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the observation of the sun movement above the horizon in the different parts on Earth.

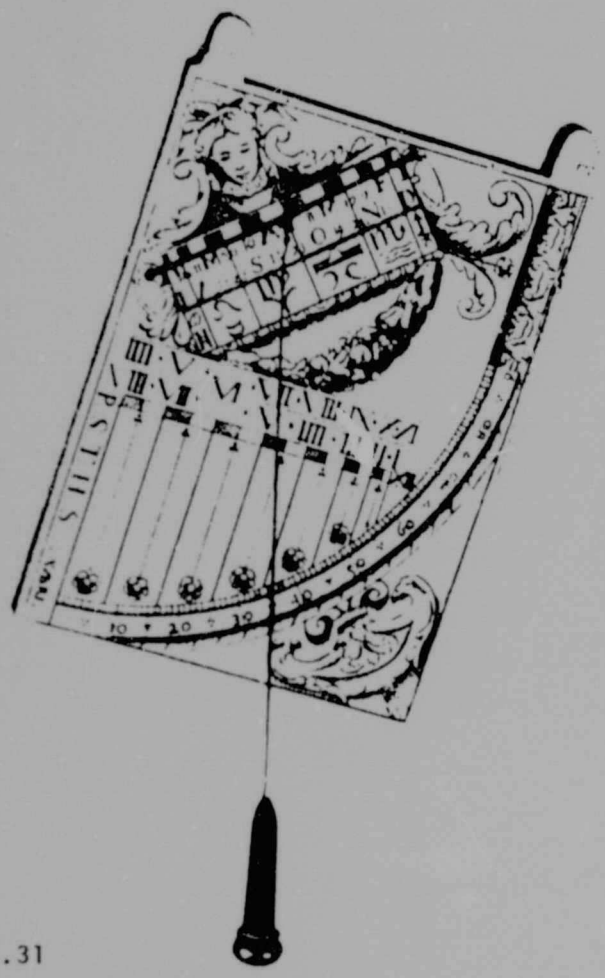

Fig.31

In the tropical regions, the Sun moves almost in a vertical plane in relation to the observer.

During the day, the most important variation is in its altitude.

If we analyse, then, the sun movement on the Temperate Zones, we will notice that it happens on an oblique plane in relation to the observer.

In this case the direction of the sun appears as a second variable to determine the exact sun position in a particular moment.

Two different types of sundials were then invented to calculate the solar time which corresponds to the sun position during the day, one is the" altitude dial" and the other the" compass dial".

The first one was invented by the equatorial people, Fig.31; the second appears later, in the Temperate Regions, Fig.32.

THE SUN ALTITUDE

To measure the sun altitude all we have to do is to point a ruler in the sun's direction and measure the angle created with the horizontal plane.

From this principle, a very simple instrument was created. Its shape is a quarter of a circle or a "quadrant" which term was generalised to name some chronometrical instruments. Fig.33

"ALTITUDE DIALS"

QUADRANT DIALS, RING DIALS, GMOMON, HEMICYCLE DIAL, SHEPHERD DIAL

The Quadrant Dial

The Quadrant Dial dates from far antiquity.

It is a plate in form of a quarter of a circle that is contained by two straight sides which form a right angle between them.

At the vertex a plumb line is suspended. The quadrant, which pivots about the point of suspension, has sights whish allows one of its sides to be aligned with the sun"s rays.

The angle which the aligned side makes with a vertical line,is the sun altitude angle. It can be read off the quadrant scale where the plumb-line crosses its calibrations Fig.33.

From the moment the sun rises on the horizon, the first hour, until the moment it gets to the highest position - the zenith - the sun's altitude will never be bigger than 90°.

Between hour 1 and the Zenith which means midday, we can divide the day time into as many fractions as we like.

The Egyptians divided their quadrant into 6 equal parts as the indigenous engineers of the sub-tropical regions did, and the Europeans copied them as we can see from the examples left to us from the Middle Ages.

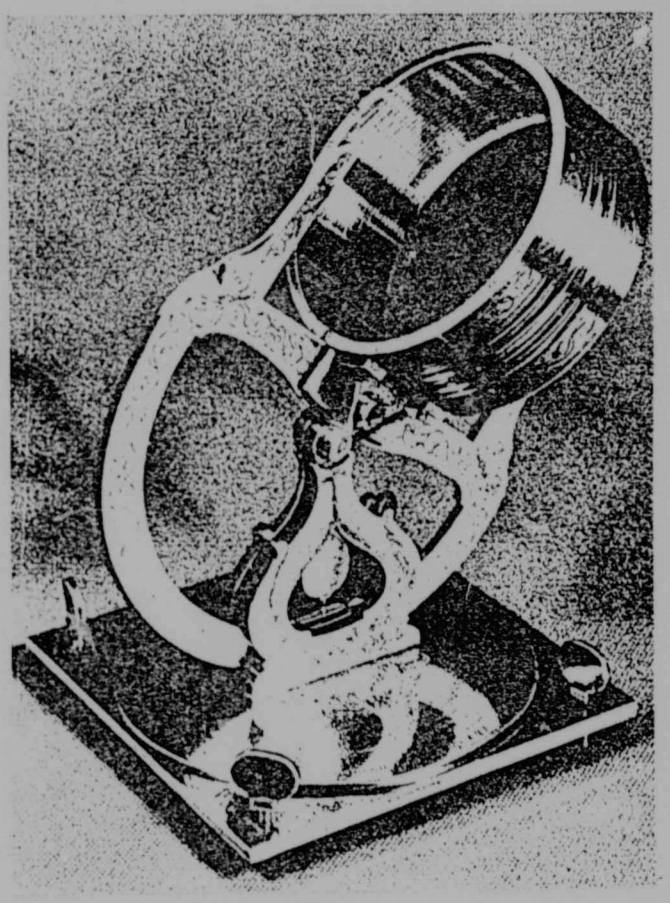

Fig.32.

As we know today, the Sun's path is

higher in Summer than in Winter which means that for the same hours during the day, the sun altitude varies during the year.

