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Computer Programs for Sun and Moon Illuminance With Contingent Tables and Diagrams

by

P. M. Janiczek and J. A. DeYoung

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Nautical Almanac Office

U. S. Naval Observatory Washington, D. C.

CORRECTIONS & NOTES

for

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1. Pages 18 and 28 contain several lines of computer code that are out of proper sequence. Replacements for these pages are attached.

2. It has come to our attention that the BASIC code listed in the Circular may not execute under Microsoft QBasic unless modified. The QBasic interpreter is very limited, especially in regard to program structure and use of subroutines.

3. The program listings provided in Circular 171 and in the attached replacement pages are provided "as is." The U. S. Naval Observatory cannot provide any additional technical support regarding these programs.

Astronomical Applications Department
U. S. Naval Observatory
June, 1999

```
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER IY,IM,ID,IH,L,I,K,N,J,IAZ,IHA
      DIMENSION A(4), B(2)
      RD = 57.29577951D0
      DR = 1.0D0/RD
      A(1) = -0.01454D0
      A(2) = -0.10453D0
      A(3) = -0.20791D0
      A(4) = +0.00233D0
      CE = 0.91775D0
      SE = 0.39715D0
100   WRITE (*,*) ' '
      WRITE (*,*) ' '
      WRITE (*,*) 'INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END) '
      READ  (*,*,END=9999) LO
      LI = DABS(LO)
      WRITE (*,*) 'INPUT LATITUDE (DEG.)'
      READ  (*,*) F
      FO = F
      F = F*DR
      SI = DSIN(F)
      CI = DCOS(F)
125   WRITE (*,*) 'INPUT YEAR (YYYY), NUMERAL'
      READ  (*,*) IY
150   WRITE (*,*) 'INPUT MONTH (MM), NUMERAL'
      READ  (*,*) IM
175   WRITE (*,*) 'INPUT DAY (DD), NUMERAL'
      READ  (*,*) ID
      C = 360.0D0
      J = 367*IY-INT(7*(IY+INT((IM+9)/12))/4)+INT(275*IM/9)+ID-730531
      WRITE (*,*) 'INPUT TIME ZONE SELECTION'
      WRITE (*,*) ' '
      WRITE (*,*) '     0 => TIME IS UT (GMT)'
      WRITE (*,*) '     1 => TIME IS STANDARD (ZONE) TIME'
      WRITE (*,*) '     2 => TIME IS LOCAL MEAN TIME'
      READ  (*,*) Z
      ZT = Z
      DT = 0
      IF (Z .EQ. 0.0D0) DT =-LO/360.0D0
      IF (Z .EQ. 1.0D0) DT = (LI-15.0D0*DINT((LI+7.5D0)/15.0D0))/C
     &  *DSIGN(1.0D0,-LO)
200   WRITE (*,*) ' '
      WRITE (*,*) ' '
      WRITE (*,*) 'INPUT TIME OF DAY AS HOURS AND MINUTES OF 24',
     &  ' HOUR CLOCK (HHMM), OR'
      WRITE (*,*) 'INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA',
     &  ' (RISE/SET, ETC.), OR'
      WRITE (*,*) 'INPUT NULL LINE TO END'
      READ  (*,*,END=9999) H
      IF (H .GE. 0.0D0) GOTO 600
      WRITE (*,205) LO,FO
```

```
10 DEF FNARCOS (ARG) = 1.570796 - ATN(ARG / SQR(1! - ARG * ARG))
20 DEF FNARCSIN (ARG) = ATN(ARG / SQR(1! - ARG * ARG))
30 DEF FNDEG (ARG) = INT(ARG) + ((ARG - INT(ARG)) * 10!) / 6!
40 DEF FNDMS (ARG) = INT(ARG) + 6! * (ARG - INT(ARG)) / 10!
50 RD = 57.29578
60 DR = 1! / RD
70 DIM A(4)
80 DIM B(2)
90 A(1) = -.01454
100 A(2) = -.10453
110 A(3) = -.20791
120 A(4) = .00233
130 CE = .91775
140 SE = .39715
150 INPUT "LONGITUDE IN DEG."; LO
160 LI = ABS(LO)
170 INPUT "LATITUDE IN DEG."; F
180 F = F * DR
190 SI = SIN(F)
200 CI = COS(F)
210 INPUT "YEAR (4 DIGITS)"; IY
220 INPUT "MONTH (NUMERAL)"; IM
230 INPUT "DAY (NUMERAL)"; ID
240 C = 360!
250 J = 367*IY - INT(7*(IY + INT((IM+9)/12))/4) + INT(275*IM/9) + ID - 730531!
260 INPUT "UNIVERSAL TIME = 0, ZONE TIME = 1, LOCAL MEAN TIME = 2"; Z
270 DT = 0!
280 IF Z = 0! THEN LET DT = -LO / C
290 IF Z = 1! THEN LET DT = -(LI - 15 * INT((LI + 7.5) / 15)) / C * SGN(LO)
300 INPUT "HOUR (4 DIGIT NUMERAL ON 24 HOUR CLOCK)"; H
310 Z0# = J - .5
320 IF H > 0 THEN GOTO 870
330 PRINT "DATA FOR "; IY; ", MONTH "; IM; ", DAY "; ID
340 FOR L = 1 TO 4
350 ON L GOTO 370, 650, 650, 360
360 C = 347.81
370 M = .5 + DT
380 K = 1
390 M = M - DT
400 E = M - LO / 360!
410 GOSUB 430
420 GOTO 530
430 D# = Z0# + E
440 IF ABS(E) >= 1 THEN LET E = E - SGN(E)
450 GOSUB 1220
460 IF L = 4 THEN GOSUB 1720
470 T = T + LO + 360! * E
480 T = T - INT(T / 360!) * 360!
490 U=T-AS
500 IF ABS(U) > 180! THEN LET U = U - 360! * SGN(U)
510 U = U / C
520 RETURN
```

CONTENTS

INTRODUCTION

There is an ever increasing need for quantitative information concerning everyday astronomical events as they affect the range of private, civil and military activities. The information most needed is usually one or a combination of the following:

1. rise and set times of the Sun and Moon,
2. beginning and ending times of twilight,
3. total number of daylight hours,
4. maximum height of the Sun or Moon above the horizon with corresponding time of occurrence,
5. at specific instants, the angular distance of the Sun or Moon from the horizon and from a cardinal direction,
6. the amount of natural light at a designated time of day or night.

These data not only may differ from day to day (continuously in the case of 5. and 6.), but also differ appreciably as experienced at one place on the Earth as opposed to another, even at the same instant.

Despite the calculational complexities implied, it is possible not only to satisfy the needs for all such data in a straightforward way, but also to place appropriate tools for producing the data directly into the hands of those who need it. This publication is intended for a large number of people who have requirements for the type of data listed, but whose education has placed no special emphasis on astronomy. In what follows there are the means for calculating the needed information either by one of the self-contained computer routines provided, or by use of tables, diagrams (also included) and simple arithmetic. There is no requirement to understand the theory of the calculations; and the mathematical development is not given. To properly specify the quantities required by the calculations and to properly interpret the results however, the associated terminology should be familiar. Section I, therefore, is a list and discussion of terms.

Electronic computing has steadily become more accessible and inexpensive. Accordingly, three versions of a self-contained computing routine are described and provided in Section II. The first is a FORTRAN program for use with a variety of personal (and larger) computers for which FORTRAN compilers are available. A version in BASIC is provided to use with personal computers for which that programming language is appropriate. A third program, also in BASIC (but in a separate dialect) is given. It was designed for so-called pocket computers and powerful, programmable calculators which incorporate BASIC interpreters. For successful implementation of a computer routine, the user must learn how to use the specific device and must satisfy the syntax requirements of its compiler or interpreter.

Use of a computing device is not always possible. But it is possible to obtain the same data, at least for the Sun, from the tables and diagrams which are included here, with instructions, as Section III.

The methods used to construct the tables, graphs and computer codes are approximate and give times of events to the nearest minute and angles to the nearest degree. At latitudes less than 60 degrees, the output of the computer routines should agree with more refined calculations to within one or two minutes of time. The tables may be expected to give less precise times (up to four minutes in certain cases) on account of those compromises in their construction which maintain simplicity. At extreme North and South latitudes more exacting calculations are generally necessary to achieve one minute of time precision; and in comparisons, the computer routines provided here produced errors of up to four minutes and, in one case, failed to find a phenomenon altogether. Although it is possible to improve the precision of both the computer procedure and the tables, the improvements are not justified for several reasons:

1. the price to be paid would be much larger, slower computer code in the first instance, and a lengthy, complex table look-up and calculation process in the second;
2. the user would be required to specify geographic coordinates and the instantaneous orientation of the Earth in space, define the actual terrain and measure atmospheric parameters to an accuracy that is not attainable except in extraordinary circumstances;
3. rising, setting and twilight are always physically uncertain to some extent, and definitely so at extreme latitudes;
4. a critical examination of the conduct of any human activity almost always demonstrates that very precise times of astronomical events and precise light levels are simply not needed.

The computer and tabular procedures were designed to be valid for the 30 year period beginning at 1985. If used beyond this interval, the degradation in precision will be gradual but definite.

SECTION I

Description of Terms

This section is meant to be read from the beginning. Terms are introduced as needed or as they occur; consequently, they are not in alphabetical order.

Meridian: At any point on the Earth one might imagine a line that passes through that point and meets the North and South poles. Such a line, known as the meridian, also intersects the Earth's equator at right angles. Any point on the Earth has only one meridian, but each meridian passes through many points.

Latitude, Longitude: In order to unambiguously specify the location of a point on the Earth, two numbers (called coordinates) are needed. One of the numbers is the latitude, or the distance of the point from the equator. Latitude is expressed as an angle and measured northward or southward from zero degrees at the equator, along the meridian of the point, to the point itself. The other required number is the longitude, which is the distance of the meridian of the point from a reference (prime) meridian. Longitude is also expressed as an angle, and it is measured eastward or westward, from the prime meridian which passes through Greenwich, England, to the meridian of the point of interest. In this system of coordinates, the maximum possible latitudes are 90 degrees North, which is the position of the North Pole, and 90 degrees South, which corresponds to the South Pole. At 180 degrees West or East of the prime meridian is the International Date Line (certain parts of the Date Line depart from 180 degrees in order to accommodate geographic boundaries) and 180 degrees is the maximum value (limit) of longitude. See Figure 1.

The latitude and longitude of a place must be known in order to use the materials in the next two sections. There are many sources for coordinates. For example, an atlas or gazetteer is a convenient reference. Survey records as well as maps and charts issued by governments are usually obtainable. Coordinates may be obtained directly from various navigation systems now in use; certainly during long distance travel in open ocean the navigation-determined position is the only source. Appendix A to this publication lists coordinates for many locations in the United States. The user should be aware that the conventional manner of stating coordinates is degrees, minutes (and sometimes also seconds) of arc. For computer input degrees and decimals of a degree is the more convenient form.

Date, Time: The complete statement of an event such as sunset or an instantaneous position such as the altitude of the moon, relative to a location on the Earth, must include the date (year, month, day) and time of day. Specification of the date (in the Gregorian Calendar) poses no special problem; but one complication may arise and it will be discussed below. The time of day may be stated in several ways. Local Mean Time, although not an everyday term, arises naturally during the

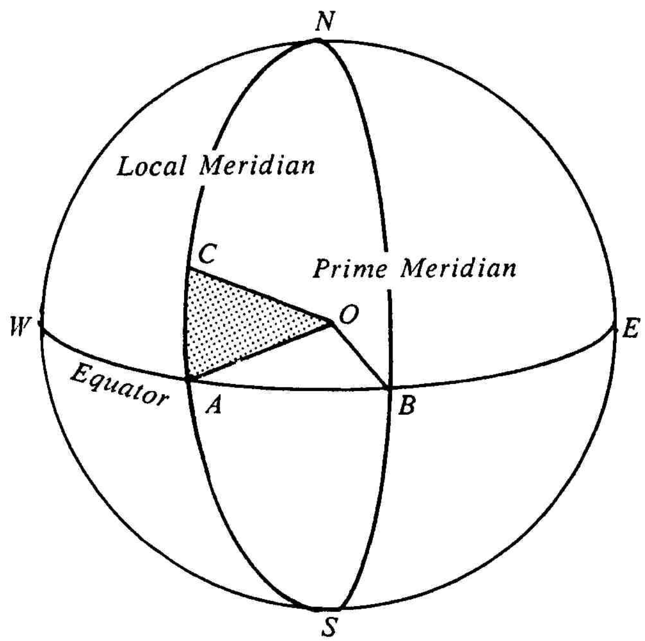


Figure 1 -- In this representation of the Earth, the North and South poles are at N and S, the equator is denoted by the arc WABE and the center of the Earth is at point O. Arc NCAS is the Local Meridian of the point C on the surface of the Earth; arc NBS is the Prime Meridian. Arc AC is the latitude of point C and is equal to the angle between the lines OC and OA. Arc BA is the longitude of point C and equal to the angle between the lines OB and OA.

procedures of Sections II and III. It is a measure of time referred to the meridian of the location of interest. As such, it is an isolated time measure of no importance to any other meridian. Times which are the input and output quantities of the computer routines may be expressed as Local Mean Time at the users discretion.

The most widely used system of specifying time is that of Zone Time or Standard Time. In that system, the Earth's 360 degree circumference is divided into 24 zones; and at all locations within each zone, all clocks are set to the same hour and minute. From any zone to the next adjacent zone, the Standard Time differs by exactly one hour. The geometrically obvious method for dividing the Earth into 24 zones is to place the boundaries at integral multiples of 15 degrees in longitude. In practice, the limits are established by considerations of commerce, transportation and political boundaries. On a global scale, the departures from uniform 15 degree divisions are small, and the methods of the next two sections provide for time adjustments based on zones that are exactly 15 degrees apart. An additional practical complication for the Standard Time zone system is a seasonal one in which the legal time for a political entity may be temporarily advanced by one or more hours. The dates of the year when these periods are in effect vary among the countries of the world which use such Daylight (Savings) or Summer Time and no general guidelines can be given for converting to and from Standard Time, except to note the necessity for the user to maintain awareness.

Universal Time, equivalent to the previously used Greenwich Mean Time for ordinary purposes, is the time kept on the Greenwich meridian -- at zero degrees longitude. It is widely used elsewhere, especially for purposes of long distance communication, since it avoids questions of zone boundaries and advanced time. The computer routines of Section II incorporate provisions for the use of Universal Time, under control of the user, and a table is given in Section III for adjusting among Mean, Zone and Universal Time systems for calculations without a computer.

When the longitudes of two places differ considerably and Universal Time is used, it is convenient to maintain time in a 24 hour notation, as it eliminates the suffix A.M. or P.M. from calculations and thereby reduces the chance for blunders. In the 24 hour notation, which maintains its advantage when computing with zone or mean time, the hours from midnight beginning the day until noon are the same as ordinary clock time. From noon until the end of the day, the hours are denoted by the numerals 12 through 23. When this system is used, the minutes part of the hour are appended to the hour to form a 4 digit number, without a colon separating the two. Thus, for example, 8:15 A.M. is written 0815 and 9:47 P.M. becomes 2147. The advantages of the 24 hours notation are so great that it is used throughout the remainder of this publication.

When the end result of calculation by the methods of the next sections produce one or more times exceeding 24 hours, the time or times may be adjusted by 24 hours provided the calendar date is advanced by one day. The computer routines should never yield negative times, but the calculations of Section III may. In those cases, 24 hours may be added to make the times positive, provided the calendar date is also retarded by one day.

Meridian Passage: For any specific meridian, the Sun will cross it at some instant during the course of a day. Put another way, at any arbitrary time during a day, the Sun is crossing some meridian of the Earth. These statements are true even for arctic regions where the Sun may not be visible for months. Generally, the same statements may be made for the Moon. However, about once per month the Moon may cross a particular meridian a little before the midnight beginning a day and again a little past the midnight beginning the next day, so that there is no crossing on the day itself. Neither the Sun nor the Moon cross any specific meridian at exactly the same time every day; but since the crossings are significant in several applications, the times of occurrence may be calculated. The time when the Sun or Moon crosses the meridian of a place is designated meridian passage.

Horizon: Wherever one is located on the surface of the Earth, the Earth in the immediate vicinity appears essentially as a flat plane, while the sky appears much like the interior of a sphere or dome. The horizon is the intersection of the sky with the plane and appears to be a large circle with its center at the observer, just as the sky appears as one-half of a large sphere also centered at the observer.

Rise, Set: During the course of a day the Earth rotates once on its axis causing the phenomena of rising and setting. All celestial bodies, stars and planets included, seem to appear in the sky at the horizon to the East of any particular place, then to cross the sky and again disappear at the horizon to the West. The most noticeable of these events, and the most significant in regard to ordinary affairs, are the rising and setting of the Sun and Moon. Because the Sun and Moon appear as circular disks and not as points of light, a definition of rise or set must be very specific, for not all of either body is seen to rise or set at once; and the quantitative information that is usually required is the time at which a rise or set occurs. Therefore, sunrise and sunset are considered to occur when the upper edge of the disk of the Sun appears to be exactly on the horizon. The same statement applies to the Moon.

The times of rising and setting produced by the methods in this publication refer to the upper edge of the Sun or Moon. In addition, the computed times are for a horizon that is unobstructed relative to the location of interest, the atmospheric conditions are average and the location is in a level region on the Earth's surface.

For points on the Earth North of the Arctic Circle and South of the Antarctic Circle, rising and setting do not occur at an unbroken daily interval. There are days when the Sun and Moon do not rise or do not set. In limiting cases during the solar year, and during the lunar month, rising and setting are physically uncertain at such extreme latitudes.

Length of the Day: The total number of hours of daylight refers to the interval from the moment of sunrise until that of sunset. The meaning of the expression length of the day is somewhat arbitrary since there is some indirect sunlight available before sunrise and after sunset. Associating the length of the day with the discrete events of rise and set permits a definite measure of time to be assigned to the interval of daylight.

Twilight: Before sunrise and again after sunset there are periods of time, twilight, during which there is natural light provided by the upper atmosphere, which scatters sunlight. Some outdoor activities may be conducted without artificial illumination during these periods, and it is useful to have some means to set limits beyond which a certain activity must be assisted by artificial lighting if possible or, if not, then terminated. The major determinant of the amount of natural light during twilight is the atmosphere. Nevertheless, it is possible to establish useful though necessarily approximate limits applicable to large classes of activities by considering only the position of the Sun below the local horizon. Several arbitrary but reasonable definitions have evolved. Thus, *civil twilight* begins in the morning and ends at sunrise or begins at sunset and ends in the evening when the Sun is geometrically six degrees below the local horizon. Before morning civil twilight and after evening civil twilight, artificial illumination is ordinarily required. *Nautical twilight* begins in the morning and ends in the evening when the Sun is geometrically 12 degrees below the horizon. As the name implies, the principal use of the term nautical twilight is in navigational astronomy, and during the intervals between civil twilight and nautical twilight the brightest stars are visible and the sea horizon is clearly defined. Before morning nautical twilight and after evening nautical twilight the horizon is generally not visible and cannot be used as a reference without aided vision. *Astronomical twilight* begins and ends when the Sun is geometrically 18 degrees below the horizon. It is of significance principally in observational astronomy and indicates those times when scattered Sunlight on a horizontal surface becomes approximately equivalent to the light of the night sky. Times of civil and nautical twilight are provided by the computer routines in Section II and from the tables of Section III. The amount of available light during twilight is so greatly dependent upon the atmosphere, and especially upon cloudiness and haze, that only the most conservative approach to interpreting the times of twilight is justified when considering outdoor activity.

Altitude: As in the case of a position on the Earth, two coordinates are required to specify the position of an object on the sky. For convenience, one coordinate is measured in the sky and is known as altitude (in some applied sciences it is called elevation). The other coordinate is measured along the horizon on the plane of the observer, which is the other "half" of the observer's " universe." From the point that is directly above the location of interest (position of the observer) an arc (curved line) may be drawn through the point occupied by the object in the sky and extended to the horizon. The arc meets the horizon at a 90 degree angle and is, therefore, perpendicular to the horizon. The altitude is an angle measured along the arc from the point where the arc meets the horizon, upward to the point occupied by the celestial object. The maximum altitude that an object may possibly have is 90 degrees, when it is directly above the geographic point of interest, and the object is then said to be "in the zenith." When meridian passage of an object occurs, the altitude is (or is nearly) a maximum (not usually 90 deg.) and the altitude at that instant takes on special significance to navigation and surveying. The Sun's altitude at meridian passage also has special interest in solar energy studies. See Figure 2.

Azimuth: On the horizon plane of an observer, or at some other location of interest, the meridian provides a North, South reference line. It may be thought of as a straight line extending from the observation point to true North (or South). Another straight line may be imagined to connect the observation point to the point on the horizon from which altitude is measured. The angle between these two lines is called the azimuth (of the object in the sky). The angle is measured along the horizon from North (zero degrees) toward East (90 degrees), and completes 360 degrees around the entire horizon. Azimuth, with altitude, allows the complete specification of a point or object in the sky, relative to a point or location on the Earth. See Figure 2.

Illuminance: This term may be defined as the flux received on a unit area of a surface. Flux is defined as the amount of radiation in a unit of time, usually the second. In the context of this publication, the definitions require qualification. Here, we refer to radiation only in the visible portion of the electromagnetic spectrum; that is, radiation capable of stimulating the human sense of sight. The illuminance calculated within the computer routines, and exhibited graphically in Section III, refers to visible natural light only. Further, the light of the sky is included and, therefore, the sea level, horizontal surface is assumed to be exposed to all parts of the sky. In ordinary terms then, illuminance is the amount of natural light reaching the surface of the Earth. The illuminance is given in lux, or lumens per square meter. The older term foot-candle may be more familiar to some, and to obtain illuminance in foot-candles, divide the quantity given in lux by 10.764. In addition to the restrictions already mentioned, the condition of the atmosphere modifies the illuminance to a considerable degree. This is accommodated in a rough way by the computer routines and graphs. At the user's option, the values of illuminance are divided by the numbers assigned to the conditions stated:

- 1 - Average clear sky, less than 70 percent covered by (scattered) clouds; the direct rays of the Sun or Moon are unobstructed relative to the location of interest.
- 2 - The Sun or Moon easily visible but direct rays obstructed by thin clouds.
- 3 - The direct rays of the Sun or Moon are obstructed by average clouds.
- 10 - Dark stratus clouds cover the entire sky.

The recommended approach to interpreting calculated illuminance is to consider the numbers as threshold values which, without additional knowledge, determine only whether a particular activity should not be planned or carried out. Even simple questions such as driving without headlamps, or detecting and identifying distant objects cannot be completely decided by knowledge of the illuminance alone. Other information specific to the illuminated surfaces, the nature of the activity, the conditions of vision, and other immediate circumstances must be included in planning and decision making processes.

The value of the illuminance calculated by the computer routines may appear in the output as a number with as many as 10 digits. Only the first two digits are significant, the remainder are necessary to accommodate the extreme variability of the illuminance - 124000 lux to .0005 lux.

Calculation of illuminance is described in more detail in Appendix B.

Percent of the Moon Illuminated: Considering the Moon as a circular disk, the ratio of its illuminated area to its total area is the fraction illuminated. The percent illuminated is the same number multiplied by 100. At New Moon the percent illuminated is 0; it is 50 at First and Last Quarters, and 100 at Full Moon. Percent of the Moon illuminated is produced by the computer routines; but independently of the fraction or percent illuminated, the amount of light provided by the Moon may vary by a factor of 300, depending upon the Moon's altitude above the horizon. The percentage illuminated, therefore, is of value principally during the initial stages of planning, preferably when it is available in the form of a daily or half-daily tabulation.

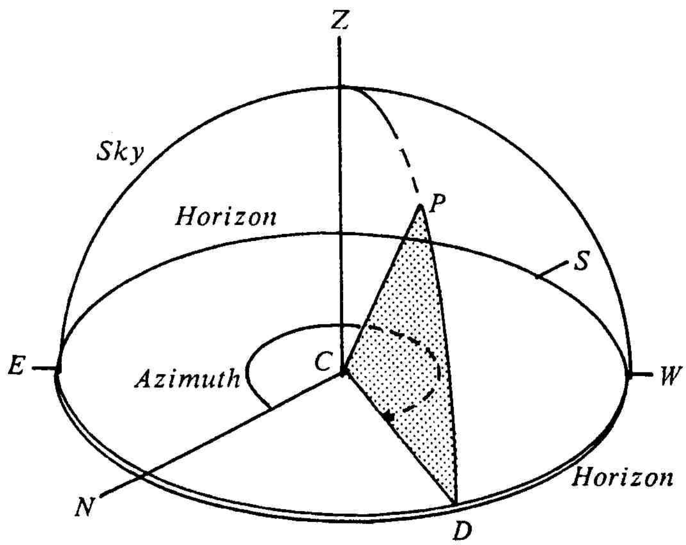


Figure 2 -- C is a point on the Earth's surface. The horizon plane, centered at C, is represented by ENDWS. The sky is shown by the arcs EZW and ZPD. The point directly overhead at C is the zenith (Z) and the direction of the vertical at C is CZ. P is the position of the Sun or Moon with direction CP as seen from C. The altitude of P is arc DP on the sky and equal to the angle between the lines CP and CD. Azimuth is the angle measured from line CN, positive eastward on the horizon plane, to line CD.

SECTION II

Computer Programs

The purpose of this section is to provide three self-contained routines for use with computers and powerful programmable calculators. The first is a FORTRAN code which was tested by compiling and executing on a large so-called main-frame computer, and with no changes, on two personal computers of different manufacture. The second version of the code is written in BASIC and was tested on three personal computers of different manufacture without modification, and two additional devices after some revisions. The third routine, again in BASIC, was written and tested on a scientific programmable calculator.

Despite the number and variety of computing devices now available, the FORTRAN and BASIC languages have much in common from one system to another. Differences among compilers and interpreters do exist in addition to machine architecture differences, however. For that reason, the computer codes given on the following pages have been kept simple and have not been optimized. In adapting them to one particular device or another, any required changes should be simple and straightforward (syntax, for example). Nevertheless, the burden of making the routines workable necessarily belongs to the user and the Naval Observatory cannot undertake to advise anyone concerning computers, software systems or alterations to the routines.

The design goal for the computer routines was 0.5 degrees in angle and, consequently, two minutes of time. Rounding of numbers may cause discrepencies larger than these amounts in some cases. A realistic interpretation of the angles and times which are the output would be to take the last digit as uncertain by one unit. Illuminance is given in lux (lumens per square meter), formally accurate to one or two digits. There are situations in which the calculated illuminance differs from the real light level by a factor of 10 or more, depending on the local atmospheric circumstances. The illuminated fraction of the Moon is independent of Earth's atmosphere, but approximations in the formulas for calculating it may produce errors of 1 or 2 units in the computed quantity.

There are characteristics common to the operation (use) of all three routines and they are, therefore, given here. Notes concerning a particular routine are provided with the routine.

The operation (execution) of the programs is primarily interactive. The programs prompt the user by displaying key words and phrases.

Dialog is initiated by the programs by requesting the longitude and latitude. These coordinates must be specified by the user as degrees and decimals. Although it is possible to enter more precise values, accuracy of the programs is such that degrees and tenths are more than adequate.

Longitude must be entered as a **positive** number if **East** of the prime meridian and a **negative** number if **West**. North latitude is entered as a positive number and South latitude entered as a negative number.

Year, month and day are next requested. These are entered sequentially in order to provide flexibility to the programs. Their format is obvious from Figure 3 which shows a complete example (using the FORTRAN version).

The system of time measurement wanted by the user is then requested. The selection is to be specified by the user by entering one digit in response. It is important to remember that the next input after selecting the time system, and even the date itself, must be expressed in the selected system. Furthermore, all output quantities will be in the selected time system.

When the program prompts the user for time of day, it should be entered in the 24 hour clock scheme, as described in the Introduction.

With time of day entered as a positive number, the program will ask for an estimate of the sky condition. Reference should be made to the discussion of illuminance in the Introduction for an explanation. The number given by the user to the computer at this point will divide calculated illuminance before it appears as output.

Following the sky condition prompt and response, the program provides the following, for the desired time and relative to the specified location:

Sun's azimuth, altitude, illuminance
Moon's azimuth, altitude, illuminance
Percent of the Moon illuminated (phase)
Total (Sun + Moon + night sky background) illuminance

As an alternative to specifying the time, any negative number may be entered. If, instead of entering a time of day, the user enters a negative number, the program provides 13 quantities relative to the Sun and Moon for the date and place specified. These are shown in Figure 3 following the entry of a "negative" time. Figure 3 is the record of an actual computer run and may be used as a test case during installation of the programs. Additional test cases are provided by Table A to assist with verification of program performance.

Special Cases

1. At high northern or southern latitudes some events may not always occur. The Moon may remain above or below the horizon for more than one day. The Sun may remain above or below the horizon for months; and, during that period, twilight may not occur, or it may last for long periods of time. When these conditions prevail, one or more lines of output will be missing from the computer output. The user may determine the significance of the missing information by examining the altitude of

```
EXECUTION BEGINS...


INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END)
?
-4.0
INPUT LATITUDE (DEG.)
?
58.0
INPUT YEAR (YYYY), NUMERAL
?
1987
INPUT MONTH (MM), NUMERAL
?
5
INPUT DAY (DD), NUMERAL
?
11
INPUT TIME ZONE SELECTION

     0 => TIME IS UT (GMT)
     1 => TIME IS STANDARD (ZONE) TIME
     2 => TIME IS LOCAL MEAN TIME
?
0


INPUT TIME OF DAY AS HOURS AND MINUTES OF 24 HOUR CLOCK (HHMM), OR
INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA (RISE/SET, ETC.), OR
INPUT NULL LINE TO END
?
2215
INPUT SKY CONDITION

     1  => SUN/MOON VISIBLE, SKY < 70% OVERCAST
     2  => SUN/MOON OBSCURED BY THIN CLOUDS
     3  => SUN/MOON OBSCURED BY AVERAGE CLOUDS
     10 => SUN/MOON OBSCURED BY DARK STRATUS CLOUDS (RARE)
?
1
AT   -4.0 DEG LONGITUDE,  58.0 DEG LATITUDE
DATA FOR 1987, MONTH  5, DAY 11, AT 2215 HOURS
SOLAR AZIMUTH (DEG.)              332
SOLAR ALTITUDE (DEG.)             -10
SOLAR ILLUMINANCE (LUX)             0.0278
LUNAR AZIMUTH (DEG.)              172
LUNAR ALTITUDE (DEG.)              18
LUNAR ILLUMINANCE (LUX)             0.0317
 ( 97% OF MOON IS ILLUMINATED)
TOTAL ILLUMINANCE (LUX)             0.0600
```

Figure 3 -- Interactive Input, Output (FORTRAN).

```
INPUT TIME OF DAY AS HOURS AND MINUTES OF 24 HOUR CLOCK (HHMM), OR
INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA (RISE/SET, ETC.), OR
INPUT NULL LINE TO END
?
-1
AT   -4.0 DEG LONGITUDE,  58.0 DEG LATITUDE
DATA FOR 1987, MONTH  5, DAY 11
TIME OF SOLAR MERIDIAN PASSAGE           1212
ALTITUDE AT MERIDIAN PASSAGE (DEG.)        50
TIME OF SUNRISE                          0402
TIME OF SUNSET                           2025
TOTAL HOURS AND MINUTES OF DAYLIGHT      1623
TIME BEGINNING CIVIL TWILIGHT            0309
TIME ENDING CIVIL TWILIGHT               2118
TIME BEGINNING NAUTICAL TWILIGHT         0144
TIME ENDING NAUTICAL TWILIGHT            2246
TIME OF LUNAR MERIDIAN PASSAGE           2248
ALTITUDE AT MERIDIAN PASSAGE (DEG.)        18
TIME OF MOONRISE                         1757
TIME OF MOONSET                          0318


INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END)
?
```

Figure 3 -- continued.

the Sun or Moon at meridian passage using the following scheme:

missing output:	*alt. at mer. pass:*	*signifies:*
rise/set	positive	body continuously above horizon
	negative	body continuously below horizon
civil twilight	Sun alt. -6 deg. or greater	twilight lasts all night
	Sun alt. less than -6 deg.	civil twilight does not occur
nautical twilight	Sun alt. -12 deg. or greater	twilight lasts all night
	Sun alt. less than -12 deg.	darkness exceeds 24 hours

Since the Earth and Moon are in continuous motion, the program tests are not infallible at extremes of latitude. For limiting cases, the calculations may deviate in the sense that predicted events may not actually take place. Or, they may occur when the program tests indicate their absence. More exacting calculations are possible, but the improvement in reliability and accuracy is marginal for the plain reason that physical conditions at the extreme latitudes render the actual occurrence of events uncertain. Also, this may be easily seen by reference to the graphs of Section III where, for example, at latitudes above 65 degrees, the track of the Sun is seen to intersect the horizon at very shallow angles during certain times of the year.

2. About once per month at any latitude, there will be a 24 hour day during which the Moon does not cross the meridian. In this case, the Moon's meridian passage will appear in the program output with a time greater than 24 hours. This is normal and merely signifies that the next meridian passage after the beginning of a day will be on the following day. Moonrise and moonset may also appear with times exceeding 24 hours. These are also normal events, with a period of about one lunar month, and can occur at any latitude.

3. At high latitudes, the Moon may rise or set twice in one day. These are very infrequent events and the computer program will produce only one of the double phenomena.

4. Occasionally, a time of an event may appear with the minutes part equal to 60 (eg., 1060). Program code to avoid this possibility was deliberately omitted, as the significance of such numbers is obvious (1060=1100).

5. For some purposes it may be necessary to have the times of events expressed both in a local Zone Time and in Universal Time. The computer routines may be used to compute the times in both systems. Some results, when compared, may appear discordant, however. For an illustration, consider the beginning and end of nautical twilight computed for 1986 September 13 at longitude 77 deg. West and latitude 39 deg. North. With Zone Time specified, the results are 0449 and 1918. With UT specified, the results are 0949 and 0020. It is known that the Zone Time differs from UT by exactly 5 hours, and it is perfectly correct to add 5 hours to the Zone Time to obtain the UT times. Adding 5 hours to the Zone Times of the events produces 0949 and 2418. The second number exceeds 24 hours and can be written 0018 provided the date is increased by one day. It is also correct procedure to subtract 5 hours from the UT times to obtain the Zone Times. The results are then 0949-0500 = 0449; and 0020-0500 = -0440, or 1920 provided the date is retarded by one day. The results are collected in the following scheme for time ending nautical twilight:

September:	*12*	*13*	*14*
Zone Time:	1920	1918	
Universal Time:		0020	0018

It is seen that, for September 13, the computer programs have given results that do not refer to the same, identical event. Once a date is specified within the computer programs, it is invariant and the programs will not change it. The date is also that date associated with the time reference meridian specified by the time zone parameter which is entered by the user. Clearly, the proper interpretation of the data shown above is that the times computed for events depend upon the date which is kept at the reference meridian of the specified time zone. As a result, computed times of events which do not agree after adjustment for longitude difference may both be correct; each within its own frame of date and time measurement, but each referring to a separate event. In the illustration, the end of nautical twilight for the given location on September 13, occurred at 1918 when reckoned according to date and time on the 75th meridian (September 14 at 0018 for date and time on the prime meridian). When reckoned according to date and time of the prime meridian it occurred on September 13 at 0020 (Sept. 12 at 1920 for date and time on the 75th meridian).

Table A. Test Cases for Program Certification

	I	II	III	IV	V	VI	VII
Longitude	+35.5	-150	-135.8	+180	+180	0	+39.5
Latitude	+46.0	+ 45	- 23.4	+ 70	+ 70	-68	+21.3
Year	1986	1986	1986	1987	1987	1988	1988
Month	7	9	12	2	2	1	8
Day	3	28	18	19	19	1	13
Zone	1	1	0	2	0	0	2
Hour	-1	-3	2100	-9	-1	-2	-3
Sky			1				
Sun merid. pass.	1142	1151		1214	0014	1203	1205
Alt. at m.p.	67	43		9	9	45	83
Sunrise	0352	0554		0819	2014		0538
Sunset	1932	1746		1610	0410		1831
Tot. daylight	1540	1152		0751	0756		1254
Beg. civil twi.	0314	0525		0712	1908		0514
End civil twi.	2010	1815		1717	0517		1855
Beg. naut. twi.	0223	0451		0601	1757		0447
End naut. twi.	2101	1849		1829	0629		1922
Moon merid. pass.	0835	0803		0340	1627	2216	1244
Alt. at m.p.	66	69		8	3	-7	81
Moonrise	0048	2504		2555	1356		0612
Moonset	1635	1558		0725	1835		1912
Hour							1831
Sky							1
Sun azimuth			346				286
Sun altitude			90				0
Sun illuminance			123786				697
Moon azimuth			282				278
Moon altitude			-62				8
Moon illuminance			0				0
(% illuminated)			94				1
Tot. illuminance			123786				697

The FORTRAN Program

The complete program consists of a main program, eight subroutines and three function statements. All are listed on succeeding pages. The following notes supplement those beginning with the first page of this section and apply to the FORTRAN code.

1. Precision

The program is in double precision for use with computers having 4 byte single precision words. If a computer can consistently maintain 8 significant digits during computation, then a single precision version of the program could be constructed.

2. Changes to the program

The leading statement IMPLICIT DOUBLE PRECISION (A-Z) may be changed to read IMPLICIT REAL*8 (A-Z) in order to satisfy syntax requirements of certain compilers.

If a single precision version of the program is desired and is possible, then all references to the following double precision functions must be converted to corresponding single precision references:

DABS	DINT	DASIN	DCOS	DEXP
DACOS	DSIGN	DSIN	DTAN	DATAN

Constants written in double precision format (D) convert to E format. The leading (IMPLICIT....) statement of the main program, subroutines and functions must be changed.

Program flow may be altered to some extent. As provided here, the flow follows certain ideas concerning probable usage. The main program statement following statement 580 may be changed to redirect execution. From GOTO 100, the statement may be altered to

GOTO 125 to rerun with a new year, month and day
GOTO 150 to input only a new month and day
GOTO 175 to input only a new day of the month
GOTO 200 to input a time during the year, month and day already specified

The main program statement following statement 805 may be altered from GOTO 200 to GOTO 125, or 150, or 175 with the same results as above. All of these changes will cause the program to produce data for the same longitude and latitude. To compute data for a different geographic place, at least one of the above GOTO statements must direct a transfer to statement 100.

3. Other changes

An experienced programmer might make changes to the program other than these described above. The programmer should be extremely cautious, however. Several of the variables are multiply-defined and certain computational sequences must not be disturbed or their results may be totally false. In the worst case, the end results may appear reasonable.

4. Operation

Once the program begins to execute, operation is interactive with prompting. The user should refer to Fig. 3 for an example, and is encouraged to reproduce the example at least once in order to gain familiarity with program usage.

```
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER IY,IM,ID,IH,L,I,K,N,J,IAZ,IHA
      DIMENSION A(4), B(2)
      RD = 57.29577951D0
      DR = 1.0D0/RD
      A(1) = -0.01454D0
      A(2) = -0.10453D0
      A(3) = -0.20791D0
      A(4) = +0.00233D0
      CE = 0.91775D0
      SE = 0.39715D0
100   WRITE (*,*) ' '
      WRITE (*,*) ' '
      WRITE (*,*) 'INPUT LONGITUDE (DEG.), ENTER NULL LINE TO END) '
      READ  (*,*,END=9999) LO
      WRITE (*,*) 'INPUT LATITUDE (DEG.)'
      READ  (*,*) F
125   WRITE (*,*) 'INPUT YEAR (YYYY), NUMERAL'
      READ  (*,*) IY
150   WRITE (*,*) 'INPUT MONTH (MM), NUMERAL'
      READ  (*,*) IM
175   WRITE (*,*) 'INPUT DAY (DD), NUMERAL'
      READ  (*,*) ID
      C = 360.0D0
      LI = DABS(LO)
      FO = F
      F = F*DR
      SI = DSIN(F)
      CI = DCOS(F)
      J = 367*IY-INT(7*(IY+INT((IM+9)/12))/4)+INT(275*IM/9)+ID-730531
      WRITE (*,*) 'INPUT TIME ZONE SELECTION'
      WRITE (*,*) ' '
      WRITE (*,*) '    0 => TIME IS UT (GMT)'
      WRITE (*,*) '    1 => TIME IS STANDARD (ZONE) TIME'
      WRITE (*,*) '    2 => TIME IS LOCAL MEAN TIME'
      READ  (*,*) Z
      ZT = Z
      DT = 0
      IF (Z .EQ. 0.0D0) DT =-LO/360.0D0
      IF (Z .EQ. 1.0D0) DT = (LI-15.0D0*DINT((LI+7.5D0)/15.0D0))/C
     &   *DSIGN(1.0D0,-LO)
200   WRITE (*,*) ' '
      WRITE (*,*) ' '
      WRITE (*,*) 'INPUT TIME OF DAY AS HOURS AND MINUTES OF 24',
     &  ' HOUR CLOCK (HHMM), OR'
      WRITE (*,*) 'INPUT ANY NEGATIVE NUMBER TO COMPUTE PHENOMENA',
     &  ' (RISE/SET, ETC.), OR'
      WRITE (*,*) 'INPUT NULL LINE TO END'
      READ  (*,*,END=9999) H
      IF (H .GE. 0.0D0) GOTO 600
      WRITE (*,205) LO,FO
```

```
205    FORMAT (' AT ',F6.1,' DEG LONGITUDE, ',F5.1,' DEG LATITUDE')
       WRITE (*,210) IY,IM,ID
210    FORMAT (' DATA FOR ',I4,', MONTH ',I2,', DAY ',I2)
       Z = J-0.5D0
       DO 580 L = 1, 4
          GOTO (260,390,390,250), L
250       C = 347.81D0
260       M = 0.5D0+DT
          K = 1
280       IF (L .LT. 4) K = K+1
             M = M-DT
             E = M-LO/360.0D0
             D = Z+E
             CALL CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
             M = M-U+DT
             GOTO (360,285,360,300,360,370), K
285          IF (M .GE. 0.0D0 .AND. M .LT. 1.0D0) GOTO 370
             GOTO 320
300          IF(M .GE. 0.0D0) GOTO 370
320          M = M-DSIGN(1.0D0,M)
360       K = K+1
          GOTO 280
370       H = DASIN(DCOS(F-DS))*RD
          IF(L .EQ. 4) H = H-.95*DCOS(H*DR)
          CALL REFR (H,DR,HA)
390       CALL HORX (A,L,SI,SD,CI,DS,C,RD,H)
          B(1) = M-H
          B(2) = M+H
          DO 560 I = 1, 2
             K = 2*I-3
             N = 1
450          IF (L .LT. 4) N = N+1
             B(I) = B(I)-DT
             E = B(I)-LO/360.0D0
             D = Z+E
             CALL CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
             CALL HORX (A,L,SI,SD,CI,DS,C,RD,H)
             B(I) = B(I)+K*H-U+DT
             GOTO (550,460,550,470,550,560), N
460          IF (B(I) .GE. 0.0D0 .AND. B(I) .LT. 1.0D0) GOTO 560
             GOTO 480
470          IF (B(I) .GE. 0.0D0) GOTO 560
480          B(I) = B(I) - DSIGN(1.0D0,B(I))
550          N = N+1
             GOTO 450
560       CONTINUE
          CALL OUT (ZT,M,HA,B,L)
580    CONTINUE
       GOTO 100
600    WRITE (*,*) 'INPUT SKY CONDITION'
       WRITE (*,*) ' '
       WRITE (*,*) '1  => SUN/MOON VISIBLE, SKY < 70% OVERCAST'
```

```
      WRITE (*,*) '2  => SUN/MOON OBSCURED BY THIN CLOUDS    '
      WRITE (*,*) '3  => SUN/MOON OBSCURED BY AVERAGE CLOUDS '
      WRITE (*,*) '10 => SUN/MOON OBSCURED BY DARK STRATUS CLOUDS',
   &  ' (RARE)'
      READ  (*,*) SK
      IH = DINT(H)
      WRITE (*,205) LO,FO
      WRITE (*,610) IY,IM,ID,IH
 610  FORMAT (' DATA FOR ',I4,', MONTH ',I2,', DAY ',I2,', AT ',I4.4,
   &  ' HOURS')
      E = DEG(H/100.0D0)/24.0D0-DT-LO/360.0D0
      D = J-0.5D0+E
      N = 1
      CALL SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
      T = T+360.0D0*E+LO
 660  IF (N .EQ. 2) CALL MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
      H = T-AS
      CALL ALTAZ (DS,H,SD,CI,SI,DR,RD,AZ)
      Z = H*DR
      H = H-0.95D0*(N-1)*DCOS(H*DR)
      CALL REFR (H,DR,HA)
      CALL ATMOS (HA,DR,M)
      HA = DSIGN(DINT(DABS(HA)+0.5D0),HA)
      GOTO (750,790), N
 750  IS = 133775.0D0*M/SK
      IAZ = DINT(AZ)
      WRITE (*,751) IAZ
 751  FORMAT (' SOLAR AZIMUTH (DEG.)',14X,I4.3)
      IHA = DINT(HA)
      WRITE (*,752) IHA
 752  FORMAT (' SOLAR ALTITUDE (DEG.)',14X,I3)
      WRITE (*,753) IS
 753  FORMAT (' SOLAR ILLUMINANCE (LUX)',9X,F11.4)
      N = 2
      GOTO 660
 790  E = DACOS(DCOS(V-LS)*CB)
      P = 0.892D0*DEXP(-3.343D0/((DTAN(E/2.0D0))**0.632D0))+0.0344D0*
   &   (DSIN(E)-E*DCOS(E))
      P = 0.418D0*P/(1.0D0-0.005D0*DCOS(E)-0.03D0*DSIN(Z))
      IL = P*M/SK
      IS = IS+IL+0.0005D0/SK
      IAZ = DINT(AZ)
      WRITE (*,801) IAZ
 801  FORMAT (' LUNAR AZIMUTH (DEG.)',14X,I4.3)
      IHA = DINT(HA)
      WRITE (*,802) IHA
 802  FORMAT (' LUNAR ALTITUDE (DEG.)',14X,I3)
      WRITE (*,803) IL
 803  FORMAT (' LUNAR ILLUMINANCE (LUX)',9X,F11.4)
      IHA = DINT(50.D0*(1.0D0-DCOS(E))+0.5D0)
      WRITE (*,804) IHA
 804  FORMAT ('  (',I3,'% OF MOON IS ILLUMINATED)')
```

```
      WRITE (*,805) IS
 805  FORMAT (' TOTAL ILLUMINANCE (LUX)',9X,F11.4)
      GOTO 200
9999  CONTINUE
      END
C-----------------------------------------------------------------------
      SUBROUTINE CRCT (D,E,L,LO,C,DR,RD,CE,SE,U,DS,SD)
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER L
      IF (DABS(E) .GE. 1.0D0) E = E-DSIGN(1.0D0,E)
      CALL SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
      IF (L .EQ. 4) CALL MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
      T = T+LO+360.0D0*E
      T = T-DINT(T/360.0D0)*360.0D0
      U = T-AS
      IF (DABS(U) .GT. 180.0D0) U = U-DSIGN(360.0D0,U)
      U = U/C
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE SUN (D,DR,RD,CE,SE,T,G,LS,AS,SD,DS)
      IMPLICIT DOUBLE PRECISION (A-Z)
      T = 280.46D0+0.98565D0*D
      T = T-DINT(T/360.0D0)*360.0D0
      IF (T .LT. 0.0D0) T = T+360.0D0
      G = (357.5D0+0.98560D0*D)*DR
      LS = (T+1.91D0*DSIN(G))*DR
      AS = DATAN(CE*DTAN(LS))*RD
      Y = DCOS(LS)
      IF (Y .LT. 0.0D0) AS = AS+180.0D0
      SD = SE*DSIN(LS)
      DS = DASIN(SD)
      T = T-180.0D0
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE MOON (D,G,CE,SE,RD,DR,V,CB,AS,SD,DS)
      IMPLICIT DOUBLE PRECISION (A-Z)
      V = 218.32D0+13.1764D0*D
      V = V-DINT(V/360.0D0)*360.0D0
      IF (V .LT. 0.0D0) V = V+360.0D0
      Y = (134.96D0+13.06499D0*D)*DR
      O = (93.27D0+13.22935D0*D)*DR
      W = (235.7D0+24.38150D0*D)*DR
      SB = DSIN(Y)
      CB = DCOS(Y)
      X = DSIN(O)
      S = DCOS(O)
      SD = DSIN(W)
      CD = DCOS(W)
      V = (V+(6.29D0-1.27D0*CD+0.43D0*CB)*SB+(0.66D0+1.27D0*CB)*SD
     &  -0.19D0*DSIN(G)-0.23D0*X*S)*DR
```

```
      Y = ((5.13D0-0.17D0*CD)*X+(0.56D0*SB+0.17D0*SD)*S)*DR
      SV = DSIN(V)
      SB = DSIN(Y)
      CB = DCOS(Y)
      Q = CB*DCOS(V)
      P = CE*SV*CB-SE*SB
      SD = SE*SV*CB+CE*SB
      AS = DATAN(P/Q)*RD
      IF (Q .LT. 0.0D0) AS = AS+180.0D0
      DS = DASIN(SD)
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE HORX (A,L,SI,SD,CI,DS,C,RD,H)
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER L
      DIMENSION A(4)
      H = (A(L)-SI*SD)/(CI*DCOS(DS))
      IF (DABS(H) .GT. 1.0D0) GOTO 5040
      H = DACOS(H)*RD/C
      RETURN
 5040 H = 1.5D0
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE ALTAZ (DS,H,SD,CI,SI,DR,RD,AZ)
      IMPLICIT DOUBLE PRECISION (A-Z)
      CD = DCOS(DS)
      CS = DCOS(H*DR)
      Q = SD*CI-CD*SI*CS
      P = -CD*DSIN(H*DR)
      AZ = DATAN(P/Q)*RD
      IF (Q.LT. 0.0D0) AZ = AZ+180.0D0
      IF (AZ .LT. 0.0D0) AZ = AZ+360.0D0
      AZ = DINT(AZ+0.5D0)
      H = DASIN(SD*SI+CD*CI*CS)*RD
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE REFR (H,DR,HA)
      IMPLICIT DOUBLE PRECISION (A-Z)
      HA = H
      IF (H .LT. (-5.0D0/6.0D0)) RETURN
      HA = H+1.0D0/(DTAN((H+8.6D0/(H+4.42D0))*DR))/60.0D0
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE ATMOS (HA,DR,M)
      IMPLICIT DOUBLE PRECISION (A-Z)
      U = DSIN(HA*DR)
      X = 753.66156D0
      S = DASIN(X*DCOS(HA*DR)/(X+1.0D0))
```

```
      M = X*(DCOS(S)-U)+DCOS(S)
      M = DEXP(-0.21D0*M)*U+0.0289D0*DEXP(-0.042D0*M)*(1.0D0+
     &  (HA+90.0D0)*U/57.29577951D0)
      RETURN
      END
C-----------------------------------------------------------------------
      SUBROUTINE OUT (ZT,M,HA,B,L)
      IMPLICIT DOUBLE PRECISION (A-Z)
      INTEGER I,L,IR1,IHA
      DIMENSION B(2)
      GOTO (3000,3050,3050,3260), L
 3000 IR1 = DINT(TIMES(M))
      IF (ZT .EQ. 1.0D0) THEN
        WRITE(*,*) '** FOR DAYLIGHT (SUMMER) TIME ADD ONE HOUR **'
      END IF
      WRITE (*,3001) IR1
 3001 FORMAT (' TIME OF SOLAR MERIDIAN PASSAGE',6X,I4.4)
 3030 IHA = DINT(DSIGN(DINT(DABS(HA)+0.5D0),HA))
      WRITE (*,3031) IHA
 3031 FORMAT (' ALTITUDE AT MERIDIAN PASSAGE (DEG.)',2X,I3)
 3050 I = 1
 3060 R = TIMES(B(I))
      IF (R .GE. 4800.0D0 .OR. R .LT. 0.0D0) GOTO 3330
      GOTO (3100,3120,3180,3200,3220,3240,3300,3320), 2*(L-1)+I
 3100 IR1 = DINT(R)
      WRITE (*,3101) IR1
 3101 FORMAT (' TIME OF SUNRISE',21X,I4.4)
      GOTO 3330
 3120 IR1 = DINT(R)
      WRITE (*,3121) IR1
 3121 FORMAT (' TIME OF SUNSET',22X,I4.4)
      R = B(2)-B(1)
      IF (R .LT. 0.0D0) R = R+1
      R = TIMES(R)
      IR1 = DINT(R)
      WRITE (*,3171) IR1
 3171 FORMAT (' TOTAL HOURS AND MINUTES OF DAYLIGHT ',I4.4)
      GOTO 3330
 3180 IR1 = DINT(R)
      WRITE (*,3181) IR1
 3181 FORMAT (' TIME BEGINNING CIVIL TWILIGHT',7X,I4.4)
      GOTO 3330
 3200 IR1 = DINT(R)
      WRITE (*,3201) IR1
 3201 FORMAT (' TIME ENDING CIVIL TWILIGHT',10X,I4.4)
      GOTO 3330
 3220 IR1 = DINT(R)
      WRITE (*,3221) IR1
 3221 FORMAT (' TIME BEGINNING NAUTICAL TWILIGHT',4X,I4.4)
      GOTO 3330
 3240 IR1 = DINT(R)
      WRITE (*,3241) IR1
```

```
3241    FORMAT (' TIME ENDING NAUTICAL TWILIGHT',7X,I4.4)
        GOTO 3330
3260    R = TIMES(M)
        IR1 = DINT(R)
        WRITE (*,3261) IR1
3261    FORMAT (' TIME OF LUNAR MERIDIAN PASSAGE',6X,I4.4)
        GOTO 3030
3300    IR1 = DINT(R)
        WRITE (*,3301) IR1
3301    FORMAT (' TIME OF MOONRISE',20X,I4.4)
        GOTO3330
3320    IR1 = DINT(R)
        WRITE (*,3321) IR1
3321    FORMAT (' TIME OF MOONSET',21X,I4.4)
3330    I = I + 1
        IF (I .LT. 3) GOTO 3060
        RETURN
        END
C-----------------------------------------------------------------------
        DOUBLE PRECISION FUNCTION TIMES (X)
        IMPLICIT DOUBLE PRECISION (A-Z)
        TIMES = DINT(100.0D0*DMS(X*24.0D0)+0.5D0)
        RETURN
        END
C-----------------------------------------------------------------------
        DOUBLE PRECISION FUNCTION DMS (X)
        IMPLICIT DOUBLE PRECISION (A-Z)
        DMS = DINT(X)+6.0D0*(X-DINT(X))/10.0D0
        RETURN
        END
C-----------------------------------------------------------------------
        DOUBLE PRECISION FUNCTION DEG (X)
        IMPLICIT DOUBLE PRECISION (A-Z)
        DEG = DINT(X)+((X-DINT(X))*10.0D0)/6.0D0
        RETURN
        END
```

The BASIC Program for Computers

This version of the program consists of a main program which begins at statement 10 and ends at statement 1210. There are several subprograms which are written in open style so that variables do not pass through calling sequences. One of these is embedded in the main program. Definition statements for such functions as *arccosine, arcsine* are at the beginning of the program, as required. These functions may be available in some interpreters. The notes which follow apply to the BASIC code for personal computers and supplement the general notes beginning with the first page of this Section.

1. Precision

The program is written using a mixed precision; that is, most of the program uses single precision. There are several calculations which produce large numbers, and to retain significance at the half-degree level, extended precision is required. The use of extended or double precision must be identified to the interpreter in some way. In the BASIC dialect given here, that is accomplished by appending the symbol # to certain variables and constants. There are some computers in which numbers are stored and manipulated with sufficient precision such that extended or double precision is not needed and is not an interpreter option. For such configurations of machine and language, the following statements should be edited and the symbol # deleted:

310, 430, 900, 1220, 1230, 1250, 1260, 1720,
1730, 1750, 1760, 1770, 1780, 1790, 1800.

2. Changes to the program

Syntax rules for BASIC interpreters vary considerably and not all possibilities can be explored here. Nevertheless, since it is to be expected that some changes will be required for implementation of the program, a few guidelines can be given.

It will be seen in the code that the words THEN and LET frequently appear in combination. In testing, it was found that LET was not required by one interpreter. Another interpreter required LET but not THEN. Still another, older interpreter required LET to precede any equality or equation statement and required it in combination with THEN in conditional statements. Obviously, the user should explore the possibilities and requirements of the particular machine/language combination for simplifications.

Many versions of BASIC allow multicharacter variable and function names to be defined. Of these, some versions will actually use only the initial two characters when referencing the function or variable. If this is not known to the programmer or user, the results can be unpredictable. In the worst case tested, some of the program output actually contained valid results. Should it be found that two character function and variable names are required, the program given here can be easily modified. Only function names, not variable names, need to be changed. In order to avoid conflicts, the following functions could be renamed as shown:

ARCOS - RC
ARCSIN - RS
DEG - DG
DMS - DM

Of course, program references to the functions must be changed accordingly.

In addition to the restriction of two-character variable and user defined function references, the interpreter may offer an expanded set of commands. Unfortunately, corresponding to the expanded command set is a similarly enlarged list of words or acronyms which are described as reserved, protected, or privileged. Since it is not possible to predict which two-character combinations will infringe upon the reserved set of every computer/interpreter configuration, the program user must be aware of possible consequences. Those should be addressed in the literature describing the interpreter and its use. Often, infringement triggers syntax error messages, so that the offending variable may be readily found and redefined.

Some versions of BASIC do not allow function definitions by the user, but do provide the functions. The user should then modify this program so that the function ARCOS is replaced, where used, by whatever is provided for computing the *arccosine*. The *arcsine* function (ARCSIN) should be replaced likewise. The functions DEG and DMS can be re-defined as subroutines, and statements 890 and 1700 modified accordingly.

Statement 1100 requires that a trigonometric *tangent* be raised to the fractional exponent .632. As given here, the operation is specified by the symbol ^. (Specifically, the character is an ASCII hexadecimal 5E or decimal 94.) This is acceptable to several versions of BASIC; but in one dialect encountered, the required symbol for the same operation was a vertical arrow. The user should be aware of this and related variations of notation.

Program flow may be altered to some extent. As provided here, the flow reflects certain ideas concerning probable usage. Other modes may be more convenient for certain applications. The statements numbered 860 and 1200 may be changed to redirect execution:

GO TO 150 to initialize all input
GO TO 170 to input a new year, month, day, etc.
GO TO 180 to input a new month, day, etc.
GO TO 190 to input a new day, etc.
GO TO 300 to input a time during the year, month and day already specified.

