Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

4 cm 8 APR

CONFIDENTIAL

CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 7

Date - February 8, 1966

Period Covered - January 15, 1966
to
February 8, 1966

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES, WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

EXCLUDED FROM AUTOMATIC REGRADING; DOD DIR 5200.10 DOES NOT APPLY

25X1

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

 CONFIDENTIAL

Corning Glass Works manufactures several different materials which are being investigated for uses in rear projection screens. Some of these materials are new such as the hollow optical fibers while other approaches are based on more conventional glass products. Theoretical studies are being made to be able to specify, to the material groups in manufacturing, specific characteristics needed to give these materials the desired light scattering properties.

I. Theoretical Studies (Mie Scattering)

Some of the materials which are being considered for use in rear projection screens, namely the glass ceramics, Fotoform and Fotoceram, and the sintered glasses, have been determined to have particle sizes in the Mie scattering range. This means particles from 1000 Å to over 20 microns in diameter. The light scattering characteristics of these materials is given by the Mie theory of light scattering[1]. Although this theory is very general it finds primary application when the size of the particle is about equal to or larger than the wavelength of the incident radiation.

The important equations derived by Mie for both the parallel and normal components of polarized light incident on a spherical particle are

$$I_{\parallel}(\theta) = \left| \sum_{n=1}^{\infty} \left\{ A_n \frac{dP_n(x)}{dx} + B_n \left[x \frac{dP_n(x)}{dx} - (1-x^2) \frac{d^2P_n(x)}{dx^2} \right] \right\} \right|^2 \qquad (1)$$

$$I_{\perp}(\theta) = \left| \sum_{n=1}^{\infty} \left\{ A_n \left[x \frac{dP_n(x)}{dx} - (1-x^2) \frac{d^2P_n(x)}{dx^2} \right] + B_n \frac{dP_n(x)}{dx} \right\} \right|^2 \qquad (2)$$

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

where $P_n(x)$ = Legendre polynomials of order n, with $x = \cos\theta$, and

$$A_n = \left[\frac{(-1)^{n+1/2}(2n+1)}{n(n+1)}\right]\left[\frac{S_n(\alpha)\frac{dS_n(\beta)}{d\beta} - m^*S_n(\beta)\frac{dS_n(\alpha)}{d\alpha}}{\phi_n(\alpha)\frac{dS_n(\beta)}{d\beta} - m^*S_n(\beta)\frac{d\phi_n(\alpha)}{d\alpha}}\right] \qquad (3)$$

$$B_n = \left[\frac{(-1)^{n+3/2}(2n+1)}{n(n+1)}\right]\left[\frac{m^*S_n(\alpha)\frac{dS_n(\beta)}{d\beta} - S_n(\beta)\frac{dS_n(\alpha)}{d\alpha}}{m^*\phi_n(\alpha)\frac{dS_n(\beta)}{d\beta} - S_n(\beta)\frac{d\phi_n(\alpha)}{d\alpha}}\right], \qquad (4)$$

where $S_n(\alpha)$ = Riccati Bessel function = $\left(\frac{\pi\alpha}{2}\right)^{\frac{1}{2}} J_{n+1/2}(\alpha)$,
$\phi_n(\alpha)$ = Riccati Hankel function = $S_n(\alpha)+j(-1)^n\left(\frac{\pi\alpha}{2}\right)^{\frac{1}{2}} J_{-n-1/2}(\alpha)$,

and $J_{n+1/2}(\alpha)$ and $J_{-n-1/2}(\alpha)$ = Bessel functions of half integral order.

Thus, the only physical parameters are:

θ = angle between direction of propagation of scattered and the reverse direction of the incident light, as shown in Figure 1,

$$\alpha = \frac{\pi D}{\lambda}, \qquad (5)$$

and

$$= m^*\alpha = \alpha(m-jk), \qquad (6)$$

where D = diameter of spherical particle
λ = wavelength of incident radiation in surrounding media
m = index of refraction of particle relative to surrounding media
k = extinction coefficient of the particle material
$j = \sqrt{-1}$.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

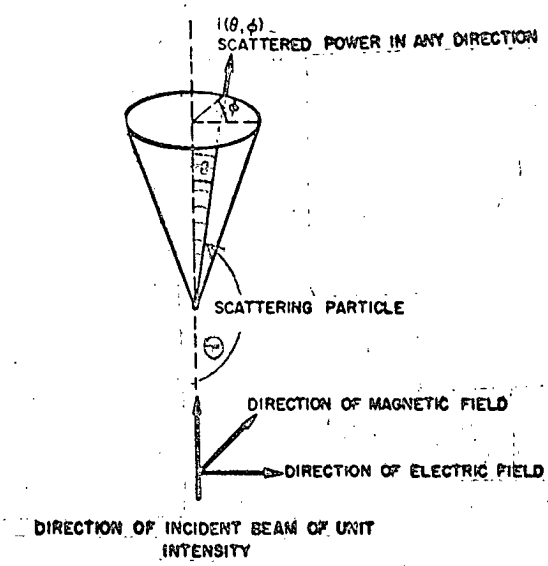


Figure 1

To solve any given problem requires tables of the real and imaginary parts of A_n and B_n and tables of the Legendre polynomials and their first derivatives[2-6]. These are then combined using a desk calculator or preferably a large digital computer into values of $I_{\parallel}(\theta)$ and $I_{\perp}(\theta)$ from which the angular distribution function $I(\theta)$ is obtained

$$I(\theta) = \frac{I_{\parallel}(\theta) + I_{\perp}(\theta)}{2\pi\alpha K} \tag{7}$$

where the scattering coefficient, i. e., the ratio of the scattering cross section to the geometrical cross section is,

$$K = \frac{2}{\alpha^2} \sum_{n=1}^{\infty} \frac{n^2(n+1)^2}{2n+1} \left(|A_n|^2 + |B_n|^2\right), \tag{8}$$

