UNIT –II

THERMAL SENSATION

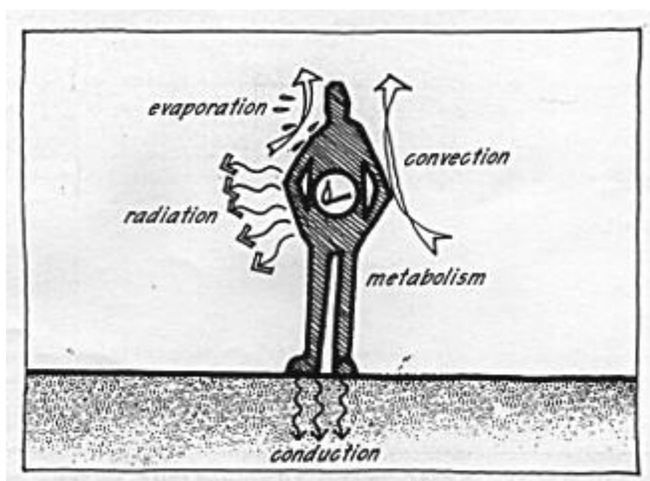
INTRODUCTION:

Thermal sensation:-The sense of temperature

In cool environments, hands and feet feel colder than other body parts. The head, insensitive to cold but sensitive to warm, feels warmer than the rest of the body in warm environments. Overallsensation and comfort follow the warmest local sensation (head) in warm environments and the coldest (hands and feet) in cool environments.

There has been limited research on how people respond, physiologically and subjectively, to thethermal non-uniformities encountered in buildings, vehicles, and the outdoors. Such non uniformities (in air temperature, air movement, radiation, and conduction to surfaces) affect the skin temperatures of the body's various parts, affecting a person's overall thermal sensation and comfort in complex ways. Even in spatially and temporally uniform environments, the body's skin temperatures are distributed non-uniformly, as are local sensations and local comfort.

BODY HEAT BALANCE:



Heat Balance

- Constant internal temperature requires a balance. Even in a thermoneutral environment, basalmetabolism produces 1 kcal_kg-1_h-1. The specific heat of human tissue only requires 0.83 kcal_kg-1 to raise internal temperature by 1°C. Therefore, without heat loss processes, internal temperature would elevate by 1°C_h-1 even at rest

The heat produced must be dissipated to the environment, or a change in body temperature will occur. The deep body temperature is about 37°C, whilst the skin temperature can vary between 31°C and 34°C under comfort conditions. Variations occur in time, but also between parts of the body, depending on clothing cover and blood circulation. There is a continuous transport of heat from deep tissues to the skin surface, from where it is dissipated by radiation, convection or (possibly) conductionand evaporation.

The body's heat balance can be expressed as

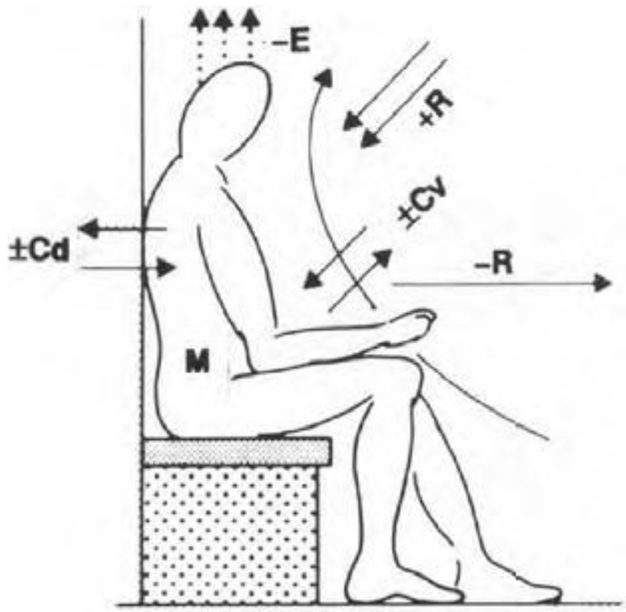
$M \pm R \pm Cv \pm Cd - E = \Delta S$ (W) ... 1.1)

where M = metabolic rate,Cv = convection; R = net radiation; Cd = conduction

E = evaporation heat loss ,ΔS = change in heat stored

If ΔS is positive, the body temperature increases, if negative, it decreases.

The heat dissipation rate depends on environmental factors, but the body is not purely passive, it is homoeothermic: it has several physiological regulatory mechanisms.



To warm conditions (or increased metabolic heat production) the body responds by vasodilation: subcutaneous blood vessels expand and increase the skin blood supply, thus the skin temperature, which in turn increases heat dissipation. If this cannot restore thermal equilibrium, the sweat glands are activated, the evaporative cooling mechanism will operate. Sweat can be produced for short periods at a rate of 4 L/h, but the mechanism is fatigable.

Thermal comfort is a term used by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, an international body. It is defined as the state of mind in humans that expresses satisfaction with the surrounding environment (ANSI/ASHRAE Standard 55[1]). Maintaining this standard of thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC (heating, ventilation, and air conditioning) design engineers.

