AFCRL—69-0005

AN ATLAS OF POLARIZATION FEATURES OF LIGHT REFLECTED BY DESERT SAND, WHITE SAND AND SOIL

AD 687109

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Department of Meteorology
University of California
Los Angeles, California 90024

Contract No. F19628-67-C-0196
Project No. 7621
Task No. 762103
Work Unit No. 76210301

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Contract Monitor: Robert W. Fenn
Optical Physics Laboratory

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CORRIGENDA

Page 77 The constant term in the series should be 7.63 instead of 6.69

Page 134 Read $-0.38 \cos \Phi$ instead of $-0.12 \cos \Phi$

Page 203

$$
\begin{aligned}
P(\Phi) = {} & 7.69 + 2.57 \cos \Phi - 0.38 \cos 2\Phi + 0.05 \cos 3\Phi \\
& - 0.02 \cos 4\Phi + 0.00 \cos 5\Phi - 0.08 \cos 6\Phi \\
& + 0.06 \sin \Phi + 0.12 \sin 2\Phi + 0.03 \sin 3\Phi \\
& - 0.06 \sin 4\Phi - 0.00 \sin 5\Phi
\end{aligned}
$$

ABSTRACT

The results of an extensive series of measurements of the degree of linear polarization of light bidirectionally reflected by samples of desert sand, white sand and soil under various conditions of illumination are presented in graphical form. Measurements have been made in three spectral intervals (bandwidth ~ 150 A) centered on λλ3970, 4865, 5890A and 'white light' with a simple 'rotating-analyzer' type reflectometer. Simple Fourier series representations have been established for the azimuthal dependence of the degree of linear polarization of the reflected light for 'white light' measurements. The results of the corresponding error analysis are shown in an error curve.

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ACKNOWLEDGMENTS

The authors are thankful to Professor Zdenek Sekera, Project Director, for his interest in the work reported here. The competent computational and technical assistance extended to the authors by Miss Barbara Skolsky and Messrs. Chesebrough, Dibble, Farnow, Fauquet and Palomino is herewith gratefully acknowledged. Mrs. Sherry Lovell is responsible for the neat execution of the manuscript.

INTRODUCTION

The study of the reflection properties of natural formations constitutes an important part of the extensive experimental research program which is being pursued in the Atmospheric Optics and Radiation Laboratory of the Department of Meteorology, University of California, Los Angeles. The results of preliminary studies have been reported upon by Chen et al[1] and Chen and Rao[2]. These studies revealed that a detailed examination of the azimuthal dependence of the polarization of light diffusely reflected by natural formations would be an important prerequisite even for a semi-empirical understanding of scattering of light by optically rough surfaces. The need for and relevance of such studies have also been keenly felt in investigations directed towards the interpretation of radiation measurements from meteorological satellites.

EXPERIMENTAL STUDIES

The experimental geometry is shown in Figure 1a. The reflecting surface of the sample defines the equatorial plane. θ_o is the angle of illumination; θ is the nadir angle of observation. The principal plane of the source S is defined by the direction of illumination and the normal to the equatorial plane. It is the reference plane for the determination of

the azimuth ϕ of the plane of observation defined by the direction of observation and the normal to the equatorial plane.

In the present measurements, the angle of illumination θ_o has been set equal to $0^\circ 00'$, $53^\circ 00'$ and $78^\circ 30'$ successively. The azimuth angle has been varied in steps of $30^\circ 00'$ over the entire circle. In any plane of observation defined by a particular value of ϕ, the reflected radiation has been examined over the region $0^\circ 00' \leq \theta \leq 80^\circ 00'$ by varying θ in steps of $10^\circ 00'$. An additional set of measurements has been obtained corresponding to $\theta = 75^\circ 00'$.

Details of the 'rotating-analyzer' type reflectometer and the data acquisition system are shown in Figures 1b,c and d. Detailed descriptions have been given elsewhere by Chen et al (Op. Cit.). Samples of white sand (gypsum derived translucent grains of dimensions of the order of 0.5 mm), desert sand (silica derived translucent grains of dimensions of the order of 0.5 mm) and soil (opaque particulates of dimensions of the order of 1 mm) have been studied when illuminated either with natural (unpolarized) light or with plane polarized light with the plane of polarization either parallel or perpendicular to the principal plane of the source. The choice of these samples in the first instance was governed by the fact that they have been frequently examined both in the laboratory and on the field by investigators elsewhere[3,4].

The degree of linear polarization of the reflected light has been measured in three narrow (bandwidth ~150 A) spectral intervals centered on λλ3970, 4865 and 5890A. In addition, 'white light' measurements have also been made with the interference filter removed from the optical train in the reflectometer.

REPRESENTATION OF THE DATA

The analog data on strip-charts has been employed to compute the degree of polarization, P, with the use of the formula $P(\phi) = 100 \frac{V_{MAX} - V_{MIN}}{V_{MAX} + V_{MIN}}$ where V_{MIN} and V_{MAX} are respectively the minimum and maximum values of the photovoltage over half a revolution of the analyzing Glan-Thompson prism. Corresponding to a given state of polarization of the illumination, angle of illumination and nadir angle of observation, measurements have been made over the azimuth circle by varying ϕ in steps of 30°00'. The instrument configuration was such that, in certain planes of observation, corresponding to particular values of θ and θ_o, meaningful results could not be obtained as the shadow of the instrument was cast on the surface of the sample. The probable values of the polarization have been determined by graphical interpolation in those cases.

The measured azimuthal dependence of the polarization of the reflected light is shown in Figures 2 to 262. In those cases when the

illumination is plane polarized, the orientation of the plane of polarization is indicated by a properly oriented arrow; thus a vertical arrow indicates that the illumination was polarized parallel to the principal plane of the source and a horizontal arrow indicates that the illumination was polarized normal to the principal plane of the source.

It is apparent from the data shown in Figures 2 through 262 that the degree of polarization of the reflected light exhibits noticeable azimuthal dependence except when the samples are illuminated with natural (unpolarized) light along the nadir direction or when $\theta = 0^{\circ}00'$. This anisotropy is uniformly noticed in all spectral intervals. It is for this reason and for the sake of brevity that only the Fourier series representations of the azimuthal dependence of the polarization of reflected 'white light' are given in the diagrams. The conventional harmonic analysis and synthesis schedules developed by Pollak[5] have been used in determing the Fourier coefficients. The results of the checks made at three arbitrarily chosen values of ϕ in the case of each of the Fourier series are shown in the relative error curve of Figure 263.

CONCLUSION

The original objective was to attempt a simple empirical representation for the degree of polarization of the reflected light taking into account the θ, θ_o and ϕ dependencies simultaneously. It has not been possible to attain this objective since the Fourier coefficients vary rather irregularly with θ and θ_o for given conditions of illumination. The information presented herein can however be used to estimate the degree of polarization of the reflected light at any desired value of the azimuth under given conditions of illumination and observation. Such computations are considered useful in aerial photographic reconnaissance studies and in the interpretation of radiation measurements performed from meteorological satellites.

REFERENCES

1. Hsi-shu Chen, C. R. Nagaraja Rao, and Z. Sekera, Scientific Report No. 2 (AFCRL067-0089), Air Force Contract No. AF19(628)-3850, Department of Meteorology, University of California, Los Angeles (1967).
2. Hsi-shu Chen and C. R. Nagaraja Rao, Brit. J. Appl. Phys. (J. Phys. D.), 1, 1191 (1968).
3. K. L. Coulson, Appl. Opt., 5, 905 (1966).
4. Vincent V. Salomonson, Atmospheric Research Paper No. 128, Department of Atmospheric Science, Colorado State University, Fort Collins (Colo.) (1968).
5. L. Pollak, All Term Guide for Harmonic Analysis and Synthesis (Dublin Stationery Office, 1949).

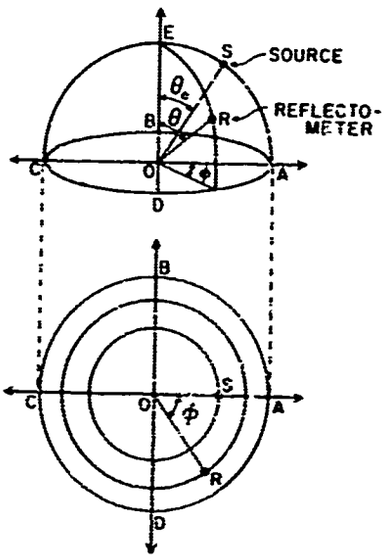


FIG. 1a. EXPERIMENTAL GEOMETRY

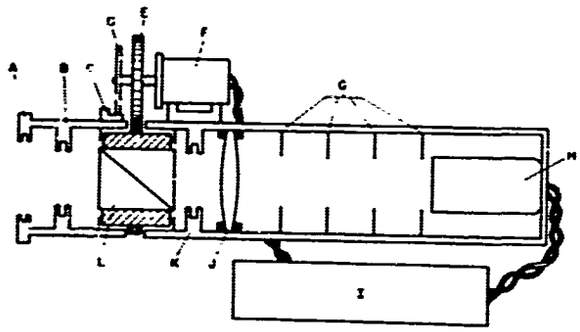


FIG 1b THE REFLECTOMETER

A HOLDER FOR NEUTRAL DENSITY WEDGE B HOLDER FOR QUARTER WAVE PLATE C- MICROSWITCH D PROGRAMMED CAM E ANALYZER DRIVING MECHANISM F. D.C. MOTOR G LIGHT-LIMITING BAFFLES H ASCOP 541-A PHOTOMULTIPLIER TUBE AUXILIARY ELECTRONICS J FUSED QUARTZ ACHROMAT K FILTER HOLDER L GLAN-THOMPSON PRISM

FIG. 1d. DATA ACQUISITION SYSTEM
A: VTVM B: Oscilloscope C. "Wyle" A/D Converter
D: Strip Chart Recorder E: Variable Gain Amplifier
F: "Digidata" Digital Recorder

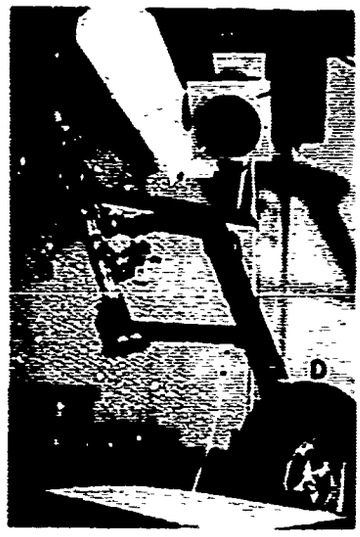


FIG. 1c. EXPERIMENTAL ARRANGEMENT
A: Source B: Reflectometer C: Sample
D: Altazimuth Drive

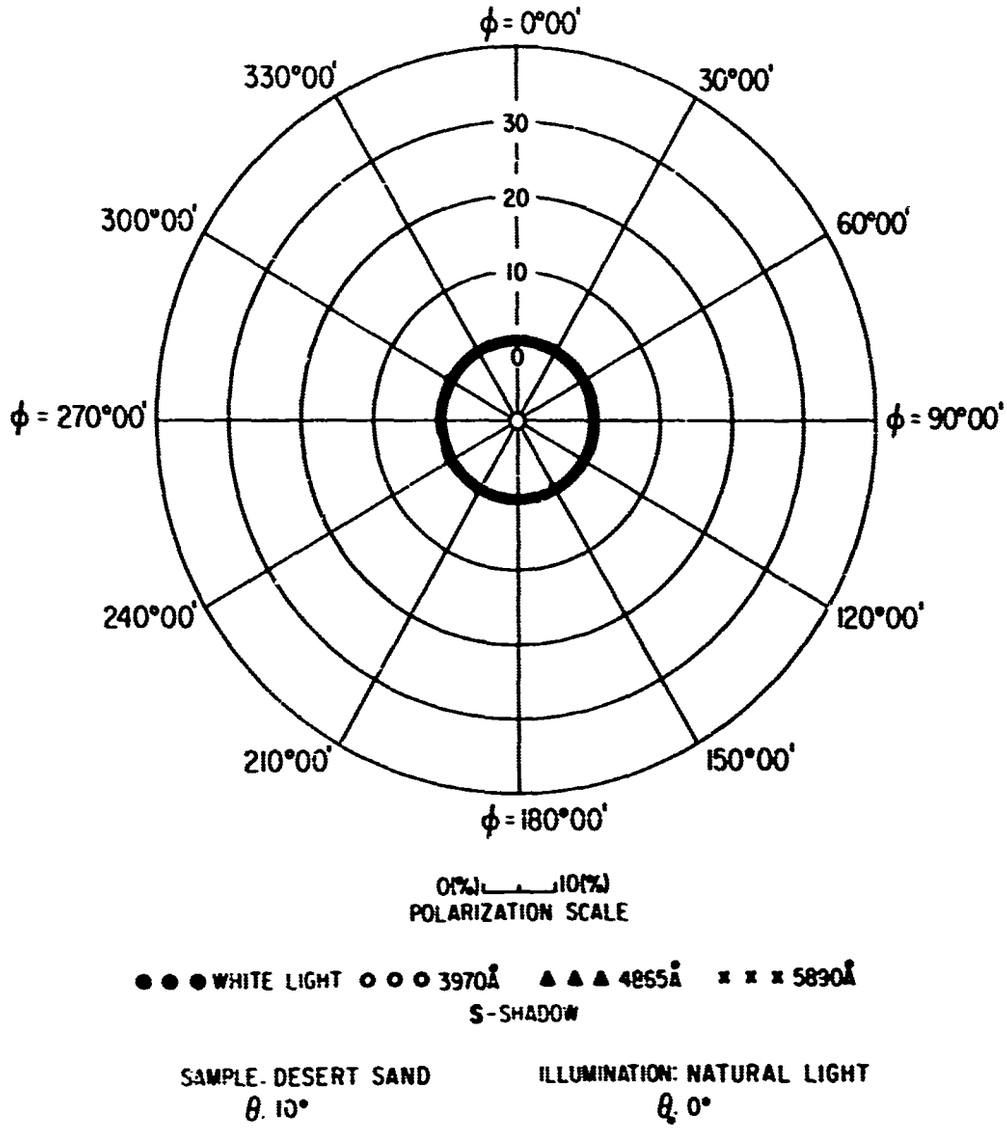
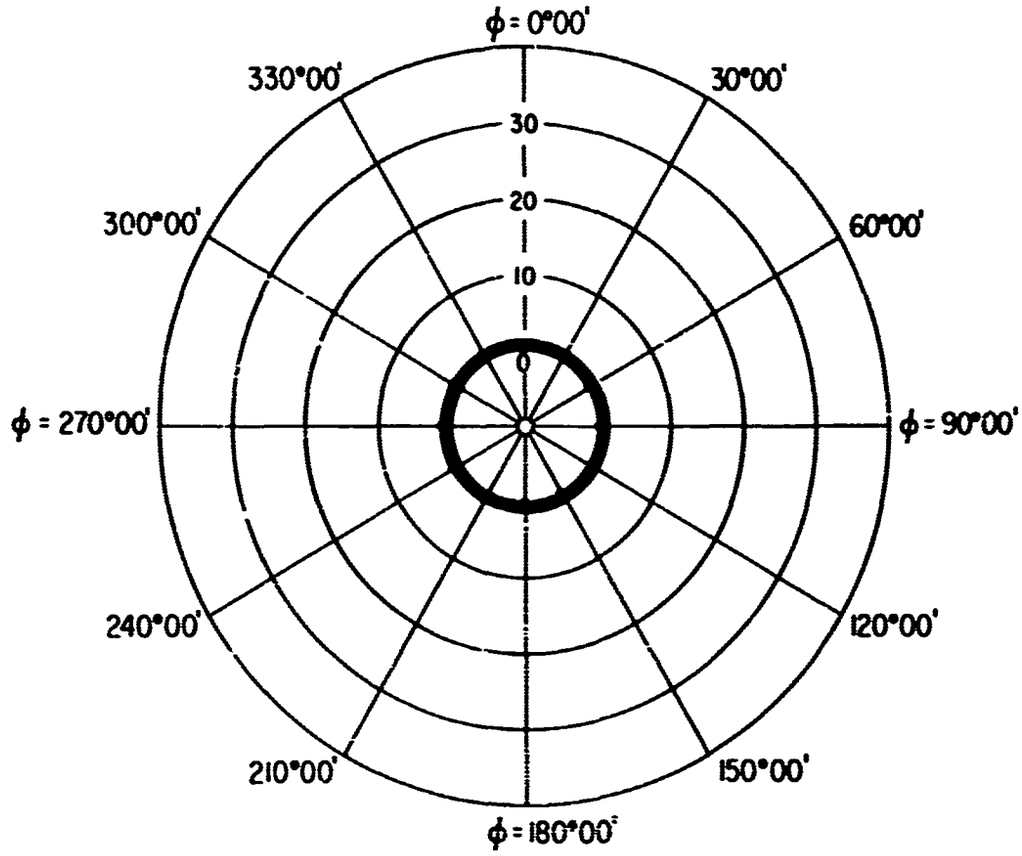


FIG 2. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ. 20°

ILLUMINATION: NATURAL LIGHT
θ_i 0°

FIG 3. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

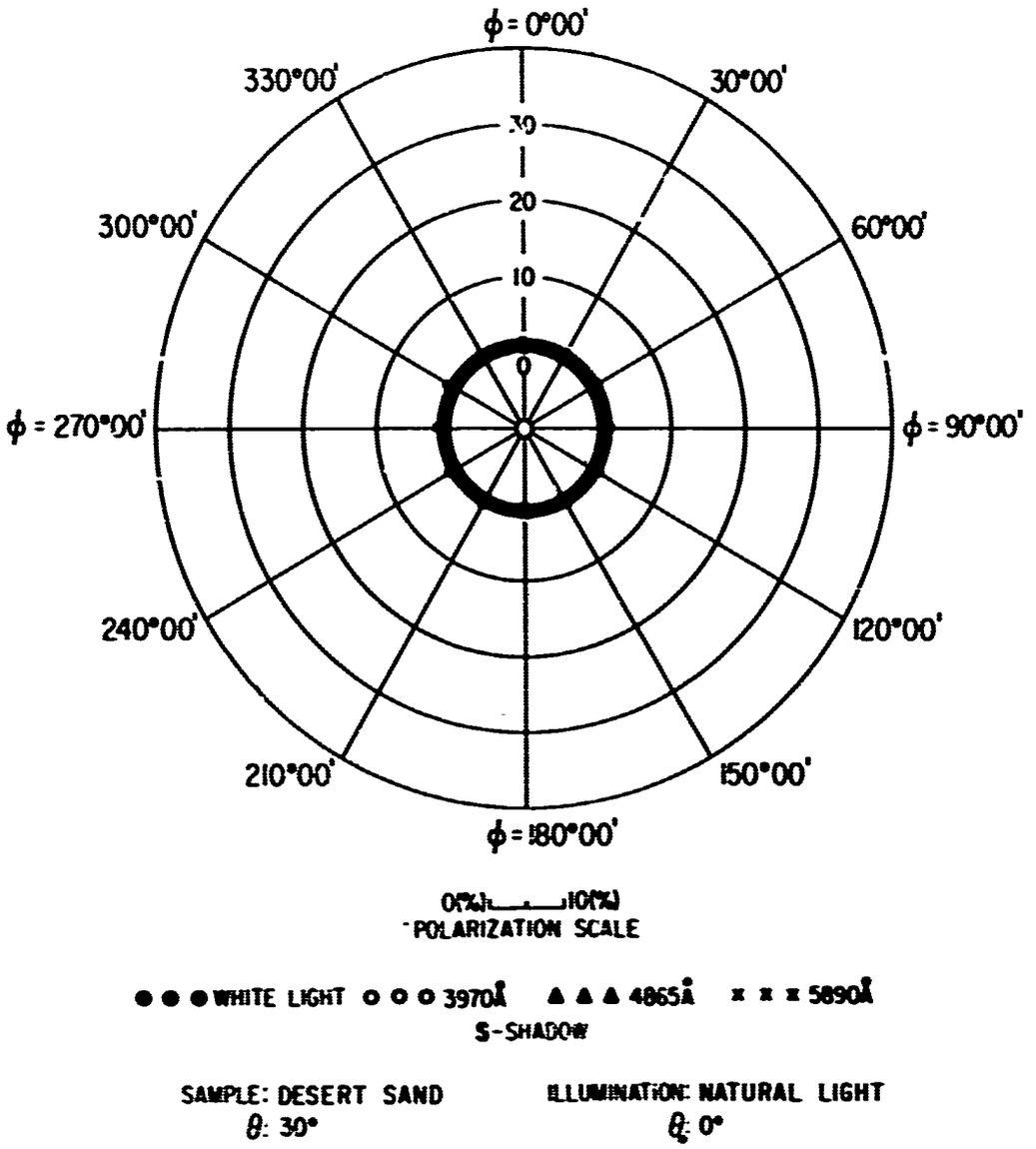
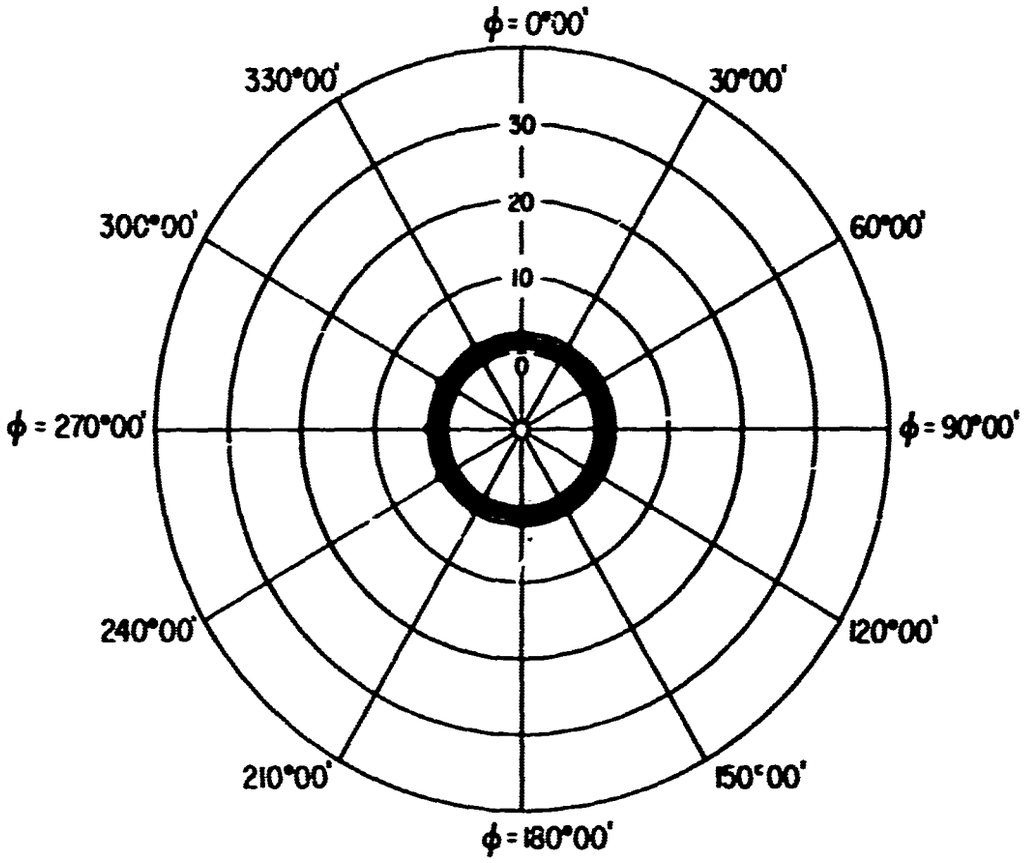


FIG. 4. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



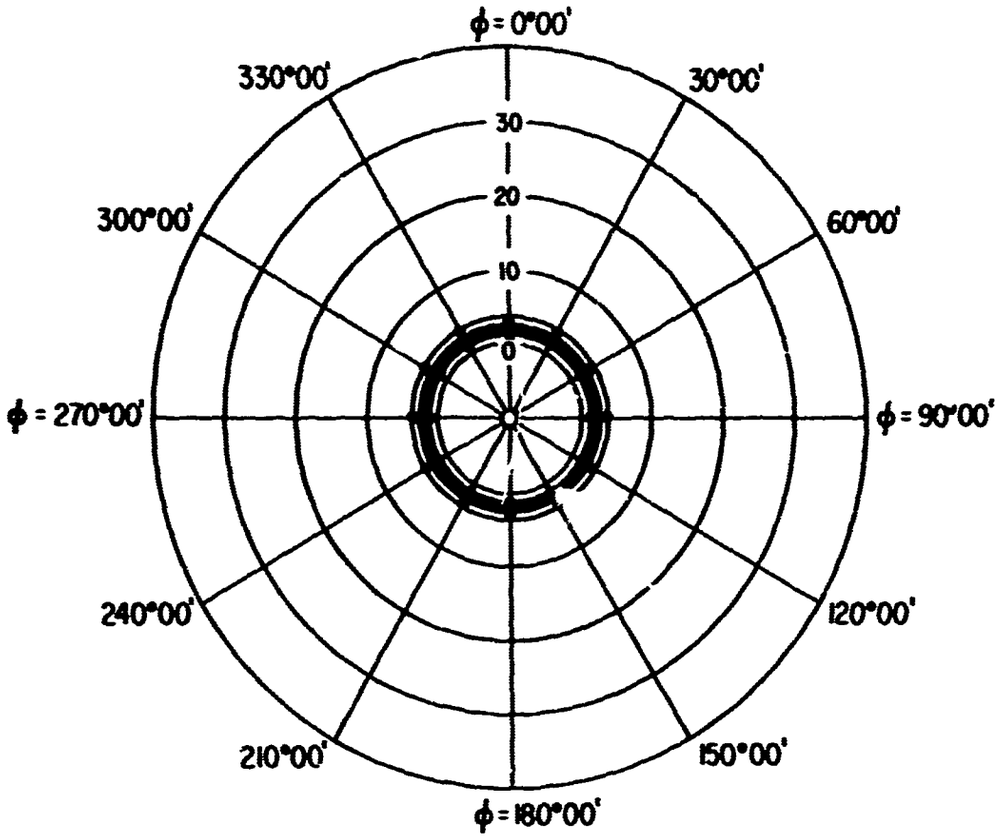
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 40°

ILLUMINATION: NATURAL LIGHT
θ_i: 0°

FIG 5. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



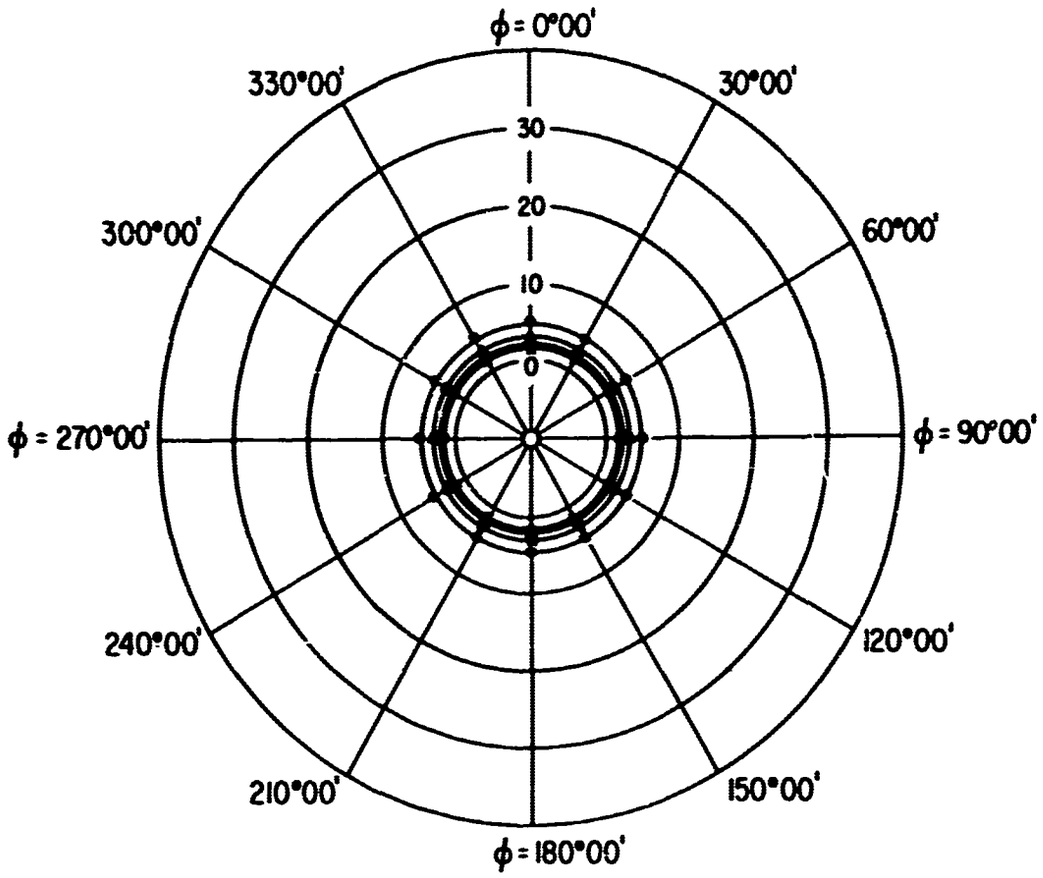
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 50°

ILLUMINATION: NATURAL LIGHT
θ_i: 0°

FIG 6. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



C(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 60°

ILLUMINATION: NATURAL LIGHT
θ_0: 0°

FIG 7. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

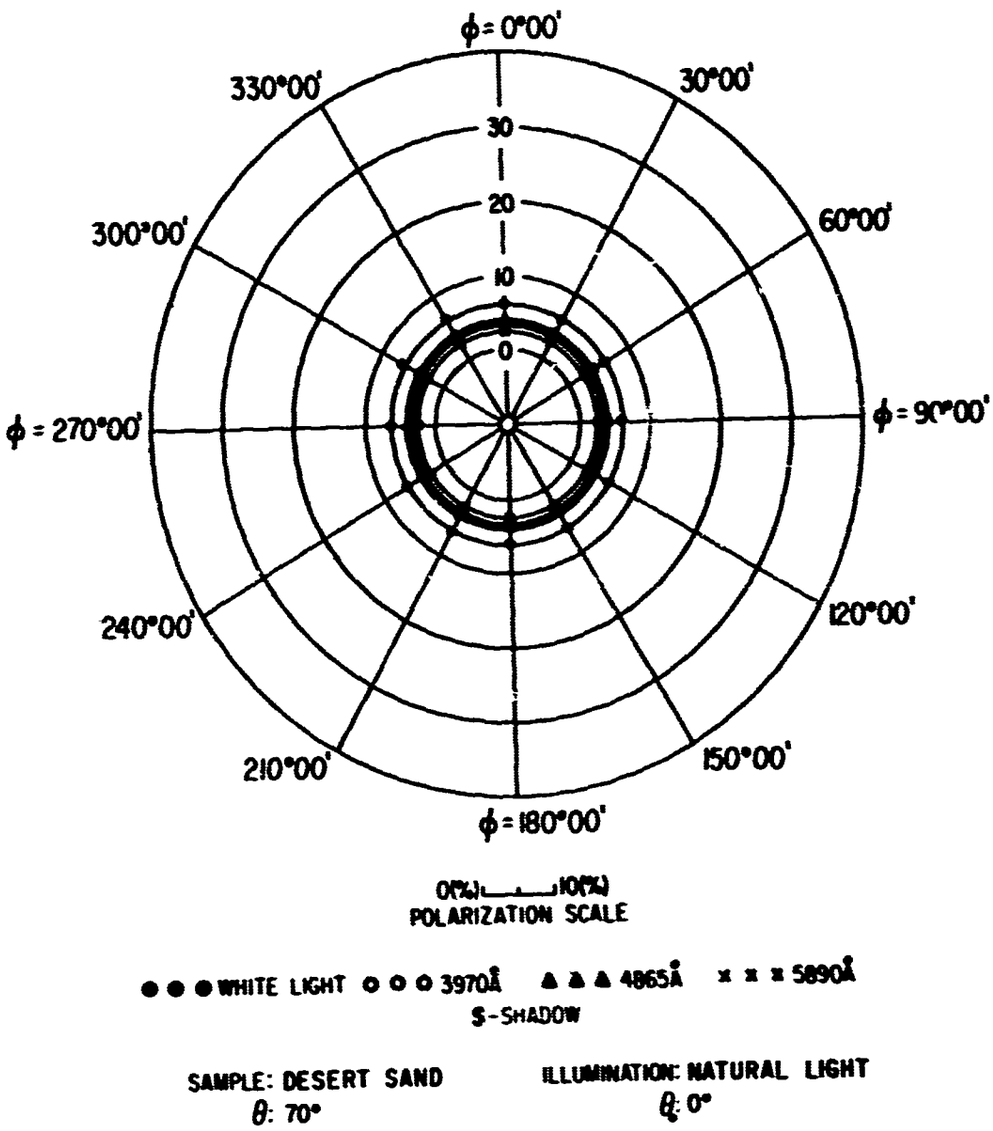


FIG. 8. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

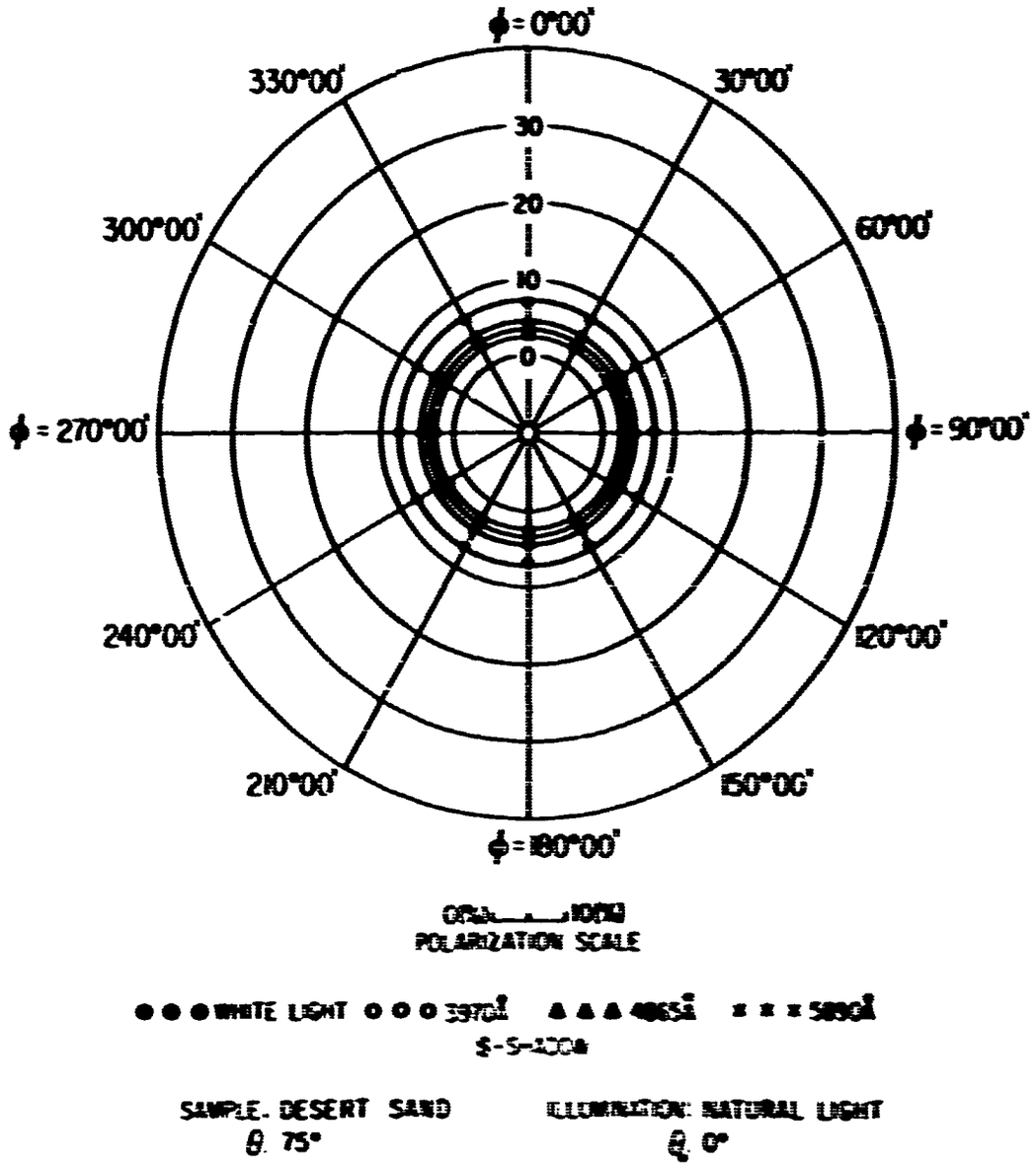


FIG. 9. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

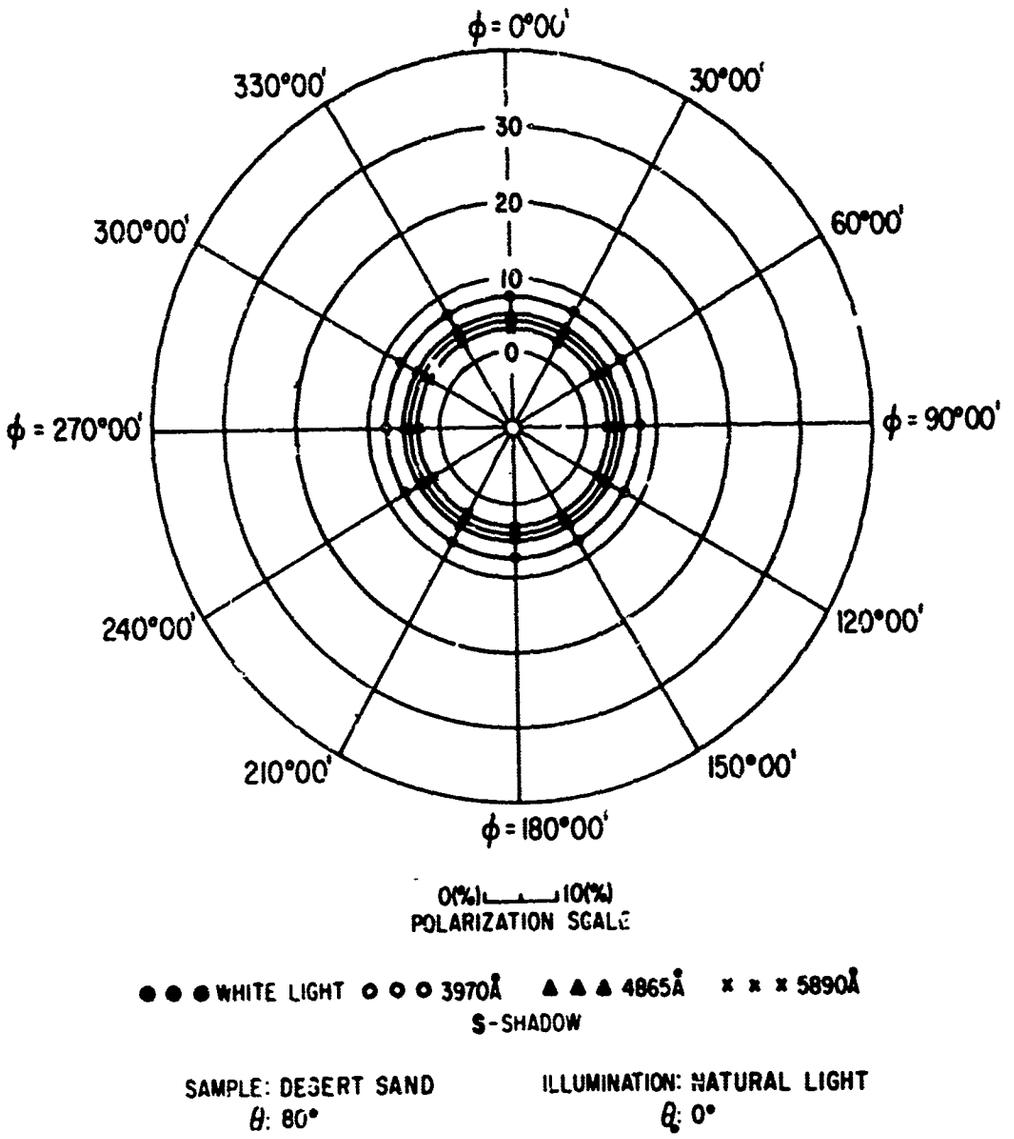


FIG. 10. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

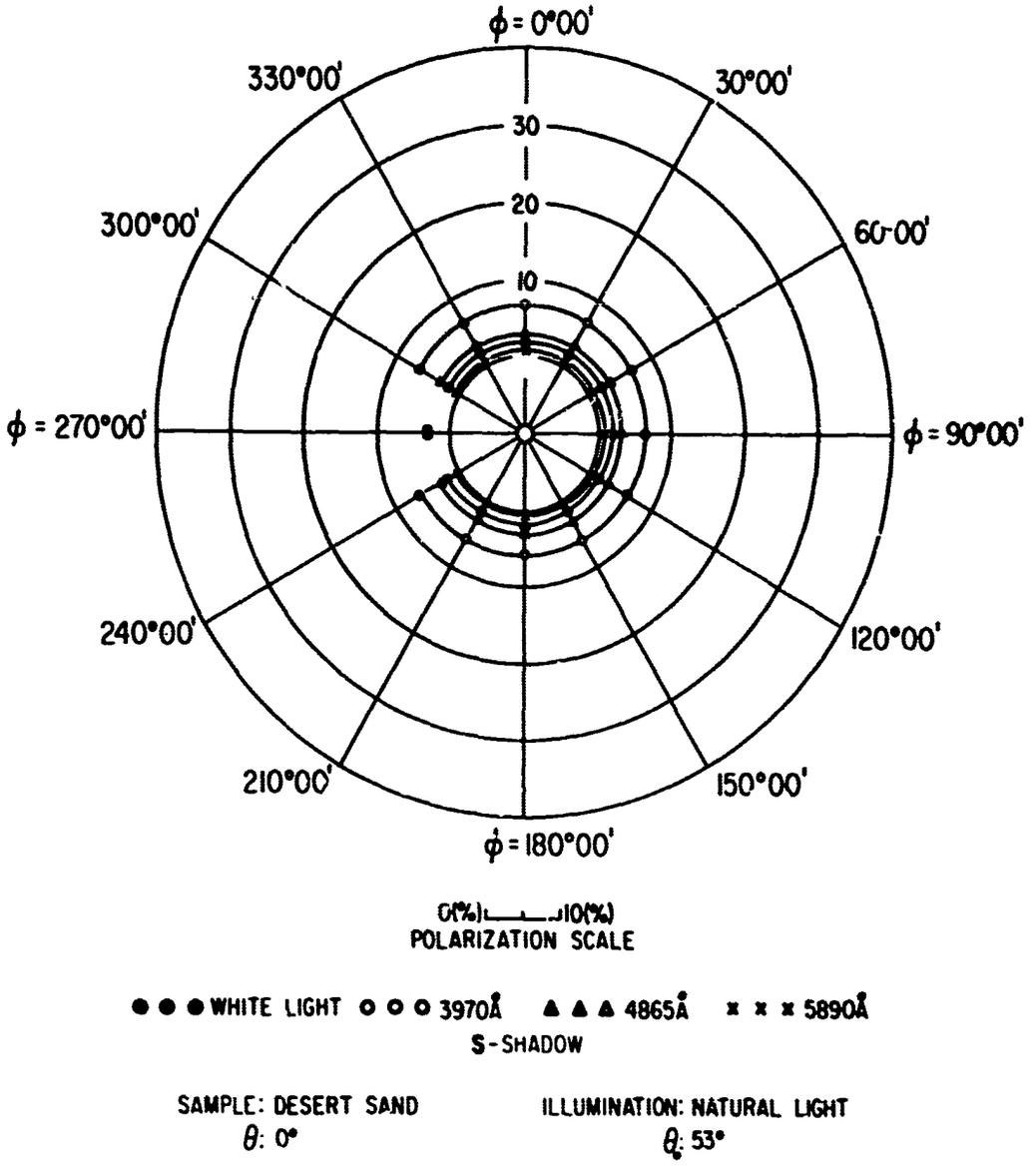
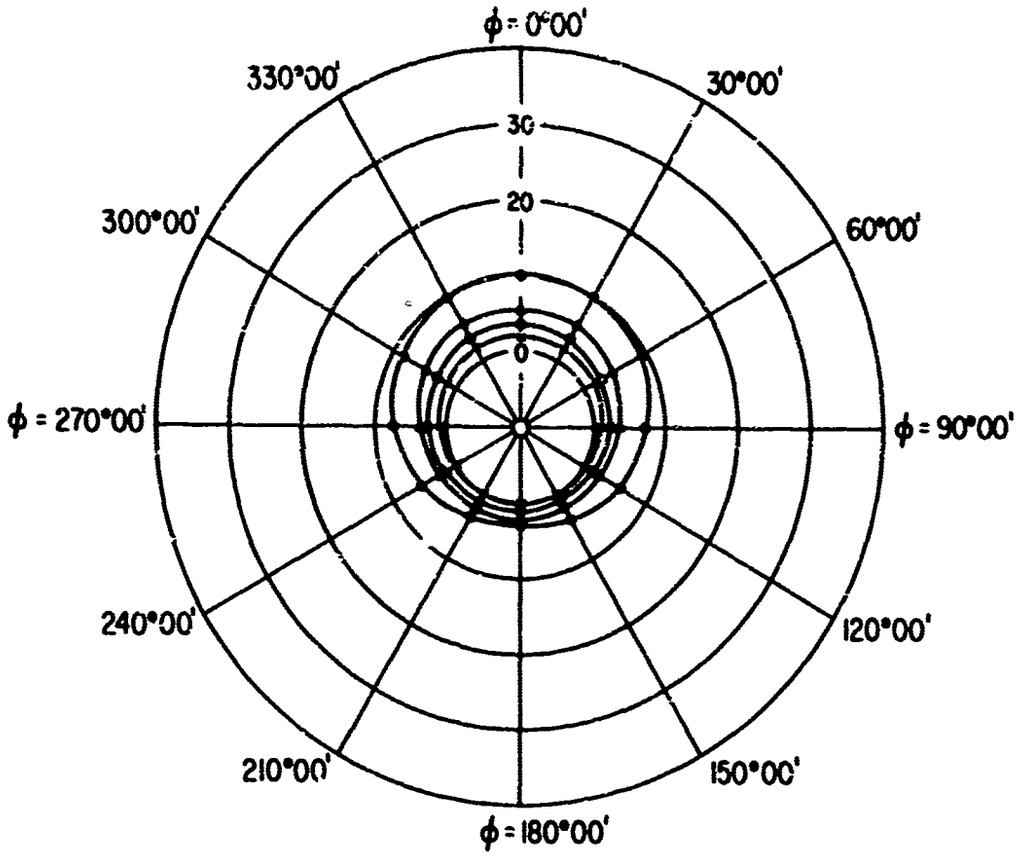


FIG 11. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

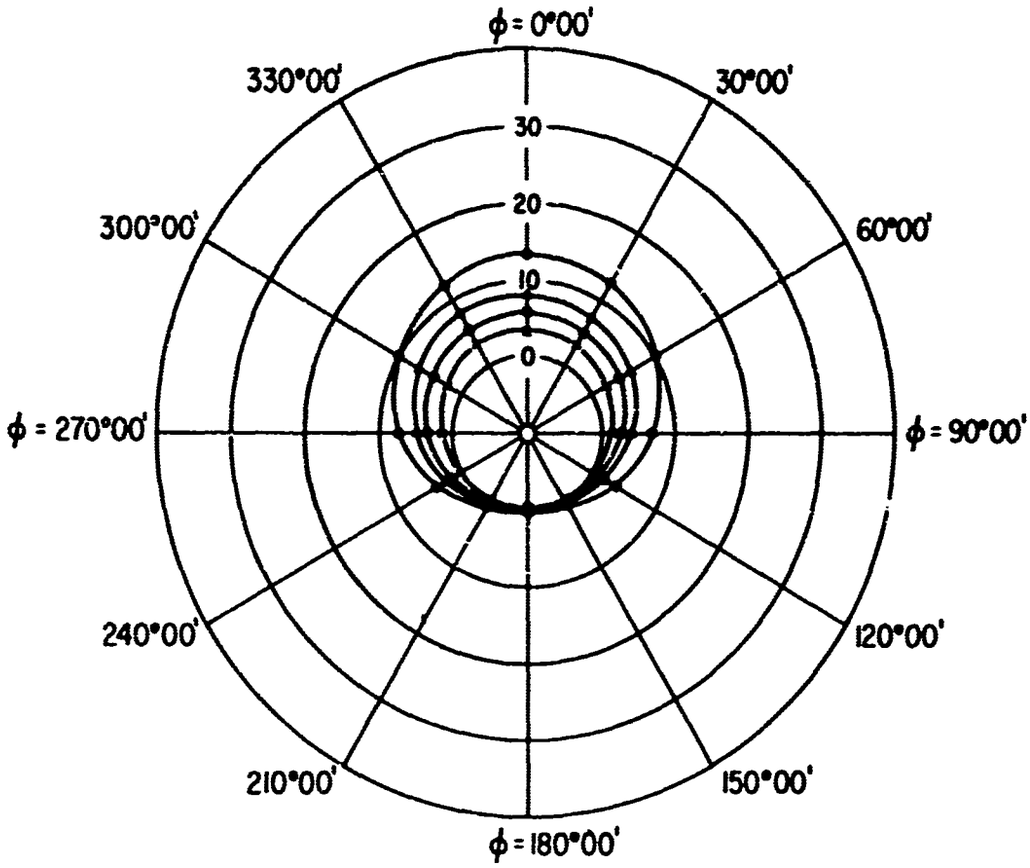
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 10°

ILLUMINATION: NATURAL LIGHT
θ_i 53°

FIG 12. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 2.27 + 1.62 \cos\varphi - 0.06 \cos 2\varphi - 0.12 \cos 3\varphi + 0.26 \cos 4\varphi - 0.25 \cos 5\varphi - 0.03 \cos 6\varphi + 0.00 \sin\varphi - 0.07 \sin 2\varphi + 0.08 \sin 3\varphi - 0.19 \sin 4\varphi + 0.18 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

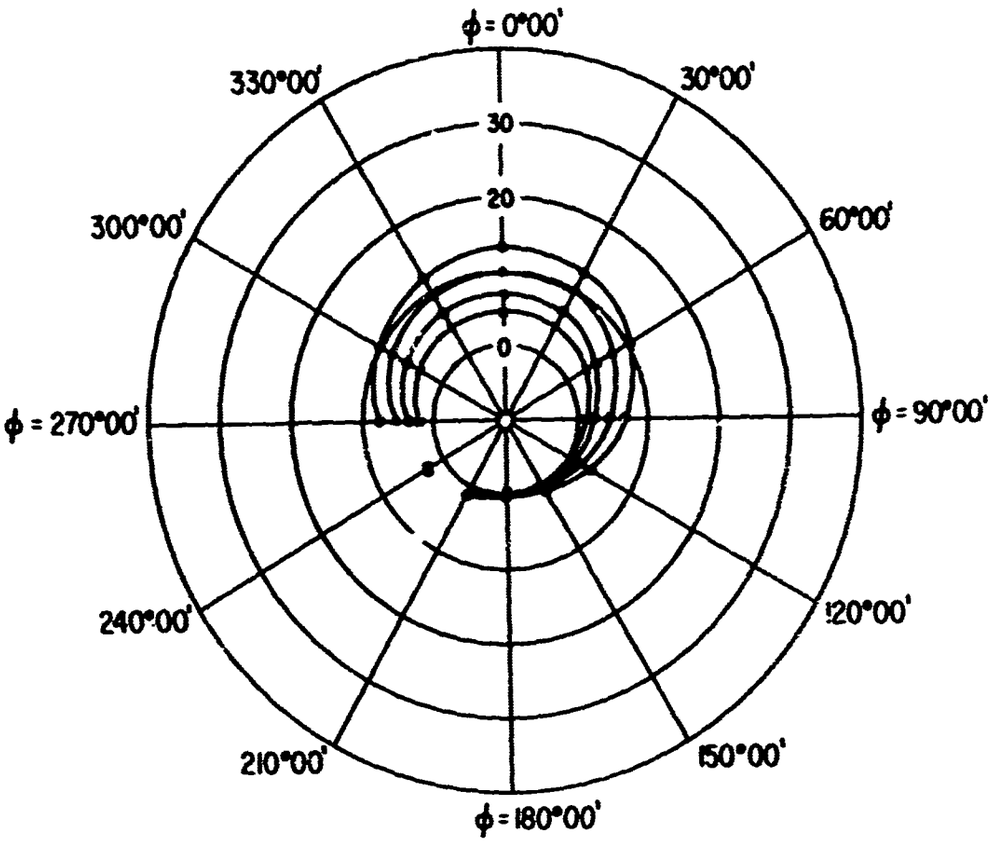
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 20°

ILLUMINATION: NATURAL LIGHT
θ_i: 53°

FIG 13. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 2.78 + 2.81 \cos\varphi - 0.02 \cos 2\varphi - 0.33 \cos 3\varphi + 0.09 \cos 4\varphi + 0.12 \cos 5\varphi - 0.10 \cos 6\varphi - 0.06 \sin\varphi + 0.01 \sin 2\varphi - 0.03 \sin 3\varphi - 0.16 \sin 4\varphi - 0.23 \sin 5\varphi$$



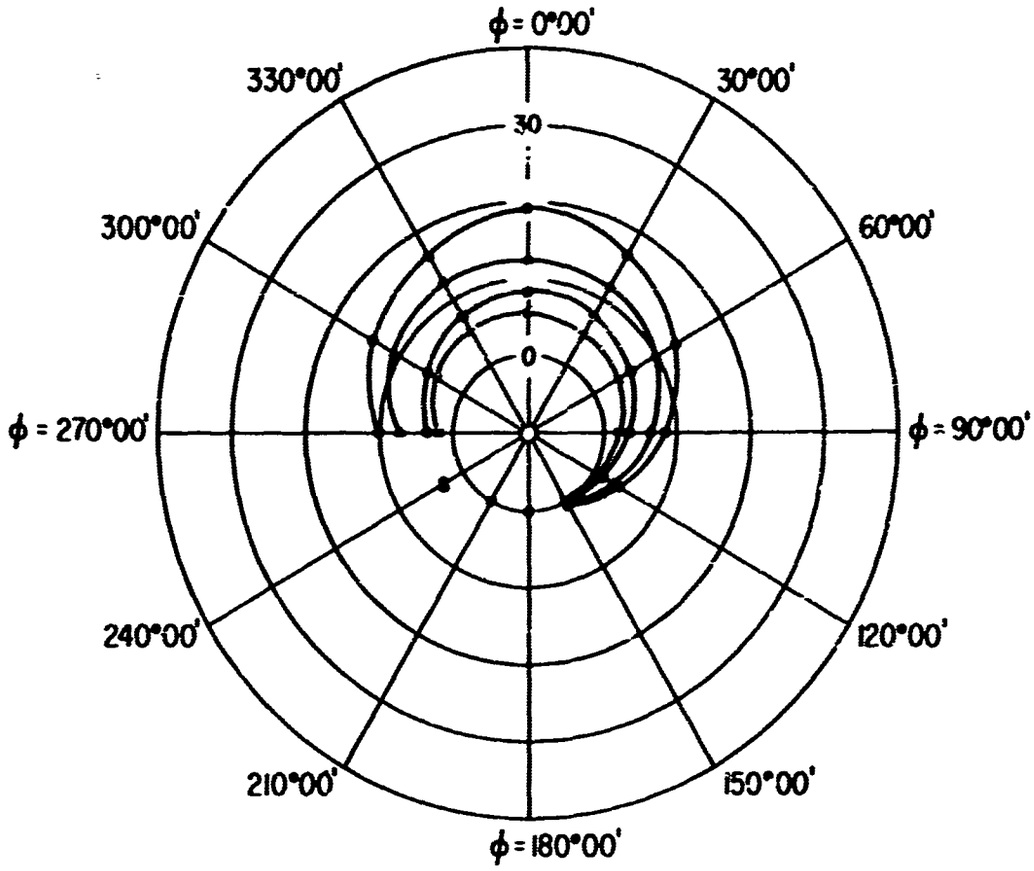
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 30°

ILLUMINATION: NATURAL LIGHT
θ_i: 53°

FIG. 14. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$F(\varphi) = 3.28 + 3.46 \cos\varphi + 0.39 \cos 2\varphi - 0.37 \cos 3\varphi + 0.02 \cos 4\varphi + 0.05 \cos 5\varphi - 0.08 \cos 6\varphi - 0.35 \sin\varphi - 0.28 \sin 2\varphi + 0.02 \sin 3\varphi - 0.02 \sin 4\varphi - 0.09 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 40°

ILLUMINATION: NATURAL LIGHT
θ_i: 53°

FIG. 15. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.82 + 4.22 \cos\phi + 0.32 \cos 2\phi - 0.07 \cos 3\phi + 0.12 \cos 4\phi + 0.00 \cos 5\phi + 0.15 \cos 6\phi - 0.24 \sin\phi - 0.19 \sin 2\phi - 0.02 \sin 3\phi + 0.02 \sin 4\phi - 0.03 \sin 5\phi$$

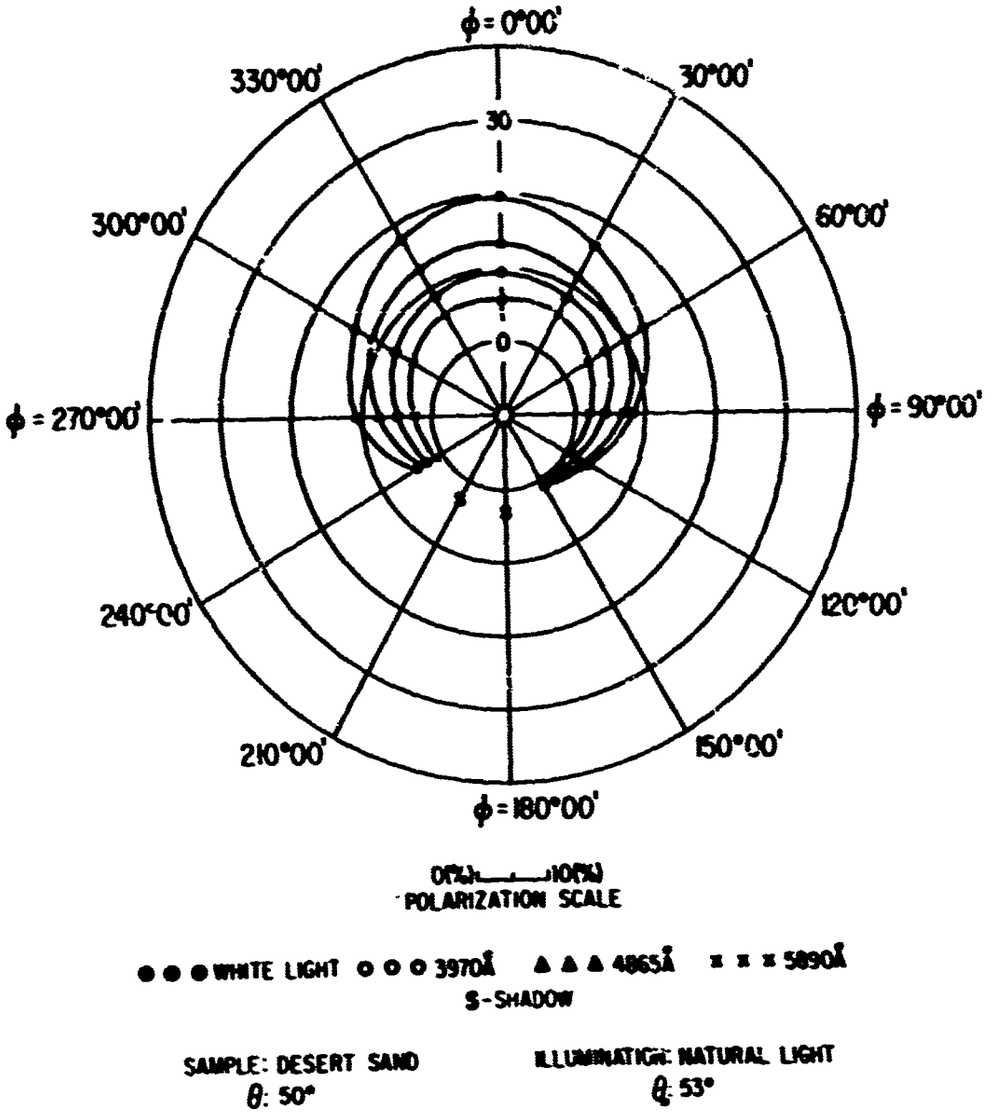
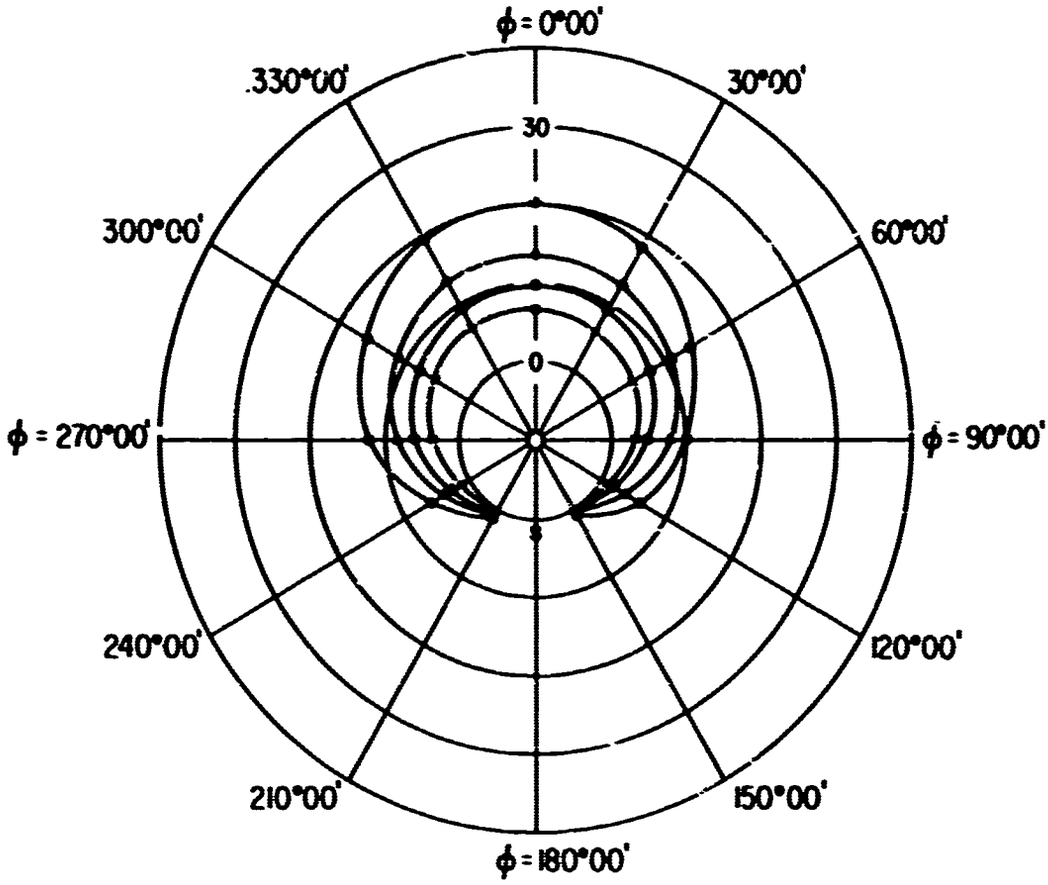


FIG 16. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.47 + 4.68 \cos\varphi + 0.13 \cos 2\varphi - 0.05 \cos 3\varphi + 0.23 \cos 4\varphi + 0.10 \cos 5\varphi + 0.03 \cos 6\varphi - 0.48 \sin\varphi - 0.06 \sin 2\varphi + 0.02 \sin 3\varphi - 0.12 \sin 4\varphi + 0.15 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

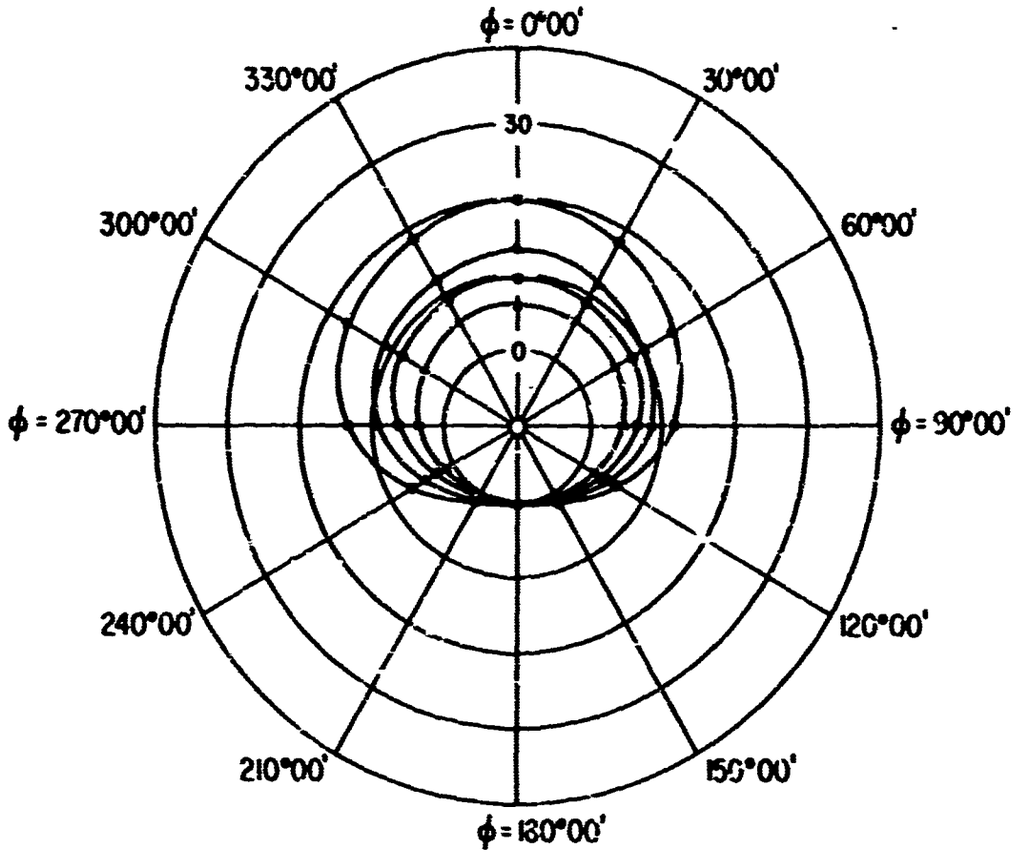
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ 60°

ILLUMINATION: NATURAL LIGHT
θ_0 53°

FIG 17. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.98 + 4.84 \cos\phi - 0.34 \cos 2\phi + 0.02 \cos 3\phi + 0.14 \cos 4\phi - 0.10 \cos 5\phi$$
$$+ 0.13 \cos 6\phi - 0.34 \sin\phi + 0.02 \sin 2\phi + 0.15 \sin 3\phi + 0.02 \sin 4\phi - 0.11 \sin 5\phi$$



0% 10%
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 70°

ELUMINATION: NATURAL LIGHT
ξ: 53°

FIG 18. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.10 + 5.07 \cos\varphi - 0.54 \cos 2\varphi - 0.50 \cos 3\varphi + 0.42 \cos 4\varphi + 0.28 \cos 5\varphi - 0.27 \cos 6\varphi + 0.40 \sin\varphi - 0.62 \sin 2\varphi - 0.03 \sin 3\varphi + 0.44 \sin 4\varphi - 0.44 \sin 5\varphi$$

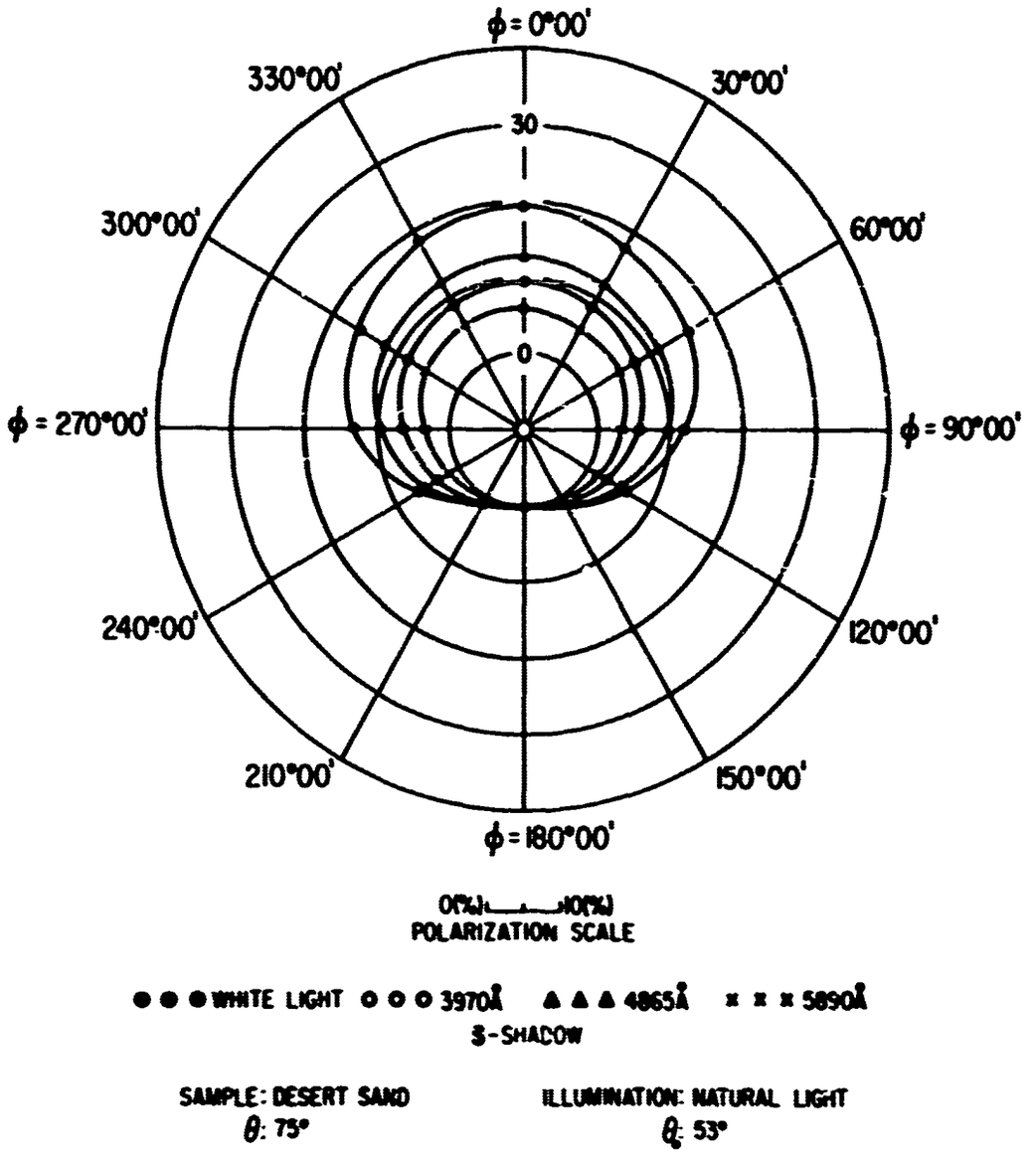


FIG. 19. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.23 + 4.47 \cos\varphi - 0.77 \cos 2\varphi + 0.08 \cos 3\varphi + 0.22 \cos 4\varphi - 0.06 \cos 5\varphi$$
$$+ 0.43 \cos 6\varphi - 0.22 \sin\varphi - 0.08 \sin 2\varphi - 0.05 \sin 3\varphi + 0.00 \sin 4\varphi - 0.02 \sin 5\varphi$$

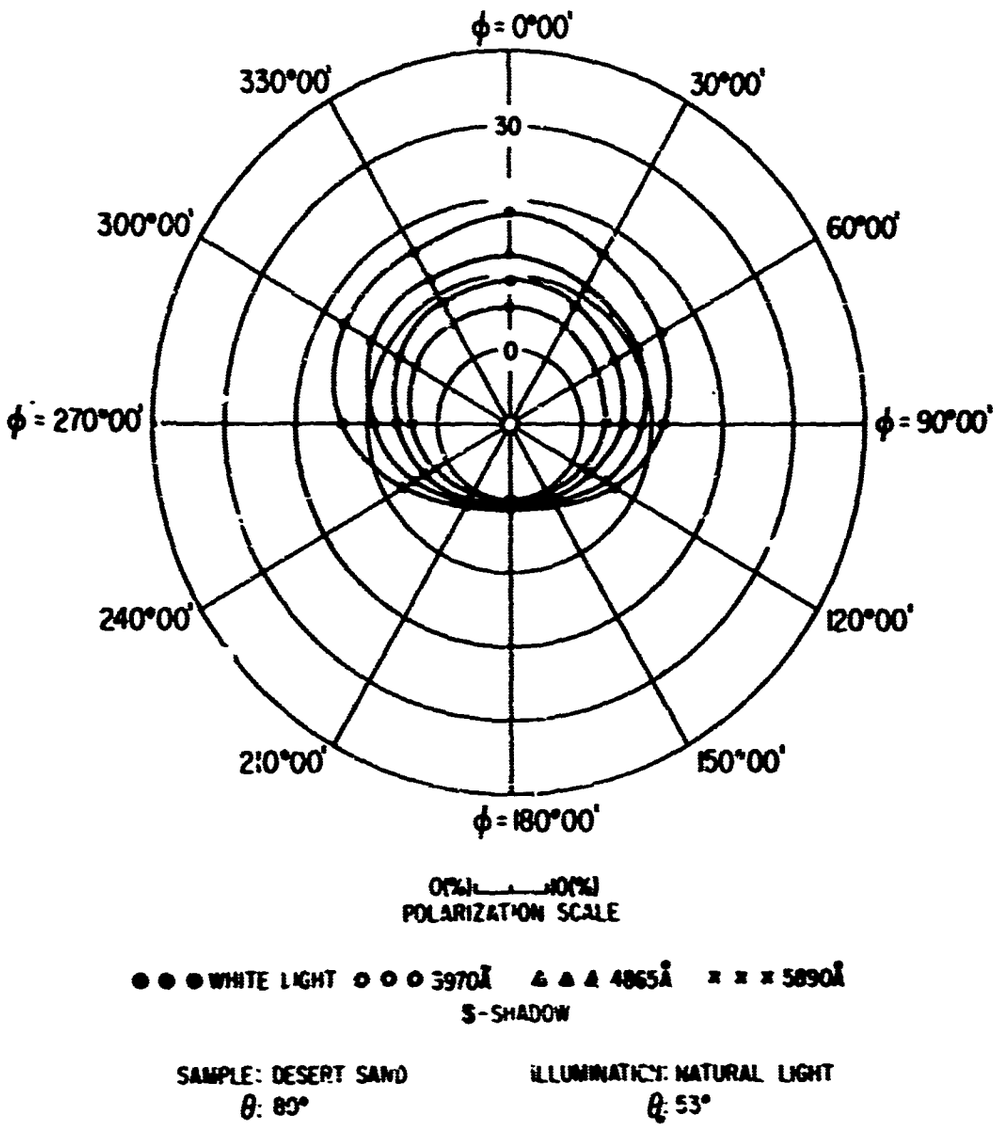


FIG. 20. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.34 + 3.60 \cos\varphi - 0.52 \cos 2\varphi + 0.07 \cos 3\varphi + 0.33 \cos 4\varphi + 0.28 \cos 5\varphi$$
$$- 0.22 \cos 6\varphi - 0.36 \sin\varphi + 0.11 \sin 2\varphi + 0.02 \sin 3\varphi - 0.09 \sin 4\varphi + 0.08 \sin 5\varphi$$

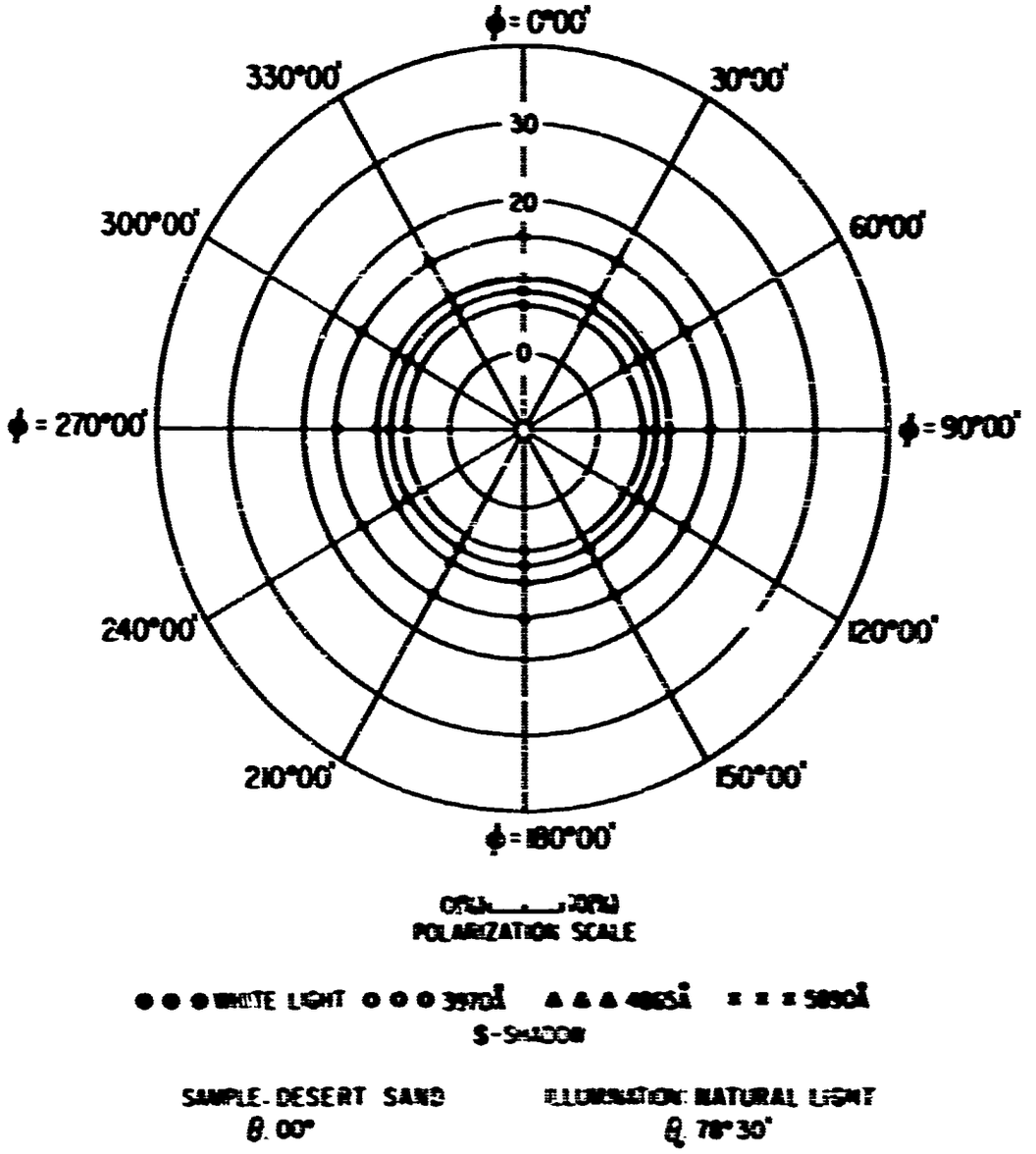
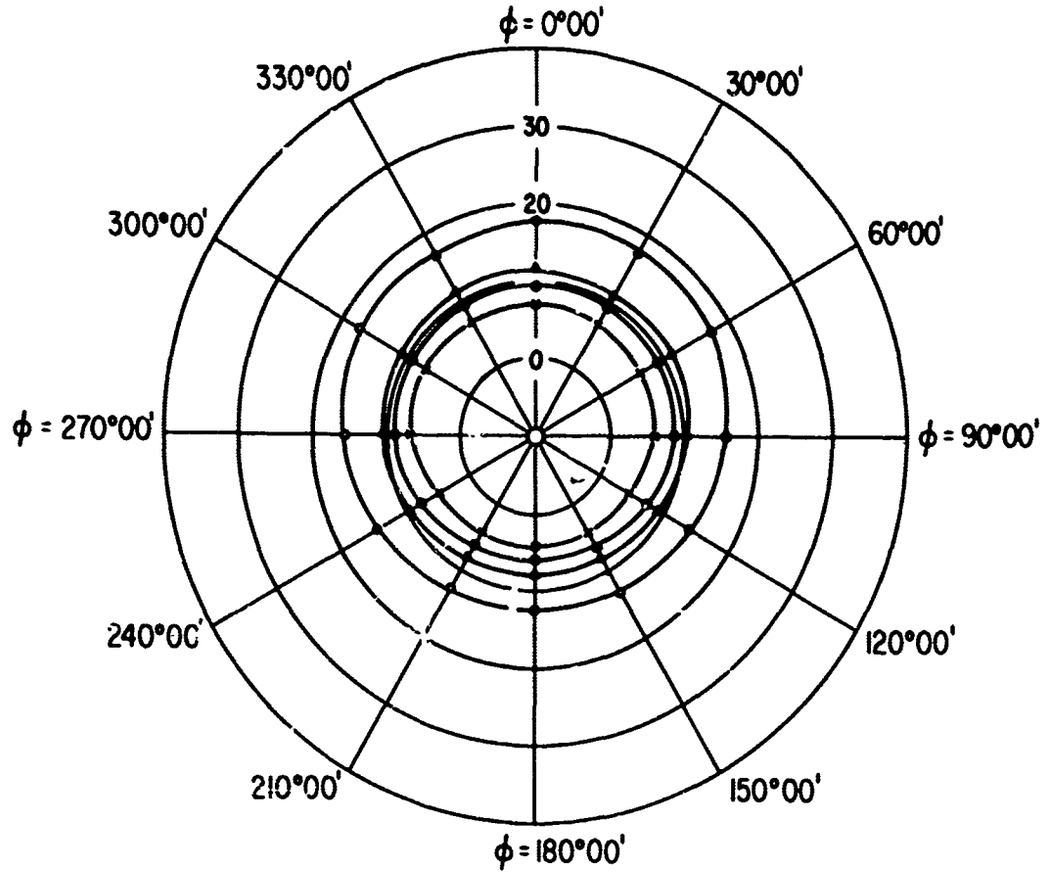


FIG 21. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

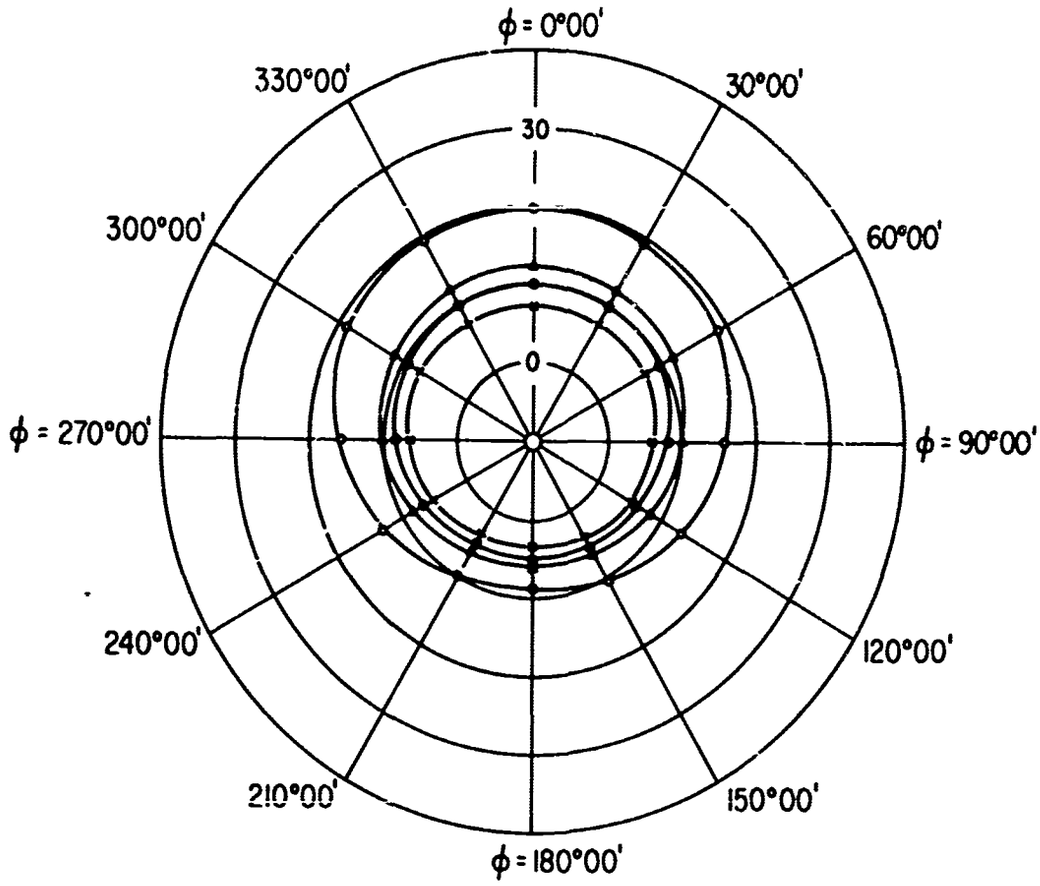
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 10°

ILLUMINATION: NATURAL LIGHT
θ_0: 78°30'

FIG 22. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.86 + 1.64 \cos\varphi - 0.07 \cos 2\varphi + 0.00 \cos 3\varphi - 0.07 \cos 4\varphi - 0.04 \cos 5\varphi + 0.15 \cos 6\varphi + 0.00 \sin\varphi - 0.09 \sin 2\varphi + 0.00 \sin 3\varphi - 0.09 \sin 4\varphi + 0.00 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

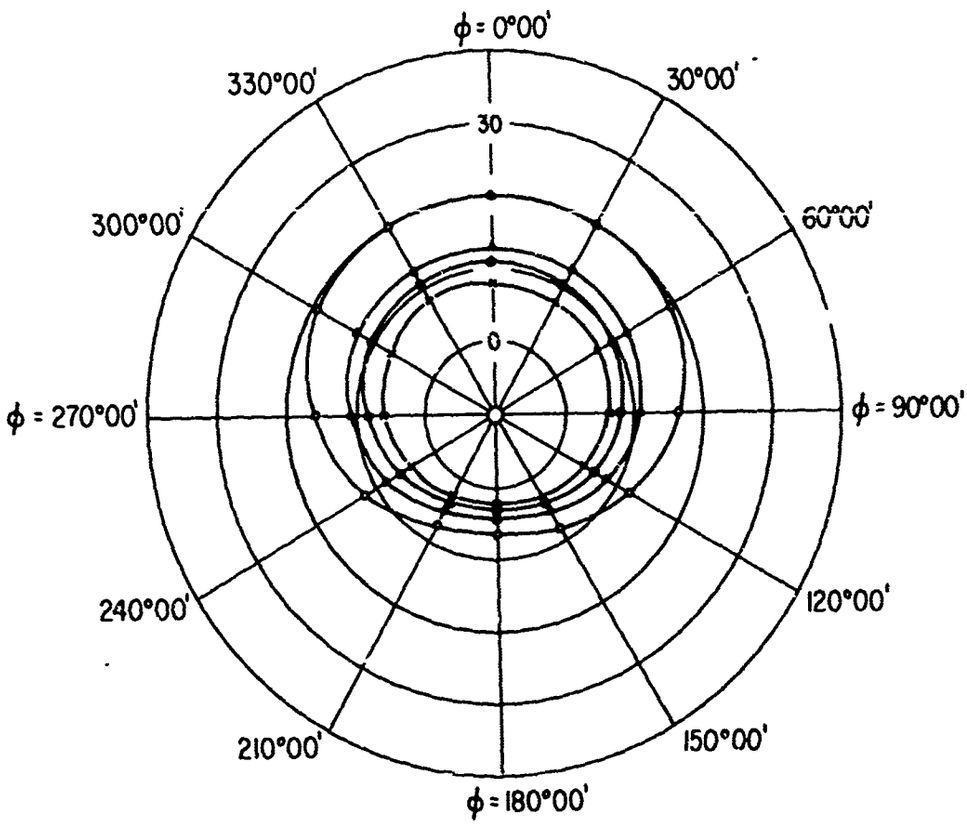
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4855Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ. 20°

ILLUMINATION: NATURAL LIGHT
θ_0: 78°30'

FIG 23. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.66 + 2.80 \cos\varphi - 0.01 \cos 2\varphi - 0.23 \cos 3\varphi + 0.14 \cos 4\varphi - 0.06 \cos 5\varphi - 0.2 \cos 6\varphi - 0.01 \sin\varphi + 0.04 \sin 2\varphi - 0.02 \sin 3\varphi - 0.04 \sin 4\varphi - 0.01 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

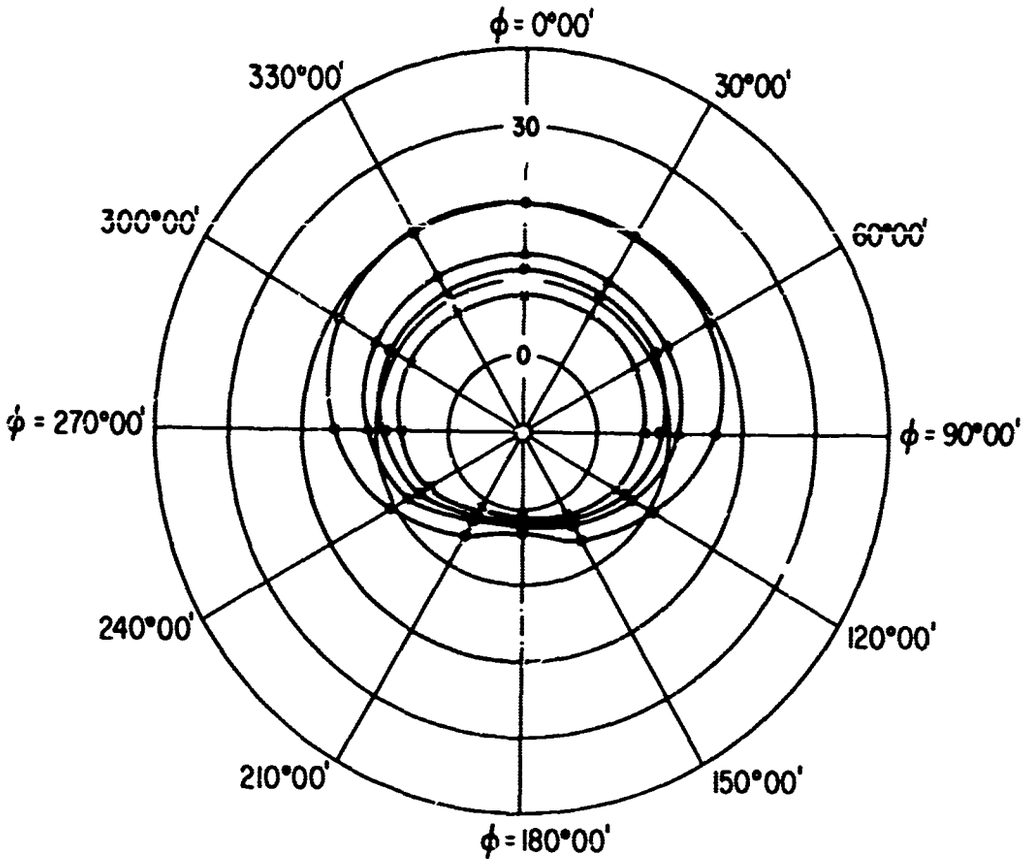
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 30°

ILLUMINATION: NATURAL LIGHT
θ_s: 78°30'

FIG. 24. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.56 + 4.00 \cos\varphi - 0.30 \cos 2\varphi + 0.27 \cos 3\varphi + 0.03 \cos 4\varphi - 0.13 \cos 5\varphi$$
$$+ 0.20 \cos 6\varphi - 0.02 \sin\varphi + 0.06 \sin 2\varphi - 0.03 \sin 3\varphi - 0.06 \sin 4\varphi - 0.02 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

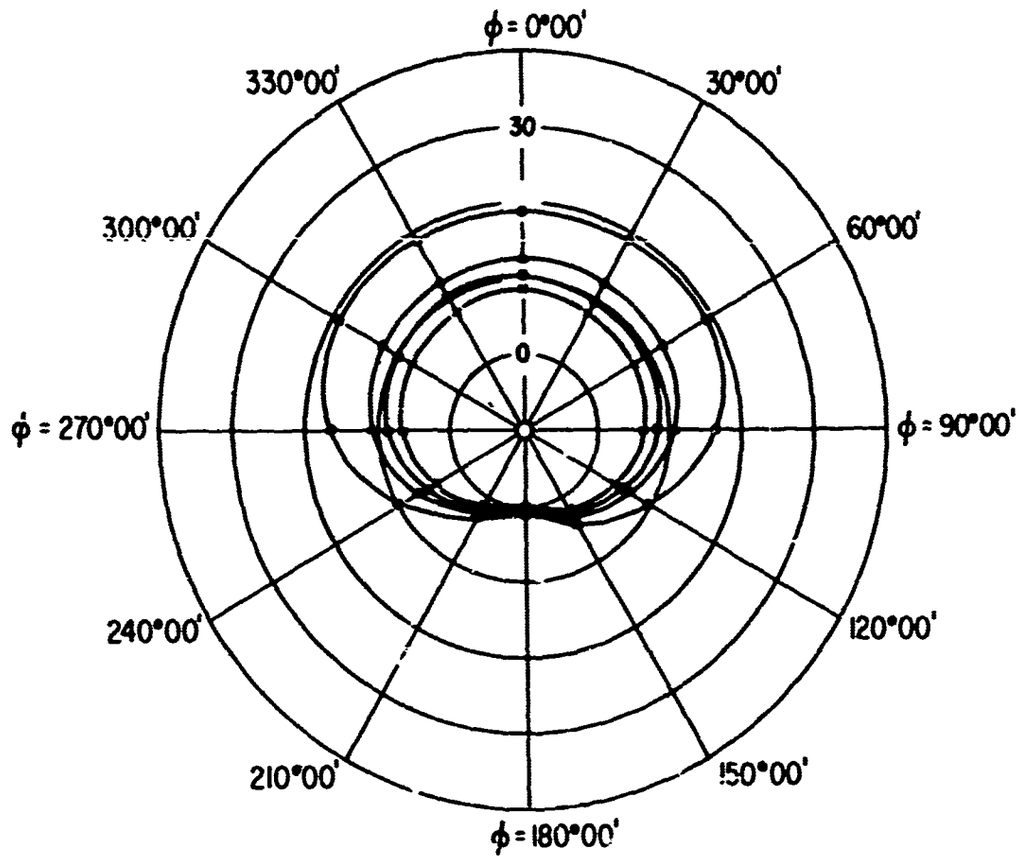
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 40°

ILLUMINATION: NATURAL LIGHT
θ_i: 78° 30'

FIG 25. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.59 + 4.74 \cos\varphi - 1.01 \cos 2\varphi + 0.00 \cos 3\varphi - 0.19 \cos 4\varphi + 0.26 \cos 5\varphi + 0.62 \cos 6\varphi - 0.01 \sin\varphi - 0.07 \sin 2\varphi - 0.02 \sin 3\varphi - 0.07 \sin 4\varphi - 0.01 \sin 5\varphi$$



SAMPLE: DESERT SAND
θ: 50°

ILLUMINATION: NATURAL LIGHT
θ_i: 78° 30'

FIG. 26. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.77 + 4.60 \cos\varphi - 1.26 \cos 2\varphi + 0.12 \cos 3\varphi + 0.06 \cos 4\varphi + 0.13 \cos 5\varphi - 0.23 \cos 6\varphi - 0.06 \sin\varphi - 0.10 \sin 2\varphi - 0.08 \sin 3\varphi - 0.10 \sin 4\varphi + 0.02 \sin 5\varphi$$

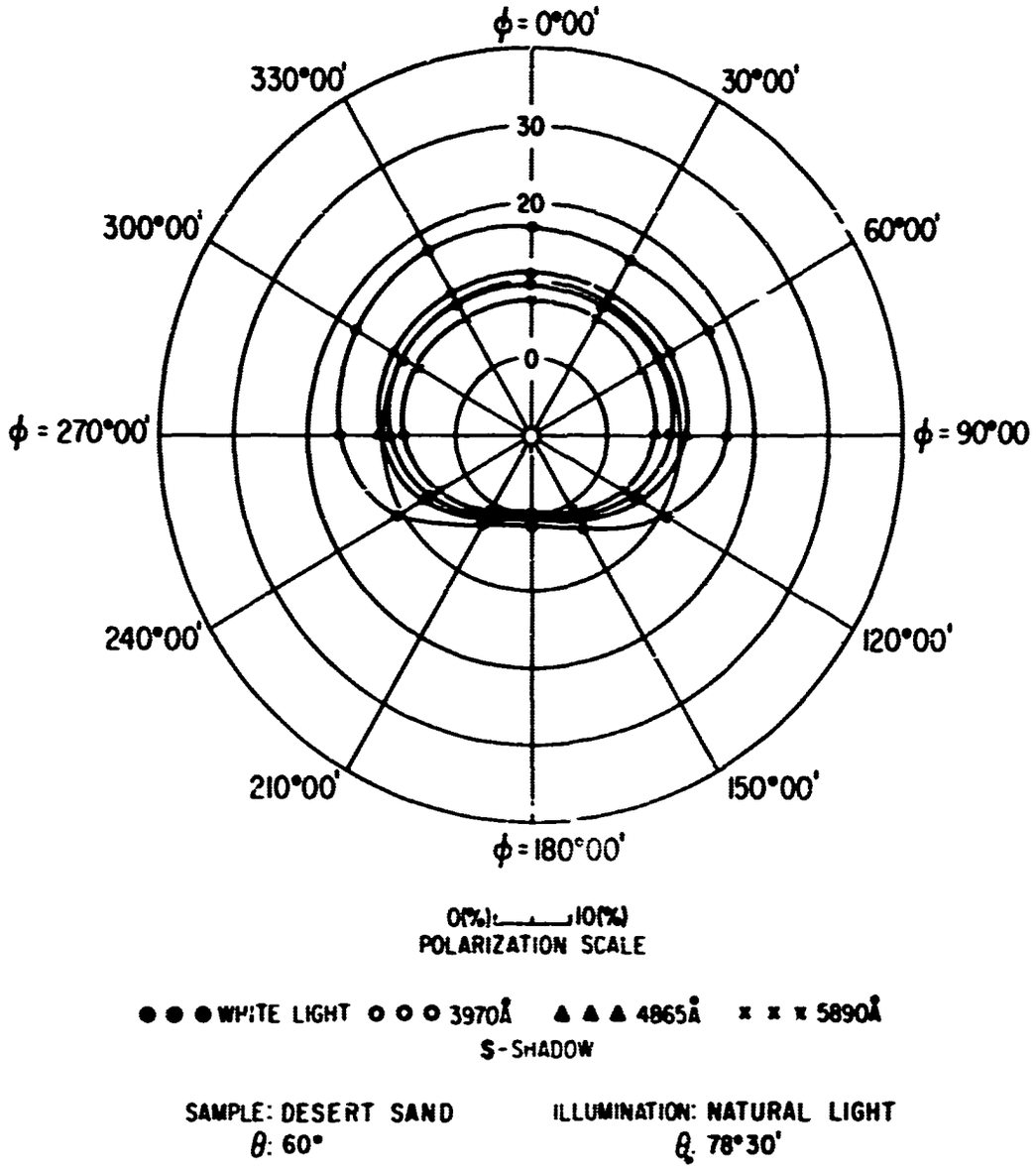


FIG 27. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.83 + 4.14 \cos\varphi - 1.99 \cos 2\varphi + 0.25 \cos 3\varphi + 0.22 \cos 4\varphi - 0.04 \cos 5\varphi$$
$$+ 0.31 \cos 5\varphi - 0.04 \sin\varphi - 0.16 \sin 2\varphi - 0.08 \sin 3\varphi - 0.16 \sin 4\varphi + 0.15 \sin 5\varphi$$

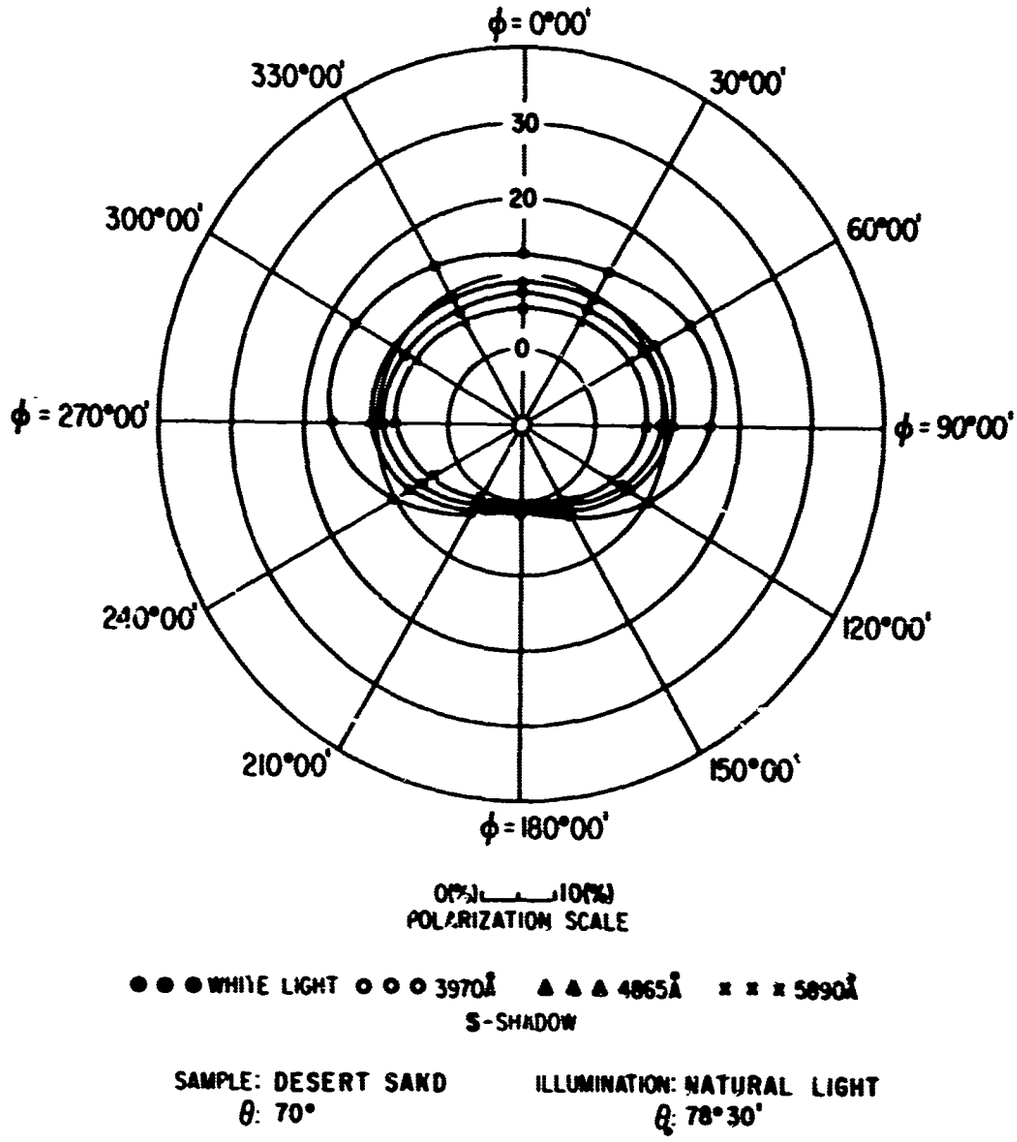
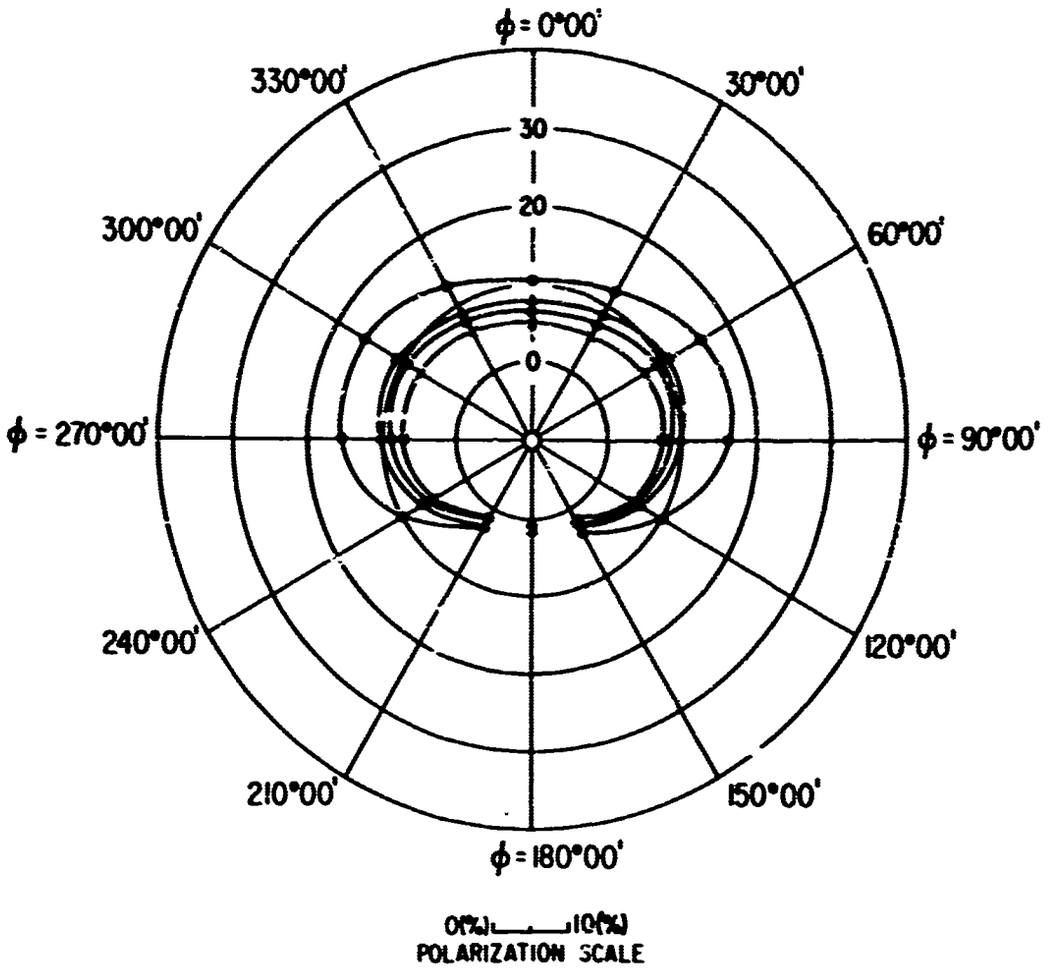


FIG 28. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.51 + 3.24 \cos\varphi - 2.45 \cos 2\varphi - 0.02 \cos 3\varphi + 0.32 \cos 4\varphi - 0.17 \cos 5\varphi + 0.35 \cos 6\varphi - 0.03 \sin\varphi - 0.06 \sin 2\varphi - 0.07 \sin 3\varphi - 0.06 \sin 4\varphi - 0.03 \sin 5\varphi$$



SAMPLE: DESERT SAND
θ: 75°

ILLUMINATION: NATURAL LIGHT
θ_i: 78° 30'

FIG 29. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.02 + 3.31 \cos\varphi - 2.37 \cos 2\varphi - 0.62 \cos 3\varphi - 0.10 \cos 4\varphi + 0.09 \cos 5\varphi + 0.18 \cos 6\varphi - 0.07 \sin\varphi - 0.12 \sin 2\varphi - 0.03 \sin 3\varphi - 0.12 \sin 4\varphi - 0.07 \sin 5\varphi$$

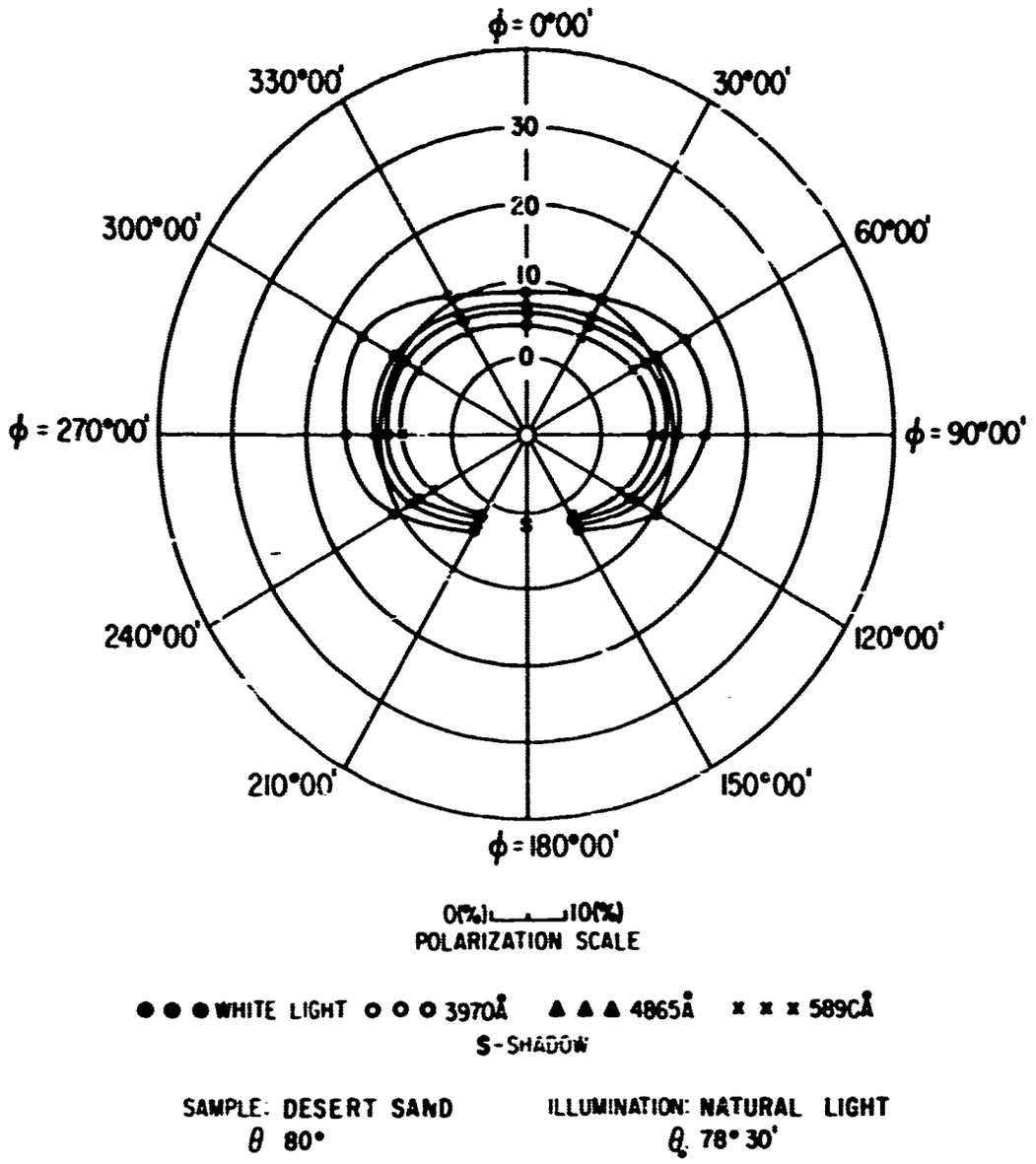


FIG 30. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.11 + 2.35 \cos\varphi - 2.76 \cos 2\varphi - 0.15 \cos 3\varphi - 0.11 \cos 4\varphi - 0.22 \cos 5\varphi$$
$$+ 0.72 \cos 6\varphi - 0.08 \sin\varphi - 0.13 \sin 2\varphi - 0.15 \sin 3\varphi - 0.13 \sin 4\varphi - 0.08 \sin 5\varphi$$

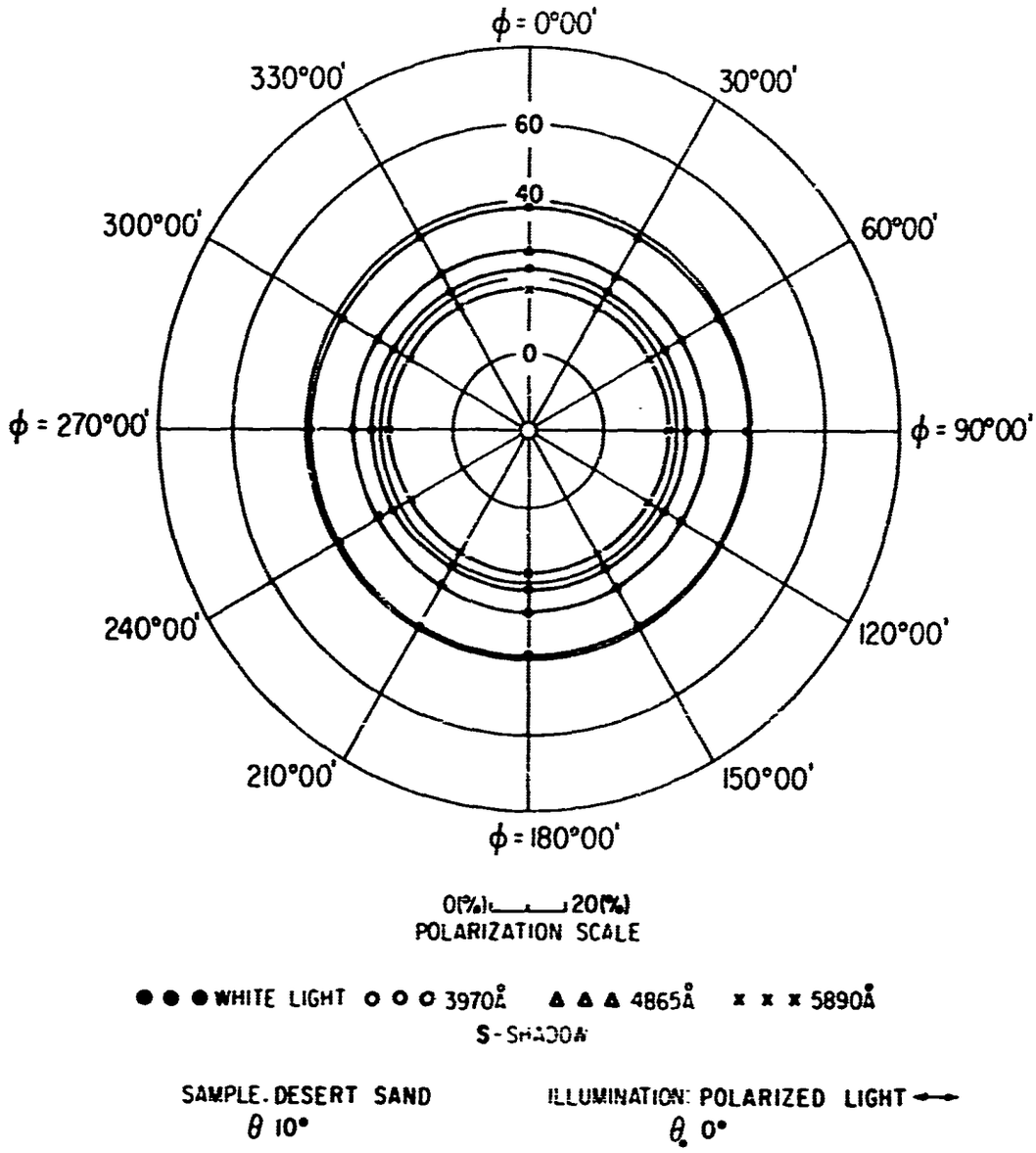


FIG 31. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.52 - 0.06\cos\varphi - 0.25\cos 2\varphi - 0.22\cos 3\varphi + 0.43\cos 4\varphi - 0.03\cos 5\varphi + 0.20\cos 6\varphi + 0.33\sin\varphi + 0.00\sin 2\varphi + 0.08\sin 3\varphi - 0.32\sin 4\varphi - 0.05\sin 5\varphi$$

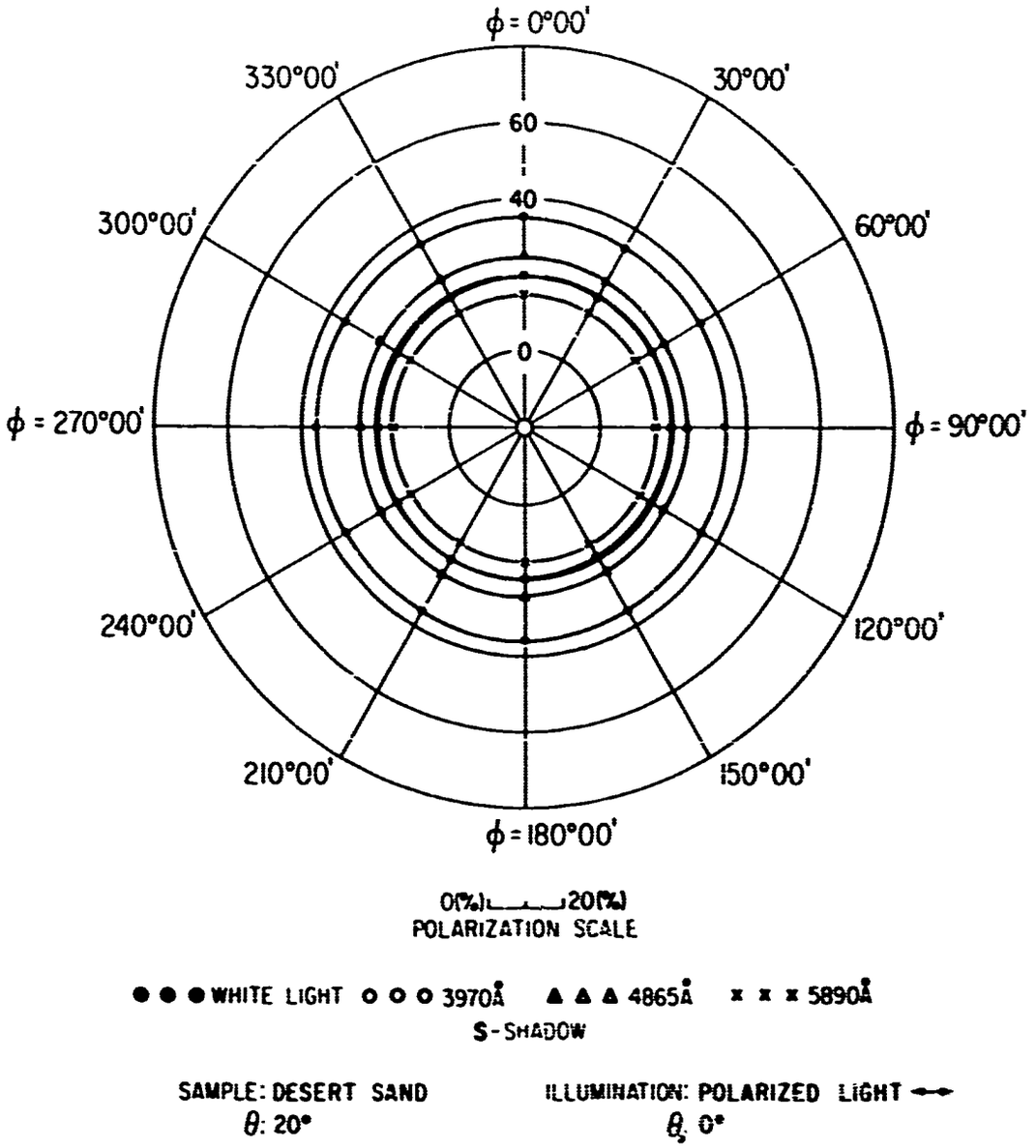


FIG 32. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.80 - 0.18\cos\varphi + 0.67\cos 2\varphi + 0.17\cos 3\varphi + 0.30\cos 4\varphi - 0.04\cos 5\varphi - 0.07\cos 6\varphi + 0.08\sin\varphi + 0.15\sin 2\varphi + 0.00\sin 3\varphi - 0.12\sin 4\varphi - 0.13\sin 5\varphi$$

