USE OF DIRECT SOLAR ENERGY IN TORRID ZONE

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RINGKASAN

Matahari ialah punca tenaga yang utama kepada keluarga planet-nya. Ia memancarkan tenaga dalam bentuk gelombang elektromag-net, yang merambut melalui ruang udarakasa dengan halaju 299, 744 km (186,270 batu) sesaat. Planet bumi melintasi sepecahan tenaga ini di dalam bentuk haba dan cahaya. Dengan ini ujudlah ke atas bumi, keadaan-keadaan asas bagi suhu dll yang mengakibatkan jiwa boleh jadi. Tenaga matahari yang bercahaya membekalkan tenaga kepada keseluruhan kitar kajihayat jiwa melalui cara foto-sintisis. Matahari, melalui sebaran tenaga yang tidak sama atas planet bumi, ialah punca utama, yang menghasilkan peredaran udara, aliran laut, pengangkutan air melalui proses cairwapan dan kerpasan sebagai hujan atau salji dan pengaliran melalui sungai.

Pemerhatian-pemerhatian mengusulkan bahawa kekuatan fizikal manusia, kebolehan rohani, keperluan tenaganya, konsep keenakan dll semuanya bergantung kepada berapa banyaknya pengdedahan kepada pancaran matahari. Oleh sebab itu, untuk memahami cara menahan jiwa, dan mengguna dengan sepenuhnya alam sekitar yang lazim serta menghasilkan keadaan-keadaan optimum bagi kehidupan dan pekerjaan, adalah sangat penting untuk memahami perhubungan antara manusia dan matahari. Kefahaman ini boleh menolong manu-sia memenuhi keperluan untuk tenaga, keperluan bagi kehidupan keenakan tanpa bergantung kepada teknologi yang mahal. Kertas kerja ini berbahaskan perhubungan antara manusia dan alam sekitar-nya yang lazim, khasnya dengan matahari.

ABSTRACT

The sun is the main source of energy to its family of planets. It radiates energy in the form of electromagnetic waves, which are propagating through space with a velocity of 299,774 km (186,270 miles) per second. The planet earth intercepts a fraction of this energy in the form of heat and light, that creates on the earth, the

basic conditions of temperature etc. which make life possible. It is the radiant solar energy, through the mechanism of photosynthesis that provides energy for the whole biological cycle of life. The sun, through its unequal distribution of energy on the planet earth, is the prime source, that is producing circulation of atmosphere, oceanic currents, transport of water through the process of evaporation and precipitation as rain or snow and flow through streams and rivers.

Observations suggest that man's physical strength, mental capabilities, his energy requirements, concept of comfort etc. all depend on the extent of his exposure to the solar radiation. Therefore, in order to understand the life sustaining mechanism, utilize the best of natural environments and create optimum conditions for living and working; it is all the more important to understand man's relation with the sun. This understanding can assist him to fulfill his needs for energy and comfortable living without much dependence on expensive technology. The paper discusses man's relationship with his natural environments, especially with the sun.

Introduction

Solar energy is available to man in abundance, free of cost and is nonpolluting. The direct use of solar energy has many advantages, as it can be harnessed through solar collectors and solar cells for heating as well as generating electric power. Therefore, during the recent energy crisis, research in the effective and direct use of solar energy has gained considerable amount of momentum, especially in the industrialized countries. The fast developing countries are receiving relatively larger amount of sun exposure. Realizing this fact, they are trying to make their contributions in this respect.

The solar energy being received from the sun is in the form of direct, diffused and reflected radiation. The amount of solar energy falling on a particular area defines the modes of climatic conditions and the energy requirements for comfortable living in that area. In certain parts of the earth this thinly scattered energy, together with heat generated by human activities, compel people to get rid of unwanted heat, i.e. people are forced to use means like airconditioning units, for creating comfortable living conditions. Whereas in certain other areas of the earth, the deficiency in energy from the sun has to be supplemented by other means, i.e. enviroments are to be heated.

This contradictory need to cool or heat the environments indicates the variations in quantities of solar energy received by any area on the surface of the earth. This is because the earth revolves around its own axis and completes one revolution in one civil day, that is defined as 24 hours. This motion of the earth is giving a concept of time that is reckoned from midnight at Greenwich meridian (i.e., with respect to zero degree longitude). The time is expressed on an hour scale from zero hours (at midnight) to 12 hours (at solar noon) to 24 hours (at midnight). The relationship of hour angle h, in degrees, to the civil time T, hours, is expressed as

$$h = 360\,(12 - T)/24, \text{ degrees} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

At solar noon, the hour angle is zero. The hour angle expresses the time of day with respect to solar noon at a given area fixed by the longitude angle.