Statement 1200 transfers control to 300. It may be changed to send control to statements 150, 170, 180 or 190, as above. At least one of the statements (860 or 1200) should direct a transfer to statement 150 if data for more than one location are to be computed during a session.

3. Other changes

An experienced programmer might make changes to the program other than those already described. However, caution must be used. Several variables are multiply-defined and certain computational sequences may not be disturbed or their results will be false. In the worst case, the end results may appear reasonable.

4. Operation

Once the program has been implemented, operation should proceed interactively with prompting by key words and phrases provided. The user should refer to Fig. 3 for an example of use. Output of the BASIC program will differ from the example in appearance, but not in data sequence or actual content.

```
10 DEF FNARCOS(ARG)=1.570796-ATN(ARG/SQR(1.-ARG*ARG))
20 DEF FNARCSIN(ARG)=ATN(ARG/SQR(1.-ARG*ARG))
30 DEF FNDEG(ARG)=INT(ARG)+((ARG-INT(ARG))*10.)/6.
40 DEF FNDMS(ARG)=INT(ARG)+6.*(ARG-INT(ARG))/10.
50 RD=57.29578
60 DR=1./RD
70 DIM A(4)
80 DIM B(2)
90 A(1)=-.01454
100 A(2)=-.10453
110 A(3)=-.20791
120 A(4)=.00233
130 CE=.91775
140 SE=.39715
150 INPUT"LONGITUDE IN DEG.";LO
160 INPUT"LATITUDE IN DEG.";F
170 INPUT"YEAR (4 DIGITS)";IY
180 INPUT"MONTH (NUMERAL)";IM
190 INPUT"DAY (NUMERAL)";ID
200 F=F*DR
210 C=360.
220 LI=ABS(LO)
230 SI=SIN(F)
240 CI=COS(F)
250 J=367*IY-INT(7*(IY+INT((IM+9)/12))/4)+INT(275*IM/9)+ID-730531.
260 INPUT"UNIVERSAL TIME = 0, ZONE TIME = 1, LOCAL MEAN TIME = 2";Z
270 DT=0.
280 IF Z=0. THEN LET DT=-LO/C
290 IF Z=1. THEN LET DT=-(LI-15*INT((LI+7.5)/15))/C*SGN(LO)
300 INPUT"HOUR (4 DIGIT NUMERAL ON 24 HOUR CLOCK)";H
310 Z0#=J-.5
320 IF H>0 THEN GOTO 870
330 PRINT"DATA FOR ";IY;", MONTH ";IM;", DAY ";ID
340 FOR L=1 TO 4
350 ON L GOTO 370,650,650,360
360 C=347.81
370 M=.5+DT
380 K=1
390 M=M-DT
400 E=M-LO/360.
410 GOSUB 430
420 GOTO 530
430 D#=Z0#+E
440 IF ABS(E)>=1 THEN LET E=E-SGN(E)
450 GOSUB 1220
460 IF L=4 THEN GOSUB 1720
470 T=T+LO+360.*E
480 T=T-INT(T/360.)*360.
490 U=T-AS
500 IF ABS(U)>180. THEN LET U=U-360.*SGN(U)
510 U=U/C
520 RETURN
```

```
530 M=M-U+DT
540 IF L<4 THEN LET K=K+1
550 ON K GOTO 600,560,600,580,600,620
560 IF M>=0. AND M<1. THEN GOTO 620
570 GOTO 590
580 IF M>=0. THEN GOTO 620
590 M=M-SGN(M)
600 K=K+1
610 GOTO 390
620 H=FNARCSIN(COS(F-DS))*RD
630 IF L=4 THEN LET H=H-.95*COS(H)
640 GOSUB 2160
650 GOSUB 2000
660 B(1)=M-H
670 B(2)=M+H
680 FOR I=1 TO 2
690 K=2*I-3
700 FOR N=1 TO 6
710 B(I)=B(I)-DT
720 E=B(I)-LO/360.
730 GOSUB 430
740 GOSUB 2000
750 B(I)=B(I)+K*H-U+DT
760 IF L<4 THEN LET N=N+1
770 ON N GOTO 820,780,820,800,820,830
780 IF B(I)>=0. AND B(I)<1. THEN GOTO 830
790 GOTO 810
800 IF B(I)>=0. THEN GOTO 830
810 B(I)=B(I)-SGN(B(I))
820 NEXT N
830 NEXT I
840 ON L GOSUB 1350,1400,1400,1610
850 NEXT L
860 GOTO 150
870 INPUT"SKY CONDITION = 1,2,3,10,";SK
880 PRINT"DATA FOR ";IY;", MONTH ";IM;", DAY ";ID;", AT ";H;" HOURS"
890 E=FNDEG(H/100.)/24.-DT-LO/360.
900 D#=Z0#+E
910 N=1
920 GOSUB 1220
930 T=T+360.*E+LO
940 IF N=2 THEN GOSUB 1720
950 H=T-AS
960 GOSUB 2060
970 Z=H*DR
980 H=H-.95*(N-1)*COS(H*DR)
990 GOSUB 2160
1000 GOSUB 2200
1010 HA=INT(ABS(HA)+.5)*SGN(HA)
1020 ON N GOTO 1030,1090
1030 IS=133775.*M/SK
1040 PRINT"SUN AZIMUTH (DEG.)       ";AZ
```

```
1050 PRINT"SUN ALTITUDE (DEG.)      ";HA
1060 PRINT"SUN ILLUMINANCE (LUX)    ";IS
1070 N=2
1080 GOTO 940
1090 E=FNARCOS(COS(V-LS)*CB)
1100 P=.892*EXP(-3.343/((TAN(E/2.))^.632))+.0344*(SIN(E)-E*COS(E))
1110 P=.418*P/(1.-.005*COS(E)-.03*SIN(Z))
1120 IL=P*M/SK
1130 IS=IS+IL+.0005/SK
1140 PRINT"MOON AZIMUTH (DEG.)      ";AZ
1150 PRINT"MOON ALTITUDE (DEG.)     ";HA
1160 PRINT"MOON ILLUMINANCE (LUX)   ";IL
1170 IL=INT(50.*(1.-COS(E))+.5)
1180 PRINT" (";IL;"% OF MOON ILLUMINATED)"
1190 PRINT"TOTAL ILLUMINANCE (LUX) ";IS
1200 GOTO 300
1210 END
1220 TD#=280.46#+.98565#*D#
1230 T=TD#-INT(TD#/360#)*360#
1240 IF T<0. THEN LET T=T+360.
1250 TD#=357.5#+.9856#*D#
1260 G=(TD#-INT(TD#/360#)*360#)*DR
1270 LS=(T+1.91*SIN(G))*DR
1280 AS=ATN(CE*TAN(LS))*RD
1290 Y=COS(LS)
1300 IF Y<0. THEN LET AS=AS+180.
1310 SD=SE*SIN(LS)
1320 DS=FNARCSIN(SD)
1330 T=T-180.
1340 RETURN
1350 R=M
1360 GOSUB 1700
1370 PRINT"SUN MERIDIAN PASSAGE AT ";R
1380 HA=INT(ABS(HA)+.5)*SGN(HA)
1390 PRINT"ALTITUDE AT MER. PASS.  ";HA
1400 FOR I=1 TO 2
1410 R=B(I)
1420 GOSUB 1700
1430 IF R>=4800. OR R<0. THEN GOTO 1680
1440 ON 2*(L-1)+I GOTO 1450,1470,1530,1550,1570,1590,1650,1670
1450 PRINT"TIME OF SUNRISE          ";R
1460 GOTO 1680
1470 PRINT"TIME OF SUNSET           ";R
1480 R=B(2)-B(1)
1490 IF R<0. THEN LET R=R+1.
1500 GOSUB 1700
1510 PRINT"TOTAL DAYLIGHT           ";R
1520 GOTO 1680
1530 PRINT"BEGIN CIVIL TWILIGHT AT ";R
1540 GOTO 1680
1550 PRINT"END CIVIL TWILIGHT AT    ";R
1560 GOTO 1680
```

```
1570 PRINT"BEGIN NAUTICAL TWILIGHT ";R
1580 GOTO 1680
1590 PRINT"END NAUTICAL TWILIGHT   ";R
1600 GOTO 1680
1610 R=M
1620 GOSUB 1700
1630 PRINT"MOON MERIDIAN PASSAGE AT";R
1640 GOTO 1380
1650 PRINT"TIME OF MOONRISE        ";R
1660 GOTO 1680
1670 PRINT"TIME OF MOONSET         ";R
1680 NEXT I
1690 RETURN
1700 R=INT(100.*FNDMS(R*24.)+.5)
1710 RETURN
1720 TD#=218.32#+13.1764#*D#
1730 V=TD#-INT(TD#/360#)*360#
1740 IF V<0. THEN LET V=V+360.
1750 TD#=134.96#+13.06499#*D#
1760 Y=(TD#-INT(TD#/360#)*360#)*DR
1770 TD#=93.27#+13.22935#*D#
1780 O=(TD#-INT(TD#/360#)*360#)*DR
1790 TD#=235.7#+24.3815#*D#
1800 W=(TD#-INT(TD#/360#)*360#)*DR
1810 SB=SIN(Y)
1820 CB=COS(Y)
1830 X=SIN(O)
1840 S=COS(O)
1850 SD=SIN(W)
1860 CD=COS(W)
1870 V=V+(6.29-1.27*CD+.43*CB)*SB+(.66+1.27*CB)*SD-.19*SIN(G)-.23*X*S
1880 V=V*DR
1890 Y=((5.13-.17*CD)*X+(.56*SB+.17*SD)*S)*DR
1900 SV=SIN(V)
1910 SB=SIN(Y)
1920 CB=COS(Y)
1930 Q=CB*COS(V)
1940 P=CE*SV*CB-SE*SB
1950 SD=SE*SV*CB+CE*SB
1960 AS=ATN(P/Q)*RD
1970 IF Q<0. THEN LET AS=AS+180.
1980 DS=FNARCSIN(SD)
1990 RETURN
2000 H=(A(L)-SI*SD)/(CI*COS(DS))
2010 IF ABS(H)>1. THEN GOTO 2040
2020 H=FNARCOS(H)*RD/C
2030 RETURN
2040 H=1.5
2050 RETURN
2060 CD=COS(DS)
2070 CS=COS(H*DR)
2080 Q=SD*CI-CD*SI*CS
```

```
2090 P=-CD*SIN(H*DR)
2100 AZ=ATN(P/Q)*RD
2110 IF Q<0. THEN LET AZ=AZ+180.
2120 IF AZ<0. THEN LET AZ=AZ+360.
2130 AZ=INT(AZ+.5)
2140 H=FNARCSIN(SD*SI+CD*CI*CS)*RD
2150 RETURN
2160 HA=H
2170 IF H<(-5./6.) THEN GOTO 2190
2180 HA=H+1./(TAN((H+8.59/(H+4.42))*DR))/60.
2190 RETURN
2200 U=SIN(HA*DR)
2210 X=753.6616
2220 S=FNARCSIN(X*COS(HA*DR)/(X+1.))
2230 M=X*(COS(S)-U)+COS(S)
2240 M=EXP(-.21*M)*U+.0289*EXP(-.042*M)*(1.+(HA+90.)*U/57.29578)
2250 RETURN
```

The BASIC Routine for Programmable Calculator

This version of BASIC was written for a particular unit having a dual mode of operation -- one as a calculator with single keystroke trigonometric, power, root and other functions, the other as a computer having a BASIC interpreter resident in read-only-memory. The salient feature of a device of the type is a random-access-memory which retains programs when power is turned off. Coupled with small size and low cost, machines having these features may become attractive for many small scale computer needs and applications and, therefore, widely owned and used. There are limitations to this type of device too. Among them is the display, which holds only one line of prompt or output at one time; and that is further limited to relatively few characters. An attached printer would be more than a convenience.

Most of the comments applicable to the BASIC routine for personal computers apply to this routine also. The notes which follow supplement the general notes which begin this Section and those applicable to the routines for personal computers.

With the exception of one embedded subroutine, the main program begins at statement 10 and ends at statement 117. The remaining statements belong to the subroutines. The user may add code in statements 1 through 9, reserved for the purpose.

1. Precision

All scientific calculators routinely provide at least 8 to 10 digits of precision, so that consideration of extended or double precision code was unnecessary.

2. Changes to the program

Any changes required by syntax rules of various versions of BASIC must be accommodated. Some of these are discussed in the notes for the personal computer version.

If the DMS (convert to degrees, minutes, seconds) and DEG (convert to degrees and decimals) functions are not built in functions, they may be coded as user defined functions or as subroutines, according to the specific dialect available. If coded as subroutines, then statements 85 and 166 must be changed to GOSUB commands. If DMS and DEG are coded as user defined functions, then statement 85 may stand as it is. In the case of change to either subroutine or defined function form, the computation performed at statement 166 must be changed such that the constant .7 is replaced by .5. Statements which define the DMS and DEG functions are to be found on lines 30 and 40 of the personal computer version of the program, and should be keyed in to this version with line numbers less than 10.

Programmable calculators generally provide for recording programs so that they may be re-loaded without keying the instruction sequence. The user may find that a label, title, or some other identification is then required at the head of the program. This may be added as statement number 1, if required.

At line 158 in the program is the single command BEEP. On some machines this produces audible tones. It was included at that point in the program to signal that a lengthy computation has been completed for the Moon; thus it allows the user to divert his attention for a time. The statement may be removed if the feature is not available or not wanted.

A printer connected to the calculator, or integrated, is a definite asset. The program may be modified to direct output to a printer by replacing all PRINT commands, (which usually only display output) if necessary, with whatever commands are necessary to produce actual printing. Examples include PRINT# and LPRINT. It may be possible, as an alternative, to issue a command which redefines the output device. One example of this is the statement PRINT=LPRINT which is required at some point in the program prior to the first PRINT command. It can be inserted in this program by assigning it using a line number less than 10. The user must not make any of the changes described before reading the requirements of the specific machine-interpreter configuration. The examples cited are not general or standard options.

Program execution may be re-directed to a limited degree. As provided here, the flow reflects certain ideas concerning probable usage. Other modes may be more convenient for some applications. Statement 82 may be altered to read GOTO 28, for entering a time of day. Statement 116 may be changed to read GOTO 18, for entering a new set of geographic coordinates and date. At least one of the statements should transfer to statement 18 for purposes of reinitializing.

3. Other changes

Relative to current programmable calculators, this is a large program. Changes other than those described in the preceding paragraph should be made with caution. Although some other changes could be made, it is possible that memory would be exceeded. Also, several variables are multiply-defined and certain computational sequences may not be disturbed or their results will be false. In the worst case, the end results (output) may appear reasonable.

4. Operation

Some devices are capable of operation with other than decimal numbers and, or, with angles in radians or grads. Decimal and degree modes must be specified before using this program.

Once the program has been implemented, operation should proceed interactively, with prompting by key words and phrases provided. Of necessity, abbreviations are used for prompting.

Figure 4 illustrates what is typically to be expected from the calculator version of the program. Two characteristics may be noted. For input to the program, no decimal points were used; the calculator is indifferent in this regard.

In the output, the times of events include decimal points, although not needed. The calculator assumes all numbers should have a decimal point. This should not trouble the user. The second characteristic is the appearance of a possibly unfamiliar notation for values of the illuminance. This form of writing a number is known as scientific notation, exponential form, or as power of 10 notation. The illuminance can vary through the course of a day by a *factor* of 100 million, yet calculated values may only contain one or two significant digits. Scientific notation is an appropriate way to represent the numbers and is, in fact, almost unavoidable. Any user who is unfamiliar with this notation can usually find it described fully in the literature which is supplied with the calculator.

```
LONG=-77
LAT=39
YEAR=1986
MONTH=9
DAY=13
UT=0,STD=1,LMT=2
1
HOUR=1955
SKY=1,2,3,10?1
SUN AZ.          291.
SUN ALT.         -19.
SUN ILL.   2.7E-06
MOON AZ.         169.
MOON ALT.         24.
MOON ILL2.0E-02
%MOON ILL.        79.
TOT. ILL   2.1E-02
HOUR=-3
SUN M.P.         1204
ALT AT MP         55.
SUNRISE          547.
SUNSET          1820.
DAYLIGHT        1233.
BEG. C.T.        520.
END C.T.        1847.
BEG. N.T.        449.
END N.T.        1918.
MOON M.P.       2039.
ALT AT MP         25.
MOONRISE        1603.
MOONSET            8.
```

Figure 4 -- Interactive Input, Output (programmable calculator).

```
10 DIM A(4)
11 DIM B(2)
12 A(1)=-.01454
13 A(2)=-.10453
14 A(3)=-.20791
15 A(4)=.00233
16 CE=.91775
17 SE=.39715
18 INPUT"LONG=";LO,"LAT=";F,"YEAR=";Y,"MONTH=";M,"DAY=";D
19 C=360
20 L=ABS LO
21 SI=SIN F
22 CI=COS F
23 J=367*Y-INT(7*(Y+INT((M+9)/12))/4)+INT(275*M/9)+D-730531
24 INPUT"UT=0,STD=1,LMT=2",Z
25 DT=0
26 IF Z=0 LET DT=-LO/C
27 IF Z=1 LET DT=-(L-15*INT((L+7.5)/15))/C*SGN LO
28 INPUT"HOUR=";H
29 Z=J-.5
30 IF H>0 GOTO  83
31 FOR L=1 TO 4
32 ON L GOTO 34,61,61,33
33 C=347.81
34 M=.5+DT
35 FOR K=1 TO 6
36 M=M-DT
37 E=M-LO/360
38 GOSUB 40
39 GOTO 50
40 D=Z+E
41 IF ABS E >=1 LET E=E-SGN E
42 GOSUB 118
43 IF L=4 GOSUB 168
44 T=T+LO+360*E
45 T=T-INT(T/360)*360
46 U=T-AS
47 IF ABS U >180 LET U=U-360*SGN U
48 U=U/C
49 RETURN
50 M=M-U+DT
51 IF L<4 LET K=K+1
52 ON K GOTO 57,53,57,55,57,58
53 IF M>=0 AND M<1 GOTO 58
54 GOTO 56
55 IF M>=0 GOTO 58
56 M=M-SGN M
57 NEXT K
58 H=ASN(COS(F-DS))
59 IF L=4 LET H=H-.95*COS H
60 GOSUB 208
61 GOSUB 192
```

```
62 B(1)=M-H
63 B(2)=M+H
64 FOR I=1 TO 2
65 K=2*I-3
66 FOR N=1 TO 6
67 B(I)=B(I)-DT
68 E=B(I)-LO/360
69 GOSUB 40
70 GOSUB 192
71 B(I)=B(I)+K*H-U+DT
72 IF L<4 LET N=N+1
73 ON N GOTO 78,74,78,76,78,79
74 IF B(I)>=0 AND B(I)<1 GOTO 79
75 GOTO 77
76 IF B(I)>=0 GOTO 79
77 B(I)=B(I)-SGN B(I)
78 NEXT N
79 NEXT I
80 ON L GOSUB 130,135,135,156
81 NEXT L
82 GOTO 18
83 INPUT"SKY=1,2,3,10?";SK
84 PRINT"AT ";H;" HOURS"
85 E=DEG(H/100)/24-DT-LO/360
86 D=Z+E
87 N=1
88 GOSUB 118
89 T=T+360*E+LO
90 IF N=2 GOSUB 168
91 H=T-AS
92 GOSUB 198
93 Z=H
94 H=H-.95*(N-1)*COS H
95 GOSUB 208
96 GOSUB 212
97 HA=INT(ABS HA+.5)*SGN HA
98 ON N GOTO 99,105
99 I=133775.*M/SK
100 PRINT"SUN AZ.",AZ
101 PRINT"SUN ALT.",HA
102 PRINT"SUN ILL.",I
103 N=2
104 GOTO 90
105 E=ACS(COS(V-LS)*CB)
106 P=.892*EXP(-3.343/((TAN(E/2))^.632))+.0344*(SIN E-E/57.29578*COSE)
107 P=.418*P/(1-.005*COS E-.03*SIN Z )
108 L=P*M/SK
109 I=I+L+.0005/SK
110 PRINT"MOON AZ.",AZ
111 PRINT"MOON ALT.",HA
112 PRINT"MOON ILL.",L
113 L=INT(50*(1-COS E)+.5)
```

```
114 PRINT"% MOON ILL.",L
115 PRINT"TOT.ILL.",I
116 GOTO 28
117 END
118 T=280.46+.98565*D
119 T=T-INT(T/360)*360
120 IF T<0 LET T=T+360
121 G=SIN(357.5+.9856*D)
122 LS=T+1.91*G
123 AS=ATN(CE*TAN LS)
124 Y=COS LS
125 IF Y<0 LET AS=AS+180
126 SD=SE*SIN LS
127 DS=ASN SD
128 T=T-180
129 RETURN
130 R=M
131 GOSUB 166
132 PRINT"SUN M.P.",R
133 HA=INT(ABS HA+.5)*SGN HA
134 PRINT"ALT AT MP",HA
135 FOR I=1 TO 2
136 R=B(I)
137 GOSUB 166
138 IF R>=4800 OR R<0 GOTO 164
139 ON 2*(L-1)+I GOTO 140,142,148,150,152,154,161,163
140 PRINT"SUNRISE",R
141 GOTO 164
142 PRINT"SUNSET",R
143 R=B(2)-B(1)
144 IF R<0 LET R=R+1
145 GOSUB 166
146 PRINT"DAYLIGHT",R
147 GOTO 164
148 PRINT"BEG. C.T.",R
149 GOTO 164
150 PRINT"END C.T.",R
151 GOTO 164
152 PRINT"BEG. N.T.",R
153 GOTO 164
154 PRINT"END N.T.",R
155 GOTO 164
156 R=M
157 GOSUB 166
158 BEEP 3
159 PRINT"MOON M.P.",R
160 GOTO 133
161 PRINT"MOONRISE",R
162 GOTO 164
163 PRINT"MOONSET",R
164 NEXT I
165 RETURN
```

```
166 R=INT(100*DMS(R*24)+.7)
167 RETURN
168 V=218.32+13.1764*D
169 V=V-INT(V/360)*360
170 IF V<0 LET V=V+360
171 Y=134.96+13.06499*D
172 O=93.27+13.22935*D
173 W=235.7+24.3815*D
174 SB=SIN Y
175 CB=COS Y
176 X=SIN O
177 S=COS O
178 SD=SIN W
179 CD=COS W
180 V=V+(6.29-1.27*CD+.43*CB)*SB+(.66+1.27*CB)*SD-.19*G-.23*X*S
181 Y=(5.13-.17*CD)*X+(.56*SB+.17*SD)*S
182 SV=SIN V
183 SB=SIN Y
184 CB=COS Y
185 Q=CB*COS V
186 P=CE*SV*CB-SE*SB
187 SD=SE*SV*CB+CE*SB
188 AS=ATN(P/Q)
189 IF Q<0 LET AS=AS+180
190 DS=ASN SD
191 RETURN
192 H=(A(L)-SI*SD)/(CI*COS DS)
193 IF ABS H>1 GOTO 196
194 H=(ACS H)/C
195 RETURN
196 H=1.5
197 RETURN
198 CD=COS DS
199 CS=COS H
200 Q=SD*CI-CD*SI*CS
201 P=-CD*SIN H
202 AZ=ATN(P/Q)
203 IF Q<0 LET AZ=AZ+180
204 IF AZ<0 LET AZ=AZ+360
205 AZ=INT(AZ+.5)
206 H=ASN(SD*SI+CD*CI*CS)
207 RETURN
208 HA=H
209 IF H<(-5/6) GOTO 211
210 HA=H+1/(TAN(H+8.6/(H+4.42)))/60
211 RETURN
212 U=SIN HA
213 X=753.66156
214 S=ASN (X*COS(HA)/(X+1))
215 M=X*(COS S-U)+COS S
216 M=EXP(-.21*M)*U+.0289*EXP(-.042*M)*(1+(HA+90)*U/57.29578)
217 RETURN
```

SECTION III

Contingent Tables and Diagrams

As the heading suggests, the tables and diagrams are for use when a computing device is not available. For the Sun, all of the data provided by the computer routines are also available from the tables and diagrams. Tables required for manual calculation of the Moon's positions and phenomena are not provided, since they would be numerous and complex. Graphs of lunar illuminance are included should the altitude and phase be available from other sources. Otherwise, the graphs will provide only an indication of available moonlight, based on whatever information concerning Moon visibility is at hand.

The terminology and descriptions found in Section I are relevant to the methods described in this section and are not repeated. Declination is a term not described in Section I. It is one of the coordinates used to specify the position of an object on the celestial sphere, in a manner analogous to latitude on the Earth. Since the Sun's declination is used here only to determine other quantities, it can be considered as an intermediate quantity, and a full description or visualization of it is not strictly necessary.

These tables and diagrams are not new; variations have appeared in handbooks and other literature in the past. Many of those publications are no longer available. Moreover, many were less extensive and more complicated to use correctly. These tables and diagrams are complete and, it is hoped, more direct. Nevertheless, at extreme latitudes, it is to be expected that they will produce times of rising, setting and twilight which may compare poorly to more refined calculations and to the times of the actual events. The altitude, azimuth diagrams for such latitudes demonstrate that the Sun's path will approach and cross the horizon slowly and at shallow angles during certain times of the year. Meteorological conditions, rarely nominal in those regions, cause wide variations in refraction, which in turn combines almost directly with the geometry of the situation to produce significant differences between calculated and observed events.

Description of the tables and diagrams:

Table 1 -- Sun Meridian Passage Increment and Declination: For each day of the year, the table provides an adjustment (MP) which must be applied to Noon and to all other event times to express them in Local Mean Time. It also gives the Sun's declination, for the date, which is required for the use of Table 2 or the altitude, azimuth diagrams. The meridian passage increment is given to the nearest minute and the Sun's declination to the nearest half-degree. The fractional degree is provided for estimating times halfway between those given by Table 2, should the

user desire. Ordinarily this will not be required. (At latitudes where the Sun will rise or set and then remain above or below the horizon for long periods, the declination column for Table 2 provides for direct entry to the nearest half-degree). Following Table 1 are graphs showing MP and DEC which may be used in place of Table 1, if desired.

Table 2: For the latitude of the location of interest, and for the Sun's declination from Table 1, Table 2 immediately provides the altitude of the Sun above the horizon when it crosses the meridian (AL) and the length of the day (LD) from sunrise to sunset. Table 2 also yields three quantities which are the core times for the calculation of sunrise, sunset (R/S), and civil (CT) and nautical (NT) twilight. The interval of latitude between 0 and 82 degrees is one degree throughout. Declination is generally at a one degree interval, but there are exceptions. The maximum solar declination is about 23.5 degrees and that value is tabulated on every page of the table. Half-degree values of solar declination near the condition which produces periods of continuous sunlight or darkness are also included.

Table 3 -- Longitude, Time Adjustments: This table, entered with longitude, provides adjustments which convert Local Mean Time to Universal Time (UT) or to Zone Time (ZC), or conversely. The interval of longitude is one degree which corresponds to the UT and ZC intervals of four minutes. The table may be interpolated visually for fractions of a degree of longitude corresponding to the nearest minute of time, if desired. In applying the adjustment from Mean Time to Zone Time, if Daylight (Summer) Time is in effect, or if the legal time of a place is not within the boundaries of the uniform system, the table may still be used with an additional hour added or subtracted afterward, as dictated by the circumstances.

Altitude, Azimuth Diagrams: These are 33 diagrams which transform a time of day and solar declination into altitude and azimuth referred to the geographic position of interest. The diagrams are drawn for whole multiples of five degrees of latitude and marked with offsets which make them useful for any latitude, from the equator to 82 degrees North and South. Cardinal directions are indicated. On the diagrams, lines extending North to South (the meridian) are intersected by lines from East to West at the origin, which point corresponds to the latitude printed at the top of the page in large type. Above and below the origin are short line segments representing one and two degrees of latitude greater or less than that for which to figure was drawn. These are used to reckon altitudes and azimuths for latitudes which are not multiples of five degrees. Azimuth is indicated for every two degrees at the edge of the diagrams, but one degree resolution is easily achieved by eye. The outermost circle (boundary) represents an altitude of six degrees below the horizon and corresponds to civil twilight. The horizon circle is drawn inside the twilight circle. On each diagram, there are curves representing the path of the Sun from morning civil twilight through rise, meridian passage and set, to evening civil twilight. The interval between these paths is two degrees of solar declination except for the limiting values of 23.5 degrees, which are also shown. Curves representing every 10 degrees of declination are accented and labelled. Time lines drawn at 10 minute intervals, with each hour accented, intersect the declination curves. The time lines are labelled at an hourly interval but, with the exception of the Noon line, only with two digits. At the foot of each diagram is an altitude scale.

When the Sun is nearly overhead, at a specific location, the azimuth is poorly determined by the diagrams. This approximates the real situation of indeterminate azimuth when the Sun is in the zenith.

The diagrams can also be used inversely to obtain times and dates when the Sun is at specific altitudes or azimuths.

Solar Illuminance Diagram: This single diagram gives the illuminance by the Sun on a horizontal surface as a function of altitude. The scale of illuminance is logarithmic. The altitude scale is expanded for solar altitude less than +10 deg., since the change in illuminance with altitude is greatest when the Sun is near the horizon. Above 10 deg. altitude the change in illuminance is less dramatic, as far as vision is concerned, and the exact amount of illuminance is less important for practical concerns. Four curves are shown in the diagram. Each corresponds to a sky condition, or factor, described in Section I and is indicated by the letter F with numerical suffix to the right of the diagram.

Lunar Illuminance Diagrams: Four diagrams are provided, each corresponding to a condition of the sky as described in Section I. Each diagram shows illuminance on a horizontal surface as a function of altitude. But the illuminance by the Moon also depends upon its phase. Phase is a continuous function of the angular separation of the Moon from the Sun (elongation), and for quantitative purposes it is better represented by the percent of the Moon illuminated than by the traditional, restrictive terms Quarter, Full, etc. At the right of each diagram, therefore, the illuminance curves are designated by percent illuminated and by corresponding values of the elongation. Values of the percent of the Moon illuminated must be taken from other sources. *The Air Almanac*, for example, gives the quantity in tabular format at semi-daily interval.

Figure 5 shows an altitude, azimuth diagram for an actual location which has an obstructed horizon. The shaded area was determined by crude measurements of altitudes and azimuths of the obstructions which included trees and buildings on rolling landscape. For example, the spike at azimuth 155 deg. is a tower supporting environmental sensors; at azimuth 350 deg. is a church tower. The profile of the shaded area was faired by hand, since the particular application of the diagram was not critical. The shading suggests collateral uses for the diagrams, as well as the obvious applications in which the availability of direct sunlight is a factor. It should also amplify the significance of the assumptions made in determining illuminance by calculation or graphically. In Figure 5, for example, it is seen that when the Sun's azimuth is greater than 212 deg. while its altitude is less than 12 deg., there is no direct sunlight. The actual illuminance would be considerably less than predicted, for the circumstances. Also, less (indirect) skylight would be available at any time, since not all of the sky is visible at the location. On the other hand, both natural and manmade obstructions reflect various amounts of incident light, so that it is not generally possible to estimate the attenuated light level from the geometry of the figure only. The safe interpretation of illuminance figures, therefore, is to postulate that they are the maximum possible amounts. This may be adequate to determine whether certain activities are possible without artificial lighting or aided vision.

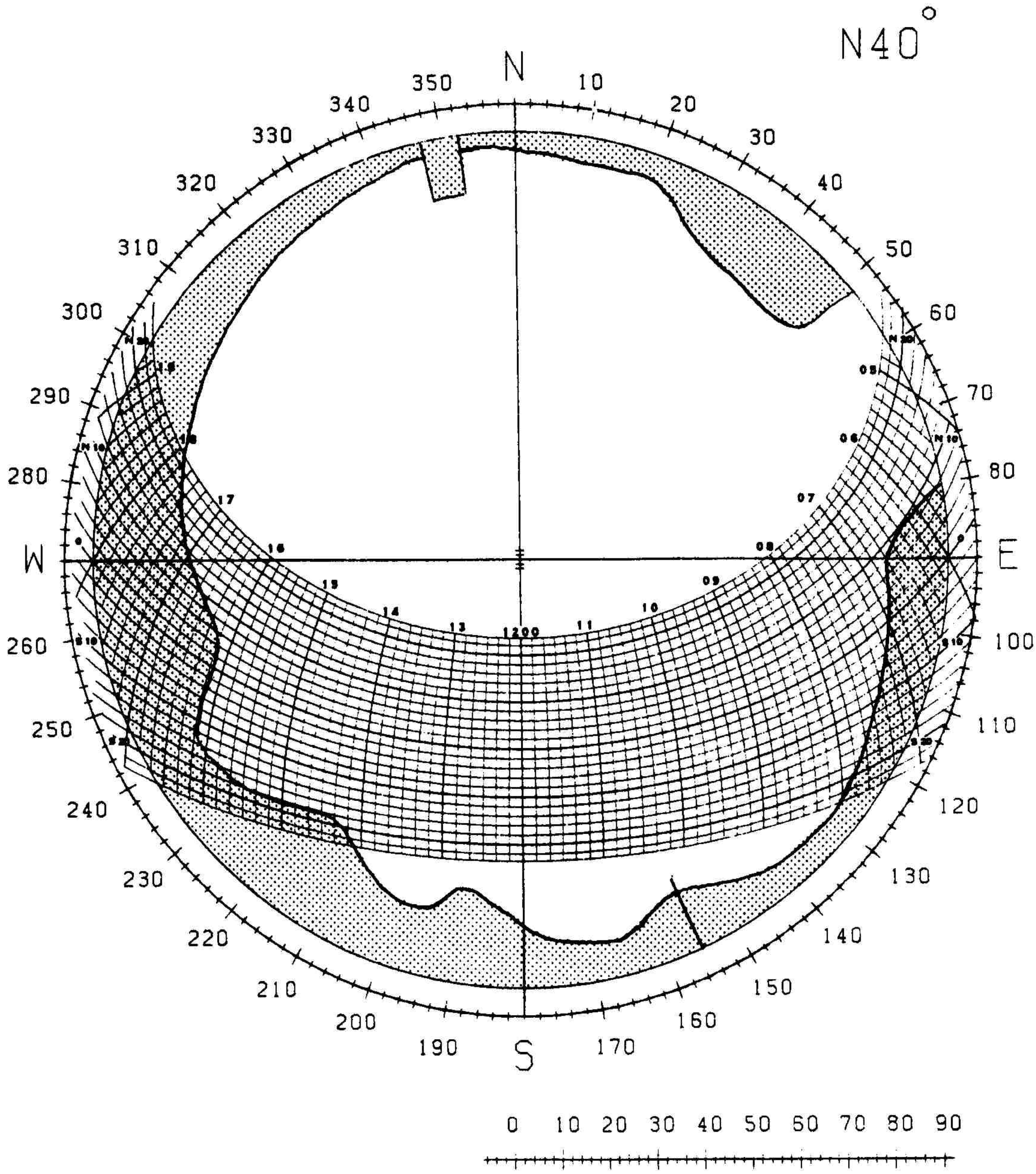


Figure 5 -- Altitude, Azimuth Diagram showing obstructed horizon.

Instructions for calculation of events using the tables:

1. Obtain and record the geographic coordinates to the nearest degree of latitude and longitude for the location of interest. Label the latitude with N or S according to whether the location is North or South of the equator. Label the longitude E or W according to whether the location is East or West of the prime meridian.

2. Enter Table 1 (page 50) at the month (column) and day of the month (row). Take out the quantity MP with its positive (+) or negative (-) sign, and DEC with its prefix N or S. Write MP with its sign under the number 1200 and perform the indicated operation of addition or subtraction. Record the result as the Local Mean Time of the Sun's meridian passage.

3. Open Table 2 (page 52) at the latitude. Two tables will be found on each page. If the latitude and DEC are both N or both S, use the table headed "Latitude and Declination SAME." If the latitude and DEC are not both N or both S use the table labelled "Latitude and Declination OPPOSITE." In the column under the numerical value of the latitude and at the row indicated by the numerical value of declination, take out and record the quantities AL, LD, R/S,CT, NT. The quantity AL is the altitude of the Sun at the time of its meridian passage (crossing), LD is the length of the day (number of hours of daylight) from sunrise until sunset.

4. Write MP with its sign under the quantities R/S, CT, NT and perform the indicated operation (addition or subtraction). The results are the Local Mean Times of sunrise and beginning morning civil and nautical twilight respectively.

5. Add LD to the LMT of sunrise. The result is the LMT of sunset.

6. Subtract the quantities CT and NT, as given by Table 2, from 24 hours. This is accomplished more readily by subtracting each from the equivalent quantity 2360.

7. Write MP with its sign under each result found by step 6. Perform the indicated operation (addition or subtraction). The results are the Local Mean Times for the end of evening civil and nautical twilight.

8. Turn to Table 3 (page 69). Identify the column and row containing the longitude, under the heading Lo. If zone (standard) time is required, continue at step 10.

9. If Universal Time is required, take from Table 3 the UT adjustment found in the same column at the same row as the longitude.

9a. If the longitude is West (W) of the prime meridian, add the UT adjustment to the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. The events are now expressed in Universal Time. Continue at step 11.

9b. If the longitude is East (E) of the prime meridian, subtract the UT adjustment from the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. The events are now expressed in Universal Time. Continue at step 11.

10. To express the times of events in zone (standard) time, find the quantity ZC (zone adjustment) in the last column of Table 3 on the same row as the longitude.

10a. If the longitude is West of the nearest standard meridian (center of the zone), add the ZC adjustment to the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight. Continue at step 11.

10b. If the longitude is East of the nearest standard meridian (center of the zone), subtract the ZC adjustment from the Local Mean Times of the Sun's meridian passage, sunrise, sunset and the beginning and ending times of civil and nautical twilight.

11. Do not apply the UT or ZC adjustments to the length of the day. After applying the adjustment to the specified events:

11a. If the time of any event is greater than 2400, subtract 2400 from the time AND increase the date by one day. This completes the calculation.

11b. If the time of any event is less than 0000, add 2400 to the time AND decrease the date by one day. This completes the calculation.

Two examples illustrating the use of the tables are given on the next page. The first is straightforward. The second includes the use of visual interpolation in Table 2 (not a requirement) and involves an addition to the date. For both examples, all information required to begin the calculations is stated on the first line, and all events have been computed. The latter is rarely required in practice. The examples might be read in conjunction with the instructions, for better comprehension of both. It is recommended that the user adopt a work form for calculation; it should reduce the possibility for error. The form used for the examples is intended to be suggestive only.

EXAMPLE 1

Date: 17 Nov., Latitude: N13, Longitude: E145, Event Times: Zone

Table 1: MP= -15 DEC= S19
Table 2: (OPPOSITE), AL= 58deg., LD= 1131, R/S= 0615, CT= 0552, NT= 0526
Table 3: (Zone Time adjustment to 150th meridian) ZC= 20

	1200	CT	0552	NT	0526
MP	-15	MP	-15	MP	-15
Merid. Pass.	1145 LMT	Beg. Civ. Twi.	0537 LMT	Beg. Naut. Twi.	0511 LMT
R/S	0615	(24 hours)	2360	(24 hours)	2360
MP	-15	CT	-0552	NT	-0526
Sunrise	0600 LMT		1808		1834
LD	1131	MP	-15	MP	-15
Sunset	1731 LMT	End Civ. Twi.	1753 LMT	End Naut. Twi.	1819 LMT

	M.P.	Rise	Set	BCT	ECT	BNT	ENT
Local Mean Time	1145	0600	1731	0537	1753	0511	1819
ZC (adjustment)	+20	+20	+20	+20	+20	+20	+20
Zone time	1205	0620	1751	0557	1813	0531	1839

EXAMPLE 2

Date: 3 Feb., Latitude: S59, Longitude: W55, Event Times: Universal

Table 1: MP= +14, DEC= S16.5
Table 2: (SAME), AL=47.5*deg., LD= 1612*, R/S= 0354*, CT= 0300*, NT=0136*
Table 3: (Universal Time adjustment) UT= 0340

	1200	CT	0300*	NT	0136*
MP	+14	MP	+14	MP	+14
Merid. Pass.	1214 LMT	Beg. Civ. Twi.	0314 LMT	Beg. Naut. Twi.	0150 LMT
R/S	0354*	(24 hours)	2360	(24 hours)	2360
MP	+14	CT	-0300*	NT	-0136*
Sunrise	0408 LMT		2100		2224
LD	1612*	MP	+14	MP	+14
Sunset	2020 LMT	End Civ. Twi.	2114 LMT	End Naut. Twi.	2238 LMT

	M.P.	Rise	Set	BCT	ECT	BNT	ENT
Local Mean Time	1214	0408	2020	0314	2114	0150	2238
UT (adjustment)	+0340	+0340	+0340	+0340	+0340	+0340	+0340
U.T., 3 Feb.	1554	0748	2400	0654	2454	0530	2618
					-2400		-2400
U.T., 4 Feb.					0054		0218

* Interpolated from Table 2 by inspection with DEC= 16.5.

Instructions for calculation of the Sun's altitude, azimuth and illuminance:

1. Obtain and record the geographic coordinates to the nearest degree of latitude and longitude for the location of interest. Label the latitude with N or S according to whether the location is in the northern or southern hemisphere. Label the longitude E or W according to whether the location is East or West of the prime meridian.

2. Enter Table 3 (page 69). Identify the column and row containing the longitude, under the heading Lo. If the time of day is given in Zone (Standard) Time, proceed at Step 3. If the time of day is given in Universal Time, take from Table 3 the UT adjustment found in the same column at the same row as the longitude.

2a. If the longitude is West of the prime meridian, subtract the UT adjustment from the given time of day. Continue at step 4.

2b. If the longitude is East of the prime meridian, add the UT adjustment to the given time of day. Continue at step 4.

3. To convert Zone Time, find the ZC adjustment in the last column of Table 3 on the same row as the longitude.

3a. If the longitude is West of the nearest standard meridian, subtract the ZC adjustment from the given time of day. Continue at step 4.

3b. If the longitude is East of the nearest standard meridian, add the ZC adjustment to the given time of day.

4. Enter Table 1 (page 50) with the month (column) and day of the month (row). Take out the MP increment and write it under the Local Mean Time found by step 2 or step 3 but with its sign changed (plus to minus or minus to plus), unless the value of MP is zero. Perform the indicated operation of combining MP with LMT to produce the reference times for the altitude, azimuth diagram. Also take the declination of the Sun (DEC) from Table 1.

5. Determine which multiple of five degrees, North or South, is nearest to the given latitude and open the diagram pages (page 70) at that latitude. To prevent deterioration through repeated use, working copies of the page should be made so that notes and azimuth (bearing) lines can be placed on the copies.

6. Near the edge of the diagram locate the Sun's declination curve which corresponds most nearly to the value of DEC taken from Table 1. Follow the declination curve to the time line which corresponds most nearly to the reference time found by step 4. Mark the intersection of the reference time line and the declination curve on the diagram.

7. Locate the origin for the given latitude on the diagram. If the given latitude is one or two degrees South of the latitude for which the diagram is drawn, the offset origin will be found at the first or second line segment below the East-West line. If the given latitude is one or two degrees North of the diagram latitude, the offset origin will be at the first or second line segment above the East-West line.

8. Place a ruler or straightedge on the diagram is such a way as to connect the latitude origin and the Sun's position determined in step 6. The straightedge or ruler should then intersect the graduated outer circle of the diagram where the azimuth is read immediately.

9. Mark the straightedge or ruler where it meets the origin for the given latitude and where it meets the Sun's indicated position (step 6). Place the straightedge parallel to the altitude scale at the bottom of the diagram so that one of the marks coincides with the point designated 90. The other mark then gives the point on the scale at which the Sun's altitude is read. Dividers may also be used to find the altitude.

10. Referring to the Solar Illuminance Diagram (page 103), locate the Sun's altitude, found above, on the horizontal scale. The appropriate illuminance curve is selected by estimating the cloud cover according to the criteria given in Section 1. The illuminance is then read from the vertical scale of the diagram.

Two examples are given to illustrate the use of an altitude, azimuth diagram, both for the location 37 deg. North and 122 deg. West, under clear skies.

Example 3: To find the azimuth, altitude and solar illuminance on 15 March at 0927 (Pacific) Standard Time.

Example 4: To find the azimuth, altitude and solar illuminance on 6 October at 0121 Universal Time.

The calculations and results are summarized on the next page, which also shows the corresponding diagram with azimuth lines drawn. Example 3 is a straightforward application of the instructions. In plotting the position of the Sun for Example 4 however, the declination and reference time indicate a point midway between grid lines, and visual interpolation was used to locate the point. Also, it should be noted that, for the given longitude, the conversion from Universal to Local Mean Time necessitates a change to the date.

EXAMPLE 3
Date: 15 Mar., Lat: N37, Long: W122
Sky: clear
Table 3: (Zone Time) ZC= 08
Table 1: MP= +09; DEC= S 2

Zone Time	0927
ZC (adjustment)	-08
LMT	0919
MP (opposite sign)	-09
Reference time	0910 (for diagram)

Diagram: Azimuth = 124 deg.
Altitude = +34 deg.
Graph: (F1) Illuminance = 60,000 lux

EXAMPLE 4
Date: 6 Oct., Lat: N37, Long: W122
Sky: clear
Table 3: (Universal Time) UT= 0808
Table 1: MP= -12, DEC= S 5

Universal Time	0121
UT (adjustment)	-0808
5 Oct., LMT	1713
MP (opposite sign)	+12
Reference time	1725 (for diagram)

Diagram: Azimuth = 260 deg.
Altitude = + 4 deg.
Graph: (F1) Illuminance = 4000 lux

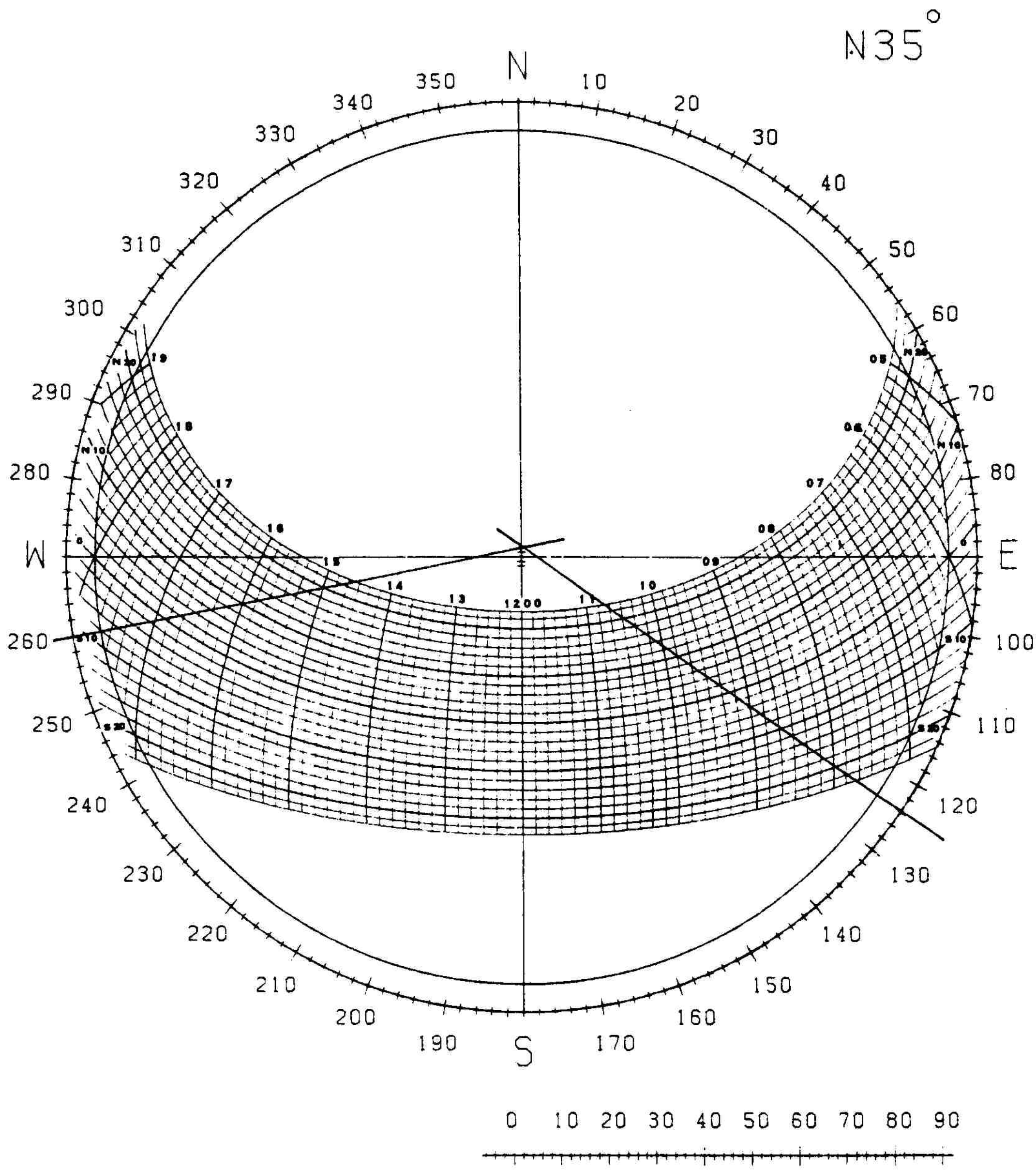


Table 1 -- Sun Meridian Passage Increment and Declination

DAY	Jan.		Feb.		Mar.		Apr.		May		June	
	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC
	m	o	m	o	m	o	m	o	m	o	m	o
1	+03	S23.0	+13	S17.0	+12	S 7.5	+04	N 4.5	-03	N15.0	-02	N22.0
2	+04	S23.0	+14	S17.0	+12	S 7.0	+04	N 5.0	-03	N15.5	-02	N22.0
3	+04	S23.0	+14	S16.5	+12	S 6.5	+03	N 5.5	-03	N15.5	-02	N22.5
4	+05	S22.5	+14	S16.0	+12	S 6.5	+03	N 6.0	-03	N16.0	-02	N22.5
5	+05	S22.5	+14	S16.0	+11	S 6.0	+03	N 6.0	-03	N16.5	-01	N22.5
6	+06	S22.5	+14	S15.5	+11	S 5.5	+02	N 6.5	-03	N16.5	-01	N22.5
7	+06	S22.5	+14	S15.5	+11	S 5.0	+02	N 7.0	-03	N17.0	-01	N22.5
8	+07	S22.0	+14	S15.0	+11	S 5.0	+02	N 7.5	-03	N17.0	-01	N23.0
9	+07	S22.0	+14	S14.5	+10	S 4.5	+02	N 7.5	-03	N17.5	-01	N23.0
10	+07	S22.0	+14	S14.5	+10	S 4.0	+01	N 8.0	-04	N17.5	-01	N23.0
11	+08	S22.0	+14	S14.0	+10	S 3.5	+01	N 8.5	-04	N18.0	00	N23.0
12	+08	S21.5	+14	S13.5	+10	S 3.0	+01	N 8.5	-04	N18.0	00	N23.0
13	+09	S21.5	+14	S13.5	+09	S 3.0	+01	N 9.0	-04	N18.5	00	N23.0
14	+09	S21.5	+14	S13.0	+09	S 2.5	00	N 9.5	-04	N18.5	00	N23.0
15	+09	S21.0	+14	S12.5	+09	S 2.0	00	N10.0	-04	N19.0	+01	N23.5
16	+10	S21.0	+14	S12.5	+09	S 1.5	00	N10.0	-04	N19.0	+01	N23.5
17	+10	S20.5	+14	S12.0	+08	S 1.5	00	N10.5	-04	N19.5	+01	N23.5
18	+10	S20.5	+14	S11.5	+08	S 1.0	-01	N11.0	-03	N19.5	+01	N23.5
19	+11	S20.5	+14	S11.5	+08	S 0.5	-01	N11.0	-03	N20.0	+01	N23.5
20	+11	S20.0	+14	S11.0	+07	0.0	-01	N11.5	-03	N20.0	+02	N23.5
21	+11	S20.0	+14	S10.5	+07	N 0.5	-01	N12.0	-03	N20.0	+02	N23.5
22	+11	S19.5	+13	S10.0	+07	N 0.5	-01	N12.5	-03	N20.5	+02	N23.5
23	+12	S19.5	+13	S10.0	+07	N 1.0	-02	N12.5	-03	N20.5	+02	N23.5
24	+12	S19.0	+13	S 9.5	+06	N 1.5	-02	N13.0	-03	N21.0	+02	N23.5
25	+12	S19.0	+13	S 9.0	+06	N 2.0	-02	N13.0	-03	N21.0	+03	N23.5
26	+12	S18.5	+13	S 8.5	+06	N 2.5	-02	N13.5	-03	N21.0	+03	N23.5
27	+13	S18.5	+13	S 8.5	+05	N 2.5	-02	N14.0	-03	N21.5	+03	N23.5
28	+13	S18.0	+12	S 8.0	+05	N 3.0	-02	N14.0	-03	N21.5	+03	N23.0
29	+13	S18.0	+12	S 7.5	+05	N 3.5	-03	N14.5	-03	N21.5	+03	N23.0
30	+13	S17.5			+04	N 4.0	-03	N15.0	-02	N22.0	+04	N23.0
31	+13	S17.5			+04	N 4.0			-02	N22.0		

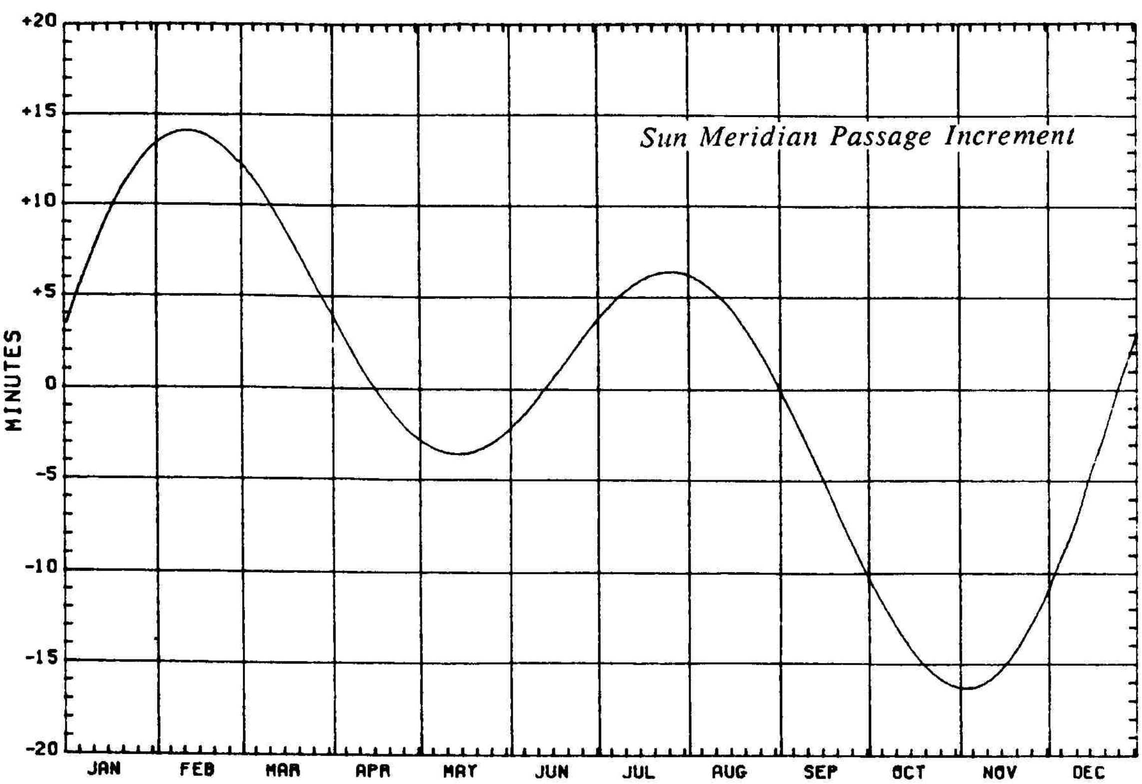


Table 1 -- Sun Meridian Passage Increment and Declination

DAY	July		Aug.		Sep.		Oct.		Nov.		Dec.	
	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC	MP	DEC
	m	o	m	o	m	o	m	o	m	o	m	o
1	+04	N23.0	+06	N18.0	00	N 8.0	-10	S 3.5	-16	S14.5	-11	S22.0
2	+04	N23.0	+06	N17.5	00	N 8.0	-11	S 3.5	-16	S15.0	-10	S22.0
3	+04	N23.0	+06	N17.5	-01	N 7.5	-11	S 4.0	-16	S15.0	-10	S22.0
4	+04	N23.0	+06	N17.0	-01	N 7.0	-11	S 4.5	-16	S15.5	-10	S22.0
5	+05	N22.5	+06	N17.0	-01	N 6.5	-12	S 5.0	-16	S15.5	-09	S22.5
6	+05	N22.5	+06	N16.5	-02	N 6.5	-12	S 5.0	-16	S16.0	-09	S22.5
7	+05	N22.5	+06	N16.5	-02	N 6.0	-12	S 5.5	-16	S16.5	-08	S22.5
8	+05	N22.5	+06	N16.0	-02	N 5.5	-12	S 6.0	-16	S16.5	-08	S22.5
9	+05	N22.5	+05	N16.0	-03	N 5.0	-13	S 6.5	-16	S17.0	-08	S23.0
10	+05	N22.0	+05	N15.5	-03	N 5.0	-13	S 6.5	-16	S17.0	-07	S23.0
11	+05	N22.0	+05	N15.0	-03	N 4.5	-13	S 7.0	-16	S17.5	-07	S23.0
12	+06	N22.0	+05	N15.0	-04	N 4.0	-13	S 7.5	-16	S17.5	-06	S23.0
13	+06	N22.0	+05	N14.5	-04	N 3.5	-14	S 8.0	-16	S18.0	-06	S23.0
14	+06	N21.5	+05	N14.5	-04	N 3.5	-14	S 8.0	-15	S18.5	-05	S23.0
15	+06	N21.5	+04	N14.0	-05	N 3.0	-14	S 8.5	-15	S18.5	-05	S23.0
16	+06	N21.5	+04	N13.5	-05	N 2.5	-14	S 9.0	-15	S19.0	-04	S23.5
17	+06	N21.0	+04	N13.5	-06	N 2.0	-15	S 9.5	-15	S19.0	-04	S23.5
18	+06	N21.0	+04	N13.0	-06	N 2.0	-15	S 9.5	-15	S19.0	-03	S23.5
19	+06	N21.0	+04	N12.5	-06	N 1.5	-15	S10.0	-14	S19.5	-03	S23.5
20	+06	N20.5	+03	N12.5	-07	N 1.0	-15	S10.5	-14	S19.5	-02	S23.5
21	+06	N20.5	+03	N12.0	-07	N 0.5	-15	S11.0	-14	S20.0	-02	S23.5
22	+06	N20.0	+03	N11.5	-07	0.0	-15	S11.0	-14	S20.0	-01	S23.5
23	+06	N20.0	+03	N11.5	-08	0.0	-16	S11.5	-13	S20.5	-01	S23.5
24	+06	N20.0	+02	N11.0	-08	S 0.5	-16	S12.0	-13	S20.5	00	S23.5
25	+06	N19.5	+02	N10.5	-08	S 1.0	-16	S12.0	-13	S21.0	00	S23.5
26	+06	N19.5	+02	N10.5	-09	S 1.5	-16	S12.5	-13	S21.0	+01	S23.5
27	+06	N19.0	+01	N10.0	-09	S 1.5	-16	S13.0	-12	S21.0	+01	S23.5
28	+06	N19.0	+01	N 9.5	-09	S 2.0	-16	S13.0	-12	S21.5	+02	S23.0
29	+06	N18.5	+01	N 9.5	-10	S 2.5	-16	S13.5	-12	S21.5	+02	S23.0
30	+06	N18.5	+01	N 9.0	-10	S 3.0	-16	S14.0	-11	S21.5	+03	S23.0
31	+06	N18.0	00	N 8.5			-16	S14.0			+03	S23.0