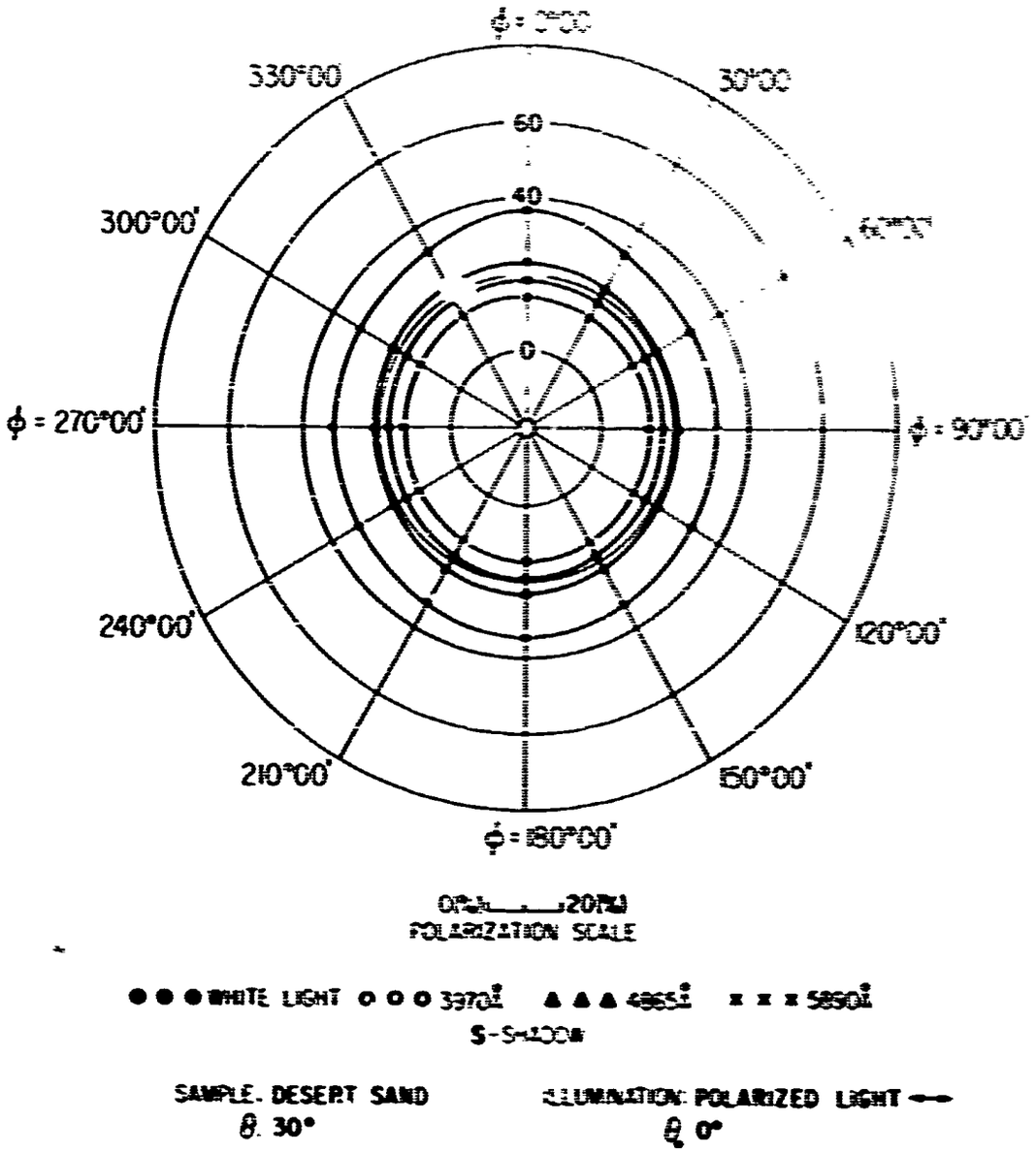
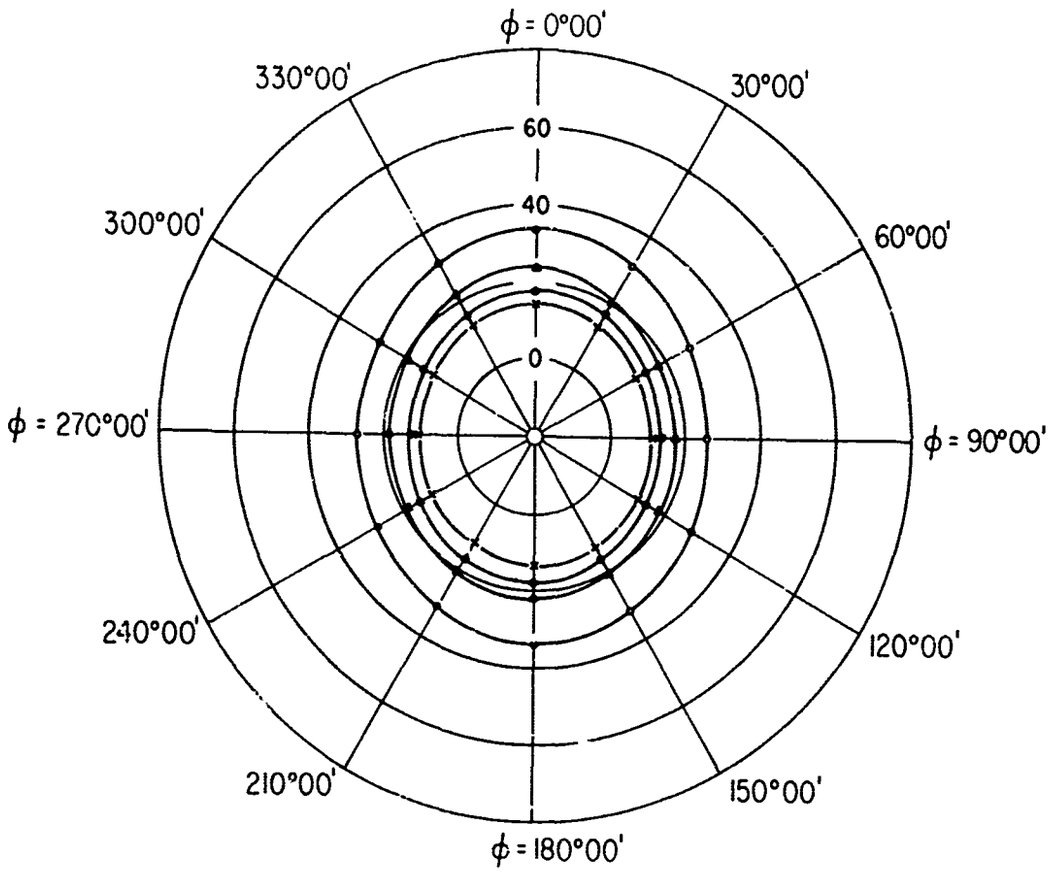


FIG 33. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.93 - 0.16\cos\varphi + 1.32\cos 2\varphi + 0.02\cos 3\varphi + 0.32\cos 4\varphi - 0.02\cos 5\varphi + 0.18\cos 6\varphi - 0.03\sin\varphi - 0.17\sin 2\varphi - 0.08\sin 3\varphi + 0.12\sin 4\varphi - 0.20\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ 40°

ILLUMINATION: POLARIZED LIGHT
θ_0 0°

FIG 34. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.08 + 0.13 \cos\varphi + 3.12 \cos 2\varphi - 0.05 \cos 3\varphi + 0.10 \cos 4\varphi - 0.40 \cos 5\varphi + 0.26 \cos 6\varphi + 0.53 \sin\varphi + 0.07 \sin 2\varphi - 0.43 \sin 3\varphi + 0.09 \sin 4\varphi + 0.68 \sin 5\varphi$$

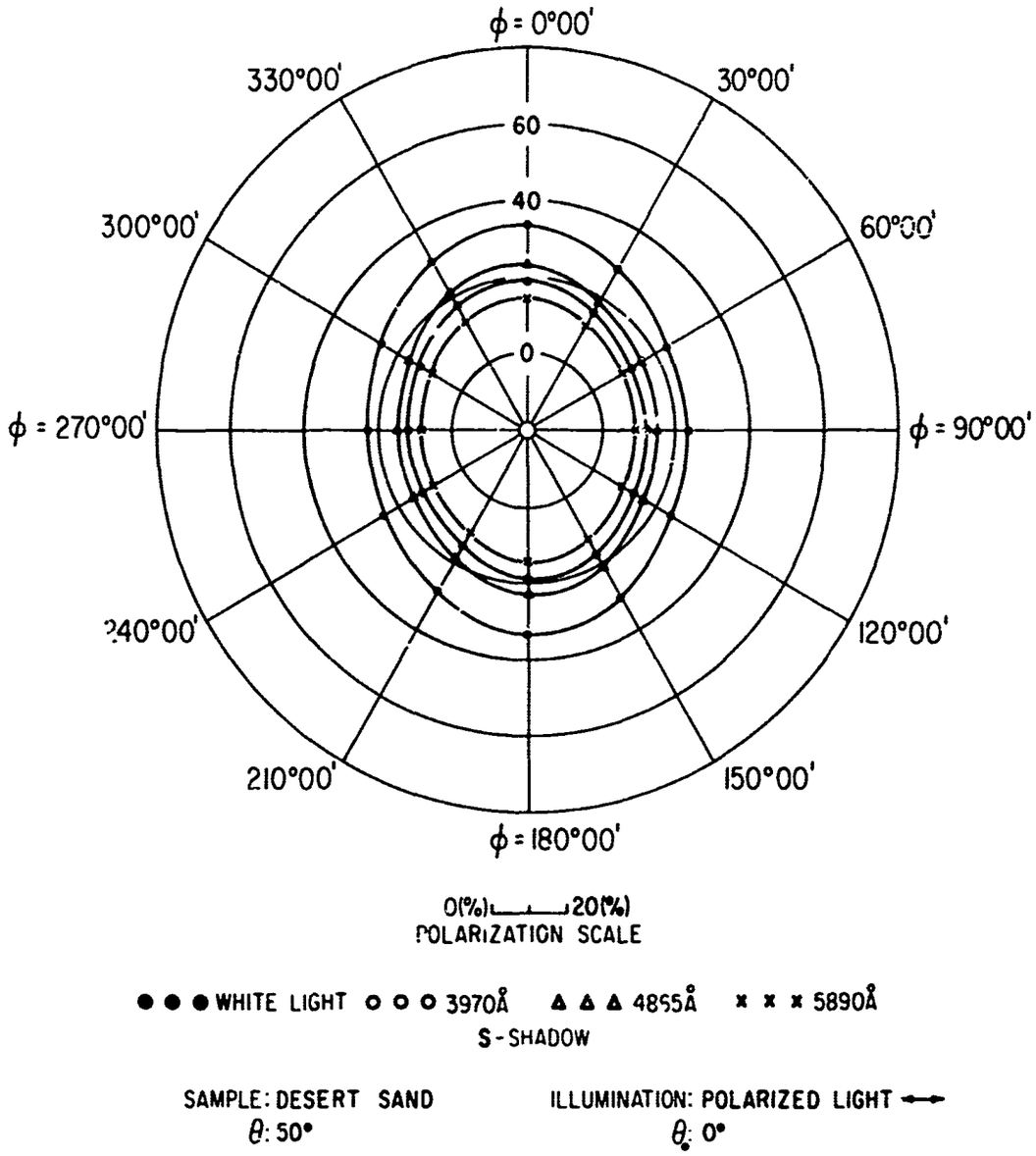


FIG 35. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 15.06 + 0.07 \cos\varphi + 3.53 \cos 2\varphi - 0.02 \cos 3\varphi + 0.97 \cos 4\varphi - 0.10 \cos 5\varphi - 0.10 \cos 6\varphi - 0.03 \sin\varphi - 0.72 \sin 2\varphi + 0.00 \sin 3\varphi - 0.43 \sin 4\varphi + 0.03 \sin 5\varphi$$

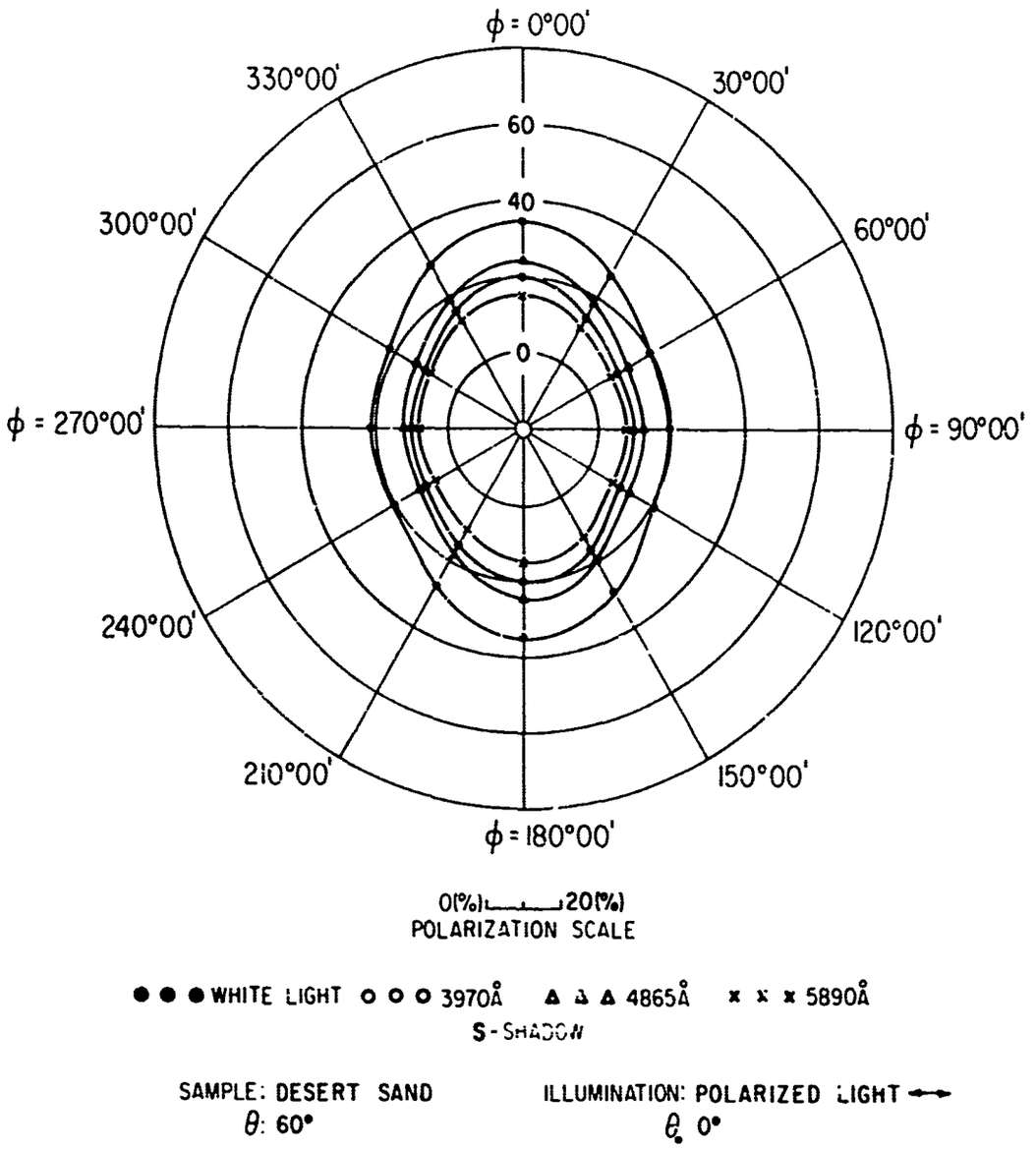
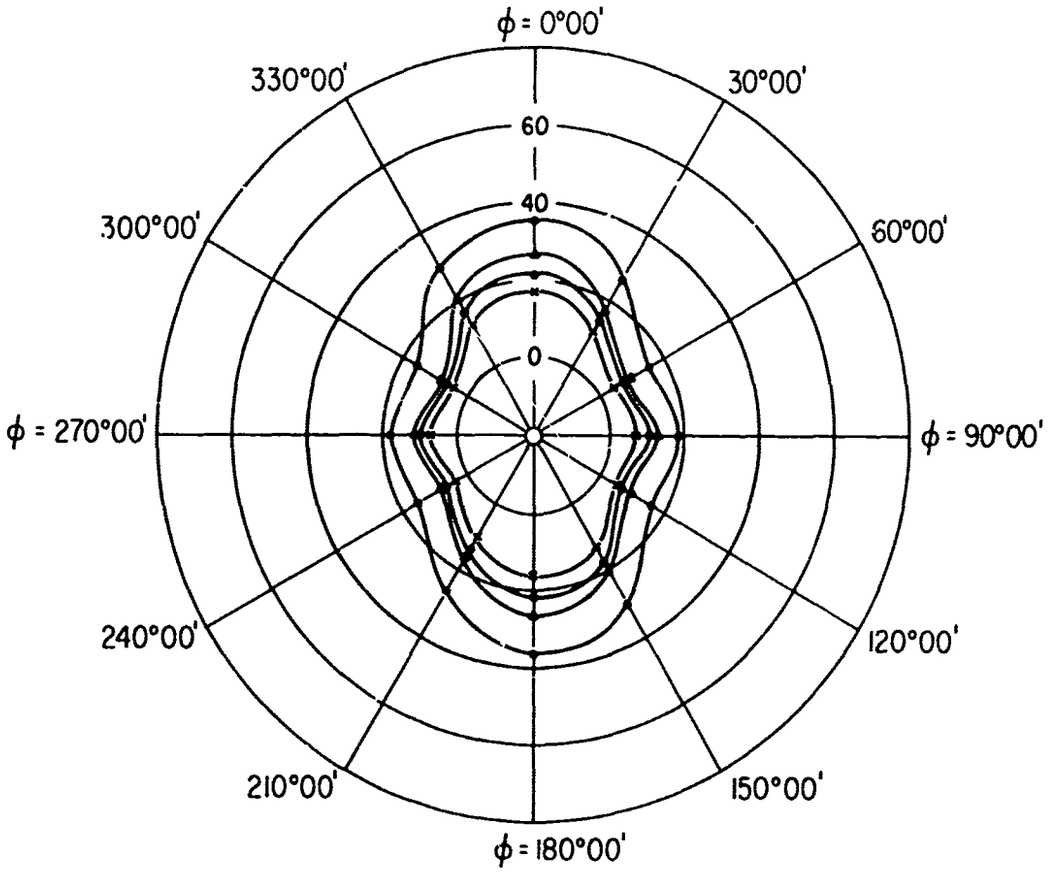


FIG 36. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.99 - 0.02\cos\varphi + 4.59\cos 2\varphi + 0.02\cos 3\varphi + 0.71\cos 4\varphi + 0.10\cos 5\varphi - 0.83\cos 6\varphi - 0.16\sin\varphi - 0.82\sin 2\varphi + 0.03\sin 3\varphi + 0.54\sin 4\varphi + 0.10\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 70°

ILLUMINATION: POLARIZED LIGHT
θ_0: 0°

FIG 37. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.18 - 0.10 \cos\varphi + 6.63 \cos 2\varphi + 0.05 \cos 3\varphi - 2.97 \cos 4\varphi - 0.10 \cos 5\varphi$$
$$- 1.90 \cos 6\varphi - 0.08 \sin\varphi - 1.01 \sin 2\varphi - 0.12 \sin 3\varphi - 0.78 \sin 4\varphi - 0.08 \sin 5\varphi$$

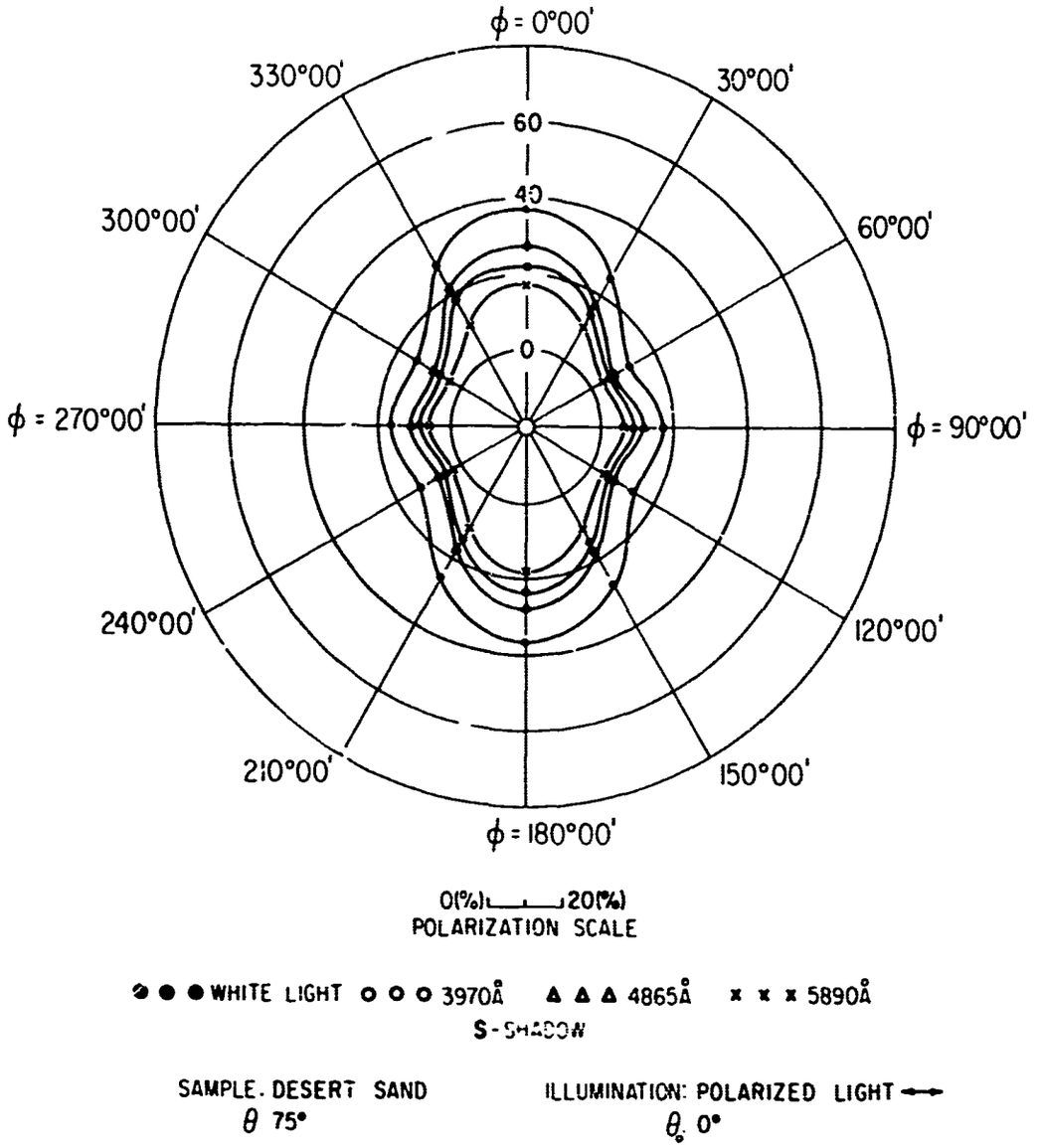


FIG 38. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.87 + 1.52 \cos\varphi + 6.97 \cos 2\varphi + 0.97 \cos 3\varphi + 1.68 \cos 4\varphi + 0.16 \cos 5\varphi - 3.50 \cos 6\varphi + 0.22 \sin\varphi - 0.32 \sin 2\varphi + 0.80 \sin 3\varphi - 0.46 \sin 4\varphi + 0.42 \sin 5\varphi$$

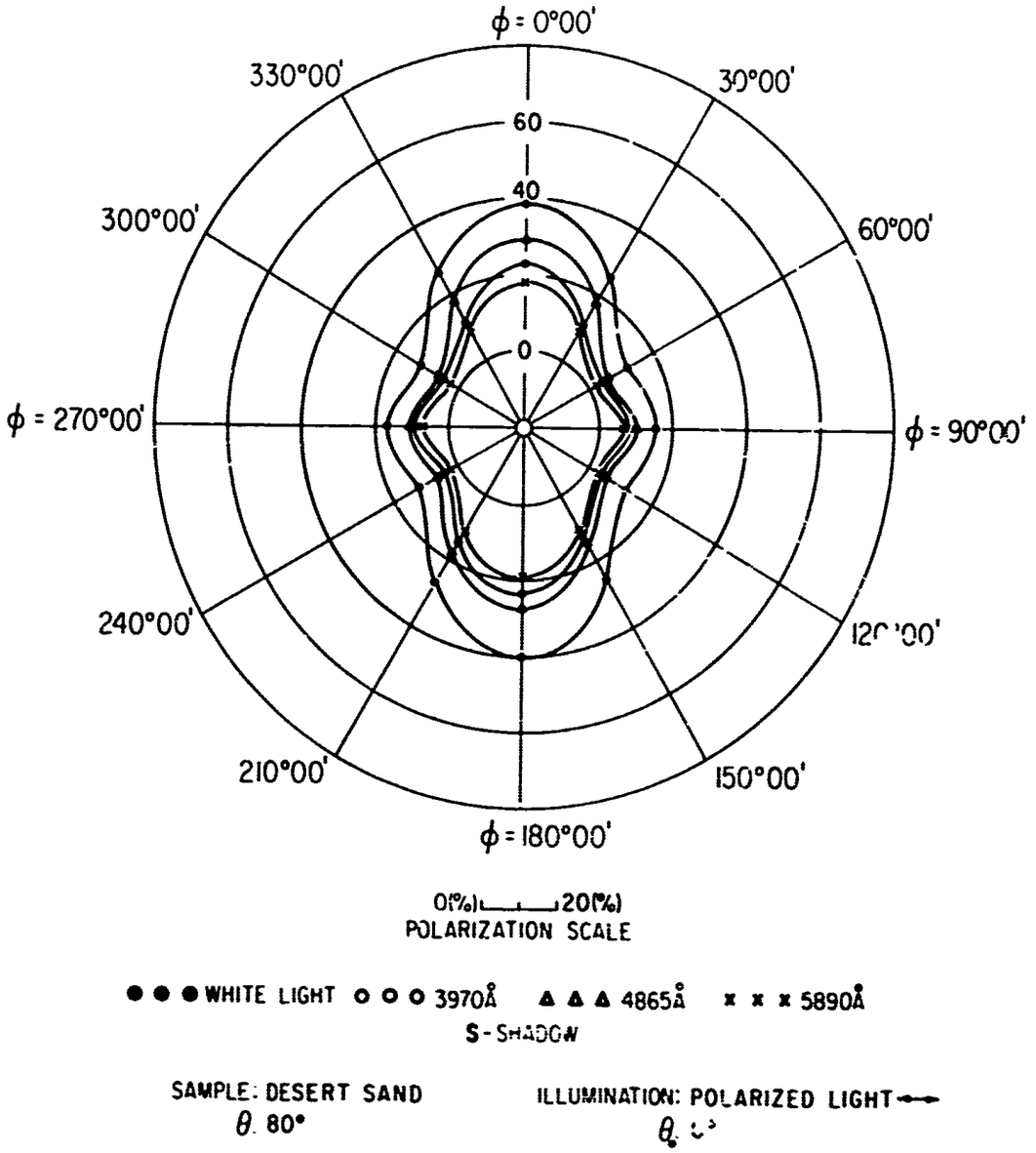


FIG 39. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.68 + 0.88 \cos\varphi + 8.70 \cos 2\varphi + 0.18 \cos 3\varphi + 3.52 \cos 4\varphi - 1.06 \cos 5\varphi - 4.00 \cos 6\varphi + 0.32 \sin\varphi - 0.22 \sin 2\varphi + 1.08 \sin 3\varphi - 0.32 \sin 4\varphi + 0.76 \sin 5\varphi$$

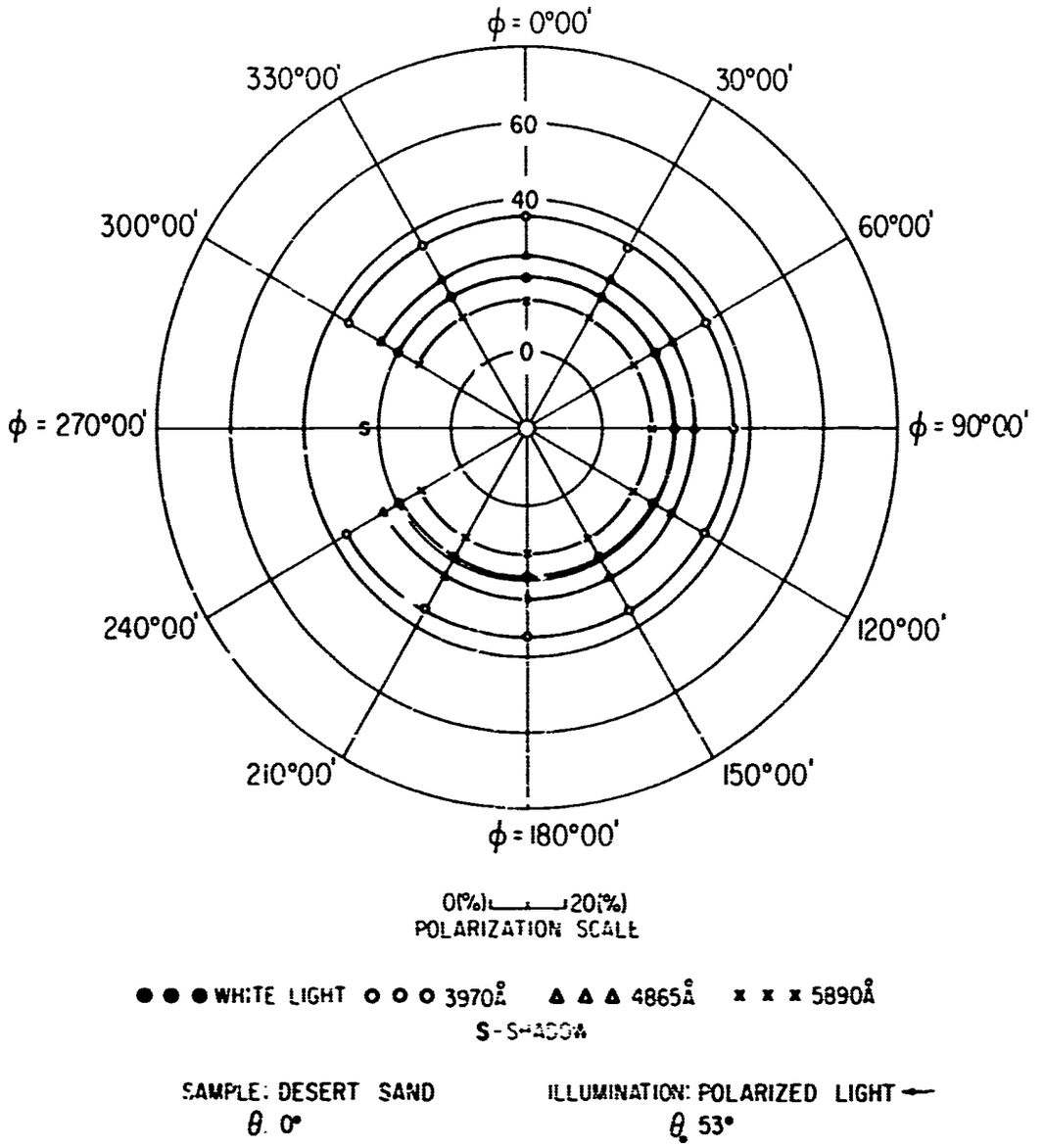


FIG 40. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

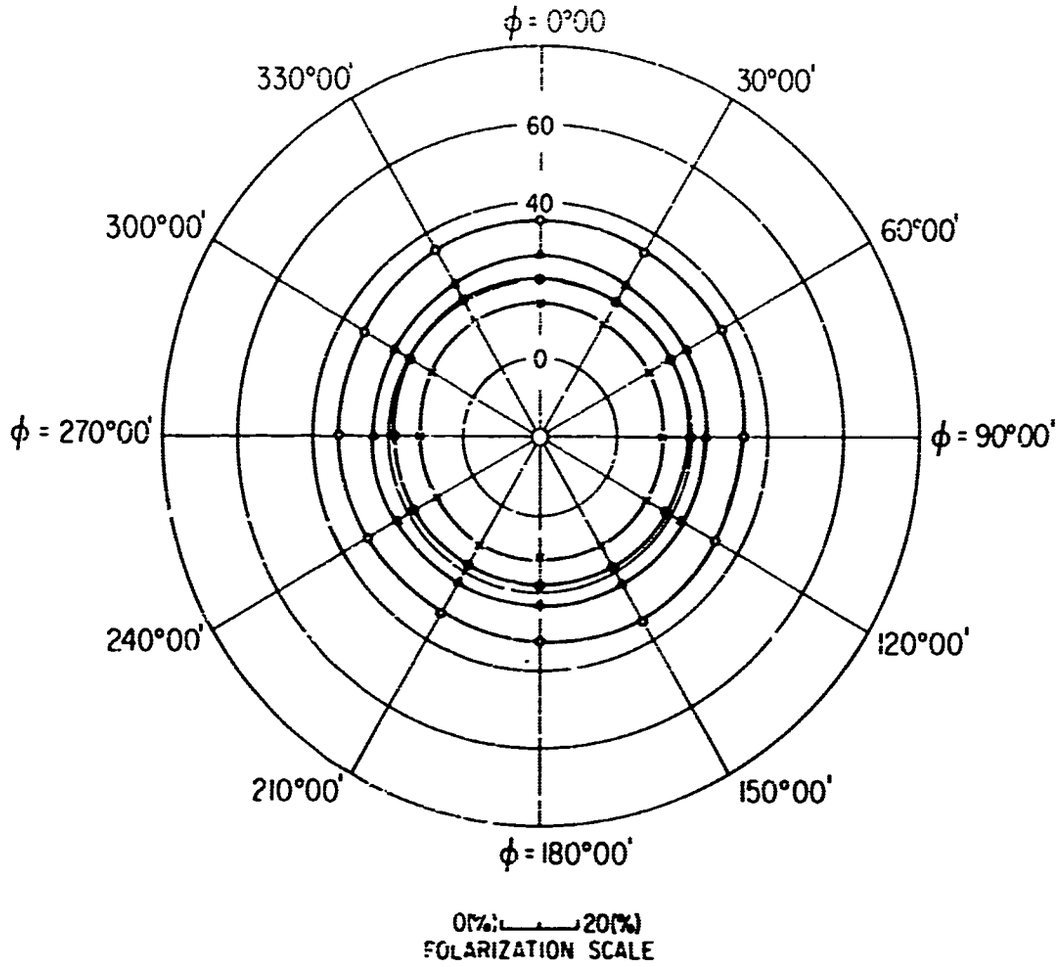


FIG 41. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 19.08 + 1.20 \cos\phi + 0.41 \cos 2\phi - 0.01 \cos 3\phi + 0.14 \cos 4\phi - 0.04 \cos 5\phi$$
$$- 0.33 \cos 6\phi - 0.07 \sin\phi - 0.07 \sin 2\phi + 0.01 \sin 3\phi - 0.16 \sin 4\phi - 0.12 \sin 5\phi$$

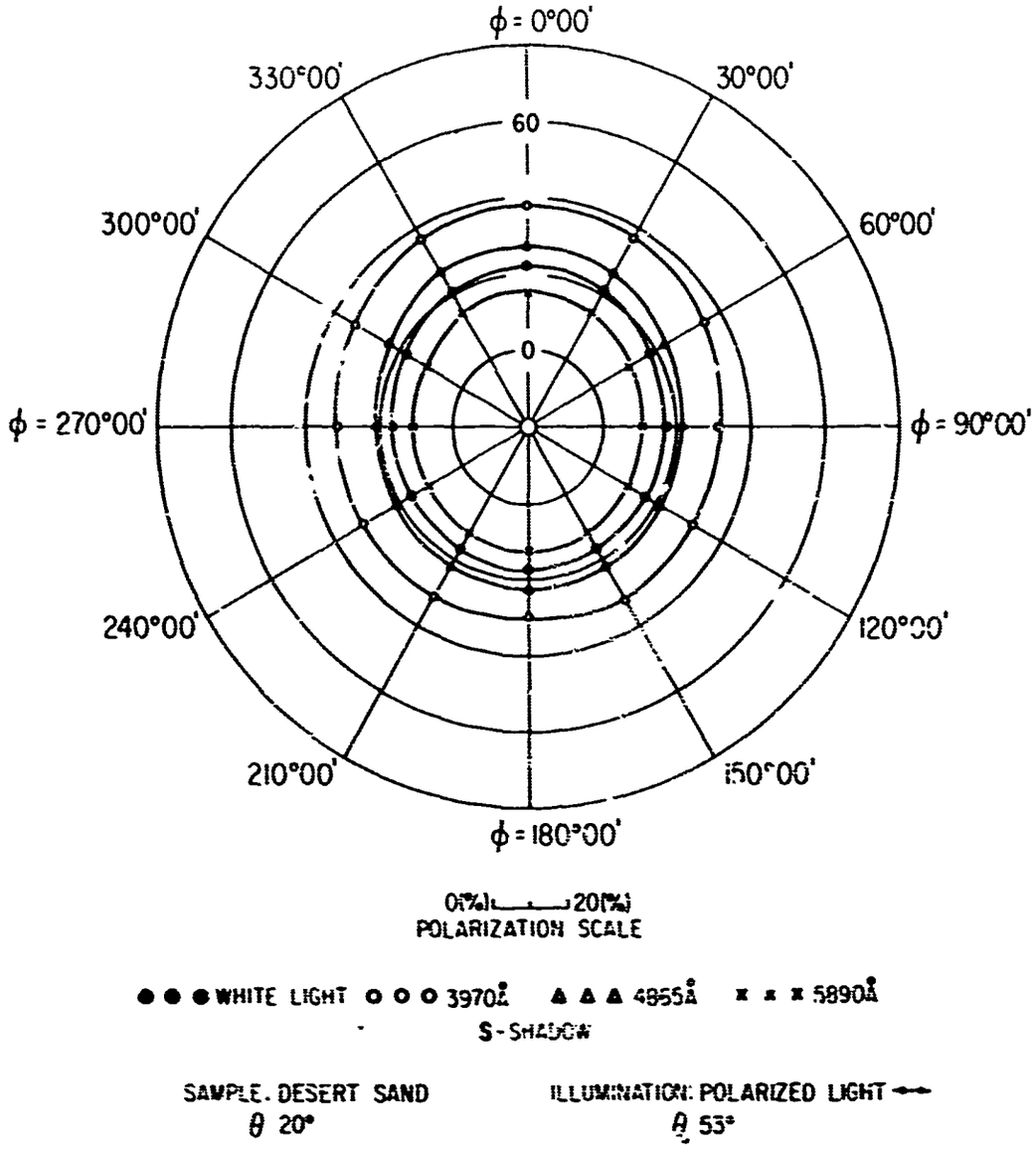
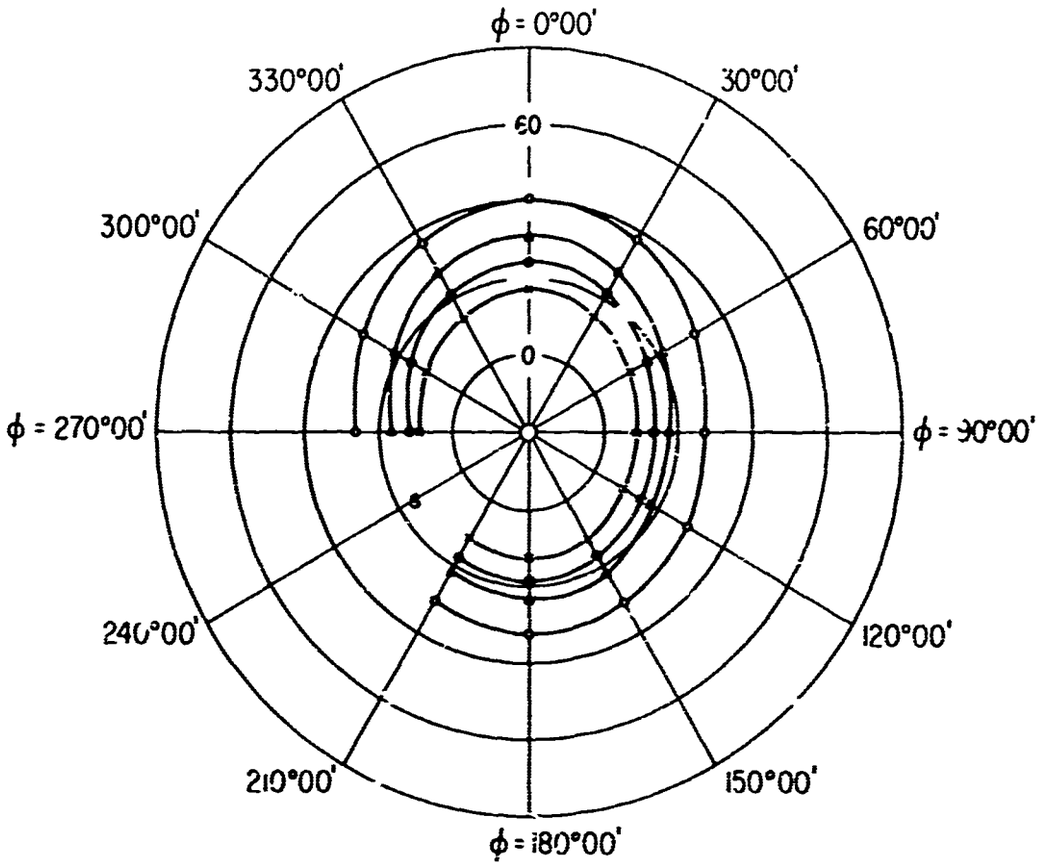


FIG 42. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 16.26 + 1.69 \cos\phi + 2.16 \cos 2\phi - 0.10 \cos 3\phi + 0.21 \cos 4\phi - 0.19 \cos 5\phi + 0.13 \cos 6\phi + 0.06 \sin\phi + 0.07 \sin 2\phi + 0.03 \sin 3\phi + 0.01 \sin 4\phi + 0.33 \sin 5\phi$$



● ● ● WHITE LIGHT c o o 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ. 30°

ILLUMINATION: POLARIZED LIGHT ←→
θ_i 53°

FIG 43. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 17.38 + 2.39 \cos\phi + 4.15 \cos 2\phi + 0.33 \cos 3\phi + 0.01 \cos 4\phi - 0.03 \cos 5\phi + 0.30 \cos 6\phi - 0.01 \sin\phi + 0.09 \sin 2\phi - 0.13 \sin 3\phi + 0.09 \sin 4\phi - 0.01 \sin 5\phi$$

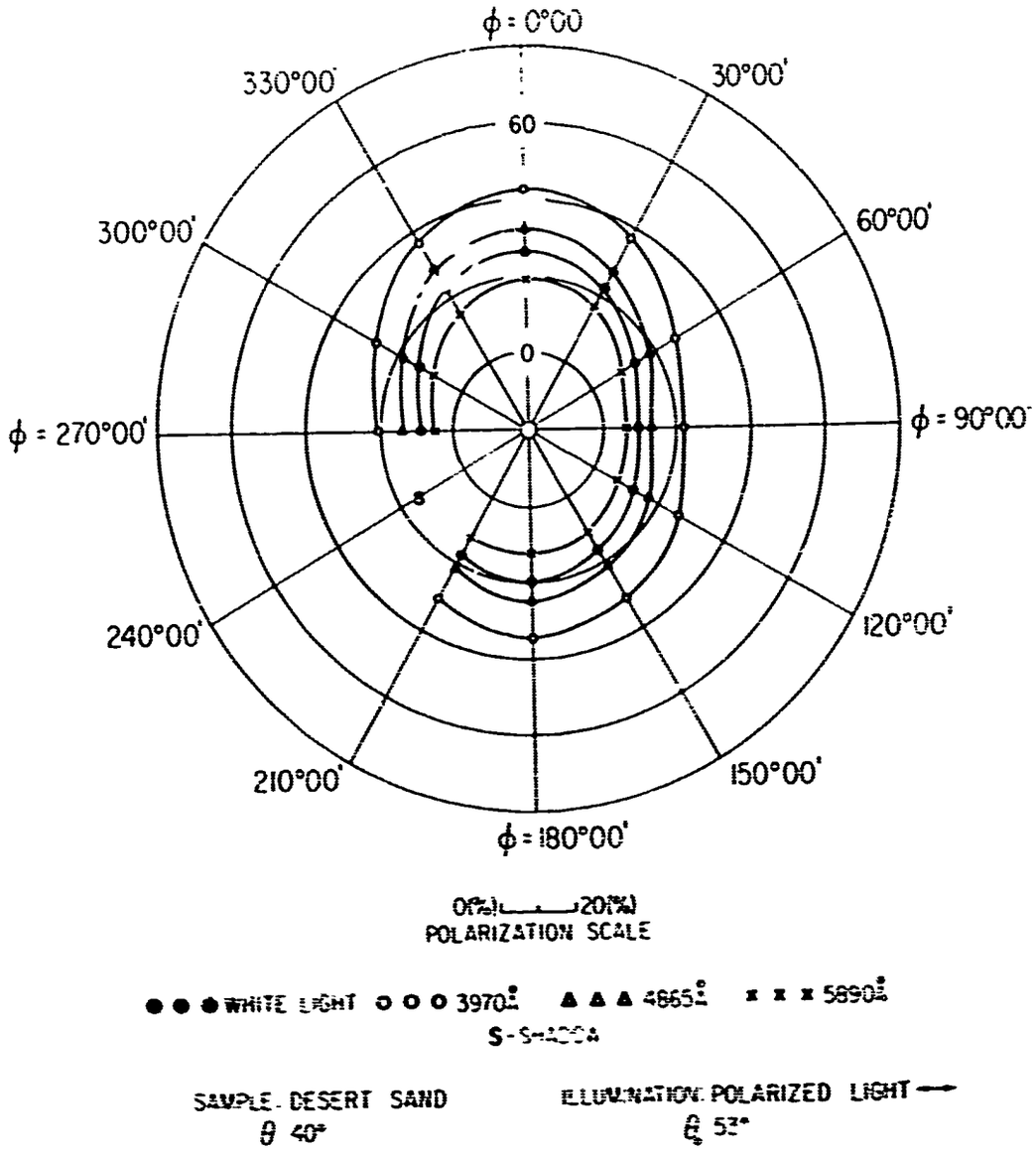


FIG 44. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 16.44 + 2.47 \cos\phi + 7.31 \cos 2\phi + 0.66 \cos 3\phi + 0.16 \cos 4\phi - 0.04 \cos 5\phi - 0.01 \cos 6\phi - 0.06 \sin\phi - 0.04 \sin 2\phi - 0.51 \sin 3\phi + 0.46 \sin 4\phi - 0.06 \sin 5\phi$$

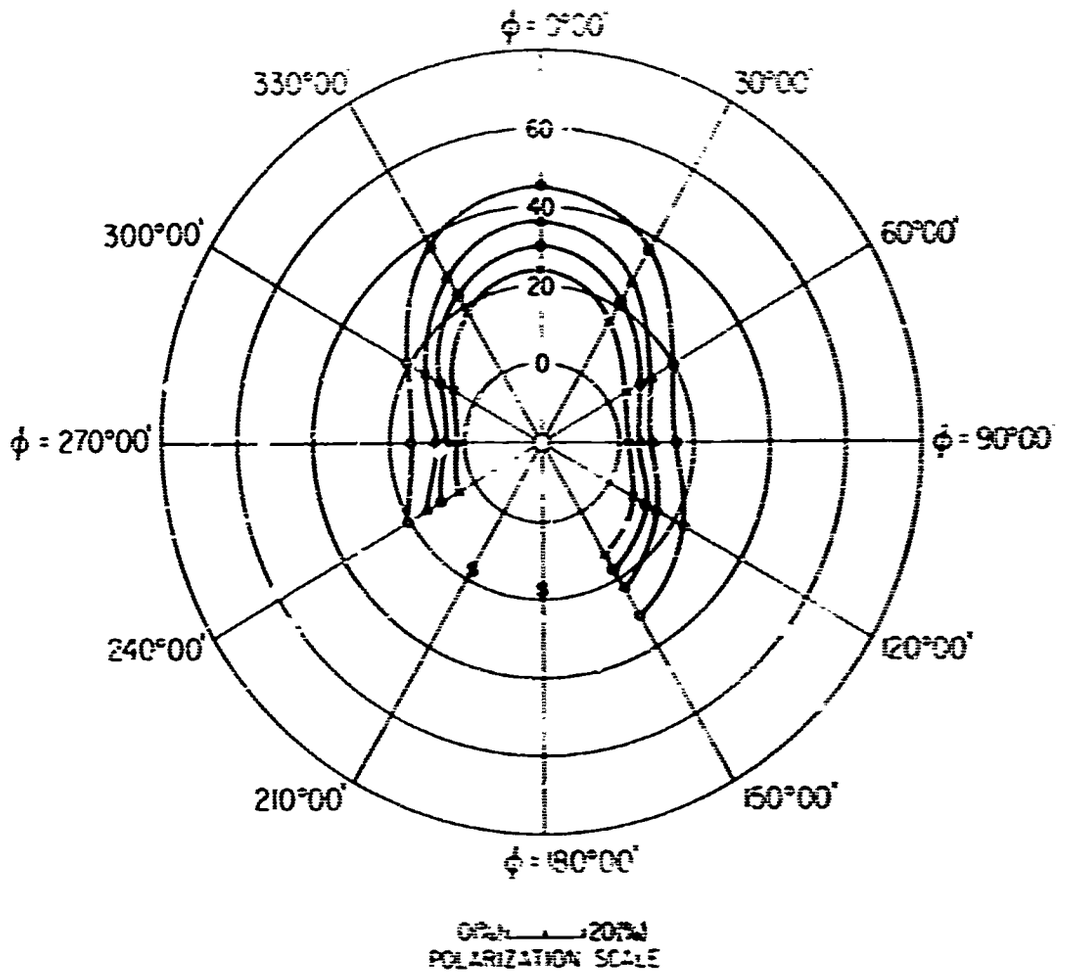


FIG 45. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 15.22 + 2.99 \cos\phi + 9.74 \cos 2\phi + 2.08 \cos 3\phi - 0.22 \cos 4\phi + 1.24 \cos 5\phi$$
$$- 0.08 \cos 6\phi - 0.10 \sin\phi - 0.48 \sin 2\phi - 0.43 \sin 3\phi - 0.05 \sin 4\phi - 0.01 \sin 5\phi$$

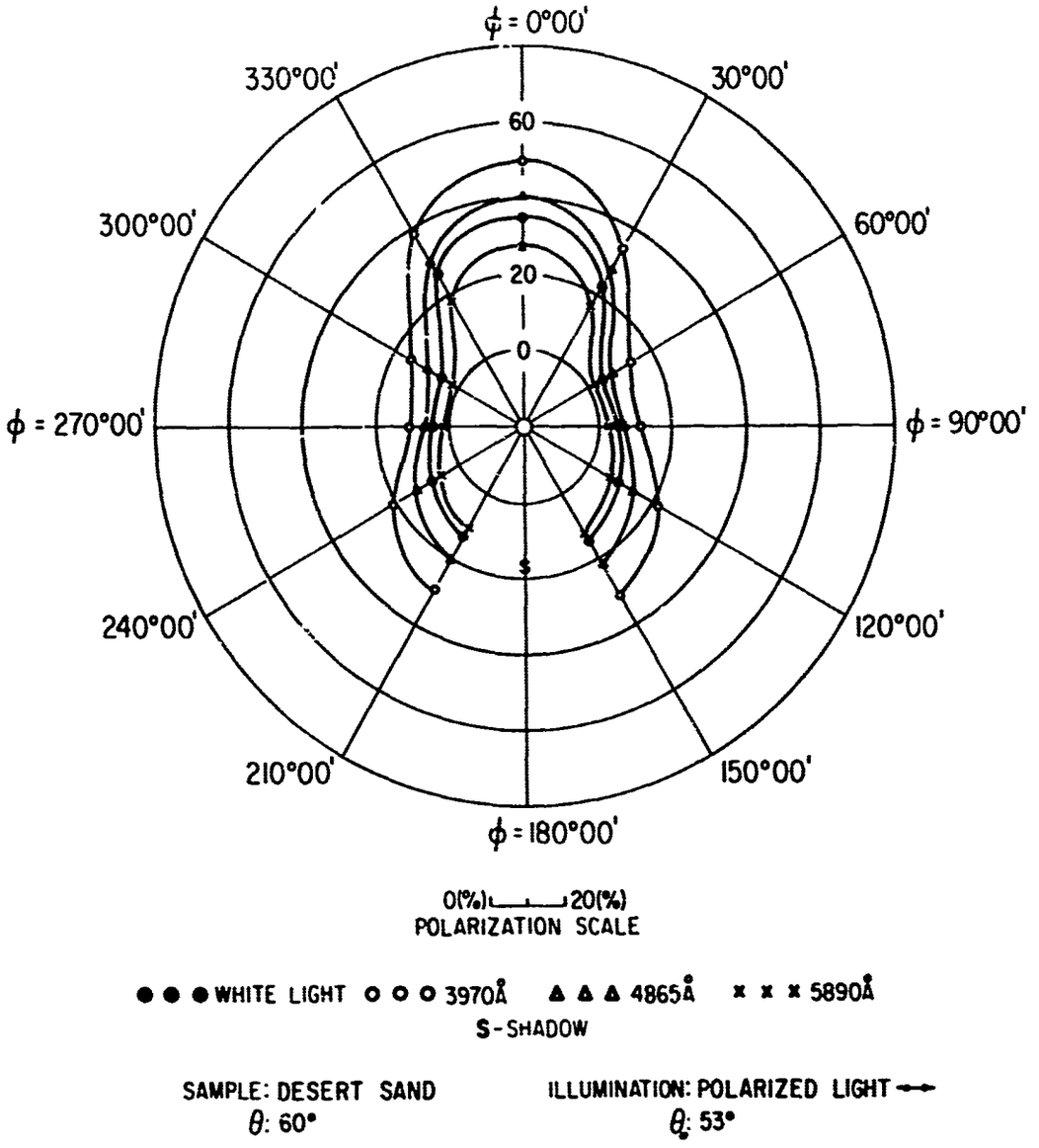


FIG 46. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.33 + 3.63\cos\varphi + 11.97\cos 2\varphi + 3.83\cos 3\varphi + 1.01\cos 4\varphi - 0.75\cos 5\varphi$$
$$+ 0.38\cos 6\varphi - 0.23\sin\varphi - 0.92\sin 2\varphi - 0.38\sin 3\varphi + 0.12\sin 4\varphi - 0.20\sin 5\varphi$$

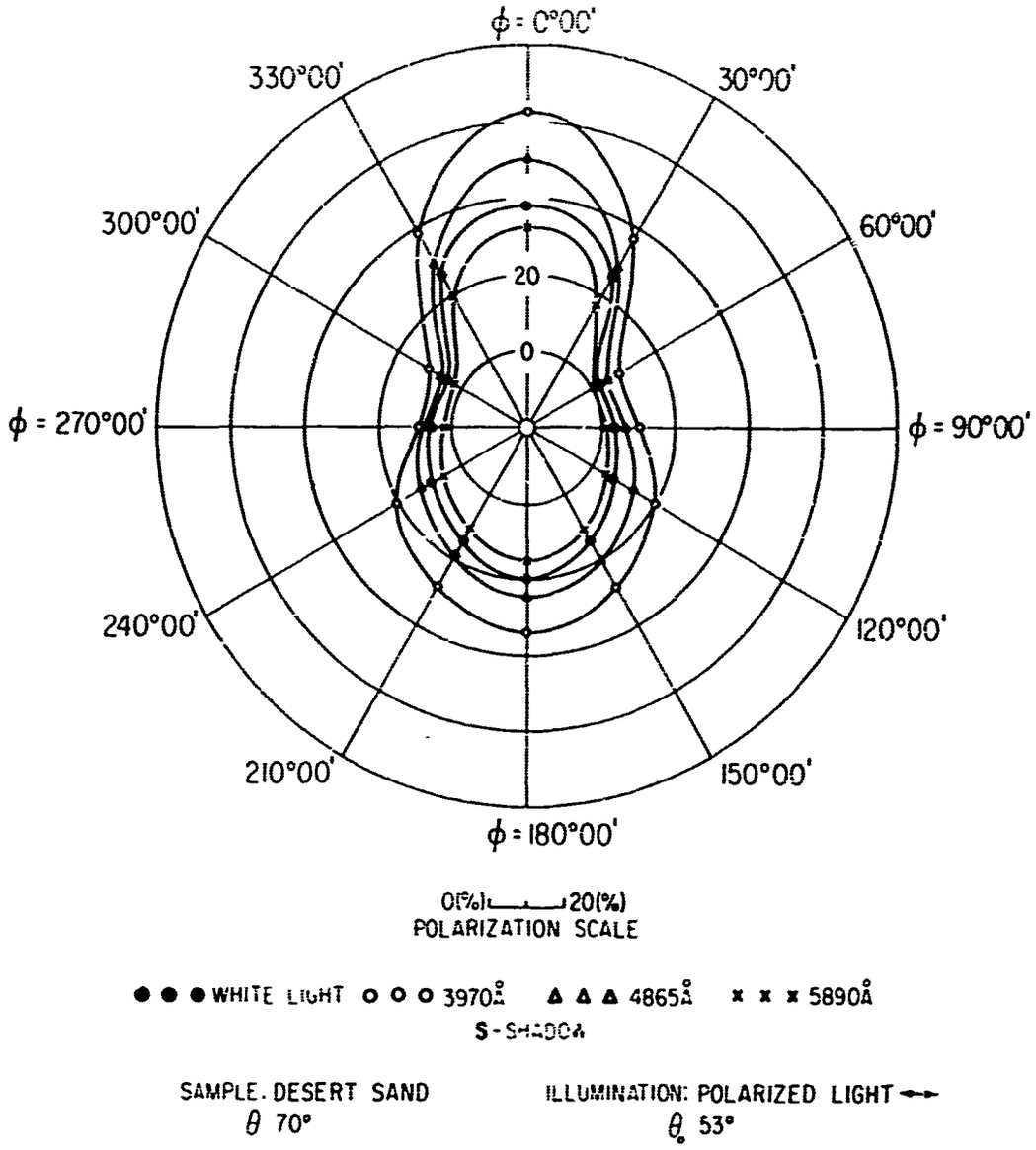


FIG 47. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.40 + 5.22 \cos\varphi + 13.06 \cos 2\varphi + 4.96 \cos 3\varphi + 1.82 \cos 4\varphi - 1.49 \cos 5\varphi - 0.80 \cos 6\varphi - 0.23 \sin\varphi - 0.48 \sin 2\varphi - 0.16 \sin 3\varphi + 0.27 \sin 4\varphi + 0.41 \sin 5\varphi$$

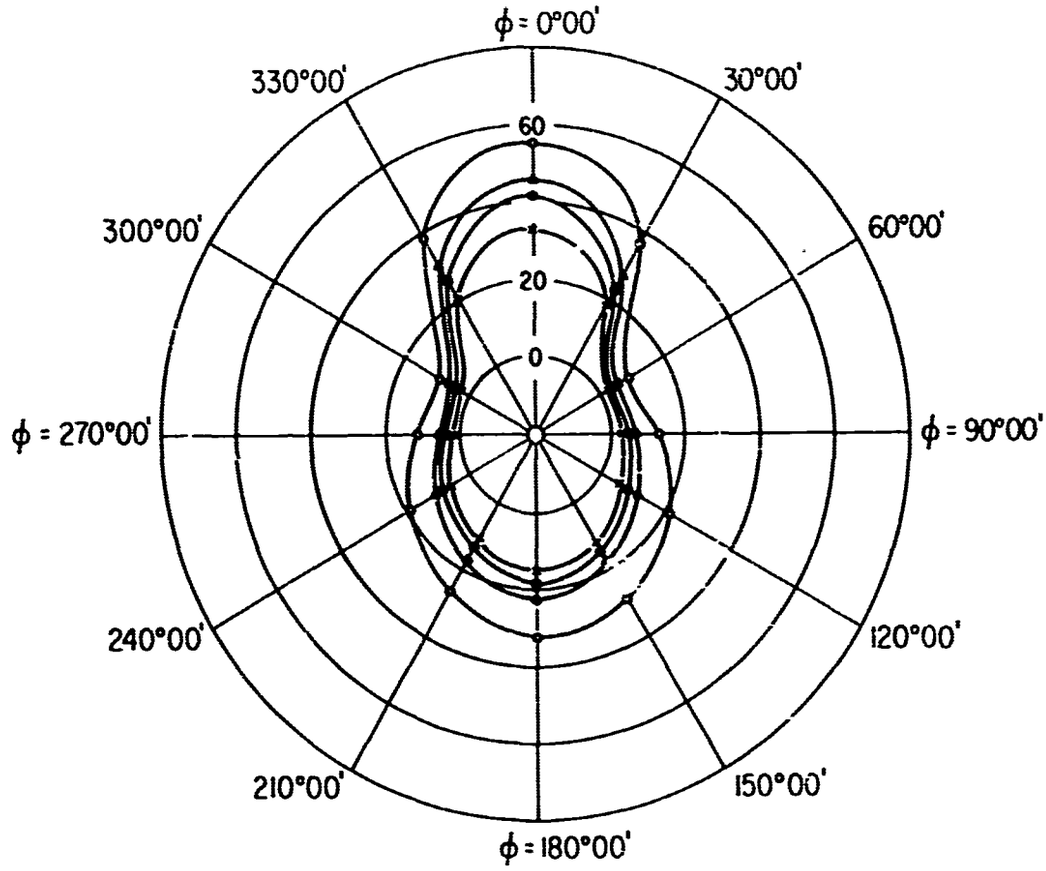
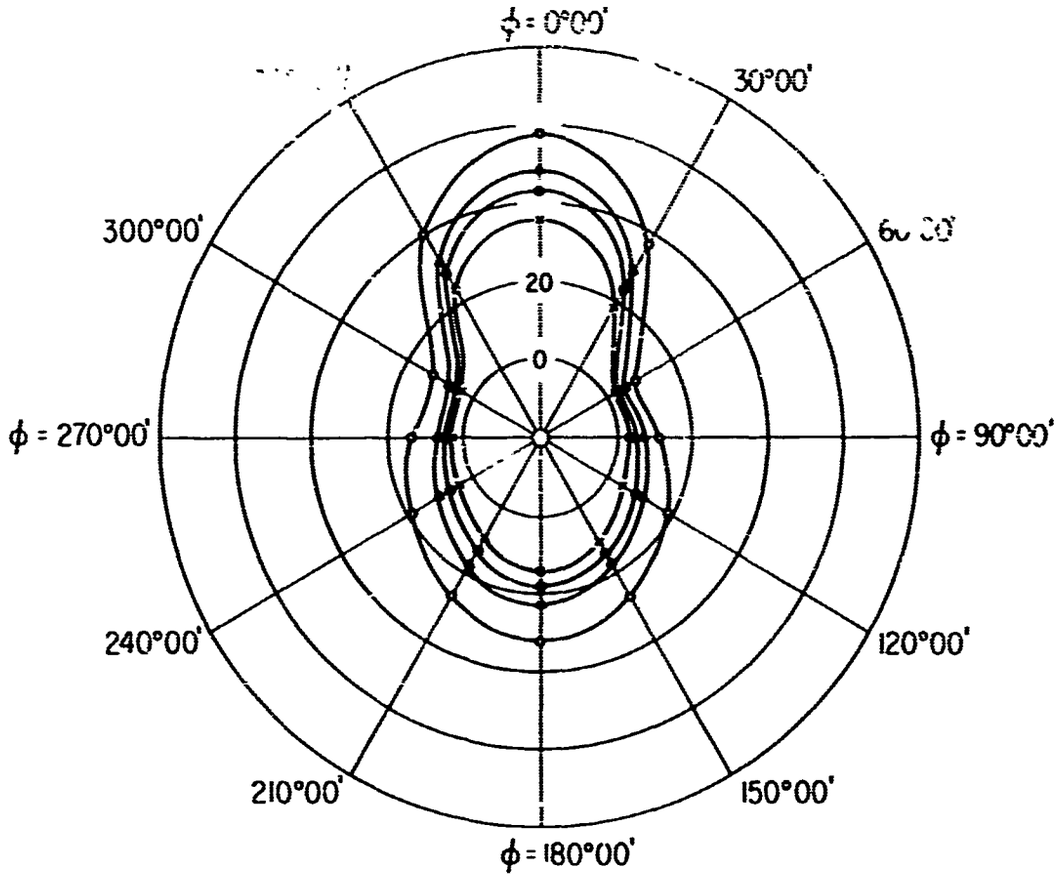


FIG 48. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.45 + 5.94\cos\varphi + 12.66\cos 2\varphi + 5.06\cos 3\varphi + 3.08\cos 4\varphi + 0.06\cos 5\varphi$$
$$+ 0.03\cos 6\varphi - 0.35\sin\varphi - 1.12\sin 2\varphi - 0.53\sin 3\varphi - 0.53\sin 4\varphi - 0.08\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 80°

ILLUMINATION: POLARIZED LIGHT
θ_0: 53°

FIG 49. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.64 + 7.08 \cos\varphi + 13.09 \cos 2\varphi + 5.12 \cos 3\varphi + 3.16 \cos 4\varphi - 0.54 \cos 5\varphi - 0.38 \cos 6\varphi - 0.44 \sin\varphi - 1.34 \sin 2\varphi - 0.76 \sin 3\varphi - 0.62 \sin 4\varphi - 1.14 \sin 5\varphi$$

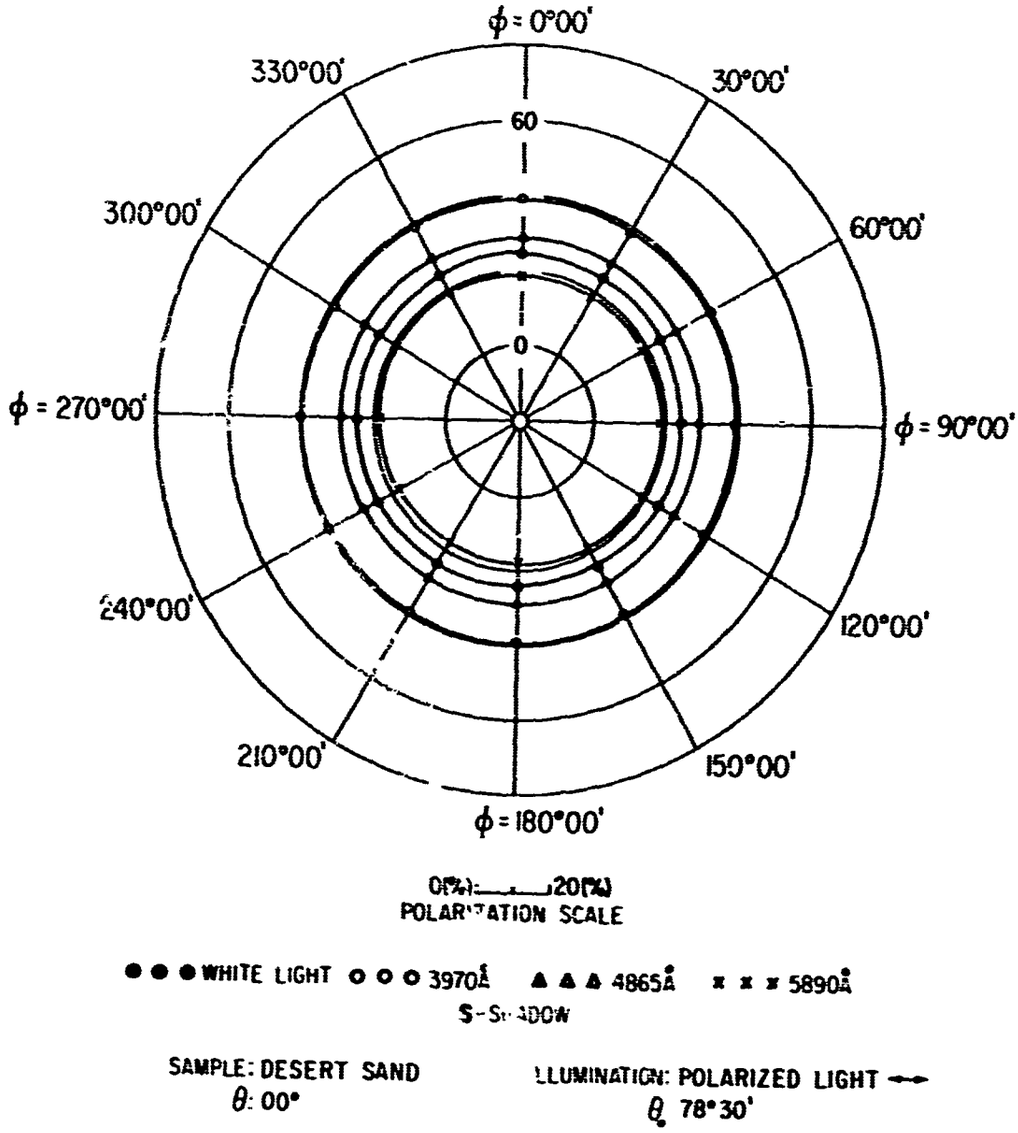


FIG 50. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

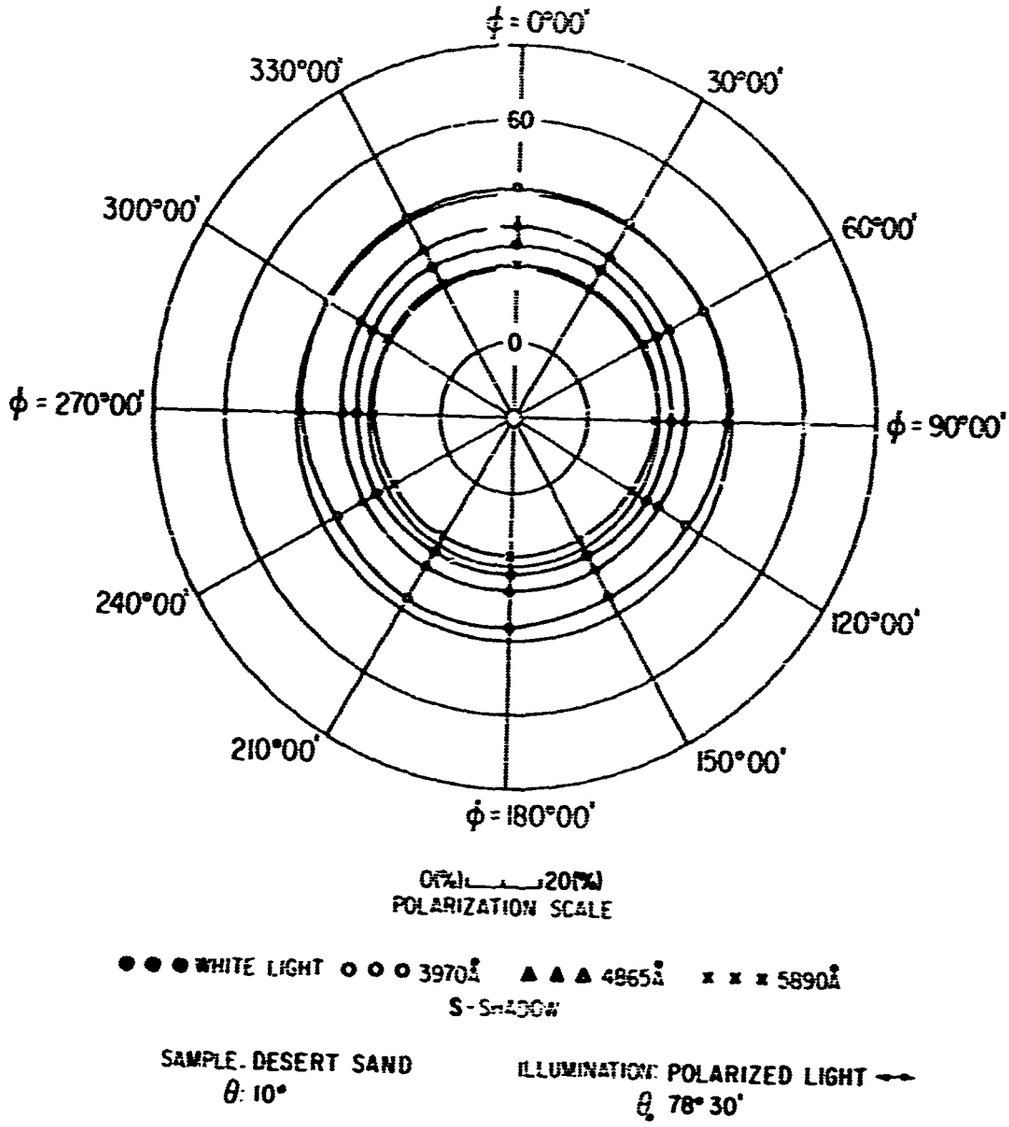


FIG 51. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.1 + 2.63\cos\varphi + 0.38\cos 2\varphi - 0.15\cos 3\varphi + 0.17\cos 4\varphi - 0.41\cos 5\varphi + 0.38\cos 6\varphi + 0.23\sin\varphi - 0.35\sin 2\varphi + 0.467\sin 3\varphi - 0.55\sin 4\varphi + 0.31\sin 5\varphi$$

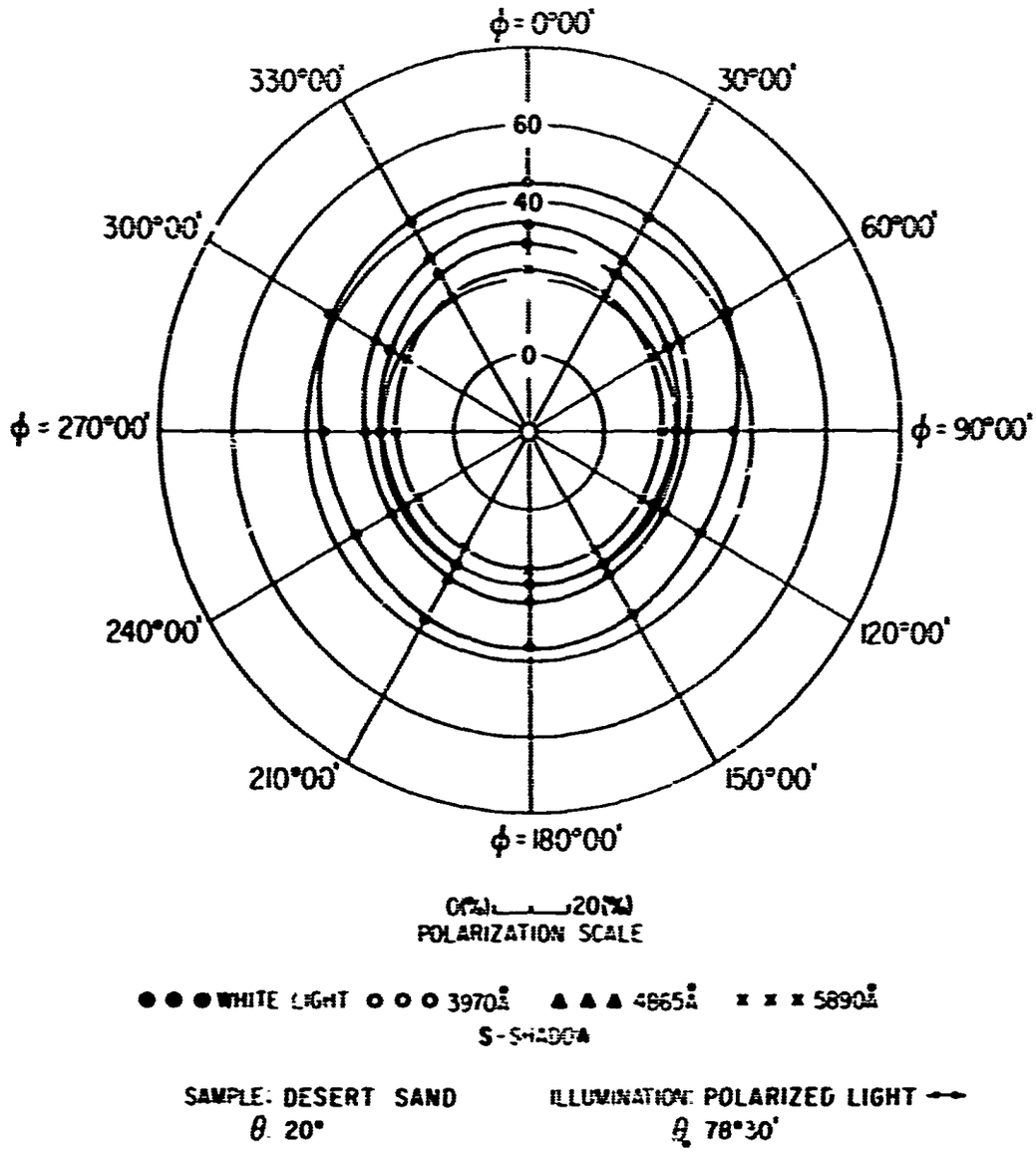


FIG 52. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.92 + 4.25 \cos\varphi + 2.41 \cos 2\varphi + 0.08 \cos 3\varphi - 0.05 \cos 4\varphi + 0.02 \cos 5\varphi - 0.28 \cos 6\varphi - 0.03 \sin\varphi + 0.06 \sin 2\varphi - 0.07 \sin 3\varphi + 0.10 \sin 4\varphi - 0.07 \sin 5\varphi$$

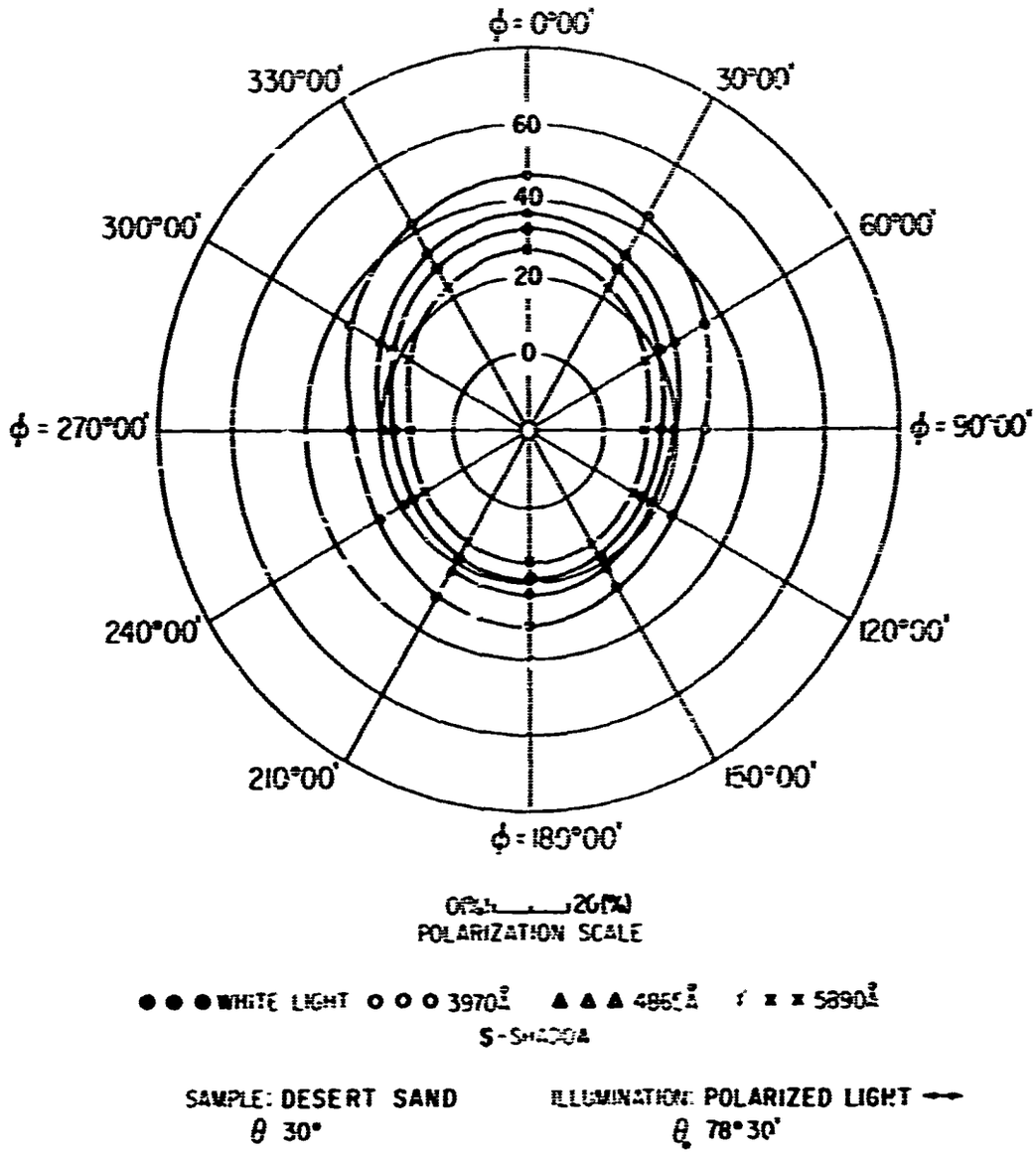


FIG 53. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 21.44 + 6.30 \cos\varphi + 6.01 \cos 2\varphi - 0.08 \cos 3\varphi - 1.11 \cos 4\varphi + 0.19 \cos 5\varphi + 0.15 \cos 6\varphi - 0.01 \sin\varphi + 0.03 \sin 2\varphi - 0.13 \sin 3\varphi + 0.03 \sin 4\varphi + 0.02 \sin 5\varphi$$

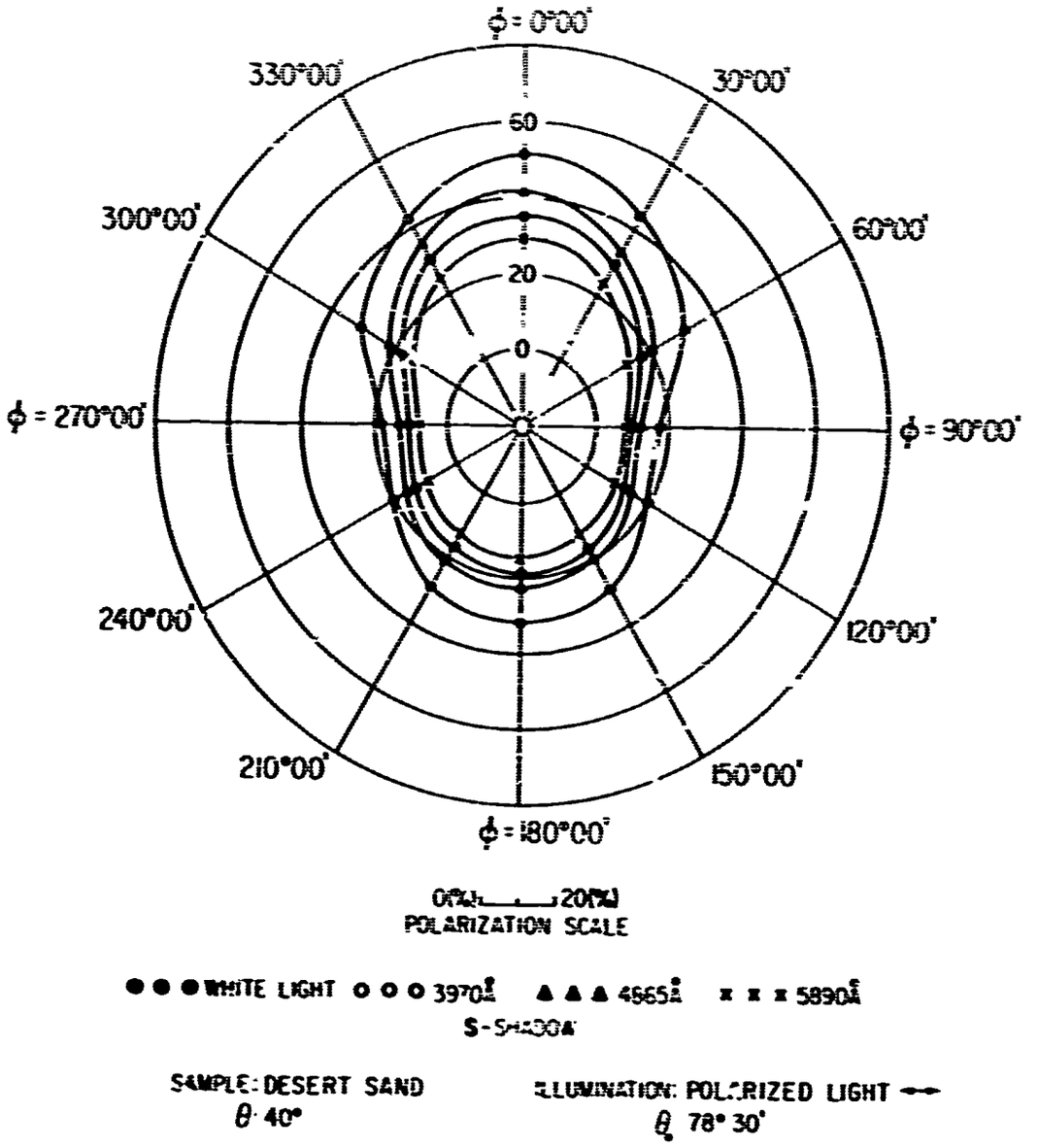
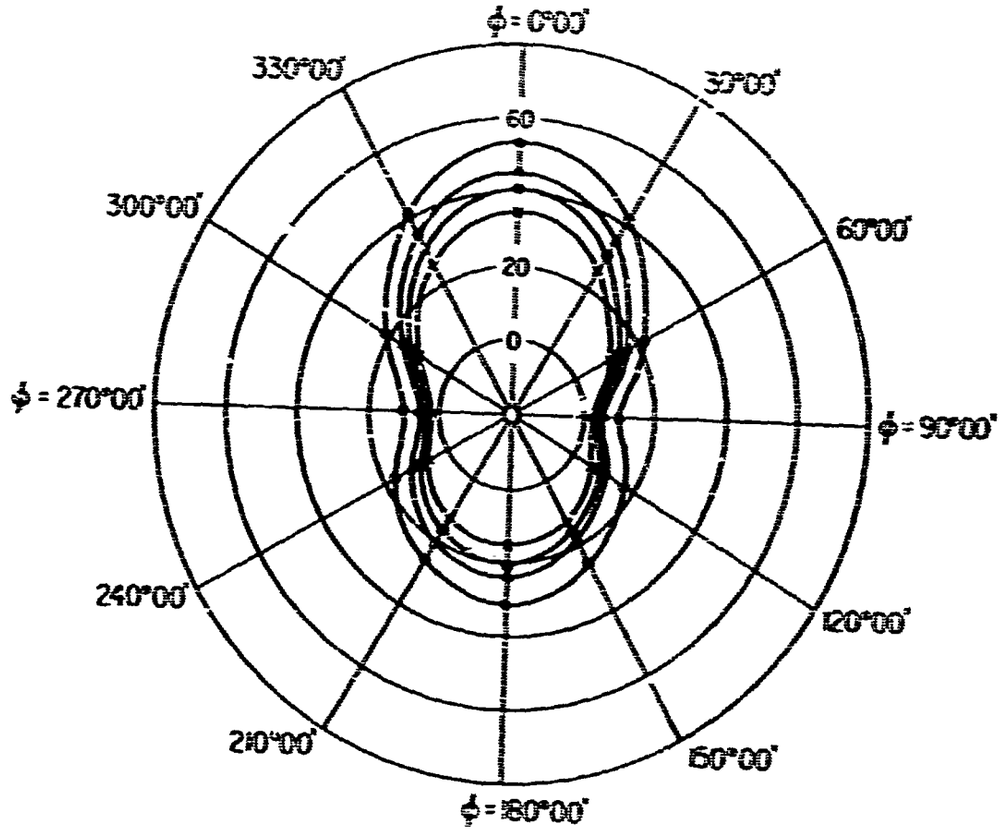


FIG 54. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 19.37 + 7.58 \cos\phi + 7.85 \cos 2\phi + 1.05 \cos 3\phi - 0.09 \cos 4\phi - 0.08 \cos 5\phi + 1.43 \cos 6\phi - 0.06 \sin\phi + 0.01 \sin 2\phi - 0.12 \sin 3\phi + 0.01 \sin 4\phi + 0.06 \sin 5\phi$$



POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å

SAMPLE: DESERT SAND
θ 50°

ILLUMINATION: POLARIZED LIGHT
θ 78°30'

FIG 55. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.82 + 7.93 \cos\varphi + 12.82 \cos 2\varphi + 1.93 \cos 3\varphi - 0.42 \cos 4\varphi + 0.00 \cos 5\varphi - 0.39 \cos 6\varphi + 0.11 \sin\varphi + 0.20 \sin 2\varphi - 0.23 \sin 3\varphi + 0.20 \sin 4\varphi - 0.13 \sin 5\varphi$$

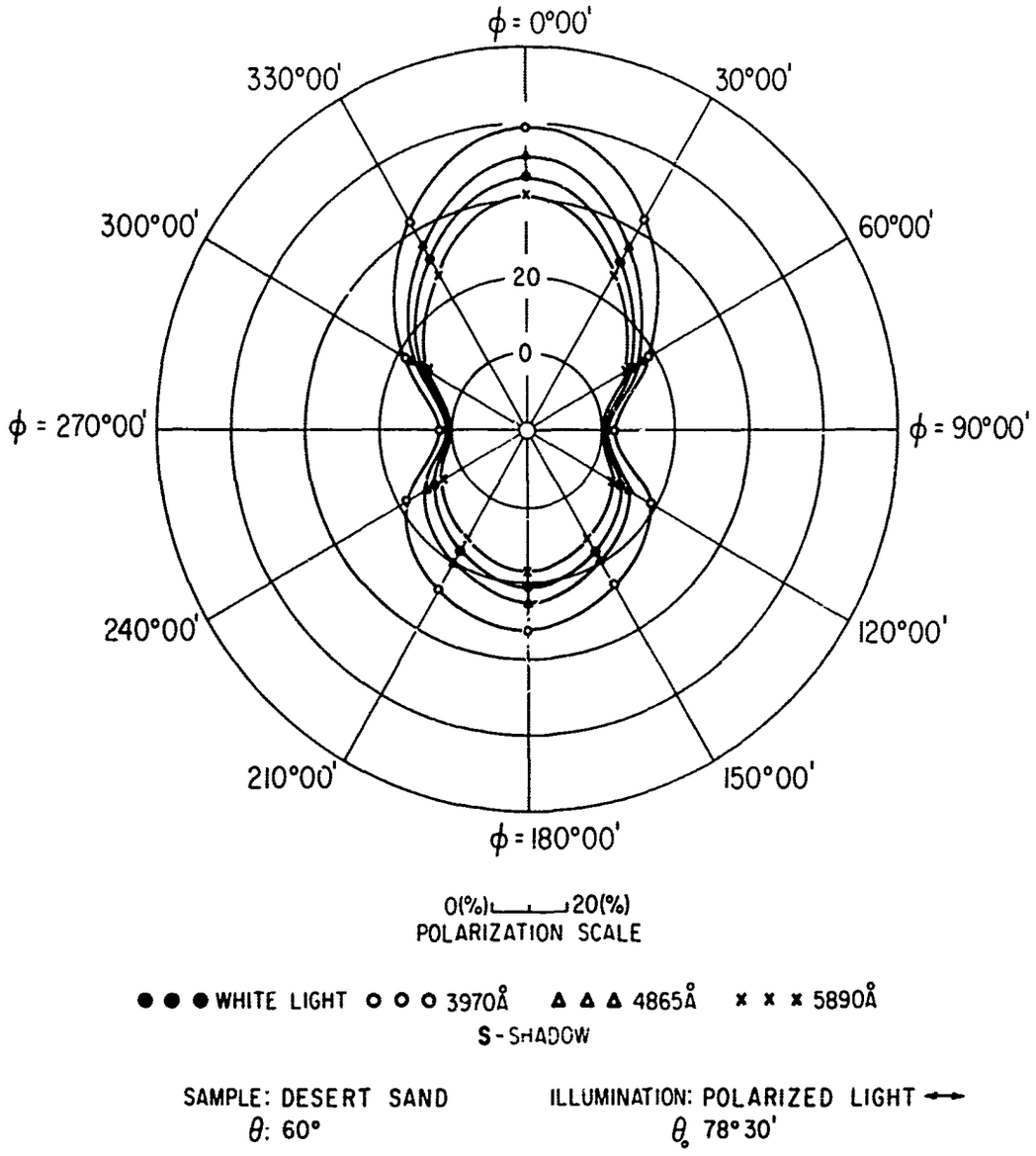
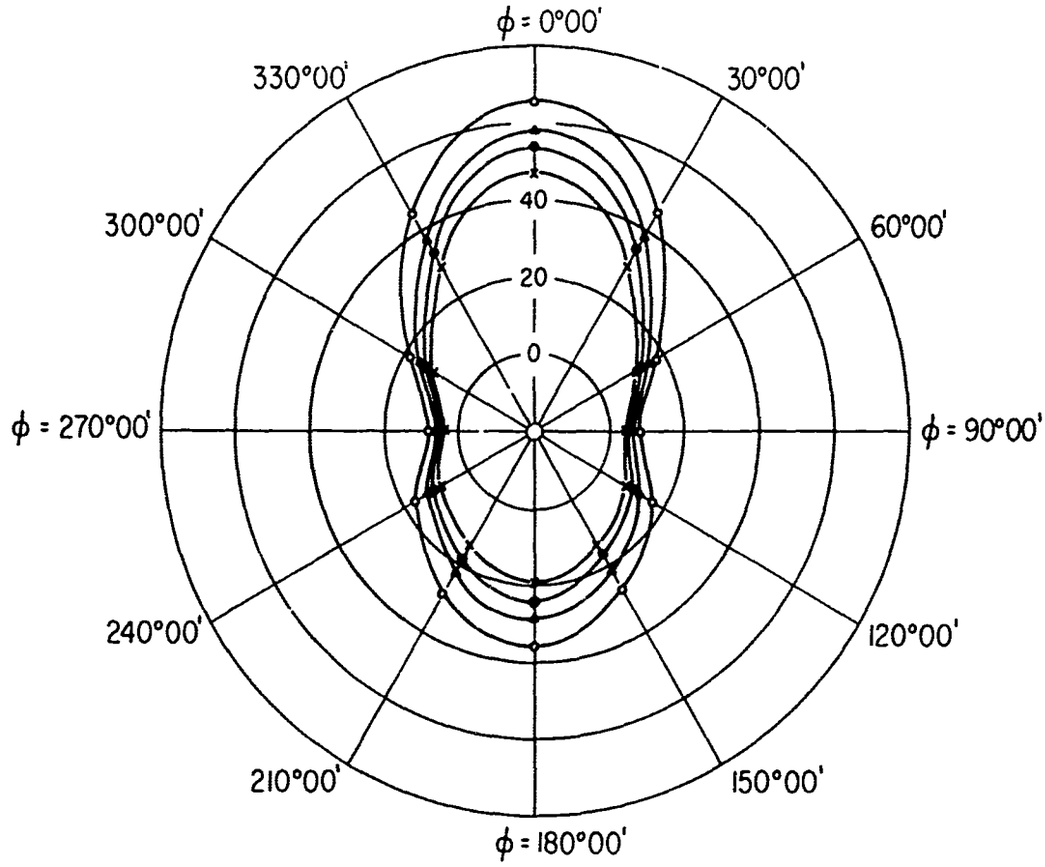


FIG 56. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.56 + 8.48 \cos\varphi + 15.39 \cos 2\varphi + 3.43 \cos 3\varphi + 0.32 \cos 4\varphi + 0.72 \cos 5\varphi + 2.62 \cos 6\varphi + 0.12 \sin\varphi + 0.48 \sin 2\varphi + 0.25 \sin 3\varphi + 0.47 \sin 4\varphi + 0.12 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

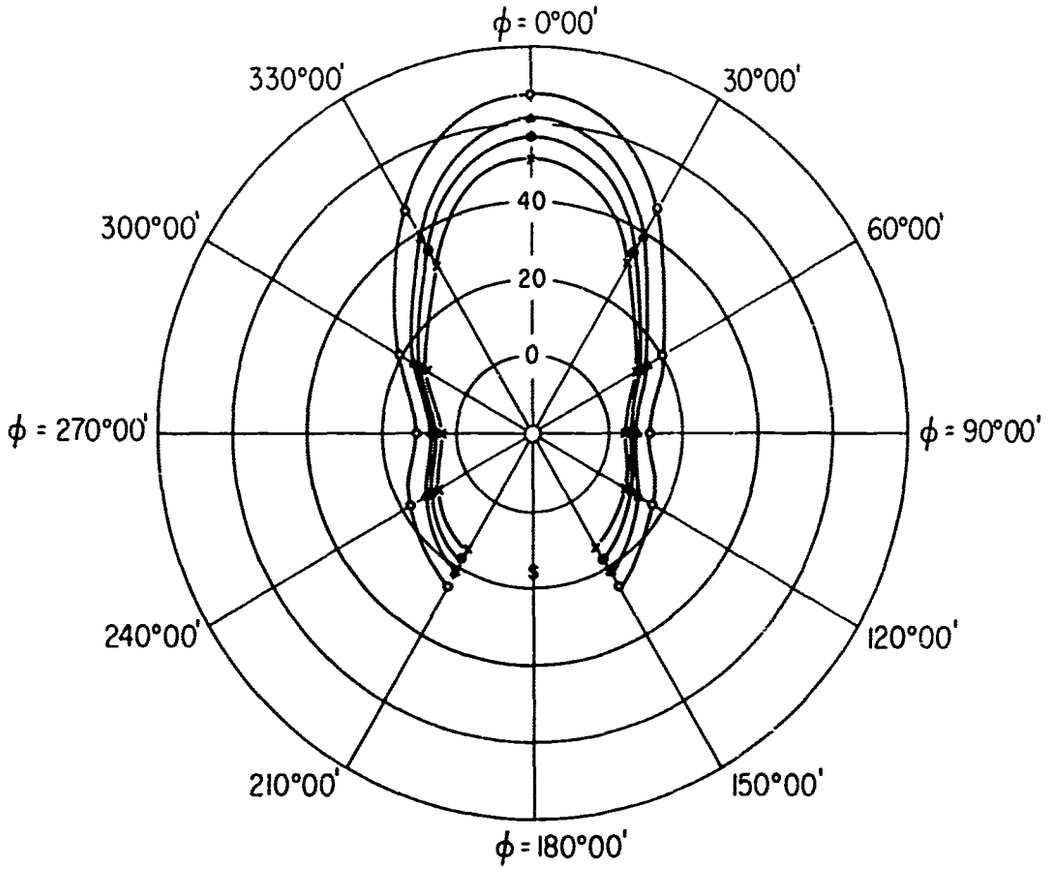
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 70°

ILLUMINATION: POLARIZED LIGHT ↔
θ_0: 78° 30'

FIG 57. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.95 + 9.99 \cos\varphi + 16.44 \cos 2\varphi + 3.88 \cos 3\varphi + 2.32 \cos 4\varphi + 0.78 \cos 5\varphi + 0.20 \cos 6\varphi + 0.02 \sin\varphi + 0.28 \sin 2\varphi + 0.05 \sin 3\varphi + 0.28 \sin 4\varphi + 0.02 \sin 5\varphi$$



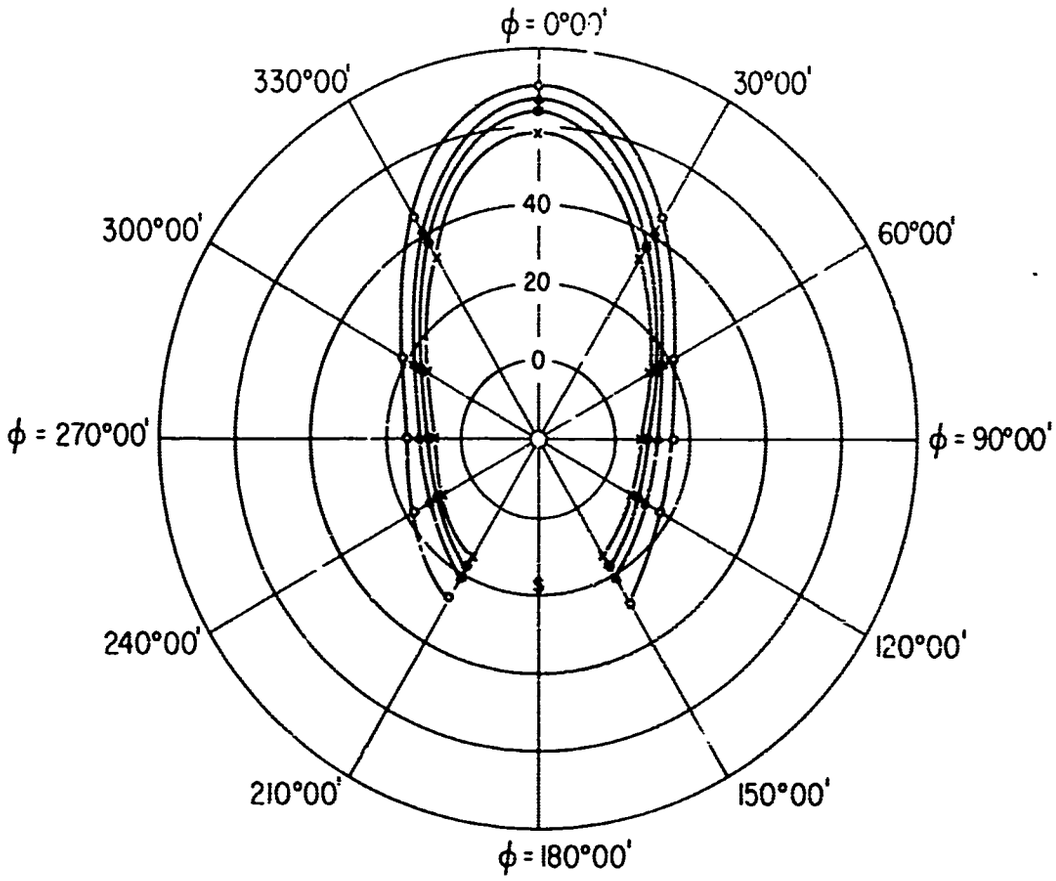
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 75°

ILLUMINATION: POLARIZED LIGHT ⟶
θ_o 78°30'

FIG 58. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 20.53 + 11.46 \cos\varphi + 15.88 \cos 2\varphi + 5.35 \cos 3\varphi + 2.26 \cos 4\varphi + 1.61 \cos 5\varphi + 1.62 \cos 6\varphi + 0.09 \sin\varphi + 0.16 \sin 2\varphi + 0.18 \sin 3\varphi + 0.16 \sin 4\varphi + 0.09 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 80°

ILLUMINATION: POLARIZED LIGHT ↔
θ_0: 78°30'

FIG 59. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.2 + 13.20 \cos\varphi + 17.58 \cos 2\varphi + 4.58 \cos 3\varphi + 3.42 \cos 4\varphi + 1.86 \cos 5\varphi + 2.90 \cos 6\varphi + 0.16 \sin\varphi + 0.28 \sin 2\varphi + 0.32 \sin 3\varphi + 0.27 \sin 4\varphi + 0.16 \sin 6\varphi$$

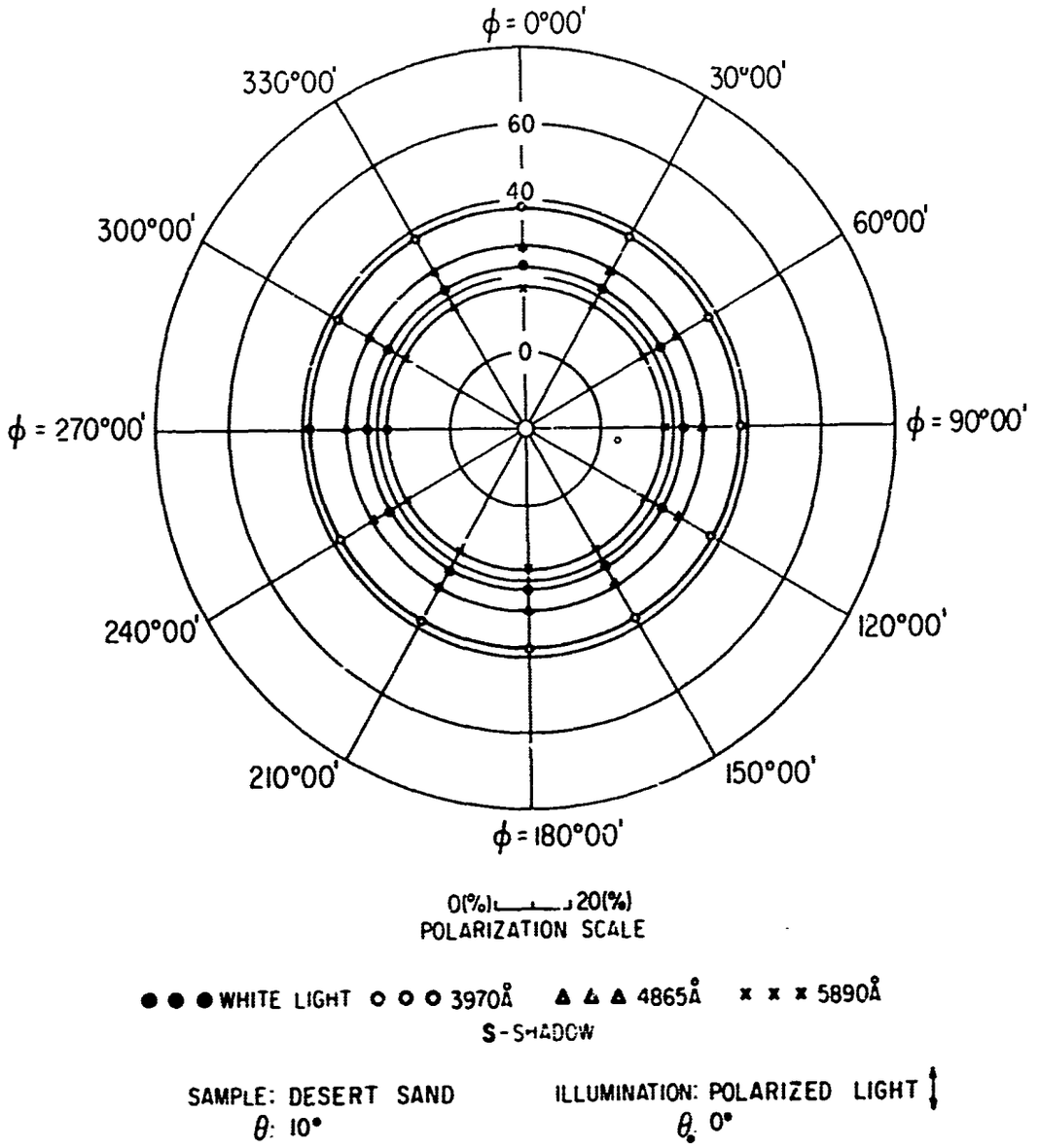


FIG 60. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.38 - 0.11 \cos\varphi + 0.36 \cos 2\varphi - 0.08 \cos 3\varphi + 0.42 \cos 4\varphi - 0.11 \cos 5\varphi + 0.02 \cos 6\varphi - 0.12 \sin\varphi + 0.13 \sin 2\varphi - 0.10 \sin 3\varphi - 0.07 \sin 4\varphi - 0.08 \sin 5\varphi$$

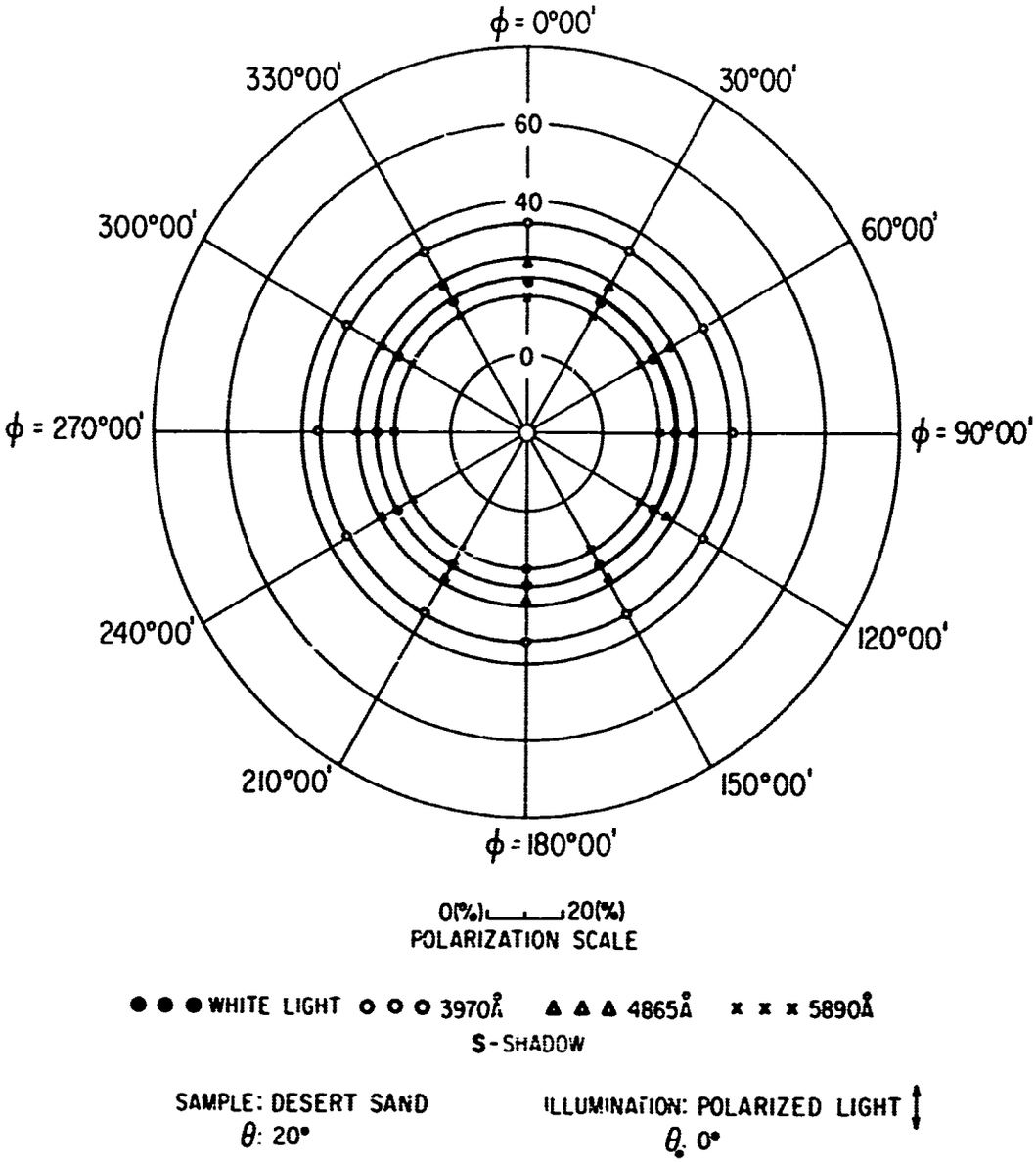


FIG 61. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.85 - 0.41 \cos\varphi - 0.18 \cos 2\varphi + 0.33 \cos 3\varphi + 0.58 \cos 4\varphi - 0.26 \cos 5\varphi + 0.30 \cos 6\varphi - 0.08 \sin\varphi + 0.10 \sin 2\varphi + 0.00 \sin 3\varphi - 0.13 \sin 4\varphi - 0.08 \sin 5\varphi$$

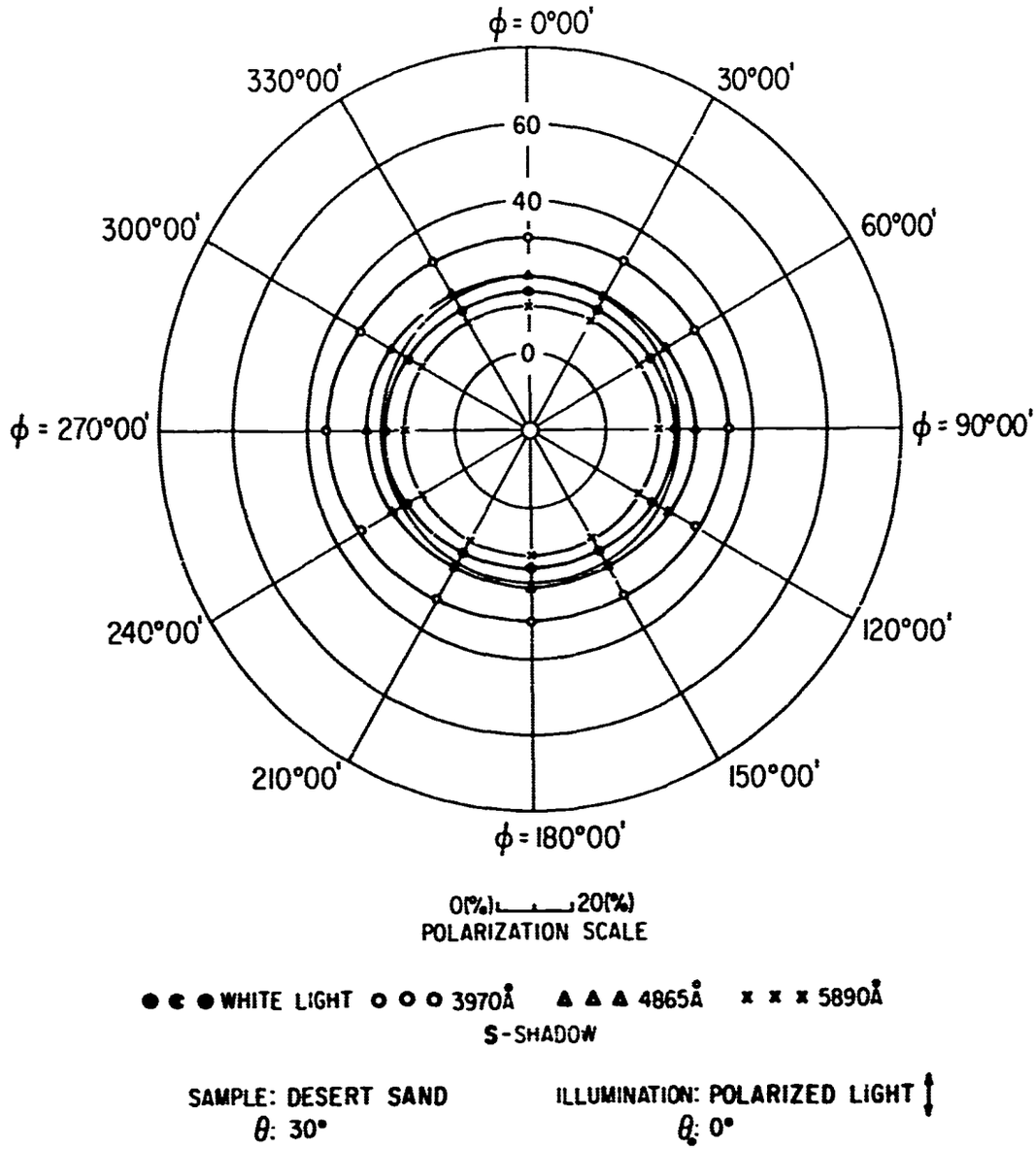
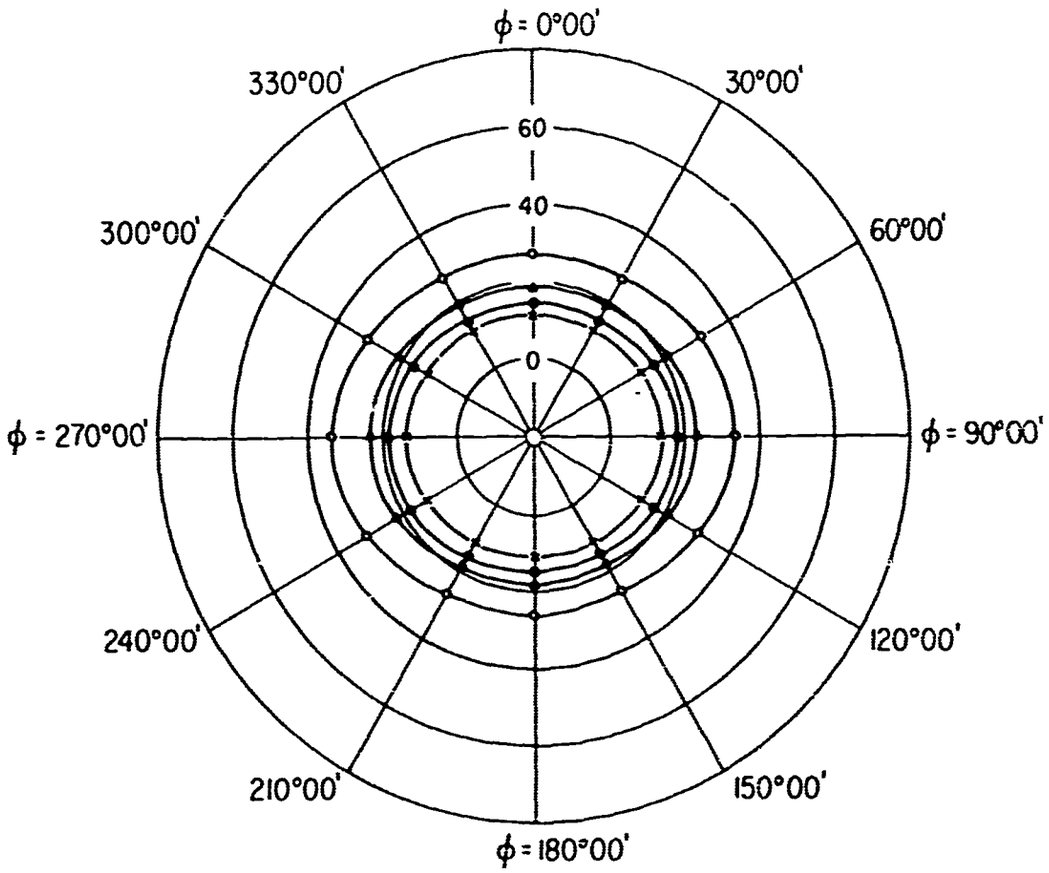


FIG 62. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.69 - 0.06\cos\varphi - 1.35\cos 2\varphi + 0.03\cos 3\varphi + 0.33\cos 4\varphi - 0.02\cos 5\varphi - 0.05\cos 6\varphi - 0.07\sin\varphi - 0.09\sin 2\varphi - 0.02\sin 3\varphi - 0.17\sin 4\varphi - 0.04\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

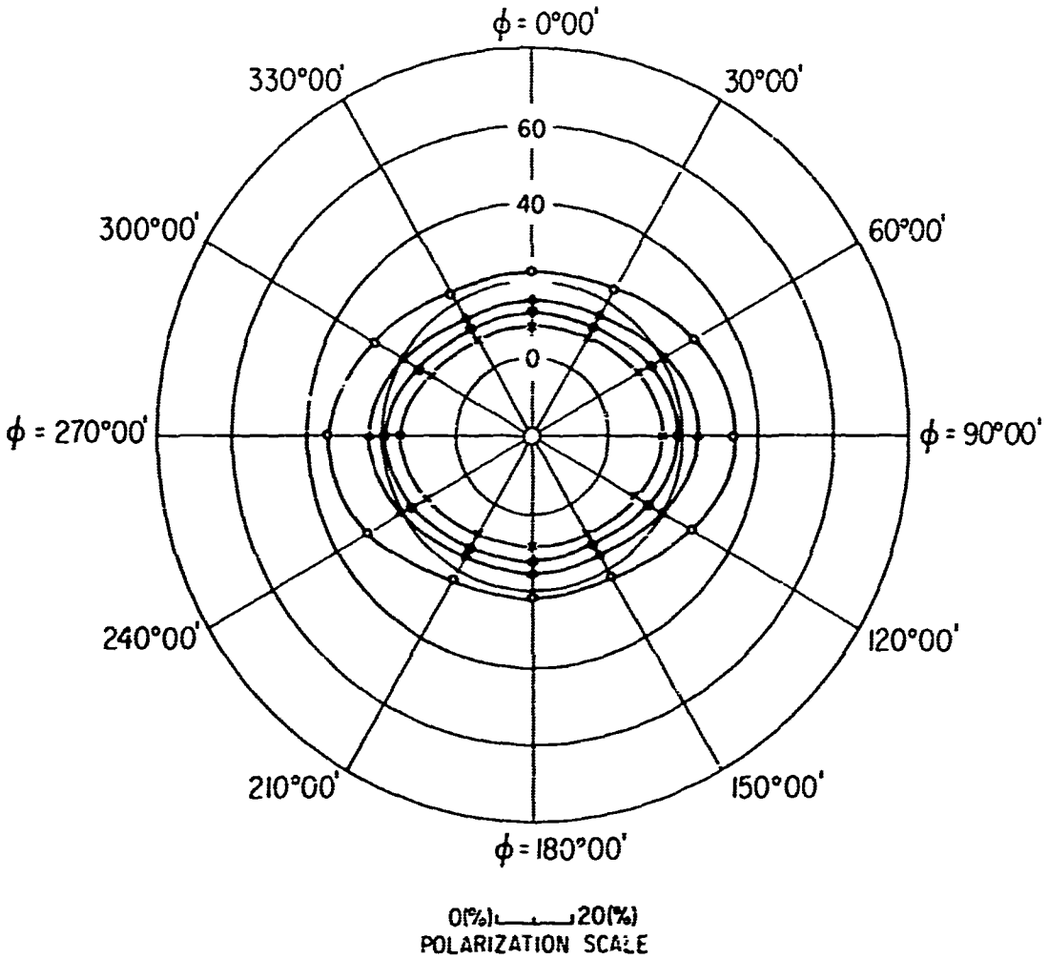
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 40°

ILLUMINATION: POLARIZED LIGHT ↕
θ_o: 0°

FIG 63. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.12 - 0.20 \cos\varphi - 2.29 \cos 2\varphi + 0.05 \cos 3\varphi + 0.46 \cos 4\varphi + 0.00 \cos 5\varphi + 0.13 \cos 6\varphi - 0.11 \sin\varphi + 0.46 \sin 2\varphi - 0.05 \sin 3\varphi - 0.14 \sin 4\varphi + 0.06 \sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 50°

ILLUMINATION: POLARIZED LIGHT
θ_0: 0°

FIG. 64. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.83 - 0.19\cos\varphi - 3.56\cos 2\varphi + 0.05\cos 3\varphi + 1.04\cos 4\varphi + 0.04\cos 5\varphi + 0.17\cos 6\varphi + 0.09\sin\varphi + 0.39\sin 2\varphi - 0.02\sin 3\varphi - 0.22\sin 4\varphi - 0.06\sin 5\varphi$$

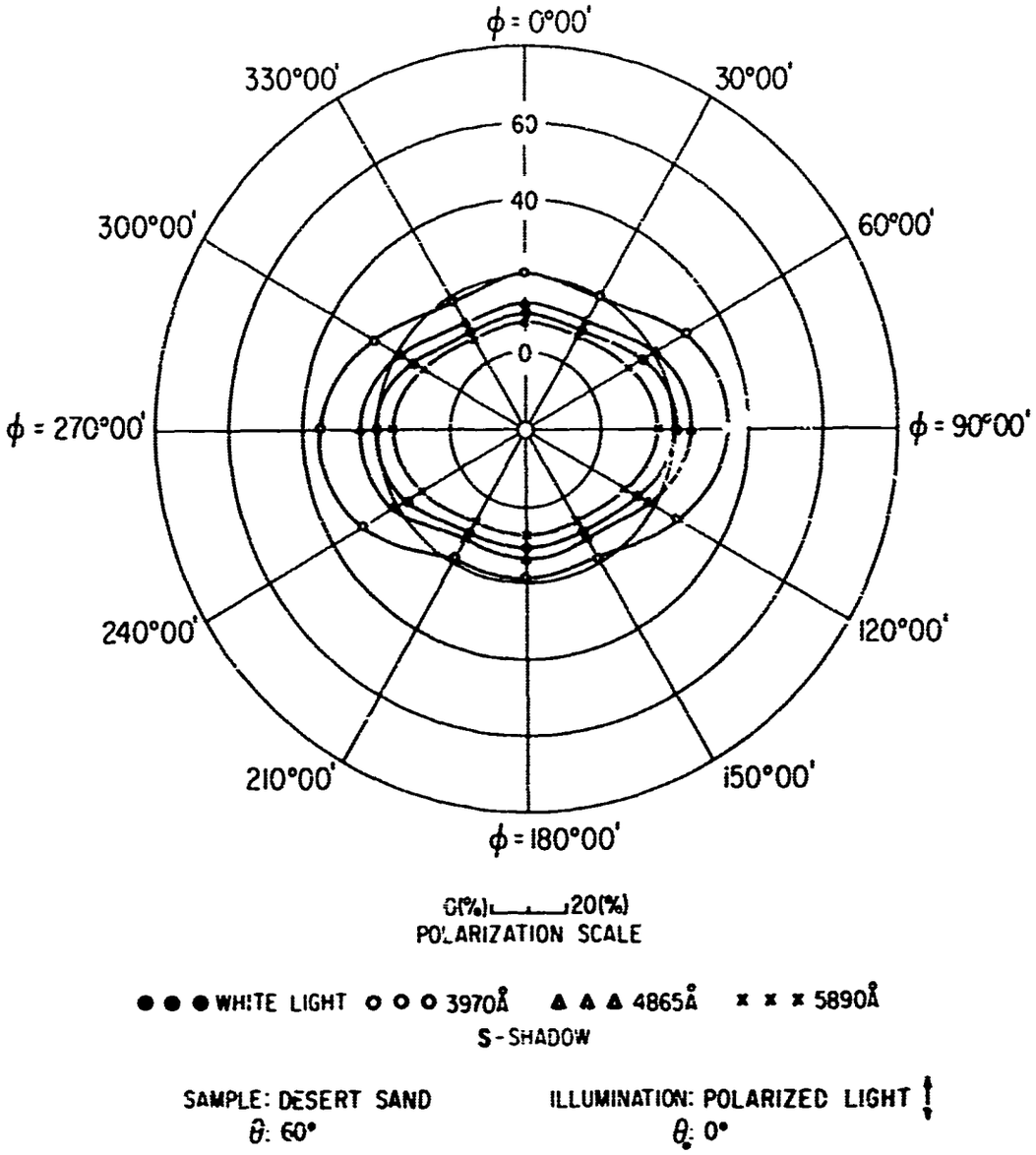


FIG. 65. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.88 - 0.18\cos\varphi - 4.98\cos 2\varphi - 0.02\cos 3\varphi + 1.72\cos 4\varphi + 0.05\cos 5\varphi + 0.67\cos 6\varphi + 0.03\sin\varphi + 0.75\sin 2\varphi + 0.02\sin 3\varphi - 0.52\sin 4\varphi + 0.14\sin 5\varphi$$