Basic Earth-Sun Angles: The earth revolves about the sun, and completes one revolution in 365¼ earth days. The axis of rotation of the earth is tilted through an angle of 23½ degrees with respect to its orbit about the sun. The sun's angle of declination is reckoned from 21st March. The relationship of declination angle δ, to a particular day d, of the year is given by:

$$\delta = 23.45^\circ \text{ Sin } (360\, d/365.2564), \text{ degrees} \quad \ldots \quad \ldots \quad (2)$$

where d = days stated as 0 – 365; d = 1 on the 22nd March.

The declination of the earth's axis and the combined effects of earth's revolution and its motion about the sun, plays an important role regarding the reception of solar energy at a certain specific area on the surface of earth, at a specific time of the day of the year. That is to say, the changes in the length of hours of daylight and darkness and changes in the seasons are the results of these two motions.

A particular area on the surface of the earth is defined by the latitude l and longitude $\propto$, angle. The latitude angle is the angular distance of a point on the surface of the earth, north or south of the equator and the longitude angle is the angular distance between the standard meridian (a vertical plane passing through Greewich) and a point, at the same latitude, on the surface of the earth, east or west of the standard meridian.

The variations in exposure to sun, of an area on the surface of the earth are also dependent on the sun's zenith angle ψ, altitude angle β, and azimuth angle ν. The sun's zenith angle, is the angle between the sun's rays and a line perpendicular to the horizontal plane. The altitude angle is the angle in vertical plane, between the sun's rays and the projection of sun's rays on the horizontal plane. The sum of the two angles, i.e. $(\psi + \beta) = \pi/2$, degrees. The azimuth angle is the angle in the horizontal plane measured from North through east, to the horizontal projection of sun's rays. All these angles are inter-related, and are related to the latitude angle (for a particular area on the surface of the earth), sun's declination angle (for a particular day of the year) and the hour angle (for a particular time of the day) as follows:

$$\text{Cos}\ \psi = \text{Cos}\ l\ \text{Cos h}.\ \text{Cos}\ \delta + \text{Sin}\ l\ \text{Sin}\ \delta$$

$$= \text{Cos}\ (\pi/2 - \beta) = \text{Sin}\ \beta \quad \cdot\cdot \quad \cdot\cdot \quad \cdot\cdot \qquad (3)$$

$$\text{Sin}\ \nu = \text{Sec}\ \beta.\ \text{Cos}\ \delta.\ \text{Sin h} \quad \cdot\cdot \quad \cdot\cdot \quad \cdot\cdot \qquad (4)$$

$$\text{Cos}\ \nu = \text{Sec}\ \beta.\ (\text{Cos}\ l.\ \text{Sin}\ \delta - \text{Cos}\ \delta.\ \text{Sin}\ l.\ \text{Cos h}) \qquad (5)$$

All these angles and their inter-relations are presented in Fig. 1 and fig. 2.

The principal characteristics of the sun and earth are given in Table 1.

Sun Plots: The equations described above can be used to determine the sun's position at any time of the day, and at any location on the surface of the earth, with a knowledge of the latitude and longitude angles.

Fig. 3 shows the sun's path across the sky vault, representated on harizontal plane for locaitons situated 3 degrees north latitude angle away from the Equator. The elliptical curves running horizontally are the projections of the sun's path on the 22nd day (approximately) of each month. The grid of vertical curves indicate the hours of the day. Fig. 4 is the same sun plot for horizontal plane for locations situated 32 degrees north latitude angle away from the Equator.

Use of the Data: One of the most important factor to be noted from the geographical map of the world, is that the industrially developed countries are mostly situated in the temperate zones, i.e., locations situated above 23½ degrees (or more) latitude angle, north/south of the Equator. And, most of the world population and the developing countries are included in the torrid zone, i.e. locations situated within 23½ degrees latitude angle on either side of the Equator. The temperate zones include all locations where the sun appears above the horizon each day but never at the zenith. Whereas the torrid zone includes all locations where the sun is at zenith at least once in a year. Fig. 3 and fig. 4 have been selected to elaborate this fact. A comparison of the two sun plots will show that the areas located in the torrid zone receive relatively larger amount of sun exposure. Another fact to be noted from the geographical world map is that the torrid zone is mostly covered with sea areas and the land area is relatively small.