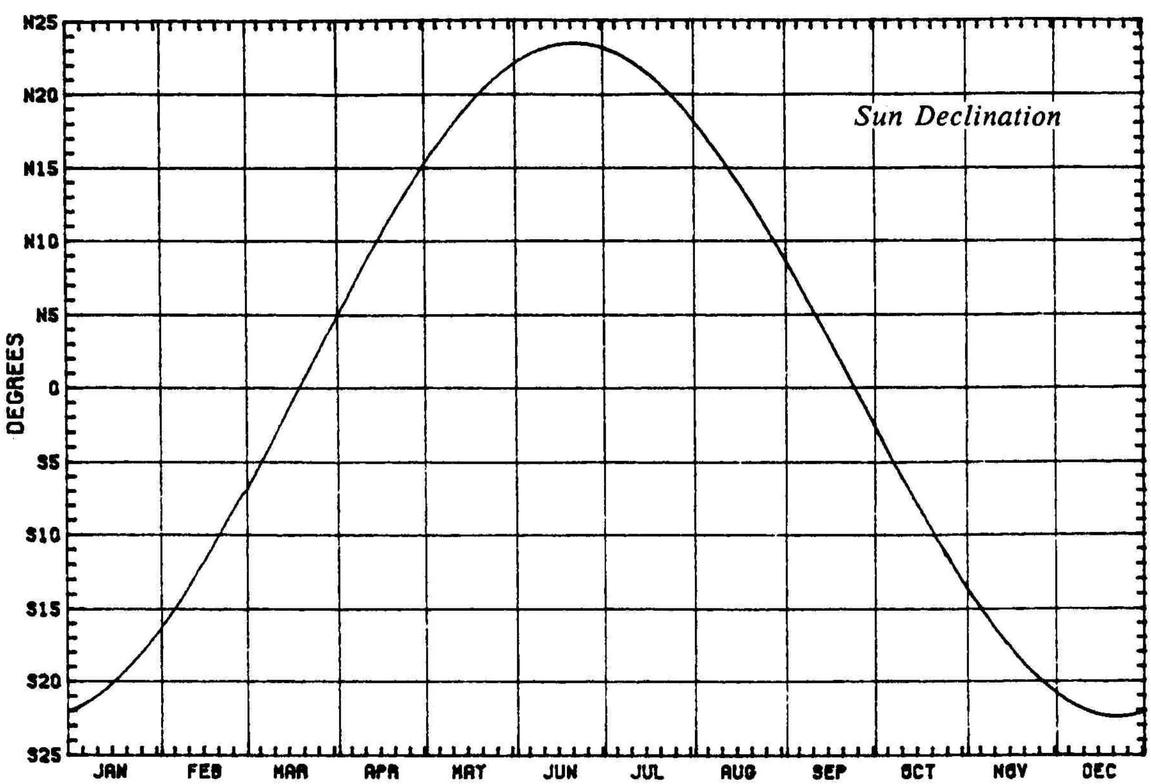


Table 2

Latitude and Declination **SAME** / Latitude and Declination **OPPOSITE**

	LAT. 2 (SAME)					LAT. 1 (SAME)					LAT. 0					LAT. 1 (OPPOSITE)					LAT. 2 (OPPOSITE)				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	88	1207	557	536	512	89	1207	557	536	512	90	1207	557	536	512	89	1207	557	536	512	88	1207	557	536	512
1	89	1207	557	536	512	90	1207	557	536	512	89	1207	557	536	512	88	1207	557	536	512	87	1206	557	536	512
2	90	1207	556	536	512	89	1207	557	536	512	88	1207	557	536	512	87	1206	557	536	512	86	1206	557	536	512
3	89	1208	556	536	511	88	1207	556	536	512	87	1207	557	536	512	86	1206	557	536	512	85	1206	557	536	512
4	88	1208	556	535	511	87	1207	556	536	512	86	1207	557	536	512	85	1206	557	536	512	84	1206	557	536	512
5	87	1208	556	535	511	86	1207	556	536	511	85	1207	557	536	512	84	1206	557	536	512	83	1205	557	537	512
6	86	1208	556	535	511	85	1208	556	535	511	84	1207	557	536	512	83	1206	557	536	512	82	1205	557	537	513
7	85	1209	556	535	511	84	1208	556	535	511	83	1207	557	536	512	82	1206	557	536	512	81	1205	558	537	513
8	84	1209	556	535	510	83	1208	556	535	511	82	1207	557	536	512	81	1206	557	536	512	80	1204	558	537	513
9	83	1209	555	534	510	82	1208	556	535	511	81	1207	557	536	511	80	1205	557	536	512	79	1204	558	537	513
10	82	1210	555	534	510	81	1208	556	535	511	80	1207	557	536	511	79	1205	557	536	512	78	1204	558	537	513
11	81	1210	555	534	509	80	1208	556	535	510	79	1207	557	536	511	78	1205	557	536	512	77	1204	558	537	513
12	80	1210	555	534	509	79	1209	556	535	510	78	1207	557	535	511	77	1205	557	536	512	76	1203	558	537	513
13	79	1211	555	533	509	78	1209	556	534	510	77	1207	557	535	511	76	1205	558	536	512	75	1203	558	537	513
14	78	1211	555	533	508	77	1209	556	534	509	76	1207	557	535	511	75	1205	558	536	512	74	1203	559	537	513
15	77	1211	554	533	508	76	1209	555	534	509	75	1207	557	535	510	74	1205	558	536	511	73	1203	559	537	512
16	76	1212	554	533	508	75	1209	555	534	509	74	1207	557	535	510	73	1205	558	536	511	72	1202	559	537	512
17	75	1212	554	532	507	74	1209	555	534	509	73	1207	557	535	510	72	1205	558	536	511	71	1202	559	537	512
18	74	1212	554	532	507	73	1210	555	533	508	72	1207	556	535	509	71	1204	558	536	511	70	1202	559	537	512
19	73	1213	554	532	506	72	1210	555	533	508	71	1207	556	535	509	70	1204	558	536	511	69	1202	559	537	512
20	72	1213	554	532	506	71	1210	555	533	507	70	1207	556	534	509	69	1204	558	536	510	68	1201	559	537	512
21	71	1213	553	531	505	70	1210	555	533	507	69	1207	556	534	509	68	1204	558	536	510	67	1201	559	537	512
22	70	1214	553	531	505	69	1210	555	532	506	68	1207	556	534	508	67	1204	558	536	510	66	1201	600	537	511
23	69	1214	553	530	504	68	1211	555	532	506	67	1207	556	534	508	66	1204	558	536	510	65	1200	600	537	511
23.5	69	1214	553	530	504	68	1211	555	532	506	67	1207	556	534	508	66	1204	558	536	509	65	1200	600	537	511

Table 2, Latitude and Declination SAME

DEC	LAT. 3					LAT. 4					LAT. 5					LAT. 6					LAT. 7				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	87	1207	557	536	512	86	1207	557	536	512	85	1207	557	536	512	84	1207	557	536	512	83	1207	557	536	512
1	88	1207	556	536	512	87	1207	556	536	512	86	1207	556	536	511	85	1208	556	535	511	84	1208	556	535	511
2	89	1208	556	536	511	88	1208	556	535	511	87	1208	556	535	511	86	1208	556	535	511	85	1209	556	535	511
3	90	1208	556	535	511	89	1208	556	535	511	88	1209	556	535	511	87	1209	555	535	510	86	1210	555	534	510
4	89	1208	556	535	511	90	1209	556	535	511	89	1210	555	534	510	88	1210	555	534	510	87	1211	555	534	509
5	88	1209	556	535	511	89	1210	555	534	510	90	1210	555	534	510	89	1211	555	534	509	88	1212	554	533	509
6	87	1209	555	535	510	88	1210	555	534	510	89	1211	555	534	509	90	1212	554	533	509	89	1213	554	533	508
7	86	1210	555	534	510	87	1211	555	534	509	88	1212	554	533	509	89	1213	554	533	508	90	1214	553	532	508
8	85	1210	555	534	510	86	1211	554	533	509	87	1212	554	533	508	88	1214	553	532	508	89	1215	553	532	507
9	84	1211	555	534	509	85	1212	554	533	509	86	1213	553	532	508	87	1214	553	532	507	88	1216	552	531	506
10	83	1211	554	533	509	84	1212	554	533	508	85	1214	553	532	507	86	1215	552	531	507	87	1217	552	530	506
11	82	1211	554	533	509	83	1213	553	532	508	84	1215	553	532	507	85	1216	552	531	506	86	1218	551	530	505
12	81	1212	554	533	508	82	1214	553	532	507	83	1215	552	531	506	84	1217	551	530	505	85	1219	551	529	504
13	80	1212	554	533	508	81	1214	553	532	507	82	1216	552	531	506	83	1218	551	530	505	84	1220	550	529	504
14	79	1213	554	532	507	80	1215	553	531	506	81	1217	552	530	505	82	1219	551	529	504	83	1221	550	528	503
15	78	1213	553	532	507	79	1216	552	531	506	80	1218	551	530	505	81	1220	550	529	503	82	1222	549	527	502
16	77	1214	553	532	506	78	1216	552	530	505	79	1218	551	529	504	80	1221	550	528	503	81	1223	548	527	501
17	76	1214	553	531	506	77	1217	552	530	505	78	1219	550	529	503	79	1222	549	527	502	80	1224	548	526	501
18	75	1215	553	531	505	76	1217	551	529	504	77	1220	550	528	503	78	1223	549	527	501	79	1225	547	525	500
19	74	1215	552	530	505	75	1218	551	529	503	76	1221	550	528	502	77	1224	548	526	500	78	1226	547	525	459
20	73	1216	552	530	504	74	1219	551	529	503	75	1222	549	527	501	76	1225	548	525	500	77	1228	546	524	458
21	72	1216	552	538	504	73	1219	550	528	502	74	1223	549	526	500	75	1226	547	525	459	76	1229	546	523	457
22	71	1217	552	529	503	72	1220	550	528	501	73	1223	548	526	500	74	1227	547	524	458	75	1230	545	522	456
23	70	1217	551	529	502	71	1221	550	527	501	72	1224	548	525	459	73	1228	546	523	457	74	1231	544	522	455
23.5	70	1218	551	529	502	71	1221	549	527	500	72	1225	548	525	458	73	1228	546	523	456	74	1232	544	521	455

Latitude and Declination OPPOSITE

DEC	LAT. 3					LAT. 4					LAT. 5					LAT. 6					LAT. 7				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	87	1207	557	536	512	86	1207	557	536	512	85	1207	557	536	512	84	1207	557	536	512	83	1207	557	536	512
1	86	1206	557	536	512	85	1206	557	536	512	84	1206	557	536	512	83	1206	557	536	512	82	1206	557	536	512
2	85	1206	557	536	512	84	1206	557	536	512	83	1205	557	537	512	82	1205	557	537	513	81	1205	558	537	513
3	84	1205	557	537	513	83	1205	557	537	513	82	1205	558	537	513	81	1204	558	537	513	80	1204	558	537	513
4	83	1205	557	537	513	82	1204	558	537	513	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514
5	82	1205	558	537	513	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514	78	1202	559	538	514
6	81	1204	558	537	513	80	1203	558	538	513	79	1203	559	538	514	78	1202	559	538	514	77	1201	600	539	514
7	80	1204	558	537	513	79	1203	559	538	514	78	1202	559	538	514	77	1201	600	539	514	76	1200	600	539	515
8	79	1203	558	537	513	78	1202	559	538	514	77	1201	559	539	514	76	1200	600	539	515	75	1159	601	540	515
9	78	1203	559	538	513	77	1202	559	538	514	76	1200	600	539	514	75	1159	600	539	515	74	1158	601	540	516
10	77	1203	559	538	513	76	1201	559	538	514	75	1200	600	539	515	74	1158	601	540	515	73	1157	602	540	516
11	76	1202	559	538	513	75	1201	600	539	514	74	1159	600	539	515	73	1157	601	540	516	72	1156	602	541	516
12	75	1202	559	538	513	74	1200	600	539	514	73	1158	601	540	515	72	1157	602	540	516	71	1155	603	541	517
13	74	1201	559	538	513	73	1159	600	539	514	72	1158	601	540	515	71	1156	602	541	516	70	1154	603	542	517
14	73	1201	600	538	514	72	1159	601	539	514	71	1157	602	540	515	70	1155	603	541	516	69	1153	604	542	517
15	72	1200	600	538	514	71	1158	601	539	515	70	1156	602	540	516	69	1154	603	541	517	68	1152	604	543	518
16	71	1200	600	538	513	70	1158	601	540	515	69	1155	602	541	516	68	1153	603	542	517	67	1151	605	543	518
17	70	1200	600	539	513	69	1157	601	540	515	68	1155	603	541	516	67	1152	604	542	517	66	1150	605	543	518
18	69	1159	600	539	513	68	1157	602	540	515	67	1154	603	541	516	66	1151	604	542	517	65	1149	606	544	518
19	68	1159	601	539	513	67	1156	602	540	515	66	1153	603	541	516	65	1151	605	543	517	64	1148	606	544	519
20	67	1158	601	539	513	66	1155	602	540	515	65	1153	604	542	516	64	1150	605	543	518	63	1147	607	545	519
21	66	1158	601	539	513	65	1155	603	540	515	64	1152	604	542	516	63	1149	606	543	518	62	1146	607	545	519
22	65	1157	601	539	513	64	1154	603	541	515	63	1151	604	542	516	62	1148	606	544	518	61	1145	608	545	519
23	64	1157	601	539	513	63	1154	603	541	515	62	1150	605	542	516	61	1147	607	544	518	60	1143	608	546	520
23.5	64	1157	602	539	513	63	1153	603	541	515	62	1150	605	542	516	61	1146	607	544	518	60	1143	609	546	520

Table 2, Latitude and Declination SAME

	LAT. 8					LAT. 9					LAT.10					LAT.11					LAT.12				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	82	1207	557	536	512	81	1207	557	536	511	80	1207	557	536	511	79	1207	557	536	511	78	1207	557	535	511
1	83	1208	556	535	511	82	1208	556	535	511	81	1208	556	535	511	80	1208	556	535	510	79	1209	556	535	510
2	84	1209	556	535	510	83	1209	555	534	510	82	1210	555	534	510	81	1210	555	534	509	80	1210	555	534	509
3	85	1210	555	534	510	84	1211	555	534	509	83	1211	554	533	509	82	1211	554	533	509	81	1212	554	533	508
4	86	1211	554	533	509	85	1212	554	533	509	84	1212	554	533	508	83	1213	553	532	508	82	1214	553	532	507
5	87	1212	554	533	508	86	1213	553	532	508	85	1214	553	532	507	84	1215	553	532	507	83	1215	552	531	506
6	88	1214	553	532	508	87	1214	553	532	507	86	1215	552	531	507	85	1216	552	531	506	84	1217	551	530	505
7	89	1215	553	532	507	88	1216	552	531	506	87	1217	552	530	506	86	1218	551	530	505	85	1219	551	529	504
8	90	1216	552	531	506	89	1217	551	530	506	88	1218	551	530	505	87	1219	550	529	504	86	1221	550	528	503
9	89	1217	551	530	506	90	1218	551	530	505	89	1220	550	529	504	88	1221	550	528	503	87	1222	549	527	502
10	88	1218	551	530	505	89	1220	550	529	504	90	1221	549	528	503	89	1223	549	527	502	88	1224	548	526	501
11	87	1219	550	529	504	88	1221	550	528	503	89	1223	549	527	502	90	1224	548	526	501	89	1226	547	525	500
12	86	1221	550	528	503	87	1222	549	527	502	88	1224	548	526	501	89	1226	547	525	500	90	1228	546	524	459
13	85	1222	549	528	503	86	1224	548	527	501	87	1226	547	526	500	88	1228	546	525	459	89	1230	545	523	458
14	84	1223	548	527	502	85	1225	547	526	501	86	1227	546	525	459	87	1229	545	524	458	88	1231	544	522	457
15	83	1224	548	526	501	84	1226	547	525	500	85	1229	546	524	458	86	1231	545	523	457	87	1233	543	521	456
16	82	1225	547	525	500	83	1228	546	524	459	84	1230	545	523	457	85	1233	544	522	456	86	1235	542	520	454
17	81	1227	547	525	459	82	1229	545	523	458	83	1232	544	522	456	84	1234	543	521	455	85	1237	542	519	453
18	80	1228	546	524	458	81	1231	545	523	457	82	1233	543	521	455	83	1236	542	520	454	84	1239	541	518	452
19	79	1229	545	523	457	80	1232	544	522	456	81	1235	542	520	454	82	1238	541	519	452	83	1241	540	517	451
20	78	1231	545	522	456	79	1234	543	521	455	80	1237	542	519	453	81	1240	540	518	451	82	1243	539	516	449
21	77	1232	544	522	455	78	1235	542	520	453	79	1238	541	518	452	80	1242	539	516	450	81	1245	538	515	448
22	76	1233	543	521	454	77	1237	542	519	452	78	1240	540	517	450	79	1243	538	515	448	80	1247	537	514	447
23	75	1235	543	520	453	76	1238	541	518	451	77	1242	539	516	449	78	1245	537	514	447	79	1249	536	512	445
23.5	75	1235	542	519	453	76	1239	541	518	451	77	1243	539	516	449	78	1246	537	514	446	79	1250	535	512	444

Latitude and Declination OPPOSITE

	LAT. 8					LAT. 9					LAT.10					LAT.11					LAT.12				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	82	1207	557	536	512	81	1207	557	536	511	80	1207	557	536	511	79	1207	557	536	511	78	1207	557	535	511
1	81	1206	557	536	512	80	1205	557	536	512	79	1205	557	536	512	78	1205	557	536	512	77	1205	557	536	512
2	80	1204	558	537	513	79	1204	558	537	513	78	1204	558	537	513	77	1204	558	537	513	76	1203	558	537	513
3	79	1203	558	537	513	78	1203	559	538	513	77	1203	559	538	513	76	1202	559	538	513	75	1202	559	538	513
4	78	1202	559	538	514	77	1202	559	538	514	76	1201	559	538	514	75	1201	600	539	514	74	1200	600	539	514
5	77	1201	559	539	514	76	1200	600	539	514	75	1200	600	539	515	74	1159	600	539	515	73	1158	601	540	515
6	76	1200	600	539	515	75	1159	600	539	515	74	1158	601	540	515	73	1157	601	540	516	72	1157	602	540	516
7	75	1159	601	540	515	74	1158	601	540	516	73	1157	602	540	516	72	1156	602	541	516	71	1155	603	541	517
8	74	1158	601	540	516	73	1157	602	541	516	72	1155	602	541	517	71	1154	603	542	517	70	1153	603	542	517
9	73	1157	602	541	516	72	1155	602	541	517	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518
10	72	1155	602	541	517	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518	68	1150	605	544	519
11	71	1154	603	542	517	70	1153	604	542	518	69	1151	604	543	518	68	1150	605	544	519	67	1148	606	545	520
12	70	1153	603	542	517	69	1151	604	543	518	68	1150	605	544	519	67	1148	606	545	520	66	1146	607	545	520
13	69	1152	604	543	518	68	1150	605	543	519	67	1148	606	544	519	66	1146	607	545	520	65	1144	608	546	521
14	68	1151	605	543	518	67	1149	606	544	519	66	1147	607	545	520	65	1145	608	546	521	64	1143	609	547	522
15	67	1150	605	544	519	66	1148	606	545	520	65	1145	607	546	521	64	1143	608	547	522	63	1141	610	548	522
16	66	1149	606	544	519	65	1146	607	545	520	64	1144	608	546	521	63	1142	609	547	522	62	1139	610	548	523
17	65	1147	606	545	519	64	1145	608	546	520	63	1142	609	547	522	62	1140	610	548	523	61	1137	611	549	524
18	64	1146	607	545	520	63	1144	608	546	521	62	1141	610	548	522	61	1138	611	549	523	60	1135	612	550	524
19	63	1145	608	545	520	62	1142	609	547	521	61	1139	610	548	523	60	1136	612	550	524	59	1134	613	551	525
20	62	1144	608	546	520	61	1141	610	547	522	60	1138	611	549	523	59	1135	613	550	524	58	1132	614	552	526
21	61	1142	609	546	521	60	1139	610	548	522	59	1136	612	549	524	58	1133	613	551	525	57	1130	615	552	526
22	60	1141	609	547	521	59	1138	611	549	522	58	1135	613	550	524	57	1131	614	552	526	56	1128	616	553	527
23	59	1140	610	547	521	58	1137	612	549	523	57	1133	613	551	524	56	1130	615	552	526	55	1126	617	554	528
23.5	59	1139	610	548	521	58	1136	612	549	523	57	1132	614	551	525	56	1129	616	553	526	55	1125	617	554	528

Table 2, Latitude and Declination SAME

	LAT.13					LAT.14					LAT.15					LAT.16					LAT.17				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	77	1207	557	535	511	76	1207	557	535	511	75	1207	557	535	510	74	1207	557	535	510	73	1207	557	535	510
1	78	1209	556	534	510	77	1209	556	534	509	76	1209	555	534	509	75	1209	555	534	509	74	1209	555	534	509
2	79	1211	555	533	509	78	1211	555	533	508	77	1211	554	533	508	76	1212	554	533	508	75	1212	554	532	507
3	80	1212	554	533	508	79	1213	554	532	507	78	1213	553	532	507	77	1214	553	532	506	76	1214	553	531	506
4	81	1214	553	532	507	80	1215	553	531	506	79	1216	552	531	506	78	1216	552	530	505	77	1217	552	530	505
5	82	1216	552	531	506	81	1217	552	530	505	80	1218	551	530	505	79	1218	551	529	504	78	1219	550	529	503
6	83	1218	551	530	505	82	1219	551	529	504	81	1220	550	529	503	80	1221	550	528	503	79	1222	549	527	502
7	84	1220	550	529	504	83	1221	550	528	503	82	1222	549	527	502	81	1223	548	527	501	80	1224	548	526	501
8	85	1222	549	528	503	84	1223	548	527	502	83	1224	548	526	501	82	1225	547	525	500	81	1227	547	525	459
9	86	1224	548	527	501	85	1225	547	526	501	84	1226	547	525	500	83	1228	546	524	459	82	1229	545	523	458
10	87	1226	547	526	500	86	1227	546	525	459	85	1229	546	524	458	84	1230	545	523	457	83	1232	544	522	456
11	88	1228	546	525	459	87	1229	545	524	458	86	1231	545	523	457	85	1233	544	522	456	84	1234	543	521	455
12	89	1230	545	523	458	88	1231	544	522	457	87	1233	543	521	456	86	1235	542	520	454	85	1237	542	519	453
13	90	1231	544	522	457	89	1233	543	521	456	88	1235	542	520	454	87	1238	541	519	453	86	1240	540	518	452
14	89	1233	543	521	456	90	1236	542	520	454	89	1238	541	519	453	88	1240	540	518	452	87	1242	539	516	450
15	88	1235	542	520	454	89	1238	541	519	453	90	1240	540	518	451	89	1242	539	516	450	88	1245	538	515	448
16	87	1238	541	519	453	88	1240	540	518	452	89	1242	539	516	450	90	1245	538	515	448	89	1248	536	514	447
17	86	1240	540	518	452	87	1242	539	516	450	88	1245	538	515	448	89	1248	536	514	447	90	1250	535	512	445
18	85	1242	539	517	450	86	1244	538	515	449	87	1247	536	514	447	88	1250	535	512	445	89	1253	534	511	443
19	84	1244	538	515	449	85	1247	537	514	447	86	1250	535	512	445	87	1253	534	511	444	88	1256	532	509	442
20	83	1246	537	514	447	84	1249	535	513	446	85	1252	534	511	444	86	1255	532	509	442	87	1259	531	507	440
21	82	1248	536	513	446	83	1251	534	511	444	84	1255	533	509	442	85	1258	531	508	440	86	1301	529	506	438
22	81	1250	535	512	445	82	1254	533	510	442	83	1257	531	508	440	84	1301	530	506	438	85	1304	528	504	436
23	80	1252	534	510	443	81	1256	532	508	441	82	1300	530	507	439	83	1304	528	504	436	84	1307	526	502	434
23.5	80	1254	533	510	442	81	1257	531	508	440	82	1301	529	506	438	83	1305	528	504	435	84	1309	526	502	433

Latitude and Declination OPPOSITE

	LAT.13					LAT.14					LAT.15					LAT.16					LAT.17				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	77	1207	557	535	511	76	1207	557	535	511	75	1207	557	535	510	74	1207	557	535	510	73	1207	557	535	510
1	76	1205	558	536	512	75	1205	558	536	512	74	1205	558	536	511	73	1205	558	536	511	72	1205	558	536	511
2	75	1203	558	537	513	74	1203	559	537	513	73	1203	559	537	512	72	1202	559	537	512	71	1202	559	537	512
3	74	1201	559	538	513	73	1201	600	538	514	72	1200	600	538	514	71	1200	600	538	513	70	1200	600	539	513
4	73	1159	600	539	514	72	1159	601	539	514	71	1158	601	539	515	70	1158	601	540	515	69	1157	601	540	515
5	72	1158	601	540	515	71	1157	602	540	515	70	1156	602	540	516	69	1155	602	541	516	68	1155	603	541	516
6	71	1156	602	541	516	70	1155	603	541	516	69	1154	603	541	517	68	1153	603	542	517	67	1152	604	542	517
7	70	1154	603	542	517	69	1153	604	542	517	68	1152	604	543	518	67	1151	605	543	518	66	1150	605	543	518
8	69	1152	604	543	518	68	1151	605	543	518	67	1150	605	544	519	66	1149	606	544	519	65	1147	606	545	519
9	68	1150	605	543	519	67	1149	606	544	519	66	1148	606	545	520	65	1146	607	545	520	64	1145	608	546	520
10	67	1148	606	544	519	66	1147	607	545	520	65	1145	607	546	521	64	1144	608	546	521	63	1142	609	547	522
11	66	1146	607	545	520	65	1145	608	546	521	64	1143	608	547	522	63	1142	609	547	522	62	1140	610	548	523
12	65	1144	608	546	521	64	1143	609	547	522	63	1141	610	548	522	62	1139	610	548	523	61	1137	611	549	524
13	64	1143	609	547	522	63	1141	610	548	523	62	1139	611	549	523	61	1137	612	550	524	60	1135	613	550	525
14	63	1141	610	548	523	62	1139	611	549	523	61	1136	612	550	524	60	1134	613	551	525	59	1132	614	552	526
15	62	1139	611	549	523	61	1136	612	550	524	60	1134	613	551	525	59	1132	614	552	526	58	1130	615	553	527
16	61	1137	612	550	524	60	1134	613	551	525	59	1132	614	552	526	58	1130	615	553	527	57	1127	616	554	528
17	60	1135	613	550	525	59	1132	614	552	526	58	1130	615	553	527	57	1127	616	554	528	56	1124	618	555	529
18	59	1133	614	551	526	58	1130	615	553	527	57	1127	616	554	528	56	1125	618	555	529	55	1122	619	556	530
19	58	1131	615	552	526	57	1128	616	554	528	56	1125	618	555	529	55	1122	619	556	530	54	1119	620	558	531
20	57	1129	616	553	527	56	1126	617	555	528	55	1123	619	556	530	54	1119	620	557	531	53	1116	622	559	532
21	56	1127	617	554	528	55	1123	618	555	529	54	1120	620	557	531	53	1117	622	559	532	52	1114	623	600	533
22	55	1125	618	555	529	54	1121	619	556	530	53	1118	621	558	532	52	1114	623	600	533	51	1111	625	601	535
23	54	1122	619	556	529	53	1119	621	557	531	52	1115	622	559	532	51	1112	624	601	534	50	1108	626	603	536
23.5	54	1121	619	556	530	53	1118	621	558	531	52	1114	623	600	533	51	1110	625	601	534	50	1107	627	603	536

Table 2, Latitude and Declination SAME

	LAT.18					LAT.19					LAT.20					LAT.21					LAT.22				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	72	1207	556	535	509	71	1207	556	535	509	70	1207	556	534	509	69	1207	556	534	509	68	1207	556	534	508
1	73	1210	555	533	508	72	1210	555	533	508	71	1210	555	533	507	70	1210	555	533	507	69	1210	555	532	506
2	74	1212	554	532	507	73	1213	554	532	506	72	1213	554	532	506	71	1213	553	531	505	70	1214	553	531	505
3	75	1215	553	531	505	74	1215	552	530	505	73	1216	552	530	504	72	1216	552	530	504	71	1217	552	529	503
4	76	1217	551	529	504	75	1218	551	529	503	74	1219	551	529	503	73	1219	550	528	502	72	1220	550	528	501
5	77	1220	550	528	503	76	1221	550	528	502	75	1222	549	527	501	74	1223	549	526	500	73	1223	548	526	500
6	78	1223	549	527	501	77	1224	548	526	500	76	1225	548	525	500	75	1226	547	525	459	74	1227	547	524	458
7	79	1225	547	525	500	78	1226	547	525	459	77	1228	546	524	458	76	1229	546	523	457	75	1230	545	522	456
8	80	1228	546	524	458	79	1229	545	523	457	78	1231	545	522	456	77	1232	544	522	455	76	1233	543	521	454
9	81	1231	545	523	457	80	1232	544	522	456	79	1234	543	521	455	78	1235	542	520	453	77	1237	542	519	452
10	82	1233	543	521	455	81	1235	542	520	454	80	1237	542	519	453	79	1238	541	518	452	78	1240	540	517	450
11	83	1236	542	520	454	82	1238	541	519	452	81	1240	540	518	451	80	1242	539	516	450	79	1243	538	515	448
12	84	1239	541	518	452	83	1241	540	517	451	82	1243	539	516	449	81	1245	538	515	448	80	1247	537	514	447
13	85	1242	539	517	450	84	1244	538	515	449	83	1246	537	514	447	82	1248	536	513	446	81	1250	535	512	445
14	86	1244	538	515	449	85	1247	537	514	447	84	1249	535	513	446	83	1251	534	511	444	82	1254	533	510	442
15	87	1247	536	514	447	86	1250	535	512	445	85	1252	534	511	444	84	1255	533	509	442	83	1257	531	508	440
16	88	1250	535	512	445	87	1253	534	511	444	86	1255	532	509	442	85	1258	531	508	440	84	1301	530	506	438
17	89	1253	534	511	443	88	1256	532	509	442	87	1259	531	507	440	86	1301	529	506	438	85	1304	528	504	436
18	90	1256	532	509	442	89	1259	531	507	440	88	1302	529	506	438	87	1305	528	504	436	86	1308	526	502	434
19	89	1259	531	507	440	90	1302	529	506	438	89	1305	527	504	436	88	1308	526	502	434	87	1312	524	500	432
20	88	1302	529	506	438	89	1305	527	504	436	90	1309	526	502	434	89	1312	524	500	431	88	1315	522	458	429
21	87	1305	528	504	436	88	1308	526	502	434	89	1312	524	500	431	90	1316	522	458	429	89	1319	520	456	427
22	86	1308	526	502	434	87	1312	524	500	432	88	1315	522	458	429	89	1319	520	456	427	90	1323	518	454	424
23	85	1311	524	500	432	86	1315	523	458	429	87	1319	521	456	427	88	1323	519	454	424	89	1327	517	452	422
23.5	85	1313	524	459	431	86	1317	522	457	428	87	1321	520	455	426	88	1325	518	453	423	89	1329	516	451	421

Latitude and Declination OPPOSITE

	LAT.18					LAT.19					LAT.20					LAT.21					LAT.22				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	72	1207	556	535	509	71	1207	556	535	509	70	1207	556	534	509	69	1207	556	534	509	68	1207	556	534	508
1	71	1204	558	536	511	70	1204	558	536	511	69	1204	558	536	510	68	1204	558	536	510	67	1204	558	536	510
2	70	1202	559	537	512	69	1202	559	537	512	68	1201	559	537	512	67	1201	559	537	512	66	1201	600	537	511
3	69	1159	600	539	513	68	1159	601	539	513	67	1158	601	539	513	66	1158	601	539	513	65	1157	601	539	513
4	68	1157	602	540	515	67	1156	602	540	515	66	1155	602	540	515	65	1155	603	540	515	64	1154	603	541	515
5	67	1154	603	541	516	66	1153	603	541	516	65	1153	604	542	516	64	1152	604	542	516	63	1151	604	542	516
6	66	1151	604	542	517	65	1151	605	543	517	64	1150	605	543	518	63	1149	606	543	518	62	1148	606	544	518
7	65	1149	606	544	518	64	1148	606	544	519	63	1147	607	545	519	62	1146	607	545	519	61	1145	608	545	519
8	64	1146	607	545	520	63	1145	608	545	520	62	1144	608	546	520	61	1142	609	546	521	60	1141	609	547	521
9	63	1144	608	546	521	62	1142	609	547	521	61	1141	610	547	522	60	1139	610	548	522	59	1138	611	549	522
10	62	1141	610	548	522	61	1139	610	548	523	60	1138	611	549	523	59	1136	612	549	524	58	1135	613	550	524
11	61	1138	611	549	523	60	1136	612	550	524	59	1135	613	550	524	58	1133	613	551	525	57	1131	614	552	526
12	60	1135	612	550	524	59	1134	613	551	525	58	1132	614	552	526	57	1130	615	552	526	56	1128	616	553	527
13	59	1133	614	551	526	58	1131	615	552	526	57	1129	616	553	527	56	1127	617	554	528	55	1125	618	555	529
14	58	1130	615	553	527	57	1128	616	554	528	56	1126	617	555	528	55	1123	618	555	529	54	1121	619	556	530
15	57	1127	616	554	528	56	1125	618	555	529	55	1123	619	556	530	54	1120	620	557	531	53	1118	621	558	532
16	56	1125	618	555	529	55	1122	619	556	530	54	1119	620	557	531	53	1117	622	559	532	52	1114	623	600	533
17	55	1122	619	556	530	54	1119	620	558	531	53	1116	622	559	532	52	1114	623	600	533	51	1111	625	601	535
18	54	1119	621	558	531	53	1116	622	559	533	52	1113	623	600	534	51	1110	625	602	535	50	1107	626	603	536
19	53	1116	622	559	533	52	1113	623	600	534	51	1110	625	602	535	50	1107	627	603	536	49	1104	628	605	537
20	52	1113	623	600	534	51	1110	625	602	535	50	1107	627	603	536	49	1103	628	605	538	48	1100	630	606	539
21	51	1110	625	602	535	50	1107	627	603	536	49	1103	628	605	538	48	1100	630	606	539	47	1056	632	608	540
22	50	1107	626	603	536	49	1104	628	605	537	48	1100	630	606	539	47	1056	632	608	540	46	1053	634	610	542
23	49	1104	628	604	537	48	1100	630	606	539	47	1057	632	608	540	46	1053	634	609	542	45	1049	636	611	543
23.5	49	1103	629	605	538	48	1059	631	607	539	47	1055	633	608	541	46	1051	634	610	543	45	1047	636	612	544

Table 2, Latitude and Declination SAME

DEC	LAT.23					LAT.24					LAT.25					LAT.26					LAT.27				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	67	1207	556	534	508	66	1207	556	534	507	65	1207	556	534	507	64	1207	556	533	507	63	1207	556	533	506
1	68	1211	555	532	506	67	1211	555	532	506	66	1211	554	532	505	65	1211	554	531	504	64	1212	554	531	504
2	69	1214	553	530	504	68	1214	553	530	504	67	1215	553	530	503	66	1215	552	529	502	65	1216	552	529	502
3	70	1217	551	529	502	69	1218	551	528	502	68	1219	551	528	501	67	1219	550	527	500	66	1220	550	527	500
4	71	1221	550	527	501	70	1222	549	526	500	69	1222	549	526	459	68	1223	548	525	458	67	1224	548	525	457
5	72	1224	548	525	459	71	1225	547	525	458	70	1226	547	524	457	69	1227	546	523	456	68	1228	546	523	455
6	73	1228	546	523	457	72	1229	546	523	456	71	1230	545	522	455	70	1231	545	521	454	69	1232	544	520	453
7	74	1231	544	522	455	73	1232	544	521	454	72	1234	543	520	453	71	1235	543	519	452	70	1236	542	518	451
8	75	1235	543	520	453	74	1236	542	519	452	73	1238	541	518	451	72	1239	541	517	450	71	1240	540	516	448
9	76	1238	541	518	451	75	1240	540	517	450	74	1241	539	516	449	73	1243	539	515	447	72	1245	538	514	446
10	77	1242	539	516	449	76	1243	538	515	448	75	1245	537	514	447	74	1247	536	513	445	73	1249	536	512	444
11	78	1245	537	514	447	77	1247	536	513	446	76	1249	535	512	444	75	1251	534	511	443	74	1253	533	510	441
12	79	1249	536	512	445	78	1251	535	511	444	77	1253	533	510	442	76	1255	532	509	440	75	1257	531	507	439
13	80	1252	534	510	443	79	1255	533	509	441	78	1257	531	508	440	77	1259	530	506	438	76	1302	529	505	436
14	81	1256	532	508	441	80	1259	531	507	439	79	1301	529	506	437	78	1304	528	504	436	77	1306	527	503	434
15	82	1300	530	507	439	81	1302	529	505	437	80	1305	527	503	435	79	1308	526	502	433	78	1311	525	500	431
16	83	1304	528	504	436	82	1306	527	503	435	81	1309	525	501	433	80	1312	524	500	431	79	1315	522	458	428
17	84	1307	526	502	434	83	1310	525	501	432	82	1313	523	459	430	81	1316	522	457	428	80	1320	520	455	426
18	85	1311	524	500	432	84	1314	523	459	430	83	1318	521	457	428	82	1321	520	455	425	81	1324	518	453	423
19	86	1315	523	458	429	85	1318	521	456	427	84	1322	519	454	425	83	1325	517	452	423	82	1329	516	450	420
20	87	1319	521	456	427	86	1322	519	454	425	85	1326	517	452	422	84	1330	515	450	420	83	1334	513	448	417
21	88	1323	519	454	424	87	1327	517	452	422	86	1331	515	450	419	85	1334	513	447	417	84	1338	511	445	414
22	89	1327	517	452	422	88	1331	515	449	419	87	1335	513	447	417	86	1339	510	445	414	85	1343	508	442	411
23	90	1331	514	449	419	89	1335	512	447	417	88	1339	510	445	414	87	1344	508	442	411	86	1348	506	440	408
23.5	90	1333	513	448	418	90	1337	511	446	415	89	1342	509	443	412	88	1346	507	441	409	87	1351	505	438	406

Latitude and Declination OPPOSITE

DEC	LAT.23					LAT.24					LAT.25					LAT.26					LAT.27				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	67	1207	556	534	508	66	1207	556	534	507	65	1207	556	534	507	64	1207	556	533	507	63	1207	556	533	506
1	66	1204	558	536	510	65	1204	558	536	509	64	1204	558	535	509	63	1204	558	535	508	62	1203	558	535	508
2	65	1200	600	537	511	64	1200	600	537	511	63	1200	600	537	511	62	1200	600	537	510	61	1159	600	537	510
3	64	1157	601	539	513	63	1157	602	539	513	62	1156	602	539	513	61	1156	602	539	512	60	1155	602	539	512
4	63	1154	603	541	515	62	1153	603	541	515	61	1152	604	541	514	60	1152	604	541	514	59	1151	604	541	514
5	62	1150	605	542	516	61	1149	605	543	516	60	1149	606	543	516	59	1148	606	543	516	58	1147	606	543	516
6	61	1147	607	544	518	60	1146	607	544	518	59	1145	608	545	518	58	1144	608	545	518	57	1143	609	545	518
7	60	1143	608	546	520	59	1142	609	546	520	58	1141	609	546	520	57	1140	610	547	520	56	1139	611	547	520
8	59	1140	610	547	521	58	1139	611	548	521	57	1137	611	548	522	56	1136	612	549	522	55	1135	613	549	522
9	58	1137	612	549	523	57	1135	612	550	523	56	1134	613	550	524	55	1132	614	551	524	54	1131	615	551	524
10	57	1133	613	551	524	56	1131	614	551	525	55	1130	615	552	525	54	1128	616	553	526	53	1126	617	553	526
11	56	1130	615	552	526	55	1128	616	553	527	54	1126	617	554	527	53	1124	618	555	528	52	1122	619	555	528
12	55	1126	617	554	528	54	1124	618	555	528	53	1122	619	556	529	52	1120	620	557	529	51	1118	621	557	530
13	54	1122	619	556	529	53	1120	620	557	530	52	1118	621	558	531	51	1116	622	558	531	50	1114	623	559	532
14	53	1119	621	557	531	52	1117	622	558	532	51	1114	623	559	532	50	1112	624	600	533	49	1109	625	601	534
15	52	1115	622	559	532	51	1113	624	600	533	50	1110	625	601	534	49	1108	626	602	535	48	1105	627	603	536
16	51	1112	624	601	534	50	1109	626	602	535	49	1106	627	603	536	48	1103	628	604	537	47	1101	630	606	538
17	50	1108	626	603	536	49	1105	627	604	537	48	1102	629	605	538	47	1059	630	606	539	46	1056	632	608	540
18	49	1104	628	604	537	48	1101	629	606	538	47	1058	631	607	539	46	1055	633	608	541	45	1052	634	610	542
19	48	1100	630	606	539	47	1057	631	607	540	46	1054	633	609	541	45	1051	635	610	542	44	1047	636	612	544
20	47	1057	632	608	540	46	1053	633	609	542	45	1050	635	611	543	44	1046	637	612	544	43	1043	639	614	546
21	46	1053	634	609	542	45	1049	635	611	543	44	1046	637	613	545	43	1042	639	614	546	42	1038	641	616	548
22	45	1049	636	611	543	44	1045	637	613	545	43	1041	639	615	546	42	1037	641	616	548	41	1033	643	618	549
23	44	1045	638	613	545	43	1041	640	615	547	42	1037	642	617	548	41	1033	644	619	550	40	1028	646	620	551
23.5	44	1043	639	614	546	43	1039	641	616	547	42	1035	643	618	549	41	1030	645	620	551	40	1026	647	621	552

Table 2, Latitude and Declination SAME

	LAT.28					LAT.29					LAT.30					LAT.31					LAT.32				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	62	1208	556	533	506	61	1208	556	533	505	60	1208	556	532	504	59	1208	556	532	504	58	1208	556	532	503
1	63	1212	554	531	503	62	1212	554	530	503	61	1212	554	530	502	60	1213	554	530	501	59	1213	554	529	501
2	64	1216	552	528	501	63	1217	552	528	500	62	1217	552	528	500	61	1217	551	527	459	60	1218	551	527	458
3	65	1220	550	526	459	64	1221	550	526	458	63	1222	549	525	457	62	1222	549	525	456	61	1223	549	524	455
4	66	1225	548	524	457	65	1225	547	524	456	64	1226	547	523	455	63	1227	546	522	454	62	1228	546	521	453
5	67	1229	546	522	454	66	1230	545	521	453	65	1231	545	520	452	64	1232	544	520	451	63	1233	544	519	450
6	68	1233	543	520	452	67	1234	543	519	451	66	1236	542	518	450	65	1237	542	517	448	64	1238	541	516	447
7	69	1238	541	517	450	68	1239	541	517	448	67	1240	540	516	447	66	1242	539	515	446	65	1243	538	514	444
8	70	1242	539	515	447	69	1243	538	514	446	68	1245	537	513	444	67	1247	537	512	443	66	1248	536	511	442
9	71	1246	537	513	445	70	1248	536	512	443	69	1250	535	511	442	68	1252	534	509	440	67	1253	533	508	439
10	72	1251	535	511	442	71	1253	534	509	441	70	1255	533	508	439	69	1257	532	507	438	68	1259	531	506	436
11	73	1255	532	508	440	72	1257	531	507	438	71	1259	530	506	436	70	1302	529	504	435	69	1304	528	503	433
12	74	1300	530	506	437	73	1302	529	504	435	72	1304	528	503	434	71	1307	527	502	432	70	1309	525	500	430
13	75	1304	528	503	435	74	1307	527	502	433	73	1309	525	500	431	72	1312	524	459	429	71	1315	523	457	427
14	76	1309	526	501	432	75	1311	524	459	430	74	1314	523	458	428	73	1317	521	456	426	72	1320	520	454	424
15	77	1313	523	459	429	76	1316	522	457	427	75	1319	520	455	425	74	1322	519	453	423	73	1325	517	451	420
16	78	1318	521	456	426	77	1321	519	454	424	76	1324	518	452	422	75	1328	516	450	419	74	1331	515	448	417
17	79	1323	519	453	423	78	1326	517	452	421	77	1330	515	450	419	76	1333	514	447	416	75	1336	512	445	414
18	80	1328	516	451	421	79	1331	514	449	418	78	1335	513	447	416	77	1338	511	445	413	76	1342	509	442	410
19	81	1333	514	448	418	80	1336	512	446	415	79	1340	510	444	412	78	1344	508	441	410	77	1348	506	439	407
20	82	1337	511	445	415	81	1341	509	443	412	80	1345	507	441	409	79	1350	505	438	406	78	1354	503	436	403
21	83	1342	509	443	411	82	1347	507	440	409	81	1351	505	438	406	80	1355	502	435	403	79	1400	500	433	359
22	84	1348	506	440	408	83	1352	504	437	405	82	1356	502	435	402	81	1401	459	432	359	80	1406	457	429	356
23	85	1353	504	437	405	84	1357	501	434	402	83	1402	459	432	358	82	1407	457	429	355	81	1412	454	426	352
23.5	86	1355	502	436	403	85	1400	500	433	400	84	1405	457	430	357	83	1410	455	427	353	82	1415	452	424	350

Latitude and Declination OPPOSITE

	LAT.28					LAT.29					LAT.30					LAT.31					LAT.32				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	62	1208	556	533	506	61	1208	556	533	505	60	1208	556	532	504	59	1208	556	532	504	58	1208	556	532	503
1	61	1203	558	535	508	60	1203	558	535	507	59	1203	558	535	507	58	1203	559	534	506	57	1203	559	534	506
2	60	1159	600	537	510	59	1159	601	537	510	58	1158	601	537	509	57	1158	601	537	509	56	1158	601	537	508
3	59	1155	603	539	512	58	1154	603	539	512	57	1154	603	539	511	56	1153	603	539	511	55	1153	604	539	511
4	58	1151	605	541	514	57	1150	605	541	514	56	1149	605	542	514	55	1149	606	542	514	54	1148	606	542	513
5	57	1146	607	543	516	56	1145	607	544	516	55	1145	608	544	516	54	1144	608	544	516	53	1143	609	544	516
6	56	1142	609	546	518	55	1141	610	546	518	54	1140	610	546	518	53	1139	611	546	518	52	1138	611	547	518
7	55	1138	611	548	520	54	1136	612	548	521	53	1135	612	548	521	52	1134	613	549	521	51	1133	614	549	521
8	54	1133	613	550	522	53	1132	614	550	523	52	1131	615	551	523	51	1129	615	551	523	50	1128	616	552	523
9	53	1129	615	552	525	52	1127	616	552	525	51	1126	617	553	525	50	1124	618	554	525	49	1123	619	554	526
10	52	1125	618	554	527	51	1123	619	555	527	50	1121	619	555	527	49	1119	620	556	528	48	1117	621	557	528
11	51	1120	620	556	529	50	1118	621	557	529	49	1116	622	558	530	48	1114	623	558	530	47	1112	624	559	531
12	50	1116	622	558	531	49	1114	623	559	531	48	1112	624	600	532	47	1109	625	601	532	46	1107	626	602	533
13	49	1111	624	600	533	48	1109	625	601	533	47	1107	627	602	534	46	1104	628	603	535	45	1102	629	604	535
14	48	1107	627	602	535	47	1104	628	603	535	46	1102	629	604	536	45	1059	630	606	537	44	1056	632	607	538
15	47	1102	629	605	537	46	1100	630	606	538	45	1057	632	607	538	44	1054	633	608	539	43	1051	634	609	540
16	46	1058	631	607	539	45	1055	633	608	540	44	1052	634	609	541	43	1049	636	610	542	42	1046	637	612	543
17	45	1053	633	609	541	44	1050	635	610	542	43	1047	637	612	543	42	1044	638	613	544	41	1040	640	614	545
18	44	1048	636	611	543	43	1045	637	612	544	42	1042	639	614	545	41	1038	641	615	546	40	1035	643	617	547
19	43	1044	638	613	545	42	1040	640	615	546	41	1037	642	616	547	40	1033	644	618	549	39	1029	645	619	550
20	42	1039	641	615	547	41	1035	642	617	548	40	1031	644	619	550	39	1027	646	620	551	38	1023	648	622	552
21	41	1034	643	618	549	40	1030	645	619	550	39	1026	647	621	552	38	1022	649	623	553	37	1018	651	625	555
22	40	1029	645	620	551	39	1025	648	622	553	38	1021	650	624	554	37	1016	652	626	556	36	1012	654	627	557
23	39	1024	648	622	553	38	1020	650	624	555	37	1015	652	626	556	36	1011	655	628	558	35	1006	657	630	600
23.5	39	1022	649	623	554	38	1017	652	625	556	37	1012	654	627	558	36	1008	656	629	559	35	1003	659	632	601

Table 2, Latitude and Declination SAME

DEC	LAT.33					LAT.34					LAT.35					LAT.36					LAT.37				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	57	1208	556	531	503	56	1208	556	531	502	55	1208	556	531	501	54	1208	556	530	500	53	1208	556	530	500
1	58	1213	553	529	500	57	1213	553	528	459	56	1214	553	528	458	55	1214	553	527	457	54	1214	553	527	457
2	59	1218	551	526	457	58	1219	551	526	456	57	1219	550	525	455	56	1220	550	524	454	55	1220	550	524	453
3	60	1224	548	523	454	59	1224	548	523	453	58	1225	548	522	452	57	1226	547	521	451	56	1226	547	521	450
4	61	1229	546	521	452	60	1230	545	520	451	59	1231	545	519	449	58	1232	544	518	448	57	1233	544	518	447
5	62	1234	543	518	449	61	1235	542	517	448	60	1236	542	516	446	59	1237	541	515	445	58	1239	541	514	444
6	63	1239	540	515	446	62	1241	540	514	445	61	1242	539	513	443	60	1243	538	512	442	59	1245	538	511	440
7	64	1245	538	513	443	63	1246	537	512	442	62	1248	536	510	440	61	1249	535	509	439	60	1251	535	508	437
8	65	1250	535	510	440	64	1252	534	509	439	63	1253	533	507	437	62	1255	532	506	435	61	1257	531	505	433
9	66	1255	532	507	437	65	1257	531	506	435	64	1259	530	504	434	63	1301	529	503	432	62	1303	528	502	430
10	67	1301	530	504	434	66	1303	529	503	432	65	1305	527	501	430	64	1307	526	500	428	63	1310	525	458	426
11	68	1306	527	501	431	67	1309	526	500	429	66	1311	525	458	427	65	1313	523	457	425	64	1316	522	455	423
12	69	1312	524	458	428	68	1314	523	457	426	67	1317	522	455	424	66	1320	520	453	421	65	1322	519	452	419
13	70	1317	521	455	425	69	1320	520	454	422	68	1323	519	452	420	67	1326	517	450	418	66	1329	516	448	415
14	71	1323	519	452	421	70	1326	517	451	419	69	1329	516	449	417	68	1332	514	447	414	67	1335	512	445	411
15	72	1329	516	449	418	71	1332	514	447	415	70	1335	512	445	413	69	1339	511	443	410	68	1342	509	441	407
16	73	1334	513	446	415	72	1338	511	444	412	71	1341	509	442	409	70	1345	508	440	406	69	1349	506	438	403
17	74	1340	510	443	411	73	1344	508	441	408	72	1348	506	439	405	71	1352	504	436	402	70	1356	502	434	359
18	75	1346	507	440	407	74	1350	505	438	405	73	1354	503	435	401	72	1358	501	433	358	71	1402	459	430	355
19	76	1352	504	437	404	75	1356	502	434	401	74	1401	500	432	357	73	1405	458	429	354	72	1409	455	426	351
20	77	1358	501	433	400	76	1403	459	431	357	75	1407	456	428	353	74	1412	454	425	350	73	1417	452	422	346
21	78	1404	458	430	356	77	1409	456	427	353	76	1414	453	424	349	75	1419	451	421	345	74	1424	448	418	342
22	79	1411	455	426	352	78	1416	452	424	348	77	1421	450	421	345	76	1426	447	417	341	75	1431	444	414	337
23	80	1417	451	423	348	79	1422	449	420	344	78	1428	446	417	340	77	1433	443	413	336	76	1439	441	410	332
23.5	81	1420	450	421	346	80	1426	447	418	342	79	1431	444	415	338	78	1437	442	411	334	77	1443	439	408	329

Latitude and Declination OPPOSITE

DEC	LAT.33					LAT.34					LAT.35					LAT.36					LAT.37				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	57	1208	556	531	503	56	1208	556	531	502	55	1208	556	531	501	54	1208	556	530	500	53	1208	556	530	500
1	56	1203	559	534	505	55	1203	559	534	505	54	1203	559	533	504	53	1202	559	533	503	52	1202	559	533	503
2	55	1158	601	537	508	54	1157	601	536	507	53	1157	602	536	507	52	1157	602	536	506	51	1156	602	536	506
3	54	1152	604	539	511	53	1152	604	539	510	52	1151	604	539	510	51	1151	605	539	509	50	1150	605	539	509
4	53	1147	606	542	513	52	1146	607	542	513	51	1146	607	542	513	50	1145	608	542	512	49	1144	608	542	512
5	52	1142	609	544	516	51	1141	609	545	516	50	1140	610	545	515	49	1139	610	545	515	48	1138	611	545	515
6	51	1137	612	547	518	50	1136	612	547	518	49	1134	613	547	518	48	1133	613	548	518	47	1132	614	548	518
7	50	1131	614	549	521	49	1130	615	550	521	48	1129	616	550	521	47	1127	616	551	521	46	1126	617	551	521
8	49	1126	617	552	523	48	1125	618	553	524	47	1123	618	553	524	46	1121	619	553	524	45	1120	620	554	524
9	48	1121	620	555	526	47	1119	620	555	526	46	1117	621	556	526	45	1116	622	556	527	44	1114	623	557	527
10	47	1116	622	557	528	46	1114	623	558	529	45	1112	624	559	529	44	1110	625	559	529	43	1107	626	600	530
11	46	1110	625	600	531	45	1108	626	601	531	44	1106	627	601	532	43	1104	628	602	532	42	1101	629	603	533
12	45	1105	628	602	533	44	1102	629	603	534	43	1100	630	604	535	42	1057	631	605	535	41	1055	633	606	536
13	44	1059	630	605	536	43	1057	632	606	537	42	1054	633	607	537	41	1051	634	608	538	40	1049	636	609	539
14	43	1054	633	608	539	42	1051	635	609	539	41	1048	636	610	540	40	1045	637	611	541	39	1042	639	612	542
15	42	1048	636	610	541	41	1045	637	612	542	40	1042	639	613	543	39	1039	641	614	544	38	1036	642	615	544
16	41	1043	639	613	544	40	1039	640	614	545	39	1036	642	616	545	38	1033	644	617	546	37	1029	645	618	547
17	40	1037	642	616	546	39	1033	643	617	547	38	1030	645	619	548	37	1026	647	620	549	36	1022	649	621	550
18	39	1031	644	618	549	38	1027	646	620	550	37	1024	648	621	551	36	1020	650	623	552	35	1016	652	625	553
19	38	1025	647	621	551	37	1021	649	623	552	36	1017	651	624	554	35	1013	653	626	555	34	1009	656	628	556
20	37	1019	650	624	554	36	1015	652	626	555	35	1011	655	627	557	34	1006	657	629	558	33	1002	659	631	559
21	36	1013	653	627	556	35	1009	656	628	558	34	1004	658	630	559	33	1000	700	632	601	32	955	703	634	602
22	35	1007	656	629	559	34	1002	659	631	600	33	958	701	633	602	32	953	704	635	604	31	948	706	638	605
23	34	1001	700	632	601	33	956	702	634	603	32	951	705	637	605	31	946	707	639	607	30	940	710	641	608
23.5	34	958	701	634	603	33	953	704	636	605	32	947	706	638	606	31	942	709	640	608	30	937	712	643	610

Table 2, Latitude and Declination SAME

LAT.38

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	52	1208	556	530	459
1	53	1215	553	526	456
2	54	1221	550	523	452
3	55	1227	546	520	449
4	56	1234	543	517	446
5	57	1240	540	513	442
6	58	1246	537	510	439
7	59	1253	534	507	435
8	60	1259	530	504	432
9	61	1306	527	500	428
10	62	1312	524	457	424
11	63	1319	521	453	420
12	64	1325	517	450	417
13	65	1332	514	446	413
14	66	1339	511	443	409
15	67	1346	507	439	405
16	68	1353	504	435	400
17	69	1400	500	431	356
18	70	1407	457	427	352
19	71	1414	453	423	347
20	72	1422	449	419	342
21	73	1429	445	415	337
22	74	1437	442	411	332
23	75	1445	438	406	327
23.5	76	1449	436	404	325

LAT.39

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	51	1209	556	529	458
1	52	1215	552	526	455
2	53	1222	549	523	451
3	54	1228	546	519	448
4	55	1235	543	516	444
5	56	1241	539	512	441
6	57	1248	536	509	437
7	58	1254	533	506	433
8	59	1301	529	502	430
9	60	1308	526	459	426
10	61	1314	523	455	422
11	62	1321	519	452	418
12	63	1328	516	448	414
13	64	1335	512	444	410
14	65	1342	509	440	406
15	66	1349	505	437	402
16	67	1357	502	433	357
17	68	1404	458	429	353
18	69	1411	454	425	348
19	70	1419	451	420	343
20	71	1427	447	416	338
21	72	1435	443	412	333
22	73	1443	439	407	328
23	74	1451	435	403	323
23.5	75	1455	433	400	320

