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# INTRODUCTORY GUIDE TO TEMPERATURE CONTROL

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**KEEPING COOL ----- ----- AND WARM**

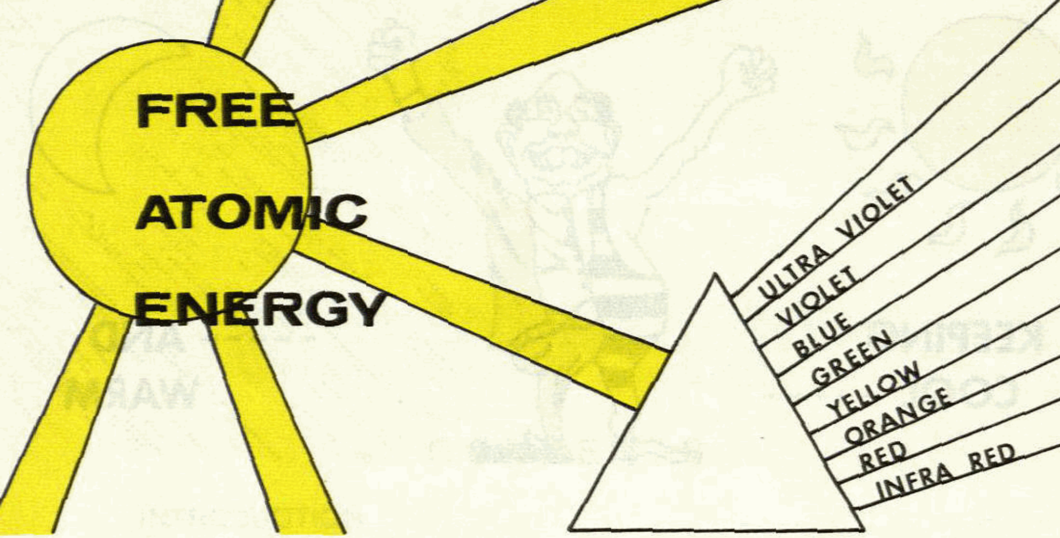
Too many people need to switch on the air-conditioning every time the sun comes up and light a fire as soon as it goes down again. The *sun is a wonderful source* of energy that comes free of charge to all of us. Whether it is an asset or liability depends entirely on what we do with it.

A man lost in a desert will very soon be killed by the merciless sun beating down on him, while if he does survive until nightfall he might freeze to death from the cold. It is *largely to protect a man from* climatic extremes that he needs a house.

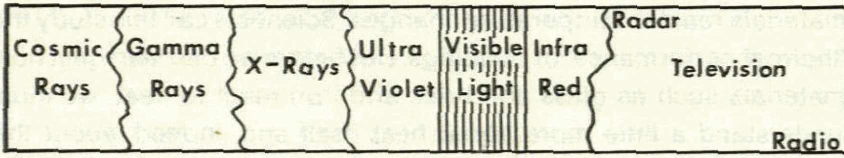
A *well-built house can provide adequate protection*, but a badly built one may still be desert-hot by day and freezing cold at night. Heat is not something that you can see. You cannot gather it in lumps and store it in your bedroom and this is why it is difficult to understand what *might be wrong if your house is not as comfortable* as you expected it to be.

*To find out* what it is that makes one house cool and comfortable and the next one like a sauna, it is necessary to understand how different materials react to temperature changes. Scientists call this study the 'thermal performance' of buildings. But before we can *learn just how materials such as glass* and brick and iron react to heat, we must understand a little more about heat itself and, indeed, about the earth's major source of heat, the sun.

# FREE ATOMIC ENERGY

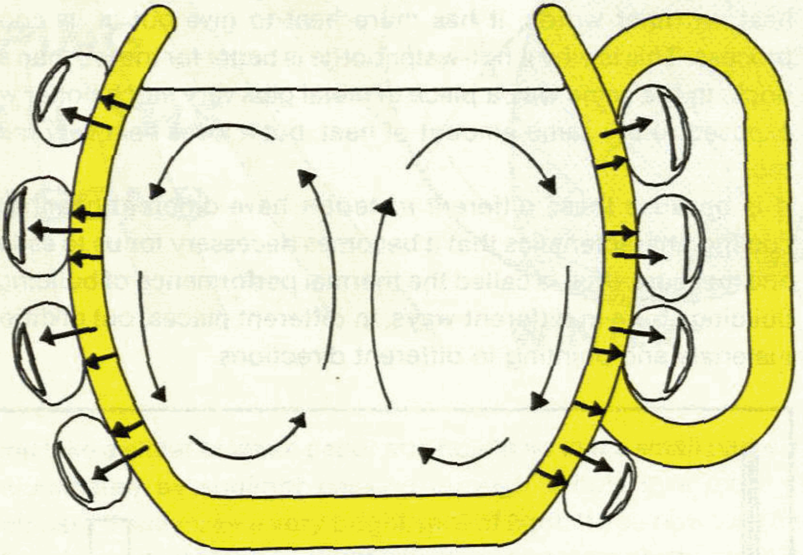



If anyone were to ask you if you had ever seen a thermo-nuclear explosion you would probably say 'No, thank heaven'. Well, you would be wrong. We all see such an explosion most days of our lives because the sun is in fact a giant hydrogen bomb! Fortunately, we are separated from it by 150 million kilometres of space, so no shock wave reaches us, but it still produces a huge spectrum of deadly radiation which races across the empty space to earth. When we see a rainbow we are looking at some of this radiation broken down into its separate components. The human eye is only sensitive to a very small part of this radiation so we see only the rainbow. What about the rays we do not see? Infra-red rays which carry the sun's heat, are so named because they are beyond the red end of the visible spectrum. Beyond them are found the radio waves. Similarly, the ultra-violet rays are beyond the visible blue while beyond these are both X-rays and cosmic radiation. Once again we are fortunate that the blanket of air which surrounds the earth filters out most of these radiations high up in the stratosphere. All the blanket lets through is the life-giving heat and light.




