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THE MEASUREMENT OF LUNAR RADIATION

. Brock Dale, Department of Physics

NASA Grant NsG-692

The first measurements of the cooling curve of the lunar surface were obtained by Pettit and Nicholson in 1930, during a lunar eclipse. The extremely high cooling rate that they observed first led to the conclusion that the surface of the moon was covered with a layer of dust. Later measurements by Pettit (2) and by Sinton (3) also obtained during eclipses, confirmed the results of the early measurements. During the lunar eclipse of March, 1960, Shorthill, Borough, and Conley (4), using a bolometer detector, discovered that certain regions cooled less rapidly than others, and during the second eclipse of that year, Saari and Shorthill (5) measured isotherms of lunar crater regions and found numerous thermal anomalies.

In 1961, Geffrion, Korner, and Sinton (6) obtained isotherms over the lunar surface over an entire lunation by scanning from the terminator into the lunar nighttime region. More recently Murray and Wildey (7) and Murray, Westphal, and Wildey (8) have used a mercury-doped germanium detector for similar measurements. The enhanced sensitivity that resulted from the use of this detector enabled them to obtain meaningful measurements from regions of the disc as much as 160 hours after the passage of the terminator, when the surface has cooled to 105°K. Whereas the earlier eclipse data gave information only about the first few millimeters below the surface, these later measurements are affected by the character of material lying as much as several centimeters below the surface. The most important gross feature of their data is the departure of the observed cooling curves from theoretical curves based on the assumption of a surface layer that is homogeneous in depth.

At the inception of our research, it was decided that it would be fruitless to attempt to make useful measurements without a mercury-doped germanium detector. Since these were not commercially available, several detectors were fabricated from germanium into which mercury had been diffused for ten days at 400°C-800°C, and a crude prototype radiometer was constructed for use with these detectors. It was intended that this apparatus, the building of which occupied the first quarter, would be used for observations during the lunar eclipse of Dec. 1964, and that it would serve to point up design problems that might not otherwise be foreseen. A glass-to-metal seal failed in the last moments before the eclipse, so that no data were obtained. The prototype instrument was abandoned after the following had been ascertained:

(a) Because of the extremely shallow penetration of mercury into germanium during diffusion, diffused detectors would be inadequate for measurements on the dark side of the terminator.

(b) The use of a nitrogen-helium dewar for cooling the detector should be avoided if possible.

(c) The noise introduced by stray fields from the power leads to the radiation chopper made it advisable to use a chopping frequency different from the power frequency (400 cps).

After some correspondence, some pieces of melt-doped Ge(Hg) were obtained on permanent loan from the Texas Instruments through the courtesy of Dr. George Pruett. The design of the detectors fabricated from this material is shown in Figure 1. The germanium is in the form of a rectangular rod, approximately 1 x 1 x 7 mm. Electrodes are indium-soldered to two opposite long faces, over an electro-deposited film of nickel. The rod is supported by one of the electrodes. This electrode is made of Kovar, because it has a temperature coefficient of expansion close to that of germanium. The other electrode is gold wire. Radiation is incident on the end (1 x 1 mm) face of the rod.

The detector is cooled by a miniature Joule-Kelvin refrigerator, operated by the expansion of nitrogen and hydrogen from compressed-gas cylinders. This unit can provide up to four watts of cooling at 20^{0}K. The refrigerator has the advantage over a double dewar, that it can be operated in any position. The detector is surrounded by an aluminum heat shield at about 20^{0}K, and this in turn is surrounded by a heat shield at 77^{0}K. Radiation is incident on a germanium window coated for maximum transmission at 10 microns. Inside the refrigerator, it passes through a filter with a sharp cutoff at 8 microns. The filter serves to eliminate atmospheric radiation in the wavelength region below 8 microns. It is mounted on the end of the low-temperature heat shield, in order to minimize radiation from the filter itself.

The area seen by the detector is defined by a circular aperture mounted about 1/2 mm ahead of the end of the detector. The back side of the aperture plate is made reflecting so that any radiation reflected from the detector will be reflected from the plate back onto the detector.

The refrigerator was delivered only two weeks before the date of this report, so that the detector has not yet been tested. After the one now installed in the refrigerator has been tested, others will be manufactured, and the best will be chosen for actual use.

A double-beam radiometer (Figure 2) has been constructed for use with the Ge(Hg) detector. It is so constructed that a rotating shutter presents radiation to the detector alternately from the object under surveillance and from empty space. These two incident beams are designated at A and B respectively in the figure. During one half-cycle, radiation along the path A is reflected onto one side of the two-sided mirror M_2, thence to M_3 and M_4. After reflection from M_4, it passes between the blades of the shutter and onto the detector. During the other half-cycle, the radiation along path B is reflected from M_1, the reverse side of M_2, the (now interposed) reflecting surface of the shutter, and thence into the detector.

The radiometer mirrors are glass flats tested to a maximum deviation from flatness of one wavelength of sodium light. They are coated with an evaporated gold film. The shutter has three blades. It is cut from a single glass flat and, like the mirrors, is gold-coated. It is fastened to a metal backing with epoxy resin, and is perpendicular to the axis of rotation within 3 min.. The shutter has been successfully tested at its operating rotation frequency of 200/sec.

The entire radiometer assembly weighs about 8 pounds, so that it is easily supported at the cassegrainian focus of the telescope. For planetary and stellar measurements, the radiometer will be mounted at the Newtonian focus of the telescope in order to take advantage of the resulting 4:1 reduction in the focal ratio. This mounting will not be completed for some weeks, however.

Signals from the detector are amplified by a PAR preamplifier and lock-in amplifier, and thence to a recorder. A digital readout unit is available, and a computer program for plotting contours has been written for the computer, so that it may eventually be possible to plot isotherms automatically. This requires the addition of a device that will transfer data from the readout tape to the computer tape.

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(2) E. Pettit, Ap. J. 91, 408 (1940)

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(4) R. W. Shorthill, H. C. Borough, and J. M. Conley, Publ. A.S.P. 77, 481, (1960)

(5) R. W. Shorthill and J. M. Saari, Icarus 2, 115 (1963)

(6) A. Geoffrion, M. Koerner, and W. M. Sinton, Lowell Obs. Bull 5, 1 (1960)

(7) B. C. Murray and R. L. Wildey, Ap. Journ. 139, 734 (1964)