LAT.40

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	50	1209	556	529	457
1	51	1215	552	525	454
2	52	1222	549	522	450
3	53	1229	546	518	446
4	54	1236	542	515	443
5	55	1242	539	511	439
6	56	1249	535	508	435
7	57	1256	532	504	432
8	58	1303	528	501	428
9	59	1310	525	457	424
10	60	1317	521	453	420
11	61	1324	518	450	416
12	62	1331	514	446	412
13	63	1338	511	442	407
14	64	1346	507	438	403
15	65	1353	503	434	358
16	66	1401	500	430	354
17	67	1408	456	426	349
18	68	1416	452	422	344
19	69	1424	448	417	339
20	70	1432	444	413	334
21	71	1440	440	408	329
22	72	1449	436	404	323
23	73	1457	431	359	318
23.5	74	1501	429	356	315

LAT.41

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	49	1209	556	528	456
1	50	1216	552	525	452
2	51	1223	549	521	449
3	52	1230	545	518	445
4	53	1237	542	514	441
5	54	1244	538	510	437
6	55	1251	535	507	434
7	56	1258	531	503	430
8	57	1305	527	459	426
9	58	1312	524	455	422
10	59	1320	520	452	417
11	60	1327	517	448	413
12	61	1334	513	444	409
13	62	1342	509	440	404
14	63	1349	505	436	400
15	64	1357	501	432	355
16	65	1405	458	427	350
17	66	1413	454	423	345
18	67	1421	450	419	340
19	68	1429	445	414	335
20	69	1438	441	409	330
21	70	1446	437	405	324
22	71	1455	433	400	318
23	72	1504	428	355	312
23.5	73	1508	426	352	309

LAT.42

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	48	1209	556	528	455
1	49	1216	552	524	451
2	50	1223	548	520	447
3	51	1231	545	517	444
4	52	1238	541	513	440
5	53	1245	537	509	436
6	54	1253	534	505	432
7	55	1300	530	502	428
8	56	1307	526	458	423
9	57	1315	523	454	419
10	58	1322	519	450	415
11	59	1330	515	446	410
12	60	1338	511	442	406
13	61	1345	507	438	401
14	62	1353	503	433	357
15	63	1401	459	429	352
16	64	1409	455	425	347
17	65	1418	451	420	342
18	66	1426	447	415	336
19	67	1435	443	411	331
20	68	1443	438	406	325
21	69	1452	434	401	319
22	70	1501	429	356	313
23	71	1510	425	351	307
23.5	72	1515	422	348	303

Latitude and Declination OPPOSITE

LAT.38

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	52	1208	556	530	459
1	51	1202	559	533	502
2	50	1156	602	536	505
3	49	1150	605	539	508
4	48	1143	608	542	512
5	47	1137	611	545	515
6	46	1131	615	548	518
7	45	1125	618	551	521
8	44	1118	621	554	524
9	43	1112	624	558	527
10	42	1105	627	601	530
11	41	1059	631	604	533
12	40	1052	634	607	536
13	39	1046	637	610	539
14	38	1039	640	613	542
15	37	1032	644	617	545
16	36	1025	647	620	548
17	35	1019	651	623	552
18	34	1012	654	626	555
19	33	1004	658	630	558
20	32	957	701	633	601
21	31	950	705	636	604
22	30	942	709	640	607
23	29	935	713	643	610
23.5	29	931	715	645	612

LAT.39

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	51	1209	556	529	458
1	50	1202	559	532	501
2	49	1156	602	536	505
3	48	1149	605	539	508
4	47	1143	609	542	511
5	46	1136	612	545	514
6	45	1130	615	549	518
7	44	1123	618	552	521
8	43	1116	622	555	524
9	42	1110	625	558	527
10	41	1103	628	601	530
11	40	1056	632	605	534
12	39	1050	635	608	537
13	38	1043	639	611	540
14	37	1036	642	615	543
15	36	1029	646	618	546
16	35	1022	649	621	549
17	34	1015	653	625	553
18	33	1007	656	628	556
19	32	1000	700	631	559
20	31	952	704	635	602
21	30	945	708	638	606
22	29	937	712	642	609
23	28	929	715	646	612
23.5	28	925	717	647	614

LAT.40

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	50	1209	556	529	457
1	49	1202	559	532	500
2	48	1155	602	535	504
3	47	1149	606	539	507
4	46	1142	609	542	511
5	45	1135	612	545	514
6	44	1128	616	549	517
7	43	1121	619	552	521
8	42	1115	623	555	524
9	41	1108	626	559	527
10	40	1101	630	602	531
11	39	1054	633	606	534
12	38	1047	637	609	537
13	37	1040	640	612	541
14	36	1033	644	616	544
15	35	1025	647	619	547
16	34	1018	651	623	550
17	33	1010	655	626	554
18	32	1003	659	630	557
19	31	955	702	633	600
20	30	947	706	637	604
21	29	939	710	641	607
22	28	931	714	644	611
23	27	923	718	648	614
23.5	27	919	721	650	616

LAT.41

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	49	1209	556	528	456
1	48	1202	559	532	500
2	47	1155	603	535	503
3	46	1148	606	539	507
4	45	1141	610	542	510
5	44	1134	613	546	514
6	43	1127	617	549	517
7	42	1120	620	552	521
8	41	1113	624	556	524
9	40	1106	627	559	528
10	39	1059	631	603	531
11	38	1051	634	606	534
12	37	1044	638	610	538
13	36	1037	642	613	541
14	35	1029	645	617	545
15	34	1022	649	621	548
16	33	1014	653	624	551
17	32	1006	657	628	555
18	31	958	701	631	558
19	30	950	705	635	602
20	29	942	709	639	605
21	28	934	713	643	609
22	27	926	717	647	612
23	26	917	721	650	616
23.5	26	913	724	652	618

LAT.42

DEC	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m
0	48	1209	556	528	455
1	47	1202	559	531	459
2	46	1155	603	535	502
3	45	1147	606	539	506
4	44	1140	610	542	510
5	43	1133	614	546	513
6	42	1126	617	549	517
7	41	1118	621	553	521
8	40	1111	625	556	524
9	39	1104	628	600	528
10	38	1056	632	604	531
11	37	1049	636	607	535
12	36	1041	639	611	538
13	35	1033	643	615	542
14	34	1026	647	618	545
15	33	1018	651	622	549
16	32	1010	655	626	552
17	31	1002	659	629	556
18	30	954	703	633	600
19	29	945	707	637	603
20	28	937	711	641	607
21	27	928	716	645	611
22	26	920	720	649	614
23	25	911	725	653	618
23.5	25	906	727	655	620

Table 2, Latitude and Declination SAME

DEC	LAT.43					LAT.44					LAT.45					LAT.46					LAT.47				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	47	1209	555	527	454	46	1209	555	527	453	45	1209	555	526	452	44	1210	555	525	450	43	1210	555	525	449
1	48	1217	552	523	450	47	1217	552	523	449	46	1217	551	522	447	45	1218	551	521	446	44	1218	551	520	444
2	49	1224	548	520	446	48	1225	548	519	445	47	1225	547	518	443	46	1226	547	517	442	45	1227	547	516	440
3	50	1232	544	516	442	49	1233	544	515	440	48	1233	543	514	439	47	1235	543	513	437	46	1236	542	512	435
4	51	1239	540	512	438	50	1240	540	511	436	49	1242	539	510	434	48	1243	539	508	433	47	1244	538	507	431
5	52	1247	537	508	434	51	1248	536	507	432	50	1250	535	505	430	49	1251	534	504	428	48	1253	534	503	426
6	53	1254	533	504	430	52	1256	532	503	428	51	1258	531	501	425	50	1300	530	500	423	49	1302	529	458	421
7	54	1302	529	500	425	53	1304	528	459	423	52	1306	527	457	421	51	1308	526	455	418	50	1310	525	454	416
8	55	1310	525	456	421	54	1312	524	454	419	53	1314	523	453	416	52	1317	522	451	414	51	1319	520	449	411
9	56	1317	521	452	417	55	1320	520	450	414	54	1323	519	448	411	53	1325	517	446	409	52	1328	516	444	406
10	57	1325	517	448	412	56	1328	516	446	409	55	1331	515	444	407	54	1334	513	442	404	53	1337	511	439	400
11	58	1333	513	444	408	57	1336	512	442	405	56	1339	510	439	402	55	1343	509	437	358	54	1346	507	434	355
12	59	1341	510	439	403	58	1344	508	437	400	57	1348	506	435	357	56	1352	504	432	353	55	1356	502	430	349
13	60	1349	505	435	358	59	1353	504	433	355	58	1357	502	430	351	57	1401	500	427	348	56	1405	457	424	344
14	61	1357	501	431	353	60	1401	459	428	350	59	1406	457	425	346	58	1410	455	422	342	57	1415	453	419	338
15	62	1406	457	426	348	61	1410	455	423	344	60	1415	453	420	340	59	1419	450	417	336	58	1424	448	414	332
16	63	1414	453	422	343	62	1419	451	419	339	61	1424	448	415	335	60	1429	446	412	330	59	1434	443	409	325
17	64	1422	449	417	338	63	1428	446	414	333	62	1433	444	410	329	61	1438	441	407	324	60	1444	438	403	319
18	65	1431	444	412	332	64	1437	442	409	327	63	1442	439	405	323	62	1448	436	401	317	61	1454	433	357	312
19	66	1440	440	407	326	65	1446	437	404	321	64	1452	434	400	316	63	1458	431	356	311	62	1505	428	352	305
20	67	1449	435	402	320	66	1455	432	358	315	65	1502	429	354	310	64	1508	426	350	304	63	1515	422	346	258
21	68	1458	431	357	314	67	1505	428	353	309	66	1512	424	349	303	65	1519	421	344	256	64	1526	417	339	250
22	69	1508	426	352	308	68	1515	423	347	302	67	1522	419	343	255	66	1529	415	338	249	65	1537	411	333	241
23	70	1517	421	346	301	69	1525	418	342	254	68	1532	414	337	248	67	1540	410	332	240	66	1549	406	326	233
23.5	71	1522	419	343	257	70	1530	415	339	251	69	1538	411	334	244	68	1546	407	328	236	67	1554	403	323	228

Latitude and Declination OPPOSITE

DEC	LAT.43					LAT.44					LAT.45					LAT.46					LAT.47				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	47	1209	555	527	454	46	1209	555	527	453	45	1209	555	526	452	44	1210	555	525	450	43	1210	555	525	449
1	46	1202	559	531	458	45	1202	559	530	457	44	1201	559	530	456	43	1201	559	530	455	42	1201	559	529	453
2	45	1154	603	535	502	44	1154	603	534	501	43	1153	603	534	500	42	1153	603	534	459	41	1153	604	533	458
3	44	1147	607	538	505	43	1146	607	538	505	42	1145	607	538	504	41	1145	608	538	503	40	1144	608	538	502
4	43	1139	610	542	509	42	1138	611	542	509	41	1137	611	542	508	40	1136	612	542	507	39	1135	612	542	507
5	42	1132	614	546	513	41	1131	615	546	513	40	1129	615	546	512	39	1128	616	546	512	38	1127	617	546	511
6	41	1124	618	550	517	40	1123	619	550	516	39	1121	619	550	516	38	1120	620	550	516	37	1118	621	551	515
7	40	1117	622	553	520	39	1115	623	554	520	38	1113	623	554	520	37	1111	624	554	520	36	1109	625	555	520
8	39	1109	625	557	524	38	1107	626	557	524	37	1105	628	558	524	36	1103	629	559	524	35	1101	630	559	524
9	38	1101	629	601	528	37	1059	630	601	528	36	1057	632	602	528	35	1054	633	603	528	34	1052	634	603	528
10	37	1054	633	604	531	36	1051	634	605	532	35	1048	636	606	532	34	1046	637	607	532	33	1043	639	608	532
11	36	1046	637	608	535	35	1043	638	609	535	34	1040	640	610	536	33	1037	641	611	536	32	1034	643	612	537
12	35	1038	641	612	539	34	1035	643	613	539	33	1032	644	614	540	32	1028	646	615	540	31	1025	648	616	541
13	34	1030	645	616	542	33	1027	647	617	543	32	1023	648	618	544	31	1019	650	619	544	30	1016	652	621	545
14	33	1022	649	620	546	32	1018	651	621	547	31	1015	653	622	548	30	1011	655	624	548	29	1006	657	625	549
15	32	1014	653	623	550	31	1010	655	625	551	30	1006	657	626	552	29	1001	659	628	553	28	957	702	630	554
16	31	1006	657	627	554	30	1001	659	629	555	29	957	702	631	556	28	952	704	632	557	27	947	706	634	558
17	30	957	701	631	557	29	953	704	633	558	28	948	706	635	600	27	943	709	637	601	26	938	711	639	602
18	29	949	706	635	601	28	944	708	637	602	27	939	711	639	604	26	933	713	641	605	25	928	716	643	606
19	28	940	710	639	605	27	935	713	641	606	26	929	715	643	608	25	924	718	646	609	24	918	721	648	611
20	27	932	714	643	608	26	926	717	645	610	25	920	720	648	612	24	914	723	650	613	23	907	726	653	615
21	26	923	719	647	612	25	917	722	650	614	24	910	725	652	616	23	904	728	655	618	22	857	732	657	620
22	25	913	723	651	616	24	907	726	654	618	23	900	730	657	620	22	853	733	659	622	21	846	737	702	624
23	24	904	728	656	620	23	857	731	658	622	22	850	735	701	624	21	843	739	704	626	20	835	742	707	628
23.5	24	859	730	658	622	23	852	734	701	624	22	845	737	704	626	21	838	741	707	628	20	830	745	710	631

Table 2, Latitude and Declination SAME

	LAT.48					LAT.49					LAT.50					LAT.51					LAT.52				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	42	1210	555	524	448	41	1210	555	523	446	40	1210	555	523	445	39	1211	555	522	443	38	1211	555	521	441
1	43	1219	551	520	443	42	1219	550	519	441	41	1220	550	518	439	40	1220	550	517	438	39	1221	549	516	436
2	44	1228	546	515	438	43	1229	546	514	436	42	1229	545	513	434	41	1230	545	512	432	40	1231	544	510	430
3	45	1237	542	510	433	44	1238	541	509	431	43	1239	540	508	429	42	1240	540	507	427	41	1242	539	505	424
4	46	1246	537	506	428	45	1247	536	504	426	44	1249	536	503	424	43	1250	535	501	421	42	1252	534	500	419
5	47	1255	533	501	423	46	1256	532	500	421	45	1258	531	458	418	44	1300	530	456	416	43	1302	529	454	413
6	48	1304	528	456	418	47	1306	527	455	416	46	1308	526	453	413	45	1310	525	451	410	44	1313	524	449	407
7	49	1313	524	452	413	48	1315	522	450	410	47	1318	521	448	407	46	1321	520	446	404	45	1323	518	443	401
8	50	1322	519	447	408	49	1325	518	445	405	48	1328	516	443	402	47	1331	515	440	358	46	1334	513	438	354
9	51	1331	514	442	403	50	1334	513	440	359	49	1338	511	437	356	48	1341	509	435	352	47	1345	508	432	348
10	52	1341	510	437	357	51	1344	508	434	353	50	1348	506	432	350	49	1352	504	429	346	48	1356	502	426	341
11	53	1350	505	432	351	52	1354	503	429	348	51	1358	501	426	343	50	1402	459	423	339	49	1407	457	420	335
12	54	1400	500	427	346	53	1404	458	424	341	52	1408	456	421	337	51	1413	453	418	332	50	1418	451	414	328
13	55	1409	455	421	340	54	1414	453	418	335	53	1419	451	415	330	52	1424	448	412	326	51	1429	445	408	320
14	56	1419	450	416	333	55	1424	448	413	329	54	1430	445	409	324	53	1435	443	405	318	52	1441	440	402	313
15	57	1429	445	411	327	56	1435	443	407	322	55	1440	440	403	317	54	1446	437	359	311	53	1452	434	355	305
16	58	1440	440	405	320	57	1445	437	401	315	56	1451	434	357	309	55	1458	431	353	303	54	1504	428	348	256
17	59	1450	435	359	313	58	1456	432	355	308	57	1503	429	351	301	56	1509	425	346	255	55	1517	422	341	248
18	60	1501	430	353	306	59	1507	426	349	300	58	1514	423	344	253	57	1521	419	339	246	56	1529	415	334	238
19	61	1511	424	347	259	60	1518	421	342	252	59	1526	417	338	245	58	1534	413	332	237	57	1542	409	327	228
20	62	1522	419	341	251	61	1530	415	336	244	60	1538	411	331	236	59	1546	407	325	227	58	1555	402	319	218
21	63	1534	413	334	242	62	1542	409	329	235	61	1550	405	323	226	60	1559	400	317	216	59	1609	356	311	206
22	64	1545	407	328	234	63	1554	403	322	225	62	1603	358	316	215	61	1613	354	309	205	60	1623	349	302	153
23	65	1557	401	320	224	64	1607	357	314	215	63	1616	352	308	204	62	1627	347	301	152	61	1637	341	253	138
23.5	66	1604	358	317	219	65	1613	353	311	209	64	1623	348	304	158	63	1634	343	256	145	62	1645	338	249	129

Latitude and Declination OPPOSITE

	LAT.48					LAT.49					LAT.50					LAT.51					LAT.52				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	42	1210	555	524	448	41	1210	555	523	446	40	1210	555	523	445	39	1211	555	522	443	38	1211	555	521	441
1	41	1201	559	529	452	40	1201	600	528	451	39	1201	600	527	450	38	1201	600	527	448	37	1201	600	526	446
2	40	1152	604	533	457	39	1152	604	533	456	38	1151	604	532	454	37	1151	605	532	453	36	1150	605	531	452
3	39	1143	608	537	501	38	1143	609	537	500	37	1142	609	537	459	36	1141	610	537	458	35	1140	610	536	457
4	38	1134	613	542	506	37	1133	613	542	505	36	1132	614	542	504	35	1131	614	542	503	34	1130	615	541	502
5	37	1125	617	546	510	36	1124	618	546	510	35	1123	619	546	509	34	1121	619	547	508	33	1119	620	547	508
6	36	1116	622	551	515	35	1115	623	551	514	34	1113	624	551	514	33	1111	624	551	513	32	1109	625	552	513
7	35	1107	626	555	519	34	1105	627	556	519	33	1103	628	556	519	32	1101	629	556	518	31	1059	631	557	518
8	34	1058	631	600	524	33	1056	632	600	524	32	1053	633	601	523	31	1051	635	601	523	30	1048	636	602	523
9	33	1049	635	604	528	32	1046	637	605	528	31	1044	638	606	528	30	1041	640	606	528	29	1038	641	607	528
10	32	1040	640	609	533	31	1037	642	609	533	30	1034	643	610	533	29	1030	645	611	533	28	1027	647	612	533
11	31	1031	645	613	537	30	1027	646	614	537	29	1024	648	615	538	28	1020	650	616	538	27	1016	652	617	538
12	30	1021	649	618	541	29	1017	651	619	542	28	1014	653	620	542	27	1009	655	621	543	26	1005	657	623	543
13	29	1012	654	622	546	28	1008	656	623	546	27	1003	658	625	547	26	959	701	626	548	25	954	703	628	548
14	28	1002	659	627	550	27	958	701	628	551	26	953	704	630	552	25	948	706	631	553	24	943	709	633	553
15	27	952	704	631	554	26	947	706	633	555	25	942	709	635	556	24	937	712	637	557	23	931	714	638	558
16	26	942	709	636	559	25	937	711	638	600	24	932	714	640	601	23	926	717	642	602	22	920	720	644	604
17	25	932	714	641	603	24	927	717	643	605	23	921	720	645	606	22	914	723	647	607	21	908	726	649	609
18	24	922	719	645	608	23	916	722	648	609	22	910	725	650	611	21	903	729	652	612	20	856	732	655	614
19	23	911	724	650	612	22	905	728	653	614	21	858	731	655	616	20	851	735	658	617	19	843	738	701	619
20	22	901	730	655	617	21	854	733	658	619	20	847	737	700	621	19	839	741	703	622	18	831	745	706	624
21	21	850	735	700	621	20	842	739	703	623	19	835	743	706	625	18	826	747	709	628	17	818	751	712	630
22	20	839	741	705	626	19	831	745	708	628	18	822	749	711	630	17	814	753	715	633	16	804	758	718	635
23	19	827	746	710	631	18	819	751	713	633	17	810	755	717	636	16	800	800	720	638	15	751	805	724	641
23.5	19	821	749	713	633	18	813	754	716	636	17	803	758	720	638	16	754	803	723	641	15	744	808	727	643

Table 2, Latitude and Declination SAME

DEC	LAT.53					LAT.54					LAT.55					LAT.56					LAT.57				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	37	1211	554	520	439	36	1211	554	519	437	35	1212	554	518	435	34	1212	554	517	433	33	1212	554	516	430
1	38	1222	549	515	433	37	1222	549	513	431	36	1223	548	512	429	35	1224	548	511	426	34	1225	548	509	424
2	39	1232	544	509	428	38	1233	543	508	425	37	1235	543	506	423	36	1236	542	505	420	35	1237	542	503	417
3	40	1243	538	504	422	39	1244	538	502	419	38	1246	537	500	416	37	1248	536	459	413	36	1249	535	457	410
4	41	1254	533	458	416	40	1256	532	456	413	39	1258	531	454	410	38	1300	530	452	406	37	1302	529	450	403
5	42	1305	528	452	410	41	1307	527	450	406	40	1309	525	448	403	39	1312	524	446	359	38	1314	523	444	355
6	43	1315	522	447	403	42	1318	521	445	400	41	1321	520	442	356	40	1324	518	440	352	39	1327	516	437	348
7	44	1326	517	441	357	43	1329	515	438	353	42	1333	514	436	349	41	1336	512	433	345	40	1340	510	430	340
8	45	1337	511	435	351	44	1341	510	432	346	43	1345	508	429	342	42	1349	506	426	337	41	1353	504	423	332
9	46	1349	506	429	344	45	1353	504	426	339	44	1357	502	423	334	43	1401	459	420	329	42	1406	457	416	324
10	47	1400	500	423	337	46	1404	458	420	332	45	1409	456	416	327	44	1414	453	413	321	43	1419	450	409	315
11	48	1411	454	417	330	47	1416	452	413	324	46	1421	449	410	319	45	1427	447	406	313	44	1432	444	401	306
12	49	1423	449	411	322	48	1428	446	407	317	47	1434	443	403	310	46	1440	440	358	304	45	1446	437	354	257
13	50	1435	443	404	315	49	1441	440	400	308	48	1447	437	356	302	47	1453	433	351	255	46	1500	430	346	247
14	51	1447	437	357	306	50	1453	433	353	300	49	1500	430	348	253	48	1507	427	343	245	47	1514	423	338	236
15	52	1459	431	351	258	51	1506	427	346	251	50	1513	423	341	243	49	1521	420	335	234	48	1529	416	329	224
16	53	1511	424	343	249	52	1519	421	338	241	51	1527	417	333	233	50	1535	412	327	223	49	1544	408	320	212
17	54	1524	418	336	240	53	1532	414	331	231	52	1541	410	325	221	51	1550	405	318	211	50	1559	400	311	158
18	55	1537	411	329	230	54	1546	407	323	220	53	1555	402	316	209	52	1605	358	309	157	51	1615	352	302	142
19	56	1551	405	321	219	55	1600	400	314	208	54	1610	355	307	156	53	1620	350	300	141	52	1632	344	251	124
20	57	1605	358	312	207	56	1615	353	305	155	55	1625	347	258	140	54	1636	342	250	123	53	1649	336	240	059
21	58	1619	351	304	154	57	1630	345	256	139	56	1641	339	248	122	55	1653	333	239	059	54	1706	327	229	000
22	59	1634	343	255	139	58	1645	337	246	121	57	1657	331	237	058	56	1711	325	227	000	55	1725	318	216	///
23	60	1649	335	245	121	59	1701	329	236	058	58	1715	323	226	000	57	1729	316	215	///	56	1744	308	202	///
23.5	61	1657	332	240	110	60	1710	325	230	041	59	1724	318	220	///	58	1738	311	208	///	57	1755	303	154	///

/// = Twilight lasts all night.

Latitude and Declination OPPOSITE

DEC	LAT.53					LAT.54					LAT.55					LAT.56					LAT.57				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	37	1211	554	520	439	36	1211	554	519	437	35	1212	554	518	435	34	1212	554	517	433	33	1212	554	516	430
1	36	1200	600	525	445	35	1200	600	525	443	34	1200	600	524	441	33	1200	600	523	439	32	1200	600	522	437
2	35	1150	605	531	450	34	1149	605	530	449	33	1149	606	530	447	32	1148	606	529	445	31	1148	606	528	443
3	34	1139	610	536	456	33	1138	611	536	454	32	1137	611	535	453	31	1136	612	535	451	30	1135	612	534	450
4	33	1129	616	541	501	32	1127	616	541	500	31	1126	617	541	459	30	1124	618	541	458	29	1123	619	541	456
5	32	1118	621	547	507	31	1116	622	547	506	30	1114	623	547	505	29	1112	624	547	504	28	1110	625	547	502
6	31	1107	626	552	512	30	1105	628	552	511	29	1103	629	552	510	28	1100	630	553	510	27	1058	631	553	509
7	30	1056	632	557	517	29	1054	633	558	517	28	1051	634	558	516	27	1048	636	559	516	26	1045	637	559	515
8	29	1045	637	603	523	28	1042	639	603	522	27	1039	640	604	522	26	1036	642	604	522	25	1033	644	605	521
9	28	1034	643	608	528	27	1031	644	609	528	26	1027	646	610	528	25	1024	648	610	527	24	1020	650	611	527
10	27	1023	648	613	533	26	1019	650	614	533	25	1015	652	615	533	24	1011	654	616	533	23	1007	657	618	533
11	26	1012	654	619	538	25	1008	656	620	539	24	1003	658	621	539	23	959	701	622	539	22	954	703	624	539
12	25	1001	700	624	544	24	956	702	625	544	23	951	704	627	545	22	946	707	628	545	21	940	710	630	546
13	24	949	705	629	549	23	944	708	631	550	22	939	711	633	550	21	933	714	635	551	20	927	717	636	552
14	23	937	711	635	554	22	932	714	637	555	21	926	717	639	556	20	920	720	641	557	19	913	724	643	558
15	22	926	717	640	600	21	919	720	643	601	20	913	724	645	602	19	906	727	647	603	18	859	731	649	604
16	21	913	723	646	605	20	907	727	648	606	19	900	730	651	607	18	852	734	653	609	17	844	738	656	610
17	20	901	729	652	610	19	854	733	654	612	18	846	737	657	613	17	838	741	700	615	16	830	745	703	616
18	19	848	736	658	616	18	841	740	700	617	17	833	744	703	619	16	824	748	706	621	15	815	753	709	623
19	18	836	742	703	621	17	827	746	706	623	16	818	751	710	625	15	809	756	713	627	14	759	801	716	629
20	17	822	749	709	626	16	813	753	713	629	15	804	758	716	631	14	754	803	720	633	13	743	809	723	635
21	16	809	756	715	632	15	759	800	719	634	14	749	806	723	637	13	738	811	727	639	12	726	817	731	642
22	15	755	803	722	638	14	744	808	725	640	13	733	813	729	643	12	721	819	734	646	11	709	826	738	649
23	14	740	810	728	643	13	729	815	732	646	12	717	821	736	649	11	704	828	741	652	10	651	835	746	655
23.5	14	733	814	731	646	13	721	819	735	649	12	709	826	740	652	11	656	832	745	655	10	641	839	750	659

Table 2, Latitude and Declination SAME

	LAT.58					LAT.59					LAT.60					LAT.61					LAT.62				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	32	1213	554	514	428	31	1213	554	513	425	30	1213	553	512	422	29	1214	553	510	418	28	1214	553	509	415
1	33	1225	547	508	421	32	1226	547	506	417	31	1227	546	505	414	30	1228	546	503	410	29	1229	545	501	406
2	34	1238	541	501	413	33	1240	540	459	410	32	1241	539	457	406	31	1243	539	455	402	30	1244	538	453	358
3	35	1251	534	455	406	34	1253	533	452	402	33	1255	532	450	358	32	1257	531	448	354	31	1300	530	445	349
4	36	1304	528	448	359	35	1307	527	445	354	34	1309	525	443	350	33	1312	524	440	345	32	1315	523	437	339
5	37	1317	521	441	351	36	1320	520	438	346	35	1323	518	435	341	34	1327	517	432	336	33	1330	515	429	330
6	38	1330	515	434	343	37	1334	513	431	338	36	1338	511	428	332	35	1342	509	424	326	34	1346	507	420	320
7	39	1344	508	427	335	38	1348	506	423	329	37	1352	504	420	323	36	1357	502	416	317	35	1402	459	412	310
8	40	1357	501	420	326	39	1402	459	416	320	38	1407	457	412	314	37	1412	454	408	307	36	1418	451	403	259
9	41	1411	455	412	318	40	1416	452	408	311	39	1421	449	404	304	38	1427	446	359	256	37	1434	443	354	247
10	42	1424	448	405	308	41	1430	445	400	301	40	1437	442	355	253	39	1443	438	350	244	38	1450	435	344	234
11	43	1439	441	357	259	42	1445	437	352	251	41	1452	434	347	242	40	1459	430	341	232	39	1507	426	335	221
12	44	1453	434	349	249	43	1500	430	343	240	42	1508	426	338	230	41	1516	422	331	219	40	1524	418	325	206
13	45	1507	426	340	238	44	1515	422	335	228	43	1524	418	328	217	42	1533	414	321	204	41	1542	409	314	149
14	46	1522	419	332	226	45	1531	415	326	215	44	1540	410	319	203	43	1550	405	311	148	42	1600	400	303	129
15	47	1538	411	323	214	46	1547	407	316	201	45	1557	402	308	146	44	1608	356	300	128	43	1619	350	251	103
16	48	1553	403	314	200	47	1604	358	306	145	46	1614	353	258	127	45	1626	347	249	102	44	1639	341	238	000
17	49	1610	355	304	144	48	1621	350	255	126	47	1632	344	246	101	46	1645	337	236	000	45	1659	330	224	///
18	50	1626	347	253	125	49	1638	341	244	101	48	1651	334	234	000	47	1705	327	222	///	46	1721	320	209	///
19	51	1644	338	242	100	50	1657	332	232	000	49	1711	325	221	///	48	1726	317	207	///	47	1743	309	152	///
20	52	1702	329	230	000	51	1716	322	219	///	50	1731	314	206	///	49	1748	306	150	///	48	1807	257	131	///
21	53	1721	320	217	///	52	1736	312	204	///	51	1753	304	149	///	50	1812	254	130	///	49	1832	244	105	///
22	54	1740	310	203	///	53	1757	301	148	///	52	1816	252	129	///	51	1837	242	104	///	50	1900	230	000	///
23	55	1801	259	147	///	54	1820	250	128	///	53	1841	240	103	///	52	1904	228	000	///	51	1930	215	///	///
23.5	56	1812	254	137	///	55	1832	244	116	///	54	1854	233	045	///	53	1918	221	///	///	52	1947	206	///	///

/// = Twilight lasts all night.

Latitude and Declination OPPOSITE

	LAT.58					LAT.59					LAT.60					LAT.61					LAT.62				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	32	1213	554	514	428	31	1213	554	513	425	30	1213	553	512	422	29	1214	553	510	418	28	1214	553	509	415
1	31	1200	600	521	434	30	1200	600	520	432	29	1159	600	519	429	28	1159	600	518	426	27	1159	600	516	423
2	30	1147	607	527	441	29	1146	607	527	439	28	1146	607	526	437	27	1145	608	525	434	26	1144	608	524	431
3	29	1134	613	534	448	28	1133	614	533	446	27	1132	614	533	444	26	1130	615	532	442	25	1129	615	531	439
4	28	1121	619	540	455	27	1120	620	540	453	26	1118	621	540	451	25	1116	622	539	449	24	1114	623	539	447
5	27	1108	626	547	501	26	1106	627	547	500	25	1104	628	547	458	24	1101	629	547	457	23	1059	631	546	455
6	26	1055	632	553	508	25	1053	634	553	507	24	1050	635	554	505	23	1047	637	554	504	22	1043	638	554	503
7	25	1042	639	559	514	24	1039	641	600	513	23	1035	642	600	512	22	1032	644	601	511	21	1028	646	602	510
8	24	1029	645	606	521	23	1025	647	607	520	22	1021	649	607	519	21	1017	652	608	519	20	1012	654	609	518
9	23	1016	652	612	527	22	1011	654	613	527	21	1007	657	614	526	20	1002	659	615	526	19	956	702	617	525
10	22	1002	659	619	533	21	957	701	620	533	20	952	704	621	533	19	946	707	623	533	18	940	710	624	533
11	21	948	706	625	540	20	943	709	627	540	19	937	712	628	540	18	931	715	630	540	17	924	718	632	540
12	20	935	713	632	546	19	928	716	634	546	18	922	719	636	547	17	915	723	638	547	16	907	726	640	548
13	19	920	720	638	552	18	914	723	641	553	17	906	727	643	554	16	858	731	645	555	15	850	735	647	555
14	18	906	727	645	559	17	858	731	648	600	16	850	735	650	601	15	842	739	653	602	14	833	744	655	603
15	17	851	734	652	605	16	843	739	655	606	15	834	743	657	608	14	825	748	700	609	13	815	753	703	610
16	16	836	742	659	612	15	827	746	702	613	14	818	751	705	615	13	807	756	708	616	12	756	802	712	618
17	15	821	750	706	618	14	811	755	709	620	13	800	800	712	622	12	749	805	716	624	11	737	811	720	626
18	14	805	758	713	625	13	754	803	716	627	12	743	809	720	629	11	731	815	724	631	10	717	821	729	633
19	13	748	806	720	631	12	737	812	724	634	11	724	818	728	636	10	711	824	733	639	9	656	832	737	641
20	12	731	814	727	638	11	719	821	732	641	10	705	827	736	643	9	651	835	741	646	8	635	843	746	649
21	11	714	823	735	645	10	700	830	740	648	9	645	837	745	651	8	629	845	750	654	7	612	854	756	657
22	10	655	832	743	652	9	640	840	748	655	8	624	848	753	658	7	607	857	759	702	6	547	906	805	706
23	9	636	842	751	659	8	620	850	756	702	7	602	859	802	706	6	543	909	808	710	5	521	920	815	714
23.5	9	626	847	755	702	8	609	855	801	706	7	551	905	807	710	6	530	915	813	714	5	507	927	820	718

Table 2, Latitude and Declination SAME

DEC	LAT.63					LAT.64					LAT.65					LAT.66					LAT.67				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	27	1215	553	507	411	26	1215	552	505	407	25	1216	552	503	402	24	1216	552	500	357	23	1217	551	458	351
1	28	1230	545	459	402	27	1232	544	456	357	26	1233	544	454	352	25	1234	543	451	346	24	1236	542	448	340
2	29	1246	537	450	353	28	1248	536	448	348	27	1250	535	445	342	26	1252	534	442	335	25	1255	533	438	328
3	30	1302	529	442	343	29	1305	528	439	338	28	1308	526	436	331	27	1311	525	432	324	26	1314	523	428	316
4	31	1318	521	434	334	30	1321	519	430	327	29	1325	517	426	320	28	1329	516	422	312	27	1333	513	417	303
5	32	1334	513	425	323	31	1338	511	421	316	30	1343	509	417	308	29	1348	506	412	259	28	1353	504	407	249
6	33	1350	505	416	313	32	1355	502	412	305	31	1401	500	407	256	30	1406	457	401	246	29	1412	454	356	234
7	34	1407	457	407	302	33	1413	454	402	253	32	1419	451	357	243	31	1425	447	351	231	30	1433	444	344	217
8	35	1424	448	358	250	34	1430	445	352	240	33	1437	441	346	228	32	1445	438	340	215	31	1453	433	332	159
9	36	1441	440	348	237	35	1448	436	342	226	34	1456	432	335	212	33	1505	428	328	157	32	1514	423	320	137
10	37	1458	431	338	223	36	1506	427	331	210	35	1515	422	324	155	34	1525	418	316	135	33	1536	412	306	108
11	38	1516	422	328	208	37	1525	418	320	153	36	1535	413	312	133	35	1546	407	303	107	34	1558	401	252	000
12	39	1534	413	317	151	38	1544	408	309	132	37	1555	402	259	106	36	1607	356	249	000	35	1621	350	237	///
13	40	1553	404	306	130	39	1604	358	256	105	38	1616	352	246	000	37	1630	345	234	///	36	1645	338	220	///
14	41	1612	354	254	104	40	1624	348	243	000	39	1638	341	231	///	38	1653	333	218	///	37	1710	325	201	///
15	42	1632	344	241	000	41	1646	337	229	///	40	1701	330	215	///	39	1718	321	159	///	38	1736	312	139	///
16	43	1653	334	227	///	42	1708	326	213	///	41	1725	318	157	///	40	1744	308	137	///	39	1805	258	110	///
17	44	1714	323	211	///	43	1731	314	155	///	42	1750	305	136	///	41	1811	254	109	///	40	1835	242	000	///
18	45	1737	311	154	///	44	1756	302	134	///	43	1817	251	108	///	42	1841	240	000	///	41	1909	226	///	///
19	46	1802	259	133	///	45	1823	249	107	///	44	1846	237	000	///	43	1914	223	///	///	42	1946	207	///	///
20	47	1828	246	106	///	46	1851	234	000	///	45	1918	221	///	///	44	1951	205	///	///	43	2030	145	///	///
21	48	1856	232	000	///	47	1923	219	///	///	46	1955	203	///	///	45	2034	143	///	///	44	2126	117	///	///
22	49	1927	217	///	///	48	1958	201	///	///	47	2037	141	///	///	46	2129	116	///	///	45	2302	029	///	///
23	50	2002	159	///	///	49	2040	140	///	///	48	2131	114	///	///	47	2303	029	///	///	46	2400	+++	...	...
23.5	51	2021	149	///	///	50	2105	128	///	///	49	2207	056	///	///	48	2400	+++	...	...	47	2400	+++	...	...

/// = Twilight lasts all night. +++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.63					LAT.64					LAT.65					LAT.66					LAT.67				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h' m	h m	o	h m	h m	h m	h m
0	27	1215	553	507	411	26	1215	552	505	407	25	1216	552	503	402	24	1216	552	500	357	23	1217	551	458	351
1	26	1159	601	515	420	25	1159	601	513	416	24	1159	601	512	412	23	1158	601	510	407	22	1158	601	508	402
2	25	1143	608	523	428	24	1142	609	522	425	23	1141	609	520	421	22	1140	610	519	417	21	1139	610	517	413
3	24	1128	616	531	437	23	1126	617	530	434	22	1124	618	529	431	21	1122	619	528	427	20	1120	620	527	423
4	23	1112	624	539	445	22	1109	625	538	442	21	1107	627	538	440	20	1104	628	537	437	19	1101	629	536	433
5	22	1056	632	546	453	21	1053	634	546	451	20	1050	635	546	449	19	1046	637	546	446	18	1042	639	546	443
6	21	1040	640	554	501	20	1036	642	554	459	19	1032	644	555	458	18	1028	646	555	455	17	1023	649	555	453
7	20	1024	648	602	509	19	1019	650	603	508	18	1014	653	603	506	17	1009	655	604	505	16	1003	658	605	503
8	19	1007	656	610	517	18	1002	659	611	516	17	956	702	612	515	16	950	705	613	514	15	943	708	614	512
9	18	951	705	618	525	17	945	708	619	524	16	938	711	620	524	15	931	715	622	523	14	923	718	623	522
10	17	934	713	626	533	16	927	717	627	532	15	919	720	629	532	14	911	724	631	532	13	903	729	633	531
11	16	917	722	634	540	15	909	726	636	541	14	900	730	638	541	13	851	734	640	541	12	841	739	643	541
12	15	859	730	642	548	14	850	735	644	549	13	841	740	647	549	12	831	745	650	550	11	820	750	653	550
13	14	841	739	650	556	13	832	744	653	557	12	821	749	656	558	11	810	755	659	559	10	757	802	702	559
14	13	823	749	658	604	12	812	754	702	605	11	800	800	705	606	10	748	806	709	608	9	734	813	713	609
15	12	804	758	707	612	11	752	804	710	613	10	739	810	714	615	9	725	818	718	617	8	709	825	723	618
16	11	744	808	715	620	10	731	814	719	622	9	717	822	724	624	8	701	829	729	626	7	644	838	734	628
17	10	724	818	724	628	9	710	825	729	630	8	654	833	734	632	7	636	842	739	635	6	616	852	745	638
18	9	703	829	733	636	8	647	837	738	639	7	629	845	744	641	6	610	855	749	644	5	547	906	756	648
19	8	641	840	742	644	7	623	849	748	647	6	603	858	754	650	5	541	909	800	654	4	516	922	808	658
20	7	617	851	752	652	6	558	901	758	656	5	535	912	805	700	4	510	925	812	703	3	441	939	820	708
21	6	552	904	802	701	5	530	915	808	705	4	505	927	816	709	3	436	942	824	713	2	401	959	833	718
22	5	525	917	812	710	4	501	930	819	714	3	432	944	827	718	2	357	1001	836	723	1	314	1023	846	729
23	4	456	932	823	718	3	428	946	831	723	2	354	1003	840	728	1	311	1025	850	734	0	211	1055	901	740
23.5	4	441	940	828	723	3	410	955	837	728	2	332	1014	846	733	1	243	1039	857	739	0	123	1119	908	745

Table 2, Latitude and Declination SAME

DEC	LAT.68					LAT.69					LAT.70					LAT.71					LAT.72				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	22	1218	551	455	345	21	1219	551	452	338	20	1219	550	449	330	19	1220	550	445	321	18	1222	549	441	311
1	23	1238	541	445	333	22	1239	540	441	325	21	1242	539	437	316	20	1244	538	433	306	19	1246	537	428	254
2	24	1258	531	434	320	23	1300	530	430	311	22	1304	528	425	301	21	1307	526	420	249	20	1311	524	414	235
3	25	1318	521	423	307	24	1322	519	418	257	23	1326	517	413	245	22	1331	515	407	231	21	1336	512	400	214
4	26	1338	511	412	253	25	1343	508	407	241	24	1349	506	400	227	23	1355	503	353	210	22	1402	459	345	149
5	27	1358	501	401	237	26	1405	458	354	224	25	1412	454	347	207	24	1419	450	339	146	23	1428	446	330	117
6	28	1419	450	349	220	27	1427	447	342	204	26	1435	443	334	143	25	1444	438	324	115	24	1454	433	314	000
7	29	1440	440	337	201	28	1449	435	329	141	27	1459	431	319	113	26	1509	425	309	000	25	1521	419	256	///
8	30	1502	429	324	139	29	1512	424	315	111	28	1523	418	304	000	27	1536	412	252	///	26	1550	405	237	///
9	31	1524	418	310	110	30	1536	412	300	000	29	1549	406	248	///	28	1603	359	233	///	27	1619	351	216	///
10	32	1547	406	256	000	31	1600	400	244	///	30	1615	353	229	///	29	1631	344	212	///	28	1650	335	150	///
11	33	1611	354	240	///	32	1626	347	226	///	31	1642	339	209	///	30	1701	330	148	///	29	1722	319	118	///
12	34	1636	342	223	///	33	1652	334	206	///	32	1711	325	145	///	31	1732	314	116	///	30	1757	302	000	///
13	35	1701	329	204	///	34	1720	320	143	///	33	1741	309	114	///	32	1806	257	000	///	31	1835	243	///	///
14	36	1729	316	141	///	35	1750	305	113	///	34	1814	253	000	///	33	1843	239	///	///	32	1917	221	///	///
15	37	1758	301	111	///	36	1822	249	000	///	35	1850	235	///	///	34	1924	218	///	///	33	2007	157	///	///
16	38	1829	246	000	///	37	1857	232	///	///	36	1930	215	///	///	35	2012	154	///	///	34	2109	125	///	///
17	39	1903	229	///	///	38	1936	212	///	///	37	2017	151	///	///	36	2113	123	///	///	35	2256	032	///	///
18	40	1941	209	///	///	39	2022	149	///	///	38	2117	122	///	///	37	2257	031	///	///	36	2400	+++	...	...
19	41	2026	147	///	///	40	2120	120	///	///	39	2258	031	///	///	38	2400	+++	...	...	37	2400	+++	...	...
20	42	2123	118	///	///	41	2300	030	///	///	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...
21	43	2301	030	///	///	42	2400	+++	...	...	41	2400	+++	...	...	40	2400	+++	...	...	39	2400	+++	...	...
22	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...	41	2400	+++	...	...	40	2400	+++	...	...
23	45	2400	+++	...	...	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...	41	2400	+++	...	...
23.5	46	2400	+++	...	...	45	2400	+++	...	...	44	2400	+++	...	...	43	2400	+++	...	...	42	2400	+++	...	...

/// = Twilight lasts all night. +++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.68					LAT.69					LAT.70					LAT.71					LAT.72				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	22	1218	551	455	345	21	1219	551	452	338	20	1219	550	449	330	19	1220	550	445	321	18	1222	549	441	311
1	21	1158	601	505	357	20	1158	601	503	351	19	1158	601	500	344	18	1157	601	457	336	17	1157	602	454	327
2	20	1138	611	516	408	19	1137	612	514	403	18	1136	612	512	357	17	1134	613	509	350	16	1132	614	507	342
3	19	1118	621	526	419	18	1116	622	524	414	17	1113	623	523	409	16	1111	625	521	403	15	1108	626	519	357
4	18	1058	631	536	430	17	1055	633	535	426	16	1051	634	534	421	15	1047	636	533	416	14	1043	639	532	411
5	17	1038	641	545	440	16	1034	643	545	437	15	1029	646	545	433	14	1023	648	544	429	13	1017	651	544	424
6	16	1018	651	555	451	15	1012	654	556	448	14	1006	657	556	445	13	959	700	556	441	12	952	704	556	437
7	15	957	701	605	501	14	950	705	606	459	13	943	709	607	456	12	935	713	608	453	11	926	717	609	450
8	14	936	712	615	511	13	928	716	616	509	12	919	720	618	507	11	910	725	619	505	10	859	731	621	503
9	13	915	723	625	521	12	906	727	627	520	11	855	732	629	518	10	844	738	631	517	9	831	744	633	515
10	12	853	734	635	531	11	842	739	638	530	10	831	745	640	529	9	817	751	643	529	8	803	759	646	528
11	11	830	745	645	541	10	818	751	648	541	9	805	758	651	540	8	750	805	655	540	7	733	814	659	540
12	10	807	756	656	551	9	753	803	659	551	8	738	811	703	551	7	721	819	707	552	6	702	829	712	552
13	9	743	808	706	600	8	728	816	710	601	7	710	825	715	602	6	651	835	720	603	5	628	846	725	605
14	8	718	821	717	610	7	701	830	722	612	6	641	840	727	613	5	618	851	733	615	4	552	904	739	617
15	7	652	834	728	620	6	632	844	733	622	5	610	855	739	625	4	544	908	746	627	3	513	924	753	629
16	6	624	848	739	630	5	602	859	745	633	4	536	912	752	636	3	505	927	800	639	2	428	946	808	642
17	5	554	903	751	641	4	528	916	758	644	3	458	931	805	647	2	422	949	814	651	1	335	1012	824	655
18	4	522	919	803	651	3	452	934	811	655	2	416	952	819	659	1	330	1015	829	703	0	225	1048	840	708
18.5	4	505	928	809	656	3	432	944	817	700	2	352	1004	827	705	1	259	1030	837	709	0	131	1114	849	715
19	3	446	937	815	702	2	411	955	824	706	1	326	1017	834	711	0	221	1049	845	716	-1	000	---	858	721
19.5	3	427	947	822	707	2	347	1006	831	712	1	255	1032	842	717	0	129	1115	854	722	-1	000	---	908	728
20	2	406	957	829	712	1	321	1019	839	717	0	218	1051	850	723	-1	000	---	903	729	-2	000	---	918	735
20.5	2	343	1008	835	718	1	252	1034	846	723	0	127	1116	858	729	-1	000	---	912	735	-2	000	---	929	742
21	1	318	1021	843	723	0	216	1052	854	729	-1	000	---	907	735	-2	000	---	922	742	-3	000	---	940	750
21.5	1	248	1036	850	729	0	126	1117	902	735	-1	000	---	916	742	-2	000	---	932	749	-3	000	---	952	757
22	0	213	1053	857	735	-1	000	---	910	741	-2	000	---	925	748	-3	000	---	943	756	-4	000	---	1006	805
22.5	0	124	1118	905	740	-1	000	---	919	747	-2	000	---	935	755	-3	000	---	955	803	-4	000	---	1021	813
23	-1	000	---	913	746	-2	000	---	928	754	-3	000	---	946	802	-4	000	---	1009	810	-5	000	---	1039	821
23.5	-1	000	---	922	752	-2	000	---	938	800	-3	000	---	958	808	-4	000	---	1024	818	-5	000	---	1103	829

--- = No Rise or Set. Sun remains below the horizon.

Table 2, Latitude and Declination SAME

DEC	LAT.73					LAT.74					LAT.75					LAT.76					LAT.77				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	17	1223	549	436	259	16	1224	548	431	244	15	1226	547	425	226	14	1228	546	418	203	13	1230	545	409	130
1	18	1249	535	422	239	17	1252	534	416	222	16	1256	532	408	159	15	1300	530	359	127	14	1305	528	349	000
2	19	1316	522	407	217	18	1320	520	400	155	17	1326	517	351	124	16	1332	514	340	000	15	1340	510	328	///
3	20	1342	509	352	152	19	1349	505	343	121	18	1357	502	333	000	17	1406	457	320	///	16	1416	452	305	///
4	21	1409	455	336	119	20	1418	451	326	000	19	1428	446	313	///	18	1439	440	258	///	17	1453	434	239	///
5	22	1437	441	319	000	21	1448	436	307	///	20	1500	430	252	///	19	1514	423	233	///	18	1531	415	209	///
6	23	1506	427	301	///	22	1518	421	246	///	21	1533	413	228	///	20	1551	405	205	///	19	1611	355	131	///
7	24	1535	413	242	///	23	1550	405	224	///	22	1608	356	200	///	21	1629	346	128	///	20	1653	333	000	///
8	25	1605	357	219	///	24	1623	348	157	///	23	1644	338	125	///	22	1709	325	000	///	21	1739	310	///	///
9	26	1637	341	153	///	25	1658	331	122	///	24	1723	318	000	///	23	1753	304	///	///	22	1830	245	///	///
10	27	1711	325	120	///	26	1736	312	000	///	25	1805	257	///	///	24	1842	239	///	///	23	1928	216	///	///
11	28	1747	307	000	///	27	1816	252	///	///	26	1852	234	///	///	25	1938	211	///	///	24	2042	139	///	///
12	29	1826	247	///	///	28	1901	229	///	///	27	1946	207	///	///	26	2048	136	///	///	25	2245	037	///	///
13	30	1910	225	///	///	29	1954	203	///	///	28	2055	133	///	///	27	2248	036	///	///	26	2400	+++	...	...
14	31	2001	200	///	///	30	2100	130	///	///	29	2250	035	///	///	28	2400	+++	...	...	27	2400	+++	...	...
15	32	2105	128	///	///	31	2252	034	///	///	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...
16	33	2254	033	///	///	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...
17	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...
18	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...
19	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...
20	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...
21	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...
22	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...	35	2400	+++	...	...
23	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...	36	2400	+++	...	...
23.5	41	2400	+++	...	...	40	2400	+++	...	...	39	2400	+++	...	...	38	2400	+++	...	...	37	2400	+++	...	...

/// = Twilight lasts all night. +++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

DEC	LAT.73					LAT.74					LAT.75					LAT.76					LAT.77				
	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	17	1223	549	436	259	16	1224	548	431	244	15	1226	547	425	226	14	1228	546	418	203	13	1230	545	409	130
1	16	1157	602	450	317	15	1156	602	446	304	14	1156	602	441	250	13	1155	602	435	231	12	1155	603	428	208
2	15	1130	615	504	333	14	1128	616	500	323	13	1126	617	456	311	12	1123	618	452	256	11	1120	620	447	237
3	14	1104	628	517	349	13	1100	630	515	340	12	1056	632	512	330	11	1051	635	509	318	10	1045	637	505	303
4	13	1038	641	530	404	12	1032	644	529	357	11	1026	647	527	348	10	1018	651	525	338	9	1010	655	522	326
5	12	1011	655	543	419	11	1003	658	543	412	10	955	703	542	405	9	945	708	541	357	8	934	713	540	347
6	11	943	708	556	433	10	934	713	557	428	9	923	718	557	422	8	911	725	557	415	7	856	732	557	407
7	10	915	722	609	447	9	904	728	611	442	8	851	735	612	438	7	835	742	613	432	6	817	751	615	426
8	9	847	737	623	500	8	833	744	625	457	7	817	752	627	453	6	758	801	629	449	5	737	812	632	444
9	8	817	752	636	513	7	801	800	639	511	6	742	809	642	509	5	720	820	646	506	4	653	833	650	502
10	7	746	807	649	527	6	727	817	653	525	5	704	828	657	524	4	638	841	702	522	3	606	857	708	520
11	6	714	823	703	540	5	651	834	708	539	4	625	848	713	539	3	553	904	719	538	2	513	924	727	537
12	5	639	840	717	553	4	613	854	723	553	3	541	910	729	554	2	502	929	737	554	1	410	955	746	554
13	4	602	859	731	606	3	531	915	738	607	2	452	934	746	609	1	402	959	755	610	0	248	1036	806	612
13.5	4	542	909	739	612	3	508	926	746	614	2	424	948	755	616	1	326	1017	805	618	0	146	1107	817	621
14	3	521	919	746	619	2	443	938	754	621	1	354	1003	804	624	0	242	1039	815	626	-1	000	---	828	629
14.5	3	459	930	754	626	2	417	952	803	628	1	319	1020	813	631	0	142	1109	825	634	-1	000	---	839	638
15	2	435	942	802	632	1	347	1006	811	635	0	237	1041	822	639	-1	000	---	835	643	-2	000	---	851	647
15.5	2	410	955	810	639	1	313	1023	820	643	0	139	1110	832	646	-1	000	---	846	651	-2	000	---	904	656
16	1	341	1010	818	646	0	233	1044	829	650	-1	000	---	842	654	-2	000	---	858	659	-3	000	---	917	705
16.5	1	308	1026	826	653	0	136	1112	838	657	-1	000	---	853	702	-2	000	---	910	708	-3	000	---	932	714
17	0	228	1046	835	659	-1	000	---	848	704	-2	000	---	904	710	-3	000	---	923	716	-4	000	---	948	724
17.5	0	134	1113	844	706	-1	000	---	858	712	-2	000	---	915	718	-3	000	---	937	725	-4	000	---	1006	733
18	-1	000	---	854	713	-2	000	---	909	720	-3	000	---	928	726	-4	000	---	952	734	-5	000	---	1027	743
19	-2	000	---	914	728	-3	000	---	932	735	-4	000	---	956	743	-5	000	---	1030	753	-6	000	---	1200	804
20	-3	000	---	936	743	-4	000	---	1000	751	-5	000	---	1033	801	-6	000	---	1200	812	-7	000	---	...	825
21	-4	000	---	1003	758	-5	000	---	1035	808	-6	000	---	1200	820	-7	000	---	...	833	-8	000	---	...	849
22	-5	000	---	1038	815	-6	000	---	1200	826	-7	000	---	...	840	-8	000	---	...	856	-9	000	---	...	915
23	-6	000	---	1200	832	-7	000	---	...	845	-8	000	---	...	901	-9	000	---	...	921	-10	000	---	...	946
23.5	-6	000	---	...	841	-7	000	---	...	856	-8	000	---	...	913	-9	000	---	...	935	-10	000	---	...	1004

--- = No Rise or Set. Sun remains below the horizon.

Table 2, Latitude and Declination SAME

	LAT.78					LAT.79					LAT.80					LAT.81					LAT.82				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	12	1232	544	359	000	11	1235	543	347	///	10	1238	541	332	///	9	1243	539	312	///	8	1248	536	245	///
1	13	1310	525	337	///	12	1316	522	322	///	11	1324	518	302	///	10	1334	513	236	///	9	1346	507	156	///
2	14	1348	506	313	///	13	1359	501	253	///	12	1411	455	227	///	11	1426	447	149	///	10	1445	437	000	///
3	15	1428	446	246	///	14	1442	439	220	///	13	1459	430	143	///	12	1521	420	000	///	11	1548	406	///	///
4	16	1508	426	214	///	15	1527	417	139	///	14	1550	405	000	///	13	1619	351	///	///	12	1656	332	///	///
5	17	1550	405	134	///	16	1614	353	000	///	15	1644	338	///	///	14	1722	319	///	///	13	1813	253	///	///
6	18	1635	342	000	///	17	1705	328	///	///	16	1743	309	///	///	15	1834	243	///	///	14	1948	206	///	///
7	19	1723	318	///	///	18	1801	300	///	///	17	1851	235	///	///	16	2003	159	///	///	15	2226	047	///	///
8	20	1816	252	///	///	19	1905	227	///	///	18	2015	153	///	///	17	2231	044	///	///	16	2400	+++	...	...
9	21	1917	221	///	///	20	2025	148	///	///	19	2235	042	///	///	18	2400	+++	...	...	17	2400	+++	...	...
10	22	2034	143	///	///	21	2239	040	///	///	20	2400	+++	...	...	19	2400	+++	...	...	18	2400	+++	...	...
11	23	2243	039	///	///	22	2400	+++	...	...	21	2400	+++	...	...	20	2400	+++	...	...	19	2400	+++	...	...
12	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...	21	2400	+++	...	...	20	2400	+++	...	...
13	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...	21	2400	+++	...	...
14	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...	22	2400	+++	...	...
15	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...	23	2400	+++	...	...
16	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...	24	2400	+++	...	...
17	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...	25	2400	+++	...	...
18	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...	26	2400	+++	...	...
19	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...	27	2400	+++	...	...
20	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...	28	2400	+++	...	...
21	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...	29	2400	+++	...	...
22	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...	30	2400	+++	...	...
23	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...	31	2400	+++	...	...
23.5	36	2400	+++	...	...	35	2400	+++	...	...	34	2400	+++	...	...	33	2400	+++	...	...	32	2400	+++	...	...

/// = Twilight lasts all night. +++ = No rise or Set. Sun remains above the horizon.