*Visible light is just a tiny part of the electro-magnetic spectrum.*

Because of the way it comes to us the sun's heat is called radiant heat. The temperature of any substance on which it falls rises as it is absorbed. In nature, things do not like to be hotter than their surroundings, and they quickly set about sharing any excess heat they have. It's very much like the fact that water always tries to find its own level. If you hold a thick china mug in your hand and pour it full of boiling water it will not be many seconds before the heat spreads out through the china. This process of passing the heat

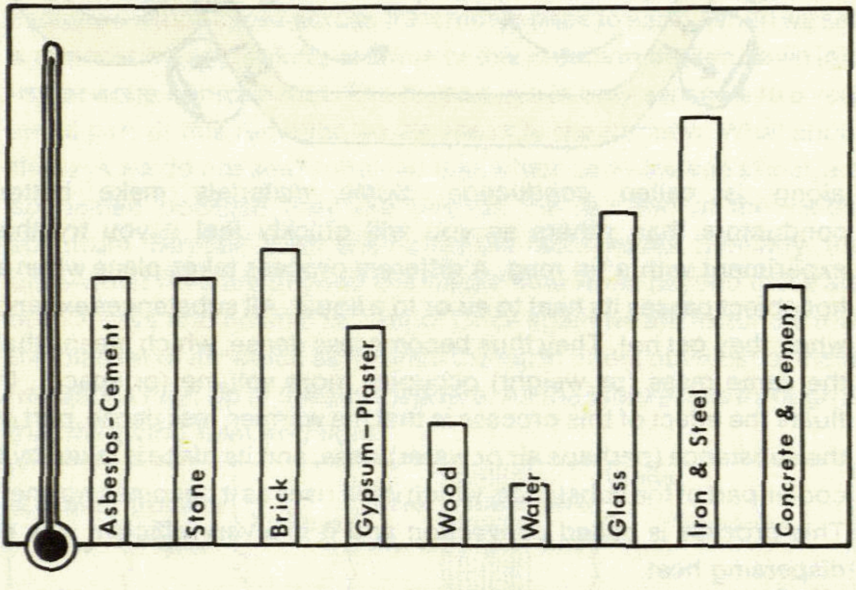


along is called *conduction.* Some materials make better conductors than others as you will quickly feel if you try this experiment with a tin mug. A different process takes place when a hot object passes its heat to air or to a liquid. All substances expand when they get hot. They thus become less dense, which means that the same mass (or weight) occupies more volume (or space). In fluids the effect of this process is that the warmer, less dense, part of the substance (perhaps air or water) rises, and its place is taken by a cooler part of the substance, which itself rises as it becomes warmer. This process is called *convection* and it is a very efficient way of dispersing heat.

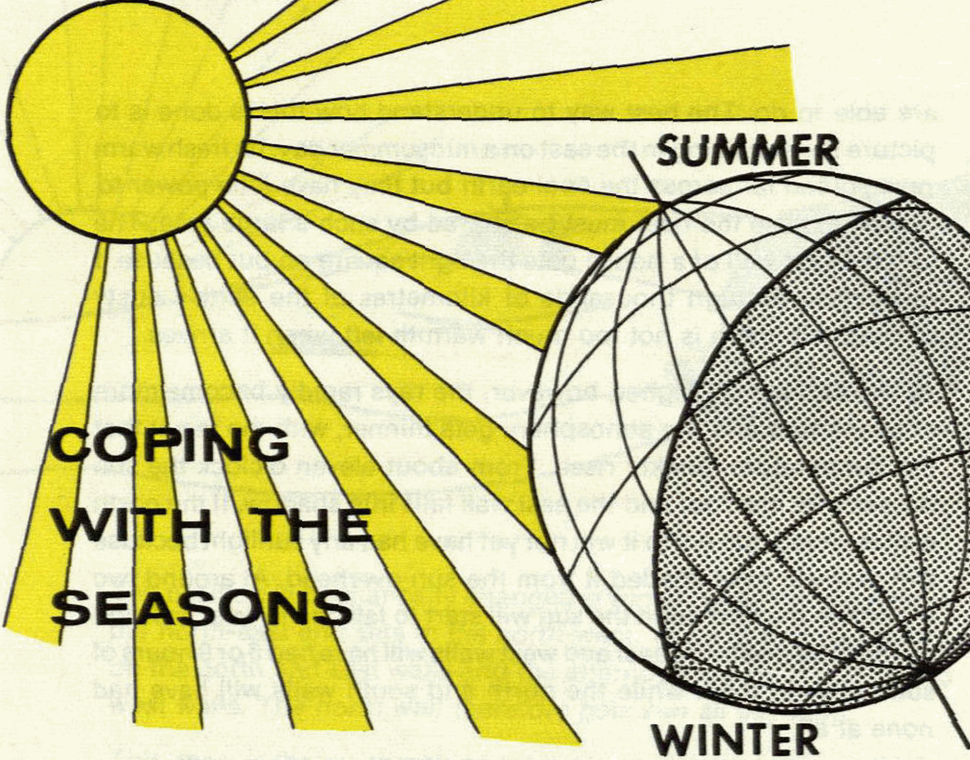
We have seen that the sun's heat reaches us in the form of *radiation* and is dispersed mainly by *conduction* and *convection.* These three methods of transferring heat all play a part in warming or cooling a house.

The next valuable piece of knowledge in this context is that a given amount of heat does not raise the temperature of all substances equally. The poor man's bed-warmer always used to be a hot brick. This is because a hot brick dissipates a good deal of heat as it gets cool. However, water of the same temperature contains *even more* heat. In other words, it has more heat to give out in its cooling *process. This is why a hot-water bottle is better for the job than a hot* brick. In the same way a piece of metal gets very much hotter when exposed to the same amount of heat, but it loses heat very rapidly too.

It is because these different materials have different heating and cooling characteristics that it becomes necessary for us to estimate and measure what is called the thermal performance of buildings — buildings built in different ways, in different places, out of different materials and pointing in different directions.