E Burkdale

Sept 7, 1965

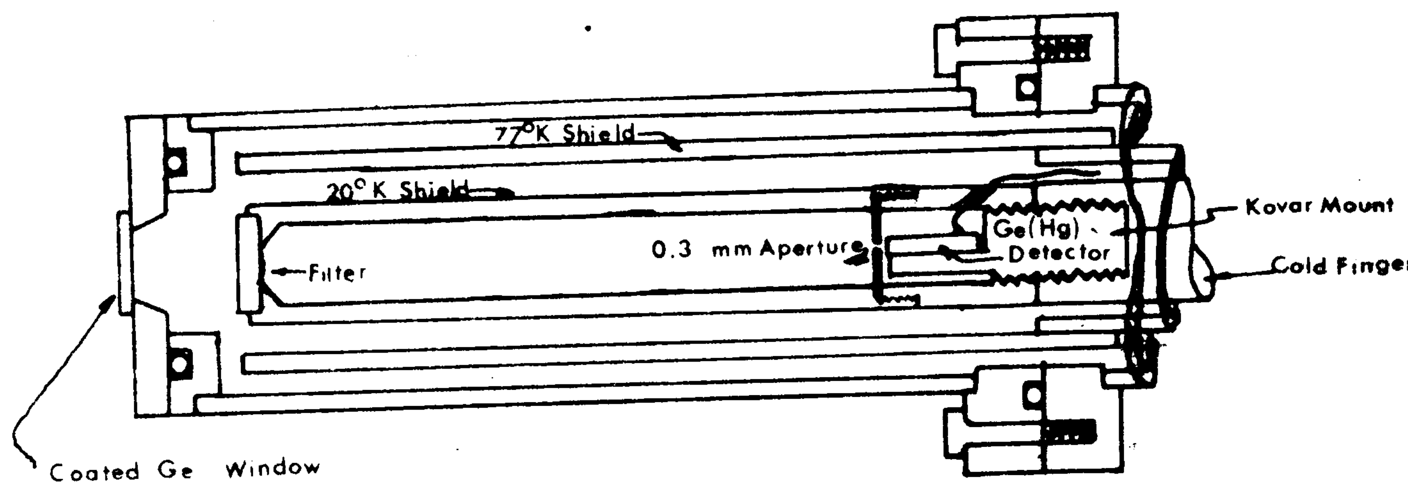


Figure 1. Mercury-doped Germanium Detector and Housing

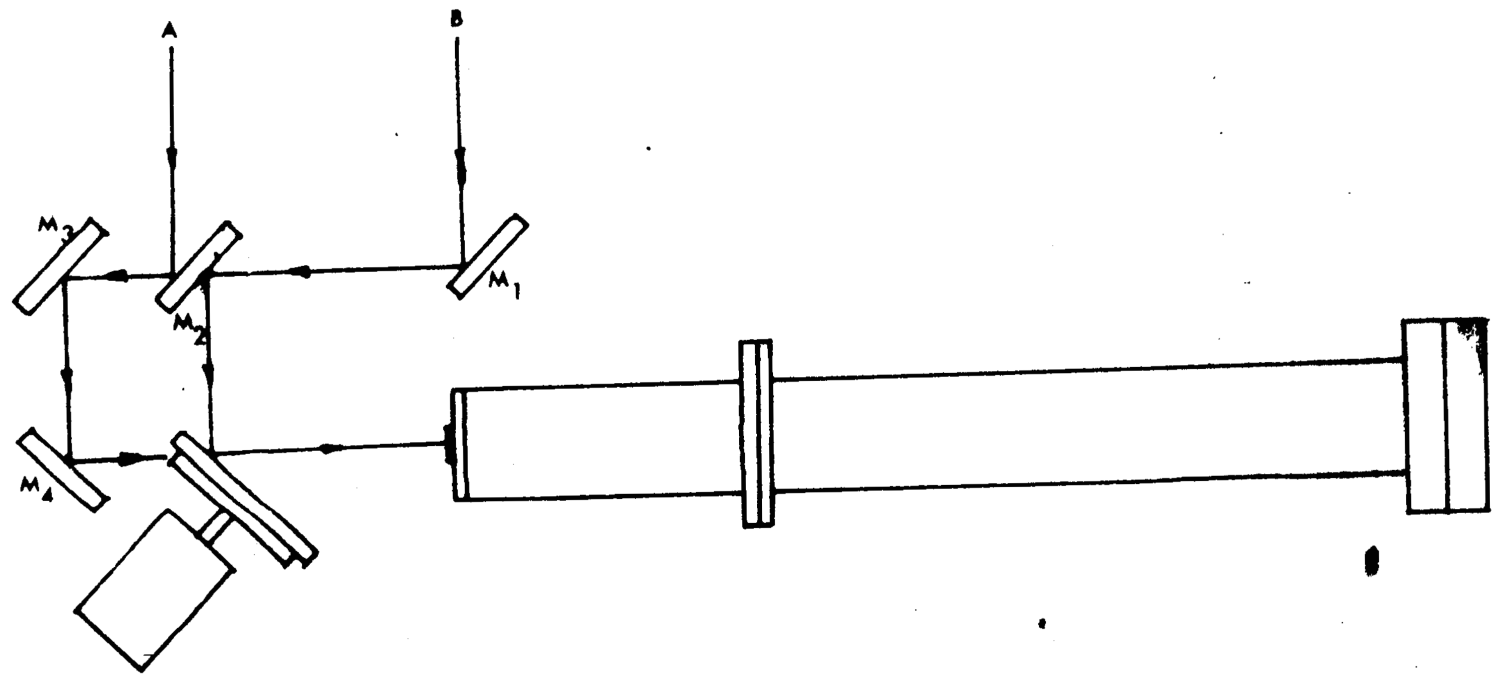


Figure 2. Infrared Radiometer Incorporating Ge(Hg) Detector

The Effect of Gravitational Fields on Enzymatic

Reaction Occurring in Inhomogeneous Systems

R. K. Burkhard, Department of Biochemistry

NASA Grant NsG-692

The study of how gravitational fields affect enzymatic reduction of neotetrazolium chloride by an enzyme system in heart mitochondria has been continued. Previously it was shown that centrifugation increased the rate of this reaction and that this increase was not simply due to a rise in temperature, nor an increase in movement of enzyme particles which would occur during centrifugation. It has since been shown that the increase in reaction rate is almost entirely due to the increased concentration of the enzyme that accompanies centrifugation.

The effect of centrifugation can be decreased by increasing the density of the reaction medium. This is probably due to an increase in viscosity and concomitant decrease in rate of movement of the enzyme. It was of interest to observe that centrifugation increased the rate of reaction even when the viscosity of the medium was greater than that of protoplasm and the centrifugation did not result in complete sedimentation of the enzyme.

The effect of centrifugation upon enzymatic activity was found to be related to relative centrifugal force. At 3000 x g the reduction of neotetrazolium chloride was 60% greater than the control; at low relative centrifugal forces (e.g., 50 x g) no effects of centrifugation could be detected.

The possible effect that centrifugation might have on a homogeneous system was studied by use of sucrose and invertase. This system was essentially unaffected by centrifugation.

The results obtained to date suggest that the metabolism of living systems can be altered by changing the gravitational field of their environment.

R. K. Burkhard

R. K. Burkhard
September 20, 1965

Analytic Studies in the Learning and Memory of Skilled Performance

Merrill E. Noble and Walter F. Daves

Department of Psychology

NASA Grant NsG 692

During the six month period ending August 31, 1965, activities included the following:

(1) The Iconix three field tachistoscope purchased earlier was modified in order to allow the presentation of stimuli differing minutely in spatial separation along the horizontal meridian. This modification was made necessary by virtue of the fact, discovered earlier, that subjects were able to perceive spatial differences smaller than could be drawn by hand.

(2) The relationship between interstimulus interval and ability to perceive the coincidence or non-coincidence between two black lines presented to the peripheral retina was investigated. The lines were presented, one above the other, to the peripheral retina (4.75° nasal) of the right eye. The offset of the top line preceded the onset of the bottom line by an interval of 10, 25, 40, 55, 70, 85, or 100 msec. Subjects were asked to report which line was nearer, and the vernier acuity, using the method of constant stimuli, was thus determined under each condition.

The rationale was as follows: if information presented briefly to the retina has only a transient effect, as numerous experiments have demonstrated, then a task requiring the combination of earlier information with later information should be sensitive to variations in interstimulus interval. In other words, the "time constant" of decay of retinal information could be determined.

The data collected in this experiment is still in the process of analysis, although preliminary results are encouraging. It is felt that the experiment should be repeated, now that techniques have been somewhat refined.

Kansas State University

Manhattan, Kansas 66504

Department of Industrial Engineering
Engineering Shops Building

September 27, 1965

To: Research Coordinating Council
Kansas State University

From: G. F. Schrader
Department of Industrial Engineering

Subject: Progress Report - NASA Grant No. NSG-692
Title: Optimization of Space System Design
Principal Investigator: Dr. G. F. Schrader

The work accomplished and progress made on this project during the period 3/1/65 to 8/31/65 is summarized as follows:

1. The discrete version of the maximum principle was applied to obtain solutions for optimum stage-weight distribution problems of multistage rocket vehicles. In the first approach the structure ratio was treated as a constant in each stage, although it was permitted to differ stage by stage. The second problem considered the variations in structural factors with stage weight. The third problem concerned the determination of optimum weight distribution which minimizes hardware weight.

2. In reference to aerospace activities, transportation type problems find a variety of applications, particularly with respect to logistics in both space vehicle and ground support system allocation. An elegant stepwise approach to the solution of transportation type problems with linear and non-linear cost functions was attempted through the application of the discrete version of the maximum principle. As a result of this study a paper entitled "A Discrete Maximum Principle Solution of Multidepot Transportation Problems with Linear Cost Function" by G. F. Schrader, C. L. Hwang, L. S. Fand and L. T. Fan was submitted for publication to the Journal of Production Research.

   Another paper entitled "Application of the Discrete Maximum Principle to Transportation Problems with Linear and Non-Linear Cost Functions" by C. L. Hwang, G. F. Schrader, et al, is under preparation.

3. The application of the maximum principle to optimal control of simple stochastic processes in both discrete and continuous cases was investigated in relation to its application to a variety of aerospace systems. The results of this study will be explained in a special report entitled "The Stochastic Discrete Maximum Principle for Simple Processes" by S. K. Chen, C. L. Hwang, G. F. Schrader and L. T. Fan

G. F. Schrader

Annual Report of the Work

of

NASA Grant NsG-692

Experiments with Ultraviolet Light

Principal Investigator: C. E. Mandeville

Department of Physics
Kansas State University
Manhattan, Kansas

1 September 1965

I. Introduction

The purpose of these investigations has been to explore the means of developing new sources of ultraviolet light. During this first year a period of time has been required to develop a laboratory for ultraviolet studies. Detectors and recording devices have been accumulated, and a search of the literature has been carried out to obtain information concerning certain ultraviolet producing effects.

II. The Effect Studied

The earliest known observations of the effect under consideration were reported by the astronomer, Jean Picard[1] in 1675. He noted that

1. A. Wolf: A History of Science, Technology, and Philosophy in the 16th and 17th Centuries (The MacMillan Co., New York, 1935) p. 303

when a mercury barometer is shaken, a visible blue-white glow develops in the region of the Torricellian vacuum. This discovery resulted in a renewed interest in electrical effects, and at the turn of the 18th century, quantitative investigations of the mercury excited "electric light" were undertaken[2] by Mr. Fra. Hauksbee, F. R. S., curator of the

2. Fra. Hauksbee, Philosophical Transactions of the Royal Society of London 24, No. 303, 2130 (1705).

Royal Society of London. Of course, the early studies concerned themselves only with visible emission, whereas later investigations have involved the ultraviolet emission as well[3].

3. Katsumi Ikenoue and Yoshiaki Sasada, Memoirs of the Defense Academy of Japan, II, No. 2, 49 (1962); ibid. II, No. 2, 57 (1962).

After much preparation, a number of studies of the effect have been carried out to determine the yield of ultraviolet photons. A portion of the apparatus employed is shown in figure 1. A ball of corning 9741 ultraviolet transmitting glass (diameter 4.83cm) is spun on the shaft of a small motor at rpm ranging from zero to about 600. From the number of rpm and the diameter of the ball, it is possible to calculate the relative velocity of the contiguous surfaces of mercury and glass. The mercury remains relatively motionless while the ball spins. The ball had been previously evacuated to 10^{-7} mm Hg before the few grams of mercury were added. The ultraviolet yield was enhanced by a factor of 10 when helium to a partial pressure of 0.6 mm Hg was added. It is evident that the added helium shortens the mean free path, yielding more collisions and thus more quanta. Ultraviolet lines are well known to be present in the arc discharge spectrum of helium.

The intensity of the ultraviolet emission, as recorded in an ultraviolet sensitive, photon counter (figure 1), is plotted as a function of relative surface velocities in figures 2 and 3. The ultraviolet sensitivity of the detector was monitored by noting its response to a standard UV source in a standard position throughout the course of the investigation. Thus, the scatter in position of points along the curve, cannot be explained by fluctuating counter sensitivity. It is thought to be related to surface effects. This point is currently under investigation.

III. Discussion of Results

The photon emission observed in these experiments results from discharge occurring when the contiguous surfaces of conductor and insulator are charged and discharged by frictional effects. The accepted picture is that of figure 4, showing metal and insulator adjacent. Electrons are considered to flow from metal to insulator at the junction, when contact is made. Electrons in the conduction band of the metal participate in this flow. When the surfaces are separated, the capacity of the region of contact decreases, the potential rises, and a discharge occurs in the gas.

IV. Future

It is planned to continue study of the effect during the coming year with emphasis upon temporal variations of the effect, spectral distribution of the energy of the radiant emission, etc. Efforts will be made to enhance the effect.

Thus far, in this program, all measurements have been essentially qualitative. The detectors thus far employed have not been given absolute calibration. The photon counters thus far utilized are not particularly stable as to response over long periods of time. Some photodiodes (photocells) have been purchased which respond to ultraviolet and visible light. One type, obtained from IT and T responds to the ultraviolet only.

