the units in the first two columns are more widely used.

Electrical Power and Energy

- This is used for determining the type of electrical circuit system that can be connected to the equipment supplied by the vendors. Units used include:
  - Type of current usually a.c. (alternative current)
  - Type of Phase: usually one or three
  - Types of voltage, usually 240V, 415V (volt)
  - Hertz usually 50Hz.

- Aside from the electric power units, thermal units are also used for systems that do not use electrical power.

Comfort

- Generally:
- optimal temperature for human comfort approximately 70°F (15°C)
- Relative Humidity between 40%-60%.
- Air movement within the space not exceeding 12m/min for air conditions for someone working in a sitting position.
- Fresh air supply sufficient to avoid excessive body odor and to ensure air cleanliness.
- Noise from equipment and ducting must be minimized.

Related Services

For an efficient air-conditioning system, 3 building services are important:

- Electricity supply for air-conditioning systems need to be 3 phase.
- Water supply for larger systems like plant rooms water is used to remove heat.
- Spaces necessary for equipment and ducting.

Basic Principles of Air Conditioning

- **Basic Principles**
- The basic principles of air-conditioning are based on the law of matter, heat and refrigeration

Principles of Refrigeration

- The process of refrigeration is to remove heat from one place to another. It is based on two characteristics of matter
- Fluids absorb heat when transforming from liquid to gas (latent heat of vaporization)
- Fluids release heat when transforming from gases to liquids (latent heat of condensation)
- Example water absorbs heat from fire and turns to steam. Steam that condenses into water releases heat.
- In the air-conditioning process a medium is used to transfer heat, liquid or fluid refrigerant absorbs heat from the air and turns to gas, The heat is transferred and released elsewhere.

Basic Theory of Air-Conditioning

Nature of Matter

- All matter is in one of three states, solid, liquid or gaseous. All matter contains molecules that move according to the energy level in the surroundings
- . The more the heat the faster the molecules vibrate. Its density varies according to the activity of the molecules.
- This determines the state of the matter, solid, liquid or gaseous.
- This is called the "theory of molecular motion". Changing the state of the matter will absorb or release heat.

Basic Theory of Air-Conditioning

Character of matter and heat.

- Heat is the determining factor in molecular motion. It determines the state of the matter.
- Example: Solid - iron

  Liquid – water

Basic Theory of Air-Conditioning

Movement of heat

- In air conditioning systems heat is to be removed from the space that is to be conditioned, and released from to the outside air. This is done via the the movement of heat from a hot area to a cold area. Energy from a molecule that is active is transferred to a less active molecule in order to achieve a balanced motion. This can happen from one material to a different material, and this forms a basic principle of air-conditioning.

Basic Theory of Air-Conditioning

Pressure and heat

- The boiling point of any matter will change according to pressure. Lower pressure will mean a lower boiling point., and vice-versa. This process is used to force liquids in air-conditioning systems to gain and release heat.

Basic Theory of Air-Conditioning

Measurement of heat

- Btuh is is still widely used to measure heat. 1Btu (0.3watt) is the heat that is requiredto raise the temperature of 1 lb of water (0.45g) by 1^{o}F (1^{o}C)at sea level

Refrigerant

- The fluid used as a medium for transferring heat from one place to another in the ac system. In most ac systems Furion 12 is used as I is safe (non-flammable), easy to handle, and does not react woth other material such as steel pipes, and metals.

Basic Theory of Air-Conditioning

Cold Air Cycle

- Basically the principle of air-conditioning is a process of air cooling. Various controls need to be in place within the process to create conditions required by the user. This can be divided into 2 major processes i.e. the refrigerant cycle and the air cycle.

Basic Theory of Air-Conditioning

Refrigerant Cycle

- This is a cooling process . It requires a medium to carry heat. Two ways in which this is done:
  - Direct expansion refrigerant
  - Absorption refrigerant

- Both these processes involve transferring excess heat from the space that needs to be cooled to the outside air.

Direct Expansion Refrigerant

- Smaller and cheaper system compared to the other type, but has higher operating costs.
- This system employs the principle of latent heat flow in matter. Furion 12 is used where in normal situations it is in gaseous state. It changes to liquid under high pressure. Figure 4.1 illustrates the process

- Heat is transferred from the evaporator unit to the condensor unit through the refrigerant circulation pipes. The whole equipment setup is sometimes called a heat pump because of its action of pumping heat from the indoors to the outdoors. Electricity is used to operate the compressor.

- The cycle consist of four main processes (figure 4.2, 4.3 and 4.3b):

Compression

- Refrigeration enters the compressor in the form of low pressure gas. This gas is compressed and exits as high compression gas which is heated. The refrigerant temperature is raised and it turns into liquid.
- (Note: it cannot change state because the latent heat of evaporation (LHE) cannot be released as the pipes are insulated).

Condensation

- The high pressure gas iflows to the condensor. Heat (LHE) is extracted and it transforms to high pressure liquid at normal temperature.

Expansion

- High pressure liquid flows to the expansion valve which returns it to its normal state. The valve controls the flow of liquid and this reduces the pressure. The boiling point of the liquid is also lowered and it becomes chilled and is easily converted to gaseous state.
- Note: as the LHE is needed for the process of evaporation it has to remain in liquid form as the pipes are insulated.

Evaporation

- Low pressure liquid flows to the evaporator where heat in the air that is cooled in the space through the process of heat flow will accomplish the evaporating process. The refrigerant converts to low pressure gas bringing the heat along with it to complete the first cycle.

Absorption refrigerant

- Another method of transferring heat in air-conditioning systems.
- It uses the same principles as the previous example but does not use mechanical means to change the state of the refrigerant.
- In this system heat is used to change the state from gaseous to liquid.
- The refrigerant used are solutions with low boiling points such as Lithium Bromide and ammonia.
- Water vapour from containers is used to create flow.

This system consists of (figure 4.4):

- Generator Unit
- Separator
- High pressure water vapour
- Evaporator Unit
- Absorber Unit
- Heat Transfer Unit
- Cooling Tower

- In the **generator unit**, the Lithium Bromide Solution (example) that is normally unstable to temperature changes, absorbs heat from water vapour that is provided for from containers. The solution will evaporate in a state of high pressure.

- The **separator unit** will separate the water vapour from the concentrated Lithium Bromide Solution and returns the solution to the heat transfer unit.

- The high pressure water vapour is cooled to remove its heat in the condenser unit. It is then forced through an expansion valve to reduce its pressure and boiling point.

- In the evaporator unit the low pressure cool vapour absorbs the latent heat to return to its original state. Heat is absorbed from the air in the air cycle.

- The **absorption unit** will dissolve the concentrated Lithiun Bromide with the water that is returned from the evaporator unit. The cooling water will facilitate this process.

- The diluted solution will return to the **Heat Transfer Unit** where it will cool down the concentrated solution from Process (2). This cycle continues until the source of vapour energy from the container is shut down

- The **cooling tower** removes the heat from the condenser via the circulation water pipes.

- It is noted here that the Lithium Bromide solution is used as an absorption media and not a heat carrier. Water that is vapourised is the actual heat transfer media. This equipment is sometimes also called a heat pump.