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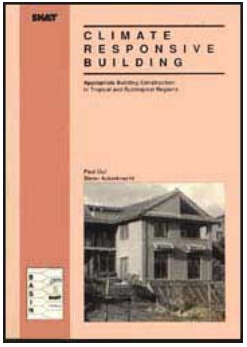

Climate Responsive Building - Appropriate Building Construction in Tropical and Subtropical Regions (SKAT, 1993, 324 p.)

5. Appendices

5.1 Physical data

The data provided in the following tables are approximate only and serve as a basis for comparing different materials. For exact calculations the properties of the specific material must be considered, which may differ from the data provided here. The data are compiled from various sources.

5.1.1 Density, thermal conductivity, specific heat

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	Density	Thermal conductivity (k)	Specific heat (Q)

	kg/m³	W/mK	Wh/kgK
a) Natural stone and earth (moist)			
Granite, marble	2800	3.5	0.26
Sandstone, limestone	2600	2.3	0.22
Sand	1700-2000	1.4	
Earth	1800	2.1	
b) Sand and earth (dry)			
Sand, gravel (loose filling)	1800-2000	0.7	0.22
Clay massive (adobe)	1000-2000	0.2-1.0	0.23
c) Concrete			
Solid concrete (RCC)	2400	1.8	0.33
Gas concrete	1000-1700	0.3-1.0	
d) Plaster			
Cement plaster	2200	1.4	0.3
Lime-cement plaster	1800	1.0	
Gypsum plaster	1200	0.6	0.26
e) Timber			
Softwood	450-500	0.15	0.55-0.66
Hardwood	600-800	0.18-0.22	0.55-0.66
f) Boards			
Gypsum	1000	0.40	0.22
Asbestos cement	1700-2000	0.48	0.24

Woodwool, cement bound	700	0.12	0.42
Wood fibre, hard	800	0.17	0.7
Wood fibre, porous	200-400	0.06	0.7
Wood chips	650	0.11	0.75
Plywood	600	0.44	0.75
g) Masonry			
Hollow brick	1200	0.47	0.26
Solid brick	1800	0.8	0.26
Cement stone	2000	1.1	0.3
Gas concrete	500-700	0.16-0.21	0.3
h) Insulation materials			
Mineral wool, glass wool	20-120	0.04	0.17
Slag wool	30-70	0.06	0.17
Grass board	200-300	0.06	0.17
Coconut matting	50-200	0.05	0.17
Hemp mat	50-200	0.05	0.17
Cork board extruded	110-140	0.04	0.42
Cork coarse	80-160	0.06	0.42
Foamglass	125	0.045	0.22
Perlite with pressed fibre	170-200	0.06	0.17
Polystyrene extruded	20-40	0.04	0.39
i) Various materials			
Steel	7850	60	0.13

Copper	9000	348	0.1
Aluminium	2700	200	0.26
Glass	2500	0.81	0.22
Water 10°C	1000	0.58	1.16
Ice	820-920	2.23	
Snow 0°C	100	0.05	
Air (theoretical case of still air)	1.2	0.02	0.28

5.1.2 Thermal transmittance (U-value), time lag values, solar heat gain factor

a) Homogeneous materials			
	Thickness in cm	**Time lag (O) hours**	**Solar heat gain factor (SHF) %**
Stone	20	5.5	
	30	8	
	40	10.5	
	60	15.5	
Sand	30	13.4	
Solid concrete	5	1.1	
	10	2.5	
	15	3.8	9
	20	5.1	

	30	7.8	7
		40	10.2
Solid brick	10	2.3	
	20	5.5	10
	30	8.5	
	40	12	
Stabilized soil, mud	10	2.4	
	15	4.0	
	20	5.2	
	30	8.1	
Wood	1.5	0.2	
	2.5	0.45	
	5	1.3	
	10	3.0	
	30	17.4	
Aluminium sheet (new)		0.5	10
Corrugated galvanized iron sheet (new)		0.5	20
Corrugated galvanized iron sheet (rusty)		0.5	34
Corrugated asbestos cement sheet (ACC)		0.5	16
Insulating board	1.5	0.1	
	2.5	0.23	
	5	0.77	
	10	2.7	

	15	5	

b) Roof constructions			
	Thickness in cm (U) W/m²K	**Time lag (O) hours**	**Solar heat gain factor (SHF) %**
Thin sheets without ceiling (Alu, CGI, ACC)	8 - 9	0.5	see above
Alu sheet + cavity+ asbestos sheet	1.9	1	4.5
ceiling ditto + 50 mm fibre glass in cavity	1.3	1	3
Rusty CGI sheet + cavity + thin sheet	1.9	1	8
ceiling ditto + 50 mm fibre glass in cavity	1.3	1	5
Concrete slab, 300 mm	2.5	9.2	7
Concrete slab, 150 mm	3.3	4	9
ditto + 50 mm woodwool slab internally	1.13	4.5	3
ditto + external and internal insulation	0.75	13.5	2
ditto + whitewashed externally	3.3	4	4
ditto + 50 mm woodwool + whitewashed ext.	1.13	4.5	1.5
ditto + ext. and int. insul. + whitewashed ext.	0.75	13.5	1

c) Wall constructions			
	Thickness in cm (U) W/m²K	**Time lag (O) hours**	**Solar heat gain factor (SHF) %**
Hollow concrete block, 250 mm, rendered on	1.7	11	5

both sides			
ditto + whitewashed externally	1.7	11	2
Window with single glazing	4	0	85
Open window	-	0	100
Solid brick wall, 230 mm	2.7	8	10
ditto + whitewashed externally	2.7	8	3.5
Brick wall 280 mm incl. 50 mm cavity	1.7	10.5	6
ditto + whitewashed externally	1.7	10.5	2
Corrugated asbestos cement sheet	8	0.5	16
ditto + 50 mm woodwool slab + cavity	1.2	0.5	2.5

5.1.3 Reflectivity and emissivity of main materials

Surface	% Reflectivity of solar radiation (6'000°C)	% Emissivity of thermal radiation (10 to 40°C)
a) Natural materials		
Sand, white	59	
White marble	54	95
Limestone	43	95
Wood, pine	40	95
Grass	20	
Sand, grey	18	
b) Concrete and masonry walling		
Cream brick	50 - 70	40 - 60
Yellow and buff brick, stone	30 - 50	85 - 95

Yellow and buff brick, stone	30 - 50	85 - 95
Concrete	35 - 45	
Red brick, stone	25 - 45	85 - 95
Asbestos cement, aged 1 year	29	95
c) Paints		
Whitewash	80	
White lead paint, light grey	71	89
Light green paint	50	92
Medium grey, yellow	45	92
Aluminium paint	45	55
Dark color (brown, grey, red)	35	92
Deep dark brown, dark red, dark green	10	92
Black, non-metallic	2 - 15	90 - 98
Black, matt	3	95
d) Metal		
Silver polished	93	2
Polished aluminium, chromium	60 - 90	2 - 8
Bright aluminium, gilt, bronze	50 - 70	40 - 60
Polished brass, copper	50 - 70	3 - 30

Dull brass, aluminium	55 - 60	20 - 30
Aluminium anodized	33	92
Galvanized iron, aged (oxidized)	10	28
e) Plaster		
White	80	97
Orange	45	97
Light green	40	97
Light brown	35	97
Brown	32	97
Dark brown	17	97
f) Glass		
Reflecting glass	50	
Clear glass	10	90 - 95

Note:

- The higher the reflectivity of the surface of a material, the less is the heat load received by radiation and, after the heat has been transmitted through the material, the heat load in the interior.

- The higher the emissivity of a surface, the more a building cools down at night.