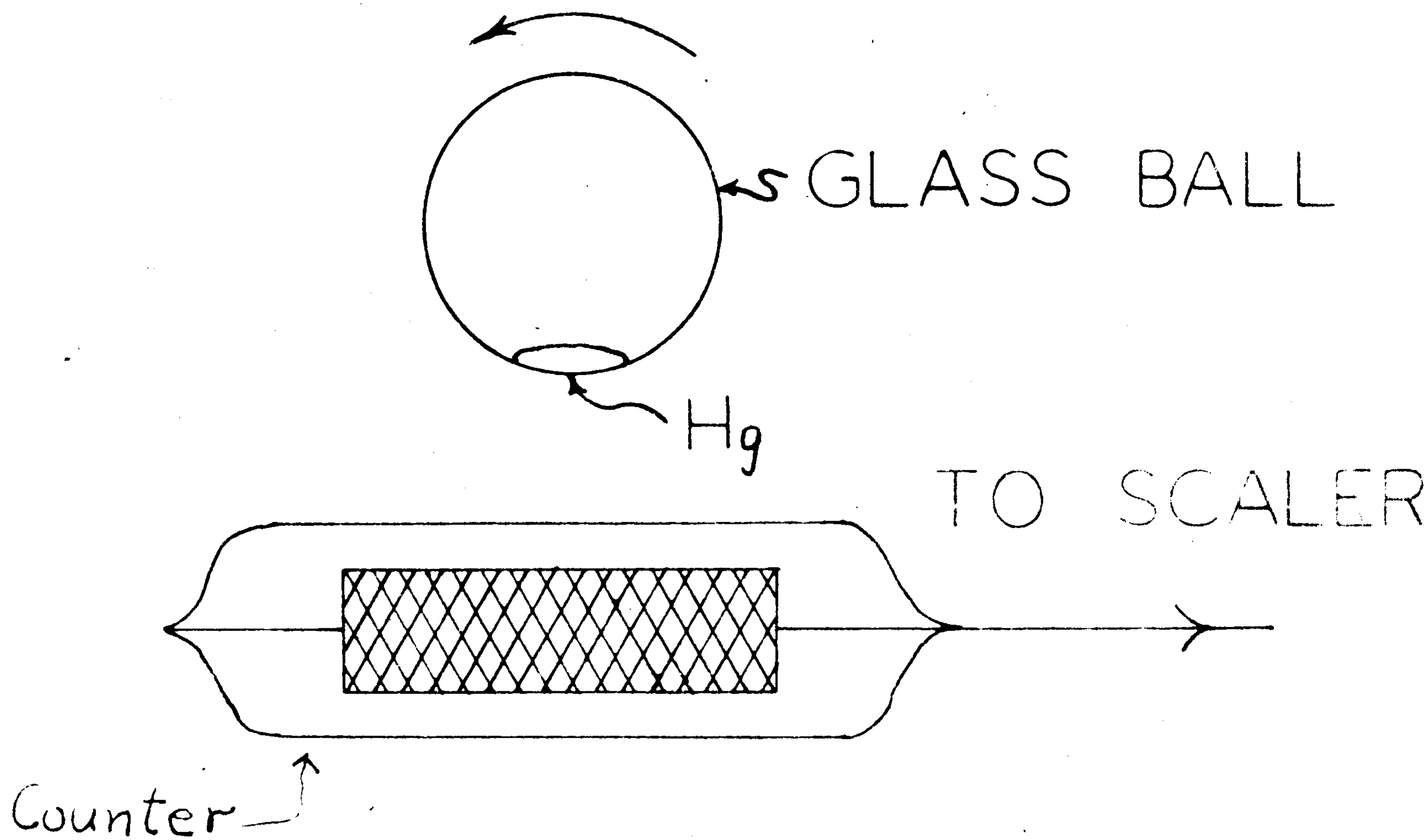
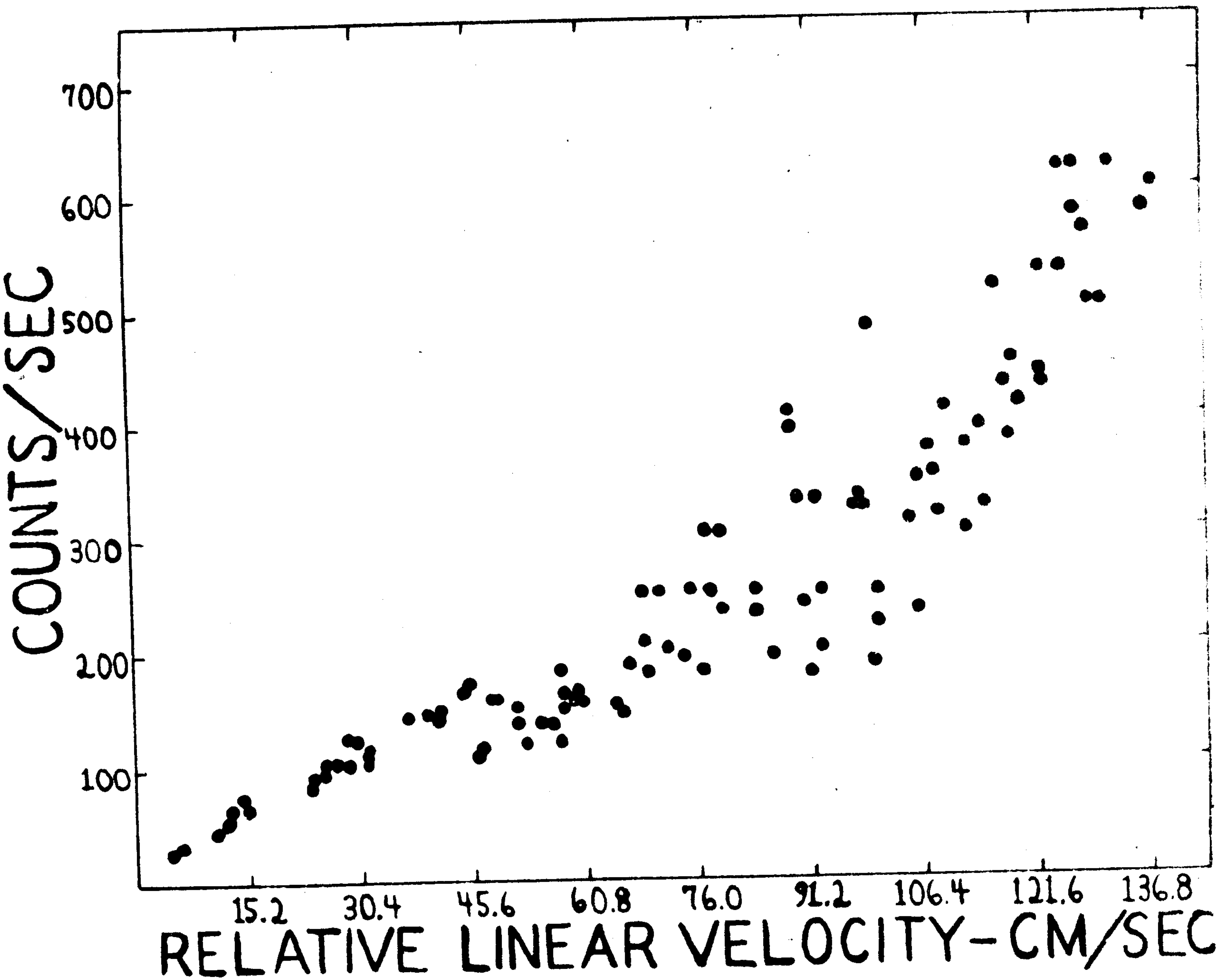


figure 1


COUNTS/SEC
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15.2
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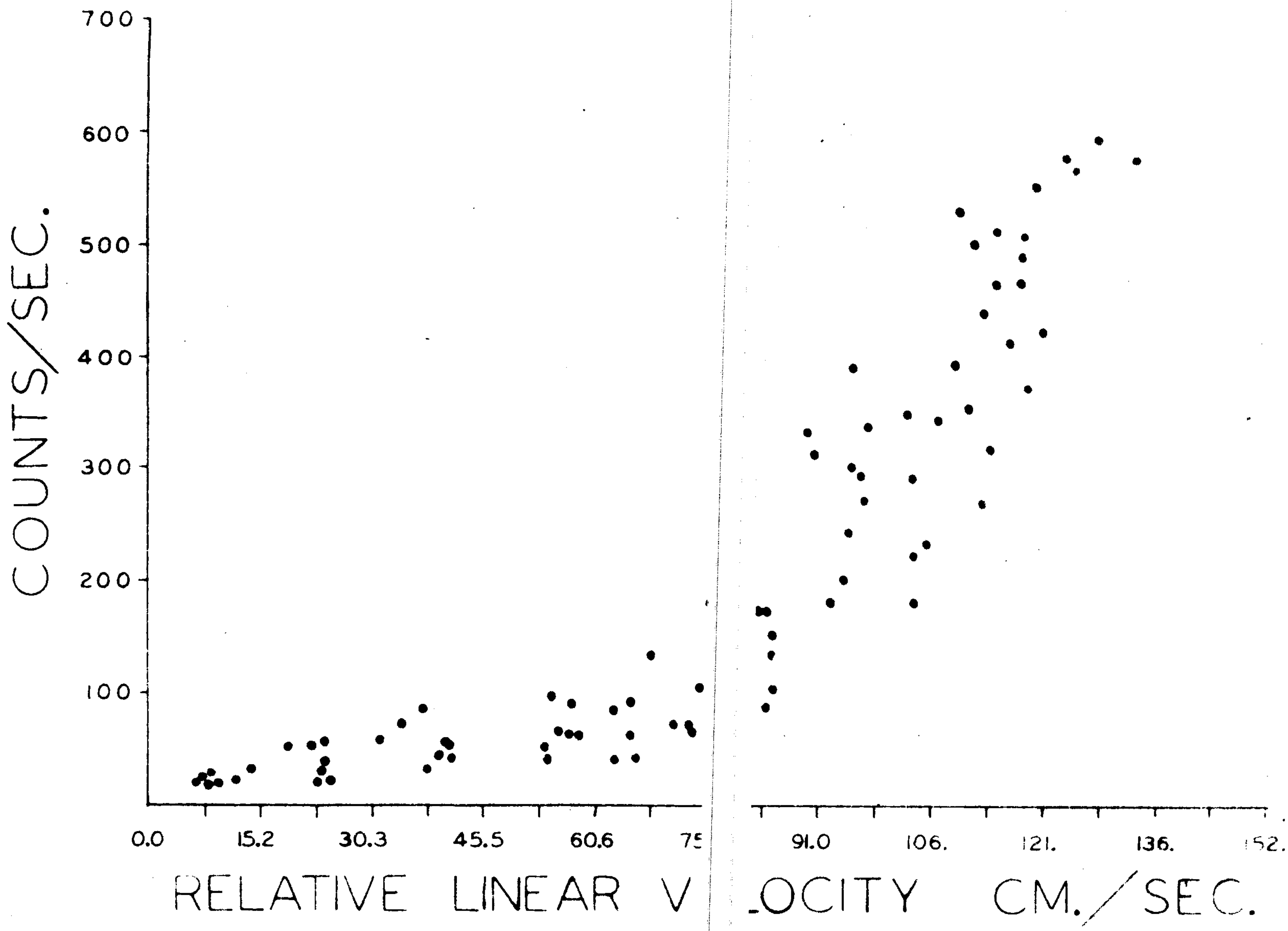
136.8
RELATIVE LINEAR VELOCITY-CM/SEC