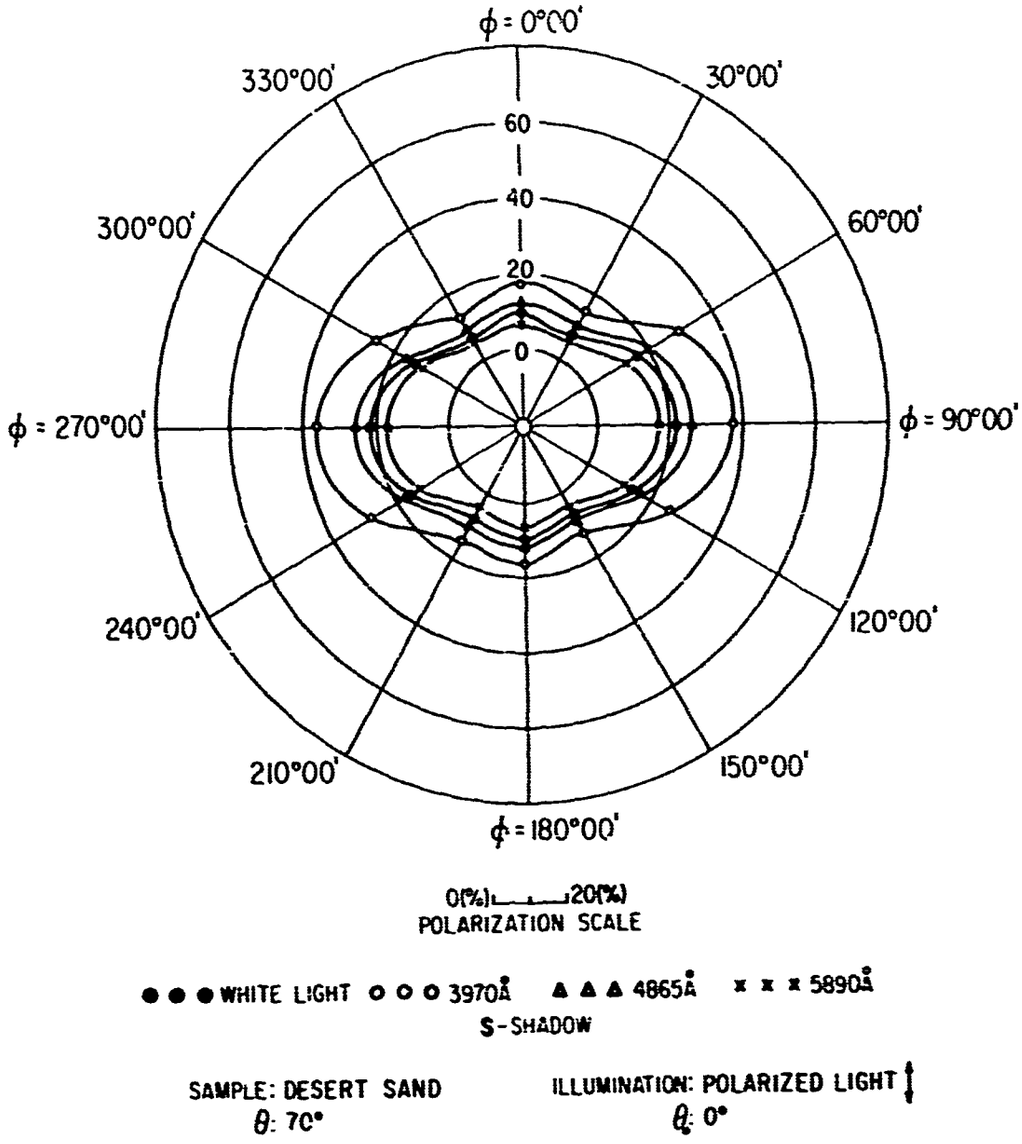


FIG 66. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.97 + 0.00 \cos\varphi - 6.21 \cos 2\varphi - 0.25 \cos 3\varphi + 2.91 \cos 4\varphi + 0.20 \cos 5\varphi + 1.20 \cos 6\varphi - 0.30 \sin\varphi + 1.30 \sin 2\varphi - 0.15 \sin 3\varphi - 1.10 \sin 4\varphi + 0.35 \sin 5\varphi$$

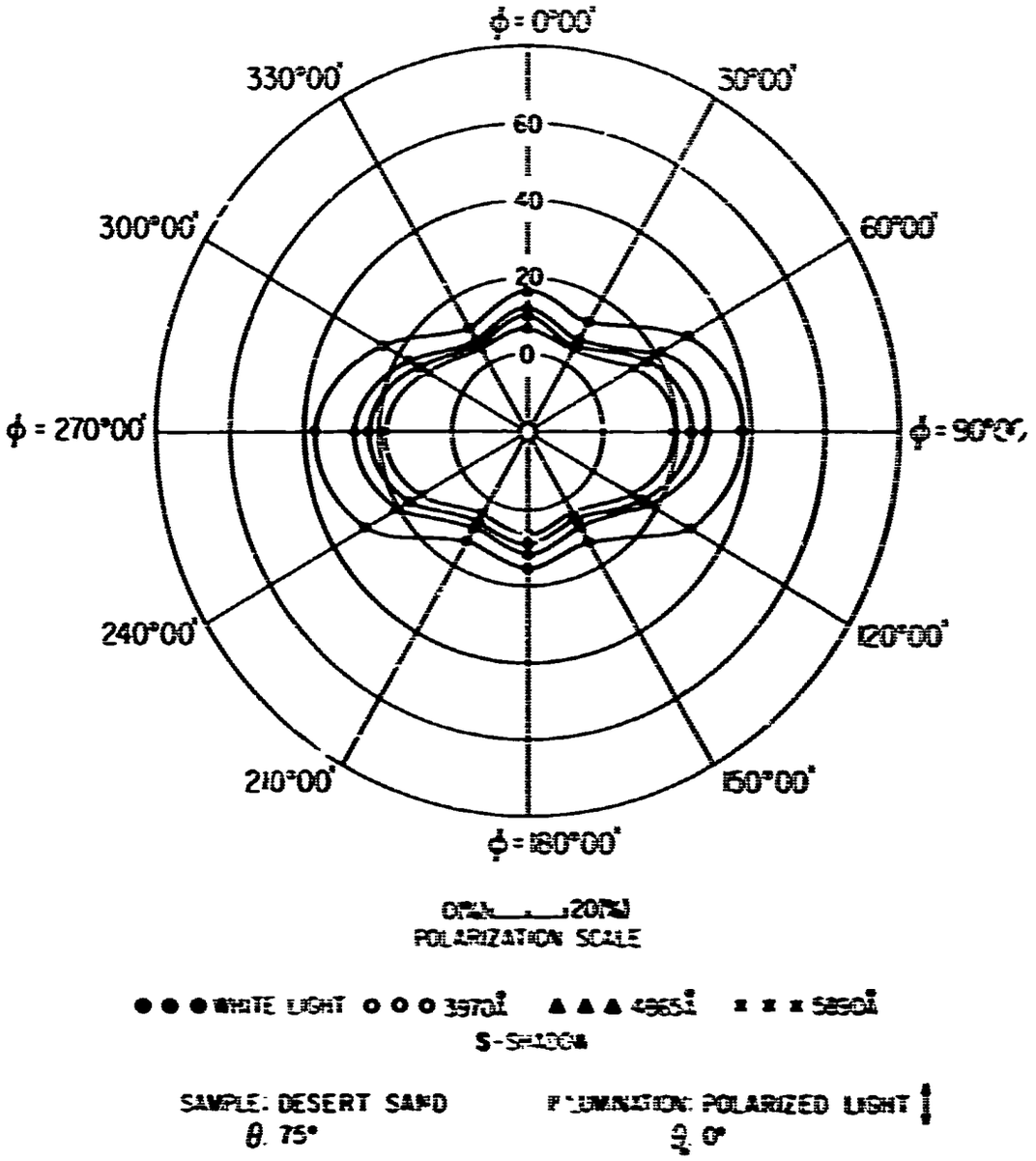
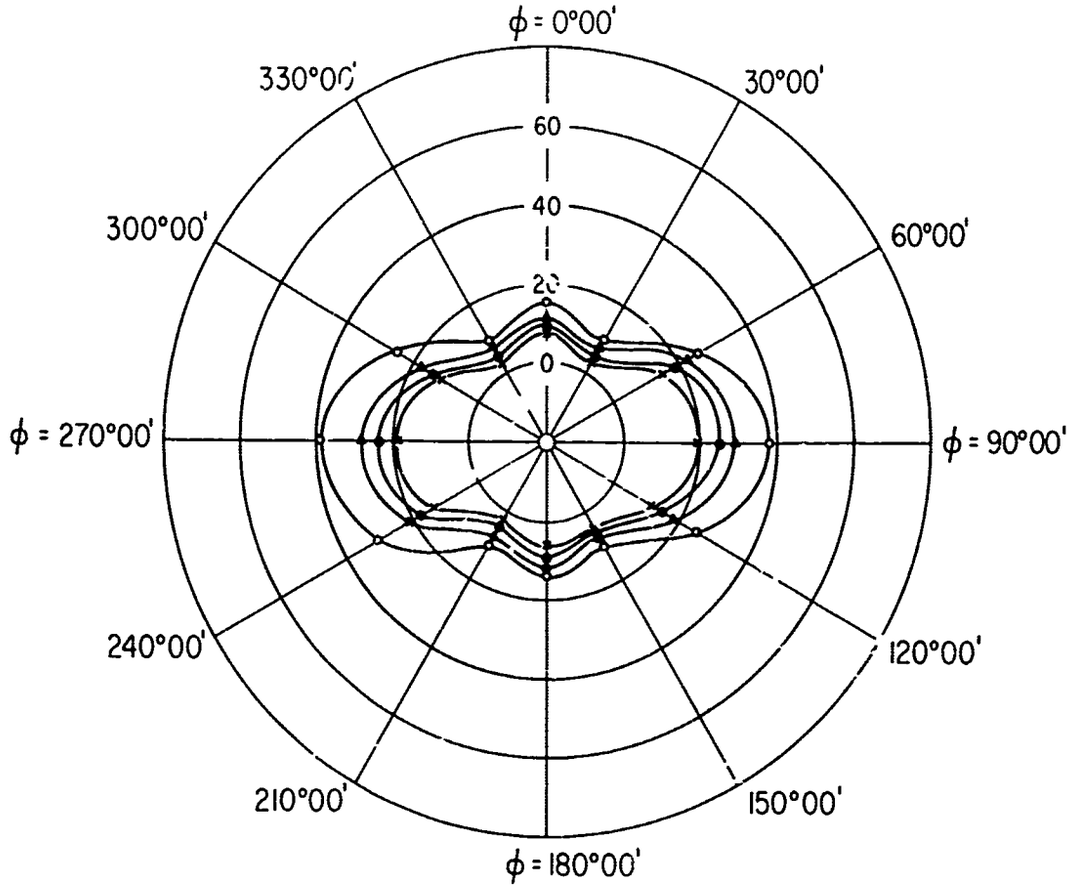


FIG 67. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 12.92 - 0.01\cos\phi - 7.18\cos 2\phi - 0.05\cos 3\phi + 3.33\cos 4\phi - 0.04\cos 5\phi + 2.07\cos 6\phi + 0.11\sin\phi + 1.01\sin 2\phi - 0.15\sin 3\phi - 0.92\sin 4\phi + 1.40\sin 5\phi$$



0(%) 20(%)
POLARIZATION SCALE

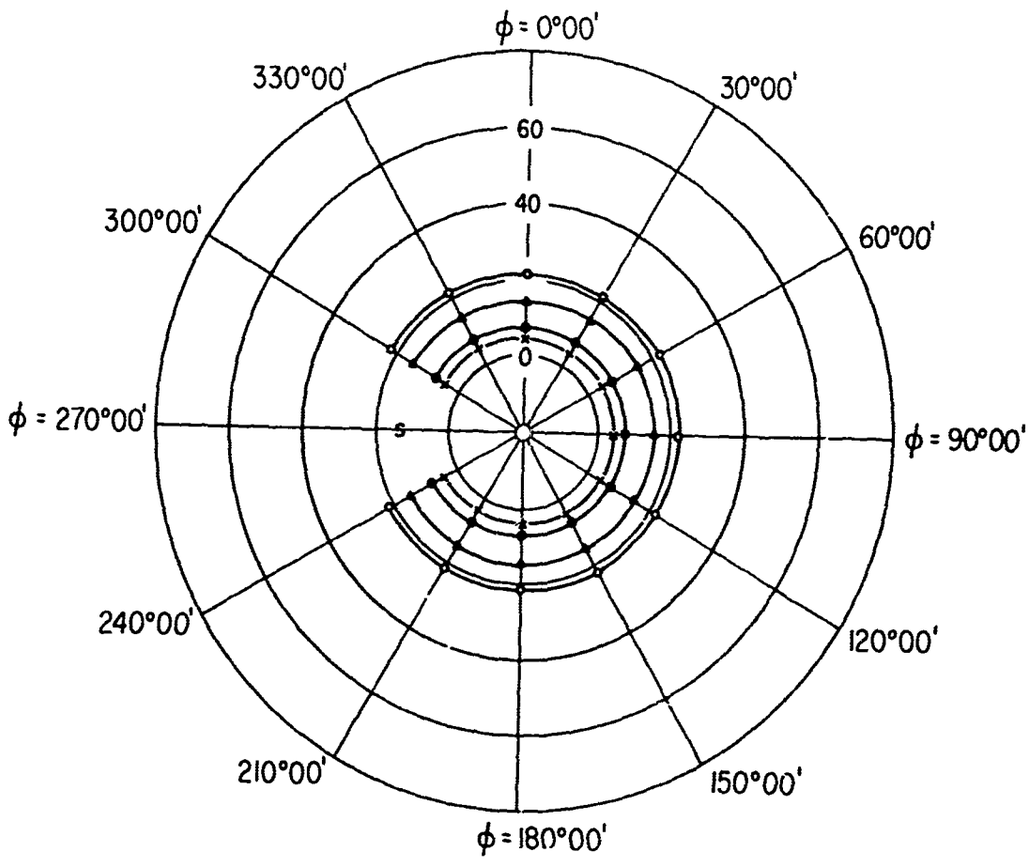
● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 80°

ILLUMINATION: POLARIZED LIGHT ↕
θ_o: 0°

FIG 68. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.9u - 0.19\cos\varphi - 8.42\cos 2\varphi + 0.20\cos 3\varphi + 4.21\cos 4\varphi + 0.04\cos 5\varphi + 3.13\cos 6\varphi + 0.36\sin\varphi + 1.05\sin 2\varphi - 0.03\sin 3\varphi - 1.28\sin 4\varphi - 0.06\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 0°

ILLUMINATION: POLARIZED LIGHT ↕
θ_i: 53°

FIG 69. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

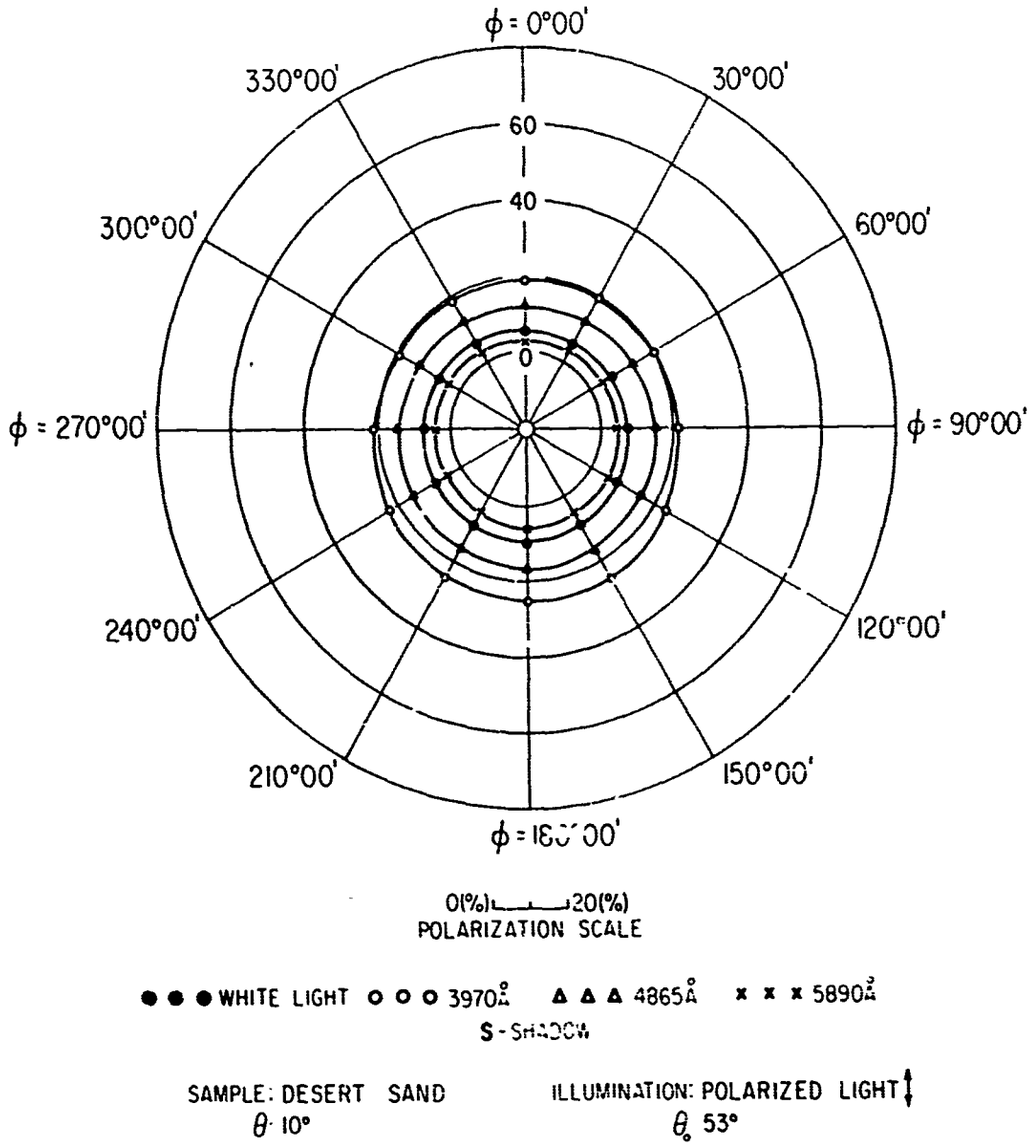


FIG 70. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.52 - 2.02\cos\varphi + 0.22\cos 2\varphi - 0.17\cos 3\varphi + 0.18\cos 4\varphi - 0.21\cos 5\varphi - 0.05\cos 6\varphi - 0.16\sin\varphi - 0.10\sin 2\varphi - 0.12\sin 3\varphi + 0.07\sin 4\varphi - 0.16\sin 5\varphi$$

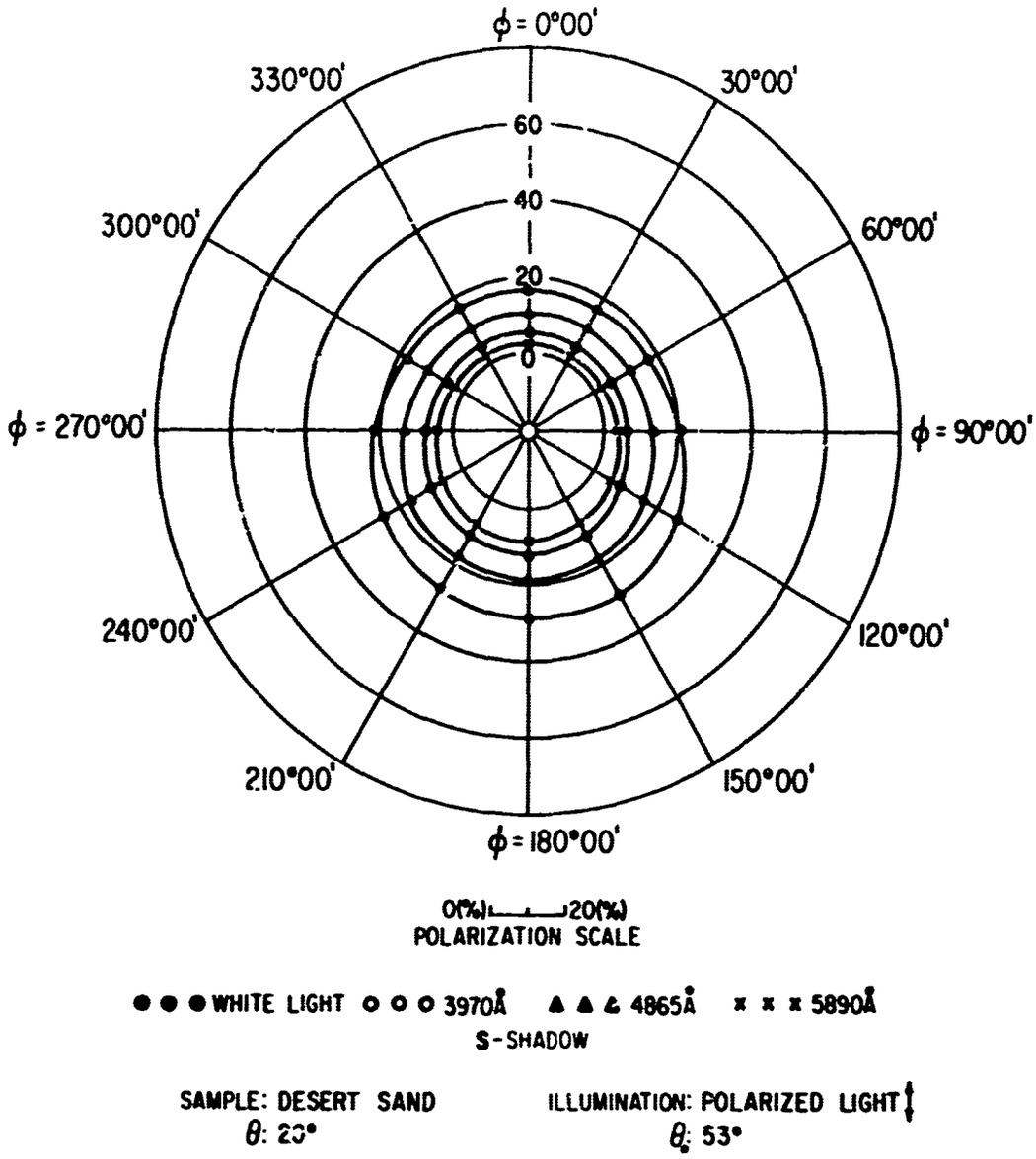
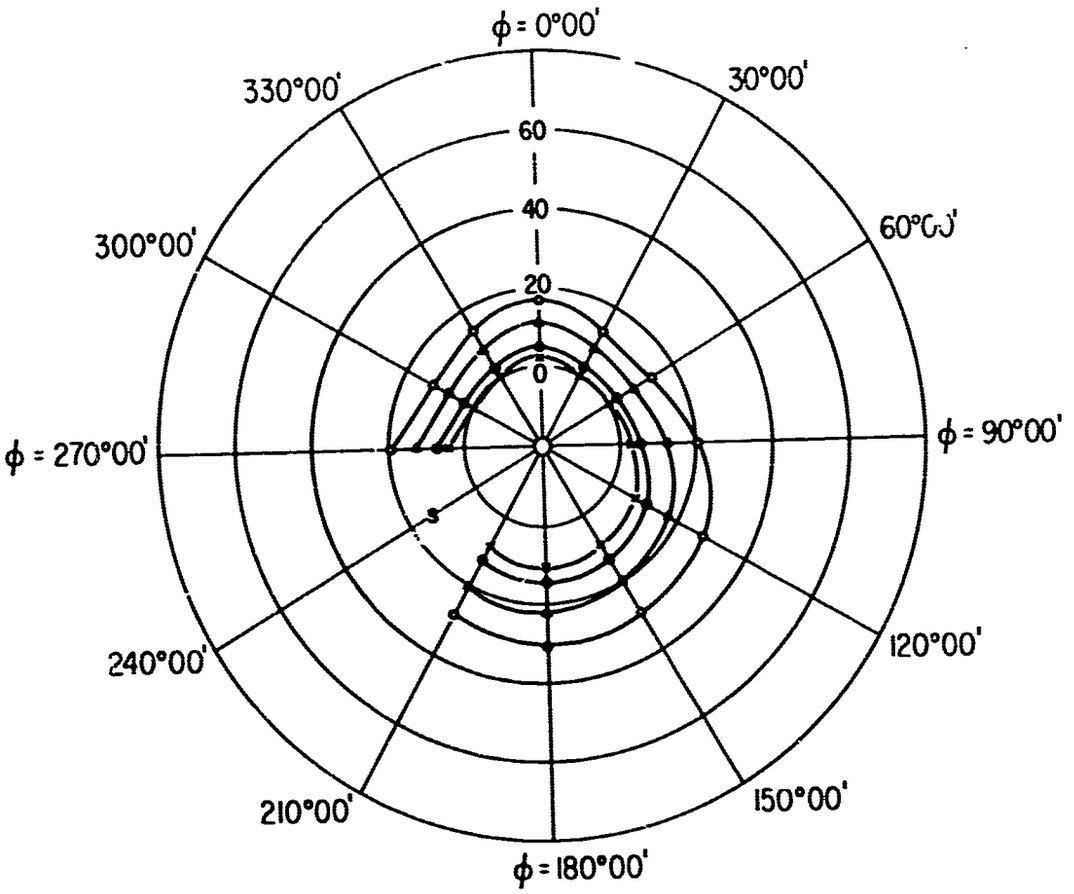


FIG. 71. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.69 - 3.90 \cos\varphi + 1.18 \cos 2\varphi + 0.55 \cos 3\varphi + 0.29 \cos 4\varphi - 0.30 \cos 5\varphi$$
$$+0.10 \cos 6\varphi - 0.22 \sin\varphi + 0.16 \sin 2\varphi + 0.05 \sin 3\varphi - 0.02 \sin 4\varphi + 0.07 \sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 30°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 53°

FIG 72. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.59 - 6.34 \cos\varphi + 1.48 \cos 2\varphi + 1.28 \cos 3\varphi + 0.83 \cos 4\varphi - 0.10 \cos 5\varphi - 0.15 \cos 6\varphi - 0.44 \sin\varphi - 0.29 \sin 2\varphi + 0.13 \sin 3\varphi + 0.12 \sin 4\varphi - 0.03 \sin 5\varphi$$

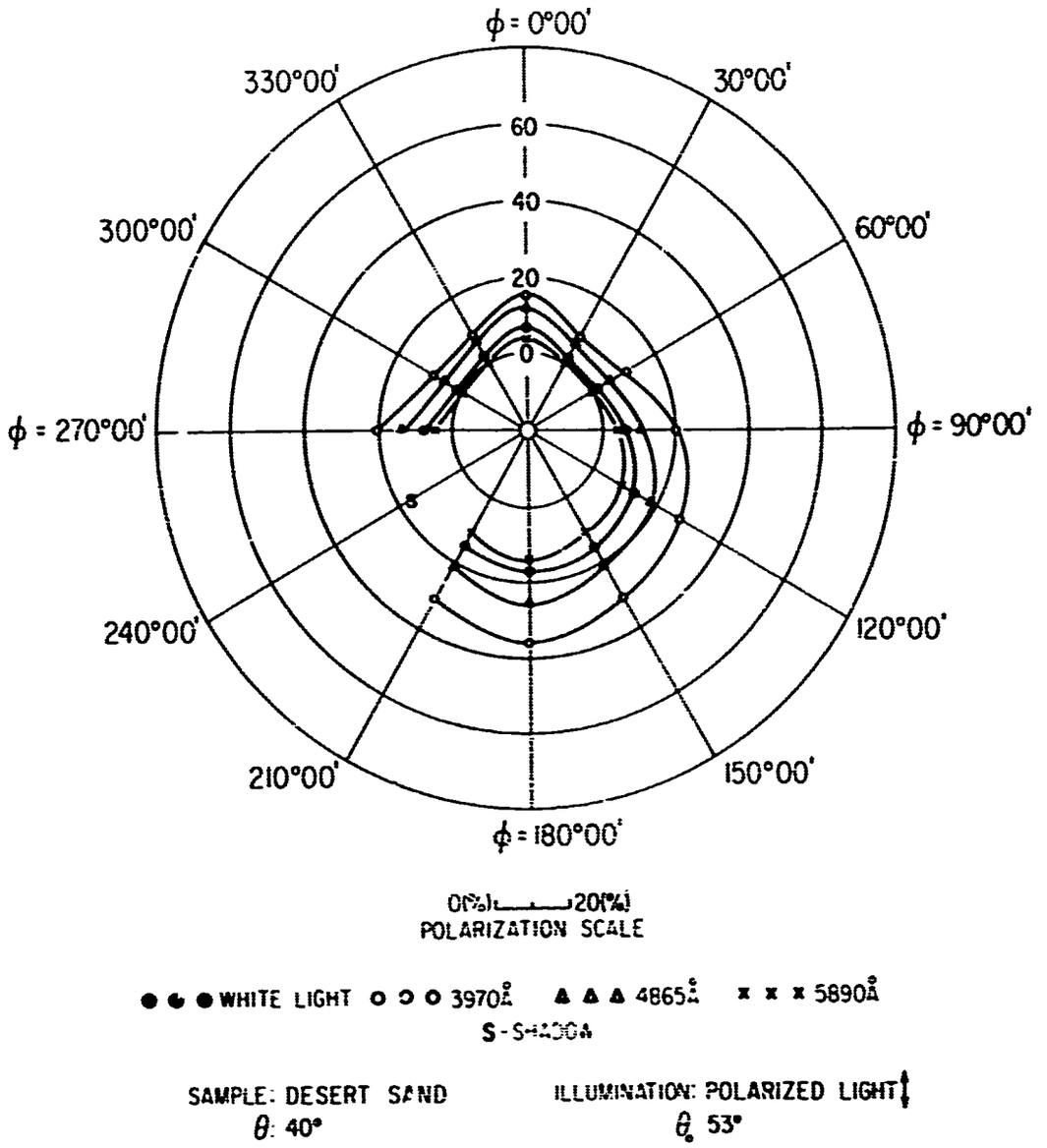
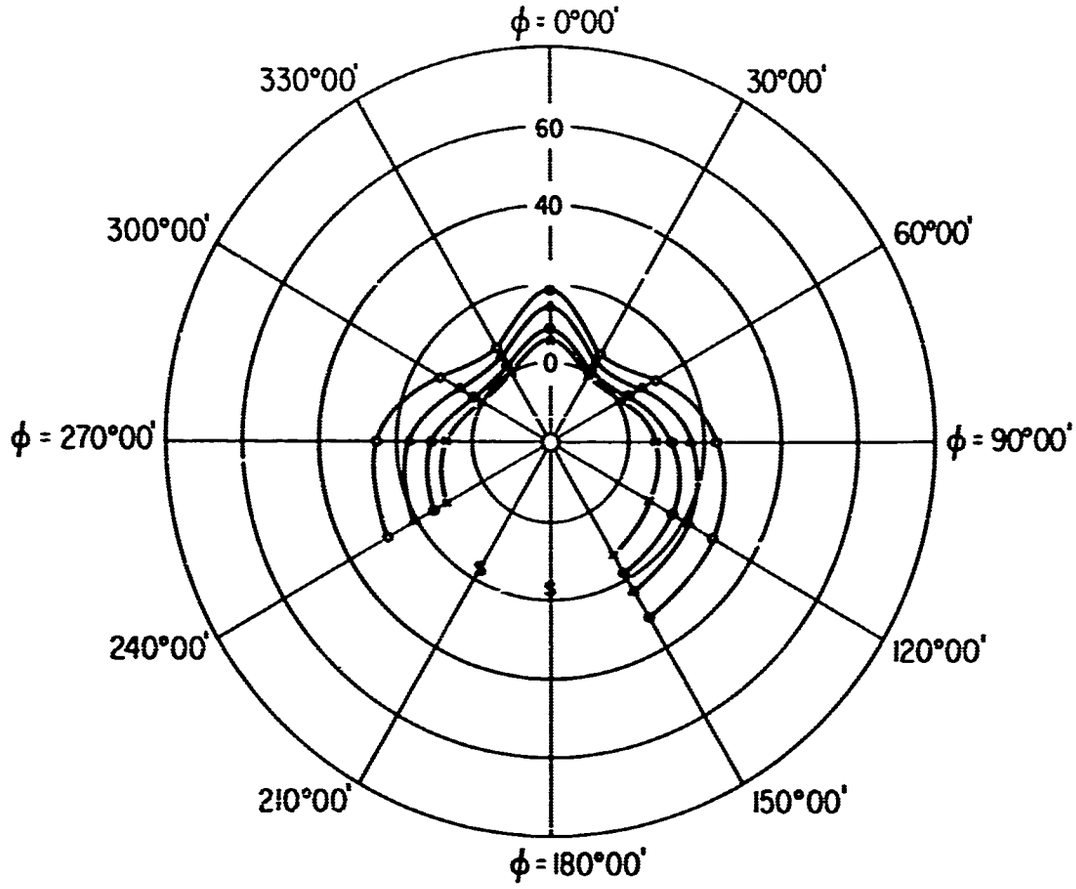


FIG 73. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.38 - 7.61 \cos\varphi + 1.90 \cos 2\varphi + 2.32 \cos 3\varphi + 1.35 \cos 4\varphi + 0.39 \cos 5\varphi - 0.25 \cos 6\varphi - 0.02 \sin\varphi - 0.18 \sin 2\varphi + 0.00 \sin 3\varphi + 0.03 \sin 4\varphi - 0.23 \sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: DESERT SAND
θ: 50°

ILLUMINATION: POLARIZED LIGHT
θ_i: 53°

FIG. 74. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 10.01 - 8.07\cos\varphi + 1.50\cos 2\varphi + 1.41\cos 3\varphi + 2.55\cos 4\varphi + 1.52\cos 5\varphi - 0.03\cos 6\varphi + 0.04\sin\varphi - 0.28\sin 2\varphi - 0.08\sin 3\varphi - 0.09\sin 4\varphi + 0.00\sin 5\varphi$$

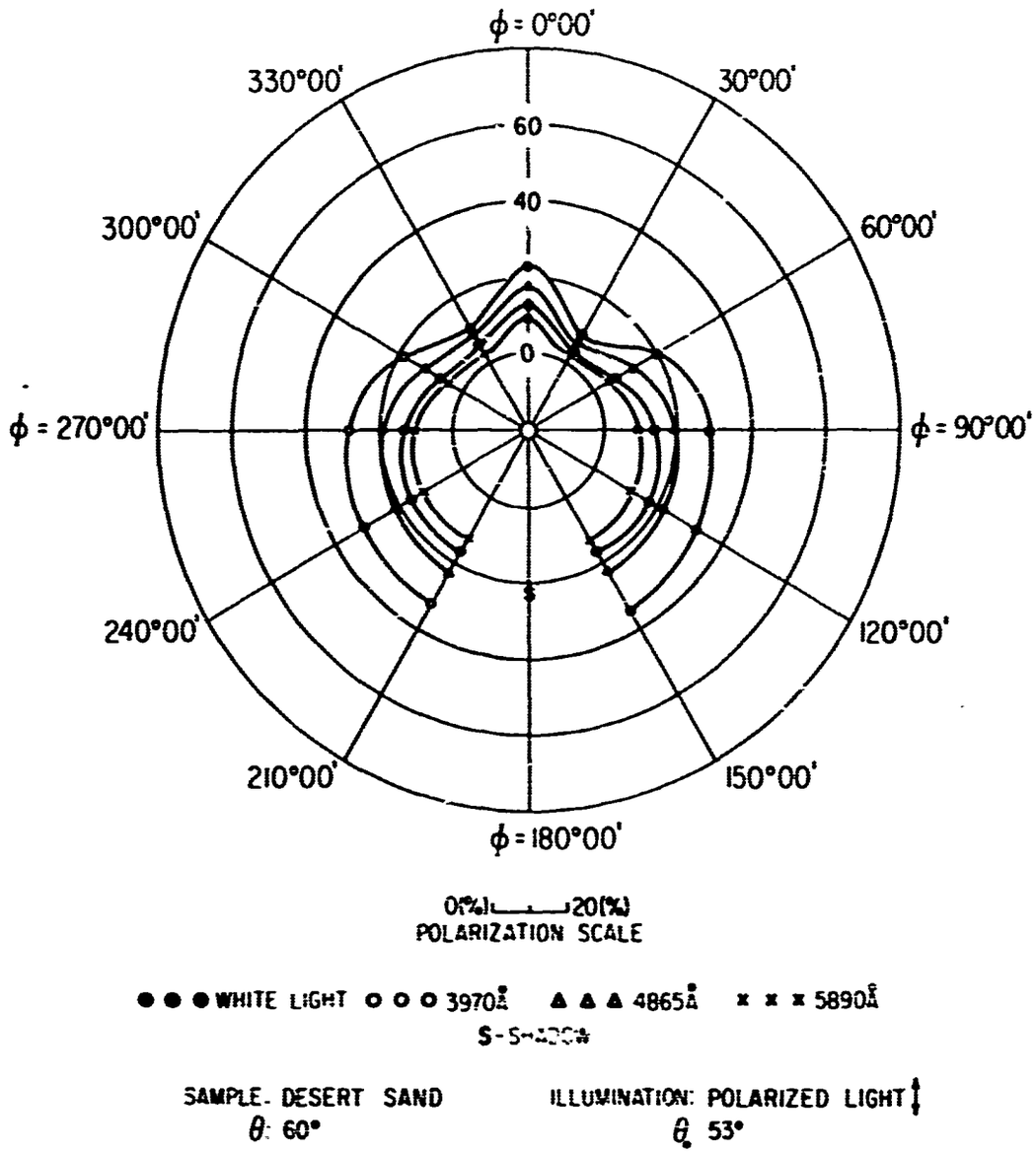
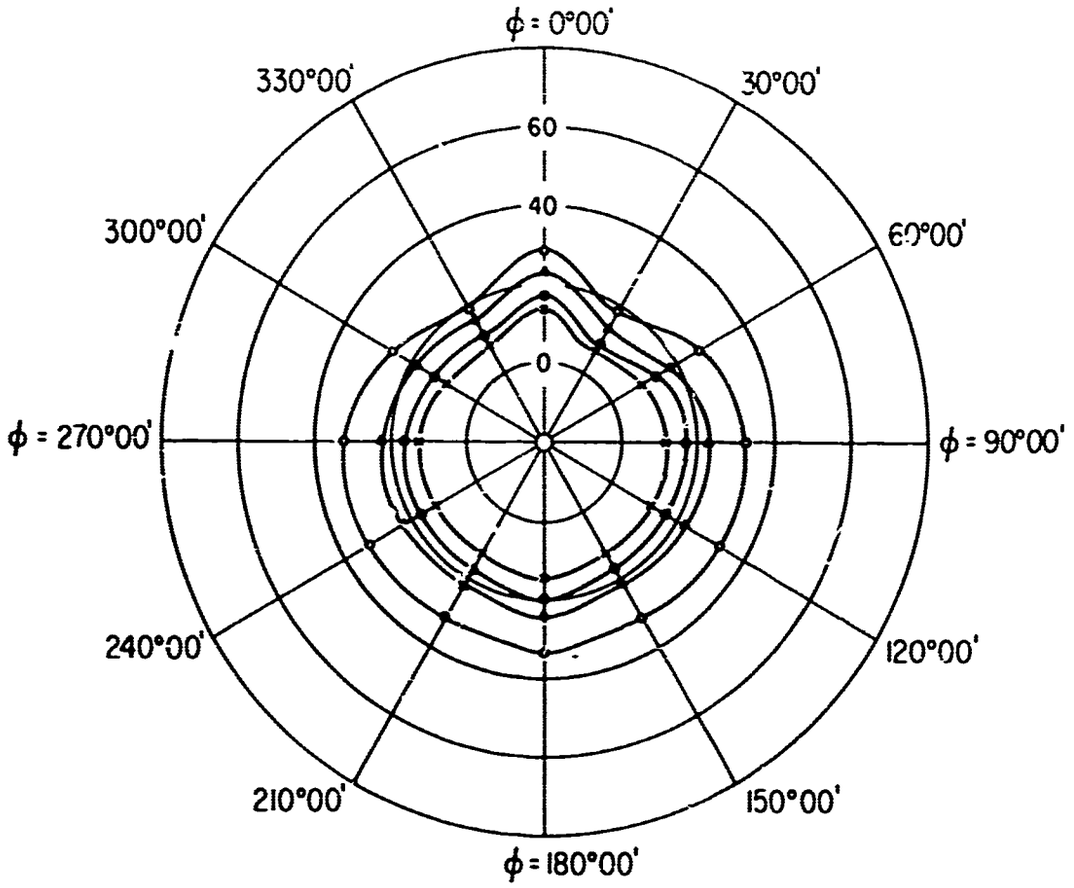


FIG 75. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 11.18 - 5.50 \cos\varphi + 0.17 \cos 2\varphi + 2.52 \cos 3\varphi + 1.90 \cos 4\varphi + 1.13 \cos 5\varphi + 1.02 \cos 6\varphi - 0.12 \sin\varphi + 0.00 \sin 2\varphi - 0.33 \sin 3\varphi - 0.16 \sin 4\varphi - 0.01 \sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW.

SAMPLE: DESERT SAND
θ: 70°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 53°

FIG. 76. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 14.34 - 2.67\cos\varphi + 0.03\cos 2\varphi + 0.83\cos 3\varphi + 2.30\cos 4\varphi + 0.67\cos 5\varphi + 2.07\cos 6\varphi - 0.14\sin\varphi + 0.03\sin 2\varphi - 0.17\sin 3\varphi - 0.52\sin 4\varphi - 0.58\sin 5\varphi$$

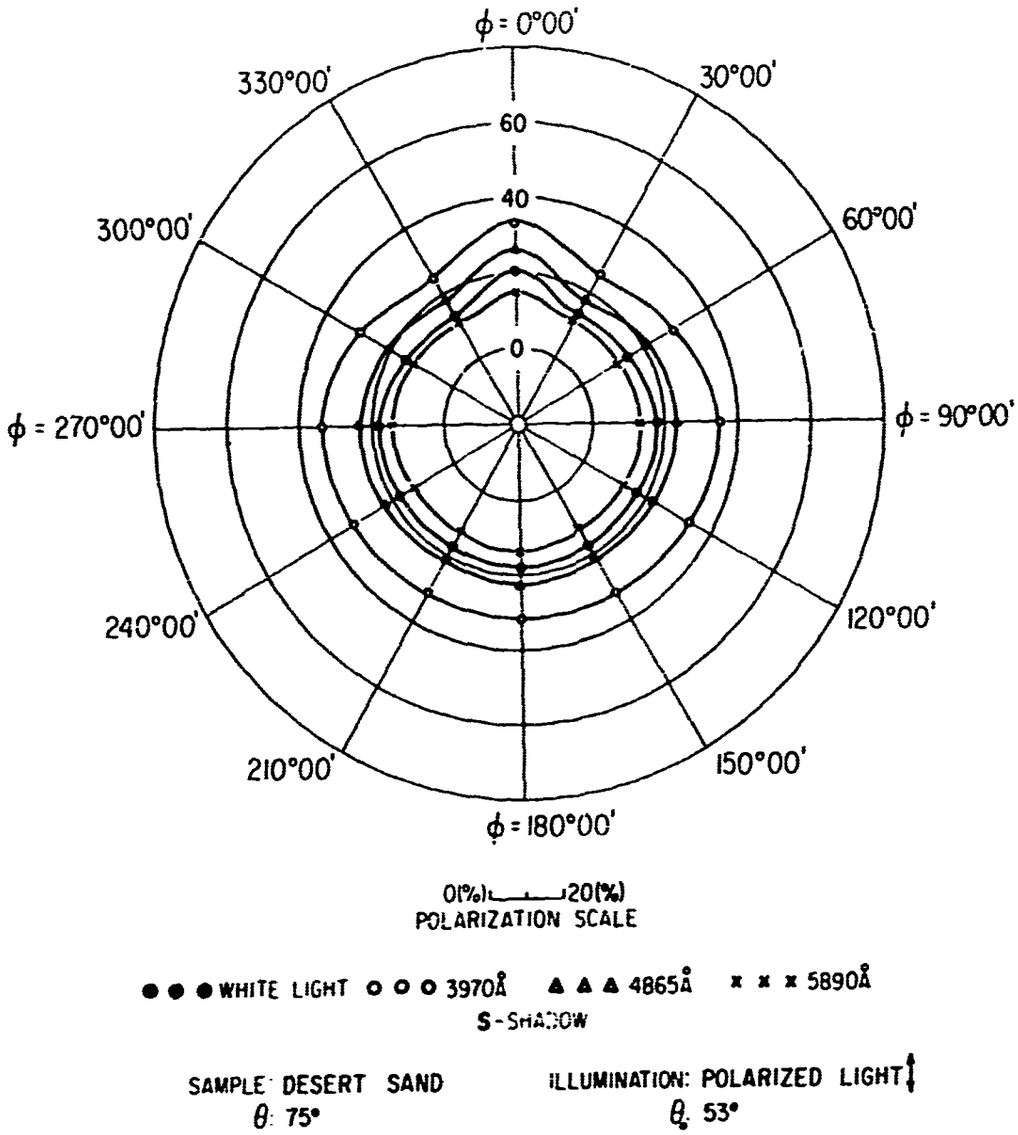


FIG 77 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.88 - 0.80\cos\varphi - 0.15\cos 2\varphi + 1.55\cos 3\varphi + 2.30\cos 4\varphi + 0.70\cos 5\varphi + 0.88\cos 6\varphi - 0.34\sin\varphi - 0.18\sin 2\varphi + 0.13\sin 3\varphi - 0.17\sin 4\varphi + 0.07\sin 5\varphi$$

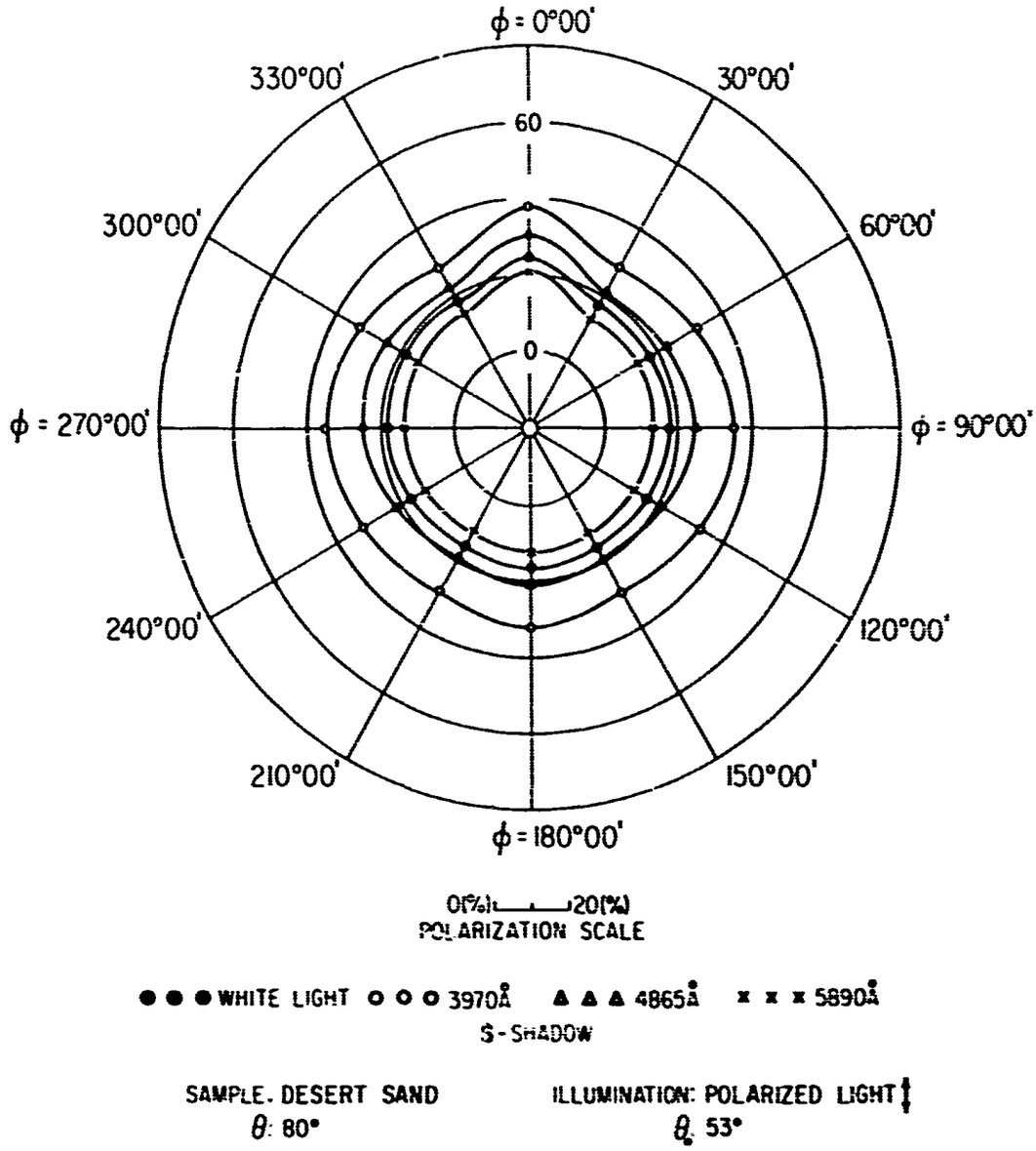


FIG 78. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 18.04 + 2.48 \cos\varphi + 0.60 \cos 2\varphi + 1.03 \cos 3\varphi + 1.48 \cos 4\varphi + 0.49 \cos 5\varphi + 1.65 \cos 6\varphi - 0.57 \sin\varphi - 0.46 \sin 2\varphi + 0.25 \sin 3\varphi - 0.16 \sin 4\varphi + 0.06 \sin 5\varphi$$

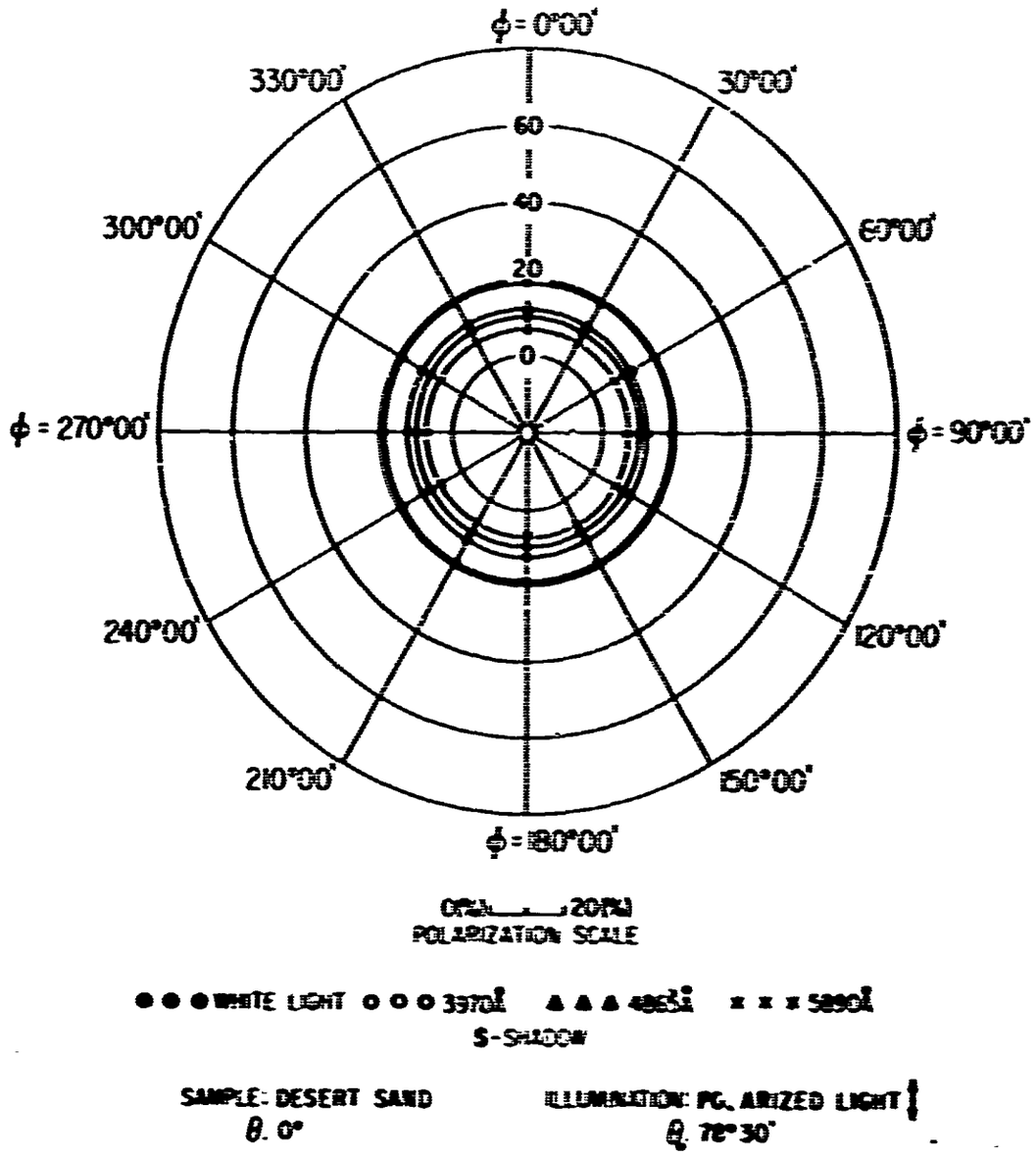
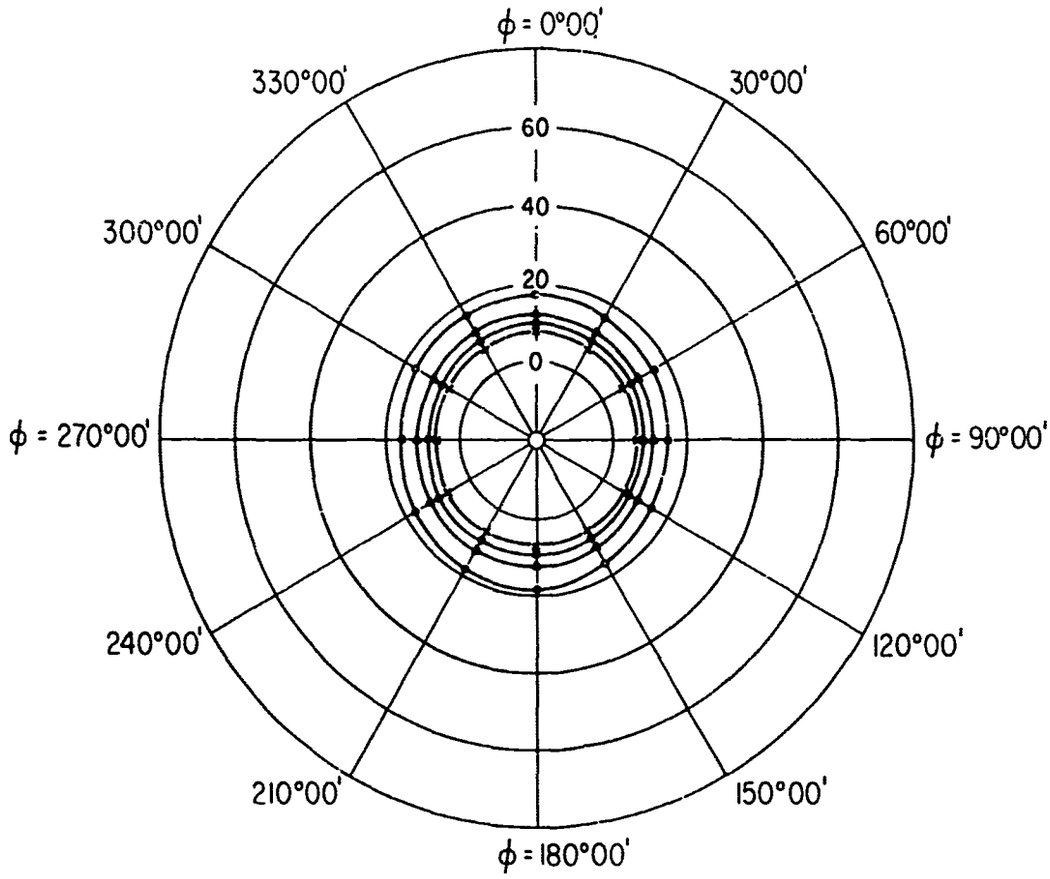


FIG 79. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 20(%)
POLARIZATION SCALE

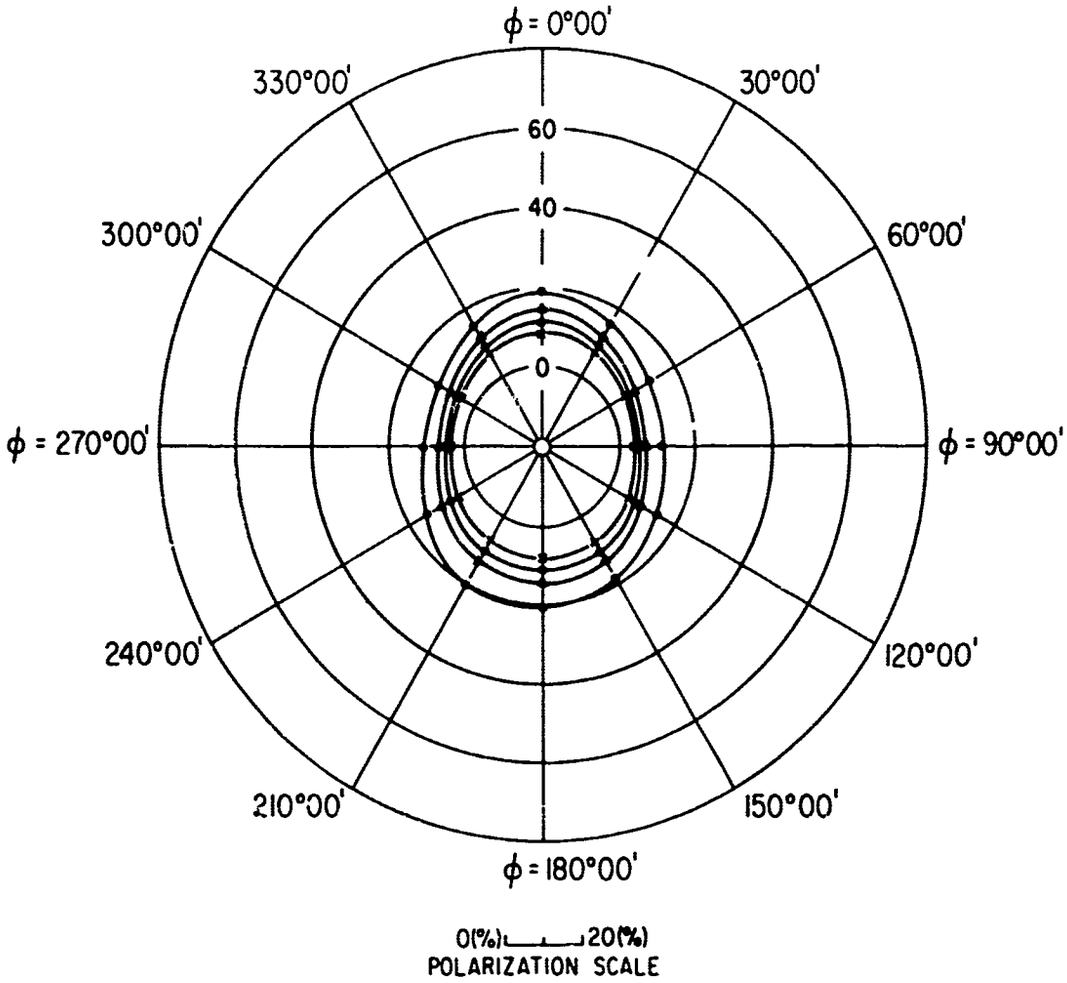
● ● ● WHITE LIGHT o o o 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. DESERT SAND
θ: 10°

ILLUMINATION: POLARIZED LIGHT ↕
θ_o 78° 30'

FIG 80. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 9.61 - 0.18\cos\varphi + 0.94\cos 2\varphi - 0.10\cos 3\varphi - 0.11\cos 4\varphi + 0.06\cos 5\varphi - 0.08\cos 6\varphi - 0.12\sin\varphi - 0.02\sin 2\varphi - 0.25\sin 3\varphi - 0.02\sin 4\varphi - 0.12\sin 5\varphi$$

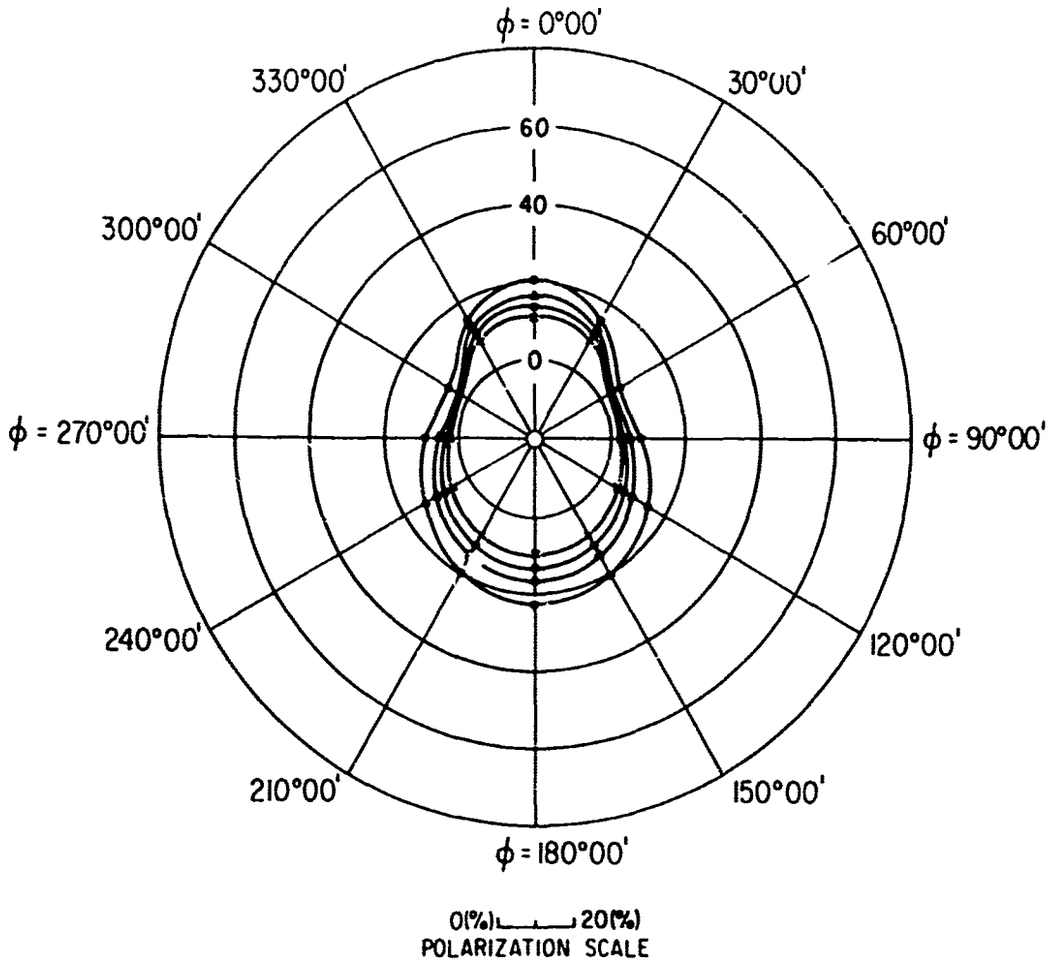


SAMPLE: DESERT SAND
θ: 20°

ILLUMINATION: POLARIZED LIGHT
θ_0: 78°30'

FIG 81. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.70 - 0.47 \cos\varphi + 3.29 \cos 2\varphi + 0.72 \cos 3\varphi - 0.12 \cos 4\varphi - 0.09 \cos 5\varphi - 0.03 \cos 6\varphi - 0.11 \sin\varphi - 0.04 \sin 2\varphi - 0.22 \sin 3\varphi - 0.06 \sin 4\varphi - 0.11 \sin 5\varphi$$



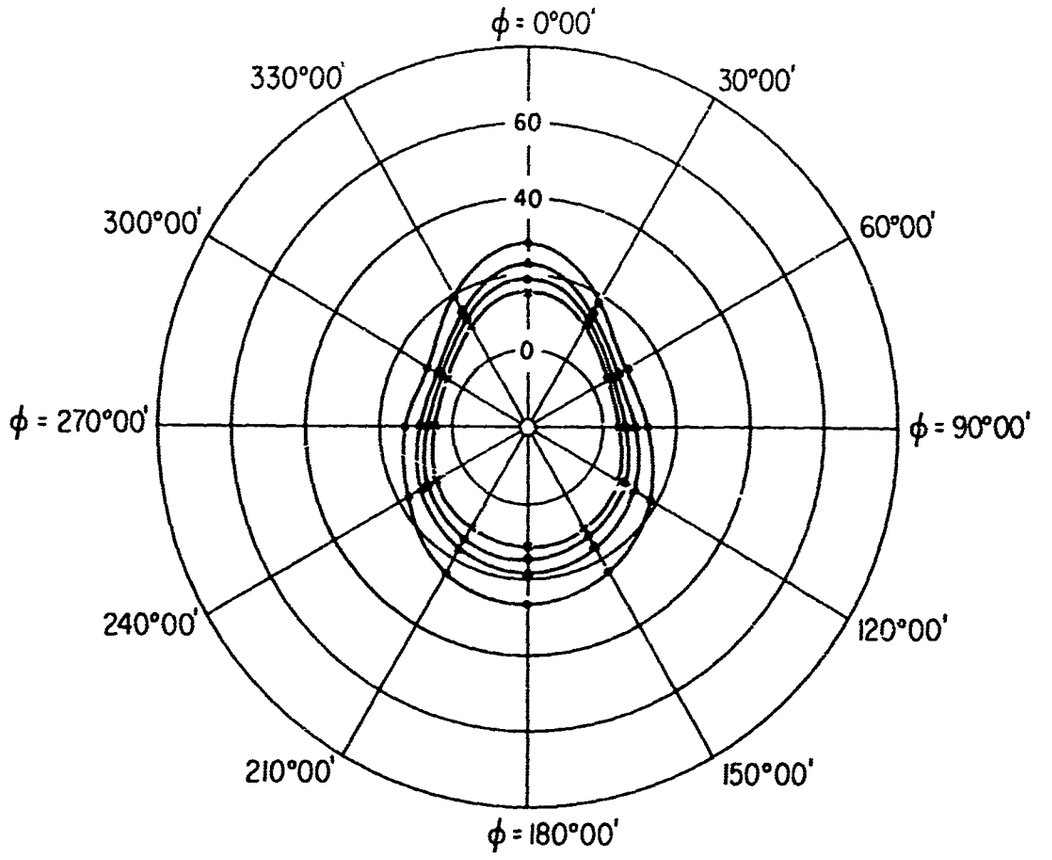
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 30°

ILLUMINATION: POLARIZED LIGHT ↕
θ_i: 78° 30'

FIG 82. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.64 - 0.25\cos\varphi + 5.66\cos 2\varphi + 1.95\cos 3\varphi + 0.33\cos 4\varphi - 0.28\cos 5\varphi - 0.38\cos 6\varphi - 0.05\sin\varphi + 0.06\sin 2\varphi - 0.10\sin 3\varphi + 0.06\sin 4\varphi - 0.05\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

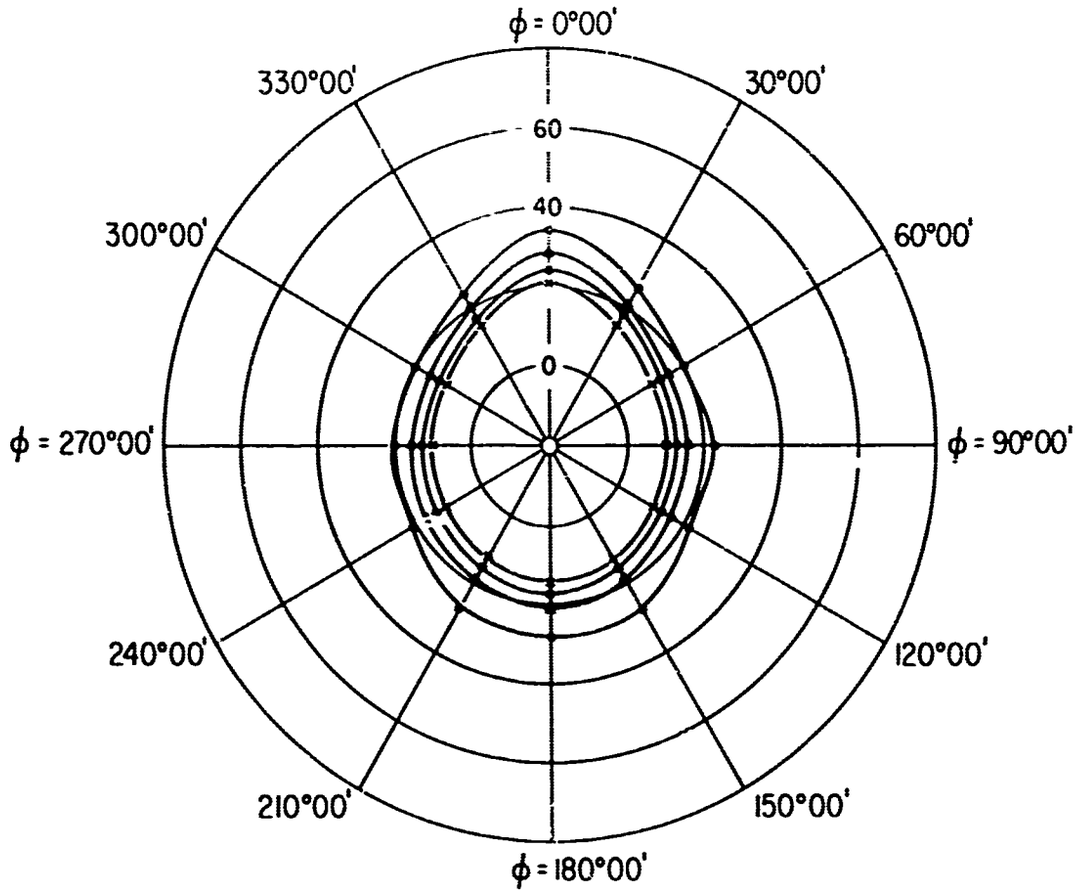
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 40°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 78° 30'

FIG 83. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 11.57 - 0.32 \cos\varphi + 5.15 \cos 2\varphi + 2.03 \cos 3\varphi + 0.88 \cos 4\varphi + 0.08 \cos 5\varphi + 0.00 \cos 6\varphi + 0.03 \sin\varphi + 0.09 \sin 2\varphi + 0.07 \sin 3\varphi + 0.09 \sin 4\varphi + 0.03 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

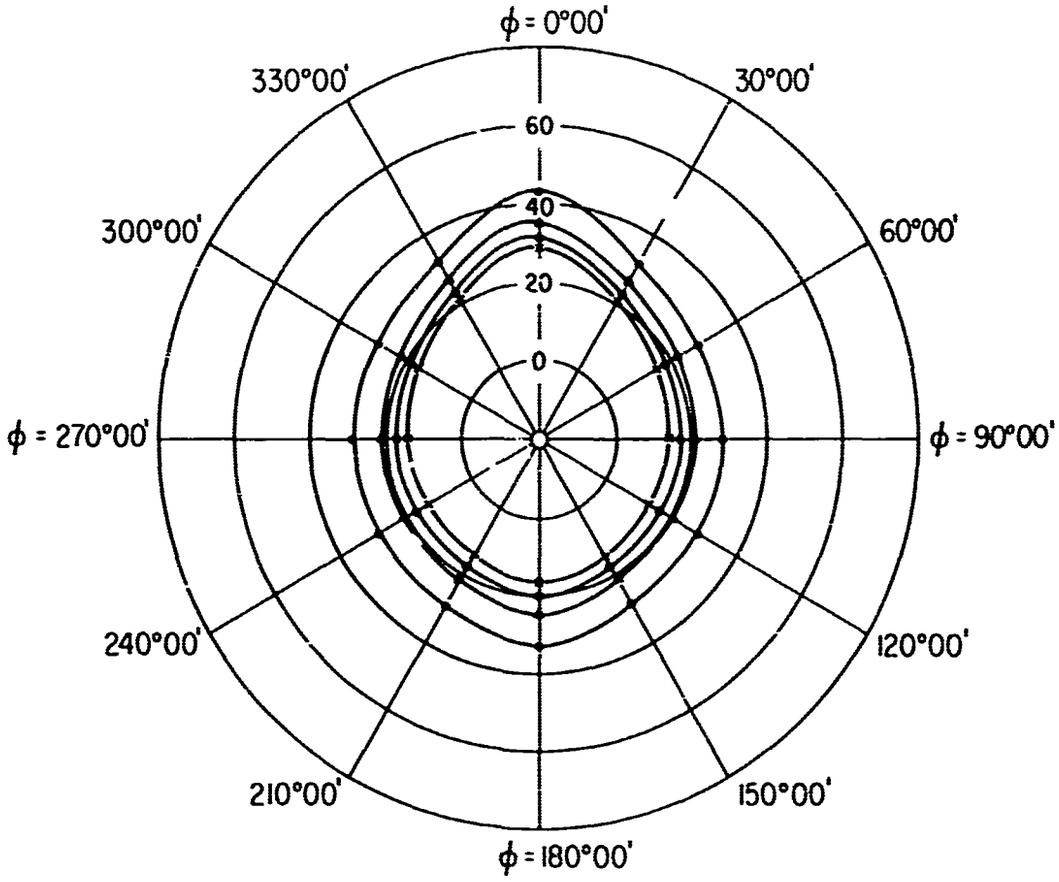
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: DESERT SAND
θ: 50°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 78° 30'

FIG 84. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 15.82 + 1.57 \cos\varphi + 4.57 \cos 2\varphi + 1.77 \cos 3\varphi + 1.33 \cos 4\varphi + 1.39 \cos 5\varphi + 0.57 \cos 6\varphi + 0.08 \sin\varphi + 0.14 \sin 2\varphi + 0.16 \sin 3\varphi + 0.14 \sin 4\varphi + 0.08 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. DESERT SAND
θ: 60°

ILLUMINATION: POLARIZED LIGHT
$\hat{\theta}_o$ 78°30'

FIG 85. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 20.97 + 4.51 \cos\varphi + 4.58 \cos 2\varphi + 1.37 \cos 3\varphi + 1.78 \cos 4\varphi + 2.00 \cos 5\varphi + 1.33 \cos 6\varphi + 0.15 \sin\varphi + 0.29 \sin 2\varphi + 0.30 \sin 3\varphi + 0.29 \sin 4\varphi + 0.15 \sin 5\varphi$$

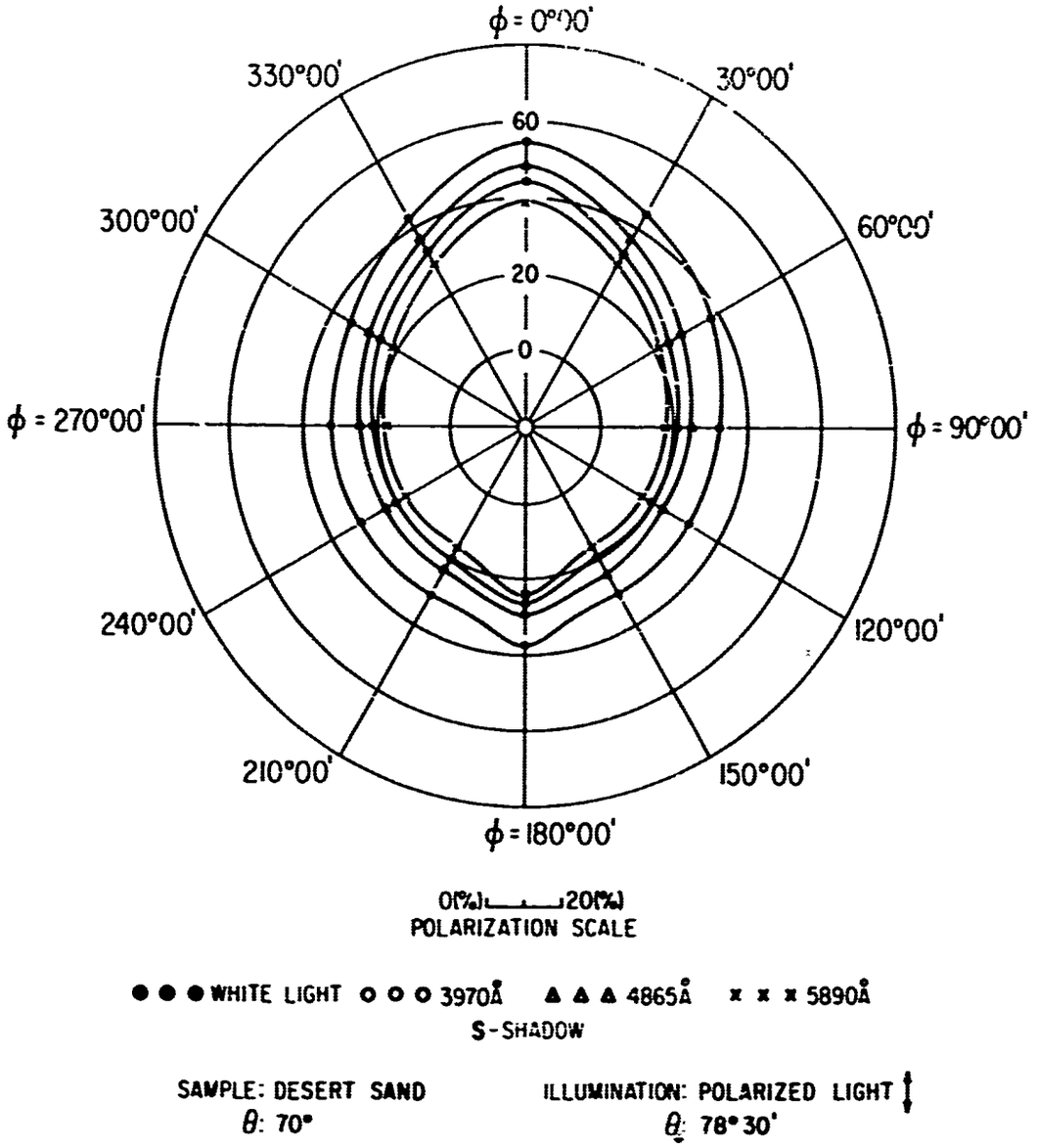


FIG 86. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 26.48 + 7.60 \cos\varphi + 5.42 \cos 2\varphi + 1.53 \cos 3\varphi + 2.62 \cos 4\varphi + 0.56 \cos 5\varphi + 1.37 \cos 6\varphi + 0.18 \sin\varphi + 0.18 \sin 2\varphi + 0.37 \sin 3\varphi + 0.18 \sin 4\varphi - 1.77 \sin 5\varphi$$

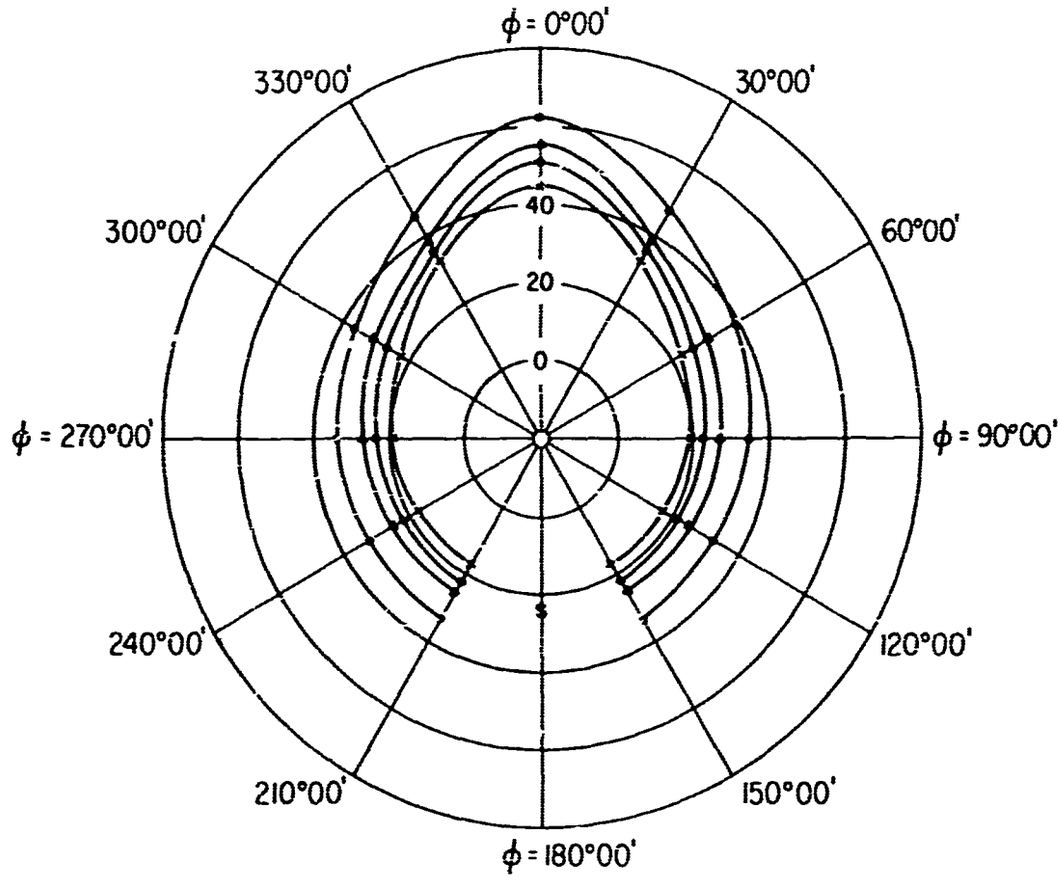


FIG 87. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 28.09 + 11.03 \cos\varphi + 6.00 \cos 2\varphi + 2.52 \cos 3\varphi + 2.13 \cos 4\varphi + 1.10 \cos 5\varphi + 0.85 \cos 6\varphi - 0.08 \sin\varphi + 0.00 \sin 2\varphi + 0.00 \sin 3\varphi + 0.00 \sin 4\varphi + 0.00 \sin 5\varphi$$

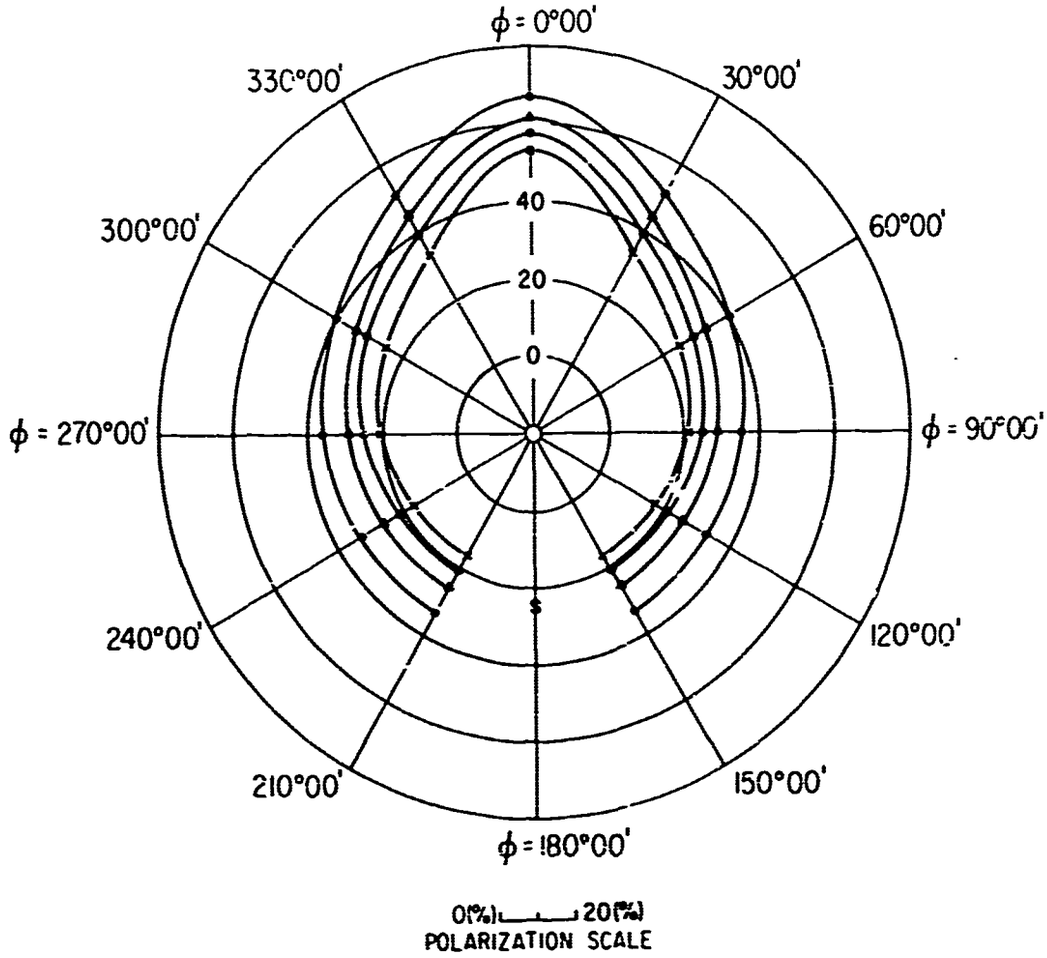
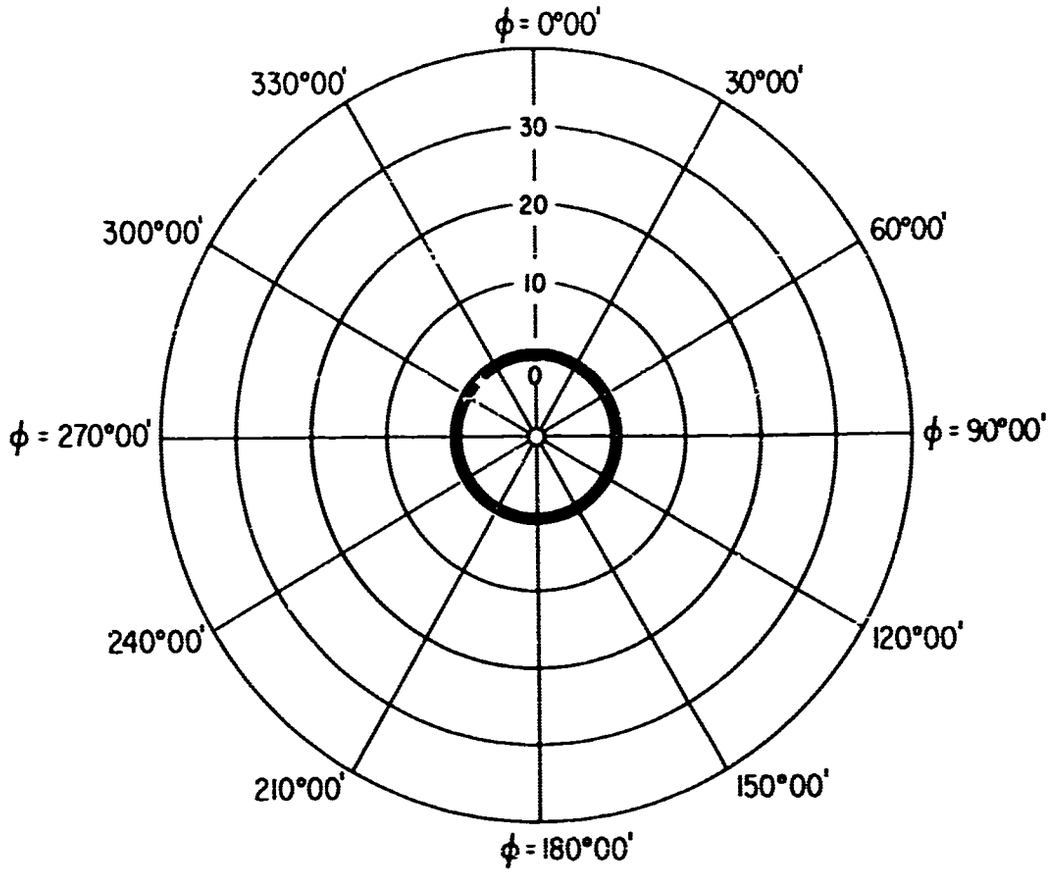


FIG 88. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 29.45 + 12.66 \cos\varphi + 7.2 \cos 2\varphi + 3.37 \cos 3\varphi + 2.80 \cos 4\varphi + 2.27 \cos 5\varphi + 1.70 \cos 6\varphi + 0.20 \sin\varphi + 0.34 \sin 2\varphi + 0.40 \sin 3\varphi + 0.34 \sin 4\varphi + 0.20 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ. 10°

ILLUMINATION: NATURAL LIGHT
$\hat{\theta}_0$ 0°

FIG 89. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

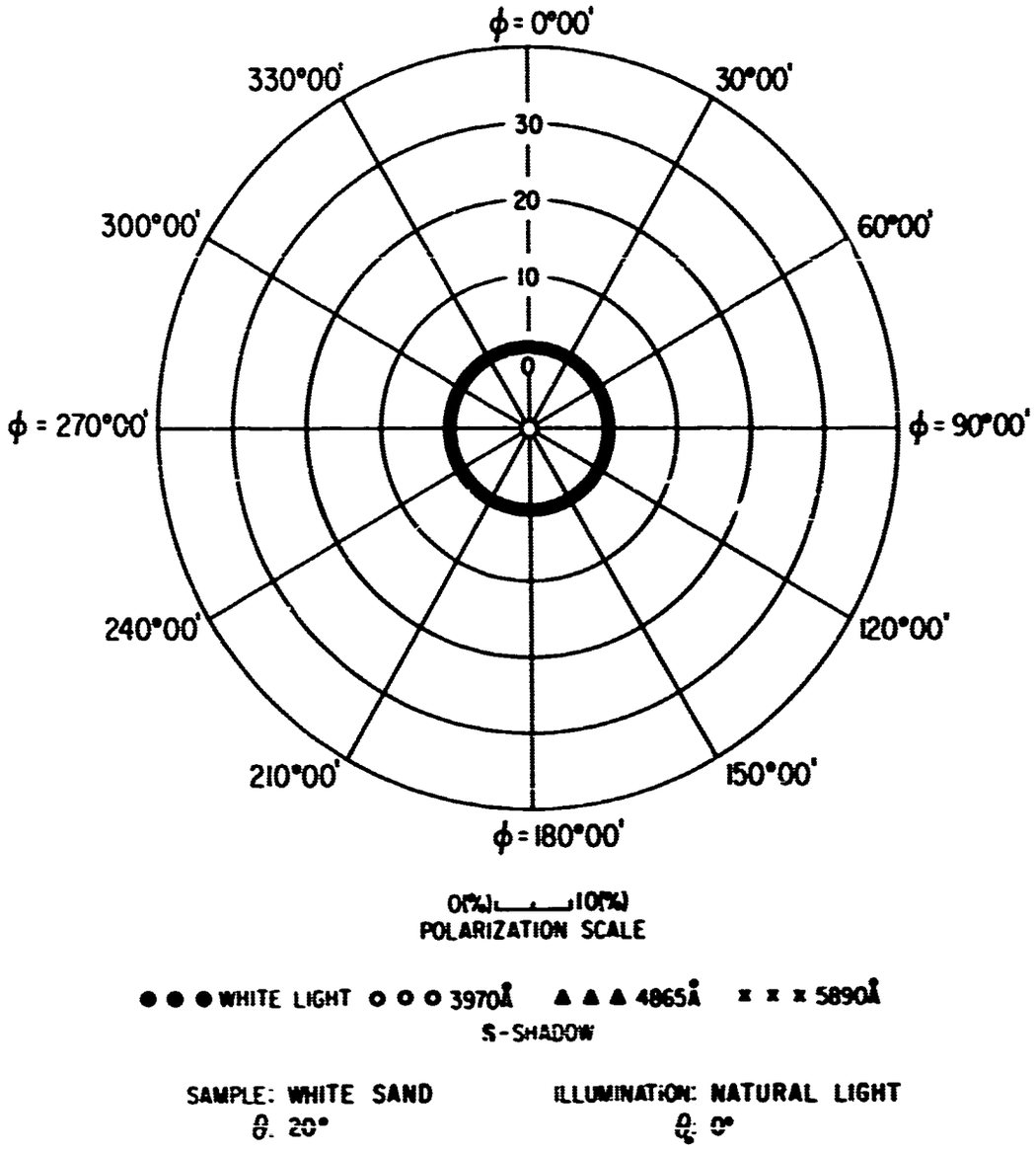


FIG 90. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

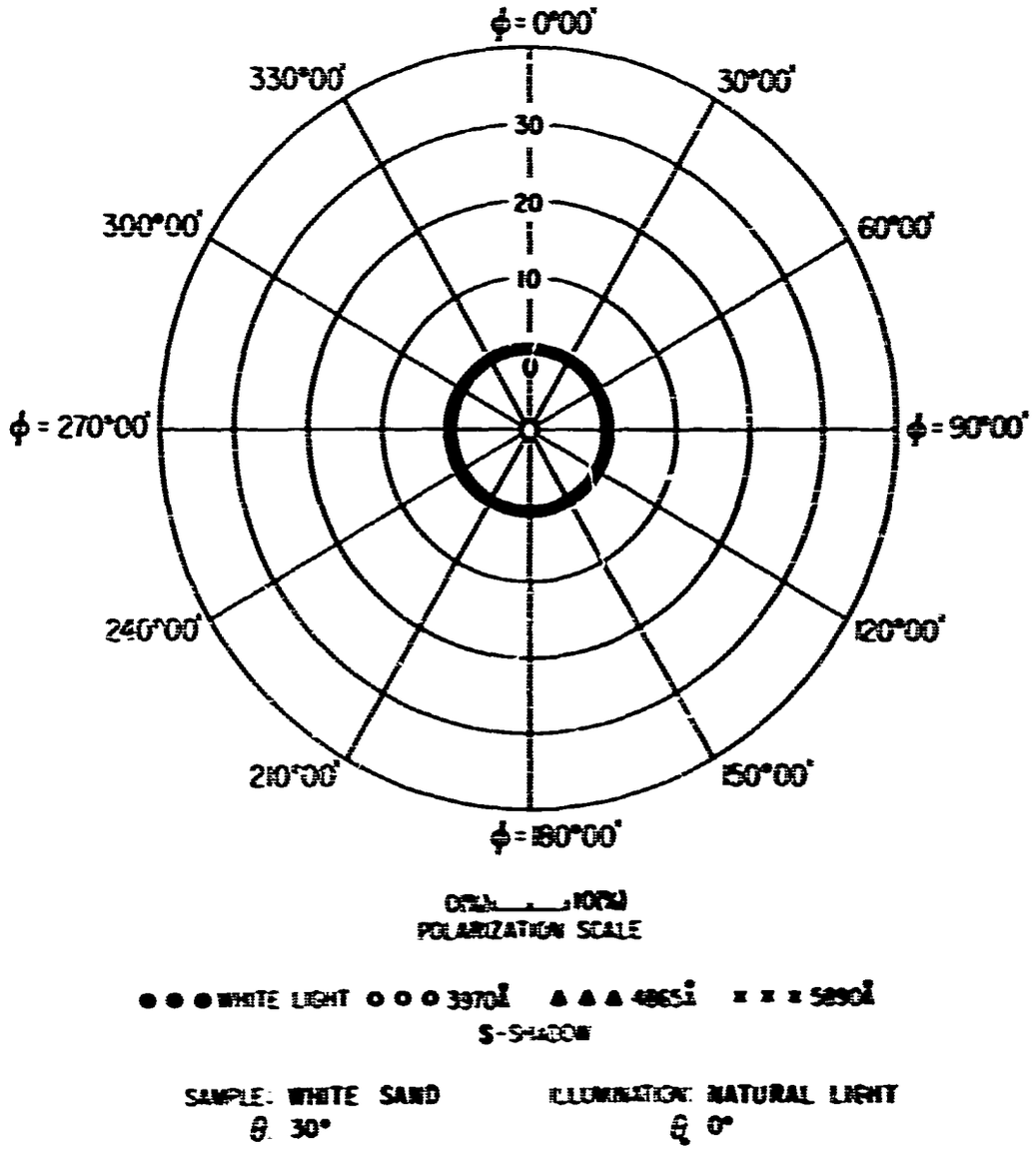
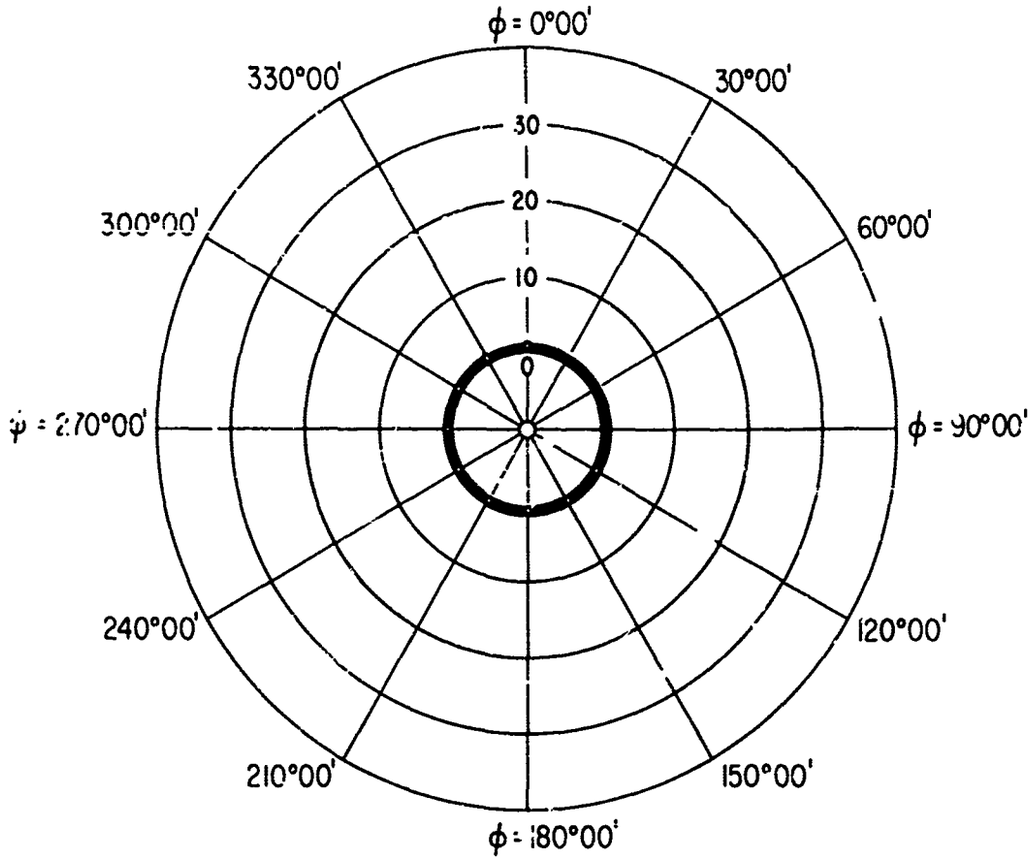


FIG 91. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 6890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 40°

ILLUMINATION: NATURAL LIGHT
θ_0: 0°

FIG 92. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

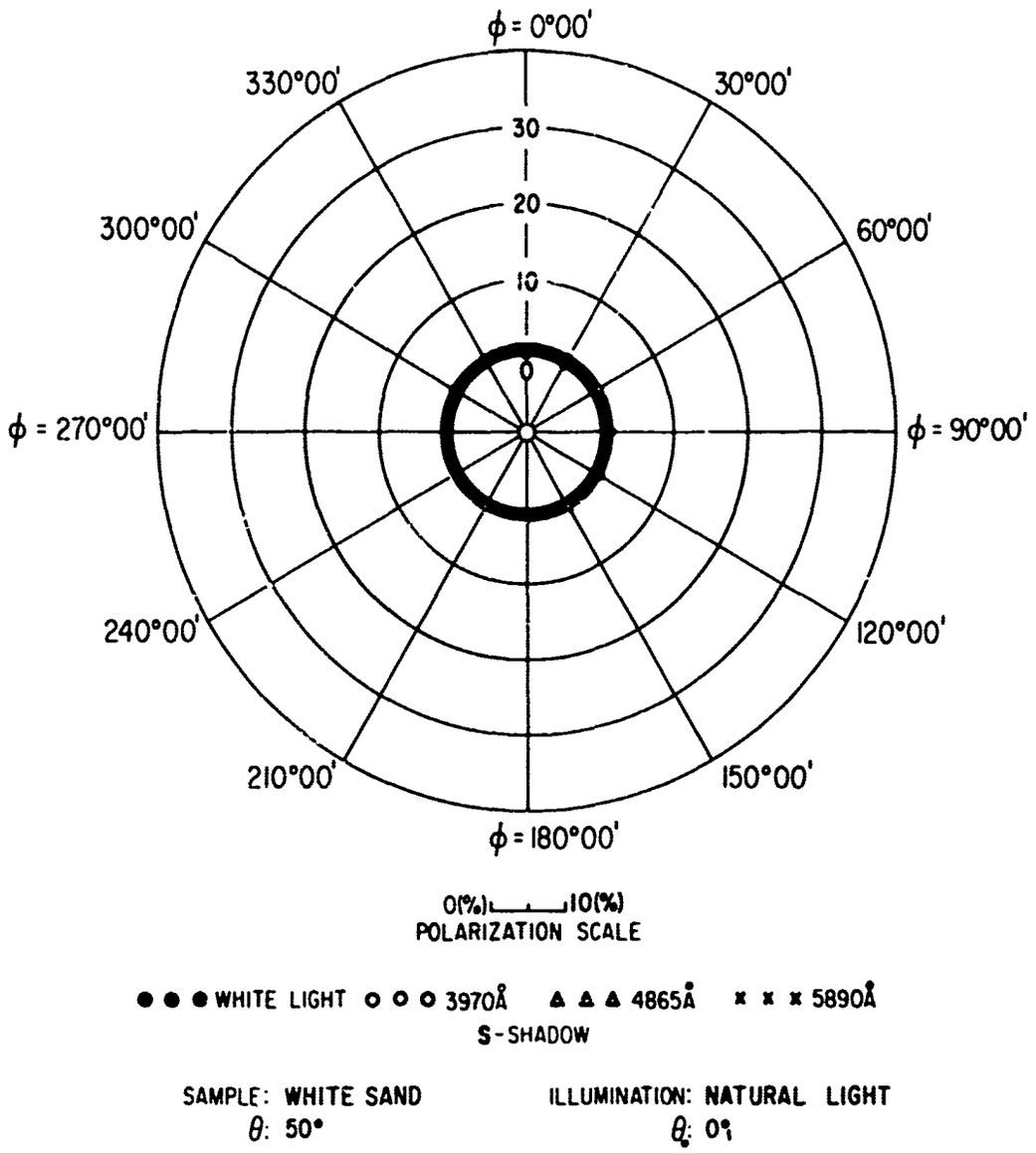
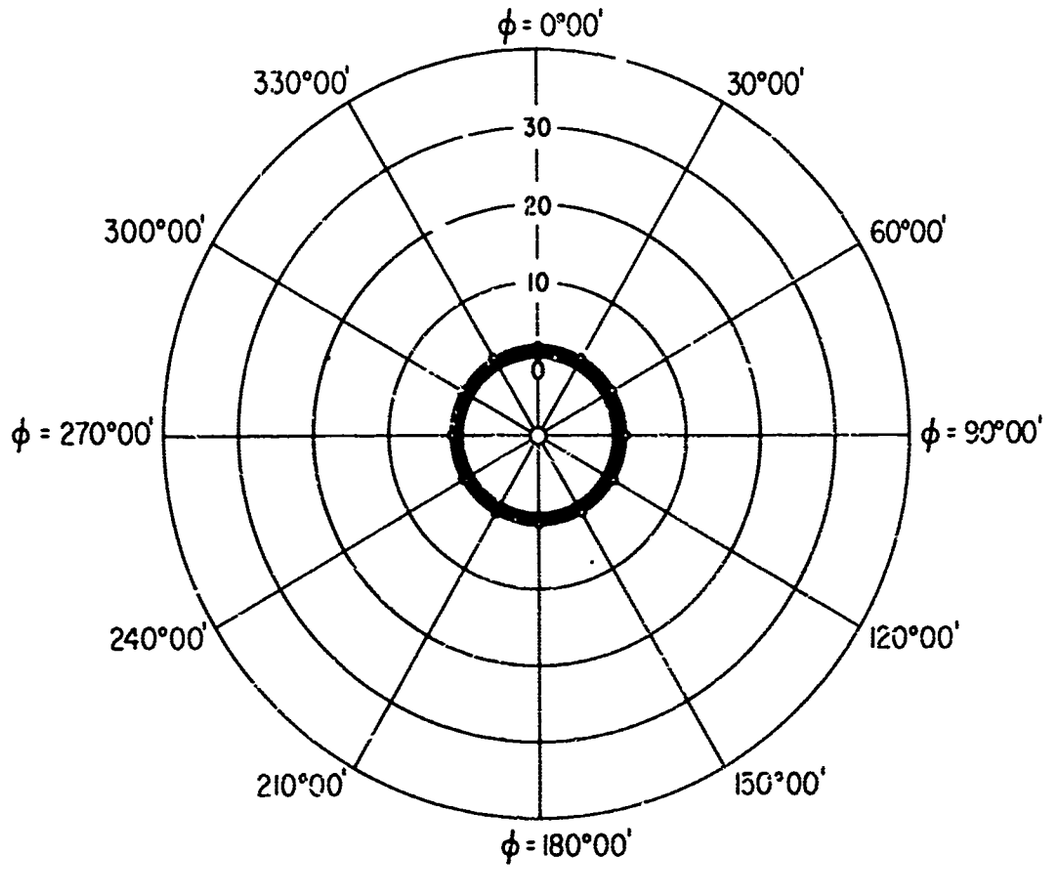


FIG 93. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



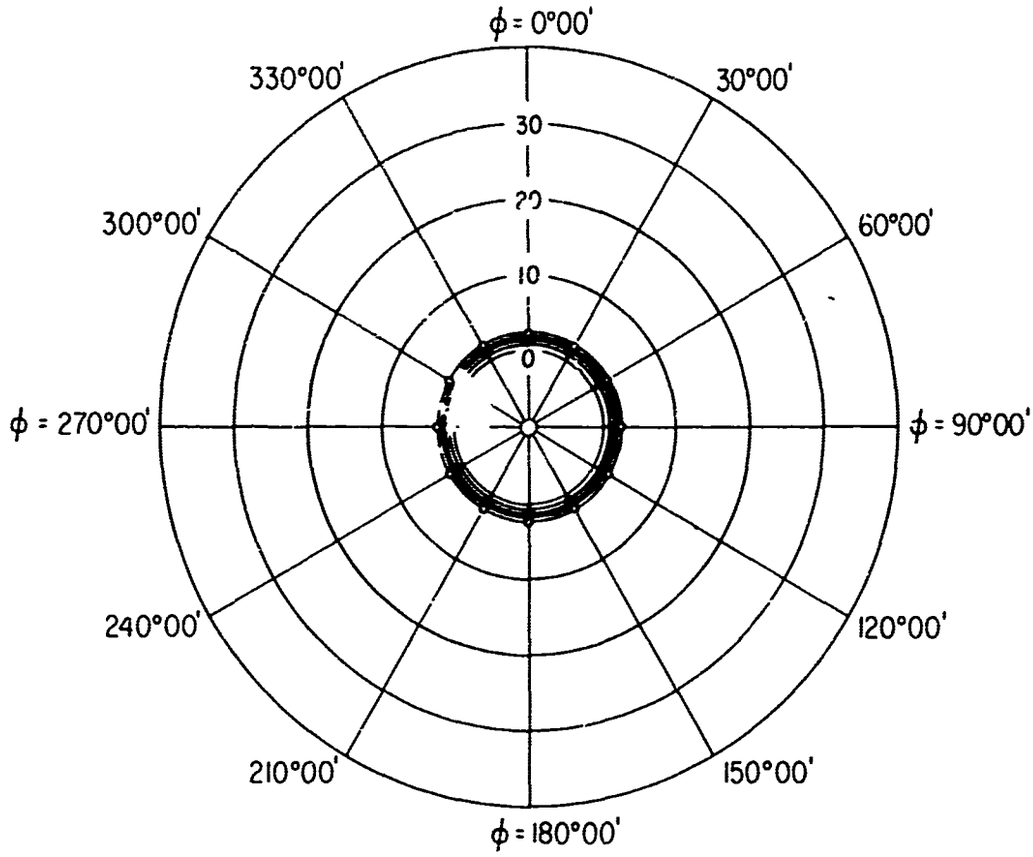
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ: 60°

ILLUMINATION: NATURAL LIGHT
θ_i: 0°

FIG 94. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



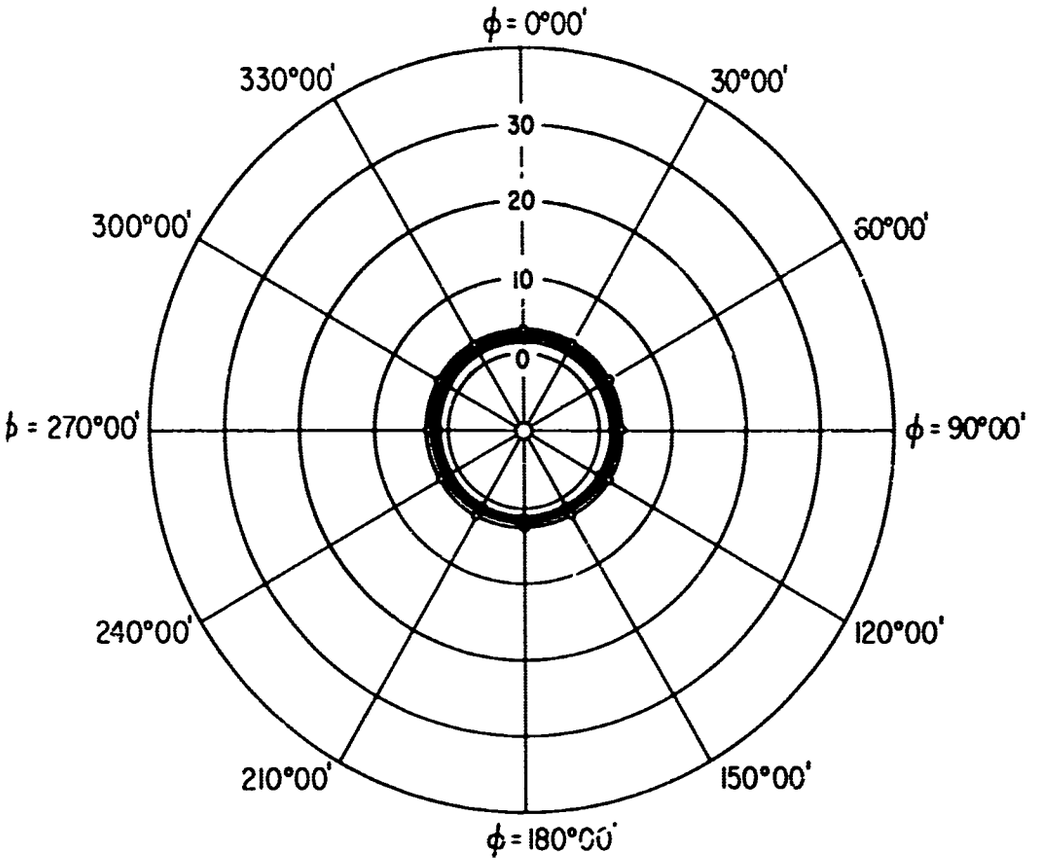
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 70°

ILLUMINATION: NATURAL LIGHT
θ_0 0°

FIG 95. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ: 75°

ILLUMINATION: NATURAL LIGHT
θ_i: 0°

FIG 96. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

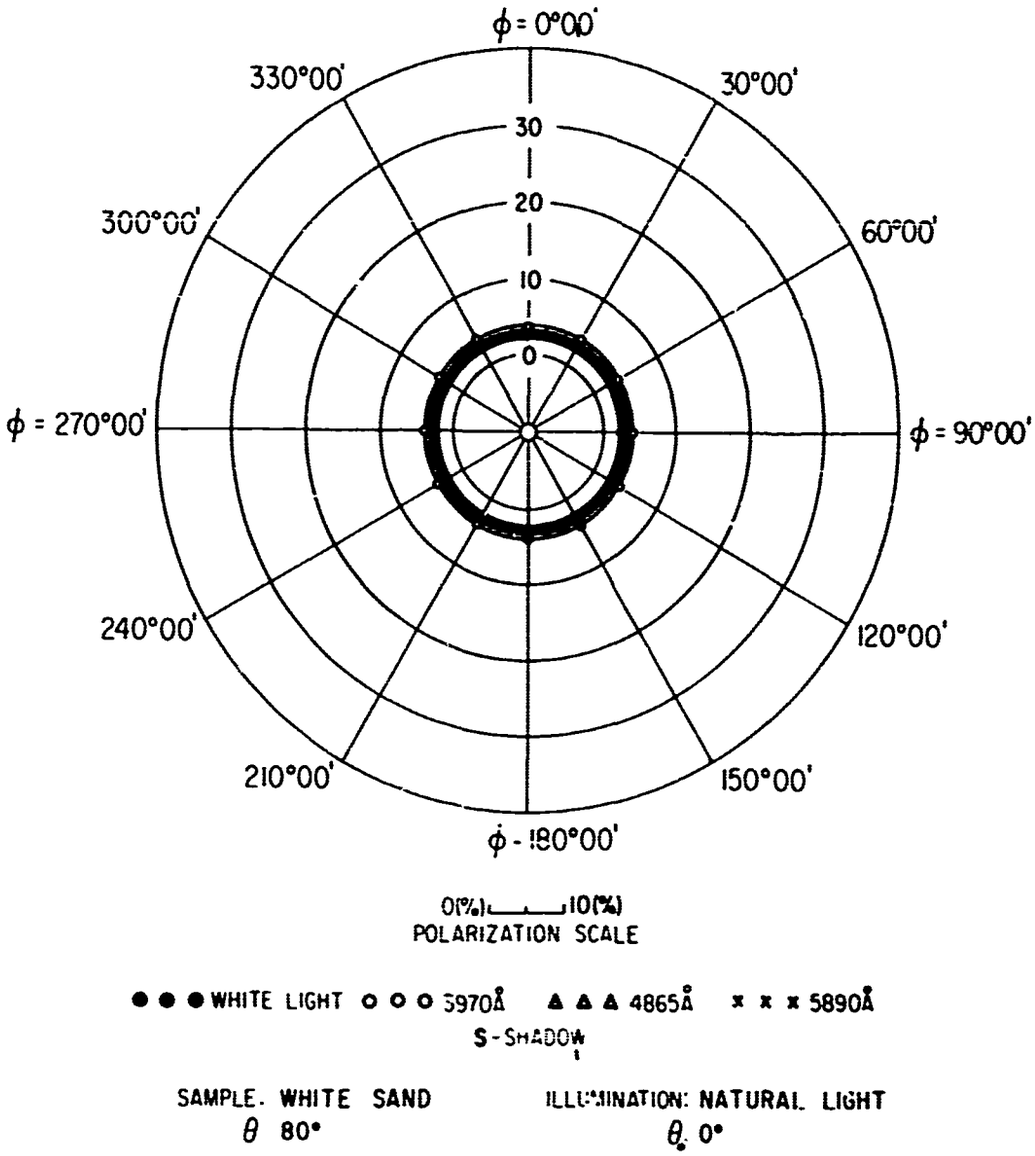


FIG 97. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

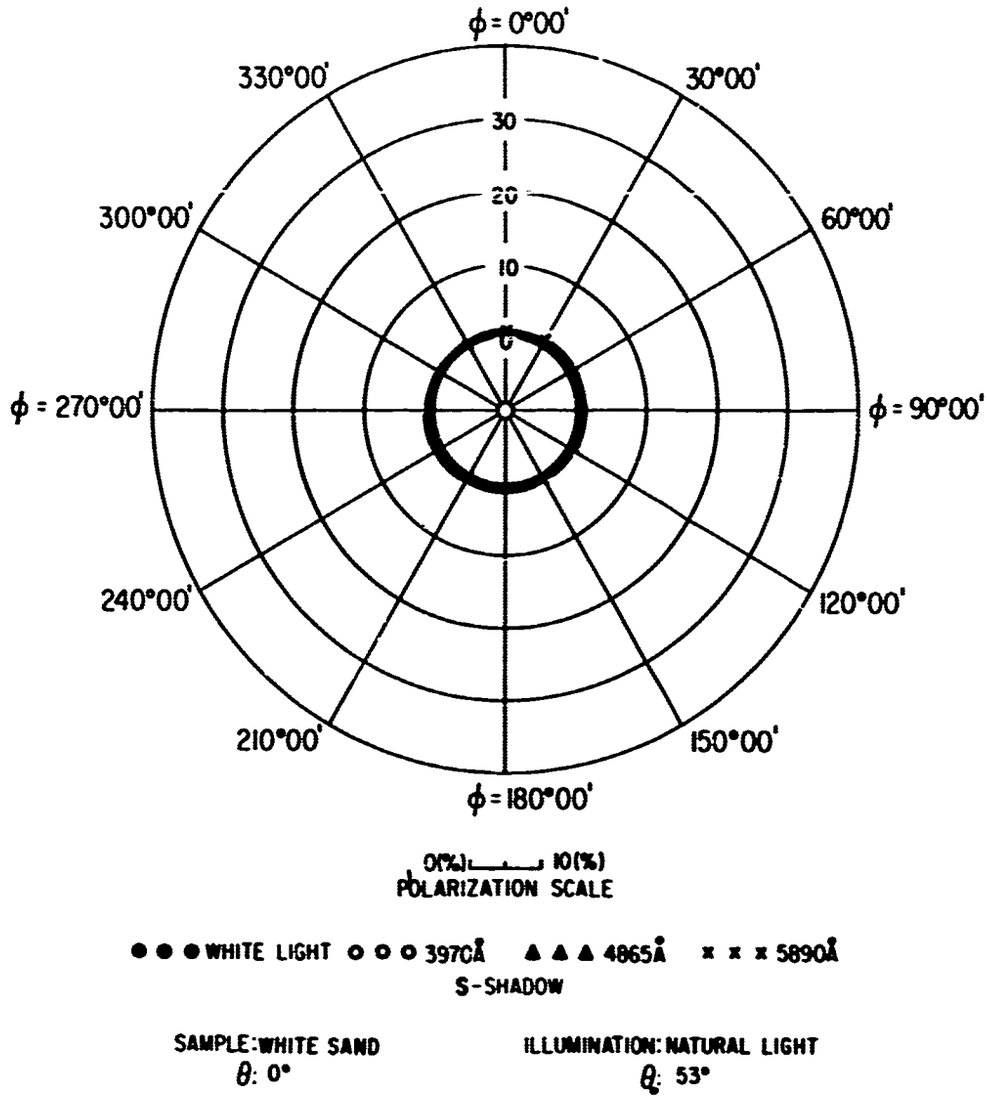
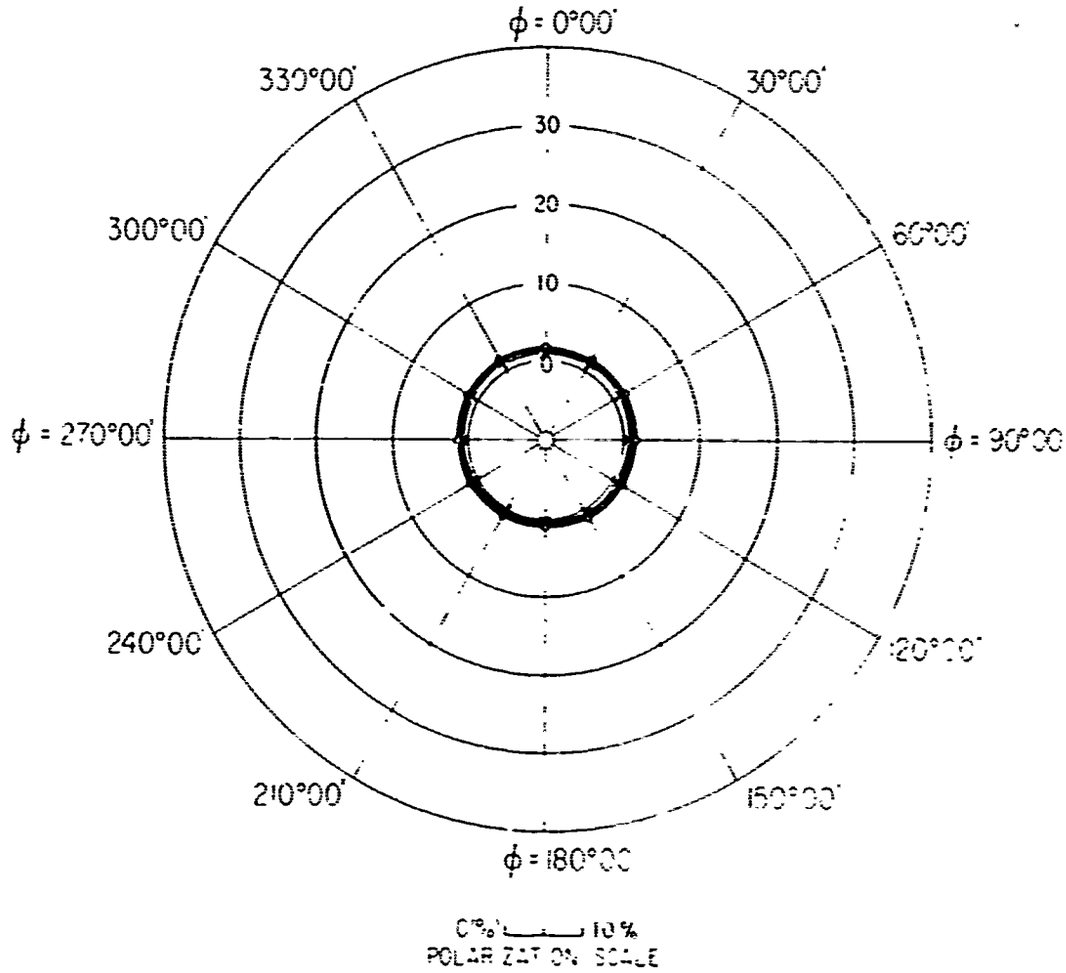