Thermal comfort is affected by heat conduction, convection, radiation, and evaporative heat loss. Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. It has been long recognised that the sensation of feeling hot or cold is not just dependent on air temperature alone.

Humans are homeothermic (i.e. body temperature is maintained independent of environmental temperature)

Body temperature often described as either: – **'Core'** (typically 36.1-37.8°C) ,**'Shell'** (ideally 33°C but up to 42°C in contracting muscle)

Body heat content usually exceeds 1500 kcal

• Metabolic heat production _70-1500 kcal_h-1, so heat transfer with the environment is essential.

• However, this operates both ways and overall heat balance can be expressed as:

Metabolic Rate ± Radiation ± Convection ± Conduction – Evaporation

Factors of comfort

The variables that affect heat dissipation from the body (thus also thermal comfort) can be grouped into three sets:

- **Environmental**: air temperature, air movement, humidity, radiation
- **Personal**: metabolic rate (activity), clothing
- **Contributing factors**: food and drink, acclimatization, bodyshape, subcutaneous fat, age and gender, state of health

Body Mechanism to regulate its temperature

The human body regulates temperature by keeping a tight balance between heat gain and heat loss. Your temperature regulation system is more analogous to the operation of a home furnace, as opposed to the function of an air conditioner. Humans regulate heat generation and preservation to maintain internal body temperature or core temperature. Normal core temperature at rest varies between 36.5 and 37.5 °Celsius (°C), which is 97.7 to 99.5 °Fahrenheit (°F). Core temperature is regulated by the hypothalamus (in the brain), which is often called the body's thermostat. The hypothalamus responds to various temperature receptors located throughout the body and makes physiological adjustments to maintain a constant core temperature. For example, on a hot day, temperature receptors located in the skin send signals to the hypothalamus to cool the body by increasing the sweat rate.

During all types of exercise the body's ability to thermoregulate is challenged. Heat is produced as a bi-product of metabolism (metabolism is defined as all of the reactions that occur in the human body). However, the human body is only 25% efficient, therefore you lose approximately 75% of energy as heat. During exercise, heat is produced mainly from working muscle contractions and core temperature can go above 40 °C (104 °F).

Mechanism of Body to lose heat

As previously discussed, the body regulates temperature like a furnace. It is constantly producing heat and then dispersing it through various processes. Heat can be lost through the processes of conduction, convection, radiation, and evaporation. Conduction is the process of losing heat through physical contact with another object or body. For example, if you were to sit on a metal chair, the heat from your body would transfer to the cold metal chair. Convection is the process of losing heat through the movement of air or water molecules across the skin. The use of a fan to cool off the body is one example of convection. The amount of heat loss from convection is dependent upon the airflow or in aquatic exercise, the water flow over the skin. Radiation is a form of heat loss through infrared rays. This involves the transfer of heat from one object to another, with no physical contact involved. For example, the sun transfers heat to the earth through radiation. The last process of heat loss is evaporation. Evaporation is the process of losing heat through the conversion of water to gas (evaporation of sweat). The primary heat loss process for aqua enthusiasts is convection, however, in an outdoor pool on hot day evaporation will also play a primary role in heat loss.

Water content in the body

Water makes up approximately 60% of your total body composition. In addition, 73% of lean body mass or muscle is composed of water. It is the essential nutrient for survival and is required for all cell functions. Water is also an important constituent in thermoregulation, because it is a major component of blood volume. It is mainly lost through sweat, respiration, and waste. However, when the body is dehydrated, most of the water lost is from the blood.

Sweat Basics

The average person has 2.6 million sweat glands. Sweat is made up of water and electrolytes such as sodium, chloride, and potassium. When the hypothalamus senses an increase in core temperature it will act by increasing blood flow to the skin, stimulating the sweat glands. The result is an increase in the rate of water lost through sweating.

During low- to moderate-intensity exercise of less than one hour, there are minimal electrolyte losses because the body reabsorbs most of the electrolytes from the sweat. However, during moderate- to high-intensity exercise of greater than one hour, the electrolyte loss in sweat becomes significant and the sweat rate is too fast for re-absorption of electrolytes.

Water loss during exercise

During high-intensity exercise, a person can lose up to 2.0 liters of water per hour! However, 1.0 liter of water per hour is more common. Sweat rate can vary depending on the environmental temperature, humidity, type of clothing worn during exercise, intensity of exercise, fitness level of the individual and acclimation of the individual to the environment. Replacing fluids during and after exercise is very important for staying hydrated and preventing dehydration. Signs of dehydration include dark colored urine (urine should be the color of water with a splash of lemon), muscle cramps, decreased sweat rate, and increased fatigue.

Best way to stay hydrated

According the American College of Sports Medicine (ACSM), before, during and following exercise, water or a carbohydrate/electrolyte drink is recommended to stay hydrated. The drink of choice should be cold in temperature and taste good to the individual. If it’s more palatable to the person, more will be ingested!