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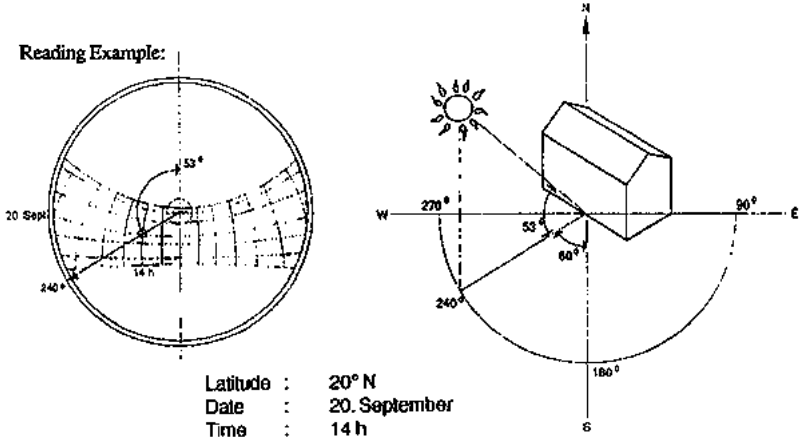
5.3 Solar ecliptic charts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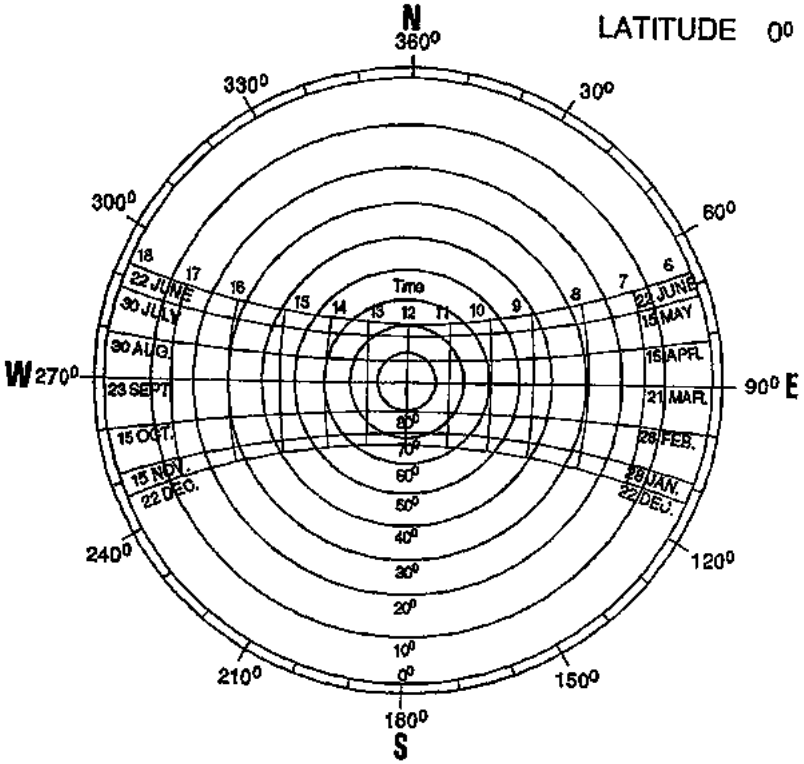
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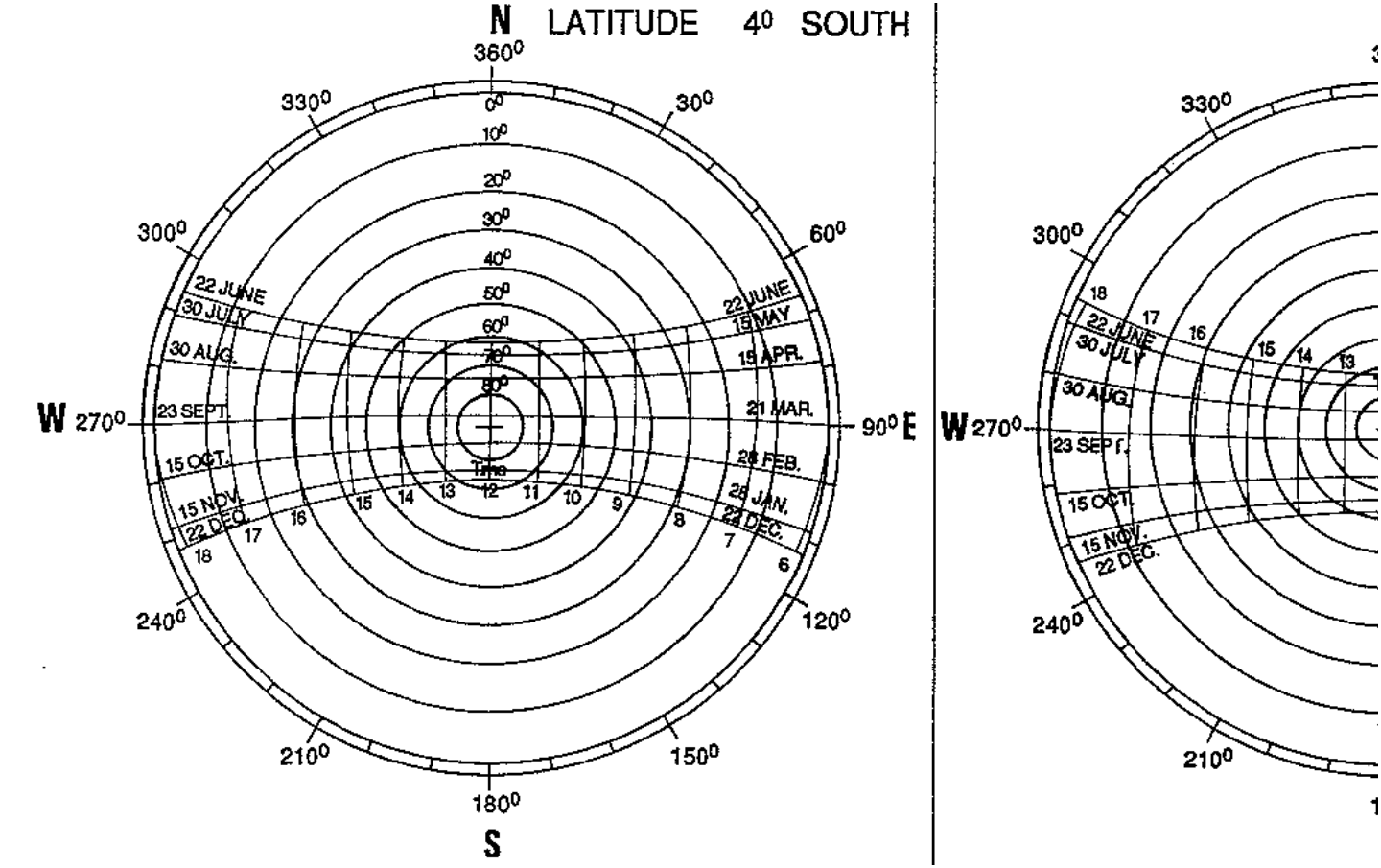
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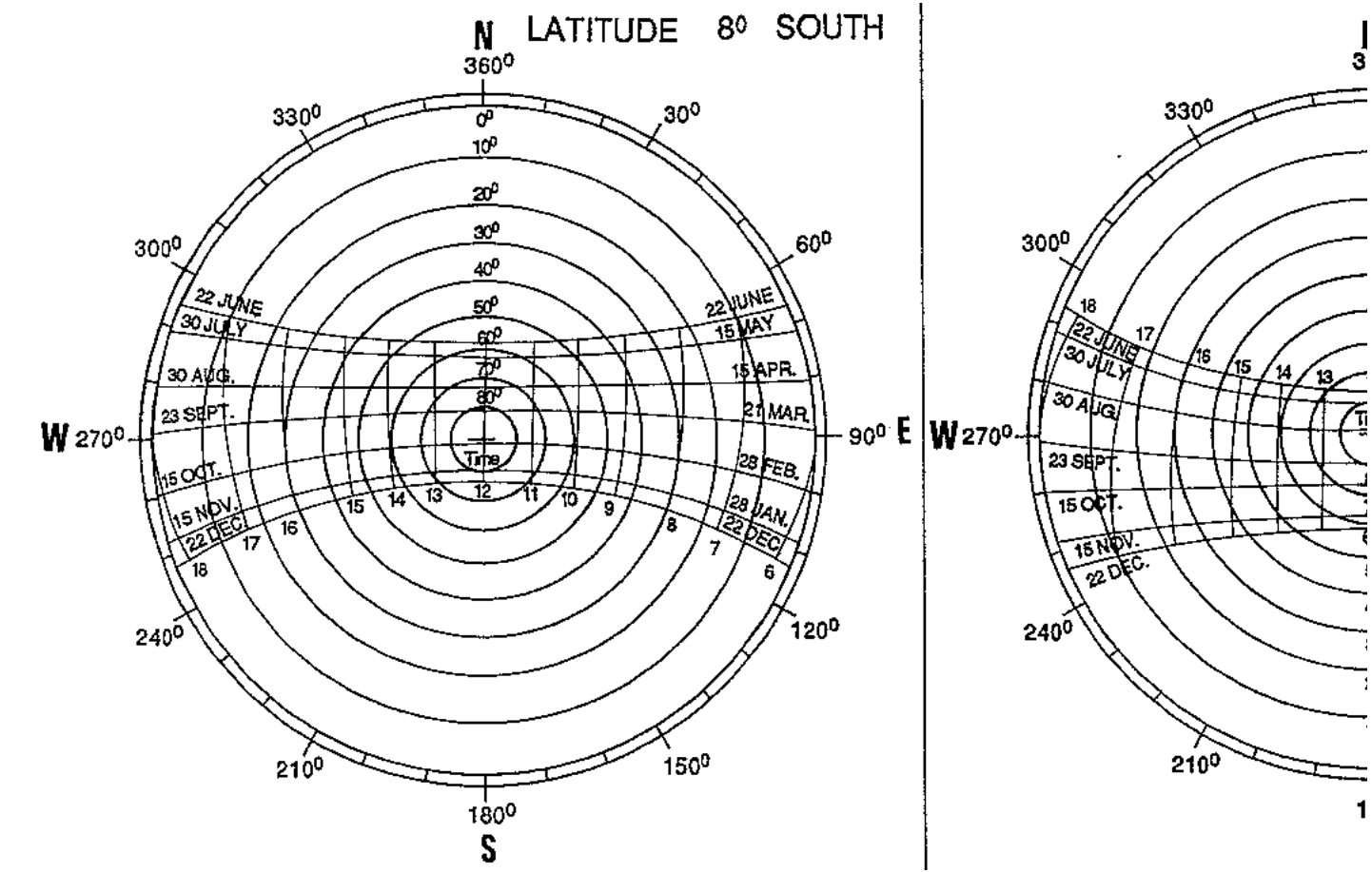
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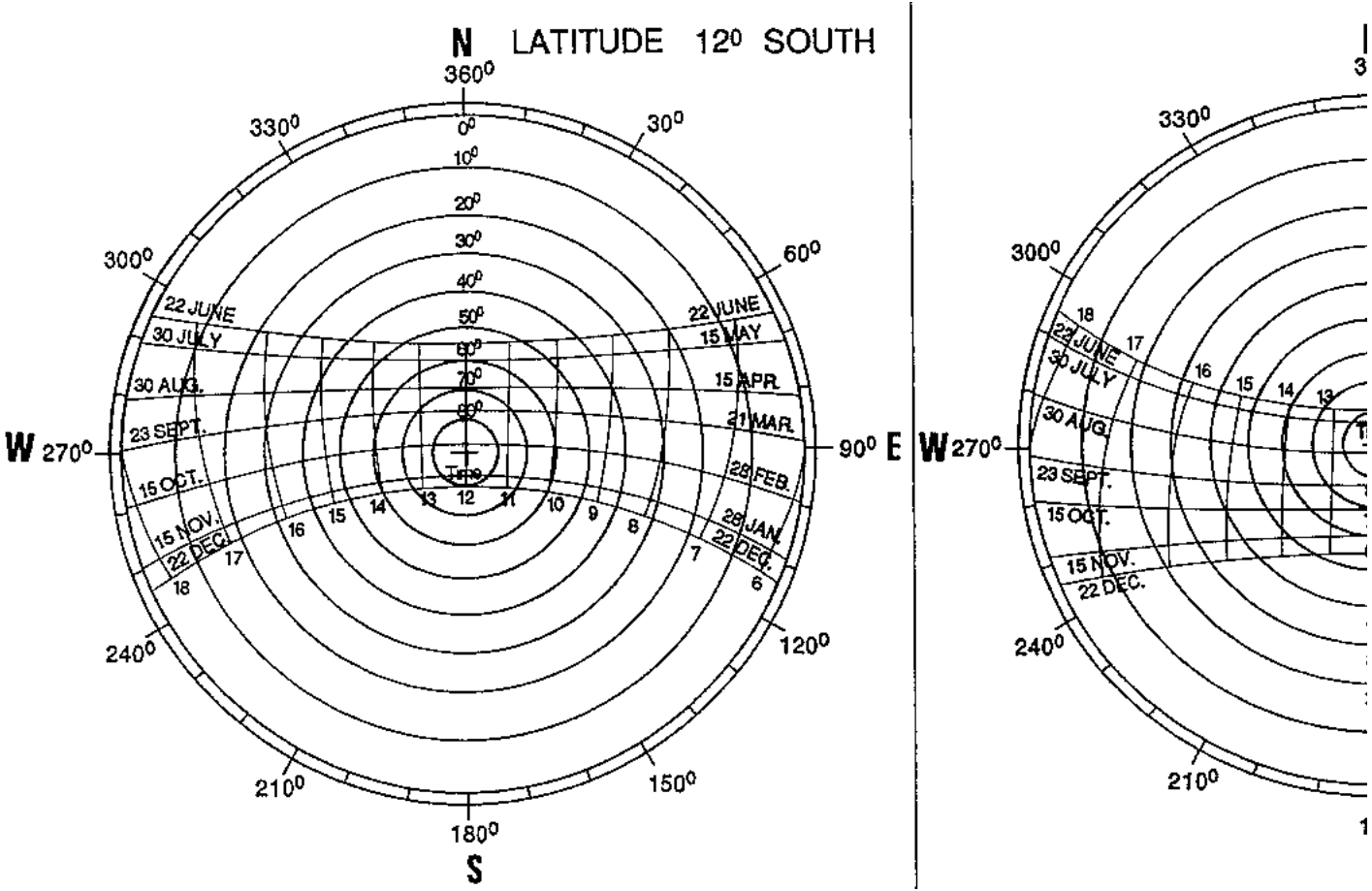