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

Hartel[7] suggested that Equations (1) and (2) could be simplified in form by the repeated use of recurrence relationships between the derivatives and products of Legendre polynomials. Recently Chu and Churchill succeeded in rearranging the Mie equations for the angular distribution of radiation scattered by nonabsorbing spheres in terms of a series of Legendre polynomials[8],

$$f(\theta) = \frac{1}{4\pi}\sum_{n=0}^{\infty} a_n(\alpha,\beta)P_n(\cos\theta) = \frac{1}{4\pi} + \frac{1}{4\pi}\sum_{n=1}^{\infty} a_n P_n(\cos\theta), \tag{9}$$

where the coefficients, a_n, are functions of α and but not of the angle and are given by

$$a_n = \frac{(2)(-1)^n}{\alpha^2 K(\alpha,\beta)}\sum_{j=1}^{\infty}\sum_{k=1}^{j}\left(\frac{2}{1+\delta_{jk}}\right)\left\{(2n+1)\left[\frac{j(j+1)+k(k+1)-n(n+1)}{2}\right]^2 w_{jkn}W_{jk} + v_{jkn}V_{jk}\right\}, \tag{10}$$

where

$$\delta_{jk} = \begin{cases} 0 & \text{for } j \neq k \\ 1 & \text{for } j = k \end{cases}, \tag{11}$$

$$W_{jk} = \mathrm{Re}(A_j)\mathrm{Re}(A_k) + \mathrm{Im}(A_j)\mathrm{Im}(A_k) + \mathrm{Re}(B_j)\mathrm{Re}(B_k) + \mathrm{Im}(B_j)\mathrm{Im}(B_k), \tag{12}$$

$$V_{jk} = \mathrm{Re}(A_j)\mathrm{Re}(B_k) + \mathrm{Im}(A_j)\mathrm{Im}(B_k) + \mathrm{Re}(B_j)\mathrm{Re}(A_k) + \mathrm{Im}(B_j)\mathrm{Im}(A_k) \tag{13}$$

$$w_{jkn} = 0, \quad \text{if } j + k - n \neq 2r, \quad r = 0,1,2\cdots k, \tag{14}$$

$$w_{jkn} = \frac{(\angle j+n-k)(\angle k+n-j)(\angle j+k-n)\left(\angle\frac{j+k+n}{2}\right)^2}{(\angle j+k+n+1)\left[\left(\angle\frac{j+n-k}{2}\right)\left(\angle\frac{k+n-j}{2}\right)\left(\angle\frac{j+k-n}{2}\right)\right]^2} \quad \text{if } j+k-n = 2r,\ r = 0,1,2\cdots k. \tag{15}$$

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

$$v_{jkn} = 0, \quad \text{if } j + k - n \neq 2r + 1, \; r = 0,1,2\cdots k, \tag{16}$$

and

$$v_{jkn} = \frac{(2n+1)(j+k-n)(j+n-k+1)(k+n-j+1)\angle j+n-k+1)(\angle k+n-j+1)(\angle j+k-n-1)\left(\angle\frac{j+k+n+1}{2}\right)^2}{4(\angle j+k+n+1)\left[\left(\angle\frac{j+n-k+1}{2}\right)\left(\angle\frac{k+n-j+1}{2}\right)\left(\angle\frac{j+k-n-1}{2}\right)\right]^2} \tag{17}$$

$$\text{if } j+k-n = 2r+1, \; r = 0,1,2\cdots k.$$

where Im = Imaginary Part,
Re = Real part,
$\angle$ = factorial.

The advantage of expressing the angular distribution of intensity in the form of Equation (9) rather than Equations (1) and (2) is obvious. The intensity at any angle for which the Legendre polynomials are available can be computed from a set of coefficients for a given α and m. In general, the number of significant terms in the series is about equal to 2α. The Legendre polynomials are available at one-degree intervals, and their behavior is better known and interpolation with respect to angle can be done more accurately than with $I_{\parallel}$ and $I_{\perp}$, $I(\theta)$ or the tabulated derivatives of the polynomials. Interpolation with respect to α and β is also easier with the coefficients, a_n than with $I_{\parallel}$ and $I_{\perp}$ or $I(\theta)$ and need be carried out but once for all angles.

Additional advantages of the representation of the angular distribution of scattered radiation by Equation (9) can be noted. The power scattered into any region, and in particular into the forward and backward hemisphere, can be obtained by simple analytical integration. By assuming

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

that a particle receives power only from adjacent particles having the same multiple-scattering distribution, Hartel developed the following equation in terms of the same coefficients, a_n, for the angular distribution of the k-th scattered radiation in a dense dispersion:

$$f_k(\theta) = \frac{1}{4\pi}\left[1 + \sum_{n=1}^{\infty} \frac{a_n{}^k}{(2n+1)^{k-1}} P_n(\cos\theta)\right] \qquad (18)$$

As complex as Equations (9-17) look, it is much simplier to evaluate (9) than Equations (1) and (2) because only values of A_n and P_n (cos θ) are required and are available[9-11]. However the tables of A_n and P_n (cos θ) are very limited while the tables of A_n and B_n are by far more complete, i. e., they are finer divisions of α and m and they cover a larger range of particle sizes. Therefore, we will use the Mie equations for single scattering investigation and to obtain data for which tables of angular coefficients do not exist; we will utilize the angular coefficients primarily for a study of multiple scattering.

Thus far a computer program to compute $I_{\parallel}(\theta)$, $I_{\perp}(\theta)$, $(I_{\parallel}(\theta)+I_{\perp}(\theta))/2$ and the percent polarization, has been written and tested. This has been used to compute the scattering function for m = 1.20, α = 1, 2, 3, 5, 8, and 10. Some of the output data is given in the data appendix. The negative sign in the percent polarization column indicates the light is polarized normal to the plane the angle θ is measured in. The computer program also computes the screen efficiency, EFF., which is the ratio of the intensity scattered into the forward hemisphere to the incident intensity I_o, EFF.

$$\mathrm{EFF}(m,\alpha) = \frac{\int_{\pi/2}^{\infty} I(m,\alpha,\theta)\, d\theta}{\int_{o}^{\pi} I(m,\alpha,\theta)\, d\theta} = \frac{1}{I_o} \int_{\pi/2}^{\pi} I(\theta)\, d\theta \qquad (19)$$

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

It is convenient to normalize the scattering function to reflect the ratio of the intensity of light scattered by a given particle, as a function of angle, to a perfect diffusor which radiates uniformly in all directions. This ratio is called Gain and is defined as

GAIN

$$\text{Gain } (m,\alpha,\theta) = \frac{I_o}{\frac{1}{\pi}\int_o^{\pi} I(m,\alpha,\theta)\, d\theta} \qquad (20)$$

These computations were also made and the gain characteristics of the light scattering functions are given as the second page of the computer print out. The angular gain characteristics for several different particle sizes are given in Figure 2.

Another parameter of interest is the relation between gain, at $\theta = 0$, and α, Figure 3. This is a simplier measure of the scattering function and easier to consider in relation to other parameters. The efficiency of different materials made up of particles of various sizes are given in Figure 4. It is surprising that these materials appear to be so efficient at such low values of α and gain, Figure 5. This indicates that if the light scattering properties of screens made from these particles are not significantly different from the single particle characteristics it may be possible to manufactur highly efficient screens which have broad viewing angles and are relatively insensitive to ambient light. Obviously a complete analysis and discussion of volume Mie scattering must be left to later when more data is available.