Latitude and Declination OPPOSITE

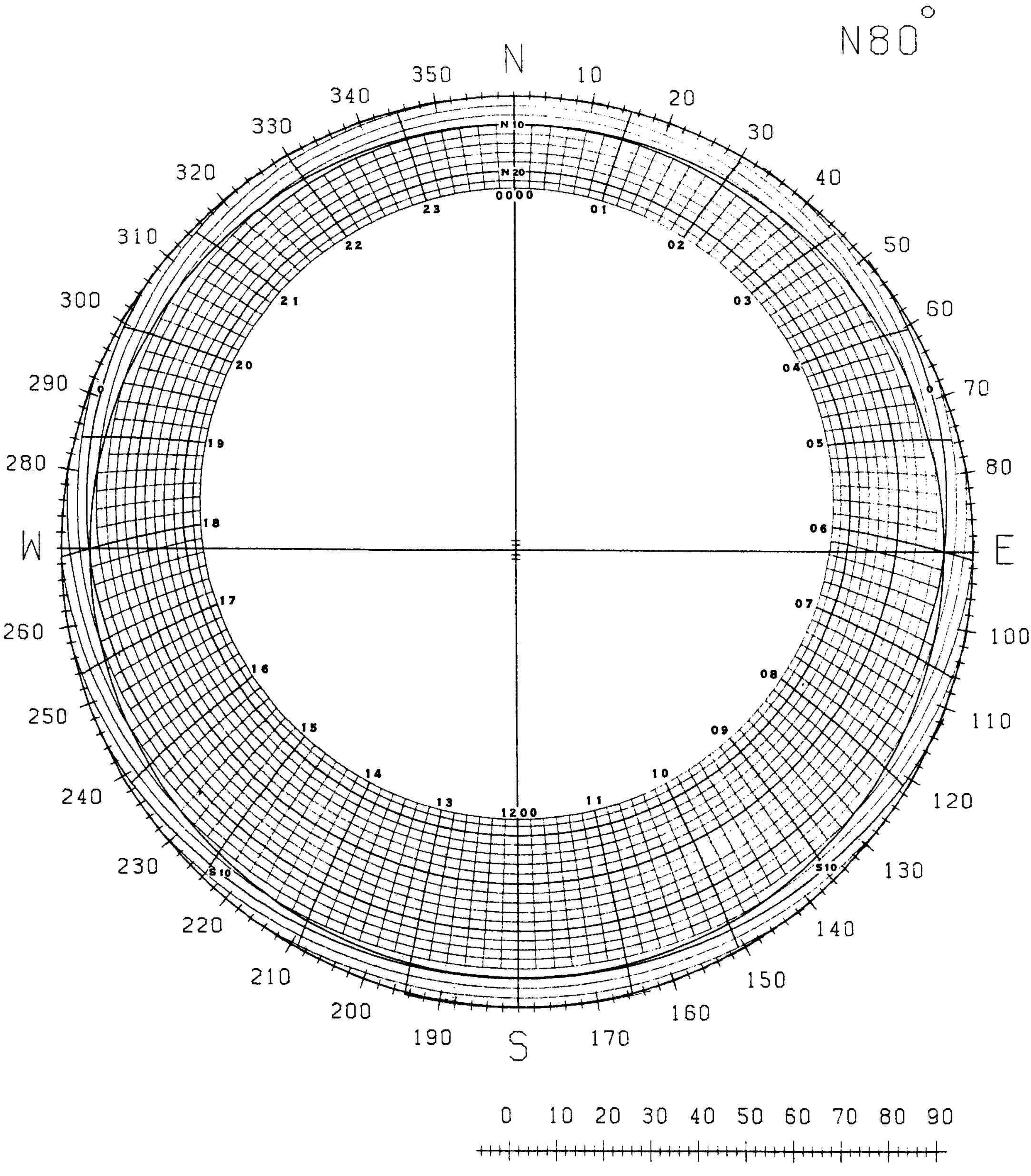
	LAT.78					LAT.79					LAT.80					LAT.81					LAT.82				
DEC	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT	AL	LD	R/S	CT	NT
o	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m	o	h m	h m	h m	h m
0	12	1232	544	359	000	11	1235	543	347	///	10	1238	541	332	///	9	1243	539	312	///	8	1248	536	245	///
1	11	1154	603	420	133	10	1154	603	411	000	9	1153	603	359	///	8	1152	604	344	///	7	1151	605	325	///
2	10	1117	622	441	213	9	1113	624	434	138	8	1108	626	425	000	7	1101	629	414	///	6	1054	633	359	///
3	9	1039	641	500	244	8	1031	645	455	219	7	1021	649	449	142	6	1010	655	441	000	5	956	702	431	///
4	8	1000	700	520	311	7	948	706	516	252	6	934	713	512	226	5	917	722	507	148	4	855	733	501	000
5	7	920	720	539	335	6	905	728	537	320	5	845	737	535	300	4	821	749	533	234	3	751	805	530	155
6	6	839	740	557	357	5	819	751	558	345	4	754	803	558	330	3	722	819	558	311	2	640	840	558	244
7	5	756	802	616	418	4	730	815	618	409	3	658	831	621	357	2	616	852	623	343	1	518	921	627	323
8	4	710	825	635	438	3	638	841	639	431	2	557	902	644	423	1	500	930	649	412	0	332	1014	656	358
8.5	4	646	837	645	448	3	610	855	650	442	2	522	919	655	435	1	415	953	702	426	0	214	1053	711	414
9	3	621	850	655	458	2	540	910	700	453	1	445	938	707	447	0	320	1020	715	439	-1	000	---	726	429
9.5	3	554	903	704	508	2	507	926	711	504	1	402	959	719	459	0	206	1057	729	452	-1	000	---	742	444
10	2	525	917	714	517	1	431	944	722	514	0	310	1025	732	510	-1	000	---	743	505	-2	000	---	758	459
10.5	2	454	933	725	527	1	351	1005	733	524	0	200	1100	744	522	-1	000	---	758	518	-2	000	---	815	514
11	1	420	950	735	536	0	302	1029	745	535	-1	000	---	757	533	-2	000	---	813	531	-3	000	---	833	528
11.5	1	341	1009	745	545	0	155	1103	757	545	-1	000	---	811	544	-2	000	---	828	544	-3	000	---	852	542
12	0	254	1033	756	555	-1	000	---	809	555	-2	000	---	825	556	-3	000	---	845	556	-4	000	---	912	557
12.5	0	150	1105	807	604	-1	000	---	822	606	-2	000	---	839	607	-3	000	---	903	609	-4	000	---	936	611
13	-1	000	---	819	614	-2	000	---	835	616	-3	000	---	855	618	-4	000	---	922	621	-5	000	---	1003	625
14	-2	000	---	844	633	-3	000	---	904	637	-4	000	---	930	641	-5	000	---	1009	647	-6	000	---	1200	654
15	-3	000	---	911	652	-4	000	---	937	658	-5	000	---	1015	705	-6	000	---	1200	714	-7	000	---	...	724
16	-4	000	---	943	712	-5	000	---	1019	720	-6	000	---	1200	729	-7	000	---	...	741	-8	000	---	...	756
17	-5	000	---	1023	732	-6	000	---	1200	743	-7	000	---	...	755	-8	000	---	...	811	-9	000	---	...	831
18	-6	000	---	1200	754	-7	000	---	...	807	-8	000	---	...	823	-9	000	---	...	843	-10	000	---	...	911
19	-7	000	---	...	817	-8	000	---	...	833	-9	000	---	...	853	-10	000	---	...	921	-11	000	---	...	1002
20	-8	000	---	...	842	-9	000	---	...	902	-10	000	---	...	929	-11	000	---	...	1008	-12	000	---	...	1200
21	-9	000	---	...	909	-10	000	---	...	935	-11	000	---	...	1014	-12	000	---	...	1200	-13	000	---	...	...
22	-10	000	---	...	941	-11	000	---	...	1018	-12	000	---	...	1200	-13	000	---	...	...	-14	000	---	...	...
23	-11	000	---	...	1022	-12	000	---	...	1200	-13	000	---	...	...	-14	000	---	...	...	-15	000	---	...	...
23.5	-11	000	---	...	1051	-12	000	---	...	...	-13	000	---	...	...	-14	000	---	...	...	-15	000	---	...	...

--- = No Rise or Set. Sun remains below the horizon. /// = Twilight lasts all night.

Table 3 -- Longitude, Time Adjustments

Lo	UT	Lo	UT	Lo	UT	Lo	UT	Lo	UT	Lo	UT	ZC
deg	h m	deg	h m	deg	h m	deg	h m	deg	h m	deg	h m	m
1	004	31	204	61	404	91	604	121	804	151	1004	04
2	008	32	208	62	408	92	608	122	808	152	1008	08
3	012	33	212	63	412	93	612	123	812	153	1012	12
4	016	34	216	64	416	94	616	124	816	154	1016	16
5	020	35	220	65	420	95	620	125	820	155	1020	20
6	024	36	224	66	424	96	624	126	824	156	1024	24
7	028	37	228	67	428	97	628	127	828	157	1028	28
												Note
8	032	38	232	68	432	98	632	128	832	158	1032	28
9	036	39	236	69	436	99	636	129	836	159	1036	24
10	040	40	240	70	440	100	640	130	840	160	1040	20
11	044	41	244	71	444	101	644	131	844	161	1044	16
12	048	42	248	72	448	102	648	132	848	162	1048	12
13	052	43	252	73	452	103	652	133	852	163	1052	08
14	056	44	256	74	456	104	656	134	856	164	1056	04
15	100	45	300	75	500	105	700	135	900	165	1100	00
16	104	46	304	76	504	106	704	136	904	166	1104	04
17	108	47	308	77	508	107	708	137	908	167	1108	08
18	112	48	312	78	512	108	712	138	912	168	1112	12
19	116	49	316	79	516	109	716	139	916	169	1116	16
20	120	50	320	80	520	110	720	140	920	170	1120	20
21	124	51	324	81	524	111	724	141	924	171	1124	24
22	128	52	328	82	528	112	728	142	928	172	1128	28
												Note
23	132	53	332	83	532	113	732	143	932	173	1132	28
24	136	54	336	84	536	114	736	144	936	174	1136	24
25	140	55	340	85	540	115	740	145	940	175	1140	20
26	144	56	344	86	544	116	744	146	944	176	1144	16
27	148	57	348	87	548	117	748	147	948	177	1148	12
28	152	58	352	88	552	118	752	148	952	178	1152	08
29	156	59	356	89	556	119	756	149	956	179	1156	04
30	200	60	400	90	600	120	800	150	1000	180	1200	00

Note: In a uniform system of time zones, boundaries are located midway between the longitudes in the table, at the lines indicated. The corresponding adjustment is 30 minutes, to be applied according to the time actually kept at the location of interest.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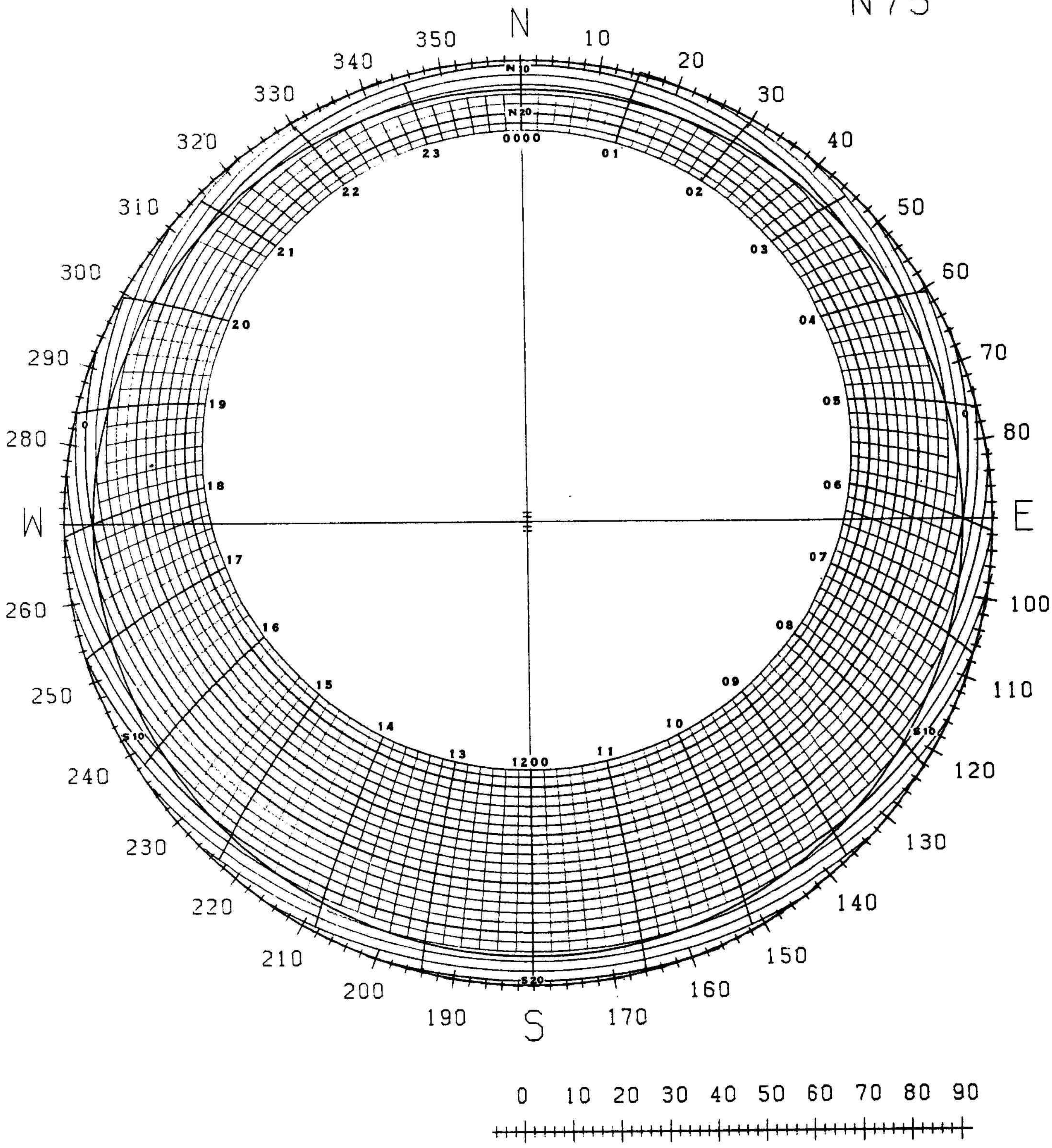
N75°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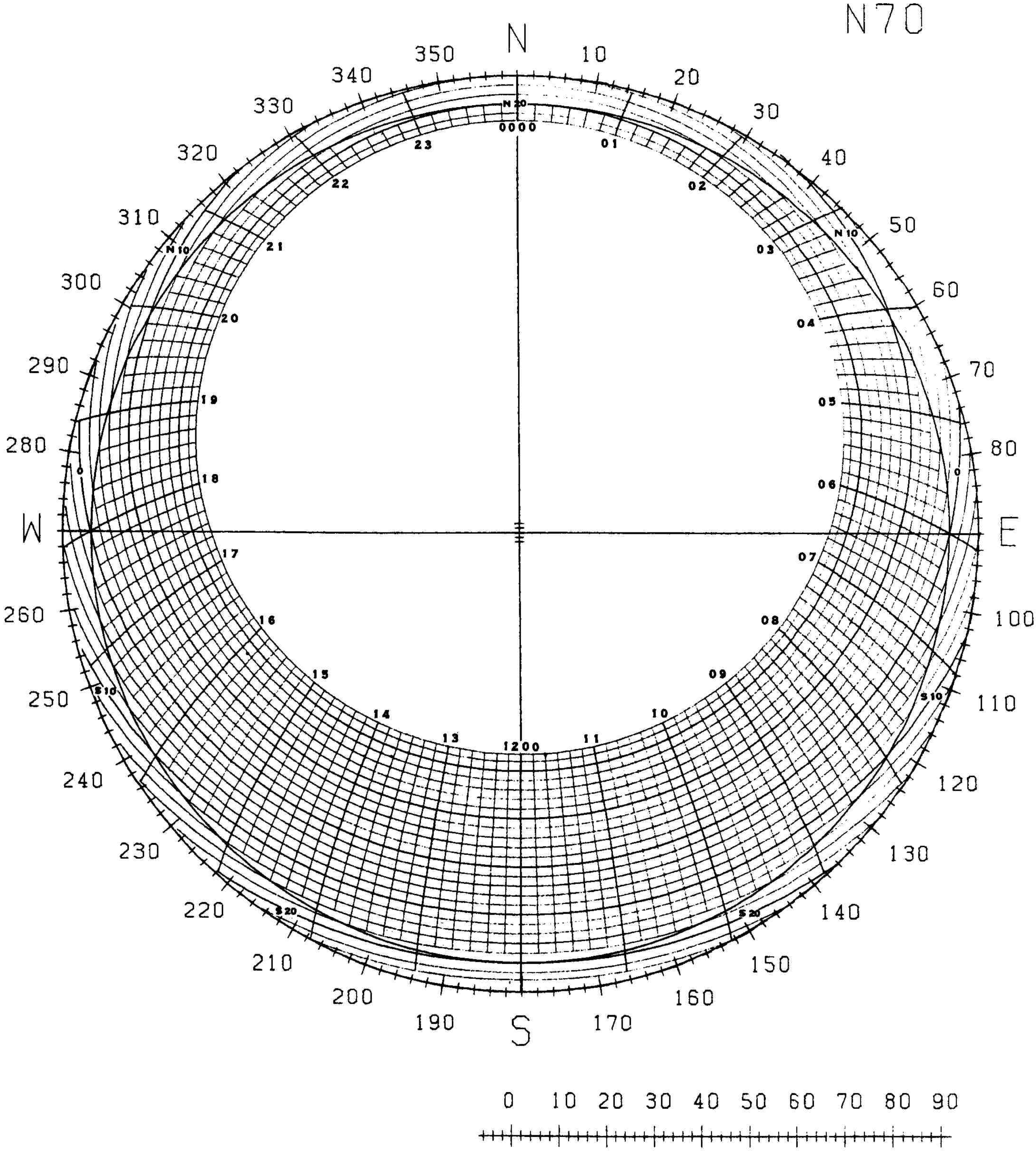
N70°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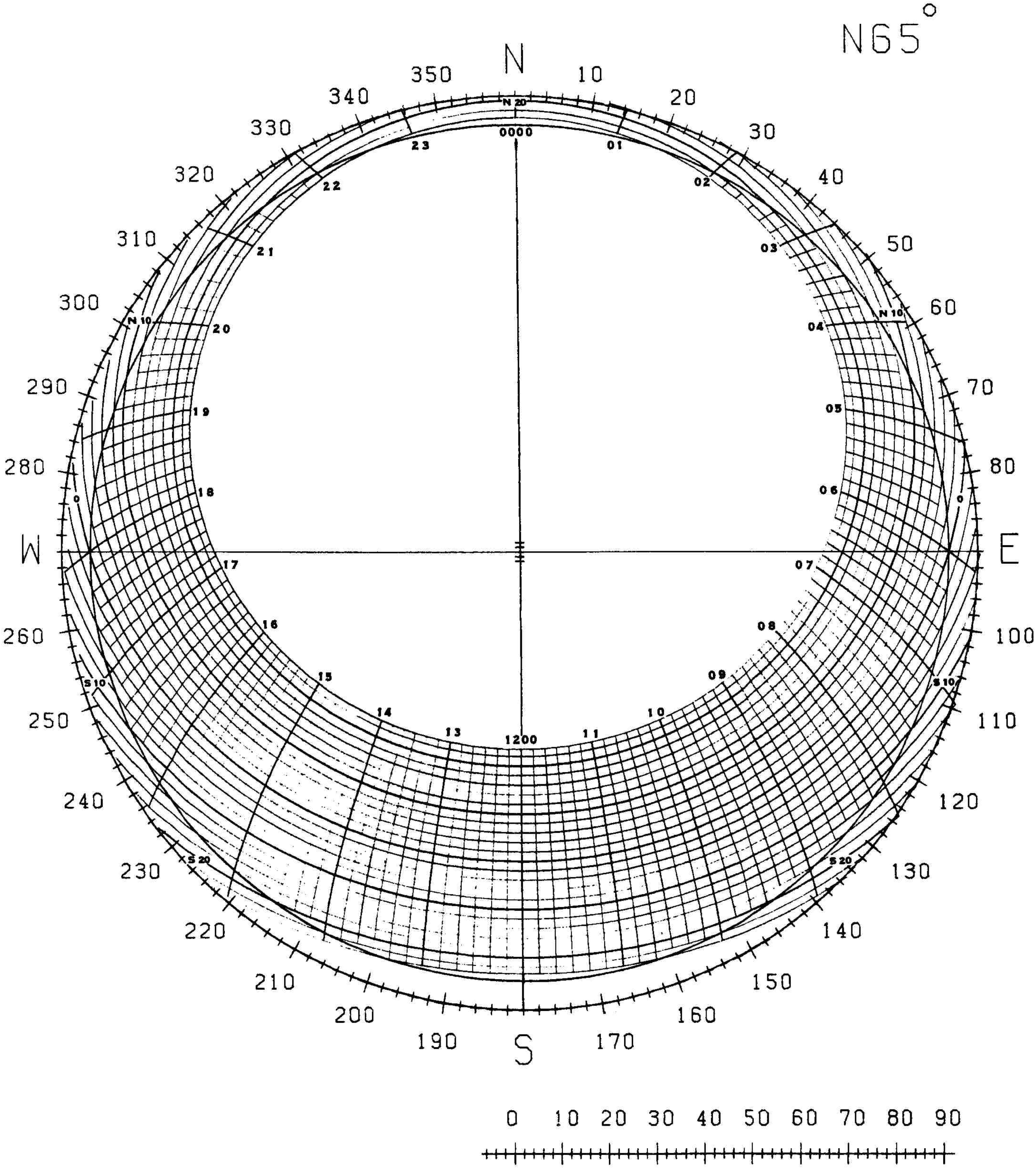
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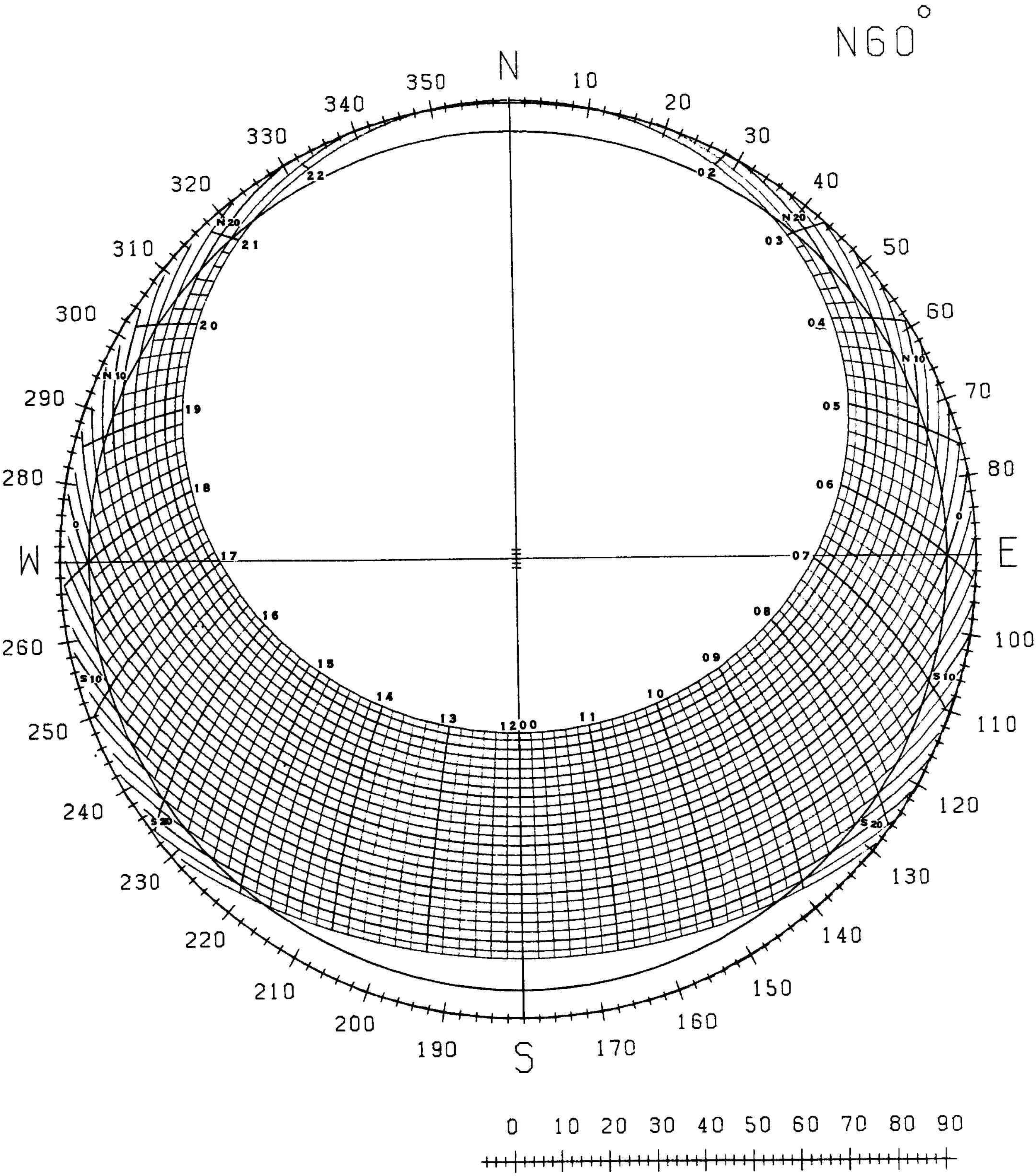
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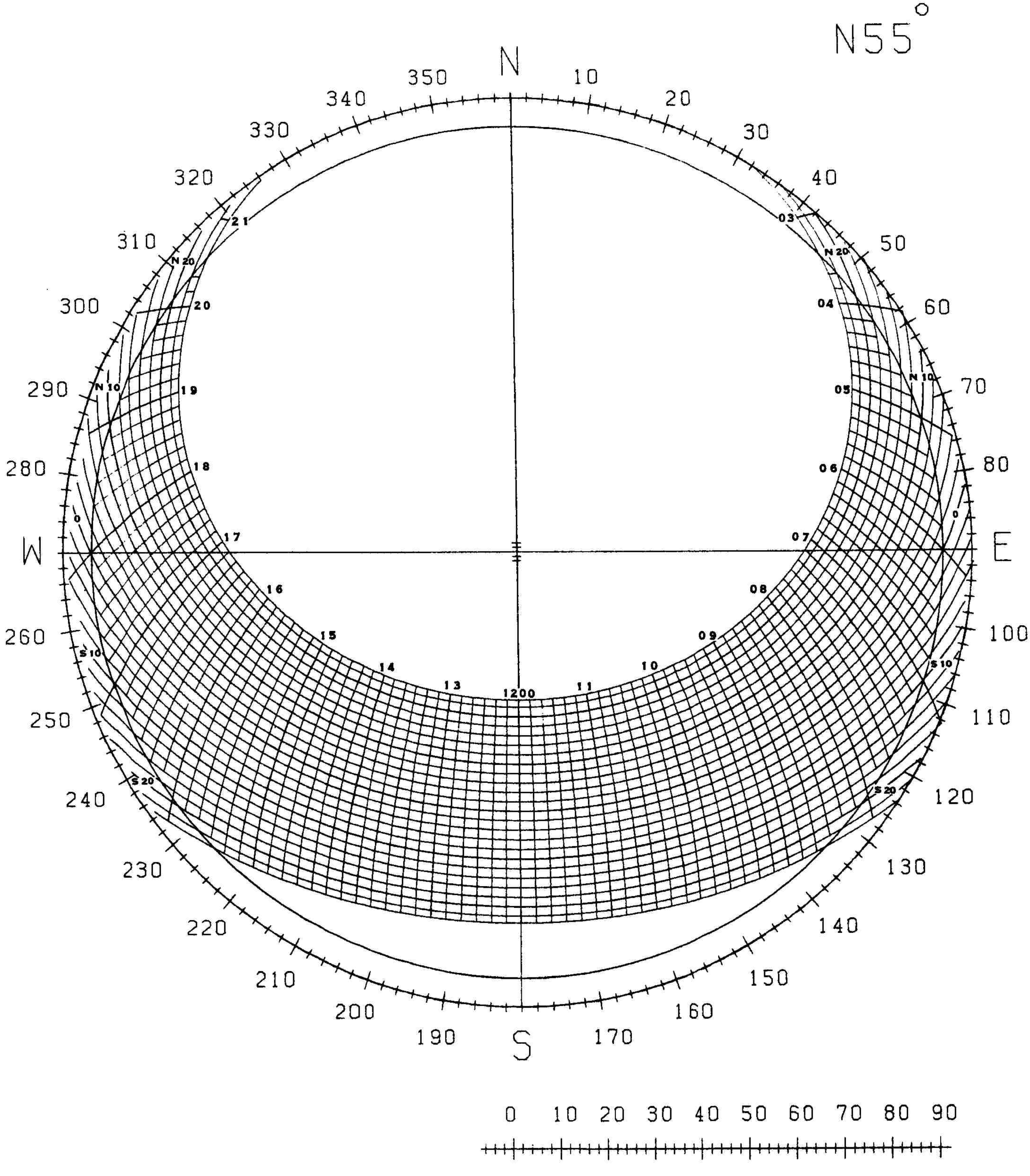
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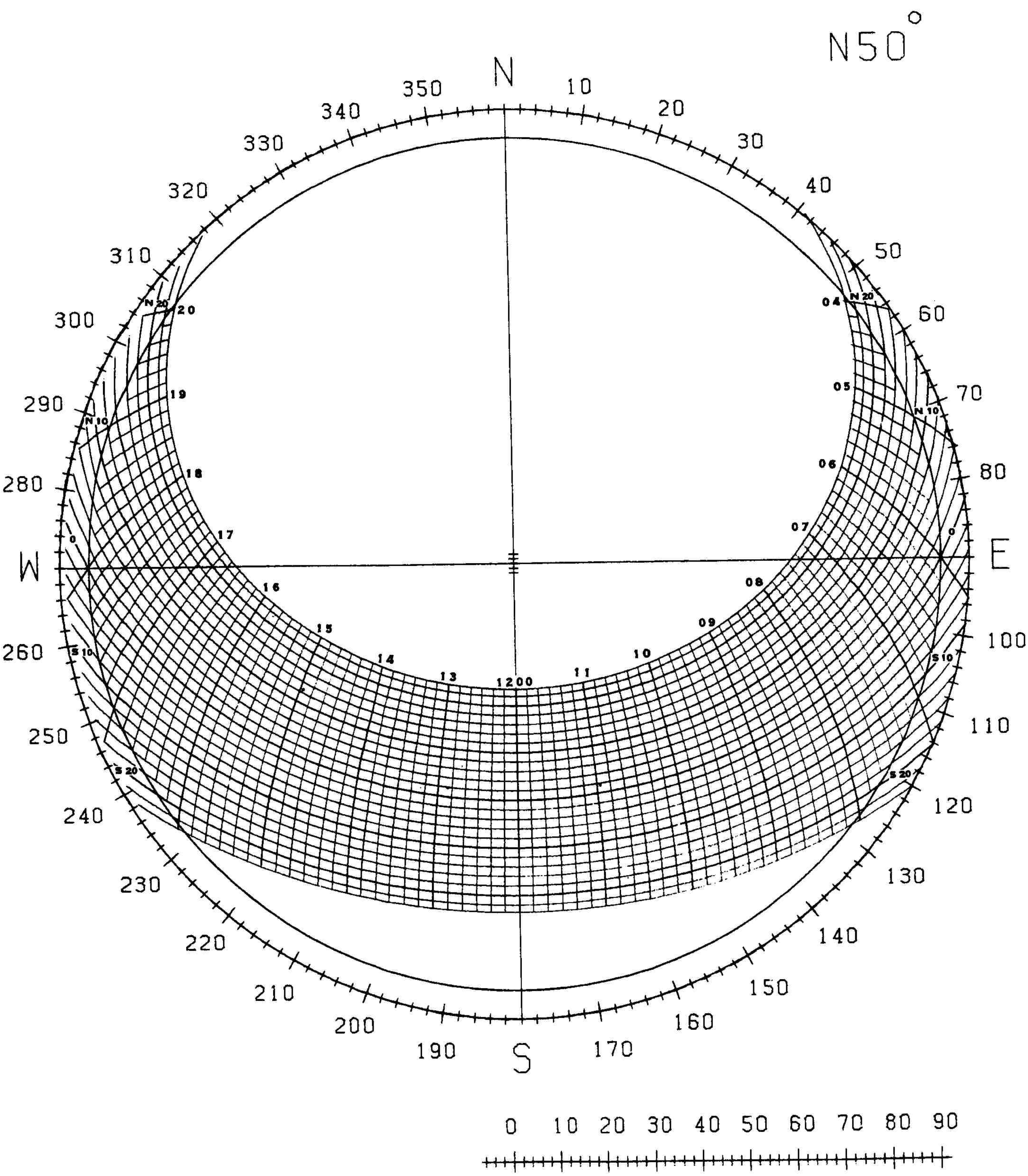

N50°
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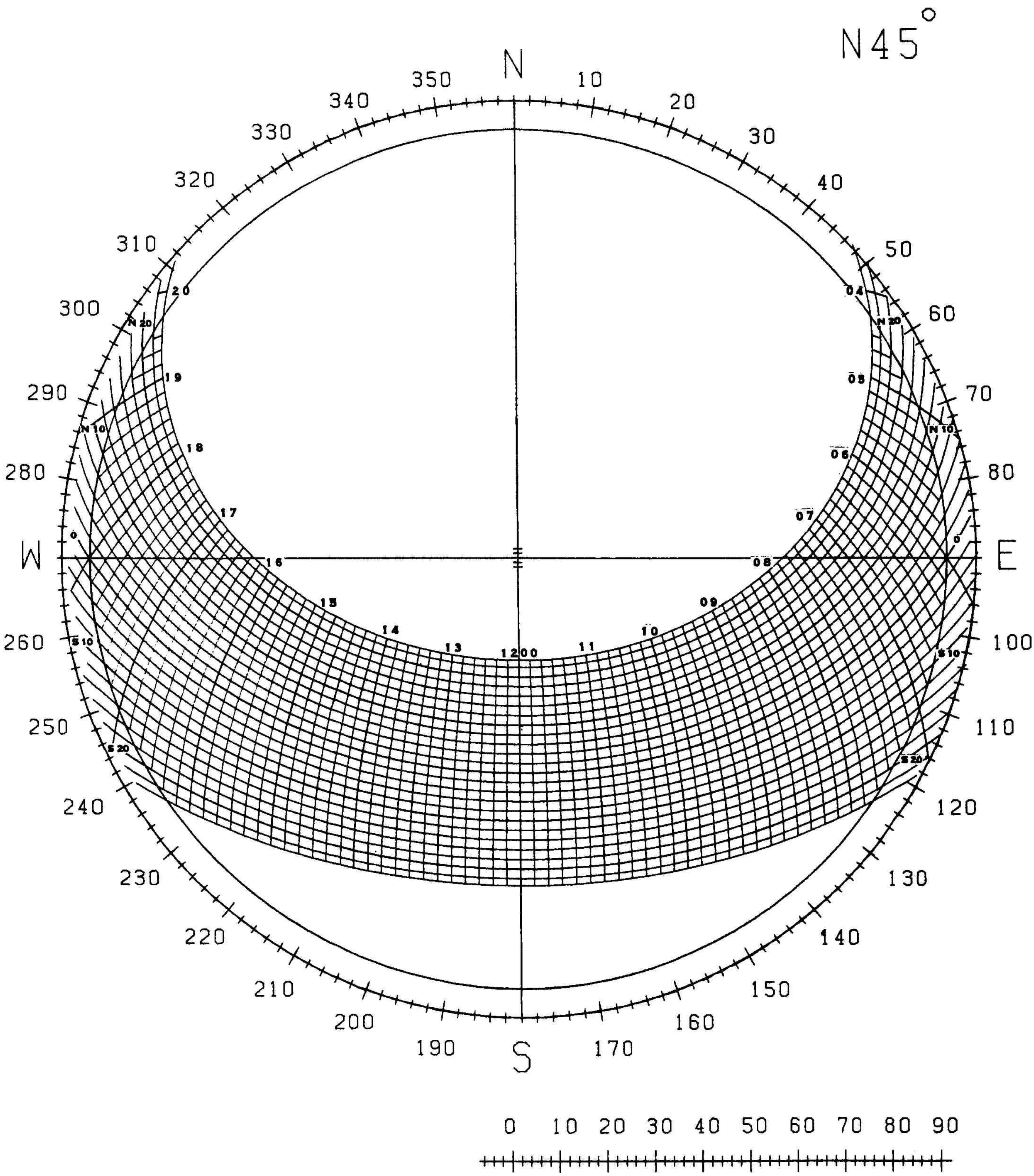
N45°
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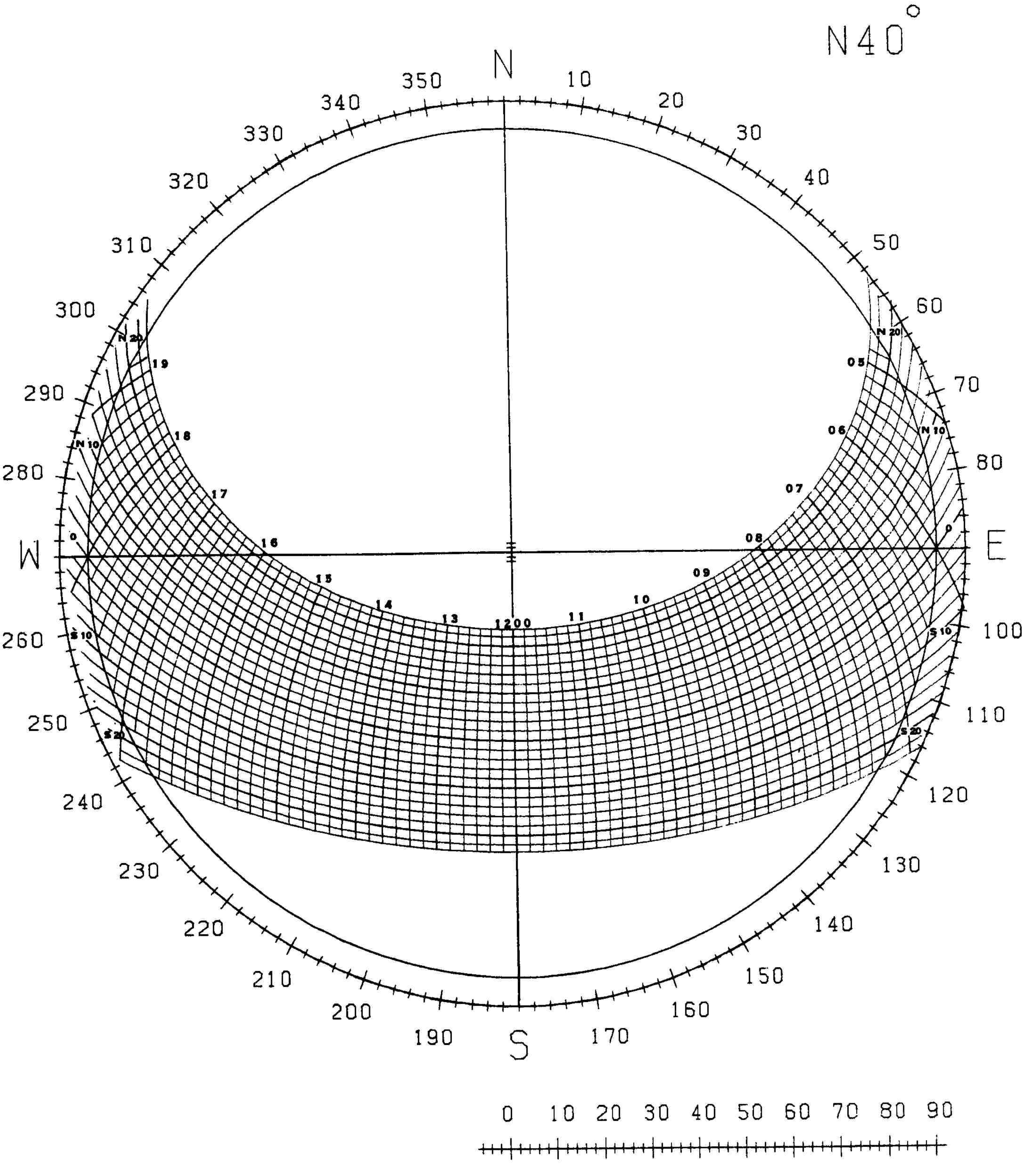
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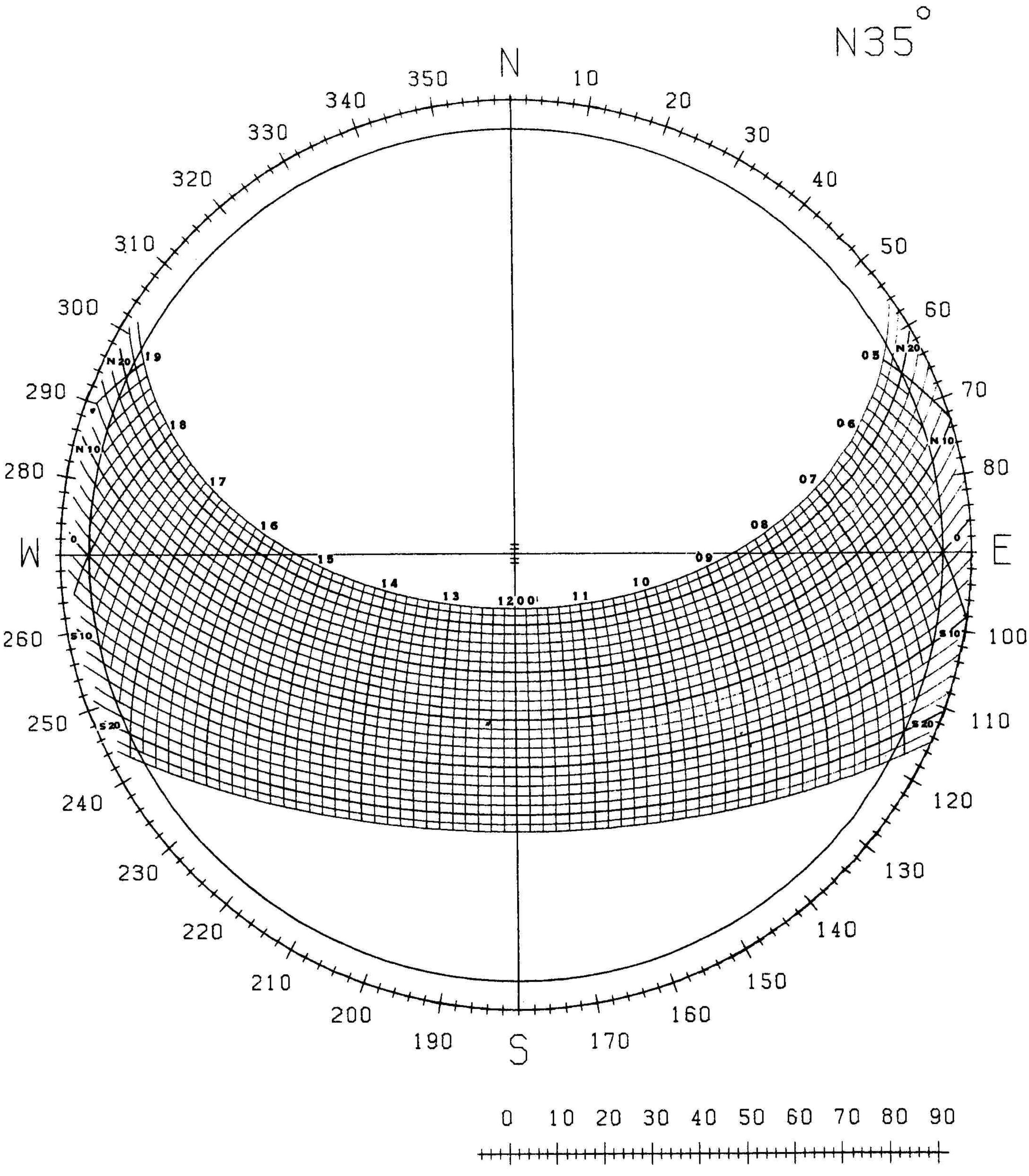
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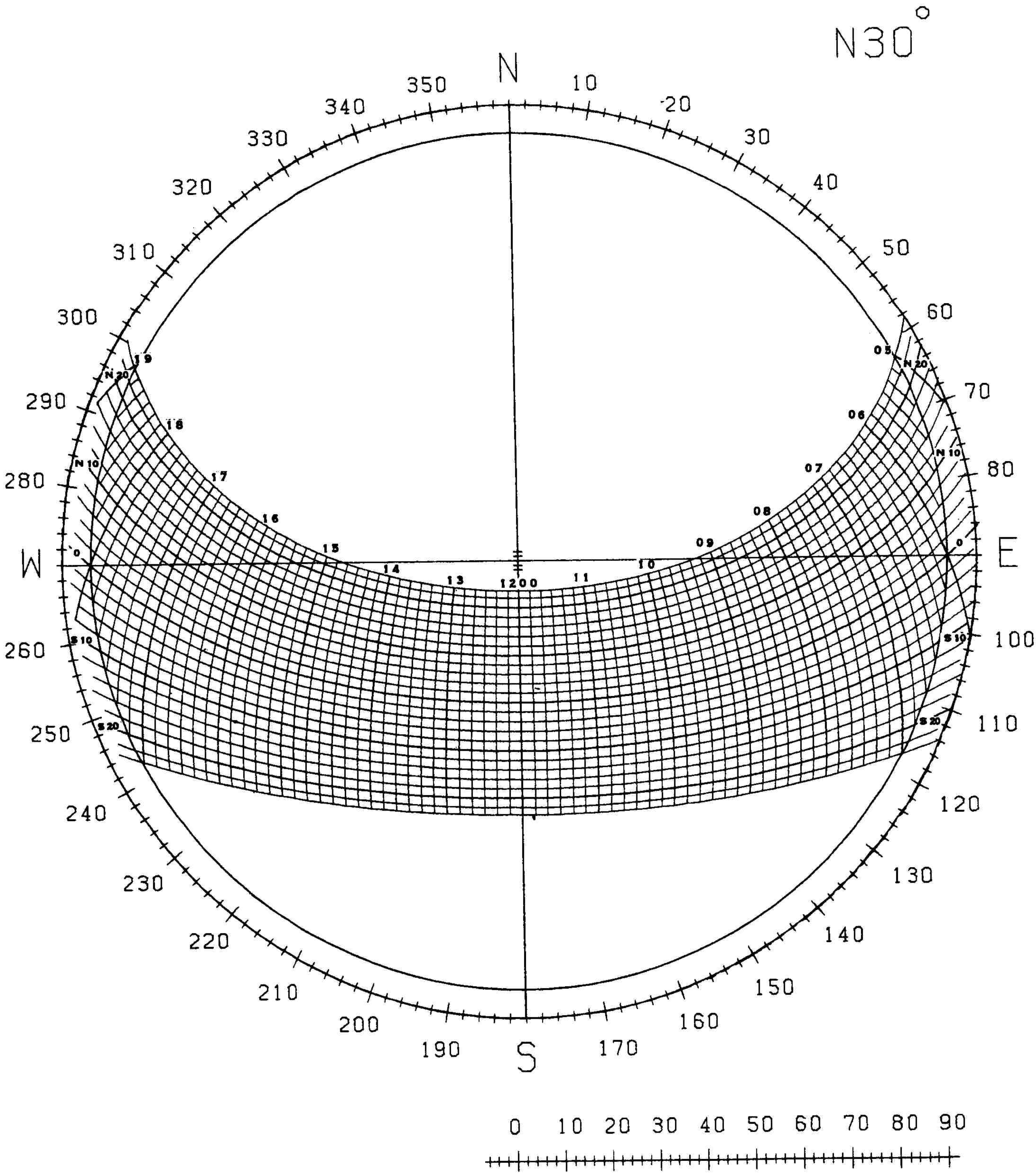
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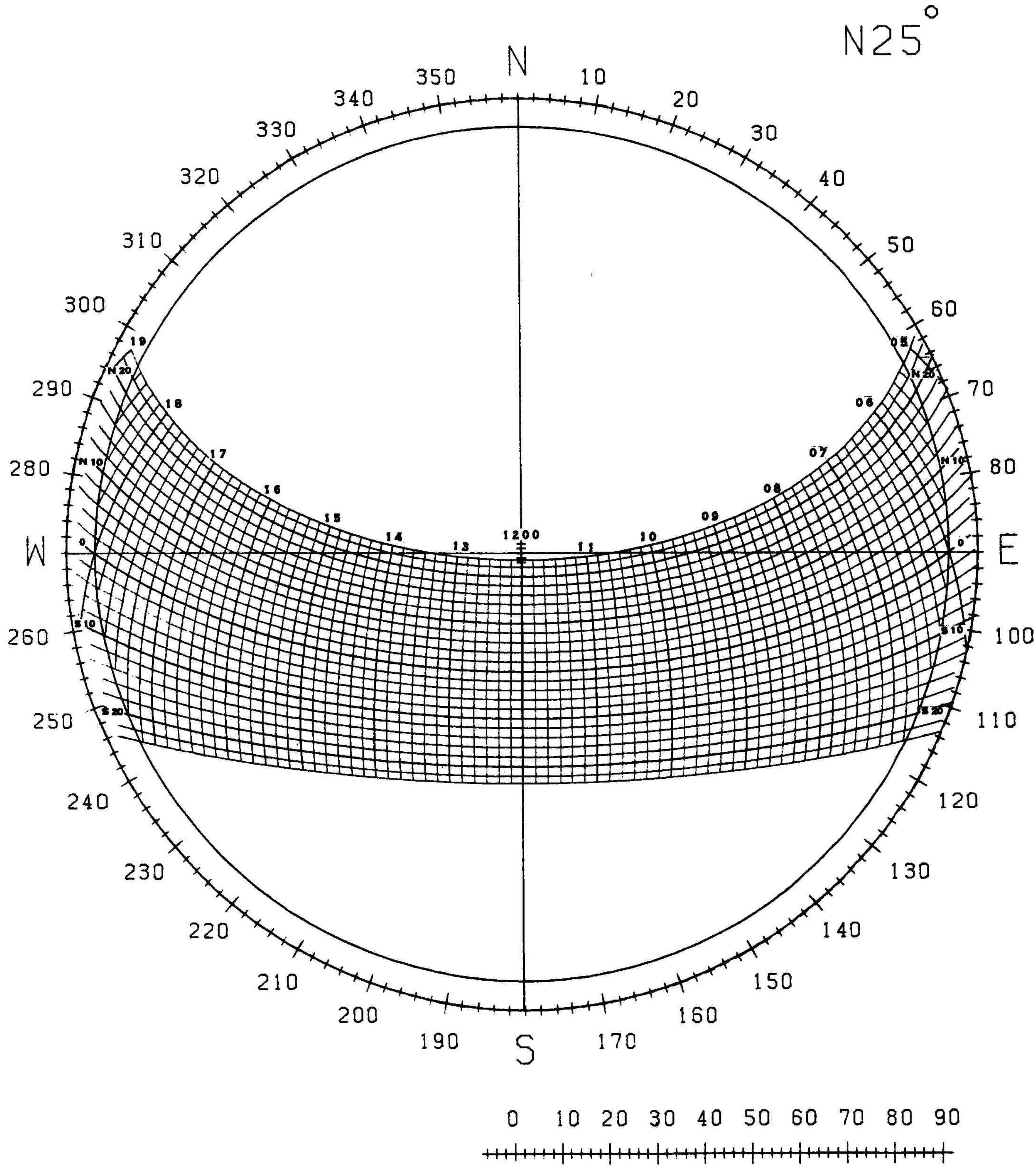
N25°
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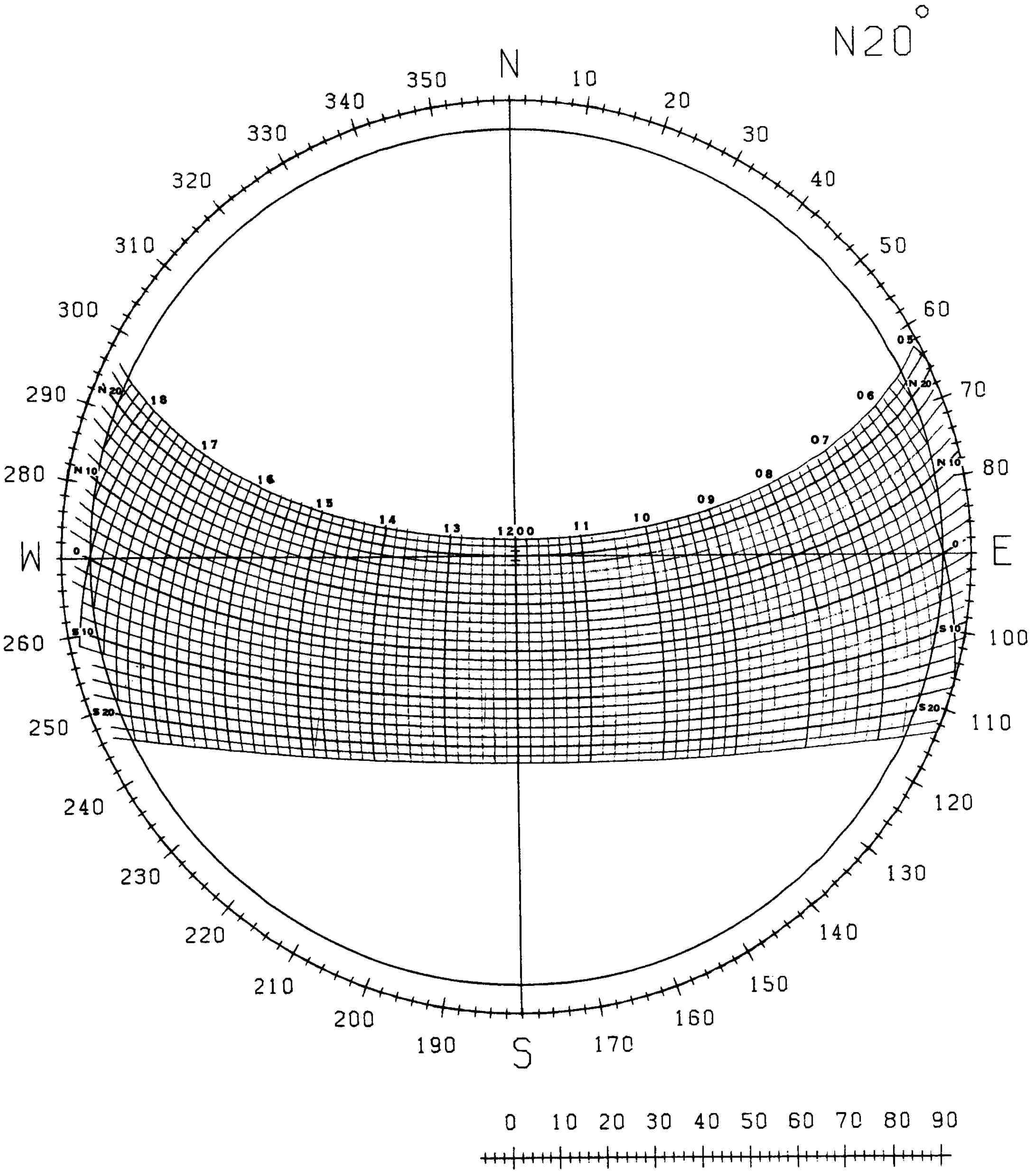
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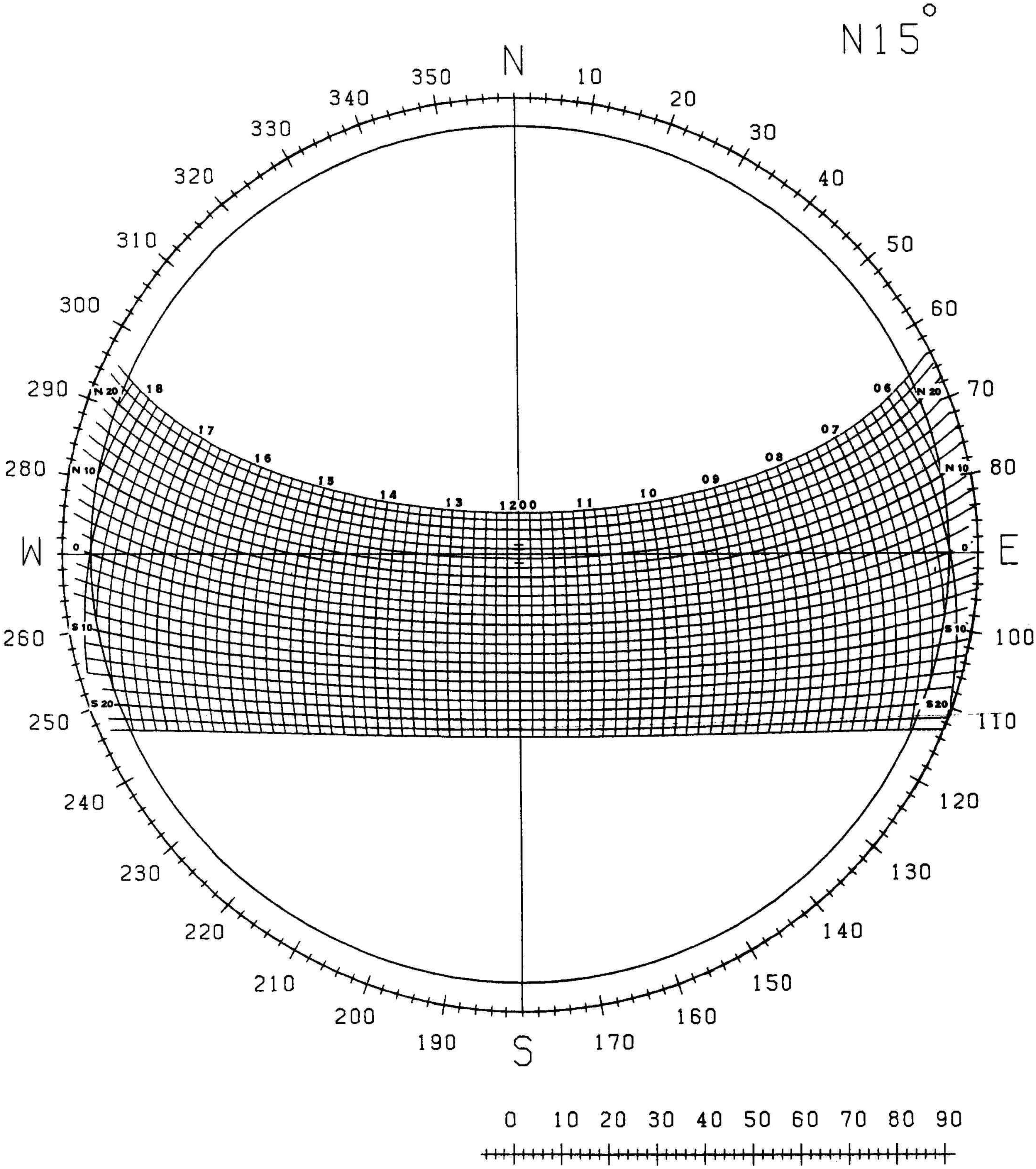
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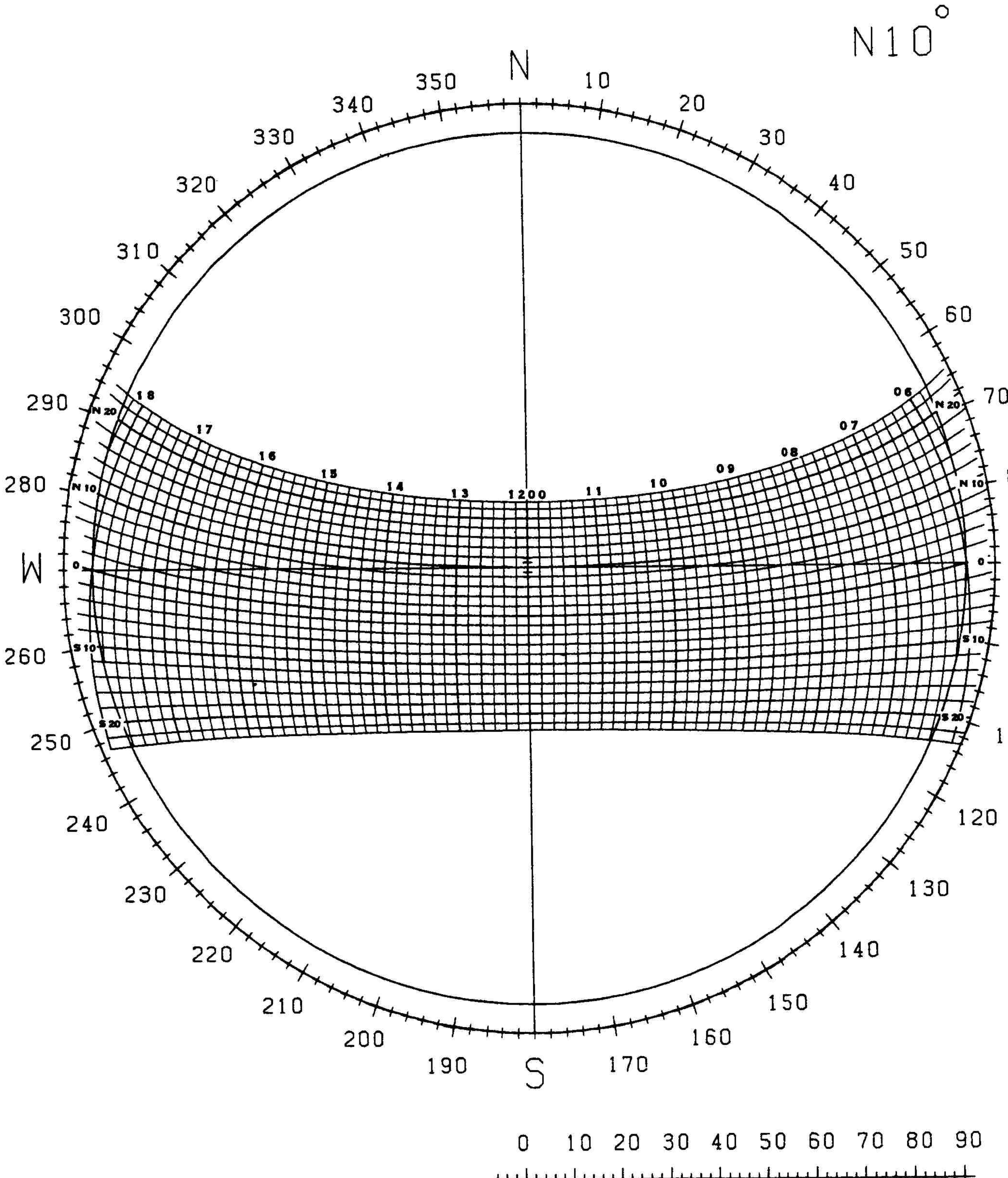
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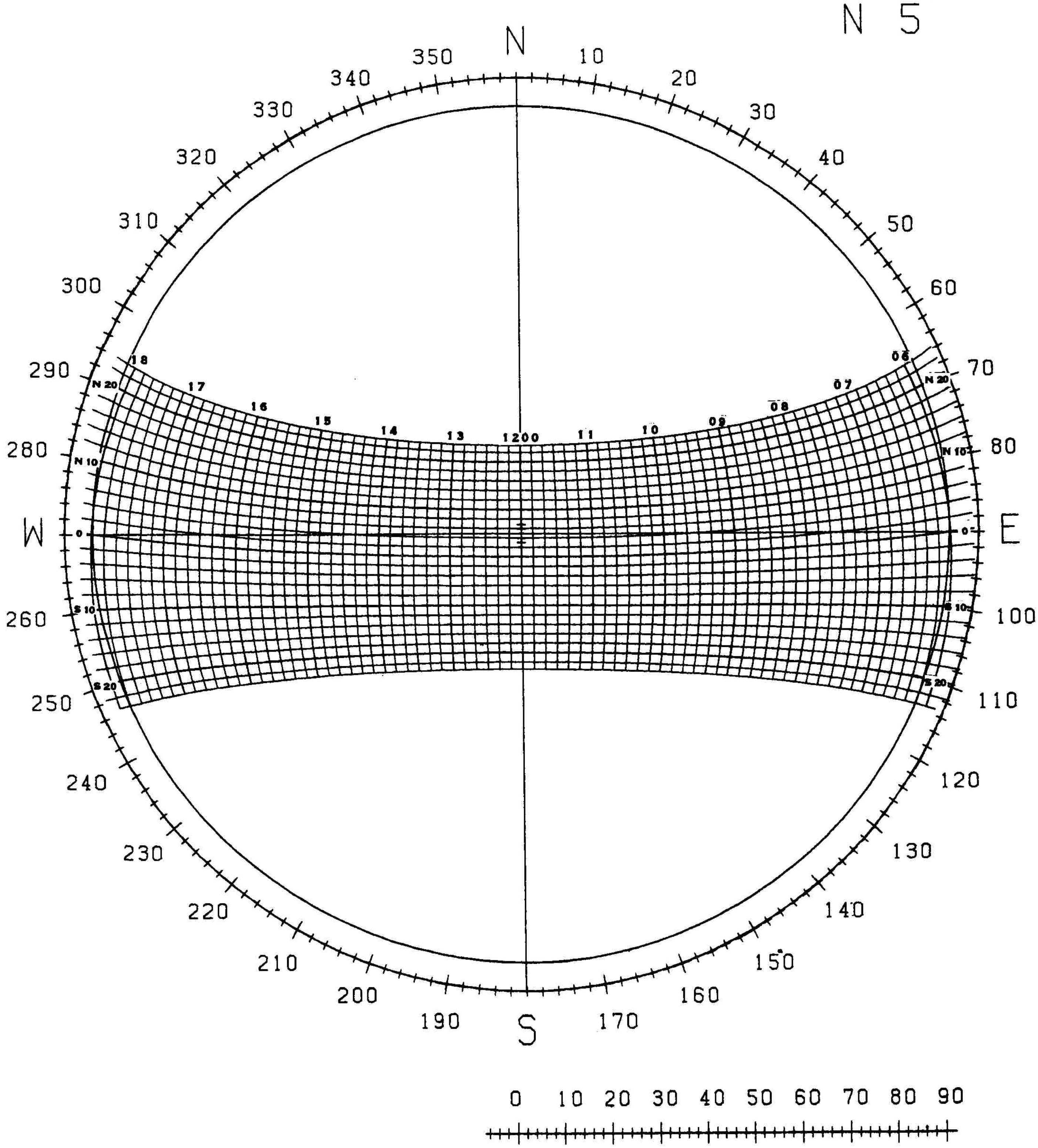
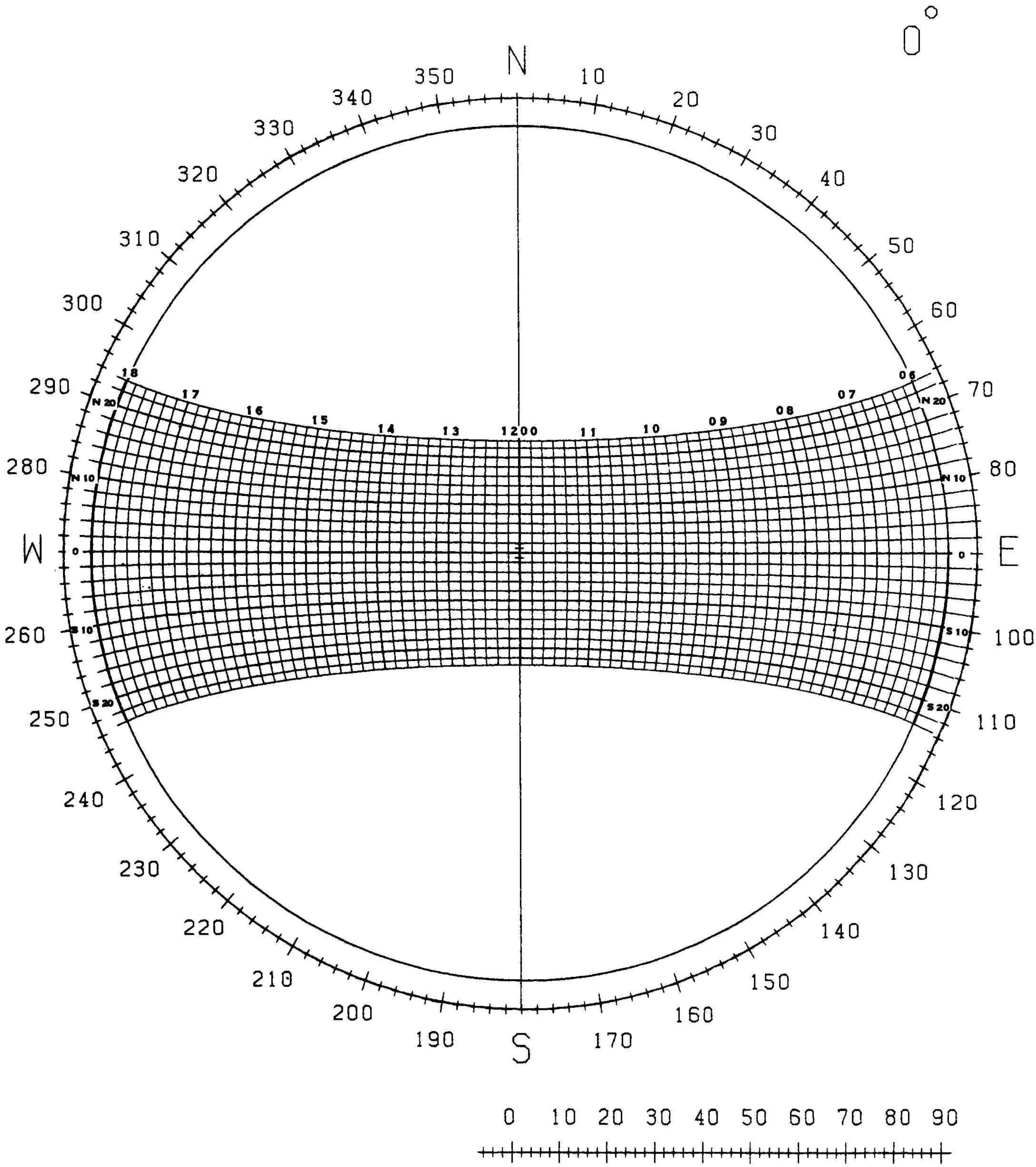
N 5°