*Given the same amount of heat equal masses of different building materials will have their temperatures raised by different amounts.*

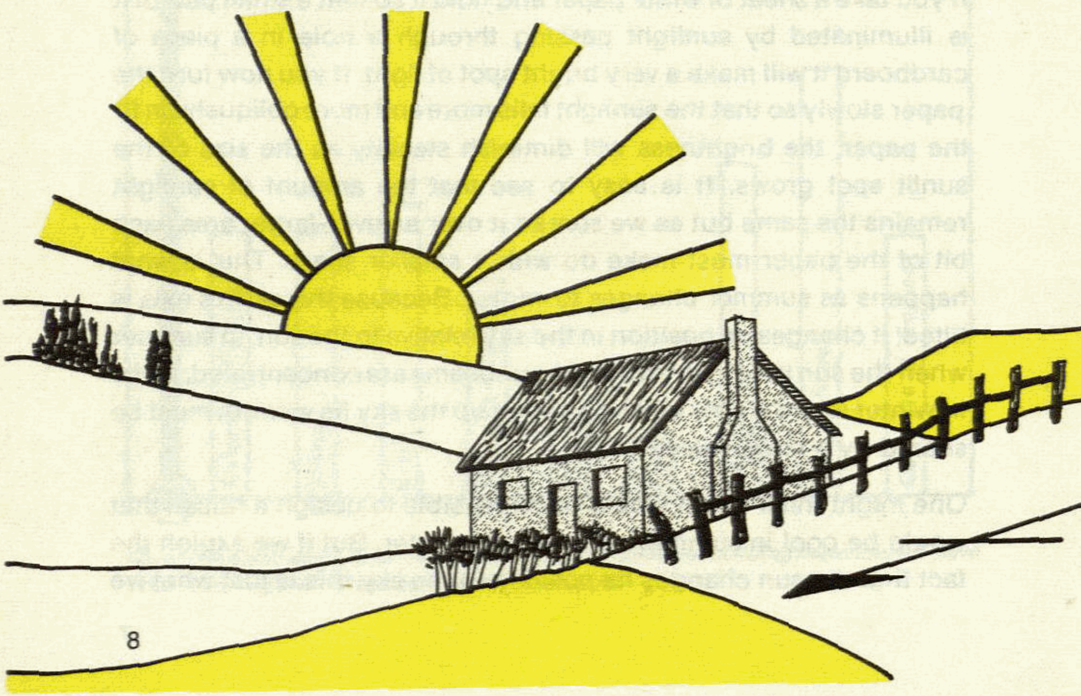


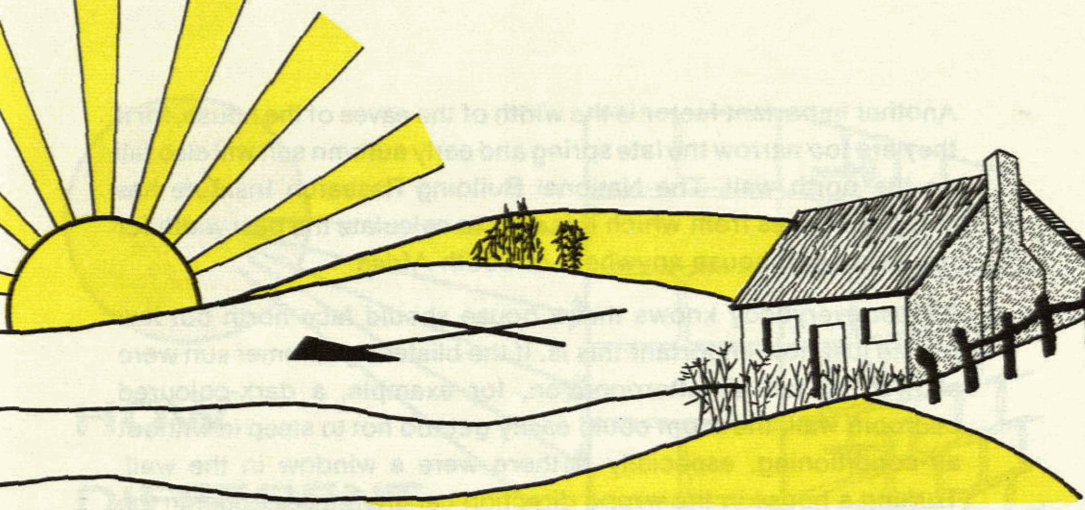

# COPING WITH THE SEASONS

*If you take a sheet of white paper and hold it so that a small part of it* is illuminated by sunlight passing through a hole in a piece of cardboard it will make a very bright spot of light. If you now turn the paper slowly so that the sun*light falls more and more obliquely on to* the paper, the brightness will diminish steadily as the size of the *sunlit spot grows. It is easy to see* that the amount of sunlight remains the same but as we spread it over an ever-larger area each bit of the paper must make do with a smaller share. This is what happens as summer changes to winter. Because the earth's axis is tilted, it changes its position in the sky relative to the sun. In summer when the sun is right overhead its sunbeams are concentrated, while in winter when it only climbs halfway up the sky its warmth must be shared by a larger area.

One might think that it would be impossible to design a house that would be cool in summer *and* warm in winter. But if we exploit the fact that the sun changes its position in the sky this is just what we are able to do. The best way to understand how this is done is to picture the sun rising in the east on a midsummer day. Its fresh warm rays spread far across the cool earth but they have little power to warm because the heat must be shared by such a large area. The vertical east wall of a house gets the light square on but because it must pass through thousands of kilometres of the earth's dusty atmosphere there is not too much warmth left when it arrives.