figure 2



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RELATIVE LINEAR V
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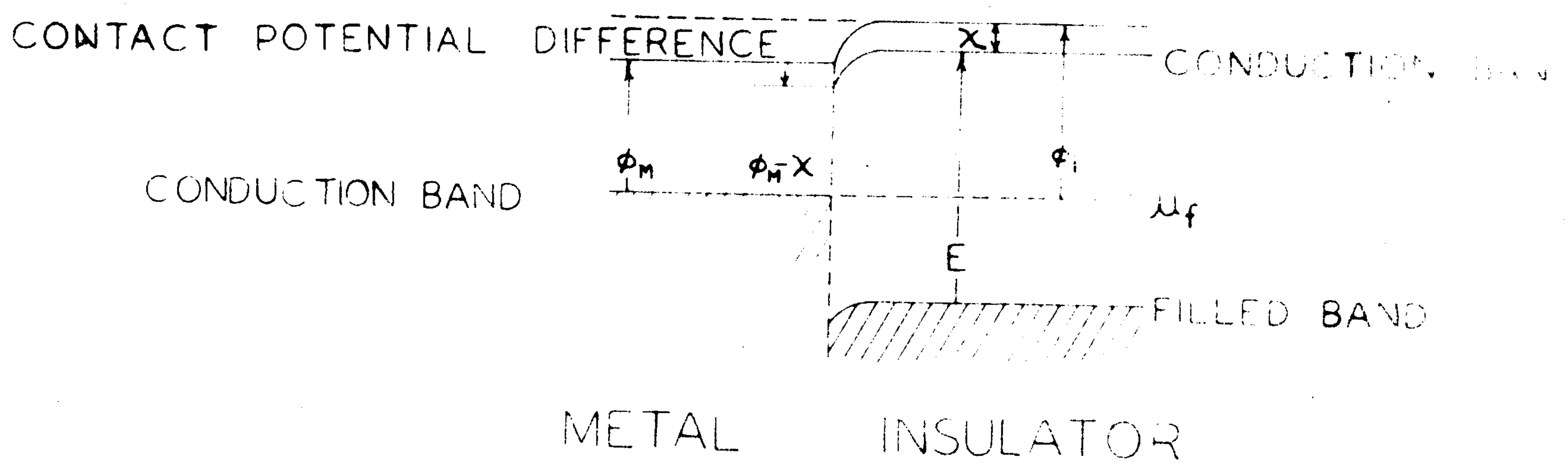
figure 3

See W.-J. Turner, Phys. Rev. 101, 1653 (1956)



ϕ_M = work function of metal before contact
ϕ_i = Energy separation of fermi level and vacuum level of insulator before contact
E = Energy gap of insulator
χ = Electron affinity of insulator

figure

NASA Grant NsG-692 Progress Report [illegible] September [illegible]

Width of the tracks of Heavy Ions in Emulsions and Other Media, Robert Katz, Principal Investigator

Two stacks of emulsion have been exposed at balloon altitudes to obtain additional heavy ion tracks for study. One stack was exposed in a flight originating over New Mexico, through the courtesy of Prof. M. Friedlander, Washington University, St. Louis, and the other stack was exposed in a flight originating at Churchill, through courtesy of Dr. Donald Guss, NASA. Both stacks were processed in Prof. Friedlander's laboratory. Through the experience gained in these operations we expect to set up our own processing facility. Both flights were successful. The stacks are now being scanned. Processing racks and other devices are now being designed.

Two papers have been presented at the March 1965 meeting of the American Physical Society, as follows:

Biological Effects of Heavy Ion Irradiation, J.J. Butts and Robert Katz, Bull. Am. Phys. Soc. II **10**, 378 (1965) Paper KF 11.

Width of Ion Tracks in Emulsion, E. J. Kobetich, J.J. Butts, and R. Katz, Bull. Am. Phys. Soc. II **10**, 379 (1965) KF 12.

Work continues in an attempt to improve the method of measurement of track width, to gain data on more tracks, and to further refine the track width computations.

Robert Katz

Bull Am Phys Soc II 10, 378 (1965)

rate of 0.357°/h. It is believed that crystal strain is the primary cause for explosions during growth.[2] Starting growth at a high temperature and uniformly cooling the sample sufficiently slowly anneals the crystal(s). This process has produced 20-50 crystals per sample vial with no explosions.

[1] F. P. Bowden and A. D. Yoffe, *Fast Reactions in Solids* (Butterworths Scientific Publications, London, 1958), p. 123.
[2] W. C. McCrone, Proc. Basic Contractors Conf., 9th, USAERDL (Oct. 1960), p. 7.

KF9. Positron Lifetimes in Metal–Ammonia Solutions.* L. H. DILTERMAN, W. E. MILLETT, AND J. C. THOMPSON, *The University of Texas.*—The lifetimes of positrons have been measured in solutions of lithium in liquid ammonia with a resolution of 0.5 nsec. The metal concentration was varied from a mole ration ($Li:NH_3$) of 0.0003 to 0.03; measurements were also made in pure NH_3, all at −65°C. A lifetime of 1.6 nsec was found in pure NH_3 for the long component; this same component had a lifetime of 0.6 nsec in the most concentrated solution. The fraction associated with this component varied from 28% to 13% over the same range, but was concentration independent at mole ratios above 0.003. At concentrations near a mole ratio of 0.005, evidence was found for a 3rd, long-lived, component.

* Research assisted by the U. S. Office of Naval Research, the National Science Foundation, and the R. A. Welch Foundation.

KF10. Soft X-Ray Disometry for Radiation-Chemistry Studies of Hydrocarbons.* OTTO H. HILL, *University of Missouri, Rolla.*—Fundamental radiation-chemistry studies dedicated to dynamic measurements of the *rates* at which particular chemical reactions are induced in a material system during exposure to a radiation field require that the radiation source be integrally mated to the analytical equipment to be employed. This may be provided by relatively low energy (<100 kV) x-ray sources. Customary reservations regarding the quality of the dosimetry available for such sources have been relieved by the design and development of homogeneous, variable plate-separation ion chambers (consisting of polyethylene bodies and utilizing ethylene as the cavity gas) to specify *absolute* energy deposition in typical hydrocarbons with an accuracy of ±7%. Specification of the energy deposition in the cavity gas, which is exempt from criticisms based upon inherent chamber inhomogeneities, is deduced from lim $\Delta I/\Delta V$ as V increases without limit, where I is the ionization current and V is the collector volume. These techniques are also exempt from criticisms based upon satisfaction of geometrical equivalence and "electronic equilibrium" in sample systems and are particularly adaptable to radiation dose specification in thin (3–15 mil) sample specimens, which are required in many analytical studies. The unique advantages provided by such sources and the associated dosimetry techniques are discussed, together with examples of dynamic analytical applications.

* Work supported at General Dynamics Corp., Fort Worth, by the U. S. Air Force Weapons laboratory.

X **KF11. Biological Effects of Heavy-Ion Irradiation.** J. J. BUTTS (introduced by Robert Katz) AND ROBERT KATZ, *Kansas State University.*—The relative inactivation cross sections for ions of different Z may be predicted by use of a recently developed theory of track width in emulsion.[1] The dose delivered to the material by δ-rays is calculated as a function of distance from the ion's path using the well-known δ-ray energy spectrum and an extrapolated range–energy relation for very slow electrons. The measured cross section is interpreted as the area of a cylinder of material inactivated by the passing ion and is calculated theoretically by assuming a threshold inactivation dose E^* characteristic of each biological material. Our calculations are in good agreement with relative cross sections measured by Dolphin and Hutchinson[2] for two different enzymes with $Z=1, 6, 8, 9$ at $\beta=0.145$. We have no need for such concepts as target size, overlap factor for δ-rays, energy per ion cluster, and sensitive volume of material, which are necessary in the customary associated volume calculation of Lea.[3]

[1] R. Katz and J. J. Butts, "Width of Ion and Monopole Tracks in Emulsion," Phys. Rev. (to be published).
[2] G. W. Dolphin and F. Hutchinson, Radiation Res. 13, 403 (1960).
[3] D. E. Lea, *Actions of Radiations on Living Cells* (Cambridge University Press, London, 1955).

X **KF12. Width of Ion Tracks in Emulsion.** E. J. KOBETICH (introduced by R. Katz), J. J. BUTTS, AND R. KATZ, *Kansas State University.*—Experimental studies of the energy flux and electron penetration through thin films of aluminum by normally incident low-energy electrons, by Kanter and Sternglass,[1] have been applied to the calculation of the width of ion tracks in emulsion. As in the width theory of Katz and Butts,[2] it is assumed that an emulsion grain is sensitized when the ionization energy deposited by δ-rays exceeds a threshold value, characteristic of the emulsion. The present model assumes δ-rays to be ejected normal to the ion's path, and ignores the difference between electrons normally incident onto a plane slab and electrons radially ejected into a solid cylinder. In general, the new model is in agreement with results of the earlier calculation, even as to the threshold dosage for grain sensitization, but the number of adjustable parameters required for the calculation has been reduced from 3 to 1, the threshold energy. Agreement with experiment is noticeably improved.

[1] H. Kanter and E. J. Sternglass, Phys. Rev. 126, 620 (1962).
[2] R. Katz and J. J. Butts, Phys. Rev. (to be published).

KF13. Radiation Dose for Earth-Orbiting Satellites. JANE B. BLIZARD, *Physics, Engineering and Chemical Corporation.*—Satellite crews would accumulate ionizing radiation doses as follows: (1) continuously from cosmic rays, (2) several hours each day from the trapped belts in passage through the South American anomaly, and (3) about twice per month, on the average, from solar flares above 60° orbital inclination. Electron flux on the satellite walls will produce bremstrahlung in the cabin. A satellite with inclination between 28° and 30° would have a tolerable dose for a 3-month duty cycle at altitudes below 300 nm (nautical miles). The dose would increase 10-fold at an altitude of 350nm. High orbital inclination

SATURDAY, 27 MARCH 1965 MUEHLEB...

(THOR L. SMITH ...

High-Polymer Ph...

Invited Pap...

KG1. Electronic Charge Transport in Polymer Solids. ... *Laboratory.* (30 min.)

KG2. Electronically Conducting Polymers. J. H. LUP... (20 min.)

Contributed P...