ACSM makes the following general recommendations for the amount and type of fluid that should be ingested before, during and after exercise:

- Approximately 24 hours before exercise, an individual is recommended to consume fluids and foods to promote hydration. Fruits, vegetables, and carbohydrates are examples of foods that promote hydration. In addition, avoid too much alcohol and caffeine, as these fluids can cause water loss and promote dehydration.
- Two hours before exercise, 16 ounces (2 cups) of fluid should be ingested to promote hydration and allow time for excretion of excess water.
- During exercise of less than an hour, it is recommended to ingest water every 15 minutes to prevent dehydration. Electrolyte loss is negligible; therefore a carbohydrate drink is not necessary.

- During exercise of greater than an hour, it is recommended to ingest a carbohydrate and electrolyte drink every 15 minutes.
- Never restrict fluids during exercise!
- After exercise ingest a carbohydrate and electrolyte solution. The carbohydrate will replenish glycogen stores (muscle carbohydrate stores) and the electrolytes will replenish sodium, chloride, and potassium lost in sweat. In addition, avoid carbonated drinks, as they make you feel full and decrease fluid intake.

Effective Temperature.

It is defined as the temperature of a still, saturated atmosphere, which would, in the absence of radiation, producethe same effect as the atmosphere in question. **It thus combines the effect of dry air temperature and humidity**. It became the most widely used index for the next 50 years, but it is now superseded.

Wet bulb globe temperature (WBGT)

It indicates the combined effect of air temperature, low temperature radiant **heat, solar radiation and airmovement.**

Operative temperature (OT)

It is defined as the temperature of a uniform, isothermal "black" enclosure in which man would exchange heat by radiation and convection at the same rate as in the given non-uniform environment

DETERMINATION OF THERMAL COMFORT TEMPERATURE

The major aim of comfort research is to find comfort temperature for an individual or group. However, 6 major variables determine how warm or cold a person feels.

Environmental factors

- air temperature
- air speed
- humidity
- mean radiant temperature

Individual factors

- activity
- clothing insulation

Thermal Comfort Indices and Standards

The combined effects of environmental and individual factors can be represented on a psychrometric chart. Basically, the psychrometric chart gives air temperature (dry bulb) along the X axis at 0% RH and then curves of equal humidity.

The ranges of indoor temperature, humidity, and air movement, under which most persons enjoy mental and physical well-being. Also known as comfort standard.

THE COMFORT ZONE

It is the combinations of temperature and humidity where people report comfort.

If conditions are to the right of the comfort zone then need to increase cooling say be increasing wind. If conditions are to the left of the comfort zone then need to increase heating say by increasing sun. Superimposed on this chart are lines of effective temperature i.e. lines of equal thermal sensation.

- **Comfort Indices (ET)** - ET is "an arbitrary index which combines into a single number the effect of dry-bulb temperature, humidity, and air motion on the sensation of warmth or cold felt by the human body".
- **Standard Effective Temperature (SET)** - For sedentary activity (1.1 met), light clothing and low air speed SET = ET* SET = ET* extended to incorporate different levels of activity and clothing SET is the temperature of an isothermal environment which has air and mean radiant temperature equal to each other, RH of 50%, still air, and in which a person with a standard level of clothing insulation would have the same heat loss at the same mean skin temperature and the same skin wettedness as the person has in the actual environment with the clothing insulation under consideration. The activity level is assumed to be the same in both environments. SET calculation involves: For a given level of activity, clothing, and air speed - psychrometric chart--lines of constant

SET. It has also been suggested that SET links directly to sensation rather than air temperature. SET is the most comprehensive comfort index, yet while in its restricted form (sedentary activity--effective temperature (ET)) it has been adopted by ASHRAE in its comfort standard, in its more general form it has yet to be widely used.