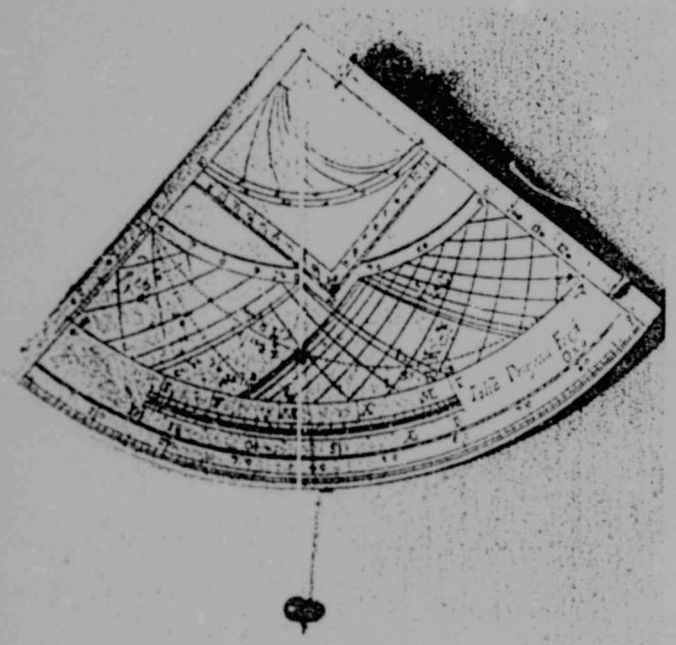

Fig.33.

It was in Europe, only as late as the XIII Century, that the design of the sundial was essentially improved by adding to the scale of hours a scale to give a relative date.

Other modifications took place like the configuration of the lines representing the hours which sometimes were straight or portions of circles depending on who the manufacturer was.

A cursor was added to the plumb-line: the former would run along the latter and its position would be fixed depending on the date.

When the sundial is turned to the sun, the shadow of the cursor will be projected over the time scale indicating the hour.

The Ring Dial

There is another instrument which measures directly the sun's altitude - the "Ring Dial".

There are a few models dating from Imperial Rome.

They are small cylindrical bracelets relatively wide for their diameter.

To use them, we suspend them orientated to the sun.

The sun's rays will pass through a little hole strategically positioned on the ring and it will strike on a scale drawn on the inside of the ring, which will give us the hour and date. Fig.34.

The Gnomon

The direct observation of the sun is difficult because of its glare.

It was a big step forward when the sun's movement was studied by means of the Gnomon shadow. Fig.35.

The term "gnomon" comes from the Greek and means "indicator". It generated the word "gnomonic" which is the science that studies the sun dials.

The indicator can have different forms as well as different dispositions.

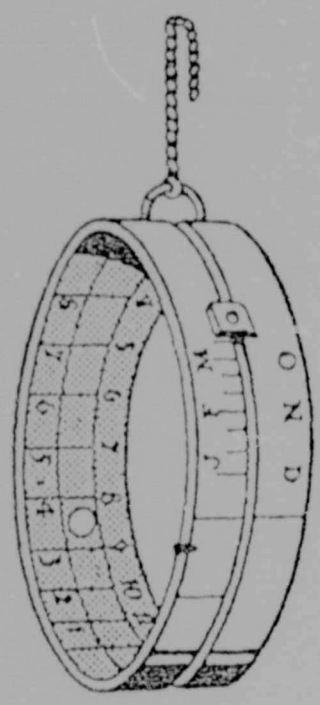

Fig.34.

It is the shadow of its tip which marks the hour on a scale drawn for that purpose.

The Egyptians left us Compass Dials based on the gnomon dating from XV Century B.C.

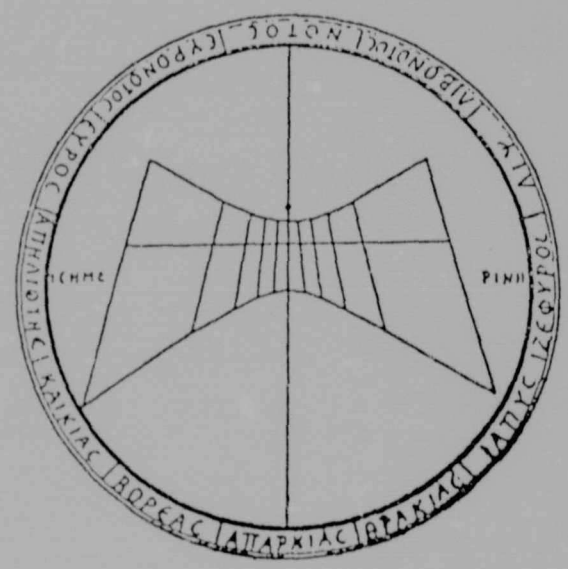

Fig.35.

"Portable Dials".

Close by Bratislava a small Roman dial was discovered that probably dates from the XII Century B.C., based on the same principle - the gmomon - with the difference that this one is much more accurate than the Egyptian ones, Fig.36

Hemicyclic Dials

Large scale sundials also existed during the Graeco-Roman time. Some, carved in

marble, survive to our days.

They consisted of a hollow hemisphere which represents the inverted image of the firmament.

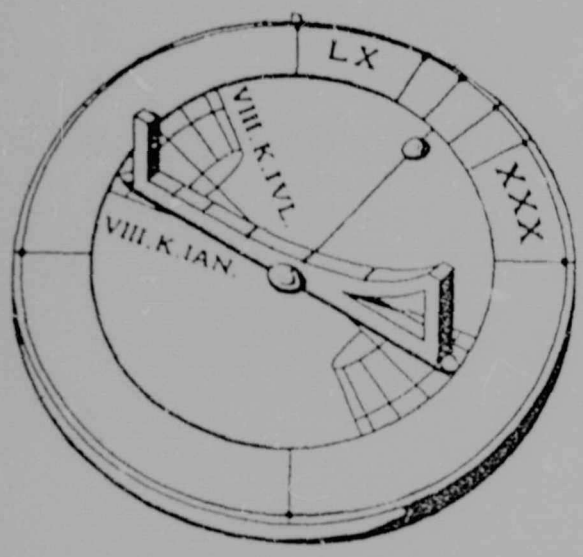

Fig.36

They are called hemicycle or hemisphere dials.

An interesting example is the one found in Pompei in 1854, Fig.37.

Some of these hemicyclic dials have a set of lines complementing the scale for the hours, representing the Zodiac signs, which gives the date.