This type of analysis will be carried out next period. We also expect to be able to start a study of multiple scattering and determine the major characteristics of it, in terms of materials and viewing parameters.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

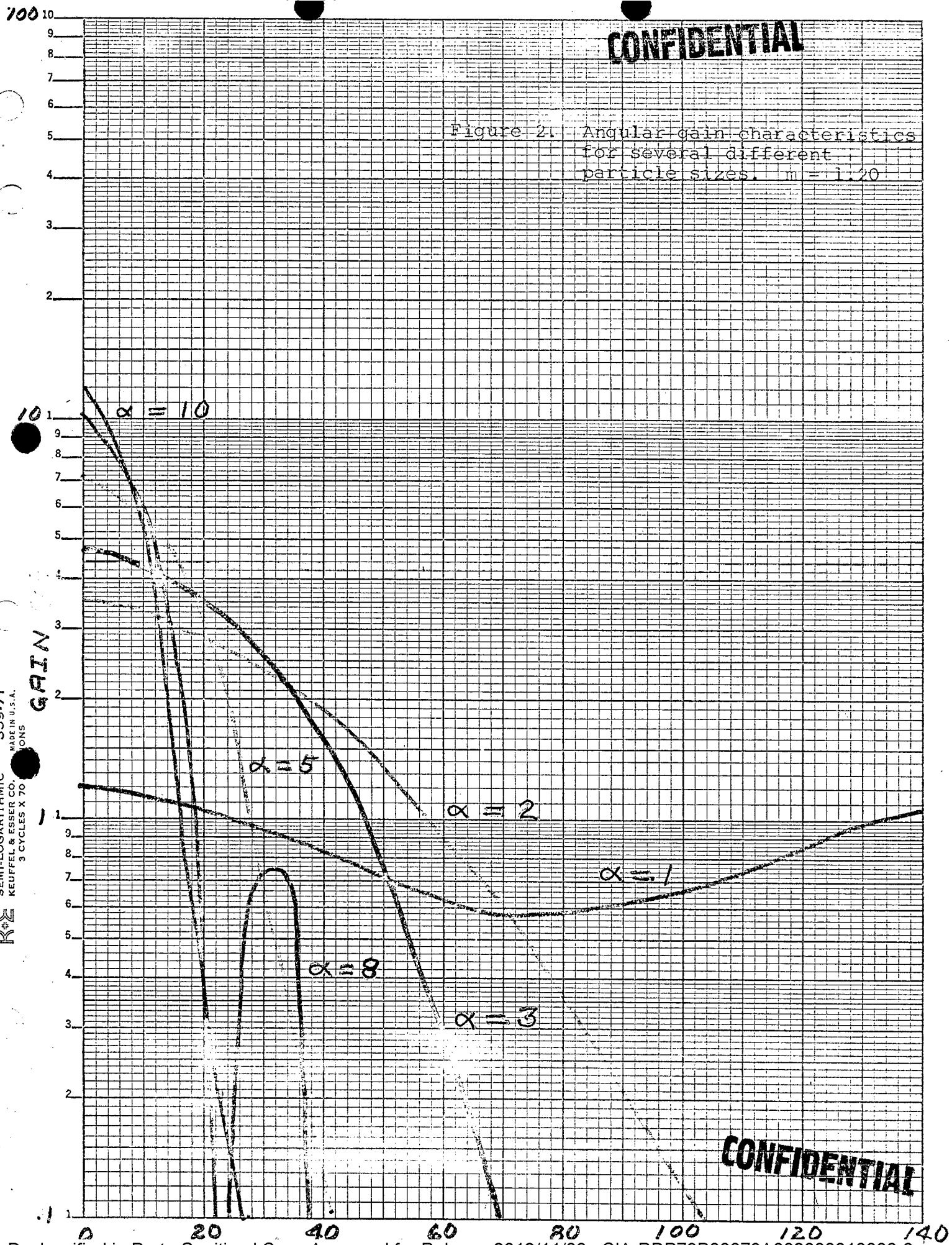


Figure 2. Angular gain characteristics for several different particle sizes. m = 1.20

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

K+E 10 X 10 TO THE ½ INCH 359-11G
KEUFFEL & ESSER CO. MADE IN U.S.A.