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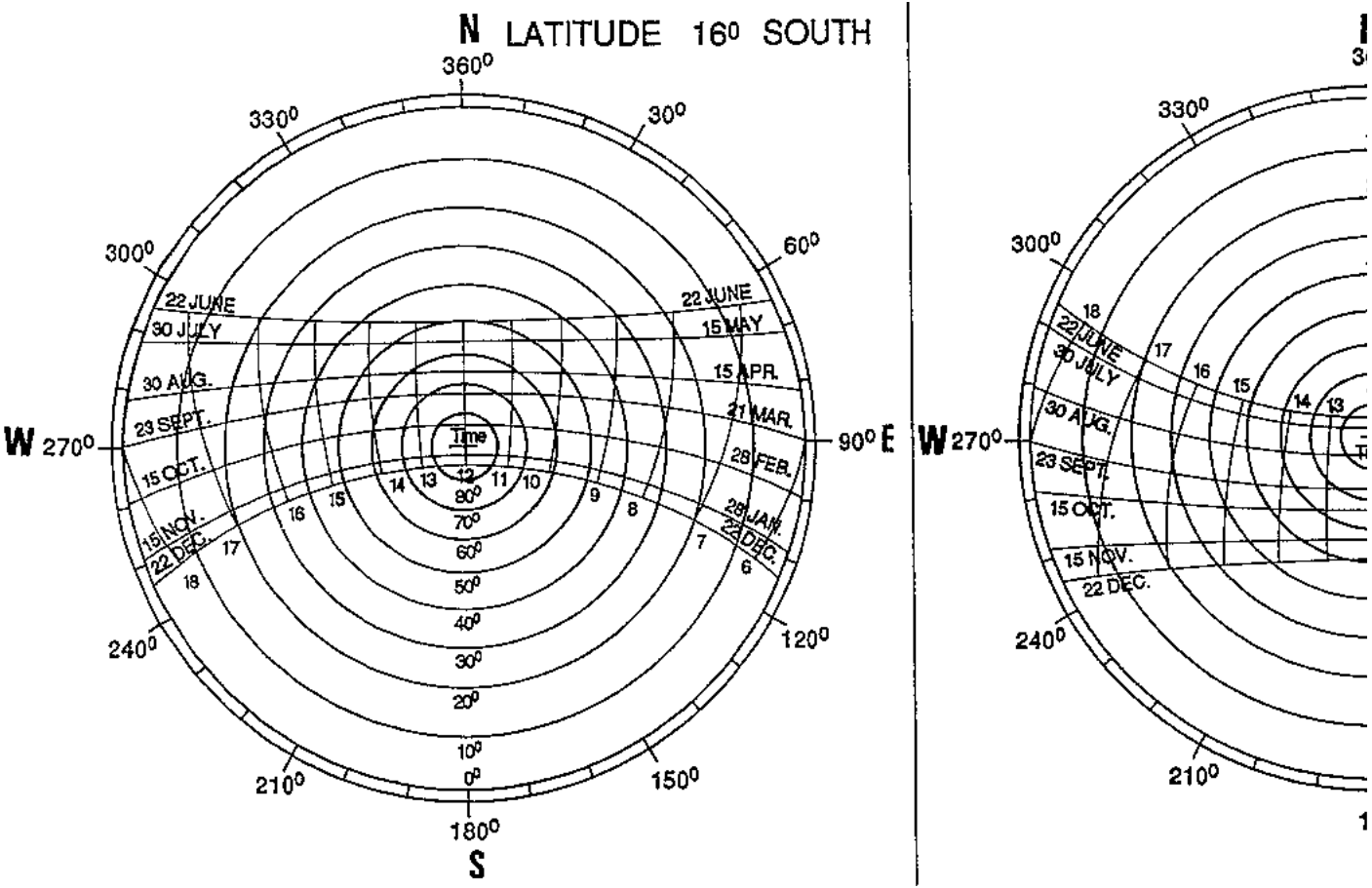
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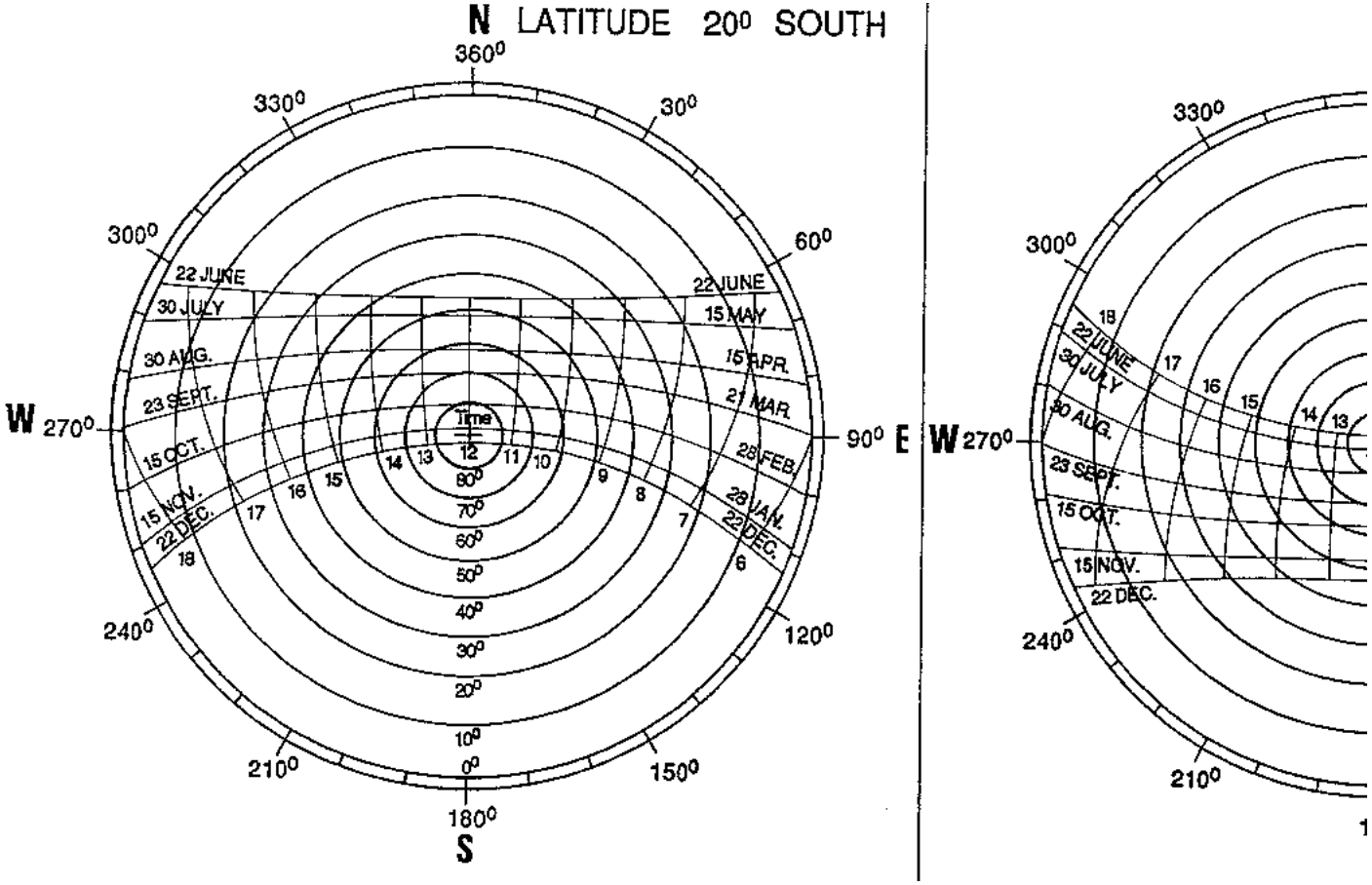
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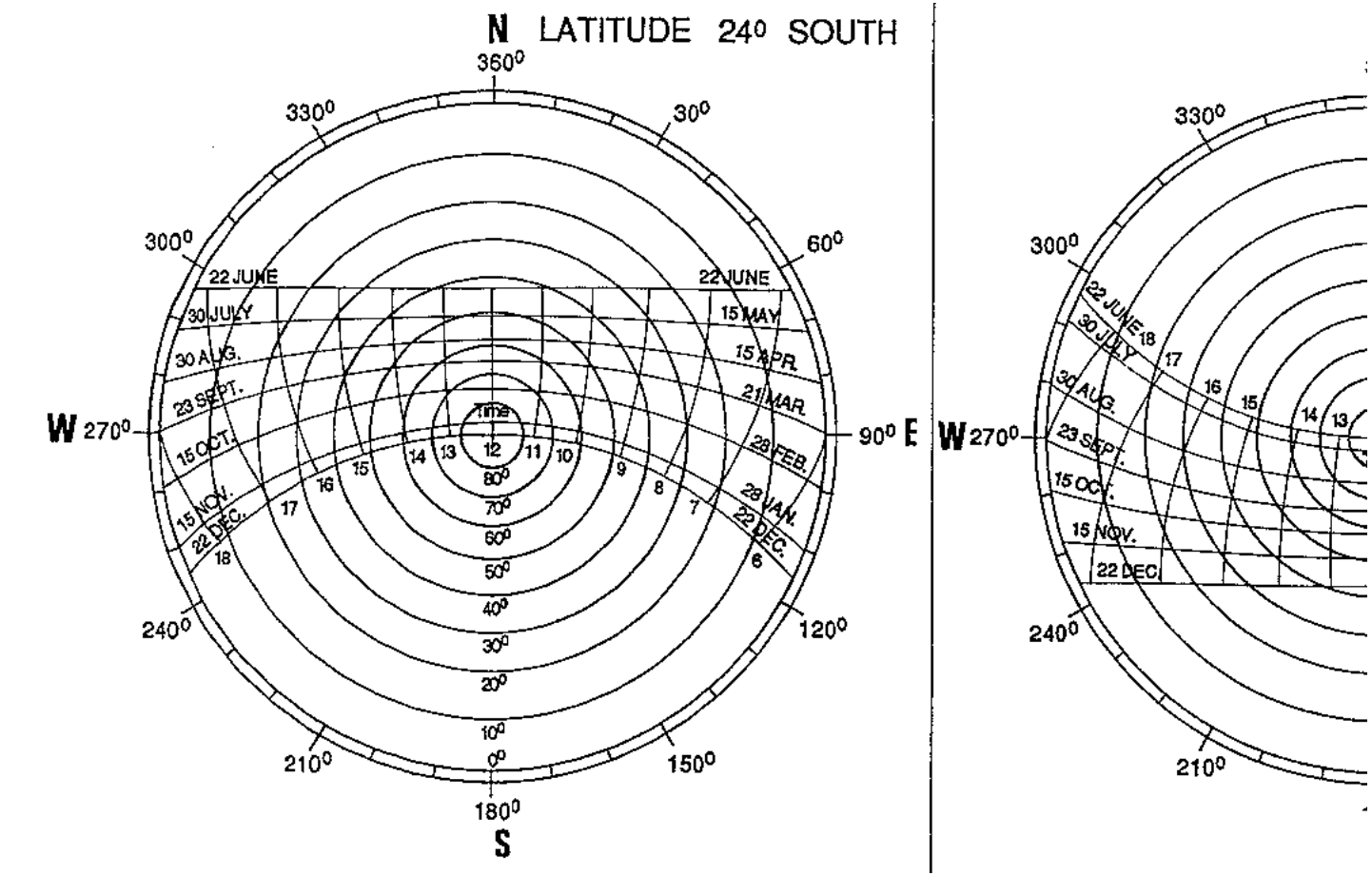
Figure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360°
330°
30°
300°
60°
W 270°
90° E
240°
120°
210°
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180°
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22 JUNE
30 JULY
30 AUG.
23 SEPT.
15 OCT.
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22 DEC.
15 MAY
15 APR.
21 MAR.
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23 JAN.
Time
80°
70°
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50°
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30°
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0°