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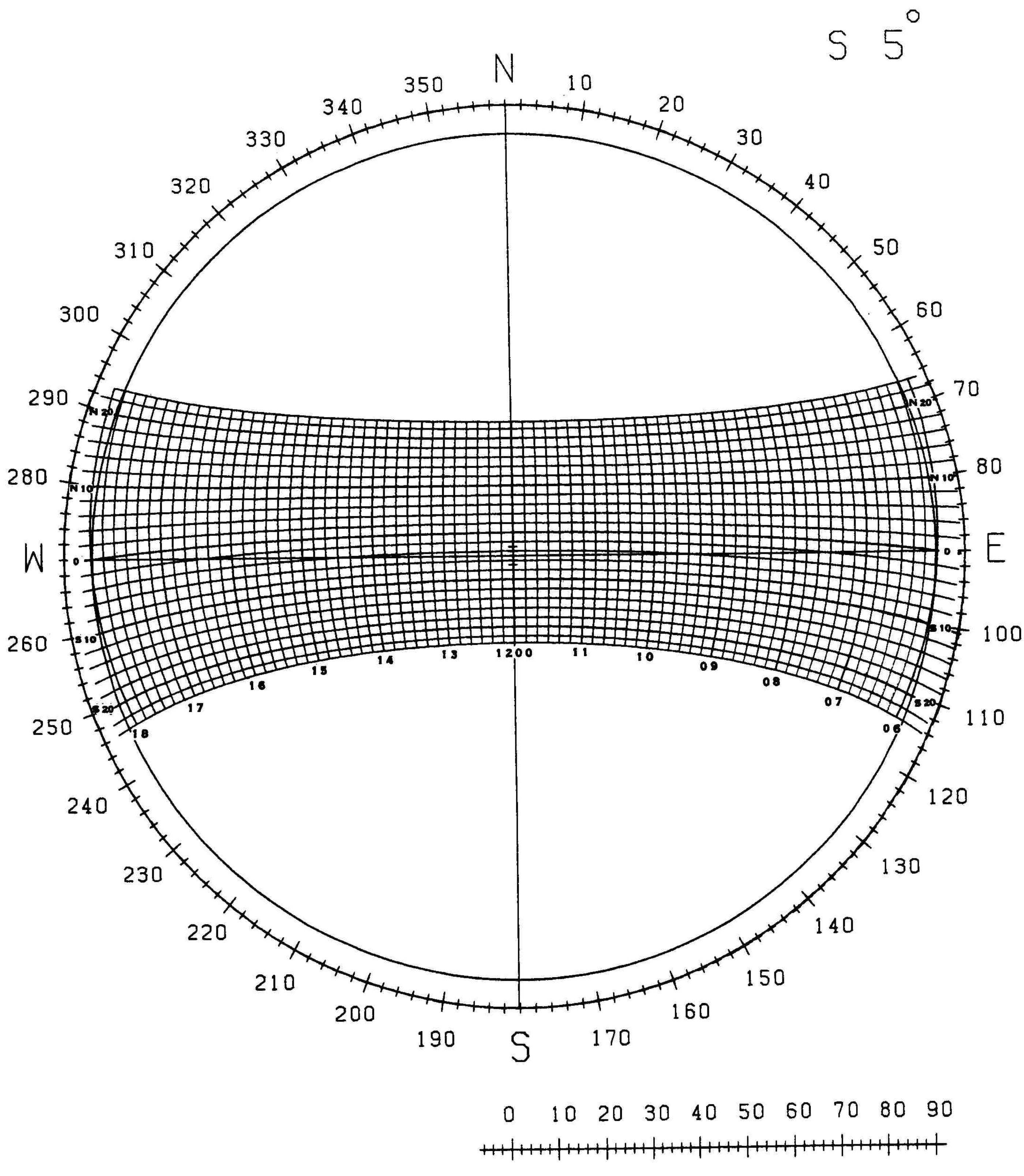
S 5°
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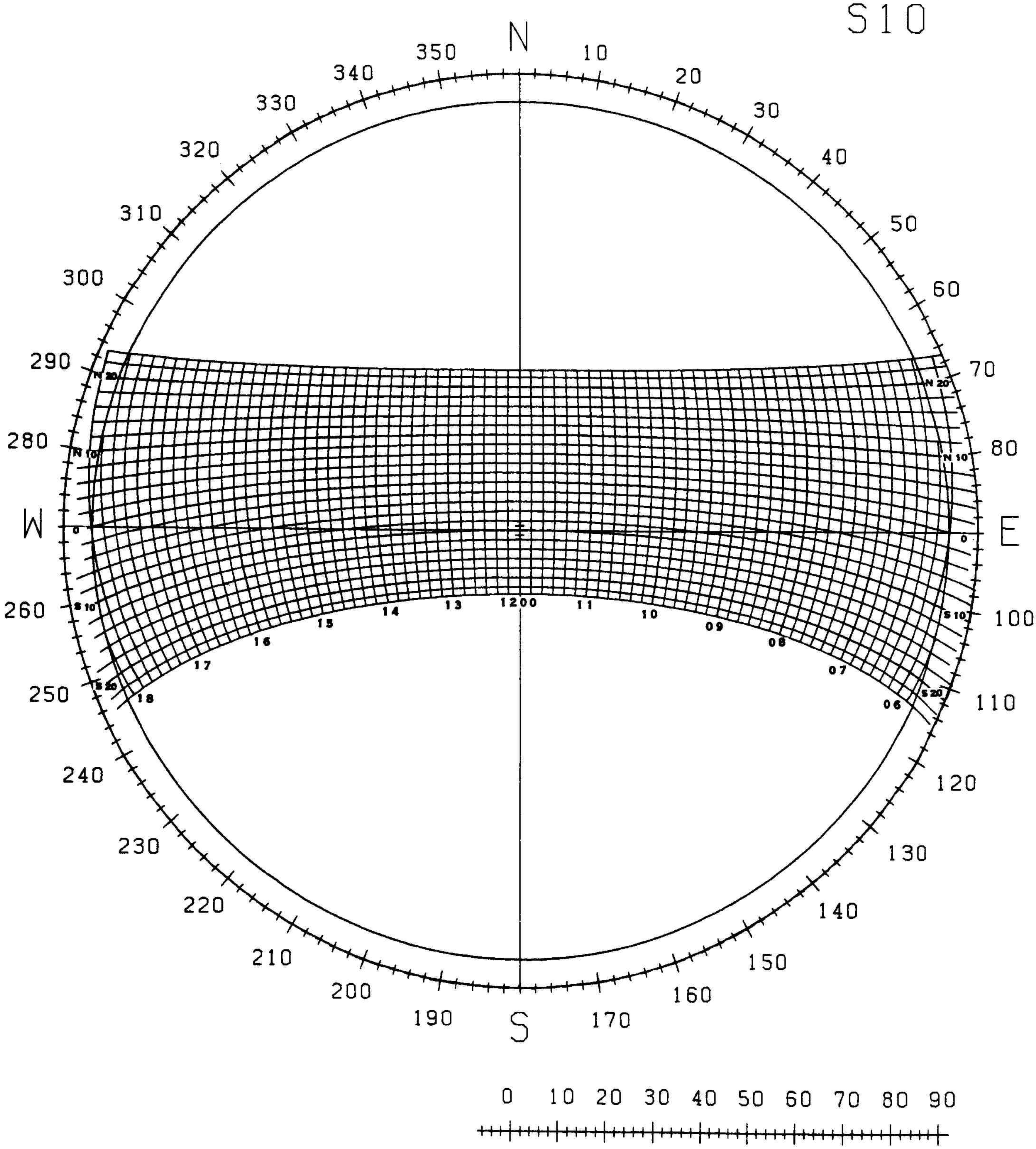
S10°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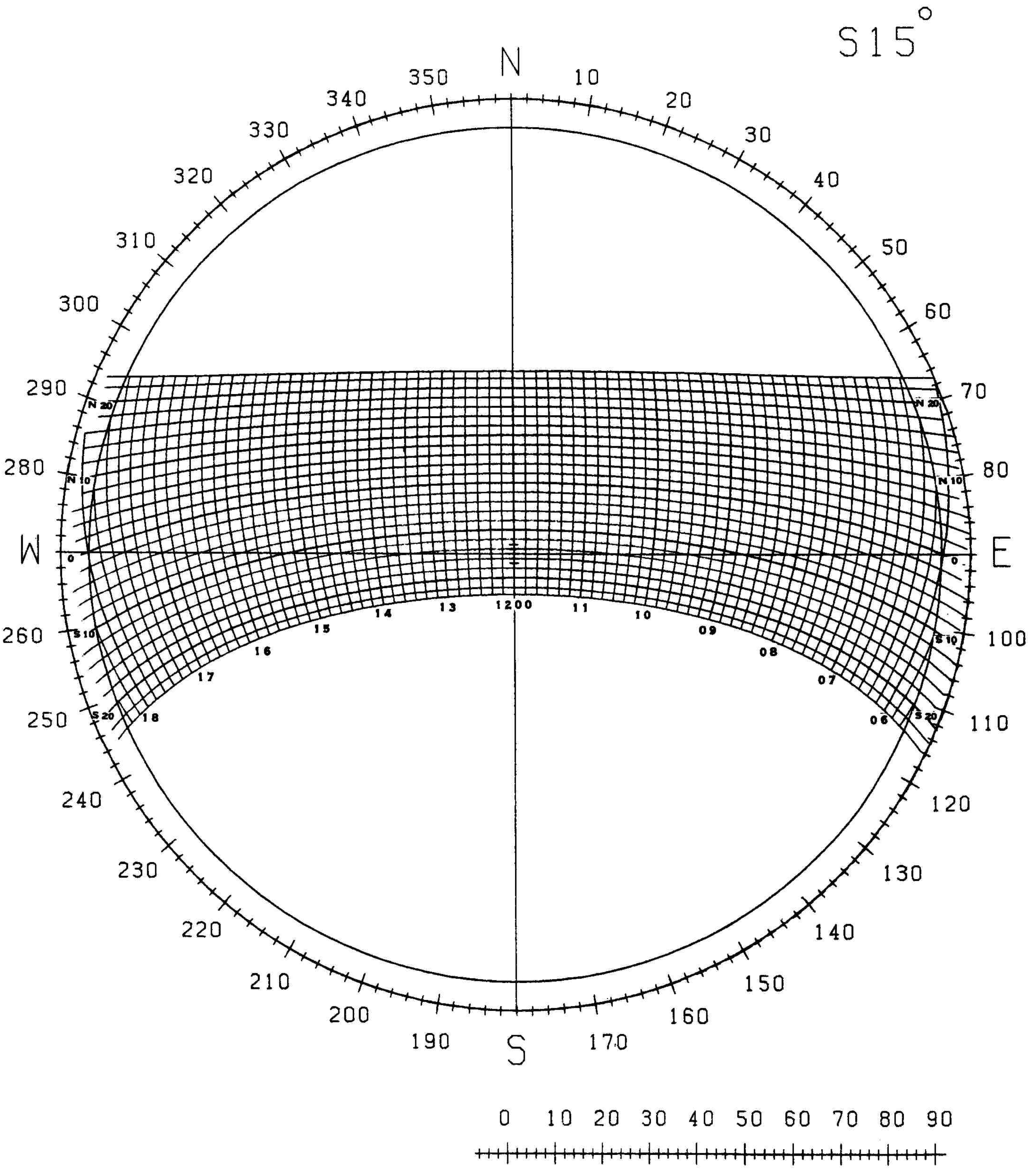
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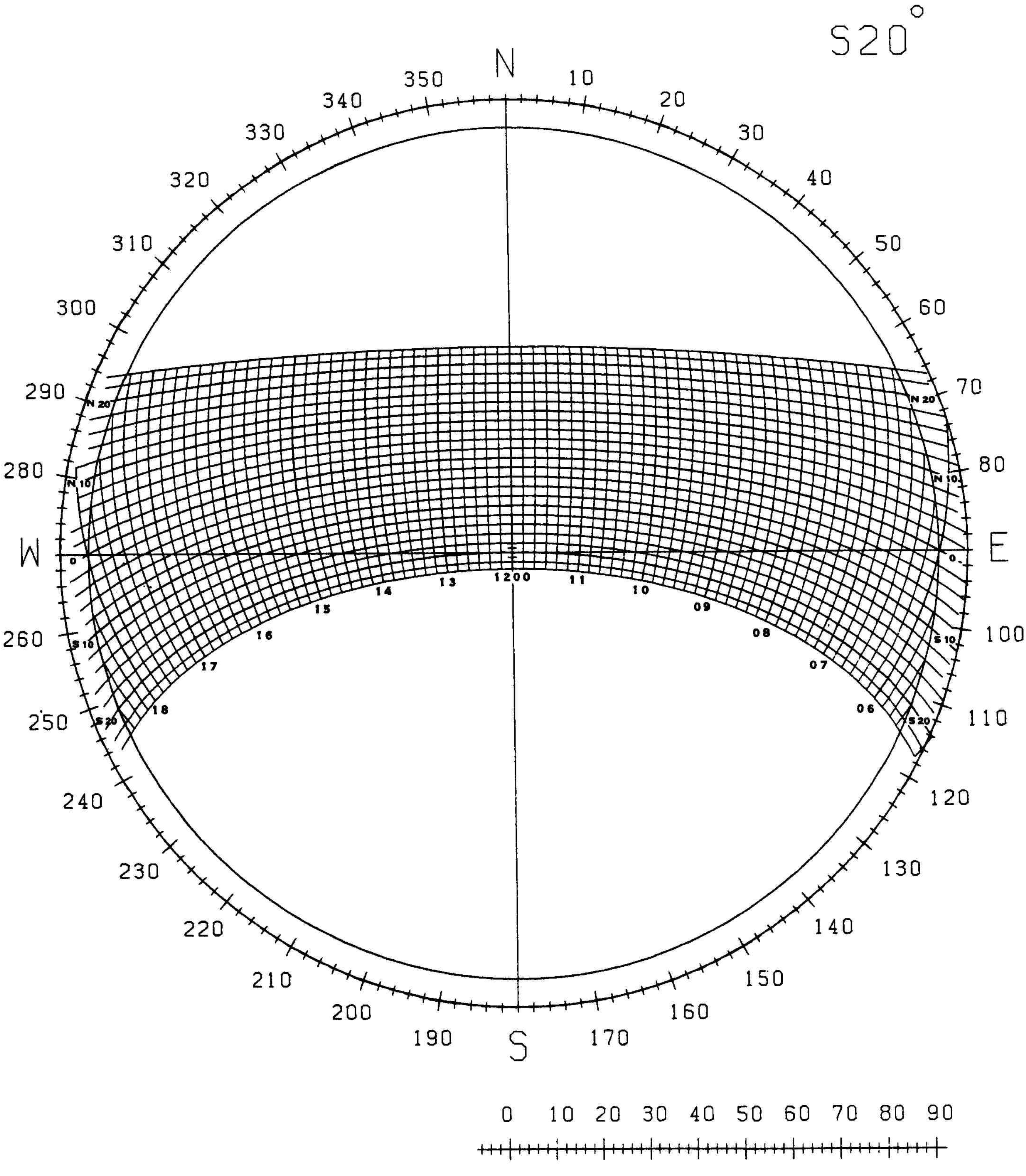
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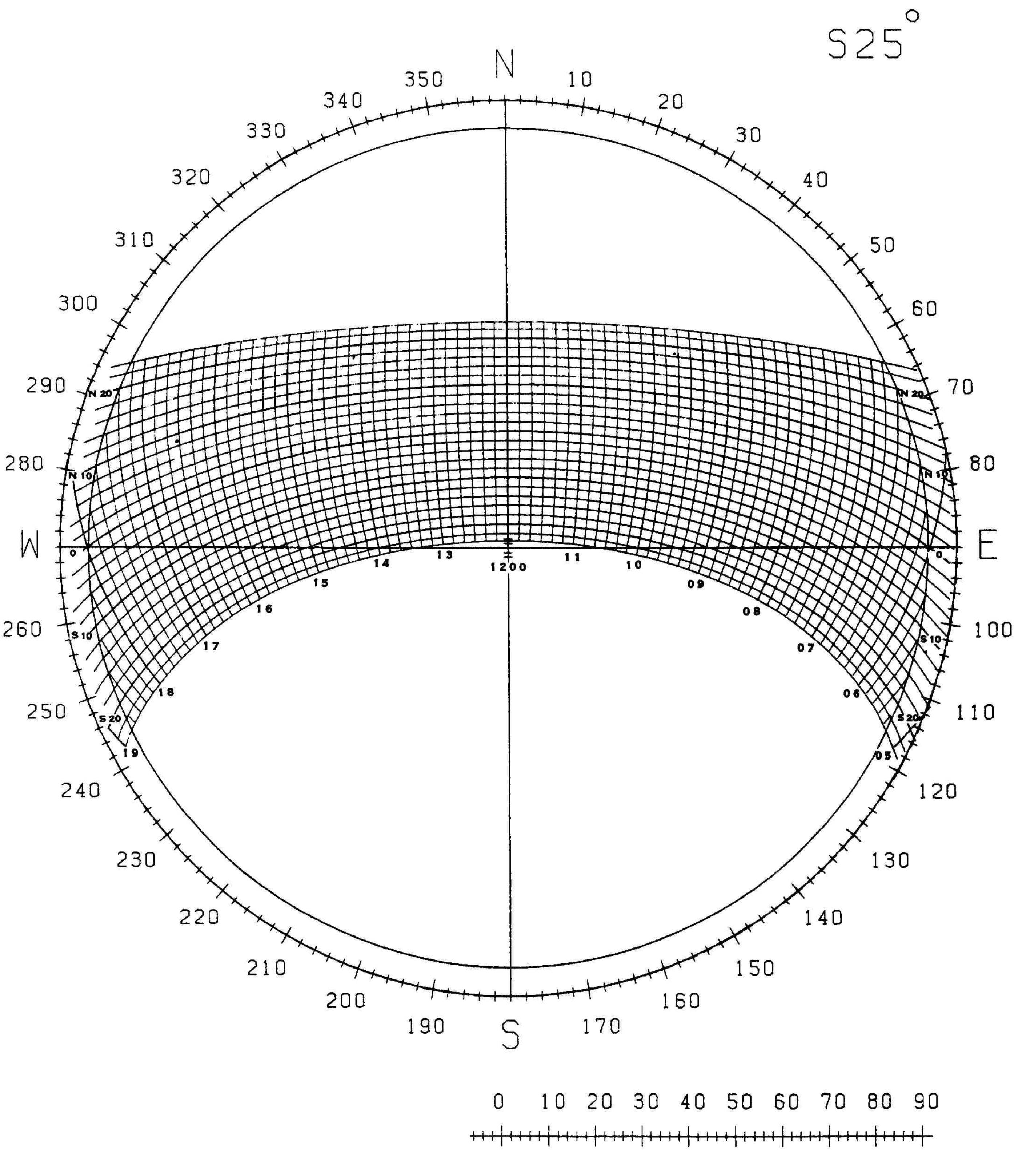
S25°
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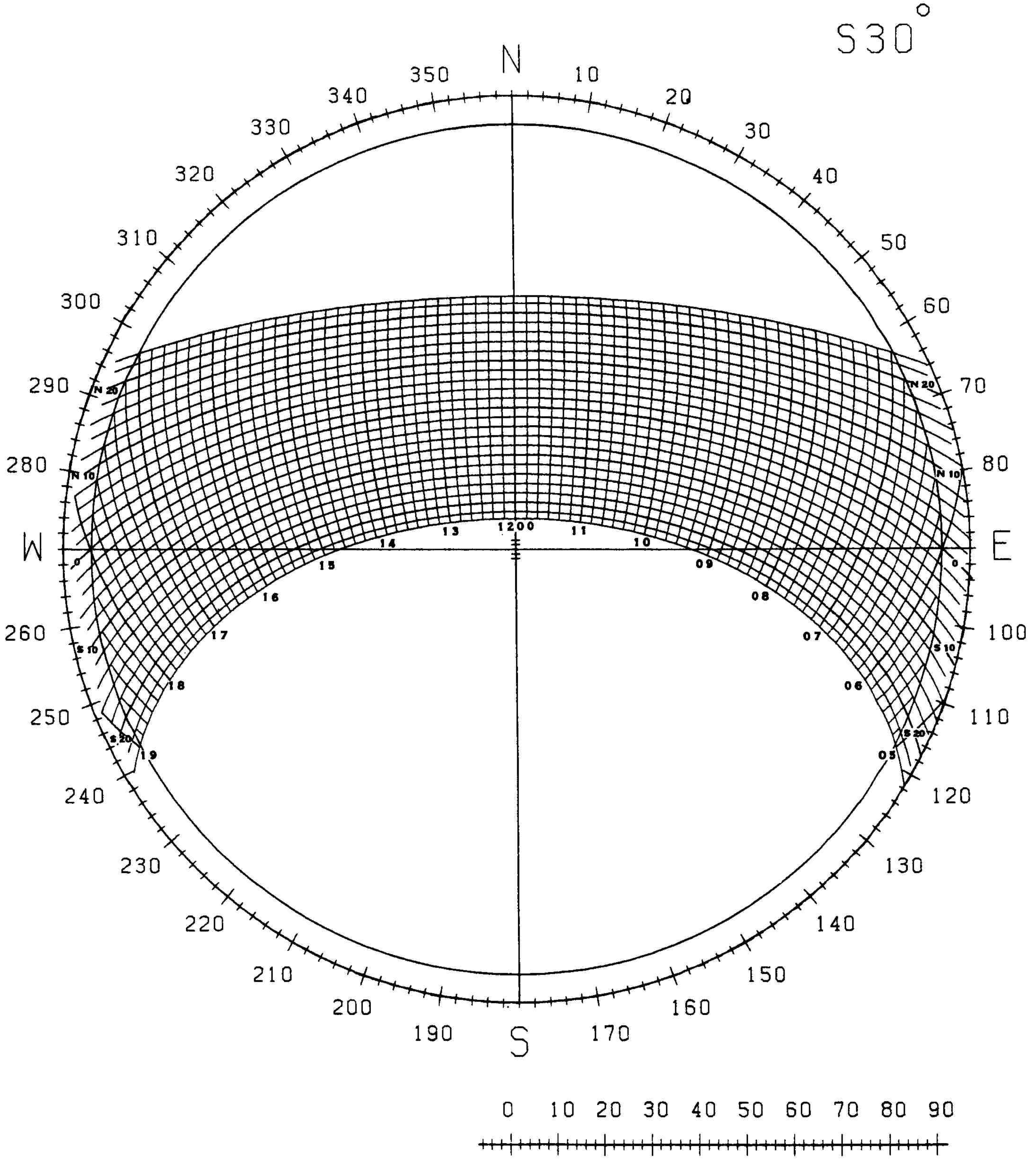

S30°
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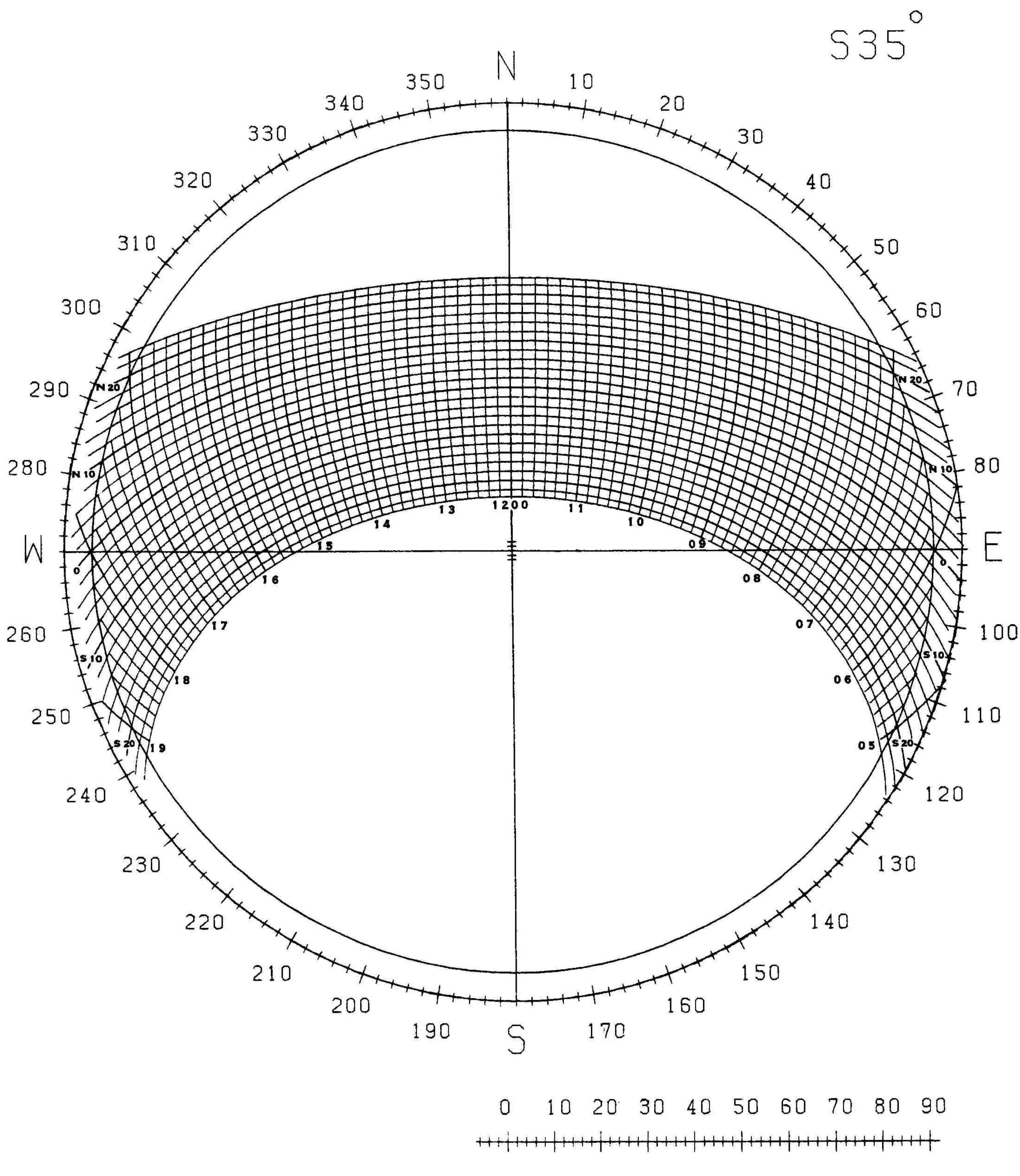
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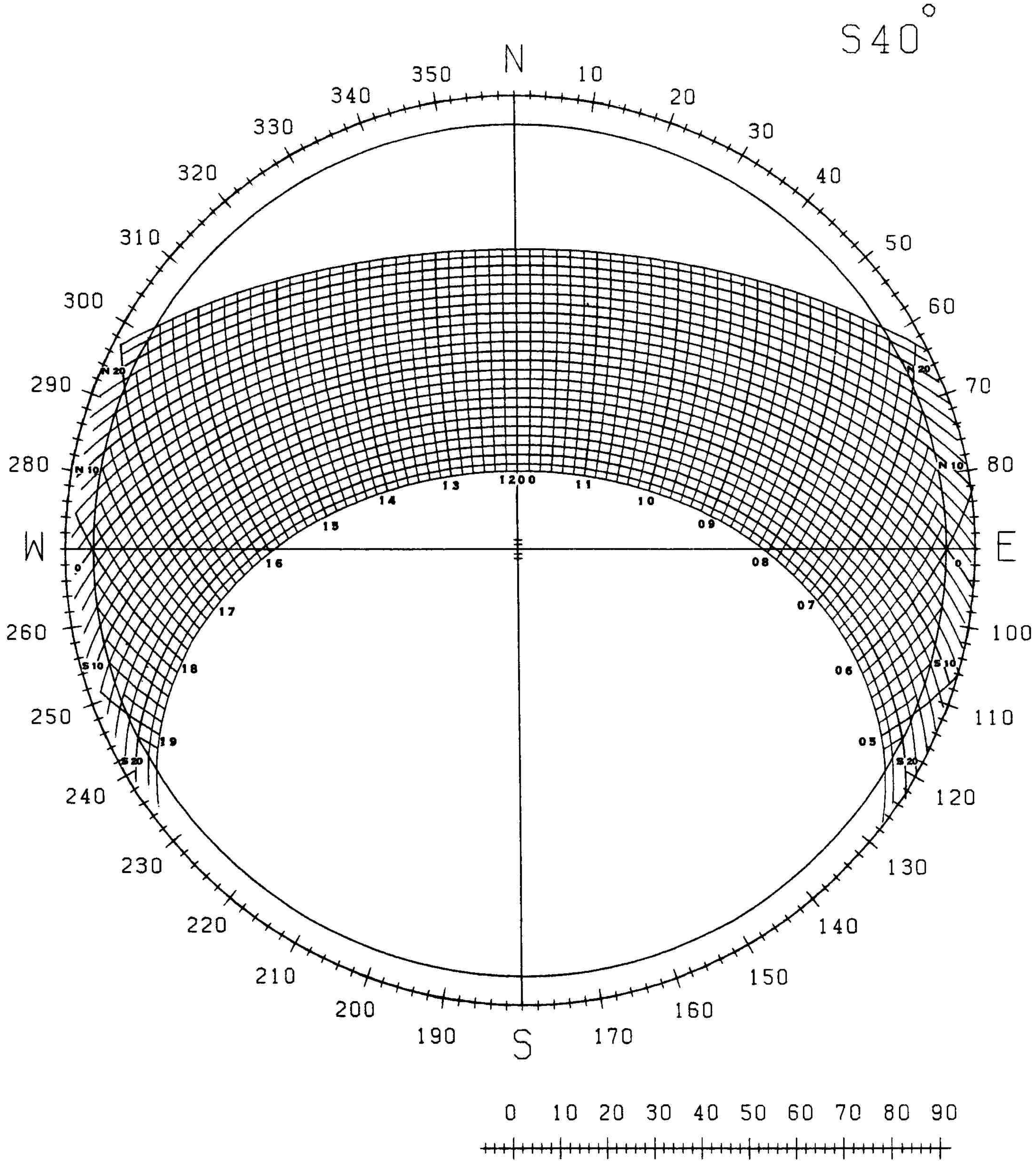
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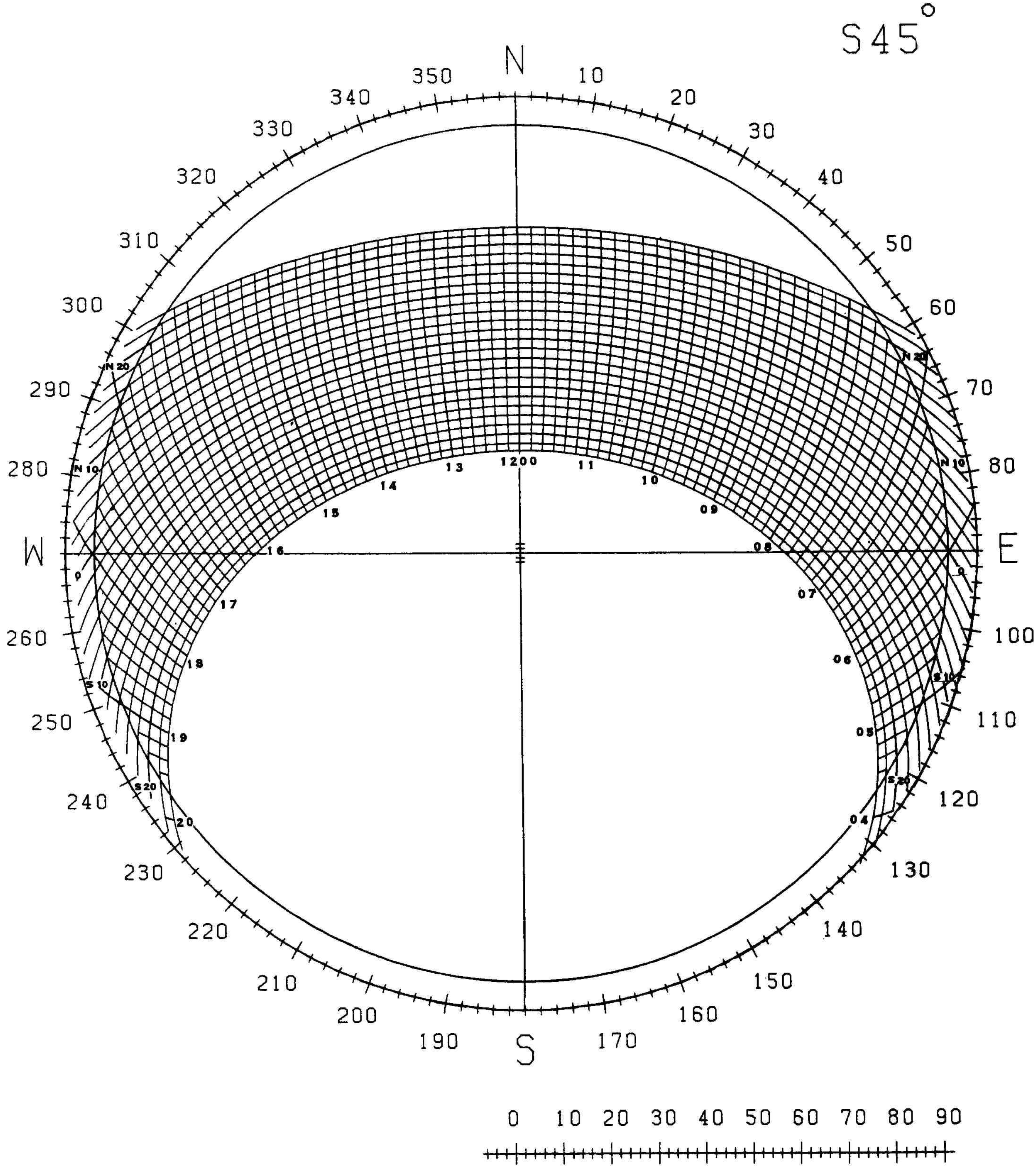
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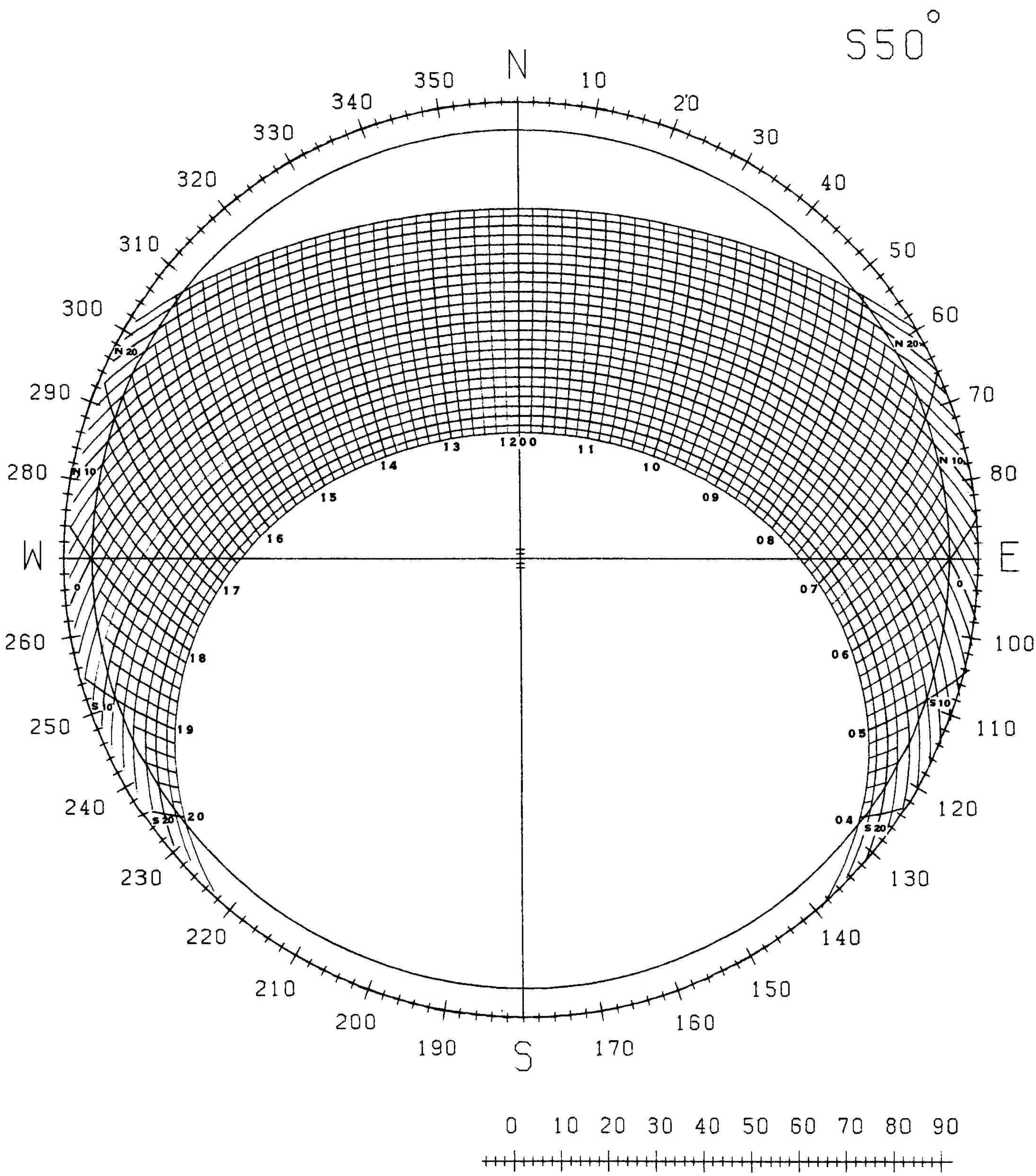