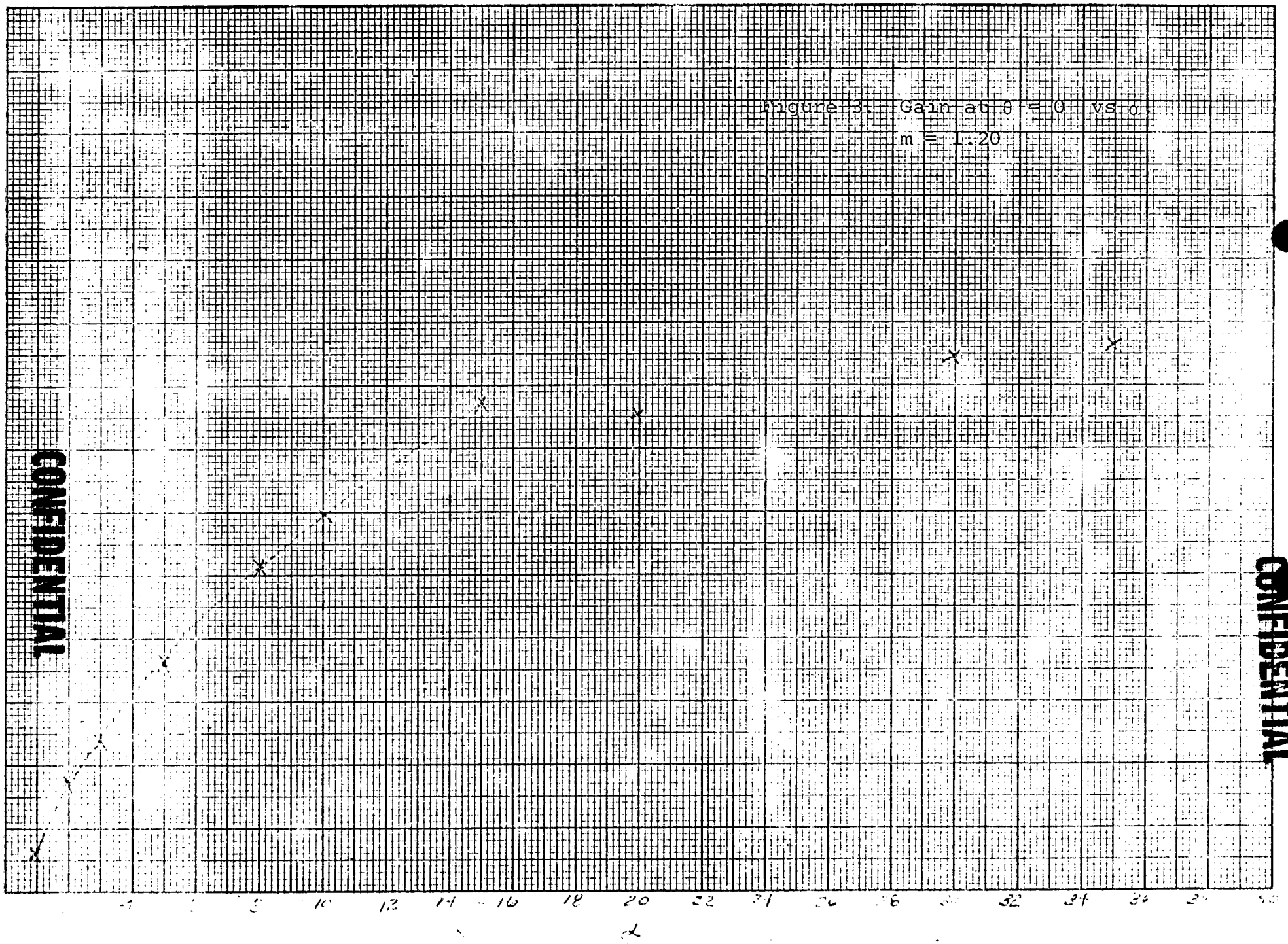


Figure 3. Gain at $\theta = 0$ vs α.
$m = 1.20$

CONFIDENTIAL

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

K+E 10 X 10 TO THE ½ INCH KEUFFEL & ESSER CO. 359-11G MADE IN U.S.A.

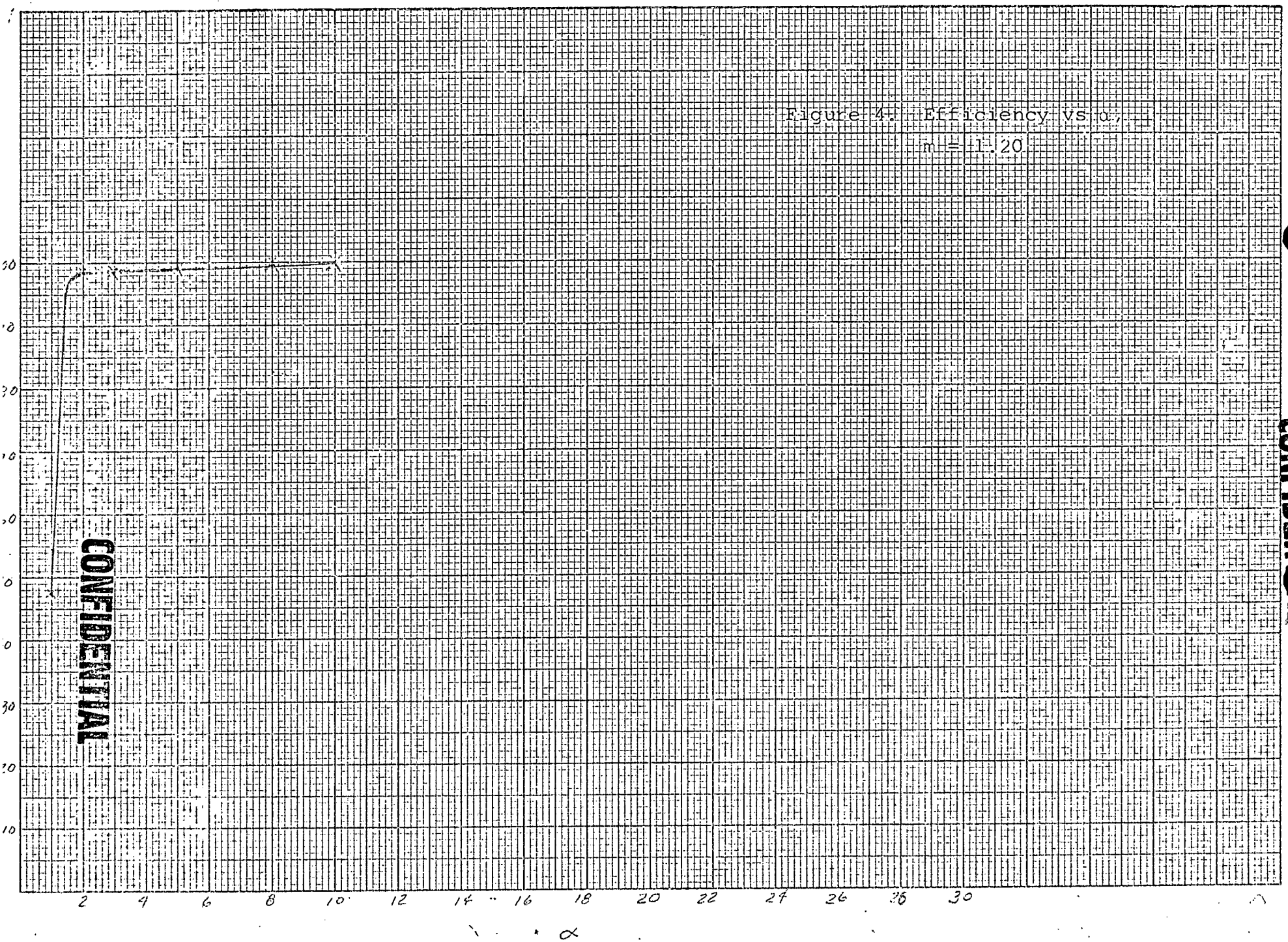


Figure 4. Efficiency vs α, m = 1.20

CONFIDENTIAL

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

K+E 10 X 10 TO THE ½ INCH 359-11
KEUFFEL & ESSER CO. MADE IN U. S. A.

