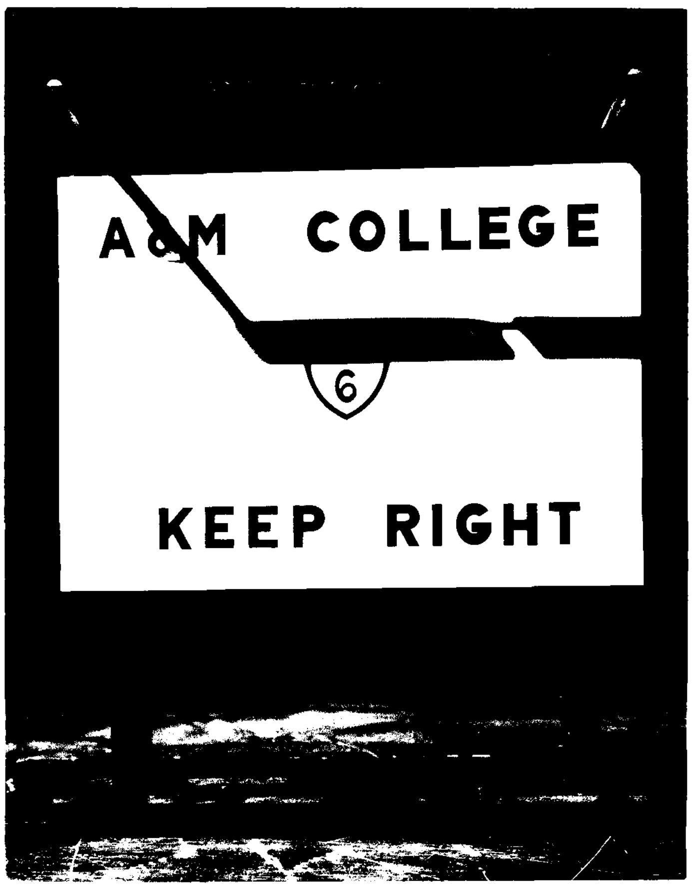
SUN-SHADOW PATTERNS ON HIGHWAY SIGNS

A Report to the Texas Highway Department
On Research Project HPS 1(23)A

By

ROBERT M. OLSON



Texas Transportation Institute
Texas A. & M. College System
College Station, Texas

June 30, 1961

Mr. T. S. Huff
Chairman, Research Committee
Texas Highway Department
Austin 14, Texas

Dear Mr. Huff:

The studies that we have been conducting under HPS 1(23)A for the Texas Highway Department on the illumination of overhead signs have shown that the largest interstate standard overhead signs will probably be inadequately illuminated by bottom-mounted standard fluorescent fixtures. In addition to investigating the illumination characteristics of other fixtures we have concerned ourselves briefly with the possibility of using top-mounted fixtures to provide the needed additional illumination.

When one considers top versus bottom mounting of fixtures, in addition to maintenance problems there are a number of factors to consider, such as the need for covers, the obscuring of the message by the fixture, specular reflection from the sign face, clearance considerations, and the shielding of lights from opposing traffic. The most important objection to top-mounted fixtures stems from the obscuring of the sign message by the sun shadow cast on the face of the sign by the fixture.

We have made a brief but intensive study of the characteristics of sun shadows created by top-mounted sign lighting fixtures. The attached report by Professor Olson of our staff presents the most significant findings of this study. Although it is impossible to eliminate sun shadows in Texas latitudes, it appears possible to partially control the time and type of shadow produced by the sun through design. As the report indicates, we have identified the magnitude of the problem and are certain that for specific field applications the burden of lengthy and complex calculations by district personnel could be eliminated.

The attached report is transmitted for your comments and suggestions as to whether or not the Texas Highway Department has an immediate interest in the extension of this study. We would be pleased to conduct additional studies involving sign or other shadow effects and to cooperate in the preparation of design procedures for field personnel. To assist us in planning our research program we would appreciate learning of your desires at an early date.