S50°
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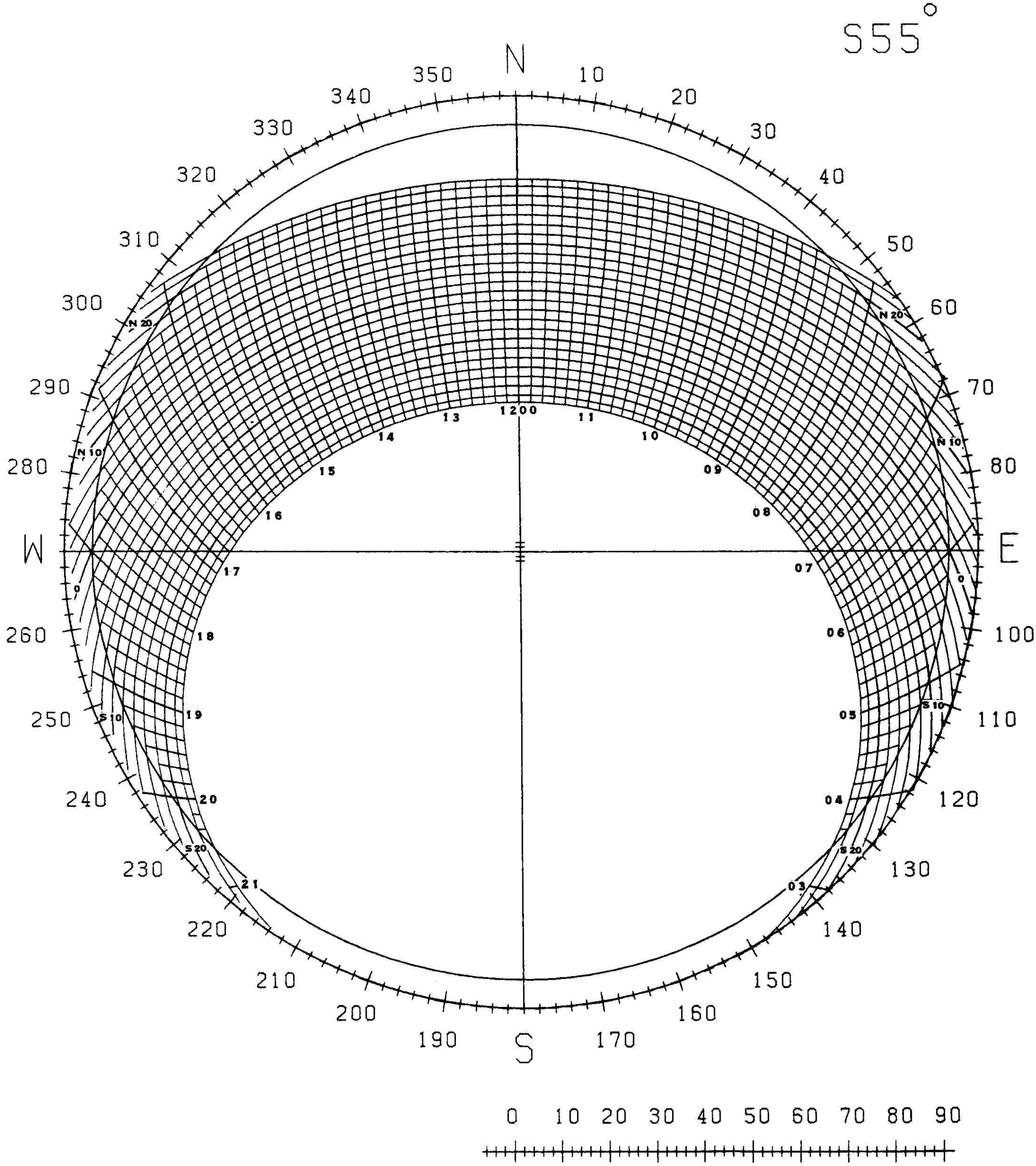
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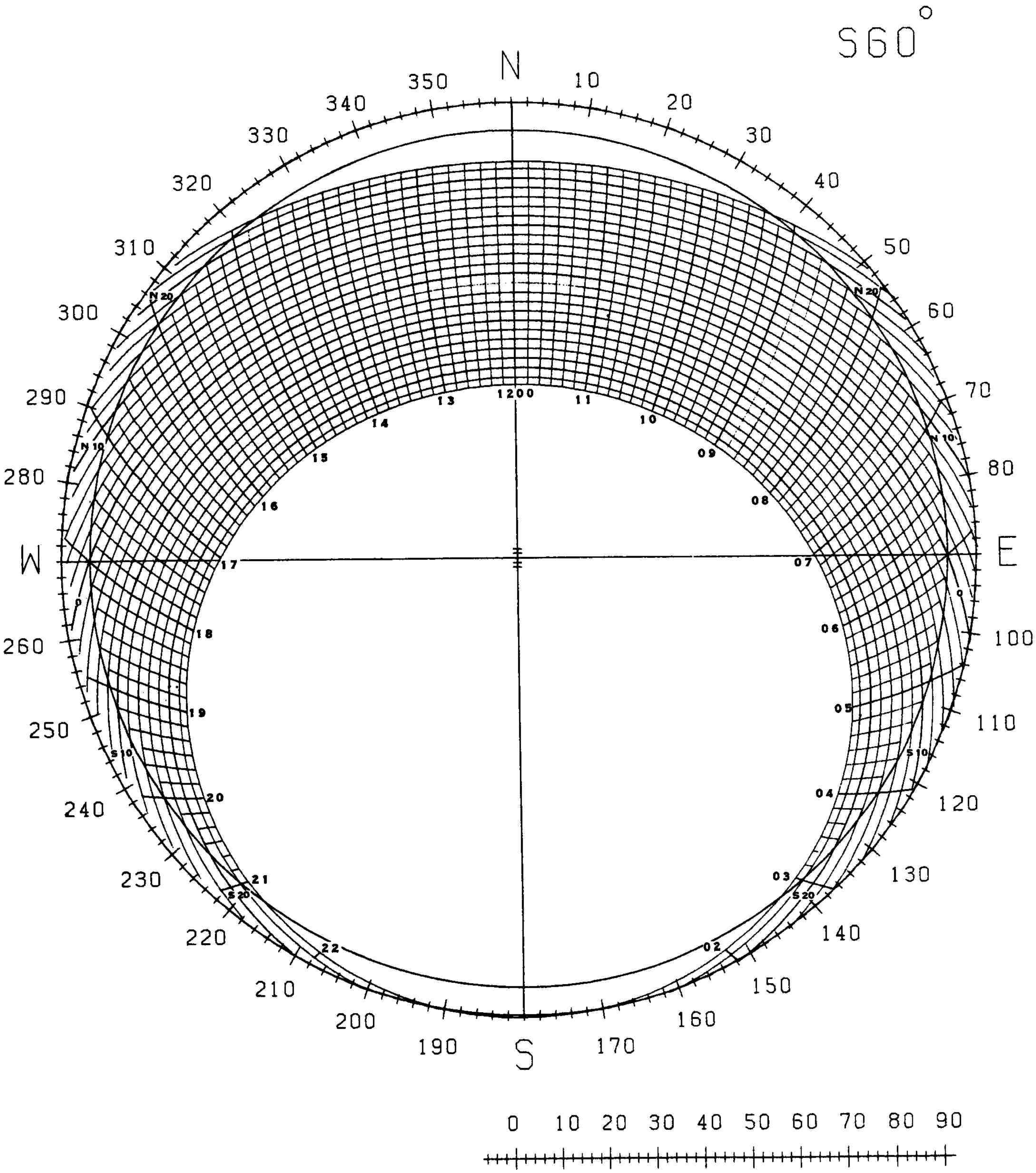
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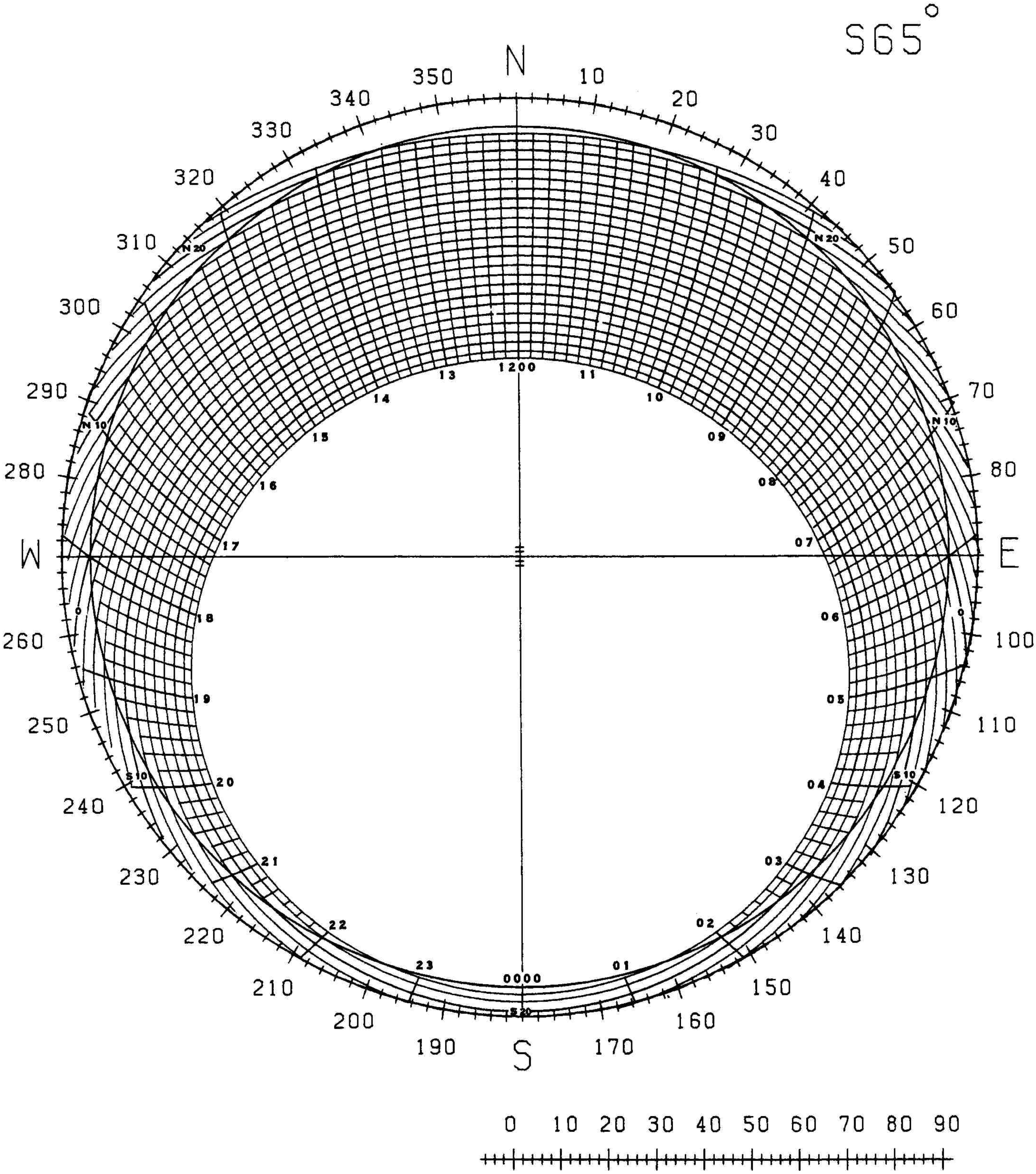
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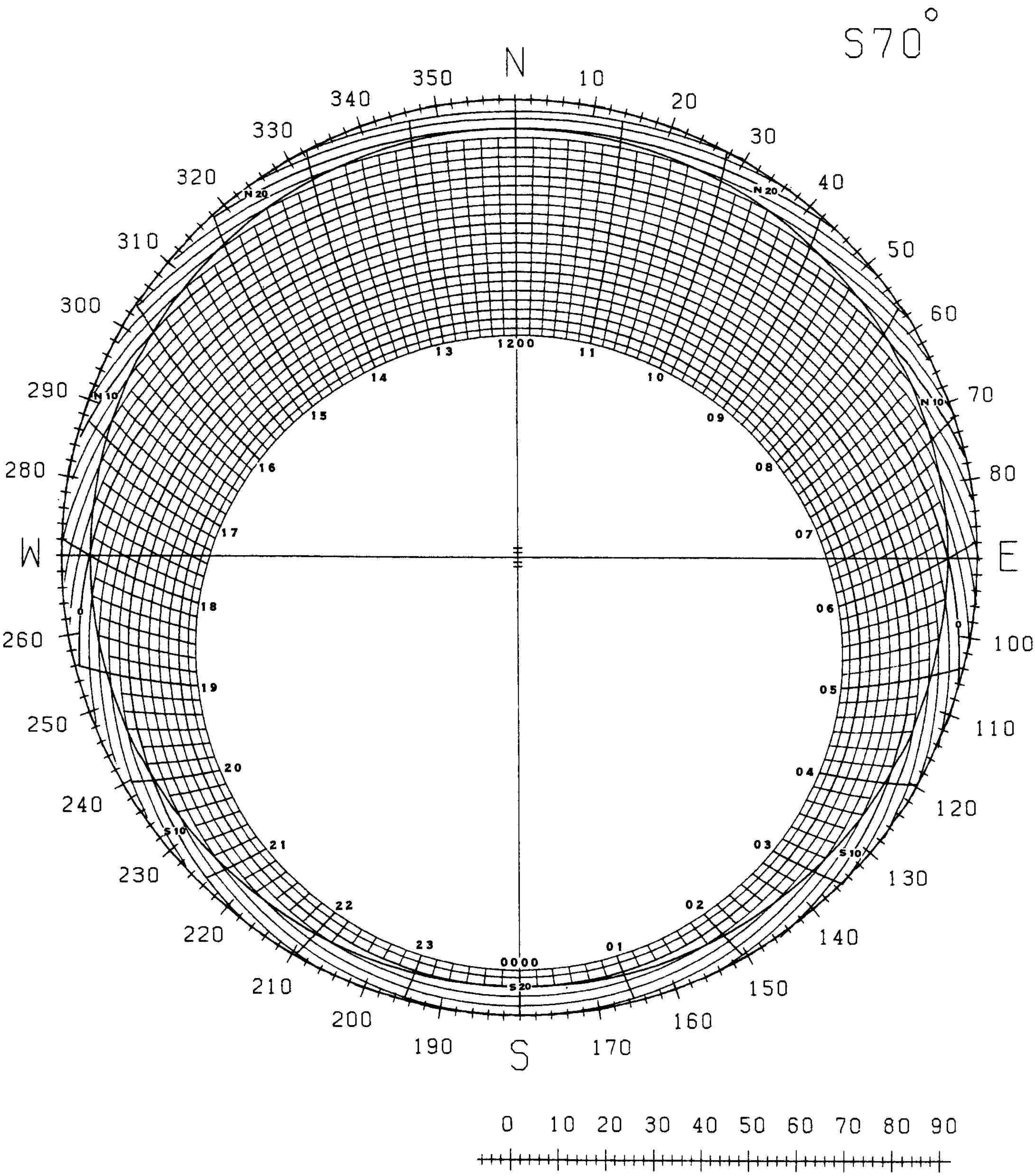
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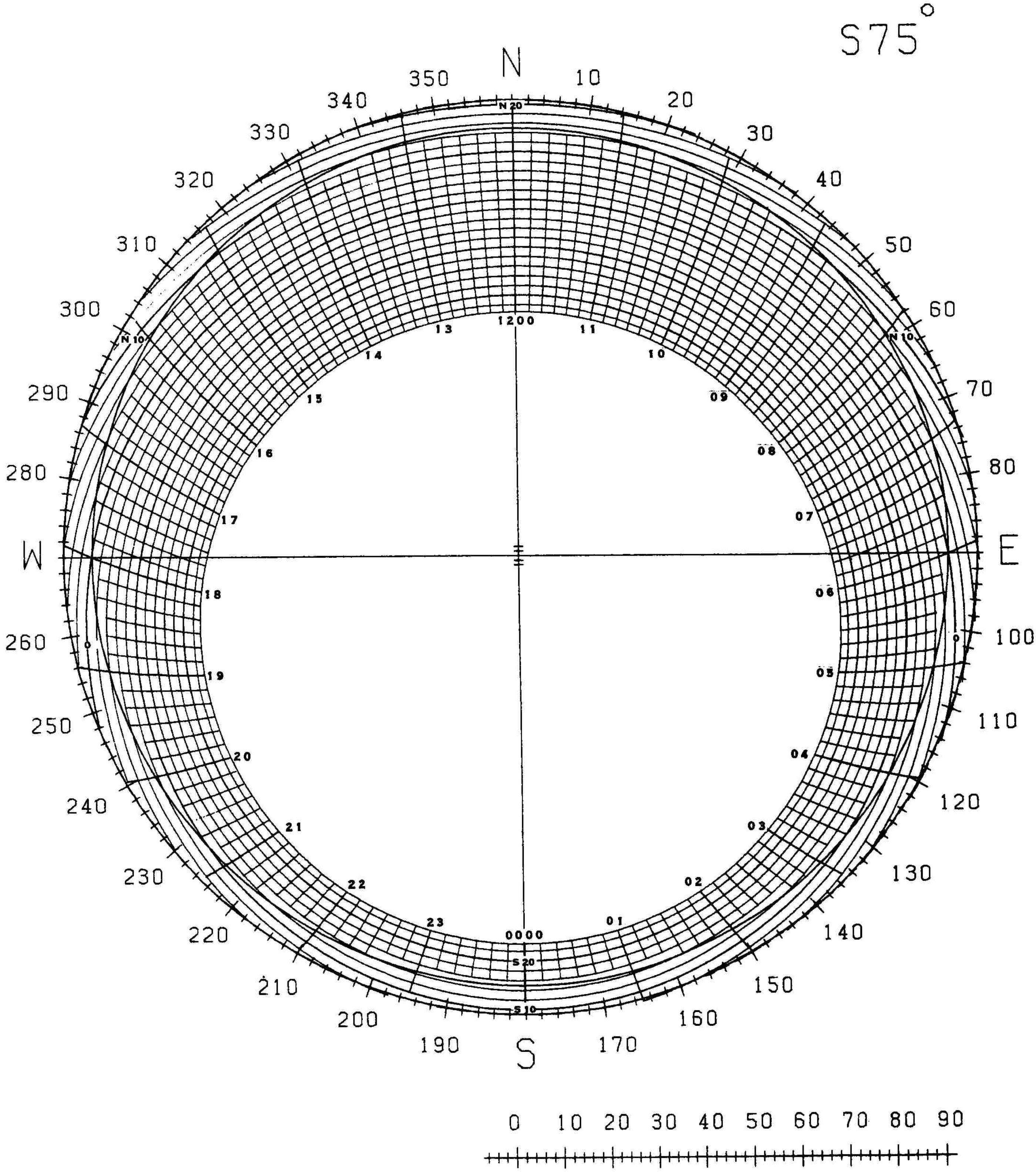
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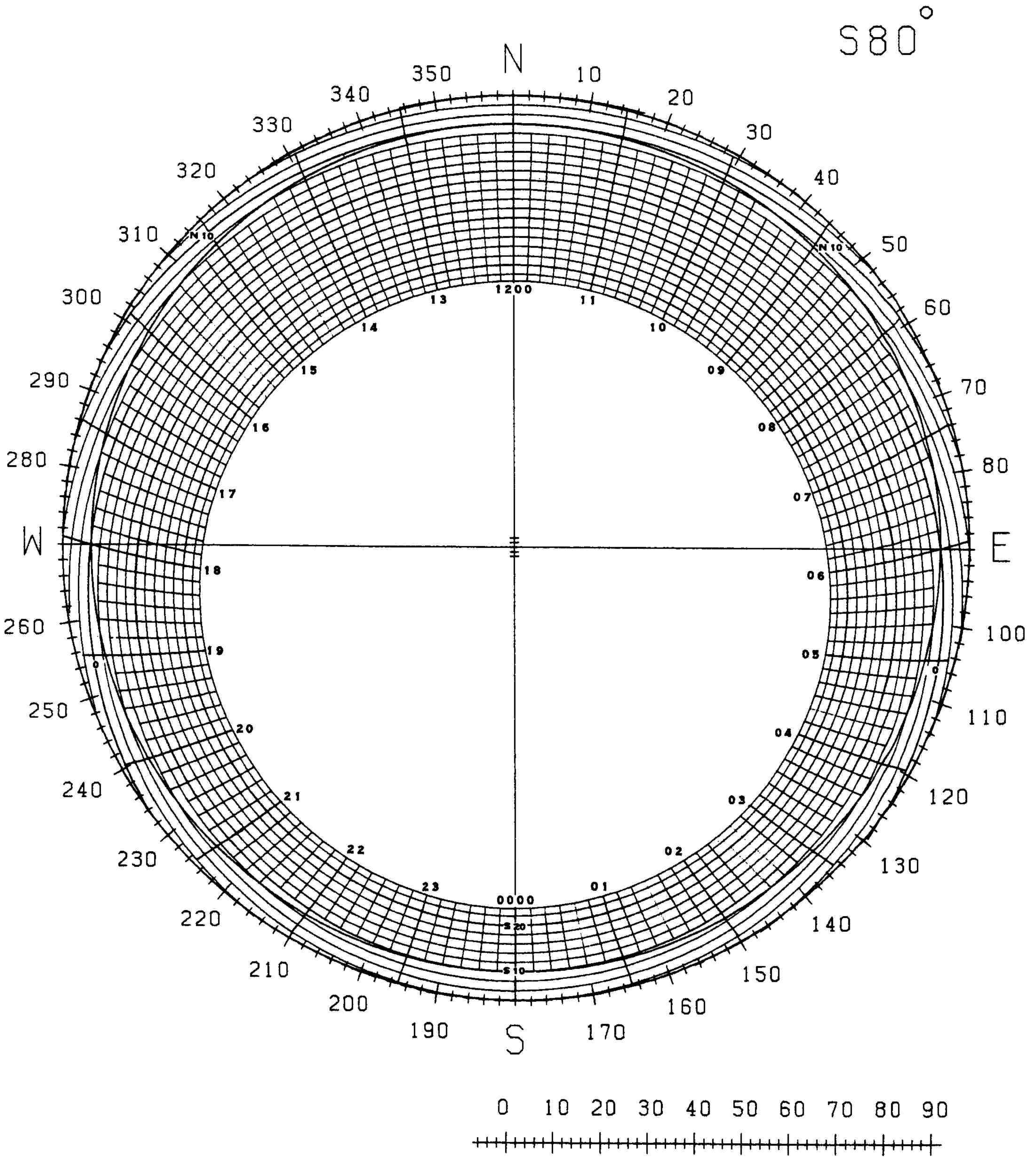
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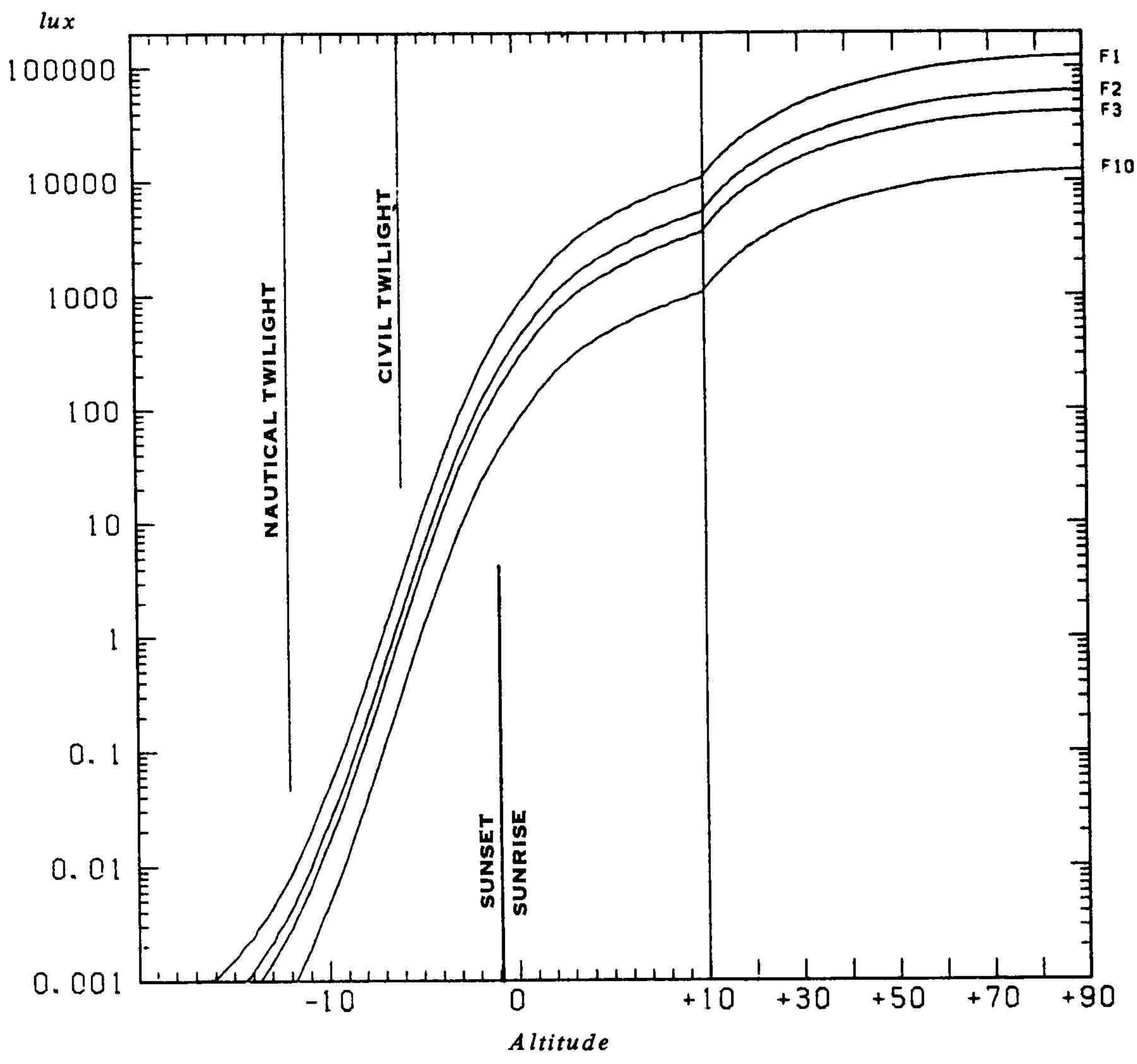
Sun Illuminance



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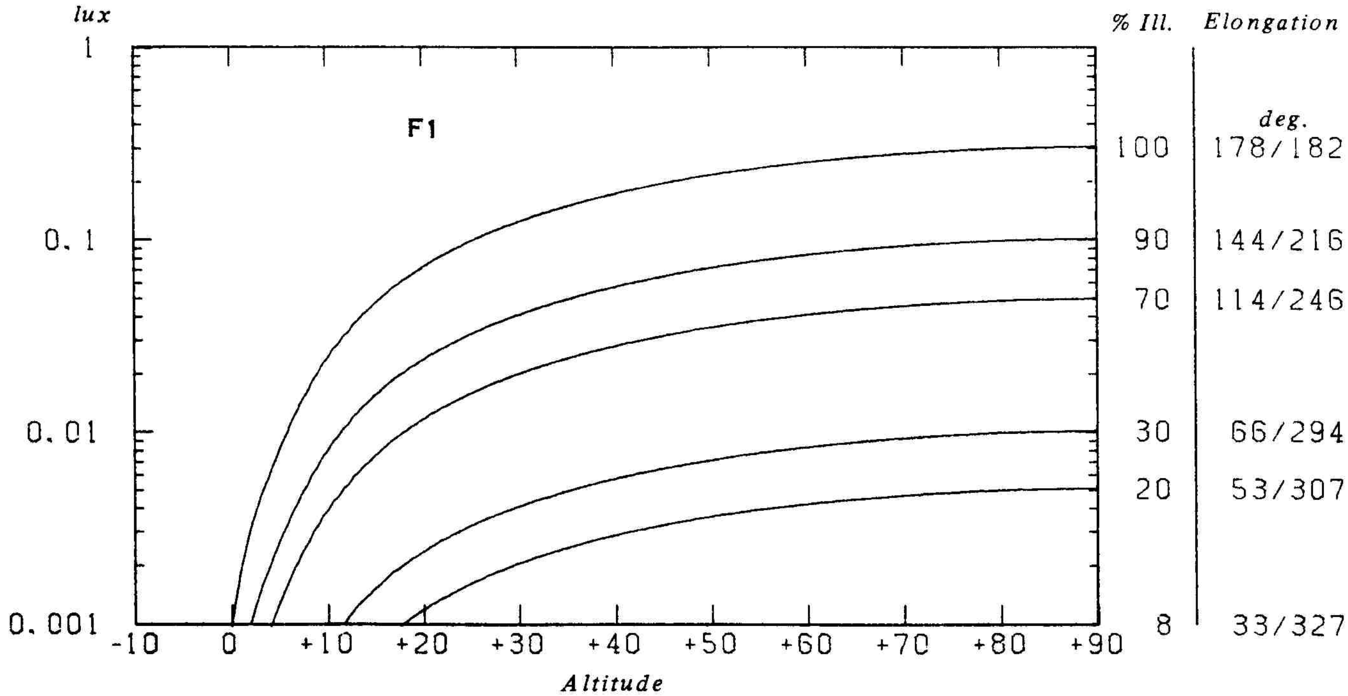
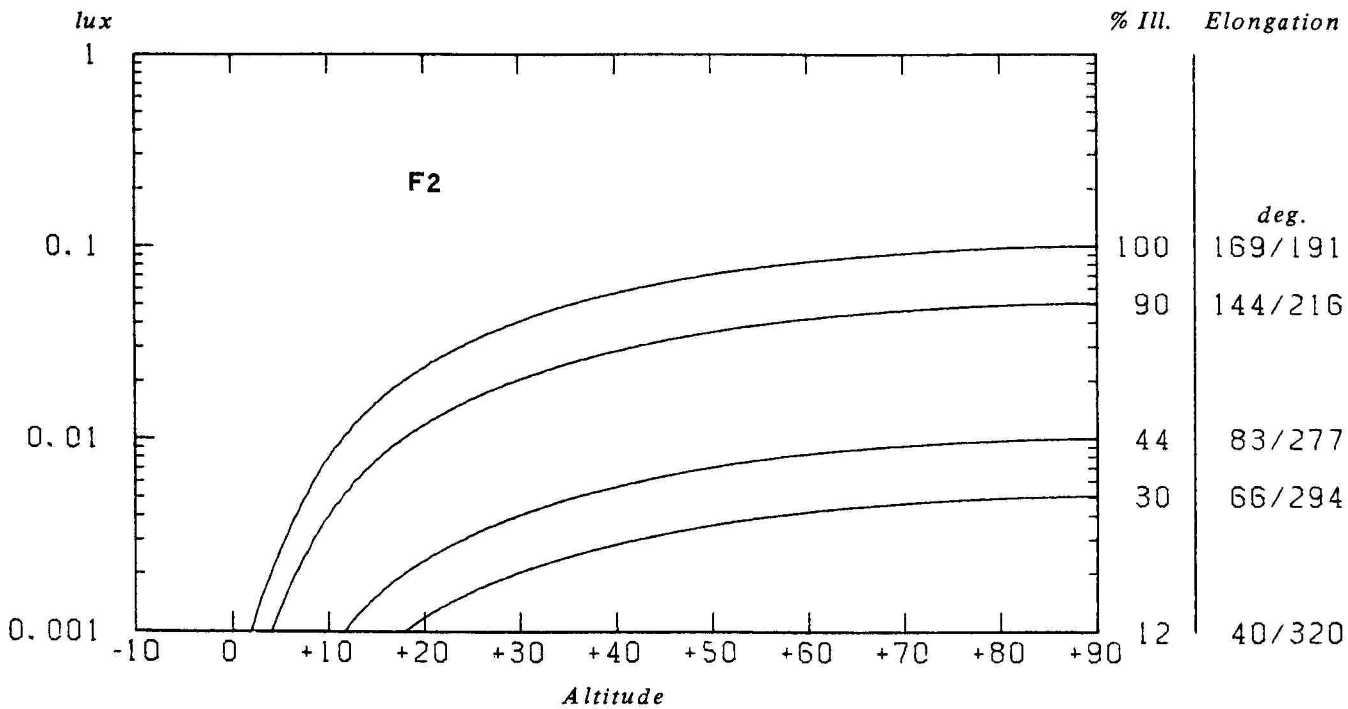
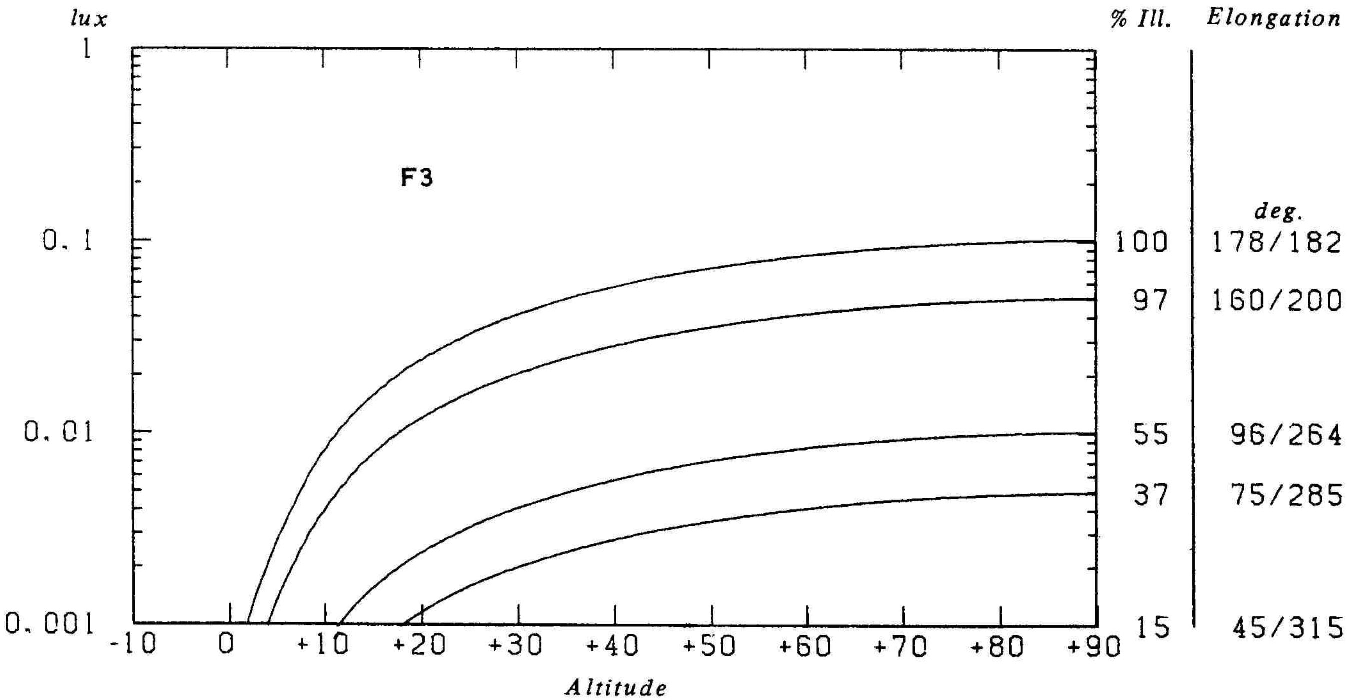
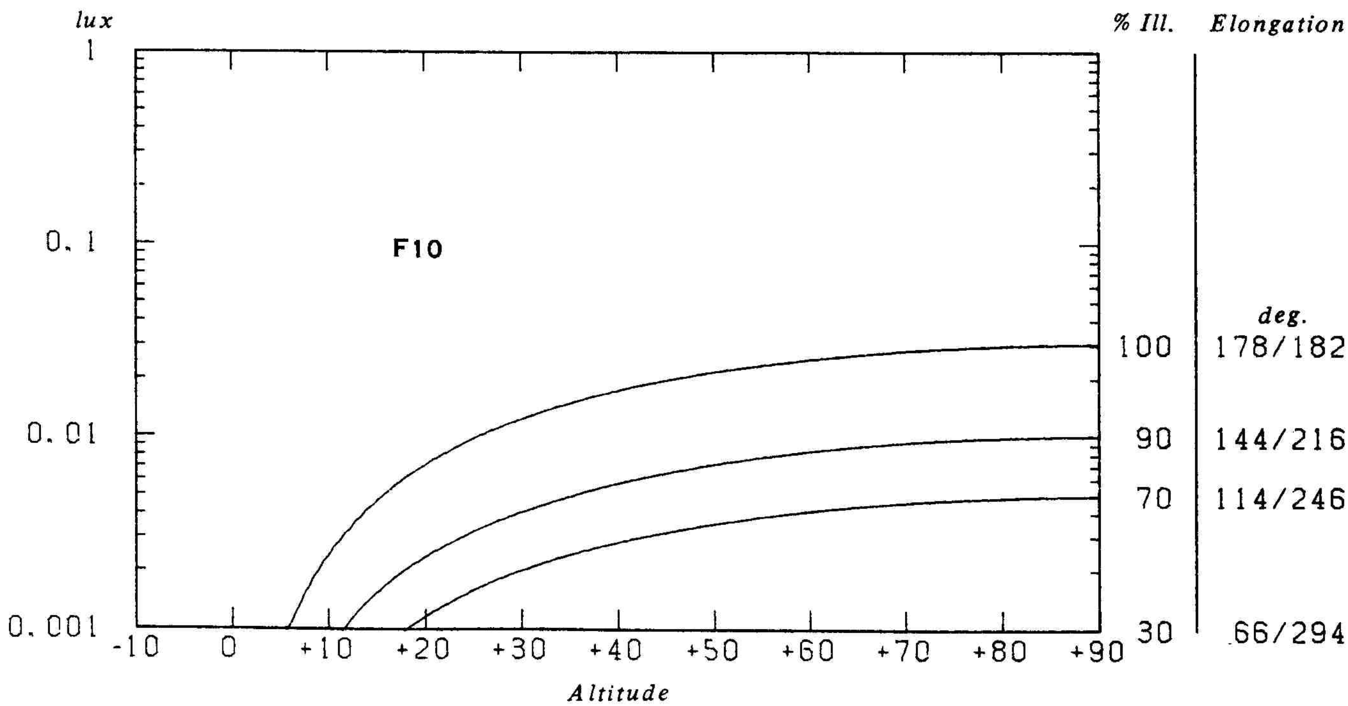




Moon Illuminance





APPENDIX A

Geographic Coordinates

This list of geographic places in the United States was compiled from data furnished by the U.S. Geological Survey and from a special purpose coordinate file maintained at the U.S. Naval Observatory. For each listed place, geographic coordinates (without headings) are given to the nearest whole degree as appropriate to, and for use with, the procedures described in the main text. West longitude and North latitude precede each place name in the list, but the list is arranged alphabetically by state and within each state for convenience.

From base data files representing approximately 140,000 geographic places, those included here were selected for the purpose of providing uniform coverage of each state in latitude and longitude primarily, and of providing specific reference places for every county or parish within each state secondarily. As a result, many densely populated places are excluded because of their proximity to similar places previously selected in the compilation process. Also, that a listed place, within a rural county for example, might be neither the county seat nor the most populous place, is another consequence of the process. Some listed places, included for the purpose of geographic and political completeness, may be recognized only by those familiar with the area. In a few instances of this type, a place may have no permanent population but nevertheless has been accorded recognition by the United States Board on Geographic Names.

Alaska is a general exception. Complete coverage according to the stated criteria was impractical. Listed coordinates thus include larger population centers only (based upon 1980 census data and projections through 1984).

ALABAMA
87 33 Alabaster
86 34 Albertville
86 33 Alexander City
88 33 Aliceville
86 34 Anniston
87 35 Athens
87 31 Atmore
85 33 Auburn
87 33 Bessemer
87 34 Birmingham
87 33 Brent
88 32 Butler
87 32 Camden
87 31 Castleberry
86 34 Centre
88 31 Chatom
87 33 Clanton
87 34 Cullman
87 35 Decatur
88 33 Demopolis
85 31 Dothan
86 31 Elba
85 32 Eufaula
88 33 Eutaw
88 34 Fayette
88 35 Florence
88 30 Foley
87 32 Fort Deposit
86 34 Fort Payne
86 34 Gadsden
86 31 Geneva
86 33 Goodwater
88 33 Greensboro
87 32 Greenville
88 34 Haleyville
88 34 Hamilton
85 31 Headland
87 35 Huntsville
88 32 Jackson
87 34 Jasper
85 33 Lanett
87 30 Lillian
86 33 Lineville
86 32 Luverne
87 33 Marion
88 31 Mobile
87 32 Monroeville
86 32 Montgomery
87 34 Moulton
86 34 Oneonta
86 31 Opp
86 31 Ozark
86 34 Pell City
85 32 Phenix City
86 32 Prattville
85 34 Ranburne
85 33 Roanoke
88 35 Russellville
86 35 Scottsboro
87 32 Selma
88 35 Sheffield
86 33 Talladega
86 33 Tallassee
86 32 Troy
88 33 Tuscaloosa
86 32 Tuskegee
86 32 Union Springs
88 34 Vernon
88 32 York

ALASKA
177 52 Adak Station
150 61 Anchorage
157 71 Barrow
162 61 Bethel
146 61 Cordova
158 59 Dillingham
147 65 Eielson
148 65 Fairbanks
146 64 Fort Greely
152 60 Homer
134 58 Juneau
151 61 Kenai
132 55 Ketchikan
152 58 Kodiak
163 67 Kotzebue
132 55 Metlakatla
151 61 Nikishka
165 65 Nome
149 62 Palmer
133 57 Petersburg
149 60 Seward
135 57 Sitka
151 60 Soldotna
167 54 Unalaska
146 61 Valdez
132 56 Wrangell

ARIZONA
113 32 Ajo
109 32 Apache
113 35 Bagdad
115 35 Berry
109 37 Bitlabito
114 36 Bonelli Landing
113 33 Buckeye
112 33 Casa Grande
109 31 Cazador
110 36 Chinle
109 33 Clifton
110 31 Douglas
109 34 Eagar
115 34 Ehrenberg
112 35 Flagstaff
109 36 Fort Defiance
113 36 Frazier Wells
113 37 Fredonia
111 33 Globe
112 36 Grand Canyon
110 35 Holbrook
110 37 Kayenta
114 35 Kingman
114 34 Lake Havasu City
114 37 Littlefield
111 31 Nogales
111 37 Page
111 34 Payson
112 33 Phoenix
110 33 Safford
115 32 San Luis
112 31 Sasabe
112 32 Sells
110 34 Show Low
110 32 Sierra Vista
109 35 St. Johns
111 36 Tuba City
111 32 Tucson
114 34 Vicksburg Junction
113 34 Wickenburg
111 35 Winslow
115 33 Yuma

ARKANSAS
93 34 Arkadelphia
94 34 Ashdown
91 35 Augusta
92 36 Batesville
93 35 Benton
94 36 Berryville
90 36 Blytheville
91 35 Brinkley
93 36 Bull Shoals
92 35 Cabot
93 34 Camden
92 36 Cave City
93 35 Clarksville
92 36 Clinton
92 35 Conway
93 36 Cotter
92 33 Crossett
93 35 Dardanelle

94 34 De Queen
91 35 Des Arc
91 34 Dumas
93 33 El Dorado
91 33 Eudora
94 36 Fayetteville
92 34 Fordyce
91 35 Forrest City
94 35 Fort Smith
92 34 Hampton
93 36 Harrison
92 35 Heber Springs
94 34 Hope
93 35 Hot Springs
91 36 Hoxie
94 36 Huntsville
93 36 Jasper
91 36 Jonesboro
92 35 Little Rock
93 33 Magnolia
93 34 Malvern
92 36 Mammoth Spring
91 35 Marianna
93 36 Marshall
92 36 Melbourne
94 35 Mena
92 34 Monticello
93 35 Morrilton
94 35 Mount Ida
92 36 Mountain View
94 34 Murfreesboro
94 34 Nashville
94 35 Ozark
91 36 Paragould
94 35 Paris
93 35 Perryville
90 36 Piggott
92 34 Pine Bluff
91 36 Pocahontas
93 34 Prescott
92 34 Rison
93 35 Russellville
92 35 Searcy
92 34 Sheridan
95 36 Siloam Springs
93 33 Stamps
92 34 Star City
92 35 Stuttgart
94 33 Texarkana
91 36 Trumann
91 36 Tuckerman
94 35 Van Buren
94 35 Waldron
92 34 Warren
91 35 West Helena
90 35 West Memphis
91 35 Wynne

CALIFORNIA
116 35 Afton
121 41 Alturas
119 35 Bakersfield
117 35 Barstow
120 38 Bear Valley
117 37 Beatty Junction
118 38 Benton
118 37 Bishop
114 34 Black Meadow Landing
115 34 Blythe
120 41 Brockman
115 36 Calada
115 33 Calexico
122 36 Carmel Valley
120 42 Cedarville
122 40 Chico
122 39 Colusa
122 38 Concord
123 40 Covelo
124 42 Crescent City
122 39 Davis
116 36 Death Valley Junction
122 42 Dorris
116 33 El Centro
121 36 El Paso de Robles
124 41 Eureka
124 39 Fort Bragg
120 37 Fresno
121 39 Grass Valley
120 36 Hanford
121 37 Hollister
116 34 Indio
121 38 Ione
123 39 Lakeport
118 35 Lancaster
122 39 Linda
118 34 Los Angeles
120 40 Loyalton
120 37 Madera
119 38 Mammoth Lakes
120 37 Mariposa
120 37 Merced
121 38 Modesto
122 38 Napa
115 35 Needles
122 38 Oakland
119 34 Oxnard
120 40 Portola
122 40 Red Bluff
122 41 Redding
124 40 Redway
119 37 Reedley
118 36 Ridgecrest
117 34 Riverside
121 39 Roseville
121 39 Sacramento
121 38 San Andreas
118 33 San Clemente
117 33 San Diego
122 38 San Francisco
122 37 San Jose
121 35 San Luis Obispo
122 38 San Mateo
123 38 San Rafael
120 34 Santa Barbara
121 37 Santa Clara
122 37 Santa Cruz
120 35 Santa Maria
123 38 Santa Rosa
117 36 Searles Valley
120 38 Sonora
120 39 South Lake Tahoe
121 38 Stockton
121 40 Susanville
121 42 Tulelake
123 39 Ukiah
122 38 Vallejo
119 36 Visalia
123 41 Weaverville
122 40 Willows
123 42 Yreka
122 39 Yuba City

COLORADO
106 37 Alamosa
107 39 Aspen
105 40 Aurora
105 40 Boulder
109 41 Bower Place
104 37 Branson
102 39 Burlington
105 38 Canon City
105 39 Castle Rock
106 38 Center
106 40 Central City
102 39 Cheyenne Wells
108 39 Clifton
105 39 Colorado Springs
107 41 Columbine
109 37 Cortez
108 41 Craig
107 38 Creede
108 39 Delta

105 40 Denver
108 37 Durango
103 38 Eads
105 39 Elizabeth
105 40 Englewood
106 40 Estes Park
106 39 Fairplay
105 41 Fort Collins
104 40 Fort Morgan
106 40 Frisco
103 38 Gilpin
109 39 Grand Junction
104 41 Grover
107 39 Gunnison
102 38 Holly
102 41 Holyoke
106 38 Hooper
103 39 Hugo
105 40 Idaho Springs
102 41 Julesburg
106 40 Kremmling
104 38 La Junta
107 38 Lake City
105 40 Lakewood
103 38 Lamar
103 38 Las Animas
106 39 Leadville
104 39 Limon
105 38 Lombard Village
108 39 Maher
106 37 Manassa
106 38 Monte Vista
108 38 Montrose
109 38 Nucla
104 38 Ordway
108 38 Ouray
107 37 Pagosa Springs
105 38 Pueblo
109 40 Rangely
108 40 Rifle
106 39 Salida
105 37 San Luis
108 38 Silverton
103 37 Springfield
107 40 Steamboat Springs
103 41 Sterling
108 38 Telluride
105 37 Trinidad
106 40 Vail
106 41 Walden
105 38 Walsenburg
102 37 Walsh
105 38 Westcliffe
105 39 Woodland Park
102 40 Wray
103 40 Yuma

CONNECTICUT
74 42 Amenia Union
73 41 Bridgeport
73 42 Hartford
73 42 Middletown
73 41 New Haven
72 41 New London
72 42 Norwich
74 41 Stamford
72 42 Storrs
72 42 Willimantic

DELAWARE
76 40 Wilmington
76 39 Dover
75 40 Claymont
75 39 Milford
75 38 Selbyville
76 38 Delmar

DISTRICT OF COLUMBIA
77 39 Washington

FLORIDA
85 30 Apalachicola
82 27 Arcadia
81 27 Belle Glade
85 30 Blountstown
86 31 Bonifay
83 27 Bradenton
83 30 Branford
85 30 Bristol
82 29 Brooksville
83 28 Clearwater
81 27 Clewiston
84 30 Crawfordville
83 30 Cross City
86 30 Crystal Lake
83 29 Crystal River
81 29 Daytona Beach
86 31 De Funiak Springs
88 31 Enon
81 31 Fernandina Beach
87 31 Ferry Pass
81 29 Flagler Beach
83 25 Fort Jefferson
80 26 Fort Lauderdale
82 27 Fort Myers
80 27 Fort Pierce
87 30 Fort Walton Beach
82 30 Gainesville
82 30 Hastings
83 28 Holiday
80 25 Homestead
81 26 Immokalee
82 30 Jacksonville
81 30 Jacksonville Beach
83 31 Jasper
82 25 Key West
81 28 Kissimmee
82 30 Lake Butler
83 30 Lake City
82 29 Leesburg
82 30 Macclenny
83 30 Madison
81 25 Marathon
85 31 Marianna
83 30 Mayo
81 28 Melbourne
80 26 Miami
87 31 Milton
84 31 Monticello
82 26 Naples
82 29 Ocala
81 27 Okeechobee
82 30 Orange Park
81 29 Orlando
82 30 Palatka
86 30 Panama City
87 30 Pensacola
84 30 Perry
82 27 Port Charlotte
85 31 Quincy
81 29 Sanford
83 27 Sarasota
81 27 Sebring
82 30 Starke
80 27 Stuart
84 30 Tallahassee
82 28 Tampa
83 30 Trenton
80 28 Vero Beach
81 27 Washington Park
82 28 Wauchula
80 27 West Palm Beach
85 30 Wewahitchka
82 29 Wildwood
82 29 Williston
82 28 Winter Haven
82 31 Yulee

GEORGIA

83 31 Adel
83 32 Ailey
83 32 Alamo
84 32 Albany
83 31 Alexis
85 33 Allendale
82 32 Alma
84 32 Americus
84 32 Andersonville
85 31 Arlington
84 32 Ashburn
83 34 Athens
84 34 Atlanta
82 33 Augusta
85 31 Bainbridge
84 33 Barnesville
82 32 Baxley
82 31 Blackshear
84 35 Blairsville
85 31 Blakely
83 33 Blountsville
84 35 Blue Ridge
84 31 Boston
85 34 Bremen
81 31 Brunswick
85 32 Buena Vista
84 33 Butler
84 31 Cairo
85 35 Calhoun
84 31 Camilla
84 34 Canton
85 34 Cartersville
81 33 Cedar Bluff Landing
85 34 Cedartown
85 35 Chatsworth
82 32 Claxton
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85 32 Columbus
83 34 Comer
83 34 Commerce
84 34 Conyers
84 32 Cordele
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84 34 Covington
83 34 Crawford
83 34 Crawfordville
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85 32 Cusseta
85 32 Cuthbert
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81 31 Darien
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84 34 Dawsonville
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85 31 Donalsonville
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83 33 Dublin
84 35 East Ellijay
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83 33 Eatonton
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84 32 Ellaville
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84 34 Gainesville
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84 34 Jasper
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84 34 Lawrenceville
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85 34 Lithia Springs
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82 32 Ludowici
85 34 Mableton
84 33 Macon
83 34 Madison
85 33 Manchester
82 34 Martinez
84 33 McDonough
83 32 McRae
82 32 Metter
83 33 Milledgeville
82 33 Millen
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82 31 Nahunta
83 31 Nashville
85 33 Newnan
84 31 Newton
84 34 North Atlanta
83 32 Ocilla
85 33 Peachtree City
83 31 Pearson
82 32 Pembroke
85 32 Preston
84 31 Quitman
85 32 Richland
84 33 Roberta
83 32 Rochelle
85 34 Rome
83 33 Sandersville
81 32 Savannah
83 32 Soperton
83 33 Sparta
82 32 Statesboro
82 30 Stokesville
85 34 Summerville
84 35 Sunnyside
82 33 Swainsboro
82 33 Sylvania
84 32 Sylvester
85 33 Talbotton
84 33 Thomaston
83 33 Thomson
84 31 Tifton
83 35 Toccoa
86 35 Trenton
83 31 Valdosta
82 32 Vidalia
84 32 Vienna
85 34 Villa Rica
84 33 Warner Robins
83 33 Warrenton
83 34 Washington
83 34 Watkinsville
85 33 Waverly Hall
82 31 Waycross
82 33 Waynesboro
85 35 Westside
84 34 Winder
83 33 Wrightsville

HAWAII

156	19	Captain Cook
155	20	Hilo
156	20	Holualoa
158	21	Honolulu
156	21	Kahului
159	22	Kapaa
160	22	Kekaha
155	19	Pahala
158	22	Wahiawa
157	21	Wailuku

IDAHO

115	45	Abstein Place
113	43	American Falls
113	44	Arco
111	44	Ashton
117	45	Bear
116	42	Bengoechea Place
112	43	Blackfoot
116	49	Bonners Ferry
115	47	Cayuse Junction
117	48	Coeur d'Alene
117	42	Crutcher Crossing
111	44	Driggs
112	44	Dubois
115	46	Elk City
116	41	Elkhorn
116	44	Emmett
115	43	Fairfield
114	46	Gibbonsville
115	43	Gooding
115	42	Hollister
116	44	Horseshoe Bend
111	43	Irwin
115	43	Jerome
116	46	Kamiah
116	48	Kellogg
114	44	Ketchum
111	45	Lake
117	49	Lamb Creek
113	45	Leadore
117	46	Lewiston
112	42	Malad City
113	42	Malta
116	45	McCall
117	43	Melba
116	44	Meridian
111	42	Montpelier
117	47	Moscow
116	43	Mountain Home
117	44	Nampa
114	42	Oakley
116	46	Orofino
117	44	Payette
117	47	Plummer
112	43	Pocatello
112	42	Preston
112	44	Rexburg
112	44	Rigby
114	43	Rupert
114	45	Salmon
114	43	Shoshone
112	43	Soda Springs
115	44	Stanley
114	43	Twin Falls
116	47	Wallace
117	44	Weiser

ILLINOIS

91	41	Aledo
89	37	Anna
90	43	Apple River
90	40	Athens
88	42	Aurora
90	40	Beardstown
90	39	Belleville
89	42	Belvidere
90	39	Breese
89	37	Cairo
90	41	Canton
89	38	Carbondale
90	39	Carlinville
88	38	Carmi
89	39	Centralia
88	40	Champaign
88	39	Charleston
90	38	Chester
88	42	Chicago
89	40	Clinton
88	42	Crystal Lake
88	40	Danville
89	42	De Kalb
89	40	Decatur
89	42	Dixon
88	41	Dwight
89	39	Effingham
88	42	Elmhurst
89	41	Eureka
88	39	Flora
90	42	Freeport
90	41	Galesburg
88	37	Golconda
90	39	Granite City
89	41	Granville
88	38	Grayville
89	39	Greenville
91	40	Hamilton
91	39	Hardin
89	38	Harrisburg
90	40	Havana
89	41	Henry
89	39	Hillsboro
90	40	Jacksonville
90	39	Jerseyville
88	42	Joliet
88	41	Kankakee
90	41	Kewanee
88	39	Lawrenceville
89	40	Lincoln
91	40	Macomb
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88	39	Marshall
89	38	McLeansboro
89	37	Metropolis
92	40	Meyer
91	41	Monmouth
89	40	Monticello
88	41	Morris
89	37	Mounds
88	38	Mount Carmel
91	40	Mount Sterling
89	38	Mount Vernon
89	38	Nashville
88	39	Neoga
88	39	Newton
89	41	Normal
88	39	Olney
91	41	Oquawka
89	41	Ottawa
88	40	Paris
88	40	Paxton
90	41	Pekin
90	41	Peoria
89	38	Pinckneyville
91	40	Pittsfield
89	42	Plano
89	41	Princeton
90	41	Princeville
91	40	Quincy
88	39	Robinson
89	42	Rochelle
91	42	Rock Island
89	42	Rockford
88	37	Rosiclare
91	40	Rushville
90	42	Savanna
88	38	Shawneetown
89	39	Shelbyville
90	40	Springfield
90	42	Sterling
89	40	Sullivan

89 40 Taylorville
88 40 Tuscola
89 39 Vandalia
89 37 Vienna
90 38 Waterloo
88 41 Watseka
88 42 Waukegan
89 38 Wayne City
89 38 West Frankfort
90 39 White Hall
90 40 Winchester

INDIANA
88 40 Ambia
86 40 Anderson
85 42 Angola
86 39 Annandale Estates
87 40 Attica
85 41 Auburn
86 39 Austin
86 41 Barbee
85 39 Batesville
86 39 Bedford
85 41 Berne
87 39 Bloomington
85 41 Bluffton
87 38 Boonville
87 40 Brazil
85 39 Brookville
86 40 Brownsburg
86 40 Carmel
85 41 Columbia City
86 39 Columbus
85 40 Connersville
86 38 Corydon
87 40 Crawfordsville
87 41 Delphi
88 41 Dyer
86 42 Elkhart
88 38 Evansville
87 40 Fairview Park
87 39 Farmersburg
85 41 Fort Wayne
87 40 Frankfort
87 42 Gary
86 40 Gas City
87 40 Greencastle
86 40 Greenfield
85 39 Greensburg
88 42 Hammond
85 40 Hartford City
85 41 Huntington
86 40 Indianapolis
87 38 Jasper
85 41 Kendallville
87 41 Kentland
86 41 Kewanna
86 40 Kokomo
87 40 Lafayette
85 42 Lagrange
85 39 Lawrenceburg
86 40 Lebanon
85 40 Liberty
87 39 Linton
86 41 Logansport
87 39 Loogootee
85 39 Madison
86 39 Martinsville
87 41 Merrillville
87 42 Michigan City
87 41 Monticello
85 40 Muncie
86 38 New Albany
85 40 New Castle
86 39 New Pekin
86 40 New Whiteland
87 41 North Judson
86 39 North Vernon
86 38 Oak Park
86 39 Paoli
86 41 Peru
87 38 Petersburg
86 41 Plymouth
87 42 Portage
85 40 Portland
88 38 Poseyville
88 38 Princeton
87 41 Rensselaer
85 40 Richmond
85 39 Rising Sun
86 41 Rochester
87 38 Rockport
87 40 Rockville
85 40 Rushville
86 39 Seymour
86 40 Shelbyville
86 42 South Bend
87 39 Spencer
87 39 Sullivan
87 38 Tell City
87 39 Terre Haute
86 40 Tipton
85 39 Vevay
88 39 Vincennes
86 41 Wabash
86 41 Warsaw
87 39 Washington
87 40 Williamsport
87 41 Winamac
85 40 Winchester

IOWA
97 43 Akron
93 41 Albia
94 43 Algona
93 42 Altoona
94 42 Ames
91 42 Anamosa
95 41 Atlantic
95 42 Audubon
95 41 Bedford
92 41 Bloomfield
94 42 Boone
91 41 Burlington
95 42 Carroll
92 43 Cedar Falls
92 42 Cedar Rapids
93 41 Chariton
93 43 Charles City
96 43 Cherokee
90 42 Clinton
95 41 Corning
96 41 Council Bluffs
92 43 Cresco
94 41 Creston
91 42 Davenport
92 43 Decorah
95 42 Denison
94 42 Des Moines
91 43 Dubuque
94 43 Eagle Grove
95 43 Emmetsburg
95 43 Estherville
92 41 Fairfield
94 43 Forest City
94 42 Fort Dodge
94 43 Garner
97 41 Genoa
96 41 Glenwood
94 41 Greenfield
93 42 Grinnell
93 42 Grundy Center
95 42 Guthrie Center
91 43 Guttenberg
96 41 Hamburg
93 43 Hampton
95 42 Harlan
94 43 Humboldt
95 42 Ida Grove
92 42 Independence
94 41 Indianola
92 42 Iowa City

93 43 Iowa Falls
94 42 Jefferson
91 40 Keokuk
92 41 Keosauqua
95 42 Kimballton
94 41 Lamoni
91 42 Manchester
91 42 Maquoketa
92 42 Marengo
93 42 Marshalltown
93 43 Mason City
96 42 Missouri Valley
93 41 Moulton
94 41 Mount Ayr
92 41 Mount Pleasant
92 43 New Hampton
93 42 Newton
93 43 Northwood
92 43 Oelwein
96 42 Onawa
96 43 Orange City
93 43 Osage
94 41 Osceola
93 41 Oskaloosa
92 41 Ottumwa
93 43 Parkersburg
93 41 Pella
94 42 Perry
95 43 Pocahontas
95 41 Red Oak
96 43 Rock Rapids
95 42 Rockwell City
95 42 Sac City
96 43 Sheldon
95 41 Shenandoah
96 43 Sibley
92 41 Sigourney
96 43 Sioux City
95 43 Spencer
95 43 Spirit Lake
95 43 Storm Lake
93 42 Tama
91 42 Tipton
92 40 Vincennes
92 42 Vinton
92 41 Washington
91 43 Waukon
92 43 Waverly
94 42 Webster City
91 42 West Liberty
94 41 Winterset

KANSAS

97 39 Abilene
96 39 Alma
98 37 Anthony
97 37 Arkansas City
100 37 Ashland
95 40 Atchison
101 40 Atwood
98 40 Belleville
98 39 Beloit
102 40 Bird City
96 38 Burlington
95 38 Chanute
100 38 Cimarron
96 37 Coffeyville
101 39 Colby
99 37 Coldwater
98 40 Concordia
97 38 Cottonwood Falls
96 39 Council Grove
100 38 Dighton
100 38 Dodge City
95 39 Dunavant
97 38 El Dorado
102 37 Elkhart
98 39 Ellsworth
96 38 Emporia
96 38 Eureka
95 38 Fort Scott
95 37 Galena
101 38 Garden City
95 38 Garnett
102 39 Goodland
99 38 Great Bend
99 38 Greensburg
99 39 Hays
96 40 Hiawatha
100 39 Hill City
97 38 Hillsboro
96 39 Holton
96 37 Howard
101 37 Hugoton
98 38 Hutchinson
95 38 Iola
100 38 Jetmore
97 39 Junction City
103 38 Kanco
95 39 Kansas City
98 38 Kingman
99 38 Kinsley
99 39 La Crosse
101 38 Lakin
96 38 Landergin
99 38 Larned

95 39 Lawrence
95 39 Leavenworth
101 38 Leoti
101 37 Liberal
98 38 Lyons
97 39 Manhattan
98 40 Mankato
102 38 Manter
97 40 Marysville
98 38 McPherson
100 37 Meade
99 37 Medicine Lodge
98 39 Minneapolis
96 37 Neodesha
100 38 Ness City
97 38 Newton
100 40 Norton
101 39 Oakley
101 40 Oberlin
96 39 Osage City
99 39 Osborne
95 39 Overland Park
95 39 Paola
95 37 Parsons
99 40 Phillipsburg
95 37 Pittsburg
99 39 Plainville
95 38 Pleasanton
99 38 Pratt
100 39 Quinter
94 38 Richmond
99 39 Russell
98 38 Saint Paul
98 39 Salina
101 38 Scott City
96 37 Sedan
101 40 Selden
96 40 Seneca
102 39 Sharon Springs
99 40 Smith Center
99 38 Stafford
101 37 Sublette
98 39 Sylvan Grove
102 38 Syracuse
96 39 Topeka
101 38 Ulysses
95 39 Valley Falls
100 39 Wa Keeney
97 39 Wakefield
96 39 Wamego
97 40 Washington
95 40 Wathena
97 37 Wellington
97 38 Wichita

96 38 Yates Center

KENTUCKY

85 37 Albany
83 37 Altro
85 38 Anderson City
85 37 Argyle
83 37 Asher
83 38 Ashland
84 38 Ashland Park
84 39 Augusta
84 37 Barbourville
85 38 Bardstown
85 37 Barrier
84 38 Beattyville
82 38 Beauty
87 37 Beaver Dam
85 39 Bedford
88 37 Benton
84 37 Booneville
86 37 Bowling Green
86 38 Brandenburg
84 37 Brodhead
85 37 Burkesville
88 37 Cadiz
85 37 Campbellsville
84 38 Campton
84 38 Carlisle
85 39 Carrollton
87 37 Central City
83 38 Clearfield
89 37 Clinton
85 37 Columbia
84 37 Corbin
85 39 Covington
83 37 Cumberland
84 38 Cynthiana
85 38 Danville
88 37 Eddyville
86 37 Edmonton
86 38 Elizabethtown
82 37 Elkhorn City
87 37 Elkton
85 38 Eminence
84 39 Falmouth
83 39 Flatwoods
84 38 Flemingsburg
85 39 Florence
85 38 Frankfort
87 37 Franklin
84 38 Frenchburg
89 37 Fulton
86 37 Glasgow
83 38 Grayson
85 37 Greensburg
86 38 Hardinsburg
85 38 Harrodsburg
83 37 Hazard
88 38 Henderson
86 37 Hillview
83 37 Hindman
86 38 Hodgenville
87 37 Hopkinsville
86 37 Horse Cave
84 38 Irvine
83 37 Jenkins
85 38 Junction City
89 37 La Center
85 38 La Grange
85 38 Lancaster
85 38 Lawrenceburg
85 38 Lebanon
86 37 Leitchfield
87 38 Lewisport
87 37 Livermore
84 37 London
83 38 Louisa
86 38 Louisville
87 37 Madisonville
84 37 Manchester
88 37 Marion
89 37 Mayfield
84 39 Maysville
84 37 McKee
88 38 Morganfield
87 37 Morgantown
84 38 Mount Sterling
88 37 Murray
84 39 Newport
85 38 Nicholasville
87 38 Owensboro
85 39 Owenton
89 37 Paducah
83 38 Paintsville
84 38 Paris
84 37 Pineville
83 38 Prestonsburg
88 37 Princeton
84 38 Richmond
85 37 Russell Springs
87 37 Russellville
84 38 Salt Lick
83 38 Salyersville
83 38 Sandy Hook
86 37 Scottsville
88 38 Sebree
85 38 Shelbyville
86 38 Shepherdsville
88 37 Smithland
85 37 Somerset
82 38 South Williamson
85 38 Springfield
85 38 Stamping Ground
85 38 Stanford
84 38 Stanton
86 37 Tompkinsville
83 39 Vanceburg
85 38 Versailles
85 39 Warsaw
83 38 West Liberty
84 37 Whitley City
89 37 Wickliffe
85 39 Williamstown
84 38 Winchester

LOUISIANA

92 31 Alexandria
91 31 Alice
93 33 Arcadia
91 31 Baker
92 33 Bastrop
91 30 Baton Rouge
90 31 Bogalusa
89 29 Boothville
94 33 Bossier City
92 30 Breaux Bridge
92 31 Bunkie
93 30 Cameron
90 30 Chalmette
91 29 Chauvin
92 32 Clarks
93 32 Colfax
93 32 Coushatta
92 30 Crowley
93 31 De Ridder
91 30 Denham Springs
91 30 Donaldsonville
91 33 Epps
92 33 Farmerville
91 33 Forest
90 29 Galliano
91 31 Greensburg
90 31 Hammond
93 33 Homer
91 31 Jackson
92 32 Jena
93 30 Jennings
93 32 Jonesboro
92 32 Jonesville
92 30 Kaplan
92 30 Lafayette
93 30 Lake Charles