These dials were manufactured until the modern era.

They were made out of many different materials, such as bronze or ivory, also varying in size.

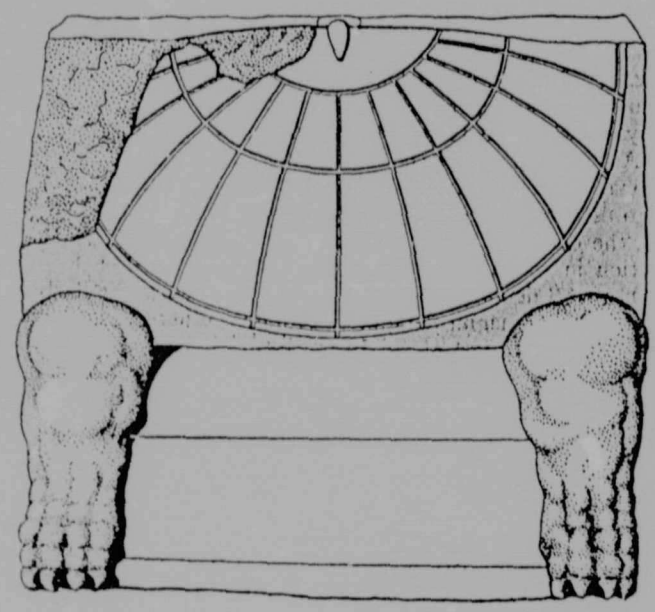

Fig.37

The Japanese, who from the XVIII Century copied the European sundials, made a hemicycle dial - "hidokei" - with only a few millimeters in diameter.

The Shepherd's Dial

A final example of the Altitude Dials is the so-called shepherd's dial.

It is basically a column the capital of which acts as a gnomon.

The capital turns and may be related to a particular month in accordance to a scale.

The gnomon is then turned to the sun, and its position is correct when its shadow is vertical

The length of the shadow gives us the hour, which we can read on the helicoidal curve representing the hours.

The Shepherd dials date from the beginning of the XI Century.

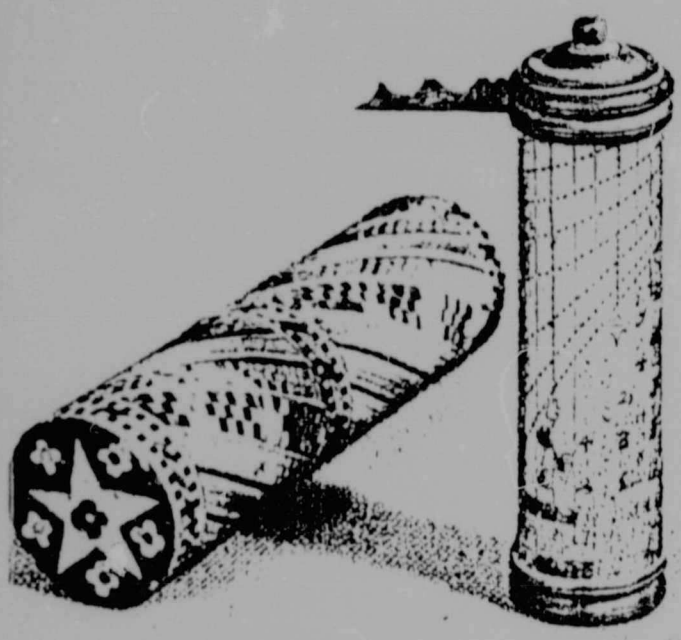

Fig.38

They are very simple and strong, but at the same time very elegant and practical. We can still find them being used today by the shepherds of the Pyrenees. Fig.38

COMPASS DIALS

ANALEMMATIC SUNDIAL, EQUINOCIAL DIAL, AND ASTRONOMIC RING DIAL

Analemmatic Sundial

If one sticks a rod or style into the ground it will be easy to see that in the Temperate Zones as the hours progress the shadow of the style will project a semi-circle on the horizontal plane.

This simple observation generated the idea of getting the time of the day by the direction of the shadow.

But as we know today, the reading of the time during the day and during the year is not as straightforward.

Only in 1644 did the french geometer Vauselard discover that the direction of the style shadow would change for the same time of the day, along the year.

Vauselard made the sun's rays pass through the top of a gnomon and he verified that the sun's movement during the day projected a cone the intersection of which with the horizontal plan was an

ellipse.

From this experiment a new sundial was created: the analemmatic sundial.

The observer would have to stand on a line graduated with a scale for the months.

The projection of the shadow of his own head would indicate the hour on the analemmatic ellipse.

Another very interesting example, based on the same principle, is the magnetic sundial invented by Dieppois Bloud in 1686.

In this case a compass is attached and its needle would point the hour on an elipse, Fig.39.

Equinocial Dial or Equatorial Dial

As mentioned above, it was only in the XIII Century after the publication of the Sacrobosco treatise that the apparent path of the sun around the Earth's axis was understood.

The Earth's axis as we know, is directed to the North Star.

If we place an axis-style orientated in the direction of the North Star, we will verify that, during the day, the sun will describe a regular movement around it.

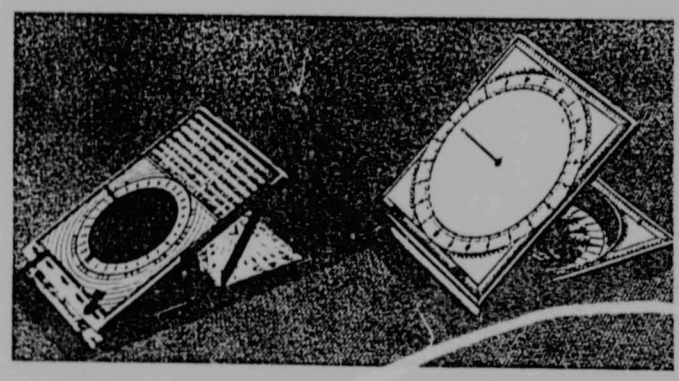

Fig.39.

For the same place, and the same hour of the day, the shadow of the axis-style will point in the same direction independently of the date.