FIG. 98 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE WHITE SAND
θ 10°

ILLUMINATION NATURAL LIGHT
θ_0 53°

FIG 99 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 1.12 + 0.41 \cos\phi + 0.12 \cos 2\phi - 0.13 \cos 3\phi - 0.07 \cos 4\phi - 0.02 \cos 5\phi - 0.03 \cos 6\phi + 0.07 \sin\phi + 0.06 \sin 2\phi + 0.00 \sin 3\phi + 0.02 \sin 4\phi - 0.02 \sin 5\phi$$

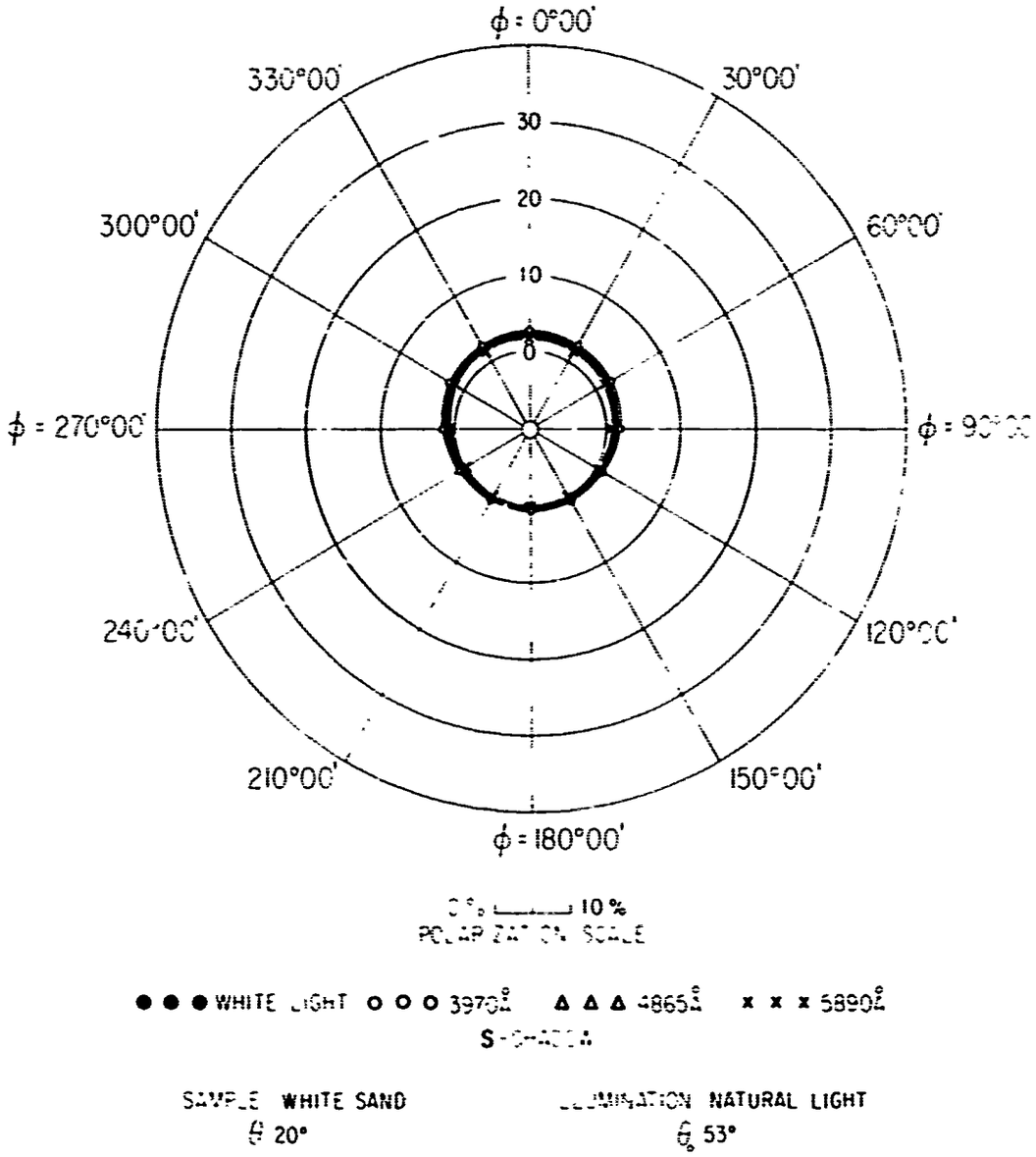
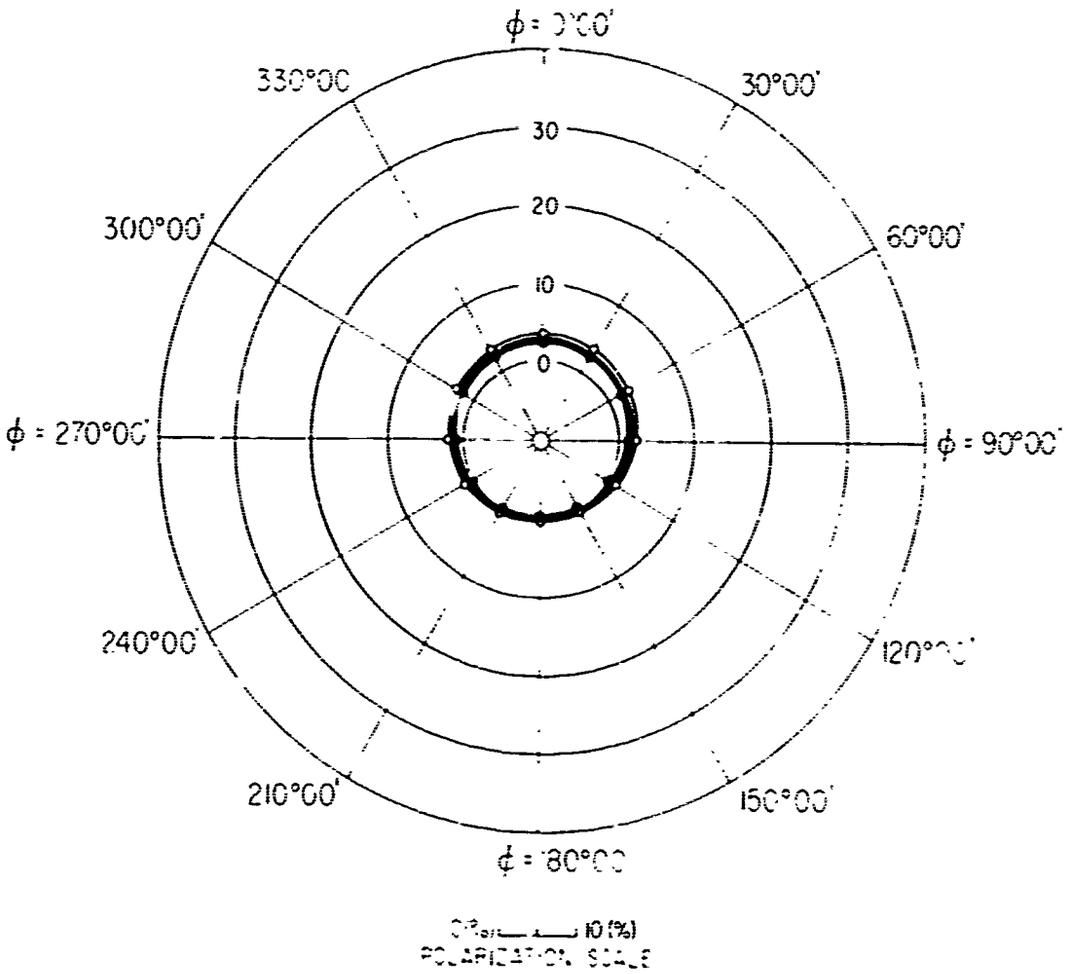


FIG 100 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 1.19 + 1.02 \cos\phi - 0.12 \cos 2\phi + 0.07 \cos 3\phi + 0.12 \cos 4\phi + 0.01 \cos 5\phi + 0.08 \cos 6\phi + 0.02 \sin\phi - 0.10 \sin 2\phi - 0.02 \sin 3\phi - 0.04 \sin 4\phi - 0.10 \sin 5\phi$$



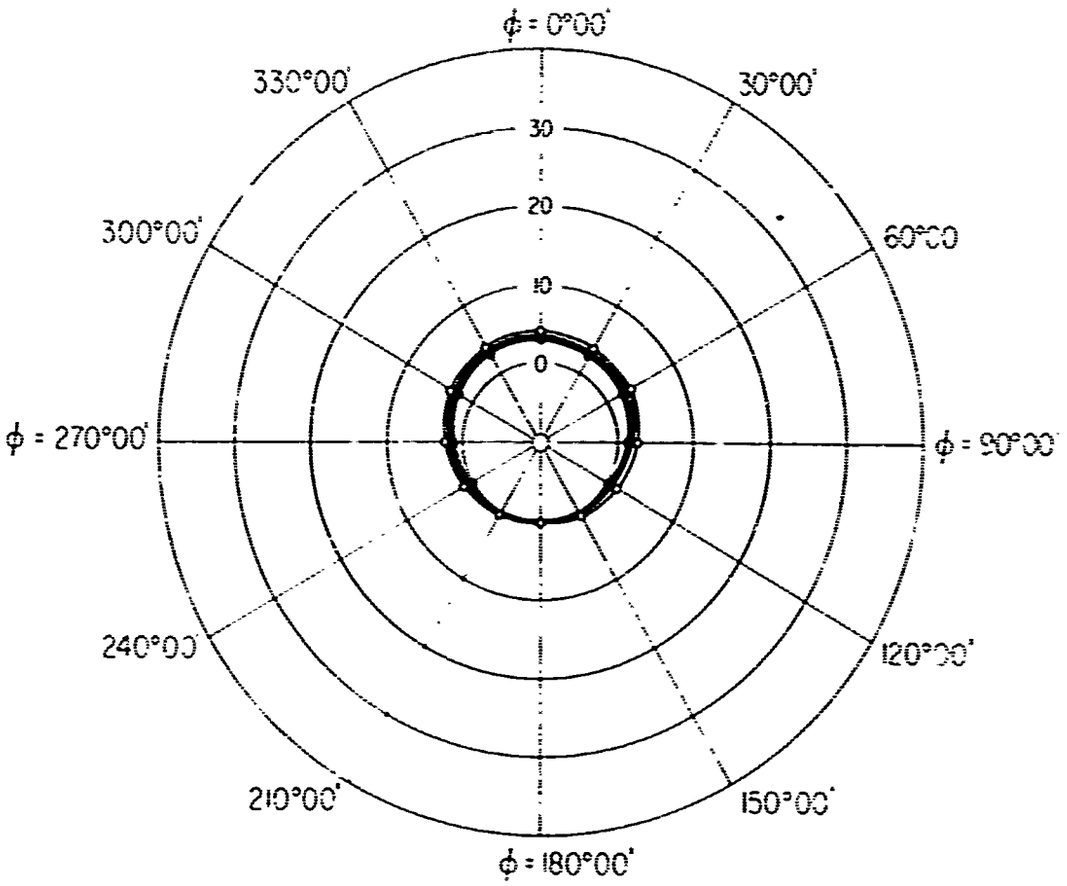
● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4965Å × × × 5890Å

SAMPLE WHITE SAND
θ 30

ILLUMINATION NATURAL LIGHT
θ_0 53°

FIG 101 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 1.49 + 1.42 \cos\varphi + 0.02 \cos 2\varphi + 0.10 \cos 3\varphi - 0.02 \cos 4\varphi - 0.02 \cos 5\varphi + 0.02 \cos 6\varphi - 0.01 \sin\varphi - 0.06 \sin 2\varphi - 0.02 \sin 3\varphi + 0.00 \sin 4\varphi + 0.04 \sin 5\varphi$$



0% 10 (%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-[illegible]

SAMPLE WHITE SAND
θ 40°

ILLUMINATION NATURAL LIGHT
ξ_0 53°

FIG 102 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 1.95 + 1.82 \cos\varphi + 0.05 \cos 2\varphi + 0.08 \cos 3\varphi + 0.00 \cos 4\varphi - 0.11 \cos 5\varphi + 0.00 \cos 6\varphi + 0.12 \sin\varphi - 0.03 \sin 2\varphi - 0.02 \sin 3\varphi - 0.06 \sin 4\varphi - 0.06 \sin 5\varphi$$

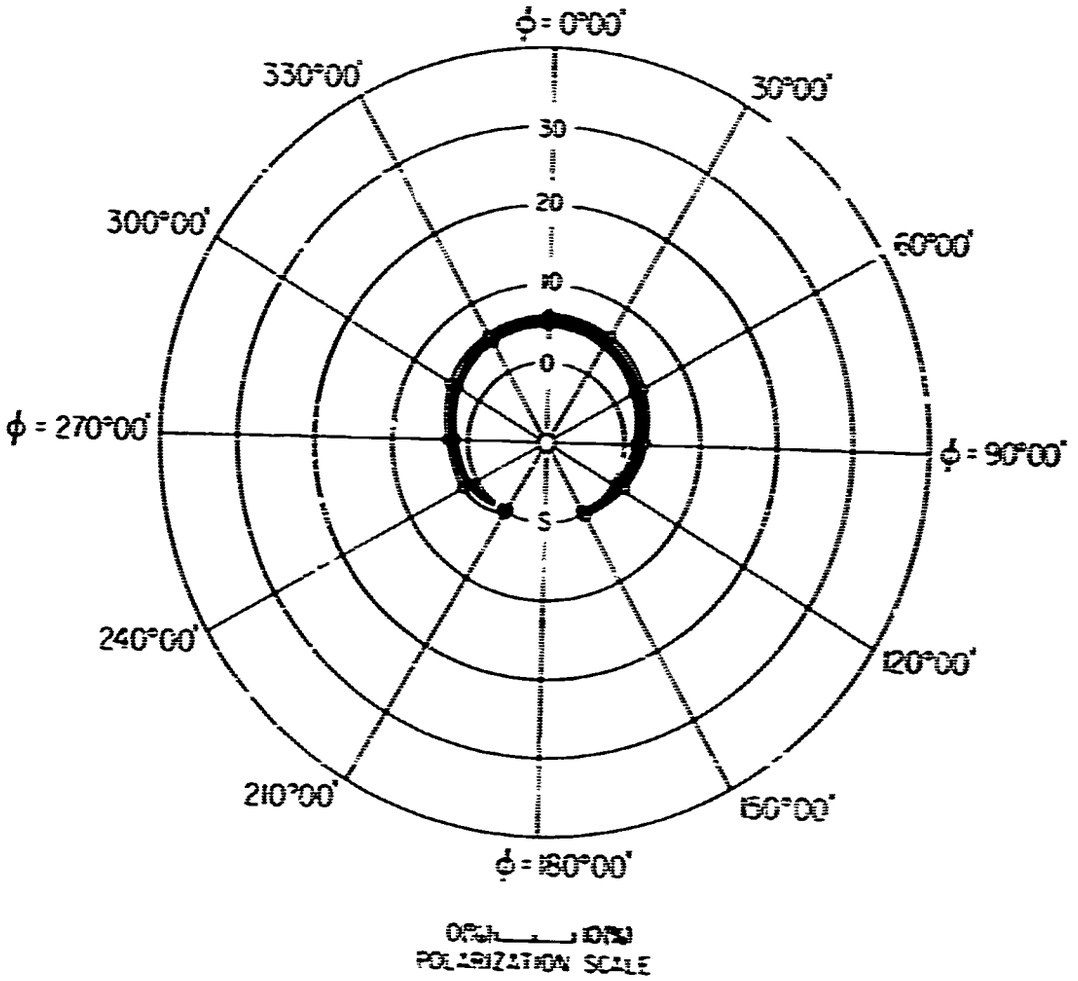
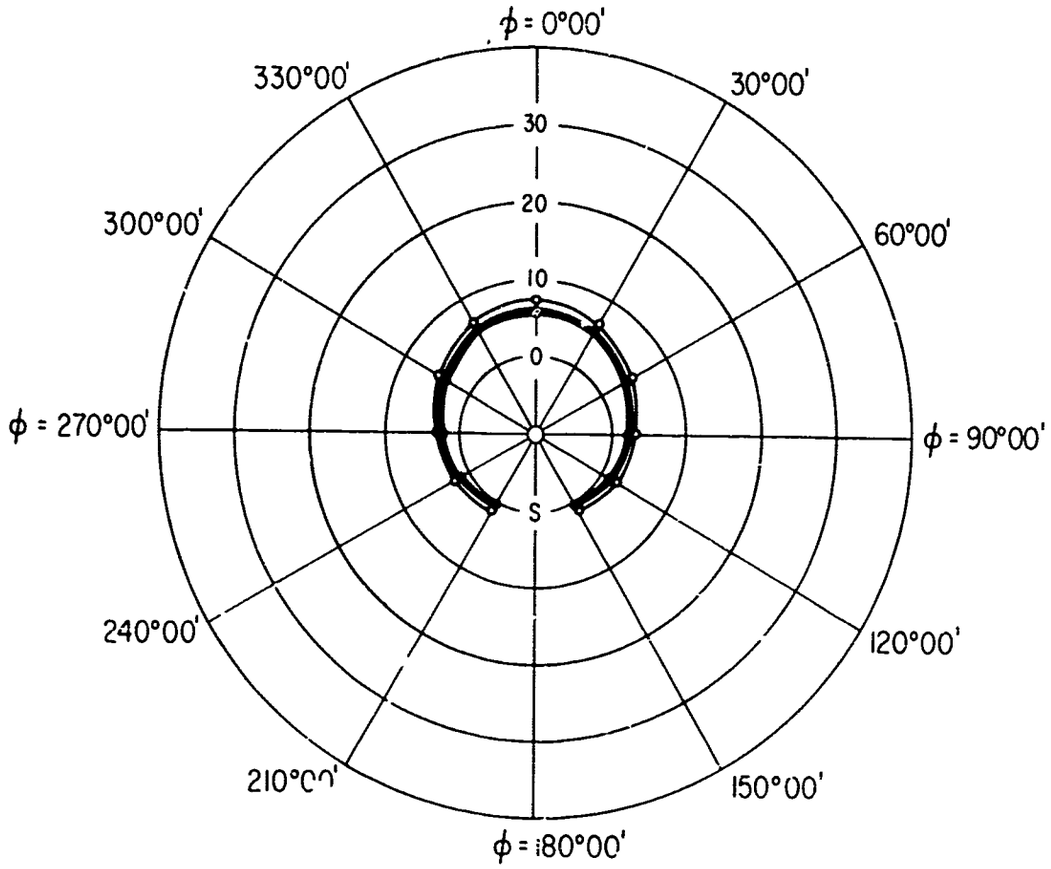


FIG 103 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 2.48 + 2.25 \cos\phi + 0.14 \cos 2\phi + 0.23 \cos 3\phi - 0.02 \cos 4\phi + 0.06 \cos 5\phi - 0.08 \cos 6\phi + 0.16 \sin\phi + 0.04 \sin 2\phi + 0.05 \sin 3\phi - 0.01 \sin 4\phi - 0.16 \sin 5\phi$$



0(%) 10(%)
POLARIZATION SCALE

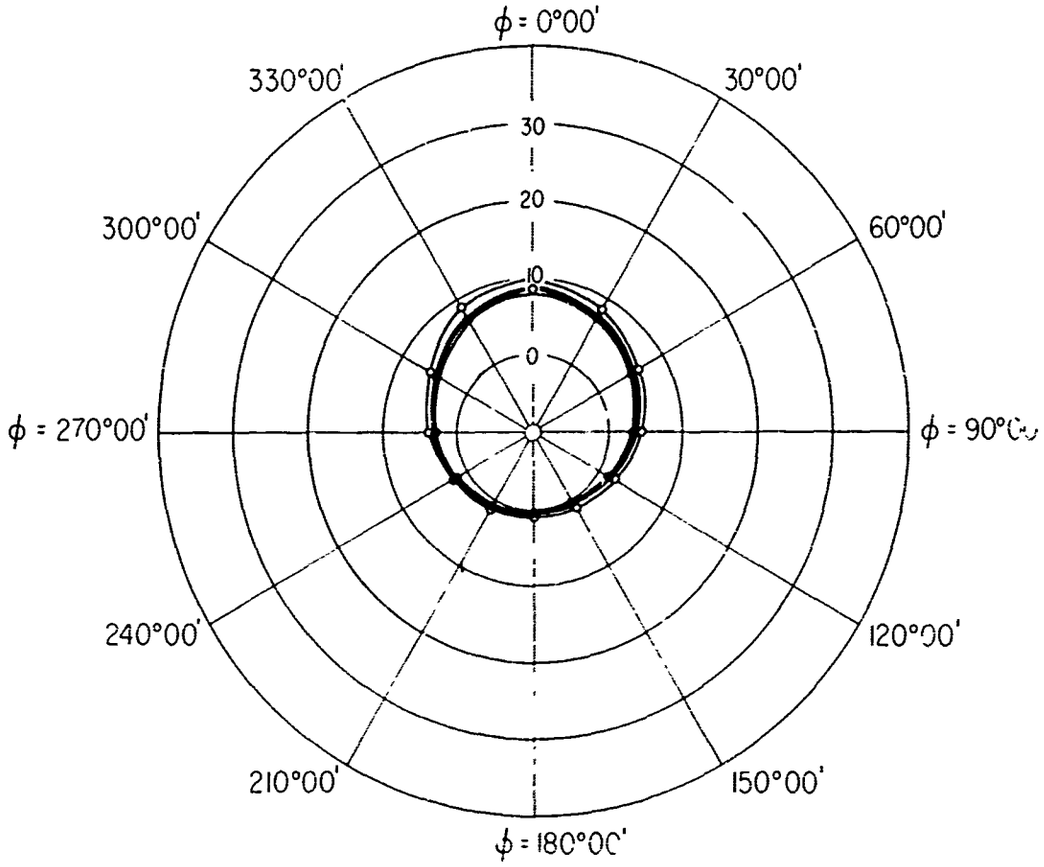
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
⌣ - SHADOW

SAMPLE. WHITE SAND
θ 60°

ILLUMINATION: NATURAL LIGHT
θ_0 53°

FIG 104 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.19 + 2.83 \cos\varphi + 0.12 \cos 2\varphi + 0.27 \cos 3\varphi - 0.07 \cos 4\varphi + 0.15 \cos 5\varphi + 0.02 \cos 6\varphi + 0.30 \sin\varphi + 0.12 \sin 2\varphi - 0.02 \sin 3\varphi - 0.03 \sin 4\varphi - 0.03 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4865Å × × × 5890Å
S - SHADOW

SAMPLE WHITE SAND
θ 70°

ILLUMINATION NATURAL LIGHT
θ_0 53°

FIG 105 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.98 + 3.57 \cos\varphi + 0.54 \cos 2\varphi + 0.32 \cos 3\varphi + 0.14 \cos 4\varphi + 0.05 \cos 5\varphi + 0.27 \cos 6\varphi + 0.08 \sin\varphi + 0.10 \sin 2\varphi + 0.08 \sin 3\varphi + 0.01 \sin 4\varphi + 0.05 \sin 5\varphi$$

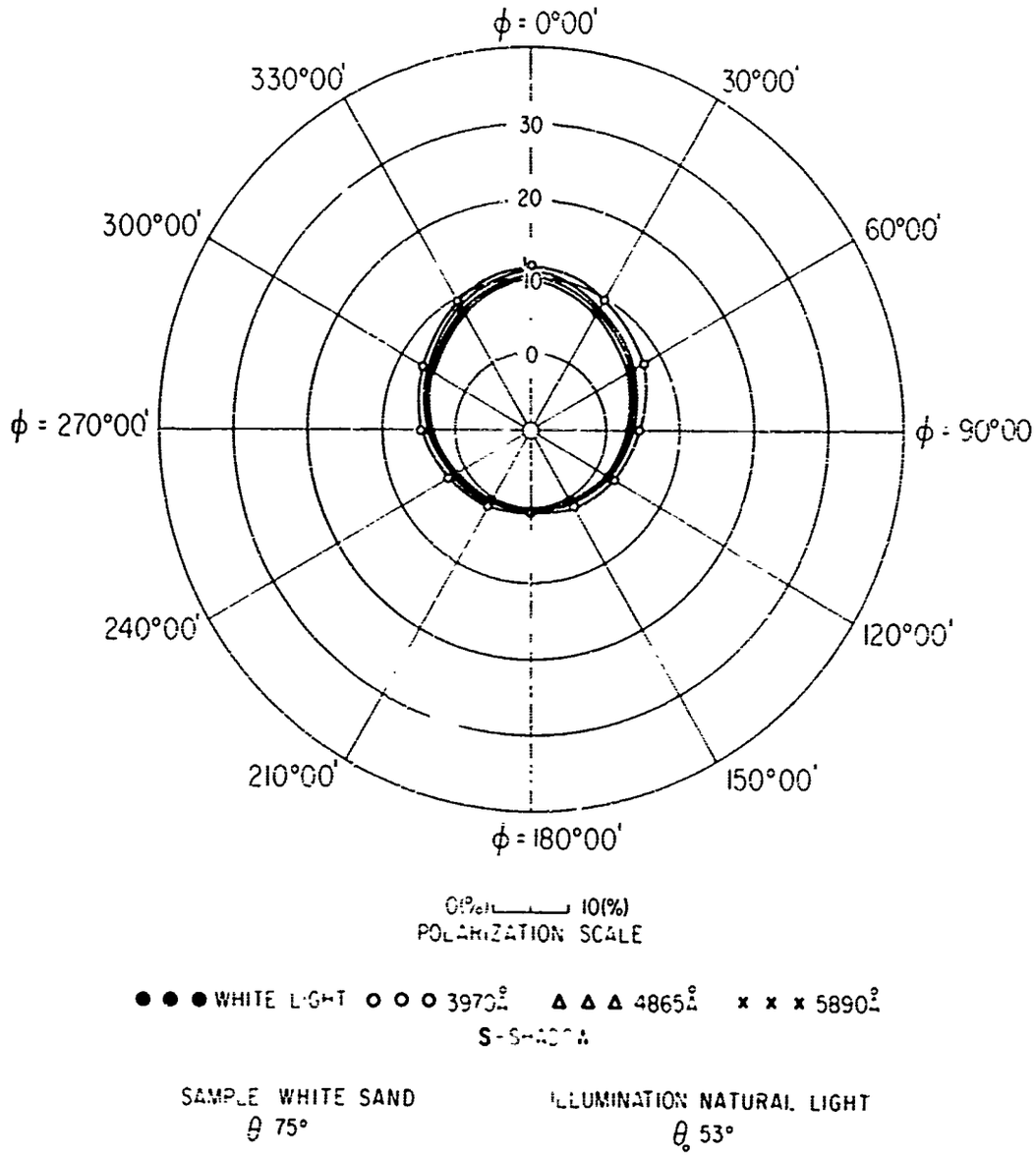


FIG 106 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.54 + 4.12 \cos\varphi + 0.73 \cos 2\varphi + 0.45 \cos 3\varphi + 0.08 \cos 4\varphi + 0.22 \cos 5\varphi + 0.08 \cos 6\varphi + 0.41 \sin\varphi + 0.12 \sin 2\varphi - 0.07 \sin 3\varphi + 0.03 \sin 4\varphi + 0.27 \sin 5\varphi$$

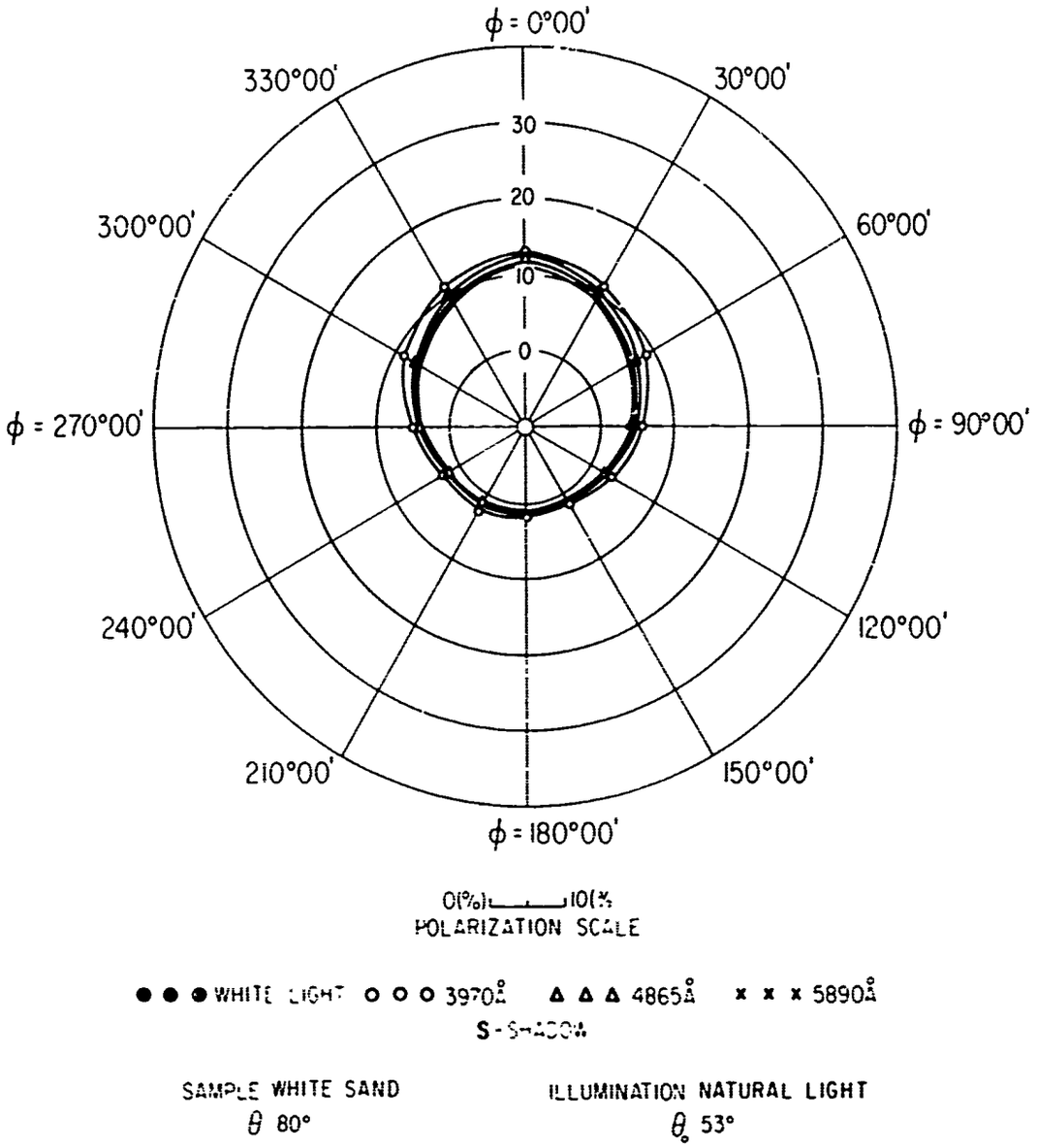


FIG 107 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.21 + 4.31 \cos\varphi + 0.95 \cos 2\varphi + 0.52 \cos 3\varphi + 0.22 \cos 4\varphi + 0.32 \cos 5\varphi + 0.35 \cos 6\varphi + 0.18 \sin\varphi + 0.00 \sin 2\varphi - 0.03 \sin 3\varphi - 0.06 \sin 4\varphi - 0.11 \sin 5\varphi$$

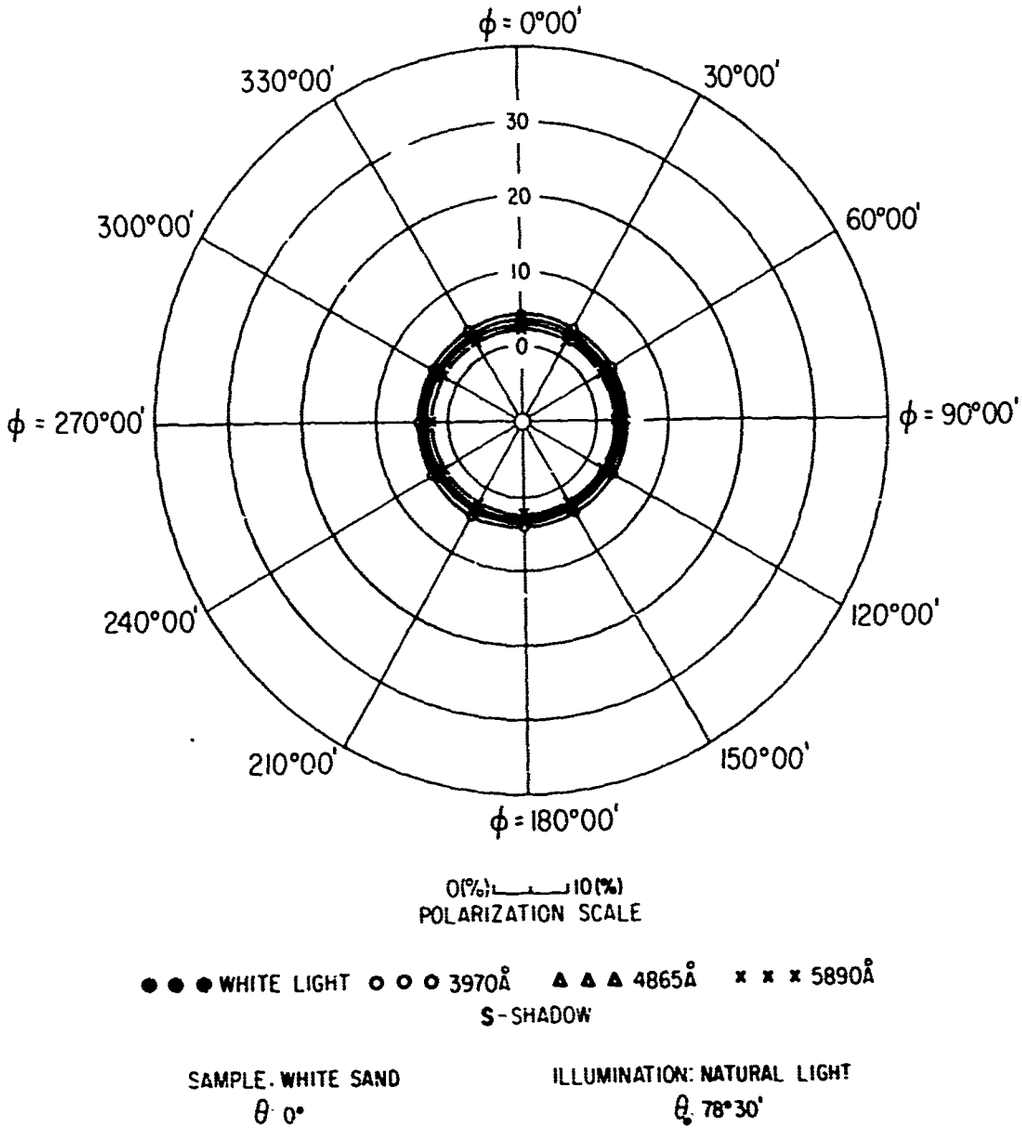


FIG 108 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

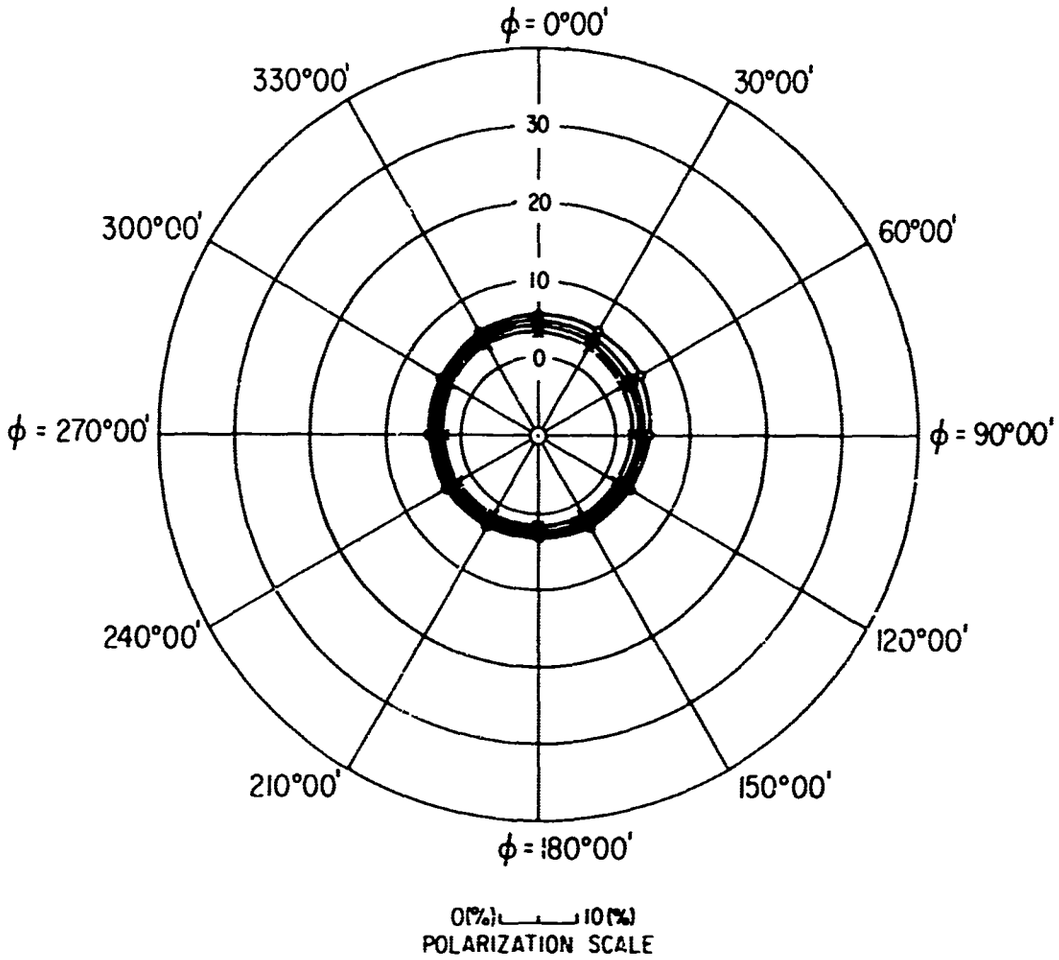
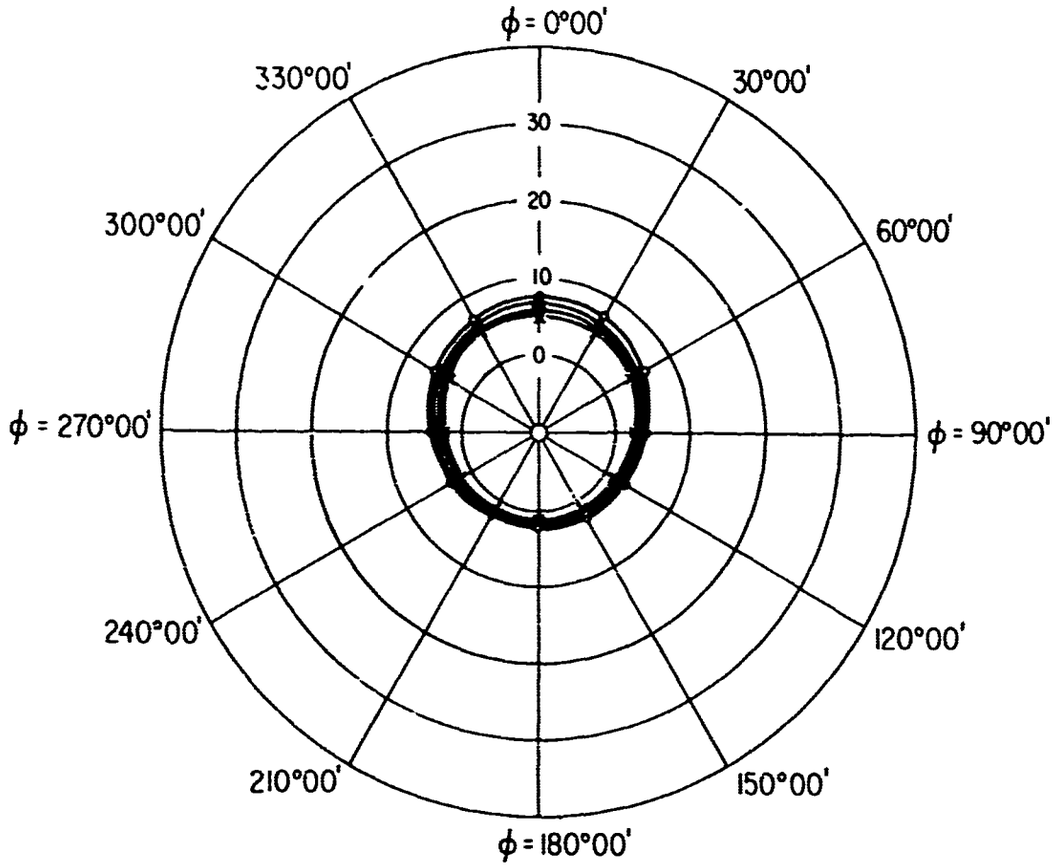


FIG 109 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.63 + 1.34 \cos\phi + 0.20 \cos 2\phi + 0.07 \cos 3\phi - 0.08 \cos 4\phi + 0.13 \cos 5\phi + 0.00 \cos 6\phi - 0.02 \sin\phi - 0.02 \sin 2\phi + 0.03 \sin 3\phi + 0.06 \sin 4\phi + 0.00 \sin 5\phi$$



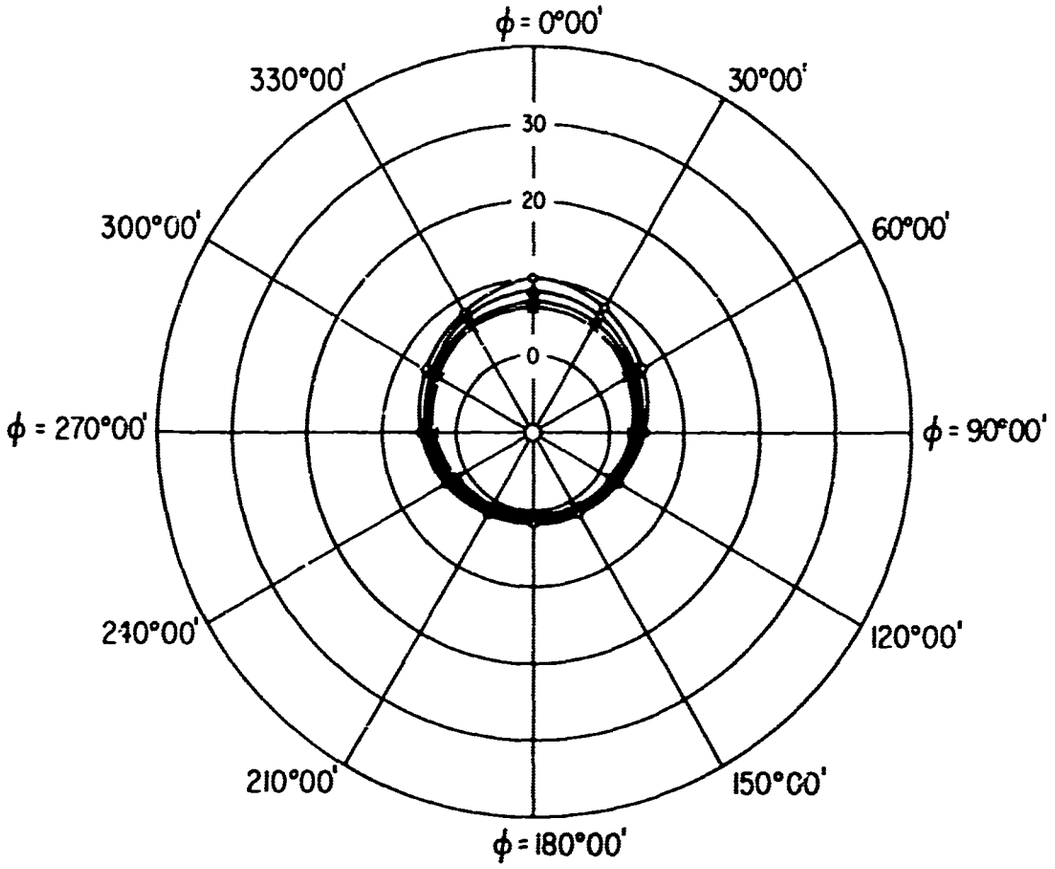
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 20°

ILLUMINATION: NATURAL LIGHT
θ_0 78°30'

FIG. 110 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.82 + 2.44 \cos\phi + 0.36 \cos 2\phi + 0.15 \cos 3\phi + 0.02 \cos 4\phi + 0.01 \cos 5\phi - 0.02 \cos 6\phi - 0.10 \sin\phi - 0.10 \sin 2\phi + 0.03 \sin 3\phi - 0.10 \sin 4\phi + 0.04 \sin 5\phi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT o o o 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 30°

ILLUMINATION: NATURAL LIGHT
θ_0 78°30'

FIG. III POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.17 + 3.66 \cos\phi + 0.46 \cos 2\phi + 0.23 \cos 3\phi + 0.11 \cos 4\phi + 0.11 \cos 5\phi + 0.13 \cos 6\phi - 0.02 \sin\phi + 0.10 \sin 2\phi - 0.03 \sin 3\phi + 0.07 \sin 4\phi - 0.07 \sin 5\phi$$

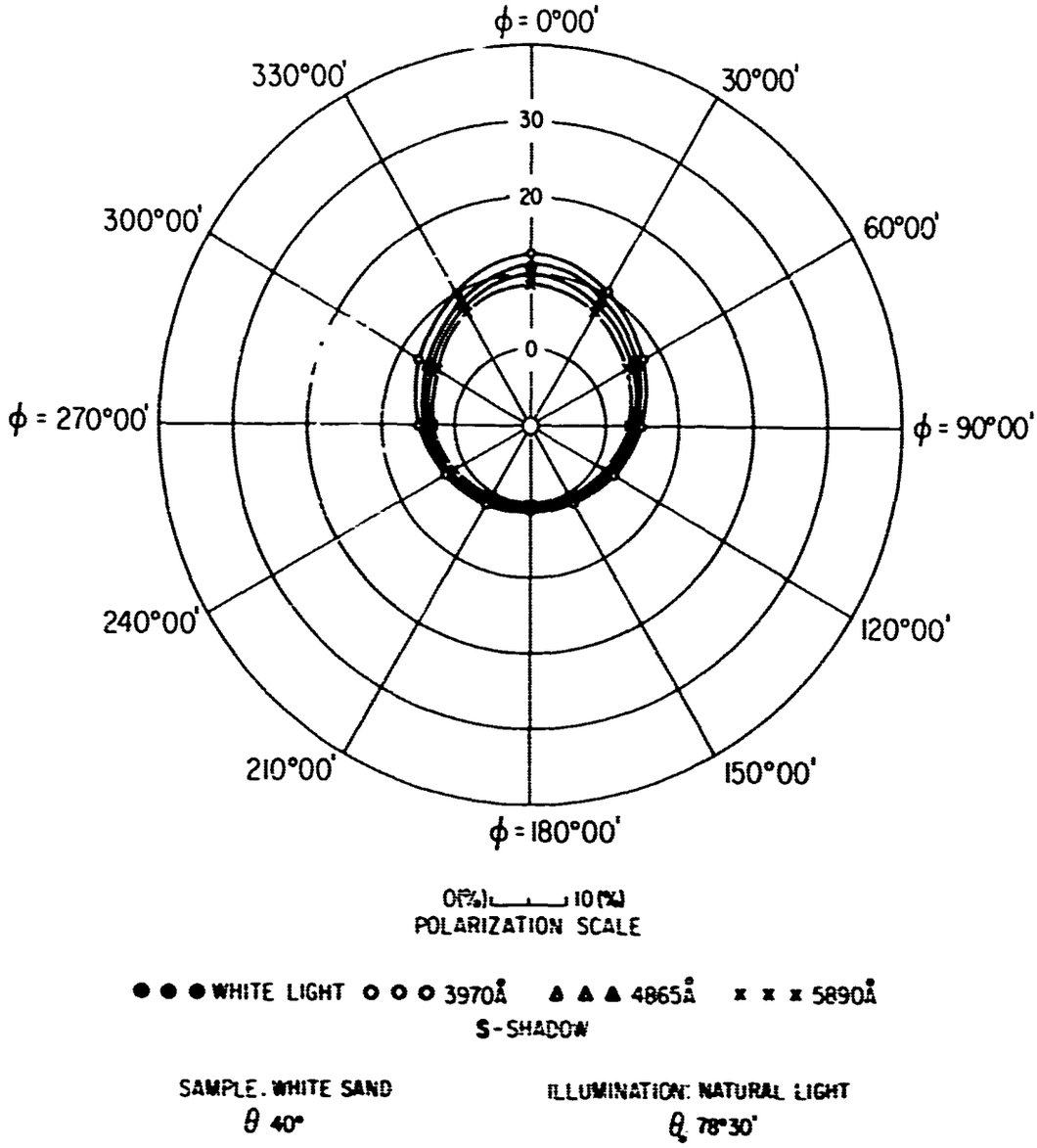


FIG 112 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.78 + 4.72 \cos\phi + 0.83 \cos 2\phi + 0.45 \cos 3\phi + 0.17 \cos 4\phi + 0.28 \cos 5\phi + 0.13 \cos 6\phi + 0.12 \sin\phi + 0.02 \sin 2\phi - 0.02 \sin 3\phi + 0.08 \sin 4\phi + 0.01 \sin 5\phi$$

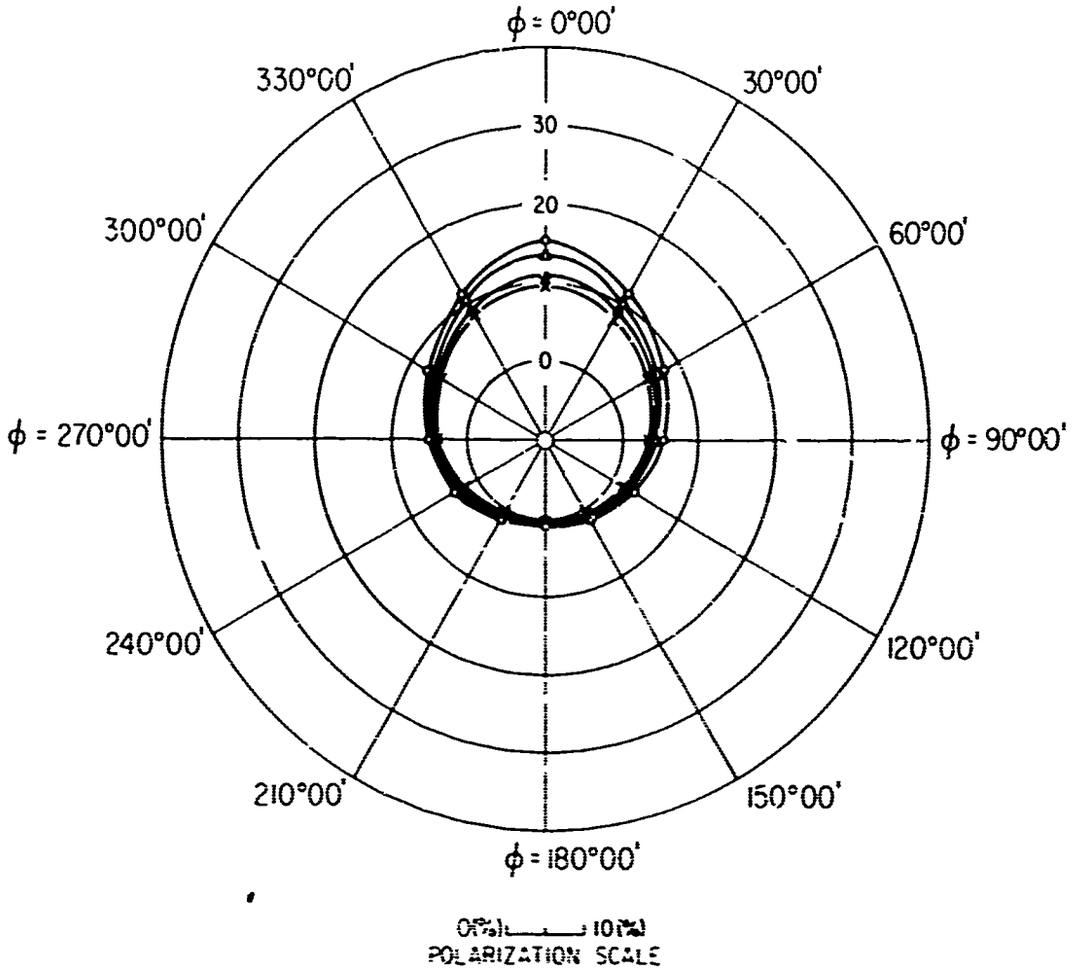
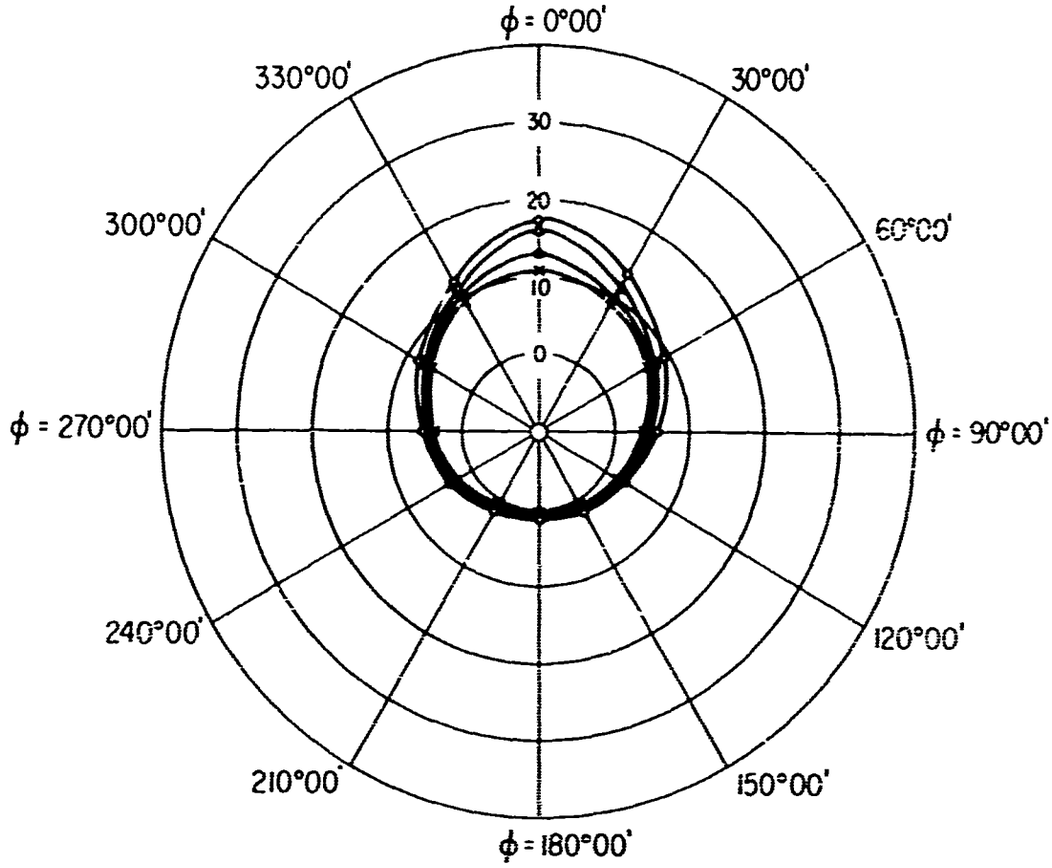


FIG 113 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 5.32 + 5.69 \cos\phi + 1.08 \cos 2\phi + 0.78 \cos 3\phi + 0.51 \cos 4\phi + 0.43 \cos 5\phi + 0.20 \cos 6\phi + 0.02 \sin\phi - 0.01 \sin 2\phi - 0.05 \sin 3\phi + 0.02 \sin 4\phi - 0.02 \sin 5\phi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 60°

ILLUMINATION NATURAL LIGHT
θ_0 78° 30'

FIG 114 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 5.75 + 6.32 \cos\phi + 1.68 \cos 2\phi + 1.13 \cos 3\phi + 0.68 \cos 4\phi + 0.49 \cos 5\phi + 0.30 \cos 6\phi - 0.04 \sin\phi - 0.24 \sin 2\phi + 0.03 \sin 3\phi + 0.13 \sin 4\phi + 0.28 \sin 5\phi$$

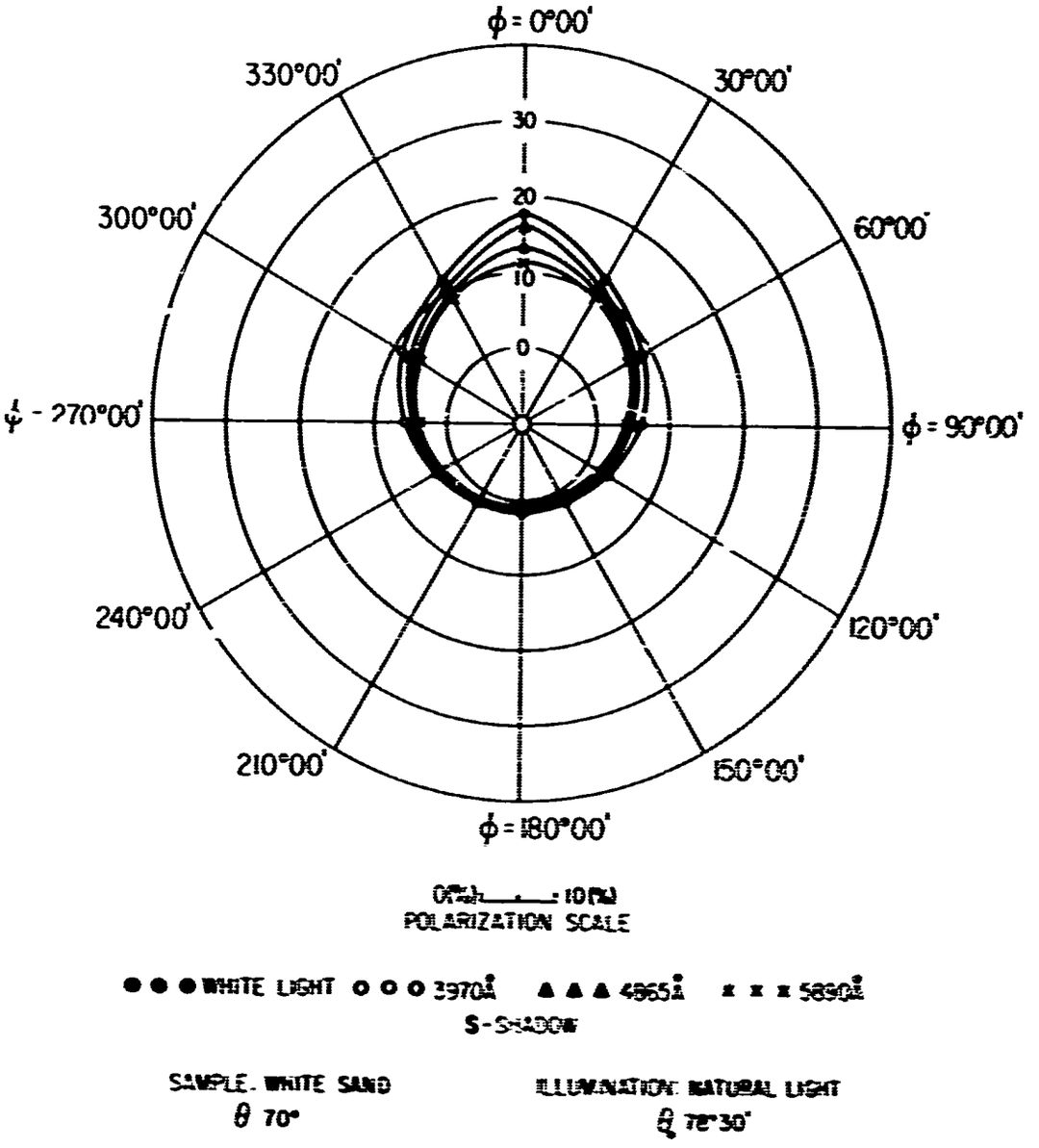
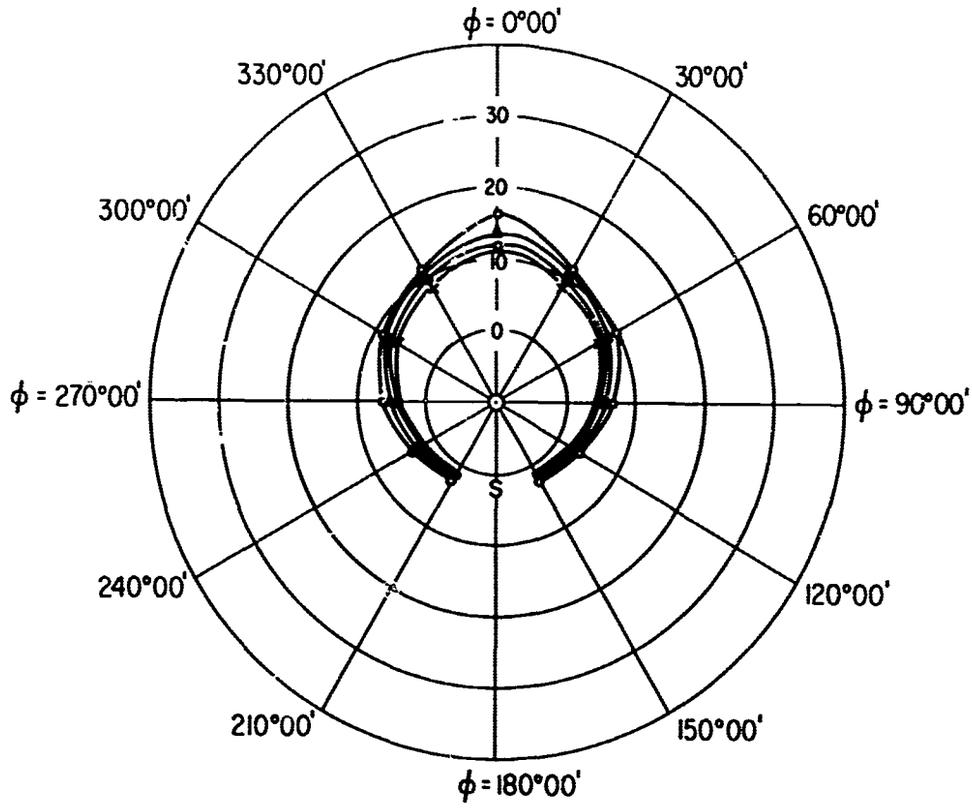


FIG 115 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.66 + 6.06 \cos\varphi + 1.80 \cos 2\varphi + 0.95 \cos 3\varphi + 0.42 \cos 4\varphi + 0.89 \cos 5\varphi + 1.45 \cos 6\varphi + 0.48 \sin\varphi - 0.06 \sin 2\varphi - 0.33 \sin 3\varphi - 0.20 \sin 4\varphi + 0.04 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 75°

ILLUMINATION: NATURAL LIGHT
θ_0: 78° 30'

FIG. 116 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.47 + 6.12 \cos\varphi + 1.24 \cos 2\varphi + 1.12 \cos 3\varphi + 0.56 \cos 4\varphi + 0.72 \cos 5\varphi + 1.38 \cos 6\varphi - 0.22 \sin\varphi + 0.42 \sin 2\varphi - 0.18 \sin 3\varphi - 0.22 \sin 4\varphi + 0.24 \sin 5\varphi$$

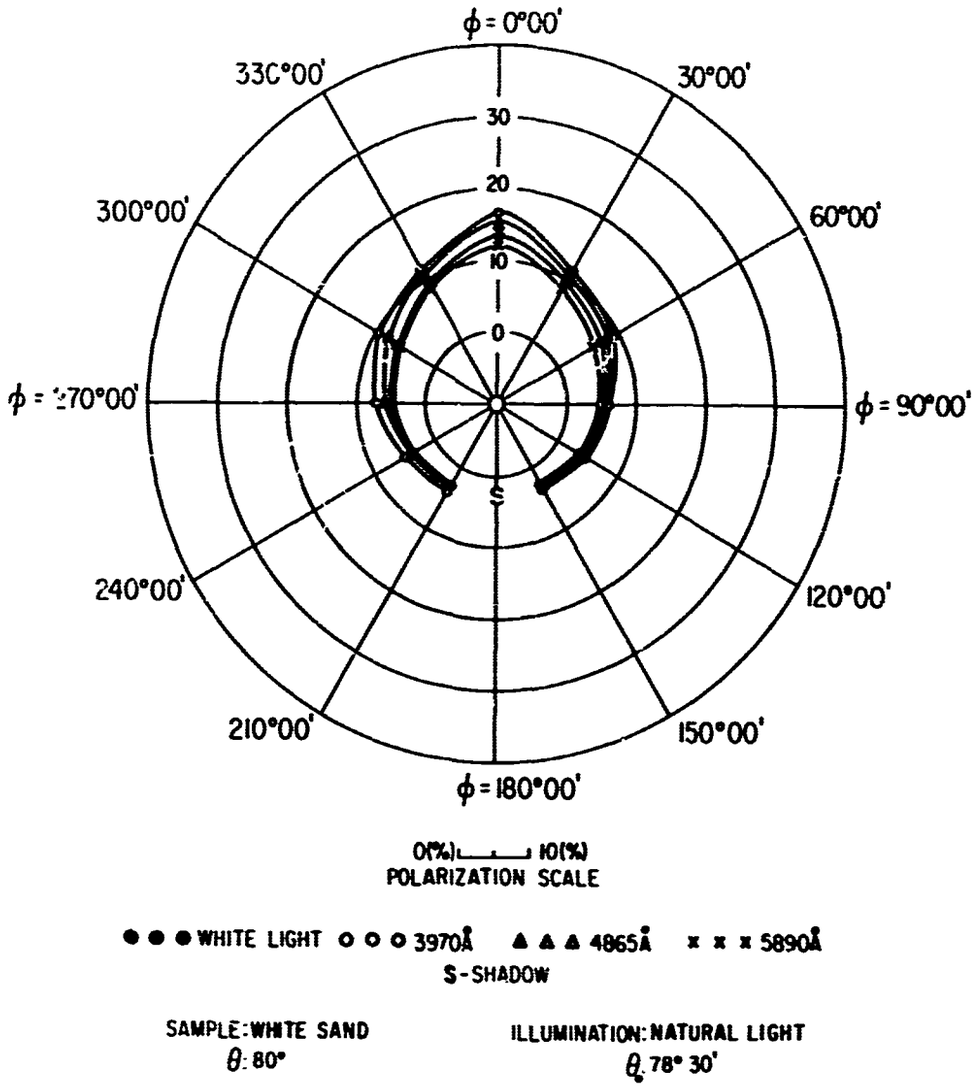


FIG. 117 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.47 + 4.97\cos\varphi + 2.02\cos 2\varphi + 0.85\cos 3\varphi + 1.01\cos 4\varphi + 1.13\cos 5\varphi + 0.90\cos 6\varphi - 1.26\sin\varphi - 0.96\sin 2\varphi - 0.05\sin 3\varphi + 0.19\sin 4\varphi + 0.01\sin 5\varphi$$

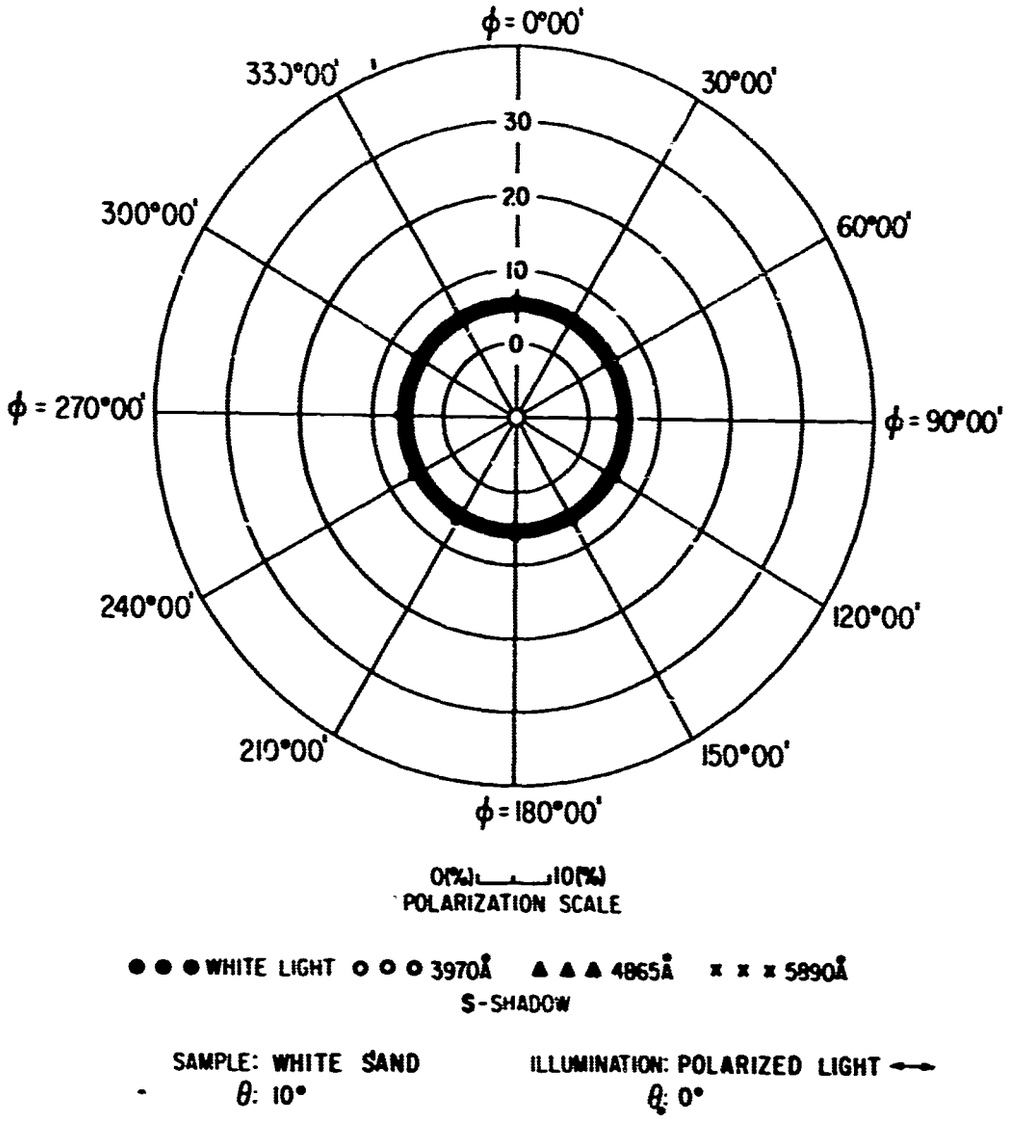
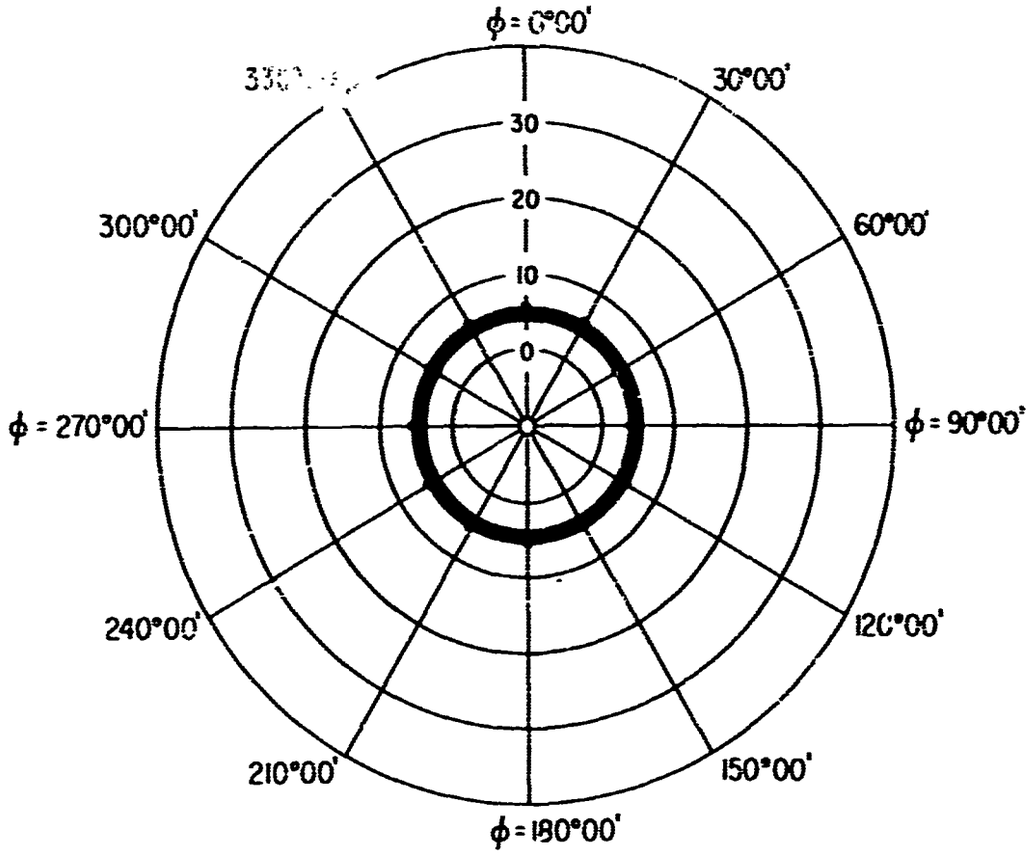


FIG 118. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.08 + 0.02\cos\varphi + 0.11\cos 2\varphi + 0.03\cos 3\varphi - 0.01\cos 4\varphi + 0.05\cos 5\varphi + 0.03\cos 6\varphi - 0.10\sin\varphi - 0.16\sin 2\varphi - 0.03\sin 3\varphi + 0.02\sin 4\varphi + 0.02\sin 5\varphi$$

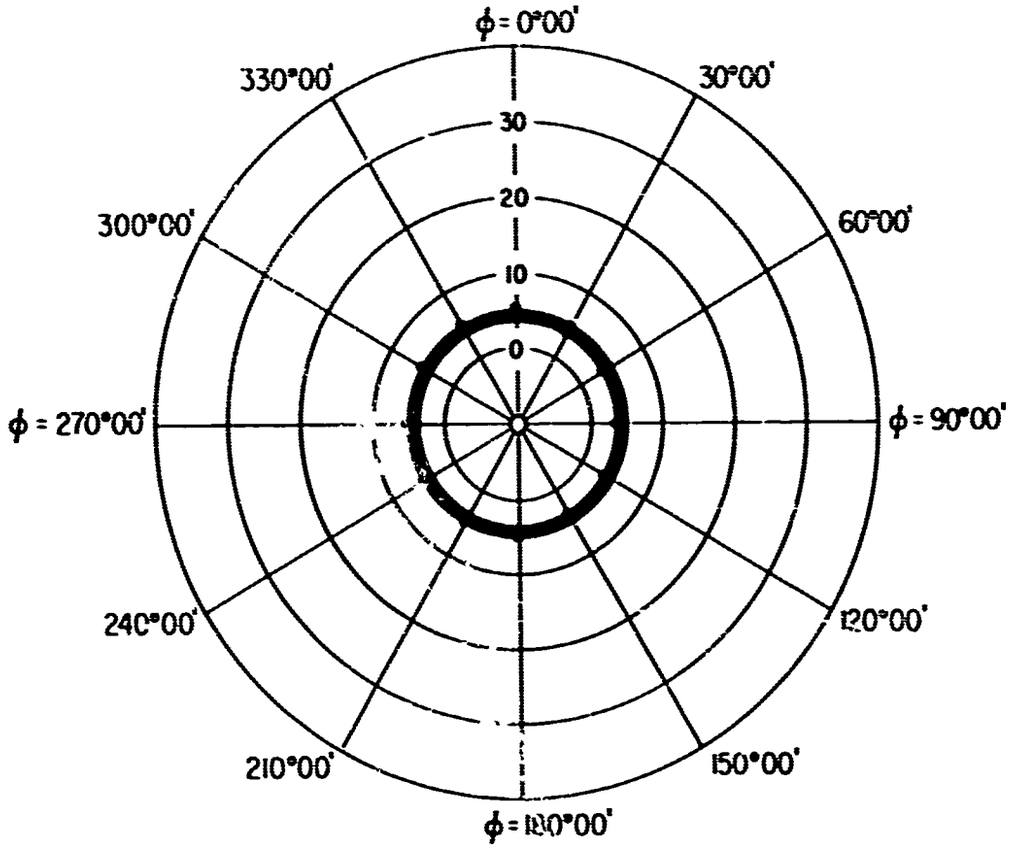


SAMPLE: WHITE SAND
θ: 20°

ILLUMINATION: POLARIZED LIGHT ←→
θ_i: 0°

FIG 119. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.50 + 0.11\cos\varphi + 0.19\cos 2\varphi + 0.07\cos 3\varphi + 0.08\cos 4\varphi + 0.02\cos 5\varphi - 0.13\cos 6\varphi - 0.04\sin\varphi - 0.07\sin 2\varphi - 0.03\sin 3\varphi - 0.07\sin 4\varphi - 0.04\sin 5\varphi$$



0(%) 50(%)
POLARIZATION SCALE

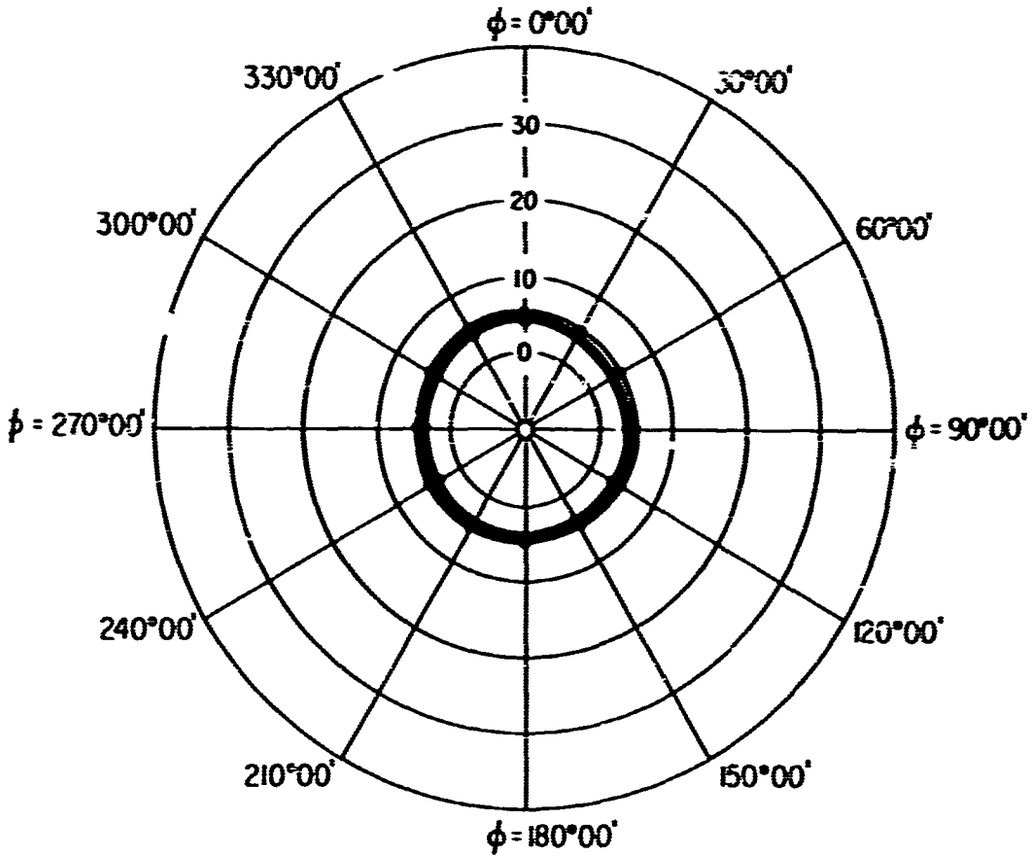
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 30°

ILLUMINATION: POLARIZED LIGHT ⟷
θ_0 0°

FIG 120. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.15 + 0.08 \cos\varphi + 0.34 \cos 2\varphi - 0.05 \cos 3\varphi + 0.08 \cos 4\varphi + 0.08 \cos 5\varphi + 0.07 \cos 6\varphi - 0.20 \sin\varphi - 0.10 \sin 2\varphi - 0.08 \sin 3\varphi + 0.10 \sin 4\varphi + 0.06 \sin 5\varphi$$



0(%) ... 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ: 40°

ILLUMINATION: POLARIZED LIGHT ⟶
θ_0 0°

FIG 121. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.87 + 0.08\cos\varphi + 0.52\cos 2\varphi - 0.03\cos 3\varphi + 0.26\cos 4\varphi + 0.05\cos 5\varphi + 0.00\cos 6\varphi - 0.06\sin\varphi - 0.13\sin 2\varphi + 0.03\sin 3\varphi - 0.13\sin 4\varphi - 0.06\sin 5\varphi$$

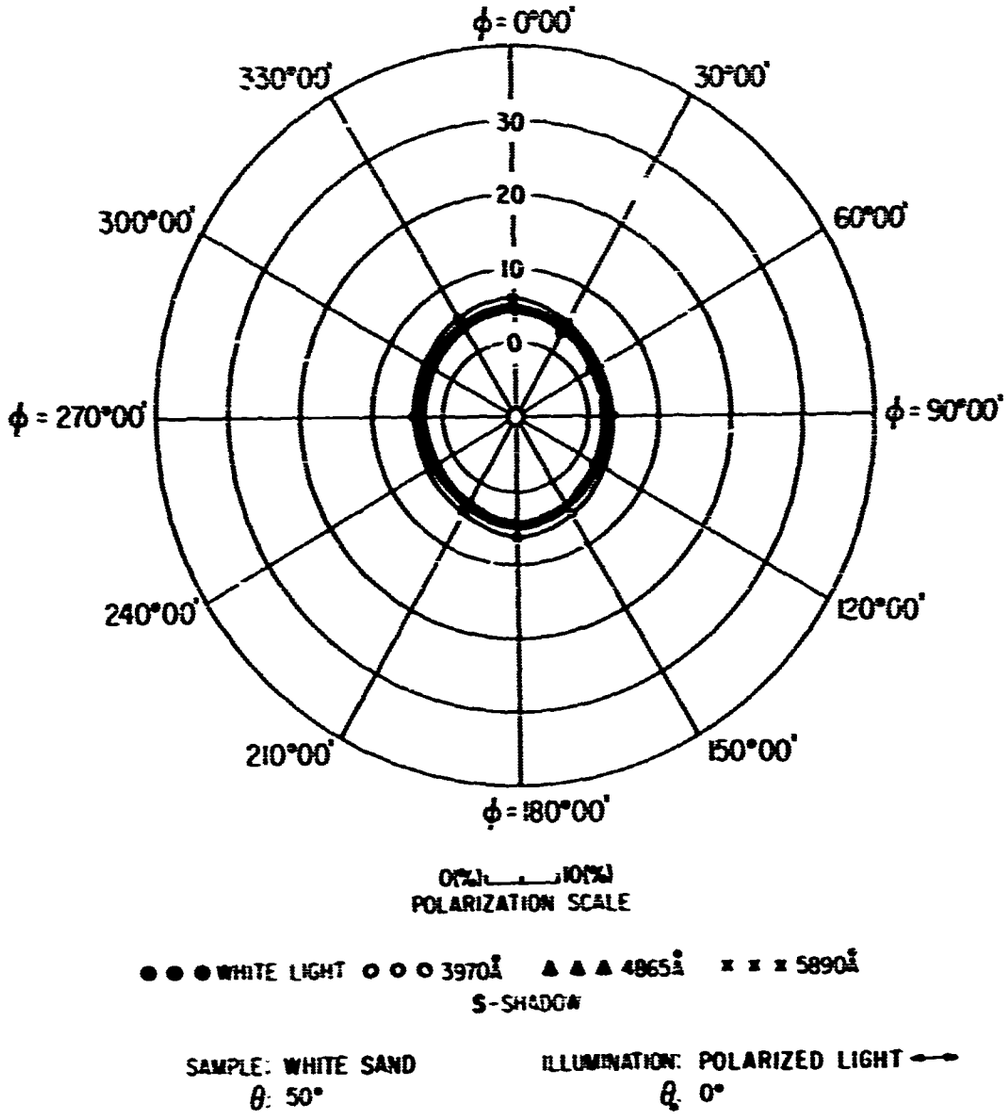


FIG 122. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.72 - 0.03\cos\phi + 0.78\cos 2\phi + 0.07\cos 3\phi + 0.18\cos 4\phi - 0.09\cos 5\phi - 0.05\cos 6\phi - 0.06\sin\phi - 0.10\sin 2\phi - 0.02\sin 3\phi - 0.13\sin 4\phi - 0.01\sin 5\phi$$

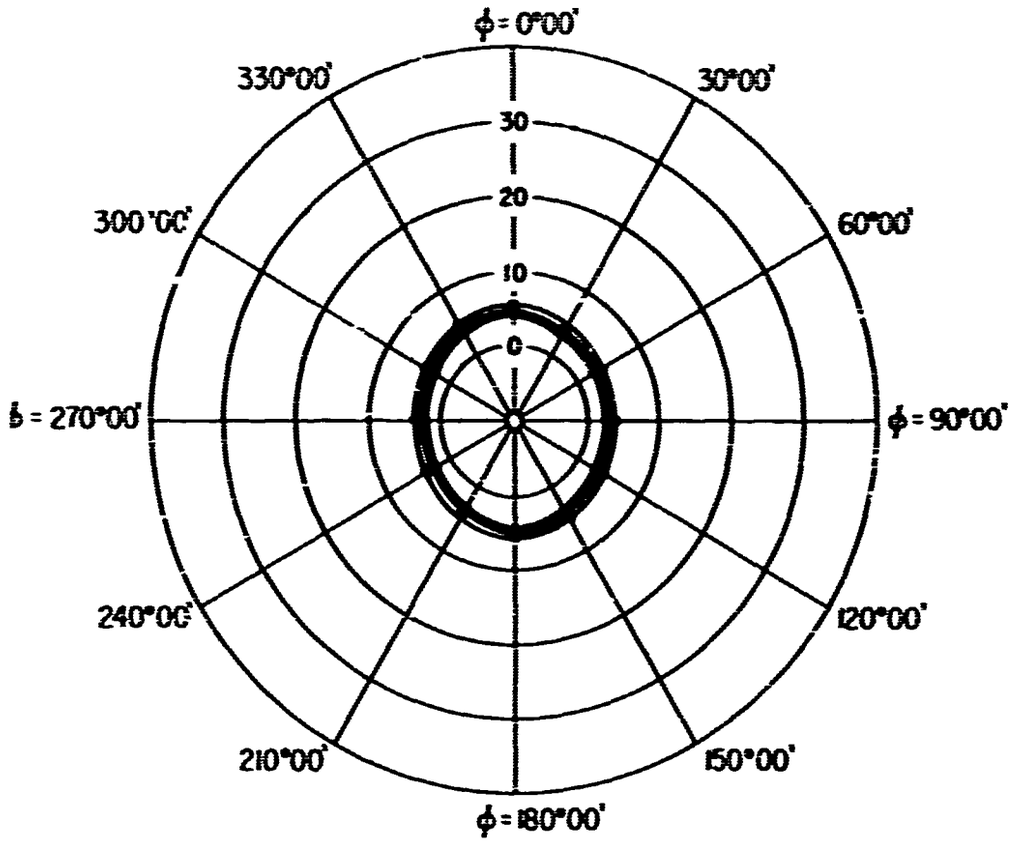


FIG 123. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.65 - 0.07\cos\varphi + 0.92\cos 2\varphi - 0.05\cos 3\varphi + 0.58\cos 4\varphi + 0.07\cos 5\varphi$$
$$- 0.00\cos 6\varphi - 0.02\sin\varphi - 0.30\sin 2\varphi - 0.08\sin 3\varphi - 0.19\sin 4\varphi + 0.04\sin 5\varphi$$

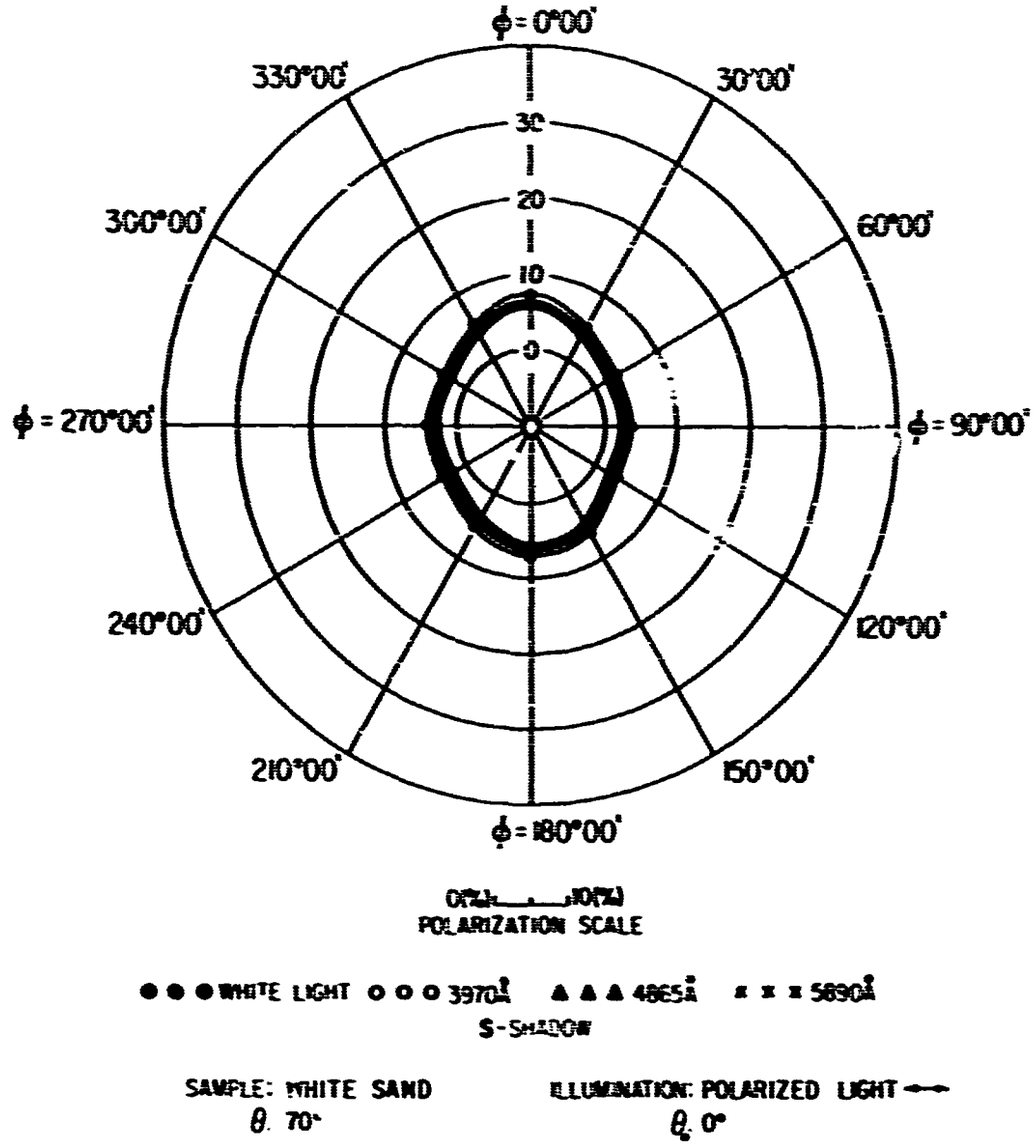
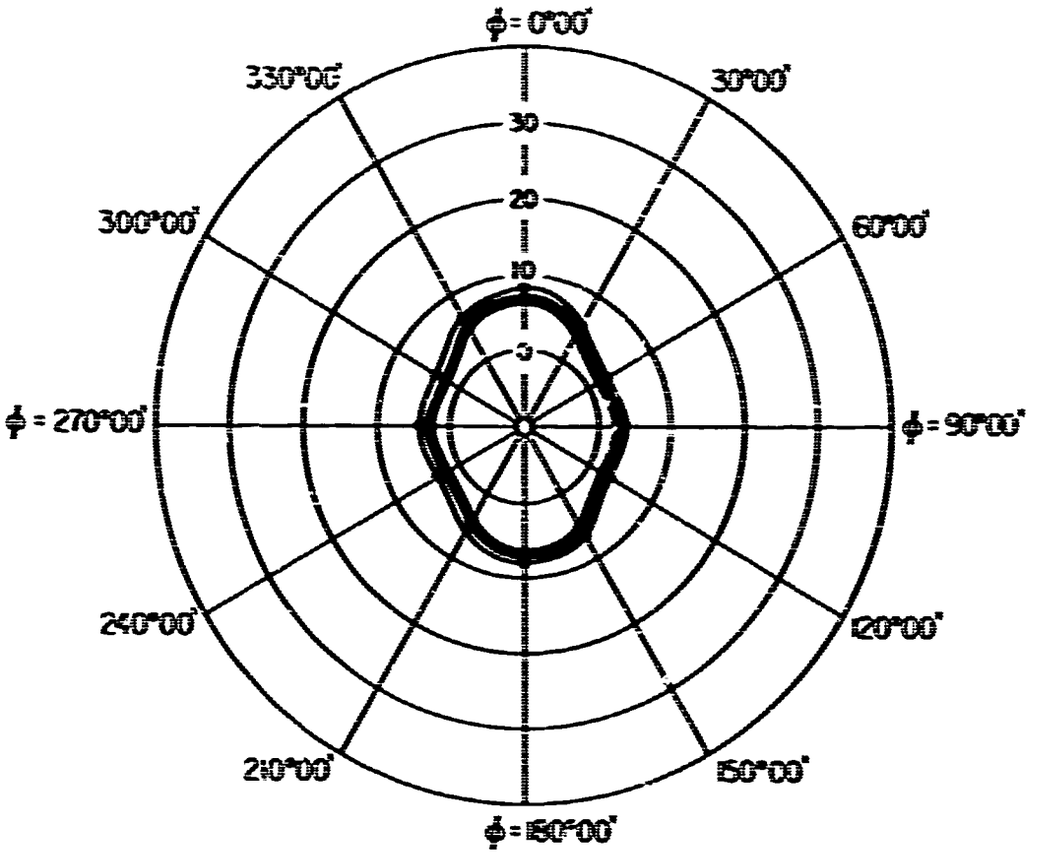


FIG 124. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.97 - 0.01 \cos\varphi + 1.16 \cos 2\varphi + 0.13 \cos 3\varphi + 0.81 \cos 4\varphi + 0.08 \cos 5\varphi - 0.13 \cos 6\varphi + 0.25 \sin\varphi - 0.33 \sin 2\varphi - 0.17 \sin 3\varphi - 0.27 \sin 4\varphi + 0.14 \sin 5\varphi$$



POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3570Å ▲ ▲ ▲ 4865Å × × × 5890Å

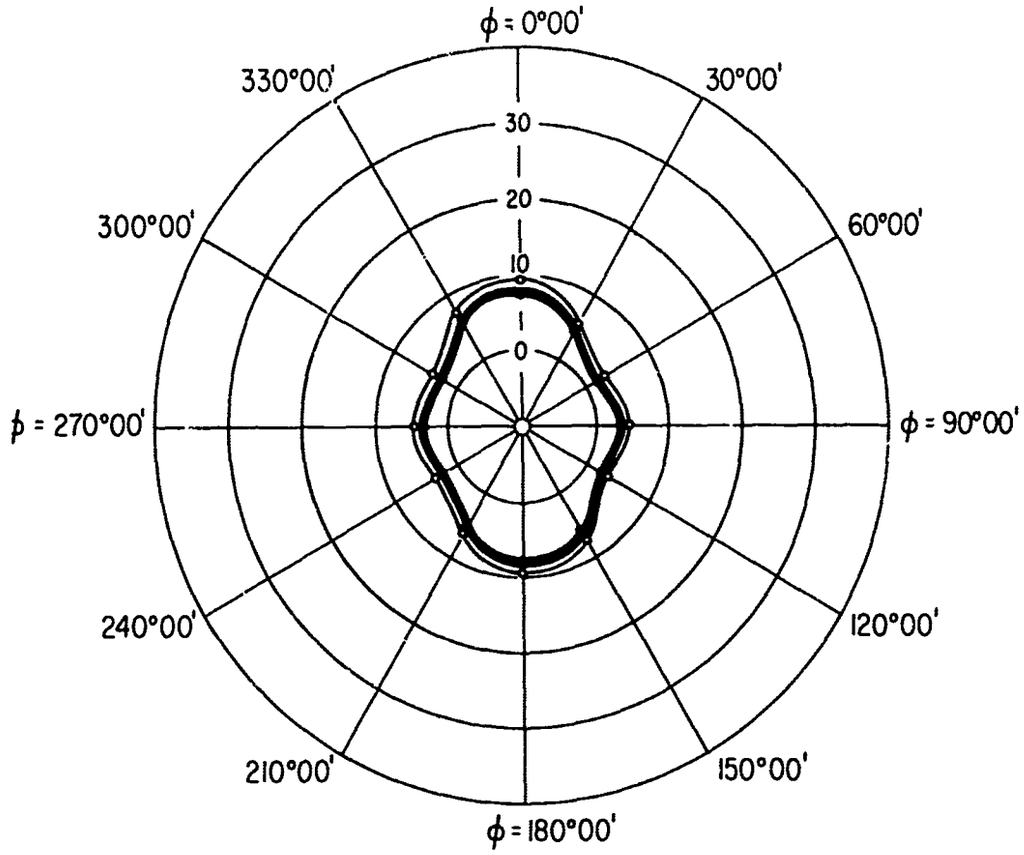
S-SILICON

SAMPLE: WHITE SAND
θ 75°

ILLUMINATION: POLARIZED LIGHT ←→
θ_i 0°

FIG 125. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.22 + 0.00 \cos\phi + 1.52 \cos 2\phi - 0.15 \cos 3\phi + 0.95 \cos 4\phi + 0.00 \cos 5\phi - 0.48 \cos 6\phi + 0.14 \sin\phi - 0.37 \sin 2\phi - 0.10 \sin 3\phi - 0.32 \sin 4\phi - 0.04 \sin 5\phi$$



0(%) 10(%
POLARIZATION SCALE

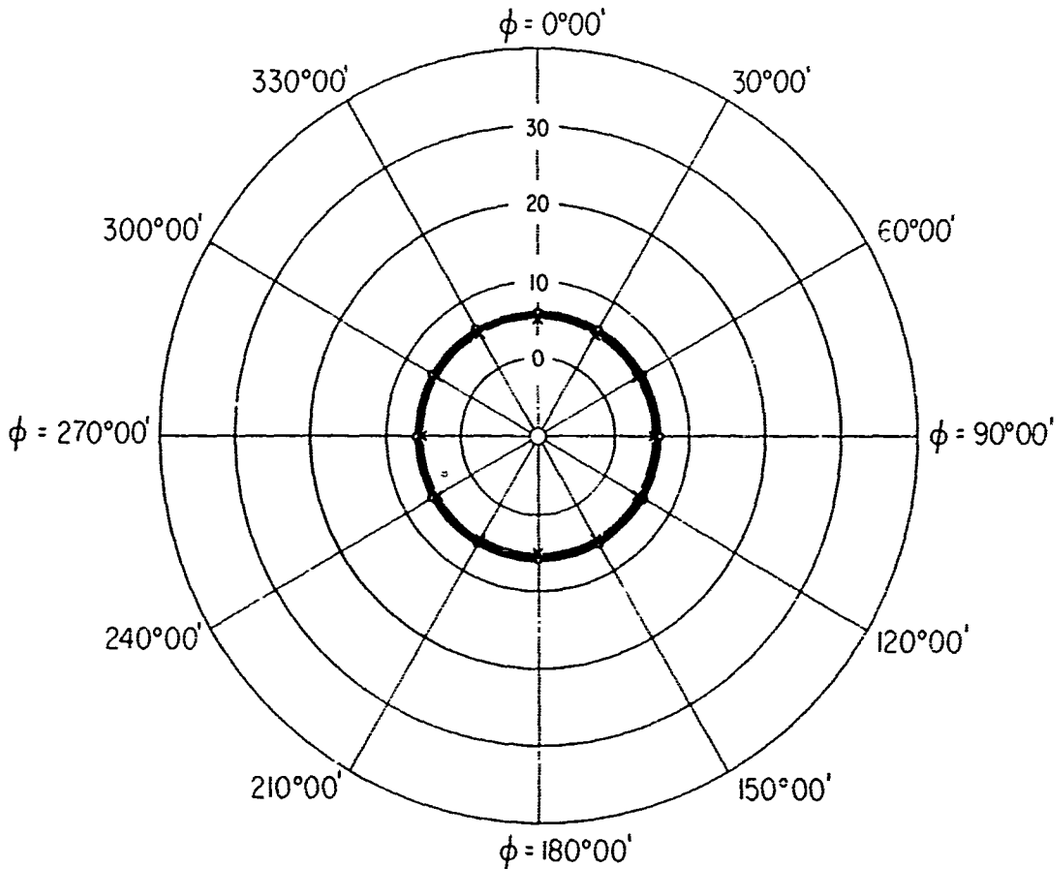
● ● ● WHITE LIGHT o o o 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 80°

ILLUMINATION: POLARIZED LIGHT ←→
θ_0: 0°

FIG 126. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.78 - 0.05\cos\varphi + 1.69\cos 2\varphi - 0.13\cos 3\varphi + 1.02\cos 4\varphi - 0.15\cos 5\varphi - 0.28\cos 6\varphi + 0.22\sin\varphi - 0.36\sin 2\varphi - 0.22\sin 3\varphi - 0.51\sin 4\varphi + 0.02\sin 5\varphi$$



0(%) 10 %
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4865Å × × × 5890Å
S - SHADOW

SAMPLE WHITE SAND
θ 0°

ILLUMINATION. POLARIZED LIGHT ↔
θ_0 53°

FIG 127 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

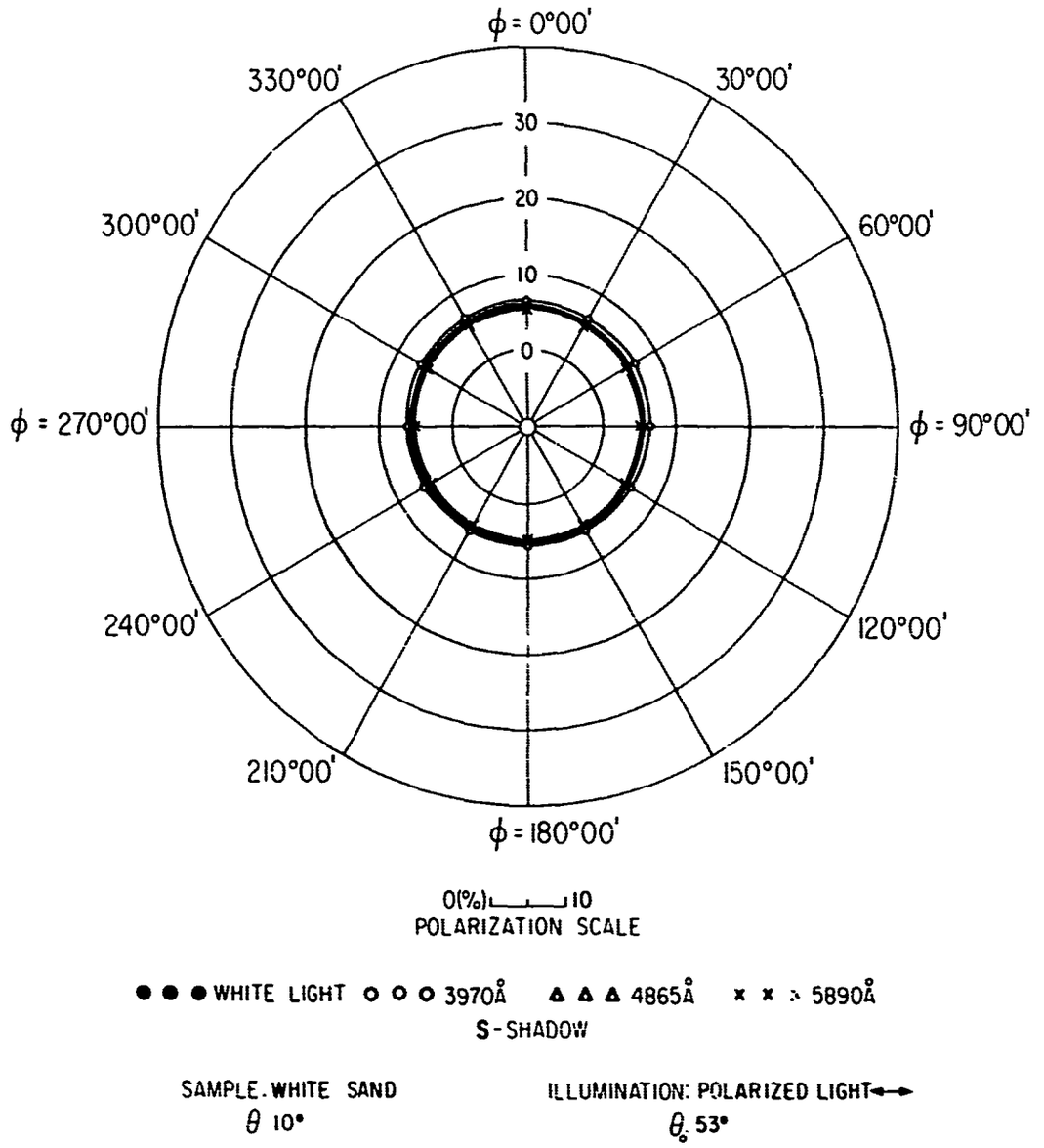


FIG 128 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.62 - 0.12\cos\varphi + 0.25\cos 2\varphi - 0.05\cos 3\varphi + 0.05\cos 4\varphi + 0.03\cos 5\varphi$$
$$- 0.05\cos 6\varphi + 0.01\sin\varphi + 0.09\sin 2\varphi - 0.03\sin 3\varphi - 0.03\sin 4\varphi - 0.04\sin 5\varphi$$

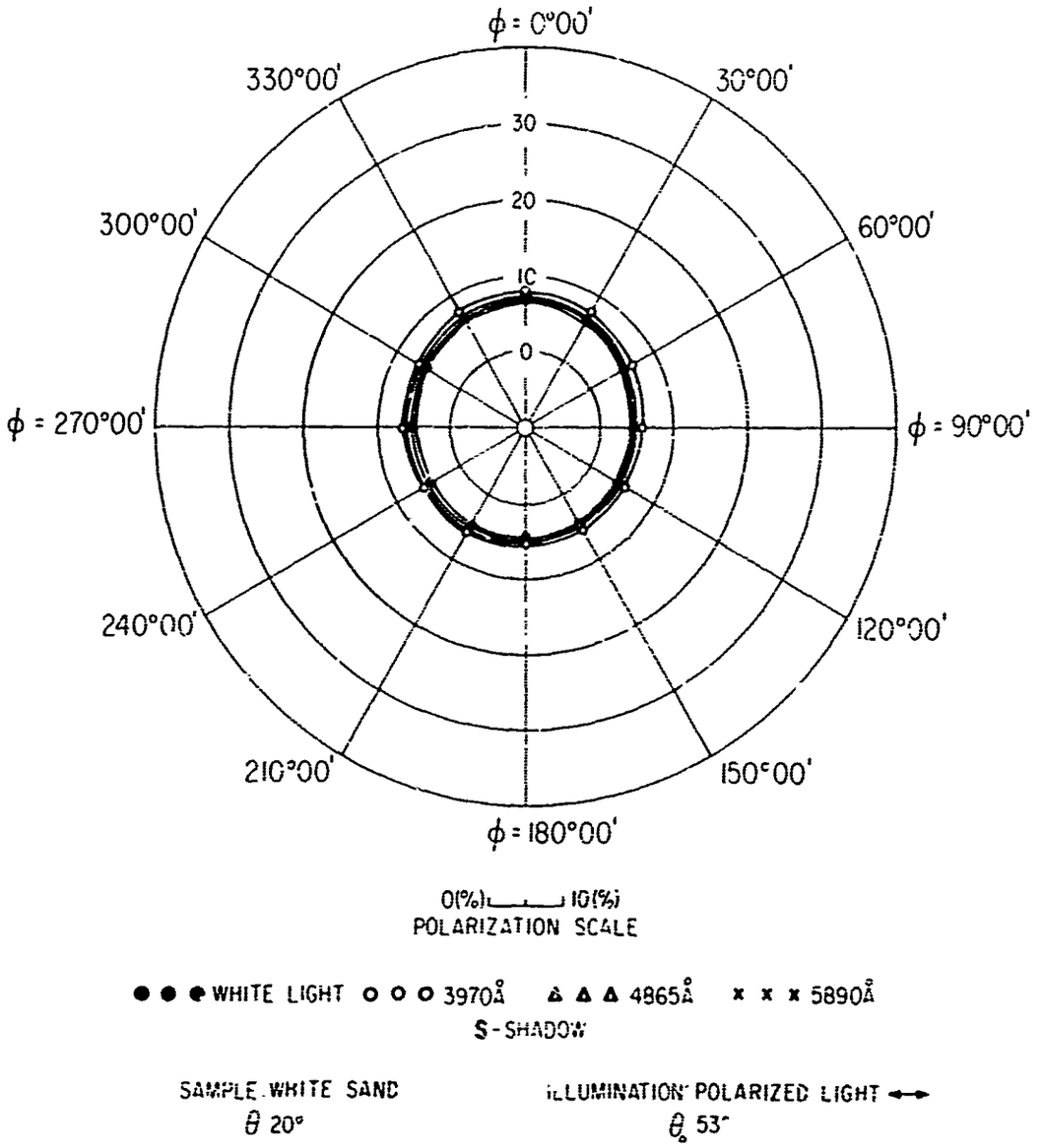


FIG 129 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.51 + 1.08 \cos\varphi + 0.70 \cos 2\varphi + 0.02 \cos 3\varphi + 0.02 \cos 4\varphi + 0.01 \cos 5\varphi - 0.05 \cos 6\varphi - 0.08 \sin\varphi - 0.03 \sin 2\varphi + 0.03 \sin 3\varphi - 0.12 \sin 4\varphi + 0.06 \sin 5\varphi$$

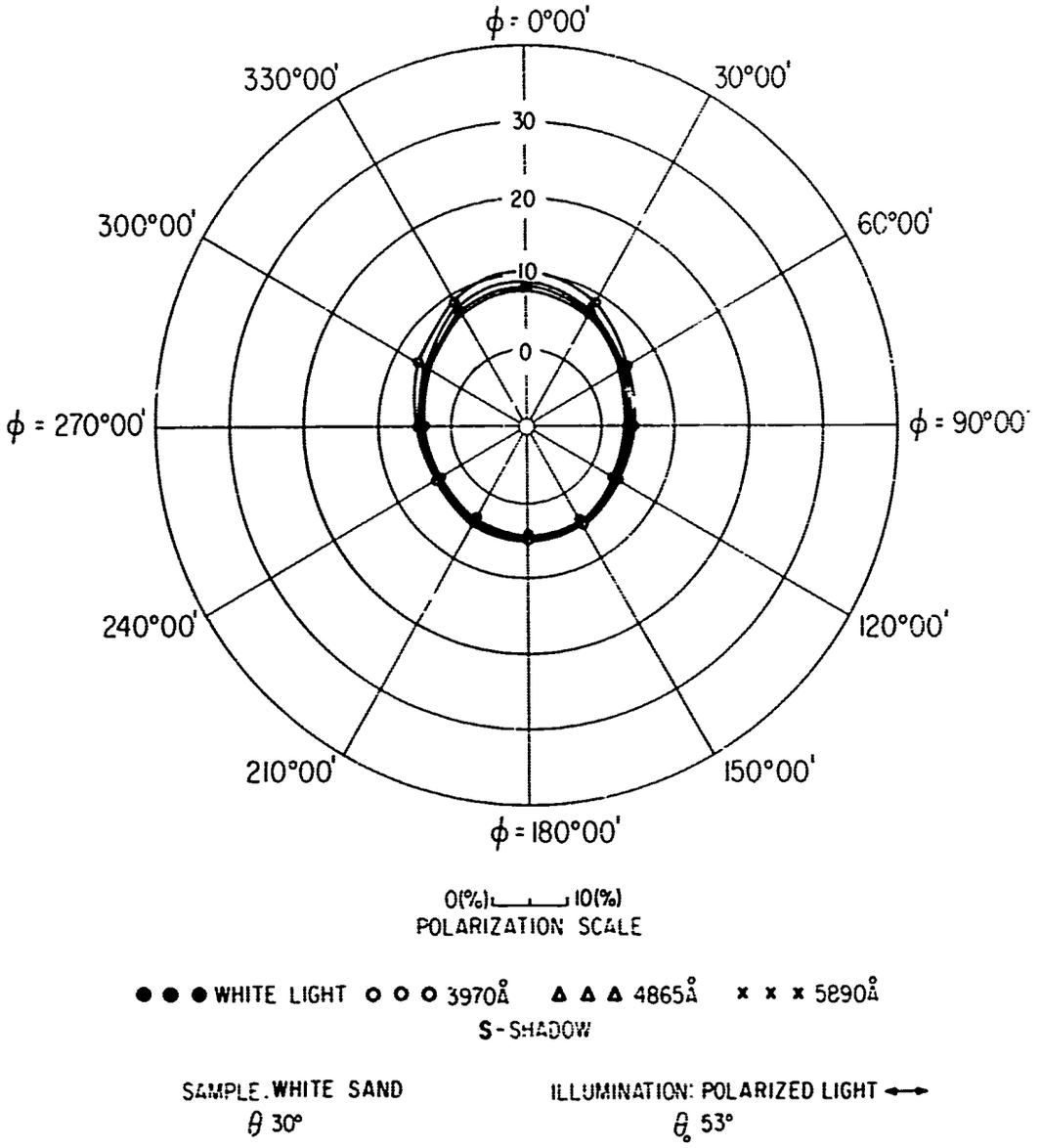


FIG 130 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.50 + 1.57 \cos\varphi + 1.36 \cos 2\varphi + 0.08 \cos 3\varphi - 0.03 \cos 4\varphi + 0.10 \cos 5\varphi + 0.03 \cos 6\varphi - 0.14 \sin\varphi - 0.04 \sin 2\varphi + 0.08 \sin 3\varphi + 0.01 \sin 4\varphi - 0.08 \sin 5\varphi$$

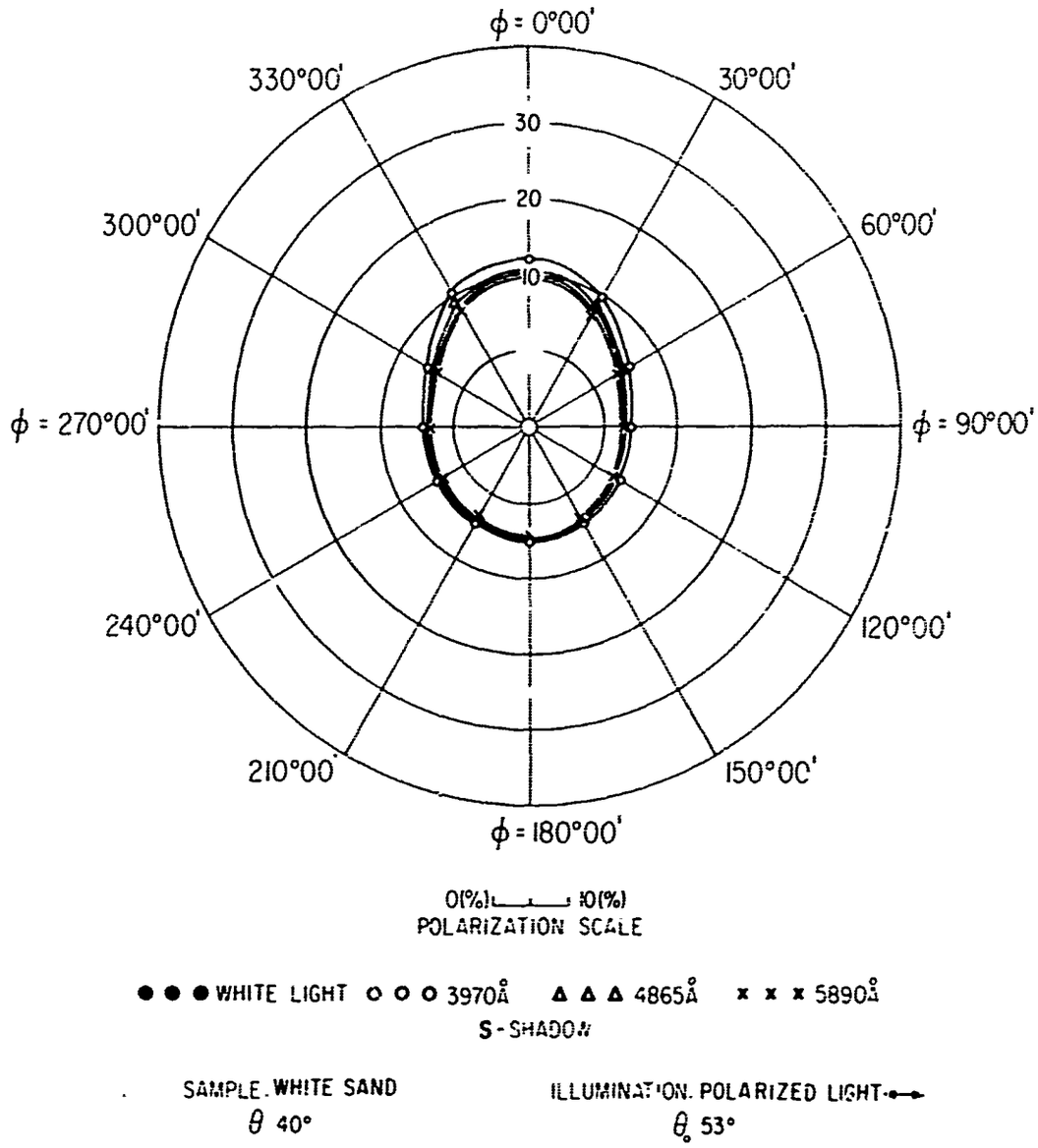


FIG 131 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.52 + 2.06 \cos\varphi + 2.23 \cos 2\varphi + 0.43 \cos 3\varphi + 0.05 \cos 4\varphi - 0.04 \cos 5\varphi + 0.08 \cos 6\varphi - 0.22 \sin\varphi + 0.06 \sin 2\varphi - 0.08 \sin 3\varphi + 0.03 \sin 4\varphi + 0.04 \sin 5\varphi$$