Very truly yours,

Donald E. Cleveland

Donald E. Cleveland
Assistant Research Engineer

DEC dl

SUN-SHADOW PATTERNS ON HIGHWAY SIGNS

by Robert M. Olson

INTRODUCTION

When an illuminating system is installed at the top of a sign, see Figure 1, the face of the sign and the sign's message area are subject to interference from the sun-shadow cast by the illuminating system. This report contains the results of an investigation of the sun-shadow patterns cast by illuminating systems. The investigation consisted of (1) Analytical prediction of shadow patterns, (2) Observation of shadow patterns by models (3) Observation of shadow patterns on an outdoor sign (4) Verification of the analytical prediction of sun-shadow patterns by model observations and by observation of an outdoor sign.

ASSUMPTIONS AND LIMITATIONS

1. Unobscured sunlight during daylight hours.
2. Calculations and data are based on solar time.
3. Calculations and data are for 32° N. Latitude.
4. Illuminating system is the same width as the sign.

DEFINITIONS

1. Interference Area (A_i): The portion of the sign subject to shadow at any moment during daylight hours. (The shaded area shown in elevation view, Figure 2.)

2. Point P: The point cast in the plane of the sign by the extreme corner points of the lighting system. Point P is

located by coordinates (x,y) measured from the upper corners of the sign and it may fall outside the actual sign but is always located in the plane containing the sign's message.

3. Overhang dimension (a): The distance to the corner points (left or right) of the lighting system (see Figure 2). The dimension "a" is located in a plane normal to the sign's surface and parallel to the horizon.

4. Profile Angle (α): An angle located in a vertical plane which is mutually perpendicular to the horizon plane and the sign's message; the profile angle is included between a horizontal line and the component of a ray of the sun in the subject plane. (See Figure 2).

5. Normal Angle (ψ): An angle located in a horizontal plane; the normal angle is included between the line normal to the message and the horizontal component of a ray of the sun (see Figure 2).

ANALYTICAL PROCEDURE

It can be shown that the point, P (x,y) is a function of the sun's altitude and bearing. The altitude and bearing of the sun being those usually defined in the horizon system widely used by surveyors and navigators. Furthermore it can be shown that the altitude and bearing of the sun are functions of the latitude of the place where the sign is located, the declination of the sun at the moment of observation and the meridian angle (or sun's hour angle). These latter variables are those usually defined in the celestial system for locating the sun, or for locating the position of a point on the earth's surface.

Based on relationships between these variables the equations indicated on Figure 2 for locating point P (x,y) have been developed. These governing relations were developed by the author based on information furnished by the Department of Meteorology and Oceanography of the A. and M. College of Texas[1] and others[2].

The analytical investigation consisted of the solution for the location of the point P on a sign located at 32° N. Latitude, during daylight hours (6 AM to 6 PM) on four critical days of the year, March 21, (Vernal Equinox), June 22 (Summer Solstice), September 23 (Autumnal Equinox), and December 22 (Winter Solstice), for eight orientations of the sign (viz: Sign facing South, South-East, East, North-East, North, North-West, West and South-West).

Interference areas were calculated and plotted for the twelve daylight hours on each of the four days considered and for the eight sign orientations selected. A typical set of interference areas are shown in Figure 3. The message area was arbitrarily chosen to be 10' x 10' and the overhang dimension was selected arbitrarily as 4 feet. The Interference Areas plotted in Figure 3 are for the South orientation. The greatest interference occurs for this orientation since the sun bears southerly from all points in the northern hemisphere.

DISCUSSION OF THE ANALYSIS

It is apparent from an examination of the interference areas that the message area of a highway sign is subject to sun-shadow interference during part of every day in the year. The greatest interference occurs on signs facing South, the least interference is encountered on signs facing North. A predictable regularity of interference exists for all sign orientations between these extremes.

It is further apparent that the equinoctial sun-shadow patterns are identical. However, the sun-shadow patterns at the soltices are not identical. Thus any analysis used for design purposes must consider the sun-shadow transit across the sign's message for the entire year.