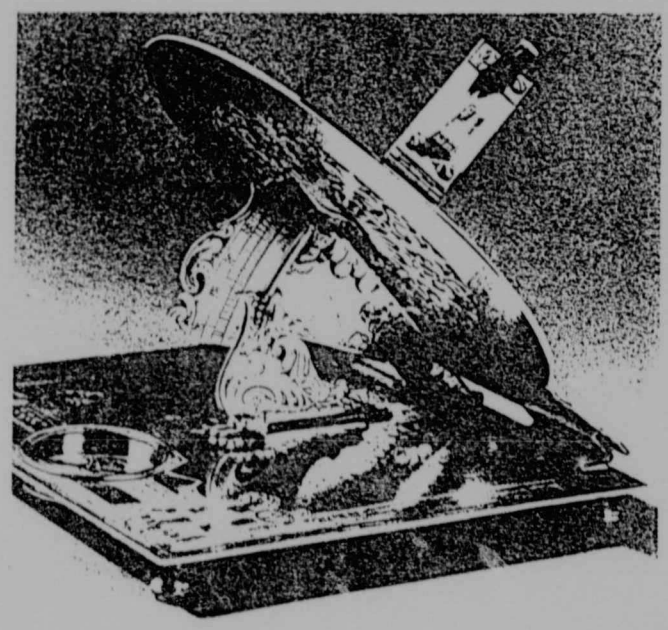

Fig.40 a)

From here, we can mark on any surface the consecutive directions pointed by the shadow for each hour.

This time-scale will then be valid for the whole year.

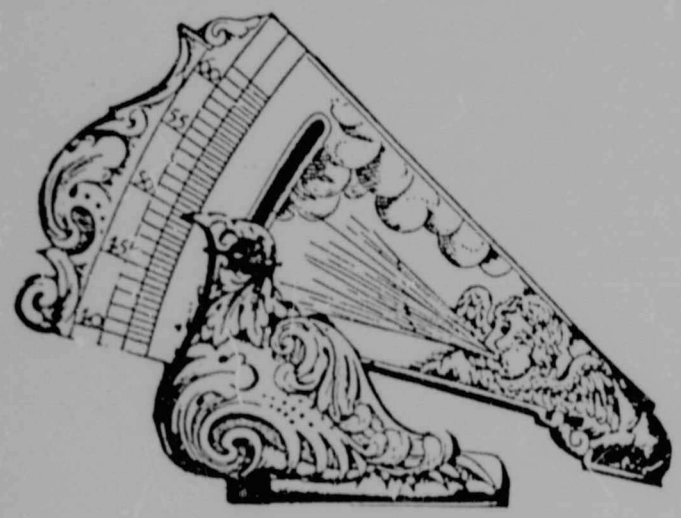

Fig.40 b)

If we place the surface containing the time-scale on a plane, perpendicular to the axis-style, this will mean that the above mentioned plane is parallel to the equator.

Because the sun's movement at the Equinoxes happens on the plane of the Equator this sundial was named the Equinocial sundial.

In this case the time demarcation is very easy because the shadow advances with a constant speed, therefore, the spaces in between the hour marks, are equidistant. Fig.32.

When an equatorial sundial is of the portable type, a compass must be attached to the axis-style base, to orientate it towards the North Star.

An adjustment according to the latitude also has to take place and for this purpose another scale must be attached.

Many types of portable equatorial sundials were evolved.



Fig.41.

In the XVII Century a french watchmaker named Regend made a model that became famous for its beauty and accuracy, Fig.32.

During the religious war this craftsman emigrated to Germany where he changed his name.

Eventually in Augsburg a family of watchmakers named Rugendas was found which was famous for its little sundials which in fact were very similar to the french model.

Michael Butterfield was also a very famous watchmaker.

Probably from an English family but domiciled in Paris, he was nominated the engineer to the crown in 1680. Fig.40.a)b).

The Astronomic Ring Dial

The Astronomic Ring Dial is a very interesting variation of the equatorial sundial.

It was created during the beginning of the XVIII Century and it was very popular because of its solid nature and pocket dimentions.

In this case the axis-style was replaced by a little square rail occupying the diametrical position of a ring, which represents the meridian, and is suspended by a small loop.

In this little rail slides a block with a pinhole in it; this being adjusted for the sun's declination by means of a scale on the plate.

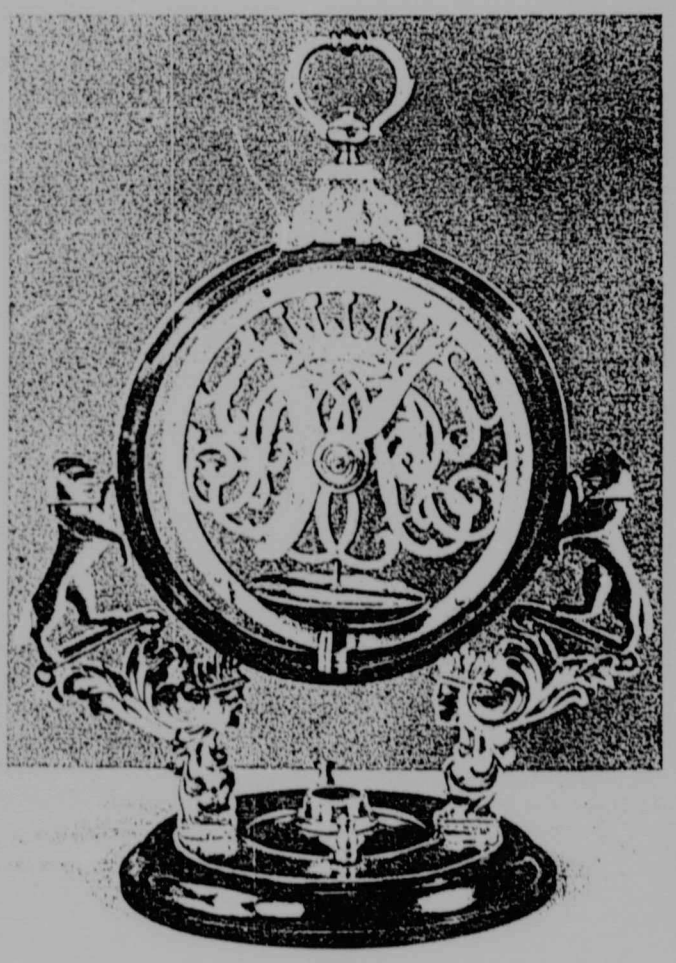

Fig.42.