KG3. Dielectric Crystalline Absorption in Oxidized Polyethylene. K. YAMAFUJI (introduced by W. P. Slichter), *Carnegie Institute of Technology,* AND Y. ISHIDA,* *Bell Telephone Laboratories.*—The dielectric crystalline absorption in oxidized polyethylene has been measured as a function of frequency over the temperature range 20°∼100°C. The materials were prepared by oxidizing Marlex-type polyethylene in the melt under ultraviolet light. The samples were crystallized from the melt or from dilute solution. The absorption strength

STATISTICAL RADAR ECHO ANALYSIS
AND ITS ~~APPLICATION TO PLANETARY RETURN~~

Kumar Krishen, Electrical Engineering Department
Dr. W. W. Koepsel, Electrical Engineering Department, Project Leader

NASA NsG-692

The last few years have been a considerable revival of interest in the problem of depolarization of an incident wave of a given polarization by a rough surface. The importance of the problem is associated with several applications, for example, polarization discrimination for television channels, circularly polarized radar or microwave relays etc. There is evidence to believe that the depolarized return will depend on the statistical properties of the "surface of reflection." In this manner, a thorough knowledge of depolarized return might in turn yield some information on the statistical constants of the surface. The depolarized return from a statistically rough surface covered by a layer will also depend on the constants of the layer in addition to the structure of the surface.

In general, depending on scattering properties of the surface a horizontally polarized incident wave is reflected as part vertically and as part horizontally polarized. In cases where the surface is 'locally flat' type we can assume that the field scattered in the incident plane will not be depolarized. It must be remarked here that a smooth conducting plane also reverses the sense of rotational polarization and in the side lobes it changes circular to elliptical polarization.

From a thorough search of available literature on the subject it is apparent that the problem has never been seriously attacked, although it was recognized quite early that different polarizations of the incident wave will give rise to different reflection factors. These reflection factors have been studies in detail (Peake 1959) and the dependence of these on the angle of incidence has also been reported (Katzin, 1960). Beckmann (1961) has shown a way of associating slope of the scattering element with the "Depolarization Factor."

The progress in this direction seems less considerable in part because of the mathematical complexity and also because of complexity in the experimental setups for the study of such a phenomenon.

This work is an attempt to include the roughness parameters in the expected value of the returned polarization factor. It will be shown that the polarization factor of the signal returned from a rough surface covered by a layer depends also on the properties of the layer. The concept of most probable polarization factor has been brought into picture because the received polarization factor obeys a certain distribution depending on the distribution of the slopes of the surface.

The average depolarization factor or cross polarization factor is seen to depend on the electric properties of the layer and the statistical parameters of the rough surface of the layer. The lack of possible methods of evaluating the complicated integrals makes it difficult to recognize the distinct part played by (a) the properties of the layer, (b) the statistical properties of the surface of the layer, separately.

An experimental investigation has been made to determine a correlation between the electrical properties of a statistically rough surface (of a dielectric or partially conducting layer) and the cross polarization distribution caused by the surface when an E. M. wave (vertically polarized) is scattered by the surface. The results can be explained easily.

BLOCK DIAGRAM OF THE PRACTICAL SET UP

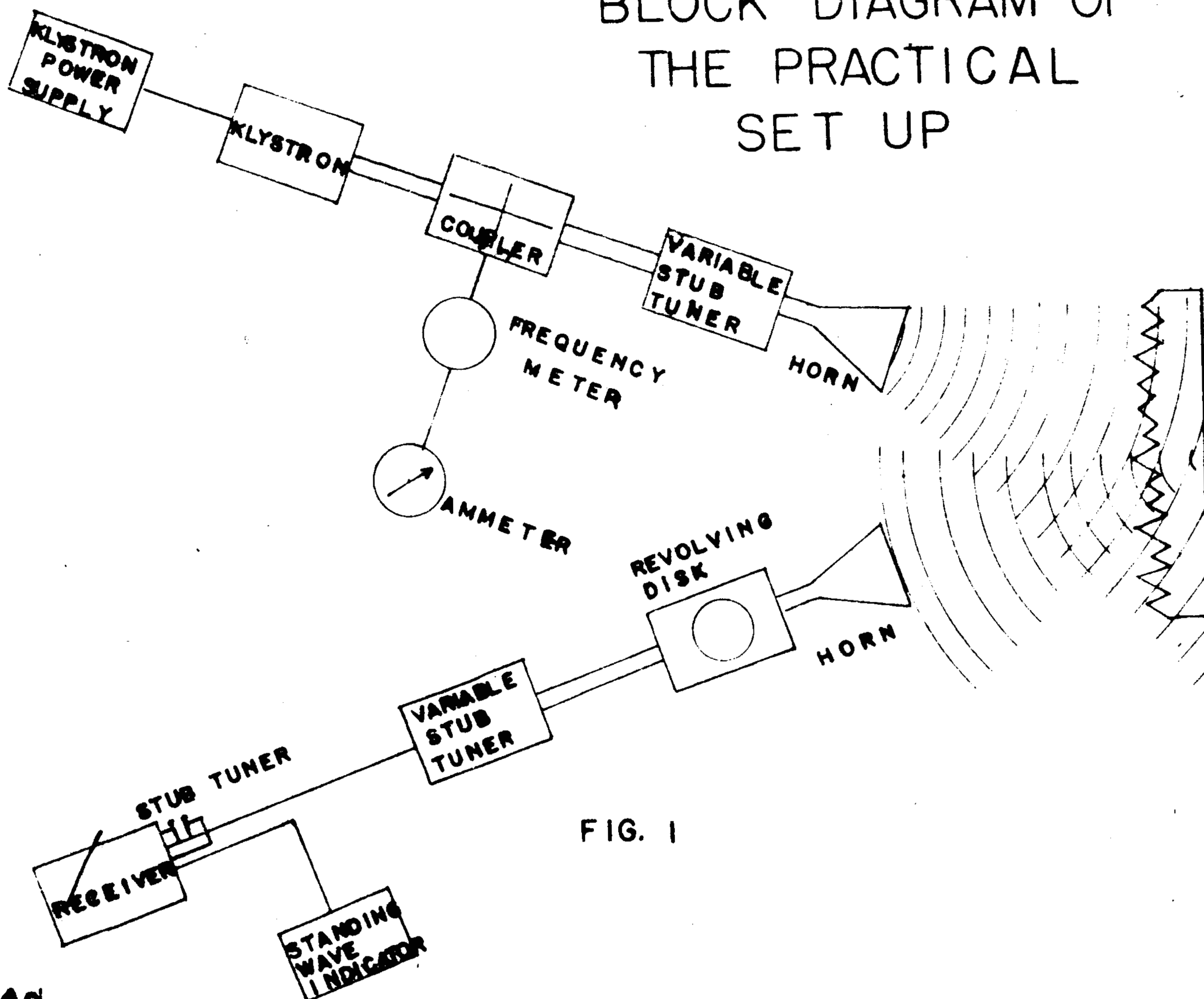


FIG. 1

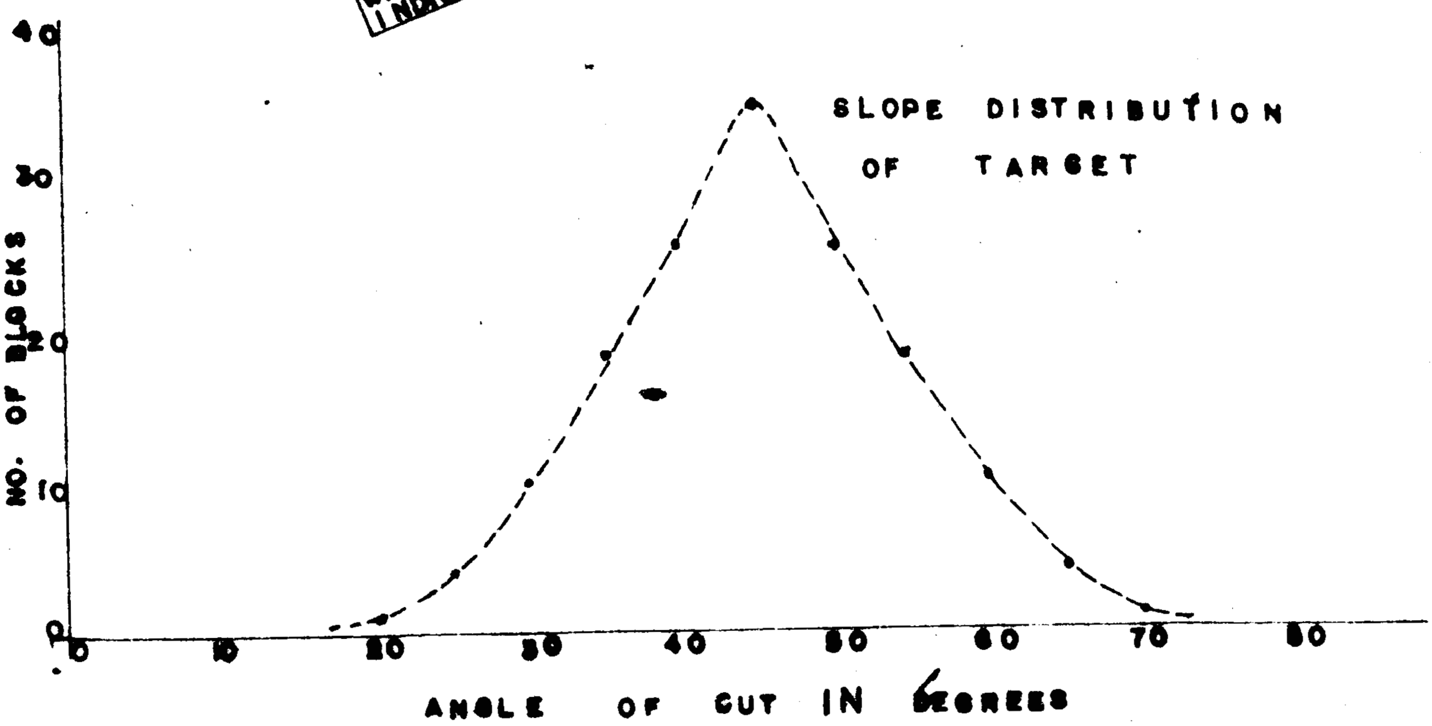


FIG.3

EQUIPMENT

The equipment used to obtain the average crosspolarization is shown in Figure 1. Two antennas are used and thus isolation between the transmitter and receiver is increased. The antennas used are DBG - 520*, 20 db gain, 15^{0} beam width horns. The receiver was a R-111/APR - 5A, microwave superhetrodyne. The input to the receiver was tuned to provide a proper match. Both horns were also tuned using DBG 919 variable stub tuners to reduce reflections. A Varian Associates 6312 klystron was used as the signal source.

In order to reduce signal variation the system stability was thoroughly checked. The possible sources of signal fluctuations are:

a) fluctuation in the transmitted amplitude

b) variation in transmitter and local oscillator frequency

c) variation in gain of receiver and video amplifier

d) motion of the trnasmitter, receiver, target due to winds

e) reception from some other sources.

However none of these is significant in our case. The amplitude of the received signal did not change by any appreciable degree while observations were made as to the amplitude stability of the system.

EXPERIMENTAL PARAMETERS

Operating frequency .... 9.85 KMC/S.