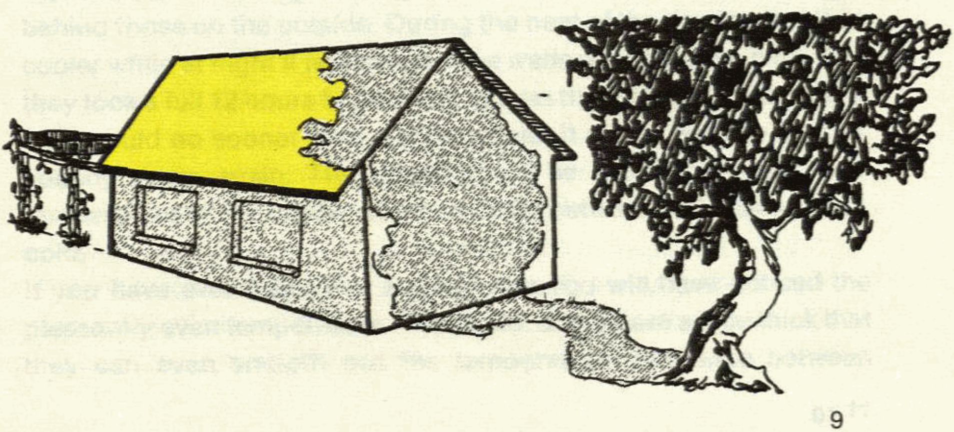
As the sun climbs higher, however, the rays rapidly become more concentrated and the atmosphere gets thinner, with the result that the temperature quickly rises. From about eleven o'clock the sun passes over the roof and the east wall falls into shadow. If the north wall is facing due north it will not yet have had any sunlight because the roof will have shaded it from the sun overhead. At around two o'clock in the afternoon the sun will start to fall on the west wall and by the time it sets the east and west walls will have had 8 or 9 hours of sun between them while the north and south walls will have had none at all.





The position is dramatically changed in winter, when the sun rises in the north-east and sets in the north-west. The morning sun shines on the north and east walls and the afternoon sun on the north and west walls. The north wall therefore gets sun all day long.

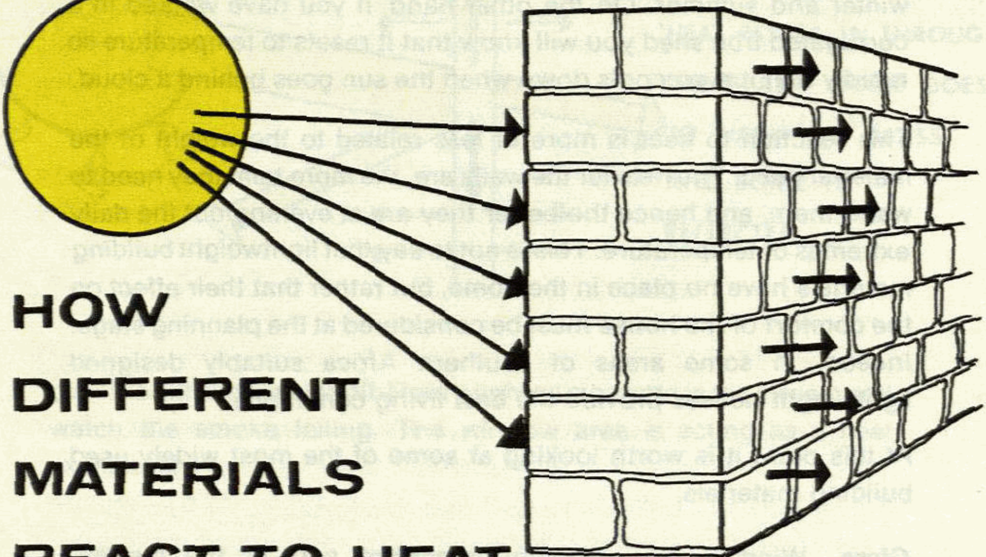
This, then, is the key to making the best use of the sun. The walls that get the sun in winter must be the longest, while those that get the sun in summer must be as short as possible. The ideal is a long thin house with a huge north wall to catch the winter sun and small east and west walls to limit the amount of summer sun that the house absorbs. Further protection can be had by planting shade trees to the east or the west or by putting a garage at either of those ends.



Another important factor is the width of the eaves of the house, for if they are too narrow the late spring and early autumn sun will also fall on the north wall. The National Building Research Institute has compiled tables from which it is easy to calculate the best width for the eaves of a house anywhere in South Africa.

Almost everybody knows that a house should face north but few realize just how important this is. If the blistering summer sun were allowed to fall all afternoon on, for example, a dark-coloured bedroom wall, the room could easily get too hot to sleep in without air-conditioning, especially if there were a window in the wall. Turning a house in the wrong direction can therefore condemn the occupant to paying a perpetual bill for cooling. A building can face up to about 15 degrees west or east of north without losing much of the benefit of the sun, but every degree beyond these limits will reduce living comfort. A house facing due west can be almost impossible to live in without artificial cooling aids.

However, orientation is only one of the factors which decide whether the house will be comfortable or not. It is just as important to consider the materials from which the structure is built.



# HOW DIFFERENT MATERIALS REACT TO HEAT

When the sun falls on the brick wall it warms the surface. As we have already seen substances strive to share their excess heat and some of this heat is therefore passed through the brick until, after a long period of time, the inside of the wall also starts to get warmer. The length of time taken to establish this situation will depend largely on the thickness of the wall. When the sun goes down the outside surface of the wall starts to cool and the heat flow is reversed, passing from the inside to the outside of the wall. It is easy to see that the temperature changes on the inside surface of the wall always lag behind those on the outside. During the heat of the day the inside is cooler while at night it is warmer. If the walls were made so thick that they took a full 12 hours for the heat to pass through, the inside of the wall would no sooner start warming than it would be time to start cooling down again. The result would be a comparatively even temperature in the house, about midway between full heat and full cold.