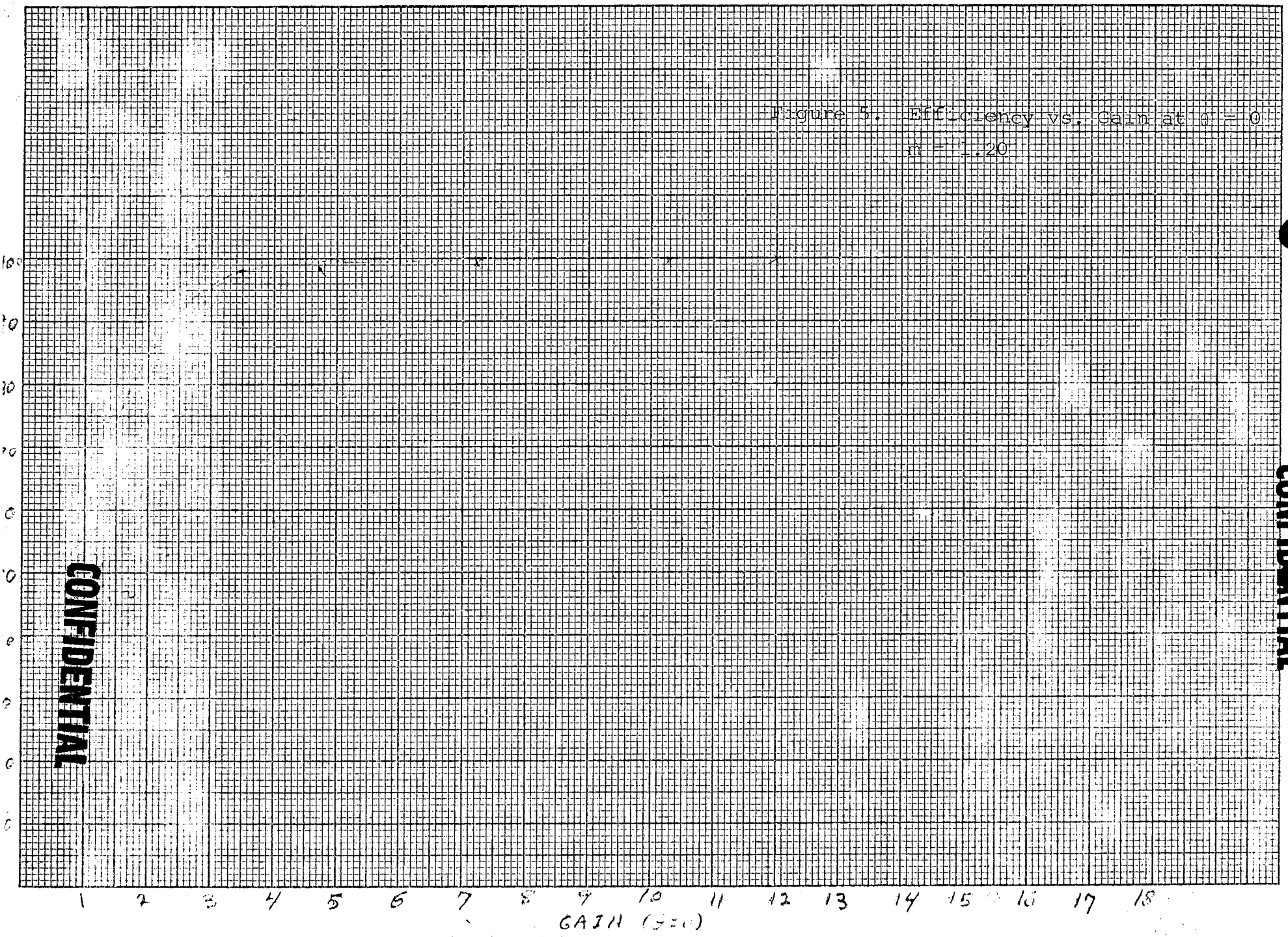


Figure 5. Efficiency vs. Gain at θ = 0
m = ±.20

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

In the final report covering the second phase of our program devoted to theoretical studies, Mie scattering will be outlined in greater detail. We will also include a complete discussion of the results obtained using the computer programs. Throughout this study emphasis will be on applying these results and generating requirements for samples of various materials from our manufacturing facilities.

II. CGW Materials

A. Hollow Fibers

We have begun to experimentally investigate the plating of hollow fibers. This work is being done in conjunction with the Microcircuits Group, in the Raleigh facility, who have much of the necessary technology.

Samples of individual fibers, Figure 6a, 6b, as well as a small array, Figure 6c, have been supplied to this group for preliminary investigations. More fibers and fiber arrays will be requested next period to continue this work. Results of the feasibility of placing highly reflective coatings in small diameter tubes are expected by the end of the quarter.

In addition to the vapor plating techniques already described[12] others will be tried. One involves the floating of millimicron sized metallic particles into the tubes using ether or a similiar inert reagent. By heating the tubes in a RF field the carrier liquid will evaporate and the metal vapor will "condense" on the walls.

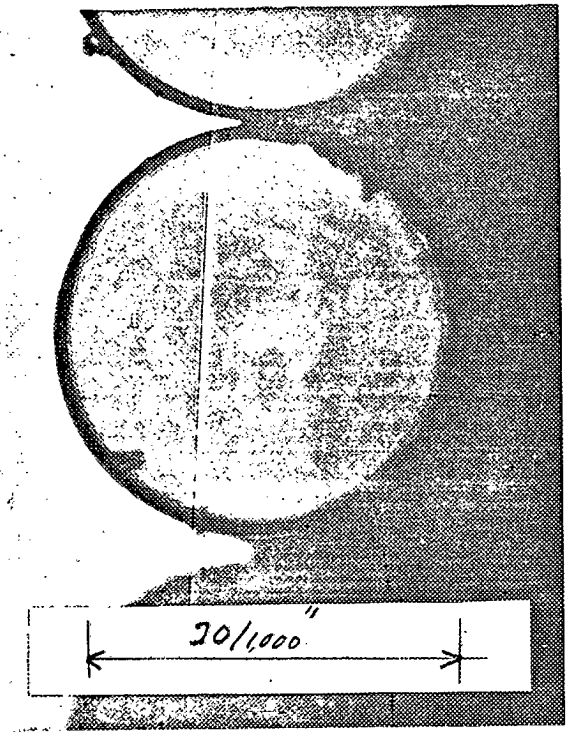
B. Porous Vycor

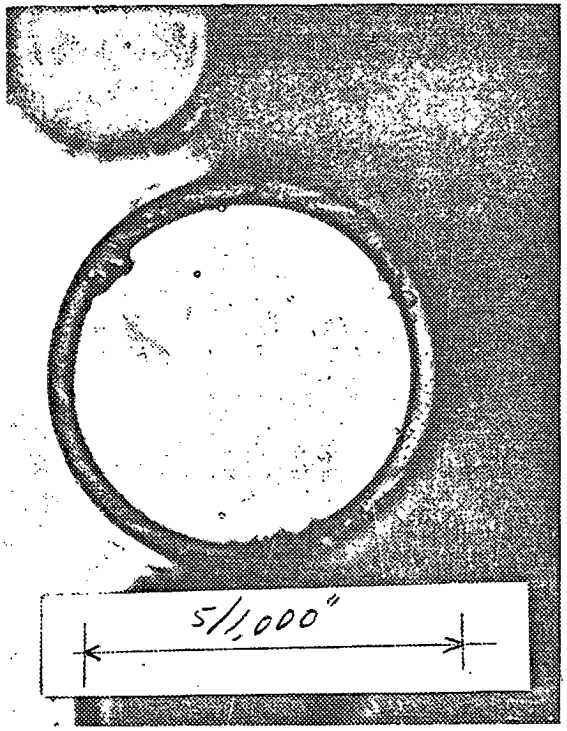
Photomicrographs of the samples delivered sometime ago were made at our facility in Corning, New York.