A definite regularity is observed for sign orientations which are located 180° from each other. That is to say, for each orientation the sun is directed at the back of a sign during a part of the day for every non-equinoctial day.

Every vertical highway sign is subject to a sun-shadow pattern of some shape at some time during the year. The shape of shadow is variable, however. By examination of Figure 3, for example, it becomes evident that the sun-shadow pattern consists of three general shapes: (1) Triangular, (2) Trapezoidal, and (3) Rectangular. The triangular shaped-pattern is composed of the shadow of the member supporting the illumination system. The trapezoidal-shaped pattern is composed of the shadow of the supporting member and the shadow of the illumination fixture. The rectangular-shaped pattern consists of the shadow of the illuminating fixture only.

These three sun-shadow shapes are of considerable significance. The horizontal portion of the pattern cast by the illuminating fixture causes greater interference than does the oblique portion cast by the cantilever overhang part.

Closer observation of Figure 3 leads to the conclusion that the horizontal portion of the sun-shadow pattern transits from a "starting" position at the vernal equinox downward beyond the limits of the sign at the Summer Solstice, then transits upwards until it reaches the "starting" position at the Autumnal Equinox. The horizontal portion then continues to transit upwards until it reaches a "maximum" position at the winter solstice. During this annual transit the horizontal portion of the sun-shadow pattern traverses the entire vertical dimension of the message.

These observations made for a sign facing South may be extended to the other orientations and can be useful in selecting luminaire and sign dimensions and other design parameters for minimizing the effect of sun-shadows.

MINIMIZATION OF SUN-SHADOW INTERFERENCE BY DESIGN

The analytical procedure described above furnishes basic information. With this basic information the opportunities for designing sign illuminating systems so as to minimize sun-shadow interference are limited only by the required illumination intensity and structural requirements, economic feasibility, and the design engineer's ingenuity.

It is apparent that a design can be made which will locate the message relative to the illuminating system so as to subject the message to the shadow of this horizontal portion during part of the winter months only. Investigation might reveal that cloud cover is extensive during these months. Thus interference with the message may be minimized even though not eliminated.

Since it is not possible to completely eliminate the sun-shadow from the face of a sign another approach might be made to the design problem. For example, the shadow cast by the overhead illuminating system might be combined with side overhangs to produce complete shadow during daylight hours. Such an approach would also protect the sign surface materials, and structural design advantages might accrue to permit savings in weight and material.

In order to assist the designer in solving sun-shadow patterns, time-trace diagrams similar to that shown in Figure 4 have been prepared for each of the twelve daylight hours, on the four seasonal days, and for the eight selected orientations. These time-trace diagrams are for an overhang dimension "a" equal to one foot. It is a simple matter to enter the diagram for the hour under consideration, read the values of x and y, multiply each by the length of overhang "a" and then plot the position of Point P (x,y) on the plane of the sign of dimensions X and Y. For example, if the dimension "a" is 4 feet and we want to determine the position of point P (x,y) at 10 AM on March 21 (Vernal Equinox) we read directly from Figure 4: x=1.1' and y=1.6', then the point P (x,y) is located at x=4.4' and y=6.4' from the upper right hand corner.

CONCLUSION

Sun-shadows on highway signs cannot be eliminated completely. It is possible to minimize the effect of these shadows, or even to put the shadows to use.

The analytical procedure outlined in this report could be programmed for digital computers.

SPECIFIC REFERENCES

1. Franceschini, Guy A., Assistant Professor of Oceanography and Meteorology, The A. and M. College of Texas, Unpublished lecture notes.

2. Hand, Irving F., "Charts to Obtain Solar Altitudes and Azimuths", <u>Heating and Ventilating</u>, October, 1948, pp. 86-88.

GENERAL REFERENCES

"Navigation and Nautical Astronomy", (Revised 1951), Benjamin Dutton, U. S. Naval Institute, Annapolis, Maryland.