A second, sliding ring or equatorial ring, within the first is drilled with a conical hole with its apex towards the inside, and divided into the 24 hours.

When the sun's rays pass through the hole, they make a spot of light upon the opposite inner face of the ring, showing the hour.

These sundials were manufactured mostly in England, Fig.41.

They are very beautiful sundials and also fairly accurate.



Fig.43.

Some relative large standing ones were made, Fig.42.

It is interesting to note that when the mechanical watches were invented, people still used the portable sundials to set the time.

MULTIPLE DIALS

In Germany talented and ambitious craftsmen created sets of astronomic instruments,of pocket size, made of gold-plated copper, finely engraved, and contained in small little boxes.

Some of these sets would include even astrolabes, Fig.43.

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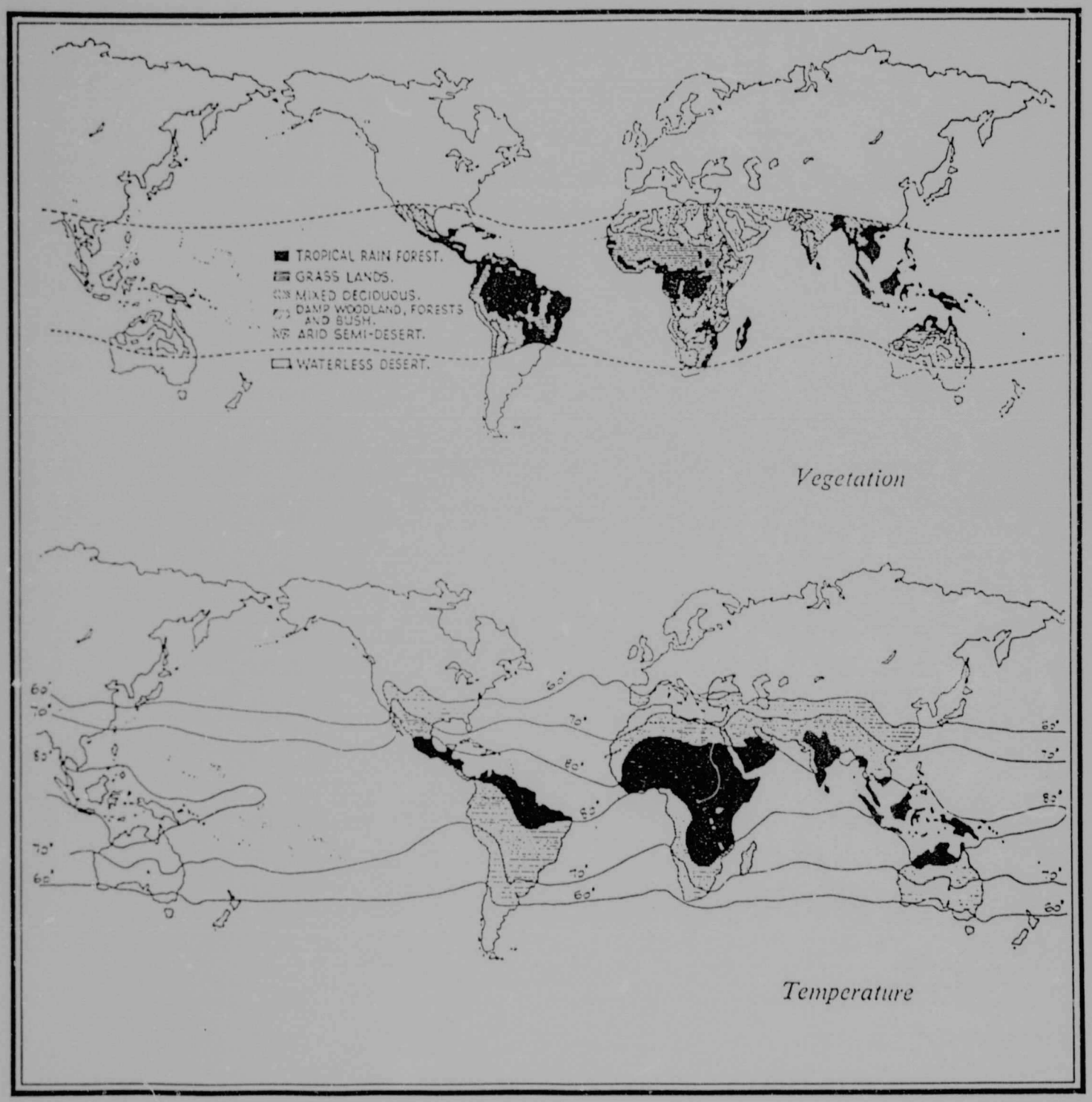
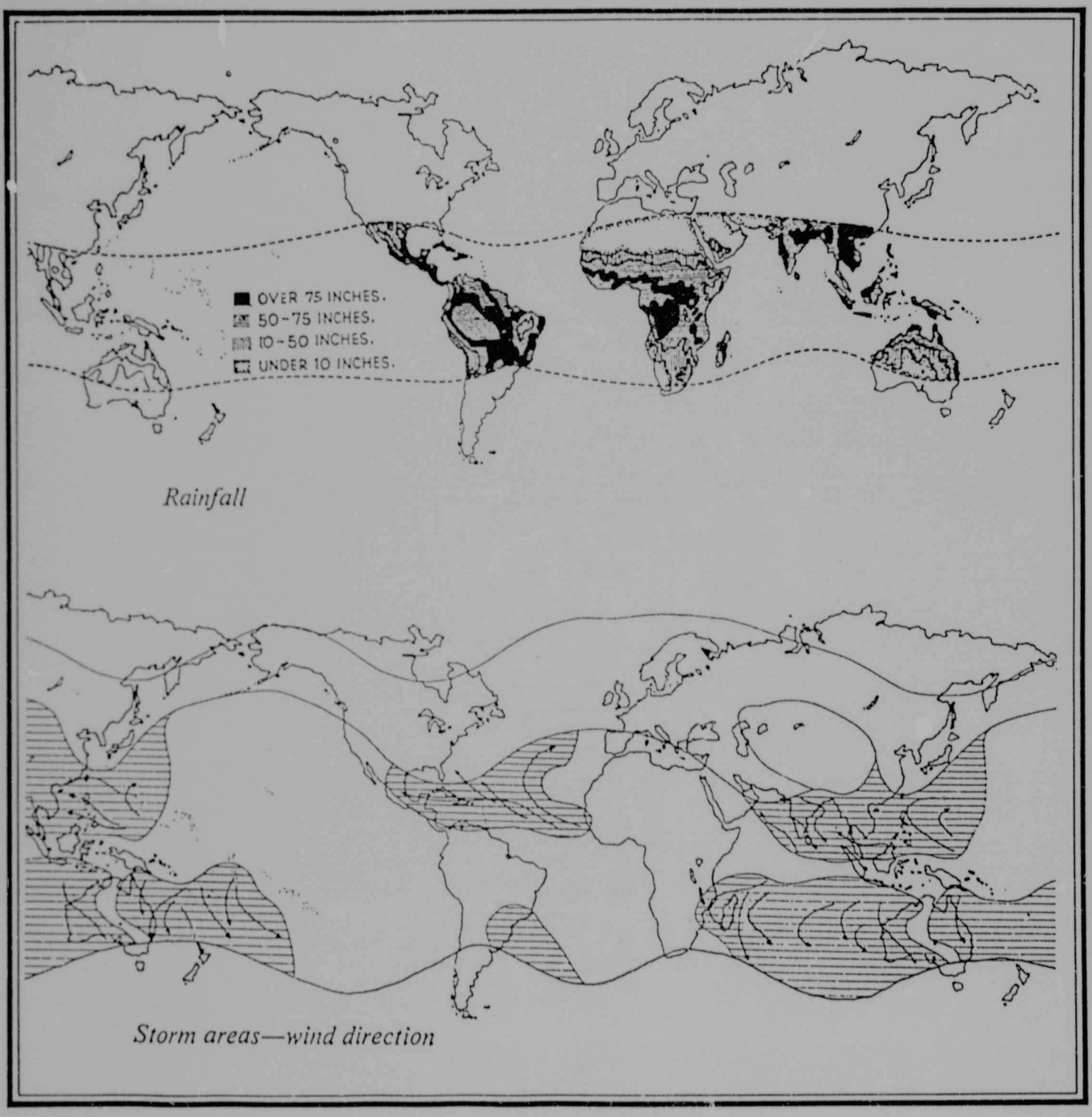
The World's Climate