CONFIDENTIAL
Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL





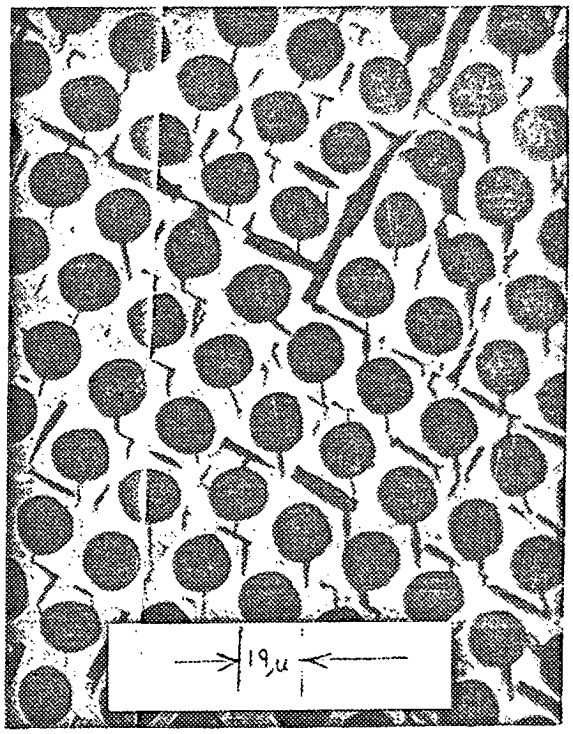


Figure 6. Photomicrographs of two samples of hollow fibers and one fiber array to be used in preliminary plating studies.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

Figure 7 shows a top view, at a magnification of 625x. The larger pores produced by leaching the glass are clearly visible, as they are in cross sectional views in Figures 7b at 310x and 7c at 625x. Most of the particles responsible for the scattering are so small, about 50 to 100 Angstroms in diameter that they are not visible. We are waiting further photomicrographs taken through the electron microscope which may show particles near this size range.

Full interpretation of these must wait for the other pictures as well as a detailed study of the ones just recently obtained.

C. Other Materials

Next period we will obtain samples of the following materials

1. Sintered Glass
2. Fotoform and Fotoceram
3. Glass Ceramics

These will be investigated and used in conjunction with the theoretical work to formulate specifications for specific materials to the manufacturing groups in Corning, New York.

III. Instrumentation

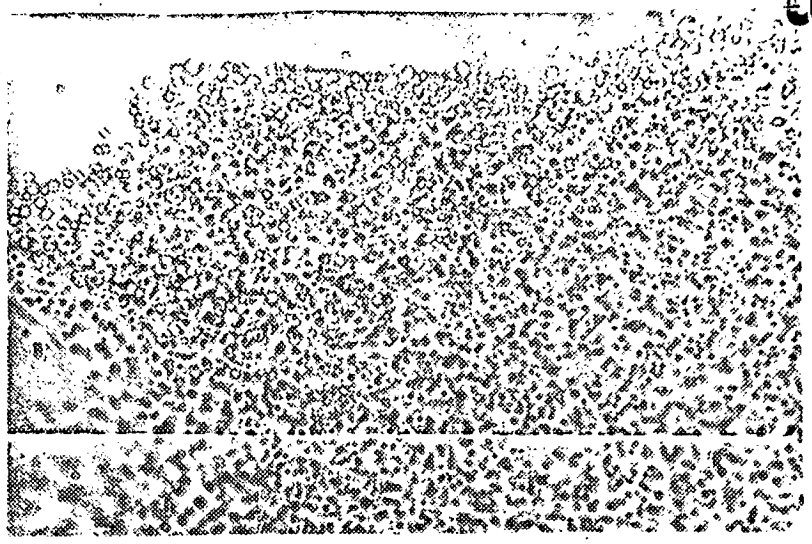
A. Goniophotometer

Construction of this instrument is on schedule and due to be completed by March 1. All of the electronics for data processing and display are being assembled, along with power supples and controls, into a control console. Subsequent testing, alignment, and calibration are scheduled to be complete by April 1.

CONFIDENTIAL
Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL



CONFIDENTIAL

Figure 7. Photomicrographs of porous Vycor brand glass, a, 625x; b, 310x; c, 625x.

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

B. Modulation Transfer Function Analyzer

Design has started on the instrument to make the sine-wave target.[12] Several different types of light modulating techniques have been investigated for this application. One optical system is shown schematically in Figure 8.

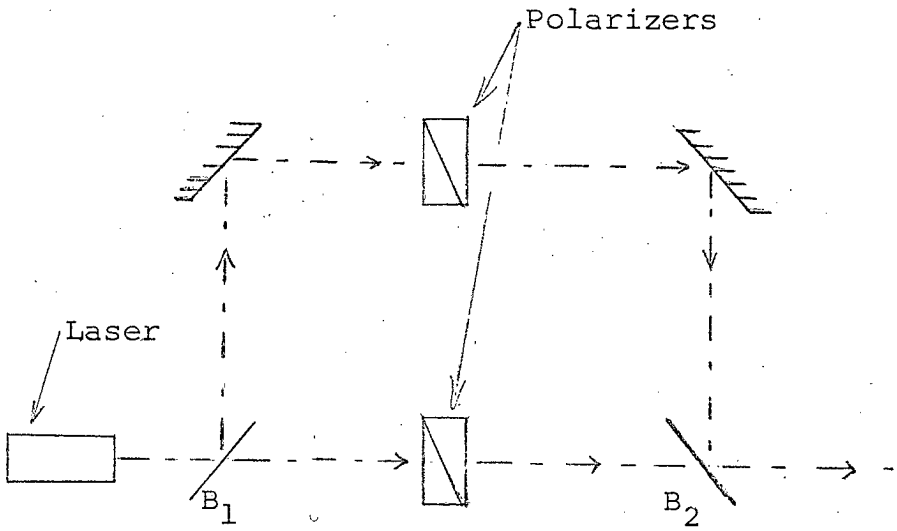


Figure 8

Light from the laser, which is polarized, is divided into two beam by the first beamsplitter. B_1 Each passes through a polarizing filter which attenuates that particular beam depending on the orientation of its axis with the direction of polarization of the laser beam, i. e.,

$$I(\theta) = K\, I_o \cos\theta$$

where $I(\theta)$ is the intensity through the filter depending on the angle, θ, between the direction of polarization of the light and the axis of the filter; K is a correction for the neutral density of the filter regardless of polarization.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

Thus to sinusoidally modulate a beam only requires the polarizing filter be rotated at a constant angular speed ω. The frequency of the modulated light ω_m will be just 2ω.

The other beam is used to add a constant light level to this modulated signal thereby setting the operating point on the linear portion of the characteristic curve of the film.

The remaining optics is used to illuminate a slit and transfer this image onto the film. The sine-wave transmission pattern on the strip of film is accomplished by moving it at constant speed across the variable intensity slit image. The construction of this device will start next period.

The components for the MTF analyzer and initial machine shop work will also begin then.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

References

1. Gustav Mie, "Beitrage zur Optik truber Medien," Ann. Physik, 25, 377-445 (1908).

2. R. O. Gumprecht and C. M. Sliepcevich, Tables of Light-Scattering Functions for Spherical Particles, University of Michigan Press, Engineering Research Institute Publications, 1951.