Antenna gain .... 20.0 db.

Polarization transmitted .... vertical

Polarization received .... vertical and horizontal

Pulse repetition frequency .... 1000.0 C/S.

Receiver bandwidth .... 50 KC/S.

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*DEMORNEY & BONARDI.

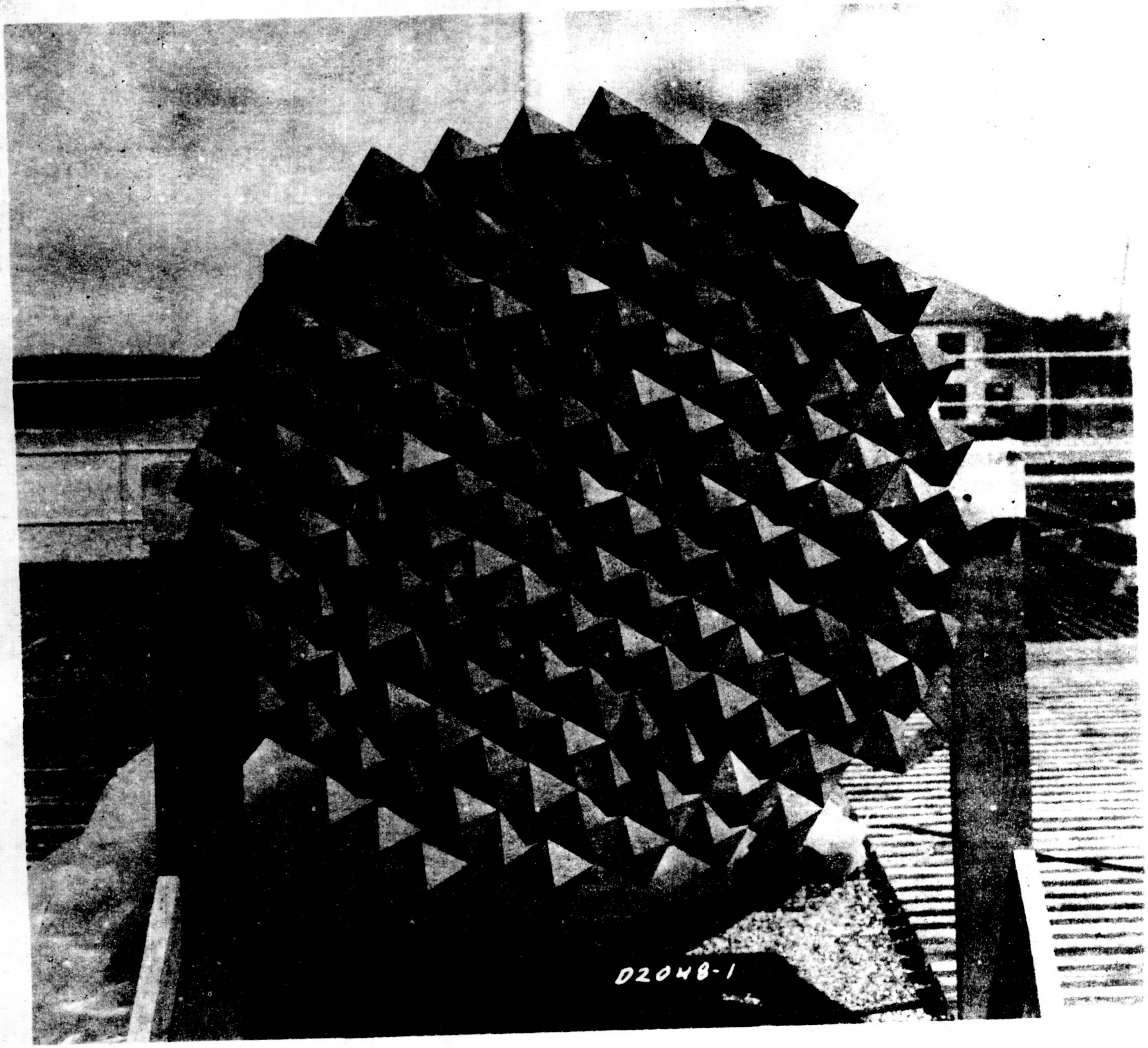

FIG.2(b) ROUGH SURFACE TARGET HEAD ON VIEW

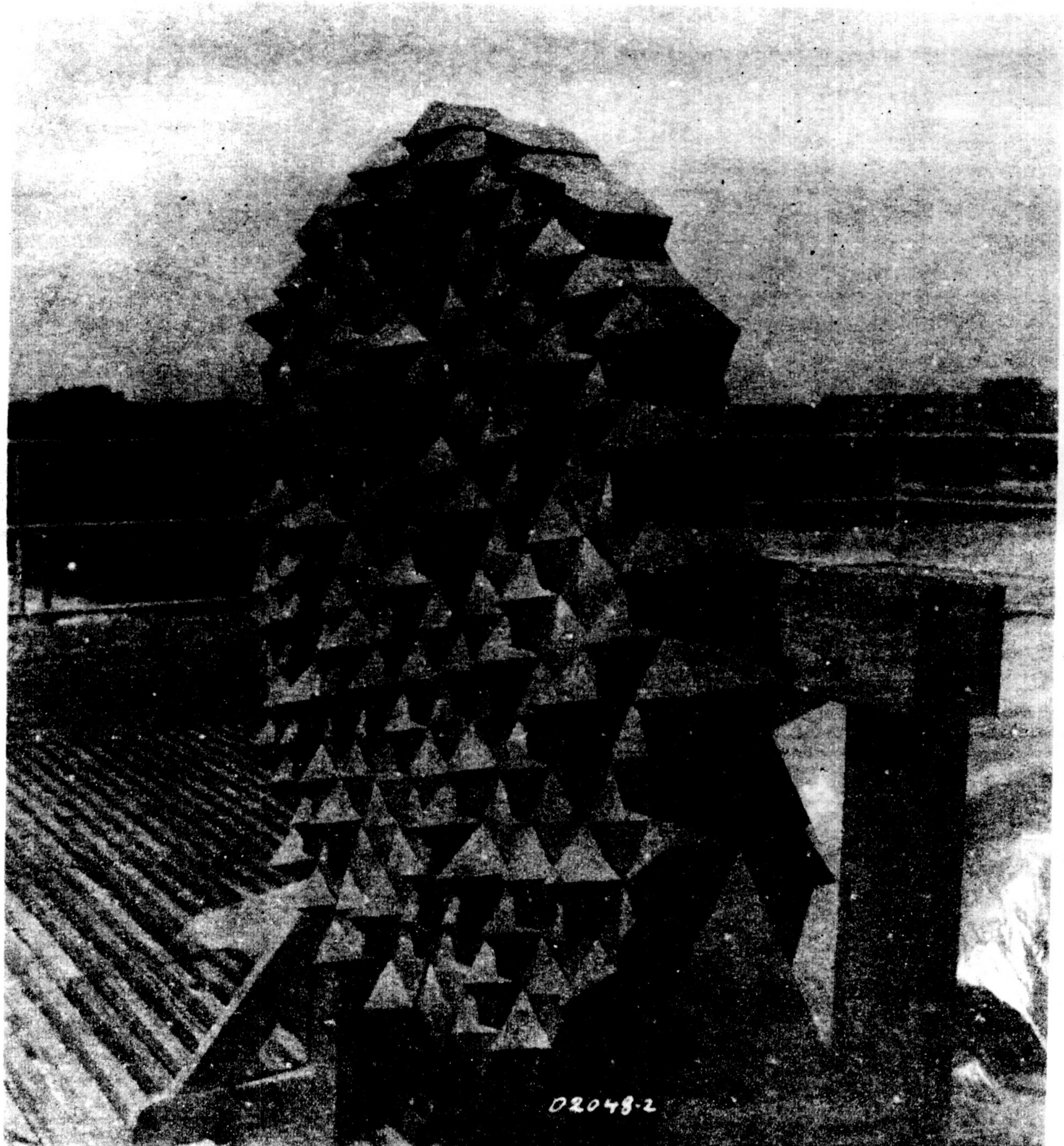

FIG. 2(a) ROUGH SURFACE TARGET OBLIQUE VIEW

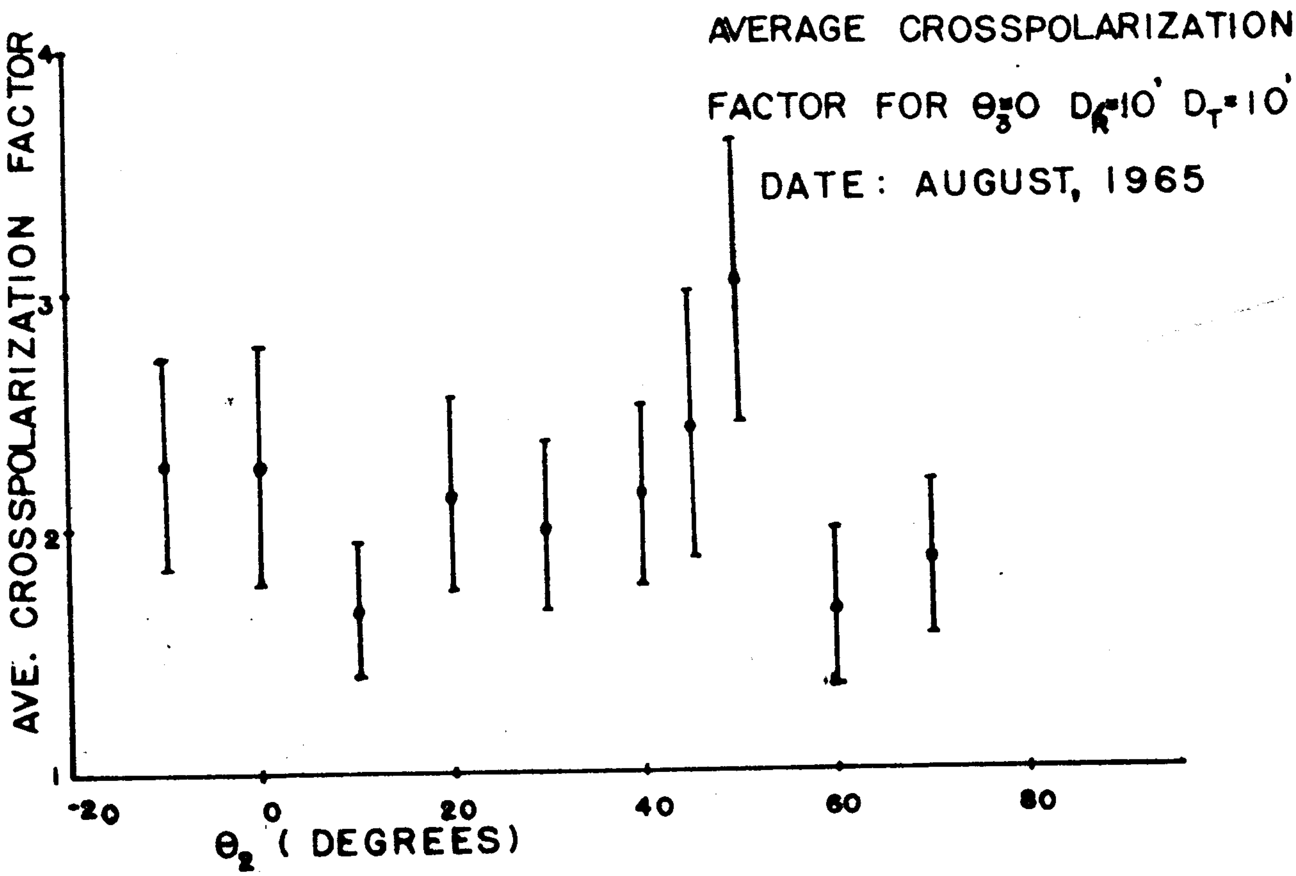
AVERAGE CROSSPOLARIZATION
FACTOR FOR θ3=0 DR=10' DT=10'
DATE: AUGUST, 1965
AVE. CROSSPOLARIZATION FACTOR
1
2
3
4
-20
0
20
40
60
80
θ2 (DEGREES)