Figure

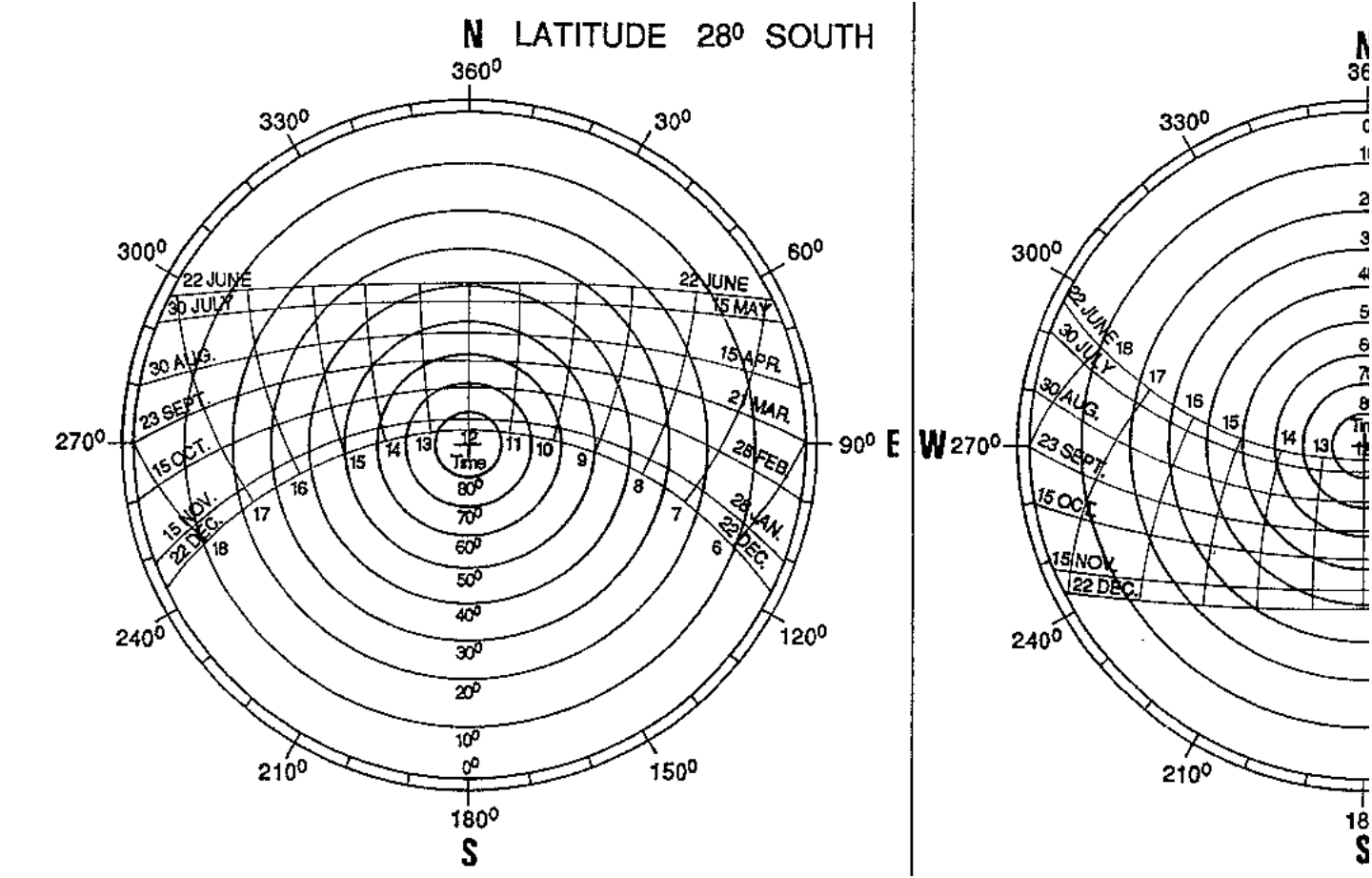
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Figure

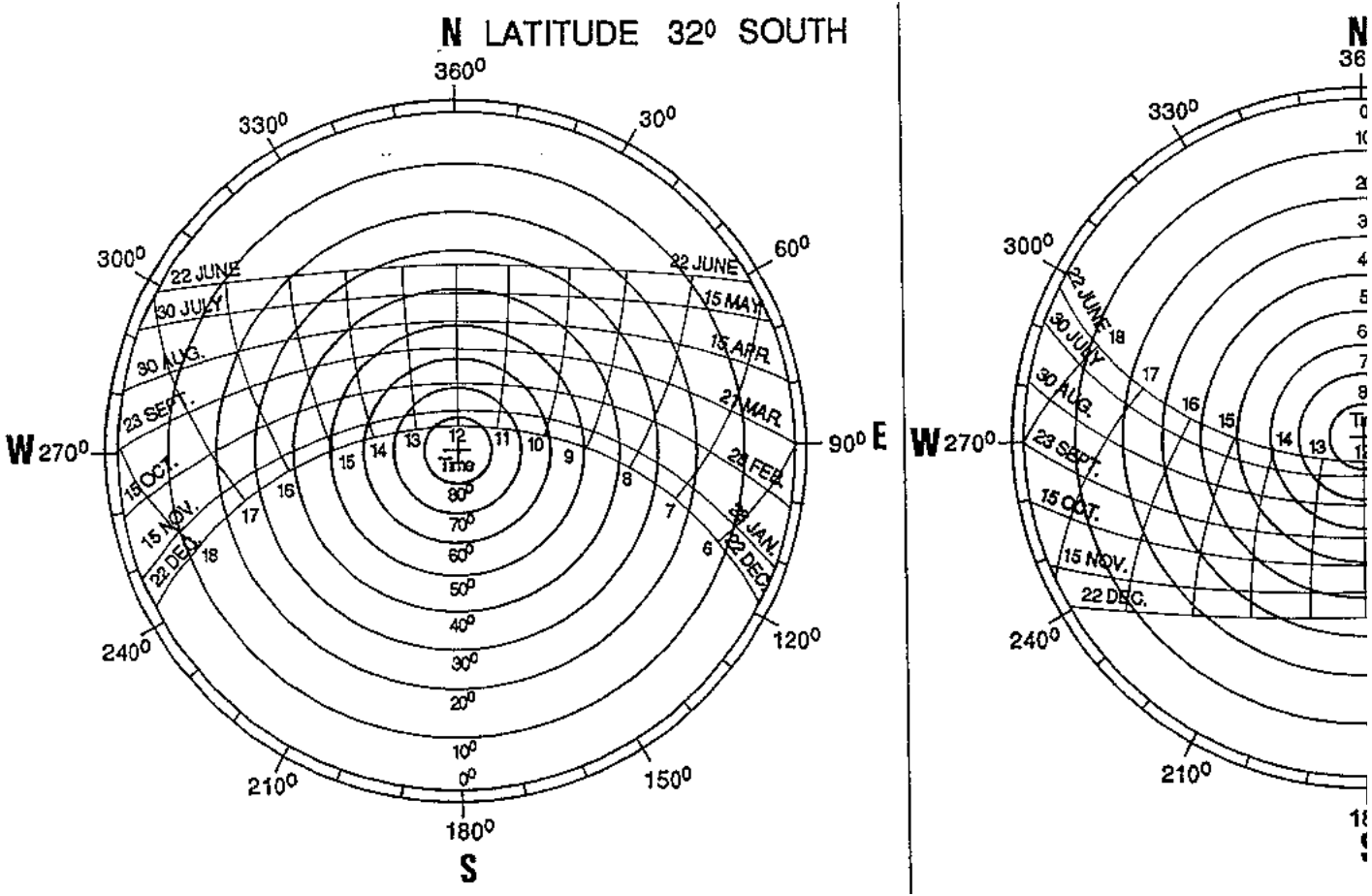
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Figure