3. R. O. Gumprecht and C. M. Sliepcevich, Tables of Riccati Bessel Functions for Large Arguments and Orders, University of Michigan Press, Engineering Research Institute Publications, 1951.

4. R. O. Gumprecht and C. M. Sliepcevich, Tables of Functions of First and Second Partial Derivatives of Legendre Polynomials, University of Michigan Press, Engineering Research Institute Publications, 1951.

5. G. C. Clark and S. W. Churchill, Tables of Legendre Polynomials, University of Michigan Press, Engineering Research Institute Publications, 1957.

6. R. H. Boll, R. O. Gumprecht, G. C. Clark, and S. W. Churchill, Light-Scattering Functions. Relative Indices of Less Than Unity, and Infinity, University of Michigan Press, Engineering Research Institute Publications, 1957 (in press).

7. W. Hartel, "Zur Theorie der Lichtstreuung durch trube Schichten, besonders Trubglaser," Das Licht, 40, 141-43, 165, 190-91, 214-15, 232-34 (1940).

8. C. M. Chu and S. W. Churchill, "Representation of the Angular Distribution of Radiation Scattered by a Spherical Particle," J. Opt. Soc. Am., 45, 958-62 (1955).

9. G. C. Clark, C. M. Chu, and S. W. Churchill, "Angular Distribution Coefficients for Radiation Scattered by a Spherical Particle," J. Opt. Soc. Am., 47, 81-84 (1957).

10. C. M. Chu, G. C. Clark, and S. W. Churchill, Tables of Angular Distribution Coefficients for Light-Scattering by Spheres, University of Michigan, Engineering Research Institute Publications: Tables; Ann Arbor, Michigan, University of Michigan Press, 1957.

11. G. C. Clark, and S. W. Churchill, "Legendre Polynomials," The University of Michigan, Engineering Research Institute Publications: Tables; Ann Arbor, Michigan, University of Michigan Press, 1957.

12. R. B. Herrick, "Improved Screen for Rear Projection Viewers," Technical Report #6, January 17, 1966.

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

DATA APPENDIX

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

SCATTERING FUNCTION FOR A = 1, M = 1.20

	ANGLE DEGREES	INTENSITY 1 PARALLEL	INTENSITY 2 NORMAL	INTENSITY 3 UNPOLARIZED	PERCENT POLARIZATION
1	.	.132709E-01	.132709E-01	.132709E-01	.000
2	5.	.132658E-01	.132080E-01	.132369E-01	.218
3	10.	.132508E-01	.130202E-01	.131355E-01	.877
4	15.	.132261E-01	.127094E-01	.129677E-01	1.992
5	20.	.131923E-01	.122792E-01	.127357E-01	3.584
6	25.	.131501E-01	.117347E-01	.124424E-01	5.687
7	30.	.131004E-01	.110831E-01	.120917E-01	8.341
8	35.	.130442E-01	.103332E-01	.116887E-01	11.596
9	40.	.129827E-01	.949648E-02	.112396E-01	15.508
10	45.	.129173E-01	.858648E-02	.107518E-01	20.139
11	50.	.128490E-01	.761961E-02	.102343E-01	25.548
12	55.	.127794E-01	.661491E-02	.969717E-02	31.785
13	60.	.127096E-01	.559412E-02	.915189E-02	38.874
14	65.	.126410E-01	.458145E-02	.861124E-02	46.796
15	70.	.125746E-01	.360328E-02	.808899E-02	55.454
16	75.	.125117E-01	.268756E-02	.759964E-02	64.635
17	80.	.124530E-01	.186311E-02	.715808E-02	73.971
18	85.	.123994E-01	.115857E-02	.677902E-02	82.909
19	90.	.123515E-01	.601292E-03	.647643E-02	90.715
20	95.	.123098E-01	.215933E-03	.626287E-02	96.552
21	100.	.122744E-01	.231088E-04	.614878E-02	99.624
22	105.	.122455E-01	.379088E-04	.614173E-02	99.382
23	110.	.122230E-01	.268556E-03	.624578E-02	95.700
24	115.	.122065E-01	.715245E-03	.646090E-02	88.929
25	120.	.121957E-01	.136927E-02	.678251E-02	79.811
26	125.	.121900E-01	.221261E-02	.720133E-02	69.274
27	130.	.121887E-01	.321794E-02	.770335E-02	58.226
28	135.	.121911E-01	.434923E-02	.827018E-02	47.410
29	140.	.121963E-01	.556296E-02	.887964E-02	37.351
30	145.	.122035E-01	.680980E-02	.950665E-02	28.368
31	150.	.122118E-01	.803687E-02	.101243E-01	20.618
32	155.	.122204E-01	.919027E-02	.107053E-01	14.152
33	160.	.122286E-01	.102179E-01	.112232E-01	8.957
34	165.	.122357E-01	.110724E-01	.116540E-01	4.990
35	170.	.122411E-01	.117136E-01	.119774E-01	2.202
36	175.	.122446E-01	.121111E-01	.121778E-01	.548
37	180.	.122458E-01	.122458E-01	.122458E-01	.000

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

SCATTERING FUNCTION FOR A = 1, M = 1.20

EFF. 1 = .4869 EFF. 2 = .3952 EFF. 3 = .4554

	ANGLE DEGREES	GAIN PARALLEL	GAIN NORMAL	GAIN UNPOLARIZED	PERCENT POLARIZATION
1	.0	1.05	2.01	1.38	.000
2	5.	1.05	2.00	1.38	.218
3	10.	1.05	1.98	1.37	.877
4	15.	1.05	1.93	1.35	1.992
5	20.	1.05	1.86	1.33	3.584
6	25.	1.04	1.78	1.30	5.687
7	30.	1.04	1.68	1.26	8.341
8	35.	1.03	1.57	1.22	11.596
9	40.	1.03	1.44	1.17	15.508
10	45.	1.02	1.30	1.12	20.139
11	50.	1.02	1.15	1.07	25.548
12	55.	1.01	1.00	1.01	31.785
13	60.	1.01	.85	.95	38.874
14	65.	1.00	.69	.90	46.796
15	70.	1.00	.54	.84	55.454
16	75.	.99	.40	.79	64.635
17	80.	.99	.28	.74	73.971
18	85.	.98	.17	.70	82.909
19	90.	.98	.09	.67	90.715
20	95.	.98	.03	.65	96.552
21	100.	.97	.00	.64	99.624
22	105.	.97	.00	.64	99.382
23	110.	.97	.04	.65	95.700
24	115.	.97	.10	.67	88.929
25	120.	.97	.20	.70	79.811
26	125.	.97	.33	.75	69.274
27	130.	.97	.48	.80	58.226
28	135.	.97	.66	.86	47.410
29	140.	.97	.84	.92	37.351
30	145.	.97	1.03	.99	28.368
31	150.	.97	1.22	1.05	20.618
32	155.	.97	1.39	1.11	14.152
33	160.	.97	1.55	1.17	8.957
34	165.	.97	1.68	1.21	4.990
35	170.	.97	1.78	1.25	2.202
36	175.	.97	1.84	1.27	.548
37	180.	.97	1.86	1.28	.000