FIG. 4(a)

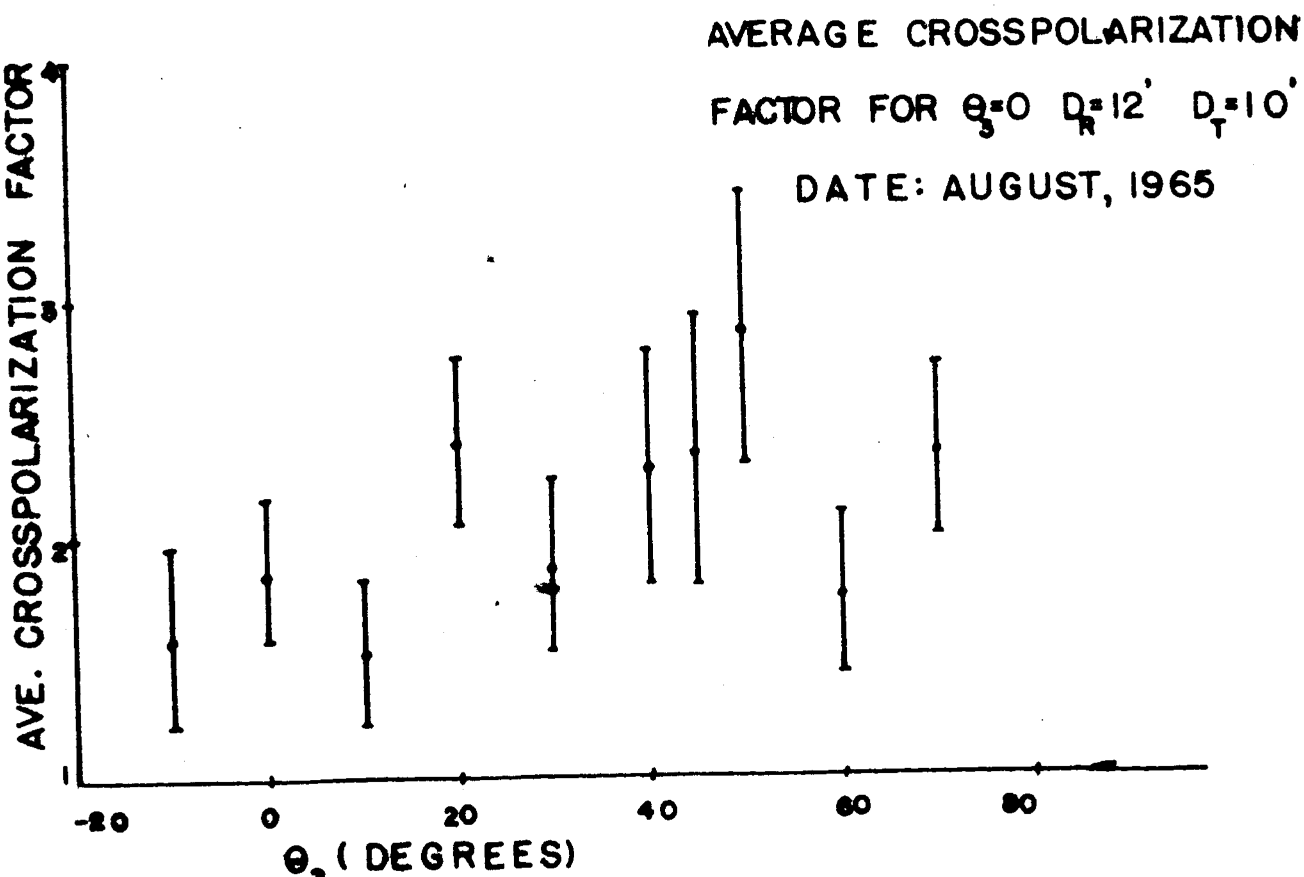
AVERAGE CROSSPOLARIZATION
FACTOR FOR θ3=0 DR=12' DT=10'
DATE: AUGUST, 1965
AVE. CROSSPOLARIZATION FACTOR
1
2
3
4
-20
0
20
40
60
80
θ2 (DEGREES)

FIG. 4 (b)

SCATTERING GEOMETRY

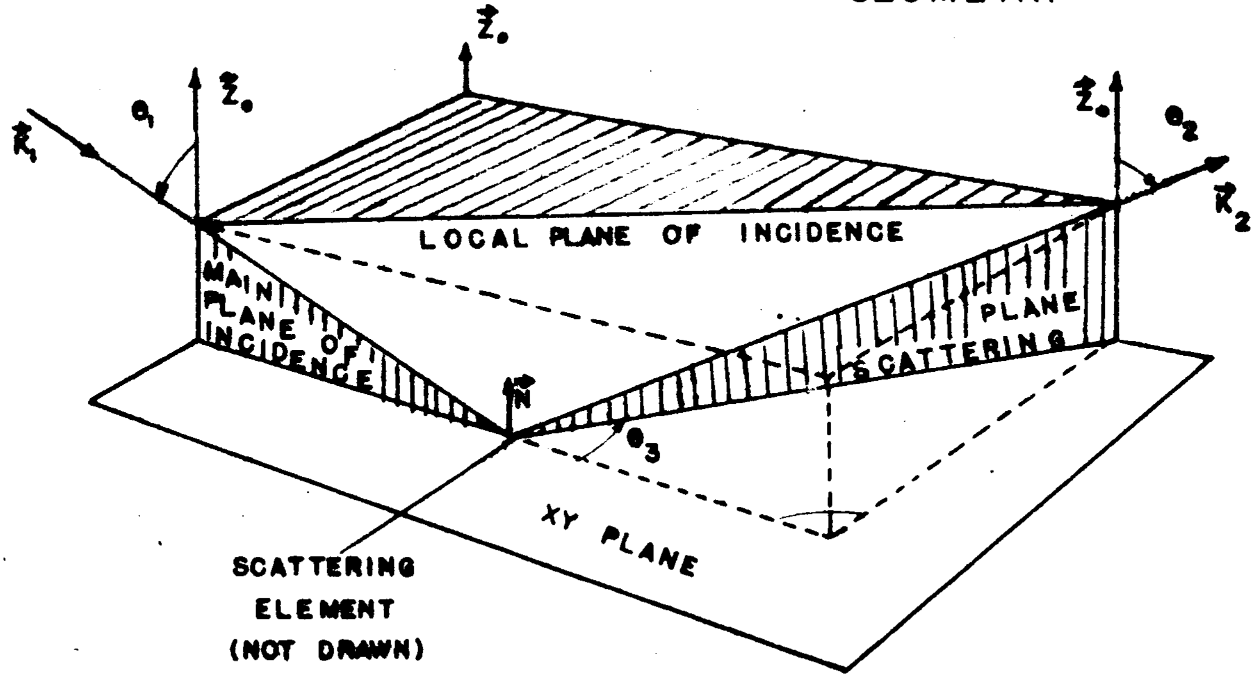

FIG. 5(a)

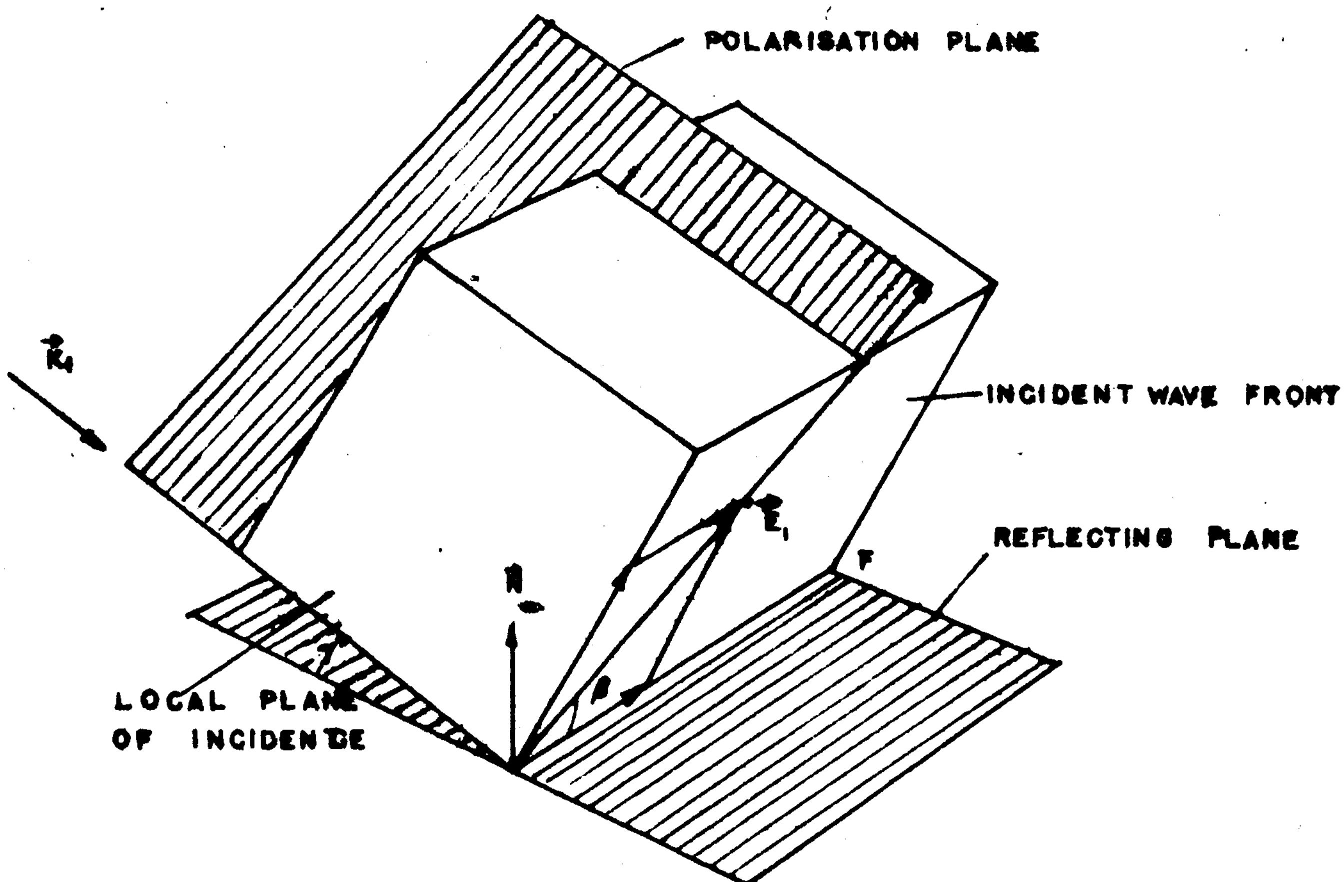

FIG. 5(b)

The receiving antenna is mounted in such way as to receive both horizontal or vertical polarization. The whole assembly can be moved with relative ease to measure the field at any particular point.