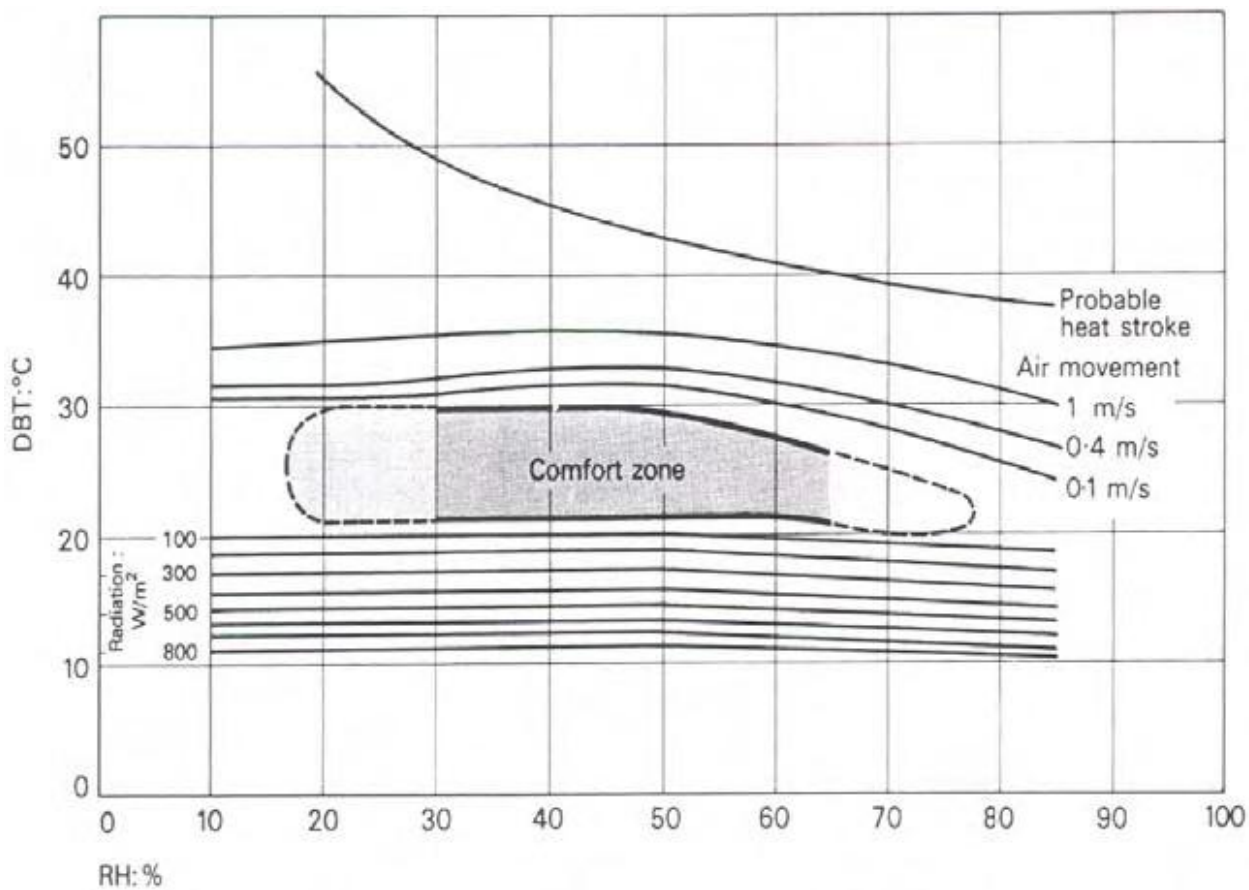
COMFORT STANDARDS

ASHRAE 55-1981

- Activity - 1.2 met, mainly sedentary
- Winter - 0.9 clo (sweater, long sleeve shirt, heavy slacks), air flow -0.15 m/s (30 fpm)
- Optimum operative temperature = 22.7ºC (71ºF) (globe temperature, MRT)
- Summer - 0.5 clo (light slacks, short sleeves or blouse), air flow -0.25 m/s (50 fpm)
- For each increased degree Kelvin up to maximum 28ºC at 0.8 m/s air, need to increase air motion by 0.275 m/s. OR by 30 fpm for every degree Fahrenheit up to 82.5ºF at 160 fpm. Optimum operative temperature = 24.4ºC (76ºF) With minimum clothes (0.05 clo) top = 27.2ºC (81ºF)

Olgyay was the first to outline the comfort zone in architectural terms, i.e. the range of environmental conditions within which the average person would feel comfortable. He did this in graphic form, with DBT on the vertical axis and RH on the horizontal. The aerofoil-shaped zone at the centre of this graph is the comfort zone. Fig.34 shows his original bioclimatic chart, together with its playful interpretation and Fig.35 is a chart converted to metric units and adjusted for warm climates.

He subsequently drew lines above the comfort zone, showing how air movement at different velocities could extend the upper boundary of the comfort zone (or: if the DBT is above the comfort limit, what air velocity would be required to restore comfort). Below the comfort zone families of lines indicate various levels of radiation that would compensate for the lower than comfortable temperatures. This chart became quite popular amongst architects. Whilst the various single-figure indices would concealthe magnitude of individual variables, this chart allows the manipulation of these variables, showing the contribution of each separately. The prevailing climatic conditions can then be plotted on the same chart, which will allow a diagnosis of the climatic problem.



It is interesting to note that the latest version of the ASHRAE Code (Standard 55-2004) reverts to the 12 g/kg upper limit of humidity, and that it abolishes the lower limit (Fig.38 f). Now there is no lower limit. It has beensuggested that this lower limit (4 g/kg) had been imposed for non-thermal reasons, so it should not be included in a thermal comfort standard. These reasons were excessive drying out of the skin, and especially of the mucous membranes. The view we accept is that if the concern is human well-being, (whether it is labelled thermal comfort on just comfort in general) then such reasons justify the inclusion of lower limits.

TRANSFER OF HEAT:

Difference between heat and temperature:

Temperatureis a measure of the amount of energy possessed by the molecules of a substance. It manifests itself as a degree of hotness, and can be used to predict the direction of heat transfer. The usual symbol for temperature is *T*. The scales for measuring temperature in SI units are the Celsius and Kelvin temperature scales.