&

"Köppen"




TROPICAL RAIN FOREST.
GRASS LANDS.
MIXED DECIDUOUS.
DAMP WOODLAND, FORESTS AND BUSH.
ARID SEMI-DESERT.
WATERLESS DESERT.
Vegetation
60°
70°
80°
Temperature



Rainfall

Storm areas—wind direction

The comparison of climatic data and the requirements for thermal comfort provides the basis for the selection of building form and building elements appropriate for the climate.

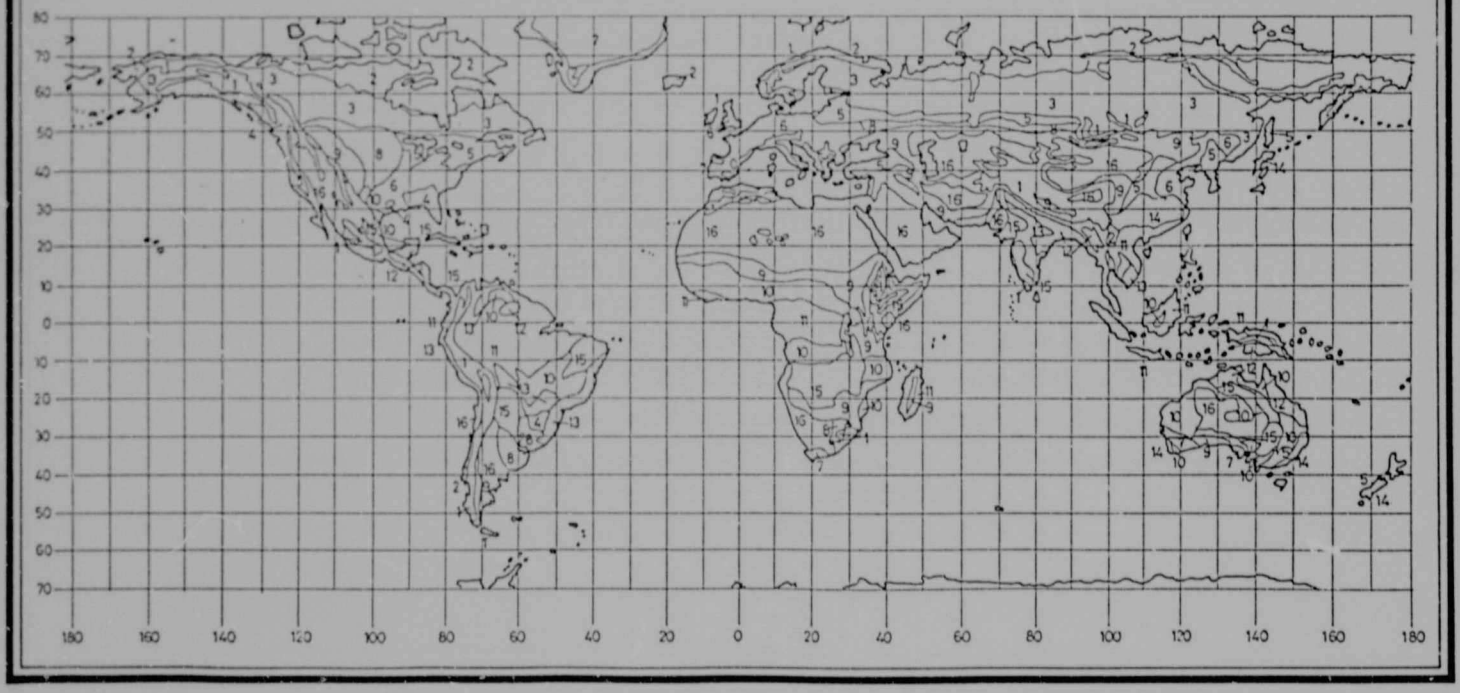
The size of windows, the insulation value of the roof, and the optimum orientation of building form can all be selected to give the required internal environment.