The target chosen was a circular 4 ft. diameter disc which could be revolved 360^0. On the disc are mounted blocks of wood (Figures 2(a) and 2(b). The tops of these blocks are cut in the form of a pyramid whose angles are specified. A 4-inch layer of wood with surface slopes specified as a Gaussian distribution have 45^0 mean (see figure 3). The apex angle of the pyramid varie from 20^0 to 70^0 in 50 steps.

The experiment was performed on the roof of the engineering building in order to avoid multiple reflections.

A Hewlett Packard standing wave indicator was used to observe the received electric field strength. The difference between the horizontal and vertical field strengths gave a measure of crosspolarization. The standing wave indicator is tuned to 1000 hz and this method of measurement reduced the noise level.

OBSERVATIONS

The target was rotated in 10^0 steps and the vertical and horizontal components of the field tabulated at different θ_2 angles. The transmitter was aligned in such a fashion as to illuminate the target at the center point. (See figure 5(a) and 5(b))

The crosspolarization factor was tabulated at each point and an average was estimated and recorded. Thus for $\theta_3 = 0$ and D_T = distance of the transmitter as 10 ft. $\theta_1 = 30^0$ and D_R = distance of the receiver as 10 ft. and 12 ft. θ_2 was varied from 30^0 to 110^{0*} and two curves were obtained. (Figure 4(a) and 4(b)) The average $\langle D \rangle$ is seen to scatter around 2.5.

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*Corresponding to -20^0 to 80^0.

THEORETICAL ASPECTS

The following assumptions have been made--for the simplication of mathematical procedure.

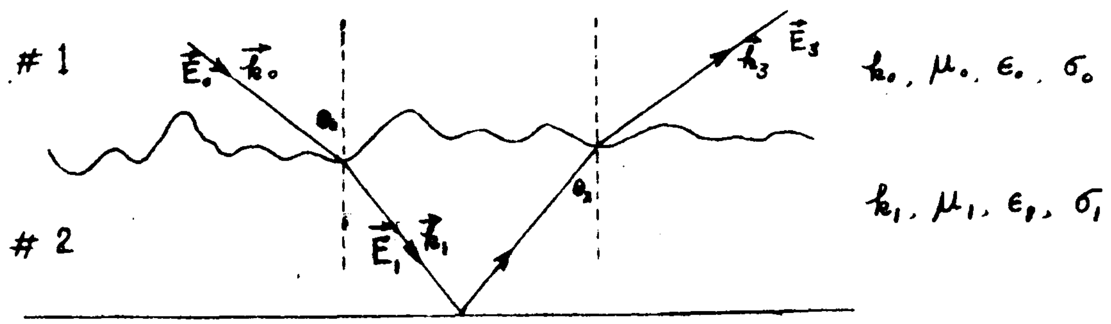
(a) The depth of the layer is greater than wave length of the incident wave.

(b) No shadowing effect has been taken into account.

(c) Standard deviation of the surface heights on the two sides of the mean value is far greater than wave length and at the same time smaller than the decorrelation distance.

(d) No multiple reflections are allowed for.

For a layer terminated by a perfect conductor



When a vertically polarized wave is reflected from the surface of a dielectric medium; the polarization is effected by both the surface roughness and the medium properties. The polarization of the reflected wave is

$$p_2 = \frac{R^- \tan\beta \, \tan\beta_1 + R^+}{R^+ \tan\beta' - R \tan\beta_2} \qquad \ldots\ldots\ldots (1)$$

where $R^+ = f_1 \, (\theta_0, \mu_0, \epsilon_0, \sigma_0)$

$R^- = f_2 \, (\theta_0, \mu_0, \epsilon_0, \sigma_0)$

and β is connected to the slopes of the rough surface by the relation

$$\cos\beta = \frac{\sin\theta_2 - \xi_x \cos\theta_2}{\sqrt{\xi_y^2 + (\sin\theta_2 - \xi_x\cos\theta_2)^2}} \quad \text{........ (2)}$$

The transmitted wave is given by

$$\vec{E}_1^+ = \frac{\omega\mu_o}{k_o}\cdot\frac{2\mu_o k_1^2\cos\theta_o\ \vec{E}_o^+}{\mu_o k_1^2\cos\theta_o + \mu_1 k_o\sqrt{k_1^2 - k_o^2\sin^2\theta_o}} \quad \text{........ (3)}$$

$$k_1\cos\theta_1 = \sqrt{k_1^2 - k_o^2\sin^2\theta_o} \quad \text{........ (4)}$$

The transmitted wave is reflected by the perfectly (smooth) conducting plane and the polarization remains unchanged. Finally we have a transmission from #2 to #1 and the electric field

$$\therefore\ \vec{E}_3^+ = f(\theta_o,\ \lambda,\ \mu_1, \mu_o\ \epsilon_1, \epsilon_o,\ \sigma_1, \sigma_o,\ \theta_2) \quad \text{........ (5)}$$

This electric field polarized in the vertical plane effects the overall polarization of the reflected wave which now is

$$p_x' = \phi(\xi_x, \xi_y, \theta_o, \theta_2, \lambda, \pi_{\#1}, \pi_{\#2}) \quad \text{........ (6)}$$

where

$$\pi_{\#1} = \sigma_o, \epsilon_o, \mu_o$$

$$\pi_{\#2} = \sigma_1, \epsilon_1, \mu_1 \quad \& \quad f_1, f_2, \phi$$ are functions.

Hence "crosspolarization constant D" is also a function of these functions.

$$\langle D_2\rangle = \int_{\xi_x}\int_{\xi_y}\int_{\theta_o}\int_{\theta_2} \phi_1\cdot p(\xi_x)\, p(\xi_y)\cdot p(\theta_o)\cdot p(\theta_2)\cdot d(\xi_x)\cdot d(\xi_y)\cdot d\theta_o\cdot d\theta_2$$

Assuming ξ_x, ξ_y, θ_o, & θ_2 are independent.

CONCLUSION

The depolarized return from a statistically rough sruface is dependent on the roughness parameters of the surface. The average crosspolarization factor is believed to contain information about the parameters of the rough surface. The problem becomes more complicated when one considers a rough layer terminated by a conducting smooth surface. The average depolarization factor and the average crosspolarization factor depend not only on the frequency of the transmitted wave, the angle of incidence and the roughness parameters of the layer but also on the properties of the layer. It is difficult to recognize the part played by these factors individually . Hence an experimental approach seems to be logical. The average crosspolarization factor for the model presented in this study has a typical value of 2. This would mean that $\frac{1}{4}$ of the power back scattered is polarized in the same plane as the incident plane. T. Hagfors (Hagfors 1965) reports that 3/4 of the backscattered energy is expected in the same plane as the incident plane. The value 2 for crosspolarization factor in our case is justified for two reasons:

(a) An unrealistic model whose mean slopes were 45^o. This was so chosen in order that $\langle D \rangle$ would be large and hence insure ease of measurement.

(b) The use of wood insured a larger degree of depolarization (Kerr, 1964). For wood $\epsilon \approx 3$ while Hagfor's

conclusions were based on $\epsilon \approx 2.6$. The value of 2 for $\langle D \rangle$ for our model seems to be an expected value.

The whole experiment will be repeated with identical factors except the layer will consist of styrofoam. The comparison of results is believed to give a marked dependence on the layer material. The results of this study will do much to aid in the prediction of lunar dielectric properties. This investigation has not previously been reported.

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FIG 6 MEASURING EQUIPMENTS

DETERMINATION OF OPTIMUM NOZZLE CONTOURS FOR THE EXPANSION OF DISSOCIATED GAS BY METHODS OF THE VARIATIONAL CALCULUS

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NASA NsG-692

The primary objectives of the task proposed at the beginning of this first year of activities have been accomplished.

Optimum nozzle contours have been obtained for a variety of reaction rates and initial conditions, and these contours have been compared with other arbitrary contours. In the sense of obtaining maximum specific impulse from the expansion of dissociated hydrogen in minimum nozzle length under balanced pressure conditions at the nozzle exit, optimum nozzle contours have been found. It has been shown that reaction rate is a scaling factor for these nozzles; for fixed initial and end conditions, the length of the optimum nozzle is inversely proportional to the reaction rate.

Optimum nozzle contours have also been obtaining for the expansion of dissociated hydrogen in the presence of a potent catalyst. The calculation of these contours required the development of a new reaction rate equation for the idealized dissociated gas in the presence of a catalyst.

The variational calculus problem which was solved in this investigation is of the Mayer type. Because the problem is of the Mayer type, one nozzle contour obtained as a solution of this problem can be considered to be the solution for one set of initial conditions and one reaction rate but for many different exit pressures, depending on where the nozzle is terminated. This is not entirely advantageous, because the nozzle is optimum in the sense of providing maximum specific impulse in a given length nozzle <u>only</u> when it is stipulated that the nozzle exit pressure is equal to the ambient atmospheric pressure.

Some of the results of this investigation, particularly those obtained for the case of dissociated hydrogen in the presence of a catalyst, have been reported in the Ph.D. dissertation of Richard R. Berns. This dissertation is entitled, "Optimum Nozzle Contours for a Dissociating Gas With a Catalyst" and was successfully defended in August, 1965. A comprehensive report covering all phases of this investigation is being prepared.