Since the daily and yearly variations of the atmospheric temperature are dominated by incoming solar energy, all other climatic factors like movement of air, natural light and heat etc., are dependent on the sun's position with reference to a particular area. This fact together with the study of sun plot given in Fig. 4 (for the temperate zone) will explain the reason for the development of four distinct seasons, namely: winter, spring, summer and autumn, experienced by the people living in temperate zones. It also explains why people have to supplement their energy needs by other means, during winter season, so as to produce comfortable living conditions. The people living in this zone are familiar with distinct seasons. When they are passing through summer, the areas are exposed to direct sunshine and sky is clear from any clouds. Therefore, with the present constraints of energy from the fossil fuels, people are talking about supplementing their energy needs from the sun, especially during winter. It is because of this reason that the people are forced to use hot water in their kitchen and bathrooms etc. during winter.

The people living in the torrid zone receive an abundance of sunshine. Since the land areas, especially close to the Equator, are mostly surrounded by sea water, there is plenty of evaporation and precipitation of water in this area. As a result, the people living in this area are relatively exposed to high temperature, high moisture environments. Observations of climatic conditions in the two areas may be better understood by the fact that, in Lahore, Pakistan (which is situated in 32 degrees latitude north of Equator), the yearly variations in dry bulb temperatures are from 0°C to 45°C (32°F to 113°F). Whereas in Subang, Kuala Lumpur, Malaysia (which is situated in 3 degrees latitude north of Equator), the yearly variations in dry bulb temperatures are $(31 \pm 1)°C$ ((88 ± 1.5) °F). Besides, statistical analysis of observed maximum atmospheric temperature in the temperate zones indicates that it occurs between 3–4 PM local time. For Subang area the statistical analysis based on data for the last ten years indicates that the frequency of highest temperature conditions occur between 11 – 12 Noon, local time.

Therefore, the needs and demands for comfortable living for the two areas are contradictory. In temperate zones, the people are forced to heat their environments during winter, and cool these environments during summer. Whereas, the people included in the torrid zones, try to get rid of unwanted heat by using airconditioning and refrigerating systems. It is the high content of moisture present in the air of torrid zones that makes environmental boundary conditions to be conditioned. This is because that for most part of the day, throughout the year, the sky is covered by clouds. In otherwords the people living in the torrid zone receive abundance of sunshine, but in an indirect way.

Conlusions: Direct use of solar heat through solar water heaters and solar cells is possible in those areas where reliable direct sunshine is available. Solar water heaters are already quite extensively used in countries like Australia, Israel, Japan, USA., and even in some parts of France. Such systems are extremely simple in construction and maintenance.

Because of hot climatic conditions (i.e., high dry bulb and thermodynamic wet bulb temperatures) together with high relative humidity etc., the only and the best possible application of direct solar energy for locations included in the torrid zones, is to use it to produce cooling effect. Only a few attempts have so far been made to power refrigeration equipment proper with solar energy. The main difficulty is to produce temperatures high enough for the purpose, with flat solar collectors. Observations at the UTM have shown that a flat plate solar collector produces a temperature of 71°C (160°F) on clear sunny day. Experiments on a small intermittent type ammonia- water absorbent refrigeration system have proved that it could be possible to produce a cooling effect of 4°C (40°F) at the evaporator side. But the main difficulty was observed regarding the direct radiation from the sun. For most part of the year, observation suggest that the sky is overcast by thick clouds from afternoons to the evenings, with heavy rains.