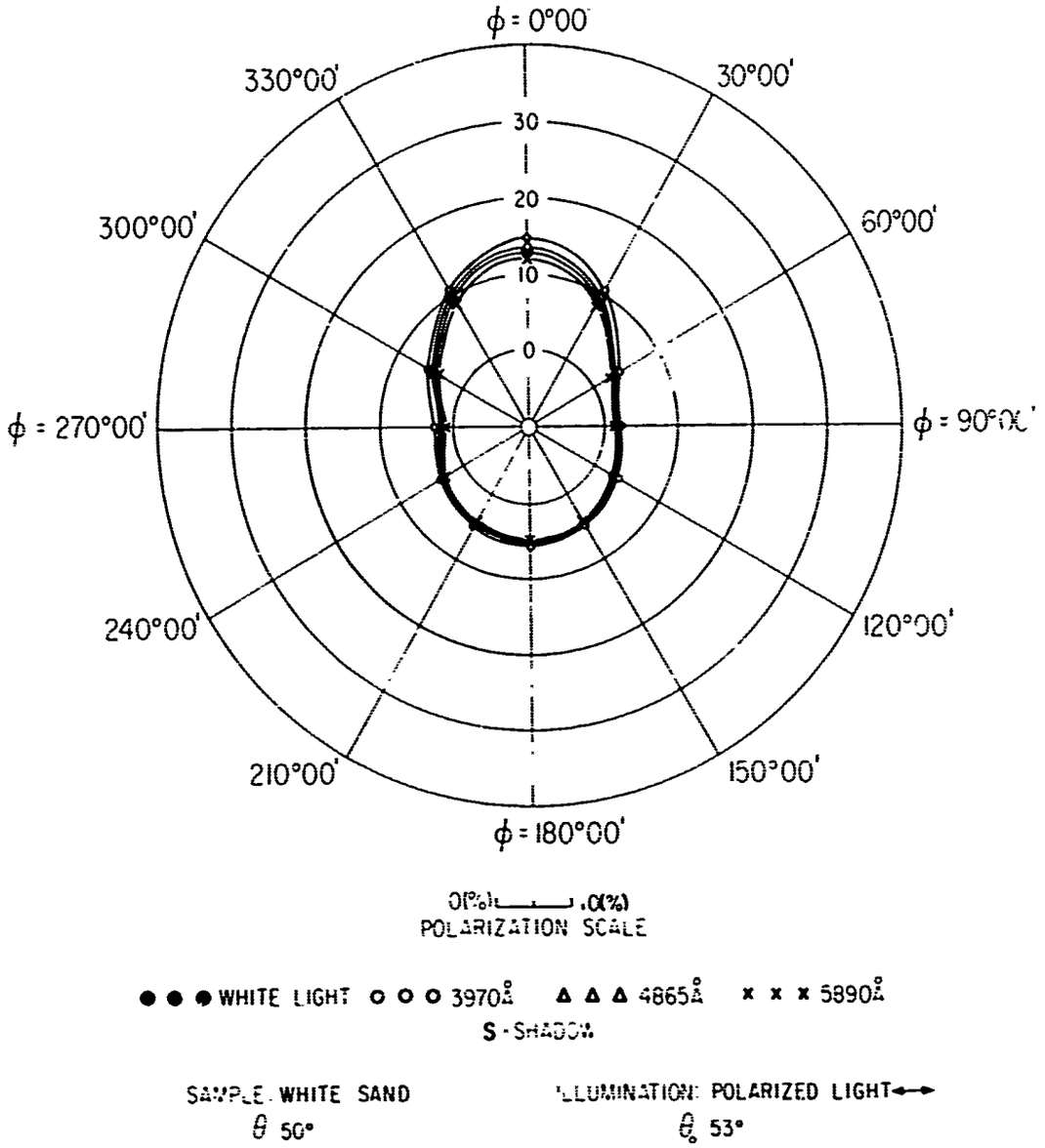
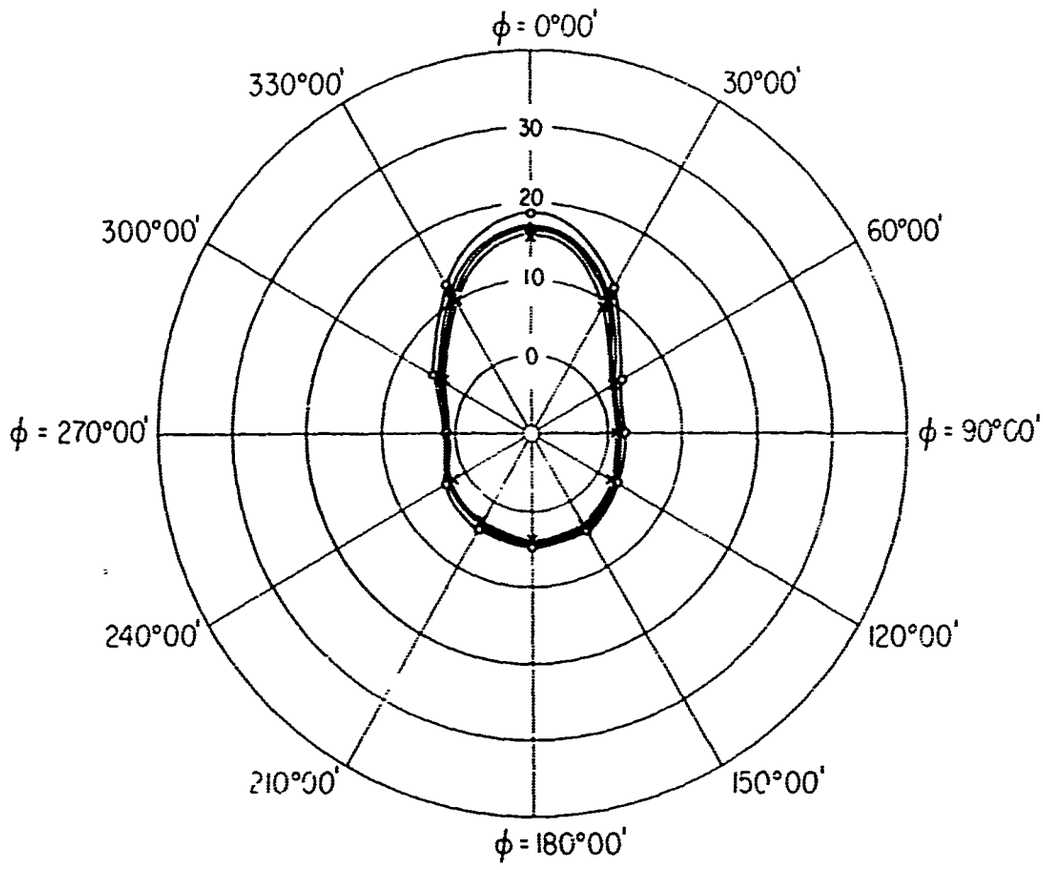


FIG 132 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.56 + 2.71 \cos\varphi + 3.19 \cos 2\varphi + 1.00 \cos 3\varphi + 0.09 \cos 4\varphi - 0.04 \cos 5\varphi + 0.01 \cos 6\varphi - 0.27 \sin\varphi - 0.07 \sin 2\varphi + 0.08 \sin 3\varphi + 0.07 \sin 4\varphi + 0.10 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

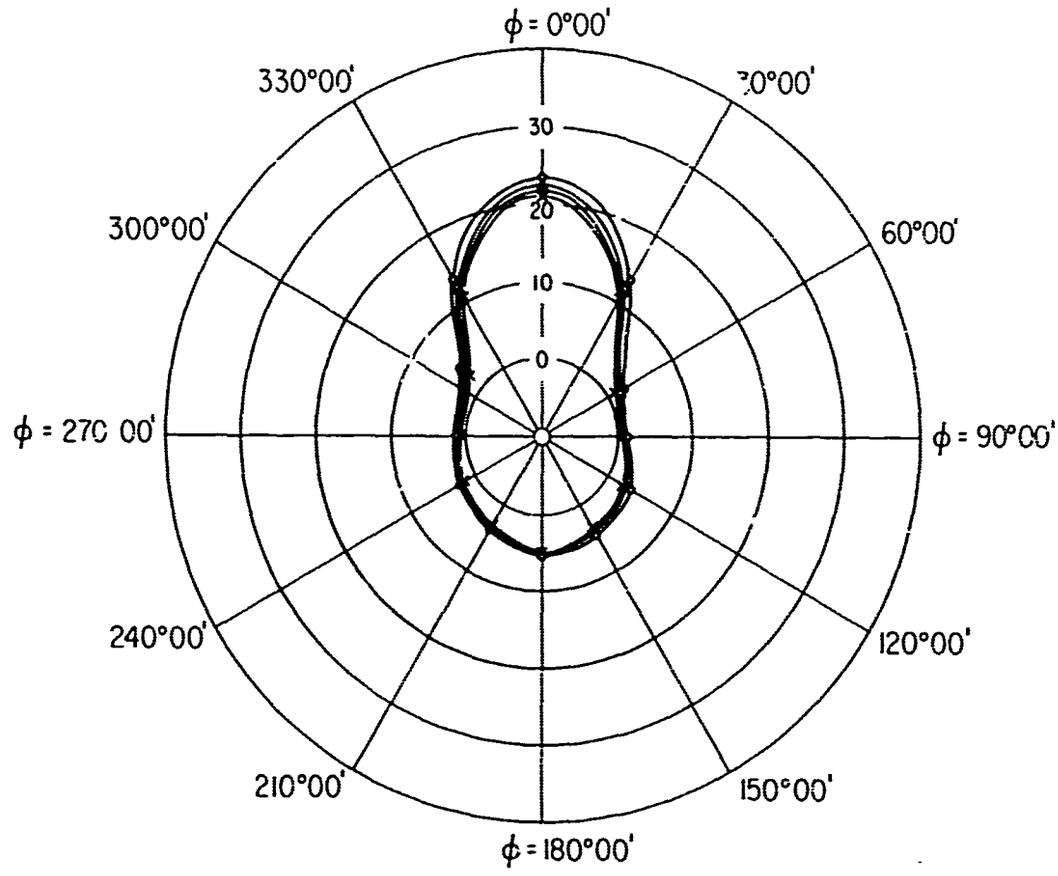
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 60°

ILLUMINATION. POLARIZED LIGHT
θ_0 53°

FIG 133 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.70 + 3.66 \cos\varphi + 4.42 \cos 2\varphi + 1.82 \cos 3\varphi + 0.48 \cos 4\varphi + 0.17 \cos 5\varphi + 0.10 \cos 6\varphi - 0.29 \sin\varphi - 0.19 \sin 2\varphi - 0.08 \sin 3\varphi - 0.10 \sin 4\varphi + 0.11 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 70°

ILLUMINATION: POLARIZED LIGHT
θ_0 53°

FIG 134 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.19 + 5.02 \cos\varphi + 5.74 \cos 2\varphi + 2.85 \cos 3\varphi + 1.66 \cos 4\varphi + 0.38 \cos 5\varphi + 0.32 \cos 6\varphi - 0.31 \sin\varphi - 0.10 \sin 2\varphi - 0.07 \sin 3\varphi + 0.07 \sin 4\varphi + 0.10 \sin 5\varphi$$

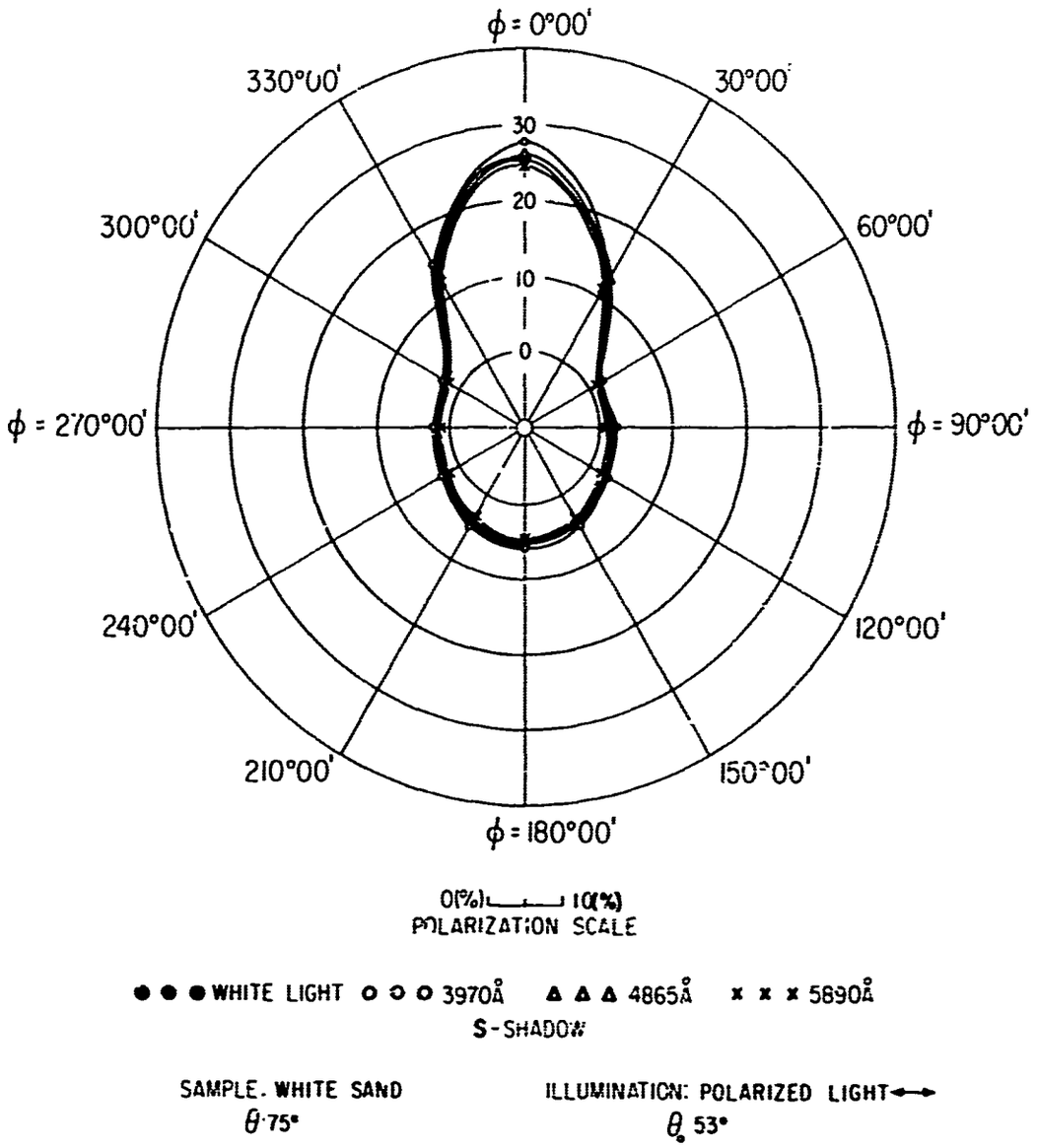


FIG. 135 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.48 + 5.50 \cos\varphi + 5.90 \cos 2\varphi + 2.88 \cos 3\varphi + 1.57 \cos 4\varphi + 0.17 \cos 5\varphi + 0.00 \cos 6\varphi - 0.21 \sin\varphi - 0.18 \sin 2\varphi + 0.08 \sin 3\varphi + 0.07 \sin 4\varphi + 0.14 \sin 5\varphi$$

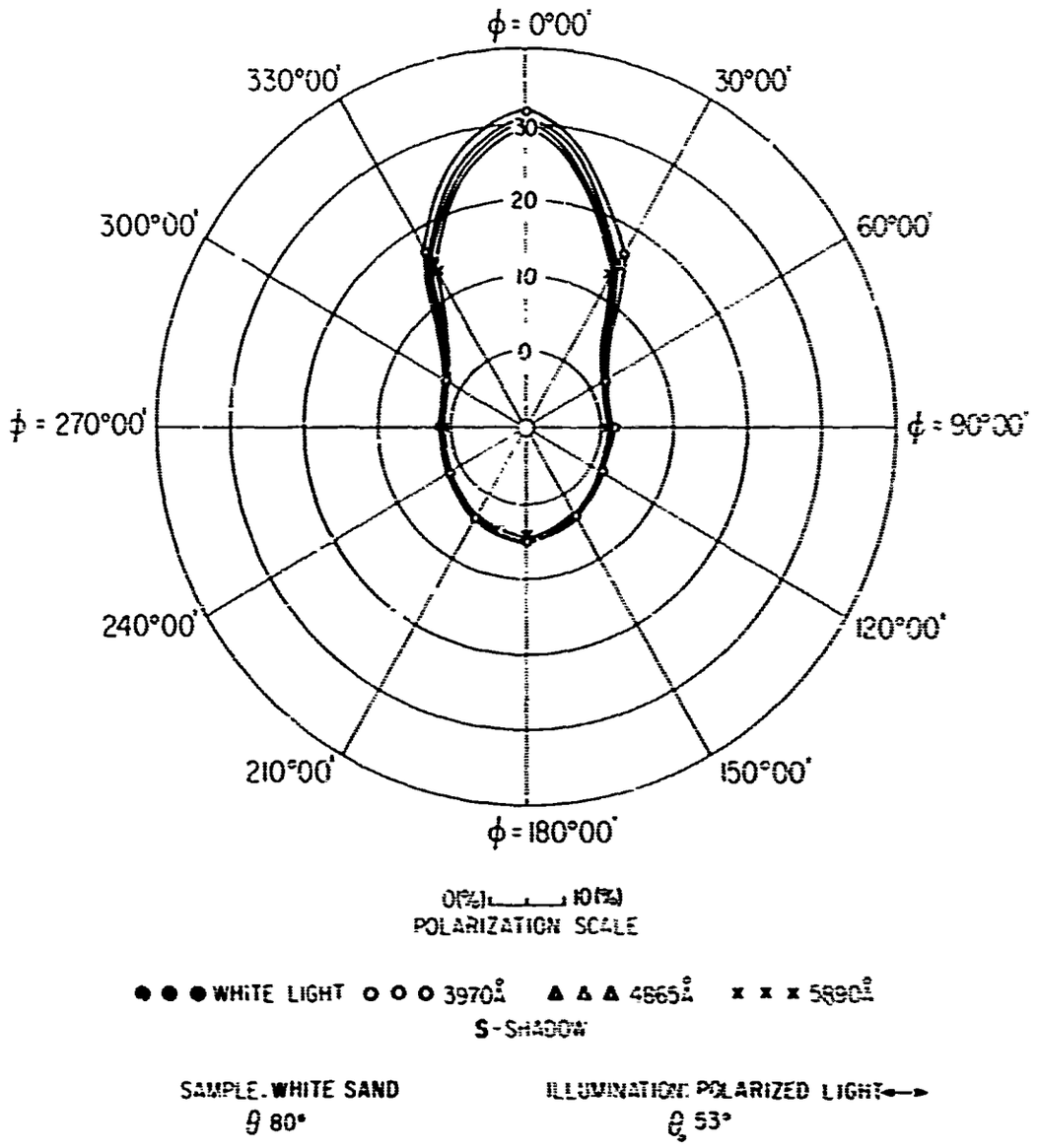


FIG 136 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.74 + 7.60 \cos\varphi + 7.28 \cos 2\varphi + 4.47 \cos 3\varphi + 3.11 \cos 4\varphi + 1.49 \cos 5\varphi + 1.45 \cos 6\varphi - 0.30 \sin\varphi + 0.18 \sin 2\varphi - 0.32 \sin 3\varphi - 0.60 \sin 4\varphi - 0.16 \sin 5\varphi$$

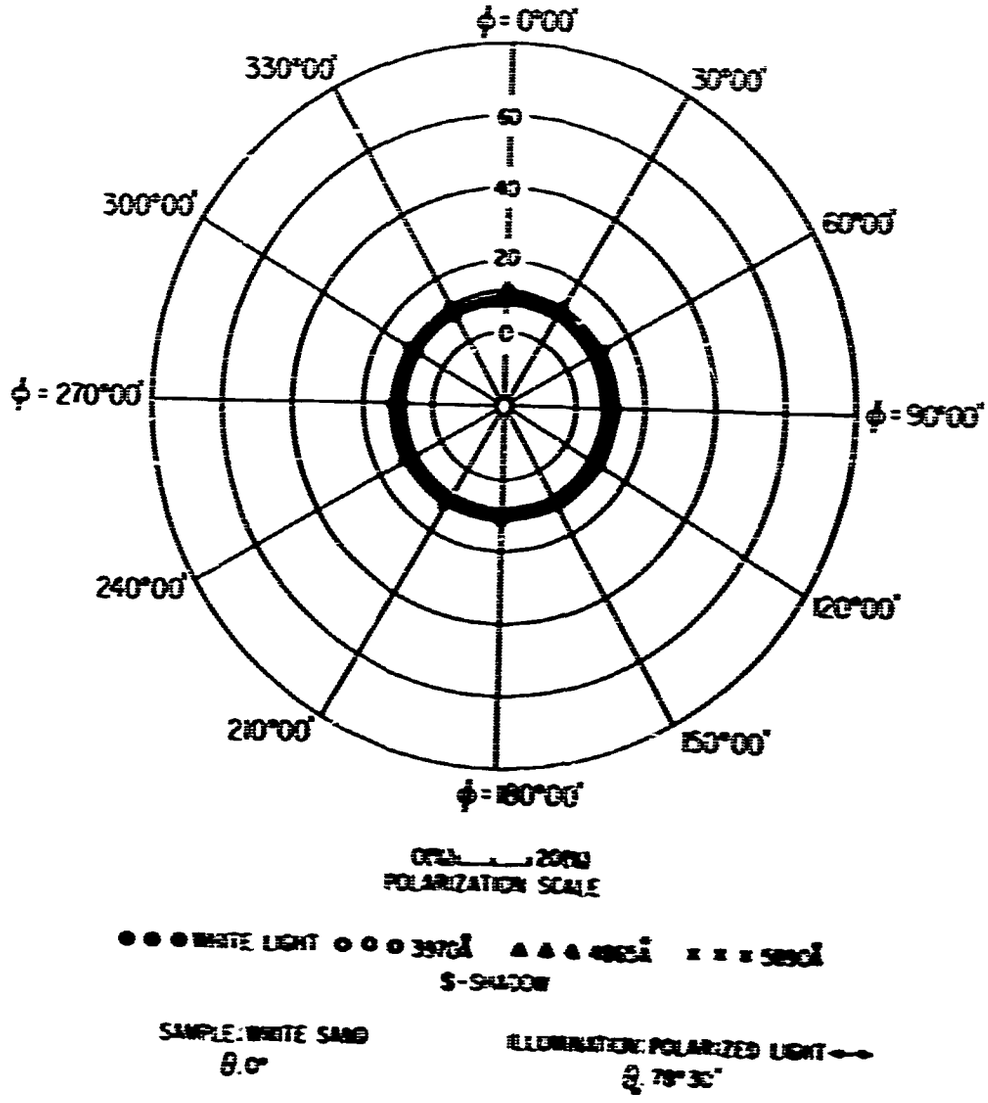


FIG.137 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

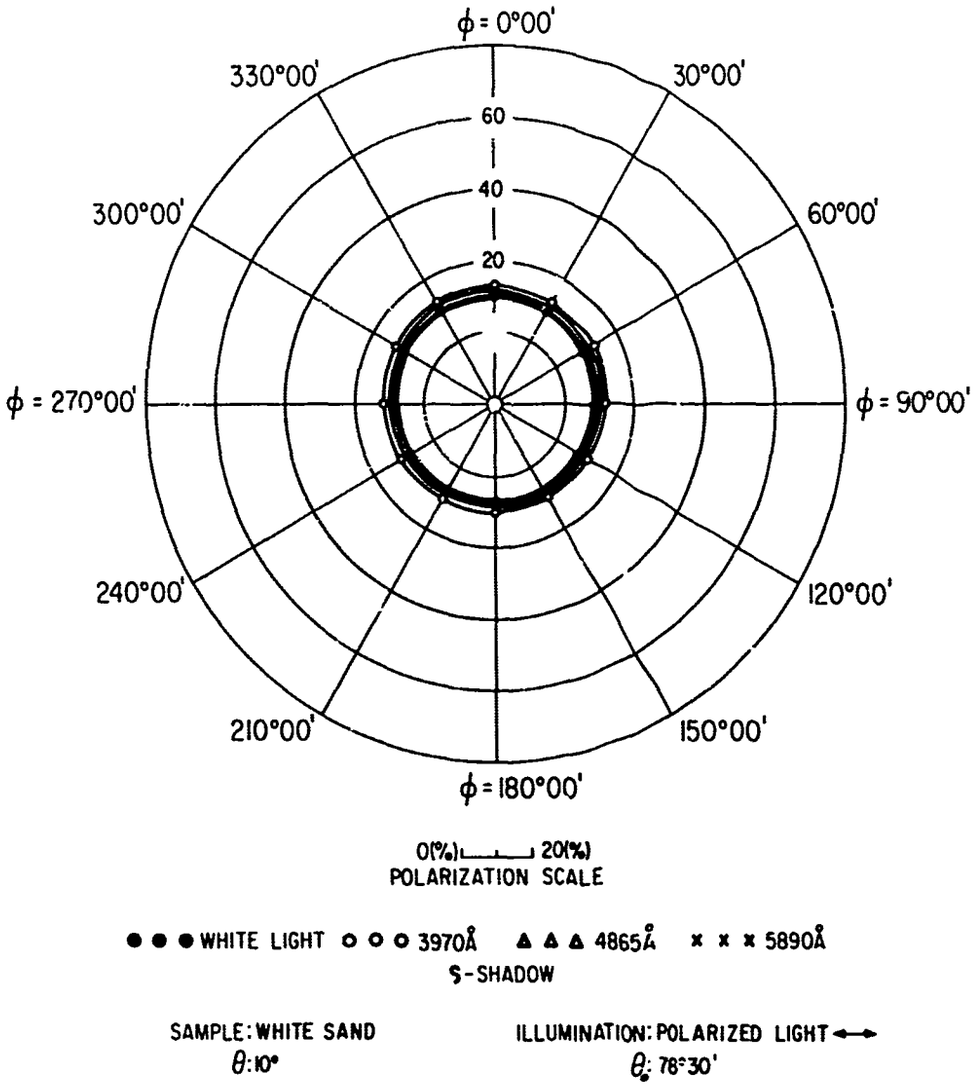


FIG.138 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.68 + 1.50 \cos\varphi + 0.27 \cos 2\varphi - 0.22 \cos 3\varphi - 0.05 \cos 4\varphi - 0.08 \cos 5\varphi - 0.02 \cos 6\varphi - 0.38 \sin\varphi - 0.20 \sin 2\varphi - 0.03 \sin 3\varphi + 0.00 \sin 4\varphi + 0.00 \sin 5\varphi$$

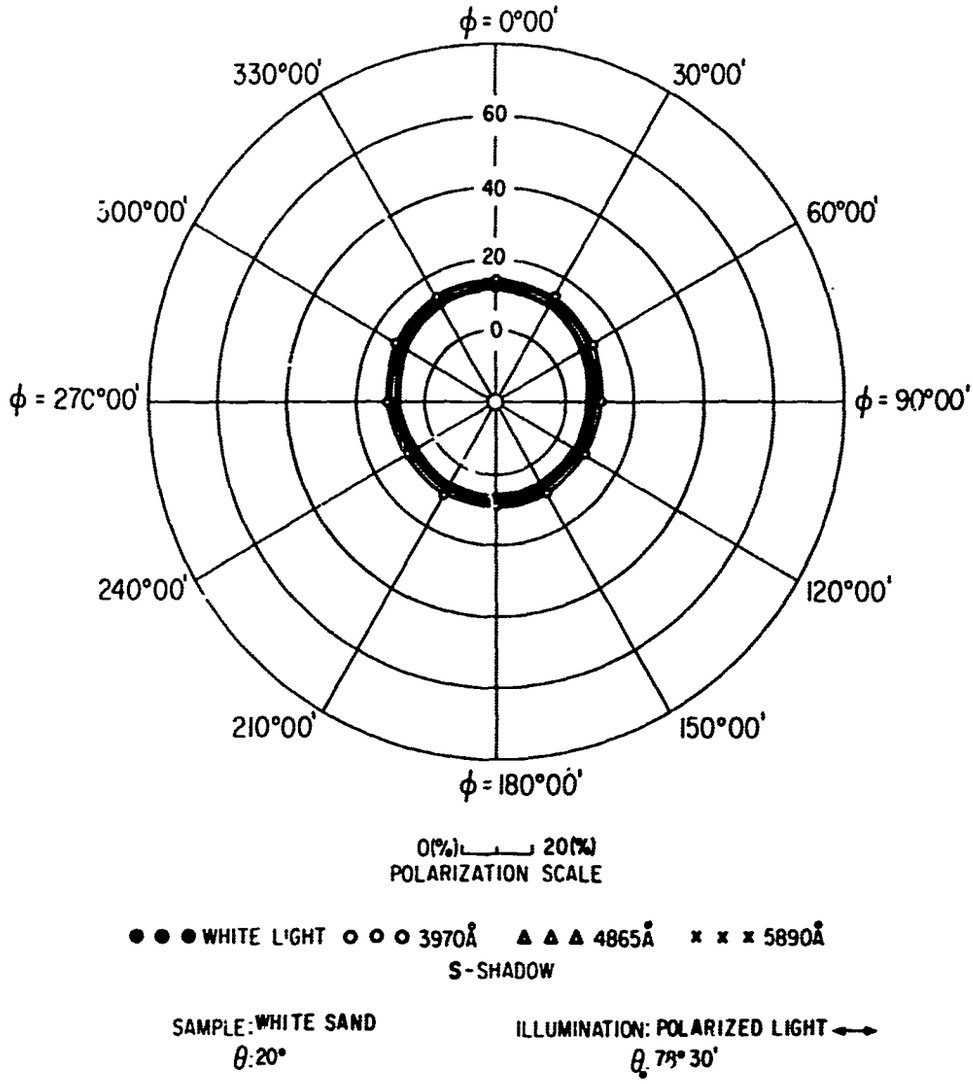


FIG 139 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.60 + 3.04 \cos\varphi + 1.01 \cos 2\varphi - 0.27 \cos 3\varphi - 0.02 \cos 4\varphi - 0.02 \cos 5\varphi - 0.27 \cos 6\varphi - 0.47 \sin\varphi - 0.39 \sin 2\varphi - 0.07 \sin 3\varphi + 0.10 \sin 4\varphi - 0.10 \sin 5\varphi$$

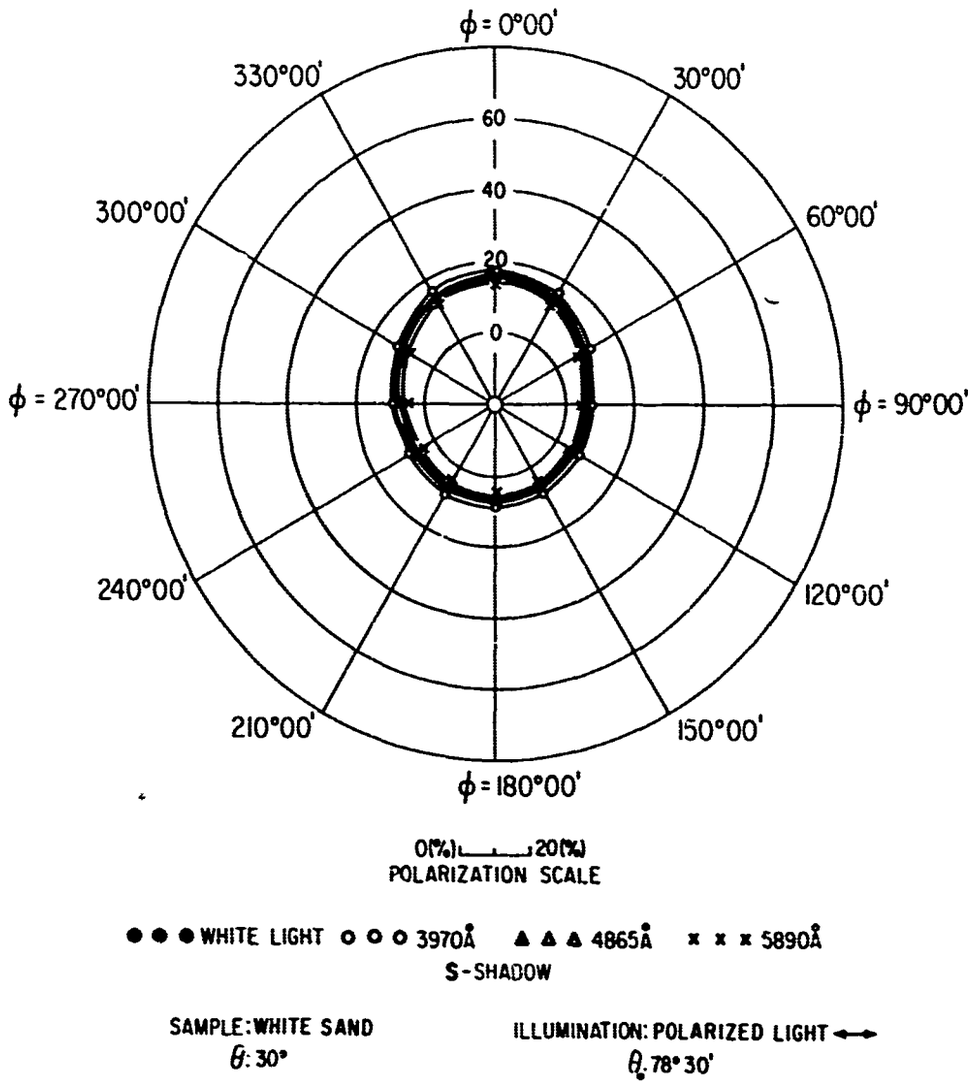
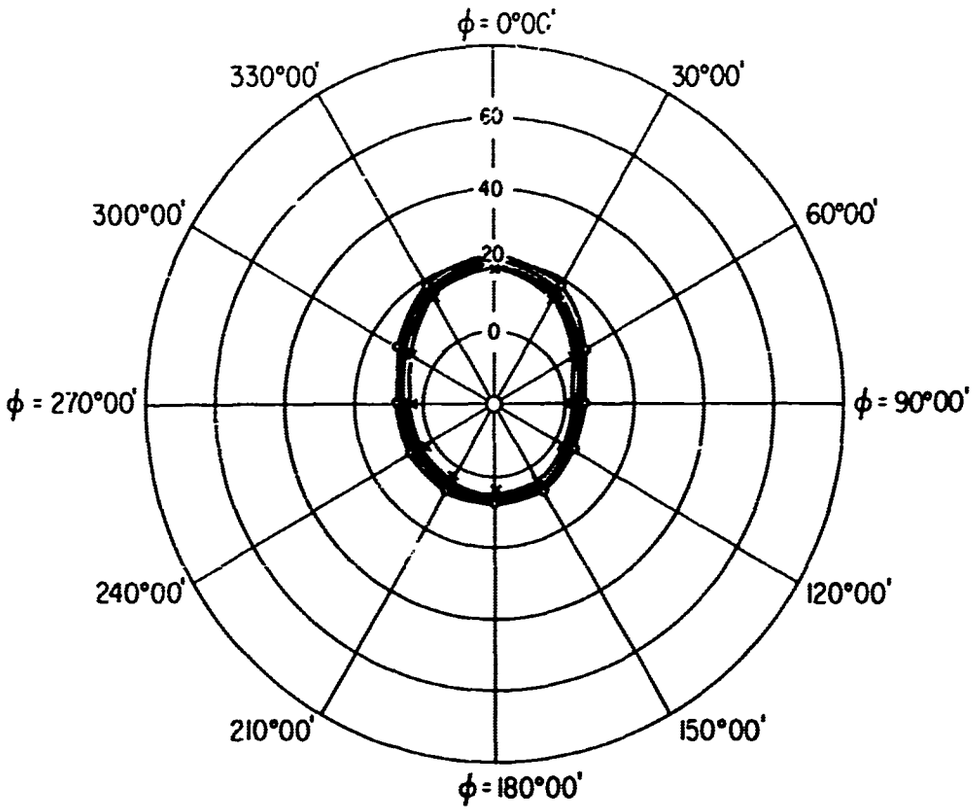


FIG. 140 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.64 + 4.40\cos\varphi + 2.16\cos 2\varphi + 0.40\cos 3\varphi - 0.12\cos 4\varphi - 0.16\cos 5\varphi + 0.18\cos 6\varphi - 1.02\sin\varphi - 0.22\sin 2\varphi - 0.12\sin 3\varphi - 0.18\sin 4\varphi + 0.05\sin 5\varphi$$



0(%) 20 (%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 40

ILLUMINATION: POLARIZED LIGHT ←→
θ_0 78°30'

FIG 141 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.30 + 6.21 \cos\varphi + 4.22 \cos 2\varphi + 0.95 \cos 3\varphi - 0.02 \cos 4\varphi - 0.11 \cos 5\varphi + 0.30 \cos 6\varphi - 1.13 \sin\varphi - 0.65 \sin 2\varphi + 0.22 \sin 3\varphi - 0.19 \sin 4\varphi - 0.15 \sin 5\varphi$$

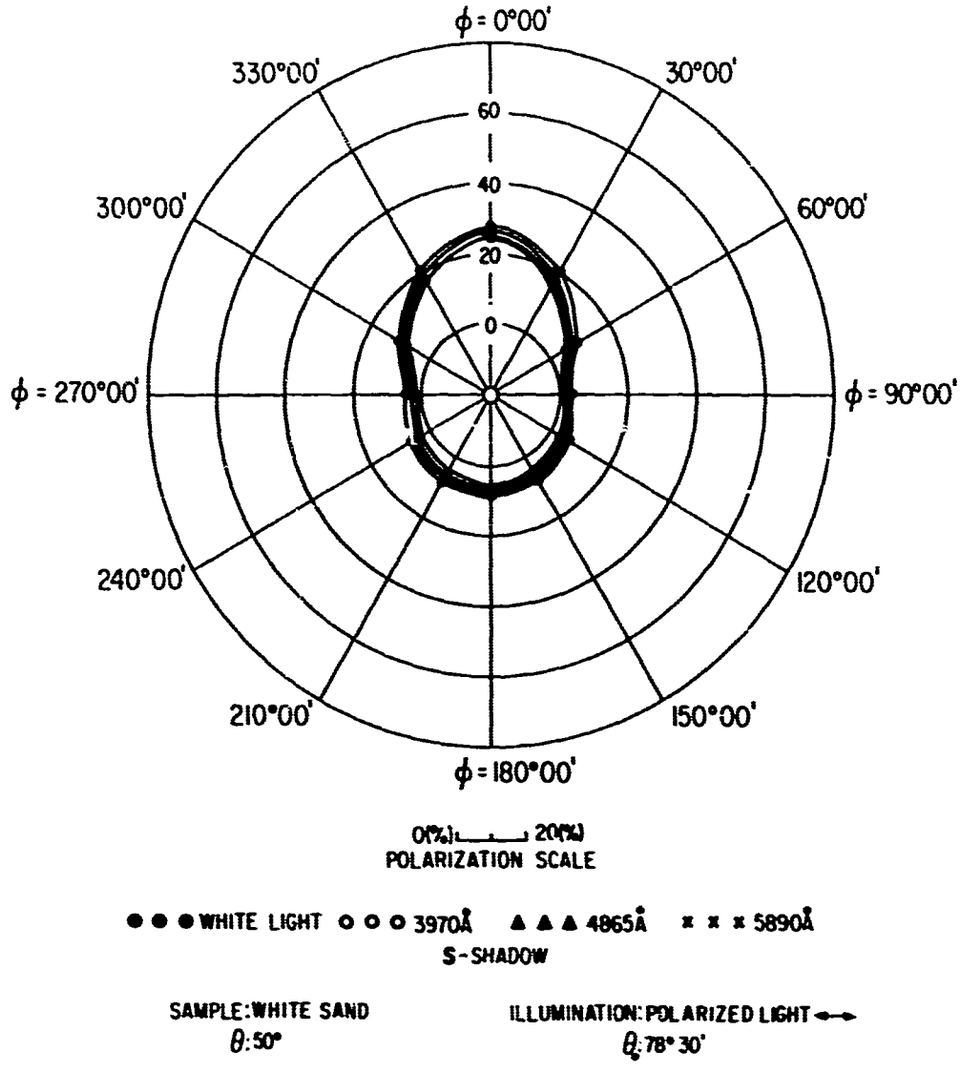


FIG. 142 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.32 + 7.48\cos\varphi + 6.37\cos 2\varphi + 2.08\cos 3\varphi + 0.75\cos 4\varphi + 0.24\cos 5\varphi + 0.72\cos 6\varphi - 0.86\sin\varphi - 0.84\sin 2\varphi - 0.27\sin 3\varphi - 0.12\sin 4\varphi + 0.15\sin 5\varphi$$

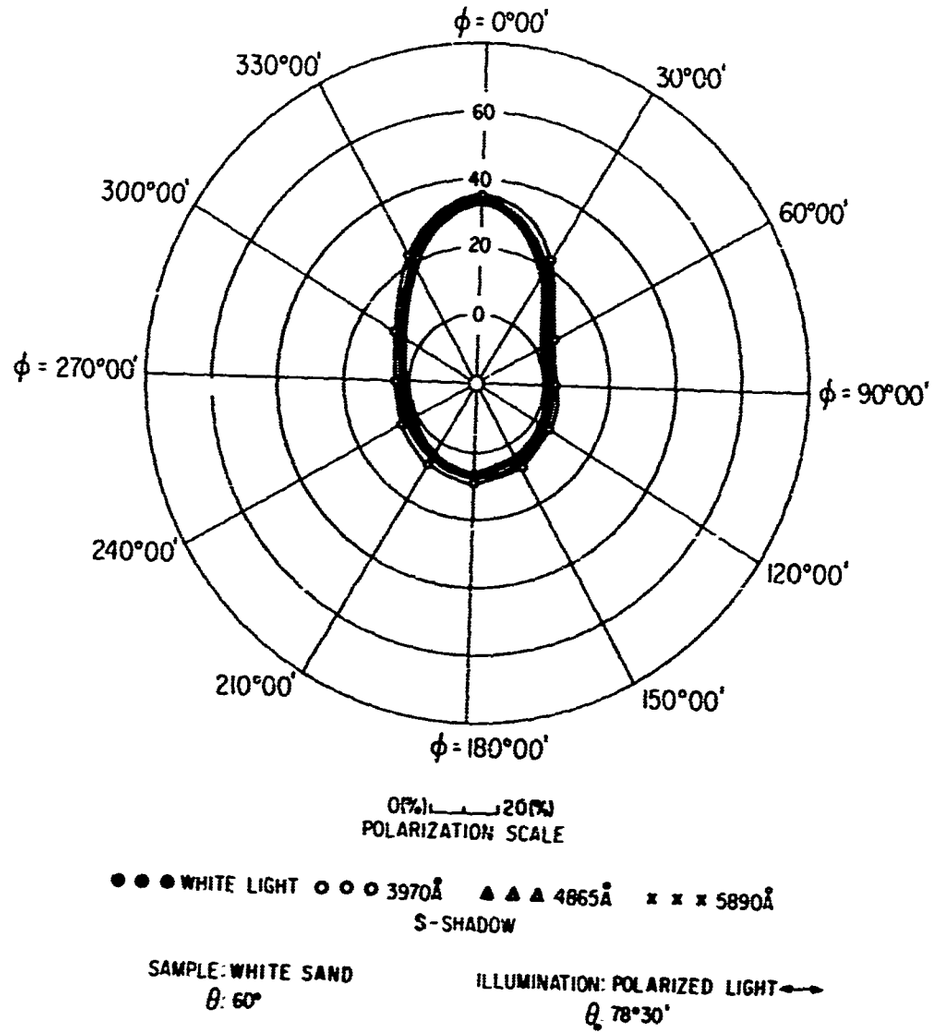


FIG.143 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.59 + 8.73\cos\varphi + 8.62\cos 2\varphi + 3.82\cos 3\varphi + 2.12\cos 4\varphi + 1.05\cos 5\varphi + 1.30\cos 6\varphi - 0.92\sin\varphi - 0.74\sin 2\varphi - 0.02\sin 3\varphi + 0.10\sin 4\varphi + 0.15\sin 5\varphi$$

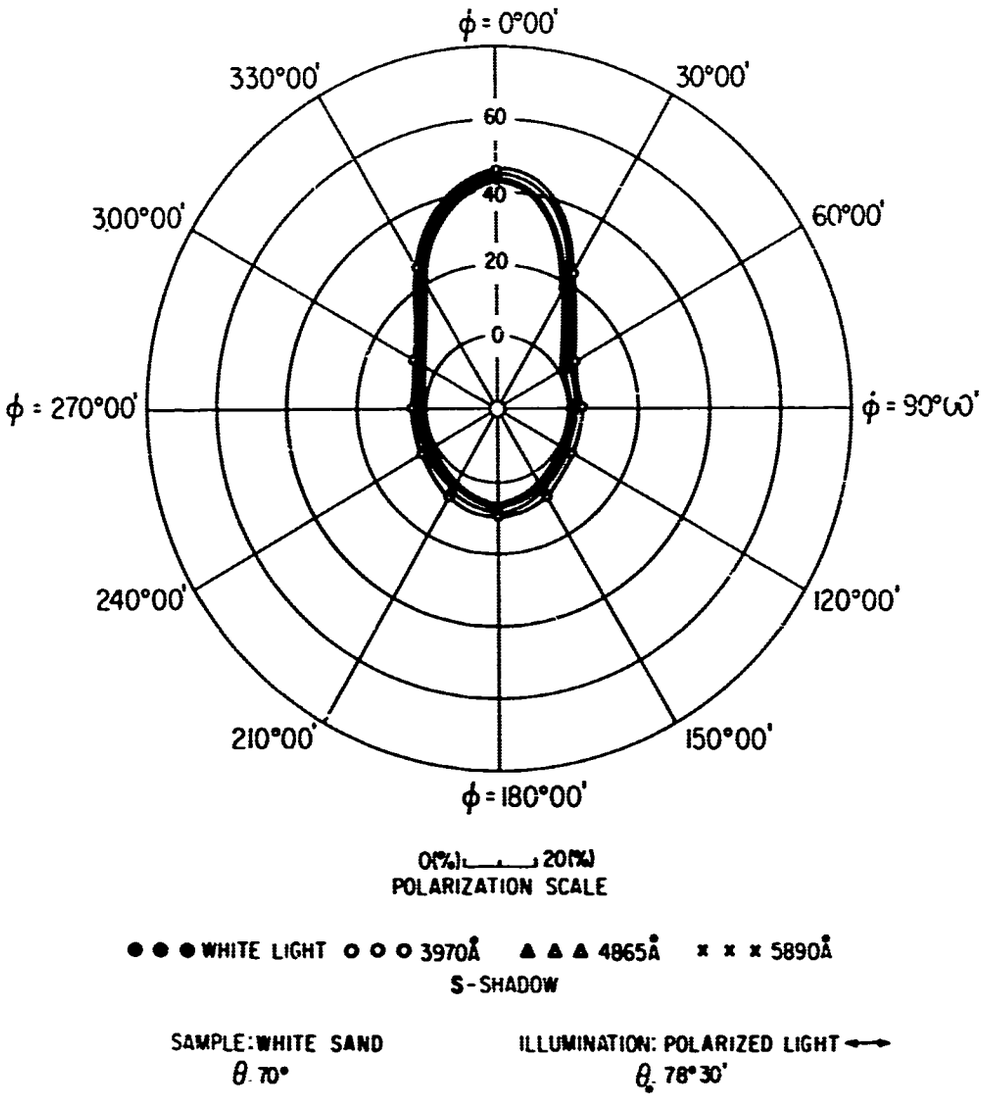


FIG 144 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 9.24 + 10.76\cos\varphi + 11.24\cos 2\varphi + 5.62\cos 3\varphi + 4.18\cos 4\varphi + 1.82\cos 5\varphi + 1.62\cos 6\varphi - 1.15\sin\varphi - 1.02\sin 2\varphi - 0.27\sin 3\varphi - 0.13\sin 4\varphi - 0.04\sin 5\varphi$$

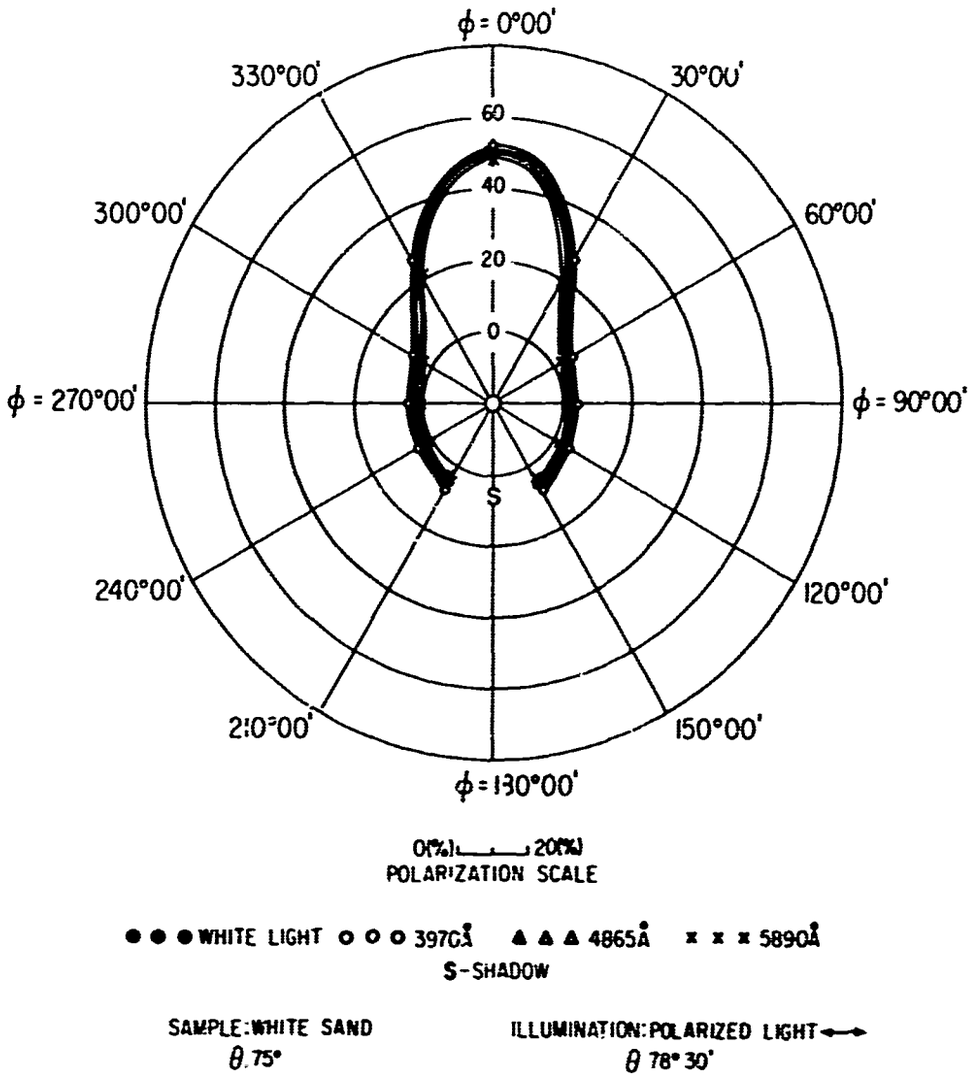


FIG. 145 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 10.57 + 12.21 \cos\varphi + 11.73 \cos 2\varphi + 7.10 \cos 3\varphi + 4.32 \cos 4\varphi + 2.94 \cos 5\varphi + 1.38 \cos 6\varphi - 0.68 \sin\varphi - 0.66 \sin 2\varphi - 0.82 \sin 3\varphi - 0.46 \sin 4\varphi - 0.24 \sin 5\varphi$$

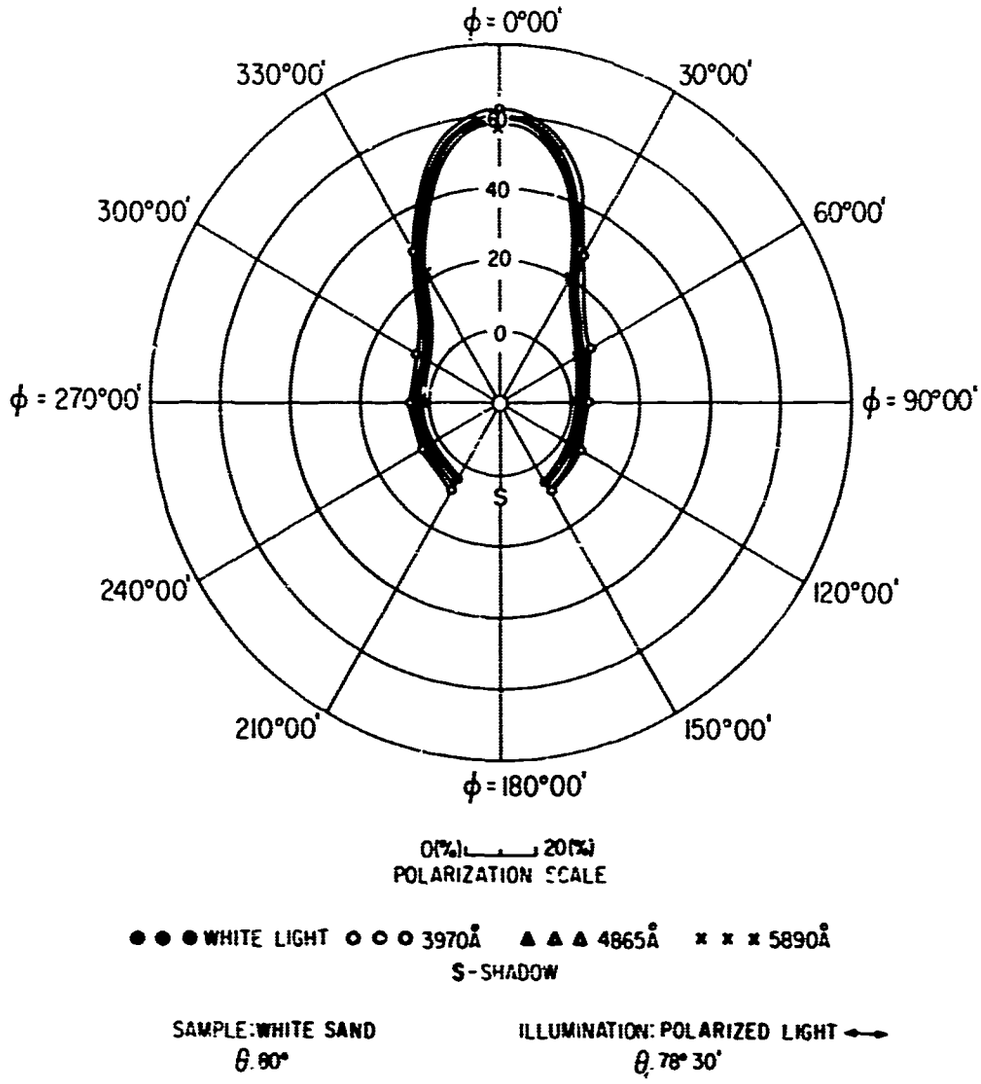
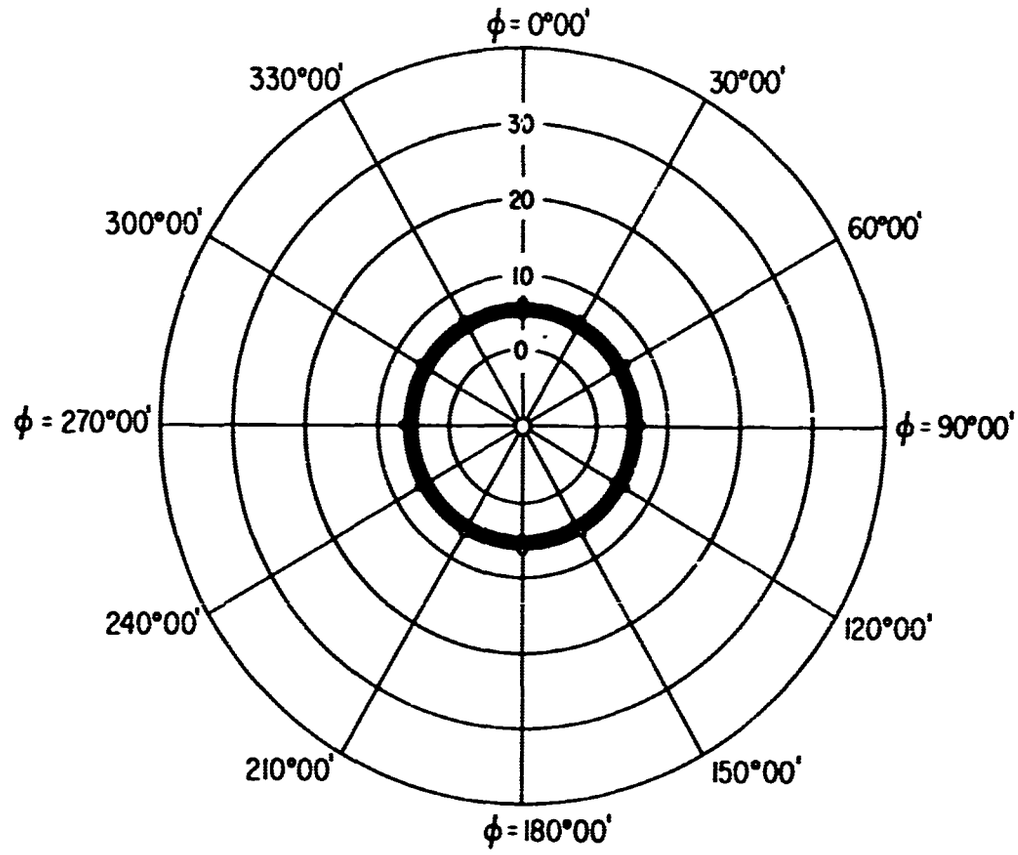


FIG 146 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 11.98 + 15.08 \cos\varphi + 12.06 \cos 2\varphi + 8.08 \cos 3\varphi + 5.36 \cos 4\varphi + 4.08 \cos 5\varphi + 3.40 \cos 6\varphi - 0.05 \sin\varphi - 0.04 \sin 2\varphi - 0.12 \sin 3\varphi - 0.85 \sin 4\varphi - 0.57 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ: 10°

ILLUMINATION: POLARIZED LIGHT ↕
θ: 0°

FIG 147 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.00 + 0.09\cos\varphi - 0.08\cos 2\varphi - 0.10\cos 3\varphi + 0.10\cos 4\varphi + 0.06\cos 5\varphi - 0.13\cos 6\varphi + 0.12\sin\varphi + 0.03\sin 2\varphi - 0.07\sin 3\varphi - 0.06\sin 4\varphi - 0.14\sin 5\varphi$$

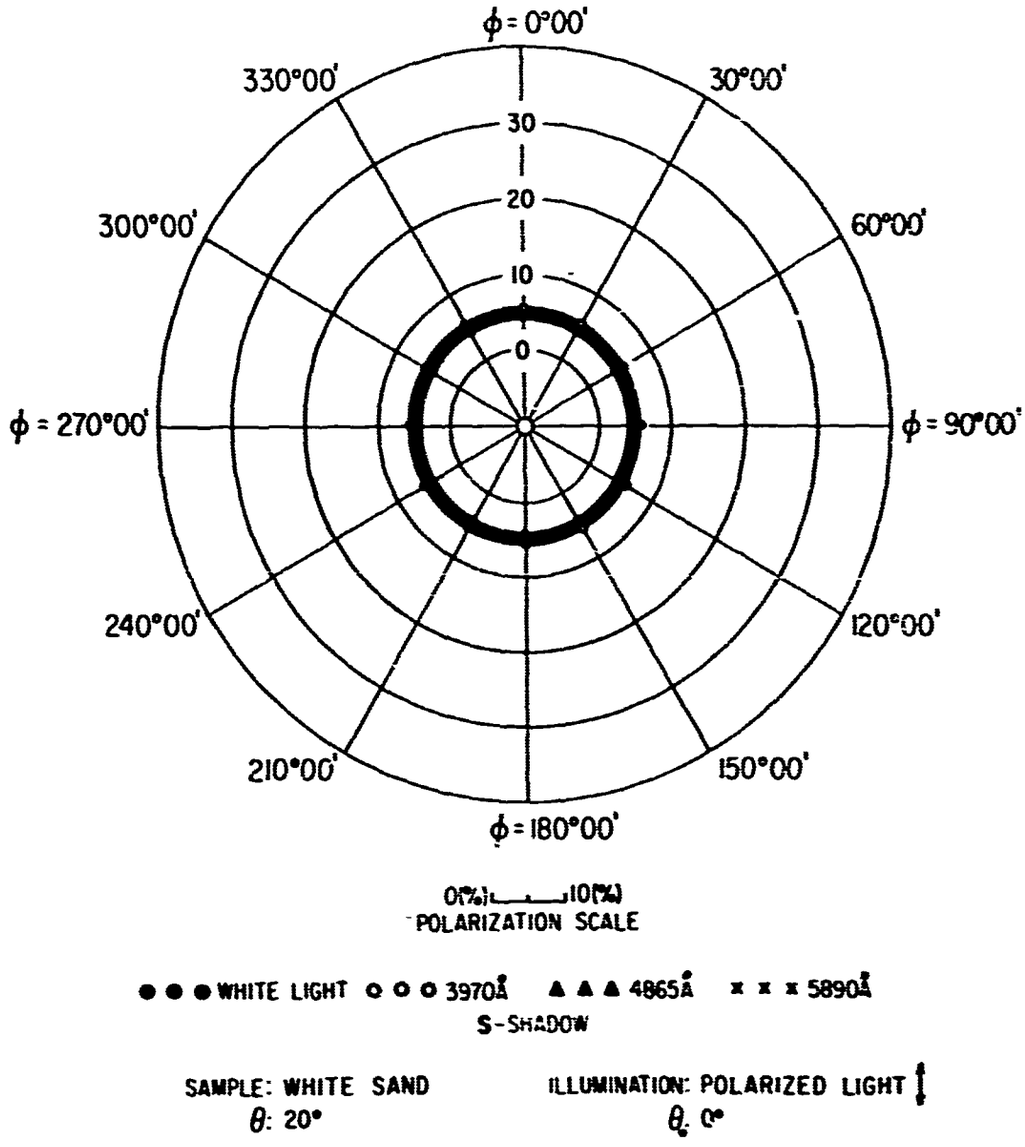


FIG. 148 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.76 + 0.18\cos\varphi - 0.15\cos 2\varphi - 0.07\cos 3\varphi + 0.02\cos 4\varphi - 0.16\cos 5\varphi - 0.25\cos 6\varphi - 0.08\sin\varphi - 0.03\sin 2\varphi - 0.05\sin 3\varphi - 0.03\sin 4\varphi - 0.02\sin 5\varphi$$

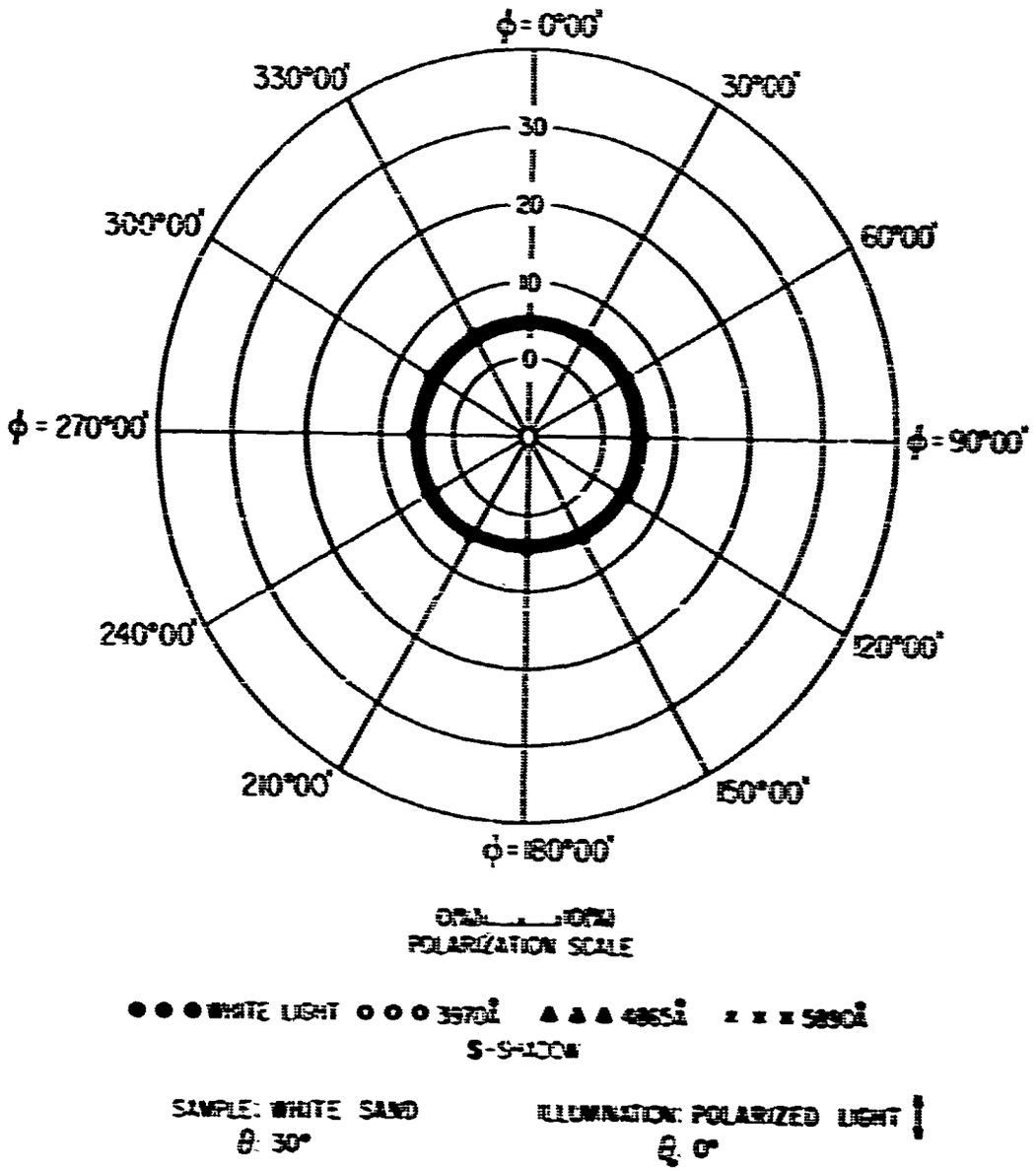


FIG 149 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.28 - 0.01 \cos\phi - 0.30 \cos 2\phi + 0.03 \cos 3\phi - 0.15 \cos 4\phi + 0.02 \cos 5\phi + 0.05 \cos 6\phi - 0.06 \sin\phi + 0.09 \sin 2\phi - 0.02 \sin 3\phi - 0.06 \sin 4\phi - 0.08 \sin 5\phi$$

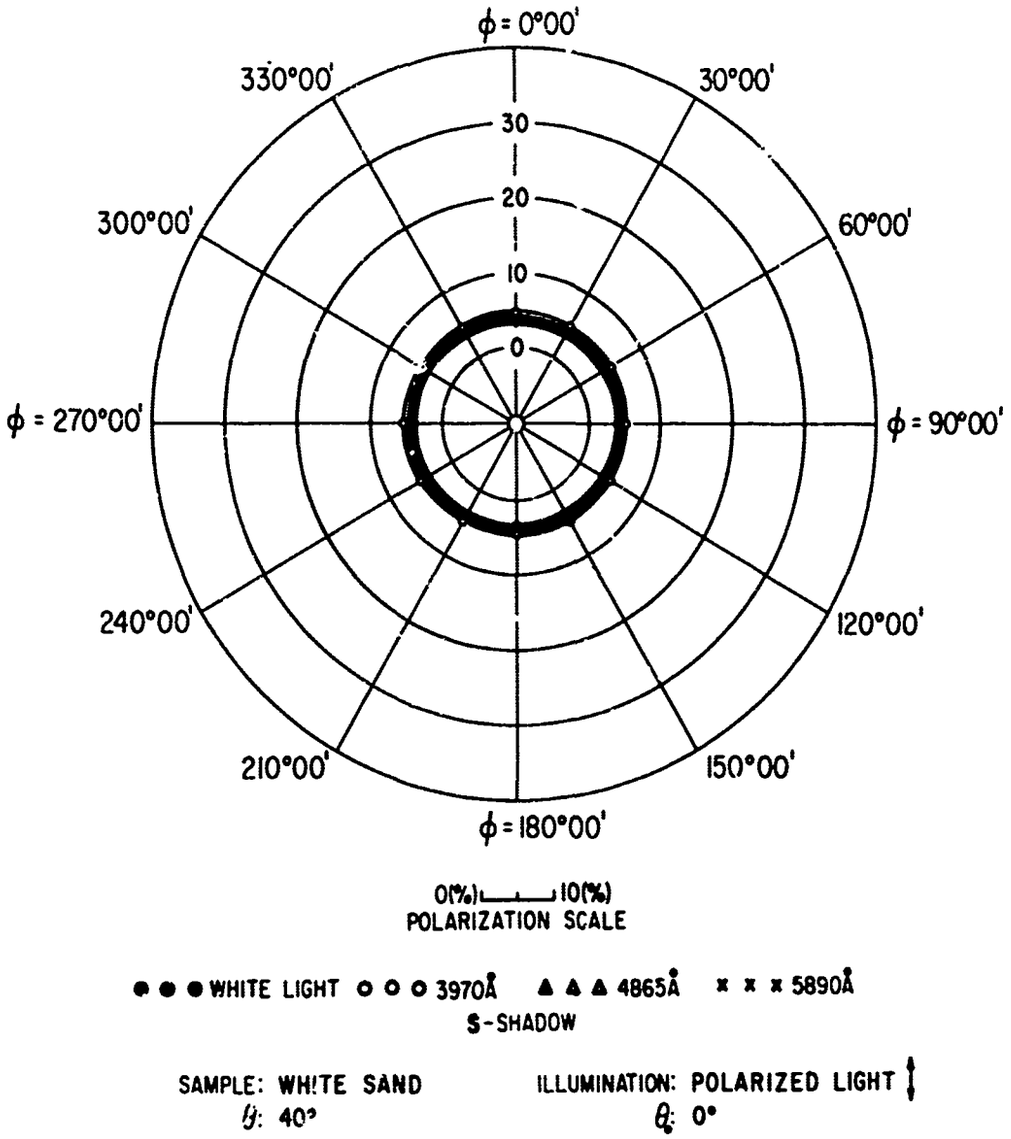


FIG. 150 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.96 - 0.00\cos\varphi - 0.53\cos 2\varphi - 0.07\cos 3\varphi + 0.12\cos 4\varphi - 0.08\cos 5\varphi$$
$$+ 0.02\cos 6\varphi - 0.01\sin\varphi + 0.09\sin 2\varphi - 0.05\sin 3\varphi + 0.00\sin 4\varphi - 0.04\sin 5\varphi$$

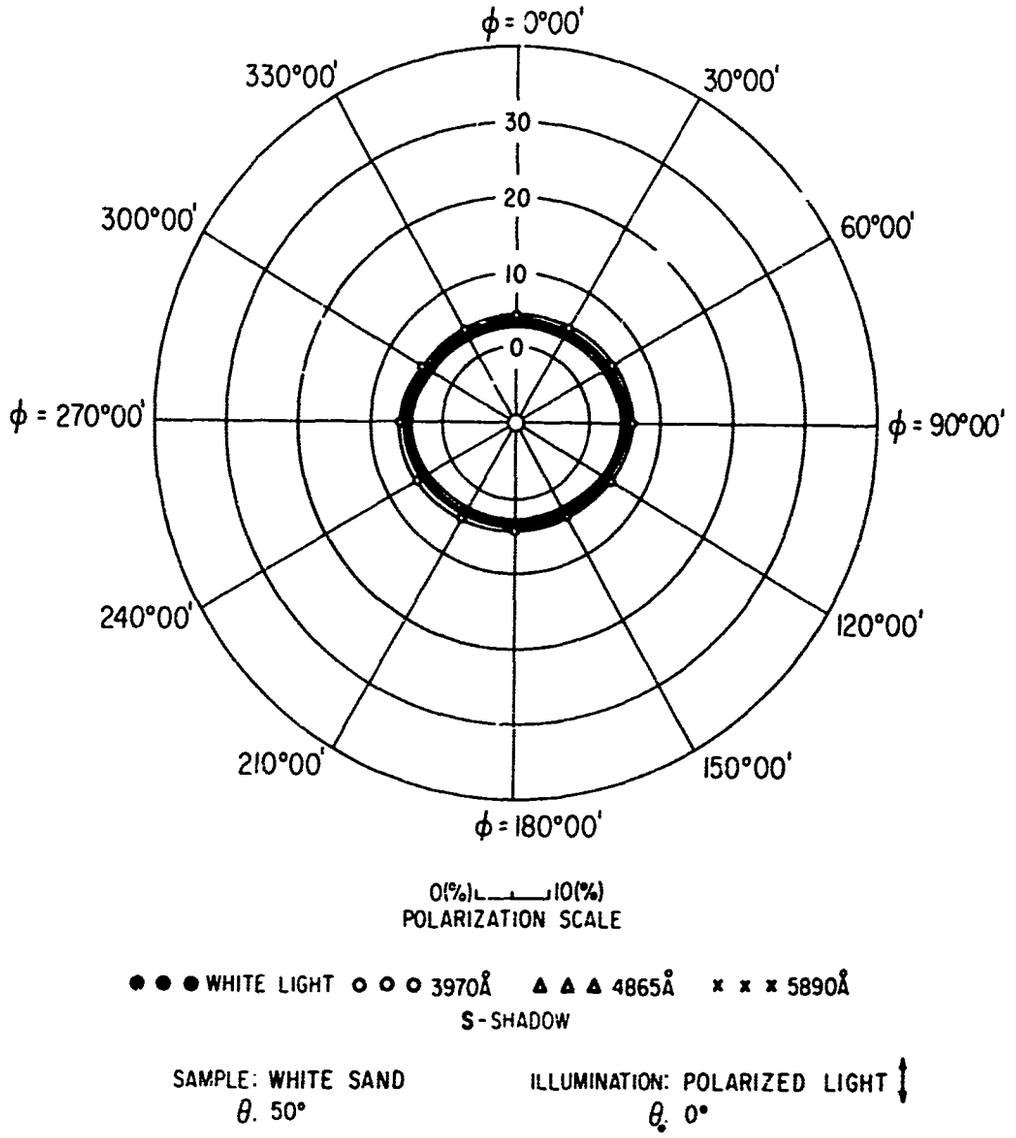
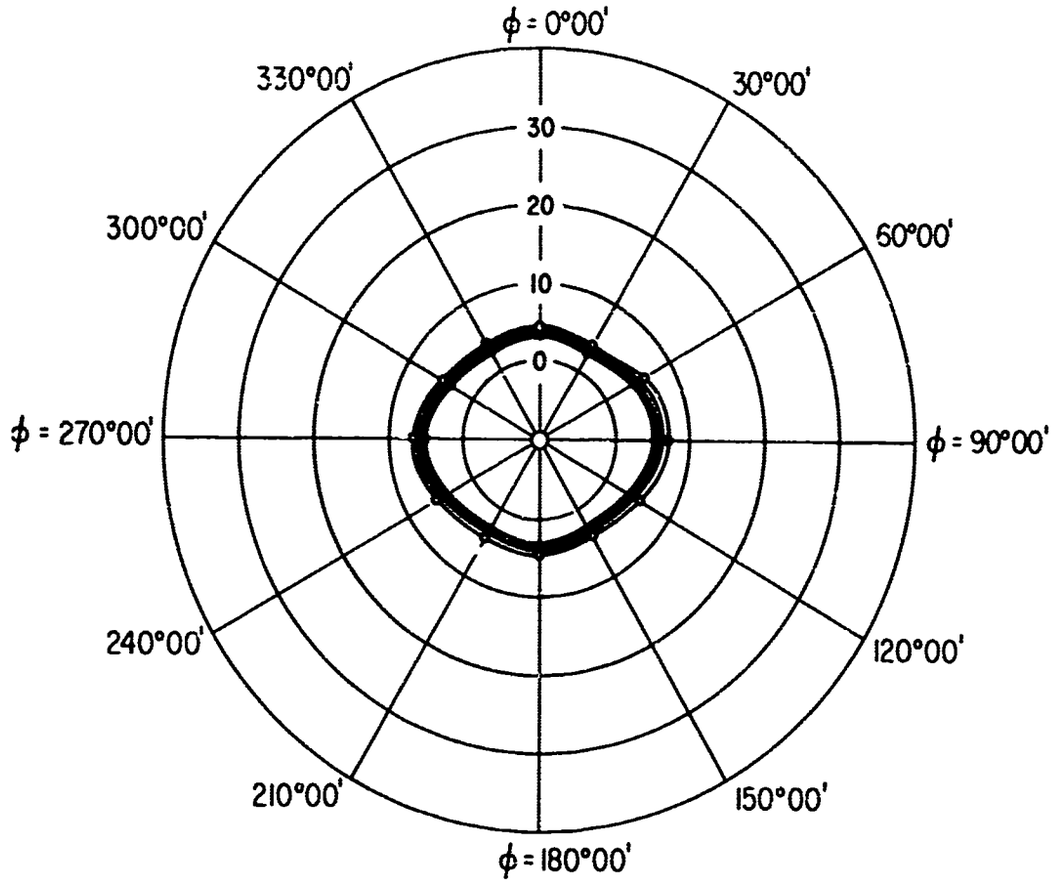


FIG 151 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.75 - 0.09\cos\varphi - 0.77\cos 2\varphi + 0.05\cos 3\varphi + 0.30\cos 4\varphi - 0.09\cos 5\varphi + 0.10\cos 6\varphi - 0.05\sin\varphi - 0.17\sin 2\varphi - 0.22\sin 3\varphi + 0.00\sin 4\varphi - 0.12\sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: WHITE SAND
θ: 60°

ILLUMINATION: POLARIZED LIGHT ↕
θ_o: 0°

FIG. 152 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.63 + 0.16 \cos\varphi - 1.10 \cos 2\varphi + 0.00 \cos 3\varphi + 0.47 \cos 4\varphi - 0.21 \cos 5\varphi + 0.20 \cos 6\varphi - 0.09 \sin\varphi + 0.23 \sin 2\varphi - 0.20 \sin 3\varphi + 0.00 \sin 4\varphi - 0.21 \sin 5\varphi$$

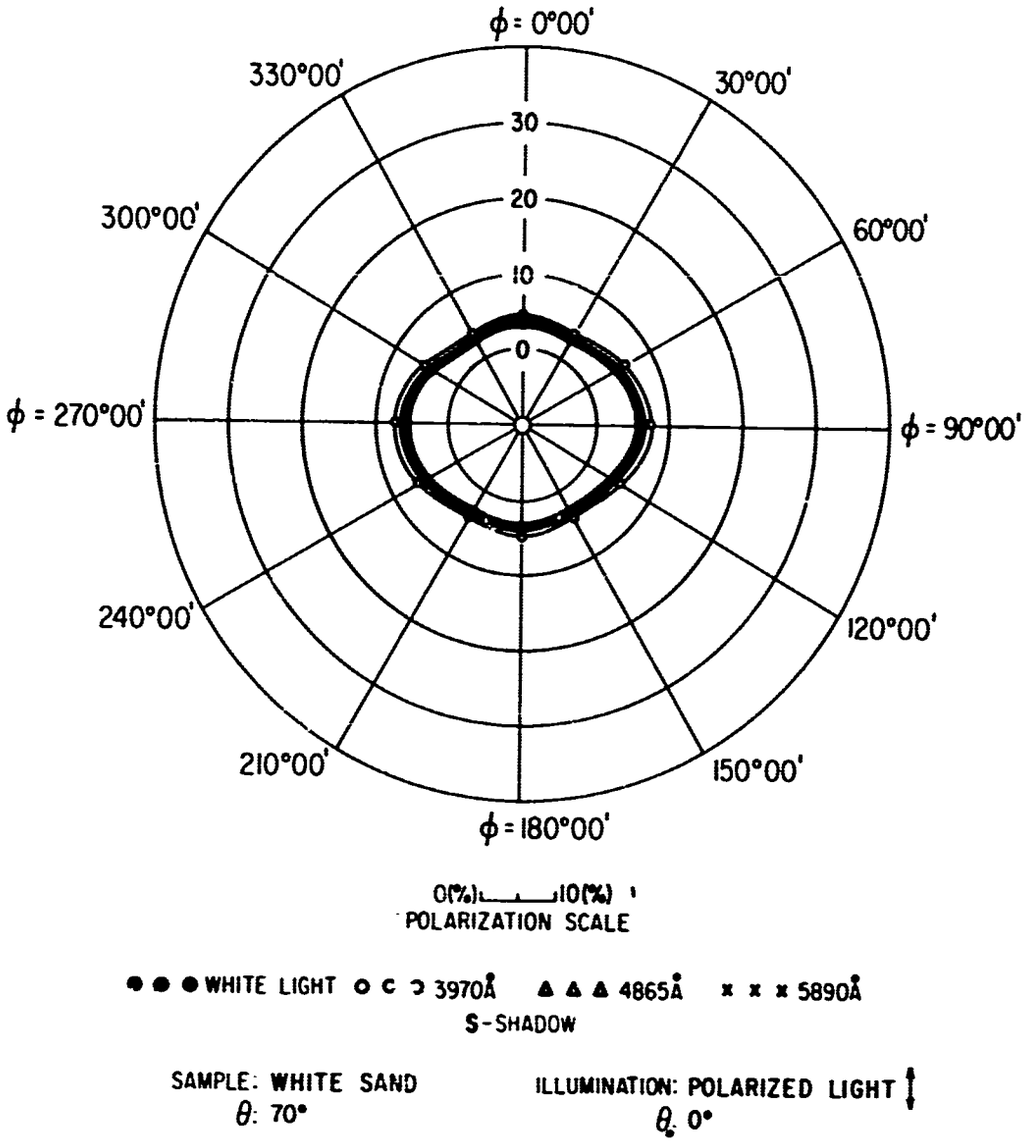
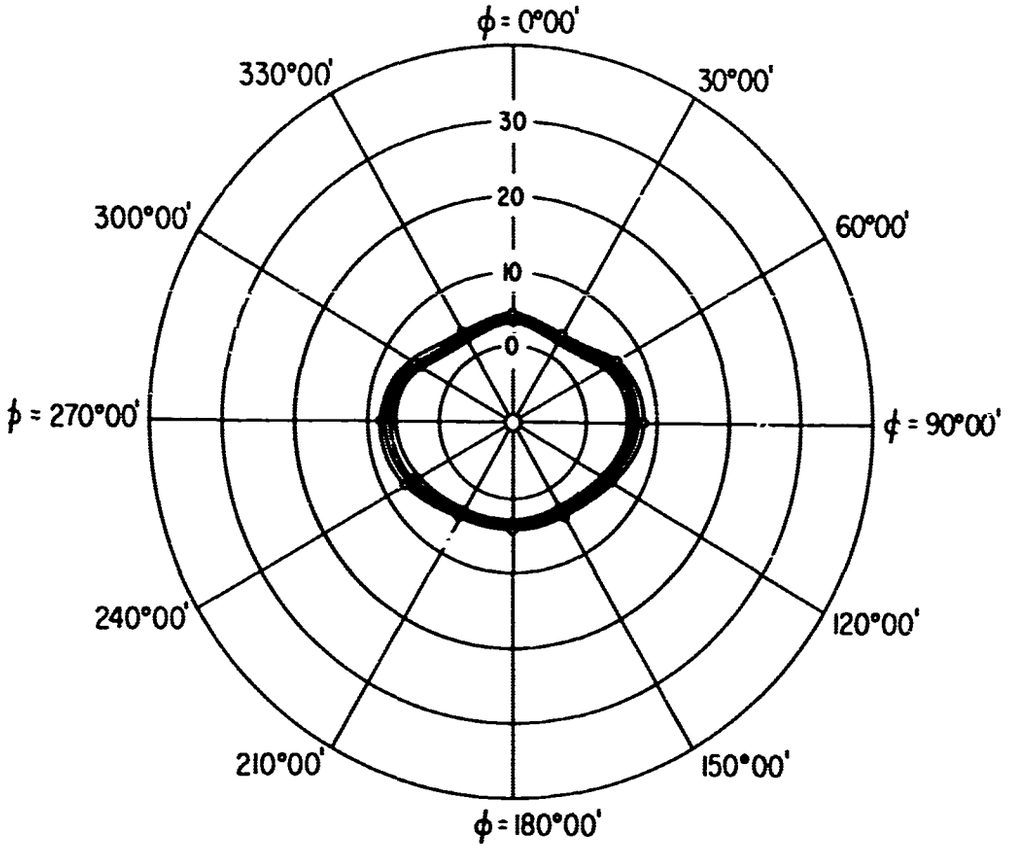


FIG 153 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 3.98 - 0.02\cos\varphi - 1.36\cos 2\varphi + 0.00\cos 3\varphi - 0.68\cos 4\varphi - 0.02\cos 5\varphi + 0.22\cos 6\varphi + 0.09\sin\varphi + 0.36\sin 2\varphi + 0.05\sin 3\varphi - 0.19\sin 4\varphi + 0.11\sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ: 75°

ILLUMINATION: POLARIZED LIGHT
θ_0: 0°

FIG. 154 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.28 - 0.18\cos\varphi - 1.47\cos 2\varphi - 0.20\cos 3\varphi + 0.97\cos 4\varphi + 0.13\cos 5\varphi + 0.17\cos 6\varphi - 0.06\sin\varphi + 0.52\sin 2\varphi - 0.07\sin 3\varphi - 0.38\sin 4\varphi + 0.14\sin 5\varphi$$

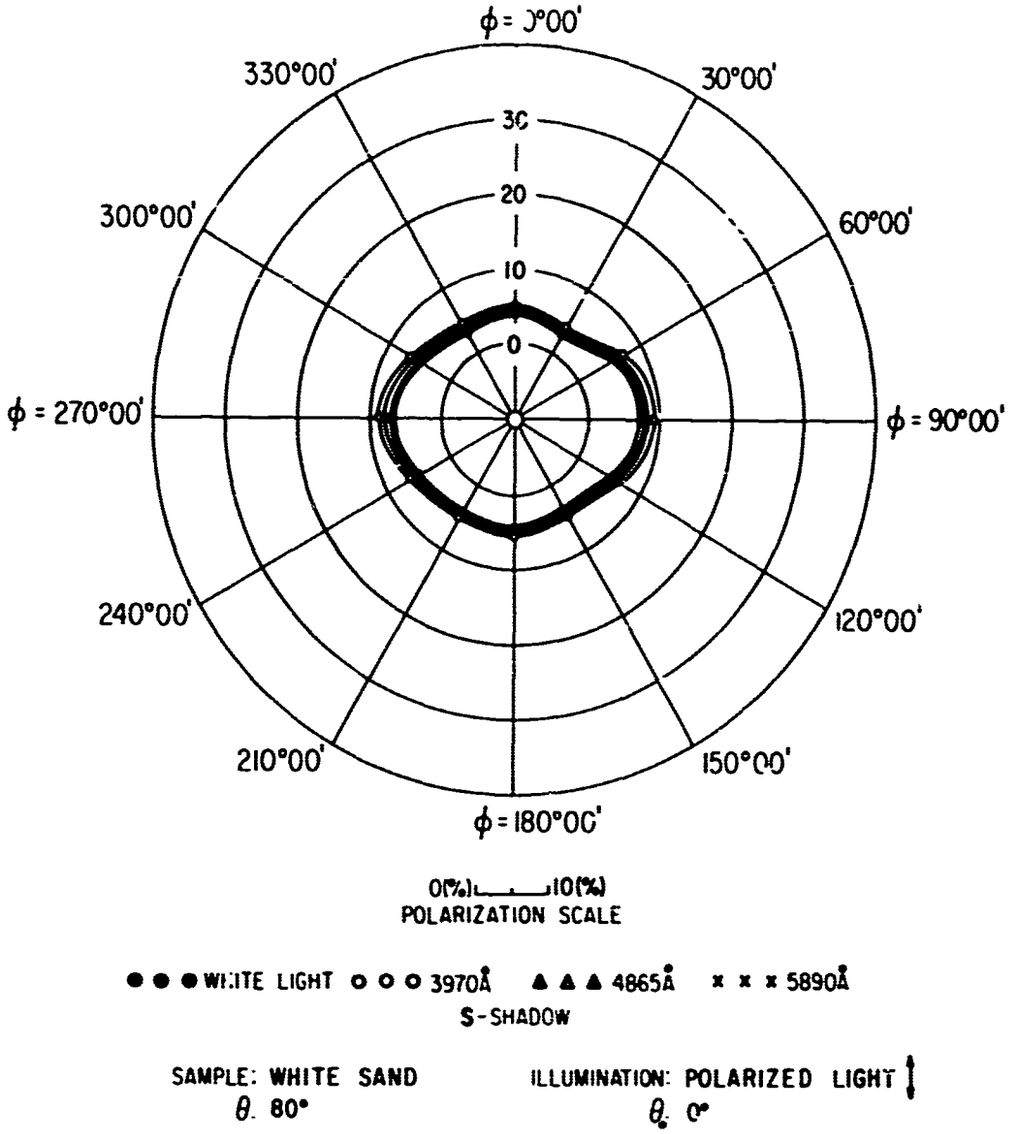


FIG 155 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 4.90 - 0.39\cos\phi - 1.81\cos 2\phi + 0.12\cos 3\phi + 0.98\cos 4\phi - 0.08\cos 5\phi + 0.57\cos 6\phi + 0.07\sin\phi + 0.30\sin 2\phi - 0.12\sin 3\phi - 0.16\sin 4\phi + 0.01\sin 5\phi$$

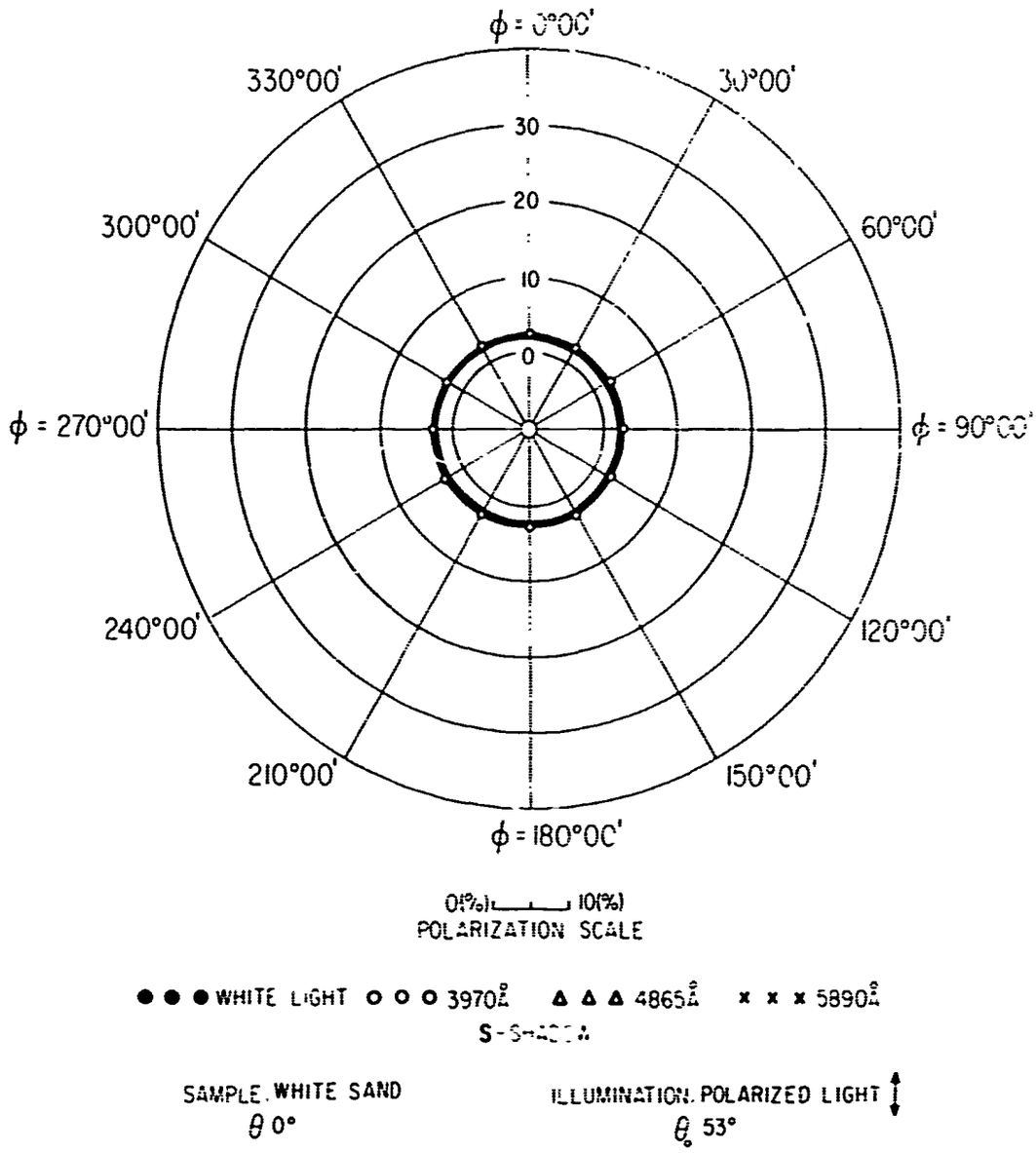


FIG 156 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

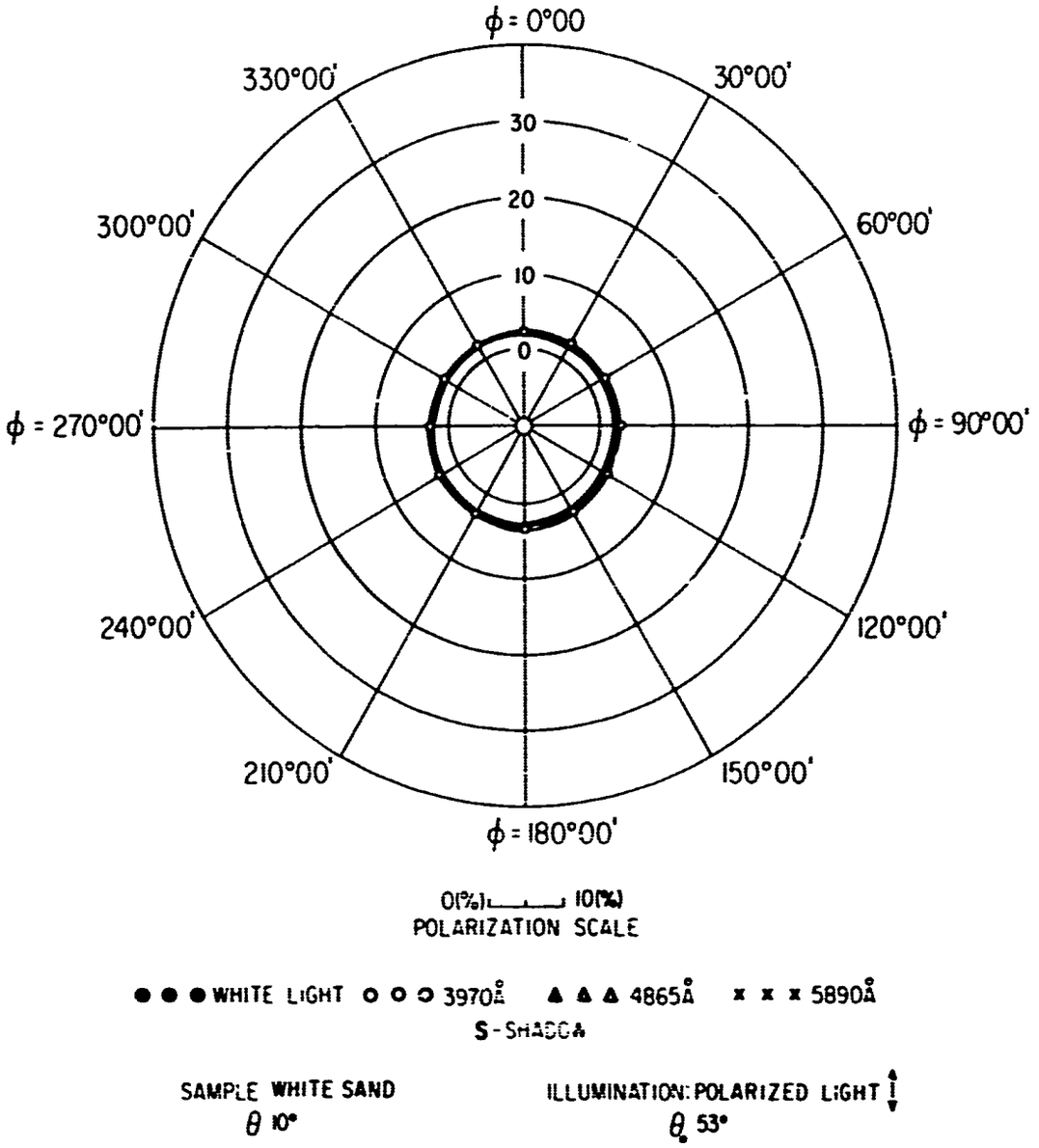


FIG 157 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 2.71 - 0.49\cos\varphi + 0.02\cos 2\varphi + 0.12\cos 3\varphi + 0.12\cos 4\varphi + 0.02\cos 5\varphi + 0.02\cos 6\varphi - 0.12\sin\varphi + 0.12\sin 2\varphi - 0.13\sin 3\varphi + 0.00\sin 4\varphi - 0.01\sin 5\varphi$$

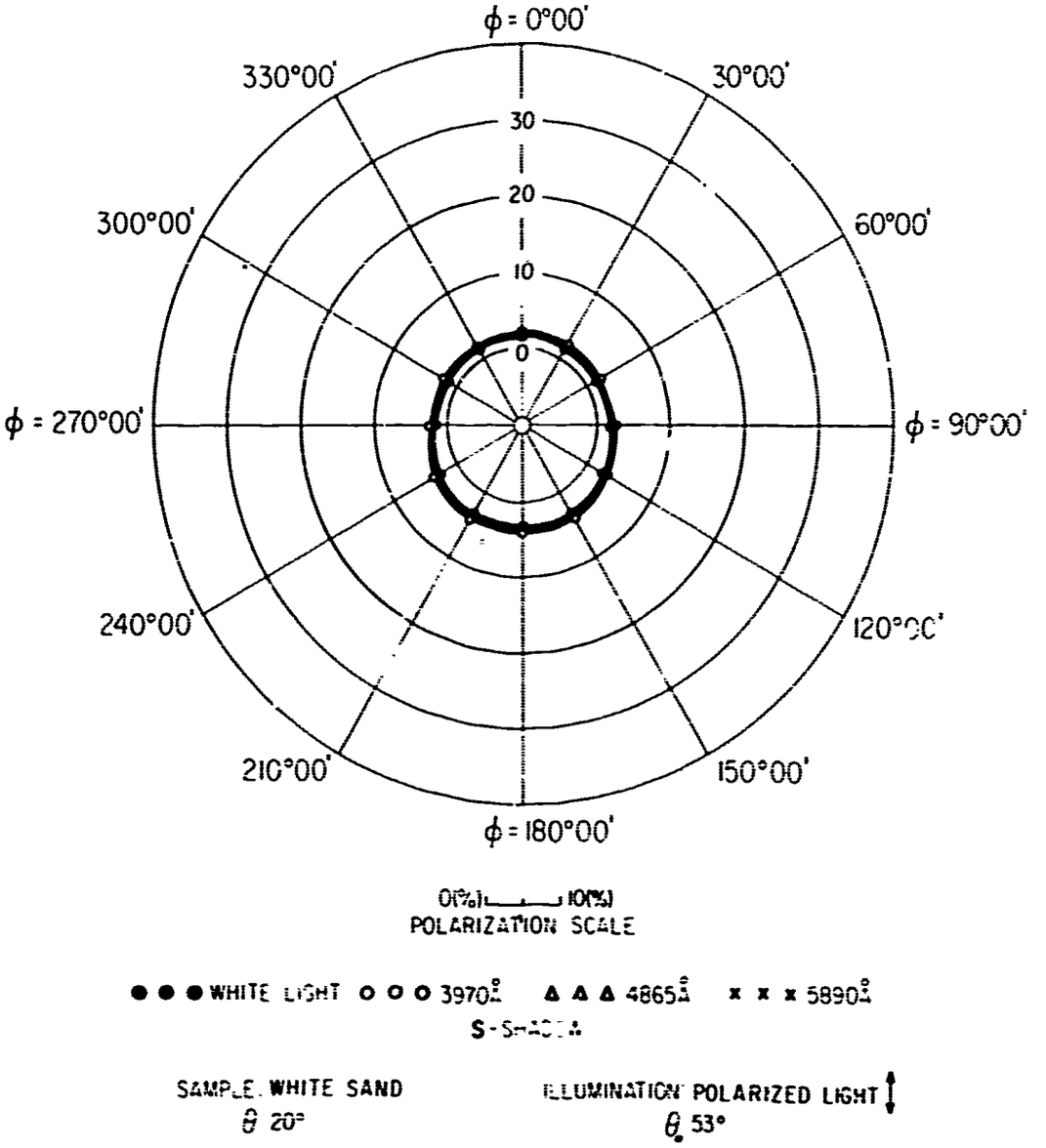


FIG 158 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 2.81 - 0.89\cos\varphi + 0.12\cos 2\varphi + 0.03\cos 3\varphi + 0.04\cos 4\varphi - 0.05\cos 5\varphi + 0.05\cos 6\varphi - 0.02\sin\varphi + 0.03\sin 2\varphi + 0.06\sin 3\varphi - 0.00\sin 4\varphi + 0.01\sin 5\varphi$$

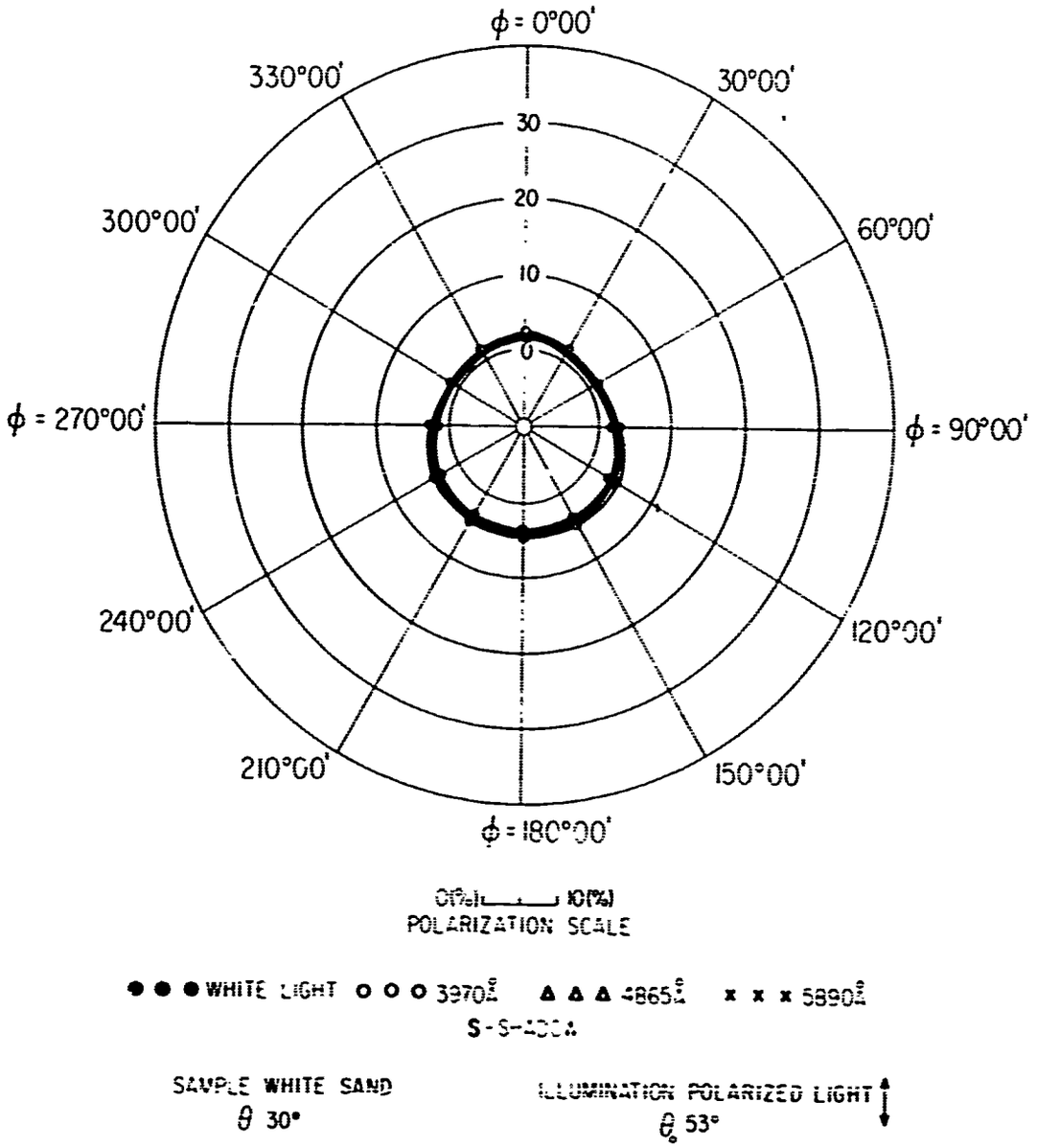


FIG 159 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.02 - 1.64 \cos\phi + 0.45 \cos 2\phi + 0.30 \cos 3\phi + 0.15 \cos 4\phi - 0.08 \cos 5\phi - 0.05 \cos 6\phi + 0.00 \sin\phi - 0.12 \sin 2\phi - 0.15 \sin 3\phi - 0.12 \sin 4\phi + 0.00 \sin 5\phi$$

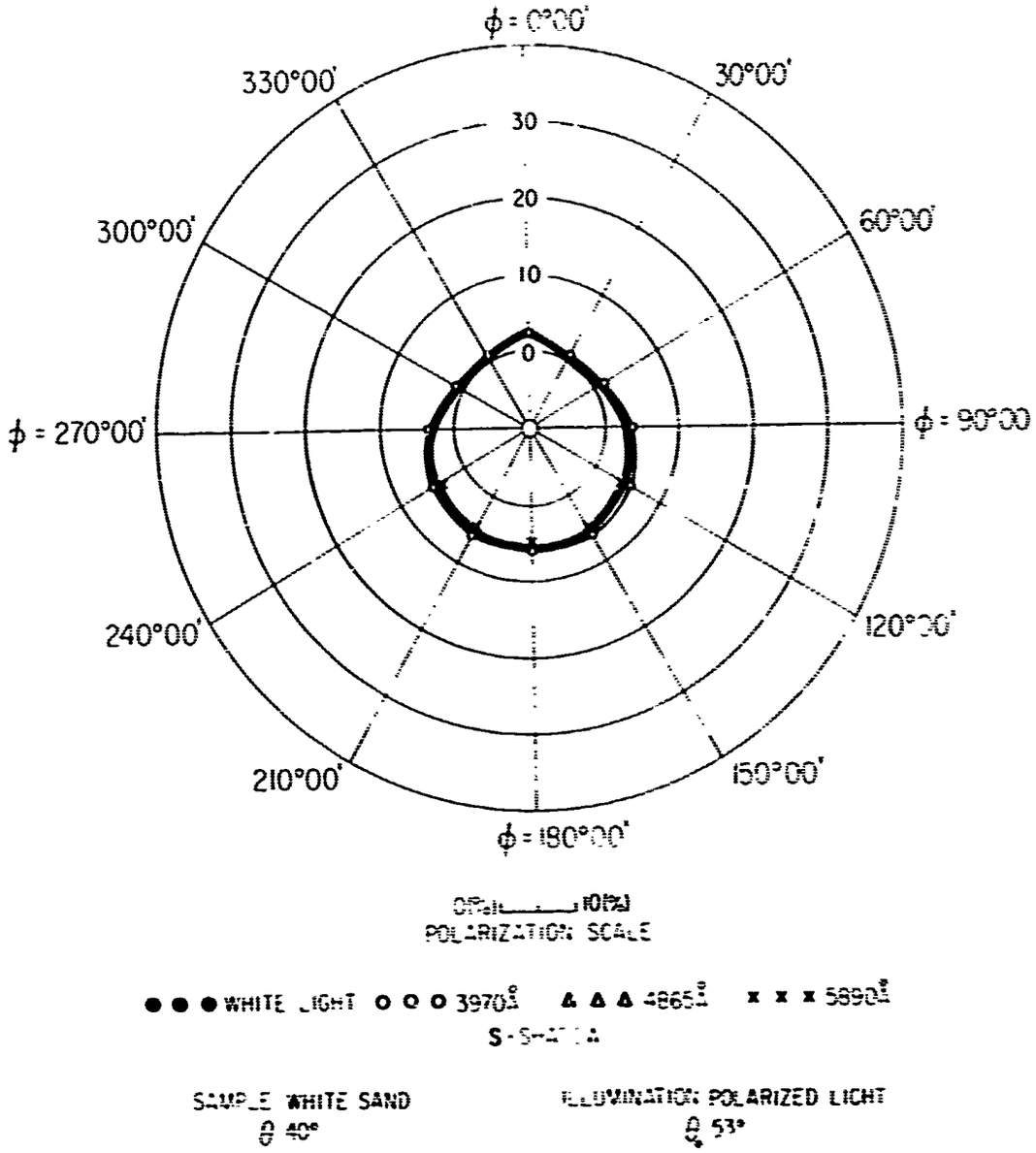


FIG 160 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.25 - 2.29\cos\phi + 0.15\cos 2\phi + 0.58\cos 3\phi + 0.55\cos 4\phi + 0.25\cos 5\phi + 0.20\cos 6\phi + 0.21\sin\phi + 0.60\sin 2\phi - 0.18\sin 3\phi + 0.60\sin 4\phi - 0.14\sin 5\phi$$

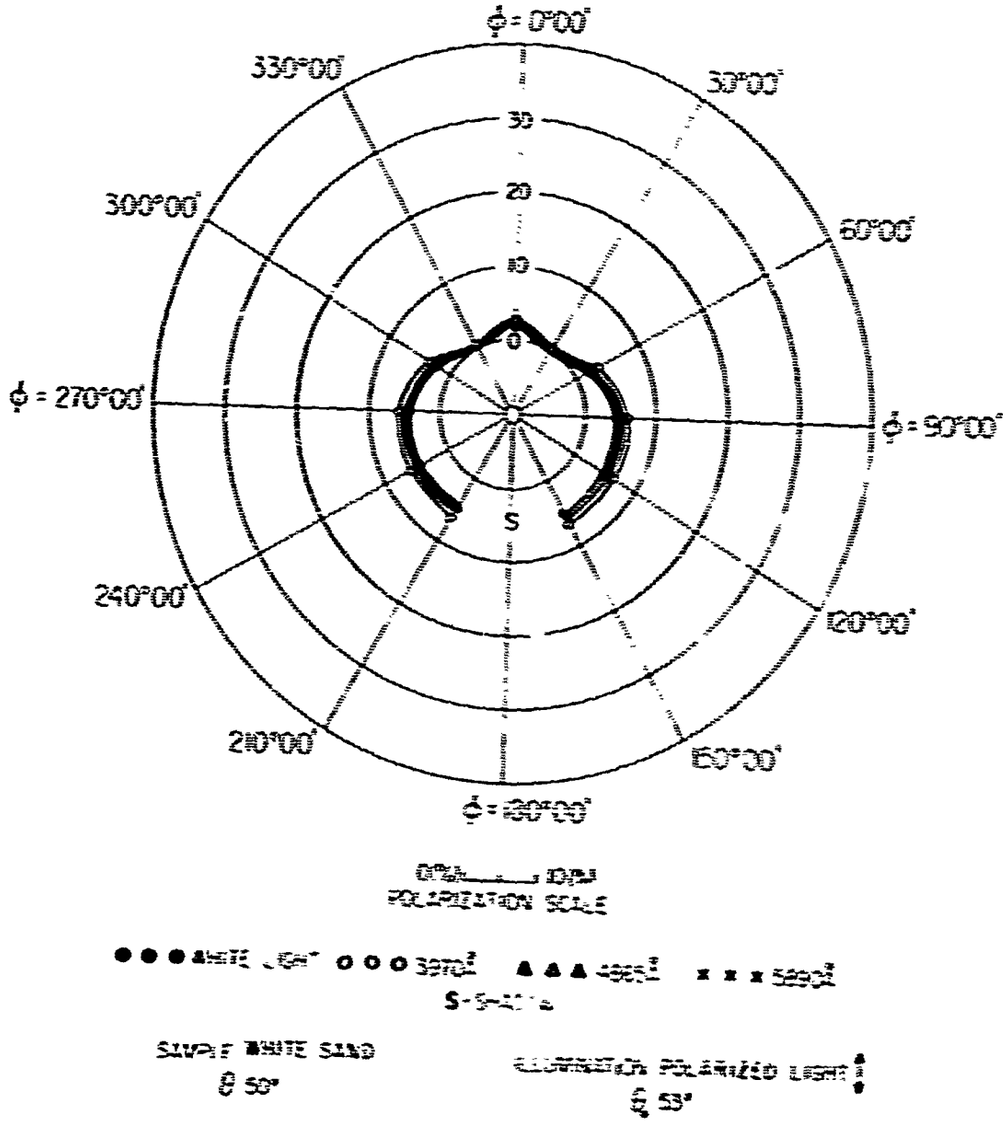


FIG 16: POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 3.83 - 2.55\cos\phi - 0.30\cos 2\phi + 0.27\cos 3\phi + 0.52\cos 4\phi + 0.54\cos 5\phi + 0.40\cos 6\phi + 0.39\sin\phi + 0.12\sin 2\phi - 0.17\sin 3\phi - 0.14\sin 4\phi - 0.10\sin 5\phi$$

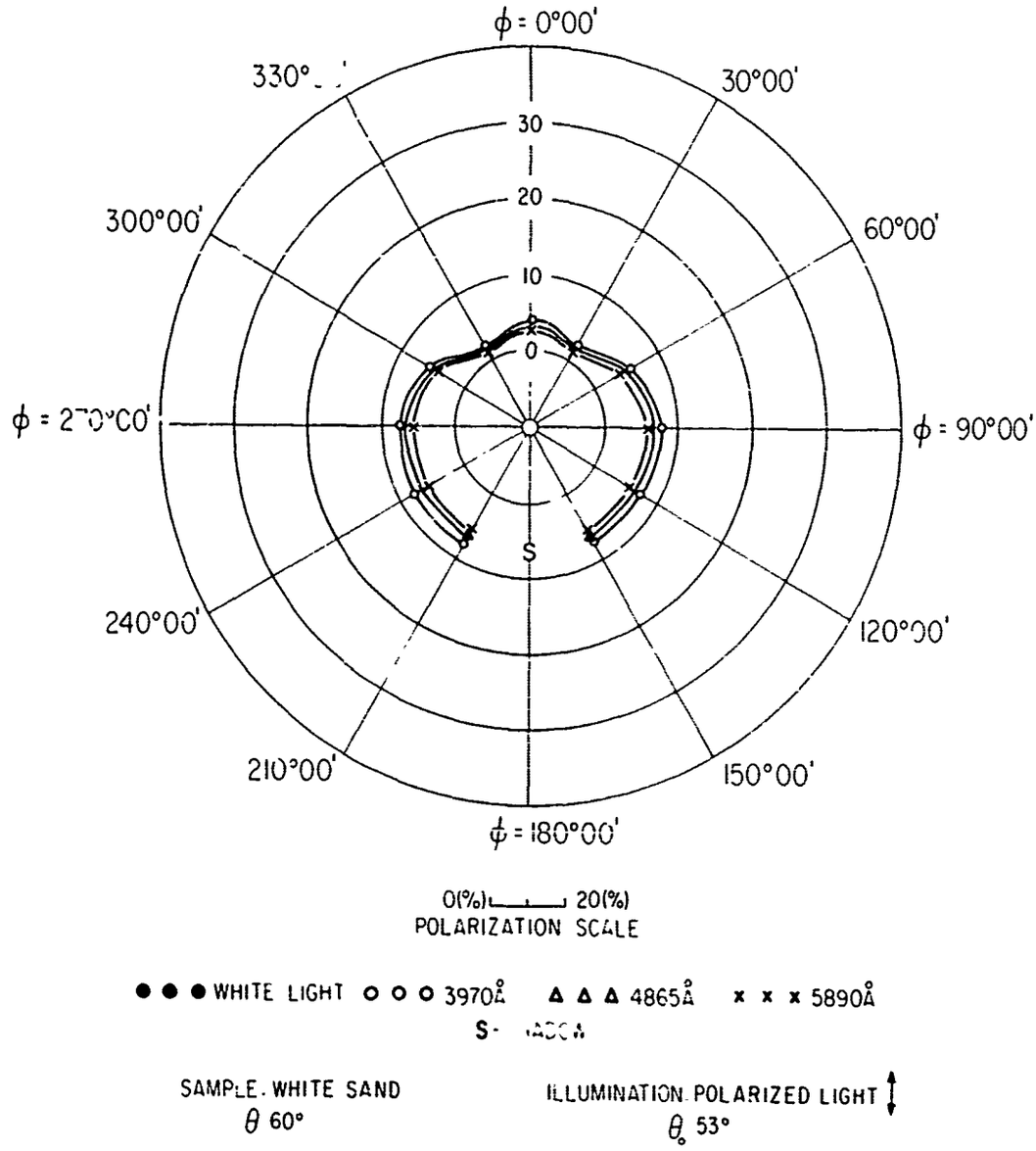


FIG 162 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.08 - 1.95\cos\varphi - 0.74\cos 2\varphi - 0.02\cos 3\varphi + 0.49\cos 4\varphi + 0.47\cos 5\varphi + 0.53\cos 6\varphi + 0.38\sin\varphi + 0.30\sin 2\varphi - 0.12\sin 3\varphi + 0.90\sin 4\varphi - 0.05\sin 5\varphi$$

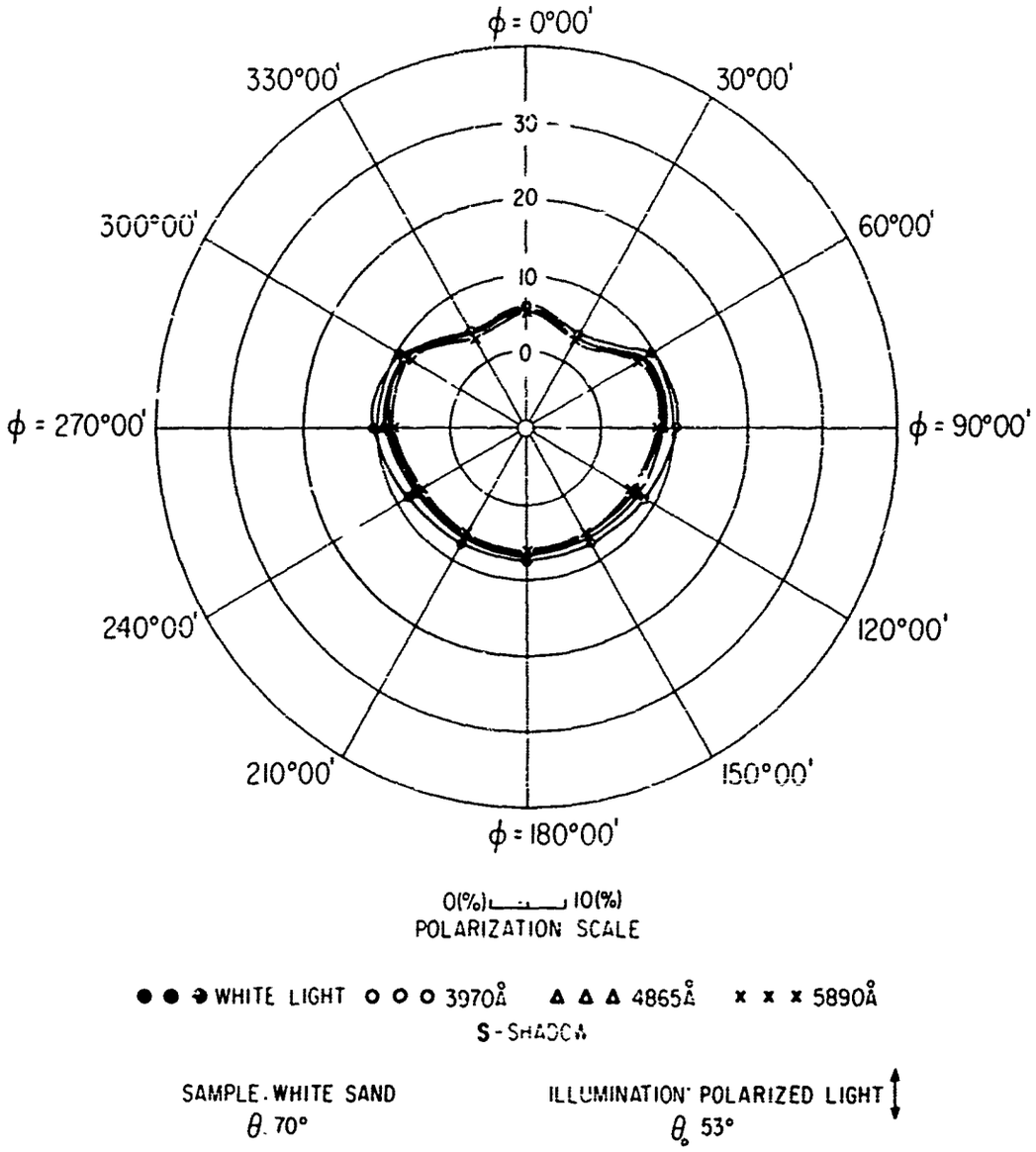
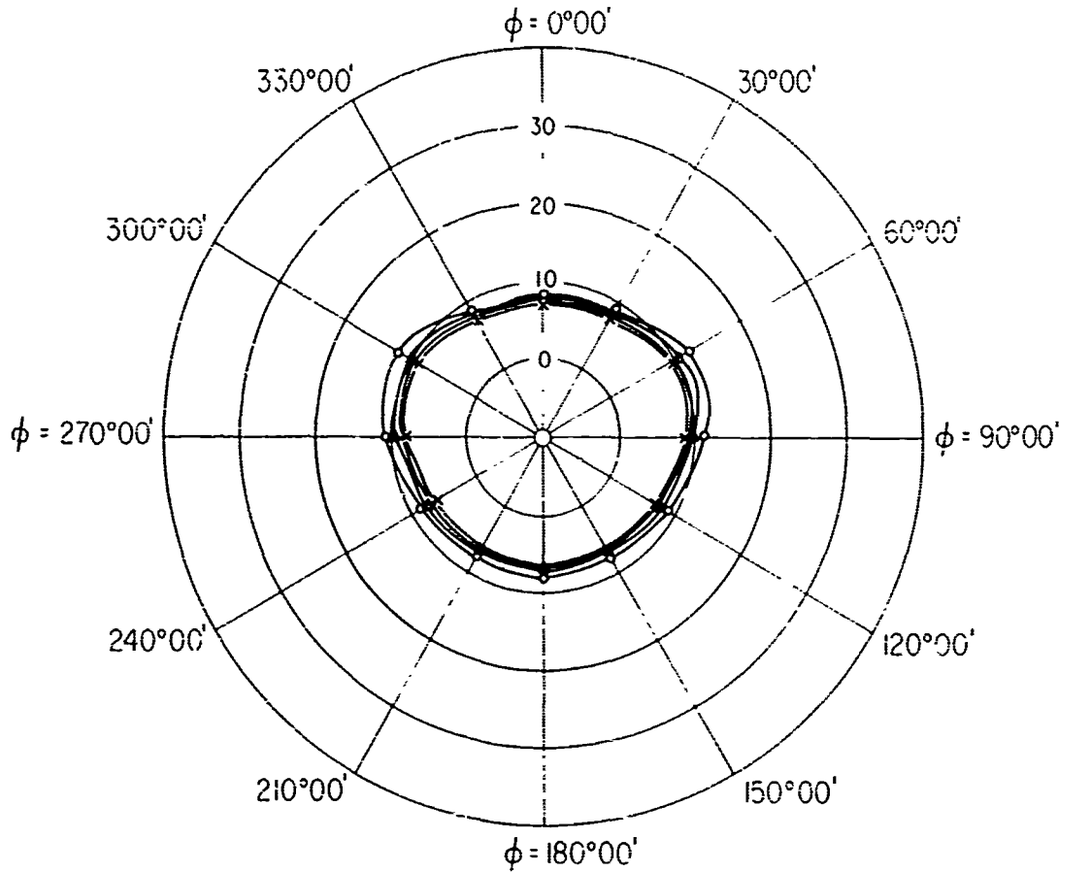


FIG 163 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.65 - 0.78\cos\varphi - 0.92\cos 2\varphi - 0.28\cos 3\varphi + 0.38\cos 4\varphi + 0.26\cos 5\varphi + 0.40\cos 6\varphi + 0.68\sin\varphi + 0.42\sin 2\varphi - 0.05\sin 3\varphi - 0.01\sin 4\varphi + 0.12\sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 75°

ILLUMINATION POLARIZED LIGHT ↕
θ_0 53°

FIG 164 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.83 + 0.55 \cos\varphi - 0.85 \cos 2\varphi - 0.32 \cos 3\varphi + 0.17 \cos 4\varphi + 0.06 \cos 5\varphi + 0.50 \cos 6\varphi + 0.43 \sin\varphi + 0.64 \sin 2\varphi + 0.18 \sin 3\varphi + 0.03 \sin 4\varphi + 0.06 \sin 6\varphi$$