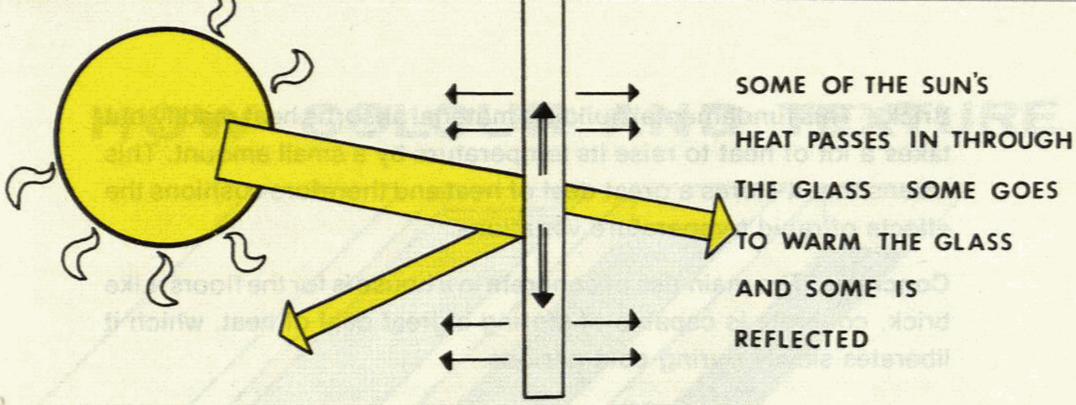
If you have ever been into a deep cave you will have noticed the pleasantly even temperature. The 'walls' of the cave are so thick that they can even smooth out the temperature difference between winter and summer. On the other hand, if you have worked in a corrugated iron shed you will know that it reacts to temperature so rapidly that it even cools down when the sun goes behind a cloud.

This reaction to heat is more or less related to the weight of the material used. The heavier the walls are, the more heat they need to warm them, and hence the better they are at evening out the daily extremes of temperature. This is not to say that lightweight building materials have no place in the home, but rather that their effect on the comfort of the house must be considered at the planning stage. Indeed, in some areas of southern Africa suitably designed lightweight houses provide the best living conditions.

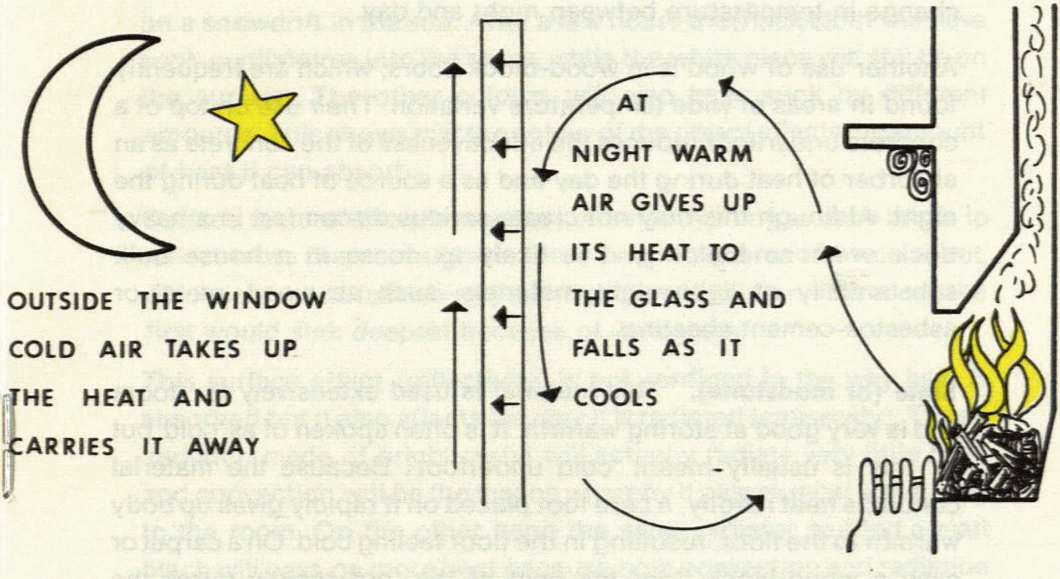
At this point it is worth looking at some of the most widely used building materials.

**Glass.** Windows play a very important part in the thermal performance of the house. This is because glass has a property not shared with other materials. This property can best be understood in the following way. When you see sunlight streaming in through a window you only have to hold your hand in its path to realize that not only the light of the sun but also its heat are passing through the glass. However, if you stand outside a window you will feel no warmth coming out, no matter how hot the room is inside. The reason for this is that glass is 'transparent' to heat from a bright source but not from a dull source. In practical terms this means that the sun's heat streams in through a glass window and heats up the curtains or furniture inside but that this heat cannot get back out again. This is known as the 'greenhouse effect' and is the cause of much discomfort to people whose houses have too much glass exposed to the sun.

On the other hand glass can warm up and *conduct* heat in the same way as other materials. So after dark the heat in the room is conducted away very rapidly by the windows, for glass is about as efficient as a sheet of corrugated iron at keeping heat in. To test this go to a window on a cold night and hold your hand just below the edge of the window-sill. You will feel a cascade of cold air pouring




over the sill like a waterfall. Hold a lighted cigarette in the stream and watch the smoke falling. The window area is acting as a heat exchanger.




Thus we see that glass areas let the heat in by day and out by night. Windows should therefore be positioned so that they give enough light and contact with the outside but so that the sun does not fall on them in summer.

**Brick.** This fundamental building material absorbs heat readily but takes a lot of heat to raise its temperature by a small amount. This means that it stores a great deal of heat and therefore cushions the effects of rapid temperature variations.

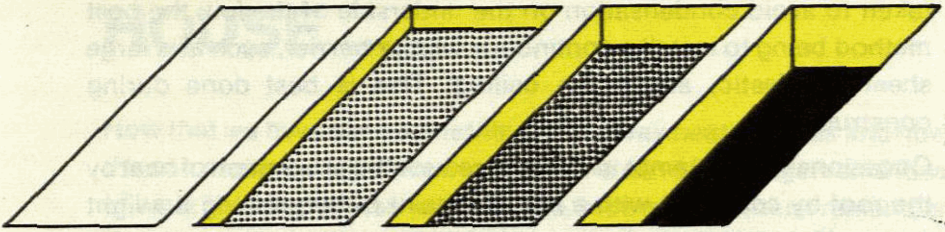
**Concrete.** The main use of concrete in a house is for the floors. Like brick, concrete is capable of storing a great deal of heat, which it liberates slowly during cold periods.