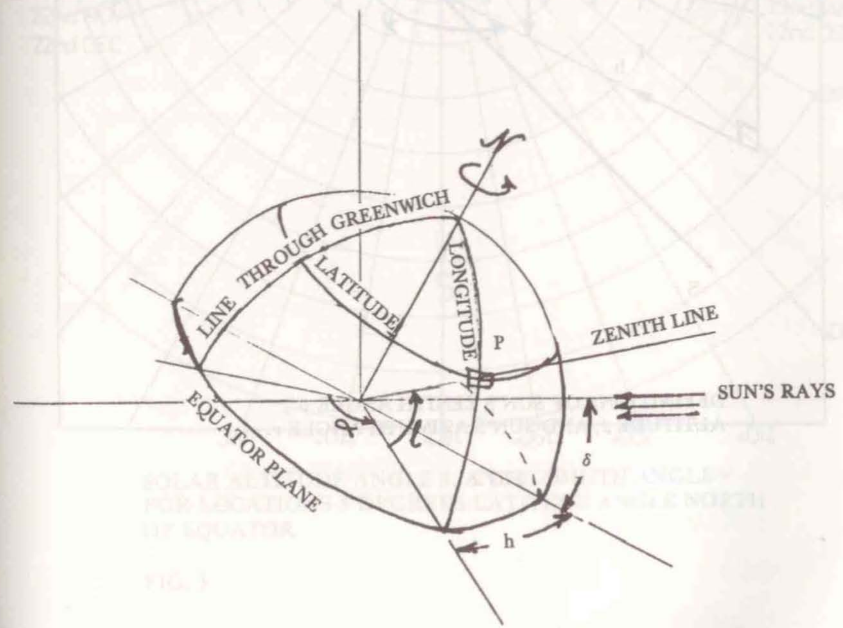
As the dry bulb temperature, say in Kuala Lumpur, stands approximately at 31°C (88°F), one can think of using diffused solar radiation for the service of man. Most of the industrial energy consuming equipment discharge as waste heat in the temperature range of 38 – 93°C (100 – 200°F), while most of steam usage occurs in the 150 – 205°C (300 – 400°F) temperature range. With such a potentially significant energy available (i.e., atmospheric temperature of 31°C), it is clearly important to determine how and when industrial heat pumps might be used to raise the level of temperature, so as to use this high temperature for producing mechanical energy or to run a vapour absorption refregeration system. The heat pump is a device consisting of heat recovery evaporator, a heat delivery condenser, a mechanical compressor, and an expansion valve. Here, the heat from the atmospheric air may be taken up through the evaporator of the heat pump. Into this, energy is added during the compression process in the compressor, thus raising the level of heat energy, i.e. temperature. The condenser heat exchanger can serve as the heat supply system to any process where heat is needed.

The sun plots described above may be constructed for any area of interest. They are very useful to the engineers and architects in the development of new areas while designing the solar energy conversion systems, (like solar collectors) and orientation of new buildings, that may have uniform heat and light capacity throughout the year.