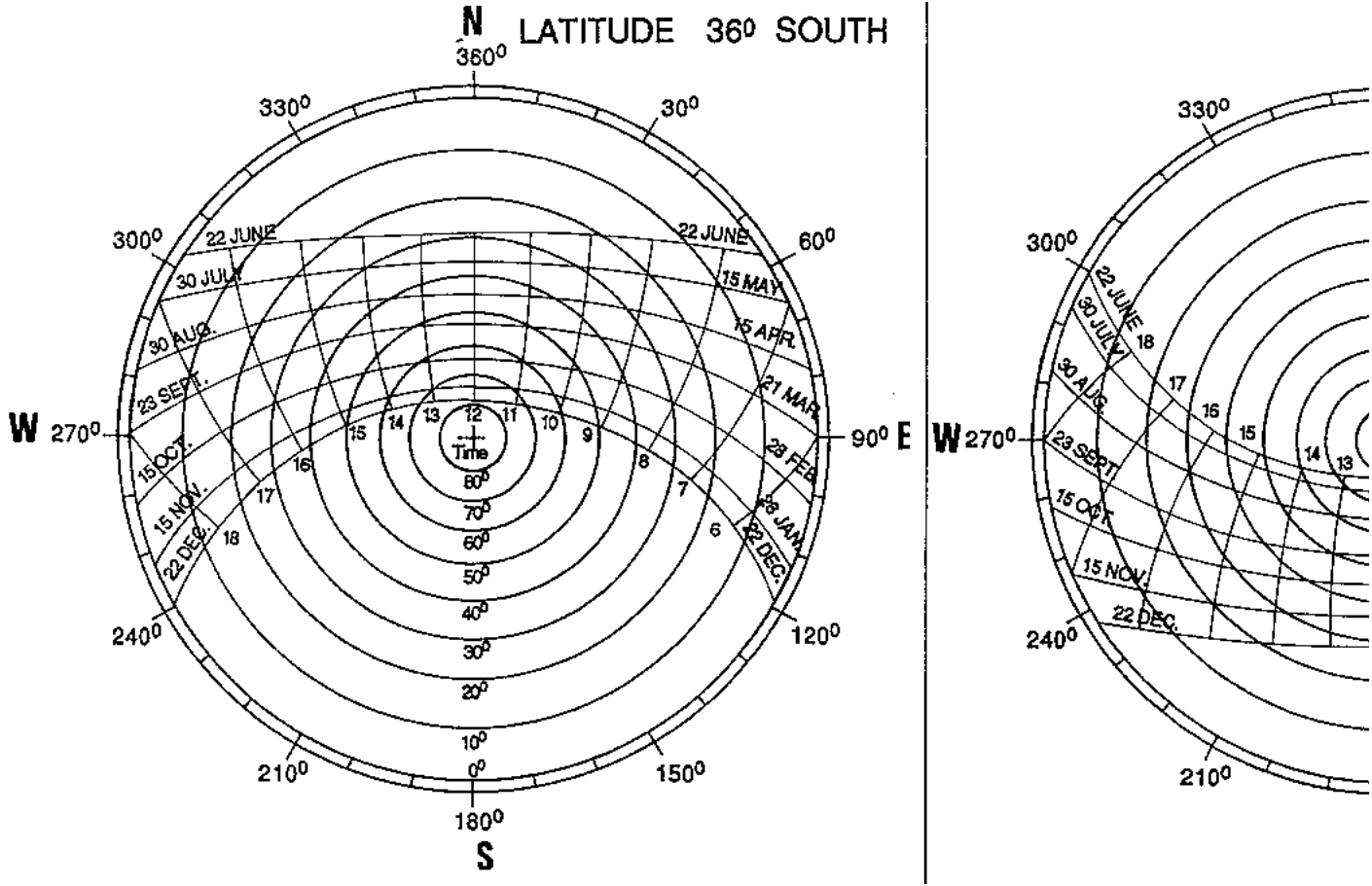
N
LATITUDE 36° SOUTH
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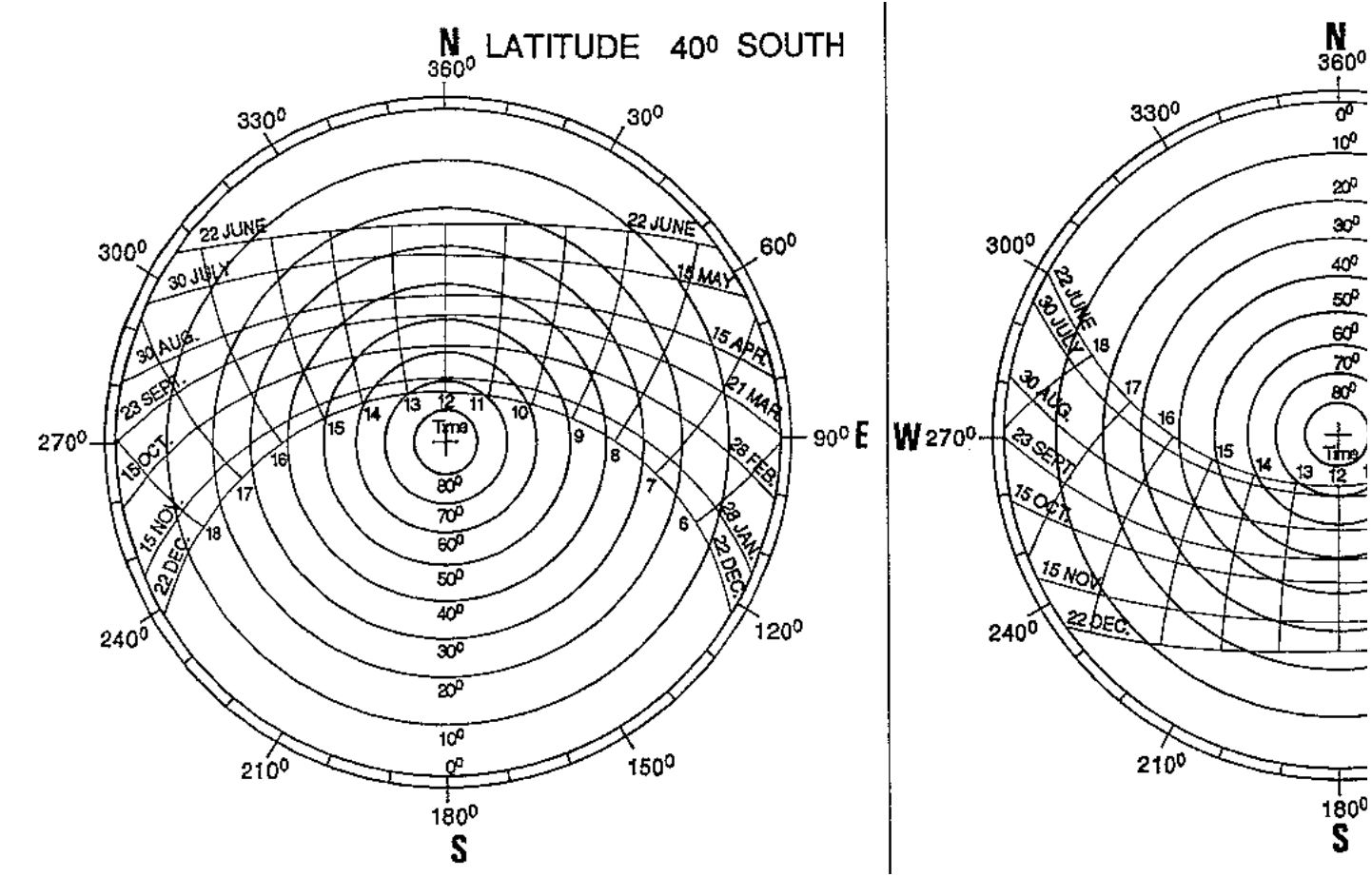
Figure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60°
270°
90° E
240°
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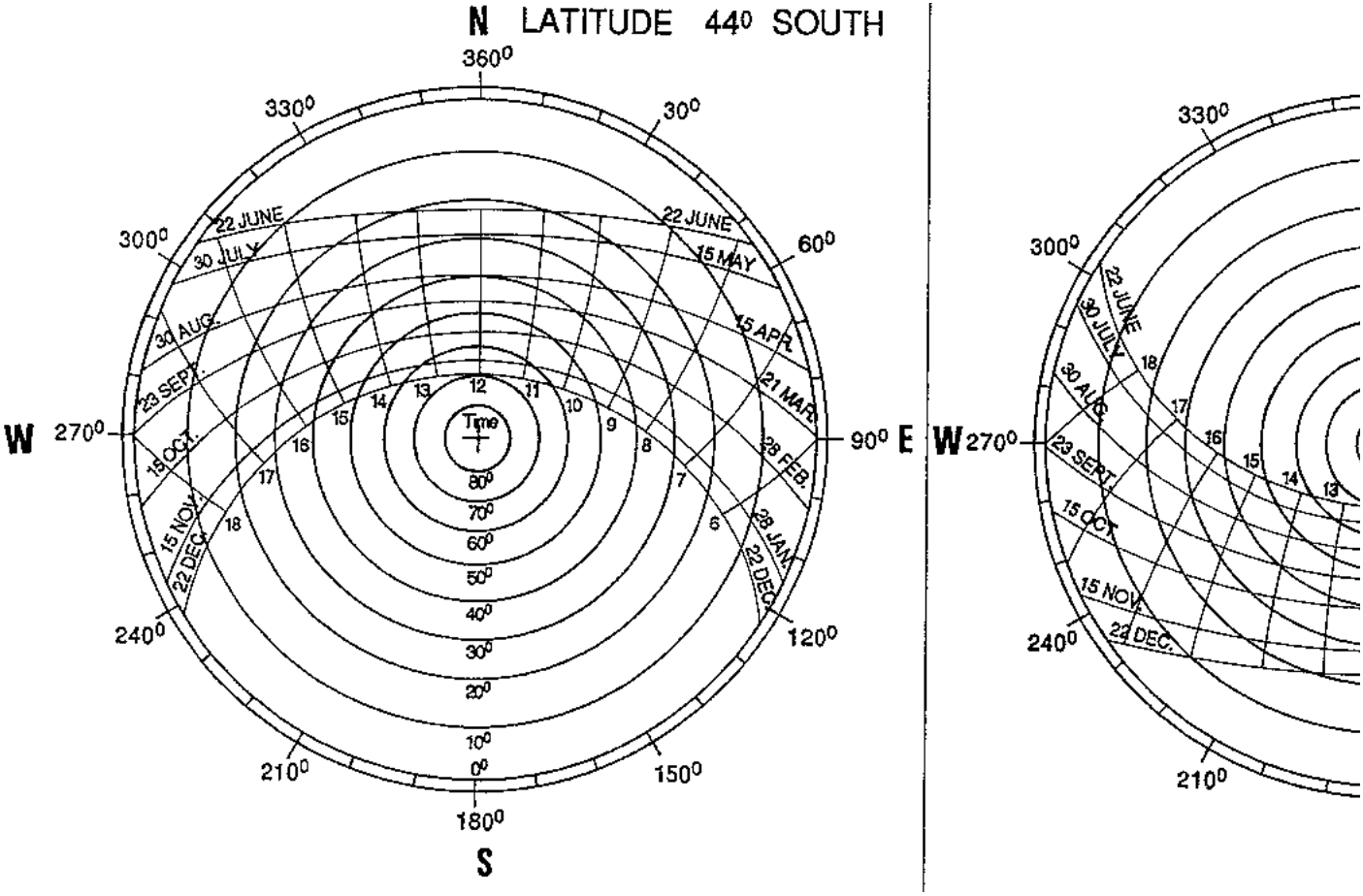
30 JULY
30 AUG.
23 SEPT.
15 OCT.
15 NOV.
22 DEC.
15 MAY
15 APR.
21 MAR.
23 FEB.
23 JAN.
Time
W 270°
0°
10°
20°
30°
40°
50°
60°
70°
80°