"Basic Marine Navigation", B. J. Bok, F. W. Wright, Houghton, Mifflin Company, New York, N.Y.

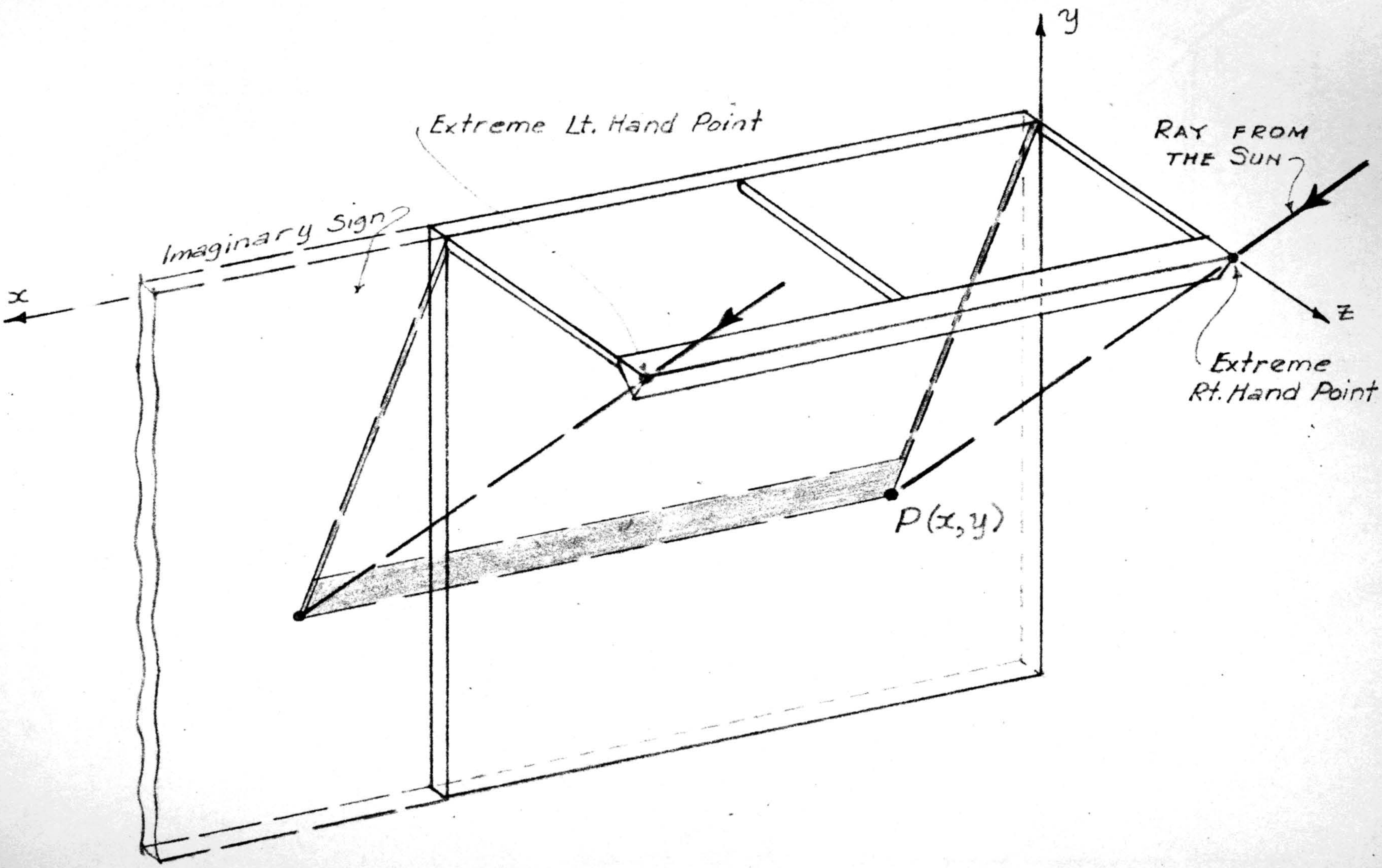