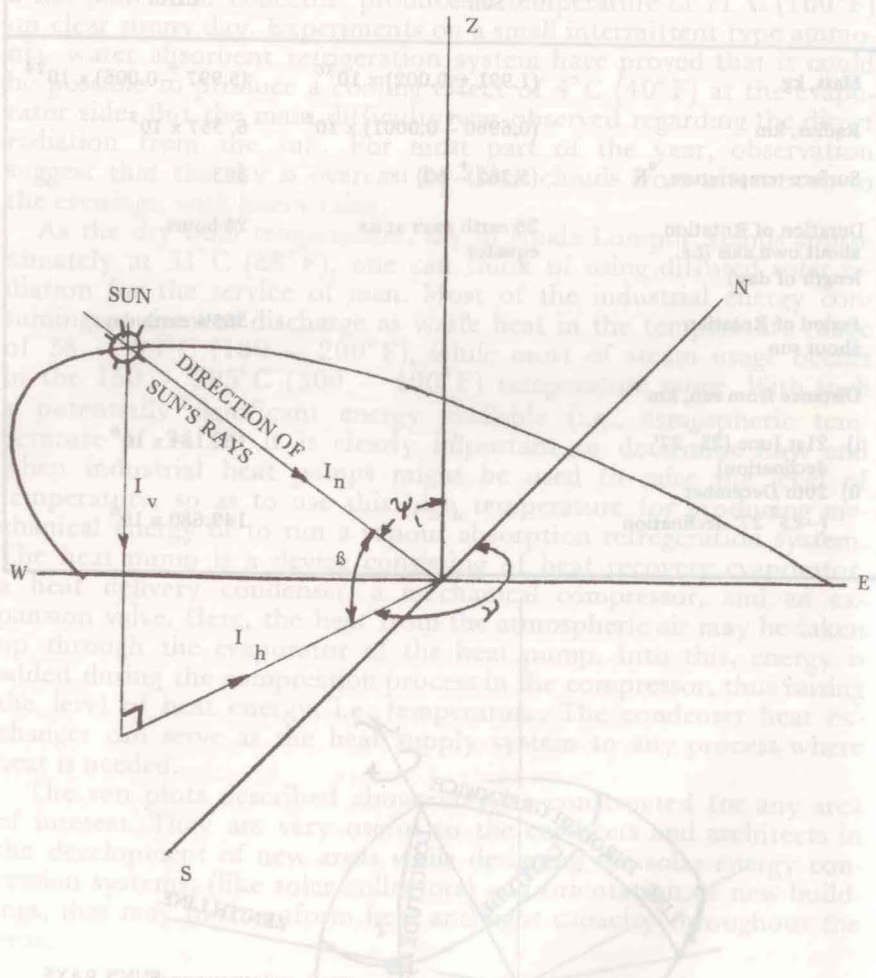
TABLE 1

Charateristics of the Sun and the Earth

	Sun	Earth
Mass, kg	$(1.991 \pm 0.002) \times 10^{30}$	$(5.997 \pm 0.006) \times 10^{24}$
Radius, km	$(0.6960 \pm 0.0001) \times 10^{6}$	6.357×10^{3}
Surface temperature, °K	$(5{,}762 \pm 50)$	303
Duration of Rotation about own axis (i.e. length of day)	25 earth days at its equator	24 hours
Period of Rotation about sun	"	365¼ earth days
Distance from sun, km		
i) 21st June (23° 27' declination)	"	152.184×10^{6}
ii) 20th December (–23° 27' declination	"	149.680×10^{6}