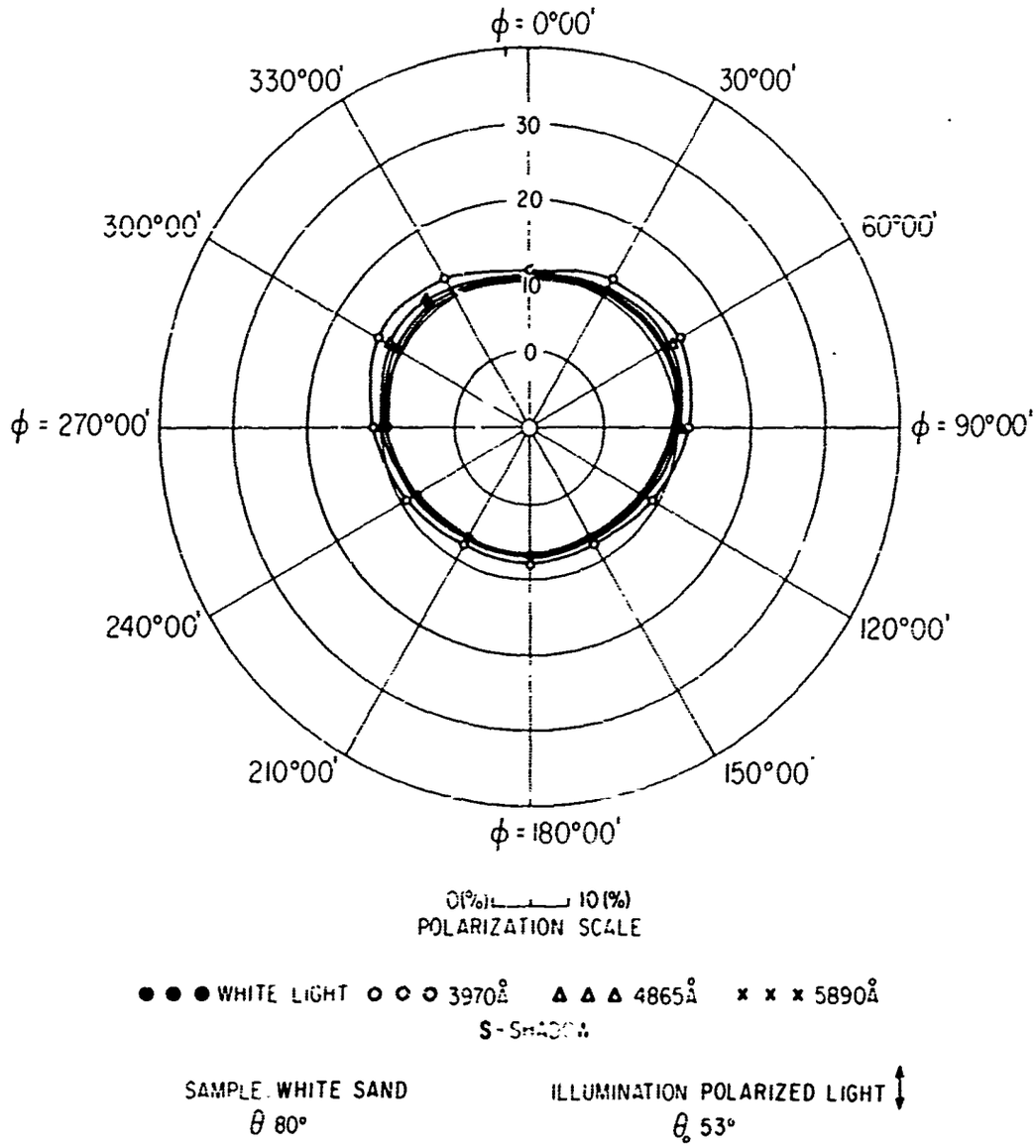
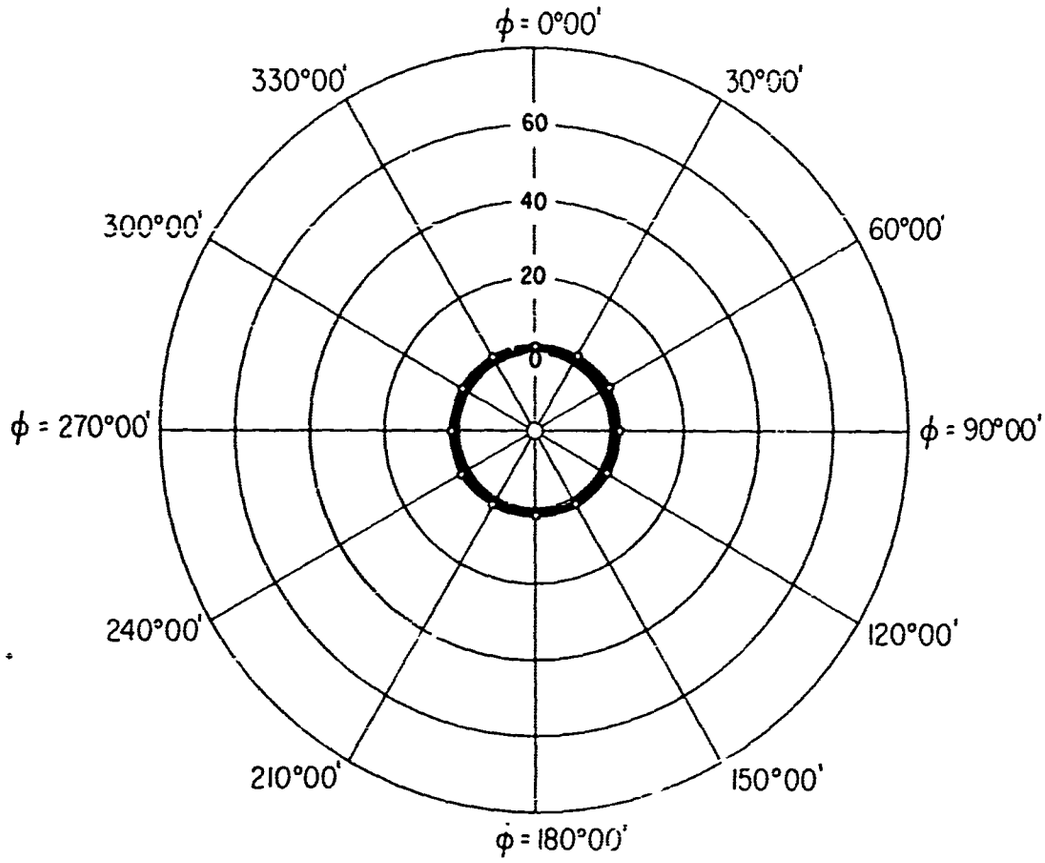


FIG 165 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 9.05 + 1.92\cos\varphi - 0.65\cos 2\varphi - 0.68\cos 3\varphi + 0.10\cos 4\varphi + 0.16\cos 5\varphi + 0.20\cos 6\varphi + 0.86\sin\varphi + 0.57\sin 2\varphi + 0.18\sin 3\varphi + 0.09\sin 4\varphi + 0.02\sin 5\varphi$$



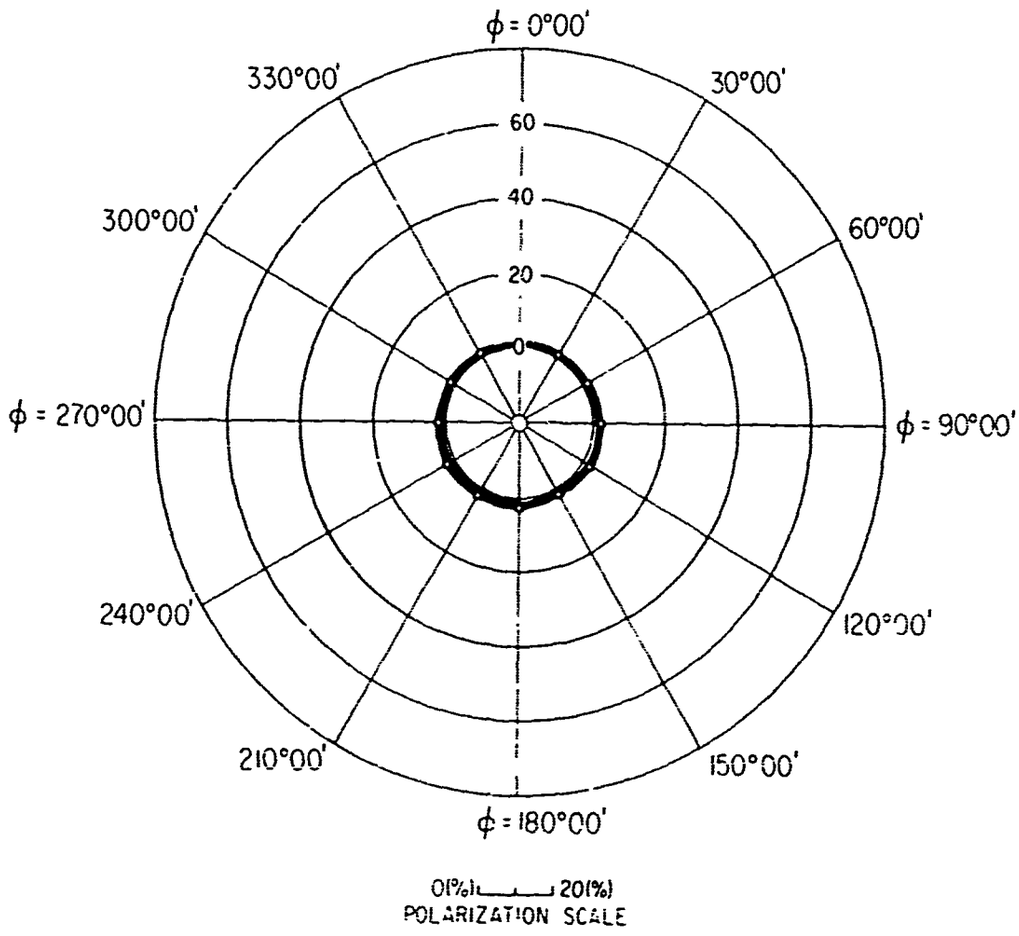
0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å △ △ △ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: WHITE SAND
θ 0°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0 78° 30'

FIG 166 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. WHITE SAND
θ 10°

ILLUMINATION POLARIZED LIGHT ↕
θ_0 78° 30'

FIG 167 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 1.42 - 0.47 \cos\varphi + 0.05 \cos 2\varphi - 0.07 \cos 3\varphi + 0.05 \cos 4\varphi - 0.07 \cos 5\varphi + 0.15 \cos 6\varphi - 0.14 \sin\varphi - 0.23 \sin 2\varphi - 0.05 \sin 3\varphi - 0.00 \sin 4\varphi + 0.04 \sin 5\varphi$$

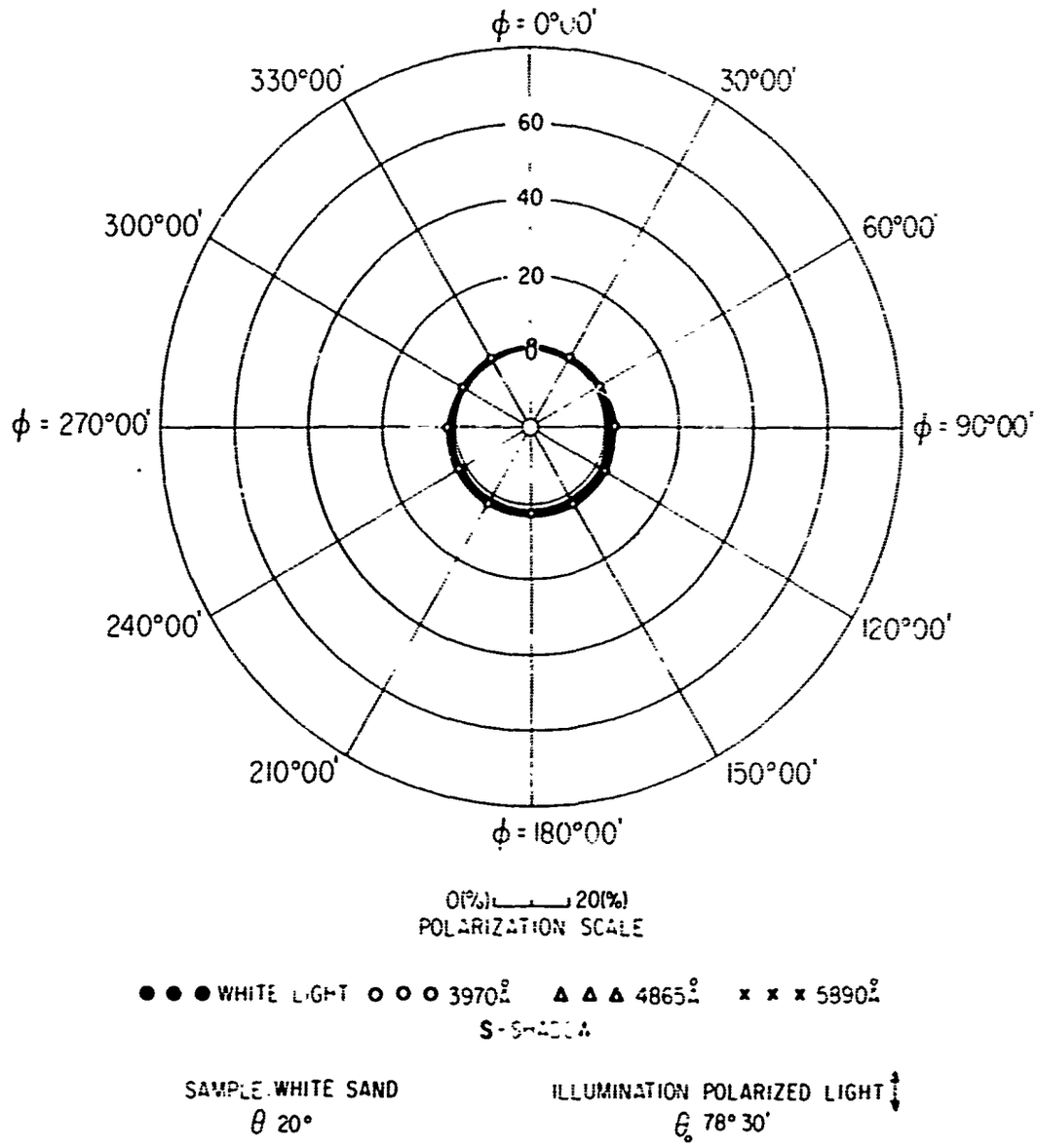


FIG.168 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 1.50 - 1.00\cos\varphi - 0.02\cos 2\varphi + 0.00\cos 3\varphi - 0.01\cos 4\varphi - 0.10\cos 5\varphi + 0.05\cos 6\varphi + 0.19\sin\varphi - 0.16\sin 2\varphi - 0.22\sin 3\varphi - 0.10\sin 4\varphi - 0.10\sin 5\varphi$$

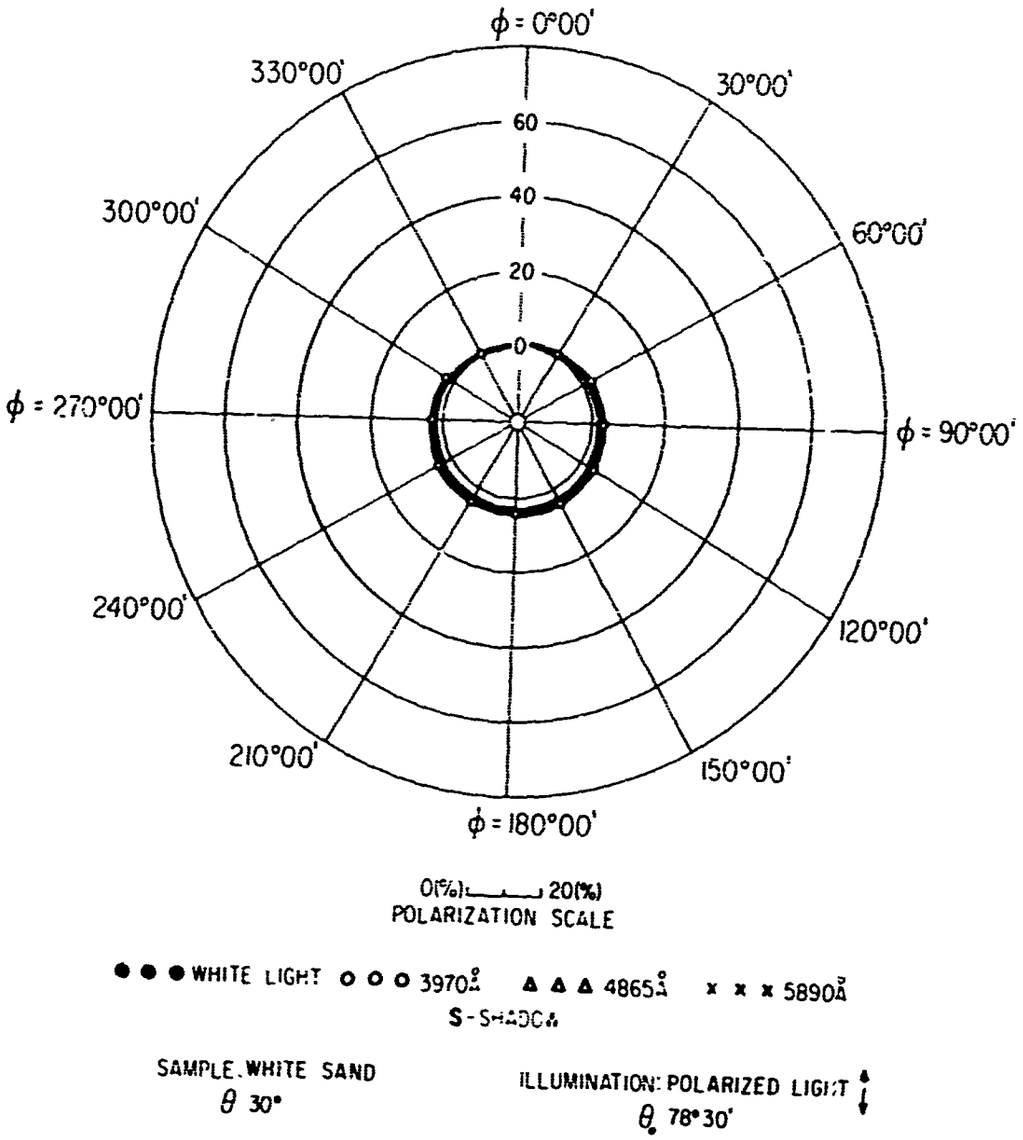


FIG 169 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 2.26 - 1.28\cos\varphi - 0.39\cos 2\varphi + 0.00\cos 3\varphi + 0.32\cos 4\varphi + 0.18\cos 5\varphi + 0.48\cos 6\varphi + 0.04\sin\varphi - 0.07\sin 2\varphi + 0.08\sin 3\varphi - 0.07\sin 4\varphi + 0.04\sin 5\varphi$$

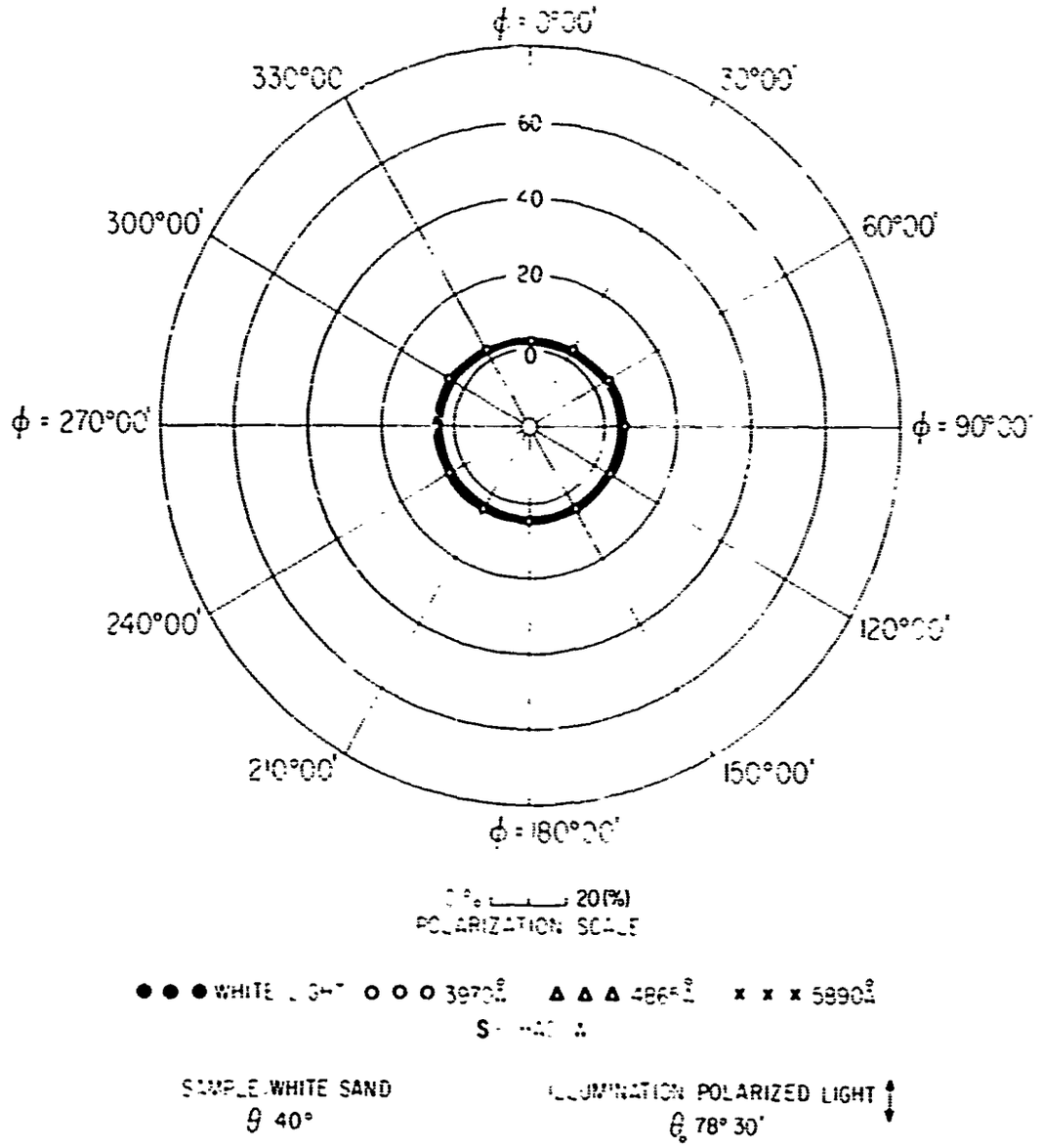


FIG 170 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\omega) = 3.88 - 0.81 \cos\omega - 0.68 \cos 2\omega - 0.42 \cos 3\omega - 0.05 \cos 4\omega + 0.28 \cos 5\omega + 0.22 \cos 6\omega + 0.00 \sin\omega + 0.00 \sin 2\omega + 0.00 \sin 3\omega + 0.00 \sin 4\omega + 0.00 \sin 5\omega$$

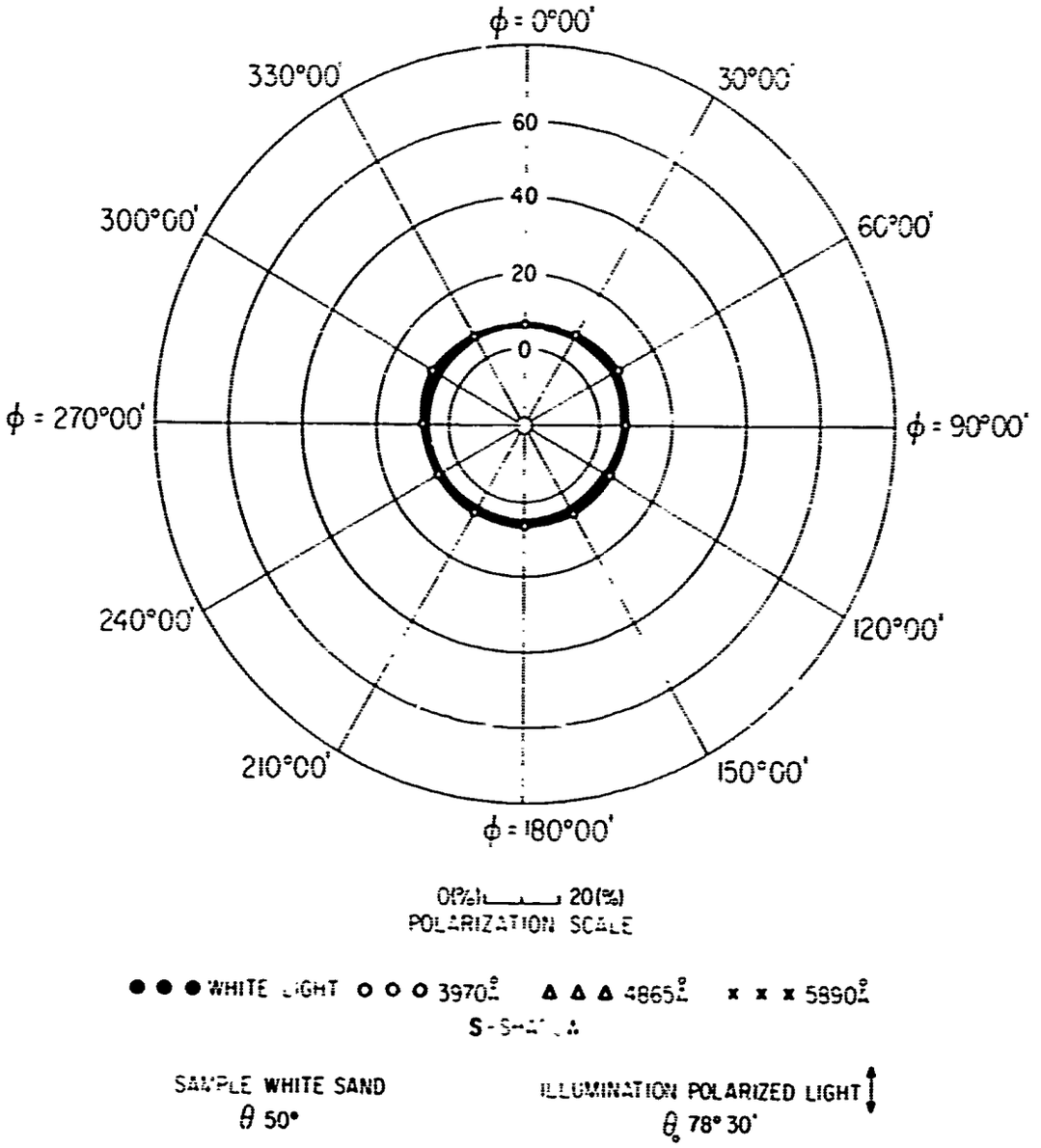


FIG. 171 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.32 + 0.95 \cos\varphi - 0.51 \cos 2\varphi - 0.65 \cos 3\varphi - 0.09 \cos 4\varphi + 0.05 \cos 5\varphi + 0.27 \cos 6\varphi + 0.02 \sin\varphi + 0.04 \sin 2\varphi + 0.05 \sin 3\varphi + 0.04 \sin 4\varphi + 0.02 \sin 5\varphi$$

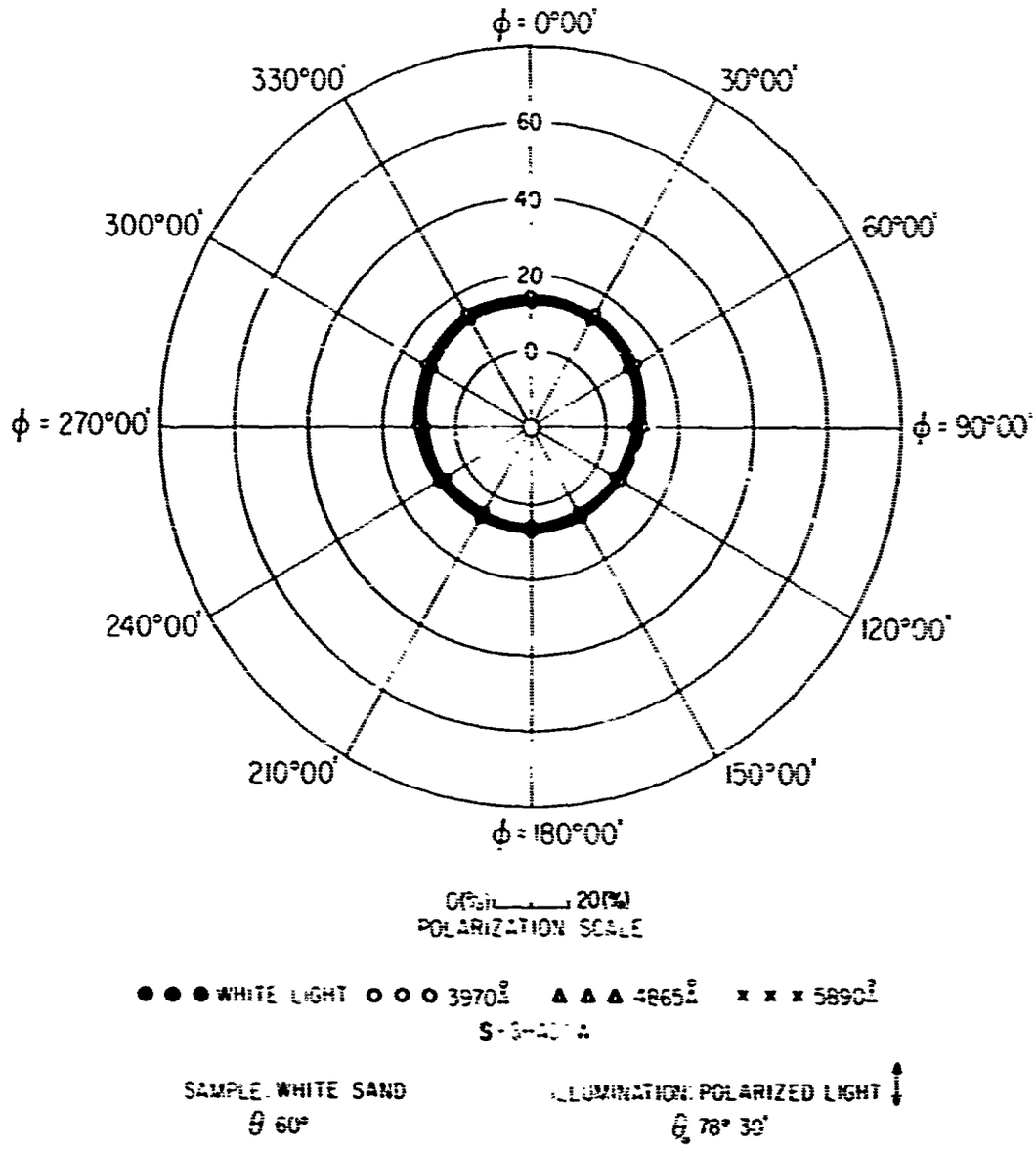


FIG 172 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 9.51 + 3.77 \cos\phi + 0.72 \cos 2\phi - 0.32 \cos 3\phi + 0.02 \cos 4\phi - 0.13 \cos 5\phi + 0.02 \cos 6\phi + 0.00 \sin\phi + 0.00 \sin 2\phi + 0.00 \sin 3\phi + 0.00 \sin 4\phi + 0.00 \sin 5\phi$$

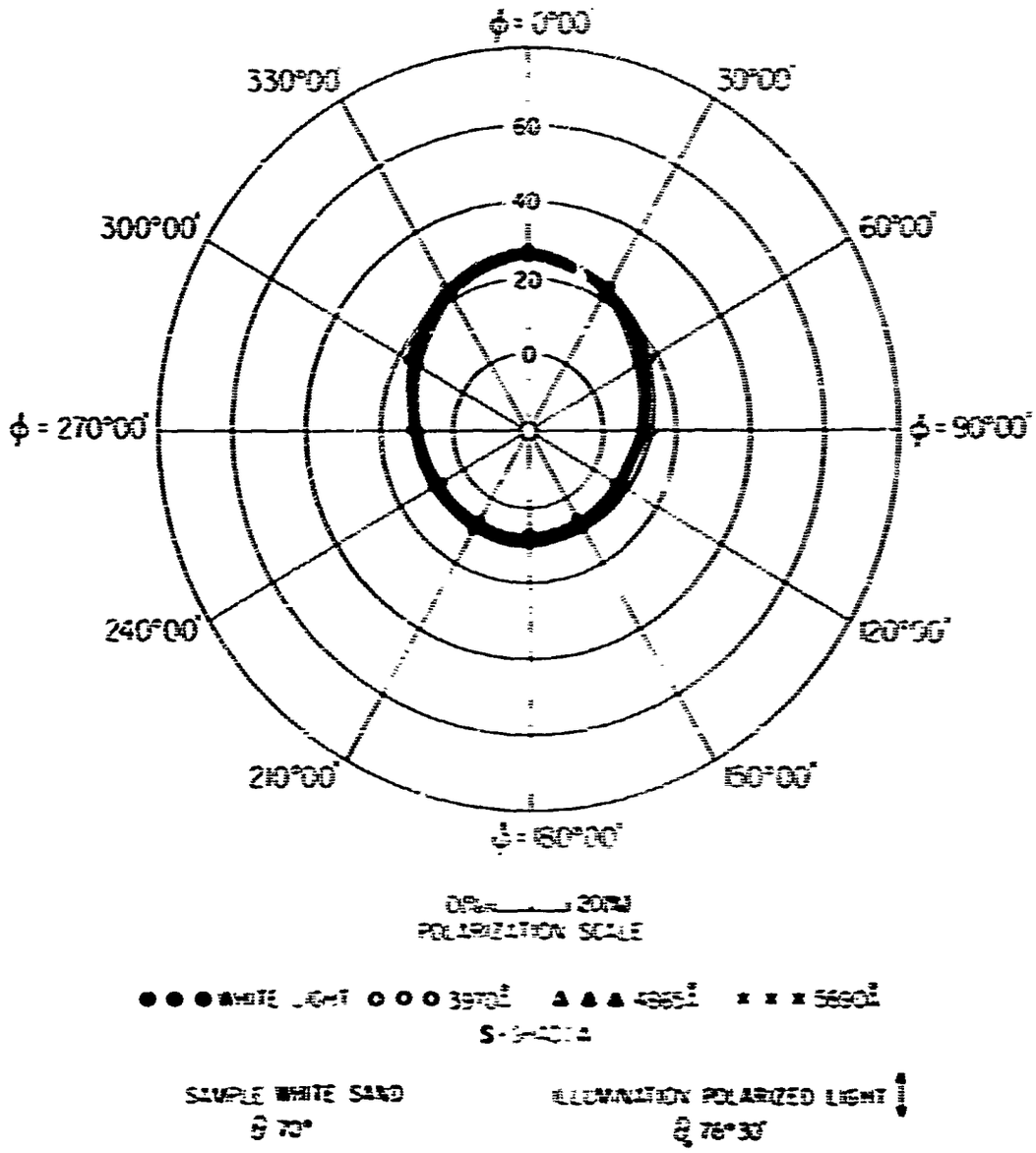


FIG. 173 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 13.43 + 8.57 \cos\phi + 3.82 \cos 2\phi + 0.67 \cos 3\phi + 0.72 \cos 4\phi - 0.03 \cos 5\phi$$
$$+ 0.27 \cos 6\phi + 0.05 \sin\phi + 0.09 \sin 2\phi + 0.10 \sin 3\phi + 0.09 \sin 4\phi + 0.05 \sin 5\phi$$

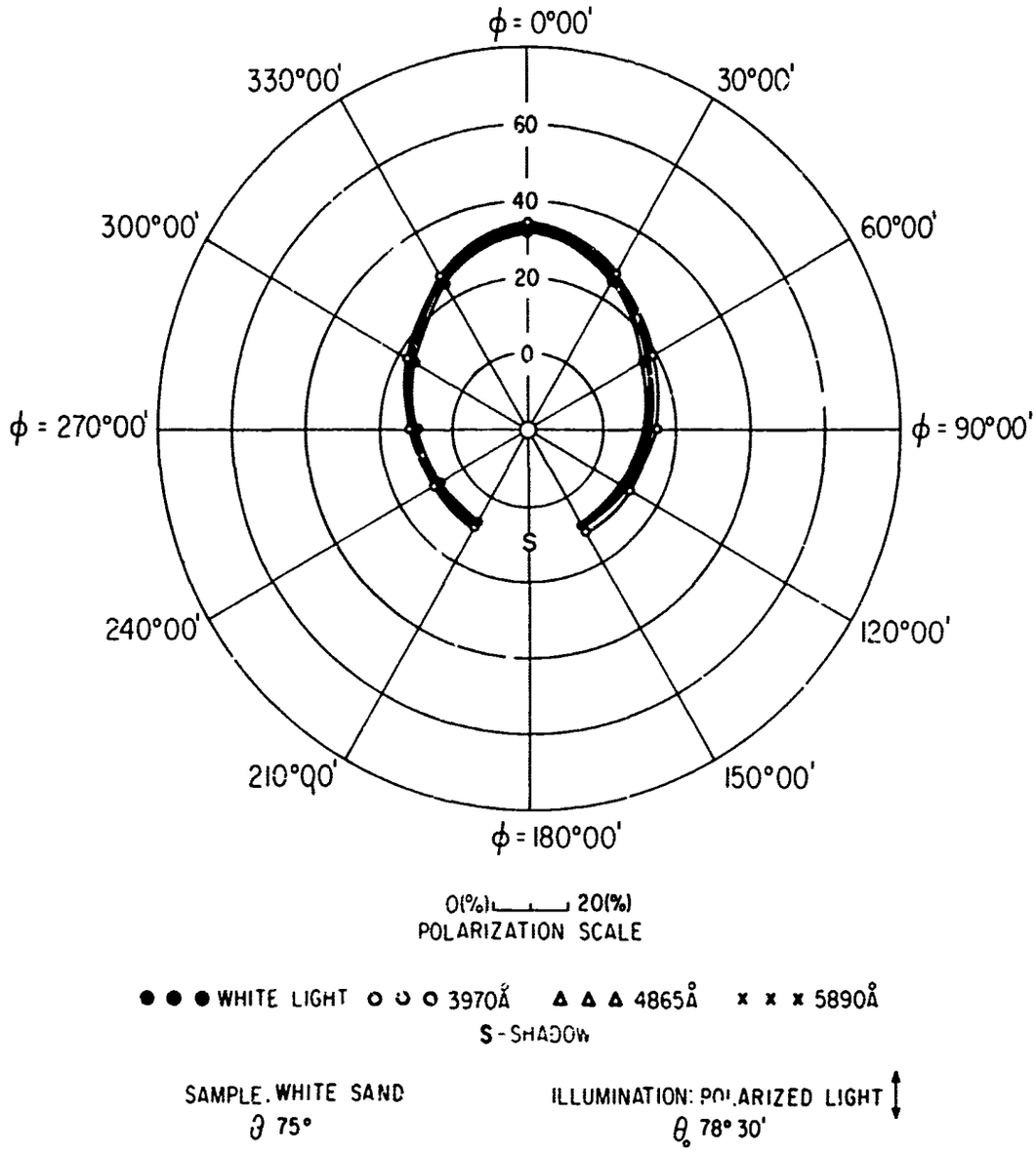


FIG 174 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 15.4 + 11.04 \cos\varphi + 4.77 \cos 2\varphi + 2.07 \cos 3\varphi + 1.10 \cos 4\varphi + 0.30 \cos 5\varphi + 0.27 \cos 6\varphi + 0.13 \sin\varphi - 0.06 \sin 2\varphi + 0.27 \sin 3\varphi - 0.06 \sin 4\varphi + 0.13 \sin 5\varphi$$

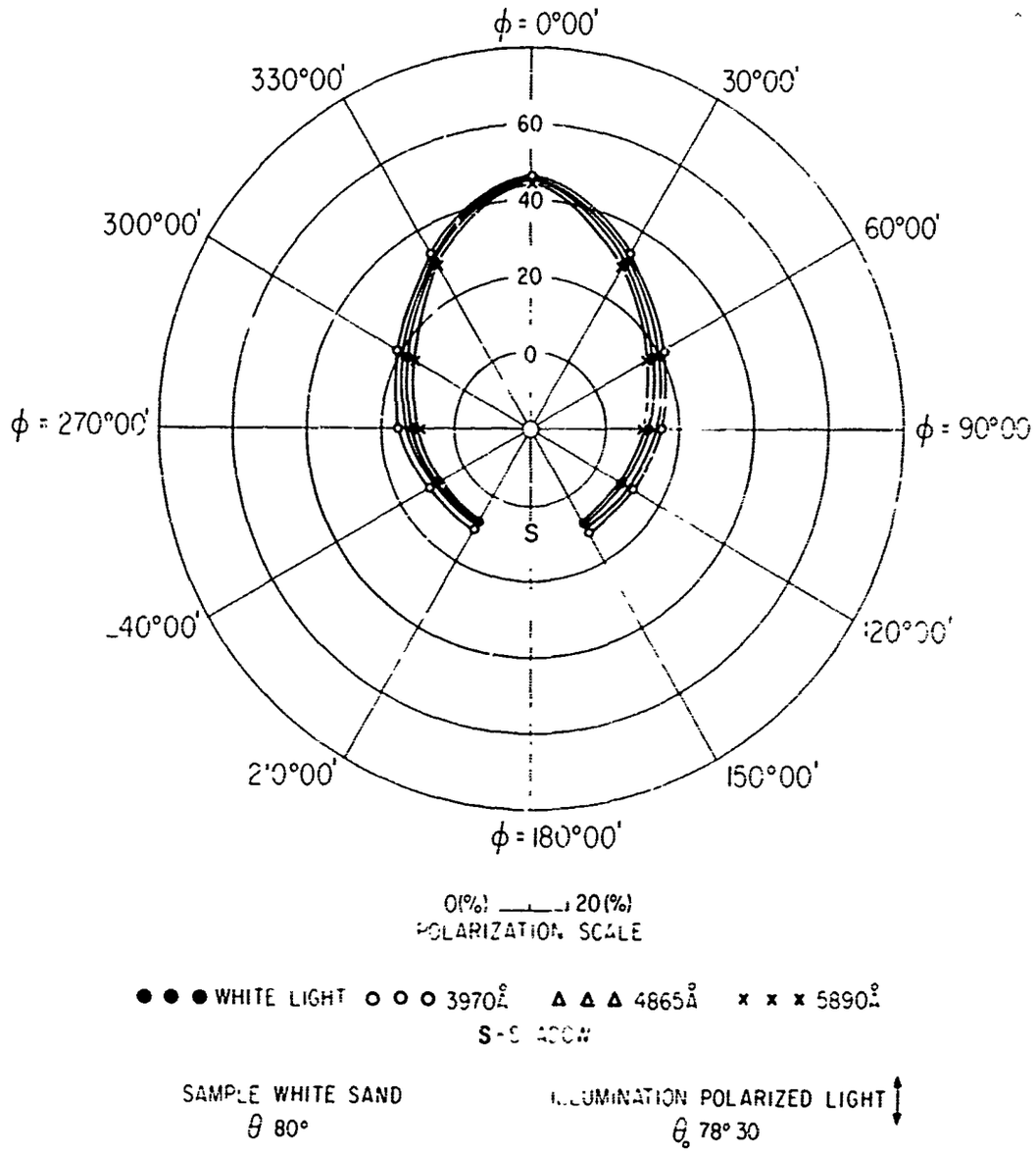
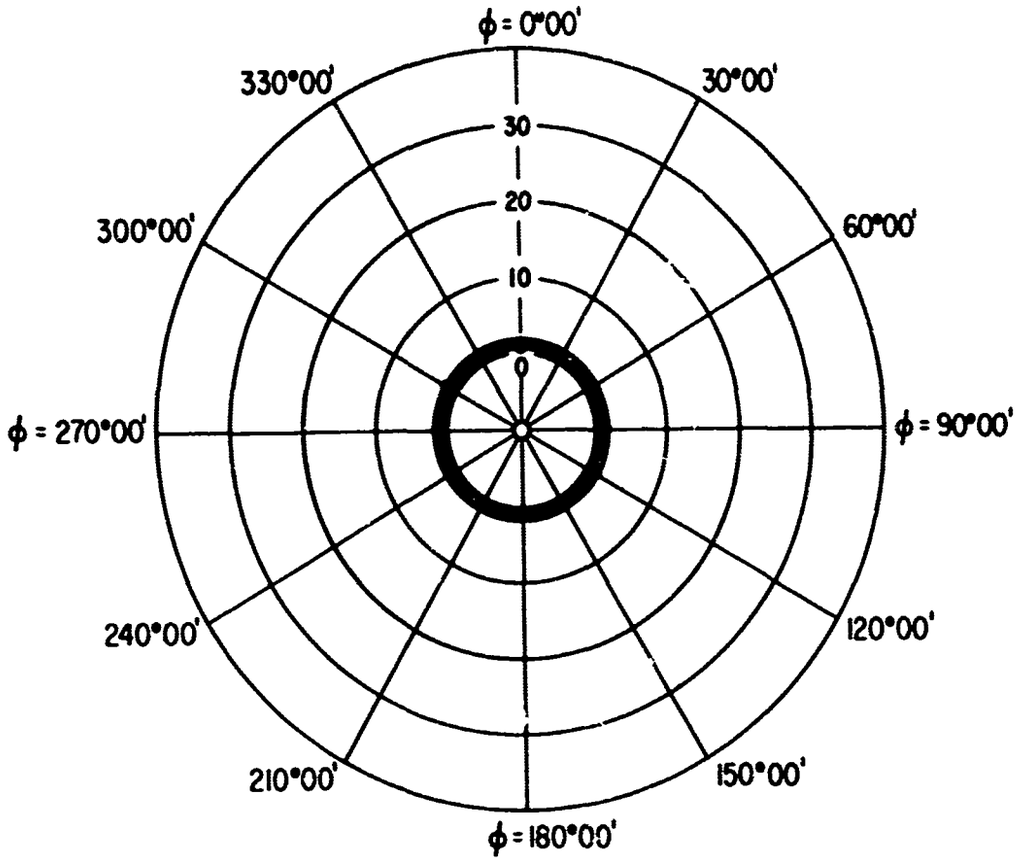


FIG 175 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.91 + 14.40 \cos\varphi + 7.53 \cos 2\varphi + 2.98 \cos 3\varphi + 1.92 \cos 4\varphi + 1.62 \cos 5\varphi + 1.28 \cos 6\varphi + 0.04 \sin\varphi + 0.06 \sin 2\varphi - 0.03 \sin 3\varphi - 0.03 \sin 4\varphi + 0.07 \sin 5\varphi$$



● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S - SHADOW

SAMPLE: SOIL
θ: 10°

ILLUMINATION: NATURAL LIGHT
θ: 0°

FIG. 176. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

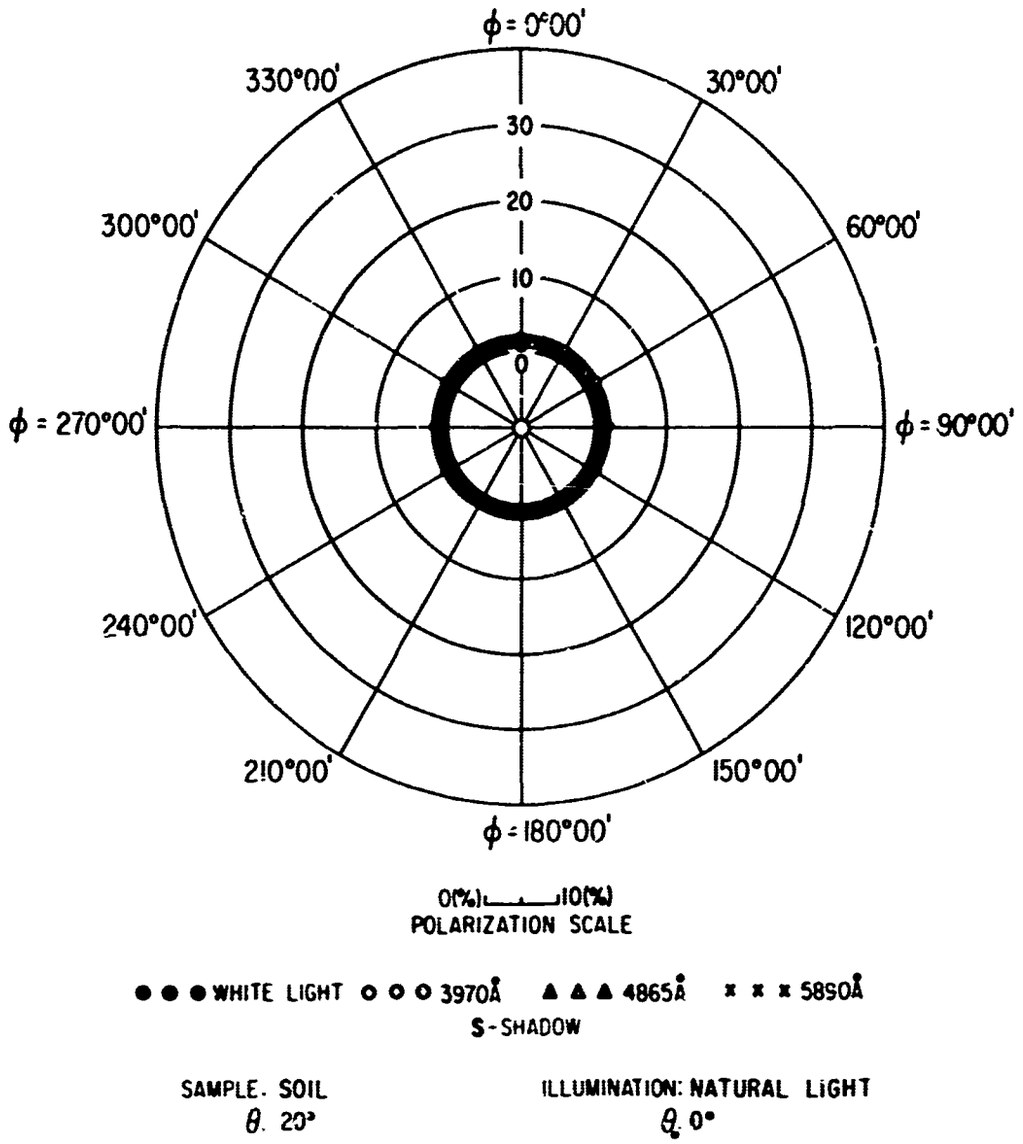
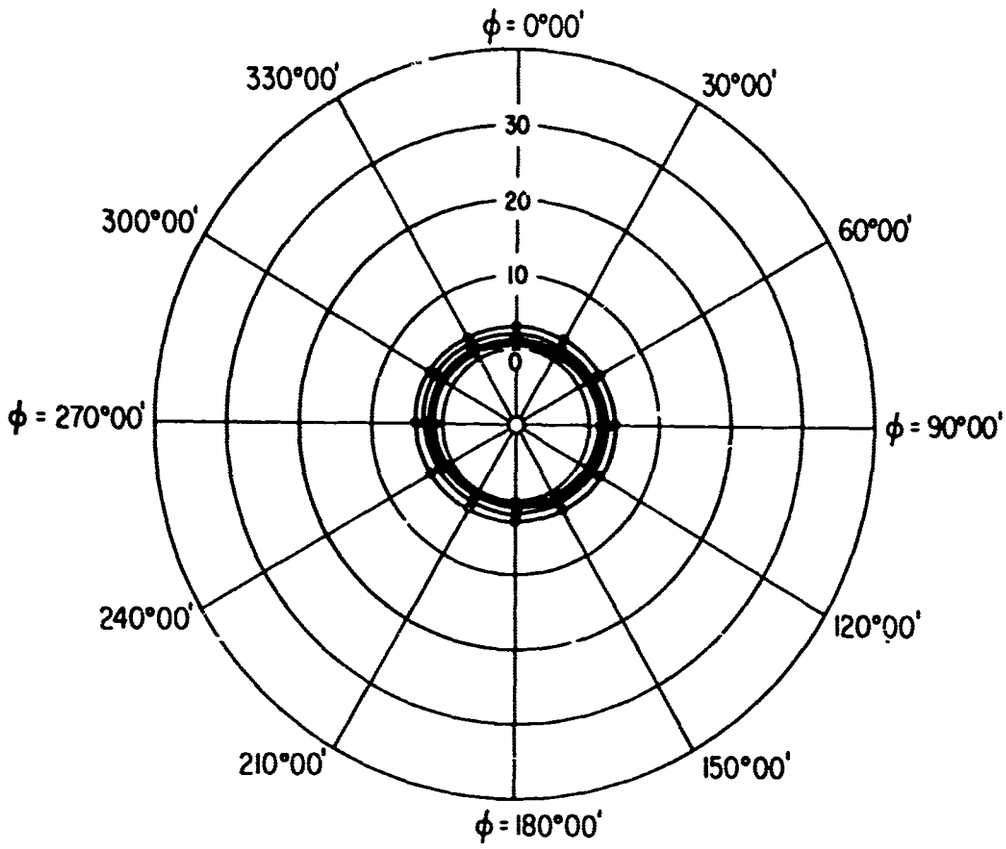


FIG. 177. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



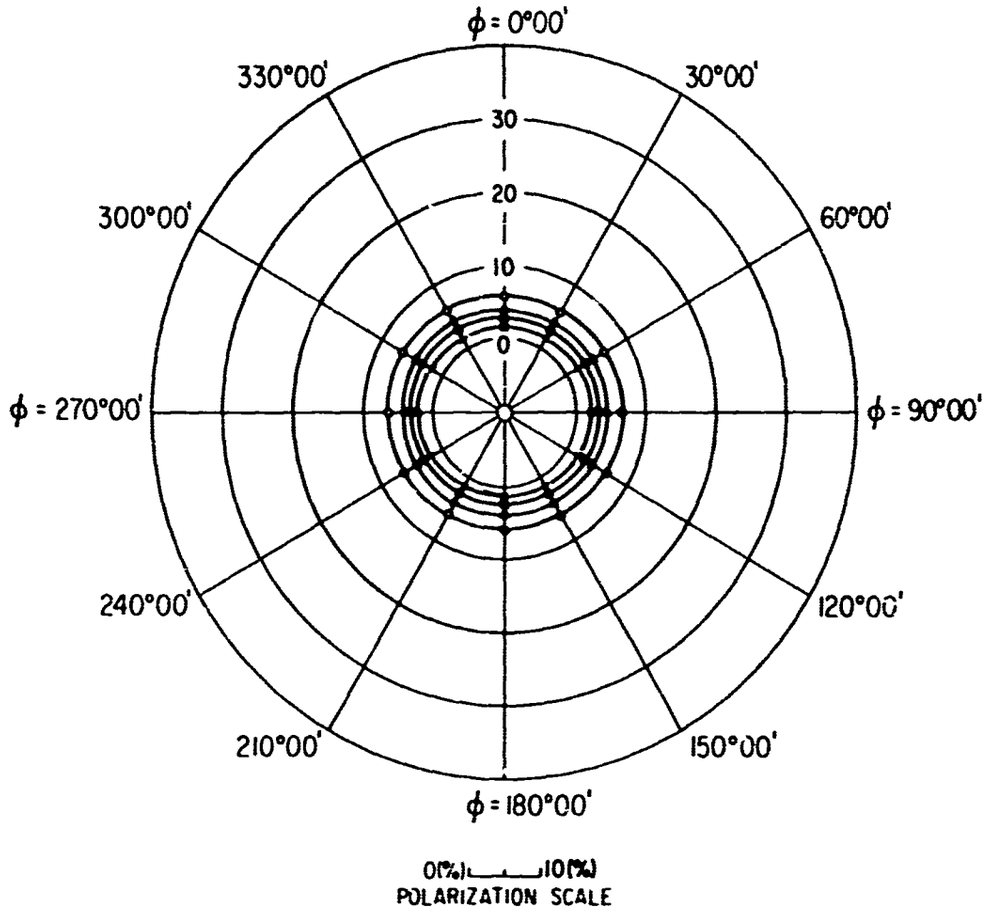
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. SOIL
θ 30°

ILLUMINATION: NATURAL LIGHT
θ_i 0°

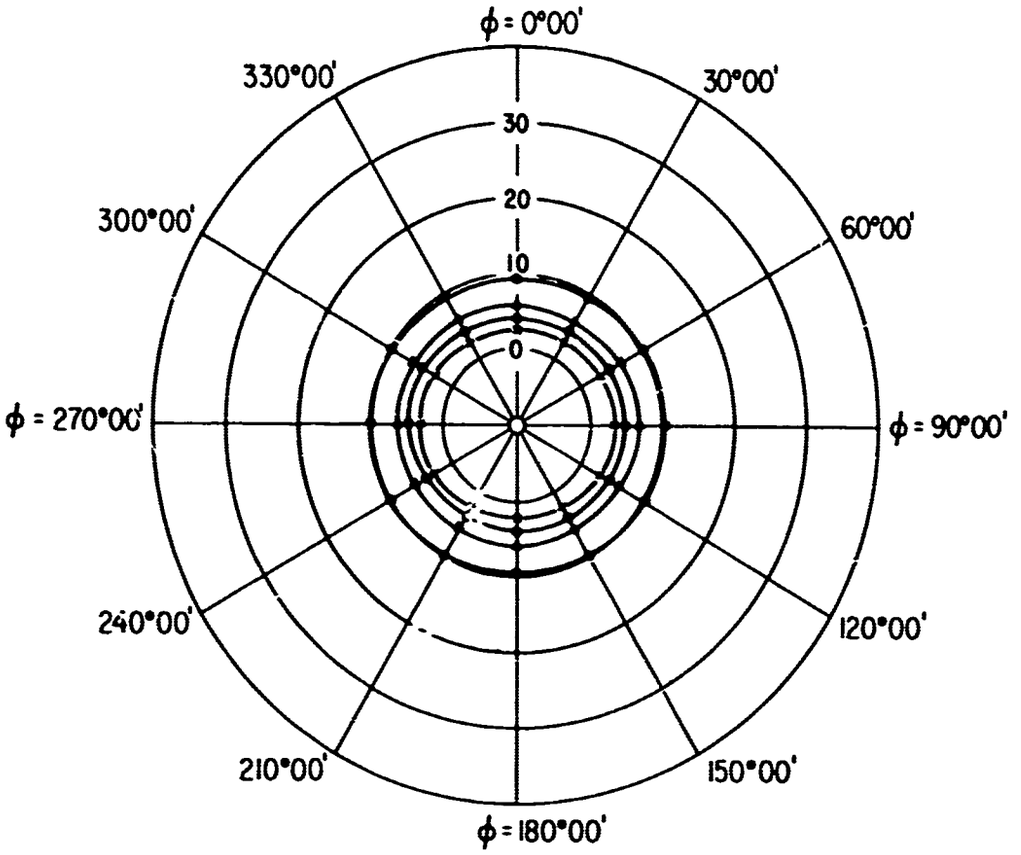
FIG. 178. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



SAMPLE. SOIL
θ 40°

ILLUMINATION: NATURAL LIGHT
θ_0 0°

FIG. 179. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



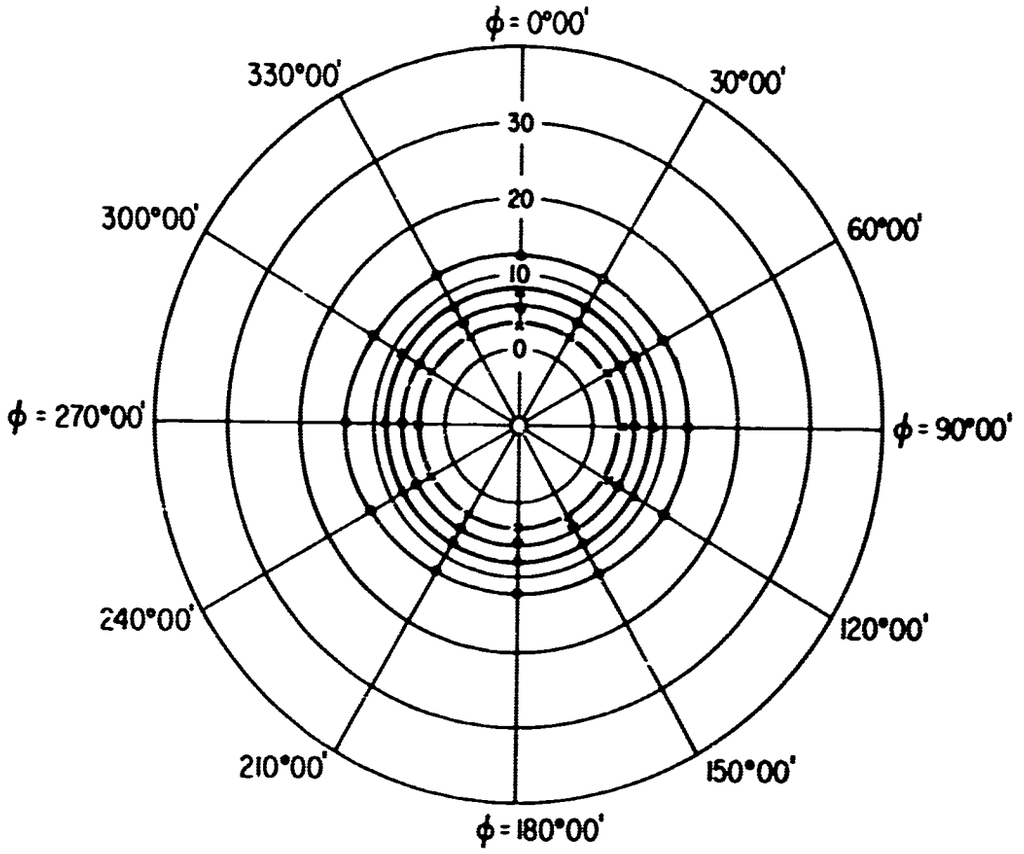
0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. SOIL
θ. 50°

ILLUMINATION: NATURAL LIGHT
θ_0 0°

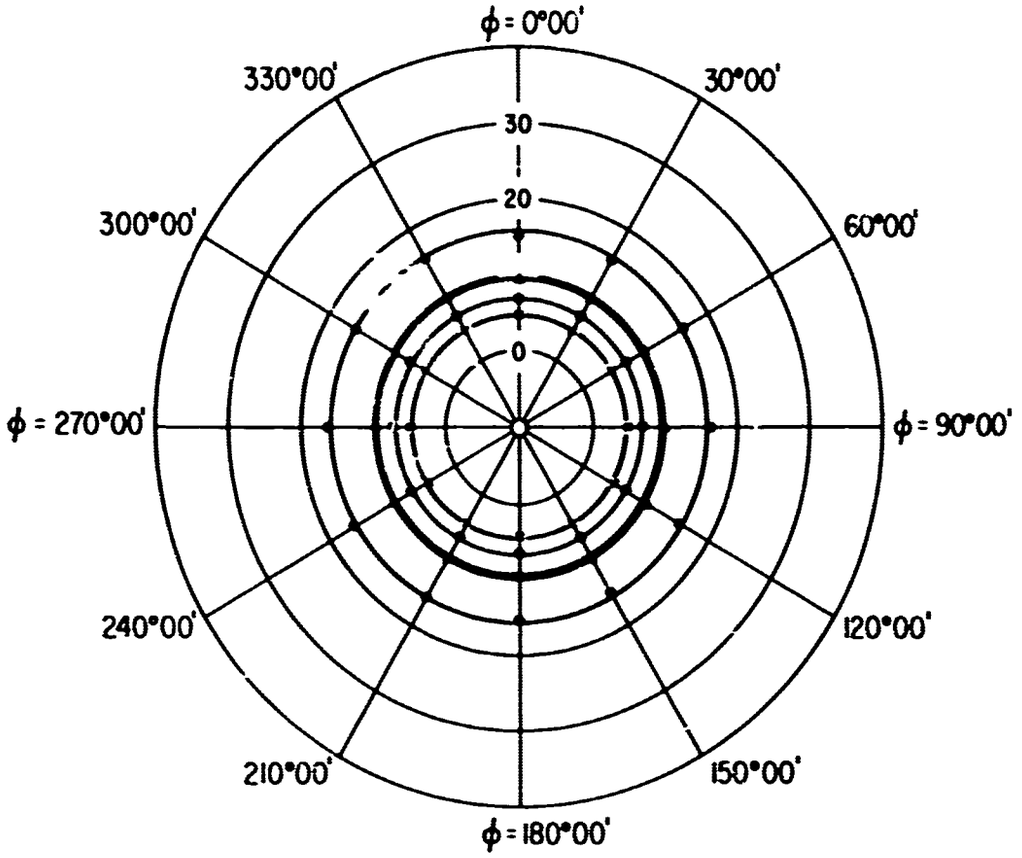
FIG. 180. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



SAMPLE. SOIL
θ 60°

ILLUMINATION: NATURAL LIGHT
θ_i 0°

FIG. 181. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å + x x x 5890Å
S - SHADOW

SAMPLE - SOIL
θ 70°

ILLUMINATION: NATURAL LIGHT
θ_0 0°

FIG. 182. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

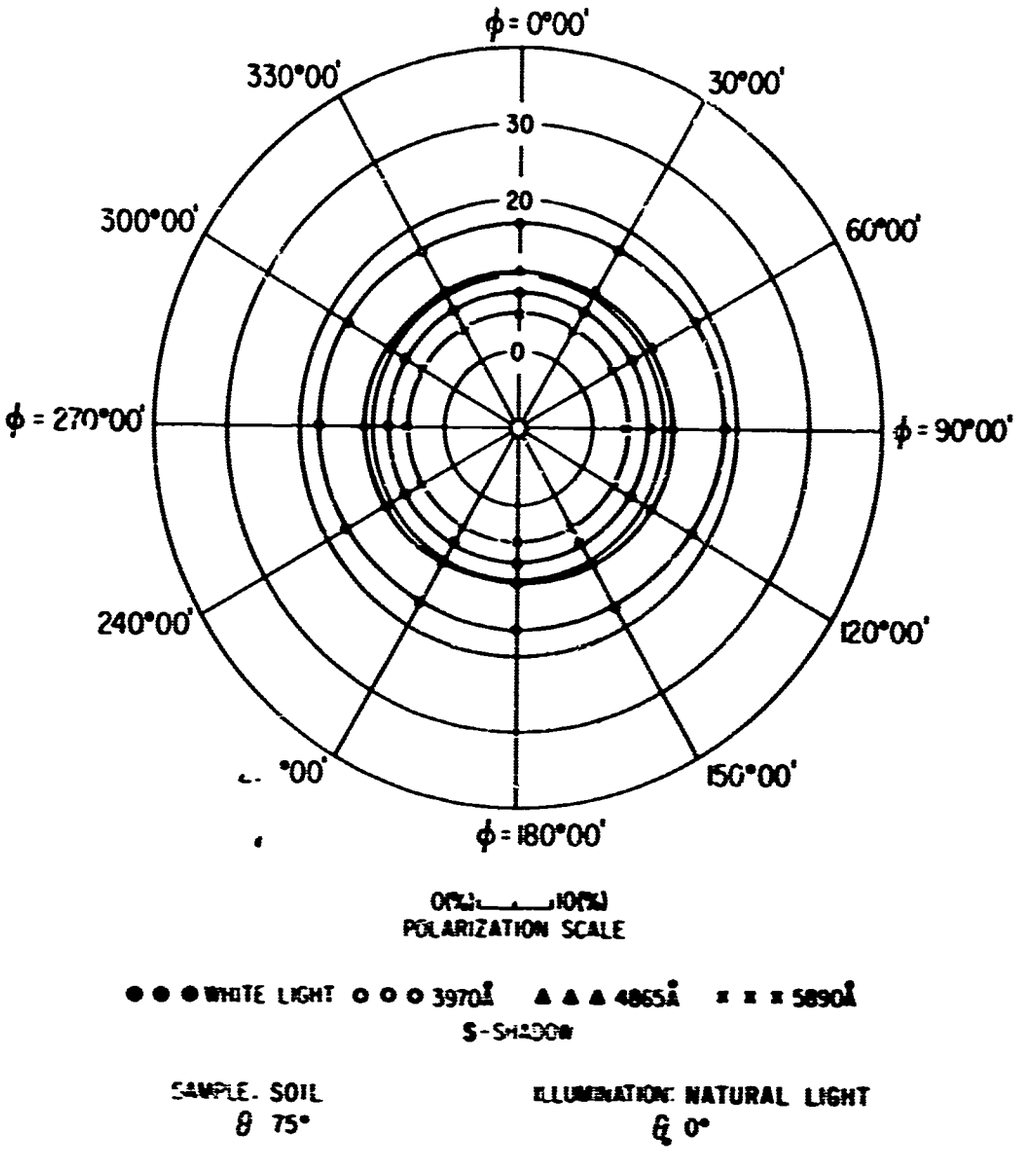


FIG. 183. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

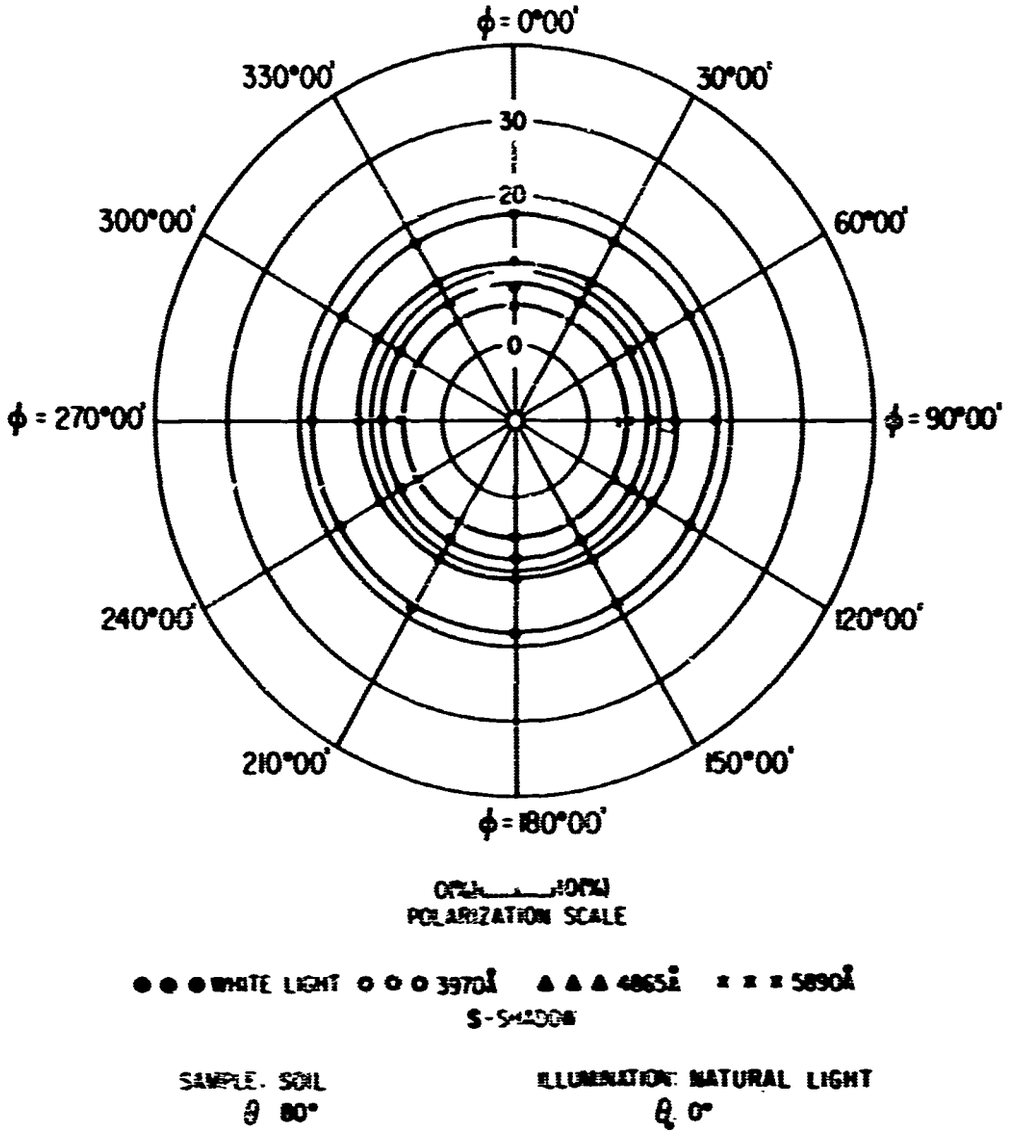


FIG. 184. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

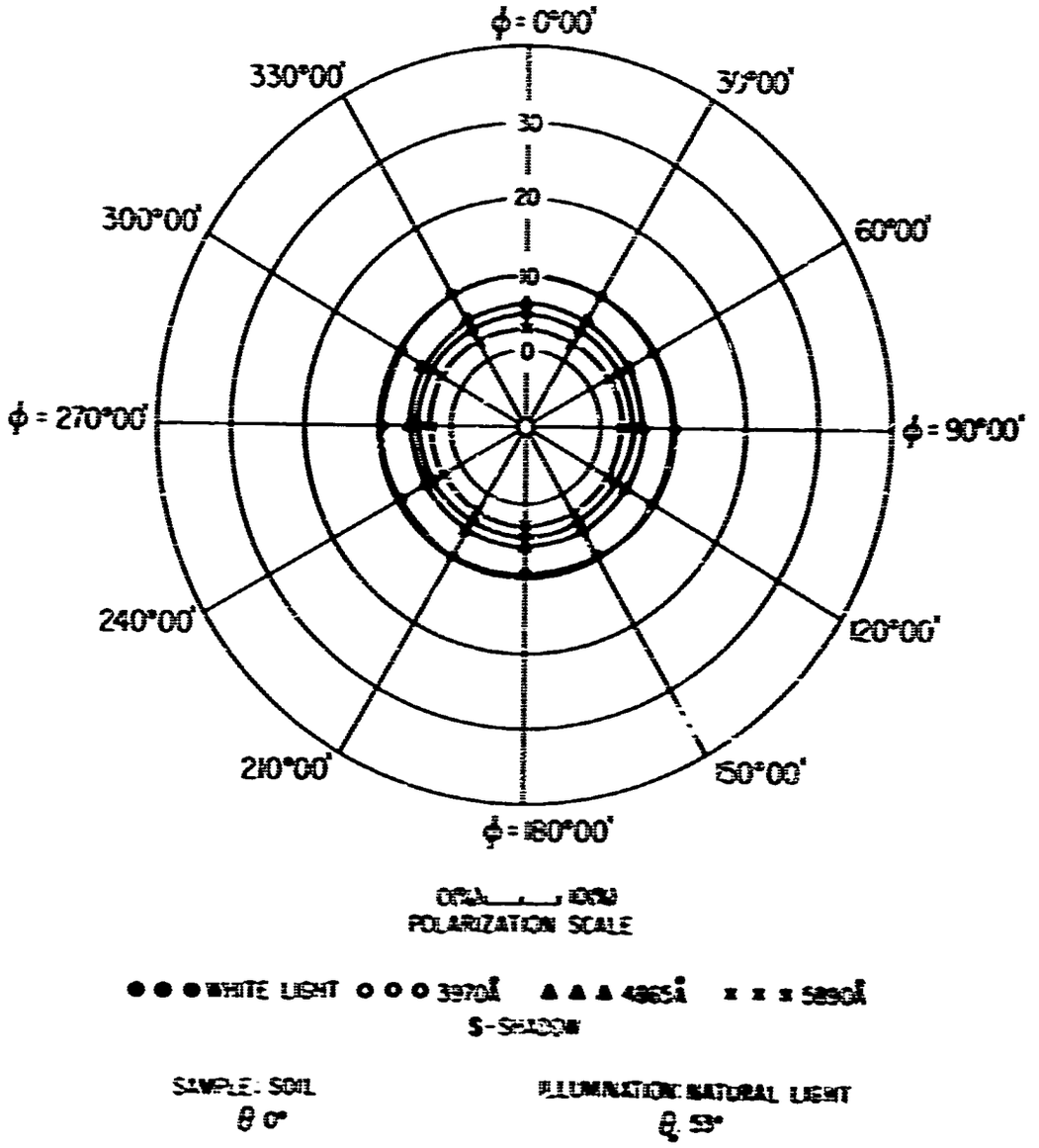
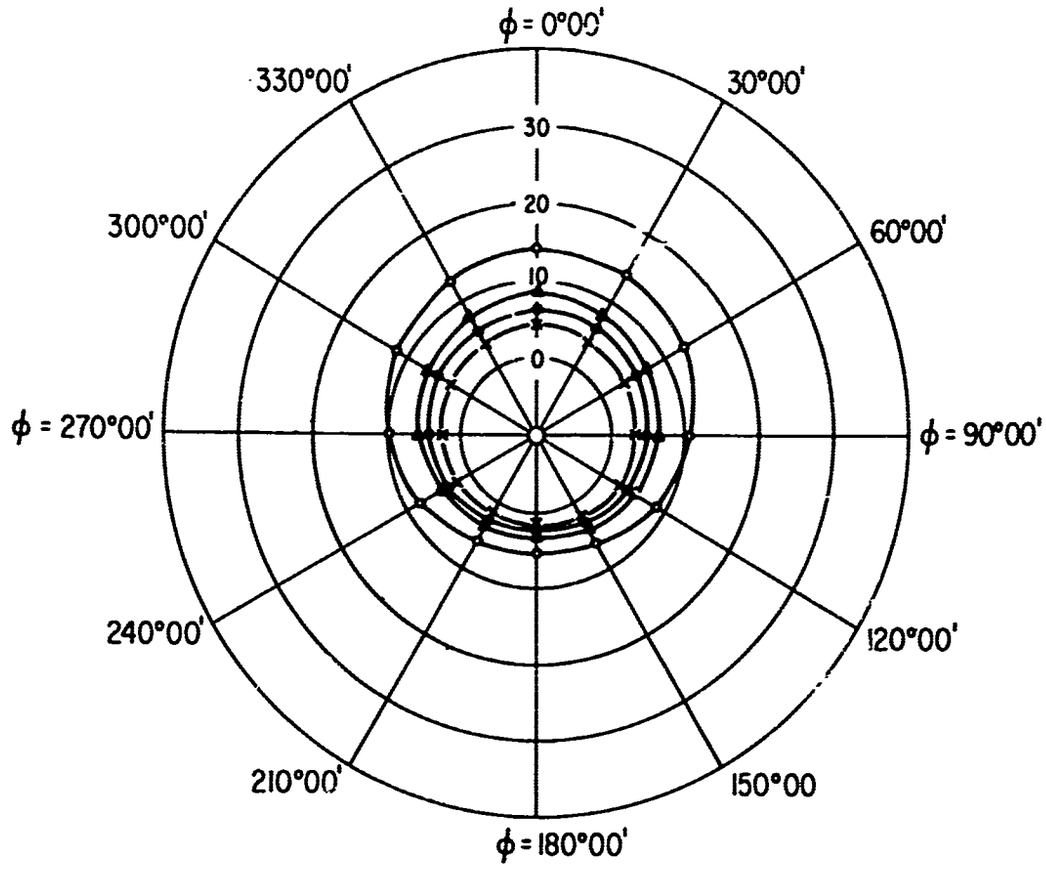


FIG 185 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT



0(%) 10(%)
POLARIZATION SCALE

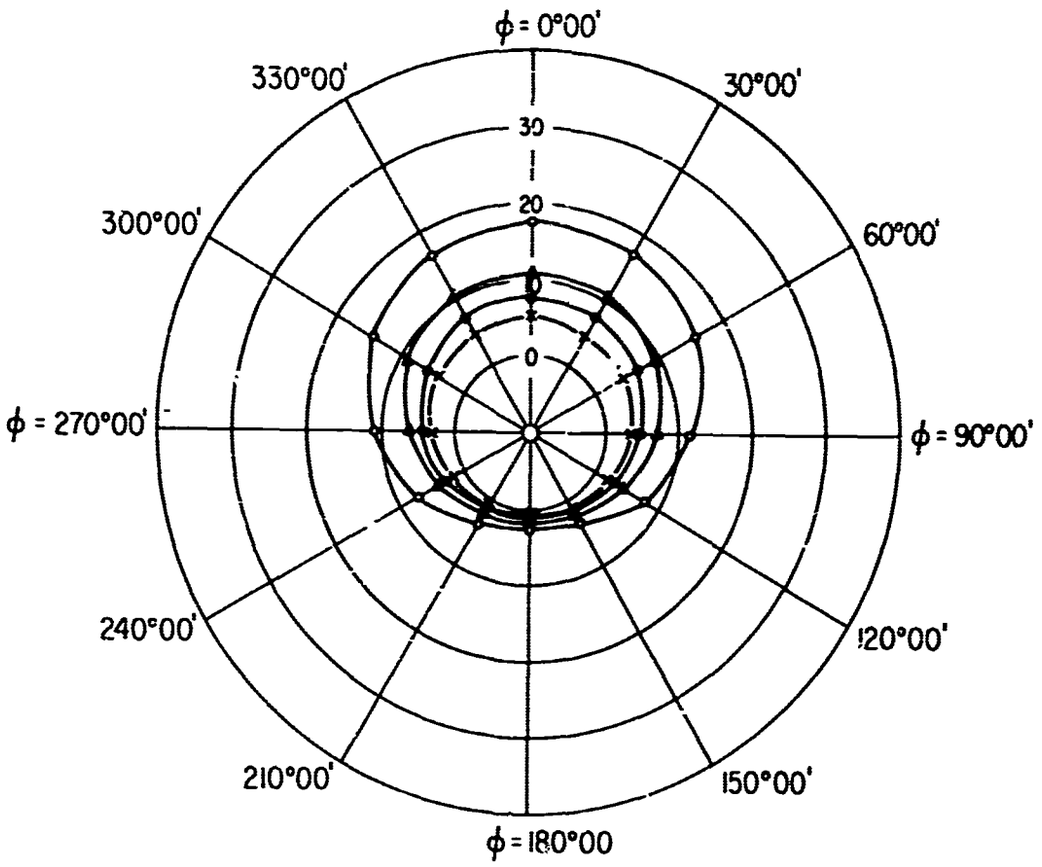
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 10°

ILLUMINATION: NATURAL LIGHT
θ_0: 53°

FIG. 186 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.62 + 1.32 \cos\varphi + 0.56 \cos 2\varphi - 0.45 \cos 3\varphi + 0.52 \cos 4\varphi - 0.47 \cos 5\varphi + 0.58 \cos 6\varphi + 0.16 \sin\varphi - 0.01 \sin 2\varphi + 0.07 \sin 3\varphi - 0.04 \sin 4\varphi + 0.01 \sin 5\varphi$$



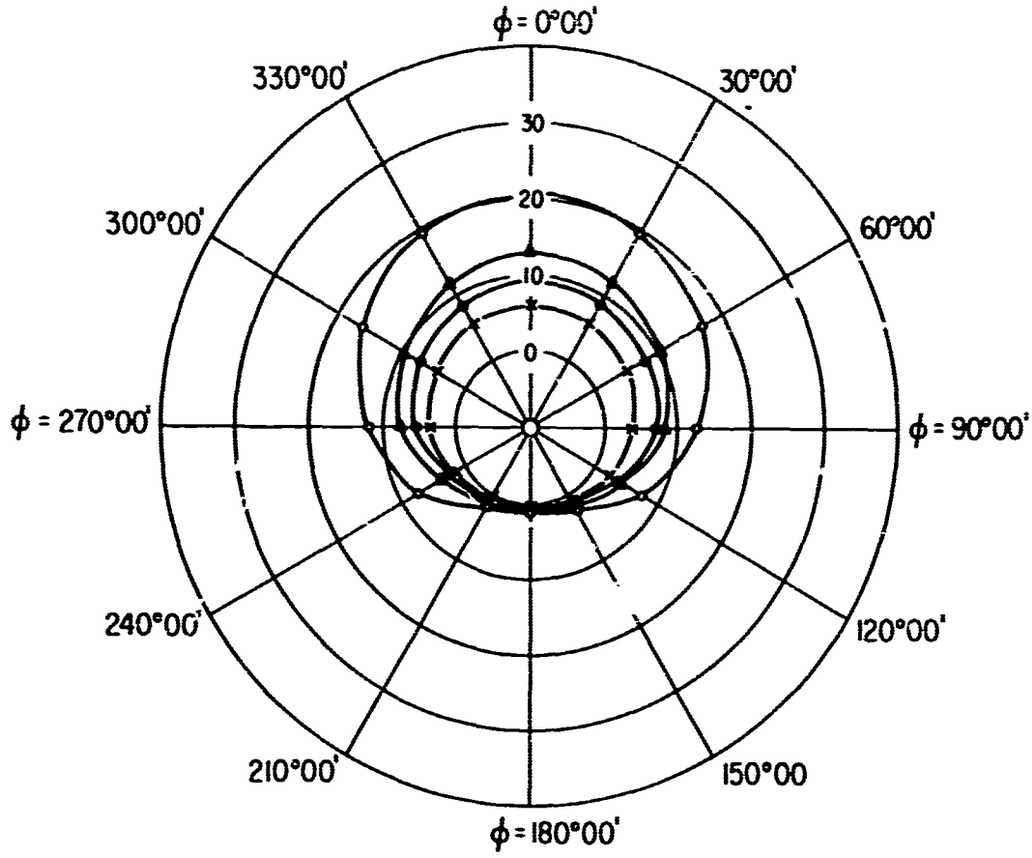
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 20°

ILLUMINATION: NATURAL LIGHT
θ_0: 53°

FIG. 187 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 4.69 + 3.32 \cos\varphi - 0.19 \cos 2\varphi + 0.02 \cos 3\varphi - 0.09 \cos 4\varphi - 0.03 \cos 5\varphi - 0.02 \cos 6\varphi + 0.05 \sin\varphi - 0.01 \sin 2\varphi - 0.03 \sin 3\varphi - 0.04 \sin 4\varphi + 0.02 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 30°

ILLUMINATION: NATURAL LIGHT
θ_0: 53°

FIG. 188 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.04 + 4.65 \cos\varphi - 0.44 \cos 2\varphi + 0.28 \cos 3\varphi + 0.01 \cos 4\varphi - 0.02 \cos 5\varphi + 0.08 \cos 6\varphi + 0.17 \sin\varphi + 0.10 \sin 2\varphi + 0.07 \sin 3\varphi + 0.04 \sin 4\varphi + 0.08 \sin 5\varphi$$

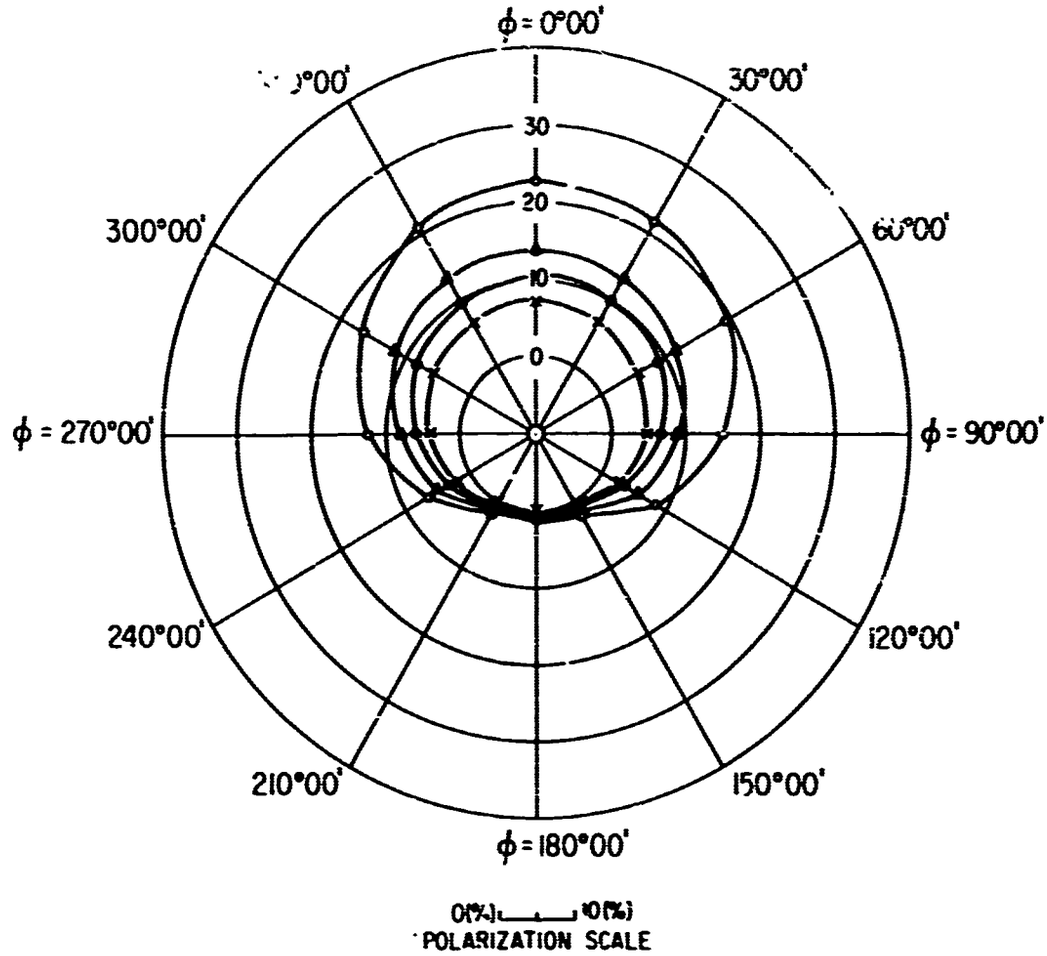
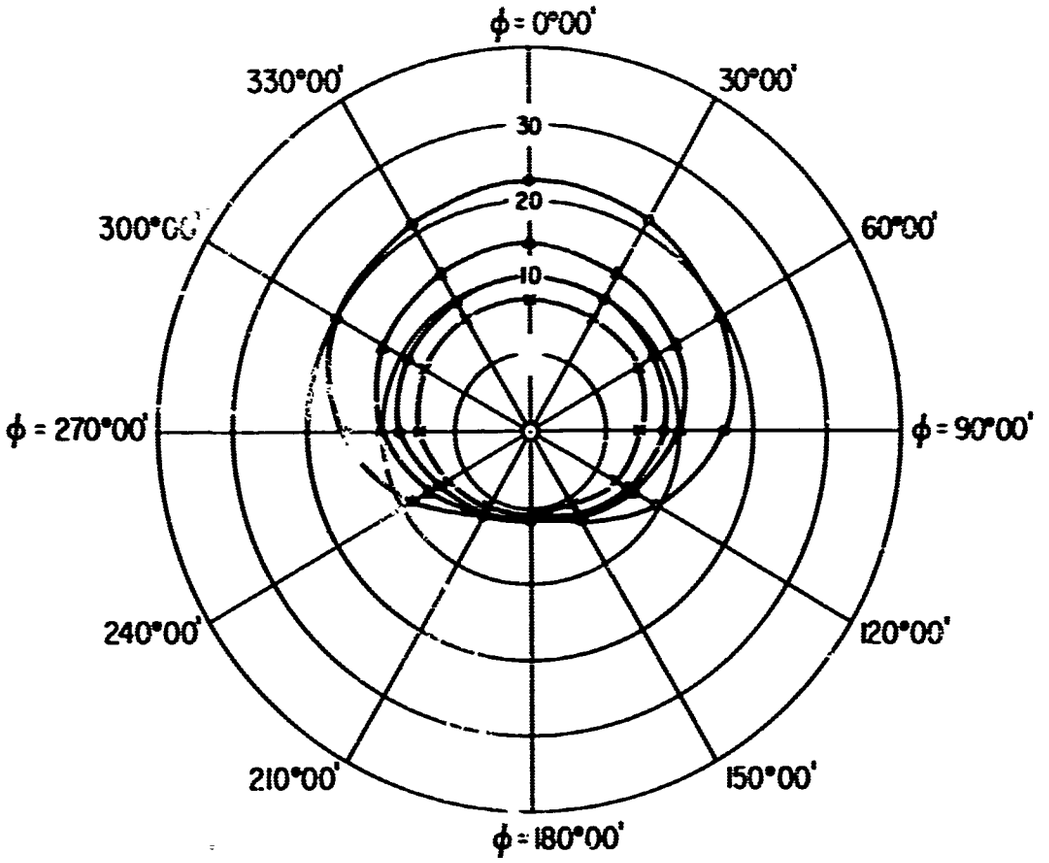


FIG.189 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.58 + 5.04\cos\varphi - 0.33\cos 2\varphi + 0.07\cos 3\varphi + 0.25\cos 4\varphi - 0.06\cos 5\varphi + 0.12\cos 6\varphi + 0.21\sin\varphi - 0.06\sin 2\varphi - 0.43\sin 3\varphi - 0.03\sin 4\varphi + 0.01\sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 50°

ILLUMINATION: NATURAL LIGHT
θ_i: 53°

FIG. 190 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.23 + 4.99 \cos\varphi - 0.76 \cos 2\varphi - 0.04 \cos 3\varphi + 0.14 \cos 4\varphi - 0.15 \cos 5\varphi + 0.17 \cos 6\varphi + 0.06 \sin\varphi + 0.04 \sin 2\varphi - 0.02 \sin 3\varphi - 0.04 \sin 4\varphi - 0.03 \sin 5\varphi$$

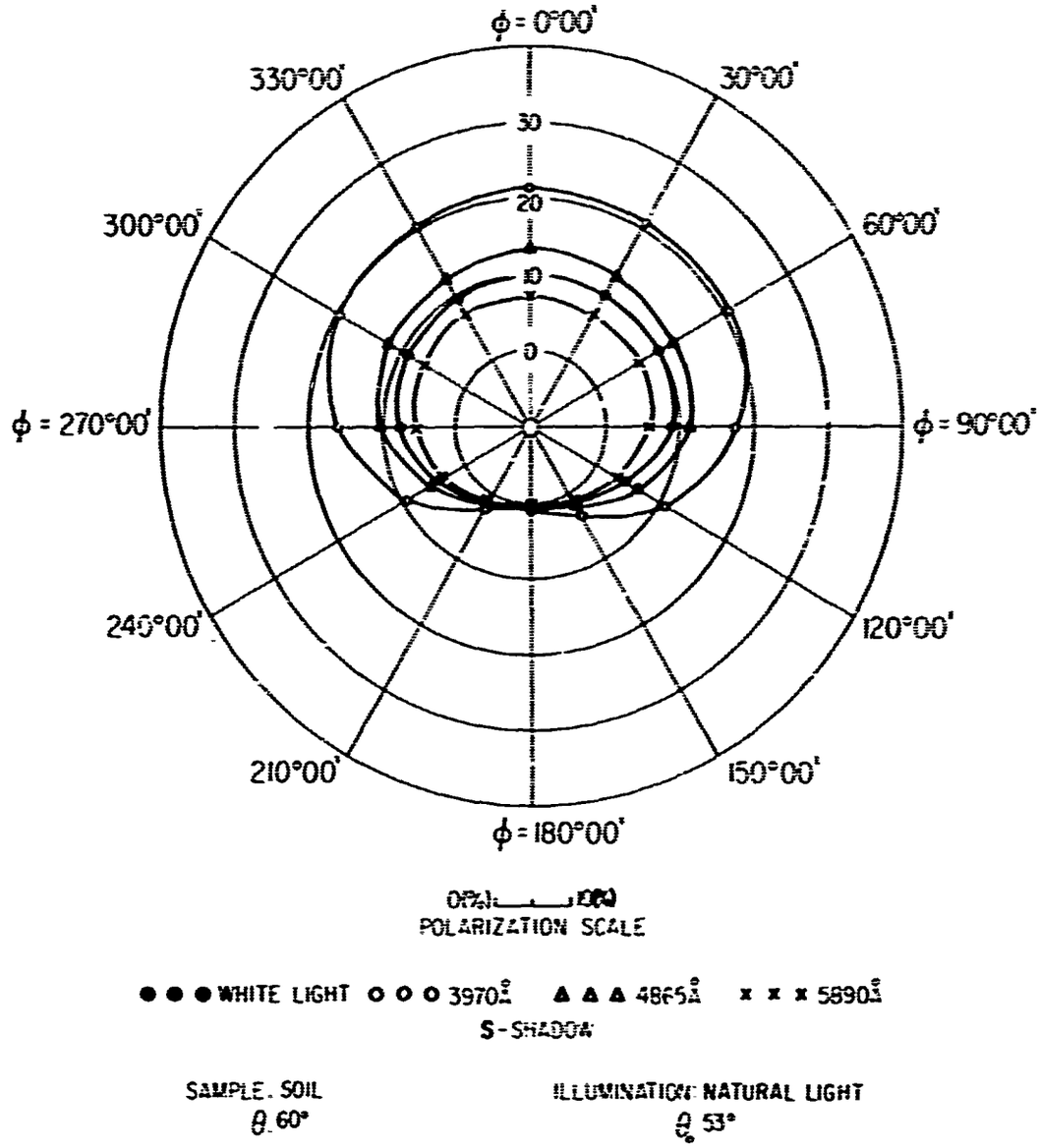


FIG. 191 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.35 + 4.80 \cos\varphi - 1.07 \cos 2\varphi - 0.23 \cos 3\varphi + 0.30 \cos 4\varphi + 0.02 \cos 5\varphi + 0.03 \cos 6\varphi + 0.03 \sin\varphi + 0.14 \sin 2\varphi + 0.07 \sin 3\varphi - 0.20 \sin 4\varphi + 0.20 \sin 5\varphi$$

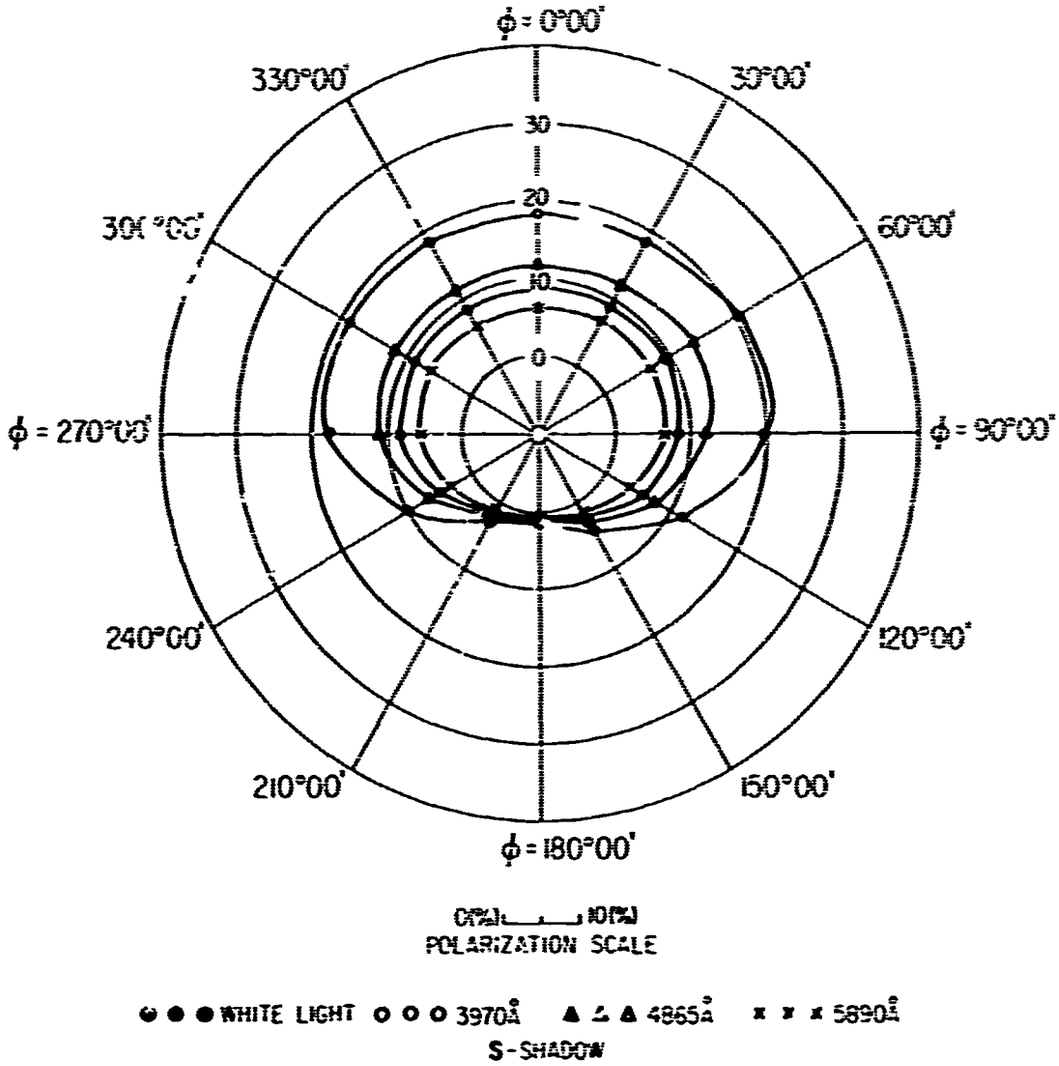


FIG. 192 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.38 + 3.85\cos\varphi - 1.76\cos 2\varphi + 0.10\cos 3\varphi + 0.09\cos 4\varphi - 0.05\cos 5\varphi + 0.37\cos 6\varphi + 0.12\sin\varphi + 0.16\sin 2\varphi + 0.17\sin 3\varphi - 0.07\sin 4\varphi - 0.11\sin 5\varphi$$

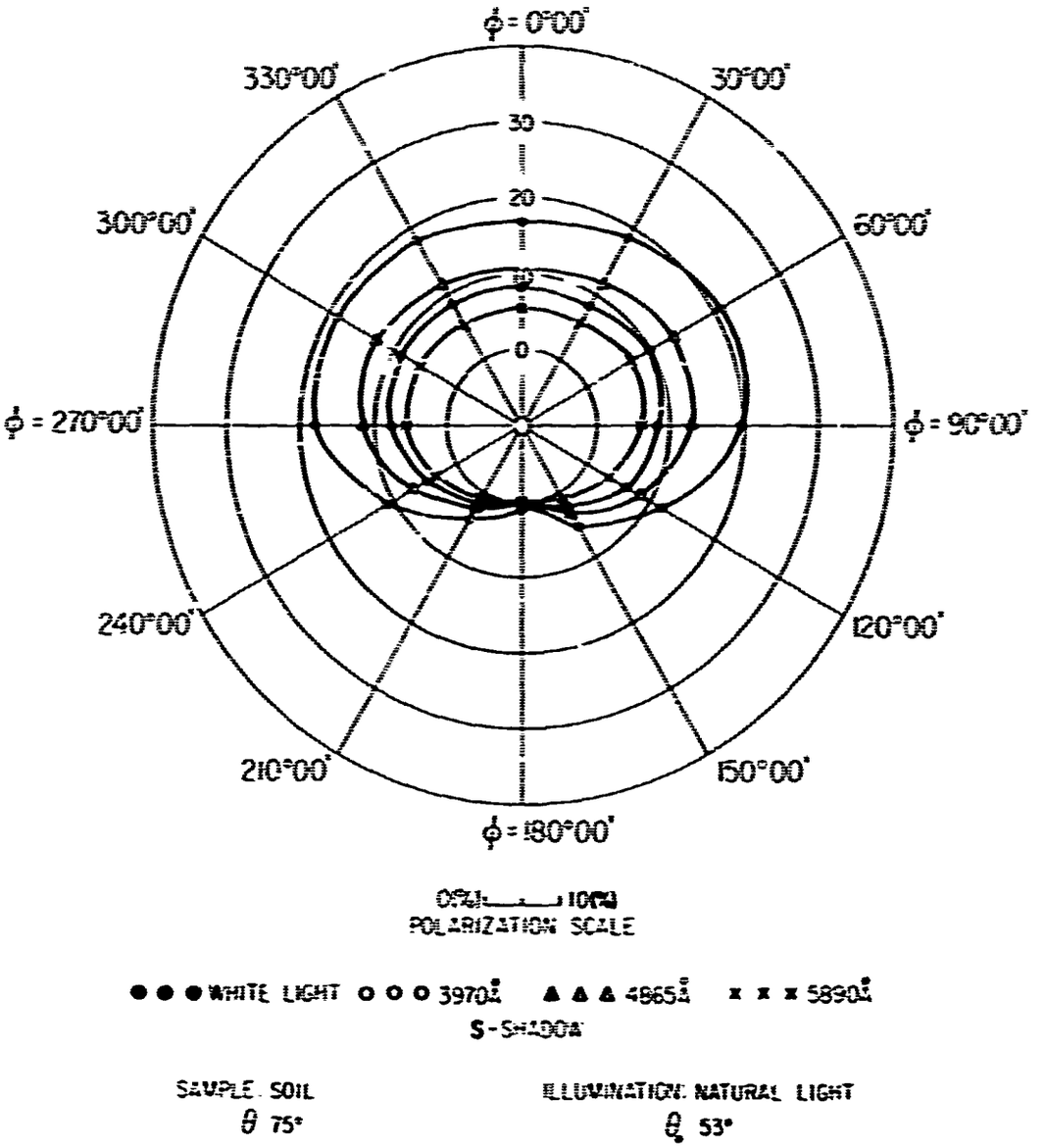


FIG 193 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 6.33 + 3.71 \cos\phi - 2.09 \cos 2\phi - 0.02 \cos 3\phi - 0.22 \cos 4\phi + 0.07 \cos 5\phi + 0.50 \cos 6\phi + 0.36 \sin\phi + 0.10 \sin 2\phi + 0.10 \sin 3\phi - 0.08 \sin 4\phi - 0.10 \sin 5\phi$$

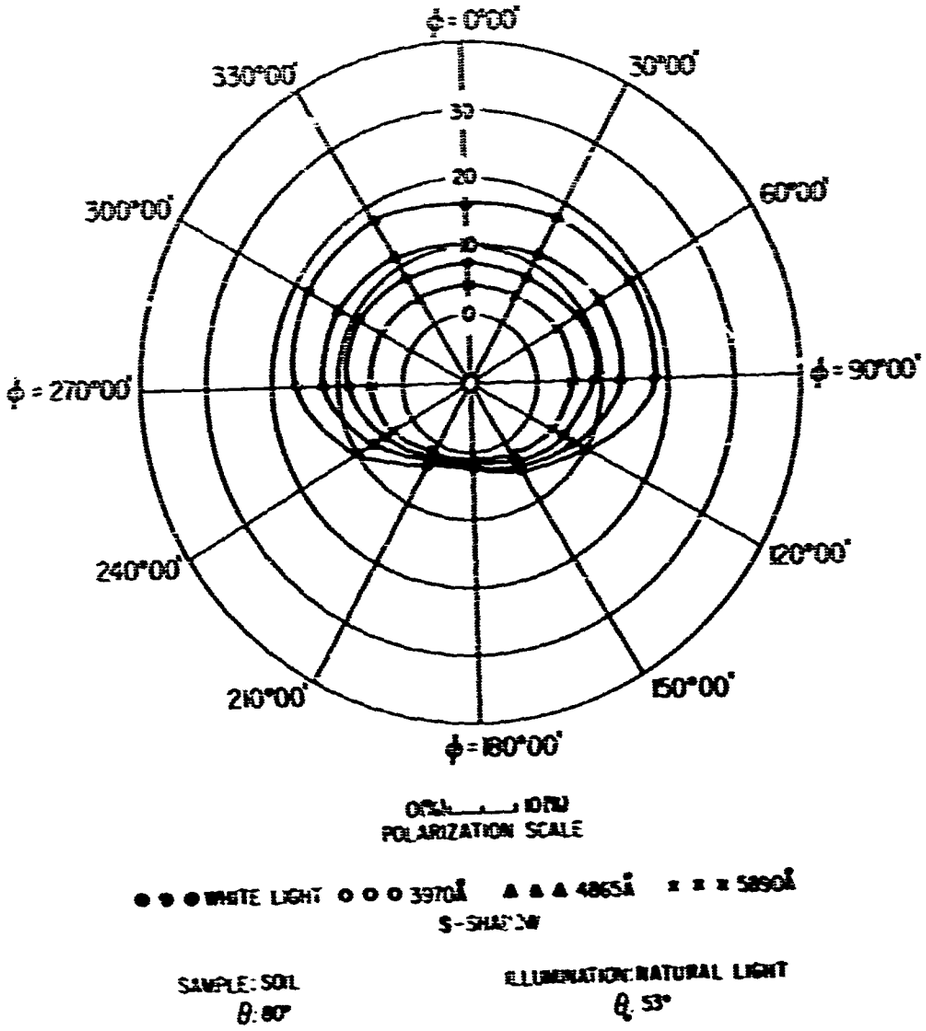


FIG. 194 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 6.32 + 2.96 \cos\phi - 1.90 \cos 2\phi - 0.43 \cos 3\phi + 0.20 \cos 4\phi + 0.07 \cos 5\phi + 0.15 \cos 6\phi + 0.38 \sin\phi + 0.32 \sin 2\phi + 0.08 \sin 3\phi + 0.08 \sin 4\phi - 0.32 \sin 5\phi$$

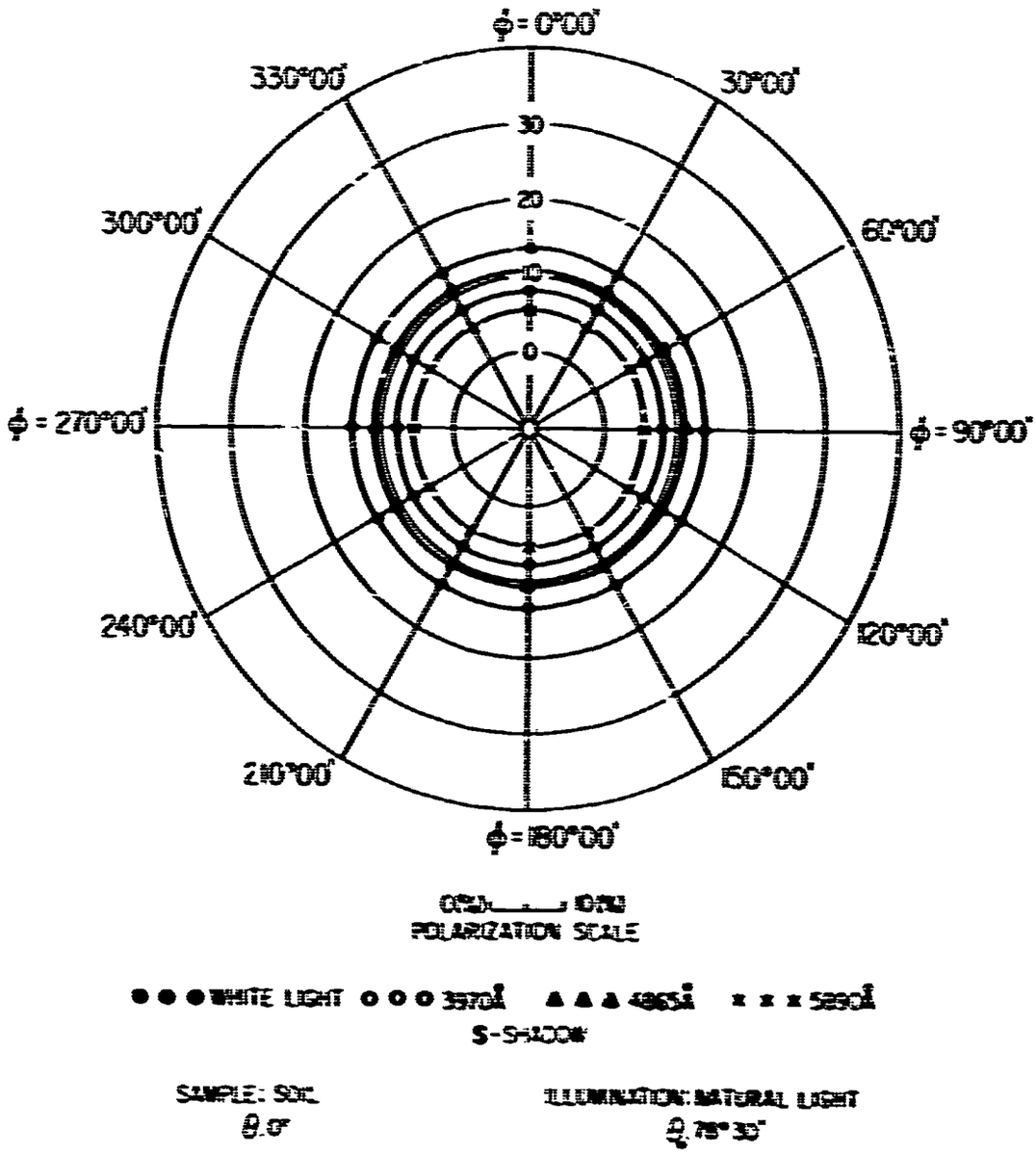


FIG. 195 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

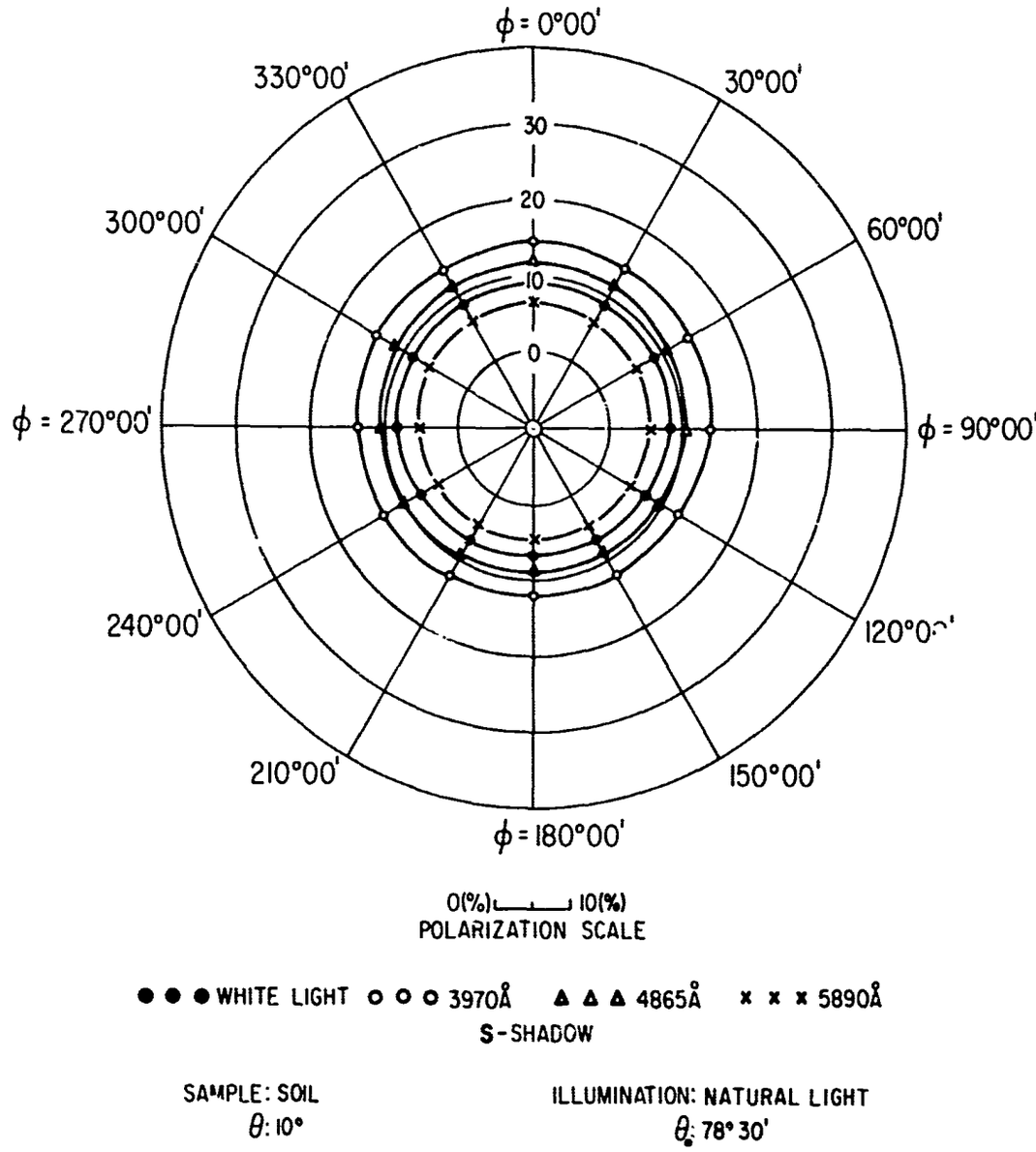
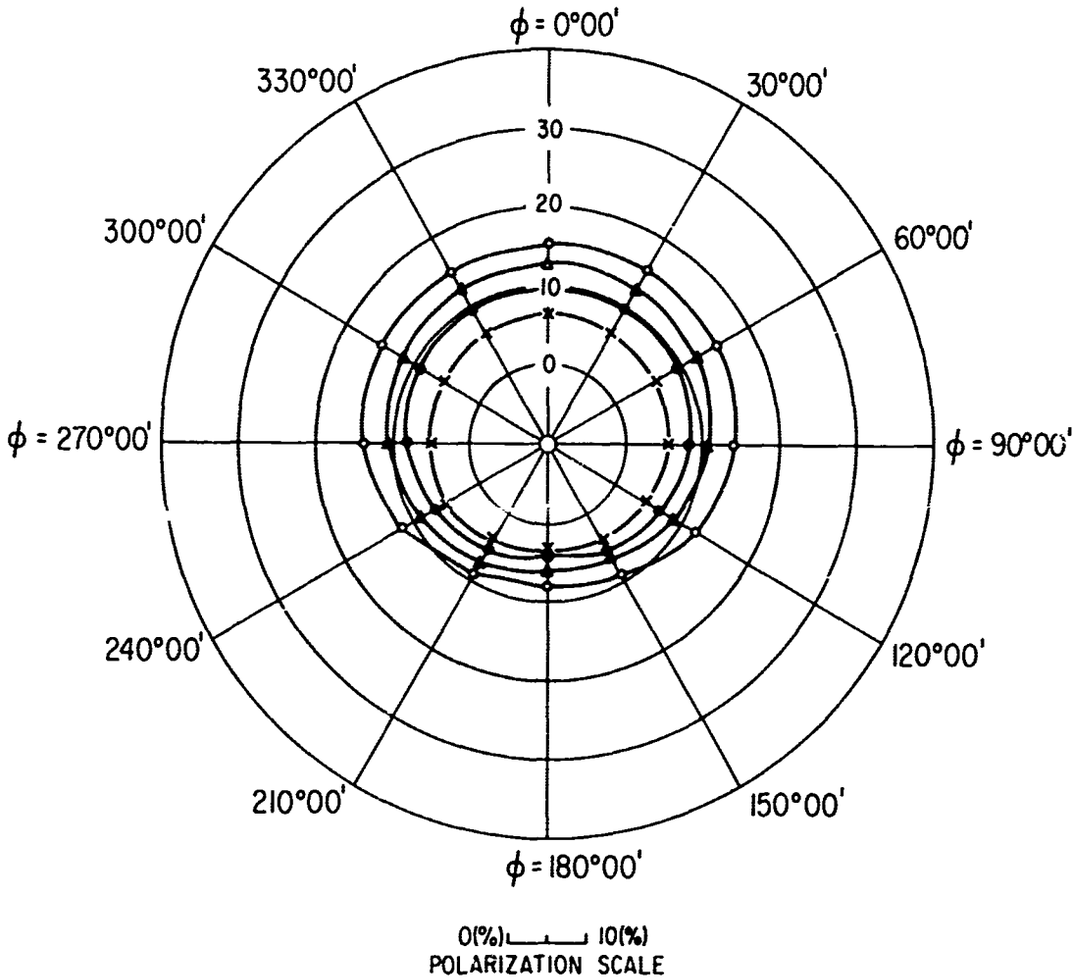


FIG. 196 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.88 + 1.34 \cos\varphi - 0.06 \cos 2\varphi + 0.02 \cos 3\varphi + 0.02 \cos 4\varphi - 0.16 \cos 5\varphi + 0.02 \cos 6\varphi - 0.03 \sin\varphi + 0.13 \sin 2\varphi - 0.03 \sin 3\varphi + 0.01 \sin 4\varphi - 0.15 \sin 5\varphi$$



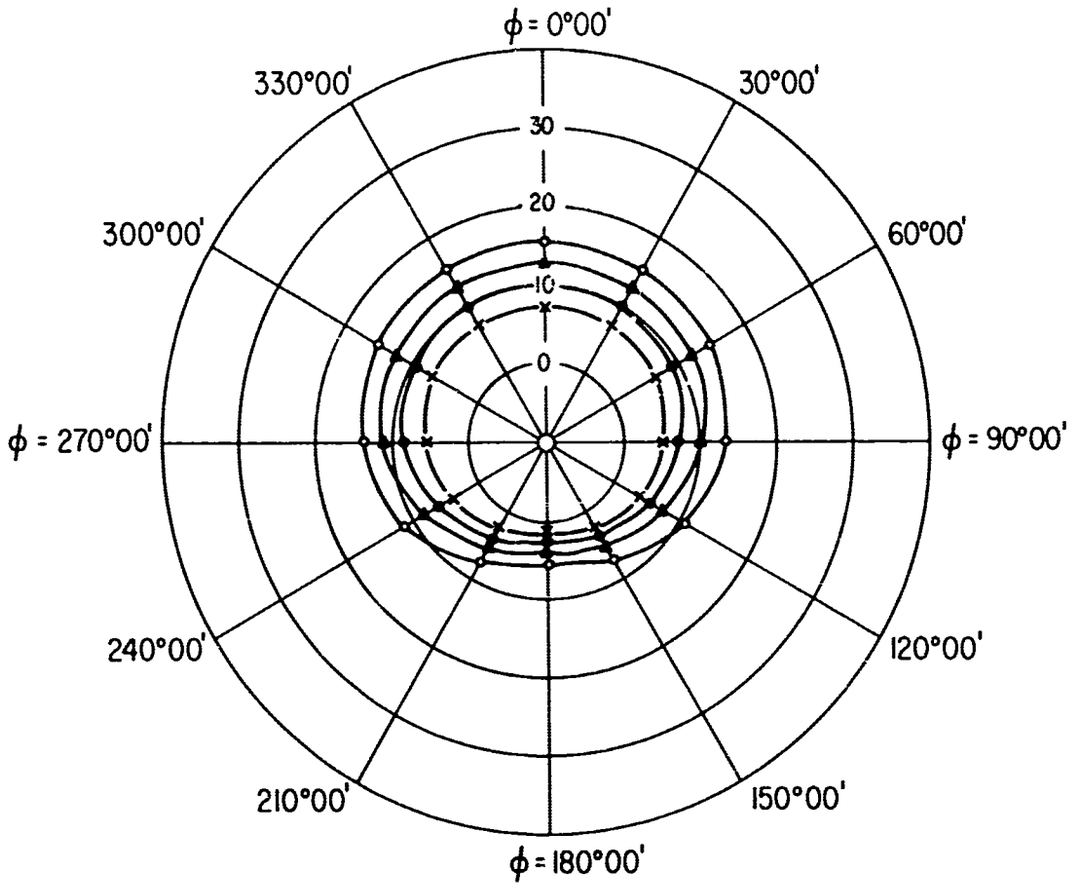
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 20°

ILLUMINATION: NATURAL LIGHT
θ_0: 78° 30'

FIG. 197 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 7.69 + 2.04 \cos\varphi - 0.92 \cos 2\varphi + 0.05 \cos 3\varphi - 0.55 \cos 4\varphi - 0.50 \cos 5\varphi - 0.08 \cos 6\varphi + 0.27 \sin\varphi + 0.12 \sin 2\varphi + 0.03 \sin 3\varphi - 0.06 \sin 4\varphi - 0.00 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