Figure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300°
60°
W 270°
90° E
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Figure

5.4 Conversion factors to SI units

Various units Imperial units Obsolescent units etc.	Conversion factors	Metric/Siunits
a) Length		
Units: inch(in)	1 in = 25.4 mm	Units: millimetre(mm)
foot(ft)	1 ft = 30.48 cm	centimetre(cm)
yard (yd)	1 yd = 91.44 cm	metre (m)
mile(mile)	1 mile = 1.6093 km	kilometre(km)
12 in = 1 ft		10 mm = 1 cm
3 ft = 1 yd		100 cm = 1 m
1760yd = 1 mile		1000 m = 1 km
b) Area		
Units: square in (sq in;in²)	1 in² = 6.4516 cm^2	Units: square mm (mm²)
square ft (sq ft; ft²)	1 ft² = 0.0929 m²	square cm (cm²)
square yd (sq yd; yd2)	1 yd² = 0.8361 m²	square m (m²)
acre	1 acre = 4046.86 m²	hectare (ha)
square mile (sq mire)	1 mile² = 2.59 km²	square km (km²)
144 in² = 1 ft²		100 mm² = 1 cm²
9 ft² = 1 yd^2		10000 cm² = 1 m²
4840 yd^2 = 1 acre		10000 m² = 1 ha
640 acre = 1 sq mile		100 ha = 1 km²
c) Volume		

Units: cubic in(cu in; in³)	1 in³ = 16.3871 cm³	Units: cubic cm(cm³)
cubic ft (cu ft; ft³)	1 ft³ = 28.32 dm³	cubic decimetre (dm³)
cubic yd (cu yd; yd³)	1 yd³ = 0.7646 m³	cubic m (m³)
1728 in³ = 1 ft³		1000 cm³ = 1 dm³
27 ft³ = 1 yd³		1000 dm³ = 1 m³
100 ft³ = 1 register ton		
d) Capacity / volume of liquids and gases		
Units: fluid ounce(floz)	1 floz (UK) = 28.4 ml	Units: millilitre (ml)
gill (UKgill)	1 gill (UK) = 142 ml	cubic cm (cm³, ccm, cc)
gill (USgill)	1 gill (US) = 118.3 ml	cubic dm (dm³)
pint (UK pt)	1 pint (UK) = 568 ml	litre (l)
pint(USpt)	1 pint(US) = 454 ml	kilo litre (kl)
quart (UK qt)	1 qt (UK) = 1136 ml	cubic m (m³)
quart (US qt)	1 qt (US) = 909	ml
gallon(UK gel)	1 gal (UK) = 4.546 l	
gallon (US gal)	1 gal (US) = 3.785 l	
barrel	1 barrel = 158.9 l	
5 floz = 1 UK gill		1 ml = 1 cm³
4 floz = 1 US gill		1000 nil = 1 l
4gill = 1 pt (UK, US)		1 l = 1 dm³
2pt = 1 qt (UK, US)		1000 l = 1 kl = 1 m³
4 qt = 1 gal (UK, US)		
1 UK gal = 1.2 US gal		

e) Weight		
Units: ounce(oz)	1 oz = 28.35 g	Units: milligram(mg)
pound(lb)	1 lb = 0.454kg	gram (g)
stone (stone)	1 stone = 6.35 kg	kilogram(kg)
hundred weight (cwt)	1 cwt = 50.8 kg	ton(t)
long ton (UK ton)	1 Ukton = 1.016 t	
short ton (US ton)	1 Uston = 0.907 t	
16 oz = 1 lb	1000 ml = 1 g	
14 lb = 1 stone	1000 g = 1 kg	
8 stone = 1 cwt	1000 kg = 1 t	
112 lb = 14 stone = 1 UK ton		
100 lb = 1 US ton		
f) Density		
Units: lb/cu ft (lb/ft3)	1 lb/ft3 = 16.02 kg/m³	Unit: kg/m³
lb/UK gal	1 lb/UK gal= 100 kg/m³	
lb/US gal	1 lb/US gal= 120 kg/m³	
g) Force		
Units: lbf	1 lbf = 4.448 N	Units: newton (N) [kgm/s²]
tonf	1 tonf = 9.964 kN	kilonewton (kN)
h) Pressure		
Units: lbf/in² (psi)	1 psi = 6895 Pa	Units: pascal (Pa)
tonf/ft² (UK)	1 tonf/ft2 = 107 kPa	kilopascal (kPa)