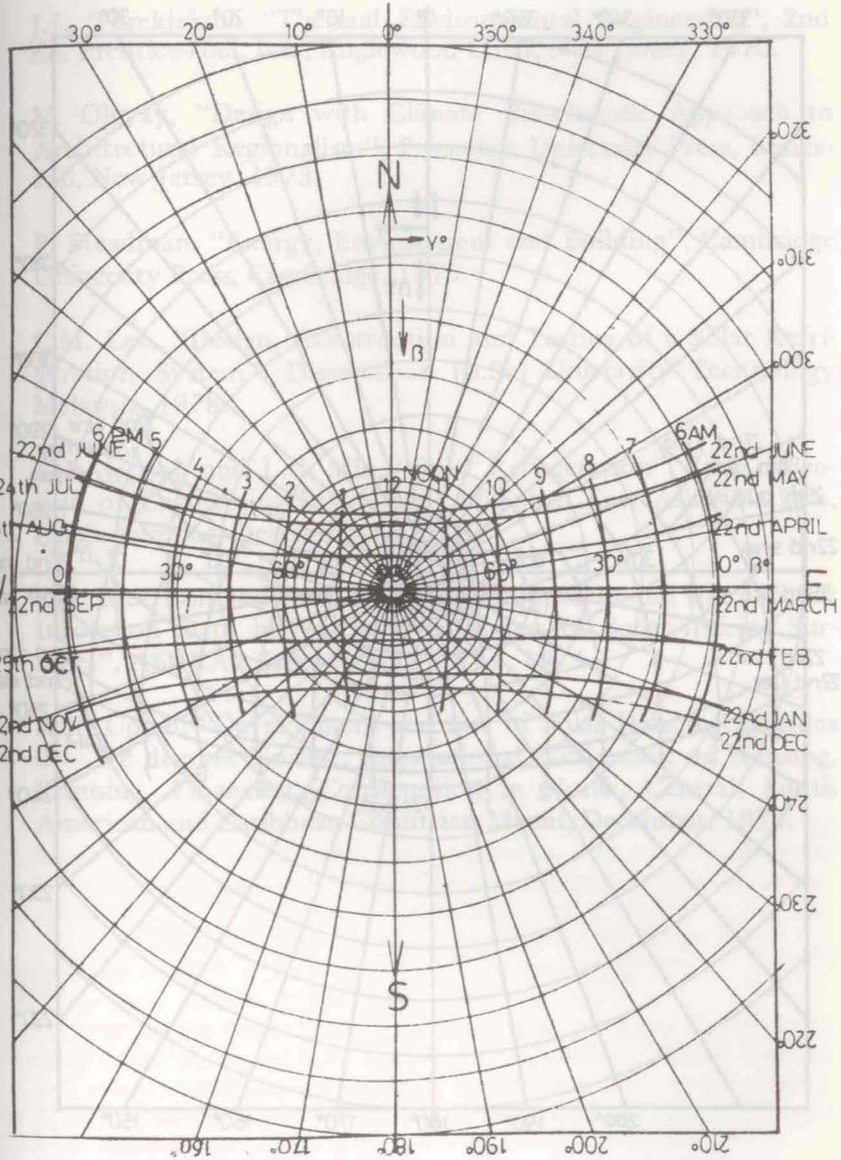


THE SCHEMATIC REPRESENTATION OF LATITUDE ANGLE l, LONGITUDE ANGLE α, HOURANGLE h, AND SUN'S DECLINATION ANGLE δ



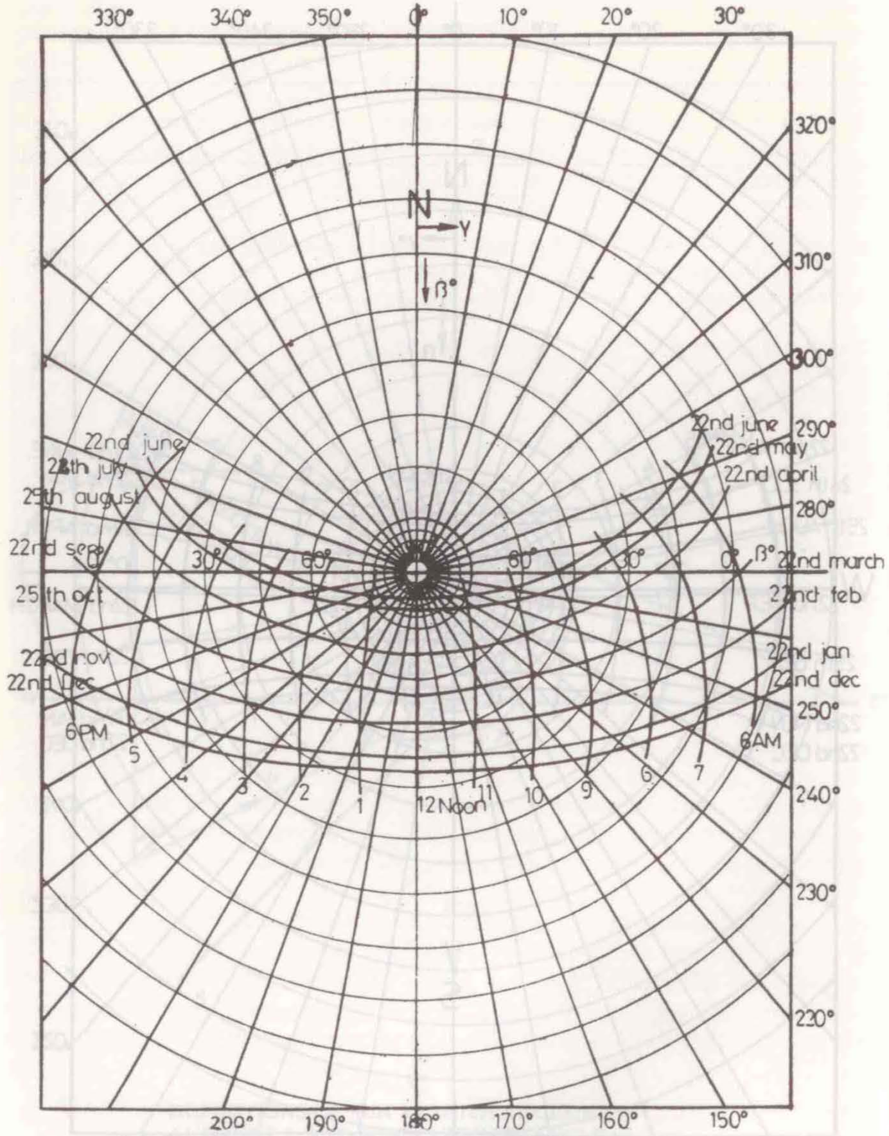
DEFINITIONS OF SUN'S ZENITH ANGLE ψ', ALTITUDE β, AND SUN'S AZIMUTH ANGLE ν.

FIG 2



SOLAR ALTITUDE ANGLE β, AND AZIMUTH ANGLE ν FOR LOCATIONS 3 DEGREES LATITUDE ANGLE NORTH OF EQUATOR

FIG. 3



SOLAR ALTITUDE ANGLE β, AND AZIMUTH ANGLE γ FOR LOCATIONS 32 DEGREES LATITUDE ANGLE, NORTH OF EQUATOR.

FIG. 4

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