It is also possible, using the same criteria, to determine zones in which certain requirements exist, and to determine the approximate boundaries where a change in the climate and a change in thermal comfort requirements should be reflected in changed building form or changed building elements.

A number of different classifications of climate zones have been developed by geographers.

The common factor which they share is that they relate to vegetation zones, and in most cases the limits of these zones relate to specific changes in climate, in particular rainfall and temperatures.[1]

Fig.44.



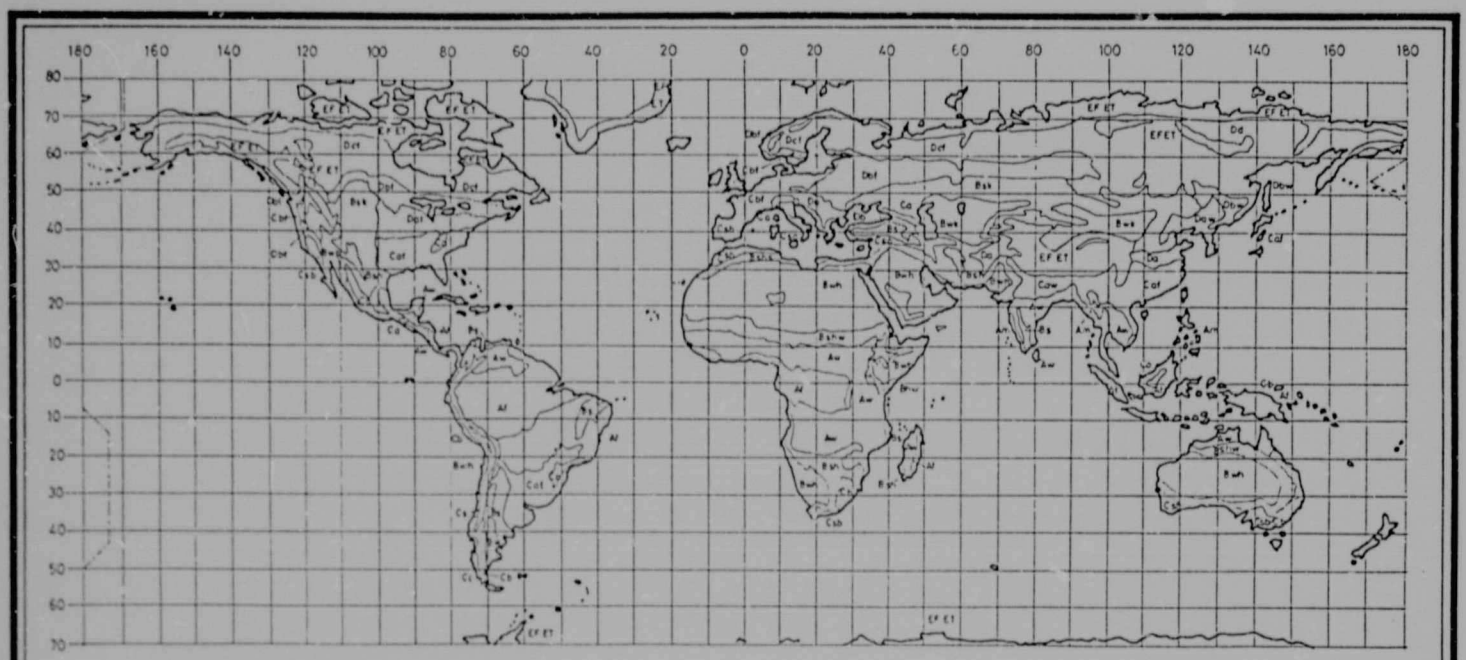


Fig.45.

Since vegetation forms the basis of most classification systems, and since vegetation (like well-designed buildings) is related to the climatic conditions which exist over the whole year, a simple descriptive classification of vegetation is considered first.

The different vegetation zones can be identified easily without reference to climatic data,Fig.44.

Table 1 shows a classification of natural vegetation.

Although approximate limits of latitude are given for each zone, there is considerable variation in these limits from continent to continent.

Topography, altitude, wind patterns, and ocean currents all cause modifications to an idealised distribution of vegetation.

In addition the lines drawn on a map are only approximate indications of the change of vegetation on the ground.

There is considerable mixing of vegetation types at the boundaries between zones.[1]

MAIN VEGETATION ZONES

No	Zone	Natural Vegetation	Typical Crops or Products	Sub-Zones	Latitude
1	Mountain vegetation	Wide variety	Sheep, Cattle	Equatorial	0-15
				Tropical	15-35
				Alpine	35-60
2	Tundra	Moss and litchen	(Reindeer)		55-80
3	Boreal forest	'Taiga', Stunted trees	Cattle		50-70
4	Conifer forest	Pine, Spruce, Larch	Oats	Mid-latitude	40-60
			(Maize)	Sub-tropical	25-35
5	Mid-latitude mixed forest	Broadleaf and conifer	Cattle, pota, toes Oats and rye		40-60
					(30-50) (In China)
6	Broadleaf	Deciduous	Sheep, cattle, wheat		30-55
7	Mediterranean scrub	Citrus, Agave	Citrus, Olive, viticulture		30-40
8	Prairie	Long grass	Cattle, wheat, maize rice, soya bean		25-50
				Prairie, N America	25-40
				Pampas, S America	35-50
9	Steppe	Short grass	Cattle, sheep	Continental	30-55
			maize, millet	Tropical	15-25
10	Savannah	Grass and scrub	Paddi rice, Sugar cane	Desert grass Tall grass	0-30
11	Tropical rain forest	Evergreen hygrophytic	Vegetable oil, bananas		0-20
		'Selva'	Mangrove		0-25
12	Monsoon forest	Moist deciduous	Rice, tea		5-30
13	Dry tropical forest	Semi-deciduous	Coffee		5-35
14	Sub-tropical forest	Dry and wet hardleaf evergreen	Fruit	Austraiasia & E Asia only	25-40
15	Dry tropical thorn forest	Thorn and scrub	Cattle	'Chaco'	0-35
16	Desert vegetation	Xerophytic shrub, grass and cactus	Dates and millet (no palms)	Hot tropical Continental	15-35 35-50
17	No vegetation			Salt flats Stone desert Sand desert Ice cap	

TABLE.1.