	1 tonf/ft² = 0.107 Mpa	megapascal (MPa)
		newton/mm² (N/mm²)
		bar (bar)
		1 Pa= 1 N/m²
		1 kPa= 1000 N/m²
		1 bar= 0.1 N/mm²
i) Energy, work, heat		
Units: British thermal unit (Btu)	1 Btu = 1055 J	Units: joule (J) [kgm²/s²]
calorie (cal)	1 cal = 4.186 J	kilojoule (kJ)
	1 cal = 0.000293 kWh	kilowatt hour (kWh)
barrel (crude oil)	1 barrel = 1700 kWh	watt second (Ws)
		newton metre (Nm)
		pascal cubicmetre (Pam³)
		1 J = 1 Nm = 1 Ws = 1 Pam³
		1 kWh = 3600 kJ
k) Power, energy flow rate		
Units: Btu/h	1 Btu/h = 0.293 W	Units: watt (W) [kgm²/s³]
ftlbf/s	1 ftlb/s = 1.356 W	joules/second (J/s)
horsepower (hp)	1 hp = 736 W	hp metric
550 ftlbf/s = 1 hp		1 W = 1 J/s
2545 Btu/h = 1 hp		735.5 W = 1 hp metric
l) Thermal conductivity (k)		
Units: Btu/ft2h°F	1 Btu/ft2h°F = 0.144 WmK	Unit: W/mK

kcal/mh°C1	kcal/mh°C = 1.163 W/mK	
0.124 kcal/mh°C = 1 Btu/ft2h°F		
m) Thermal transmittance (U)		
Units: Btu/ft2h°F	1 Btu/ft2h°F = 5.678 W/m²K	Unit: W/m²K
kcal/m²h°C	1 kcal/m²h°C = 1.163 W/m²K	
n) Density of energy flow rate, intensity		
Units: Btu/ft2h	1 Btu/ft2h = 3.155 W/m²	Unit: W/m²
kcal/m²h	1 kcal/m²h = 1.163 W/m²	langley/h
langley/h	1 langley/h = 11.63 W/m²	
o) Thermal capacity		
Units: Btu/°F	1 Btu/°F = 1899 J/K	Unit: J/K
kcal/°C	1 kcal/°C= 4187 J/K	
p) Specific heat		
Units: Btu/lb °F	1 Btu/lb °F = 4.187 J/kgK	Units: J/kgK
Btu/ft³ °F	1 Btu/ft3 °F = 67 kJ/m³	KJ/m³K
kcal/kg °C	1 kcal/kg °C = 4.187 kJ/kgK	
kcal/m³ °C	1 kcal/m³ °C= 4.187 kJ/m³ K	
kcal/l °C	1 kcal/l °C= 4.187 MJ/m³ K	
	Density x specific heat (J/kgK) = specific heat (J/m³ K)	
q) Velocity		
Units: ft/s	1 ft/s = 0.305 m/s	Units: m/s
miles/h (mph)	1 mph =1.609 km/h	km/h

knot (kn)	1 kn = 1.85 km/h	
	= 0.51 m/s	
		1 m/s= 3.6 km/h
r) Temperature		
Unit: degree Fahrenheit (°F)	1 °F = 0.5556°C	Units: degree Celsius or Centigrade (°C)
	1 °F = 0.5556 K	Kelvin (K)
		1 K = 1°C
		K = °C + 273
		0°C = water freezing point *
		100°C = water boiling point *
		(* at air pressure of 101 kPa)

Conversion of temperature level °F - °C:

°F = 9/5 x °C + 32
°C = 5/9 (°F - 32)

Fahrenheit	**Celsius**
212 °F =	100 °C
194 °F =	90 °C
176 °F =	80 °C

158 °F =	70 °C
140 °F =	60 °C
122 °F =	50 °C
104 °F =	40 °C
80 °F =	30 °C
68 °F =	20 °C
50 °F =	10 °C
32 °F =	0 °C
14 °F =	- 10 °C
- 4 °F =	- 20 °C
- 22 °F =	- 30 °C
- 40 °F =	- 40 °C

5.5 List of possible plant species

Source:Kaiser Talib [-++-]

Scientific Name	Common Name	Characteristics / Uses
a) Shading trees, windbreaks		
Acacia seyal	Acacia	Thorny tree, soil binder for rocky sandy soil
Albizzia julibrissin	Siris	Rapid growth, shade, timber-yielding
Casuarina equisetifolia	She-oak	Evergreen, ideal windbreak, salt tolerant
Eucalyptus	River	Red-GumTall evergreen windbreak, soil binder

camaldulensis		
Eucalyptus citriodora	Lemon-scented gum	Evergreen, multi-trunk, windbreak
Ficus bengalensis	Banyan tree	Excellent shade, dust control, windbreak
Ficus altissima	Pipal	Deciduous, compact crown, cool shade, dangerous roots for buildings
Melia azedarach	China-berry	Deciduous, cool shade, dust erosion control
Prosopis juliflora	Mesquite	Small deciduous tree, deep-rooted soil binder
Tamarix aphylla	Tamarisk	Evergreen, excellent soil binder, salt resistant
b) Ornamental shrub-trees		
Caesalpinia pulcherima	Barbados pride	Spiny shrub, screen, erosion control
Lawsonia inermis	Henna	Evergreen, soil binder, wind and salt resistant
Ficus nitida	Ficus	Evergreen, crown compact, windbreak
Hibiscus rosa sinensis	China rose	Erosion control, drought tolerant, ornamental
Moringa peregrina	Drumstick	Deciduous, soil binder, erosion control
Nerium oleander	Common oleander	Excellent screen, hedge, windbreak
Parkinsonia aculeata	Jerusalem Thorn	Evergreen, drought resistant, soil binder
Plumeria rubra	Frangipani	Succulent shrub, light shade, erosion control
Terrminalia catappa	Indian almond	Deciduous, soil binder, dust control
Thevetia nerifolia	Yellow oleander	Poisonous, soil binder, heat tolerant
c) Palms		
Phoenix dactylifera	Date palm	Evergreen, erosion, dust and glare control

Phoenix canariensis	Canary Island palm	Dwarf form, erosion and reflection control
Washingtonia filifera	Washingtonia palm	Dust control, avenue tree, slow grower
Washington robusta	Washingtonia palm	Dust control, avenue tree, slow grower
d) Ground covers		
Asparagus sprengeri	Asparagus	Evergreen creeper, soil binder, glare control
Bougainvillea spectabilis	Bougainvillea	Thorny timber, erosion & reflection control
Carissa grandiflora	Natal plum	Excellent erosion control, moisture retainer
Clerodendron inerme	False jasmine	Ideal hedge, slope stabilizer etc.
Dodonaea viscosalinn	Clammy hopseed	Woody shrub, ideal hedge, windbreak
Ipomoea pescaprae	Morning glory	Trailing vine, ideal soil binder, ground cover
Jasminum azoricum	Azores jasmine	Shrubby twiner, reflection and heat control
Ocimum basilicum	Sweet basil	Aromatic, ideal for erosion control
e) Cacti / succulents		
Agave americana	Century plant	Ideal slope stabilizer for sandy soil
Americana marginata	Caribbean Aloe	Rock plant, checks glare & erosion
Aloe vera	Aloe	Medicinal, noise and erosion control
Mesembryanthemum sp.	Ice plant	Excellent ground cover, natural desalinator
Opuntia fiscus indica	Prickly pear	Thornless cactus, slope stabilizer, fruit edible