Heat, on the other hand, is energy in transit. Spontaneously, heat flows from a hotter body to a colder one. The usual symbol for heat is Q. In the SI system, common units for measuring heat are the Joule and calorie.

Difference between thermodynamics and heat transfer

Thermodynamics tells us:

- how much heat is transferred (dQ)
- how much work is done (dW)
- final state of the system

Heat transfer tells us:

- how (with what **modes**) dQ is transferred
- at what **rate** dQ is transferred
- temperature distribution inside the body

Heat transfer complementary Thermodynamics

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems. Heat transfer is classified into various mechanisms, such as heat conduction, convection, thermal radiation, and transfer of energy by phase changes.

Modes of Heat Transfer

The fundamental modes of heat transfer are:

Conduction or diffusion

The transfer of energy between objects that are in physical contact

Convection

The transfer of energy between an object and its environment, due to fluid motion

Radiation

The transfer of energy to or from a body by means of the emission or absorption of electromagnetic radiation

Mass transfer

The transfer of energy from one location to another as a side effect of physically moving an object containing that energy

Thermal Conductivity, k

As noted previously, thermal conductivity is a thermodynamic property of a material. From theState Postulate given in thermodynamics, it may be recalled that thermodynamic properties of puresubstances are functions of two independent thermodynamic intensive properties, say temperatureand pressure. Thermal conductivity of real gases is largely independent of pressure and may beconsidered a function of temperature alone. For solids and liquids, properties are largelyindependent of pressure and depend on temperature alone.

Heat Transfer in the Human Body

The principles of heat transfer in engineering systems can be applied to the human body in order to determine how the body transfers heat. Heat is produced in the body by the continuous metabolism of nutrients which provides energy for the systems of the body.[17] The human body must maintain a consistent internal temperature in order to maintain healthy bodily functions. Therefore, excess heat must be dissipated from the body to keep it from overheating. When a person engages in elevated levels of physical activity, the body requires additional fuel which increases the metabolic rate and the rate of heat production. The body must then use additional methods to remove the additional heat produced in order to keep the internal temperature at a healthy level.

Heat transfer by convection is driven by the movement of fluids over the surface of the body. This convective fluid can be either a liquid or a gas. For heat transfer from the outer surface of the body, the convection mechanism is dependent on the surface area of the body, the velocity of the air, and the temperature gradient between the surface of the skin and the ambient air.[18] The normal temperature of the body is approximately 37°C. Heat transfer occurs more readily when the temperature of the surroundings is significantly less than the normal body temperature. This concept explains why a person feels “cold” when not enough covering is worn when exposed to a cold environment. Clothing can be considered an insulator which provides thermal resistance to heat flow over the covered portion of the body.[19] This thermal resistance causes the temperature on the surface of the clothing to be less than the temperature on the surface of the skin. This smaller temperature gradient between the surface temperature and the ambient temperature will cause a lower rate of heat transfer than if the skin were not covered.

In order to ensure that one portion of the body is not significantly hotter than another portion, heat must be distributed evenly through the bodily tissues. Blood flowing through blood vessels acts as a convective fluid and helps to prevent any buildup of excess heat inside the tissues of the body. This flow of blood through the vessels can be modeled as pipe flow in an engineering system. The heat carried by the blood is determined by the temperature of the surrounding tissue, the diameter of the blood vessel, the thickness of the fluid, velocity of the flow, and the heat transfer coefficient of the blood. The velocity, blood vessel diameter, and the fluid thickness can all be related with the Reynolds Number, a dimensionless number used in fluid mechanics to characterize the flow of fluids.

Latent heat loss, also known as evaporative heat loss, accounts for a large fraction of heat loss from the body. When the core temperature of the body increases, the body triggers sweat glands in the skin to bring additional moisture to the surface of the skin. The liquid is then transformed into vapor which removes heat from the surface of the body.[20] The rate of evaporation heat loss is directly related to the vapor pressure at the skin surface and the amount of moisture present on the skin.[18] Therefore, the maximum of heat transfer will occur when the skin is completely wet. The body continuously loses water by evaporation but the most significant amount of heat loss occurs during periods of increased physical activity.

PERIODIC HEAT FLOW

In nature the variation of climatic conditions produces a non- steady state. Diurnal variations produce an approximately repetitive 24-hour cycle of increasing and decreasing temperatures. The effect of this on a building is that in the hot period heat flows from the outdoors into the building, where some of it is stored, and at night during the cool period the heat flow is reversed: from the building to the outside. As this cycle is repetitive, it is described as periodic heat flow.

The diurnal variations of external and internal temperatures is a periodic cycle. In the morning, as the outdoor temperature increases, heat starts entering the outer surface of the wall. Each particle in the wall will absorb a certain amount of heat for every degree rise in temperature, depending on the specific heat of the wall material. Heat to the next particle will only be transmitted after the temperature of the first particle is increased. Thus the corresponding increase in the internal temperature will be delayed.

The outdoor temperature reaches its peak and starts decreasing, before the inner surface temperature has reached the same level. From this moment the heat stored in the wall will be dissipated partly to the outside and only partly to the inside. As the outdoor air cools, an increasing proportion of this stored heat flows outwards, and when the wall temperature falls below the indoor temperature the direction of the heat flow is completely reversed.