Another problem in defining zones is that there are some areas of the world where a "natural" vegetation no longer exists.

Many centuries of cultivation, irrigation and man-made changes to the landscape have obliterated natural flora.

In order to overcome the difficulties which result when vegetation is used as an index for, and to classify climates according to, the vegetation that may be grown, rather than the vegetation that exists, a number of different classification systems have been developed.

One of the most well-known and widely used is the classification developed by Köppen.

A number of different versions have been published, since the initial classification was proposed in 1900, but the simpler version is the most widely used.

A slightly amended version is shown in Table 2.

Major zones and sub-zones are distinguished according to the average monthly temperatures of the warmest and coolest month, the annual average temperature and the minimum and maximum monthly rainfall and the annual average rainfall. Fig.45.

The major division between zones A; BW; BS and the others depends on the annual rainfall.

But when the rain falls in the hottest part of the year the evaporation is higher than when rainfall occurs in the cooler months.

The formula for classifying climates with a summer dry season (when the rainfall in the driest month is less than the rainfall in the wettest month) is therefore different from the formula for climates with a winter dry season (when the rain in the driest winter month is less than one tenth of the rain in the wettest summer month).

A further formula is applied to climates in which the rainfall is distributed fairly evenly throughout the year and which do not have a distinct dry season.

These criteria are intended to relate to vegetation, but will not correspond closely with the requirements for building.

The divisions within and between zones C, D and E are based on average monthly temperatures of 0°, 10°, 18°, and 22°C.1

MODIFIED KOPPEN CLIMATE CLASSIFICATION

Class	Minimum average monthly temp(w)	Maximum average monthly temp(s)	Annual mean temp (t°C)	Dry Season	Minimum monthly rainfall (a mm)	Annual rainfall (r mm)	Notes
EQUATORIAL.A							
A f	w≥18	-	-	-	a≥60	r≥20t-140	Heavy rain all year
A m	w≥18	-	-	short	a<60	r<100-a r<20t-140	Heavy rain except for short dry season
A w	w≥18	-	-	winter	a<60	r<100-a r 20t-140	Marked seasonal rhythm in climate
A s	w≥18	-	-	summer	a<60	r<100-a r≥20t	(E coast of S India)
DESERT.BW							
BWhs	w≥0	-	(≥18)	summer	-	r<10t	
BWhw	w≥0	-	(≥18)	winter	-	r<10t-140	
BWk	w<0	-	(<18)	-	-	r<10t-70	No distinct dry season. Frequent fog (Coast of Peru)
BWn							
STEPPE.BS							
BShs	w≥0	-	(≥18)	summer	a<1/3 wettest month	r≥10t	
BShw	w≥0	-	(≥18)	winter	a<1/10 wettest month	r≥10t-140	
BSh	w≥0	-	(≥18)	-		r≥10t-70	No distinct dry season
	w<0	-	(<18)	-		r≥10t-70 r<20t-140	No distinct dry season
BSk							
TEMPERATE.C							
Csa	0<w<18	s≥22	-	summer	a<1/3 wettest month	r≥20t-280	
Csb	0<w<18	10<s<22	-	summer	a<1/3 wettest month	r≥20t-280	
Caf	0<w<18	s≥22	-	none	a≥60(a 30)	r≥20t-140	
Caw	0<w<18	s≥22	-	winter	a<1/10 wettest month	r≥20t	
Cbf	0<w<18	10<s<22	-	none	a≥60(a 30)	r≥20t-140	
Cbw	0<w<18	10<s<22		winter	a<1/10 wettest month	r≥20t	
Cc	0<w<18	s≥10	-				Less than 4 months over 10°C
COLD TEMPERATE.D							
Dcf	w<0	s≥10	-	none		r≥20t-140	Less than 4 months over 10°C, humid winter
Dbf	w<0	s≥10	-	none	a≥60	r≥20t-140	More than 4 months over 10°C, humid winter
Daf	w<0	s≥22	-	none	-	r≥20t-140	Humid winter
Daw	w<0	s≥22	-	winter	-	r≥20t	
Das	w<0	s≥22	-	summer	-	r≥20t-280	
Ddw	w< -38	s≥10	-	winter	-.	r≥20t	Less than 4 months over 10° C
ARTIC AND SUB-ARTIC.E							
ET	-	0<s<10	-	-	-	-	Tundra
EF	-	s<0	-	-	-	-	Perpetual frost
MOUNTAIN CLIMATES.H							
H	No specific limits, found in all latitudes						

TABLE.2.

These temperatures are related to important comfort limits, or heating and insulation criteria which are established.

22°C is the lower limit of comfort for low activity rates when wearing light clothing; and 18°C is the corresponding limit for normal clothing.

10°C is the limit below which heating systems are likely to be required. 0°C is also an important limit below which a number of special building requirements may become necessary.

For example: the lagging of pipes to prevent freezing; additional insulation to prevent heat loss; and adequate structures to resist snow loads.

(Köppen's original definition of this limit was -3°C and was intended to indicate one month's snow cover, but this was modified to 0°C by Trewatha.)

The rainfall limits of Köppen are not related to comfort or to waterproofing requirements.

When the rainfall exceeds about 200mm per month it will interrupt external circulation considerably and schools for example may require covered pathways between buildings; this condition may occur in a climate where the minimum monthly rainfall is 60mm or less.

But protection against heavy rain is required in all equatorial climates, and also in some steppe (BS) climates.

Waterproofing of roofs is even required in desert (BW) climates as rain, though infrequent, may still on rare occasions exceed 25mm in 24 hours.

From this short summary it should be clear that climate classifications based on vegetation, or on rainfall and temperature alone, will not necessarily be related to zones of climate related to building design for thermal comfort.

The minimum criteria for this purpose will include humidity, temperature and temperature range.

Humidity is not only related directly to thermal comfort, but is also indirectly related to cloud cover, the intensity of solar radiation, and daylight levels.

The absence of humidity from Köppen classification makes it impossible to distinguish the humid maritime desert climate from the dry desert climate.

But these drawbacks cannot detract from the usefulness of the classification.

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