91 33 Lake Providence
90 30 Laplace
93 31 Leesville
91 30 Lutcher
94 32 Mansfield
93 32 Many
94 31 Merryville
90 30 Metairie
93 33 Minden
92 33 Monroe
91 30 Morgan City
93 32 Natchitoches
92 30 New Iberia
90 30 New Orleans
91 31 New Roads
91 32 Newellton
90 30 Norco
93 31 Oakdale
92 31 Opelousas
91 30 Pierre Part
91 30 Plaquemine
91 30 Port Allen
92 32 Rayville
91 30 Rhodes
93 33 Ruston
94 33 Shreveport
90 30 Slidell
91 32 Tallulah
91 32 Vidalia
92 31 Ville Platte
94 30 Vinton
93 32 Winnfield
92 32 Winnsboro

MAINE
70 46 Attean
69 45 Bangor
68 44 Bar Harbor
70 44 Bath
69 44 Belfast
70 43 Biddeford
70 44 Boothbay Harbor
67 45 Calais
70 47 Clayton Lake
69 45 Dover-Foxcroft
68 45 Ellsworth
69 47 Fort Kent
68 46 Houlton
71 46 Keough
70 44 Lewiston
69 46 Millinocket
71 44 Norway
70 44 Portland
68 47 Presque Isle
69 44 Rockland
71 45 Rumford
71 43 Sanford
67 46 Vanceboro
70 45 Waterville

MARYLAND
77 39 Baltimore
78 39 Brunswick
77 38 California
76 39 Cambridge
76 39 Centreville
76 39 Chestertown
77 39 Columbia
76 38 Crisfield
79 40 Cumberland
76 39 Easton
76 40 Elkton
77 40 Emmitsburg
76 39 Essex
76 39 Federalsburg
77 39 Glen Burnie
78 40 Hagerstown
78 40 Halfway
76 40 Havre De Grace
75 38 Ocean City
77 39 Oxon Hill
77 39 Prince Frederick
76 38 Salisbury
77 39 Silver Spring
77 39 Waldorf
79 39 Westernport
77 40 Westminster

MASSACHUSETTS
71 42 Boston
71 42 Brockton
72 43 Fitchburg
73 43 Greenfield
70 42 Hyannis
71 43 Lowell
71 42 Lynn
70 41 Nantucket
71 42 New Bedford
73 43 North Adams
73 42 Northampton
71 42 Quincy
73 42 Springfield
71 41 Vineyard Haven
72 42 Worcester

MICHIGAN
84 42 Adrian
86 43 Allegan
85 43 Alma
83 45 Alpena
84 42 Ann Arbor
87 45 Arthur Bay
83 44 Bad Axe
86 44 Baldwin
85 42 Battle Creek
84 44 Bay City
85 44 Big Rapids
84 45 Biggs Settlement
85 45 Boyne City
84 47 Brassar
84 43 Burton
85 44 Cadillac
83 43 Caro
85 43 Charlotte
84 46 Cheboygan
85 44 Clare
85 42 Coldwater
86 47 Deer Park
83 42 Detroit
86 42 Dowagiac
83 44 East Tawas
85 45 Elk Rapids
85 47 Emerson
87 46 Escanaba
84 43 Flint
86 45 Frankfort
86 43 Fremont
85 45 Gaylord
84 44 Gladwin
85 45 Grayling
85 43 Greenville
83 45 Harrisville
84 45 Hillman
85 42 Hillsdale
86 43 Holland
89 47 Houghton
85 44 Houghton Lake
84 43 Howell
85 43 Ionia
88 46 Iron Mountain
89 46 Iron River
90 46 Ironwood
84 42 Jackson
86 42 Kalamazoo
85 45 Kalkaska
88 47 L'Anse
85 44 Lake City
85 43 Lansing
83 43 Lapeer
88 47 Laurium
87 44 Little Point Sable
86 44 Ludington

85 46 Mackinac Island
85 46 Mackinaw City
86 44 Manistee
86 46 Manistique
87 47 Marquette
88 45 Menominee
85 43 Middleville
84 44 Midland
83 42 Monroe
87 46 Munising
86 43 Muskegon
87 42 New Buffalo
86 45 Northport
84 43 Ovid
85 45 Petoskey
83 43 Pontiac
82 43 Port Huron
86 44 Reed City
88 48 Rock Harbor Lodge
84 45 Rogers City
84 43 Saginaw
83 43 Sandusky
85 44 Shepherd
86 42 South Haven
84 44 Standish
83 43 Sterling Heights
85 42 Sturgis
86 45 Traverse City
84 44 West Branch
90 47 White Pine
89 48 Windigo
86 43 Wyoming

MINNESOTA

94 47 Aitkin
93 44 Albert Lea
95 46 Alexandria
93 44 Austin
95 48 Bagley
95 49 Baudette
95 47 Bemidji
96 45 Benson
94 49 Birchdale
94 44 Blue Earth
97 45 Bonanza Grove
94 46 Brainerd
97 46 Breckenridge
94 45 Buffalo
93 45 Burnsville
91 44 Caledonia
93 46 Cambridge
95 47 Cass Lake
94 45 Chaska
93 47 Chisholm
91 48 Clear Lake
93 45 Coon Rapids
93 45 Cottage Grove
97 48 Crookston
96 47 Detroit Lakes
92 47 Duluth
96 46 Elbow Lake
92 48 Ely
94 44 Fairmont
93 44 Faribault
96 46 Fergus Falls
92 45 Frontenac
94 45 Gaylord
95 46 Glenwood
90 48 Grand Marais
94 47 Grand Rapids
96 45 Granite Falls
97 49 Hallock
92 46 Holyoke
94 45 Hutchinson
93 49 International Falls
95 44 Jackson
93 44 Kasson
92 44 Lake City
93 45 Lindstrom
95 45 Litchfield
94 46 Little Falls
94 48 Littlefork
96 44 Luverne
94 44 Madelia
96 45 Madison
96 47 Mahnomen
94 44 Mankato
96 44 Marshall
93 45 Minneapolis
94 45 Minnetonka
96 45 Montevideo
97 47 Moorhead
93 46 Mora
96 46 Morris
94 45 New Prague
94 44 New Ulm
94 44 North Mankato
95 45 Olivia
93 44 Owatonna
95 47 Park Rapids
93 46 Pine City
96 44 Pipestone
94 46 Princeton
96 48 Red Lake Falls
95 45 Redwood Falls
92 44 Rochester
96 49 Roseau
93 45 Roseville
95 46 Sauk Centre
94 46 Sauk Rapids
94 45 Shakopee
91 47 Silver Bay
96 44 Slayton
92 44 Spring Valley
95 46 Staples
96 48 Thief River Falls
96 47 Twin Valley
96 44 Tyler
93 48 Virginia
95 46 Wadena
97 48 Warren
95 49 Warroad
94 44 Waseca
96 46 Wheaton
95 45 Willmar
95 44 Windom
92 44 Winona
96 44 Worthington

MISSISSIPPI

90 35 Abbeville
89 33 Ackerman
88 34 Amory
90 34 Batesville
89 32 Bay Springs
89 31 Beatrice
89 31 Beaumont
90 33 Belzoni
89 30 Biloxi
89 35 Booneville
90 32 Brandon
90 32 Brookhaven
89 34 Bruce
91 31 Bude
90 35 Byhalia
90 33 Canton
91 31 Centreville
90 34 Charleston
91 34 Clarksdale
90 32 Collins
90 31 Columbia
88 33 Columbus
90 32 Crystal Springs
89 33 De Kalb
90 33 Durant
89 34 Eupora
91 32 Fayette
89 32 Forest
88 34 Fulton
90 30 Gainesville
91 31 Gloster
91 33 Greenville

90	34	Grenada
89	31	Hattiesburg
88	30	Helena
90	35	Hernando
89	35	Hickory Flat
89	34	Houston
88	32	Hurricane Creek
91	33	Indianola
90	33	Itta Bena
88	35	Iuka
90	32	Jackson
91	35	Jeffries
92	31	Kienstra
90	33	Kosciusko
89	32	Laurel
90	33	Lena
89	33	Louisville
89	31	Lucedale
89	33	Macon
90	32	Magee
90	34	Marks
91	33	Mayersville
90	31	McComb
89	32	Meridian
90	32	Monticello
91	34	Mound Bayou
89	34	New Albany
89	32	Newton
89	33	Philadelphia
90	31	Picayune
89	34	Pontotoc
91	32	Port Gibson
90	32	Prentiss
89	31	Purvis
90	32	Raleigh
89	35	Rienzi
89	35	Ripley
91	33	Rolling Fork
90	35	Senatobia
89	33	Starkville
88	31	State Line
90	35	Tunica
89	34	Tupelo
90	31	Tylertown
90	33	Vaiden
91	32	Vicksburg
90	34	Water Valley
89	32	Waynesboro
89	34	West Point
90	33	Winona
90	33	Yazoo City

MISSOURI

92	41	Anson
94	38	Appleton City
90	38	Arnold
94	37	Aurora
93	37	Ava
91	39	Ballwin
92	38	Belle
93	36	Blue Eye
93	38	Bolivar
93	39	Boonville
93	37	Branson
93	40	Brookfield
93	38	Buffalo
94	38	Butler
93	39	California
93	38	Camdenton
92	40	Canton
90	37	Cape Girardeau
93	39	Carrollton
94	37	Carthage
90	36	Caruthersville
94	36	Caverna
89	37	Charleston
94	40	Chillicothe
92	39	Columbia
92	36	Cornertown
91	38	Cuba
91	36	Current View
90	37	Dexter
95	38	Drexel
92	40	Edina
93	38	Eldon
91	37	Ellington
90	38	Farmington
93	39	Fayette
91	38	Flat River
90	38	Fredericktown
92	39	Fulton
92	37	Gainesville
94	40	Gallatin
95	39	Gladstone
94	40	Grant City
94	37	Greenfield
94	40	Hamilton
91	40	Hannibal
91	39	Hermann
95	41	Hopkins
92	37	Houston
94	39	Independence
91	38	Ironton
92	39	Jefferson City
95	37	Joplin
95	39	Kansas City
90	36	Kennett
93	40	Kirksville
94	37	Lamar
93	41	Lancaster
93	38	Lebanon
94	39	Lexington
92	38	Linn
91	39	Louisiana
90	37	Lutesville
92	40	Macon
93	39	Marshall
93	37	Marshfield
94	40	Maysville
92	40	Memphis
94	41	Mercer
92	39	Mexico
93	40	Milan
92	39	Moberly
94	37	Monett
92	40	Monroe City
92	39	Montgomery City
95	40	Mound City
92	37	Mountain Grove
94	37	Neosho
94	38	Nevada
91	39	O'Fallon
93	37	Ozark
92	39	Paris
90	38	Perryville
91	37	Piedmont
95	39	Platte City
94	40	Plattsburg
90	37	Poplar Bluff
90	36	Portageville
91	38	Potosi
94	39	Richmond
94	40	Ridgeway
92	38	Rolla
95	40	Saint Joseph
92	38	Salem
93	39	Salisbury
95	40	Savannah
93	39	Sedalia
92	40	Shelbina
90	37	Sikeston
93	37	Springfield
90	39	St. Louis
95	40	Stanberry
94	38	Stockton
92	37	Thayer
94	40	Trenton
91	39	Troy
91	38	Union
93	40	Unionville
91	37	Van Buren
93	38	Versailles

94	39	Warrensburg
93	38	Warsaw
91	39	Washington
96	40	Watson
92	38	Waynesville
94	38	Weaubleau
92	37	West Plains
94	39	Windsor
91	37	Winona

MONTANA

104	45	Albion
110	45	Alpine
113	46	Anaconda
114	49	Apgar
104	46	Baker
110	48	Big Sandy
110	46	Big Timber
109	46	Billings
107	49	Bone Crossing
116	47	Borax
112	46	Boulder
111	46	Bozeman
105	45	Broadus
113	49	Browning
113	46	Butte
111	49	Chester
109	49	Chinook
113	48	Choteau
106	47	Circle
109	46	Columbus
112	48	Conrad
112	49	Cut Bank
113	46	Deer Lodge
113	45	Dillon
113	47	Drummond
105	46	Ekalaka
112	45	Ennis
115	49	Eureka
107	46	Forsyth
108	45	Fort Smith
107	48	Glasgow
105	47	Glendive
111	48	Great Falls
114	46	Hamilton
108	46	Hardin
110	46	Harlowton
110	49	Havre
112	47	Helena
107	46	Hysham
107	47	Jordan
114	48	Kalispell
109	47	Lewistown
116	48	Libby
111	46	Livingston
107	45	Lodge Grass
108	48	Malta
108	47	Melstone
106	46	Miles City
114	47	Missoula
106	49	Opheim
115	47	Plains
105	49	Plentywood
114	48	Polson
105	48	Poplar
106	45	Quietus
109	48	Rattlesnake
109	45	Red Lodge
109	46	Ryegate
105	49	Scobey
112	49	Shelby
104	48	Sidney
110	47	Stanford
116	49	Sylvanite
105	47	Terry
115	48	Thompson Falls
112	46	Townsend
108	49	Turner
111	45	West Yellowstone
104	49	Westby
111	47	White Sulphur Springs
104	47	Wibaux
108	47	Winnett
106	48	Wolf Point

NEBRASKA

100	43	Ainsworth
98	42	Albion
99	40	Alma
100	42	Anselmo
102	42	Arthur
99	43	Atkinson
96	40	Auburn
98	41	Aurora
99	42	Bartlett
100	43	Bassett
97	40	Beatrice
96	41	Bellevue
102	40	Benkelman
96	42	Blair
98	43	Bloomfield
103	42	Bridgeport
99	42	Burwell
100	40	Cambridge
98	41	Central City
103	43	Chadron
102	41	Chappell
97	41	Columbus
101	41	Curtis
99	41	Dannebrog
97	41	David City
100	42	Dunning
100	41	Elwood
97	40	Fairbury
96	40	Falls City
101	42	Flats
99	40	Franklin
96	41	Fremont
98	41	Fullerton
98	41	Geneva
102	43	Gordon
98	41	Grand Island
102	41	Grant
104	43	Harrison
97	43	Hartington
98	41	Hastings
97	41	Havelock
101	41	Hayes Center
98	40	Hebron
103	42	Hemingford
99	40	Holdrege
97	40	Hubbell
102	42	Hyannis
102	41	Imperial
99	41	Kearney
104	41	Kimball
100	41	Lexington
97	41	Lincoln
99	41	Loup City
97	42	Madison
101	40	McCook
99	40	Minden
101	42	Mullen
96	41	Nebraska City
98	42	Neligh
101	41	North Platte
99	42	O'Neill
102	41	Ogallala
96	41	Omaha
99	42	Ord
102	41	Oshkosh
96	40	Pawnee City
97	42	Pender
98	42	Pierce
96	41	Plattsmouth
99	40	Red Cloud
103	42	Redington
95	40	Rulo
97	41	Schuyler
104	42	Scottsbluff
97	41	Seward
103	41	Sidney

96 42 South Sioux City
98 42 Spalding
99 43 Spencer
100 43 Springview
97 42 Stanton
101 41 Stapleton
98 41 Stromsburg
98 40 Superior
98 41 Sutton
99 42 Taylor
96 40 Tecumseh
96 42 Tekamah
101 42 Thedford
101 40 Trenton
101 43 Valentine
97 41 Wahoo
97 42 Wakefield
97 42 Wayne
97 42 West Point
97 40 Wilber
98 41 York

NEVADA
114 38 Acoma
117 39 Adits Mill
116 40 Alpha
117 40 Amador
115 37 Arrowhead
114 39 Baker
119 40 Bango
117 41 Battle Mountain
118 38 Blair
116 39 Bull Fork
116 37 Cactus Springs
115 38 Caliente
120 39 Carson City
117 42 Cathcart
120 41 Cavin Place
116 42 Charleston
116 36 Charleston Park
119 42 Chinatown
119 40 Clark
114 41 Clifside
115 42 Contact
115 40 Currie
119 38 Del Monte
116 41 Elko
115 39 Ely
119 39 Fallon
118 39 Gabbs
114 36 Gold Butte
117 37 Gold Point.
116 40 Jiggs
115 36 Las Vegas
115 35 Laughlin
118 40 Lovelock
118 42 McDermitt
120 39 Minden
114 37 Overton
120 40 Reno
119 41 Sulphur
116 38 Tempiute
114 40 Tippett
117 38 Tonopah
120 42 Vya
115 41 Wells
118 41 Winnemucca
119 39 Yerington

NEW HAMPSHIRE
72 43 Claremont
71 45 Colebrook
72 43 Concord
71 43 Dover
72 45 Groveton
71 44 Laconia
72 44 Lebanon
71 43 Manchester
73 43 North Hinsdale
71 43 Portsmouth
71 44 Wolfeboro

NEW JERSEY
74 39 Atlantic City
75 40 Camden
74 41 Elizabeth
75 41 Flemington
75 40 Glassboro
75 41 Hopatcong
74 41 Jersey City
74 40 Lakewood
74 40 Long Branch
74 41 Madison
74 41 Newark
74 41 North Plainfield
75 39 Ocean City
74 41 Paterson
76 40 Pennsville
75 41 Phillipsburg
74 40 Piscataway
74 41 Teaneck
75 40 Trenton
75 39 Vineland
75 40 Willingboro

NEW MEXICO
108 31 Alamo Hueco
107 35 Albuquerque
109 31 Antelope Wells
104 33 Artesia
103 37 Atencio
109 35 Black Rock
108 34 Box Bar Place
104 32 Carlsbad
106 34 Carrizozo
105 37 Cimarron
103 36 Clayton
103 34 Clovis
108 36 Crownpoint
108 32 Deming
107 37 Dulce
103 32 Eunice
108 37 Farmington
104 34 Fort Sumner
105 32 Four Wells
109 36 Gallup
108 35 Grants
103 33 Hobbs
107 36 Jemez Pueblo
107 32 Las Cruces
103 35 Logan
109 32 Lordsburg
105 36 Los Alamos
105 34 Mesa
106 35 Moriarty
103 34 Portales
106 37 Questa
104 37 Raton
109 34 Reserve
105 33 Roswell
104 36 Roy
106 33 Ruidoso
106 35 San Felipe Pueblo
106 36 Santa Fe
105 35 Santa Rosa
109 37 Shiprock
108 33 Silver City
107 34 Socorro
107 33 Truth Or Consequences
104 35 Tucumcari
106 33 Tularosa
106 36 Upper Frijoles Crossing
109 33 Virden
105 36 Wagon Mound
106 32 White Sands

NEW YORK
74 41 Adelphi
74 43 Albany
74 43 Amsterdam
74 41 Annadale
77 43 Auburn

73 42 Austerlitz
78 43 Batavia
76 42 Binghamton
73 41 Brentwood
79 43 Buffalo
74 42 Catskill
75 41 Centereach
74 43 Cobleskill
77 42 Corning
76 43 Cortland
71 41 East Hampton
74 41 Eastchester
77 42 Elmira
78 43 Geneseo
77 43 Geneva
74 43 Gloversville
75 44 Gouverneur
73 43 Hoosick Falls
75 43 Ilion
76 42 Ithaca
74 41 Jamaica
79 42 Jamestown
74 42 Kingston
74 42 Levittown
76 44 Lowville
74 41 Mahopac
74 45 Malone
78 43 Medina
75 42 Monticello
76 45 Morristown
74 41 New City
74 41 New York
77 43 Newark
74 42 Newburgh
79 43 Niagara Falls
76 43 Norwich
75 45 Ogdensburg
78 42 Olean
76 43 Oneida
75 42 Oneonta
77 43 Oswego
77 43 Penn Yan
78 43 Perry
73 45 Plattsburgh
74 42 Poughkeepsie
78 43 Rochester
74 44 Saranac Lake
74 43 Saratoga Springs
74 43 Schenectady
77 43 Seneca Falls
75 42 Sidney
72 41 South Hampton
72 41 Southampton
74 43 Speculator
76 43 Syracuse
75 43 Utica
76 44 Watertown
77 42 Watkins Glen
77 42 Waverly
78 42 Wellsville
74 40 West Glens Falls
80 42 Westfield
73 44 Whitehall
74 41 Yonkers

NORTH CAROLINA

77 36 Ahoskie
80 35 Albemarle
76 36 Alder Branch
82 37 Apple Grove
80 36 Asheboro
83 36 Asheville
76 35 Atlantic
82 36 Bacchus
82 36 Banner Elk
77 35 Bayboro
77 36 Belhaven
76 35 Beulah
82 36 Boone
83 35 Brevard
83 35 Bryson City
78 35 Burgaw
79 36 Burlington
79 36 Carrboro
80 37 Central Area
81 35 Charlotte
78 35 Clinton
76 36 Columbia
82 35 Columbus
76 37 Corys
79 35 Dunn
79 36 Durham
77 36 Edenton
76 36 Elizabeth City
78 36 Elm City
79 35 Fayetteville
78 37 Gaston
81 35 Gastonia
77 36 Gatesville
78 35 Goldsboro
80 36 Greensboro
77 36 Greenville
77 35 Havelock
84 35 Hayesville
78 36 Henderson
82 35 Hendersonville
76 36 Hertford
83 35 Highlands
78 35 Hookerton
81 35 Kannapolis
80 36 King
78 35 Kinston
79 35 Laurinburg
82 36 Lenoir
80 36 Lexington
81 35 Lincolnton
75 35 Little Kinnakeet
80 35 Locust
78 34 Long View
78 36 Louisburg
79 35 Lumberton
82 36 Marion
83 36 Mars Hill
77 35 Maysville
79 37 Milton
81 36 Mocksville
81 35 Monroe
82 36 Morganton
84 35 Murphy
81 36 Newton
81 36 North Wilkesboro
79 36 Oxford
77 36 Plymouth
79 35 Raeford
79 36 Raleigh
78 36 Roanoke Rapids
84 35 Robbinsville
80 35 Rockingham
78 36 Rocky Mount
75 36 Rodanthe
79 36 Roxboro
80 36 Salisbury
79 35 Sanford
77 37 Severn
82 35 Shelby
79 36 Siler City
78 36 Smithfield
79 35 Southern Pines
78 34 Southport
81 37 Sparta
82 36 Spruce Pine
81 36 Statesville
83 35 Sylva
78 36 Tarboro
81 36 Taylorsville
77 34 Thomas Landing
81 37 Toast
80 35 Troy
80 35 Wadesboro
78 36 Warrenton
78 35 Warsaw
83 35 Waynesville

79 34 Whiteville
77 36 Williamston
78 34 Wilmington
77 36 Windsor
80 36 Winston-Salem
81 36 Yadkinville

NORTH DAKOTA
99 46 Ashley
104 47 Beach
100 49 Belcourt
102 47 Beulah
101 47 Bismarck
100 49 Bottineau
102 49 Bowbells
103 46 Bowman
99 48 Cando
99 47 Carrington
101 47 Center
98 47 Cooperstown
103 49 Crosby
99 48 Devils Lake
103 47 Dickinson
97 49 Drayton
102 46 Elgin
99 46 Ellendale
103 47 Fairfield
97 47 Fargo
98 48 Finley
101 46 Fort Yates
101 48 Garrison
97 48 Grand Forks
104 49 Grenora
98 46 Gwinner
100 48 Harvey
103 46 Hettinger
99 47 Jamestown
102 49 Kenmare
103 47 Killdeer
98 46 La Moure
98 48 Lakota
98 49 Langdon
99 48 Leeds
100 46 Linton
98 46 Lisbon
101 47 Mandan
104 46 Marmarth
97 47 Mayville
100 47 McClusky
101 48 Minot
102 49 Mohall
102 46 Mott
99 49 Munich
100 47 Napoleon
99 48 New Rockford
98 48 Park River
104 46 Rhame
100 48 Rugby
102 48 Stanley
100 47 Steele
98 47 Valley City
101 48 Velva
97 46 Wahpeton
103 48 Watford City
101 49 Westhope
104 48 Williston

OHIO
82 41 Akron
82 41 Ashland
81 42 Ashtabula
82 39 Athens
84 40 Bellefontaine
84 41 Bowling Green
82 41 Brunswick
83 41 Bucyrus
82 40 Byesville
81 40 Cadiz
82 40 Caldwell
81 41 Canton
81 41 Carrollton
85 41 Celina
81 42 Chardon
82 38 Chesapeake
83 39 Chillicothe
84 39 Cincinnati
83 40 Circleville
82 41 Cleveland
83 40 Columbus
82 40 Coshocton
82 40 Crooksville
84 40 Dayton
84 41 Defiance
83 40 Delaware
85 39 Delhi Hills
81 41 East Liverpool
82 42 Euclid
84 40 Fairborn
84 41 Findlay
84 41 Fort Shawnee
84 40 Franklin
83 41 Fremont
82 39 Gallipolis
85 40 Greenville
84 39 Hillsboro
84 40 Jamestown
81 41 Kent
84 41 Kenton
83 40 Lancaster
82 40 Logan
82 41 Lorain
83 41 Mansfield
81 39 Marietta
83 41 Marion
81 40 Martins Ferry
82 39 McArthur
82 40 McConnelsville
81 42 Mentor
82 39 Middleport
84 39 Milford
82 41 Millersburg
83 41 Mount Gilead
82 40 Mount Vernon
84 41 Napoleon
85 40 New Paris
81 40 New Philadelphia
82 40 Newark
83 41 Norwalk
83 42 Oregon
84 41 Ottawa
85 40 Oxford
85 41 Paulding
83 39 Piketon
85 42 Pioneer
84 40 Piqua
83 40 Plain City
83 42 Port Clinton
83 39 Portsmouth
83 40 Richwood
84 39 Ripley
83 41 Sandusky
84 40 Sidney
83 38 South Point
84 40 Springfield
81 40 Steubenville
83 41 Tiffin
84 42 Toledo
83 41 Upper Sandusky
84 40 Urbana
85 41 Van Wert
84 41 Wapakoneta
81 41 Warren
84 42 Wauseon
83 39 Wellston
84 39 West Union
84 39 Wilmington
81 40 Woodsfield
82 41 Wooster
81 41 Youngstown
82 40 Zanesville

OKLAHOMA

97	35	Ada
99	35	Altus
99	37	Alva
98	35	Anadarko
96	34	Antlers
97	34	Ardmore
96	34	Atoka
96	37	Bartlesville
101	37	Beaver
103	37	Boise City
99	35	Burns Flat
96	35	Checotah
98	37	Cherokee
100	36	Cheyenne
98	35	Chickasha
95	36	Chouteau
96	36	Claremore
96	36	Cleveland
96	35	Coalgate
98	35	Duncan
96	34	Durant
94	34	Eastport
100	34	Eldorado
99	35	Elk City
98	36	Enid
98	36	Fairview
99	34	Frederick
102	37	Goodwell
95	37	Grove
97	36	Guthrie
101	37	Guymon
101	36	Hitchland
99	35	Hobart
96	35	Holdenville
100	35	Hollis
96	34	Hugo
95	34	Idabel
98	36	Kingfisher
100	37	Laverne
98	35	Lawton
97	34	Madill
100	35	Mangum
97	34	Marietta
96	35	McAlester
98	37	Medford
95	37	Miami
95	36	Muskogee
97	35	Norman
96	37	Nowata
96	35	Okemah
98	35	Oklahoma City
96	36	Okmulgee
97	35	Pauls Valley
96	37	Pawhuska
97	36	Perry
94	35	Pocola
97	37	Ponca City
95	35	Poteau
97	35	Purcell
95	35	Sallisaw
96	36	Sapulpa
99	36	Seiling
97	35	Seminole
100	36	Shattuck
97	35	Shawnee
95	35	Stigler
97	36	Stillwater
95	36	Stilwell
97	36	Stroud
97	35	Sulphur
95	36	Tahlequah
97	34	Tishomingo
96	36	Tulsa
95	37	Vinita
95	36	Wagoner
98	34	Walters
98	36	Watonga
98	34	Waurika
99	36	Weatherford
95	35	Wilburton
99	36	Woodward
98	36	Yukon

OREGON

123	45	Albany
122	42	Altamont
119	42	Andrews
124	46	Astoria
119	43	Frenchglen
117	46	Bartlett
118	42	Basque
123	45	Beaverton
121	44	Bend
120	46	Boardman
124	42	Brookings
119	44	Burns
122	43	Chiloquin
121	46	City of The Dalles
120	45	Condon
124	43	Coos Bay
123	45	Corvallis
123	45	Dallas
120	44	Dayville
118	43	Dunnean
117	45	Enterprise
123	44	Eugene
120	45	Fossil
123	42	Grants Pass
122	45	Gresham
122	46	Gresham
120	45	Heppner
122	46	Hood River
117	43	Jordan Valley
118	45	La Grande
123	45	Lake Oswego
120	42	Lakeview
121	45	Madras
121	42	Malin
123	45	McMinnville
123	42	Medford
118	46	Milton
124	45	Newport
122	44	Oakridge
117	44	Ontario
121	43	Paisley
119	46	Pendleton
119	45	Pilot Rock
123	46	Portland
121	44	Prineville
124	44	Reedsport
123	43	Roseburg
123	45	Salem
123	46	St. Helens
124	45	Tillamook
118	44	Unity
120	43	Wagontire
121	46	Wasco

PENNSYLVANIA

80	41	Aliquippa
75	41	Allentown
78	41	Altoona
79	40	Bedford
76	41	Berwick
75	41	Bethlehem
79	42	Bradford
80	41	Butler
76	42	Carbondale
77	40	Carlisle
78	40	Chambersburg
79	41	Clarion
78	42	Coudersport
77	41	Danville
79	41	Du Bois
76	42	Dushore
75	41	East Stroudsburg
78	42	Emporium
80	42	Erie
75	42	Forest City
77	40	Gettysburg
77	40	Harrisburg

75	42	Honesdale
78	40	Huntingdon
79	41	Indiana
80	40	Jefferson
79	40	Johnstown
80	41	Kittanning
76	40	Lancaster
76	40	Lebanon
76	41	Lehighton
77	41	Lewisburg
78	41	Lewistown
77	41	Lock Haven
77	42	Mansfield
77	40	Marysville
75	41	Matamoras
78	40	Mc Connellsburg
80	41	New Castle
80	41	New Kensington
75	40	Norristown
80	41	Oil City
81	42	Pennline
75	40	Philadelphia
80	40	Pittsburgh
77	41	Port Royal
76	41	Pottsville
79	41	Punxsutawney
76	40	Reading
77	42	Sayre
76	41	Scranton
77	41	Selinsgrove
81	41	Sharon
79	40	Somerset
79	41	St. Marys
78	41	State College
77	41	Sunbury
79	42	Tionesta
76	42	Tunkhannock
80	40	Uniontown
75	40	Upper Darby
75	40	Warminster
79	42	Warren
81	40	West Alexander
76	40	West Chester
76	41	Wilkes-Barre
77	41	Williamsport
77	40	York

RHODE ISLAND

71	42	Bristol
71	41	Newport
71	42	Providence
71	42	Warwick
72	41	Westerly
72	42	Woonsocket

SOUTH CAROLINA

82	34	Abbeville
81	33	Allendale
83	35	Anderson
81	33	Barnwell
80	35	Bennettsville
80	34	Bishopville
81	34	Camden
81	34	Cameron
81	34	Cayce
80	33	Charleston
80	35	Cheraw
81	35	Chester
82	33	Clearwater
81	34	Columbia
80	34	Darlington
81	33	Denmark
83	35	Easley
82	34	Edgefield
80	32	Edisto Beach
80	34	Florence
82	35	Gaffney
79	33	Georgetown
80	33	Goose Creek
82	35	Greenville
82	34	Greenwood
81	33	Hampton
81	32	Hardeeville
81	32	Hilton Head Island
83	34	Homeland Park
80	34	Kingstree
81	35	Lancaster
82	34	Laurens
81	35	Lockhart
80	34	Manning
79	34	Marion
82	34	McCormick
79	35	Minturn
79	34	Myrtle Beach
82	34	Newberry
81	33	Orangeburg
82	34	Saluda
33	35	Seneca
82	35	Spartanburg
80	33	Summerville
80	34	Sumter
81	33	Walterboro
81	34	Winnsboro
81	35	York

SOUTH DAKOTA

98	45	Aberdeen
98	44	Alexandria
98	43	Armour
104	45	Belle Fourche
96	45	Big Stone City
98	46	Britton
97	44	Brookings
104	46	Buffalo
97	43	Canton
99	44	Chamberlain
98	45	Clark
97	45	Clear Lake
104	44	Custer
98	44	De Smet
102	45	Dupree
101	45	Eagle Butte
104	43	Edgemont
97	45	Estelline
102	45	Faith
99	45	Faulkton
97	44	Flandreau
100	44	Fort Pierre
99	44	Fort Thompson
100	45	Gettysburg
99	43	Gregory
100	46	Herreid
99	45	Highmore
102	43	Hisle
103	43	Hot Springs
98	44	Howard
98	44	Huron
99	45	Ipswich
102	44	Kadoka
102	46	Lemmon
99	46	Leola
103	46	Ludlow
97	44	Madison
102	43	Martin
101	46	McLaughlin
99	45	Miller
101	43	Mission
98	44	Mitchell
100	46	Mobridge
101	44	Murdo
103	45	Newell
96	43	North Sioux City
100	45	Onida
97	43	Parker
98	43	Parkston
102	44	Philip
100	44	Pierre
103	43	Pine Ridge
98	44	Plankinton
100	44	Presho
103	44	Rapid City
99	45	Redfield
97	44	Salem

97 44 Sioux Falls
97 46 Sisseton
104 44 Spearfish
98 43 Springfield
96 44 Valley Springs
97 43 Vermillion
98 43 Wagner
97 45 Watertown
98 45 Webster
99 44 Wessington Springs
101 44 White River
100 43 Winner
98 44 Woonsocket
97 43 Yankton

TENNESSEE

89 36 Alamo
87 36 Ashland City
85 35 Benton
84 36 Blaine
89 35 Bolivar
82 37 Bristol
89 36 Brownsville
85 37 Byrdstown
88 36 Camden
86 36 Carthage
86 37 Celina
87 36 Centerville
85 35 Chattanooga
87 37 Clarksville
85 35 Cleveland
87 36 Columbia
86 36 Cookeville
90 36 Covington
88 37 Crossland
85 36 Crossville
85 35 Dayton
85 36 Decatur
87 36 Dickson
88 36 Dover
85 35 Dunlap
89 36 Dyersburg
82 36 Elizabethton
84 35 Englewood
88 36 Erin
82 36 Erwin
87 35 Fayetteville
87 36 Franklin
86 36 Gainesboro
83 36 Greeneville
85 36 Harriman
86 36 Hartsville
89 35 Henderson
87 36 Hendersonville
88 36 Hohenwald
89 36 Humboldt
89 36 Jackson
85 36 Jamestown
83 36 Jefferson City
84 37 Jellico
82 36 Johnson City
83 37 Kingsport
84 36 Knoxville
86 37 Lafayette
87 35 Lawrenceburg
86 36 Lebanon
84 36 Lenoir City
87 35 Lewisburg
88 36 Lexington
88 36 Linden
85 36 Livingston
86 35 Lynchburg
89 36 Martin
84 36 Maryville
84 36 Maynardville
86 36 Mc Minnville
89 36 Mckenzie
90 35 Memphis
83 36 Morristown
82 36 Mountain City
86 36 Murfreesboro
87 36 Nashville
83 36 Newport
84 36 Oak Ridge
84 36 Oliver Springs
85 37 Oneida
88 36 Paris
88 36 Parsons
85 36 Pikeville
87 35 Pulaski
90 36 Ripley
88 35 Savannah
89 35 Selmer
84 36 Sevierville
86 35 Shelbyville
86 36 Smithville
83 37 Sneedville
89 35 Somerville
89 37 South Fulton
86 35 South Pittsburg
85 36 Sparta
85 36 Spencer
87 37 Springfield
84 36 Sweetwater
84 36 Tazewell
89 36 Tiptonville
86 35 Tracy City
86 35 Tullahoma
88 36 Waverly
88 35 Waynesboro
86 35 Winchester
86 36 Woodbury

TEXAS

100 32 Abilene
99 33 Albany
98 28 Alice
104 30 Alpine
102 35 Amarillo
95 30 Anahuac
103 32 Andrews
107 32 Anthony
99 34 Archer City
98 27 Armstrong
100 33 Aspermont
96 32 Athens
94 33 Atlanta
98 30 Austin
100 32 Ballinger
99 30 Bandera
94 34 Barkman
103 29 Basin Junction
96 29 Bay City
94 30 Beaumont
98 28 Beeville
101 31 Big Lake
101 32 Big Spring
98 30 Blanco
99 30 Boerne
96 34 Bonham
101 36 Booker
101 36 Borger
105 30 Borrachio
98 34 Bowie
100 29 Brackettville
99 31 Brady
99 33 Breckenridge
96 30 Brenham
102 33 Brownfield
97 26 Brownsville
99 32 Brownwood
96 31 Buffalo
98 31 Burnet
97 31 Caldwell
98 28 Calliham
97 31 Cameron
100 30 Camp Wood
100 36 Canadian
96 33 Canton
100 29 Carrizo Springs
101 30 Carta Valley
94 32 Carthage

104 29 Castolon
94 32 Center
100 34 Childress
99 32 Cisco
101 35 Clarendon
95 34 Clarksville
101 35 Claude
97 32 Cleburne
95 30 Cleveland
98 32 Clifton
99 32 Clyde
99 32 Coleman
96 31 College Station
101 32 Colorado City
97 30 Columbus
99 32 Comanche
95 30 Conroe
96 33 Cooper
98 31 Copperas Cove
97 28 Corpus Christi
96 32 Corsicana
99 28 Cotulla
102 31 Crane
95 31 Crockett
100 34 Crowell
100 29 Crystal City
97 29 Cuero
95 33 Daingerfield
103 36 Dalhart
97 33 Dallas
98 33 Decatur
101 29 Del Rio
105 32 Dell City
97 33 Denton
103 33 Denver City
102 35 Dimmitt
102 36 Dumas
100 29 Eagle Pass
96 30 East Bernard
100 31 Eden
97 29 Edna
96 29 El Campo
97 27 El Martillo
106 32 El Paso
101 31 Eldorado
97 30 Elgin
96 33 Emory
96 32 Fairfield
98 27 Falfurrias
103 30 Farwell
100 34 Finney
98 29 Floresville
101 34 Floydada
103 31 Fort Stockton
97 33 Fort Worth
99 30 Fredericksburg
103 35 Friona
101 33 Gail
97 34 Gainesville
95 29 Galveston
101 32 Garden City
98 28 George West
97 30 Giddings
95 33 Gladewater
98 32 Glen Rose
99 31 Goldthwaite
97 29 Goliad
97 30 Gonzales
99 33 Graham
98 32 Granbury
96 33 Greenville
97 29 Hallettsville
98 32 Hamilton
100 33 Hamlin
100 33 Haskell
97 31 Hearne
99 27 Hebbronville
94 31 Hemphill
95 32 Henderson
98 34 Henrietta
102 35 Hereford
97 32 Hillsboro
99 29 Hondo
95 30 Houston
96 31 Huntsville
98 33 Jacksboro
95 32 Jacksonville
94 31 Jasper
101 33 Jayton
94 33 Jefferson
100 30 Junction
98 29 Kenedy
103 32 Kermit
99 30 Kerrville
98 31 Killeen
98 31 Kingsland
98 28 Kingsville
97 30 La Grange
106 31 La Isla
95 29 Lake Jackson
101 35 Lakeview
102 33 Lamesa
98 31 Lampasas
100 28 Laredo
102 34 Levelland
102 34 Littlefield
95 31 Livingston
98 30 Lockhart
95 33 Longview
102 34 Lubbock
95 31 Lufkin
96 31 Madisonville
97 31 Marlin
94 33 Marshall
99 31 Mason
101 34 Matador
102 31 Mc Camey
98 26 McAllen
100 31 Menard
104 32 Mentone
101 31 Mertzon
96 32 Mexia
101 36 Miami
102 32 Midland
95 33 Mineola
98 33 Mineral Wells
96 30 Missouri City
103 32 Monahans
103 34 Morton
95 33 Mount Pleasant
103 34 Muleshoe
100 33 Munday
95 32 Nacogdoches
96 30 Navasota
98 30 New Braunfels
94 31 Newton
102 32 Odessa
104 32 Old Christian Place
94 30 Orange
101 31 Ozona
100 34 Paducah
96 32 Palestine
101 36 Pampa
101 35 Panhandle
96 34 Paris
99 29 Pearsall
103 31 Pecos
101 36 Perryton
95 33 Pittsburg
102 34 Plainview
97 33 Plano
98 29 Pleasanton
96 28 Port O'Conner
97 28 Portland
101 33 Post
96 30 Prairie View
100 34 Quanah
101 34 Ralls
98 26 Raymondville
97 28 Refugio
99 26 Rio Grande City
97 28 Rockport

96 33 Rockwall
98 31 Round Rock
100 31 San Angelo
98 29 San Antonio
94 32 San Augustine
98 28 San Diego
98 30 San Marcos
99 31 San Saba
102 30 Sanderson
96 30 Sealy
98 30 Seguin
103 33 Seminole
99 34 Seymour
100 35 Shamrock
95 30 Shepherd
97 34 Sherman
94 30 Silsbee
101 34 Silverton
101 33 Snyder
101 31 Sonora
101 36 Spearman
101 33 Spur
100 33 Stamford
102 32 Stanton
98 32 Stephenville
101 32 Sterling City
102 36 Stratford
96 33 Sulphur springs
100 32 Sweetwater
102 33 Tahoka
97 31 Temple
96 33 Terrell
94 33 Texarkana
99 33 Throckmorton
95 31 Trinity
102 35 Tulia
95 32 Tyler
100 29 Uvalde
104 31 Valentine
105 31 Van Horn
102 35 Vega
99 34 Vernon
97 29 Victoria
97 32 Waco
97 32 Waxahachie
98 33 Weatherford
100 35 Wellington
98 34 Wichita Falls
95 33 Winnsboro
94 31 Woodville
99 27 Zapata

UTAH
112 37 Alton
109 37 Aneth
113 38 Beaver
109 38 Blanding
110 37 Bluff
109 40 Bonanza
112 41 Bountiful
114 40 Callao
113 38 Cedar City
112 38 Circleville
109 39 Cottonwood
113 39 Delta
113 40 Dugway
109 41 Dutch John
114 38 Enterprise
112 39 Ephraim
114 39 Eskdale
111 37 Halls Crossing
111 41 Heber
110 38 Hite
113 41 Hogup
111 39 Huntington
113 37 Hurricane
112 42 Logan
110 39 Moab
112 41 Morgan City
112 41 Ogden
112 38 Panguitch
111 41 Park City
111 40 Price
112 40 Provo
111 42 Randolph
112 39 Richfield
110 41 Roosevelt
112 41 Salt Lake City
113 42 Snowville
114 37 St. George
111 38 Torrey
110 40 Vernal
114 41 Wendover
114 42 Yost

VERMONT
73 45 Alburg
73 44 Barre
73 43 Bennington
73 43 Brattleboro
73 44 Burlington
72 45 Hardwick
72 45 Island Pond
73 44 Middlebury
73 45 Morrisville
72 45 Newport
73 44 Randolph
73 44 Rutland
72 43 Springfield
73 45 Swanton
72 44 White River Junction

VIRGINIA
82 37 Abingdon
77 39 Alexandria
78 37 Amelia Court House
77 39 Annandale
79 37 Appomattox
77 39 Arlington
77 37 Barnetts
80 37 Bedford
78 39 Berryville
83 37 Big Stone Gap
78 37 Blackstone
81 37 Bland
80 39 Blue Grass
80 37 Blue Ridge
81 37 Bluefield
77 38 Bowling Green
82 37 Bristol
79 38 Buena Vista
76 37 Cape Charles
78 38 Charlottesville
76 37 Chesapeake
77 37 Chester
75 38 Chincoteague
80 37 Christiansburg
77 37 Claremont
80 38 Clifton Forge
82 37 Clintwood
77 38 Colonial Beach
77 37 Colonial Heights
77 37 Courtland
80 38 Covington
78 38 Culpeper
77 39 Dale City
79 37 Danville
76 38 Deltaville
78 38 Dillwyn
78 37 Emporia
77 39 Falls Church
78 37 Farmville
78 38 Farmville (Cumberland)
80 37 Floyd
77 37 Fort Lee
77 37 Franklin
77 38 Fredericksburg
78 39 Front Royal
81 37 Galax
83 37 Gate City

84	37	Gibson Mill
79	37	Glenwood
76	37	Gloucester Point
78	38	Goochland
76	37	Hampton
79	38	Harrisonburg
76	38	Heathsville
81	37	Hillsville
77	37	Hopewell
81	37	Independence
78	38	Jefferson
77	37	Jericho
78	37	Keysville
76	38	Kilmarnock
77	38	King George
78	37	Lawrenceville
82	37	Lebanon
79	38	Lexington
78	38	Louisa
79	38	Lovingston
78	39	Luray
79	37	Lynchburg
78	38	Madison
79	37	Madison Heights
77	39	Manassas Park
82	37	Marion
80	37	Martinsville
76	37	Mathews
78	37	Mc Kenny
77	38	Mechanicsville
81	37	Narrows
77	38	New Kent
80	38	Newcastle
76	37	Newport News
76	37	Norfolk
83	37	Norton
76	38	Onancock
78	38	Orange
77	37	Petersburg
76	37	Poquoson
76	37	Portsmouth
81	37	Pulaski
77	39	Quantico Station
81	37	Radford
77	38	Richmond
80	37	Roanoke
80	37	Rocky Mount
80	37	Salem
78	38	Scottsville
77	38	Shacklefords
77	37	Smithfield
79	37	South Boston
78	37	South Hill
78	38	Spotsylvania
78	38	Stanardsville
79	38	Staunton
77	39	Sterling Park
80	37	Stuart
77	37	Suffolk
77	38	Tappahannock
79	37	Timberlake
78	38	Tuckahoe
82	37	Vansant
78	37	Victoria
76	37	Virginia Beach
80	38	Warm Springs
78	39	Warrenton
77	38	Warsaw
78	39	Washington
77	37	Waverly
79	38	Waynesboro
77	38	West Point
77	37	Williamsburg
78	39	Winchester
79	37	Wolf Trap
79	39	Woodstock
81	37	Wytheville

WASHINGTON

123	47	Agate
123	49	Anacortes
122	49	Bellingham
123	48	Bremerton
122	46	Camas
123	46	Cathlamet
123	47	Centralia
118	47	Cheney
117	46	Clarkston
118	49	Colville
120	49	Conconully
121	49	Corkindale
119	48	Coulee Dam
118	48	Davenport
120	47	East Wenatchee
121	47	Ellensburg
122	48	Everett
124	48	Forks
123	49	Friday Harbor
121	46	Goldendale
124	47	Hoquiam
117	49	Ione
119	46	Kennewick
125	48	La Push
121	48	Leavenworth
124	46	Long Beach
123	46	Longview
118	48	Medical Lake
119	47	Moses Lake
122	46	North Bonneville
123	48	Oak Harbor
123	47	Olympia
120	48	Omak
119	49	Oroville
119	47	Othello
119	46	Pasco
118	46	Pomeroy
123	48	Port Townsend
117	47	Pullman
119	49	Republic
122	48	Seattle
117	48	Spokane
118	47	Starbuck
122	47	Tacoma
120	46	Toppenish
123	46	Vancouver
118	46	Walla Walla
120	47	Wenatchee
121	47	Yakima

WEST VIRGINIA

81	38	Beckley
81	39	Belmont
81	37	Bluefield
79	39	Brandywine
80	39	Buckhannon
78	39	Charles Town
82	38	Charleston
81	41	Chester
80	39	Clarksburg
81	38	Clay
81	38	Cowen
81	39	Elizabeth
80	39	Elkins
80	39	Fairmont
81	38	Fayetteville
81	40	Follansbee
81	39	Gassaway
81	39	Glenville
80	39	Grafton
81	39	Grantsville
82	38	Hamlin
81	39	Harrisville
78	40	Hedgesville
81	38	Hinton
82	38	Huntington
82	38	Hurricane
83	38	Kenova
79	39	Keyser
80	39	Kingwood
82	38	Logan
82	38	Madison
80	38	Marlinton

78	39	Martinsburg
79	39	Moorefield
80	40	Morgantown
81	40	Moundsville
81	38	Mullens
81	40	New Martinsville
78	39	Oakland
81	40	Paden City
82	39	Parkersburg
80	39	Parsons
79	39	Petersburg
80	39	Philippi
82	39	Point Pleasant
82	39	Ravenswood
81	38	Richwood
79	39	Romney
81	39	Spencer
80	37	Waiteville
82	37	Welch
81	39	West Union
80	39	Weston
81	40	Wheeling
80	38	White Sulphur Springs
79	40	Wiley Ford
82	38	Williamson

WISCONSIN

87	45	Algoma
92	45	Amery
89	45	Antigo
88	44	Appleton
92	44	Arcadia
91	47	Ashland
88	46	Aurora
90	43	Baraboo
89	43	Beaver Dam
89	42	Bergen
89	44	Berlin
91	44	Black River Falls
90	47	Cedar
91	45	Chippewa Falls
89	46	Crandon
90	43	Darlington
90	43	Dodgeville
92	45	Durand
89	46	Eagle River
91	45	Eau Claire
88	44	Fond du Lac
90	44	Friendship
88	42	Genoa City
93	46	Grantsburg
88	45	Green Bay
91	46	Hayward
93	45	Hudson
88	43	Kenosha
91	44	La Crosse
91	45	Ladysmith
89	43	Madison
88	44	Manitowoc
90	44	Mauston
90	45	Medford
92	45	Menomonie
88	43	Mequon
90	45	Merrill
90	43	Middleton
88	43	Milwaukee
92	45	Mondovi
90	43	Monroe
89	44	Montello
91	45	Neillsville
89	45	Neopit
88	44	New Holstein
89	44	New London
88	46	Niagara
88	45	Oconto
89	44	Oshkosh
90	46	Park Falls
90	43	Platteville
89	44	Portage
91	43	Prairie du Chien
88	43	Racine
89	46	Rhinelander
92	46	Rice Lake
90	43	Richland Center
93	45	River Falls
89	45	Shawano
88	44	Sheboygan
92	46	Spooner
90	45	Stevens Point
87	45	Sturgeon Bay
92	47	Superior
91	44	Tomah
91	44	Viroqua
91	47	Washburn
89	43	Watertown
88	43	Waukesha
90	45	Wausau
89	44	Wautoma
88	43	West Bend
90	44	Wisconsin Rapids

WYOMING

104	45	Aladdin
107	43	Alcova
111	44	Alta
108	41	Baggs
110	45	Bannock Ford
107	44	Buffalo
106	43	Casper
105	41	Cheyenne
106	45	Clearmont
109	45	Cody
105	43	Douglas
110	44	Dubois
111	41	Evanston
109	41	Firehole Canyon
106	44	Gillette
105	45	Hulett
111	43	Jackson
108	42	Jeffrey City
111	42	Kemmerer
110	42	La Barge
109	43	Lander
106	41	Laramie
108	45	Lovell
104	43	Lusk
110	41	Lyman
111	45	Mammoth
106	42	Medicine Bow
109	44	Meeteetse
104	44	Newcastle
104	41	Pine Bluffs
110	43	Pinedale
107	42	Rawlins
108	43	Riverton
109	42	Rock Springs
107	41	Saratoga
107	45	Sheridan
108	44	Thermopolis
104	42	Torrington
105	44	Upton
105	42	Wheatland
108	44	Worland

APPENDIX B

Illuminance

The light of the Sun, Moon and night sky which reaches the surface of the Earth is modified by the atmosphere, which refracts, absorbs, polarizes and scatters the radiation passing through it in rather complex ways. For practical work it is often impossible to obtain measurements of atmospheric parameters that would be required to support a detailed and precise calculation of illuminance. Consequently, some general approximations must be made.

For the direct rays of the Sun or Moon, it is necessary to specify the location of each body relative to the point on the Earth in question. The mathematical methods adopted for the computer programs, tables and diagrams to provide altitude and azimuth are explained in textbooks on spherical astronomy (1,2) and are not reproduced here. Some additional considerations in the formulation, needed to compute illuminance, are discussed below.

The model for illuminance calculation recognizes three contributions at ground level: the direct rays of the Sun and Moon, indirect or skylight and the light of the night sky background. With the angular distance from the horizon of the Sun or Moon known, the effect of the atmosphere was modelled using the computed altitude as independent variable. For the direct rays of the Sun or Moon, the illuminance is that at the top of the atmosphere, reduced by the scattering and absorption of the mass of air along the light path to the surface. To approximate the atmosphere, we have adopted a spherical, homogeneous (or constant density) model; and for the air mass, the values determined by Bemporad (3) were fit. The formulation thus reduces to a simple differential equation, the solution of which introduces a parameter specifying the extinction of light per unit of air mass. To estimate the extinction coefficient, the data provided by Jones and Condit (4) as a result of their exhaustive study were used. The resulting expression for the direct rays is then a simple exponential formula, factored by the *sine* of the altitude to provide the horizontal component of illuminance by direct radiation.

For the light of the sky with direct rays excluded, the second contribution to total illuminance, a purely empirical representation was built up from the tables for indirect light provided by Jones and Condit. The tables give values for altitude ranging from the zenith to three degrees above the horizon.

Altitudes of the Sun closer to the horizon are of special importance in many applications, however. In order to model the situation near rising, setting and twilight, the formulas were extended to fit data collected and reduced by Brown (5), which provide light levels for solar altitude ranging from +90 deg. to -90 deg. The data published by Brown are of a different character than those of Jones and Condit. The separate contributions to illuminance by direct and scattered light are not distinguished. However, the data represent a more complete range of solar altitude, collected over a vast geographic area, and the final values are based on smoothing of an impressive number of measurements. The basic curve constructed by Brown is still relied upon for assessments of natural lighting and has appeared intact or enhanced in numerous studies and handbooks. But the original report by Brown is no longer readily accessible and his instrumental and reduction procedures are not well known. A digression in order to quote all relevant parts of his original report appears to be justified:

> "*Derivation of Basic Curve and Table.* More than 12,000 measurements were made by the author in the Arctic, Antarctic, and the temperate and torrid zones of both hemispheres between January 1943 and May 1947. Photoelectric illuminometers manufactured by the General Electric Company were used for the measurement of light levels above one foot candle. Lower levels were measured by means of a Luckiesh-Taylor Brightness Meter and a calibrated test plate. The illuminometers were calibrated by the U.S. Bureau of Standards before and after the measurements were made. The brightness photometers were calibrated by the Nela Park Laboratory of the General Electric Company.
>
> "The original data were plotted at large scale and a smooth curve was drawn. This basic curve was found to be in good agreement with fractional curves published in the scientific literature by Jones and Condit and others.
>
> "The first plate (unnumbered) is the basic curve which gives the illumination as a function of solar altitude. The second plate (also unnumbered) is a table of illumination values corresponding to each degree of altitude of the sun from -90 to -21 degrees and from 65 to 90 degrees. Illumination values are given for each tenth of degree of solar altitude from -20 to 64 degrees. In most cases, the figures given are representative of the precision indicated; however, in the lowest levels of illumination, below 5 X 10 (when the sun is 19.5 degrees or more below the horizon), three significant figures are not justified by the data. Likewise, above 1000-foot candles (9.9 degrees solar altitude and above) the value of illumination is considered significant to no more than three figures although four are occasionally given in the table. Actually, the values given in the table were taken from a minute reading of the basic curve, greatly enlarged in scale, and present a truer picture of the curve than could be made by straight interpolation of the table had only two or three figures been given."

In regard to departures from a clear sky, Brown first notes that his basic graph refers to an average, not exceptionally, clear sky:

> "*Clear vs. Cloudy Conditions.* The charts and tables contained herein, refer to light conditions during average clear days, clear days being defined as less than seven tenths overcast and with the sun's rays unobstructed to the locality in question.

When the sun is obstructed by thin clouds, the values given should be divided by two. For average cloud conditions obstructing the sun's rays, the values given for clear days should be divided by three. Occasionally, for dark stratus clouds preceding a heavy thunder storm, the values given should be divided by ten. However, this is not common."

The formula finally adopted in the present work represents the data of the two cited works for altitudes of the Sun from the zenith to that of nautical twilight. The third component of illuminance, which can vary unpredictably, has been represented by a constant, additive term equal to .0005 lux.

Thus far, what has been described applies to sunlight and the night sky. The same applies to illuminance by the Moon, with additional considerations. In addition to atmospheric attenuation of light, the Moon's illuminance depends upon its phase and its distance from the point on the Earth's surface being considered. For the phase function, the approximation derived by Lumme and Bowell (6) was adopted, using representative values of the multiple scattering factor and zero phase magnitude published by Lumme and Irvine (7) for the visible part of the spectrum. To account for the eccentricity of the lunar orbit and a topocentric (rather than geocentric) reference point, the ratio of mean to true distances was formulated and introduced as a factor of the Moon's illuminance. This is one exception to ordinary calculations of the Moon's position in which only the direction (altitude and azimuth) is of interest.

Another exception to the straightforward calculation for either the Sun or Moon should be noted. The usual situation in navigation, astronomy and other disciplines is one in which an observed altitude of the celestial body must be corrected for refraction in order to obtain a strictly geometric altitude. The calculation of air mass, needed for determination of extinction, requires apparent altitude; that is, the altitude affected by refraction. Theories and tables for refraction give corrections for the usual case: the reduction from observed to geometric altitude. Formulas derived by Bennett (8) are succinct and particularly attractive for such purposes. It was found that by changing one constant in Bennett's first approximate formula, his equation G, the same expression produced the amount of refraction to be added to the geometric altitude in order to obtain the apparent altitude required for the computation of air mass. The modified formula was coded into the computer routines of this work.

It is important to note a few of the limitations of the computer programs which have not been explicitly stated. Of the many factors which influence the real illuminance, it was not possible to include the effect of height above sea level, the moisture or dust content of air, the albedo of the ground itself, or the non-uniform distribution of illuminance from the sky (which may be important near times of sunrise or sunset). Also, isothermal and polytropic models of the atmosphere would be more realistic than the one adopted. That the criteria for factoring illuminance to accommodate cloud cover is questionable is acknowleged. However, the main purpose of the work is to provide manageable tools for ordinary purposes and means. To include many of the refinements would be to expand the computer programs and to make their use both complicated and dependent on direct measurements of the atmosphere. In regard to the factors for clouds, it was thought best to maintain the criteria stated by Brown, since it does not seem possible to retrieve his original raw data and notes. But the factors are entered into the computer routines directly, so that it is entirely possible for a user to compare measured values of illuminance with computed, and to devise and apply a set of factors more suited to particular circumstances, without making any program changes.

With shortcomings noted, it is worthwhile to repeat a point that has been stated throughout: Calculated values of illuminance should be regarded with caution.

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