**Wood.** This is a typical lightweight material. It does not take much heat to raise its temperature. The fact that it is slow to conduct heat away means that there can be a much larger difference between inside and outside surface temperatures in a wooden wall than in a brick one of the same thickness. Because it does not store much heat, a thin lightweight wall will cool down rapidly. Wooden construction is thus best for warm areas where there is not a wide change in temperature between night and day.

Another use of wood is in wood-block floors, which are frequently found in areas of wide temperature variation. Their use on top of a concrete underfloor reduces the effectiveness of the concrete as an absorber of heat during the day and as a source of heat during the night. Although this may not create serious discomfort in a heavy brick or stone building, it is likely to do so in a house built substantially of lightweight materials, such as wood, metal or asbestos-cement sheeting.

**Slate (or mudstone).** This material is used extensively for floors and is very good at storing warmth. It is often spoken of as 'cold' but by this is usually meant 'cold underfoot'. Because the material conducts heat readily, a bare foot placed on it rapidly gives up body warmth to the floor, resulting in the floor feeling cold. On a carpet or even a wood-block floor the heat of the foot rapidly raises the temperature of the surface of the floor to body heat, so that these materials feel warm. The answer is not to abandon slate floors in favour of warmer-feeling floors, but to wear slippers! This is because rooms with stone (or concrete or slate) floors will be warmer on a cold night than rooms with carpeted or wood-block floors.

# HOW COLOUR AND TEXTURE



# AFFECT HEAT ABSORPTION

The way any material handles heat depends not only on the material itself but on its surface properties.

A favourite experiment with schoolchildren in colder climates is to cut squares out of different-coloured pieces of cloth andto lay them on a snowdrift in the sun. After a few hours theblack cloth will have sunk centimetres into the snow, while the white piece will still be on the surface. The other colours will also have sunk by different amounts. This shows that the colour of the object affects the amount of heat it can absorb.

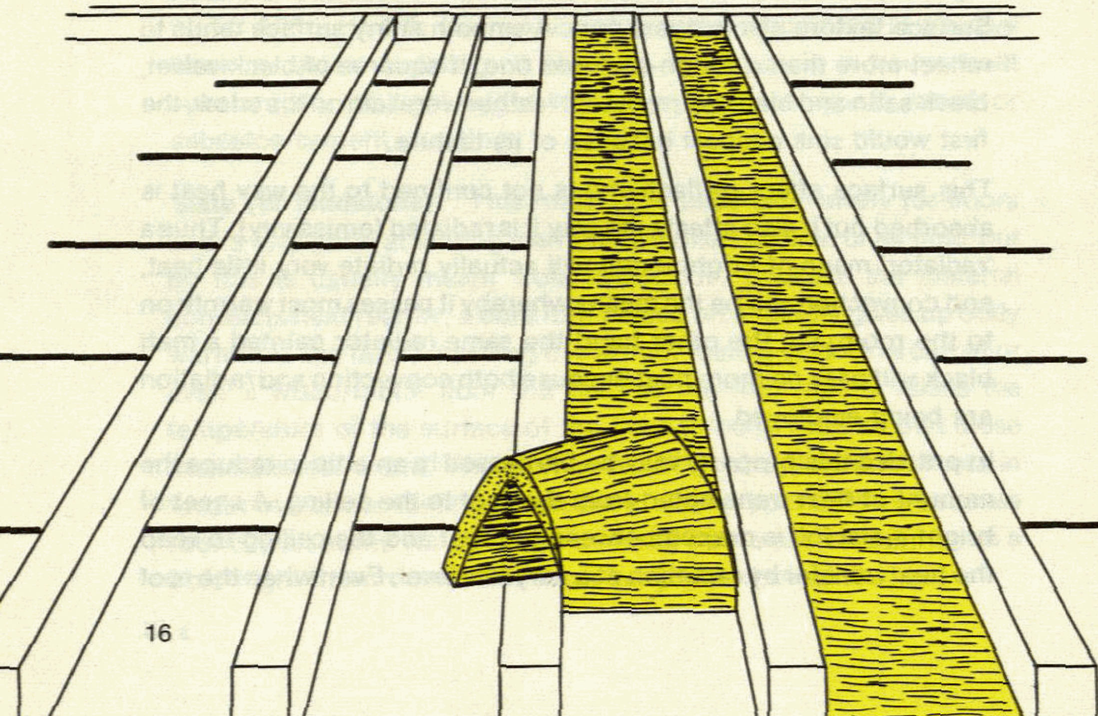
Surface texture also plays a part. A smooth shiny surface tends to reflect more than a rough-textured one. If squares of black velvet, black satin and black shiny patent leather were lain on the snow, the first would sink deepest because of its texture.

This surface effect (reflectivity) is not confined to the way heat is absorbed but it also affects the way it is radiated (emissivity). Thus a 'radiator' made of bright metal will actually radiate very little heat, and convection will be the means whereby it passes most warmth on to the room. On the other hand the same radiator painted a matt black will pass on more heat because both convection and radiation are being employed.

In practice this property may be harnessed in an attic to reduce the amount of heat transmitted from the roof to the ceiling. A sheet of bright metal foil is draped between the roof and the ceiling to keep the heat transfer by radiation at a very low level. Even when the roof gets extremely hot the amount of heat re-radiated on to the ceiling is reduced considerably. In damp regions, however, steps must be taken to avoid condensation on the underside of the foil, the best method being to install a continuous vapour barrier, such as a large sheet of plastic, above the ceiling. This is best done during construction.

Occasionally an attempt is made to reduce the absorption of heat by the roof by coating it with a metallic paint or by painting it a light colour. Unfortunately, dust and oxidation quickly dull the reflective surface and the relief is usually short-lived.

Another way to keep heat in or out is by preventing efficient conduction from taking place. One of the poorest conductors is air and when it is trapped in quantities too small for convection to take place it makes a very good insulator. The blanket on your bed keeps you warm at night because of the air that is trapped in and around its fibres. Those feather-light polystyrene coolers also insulate their contents because of the air that is trapped within the plastic foam. A blanket of insulating material, such as mineral wool, laid on the upper surface of a ceiling keeps the warmth in at night and the heat out during the day.