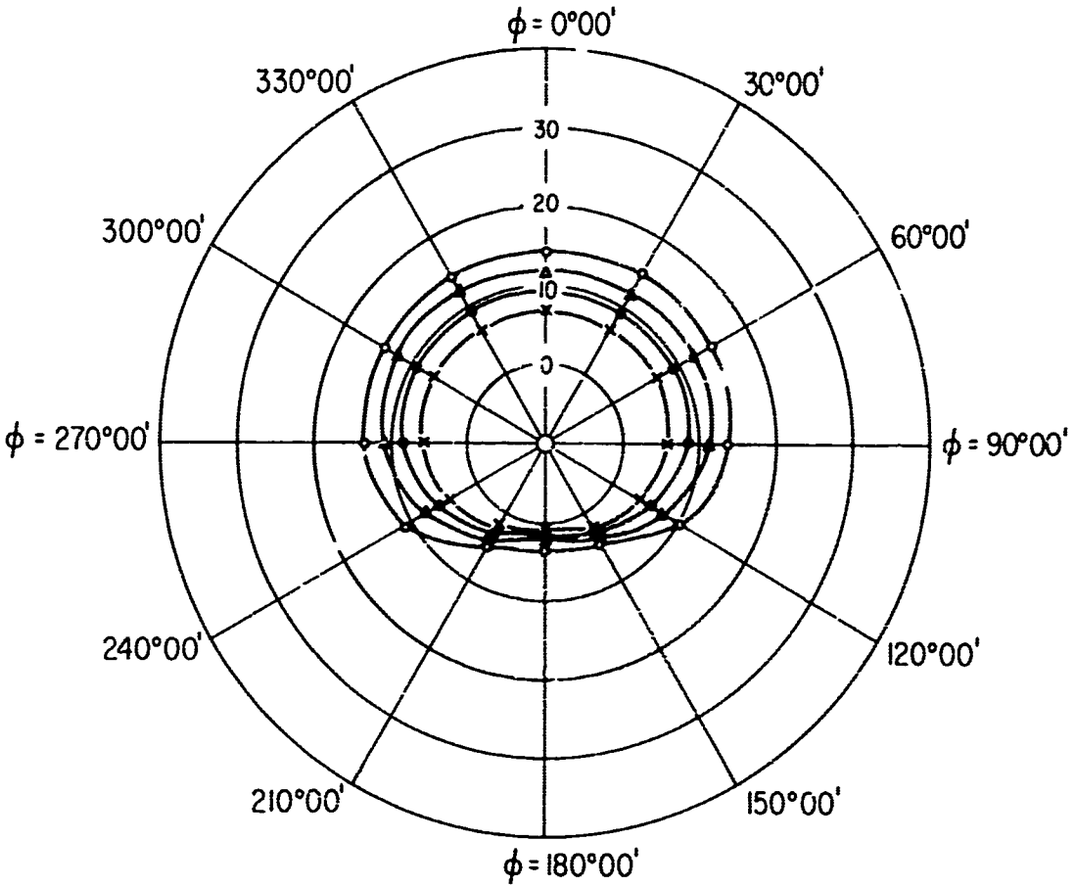
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 30°

ILLUMINATION: NATURAL LIGHT
θ_0: 78° 30'

FIG. 198 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.96 + 3.24 \cos\varphi - 0.52 \cos 2\varphi + 0.25 \cos 3\varphi - 0.18 \cos 4\varphi - 0.08 \cos 5\varphi - 0.22 \cos 6\varphi - 0.30 \sin\varphi - 0.09 \sin 2\varphi - 0.13 \sin 3\varphi - 0.09 \sin 4\varphi - 0.08 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

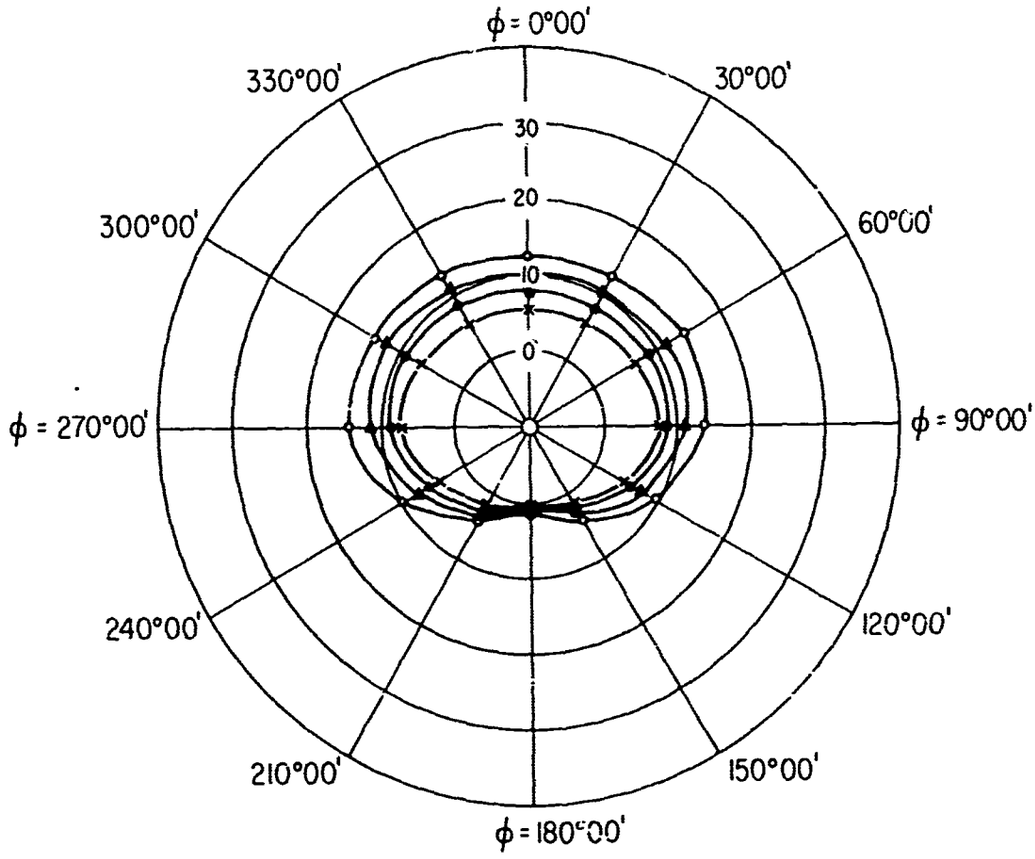
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: SOIL
θ: 40°

ILLUMINATION: NATURAL LIGHT
θ_0: 78°30'

FIG. 199 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.82 + 3.78 \cos\varphi - 1.38 \cos 2\varphi + 0.18 \cos 3\varphi + 0.05 \cos 4\varphi + 0.09 \cos 5\varphi - 0.09 \cos 6\varphi - 0.08 \sin\varphi + 0.09 \sin 2\varphi + 0.00 \sin 3\varphi - 0.09 \sin 4\varphi - 0.02 \sin 5\varphi$$



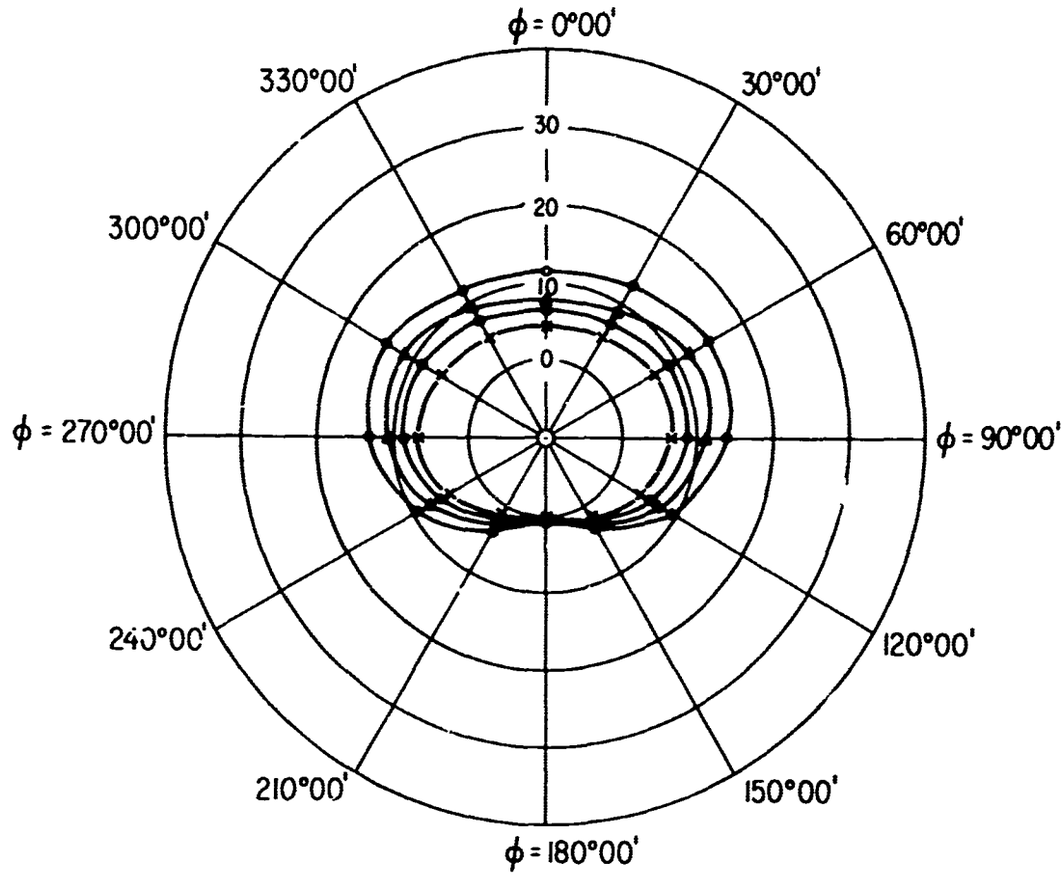
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 50°

ILLUMINATION: NATURAL LIGHT
θ_0 78° 30'

FIG. 200 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 6.32 + 3.57 \cos\varphi - 2.28 \cos 2\varphi + 0.18 \cos 3\varphi - 0.08 \cos 4\varphi + 0.15 \cos 5\varphi - 0.15 \cos 6\varphi - 0.22 \sin\varphi - 0.05 \sin 2\varphi - 0.10 \sin 3\varphi - 0.08 \sin 4\varphi - 0.08 \sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

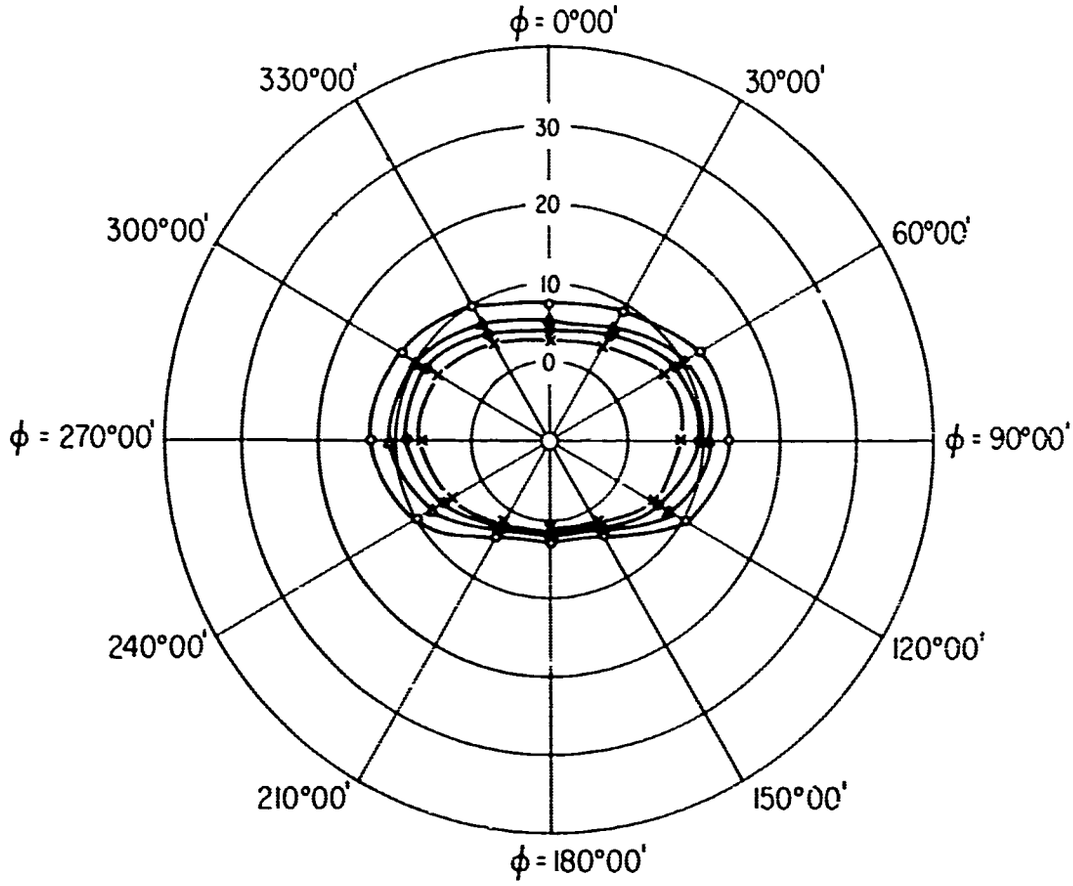
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 60°

ILLUMINATION: NATURAL LIGHT
θ_0: 78° 30'

FIG.201 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.86 + 3.07\cos\varphi - 2.58\cos 2\varphi - 0.12\cos 3\varphi - 0.22\cos 4\varphi - 0.05\cos 5\varphi - 0.15\cos 6\varphi + 0.05\sin\varphi - 0.16\sin 2\varphi - 0.13\sin 3\varphi - 0.02\sin 4\varphi - 0.09\sin 5\varphi$$



0(%) 10(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. SOIL
θ 70°

ILLUMINATION: NATURAL LIGHT
θ_0 78° 30'

FIG. 202 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.71 + 1.82\cos\varphi - 3.20\cos 2\varphi - 0.25\cos 3\varphi + 0.07\cos 4\varphi - 0.32\cos 5\varphi + 0.60\cos 6\varphi + 0.46\sin\varphi - 0.23\sin 2\varphi - 0.22\sin 3\varphi + 0.17\sin 4\varphi - 0.12\sin 5\varphi$$

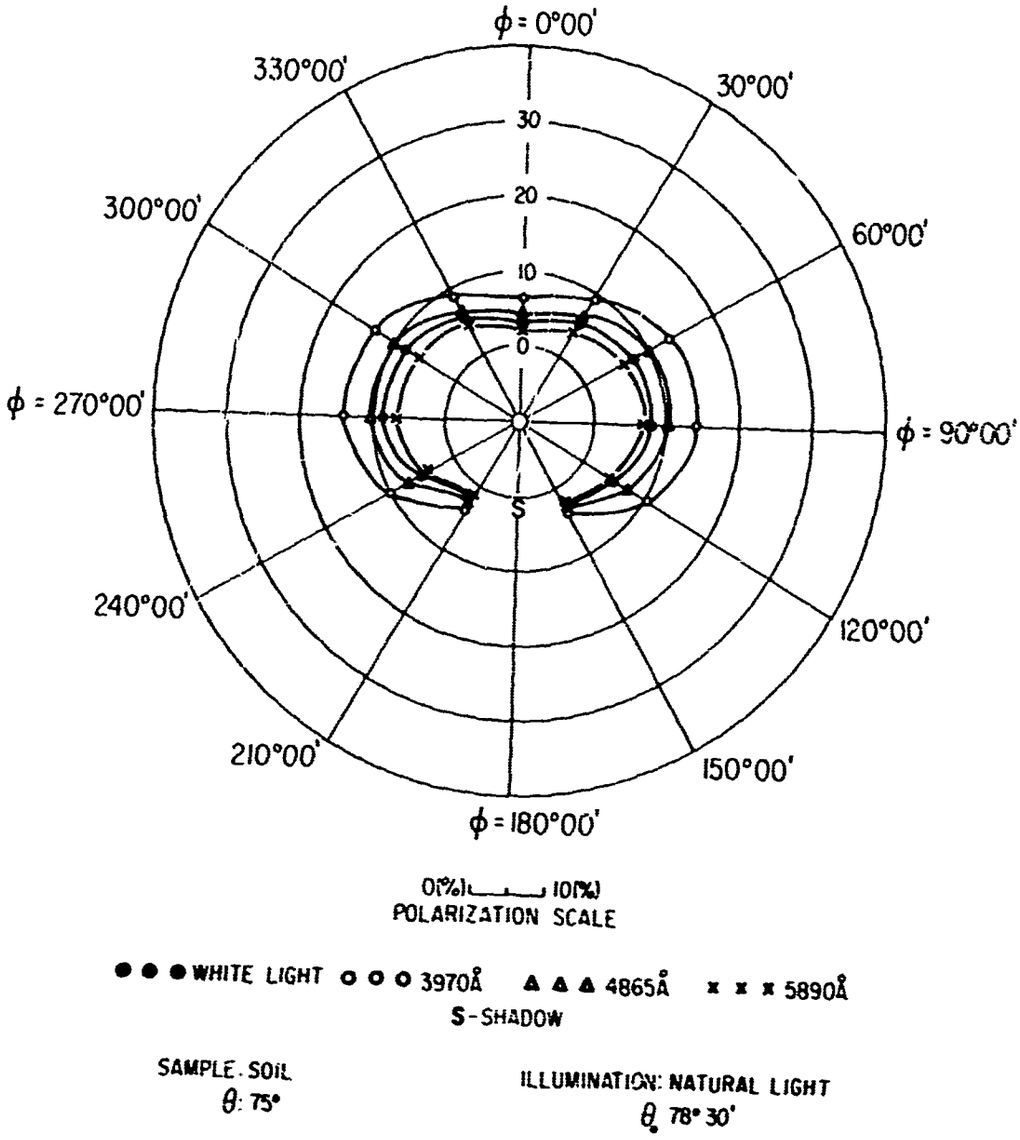
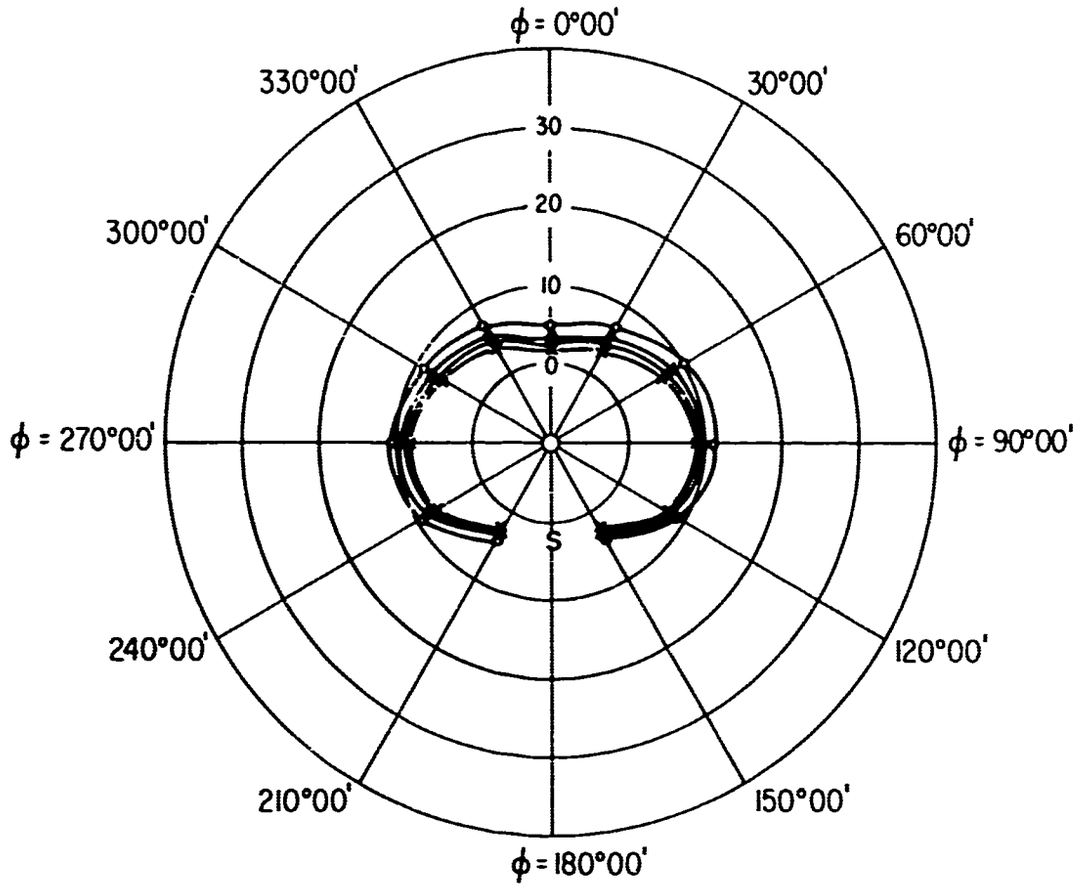


FIG.203 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\omega) = 5.12 + 1.82\cos\omega - 2.77\cos 2\omega - 0.92\cos 3\omega + 0.30\cos 4\omega - 0.15\cos 5\omega - 0.22\cos 6\omega - 0.29\sin\omega - 0.09\sin 2\omega + 0.17\sin 3\omega - 0.08\sin 4\omega + 0.06\sin 5\omega$$



0(%) 10(%)
POLARIZATION SCALE

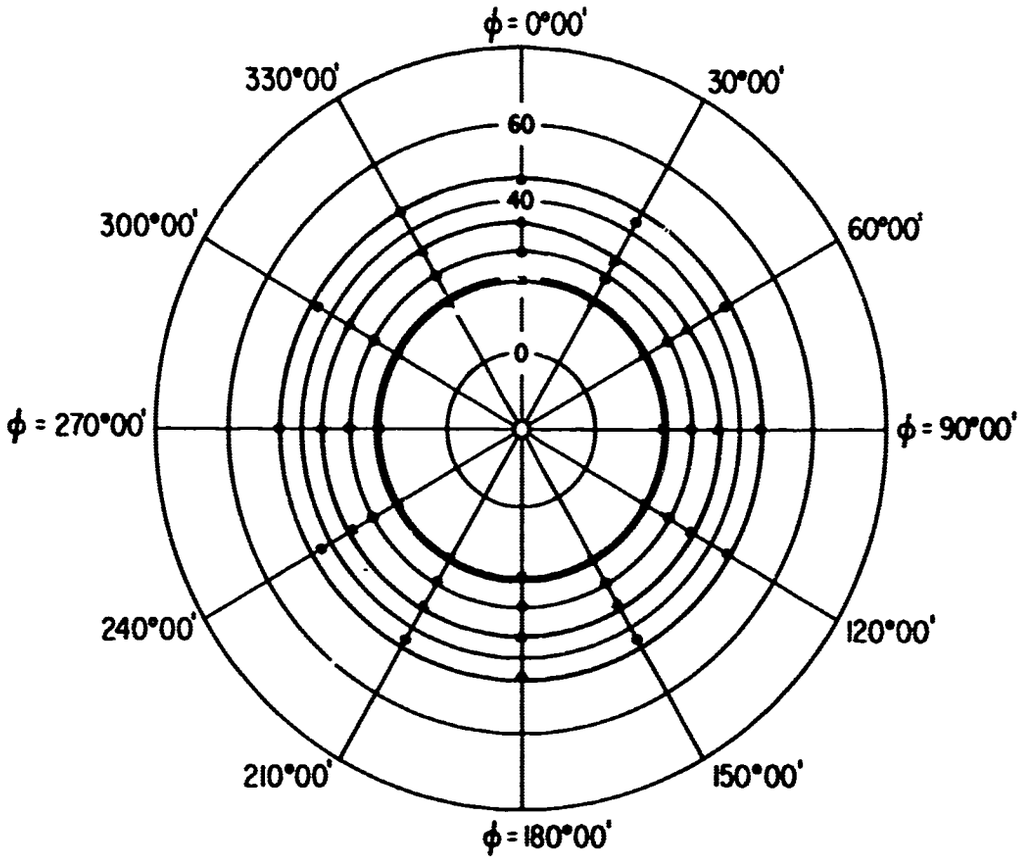
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 80°

ILLUMINATION: NATURAL LIGHT
θ_0 78°30'

FIG.204 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 5.38 + 0.62\cos\varphi - 3.32\cos 2\varphi + 0.10\cos 3\varphi - 0.02\cos 4\varphi - 0.47\cos 5\varphi + 0.03\cos 6\varphi - 0.39\sin\varphi - 0.30\sin 2\varphi - 0.13\sin 3\varphi - 0.28\sin 4\varphi - 0.39\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 10°

ILLUMINATION: POLARIZED LIGHT
θ_i: 0°

FIG. 205. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 26.36 - 0.40\cos\phi - 0.02\cos 2\phi + 0.00\cos 3\phi + 0.22\cos 4\phi - 0.10\cos 5\phi + 0.08\cos 6\phi - 0.17\sin\phi - 0.06\sin 2\phi - 0.05\sin 3\phi - 0.06\sin 4\phi - 0.23\sin 5\phi$$

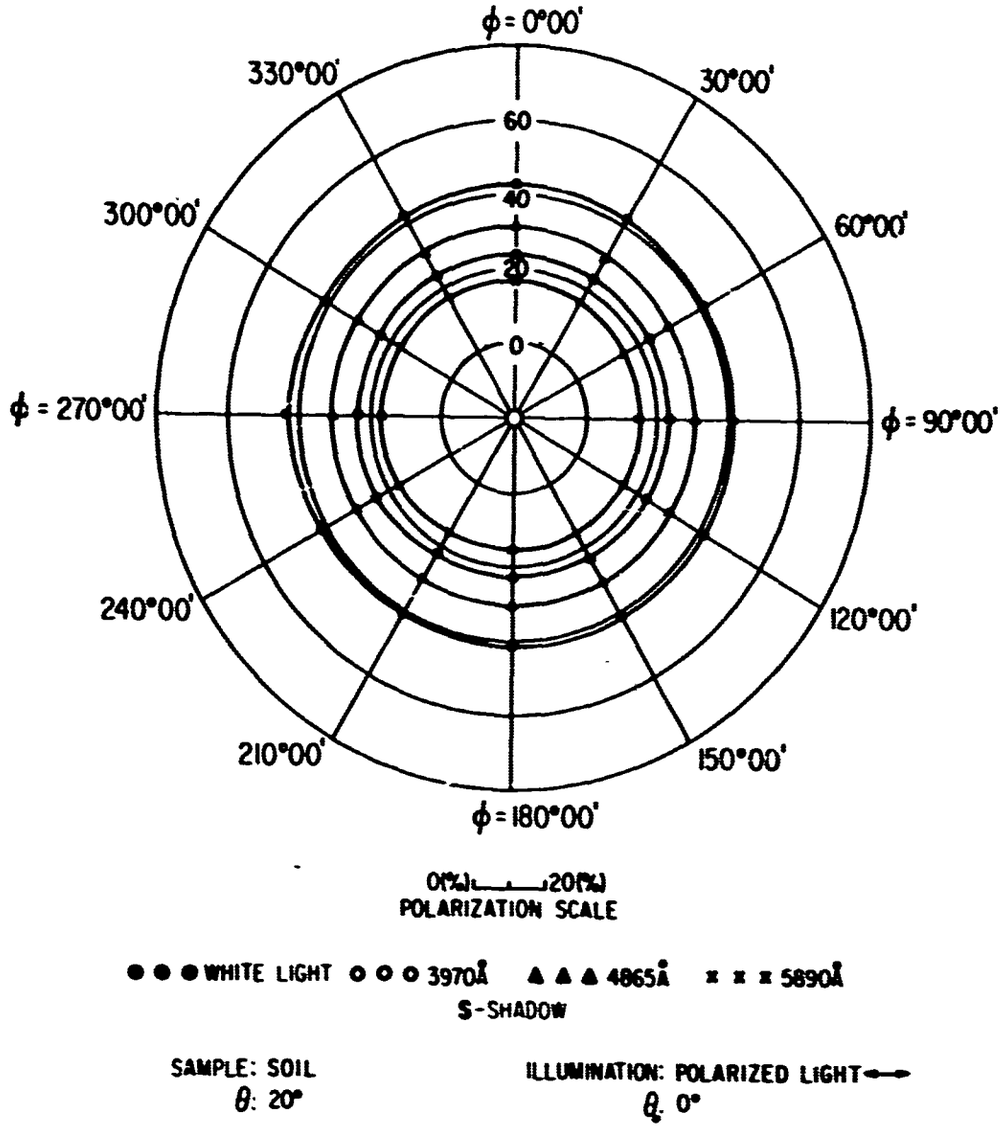


FIG. 206. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.27 - 0.01 \cos\varphi - 0.63 \cos 2\varphi - 0.30 \cos 3\varphi + 0.53 \cos 4\varphi + 0.11 \cos 5\varphi - 0.27 \cos 6\varphi - 0.04 \sin\varphi - 0.32 \sin 2\varphi - 0.10 \sin 3\varphi - 1.41 \sin 4\varphi - 0.16 \sin 5\varphi$$

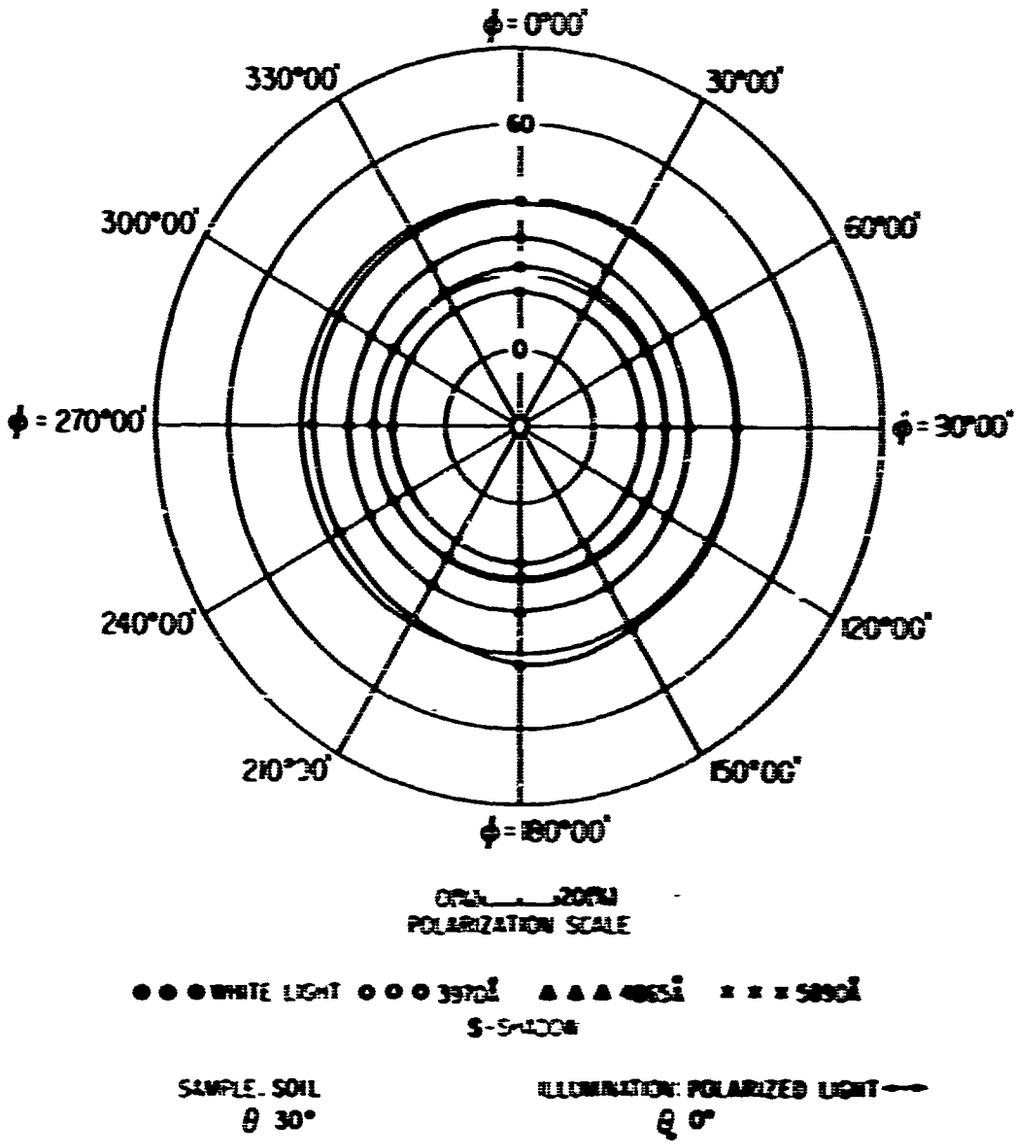
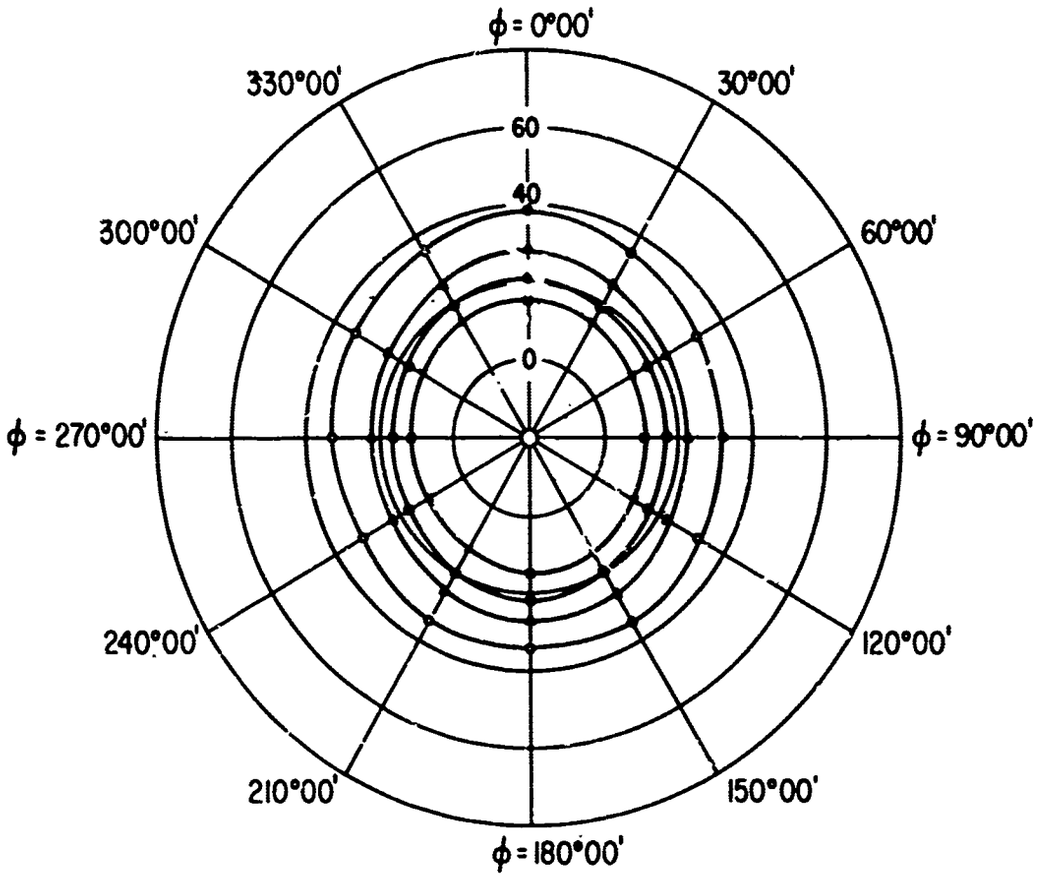


FIG. 207. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 20.72 - 0.14\cos\phi + 1.39\cos 2\phi + 0.00\cos 3\phi + 0.41\cos 4\phi - 0.06\cos 5\phi - 0.03\cos 6\phi + 0.10\sin\phi - 0.10\sin 2\phi - 0.13\sin 3\phi - 0.16\sin 4\phi - 0.08\sin 5\phi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 40°

ILLUMINATION: POLARIZED LIGHT ↔
θ_0: 0°

FIG. 208. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 18.61 - 0.45 \cos\varphi + 2.51 \cos 2\varphi - 0.18 \cos 3\varphi + 0.54 \cos 4\varphi + 0.13 \cos 5\varphi + 0.08 \cos 6\varphi + 0.01 \sin\varphi - 0.22 \sin 2\varphi + 0.03 \sin 3\varphi + 0.16 \sin 4\varphi - 0.08 \sin 5\varphi$$

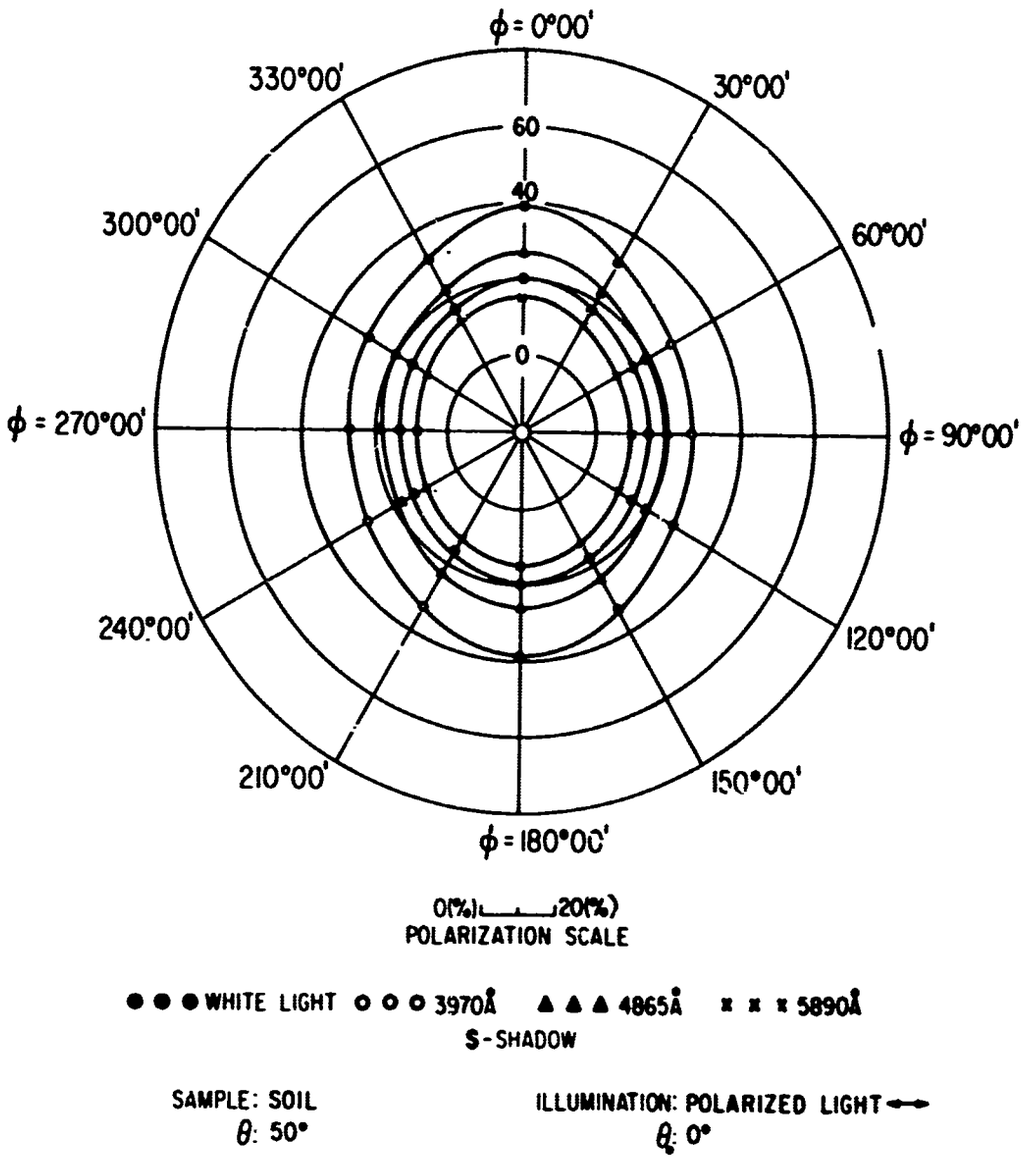


FIG. 209. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.10 + 0.10 \cos\varphi + 6.54 \cos 2\varphi + 0.05 \cos 3\varphi + 2.58 \cos 4\varphi + 0.05 \cos 5\varphi - 1.63 \cos 6\varphi - 0.23 \sin\varphi - 1.17 \sin 2\varphi - 0.08 \sin 3\varphi - 0.97 \sin 4\varphi + 0.20 \sin 5\varphi$$

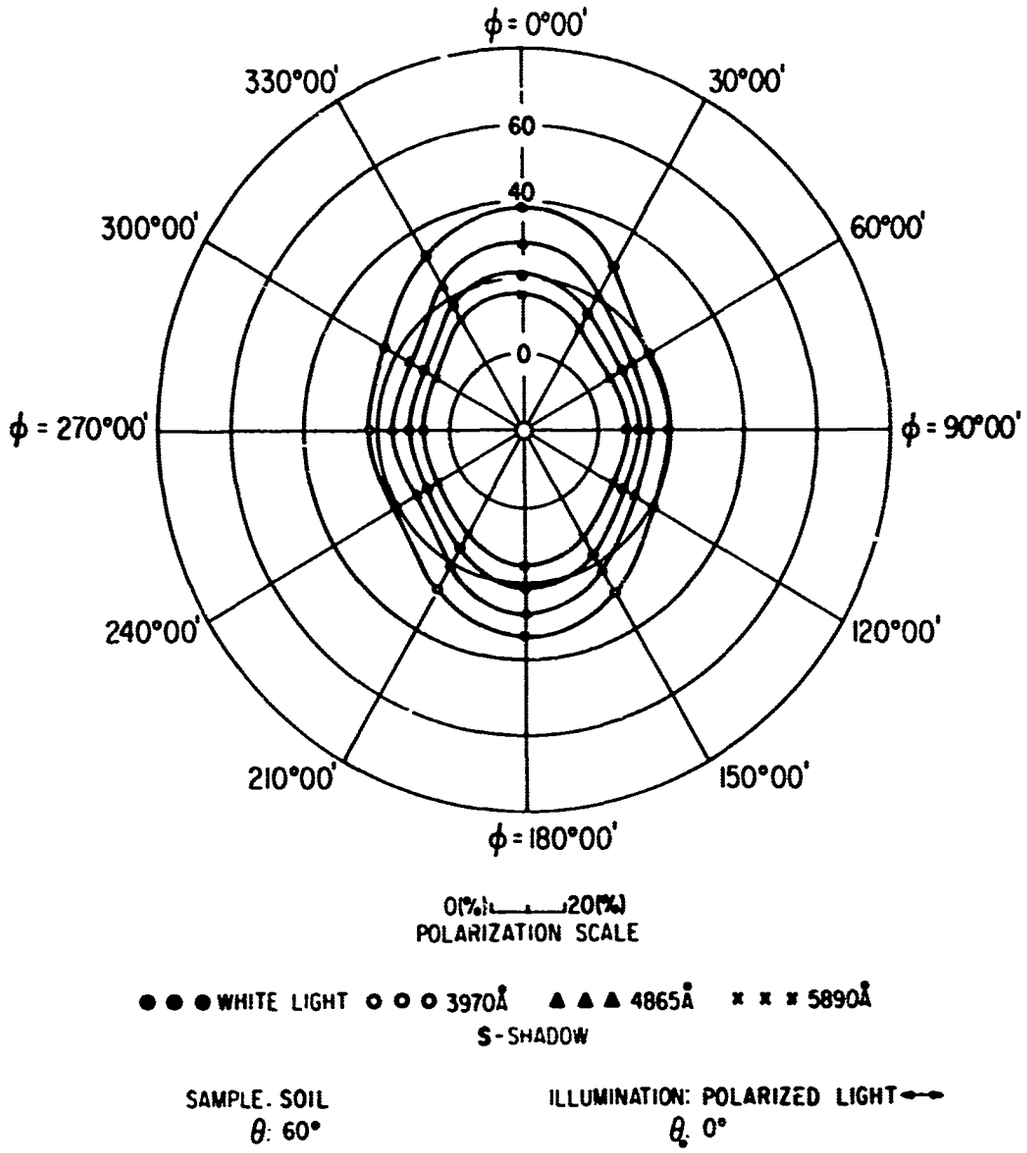


FIG. 210. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.48 - 0.07\cos\varphi + 5.05\cos 2\varphi - 0.13\cos 3\varphi + 1.80\cos 4\varphi - 0.04\cos 5\varphi - 0.60\cos 6\varphi - 0.14\sin\varphi - 0.58\sin 2\varphi - 0.13\sin 3\varphi - 0.38\sin 4\varphi + 0.05\sin 5\varphi$$

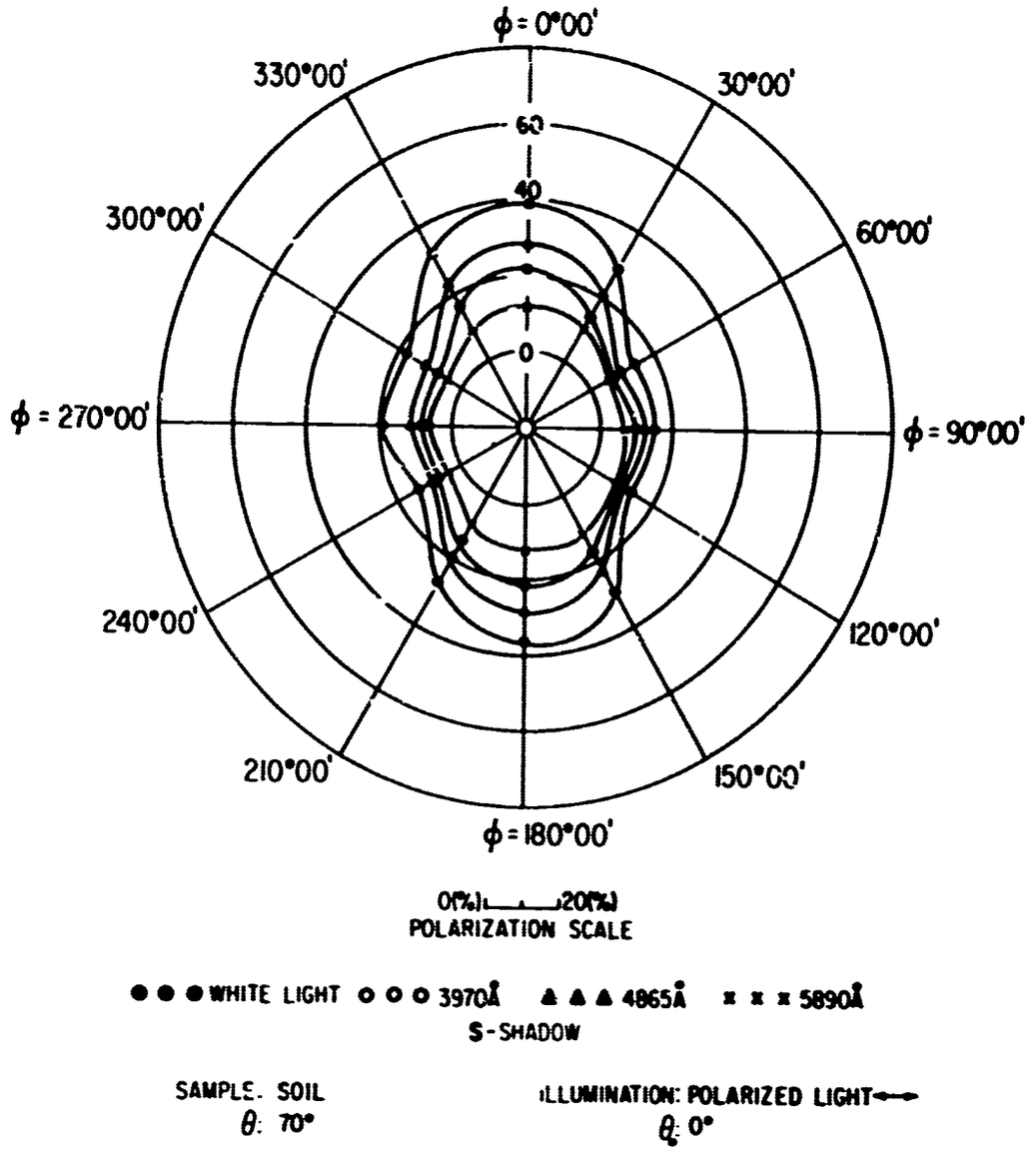


FIG. 211. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 12.93 - 0.06\cos\phi + 6.69\cos 2\phi + 0.27\cos 3\phi + 2.54\cos 4\phi - 0.20\cos 5\phi - 1.13\cos 6\phi - 0.11\sin\phi - 1.11\sin 2\phi - 0.43\sin 3\phi - 0.59\sin 4\phi + 0.12\sin 5\phi$$

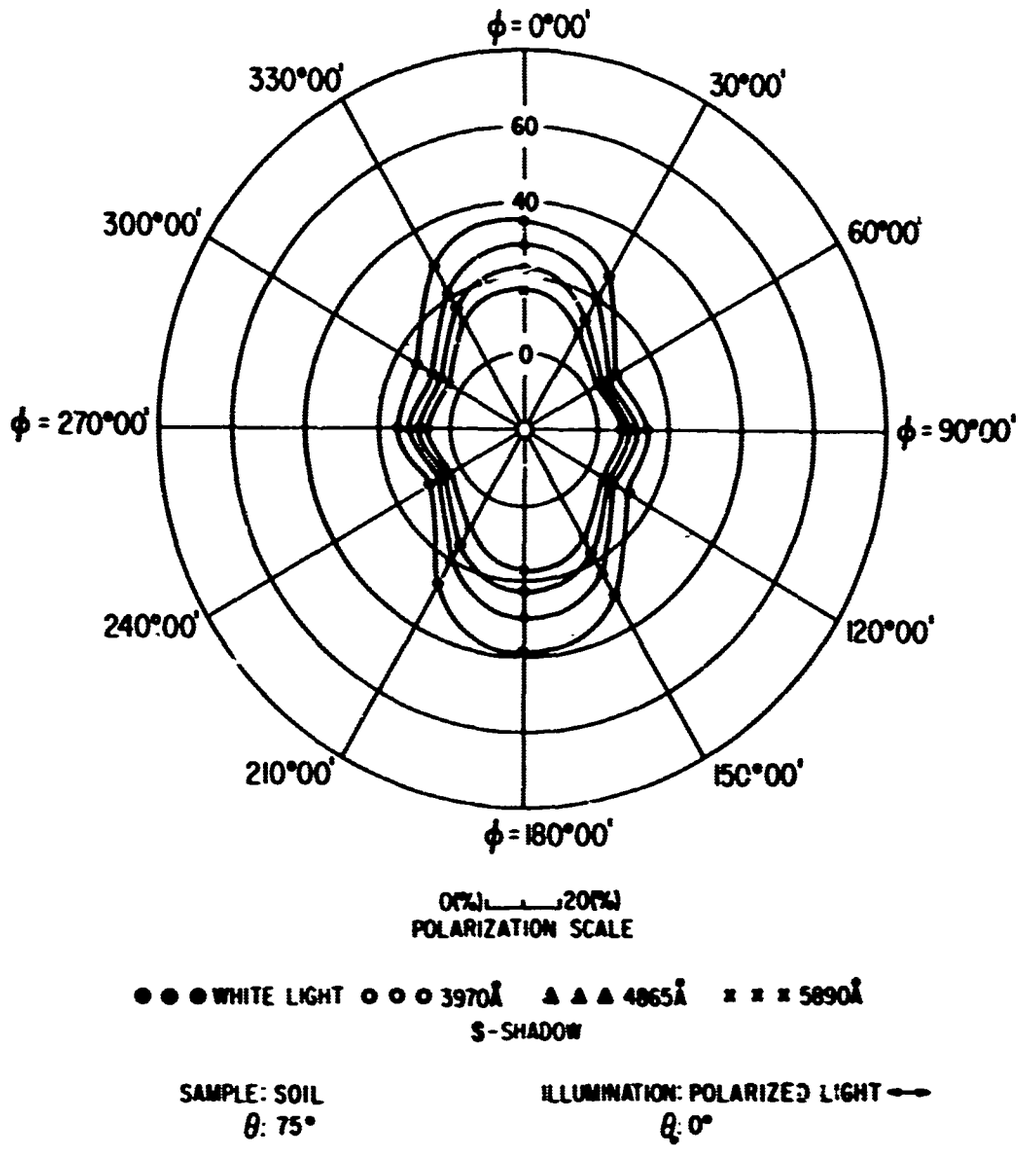
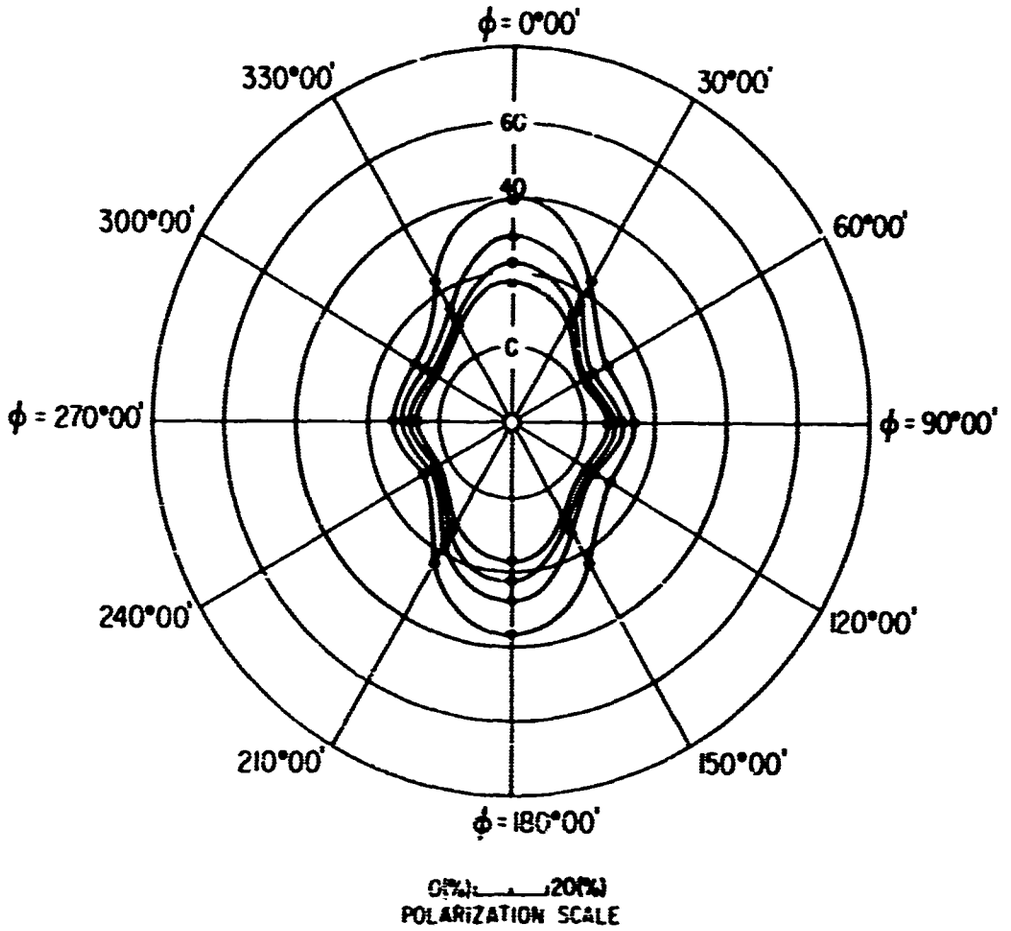


FIG. 212. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.54 - 0.06\cos\varphi + 7.47\cos 2\varphi + 0.27\cos 3\varphi + 3.28\cos 4\varphi - 0.15\cos 5\varphi - 2.08\cos 6\varphi + 0.01\sin\varphi - 1.47\sin 2\varphi - 0.04\sin 3\varphi - 0.98\sin 4\varphi + 0.04\sin 5\varphi$$

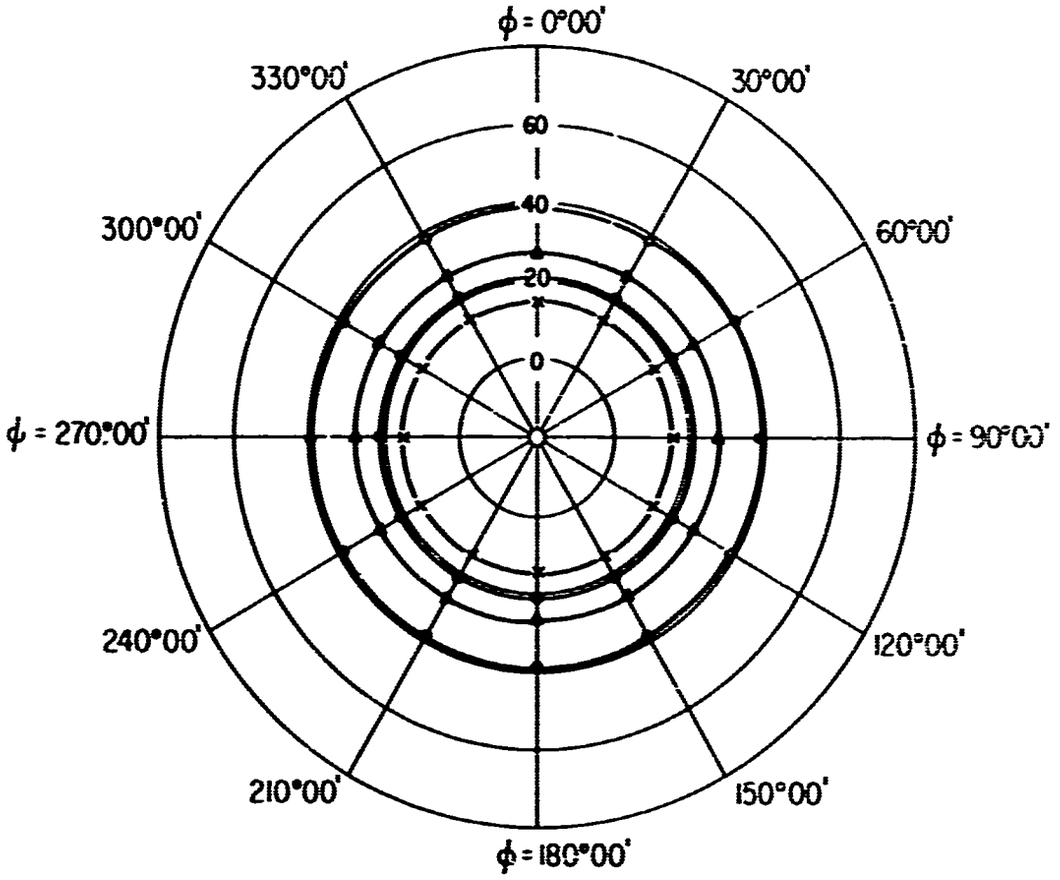


SAMPLE. SOIL
θ 80°

ILLUMINATION: POLARIZED LIGHT
θ_i 0°

FIG. 213. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.71 - 0.20\cos\varphi + 7.90\cos 2\varphi + 0.53\cos 3\varphi + 3.60\cos 4\varphi - 0.34\cos 5\varphi - 2.22\cos 6\varphi + 0.20\sin\varphi - 1.86\sin 2\varphi - 0.05\sin 3\varphi - 0.65\sin 4\varphi - 0.37\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ.0°

ILLUMINATION: POLARIZED LIGHT
θ_0.53°

FIG.214 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

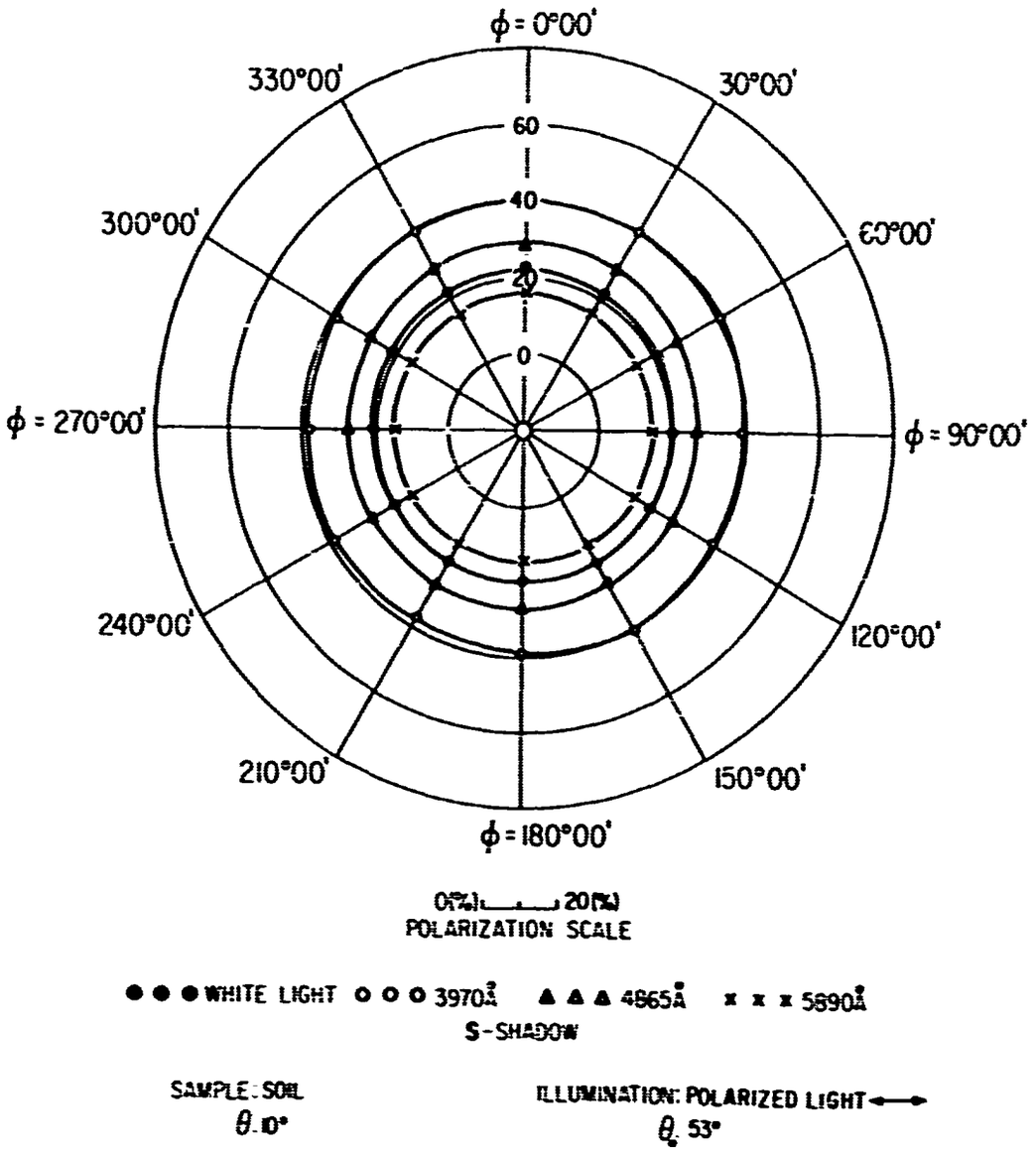
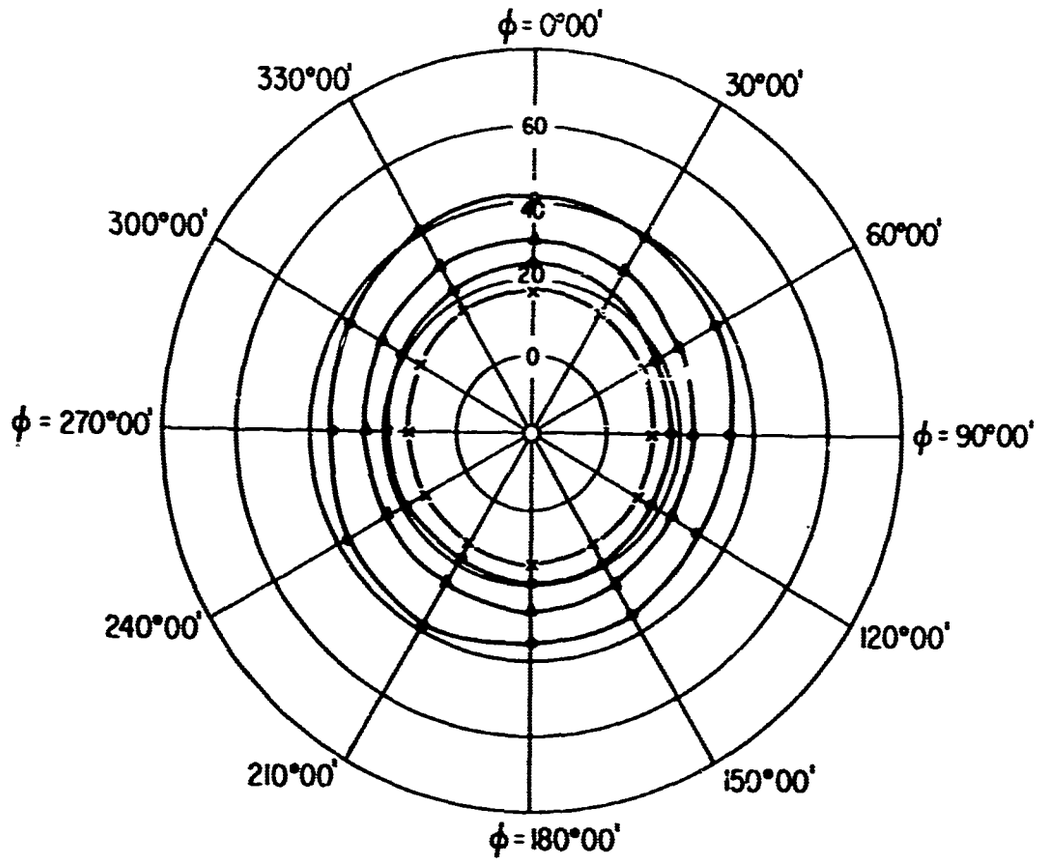


FIG. 215 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 20.5 + 1.16 \cos\phi + 0.51 \cos 2\phi - 0.05 \cos 3\phi - 0.01 \cos 4\phi + 0.04 \cos 5\phi + 0.03 \cos 6\phi - 0.20 \sin\phi + 0.01 \sin 2\phi - 0.03 \sin 3\phi - 0.04 \sin 4\phi - 0.18 \sin 5\phi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 20°

ILLUMINATION: POLARIZED LIGHT ←→
θ_i: 53°

FIG. 216 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.58 + 2.08 \cos\varphi + 2.04 \cos 2\varphi + 0.38 \cos 3\varphi + 0.39 \cos 4\varphi + 0.32 \cos 5\varphi + 0.17 \cos 6\varphi - 0.36 \sin\varphi - 0.16 \sin 2\varphi + 0.42 \sin 3\varphi - 0.44 \sin 4\varphi + 0.28 \sin 5\varphi$$

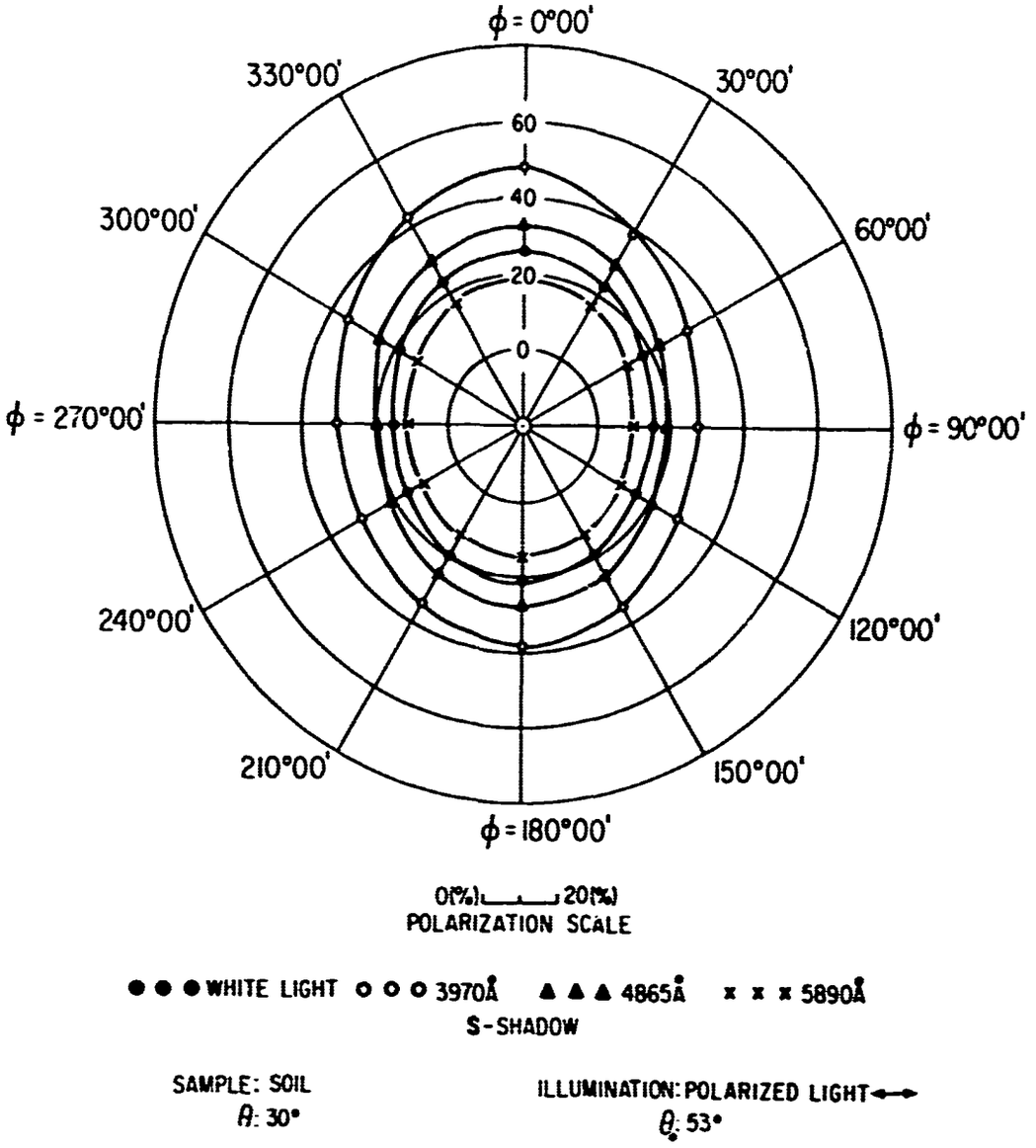


FIG. 217 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\omega) = 19.8 + 3.15 \cos\omega + 3.52 \cos 2\omega - 0.66 \cos 3\omega + 0.20 \cos 4\omega + 0.06 \cos 5\omega - 0.33 \cos 6\omega - 1.85 \sin\omega - 1.33 \sin 2\omega - 0.03 \sin 3\omega + 0.49 \sin 4\omega - 0.03 \sin 5\omega$$

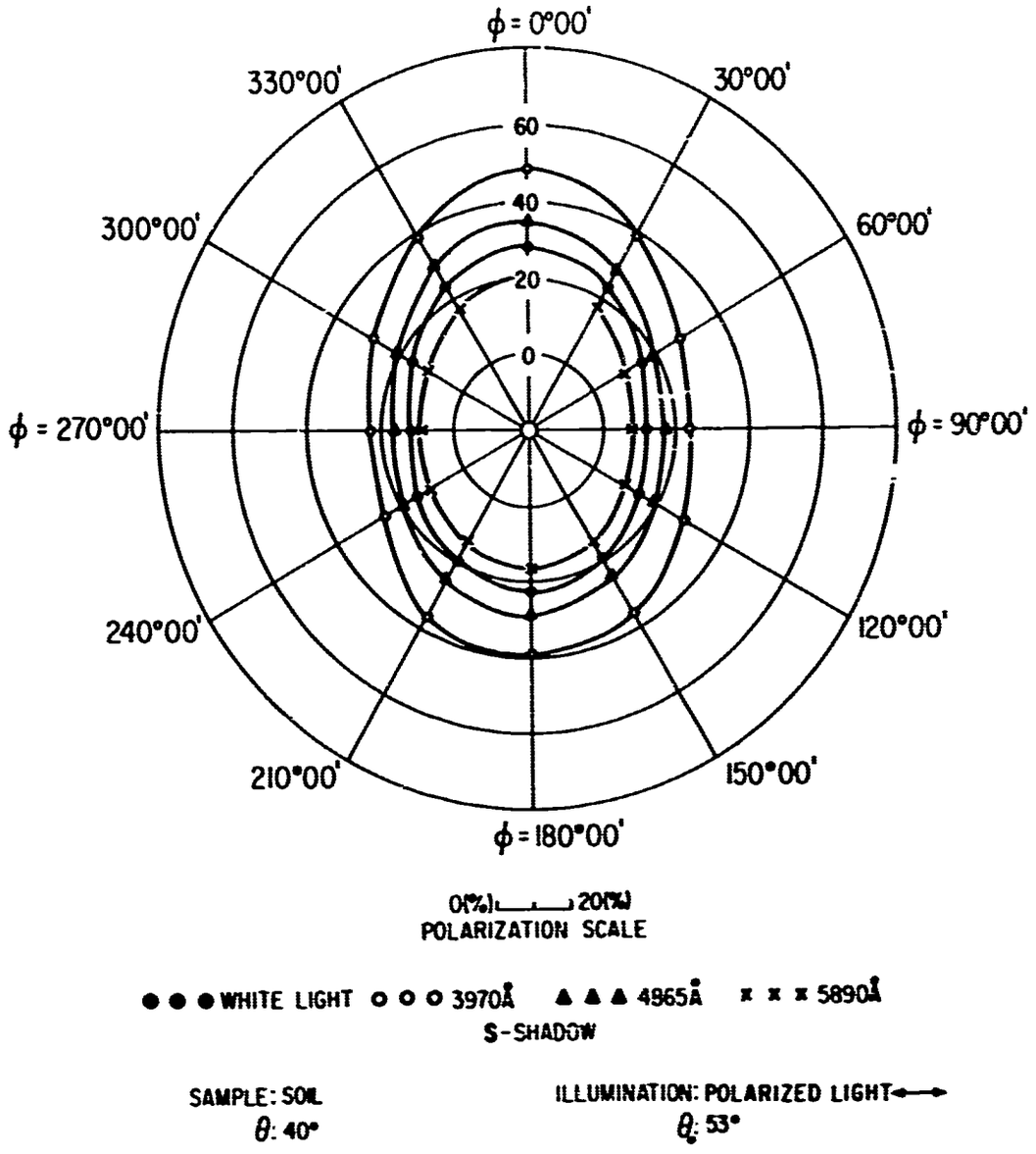


FIG. 218 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 18.21 + 2.49\cos\varphi + 6.83\cos 2\varphi + 0.23\cos 3\varphi + 0.12\cos 4\varphi - 0.08\cos 5\varphi + 0.98\cos 6\varphi - 0.49\sin\varphi + 0.00\sin 2\varphi - 0.05\sin 3\varphi - 0.26\sin 4\varphi - 0.35\sin 5\varphi$$

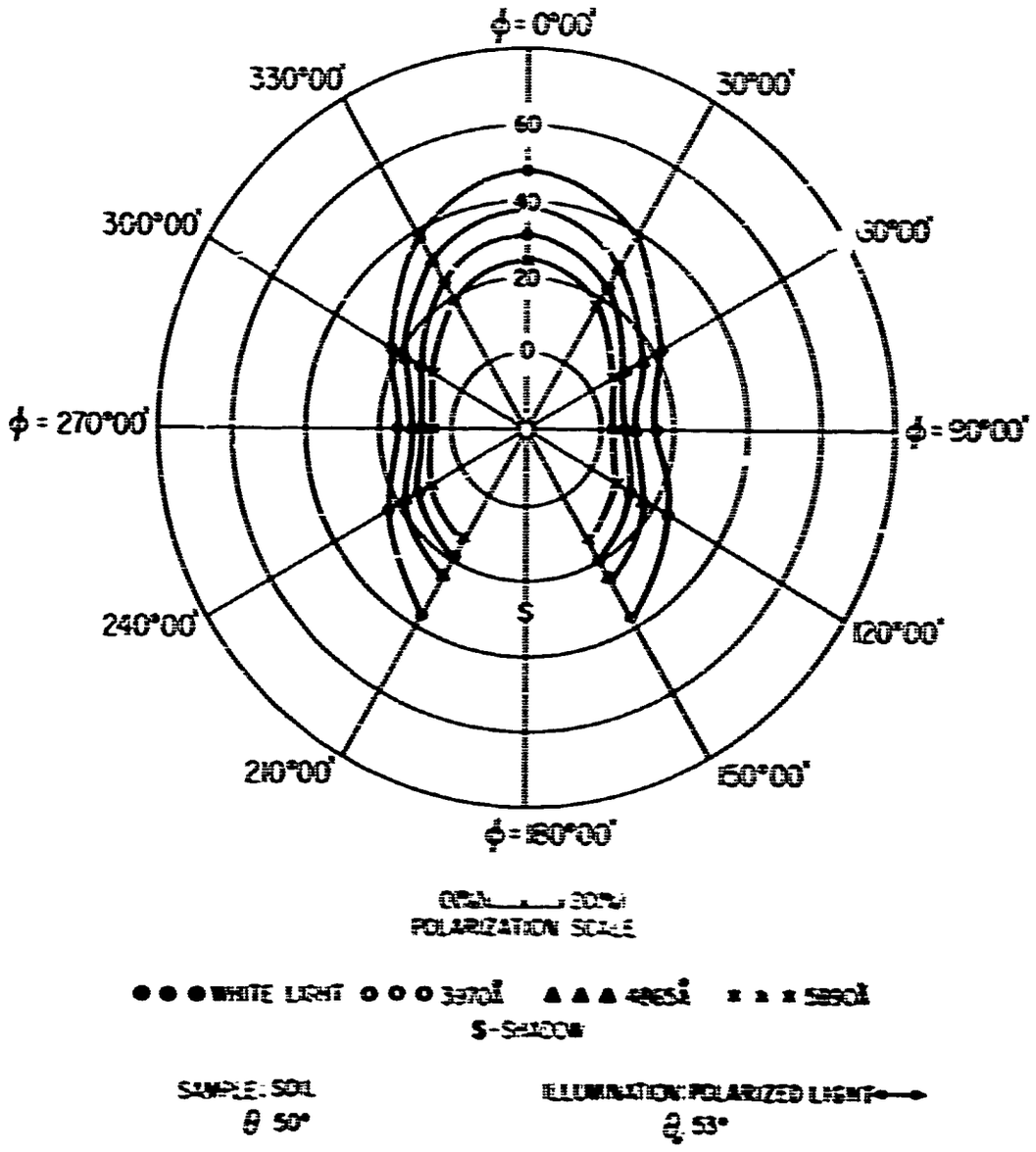


FIG. 219 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 17.07 + 2.44 \cos\phi + 9.38 \cos 2\phi + 2.15 \cos 3\phi + 0.48 \cos 4\phi + 0.68 \cos 5\phi$$
$$+ 0.43 \cos 6\phi + 0.56 \sin\phi - 0.46 \sin 2\phi - 0.08 \sin 3\phi + 0.11 \sin 4\phi + 0.13 \sin 5\phi$$

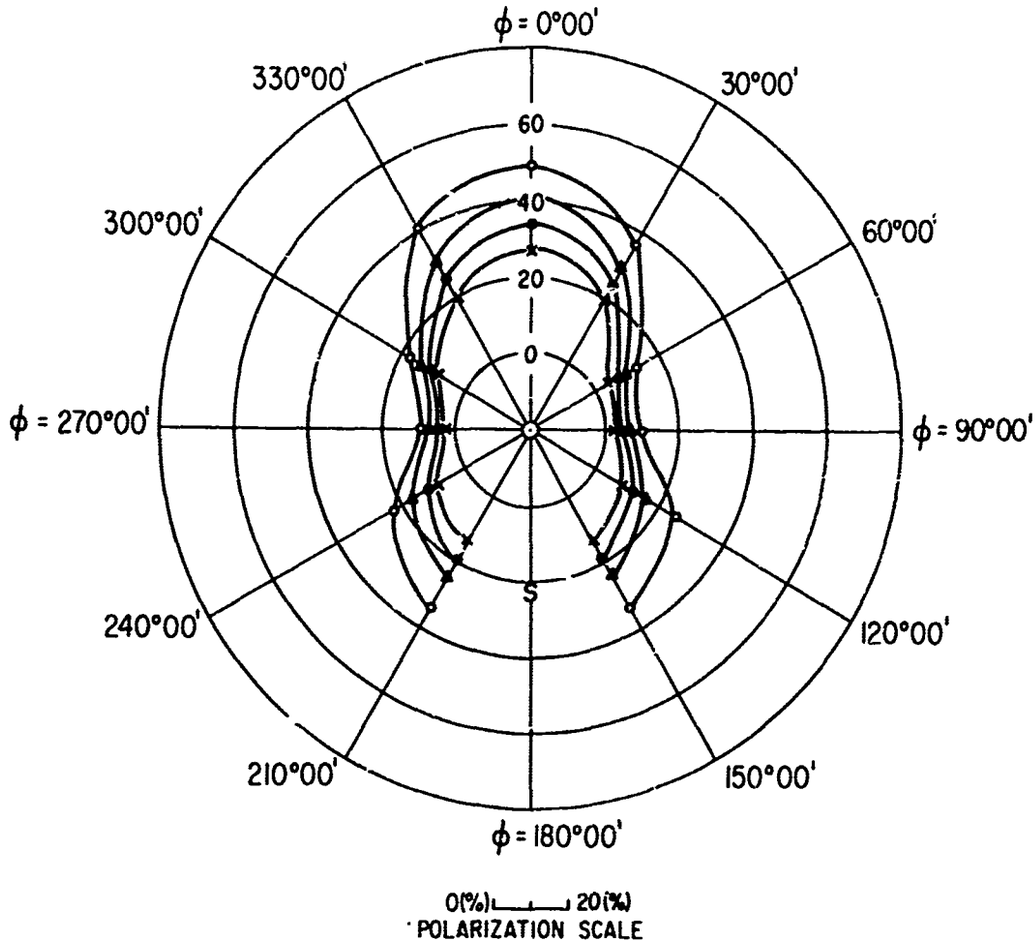
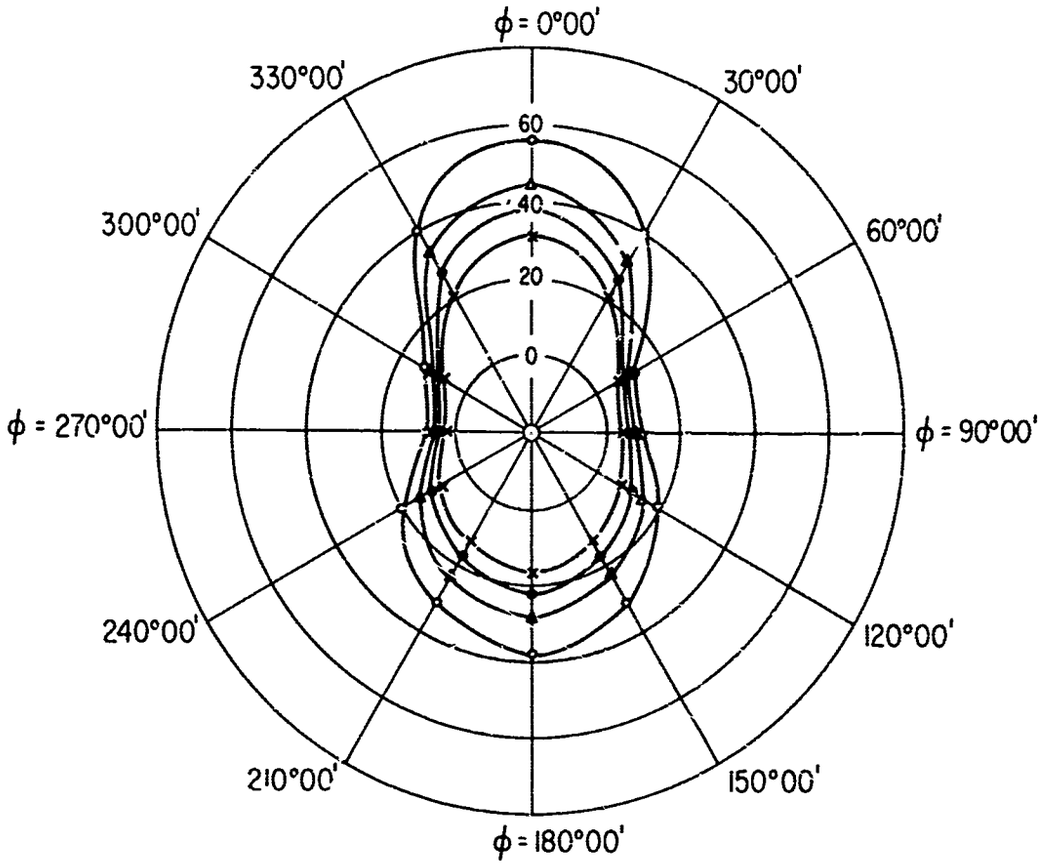


FIG. 220 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.43 + 3.16 \cos\varphi + 11.80 \cos 2\varphi + 3.05 \cos 3\varphi + 0.32 \cos 4\varphi - 0.51 \cos 5\varphi + 0.30 \cos 6\varphi - 0.80 \sin\varphi + 0.61 \sin\varphi - 0.48 \sin 3\varphi + 0.23 \sin 4\varphi + 0.21 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 70°

ILLUMINATION: POLARIZED LIGHT ←→
θ: 53°

FIG.221 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.49 + 4.87 \cos\varphi + 12.48 \cos 2\varphi + 3.62 \cos 3\varphi + 1.23 \cos 4\varphi - 0.59 \cos 5\varphi - 0.02 \cos 6\varphi - 0.18 \sin\varphi - 0.40 \sin 2\varphi - 0.60 \sin 3\varphi + 0.09 \sin 4\varphi + 0.33 \sin 5\varphi$$

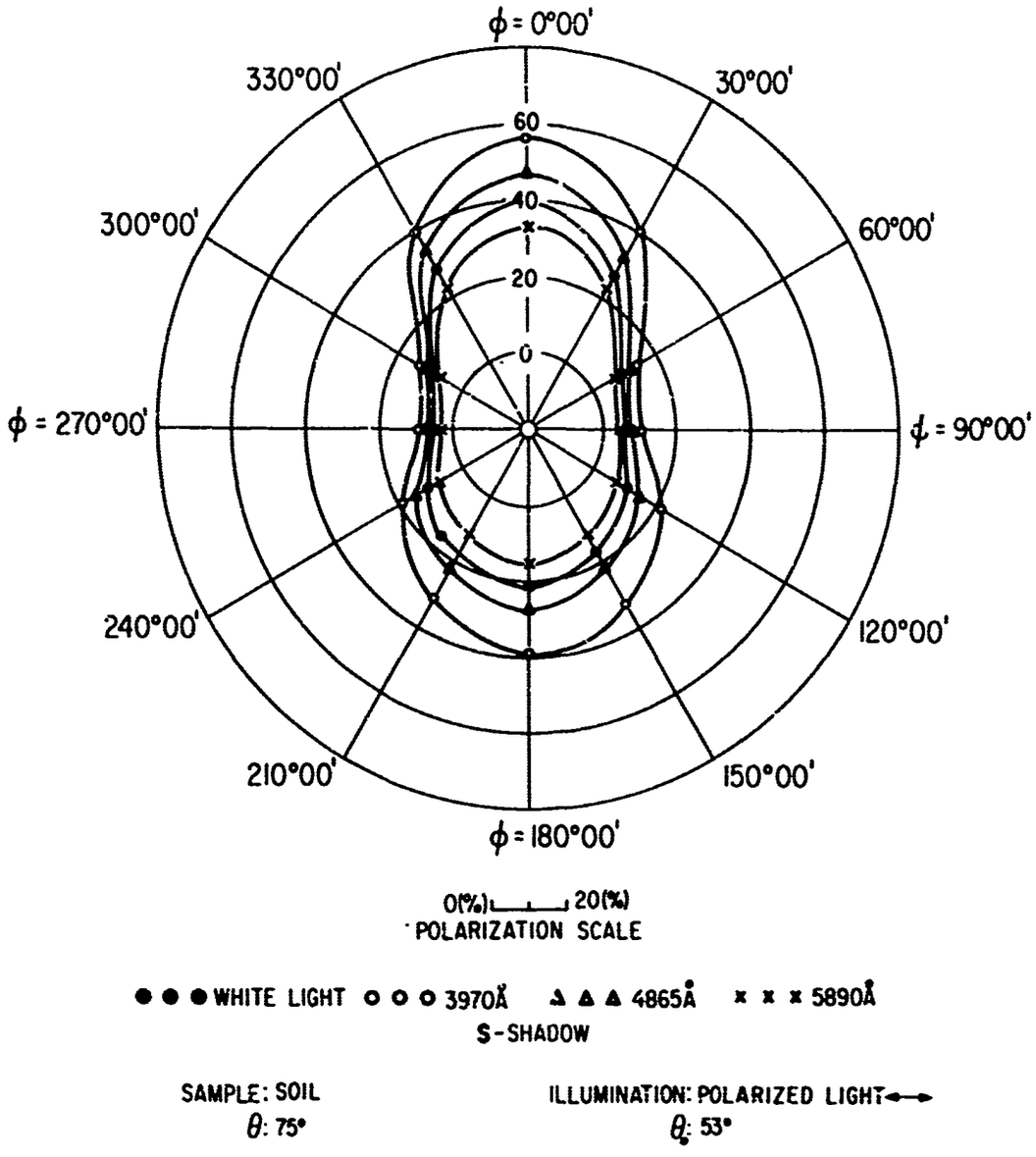


FIG.222 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 16.94 + 6.09\cos\varphi + 12.61\cos 2\varphi + 3.82\cos 3\varphi + 1.61\cos 4\varphi - 0.61\cos 5\varphi - 0.32\cos 6\varphi - 0.29\sin\varphi - 0.27\sin 2\varphi - 0.40\sin 3\varphi - 0.19\sin 4\varphi + 0.09\sin 5\varphi$$

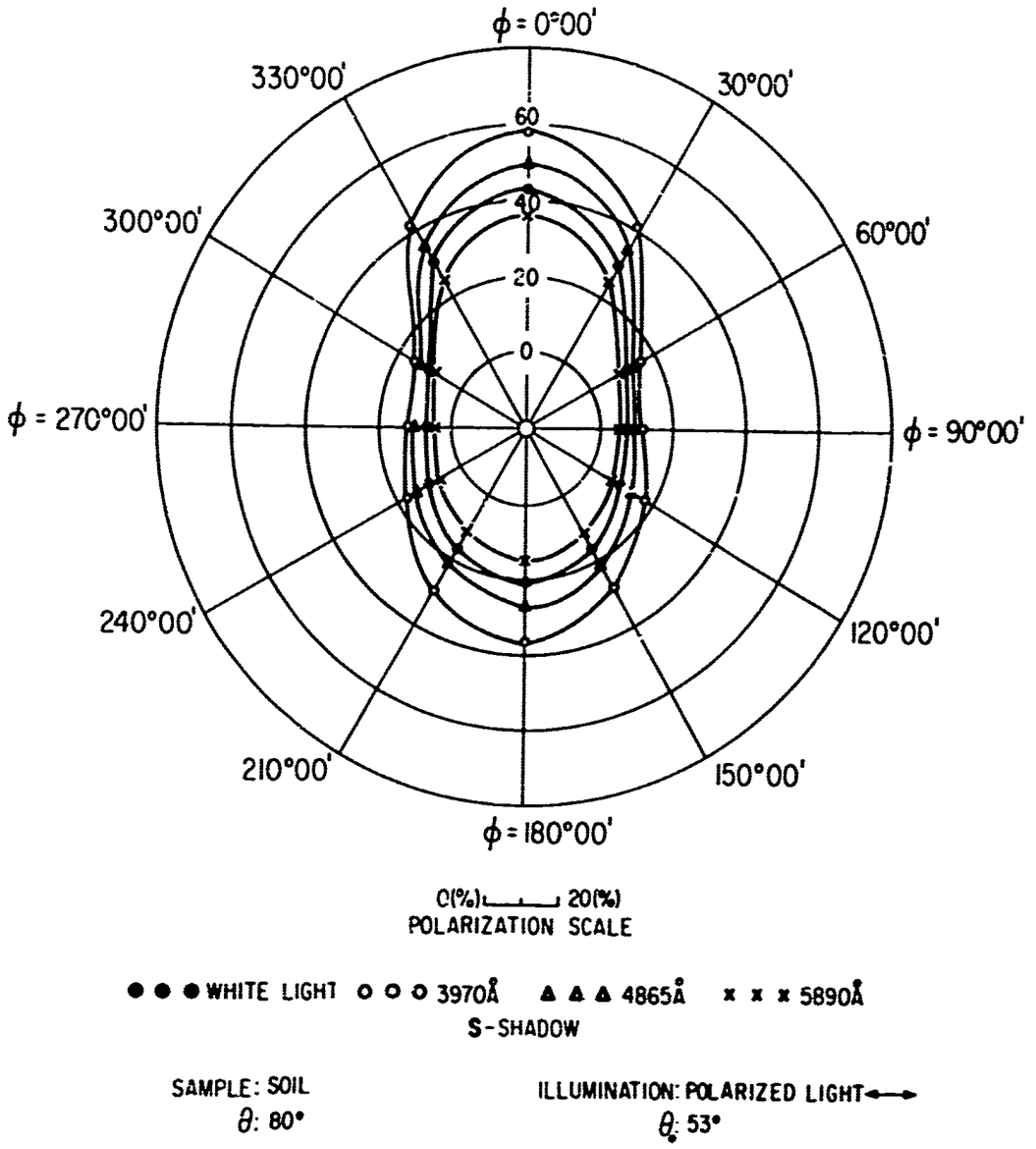


FIG.223 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.83 + 7.83\cos\varphi + 12.93\cos 2\varphi + 3.37\cos 3\varphi + 1.92\cos 4\varphi - 0.15\cos 5\varphi - 0.67\cos 6\varphi - 0.06\sin\varphi - 0.20\sin 2\varphi - 0.33\sin 3\varphi - 0.17\sin 4\varphi + 0.08\sin 5\varphi$$

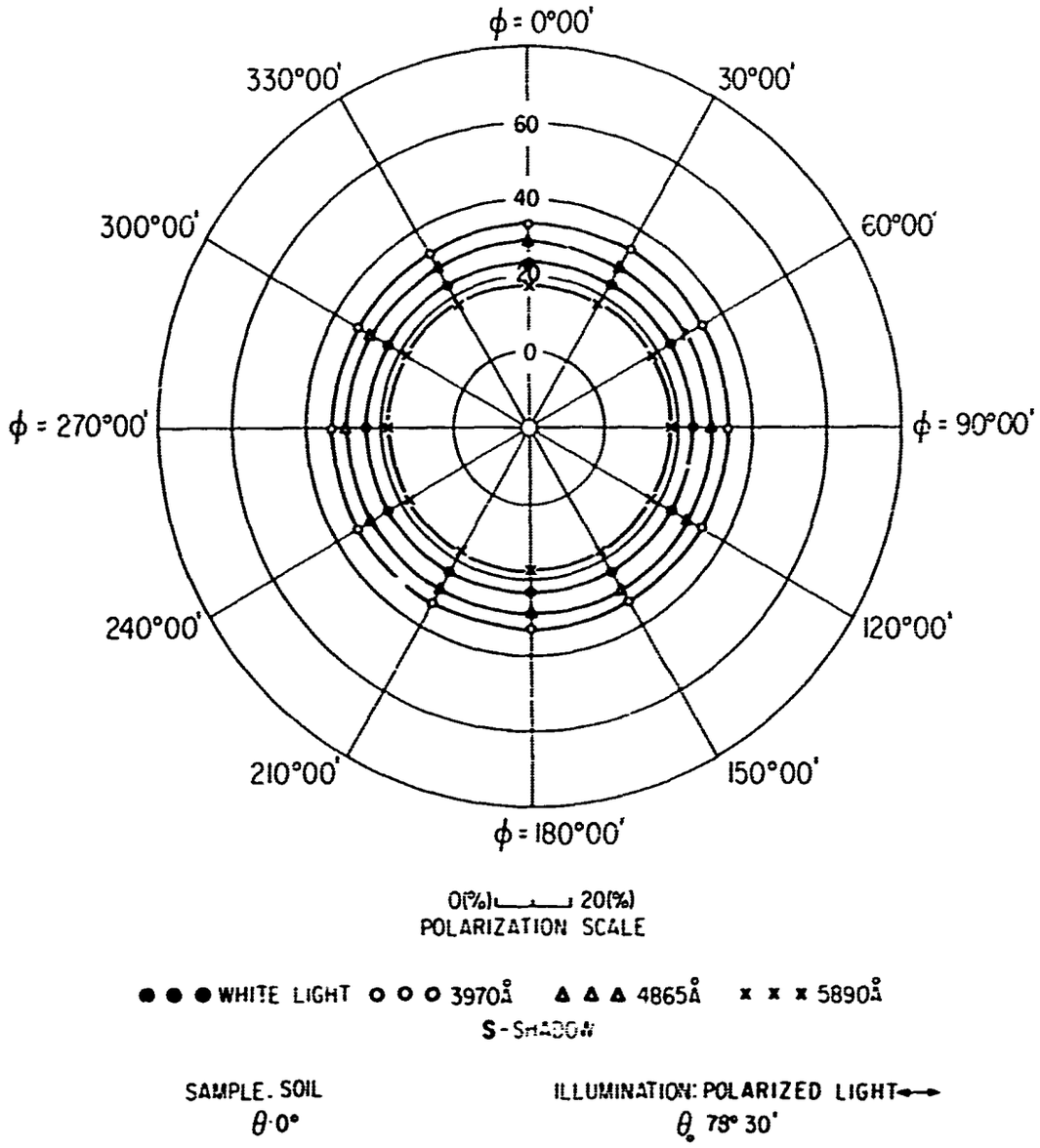


FIG 224 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

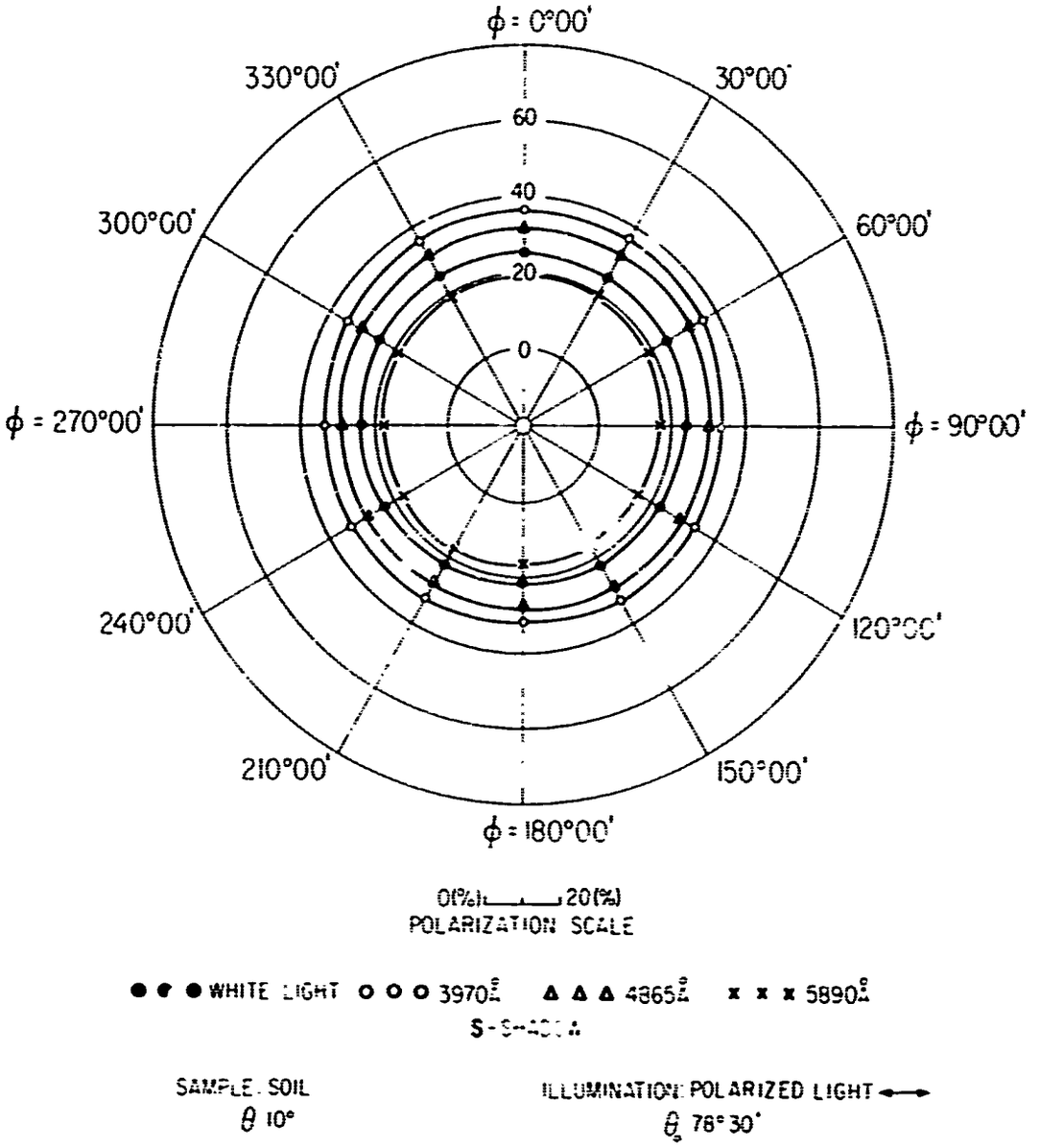


FIG 225 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.18 + 2.47\cos\varphi + 0.53\cos 2\varphi + 0.05\cos 3\varphi - 0.03\cos 4\varphi - 0.27\cos 5\varphi - 0.07\cos 6\varphi - 0.73\sin\varphi + 0.39\sin 2\varphi + 0.05\sin 3\varphi + 0.79\sin 4\varphi - 0.27\sin 5\varphi$$

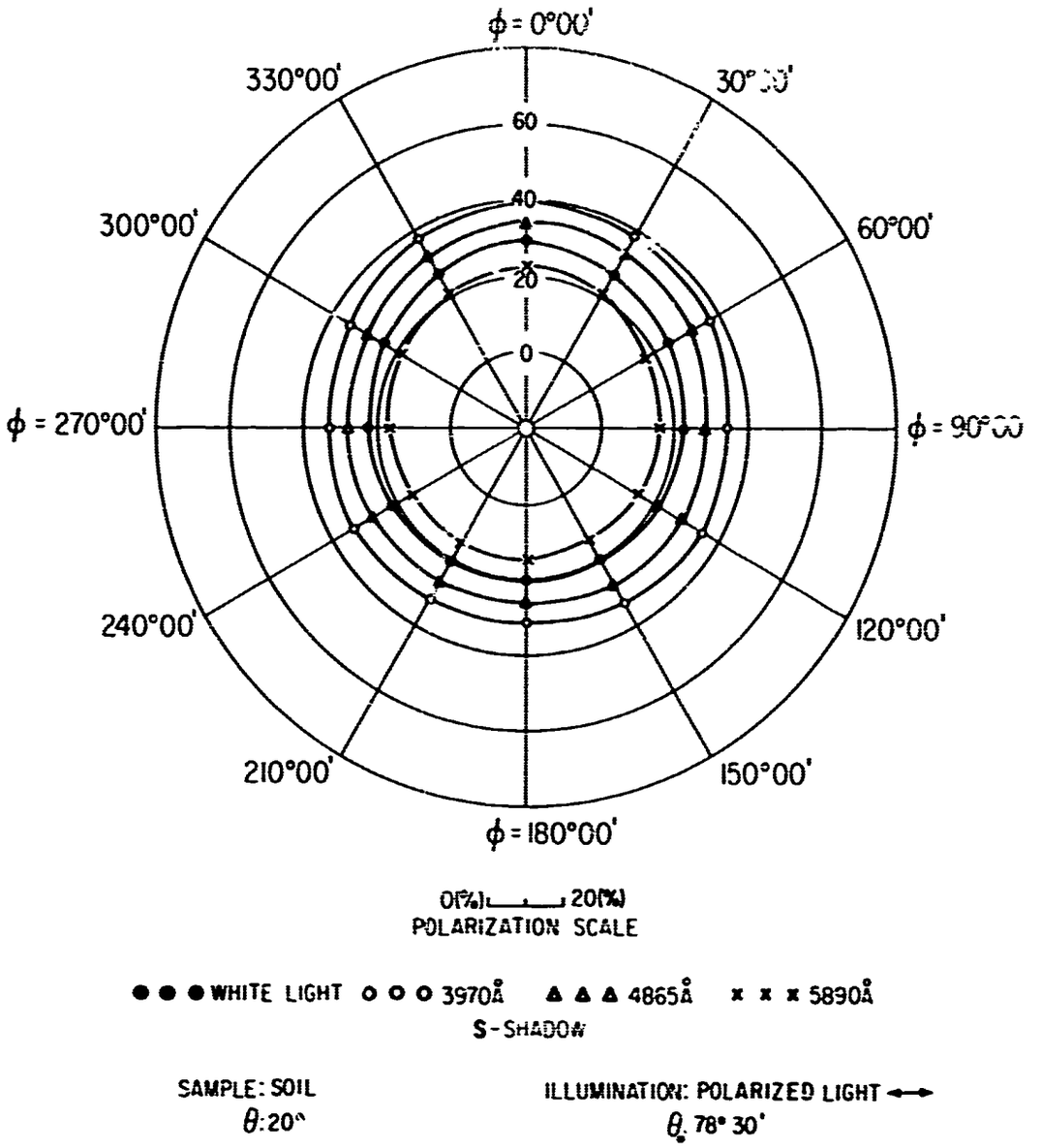


FIG 226 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.98 + 3.91 \cos\varphi + 1.05 \cos 2\varphi + 0.57 \cos 3\varphi + 0.35 \cos 4\varphi - 0.08 \cos 5\varphi + 0.30 \cos 6\varphi - 0.38 \sin\varphi - 0.15 \sin 2\varphi - 0.50 \sin 3\varphi + 0.49 \sin 4\varphi - 0.02 \sin 5\varphi$$

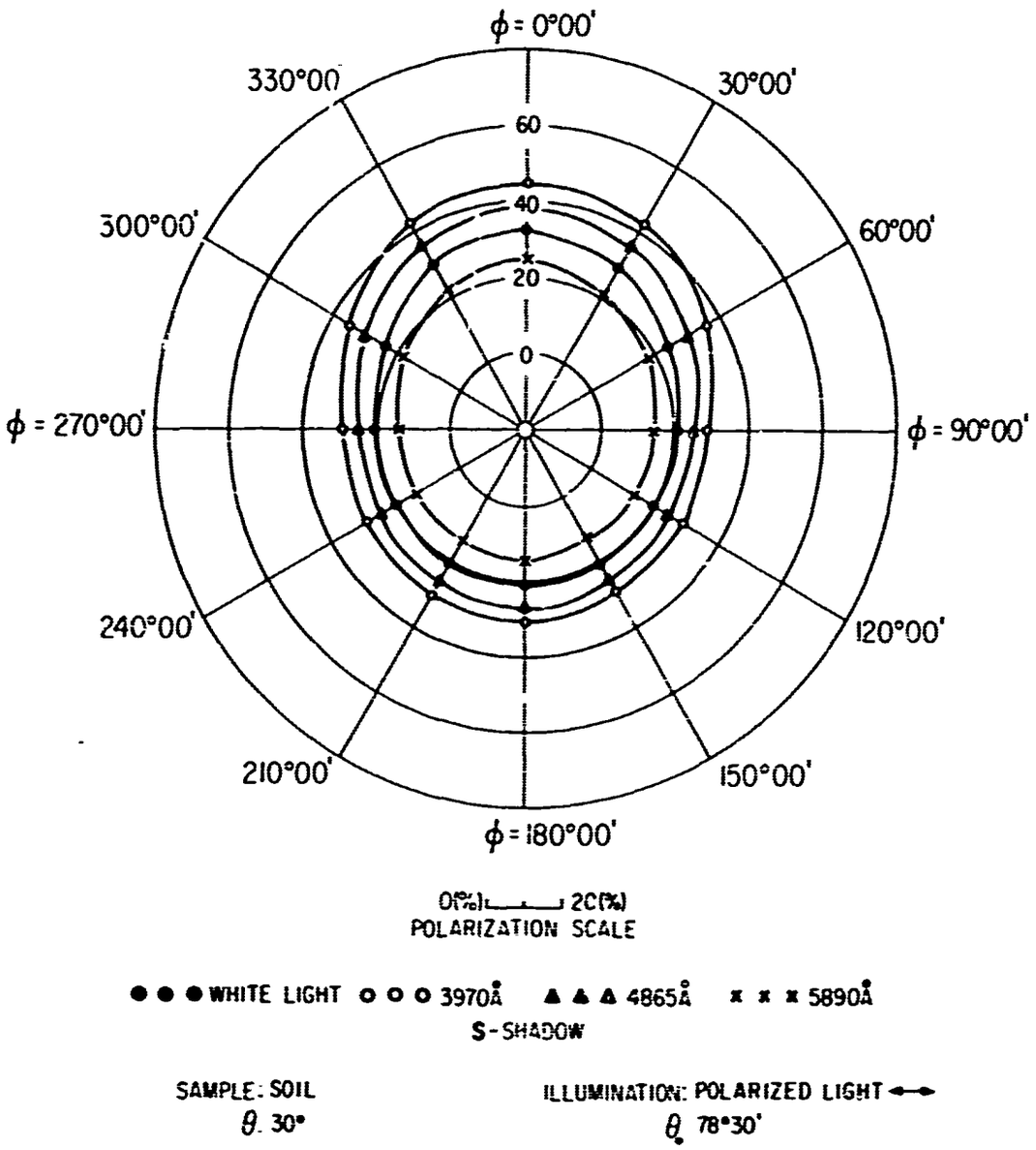


FIG.227 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 22.88 + 5.76 \cos\varphi + 2.78 \cos 2\varphi + 0.02 \cos 3\varphi + 0.54 \cos 4\varphi + 0.34 \cos 5\varphi + 0.40 \cos 6\varphi + 0.06 \sin\varphi + 0.56 \sin 2\varphi - 0.95 \sin 3\varphi - 0.79 \sin 4\varphi - 0.76 \sin 5\varphi$$

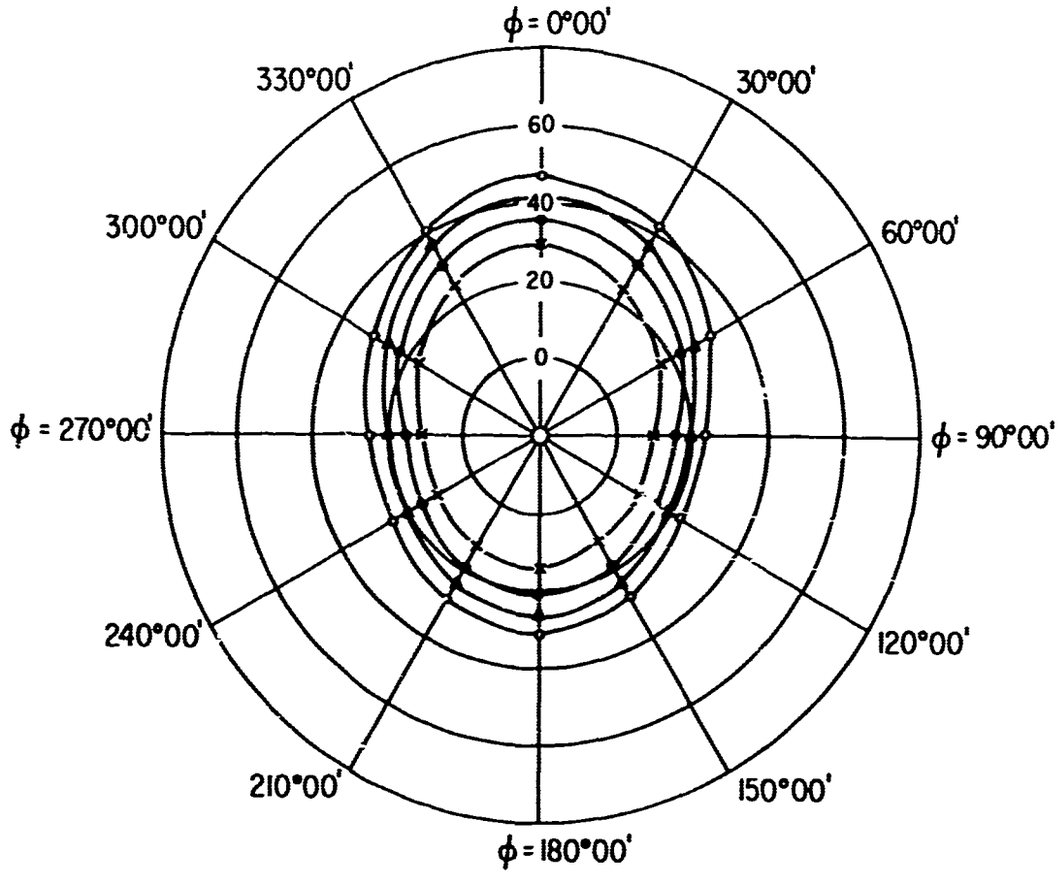


FIG.228 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 21.31 + 7.33\cos\varphi + 6.00\cos 2\varphi + 0.40\cos 3\varphi + 0.22\cos 4\varphi + 0.32\cos 5\varphi + 1.25\cos 6\varphi - 0.46\sin\varphi - 0.06\sin 2\varphi - 0.82\sin 3\varphi - 0.09\sin 4\varphi - 0.36\sin 5\varphi$$

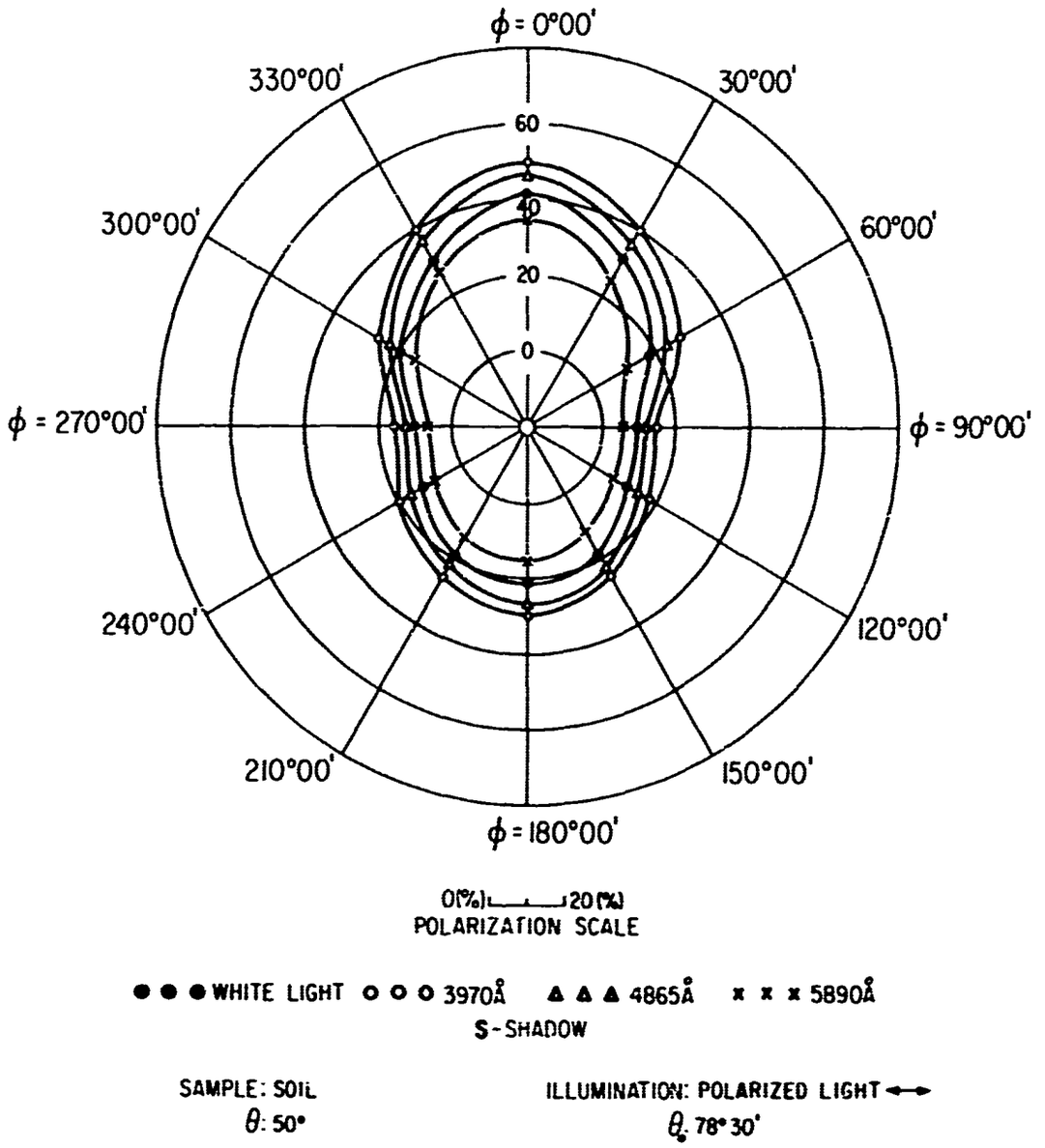
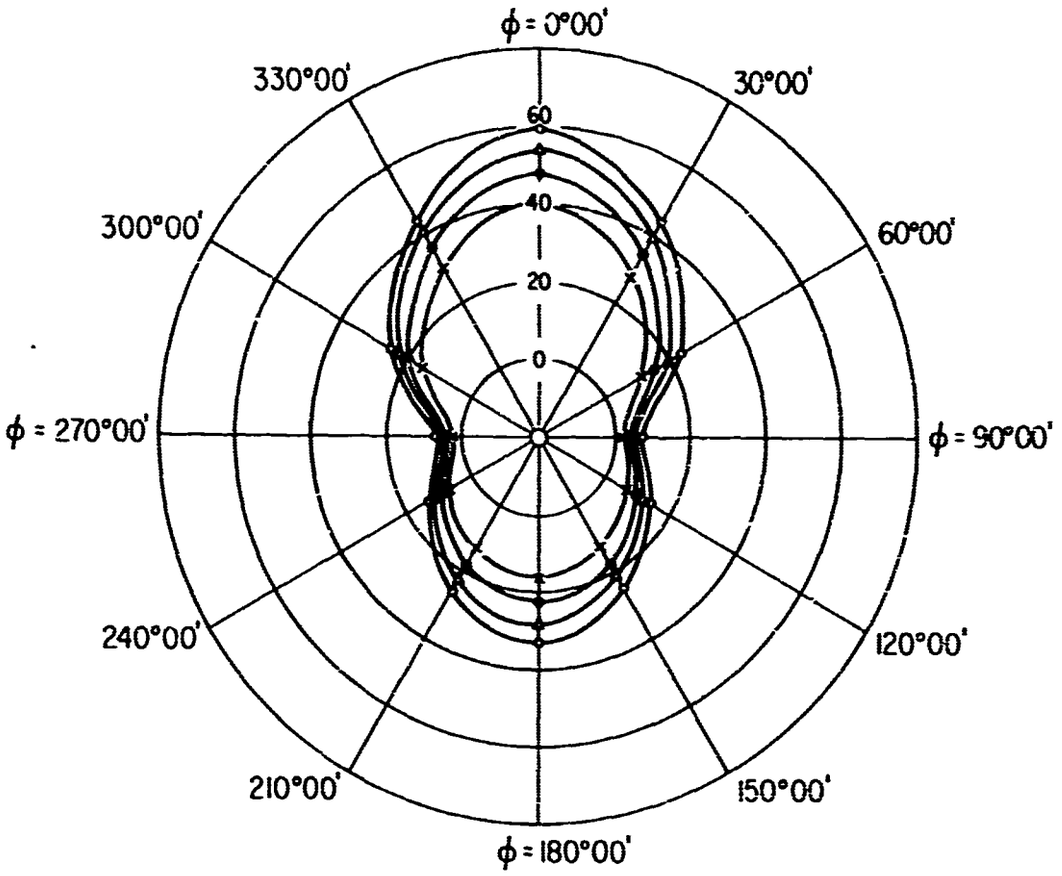


FIG.229 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 20.44 + 8.89 \cos\varphi + 10.59 \cos 2\varphi + 0.20 \cos 3\varphi + 0.01 \cos 4\varphi + 1.11 \cos 5\varphi + 1.12 \cos 6\varphi - 1.29 \sin\varphi + 0.10 \sin 2\varphi - 0.98 \sin 3\varphi - 0.13 \sin 4\varphi + 0.31 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 60°

ILLUMINATION: POLARIZED LIGHT ←→
θ_0 78°30'

FIG.230 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.24 + 10.79 \cos\varphi + 15.30 \cos 2\varphi + 0.70 \cos 3\varphi - 0.68 \cos 4\varphi + 1.16 \cos 5\varphi + 2.85 \cos 6\varphi - 0.25 \sin\varphi - 0.29 \sin 2\varphi - 0.28 \sin 3\varphi - 0.26 \sin 4\varphi - 0.63 \sin 5\varphi$$