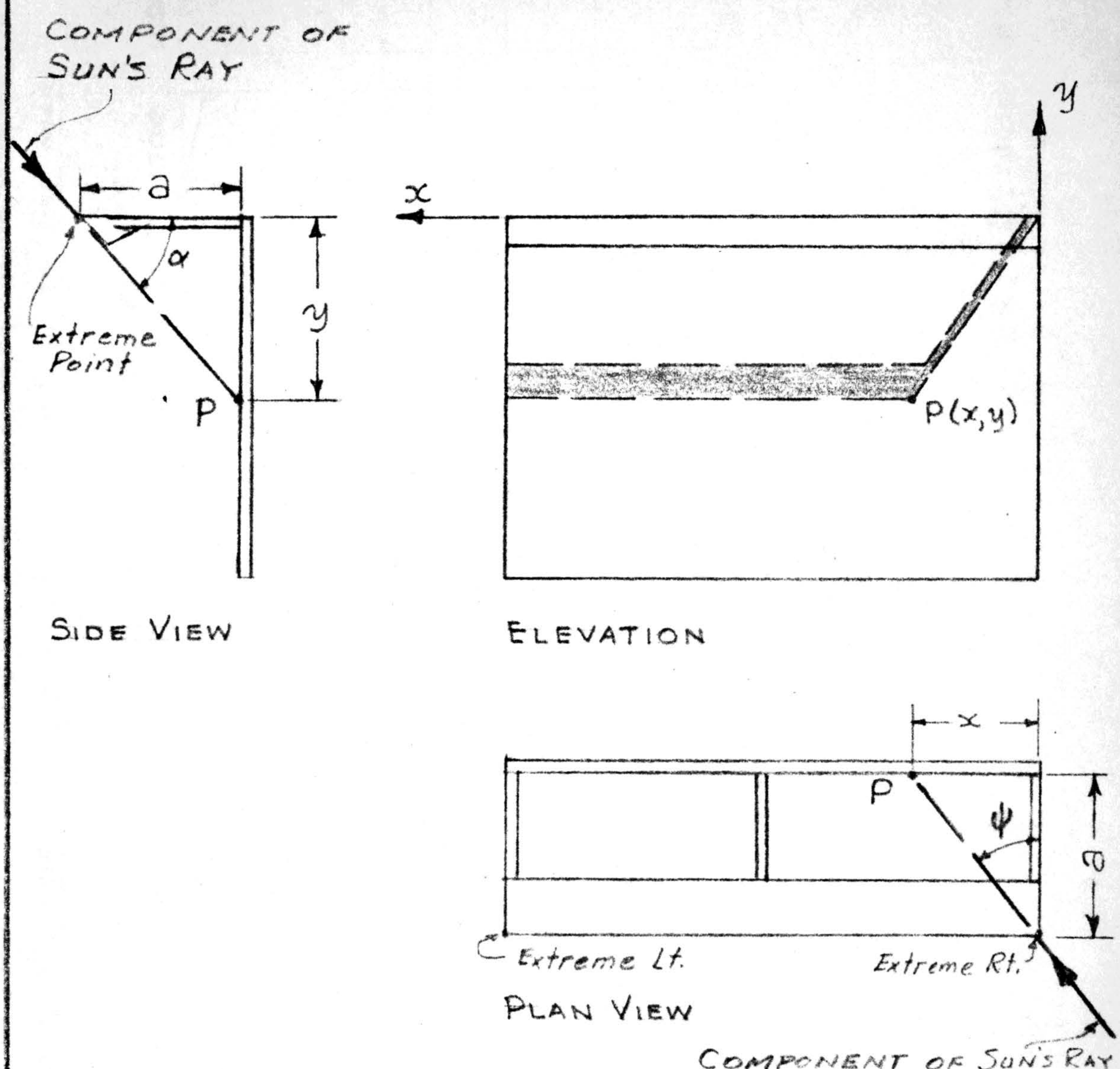

y
Extreme Lt. Hand Point
RAY FROM
THE SUN
Imaginary Sign
x
z
Extreme
Rt. Hand Point
P(x,y)

FIGURE 1

R.M.O.