The two quantities characteristic of this periodic change are the time lag (φ) and the decrement factor (ù). Decrement factor is the ratio of the maximum outer and inner surface temperature amplitudes taken from the daily mean. The Division of Building Research i s currently reexamining and appraising the methods employed i n predicting the thermal energy exchange between the indoor and the outdoorenvironment through the enclosing walls and roofs of buildings, Summer conditions which give r is e to periodic flow are of special in t e r e s t , and heat exchange between the ground surface and the outdoor environment is also of' concern. Although the path of the thermal energy exchange between -in doors and outdoor may be broken into p a r t s for special study, these are actually inter-related and in a rigorous treatment must be considered together , It became necessary in dealing with the exchange between exterior surfaces and the outdoor environment to consider also c e r t a in aspects of the heat flow through the building enclosure itself , One aspect of t h is , the ease of periodic heat flow i n walls and roofs, and of methods by which it may be calculated is now considered, Certain aspects of the thermal exchange between the exterior surface of a building and the outdoor environment were dealt within DBR Report Moo 1210 It is not apparent that the material contained i n this report will be of sufficient interest to others to warrant publication, Opinions on this, together with any criticism and other comments are invited, Two methods of calculating the periodic heat flow through solid walls or roofs are described.

Matrix methods and vector methods

The matrix method gives the accurate value of heat flow through a solid wall whether homogeneous or multilayer. One of the advantages of this method is the ease with which different surface heat transfer coefficients can be accounted for. A much simpler vector diagram method is presented for calculating the complex thermal impedance of a wall or roof. The errors which occur with this method are chiefly due to representing a continuous wall by a lumped resistance capacitance network. 'The lumping error for a "T" network representation of a homogeneous wall is evaluated analytically: the same method can be applied to more complex circuits.

The heat flow through the walls o r roof of a building rarely reaches a steady state, so for an accurate calculation of heating o r cooling load it is necessary t o take account of the heat storage capacity of the wall or roof. Nackey and Wright (1, 2) have reported an accurate and approximate method for calculating the periodic heat flow through .homogeneous and multilayer walls. Their work was based on the following **assumptions:**

(1) Periodic sol - air temperature

(2) Constant indoor air temperature

(3) The outdoor air film coefficient of heat transfer

(4) The indoor air film coefficient of heat t r a n s f e r

(5) One dimensional heat flow through the wall.

Periodic sol - air temperature

Sol-air temperature (Tsol-air) is a variable used to calculate cooling load of a building and determine the total heat gain through exterior surfaces.

$$T_{\text{sol-air}} = T_o + \frac{(a \cdot I - \Delta Q_{ir})}{h_o}$$

where

a = solar radiation absortivity of a surface [-]

I = global solar irradiance [W/m²]

ΔQ_{ir} = extra infrared radiation due to difference between the external air temperature and the apparent sky temperature. = $F_r * h_r * \Delta T_{o-sky}$ [W/m²]

Constant indoor air temperature

It is not always true that environmental quality for preservation has to be sacrificed for energy saving: we know of no evidence that allowing a drift to lower winter temperature does harm. The period of summer temperature above the standard specification can be reduced by careful attention to lighting efficiency and to the thermal and humidity capacity of the building envelope and interior structures. Our research effort should be directed towards highly buffered building design, design of buildings and sites which optimise solar gain, and efficient use of light, both natural and artificial.

TIME LAG AND DECREMENT FACTOR

Thermal mass:

Thermal mass is a concept in building design which describes how the mass of the building provides "inertia" against temperature fluctuations, sometimes known as the thermal flywheel effect. For example, when outside temperatures are fluctuating throughout the day, a large thermal mass within the insulated portion of a house can serve to "flatten out" the daily temperature fluctuations, since the thermal mass will absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler, without reaching thermal equilibrium. This is distinct from a material's insulative value, which reduces a building's thermal conductivity, allowing it to be heated or cooled relatively separate from the outside, or even just retain the occupants' thermal energy longer.

Materials commonly used for Thermal mass:

Water, clay, concrete, Bricks, Rammed earth, Natural rocks and stones

Time lag:

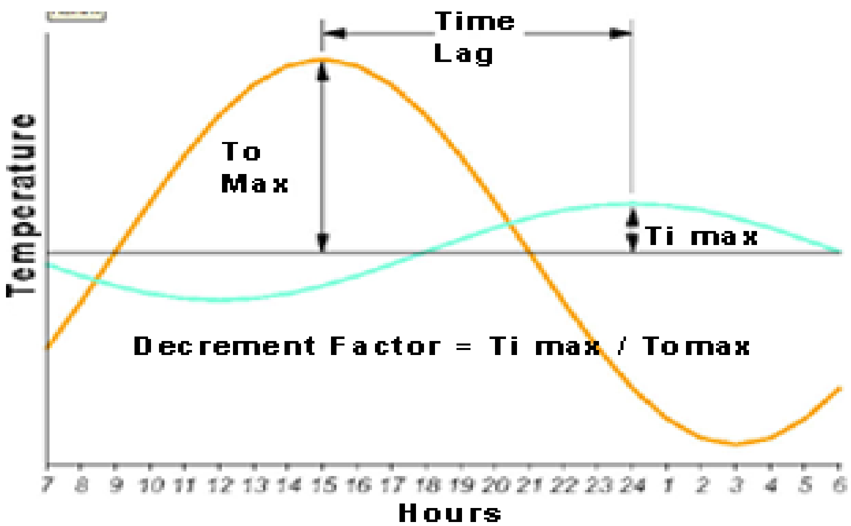
The time delay due to the thermal mass is known as a time lag.