# BUILDING THE IDEAL HOUSE ......

Now that we have seen something of the way heat behaves and how the sun changes its position in the sky we can begin to get some idea of what the ideal house will look like. However, we must remember that a perfect house on the interior plateau of the country would not necessarily be ideal if it were placed in Durban or elsewhere along the coast. We must therefore consider the two main types of climate found in southern Africa.

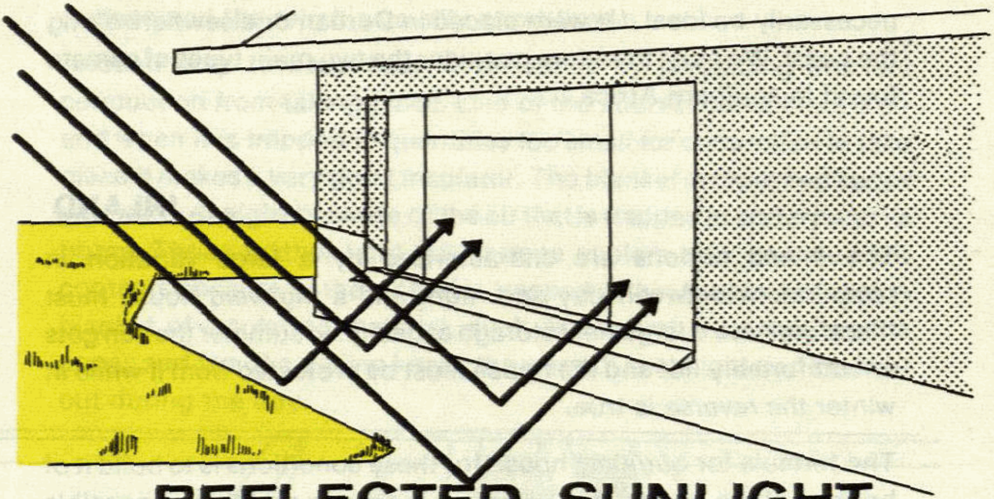
## ..... INLAND

The inland regions are characterized by a large variation in temperature between day and night and a highveld house must therefore have a large heat storage capacity. In summer the sun gets uncomfortably hot and the house must be protected from it while in winter the reverse is true.

The formula for our ideal house for these conditions is to build it of brick or stone, to see that its shape is as long and thin as possible with the long frontage facing north. The east and west walls should be shaded from the sun by trees or a garage or a screen wall and any exposed west walls should be built with a cavity. Any windows in the east and west walls should be very small and should preferably be shaded in some way. The north wall will be as thick as possible to store the heat and it will be shaded from the summer sun by wide eaves. Whatever the roof material, steps will be taken to prevent it from radiating heat down into the house. There will thus usually be either a reflecting surface between the roof and the ceiling or a layer of insulating material above the ceiling.

This ideal house will have windows that are strictly functional and comparatively small, because large areas of glass allow a house to cool quickly at night, thus wasting the heat that has been stored.

As to the finish of the house, rough dark bricks will soak up more heat than smooth white walls. A long house with the long side facing north can therefore afford to be left in dark brick. On the other hand if the shape of the stand has forced the designer to have fairly long east and west walls, then a light-coloured finish — at least to these walls — will be preferable, so that as much heat as possible is reflected.



**REFLECTED SUNLIGHT**

Reflection can also cause a house to heat up in summer. Light-coloured concrete paths or white stone chippings can reflect the sun's heat up under the eaves. It pays to plan the garden so that *rough non-reflective surfaces such as grass or soil lie in front of any picture windows.*

The floors will be of a massive material such as concrete in order that as much heat as possible may be stored in them. Ideally they should be covered with slate, stone or quarry tiles or with thin plastic tiles so as not to prevent the heat stored in the floor from warming the house at night. As we have already seen, this factor is not as important when the house is built with thick brick or stone walls as it is when the house has a lightweight frame.

## ..... AT THE COAST

These regions are characterized by hot sultry nights. The temperature at night-time is very little less than it is during the day. A house with massive walls and floors (such as the one most suitable for inland areas) would keep pumping heat into the house long after the sun had gone down and the occupants would probably be driven to install air-conditioning in order to be able to sleep. The mechanism that created the conditions for heat storage on the highveld was the big temperature difference on the inside and outside of a heavy brick or stone wall. But at the coast this temperature gradient must not be allowed to develop.

First of all, the house must be shaded from the sun to keep noon temperatures down as far as possible. It must also be built in such a way that it gives up its stored heat rapidly so as to take advantage of the slightest drop in air temperature. But when it does get cold outside there must still be a reserve of warmth to heat the house. A solution to these conflicting conditions and demands does not seem possible, but proper design *can* provide such a solution.

Let us start by looking at the roof. The ideal roofing material will be thin, but to prevent it getting too hot by day it must be shaded by a layer of tiles (or other similar material) so that there is an air space of at least 20 mm between the outer layer and the inner roofing material. By day the sun will heat the outer layer creating a convection current between the inner and outer layers of the roof, and keeping the inner layer cool. At night the heat of the house is conducted very rapidly out through the thin roofing and the same convection currents will carry the heat away.

The walls must not store heat, so lightweight materials such as asbestos-cement, wood or metal are preferable. Although the windows can be relatively large, too much glass can allow a house to overheat because even though the windows may be shaded from the direct rays of the sun quite a lot of heat can be reflected into them from neighbouring surfaces such as concrete paths.