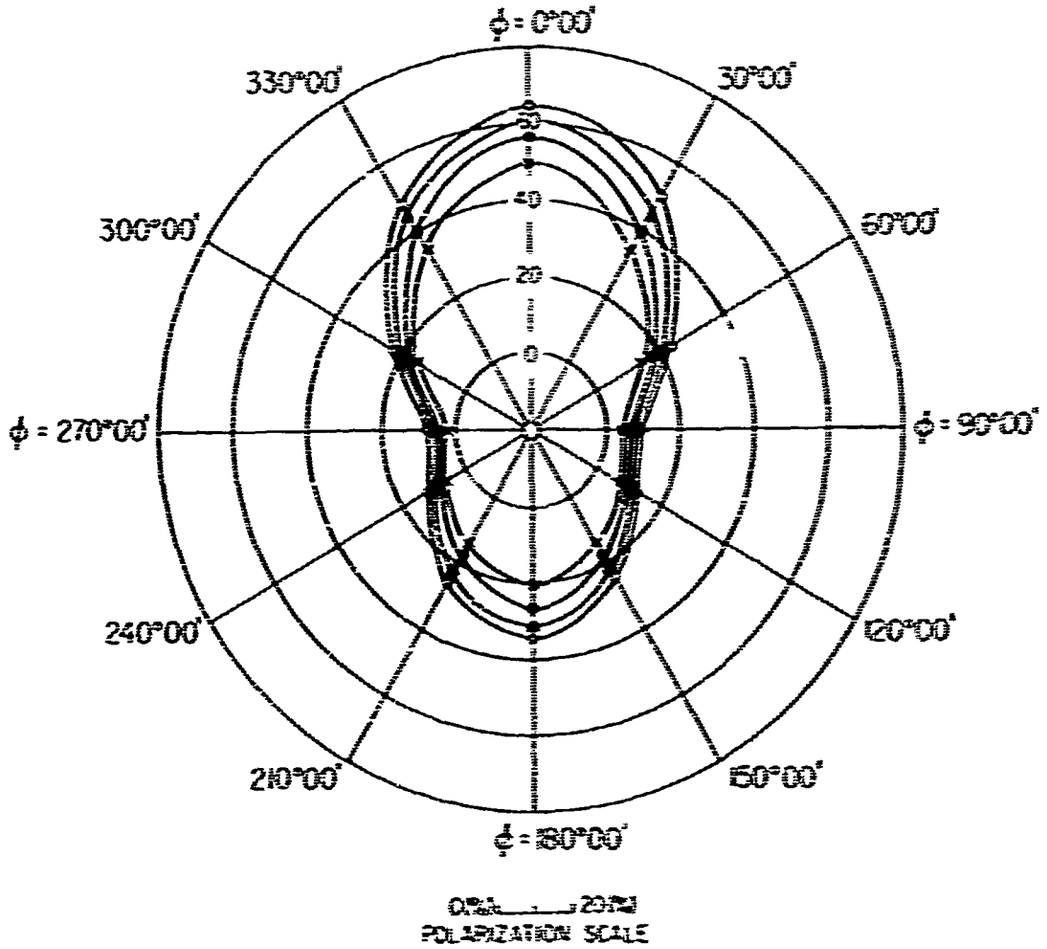
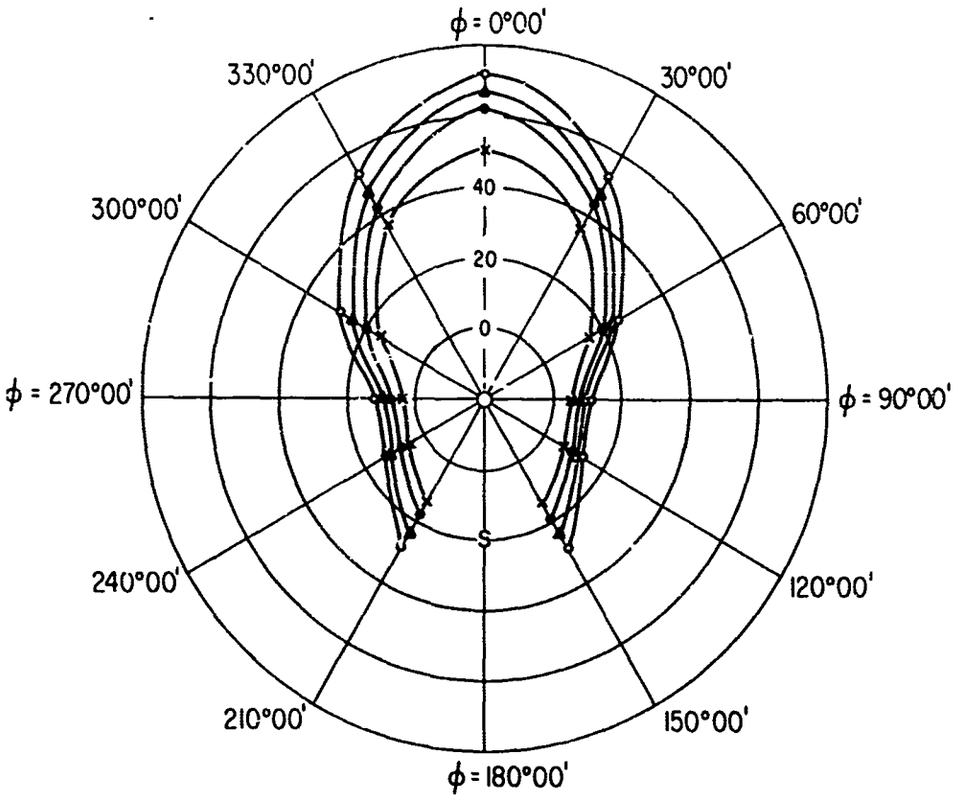


FIG 231 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 21.28 + 12.48 \cos\varphi + 17.64 \cos 2\varphi + 1.90 \cos 3\varphi + 2.11 \cos 4\varphi + 0.27 \cos 5\varphi + 1.25 \cos 6\varphi + 0.10 \sin\varphi - 0.58 \sin 2\varphi - 0.22 \sin 3\varphi + 0.37 \sin 4\varphi + 0.07 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ. 75°

ILLUMINATION: POLARIZED LIGHT ←→
θ_0: 78° 30'

FIG.232 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.44 + 14.99 \cos\varphi + 18.82 \cos 2\varphi + 3.33 \cos 3\varphi + 3.53 \cos 4\varphi + 0.93 \cos 5\varphi + 0.92 \cos 6\varphi + \text{[illegible]}\ 96 \sin\varphi - 0.03 \sin 2\varphi + 0.28 \sin 3\varphi + 0.06 \sin 4\varphi + 0.20 \sin 5\varphi$$

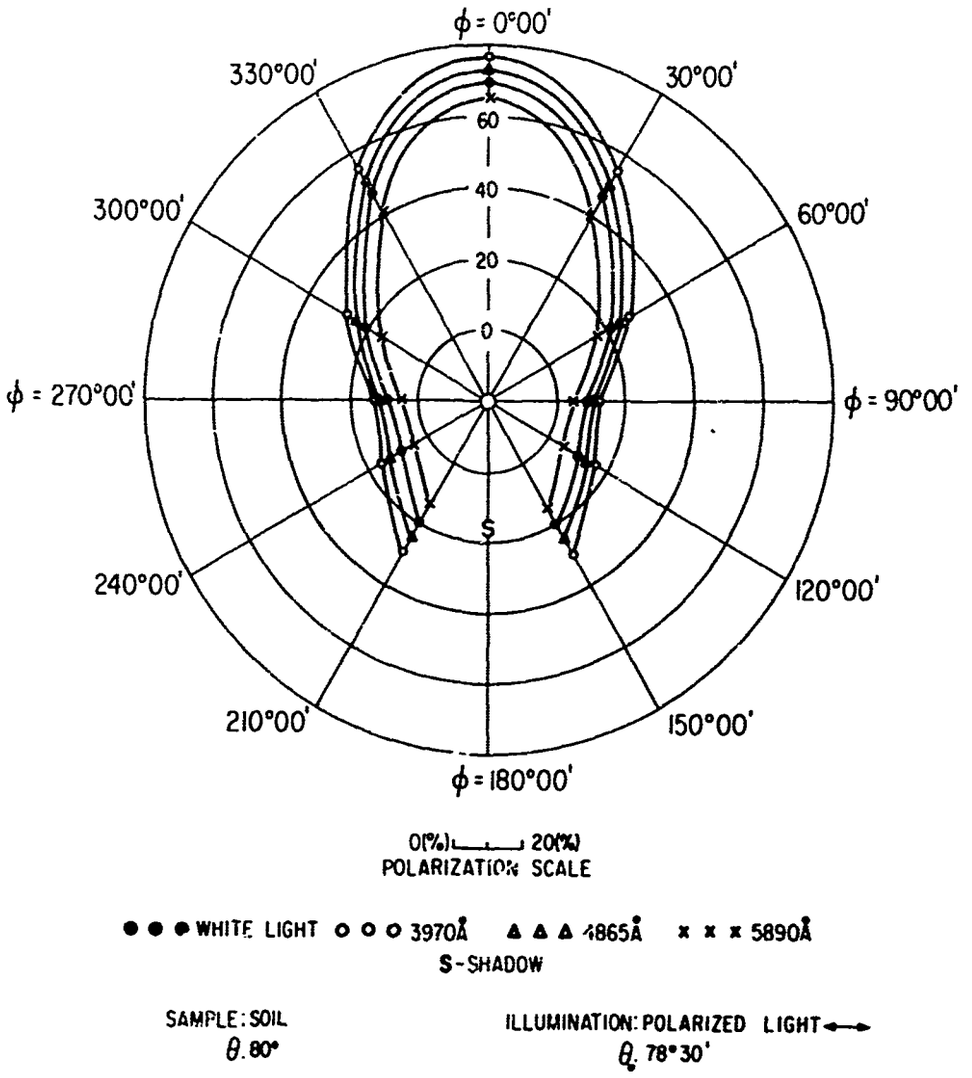


FIG.233 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 26.24 + 16.34 \cos\varphi + 19.53 \cos 2\varphi + 3.47 \cos 3\varphi + 2.27 \cos 4\varphi + 1.10 \cos 5\varphi + 1.38 \cos 6\varphi + 0.59 \sin\varphi - 0.90 \sin 2\varphi - 0.75 \sin 3\varphi - 0.02 \sin 4\varphi + 0.01 \sin 5\varphi$$

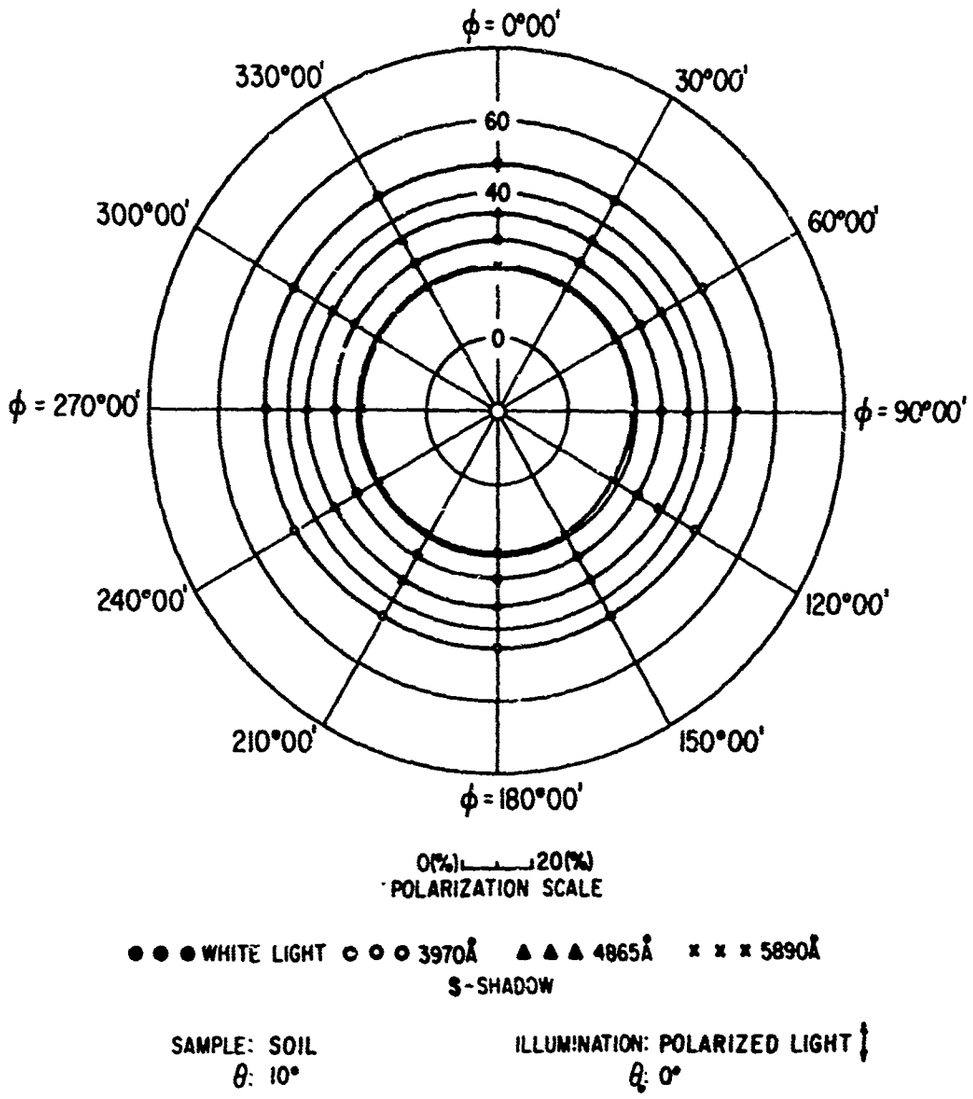


FIG. 234. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 26.45 + 0.02\cos\varphi + 0.14\cos 2\varphi - 0.07\cos 3\varphi + 0.12\cos 4\varphi - 0.0\cos 5\varphi - 0.03\cos 6\varphi + 0.14\sin\varphi + 0.33\sin 2\varphi + 0.07\sin 3\varphi - 0.04\sin 4\varphi - 0.07\sin 5\varphi$$

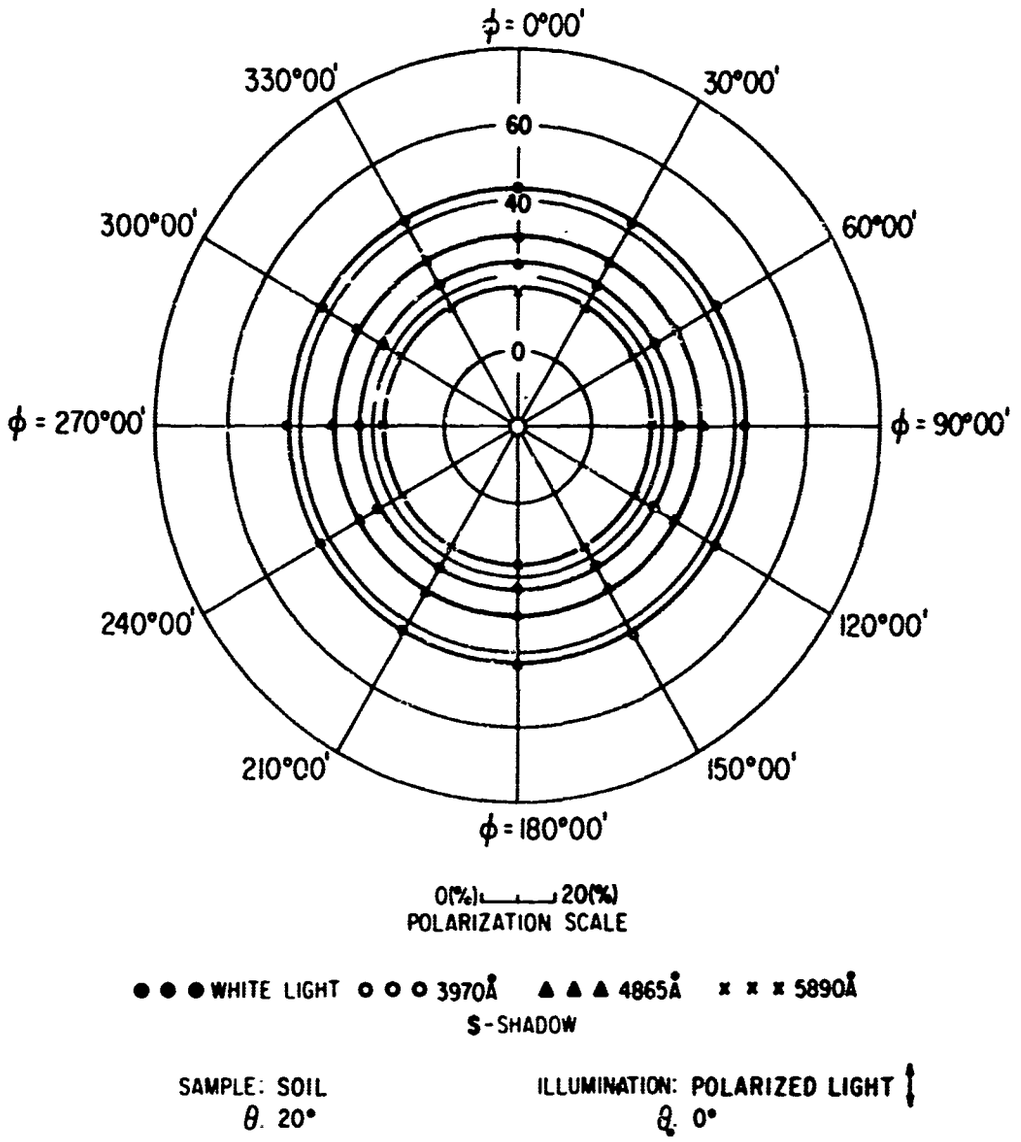


FIG. 235. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.18 + 0.05\cos\varphi - 0.76\cos 2\varphi + 0.18\cos 3\varphi + 0.59\cos 4\varphi - 0.02\cos 5\varphi$$
$$- 0.13\cos 6\varphi - 0.14\sin\varphi + 0.13\sin 2\varphi + 0.15\sin 3\varphi + 0.05\sin 4\varphi - 0.02\sin 5\varphi$$

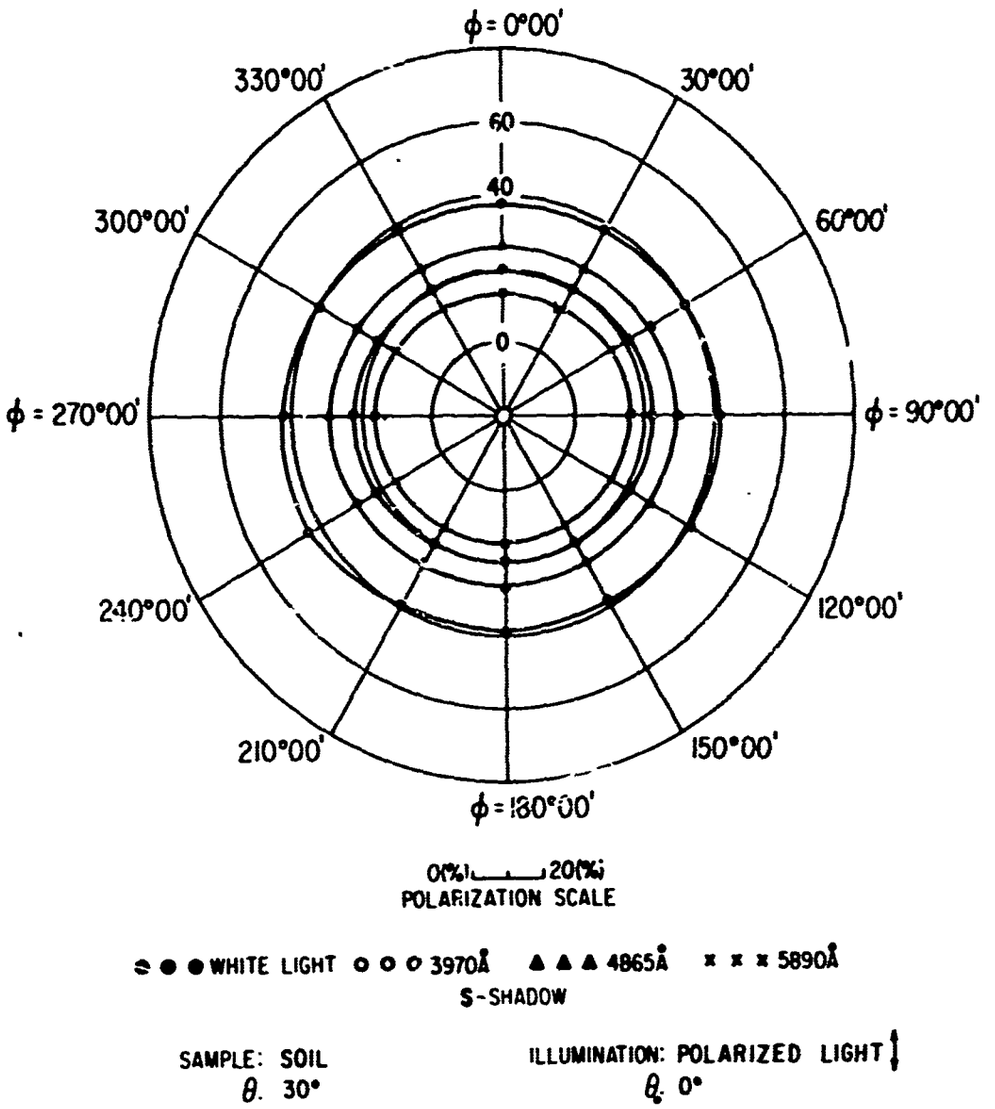
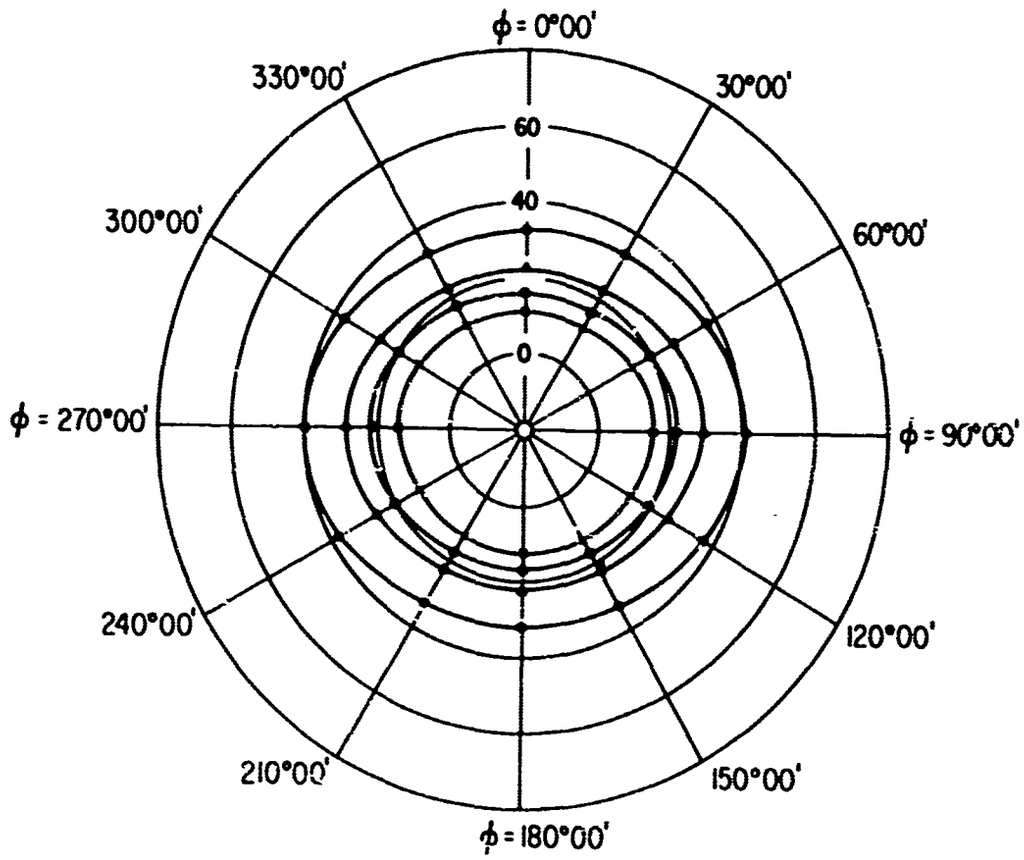


FIG. 236. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 20.62 - 0.08 \cos\varphi - 1.53 \cos 2\varphi + 0.05 \cos 3\varphi + 0.31 \cos 4\varphi + 0.11 \cos 5\varphi + 0.00 \cos 6\varphi - 0.10 \sin\varphi + 0.39 \sin 2\varphi - 0.05 \sin 3\varphi - 0.27 \sin 4\varphi + 0.10 \sin 4\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE: SOIL
θ 40°

ILLUMINATION: POLARIZED LIGHT
θ_0 0°

FIG. 237. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 18.48 - 0.15\cos\varphi - 2.57\cos 2\varphi + 0.18\cos 3\varphi + 0.37\cos 4\varphi - 0.08\cos 5\varphi + 0.33\cos 6\varphi - 0.05\sin\varphi + 0.58\sin 2\varphi - 0.02\sin 3\varphi + 0.17\sin 4\varphi + 0.18\sin 5\varphi$$

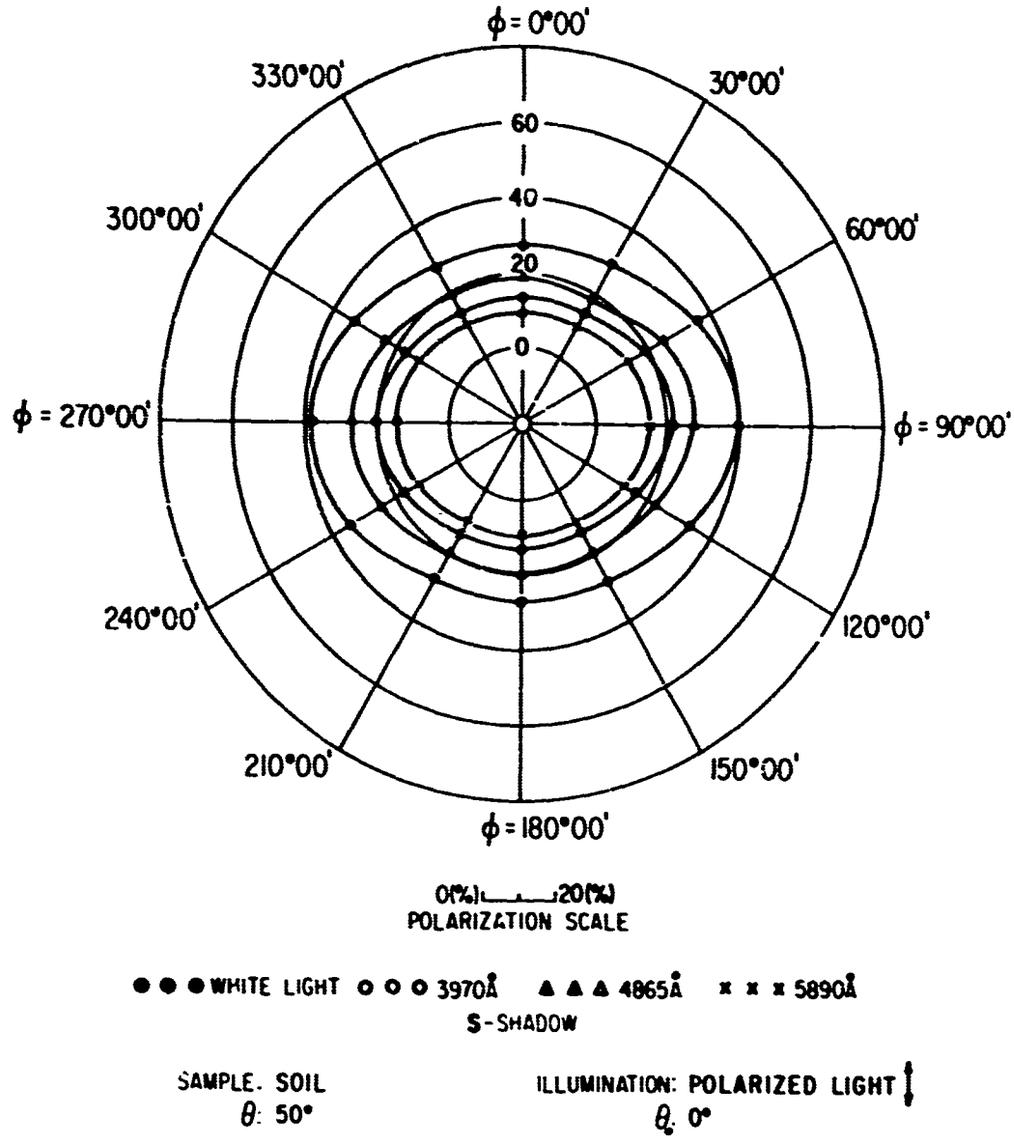


FIG. 238. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 15.65 + 0.60 \cos\varphi - 3.27 \cos 2\varphi - 1.42 \cos 3\varphi + 1.60 \cos 4\varphi + 0.66 \cos 5\varphi - 1.07 \cos 6\varphi + 1.09 \sin\varphi - 0.61 \sin 2\varphi - 0.08 \sin 3\varphi + 0.89 \sin 4\varphi - 0.92 \sin 5\varphi$$

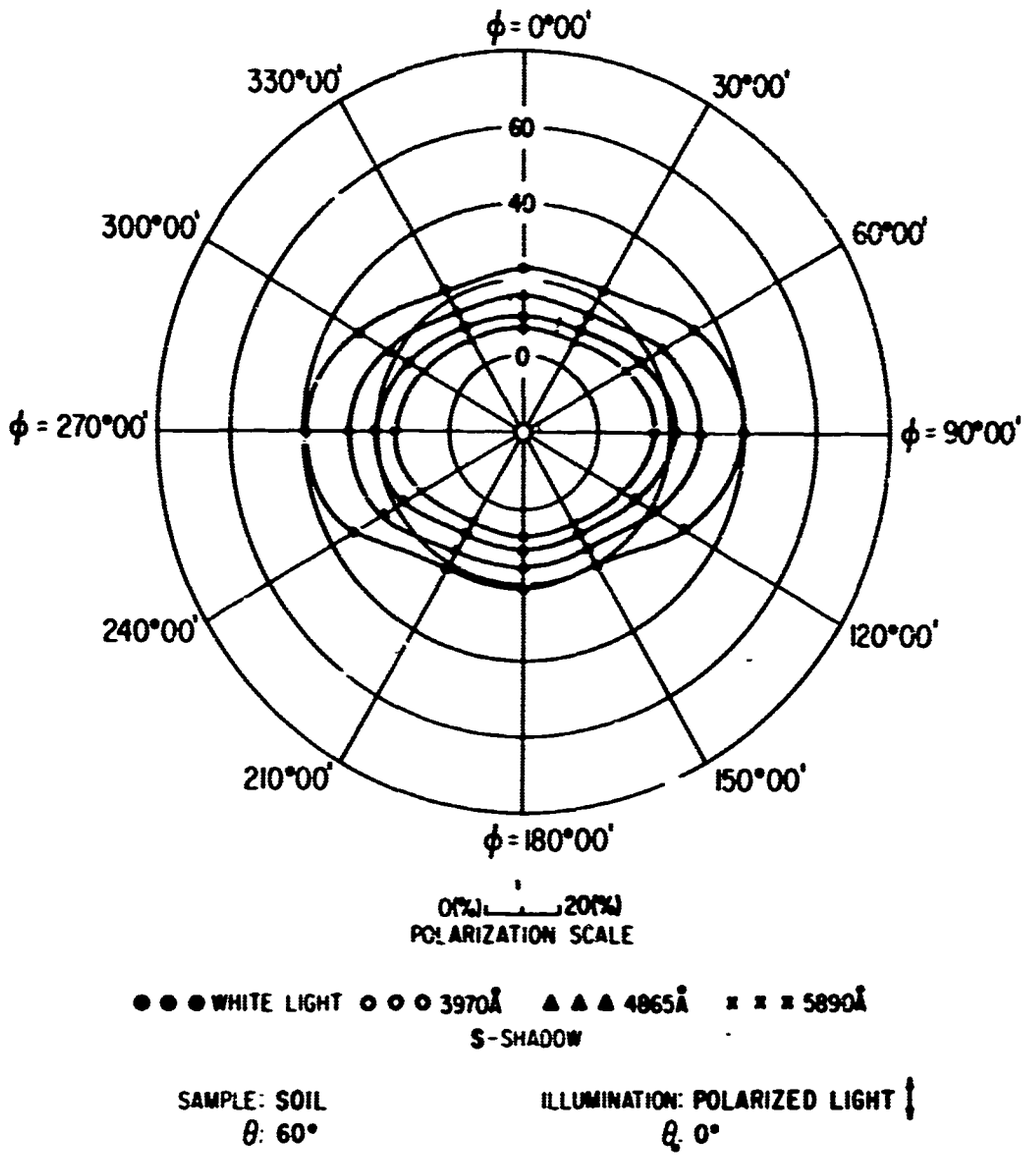
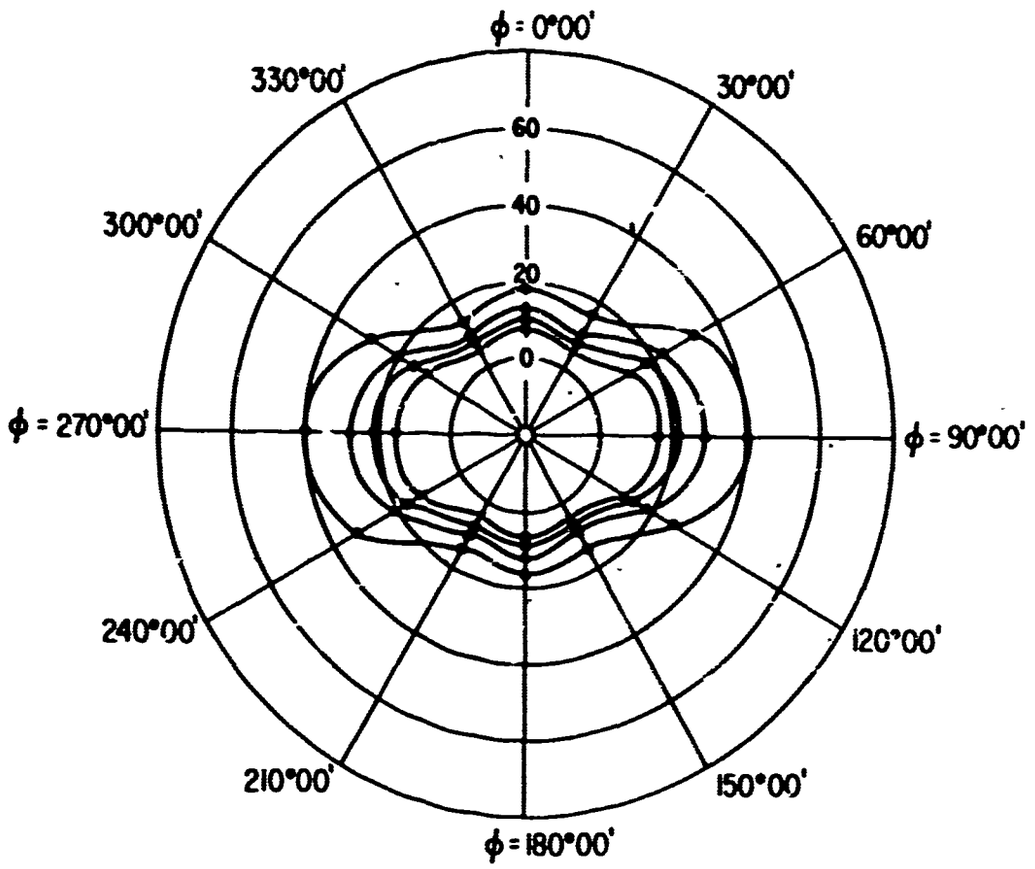


FIG. 239. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.95 + 0.06\cos\varphi - 4.07\cos 2\varphi - 0.13\cos 3\varphi + 0.65\cos 4\varphi - 0.08\cos 5\varphi + 1.43\cos 6\varphi + 1.06\sin\varphi + 0.66\sin 2\varphi - 1.11\sin 3\varphi - 0.58\sin 4\varphi + 0.92\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S - SHADOW

SAMPLE: SOIL
θ: 70°

ILLUMINATION: POLARIZED LIGHT ↕
θ: 0°

FIG. 240. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.07 - 0.15\cos\varphi - 6.72\cos 2\varphi + 0.08\cos 3\varphi + 2.61\cos 4\varphi + 0.14\cos 5\varphi + 1.52\cos 6\varphi - 0.08\sin\varphi + 1.08\sin 2\varphi - 0.22\sin 3\varphi - 0.56\sin 4\varphi + 0.01\sin 5\varphi$$

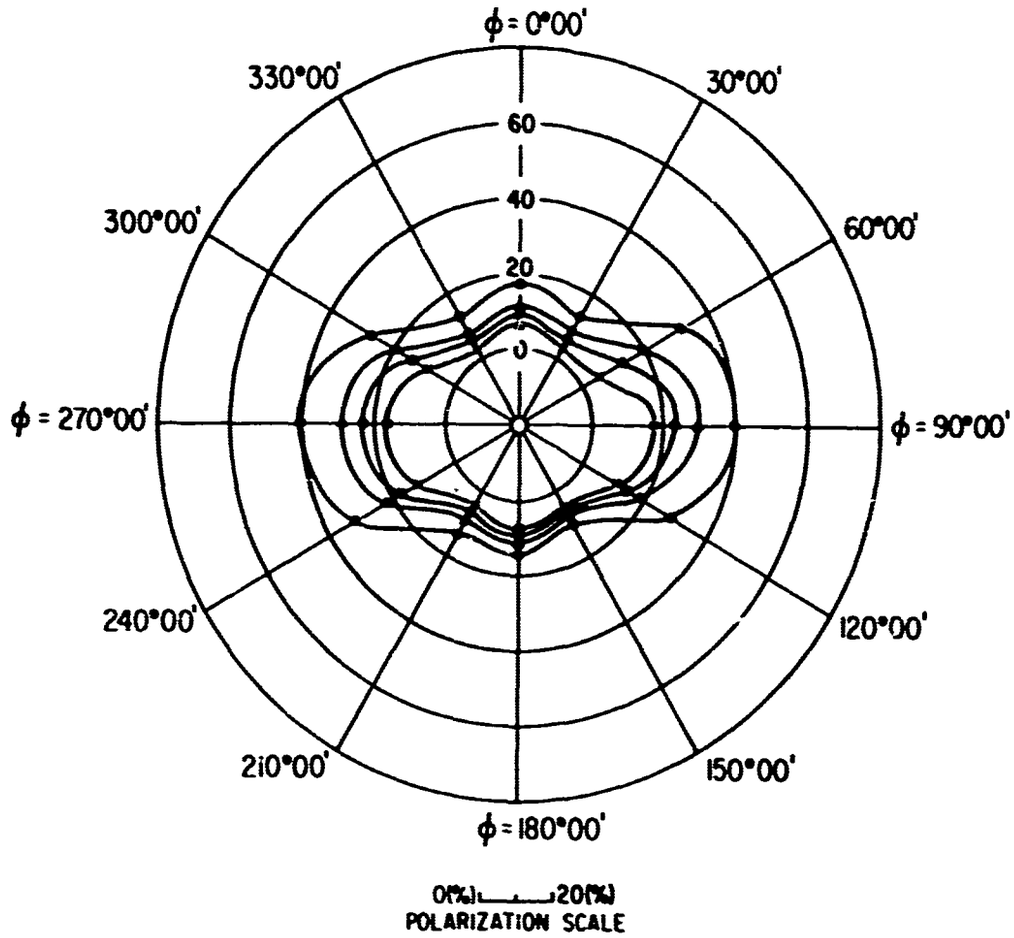


FIG. 241. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.22 + 0.71 \cos\varphi - 6.91 \cos 2\varphi + 0.20 \cos 3\varphi + 2.69 \cos 4\varphi - 0.96 \cos 5\varphi + 1.10 \cos 6\varphi - 0.63 \sin\varphi + 0.30 \sin 2\varphi - 1.10 \sin 3\varphi - 2.04 \sin 4\varphi - 0.54 \sin 5\varphi$$

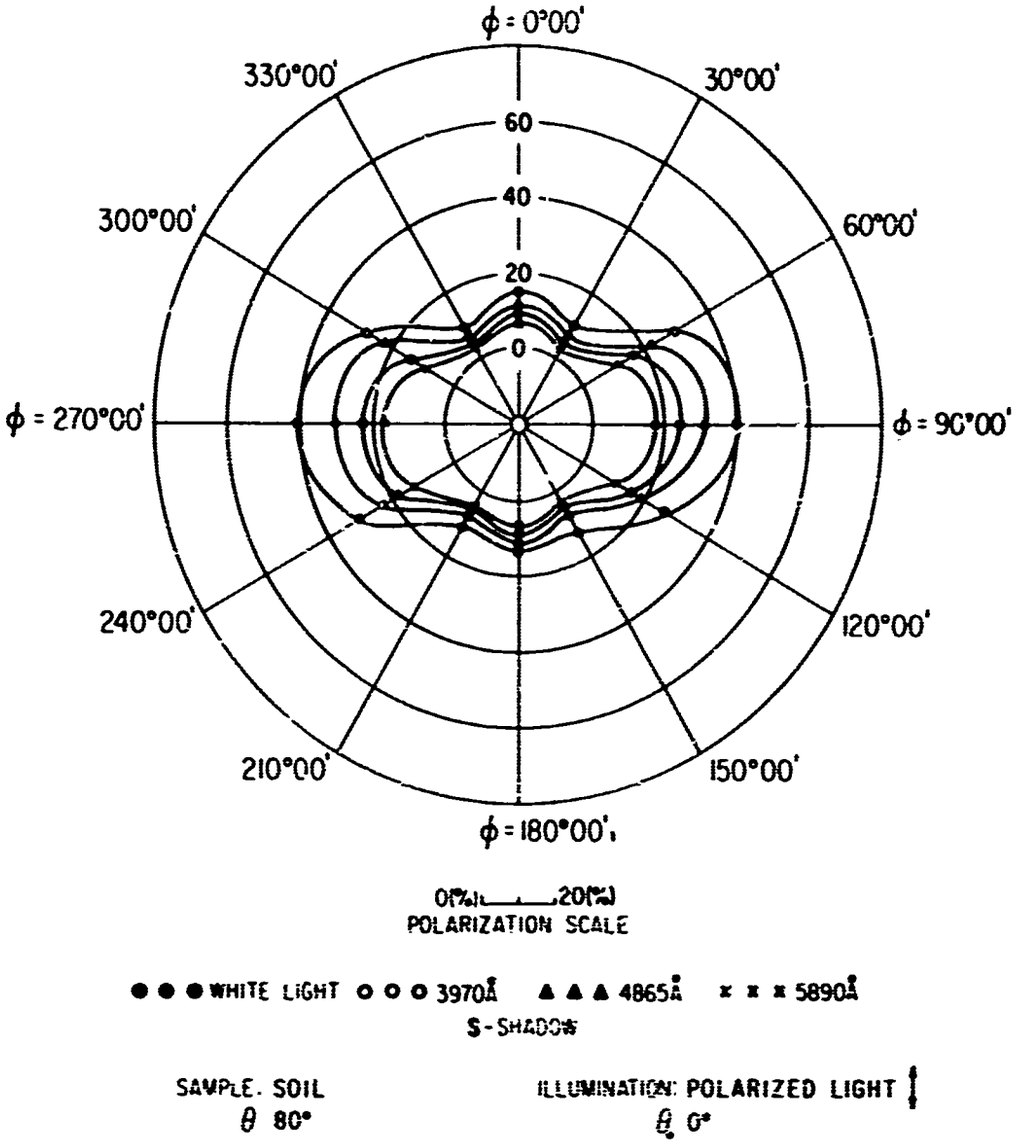


FIG. 242. POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.79 - 1.09\cos\varphi - 8.05\cos 2\varphi + 0.40\cos 3\varphi + 3.38\cos 4\varphi + 0.29\cos 5\varphi + 2.95\cos 6\varphi + 0.04\sin\varphi + 1.59\sin 2\varphi - 0.98\sin 3\varphi + 0.03\sin 4\varphi - 0.77\sin 5\varphi$$

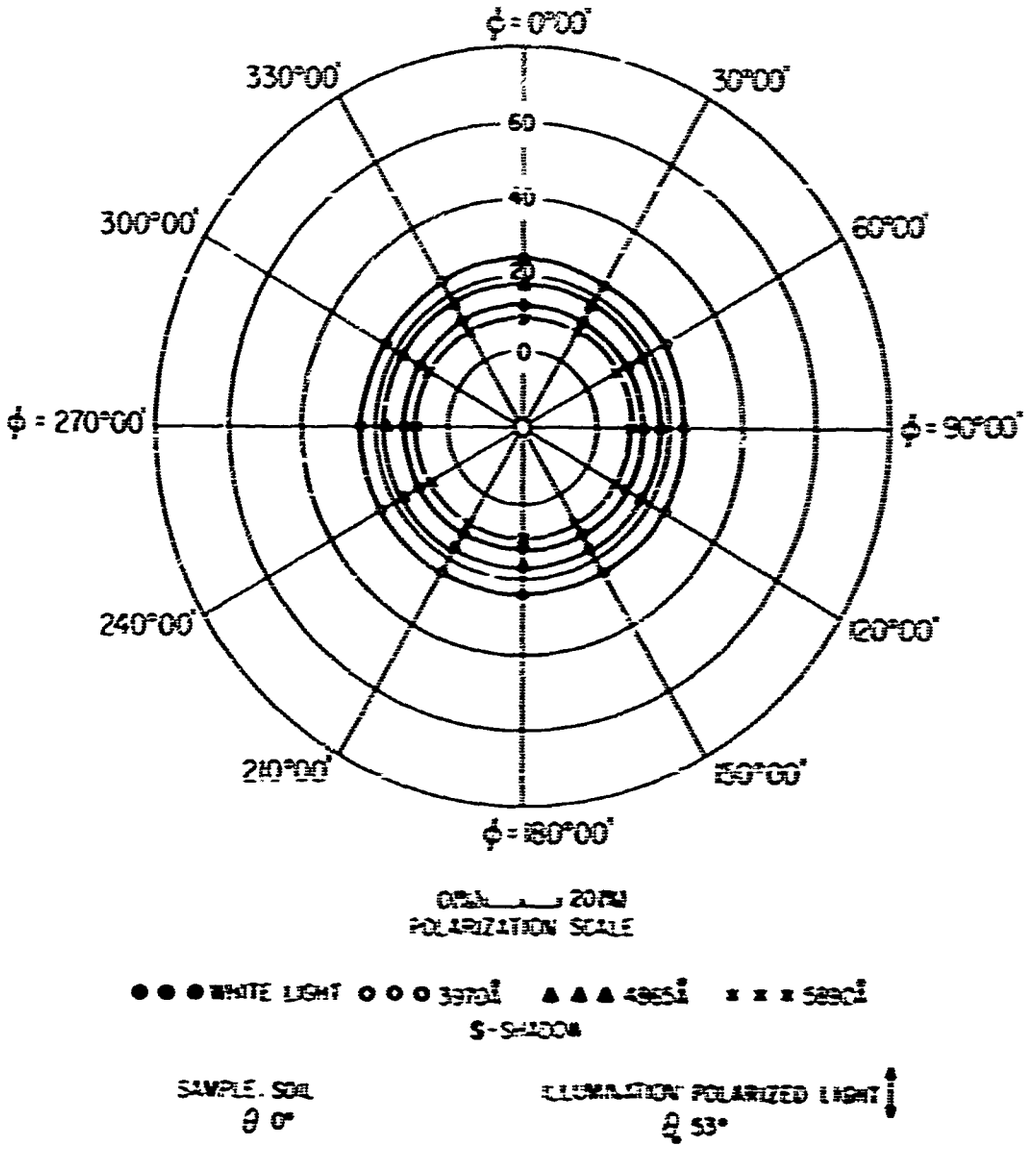


FIG 243 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

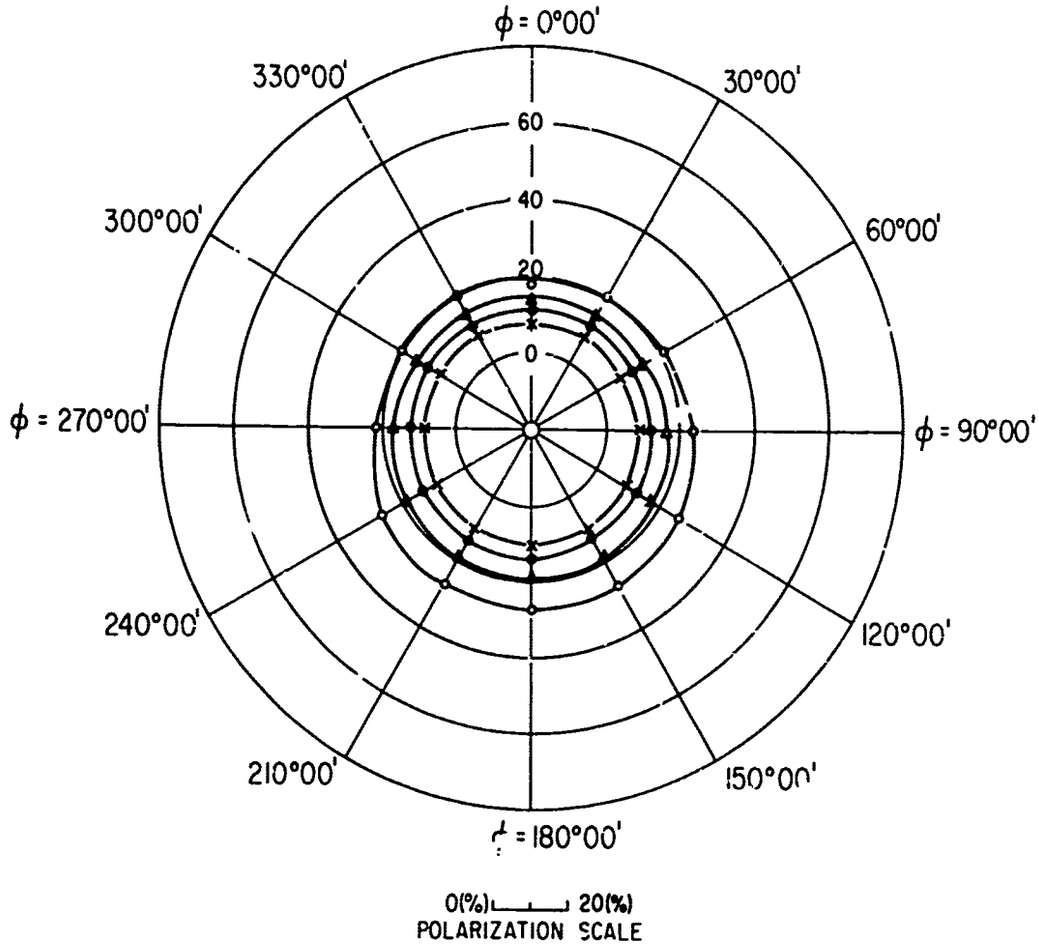


FIG.244 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.33 - 1.94\cos\varphi + 0.05\cos 2\varphi + 0.07\cos 3\varphi - 0.08\cos 4\varphi - 0.03\cos 5\varphi + 0.20\cos 6\varphi - 0.29\sin\varphi - 0.06\sin 2\varphi - 0.13\sin 3\varphi - 0.06\sin 4\varphi + 0.06\sin 5\varphi$$

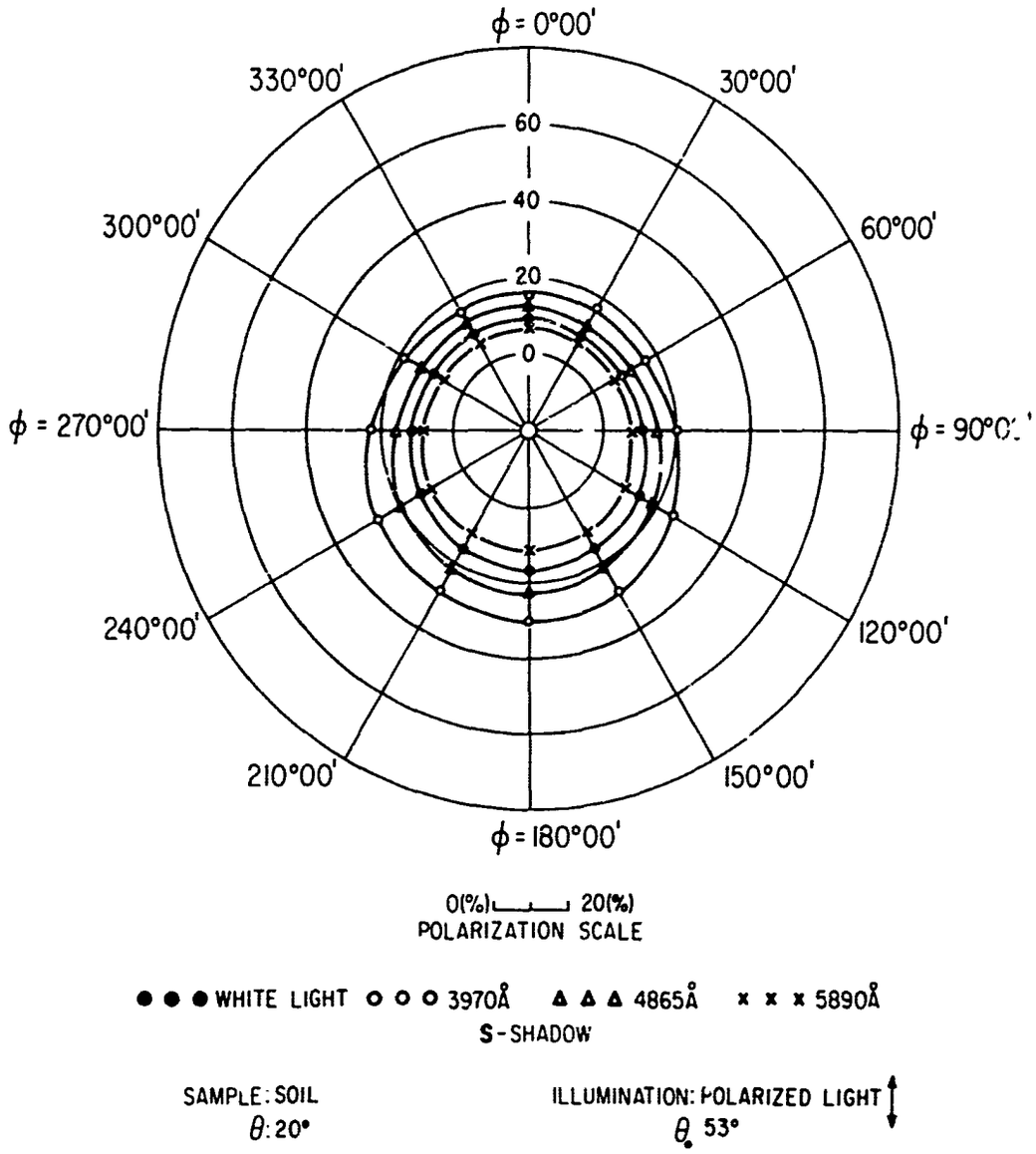


FIG.245 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.02 - 3.99\cos\varphi + 0.97\cos 2\varphi + 0.37\cos 3\varphi + 0.15\cos 4\varphi + 0.08\cos 5\varphi$$
$$+ 0.22\cos 6\varphi - 0.23\sin\varphi - 0.20\sin 2\varphi - 0.12\sin 3\varphi + 0.06\sin 4\varphi - 0.08\sin 5\varphi$$

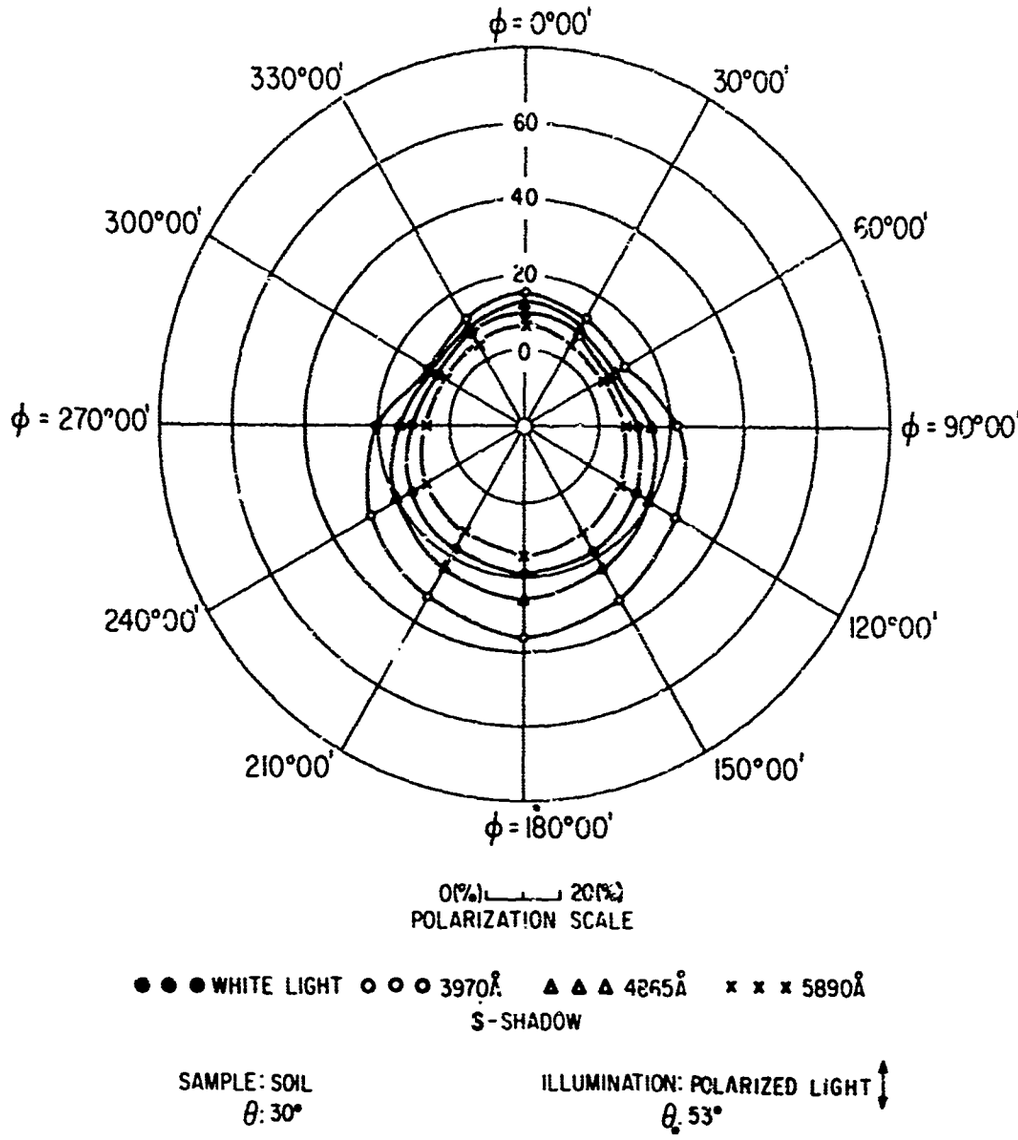
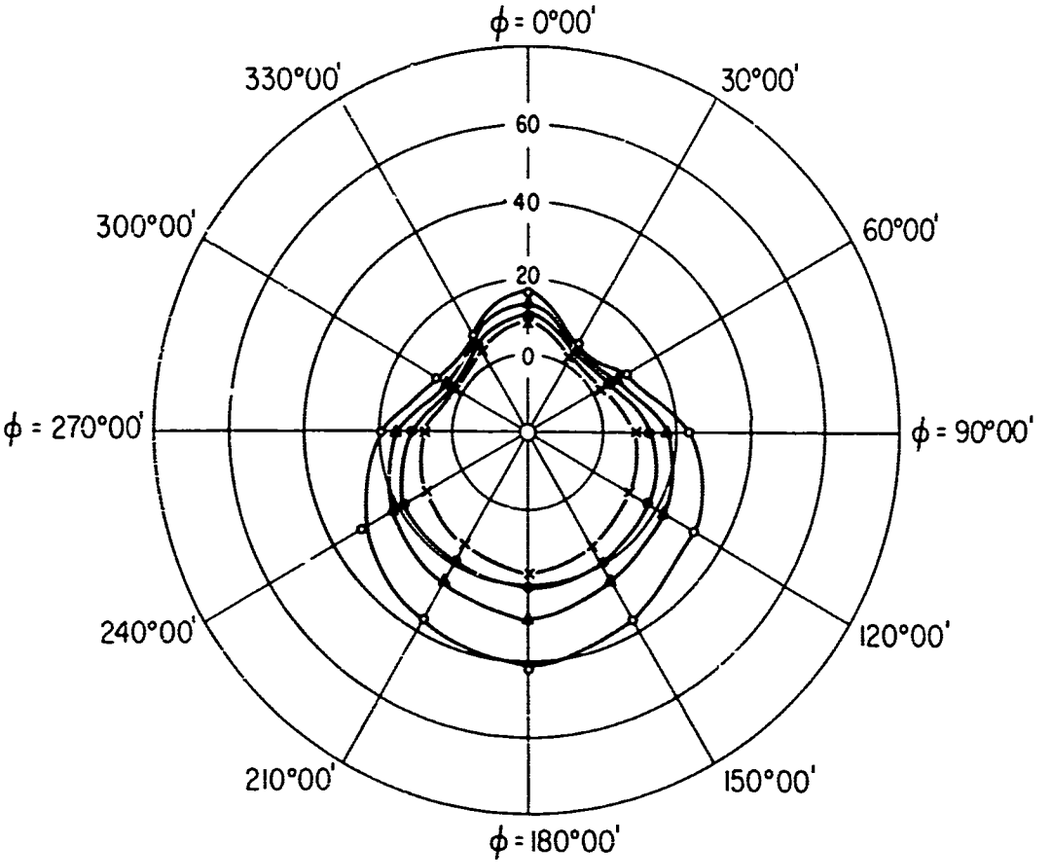


FIG.246 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.20 - 6.08 \cos\varphi + 2.09 \cos 2\varphi + 1.25 \cos 3\varphi + 0.58 \cos 4\varphi - 0.36 \cos 5\varphi - 0.23 \cos 6\varphi + 0.05 \sin\varphi - 0.10 \sin 2\varphi + 0.02 \sin 3\varphi + 0.01 \sin 4\varphi + 0.09 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. SOIL
θ 40°

ILLUMINATION: POLARIZED LIGHT ↕
θ_o 53°

FIG 247 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 12.13 - 7.73 \cos\phi + 2.16 \cos 2\phi + 2.27 \cos 3\phi - 1.64 \cos 4\phi + 0.27 \cos 5\phi$$
$$- 0.07 \cos 6\phi - 0.25 \sin\phi + 0.46 \sin 2\phi - 0.66 \sin 3\phi - 1.07 \sin 4\phi + 0.24 \sin 5\phi$$

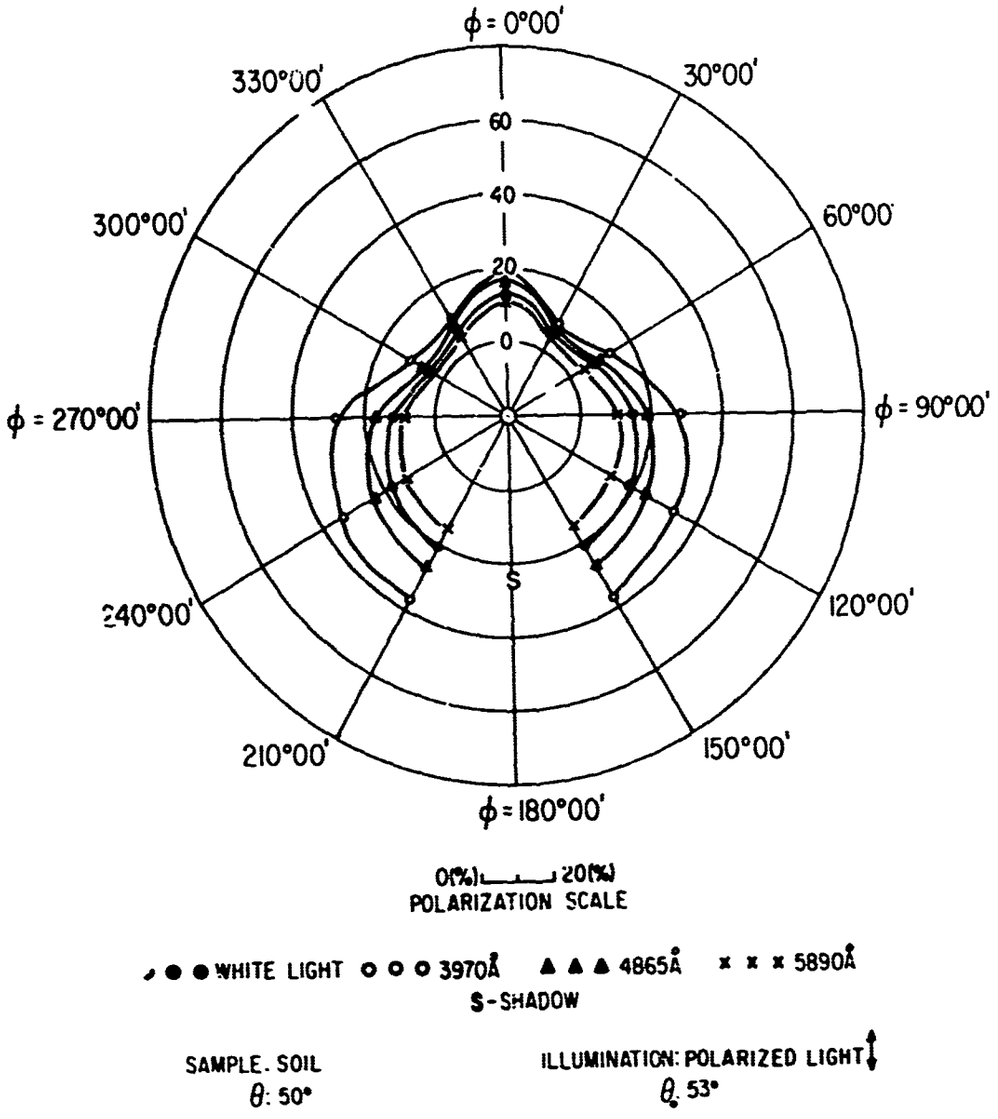
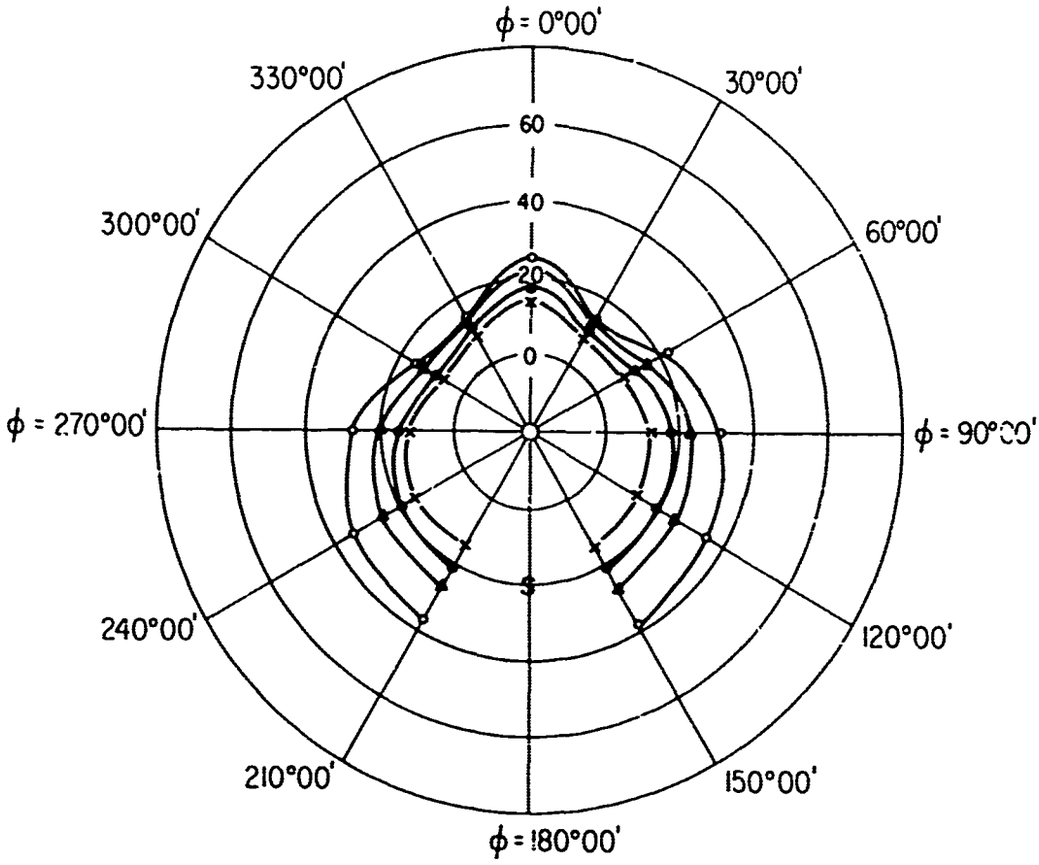


FIG. 248 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 13.59 - 7.16\cos\varphi + 1.75\cos 2\varphi + 2.52\cos 3\varphi + 1.73\cos 4\varphi + 0.84\cos 5\varphi - 0.84\cos 6\varphi + 0.99\sin\varphi + 0.23\sin 2\varphi + 0.63\sin 3\varphi - 0.60\sin 4\varphi - 0.37\sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S - SHADOW

SAMPLE. SOIL
θ 60°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0 53°

FIG 249 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\omega) = 14.52 - 4.83 \cos\omega + 1.39 \cos 2\omega + 2.20 \cos 3\omega + 3.69 \cos 4\omega + 0.86 \cos 5\omega + 0.42 \cos 6\omega + 0.78 \sin\omega + 0.45 \sin 2\omega - 0.47 \sin 3\omega - 0.42 \sin 4\omega - 0.20 \sin 5\omega$$

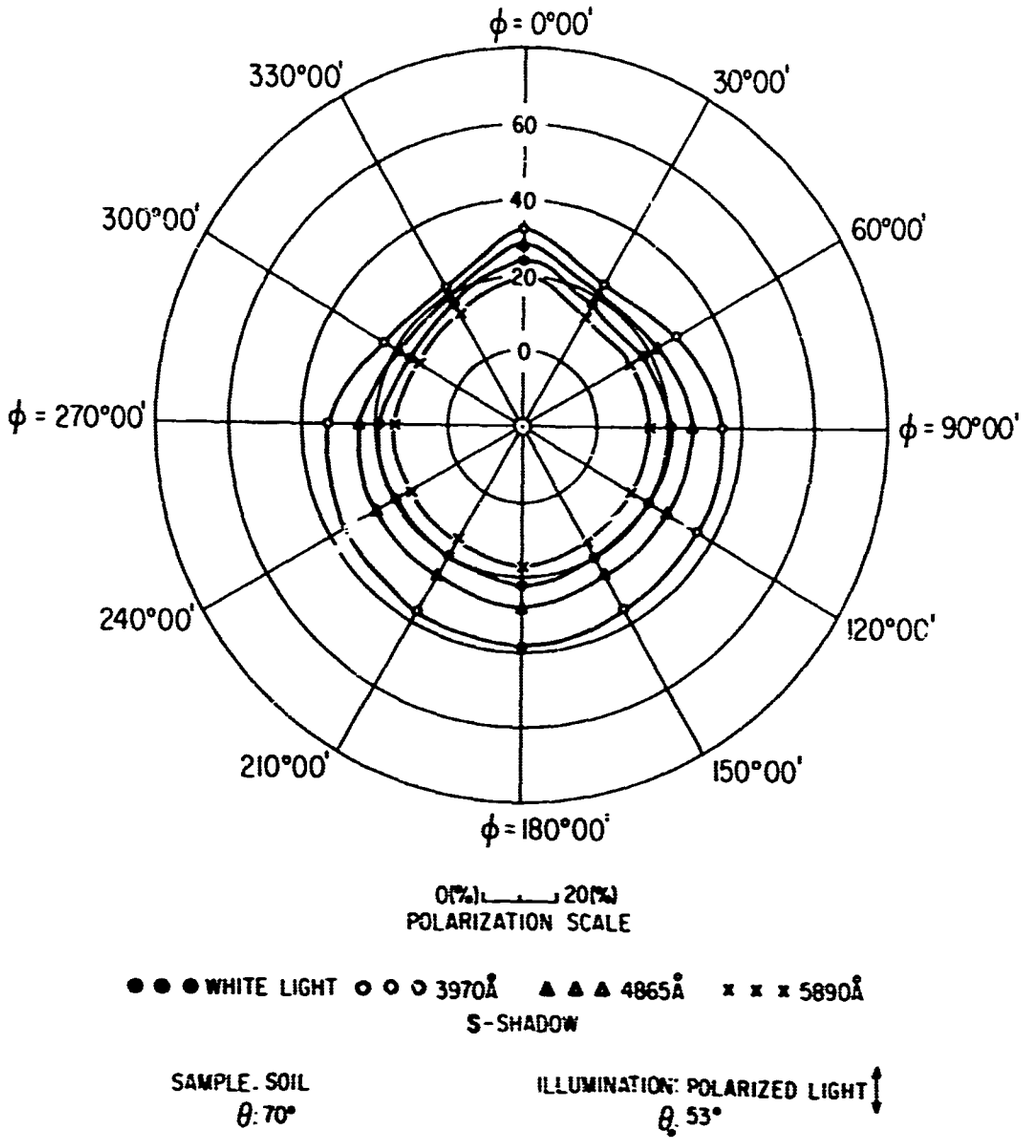


FIG 250 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.58 - 0.88 \cos\varphi + 1.51 \cos 2\varphi + 1.27 \cos 3\varphi + 2.06 \cos 4\varphi + 0.31 \cos 5\varphi + 0.73 \cos 6\varphi + 0.01 \sin\varphi - 0.03 \sin 2\varphi - 0.30 \sin 3\varphi + 0.29 \sin 4\varphi + 0.33 \sin 5\varphi$$

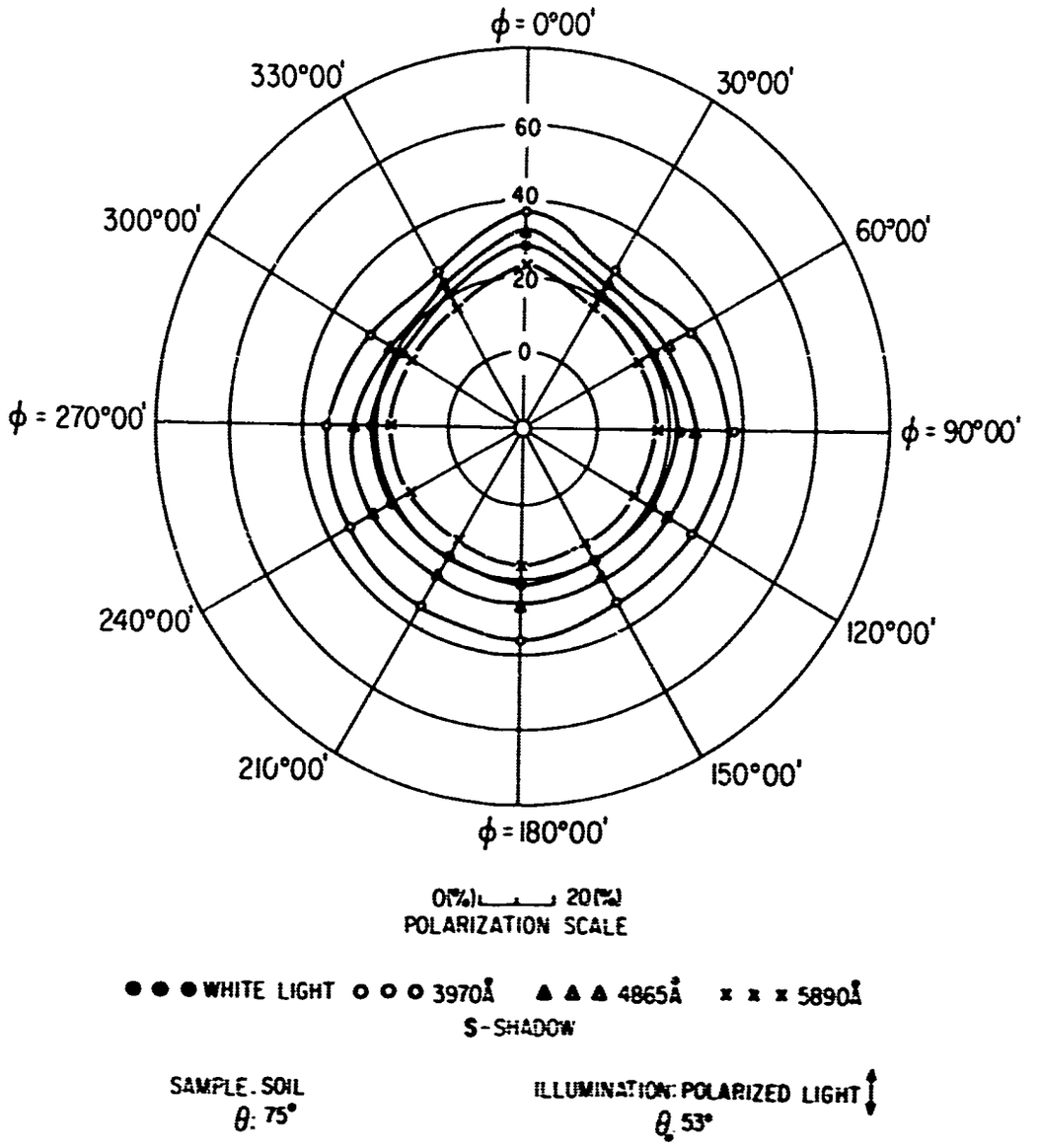


FIG.251 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 21.21 + 1.73\cos\phi + 1.15\cos 2\phi + 1.37\cos 3\phi + 2.07\cos 4\phi + 0.36\cos 5\phi - 0.85\cos 6\phi + 0.54\sin\phi + 0.49\sin 2\phi - 0.35\sin 3\phi - 0.17\sin 4\phi - 0.19\sin 5\phi$$

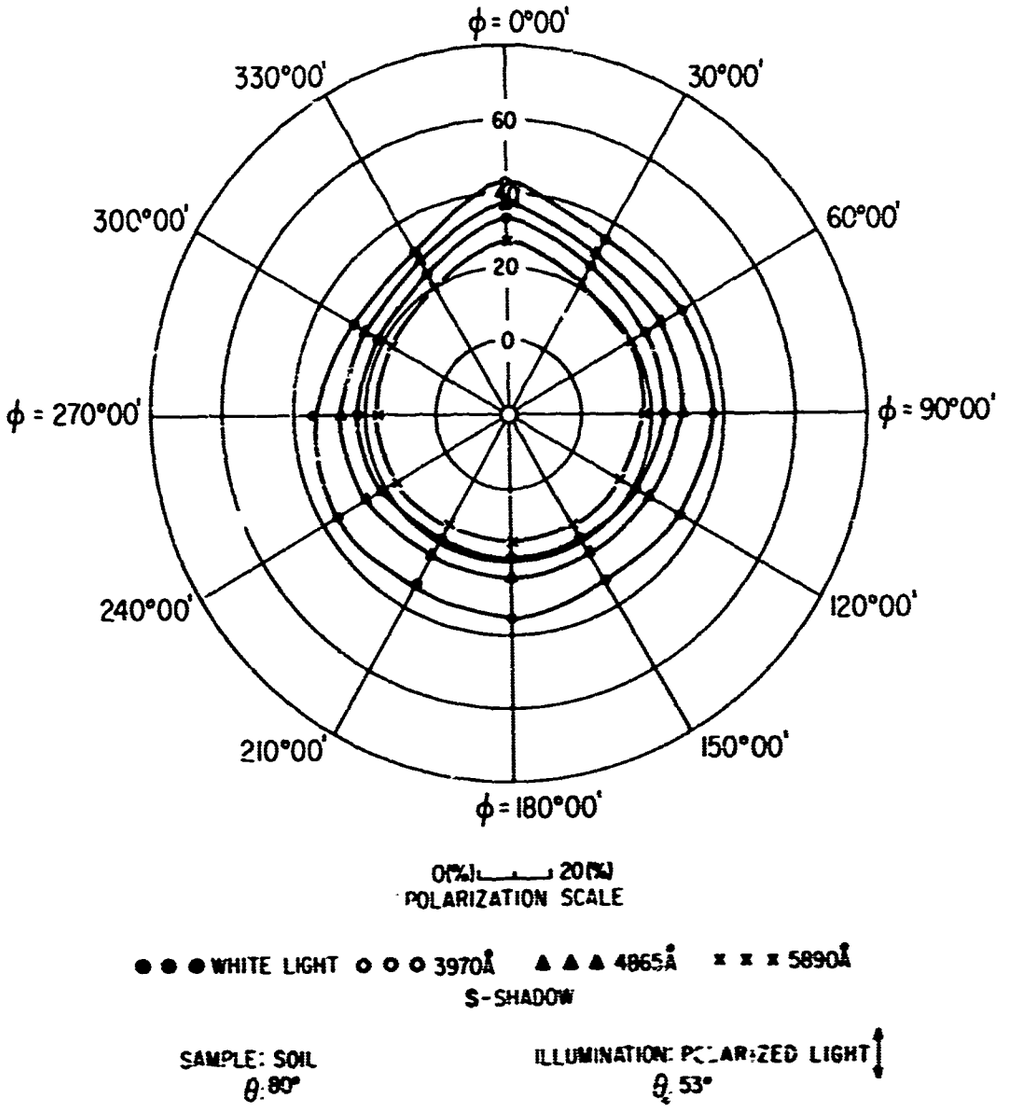


FIG. 252 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 22.82 + 4.49 \cos\phi + 1.33 \cos 2\phi + 1.47 \cos 3\phi + 1.90 \cos 4\phi + 0.74 \cos 5\phi + 1.28 \cos 6\phi - 0.64 \sin\phi + 0.96 \sin 2\phi - 0.05 \sin 3\phi + 0.03 \sin 4\phi + 0.06 \sin 5\phi$$

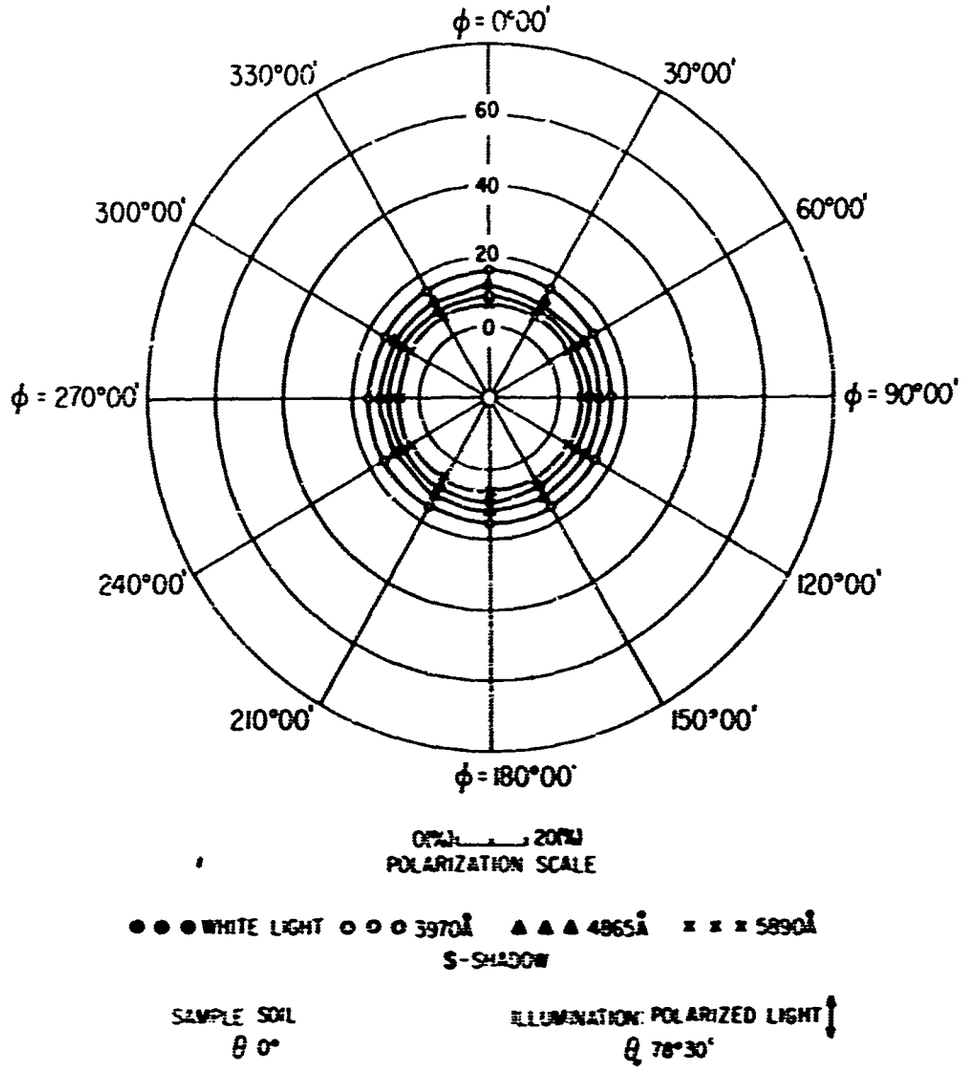


FIG 253 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

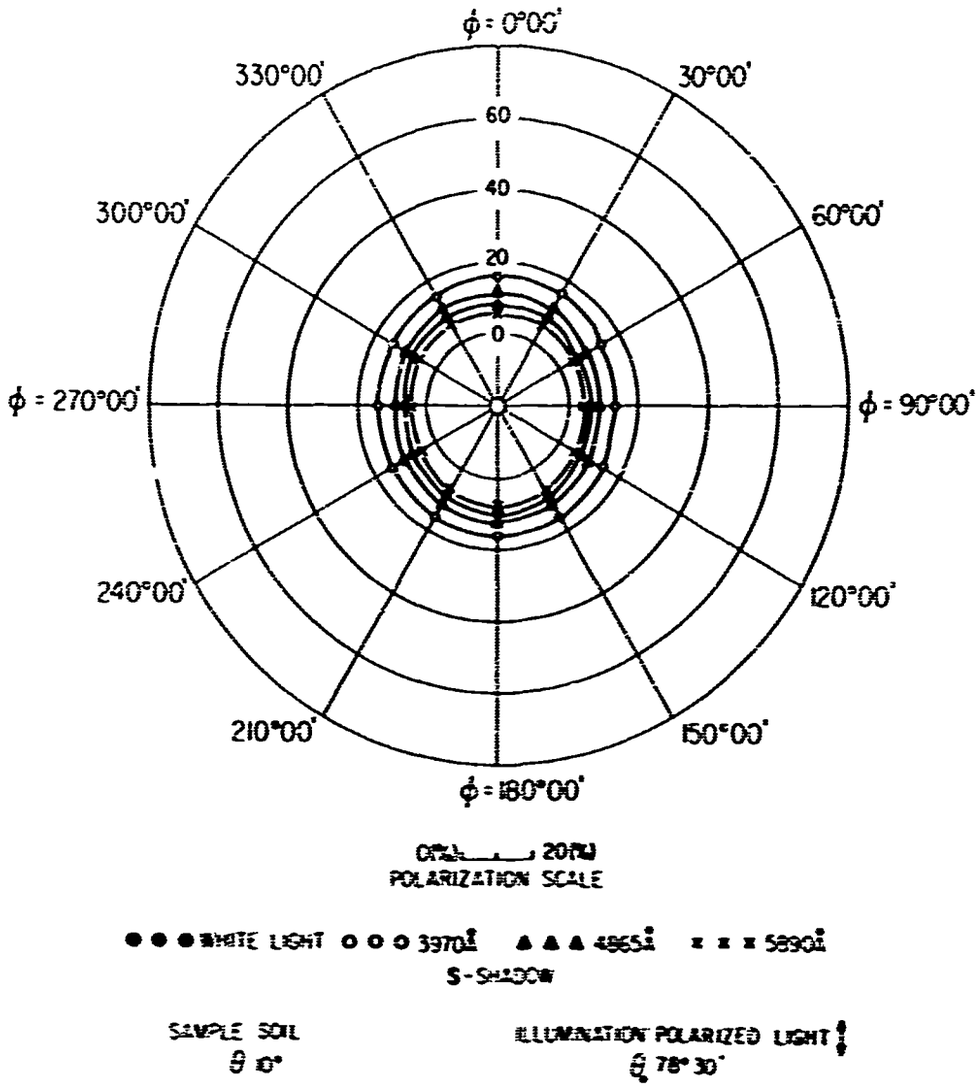


FIG 254 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\phi) = 8.56 - 0.10 \cos\phi + 0.54 \cos 2\phi + 0.03 \cos 3\phi - 0.06 \cos 4\phi + 0.01 \cos 5\phi + 0.02 \cos 6\phi - 1.24 \sin\phi - 0.13 \sin 2\phi + 0.02 \sin 3\phi - 0.04 \sin 4\phi + 0.00 \sin 5\phi$$

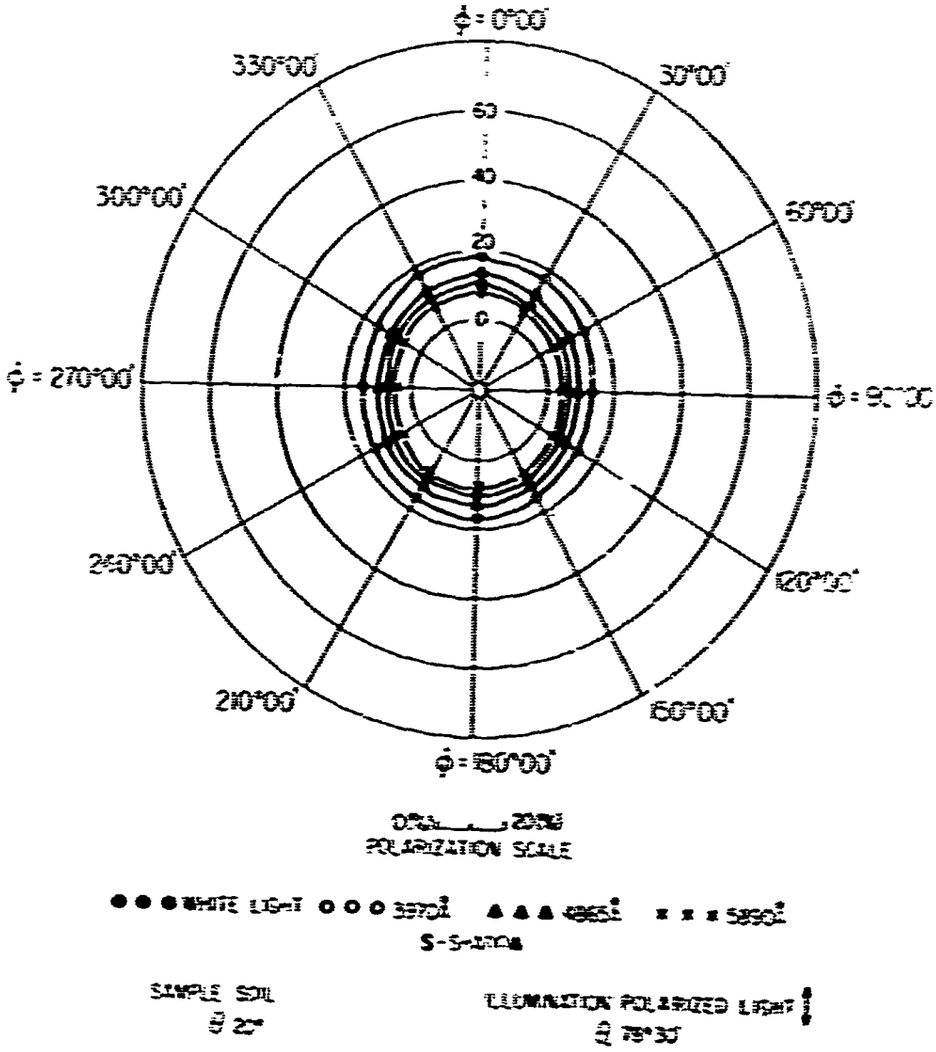


FIG 255 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 8.72 - 0.10 \cos\varphi + 2.13 \cos 2\varphi - 0.17 \cos 3\varphi + 0.23 \cos 4\varphi + 0.13 \cos 5\varphi + 0.23 \cos 6\varphi - 1.02 \sin\varphi - 0.11 \sin 2\varphi - 0.33 \sin 3\varphi - 0.29 \sin 4\varphi + 0.08 \sin 5\varphi$$

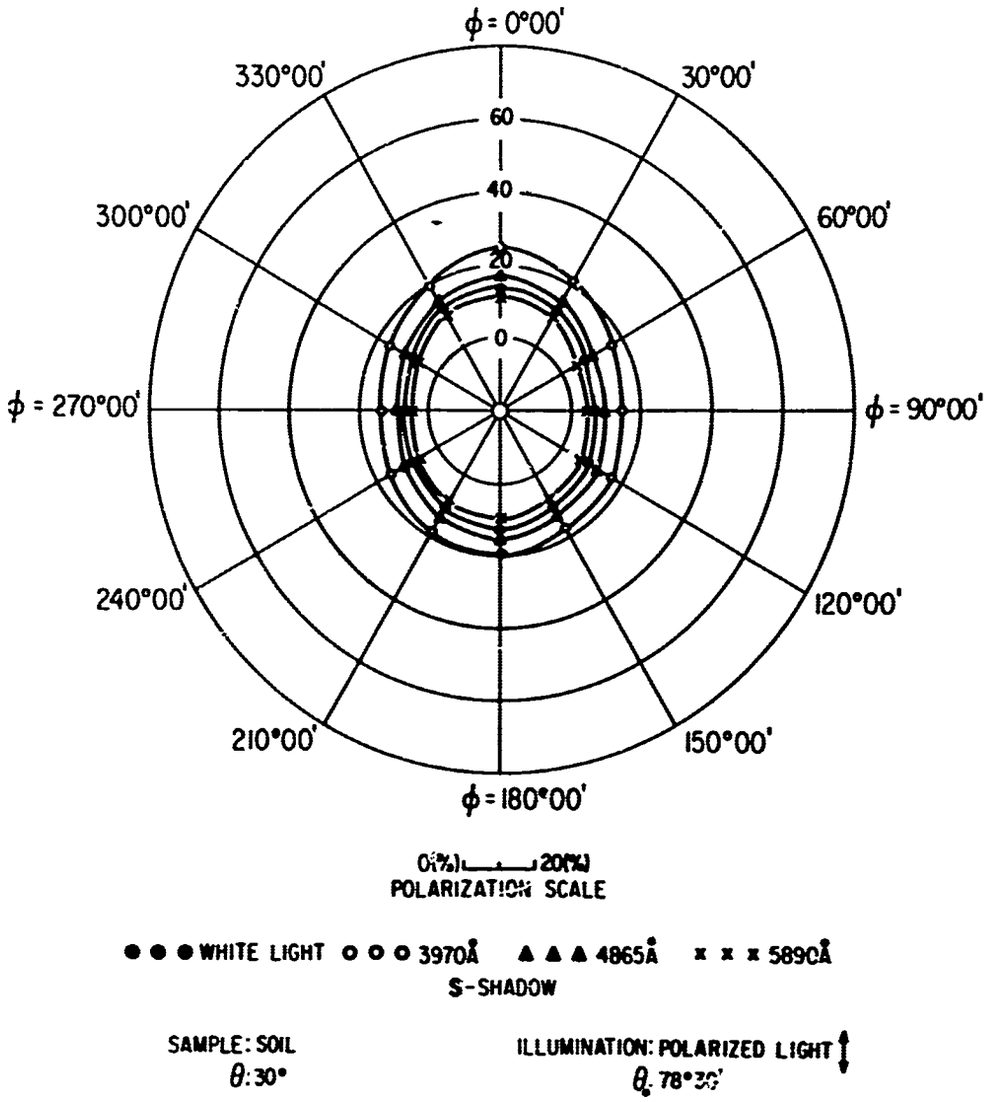


FIG.256 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 9.84 + 0.16\cos\varphi + 3.89\cos 2\varphi + 0.88\cos 3\varphi + 0.81\cos 4\varphi + 0.01\cos 5\varphi + 0.18\cos 6\varphi - 0.22\sin\varphi - 0.42\sin 2\varphi - 0.43\sin 3\varphi - 0.24\sin 4\varphi - 0.15\sin 5\varphi$$

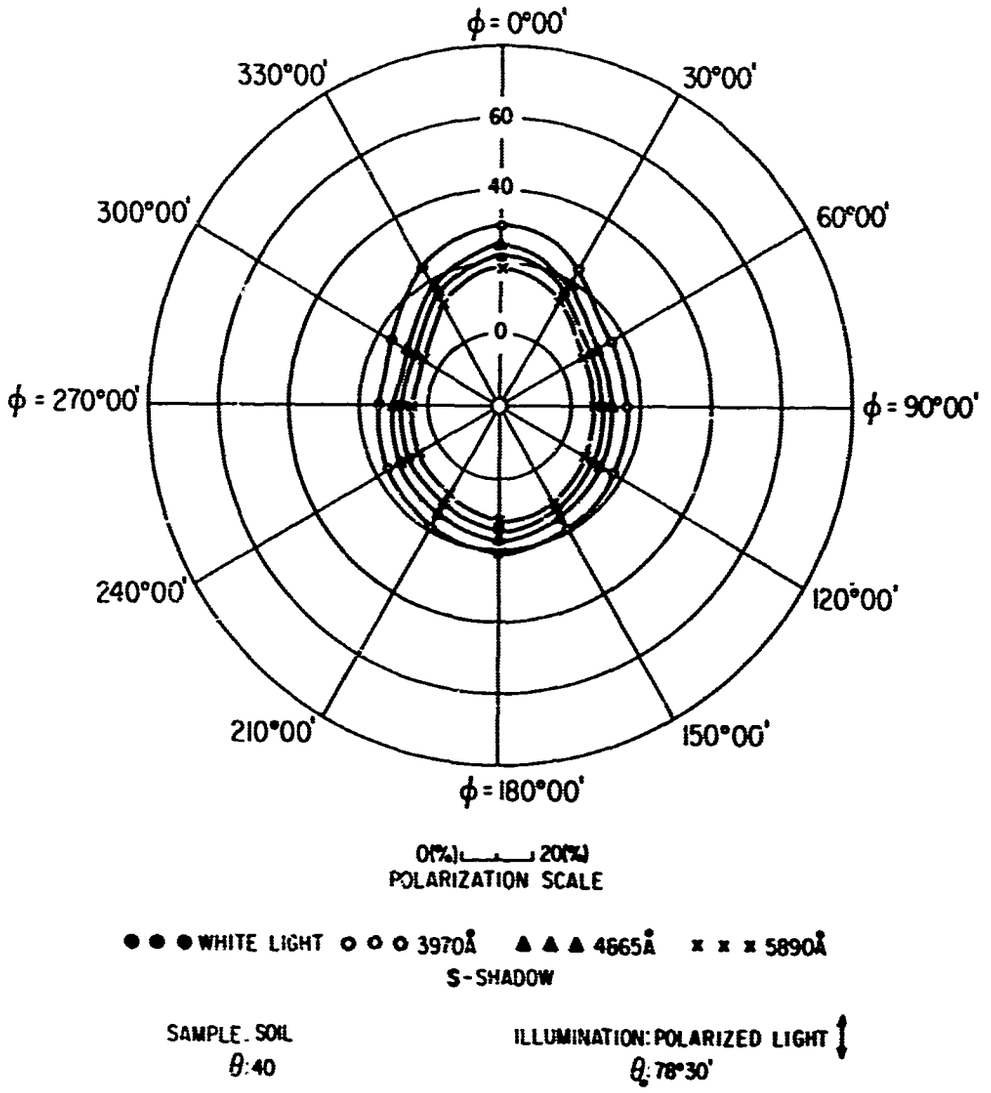
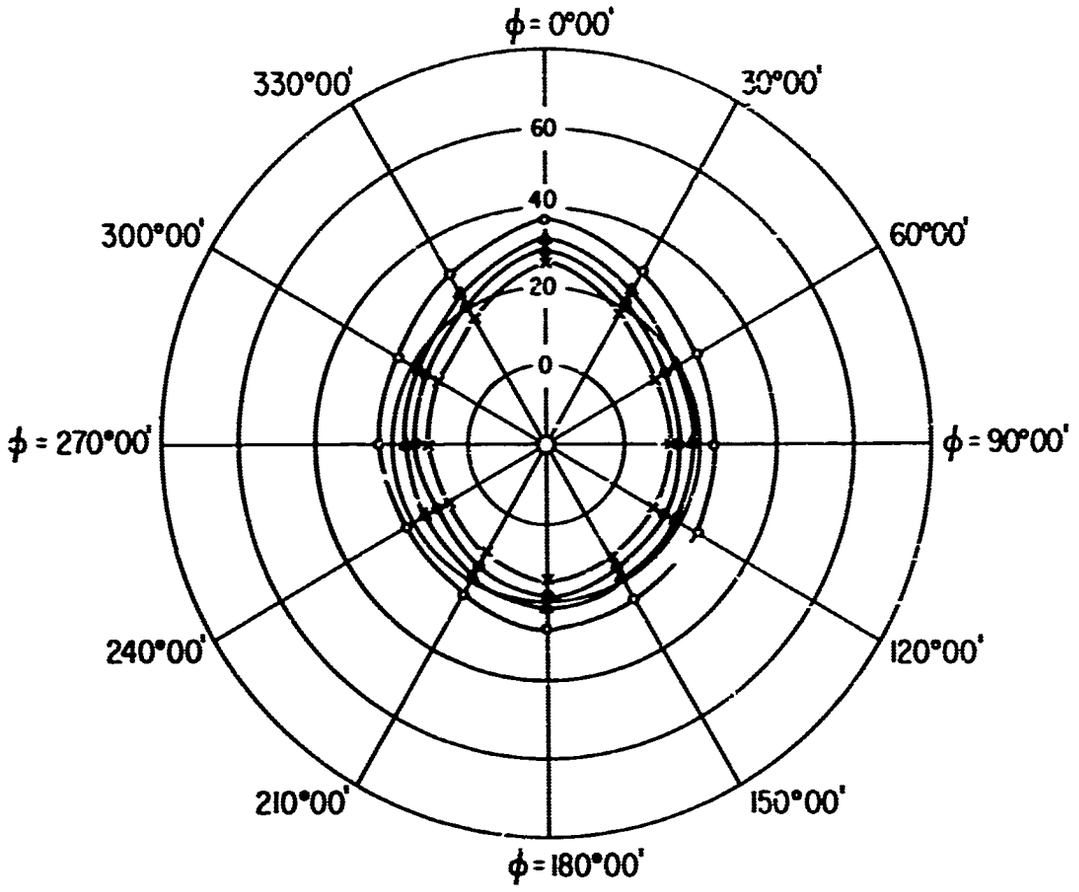


FIG. 257 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 12.38 + 1.13 \cos\varphi + 5.29 \cos 2\varphi + 1.60 \cos 3\varphi + 1.08 \cos 4\varphi - 0.07 \cos 5\varphi - 0.48 \cos 6\varphi + 0.84 \sin\varphi - 0.22 \sin 2\varphi - 0.22 \sin 3\varphi - 0.16 \sin 4\varphi - 0.66 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

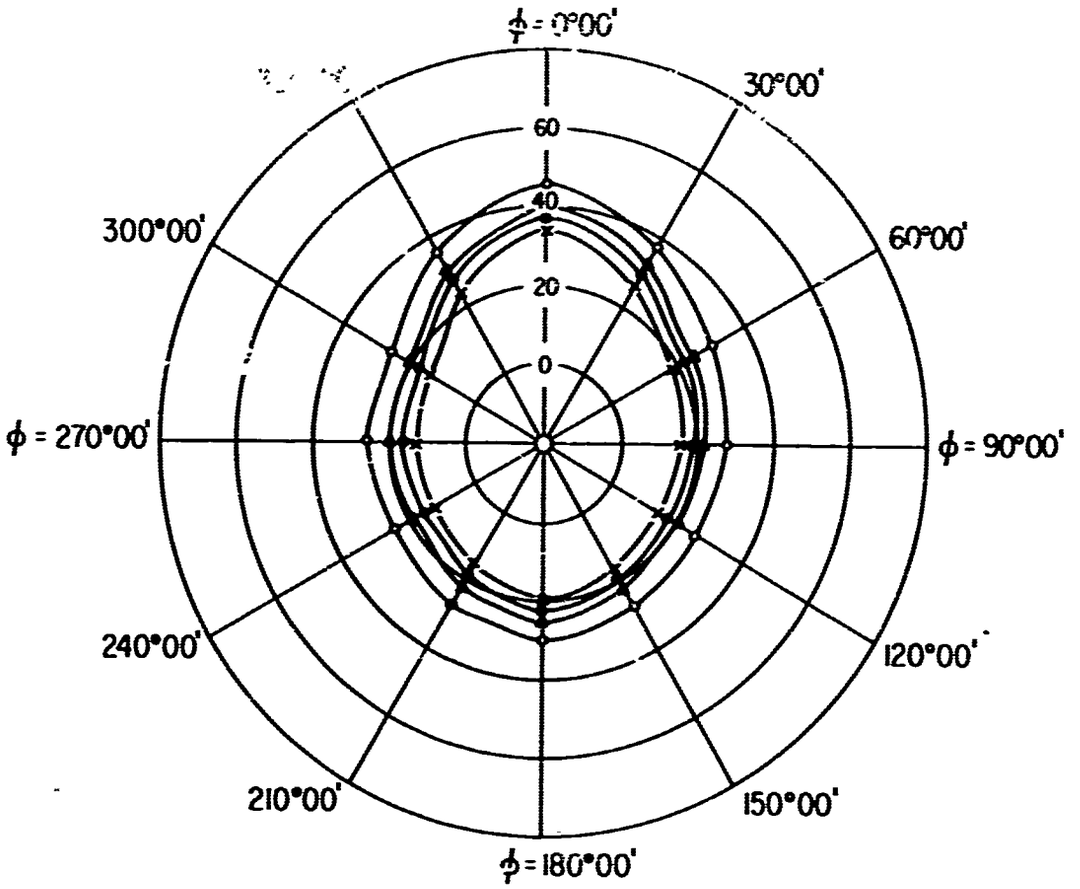
● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å × × × 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 50°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 78° 30'

FIG.258 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 17.62 + 3.79 \cos\varphi + 4.36 \cos 2\varphi + 0.73 \cos 3\varphi + 2.16 \cos 4\varphi + 0.73 \cos 5\varphi - 0.30 \cos 6\varphi + 0.34 \sin\varphi - 0.65 \sin 2\varphi + 0.77 \sin 3\varphi + 0.59 \sin 4\varphi - 0.67 \sin 5\varphi$$



0(%) 20(%)
POLARIZATION SCALE

● ● ● WHITE LIGHT ○ ○ ○ 3970Å ▲ ▲ ▲ 4865Å x x x 5890Å
S-SHADOW

SAMPLE: SOIL
θ: 60°

ILLUMINATION: POLARIZED LIGHT ↕
θ_0: 78° 30'

FIG.259 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 21.98 + 6.14 \cos\varphi + 6.46 \cos 2\varphi + 1.57 \cos 3\varphi + 2.22 \cos 4\varphi + 0.14 \cos 5\varphi + 0.18 \cos 6\varphi + 1.81 \sin\varphi + 0.30 \sin 2\varphi + 0.05 \sin 3\varphi - 0.19 \sin 4\varphi - 0.71 \sin 5\varphi$$

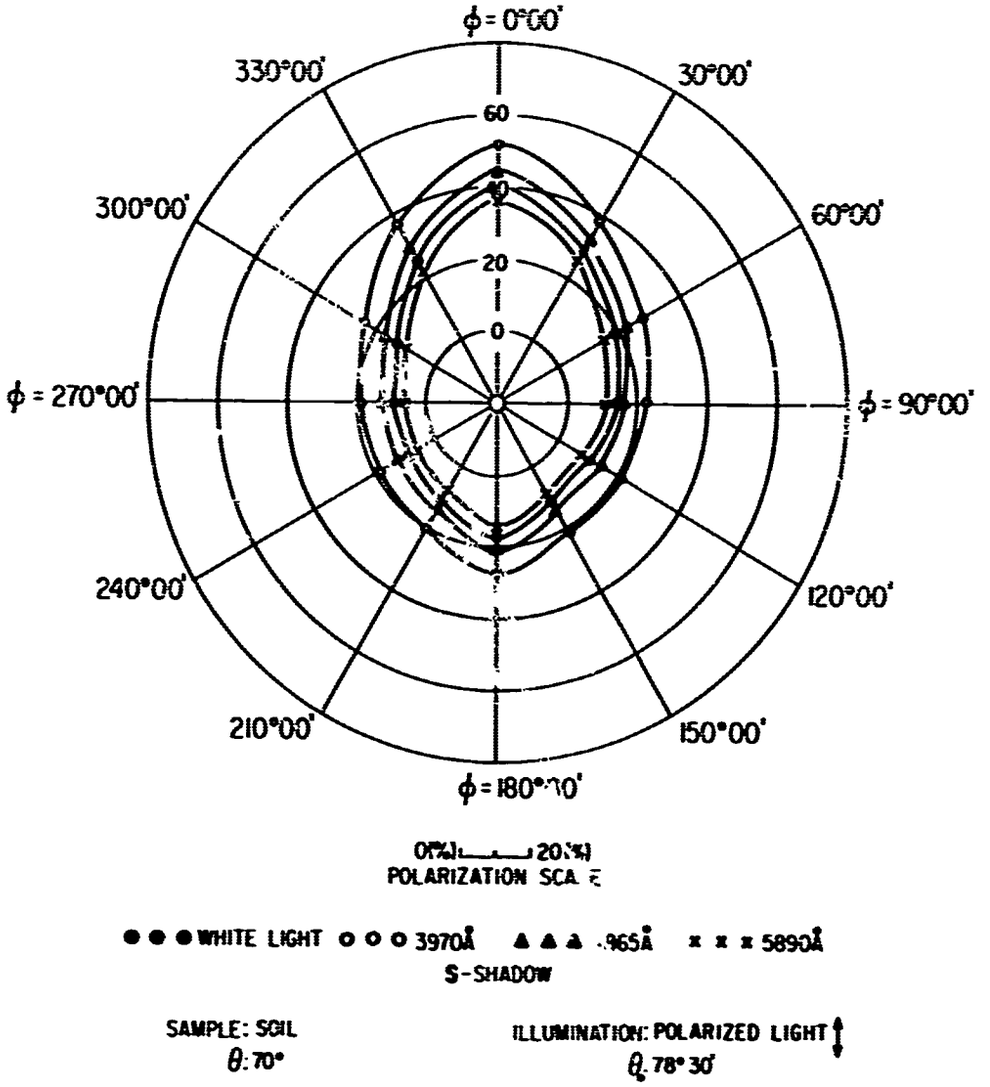


FIG. 260 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 18.78 + 9.52 \cos\varphi + 6.65 \cos 2\varphi + 1.35 \cos 3\varphi + 2.85 \cos 4\varphi + 0.18 \cos 5\varphi + 1.35 \cos 6\varphi + 0.00 \sin\varphi + 0.00 \sin 2\varphi + 0.00 \sin 3\varphi + 0.00 \sin 4\varphi + 0.00 \sin 5\varphi$$

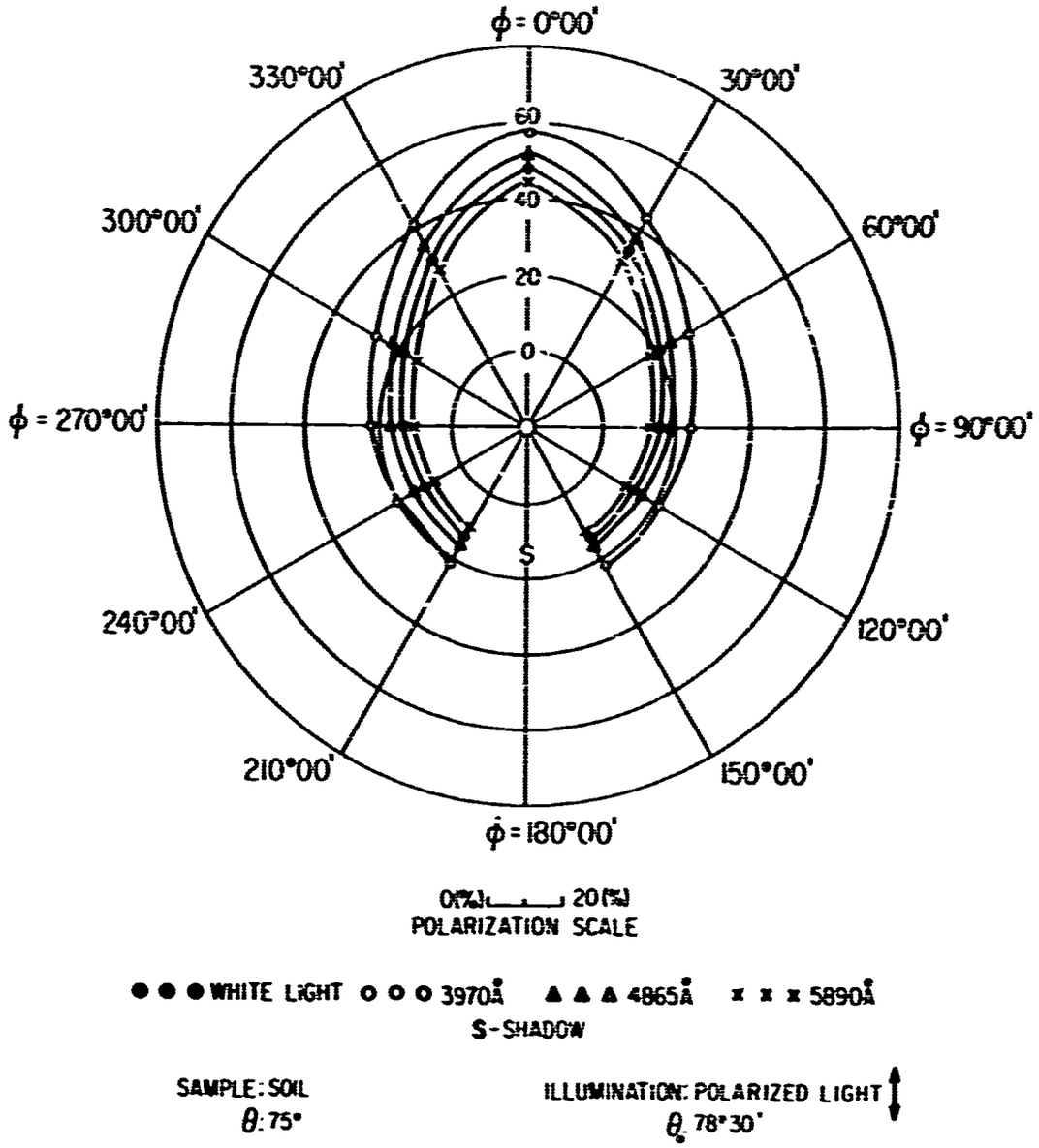


FIG. 261 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 19.70 + 9.97 \cos\varphi + 6.01 \cos 2\varphi + 3.15 \cos 3\varphi + 3.42 \cos 4\varphi + 3.93 \cos 5\varphi + 3.83 \cos 6\varphi + 0.10 \sin\varphi - 0.04 \sin 2\varphi - 0.08 \sin 3\varphi - 0.10 \sin 4\varphi - 0.08 \sin 5\varphi$$

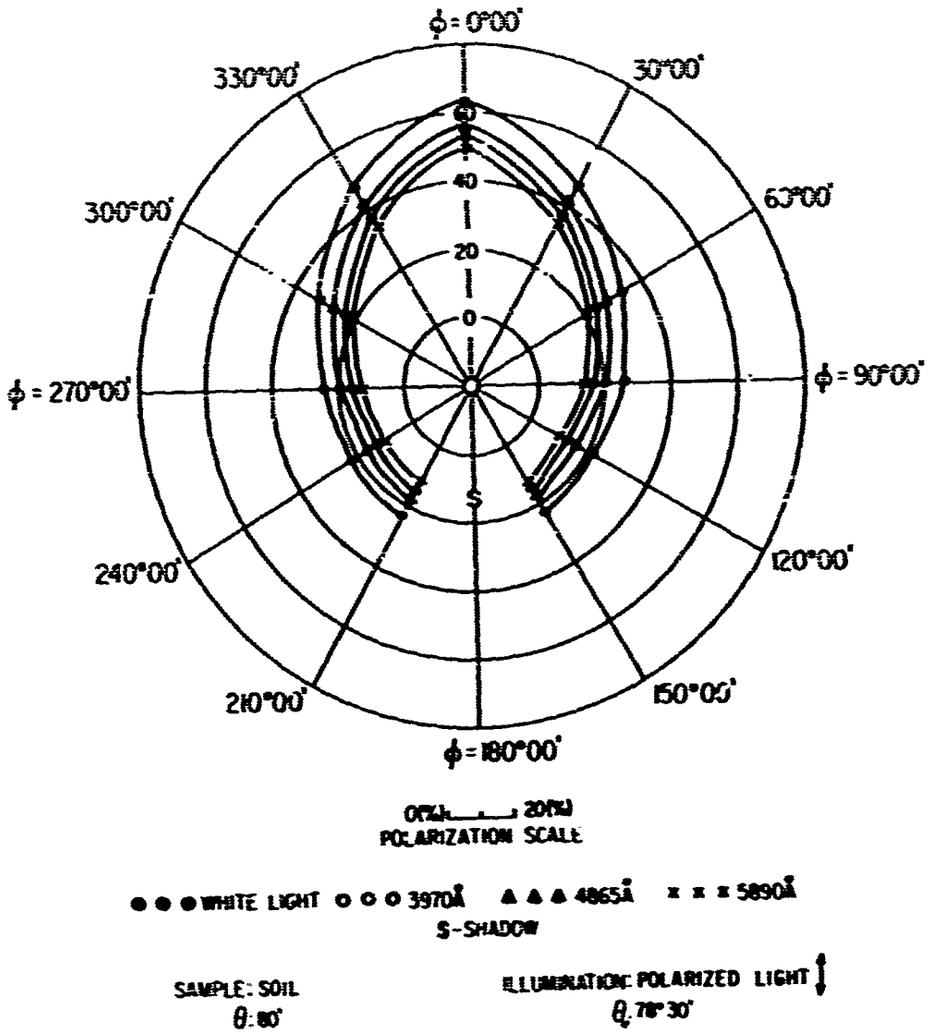


FIG 262 POLAR DIAGRAM SHOWING AZIMUTHAL VARIATION OF THE POLARIZATION OF REFLECTED LIGHT

$$P(\varphi) = 23.59 + 15.06 \cos\varphi + 8.92 \cos 2\varphi + 3.30 \cos 3\varphi + 2.48 \cos 4\varphi + 2.14 \cos 5\varphi + 1.02 \cos 6\varphi + 0.20 \sin\varphi + 0.14 \sin 2\varphi + 0.08 \sin 3\varphi + 0.08 \sin 4\varphi + 0.03 \sin 5\varphi$$

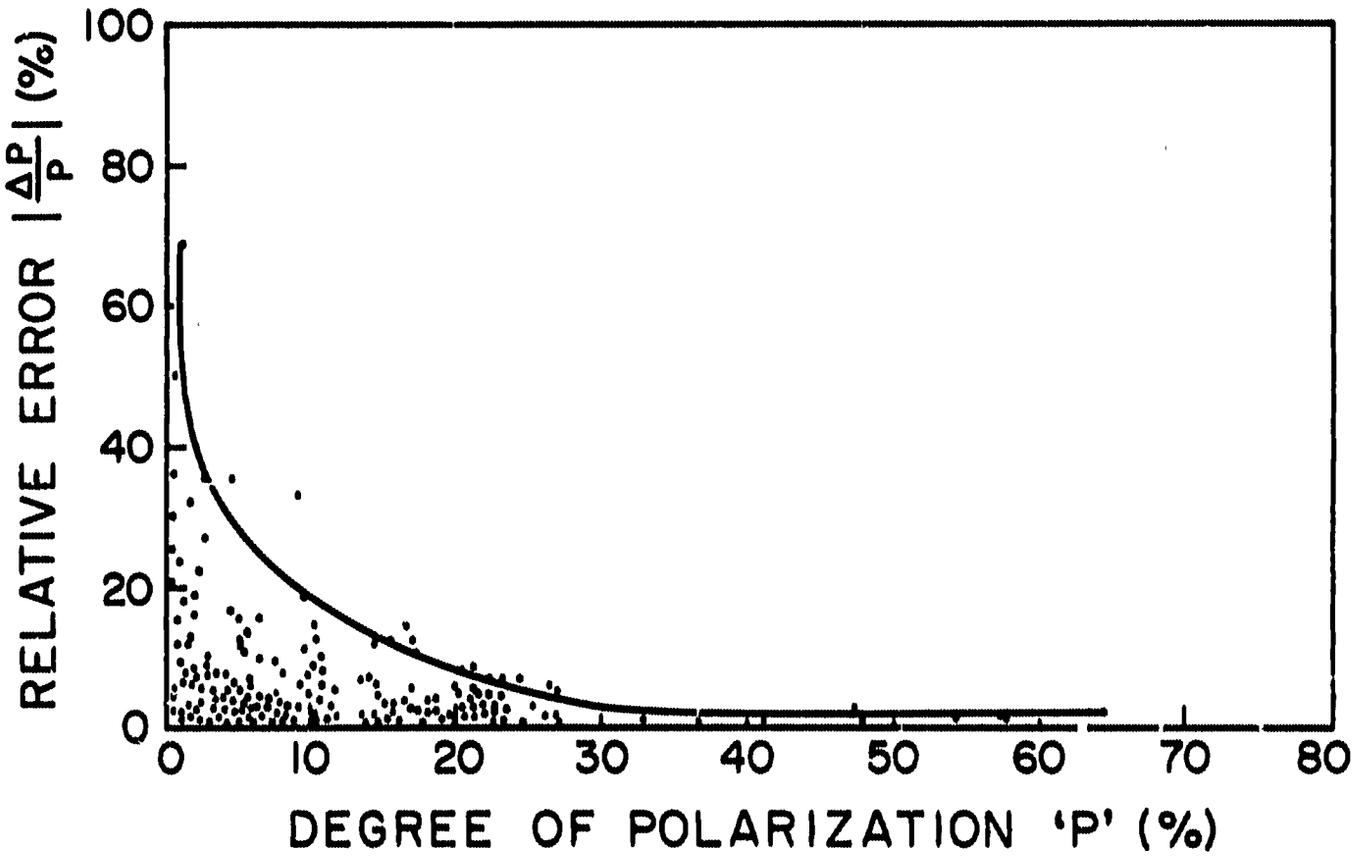


FIG. 263. THE ERROR CURVE

Unclassified

DOCUMENT CONTROL DATA - R & D

Department of Meteorology
University of California
Los Angeles, California 90024

Unclassified

AN ATLAS OF POLARIZATION FEATURES OF LIGHT REFLECTED BY DESERT SAND, WHITE SAND AND SOIL

Scientific. Interim.

C. R. Nagaraja Rao
Hsi-shu Chen

January 1969	273	5

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7621-03-01
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AFCRL-69-0005

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The results of an extensive series of measurements of the degree of linear polarization of light bidirectionally reflected by samples of desert sand, white sand and soil under various conditions of illumination are presented in graphical form. Measurements have been made in three spectral intervals (bandwidth ~ 150 A) centered on λλ 3970, 4865 and 5890A and 'white light' with a simple rotating analyzer type reflectometer. Simple Fourier series representations have been established for the azimuthal dependence of the degree of linear polarization of the reflected light for 'white light' measurements. The results of the corresponding error analysis are shown in an error curve.

DD FORM 1473

Unclassified
Security Classification

[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
POLARIZATION OF REFLECTED LIGHT	8	3						