GOVERNING RELATIONS

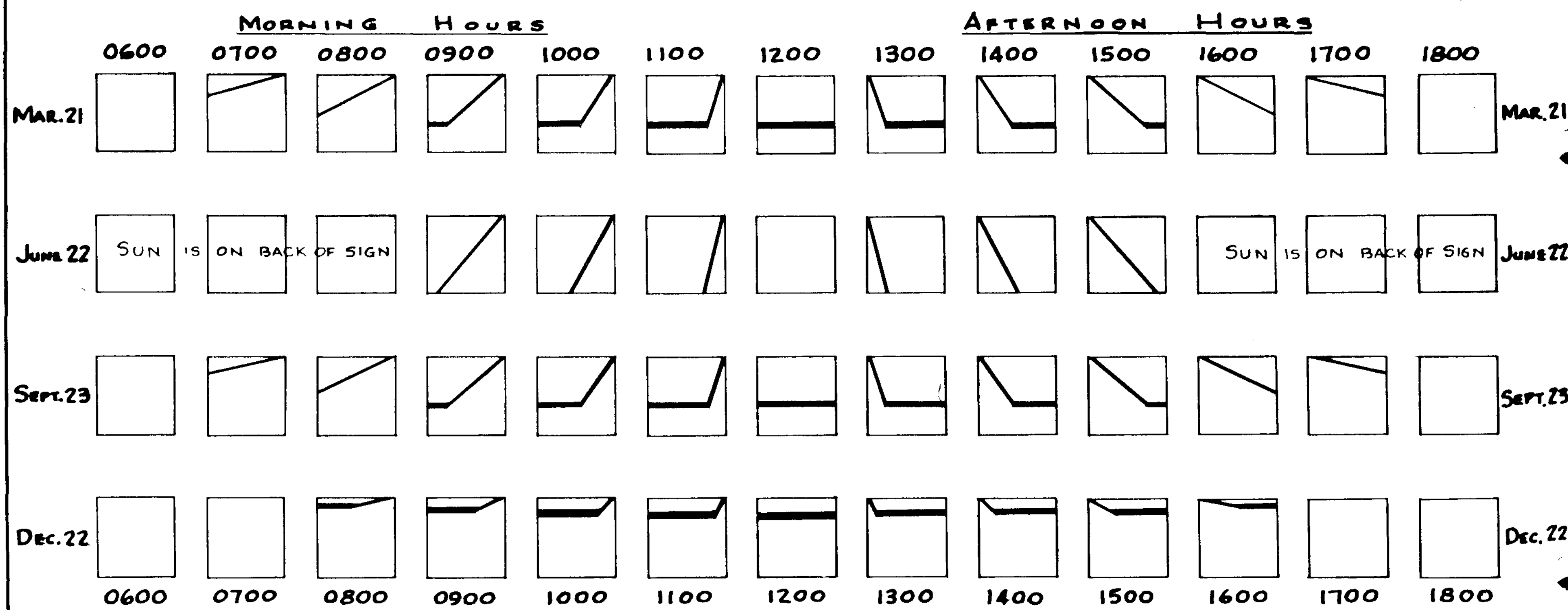
$$x = a \cdot \tan \psi$$

$$y = a \cdot \tan \alpha$$

FIGURE 2

R.M.O.