Decrement Factor:

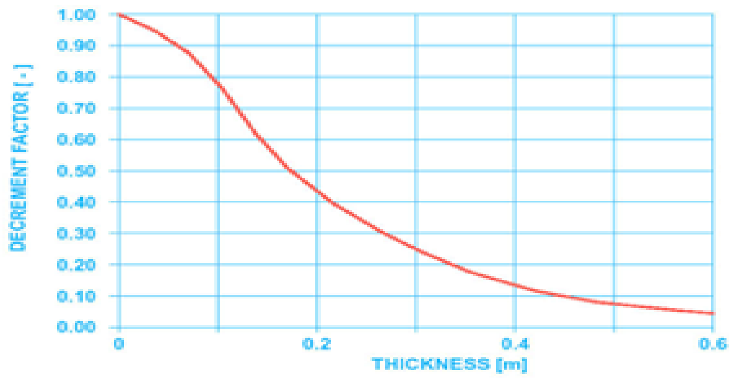
The thicker and more resistive the material, the longer it will take for heat waves to pass through.

The reduction in cyclical temperature on the inside surface compared to the outside surface is known as decrement.

Thus, a material with a decrement value of 0.5 which experiences a 20 degree diurnal variation in external surface temperature would experience only a 10 degree variation in internal surface temperature.



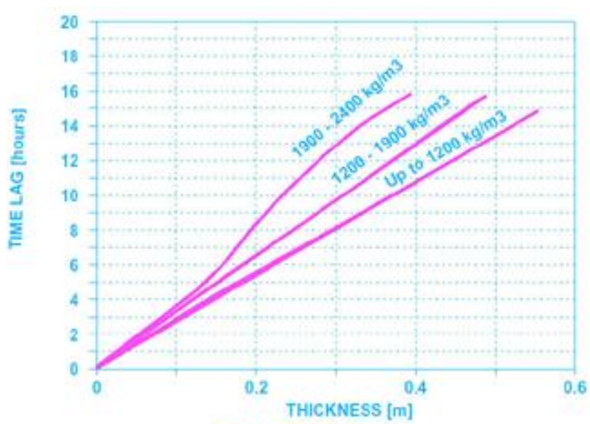
Thermal Mass Introduces Time Lag Decrement Factor



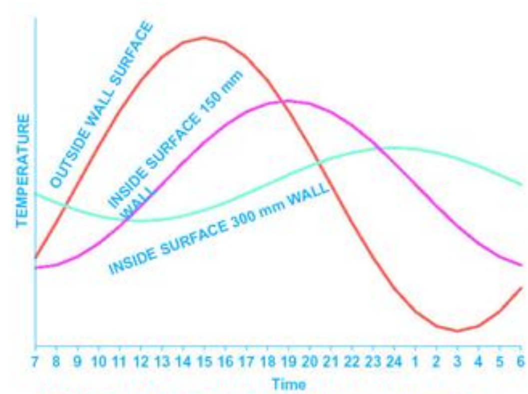
DECREMENT FACTOR

This effect is particularly important in the design of buildings in environments with a high diurnal range. In some deserts, for example, the daytime temperature can reach well over 40 degrees. The following night, however, temperatures can fall to below freezing. If materials with a thermal lag of 10-12 hours are carefully used, then the low night-time temperatures will reach the internal surfaces around the middle of the day, cooling the inside air down. Similarly, the high daytime temperatures will reach the internal surfaces late in the evening, heating the inside up.