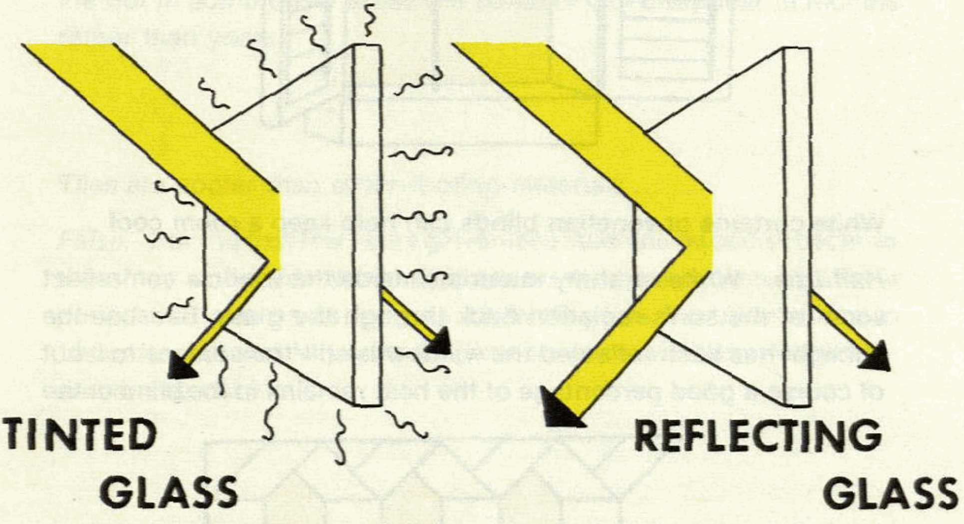
The key to the solution is for the house to be made of lightweight materials which are kept permanently shaded from the sun. This arrangement creates a kind of one-way valve that lets heat out easily and yet makes it difficult for the heat to get in. Because the lightweight walls store little heat they can be more easily cooled at night.

But this is not yet a complete solution. What about the occasional cold night? The answer lies in the floor. It should be of massive concrete laid right on top of the ground. During the warmer months the floor slab and the ground for several metres below it will take in heat and reach an 'average' temperature. When the air temperature drops below average the floor starts feeding heat back into the house and it will only be necessary to close the windows against the chill outside air. This heavy floor also comes into its own in the middle of the day when, no matter how good the insulation, the temperature rises. This is the time when the floor, cooler than its surroundings will absorb this excess heat. It is of course important that the floor should not be covered with insulating materials such as wood blocks or carpet or this advantage will be lost.

# FAMOUS FALLACIES

If the house is nicely laid out, it doesn't really matter which way it faces ....

*False.* If an otherwise satisfactorily designed house is built so as to face west real discomfort can result in summer. When buying a house check the orientation with a pocket compass and reject houses which face more than 30° from true north unless there are important extenuating circumstances. If in doubt write to the NBRI for advice.



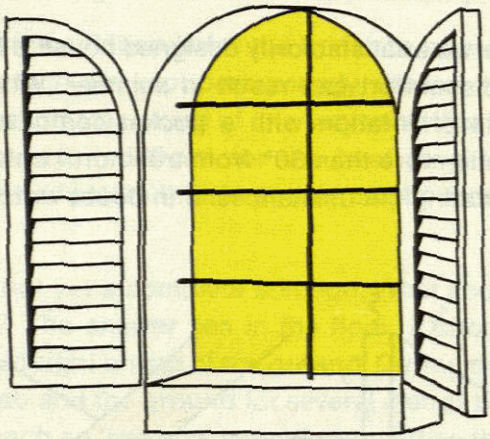

Special glass can be fitted in windows to keep the heat out ....

*Half true.* Tinted glasses will cut out some of the direct radiant heat but in the process the windows themselves get hot, with the result that the eventual cooling effect is not as great as we might have supposed from the amount of sunshine excluded.

On the other hand reflecting glass will turn the sun's heat back at the outside surface.

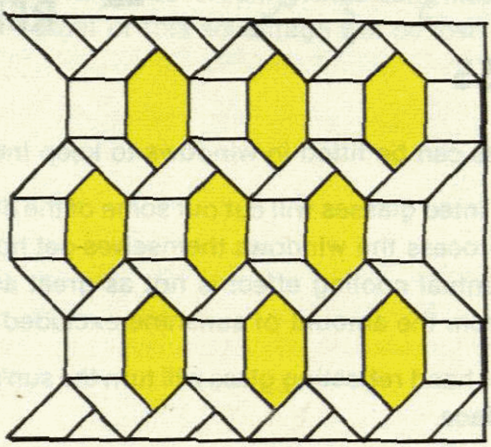
Sunfilter curtains keep the heat out ...

*False.* The curtains absorb most of the heat and once it is inside the room it cannot be radiated back out again. The most effective way to shade a room is with louvres or awnings *outside* the window.



White curtains or venetian blinds can help keep a room cool ...

*Half true.* White or shiny materials inside the window can reflect some of the sun's radiation back through the glass. Because the sunlight has been reflected the window is still 'transparent' to it but of course a good percentage of the heat remains in the blind or the



curtain. This re-reflected heat can actually crack untoughened tinted glasses. The best place to stop the sun is still *outside* the window.

Painting the roof with a white or shiny metallic paint will keep the house cooler ...

*Half true.* The paint does reflect a lot of the heat that would otherwise enter the house. The trouble is that a very fine film of dust gradually settles on the roof. This film absorbs the heat and passes it to the roof by conduction and in this way the reflective surface has been by-passed. This would not matter if the system had a very long life but in some dusty areas the benefits can disappear in months rather than years.

Tiles are cooler than other roofing materials ...

*False.* For the first few years galvanized steel will be cooler because the shiny underside does not pass on the heat. However, after a period that can be as long as 15 to 20 years the underside also becomes dull and only from this time onwards will tiles or asbestos-cement be cooler.

When rating a home for 'livability', remember that thermal performance, although a vital factor in home comfort, is no more than just one factor. Picture windows are unpopular with experts in this field though scientists dealing with illumination look on them with much more favour. The acoustics expert at the NBRI left to his own devices might well banish windows altogether.

The moral of this is that every factor must be weighed carefully to determine the role it must play in *your* house. The information given in this booklet should help you to decide what importance to attach to most of the choices that are open to you. But remember that no single rule is sacrosant. If you feel that you must have wall-to-wall carpeting, for example, go ahead but accept that as a result you will sometimes need to heat or cool your house to make it comfortable.