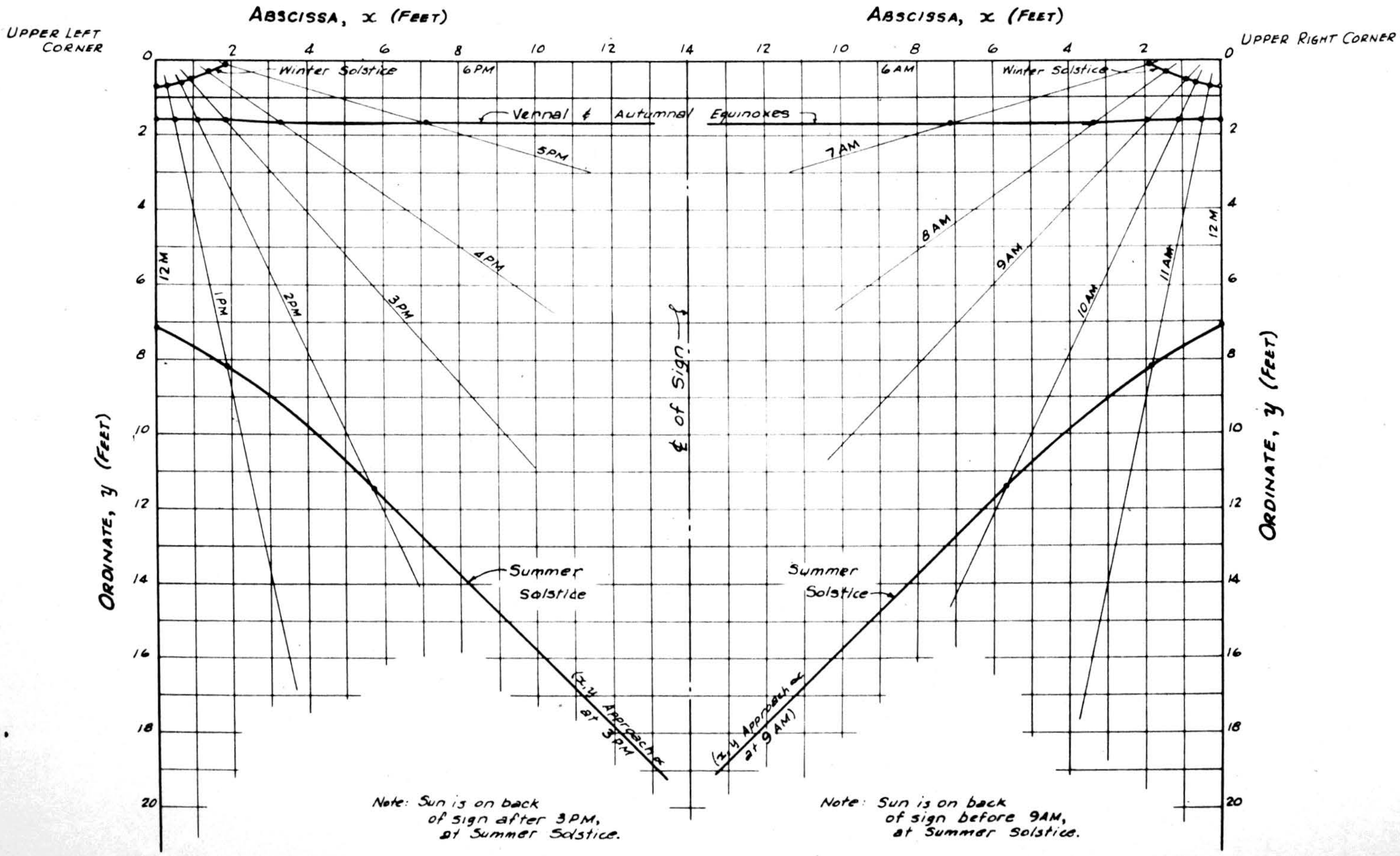
32° N. LAT. SIGN FACING SOUTH 4' OVERHANG 10' x 10' MESSAGE AREA



INTERFERENCE AREAS

FIGURE 3

S.V.W.



TIME TRACE DIAGRAM OF POINT P (x, y)
32° N. LATITUDE, SIGN FACING SOUTH, UNIT OVERHANG (a = 1')
FOR THE EQUINOCTIAL AND SOLSTITIAL DAYS

FIGURE 4

R.M.O.