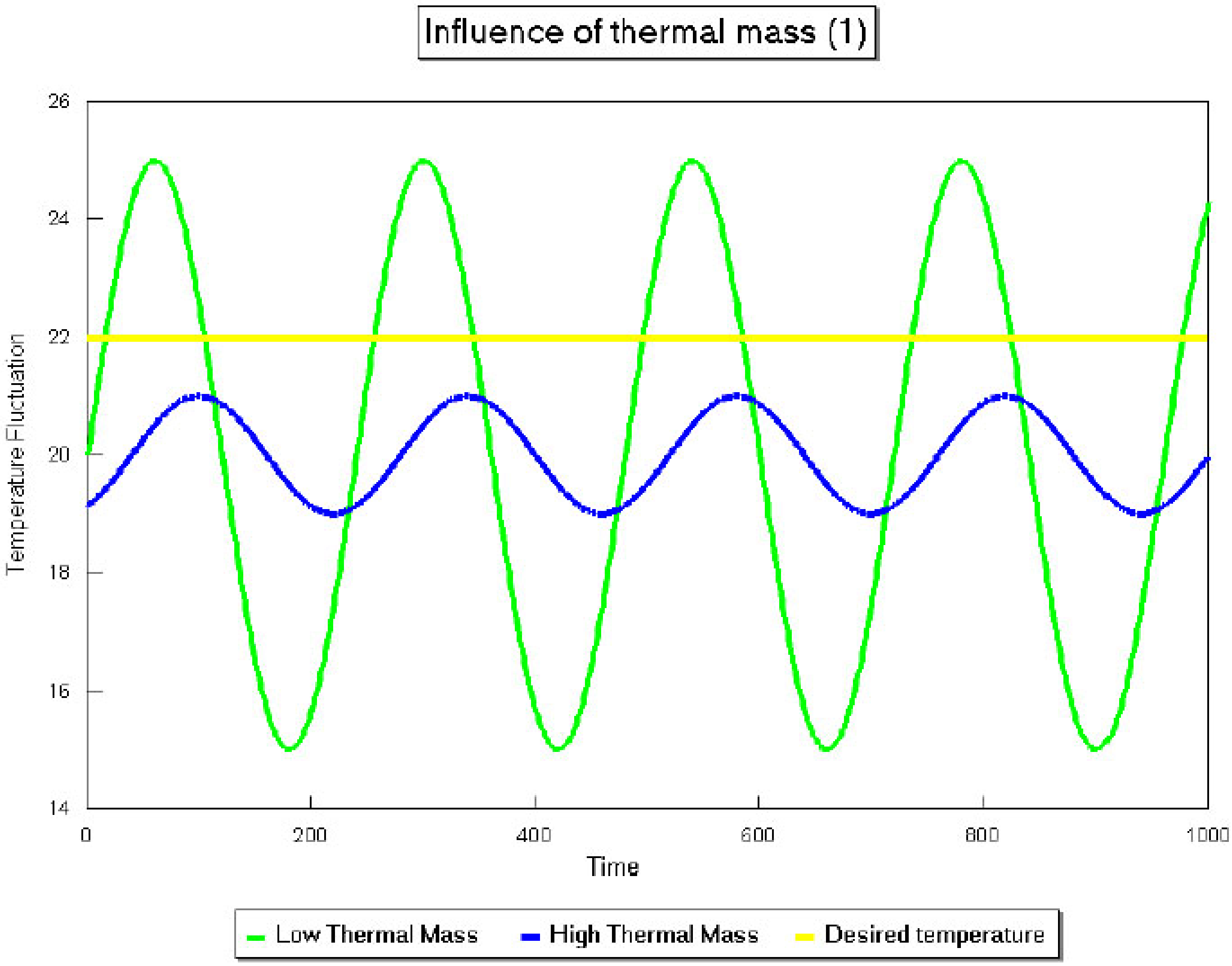
In climates that are constantly hot or constantly cold, the thermal mass effect can actually be detrimental. This is because both surfaces will tend towards the average daily temperature which, if it is above or below the comfortable range, will result in even more occupant discomfort due to unwanted mean radiant gains or losses. Thus in warm tropical and equatorial climates, buildings tend to be very open and lightweight. In very cold and sub-polar regions, buildings are usually highly insulated with very little exposed thermal mass, even if it is used for structural reasons.



TIME LAG



Wall Surface Temperature Fluctuation



THERMAL GLASS:

With increasing environmental awareness as well as the rising costs of energy, more emphasis is now being placed on ways to save energy in all types of domestic, commercial and public buildings. Government regulations specifying minimum requirements for the energy efficiency of new homes are being gradually tightened to achieve zero carbon by 2016. At the same time, it is important to improve the existing housing stock so requirements for refurbishments such as replacement windows are also being tightened.

Energy-efficient glass can play an important role in achieving these targets for thermal insulation of homes.

By replacing your existing single glazed window glass with Pilkington energiKare™ thermally insulated windows, you could reduce the amount of energy lost through your windows by up to 75% and lower your heating bills by up to 20% each year. Significant savings can also be achieved by upgrading double glazed windows which were installed before regulations were significantly tightened in 2002.

Heat loss is normally measured by the thermal transmittance or U value, usually expressed in W/m2K and, in its most basic terms, the lower the U value, the greater the thermal insulation. However, the amount of free heat energy from the sun, the solar gain or g-value can also have a big impact. Window Energy Ratings, which take account of solar gain, were introduced by the British Fenestration Rating Council (BFRC) in 2006 and they can provide a good indicator of how energy-efficient windows for homes can be. The Window Energy Ratings Scheme is based on a scale of A through to G, with A-rated windows being the most energy-efficient. Thermally insulated glass units or double glazed units incorporate low-emissivity glass such as Pilkington K Glass™ and can significantly improve the overall thermal performance of a window. Therefore the thermal insulation value is just one aspect of how much energy can be saved.