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

SCATTERING FUNCTION FOR A = 2, M = 1.20

	ANGLE DEGREES	INTENSITY 1 PARALLEL	INTENSITY 2 NORMAL	INTENSITY 3 UNPOLARIZED	PERCENT POLARIZATION
1	.	.341572E-02	.341572E-02	.341572E-02	.000
2	5.	.338308E-02	.334681E-02	.336494E-02	.538
3	10.	.329817E-02	.314955E-02	.322386E-02	2.304
4	15.	.320079E-02	.285099E-02	.302589E-02	5.780
5	20.	.315946E-02	.249145E-02	.282546E-02	11.821
6	25.	.327471E-02	.211789E-02	.269630E-02	21.452
7	30.	.368353E-02	.177544E-02	.272949E-02	34.953
8	35.	.456470E-02	.149828E-02	.303149E-02	50.575
9	40.	.614487E-02	.130123E-02	.372305E-02	65.049
10	45.	.870494E-02	.117421E-02	.493957E-02	76.228
11	50.	.125861E-01	.108204E-02	.683408E-02	84.166
12	55.	.181950E-01	.972366E-03	.958369E-02	89.853
13	60.	.260067E-01	.794572E-03	.134006E-01	94.070
14	65.	.365651E-01	.531987E-03	.185485E-01	97.131
15	70.	.504785E-01	.248478E-03	.253634E-01	99.020
16	75.	.684094E-01	.148497E-03	.342789E-01	99.566
17	80.	.910581E-01	.646716E-03	.458524E-01	98.589
18	85.	.119137E 00	.243982E-02	.607884E-01	95.986
19	90.	.153336E 00	.656921E-02	.799527E-01	91.783
20	95.	.194280E 00	.144596E-01	.104370E 00	86.145
21	100.	.242477E 00	.279172E-01	.135197E 00	79.350
22	105.	.298256E 00	.490701E-01	.173663E 00	71.744
23	110.	.361713E 00	.802385E-01	.220976E 00	63.689
24	115.	.432643E 00	.123729E 00	.278186E 00	55.522
25	120.	.510489E 00	.181561E 00	.346025E 00	47.529
26	125.	.594305E 00	.255140E 00	.424722E 00	39.927
27	130.	.682727E 00	.344919E 00	.513823E 00	32.871
28	135.	.773987E 00	.450092E 00	.612040E 00	26.460
29	140.	.865939E 00	.568371E 00	.717155E 00	20.746
30	145.	.956130E 00	.695904E 00	.826017E 00	15.751
31	150.	.104189E 01	.827367E 00	.934632E 00	11.476
32	155.	.112049E 01	.956261E 00	.103837E 01	7.907
33	160.	.118921E 01	.107538E 01	.113230E 01	5.026
34	165.	.124559E 01	.117747E 01	.121153E 01	2.811
35	170.	.128751E 01	.125586E 01	.127168E 01	1.244
36	175.	.131334E 01	.130521E 01	.130928E 01	.310
37	180.	.132207E 01	.132207E 01	.132207E 01	.000

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

SCATTERING FUNCTION FOR A = 2, M = 1.20

EFF. 1 = .9624 EFF. 2 = .9968 EFF. 3 = .9766

	ANGLE DEGREES	GAIN PARALLEL	GAIN NORMAL	GAIN UNPOLARIZED	PERCENT POLARIZATION
1	.	.00	.01	.01	.000
2	5.	.00	.01	.00	.538
3	10.	.00	.01	.00	2.304
4	15.	.00	.01	.00	5.780
5	20.	.00	.00	.00	11.821
6	25.	.00	.00	.00	21.452
7	30.	.00	.00	.00	34.953
8	35.	.01	.00	.00	50.575
9	40.	.01	.00	.01	65.049
10	45.	.02	.00	.01	76.228
11	50.	.03	.00	.02	84.166
12	55.	.04	.00	.02	89.853
13	60.	.06	.00	.03	94.070
14	65.	.09	.00	.05	97.131
15	70.	.12	.00	.07	99.020
16	75.	.17	.00	.10	99.566
17	80.	.22	.00	.13	98.589
18	85.	.29	.00	.17	95.986
19	90.	.38	.02	.23	91.783
20	95.	.48	.05	.30	86.145
21	100.	.60	.09	.39	79.350
22	105.	.74	.17	.51	71.744
23	110.	.90	.28	.65	63.689
24	115.	1.08	.44	.81	55.522
25	120.	1.27	.64	1.04	47.529
26	125.	1.48	.91	1.24	39.927
27	130.	1.70	1.23	1.51	32.871
28	135.	1.93	1.60	1.80	26.460
29	140.	2.16	2.02	2.10	20.746
30	145.	2.39	2.48	2.43	15.751
31	150.	2.60	2.95	2.74	11.476
32	155.	2.80	3.41	3.05	7.907
33	160.	2.97	3.83	3.33	5.026
34	165.	3.11	4.20	3.56	2.811
35	170.	3.22	4.48	3.74	1.244
36	175.	3.28	4.65	3.85	.310
37	180.	3.30	4.71	3.88	.000

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

CONFIDENTIAL

SCATTERING FUNCTION FOR A = 3, M = 1.20

	ANGLE DEGREES	INTENSITY 1 PARALLEL	INTENSITY 2 NORMAL	INTENSITY 3 UNPOLARIZED	PERCENT POLARIZATION
1	0.	.101300E 00	.101300E 00	.101300E 00	.000
2	5.	.101794E 00	.100485E 00	.101139E 00	.647
3	10.	.103364E 00	.980814E-01	.100722E 00	2.622
4	15.	.106250E 00	.941991E-01	.100224E 00	6.012
5	20.	.110791E 00	.890028E-01	.998971E-01	10.905
6	25.	.117331E 00	.826869E-01	.100009E 00	17.320
7	30.	.126099E 00	.754605E-01	.100780E 00	25.123
8	35.	.137075E 00	.675487E-01	.102312E 00	33.977
9	40.	.149846E 00	.592160E-01	.104531E 00	43.350
10	45.	.163488E 00	.508082E-01	.107148E 00	52.581
11	50.	.176493E 00	.427980E-01	.109645E 00	60.967
12	55.	.186786E 00	.358062E-01	.111296E 00	67.827
13	60.	.191863E 00	.305709E-01	.111217E 00	72.512
14	65.	.189116E 00	.278383E-01	.108477E 00	74.337
15	70.	.176361E 00	.281794E-01	.102270E 00	72.446
16	75.	.152610E 00	.317824E-01	.921963E-01	65.527
17	80.	.119073E 00	.383321E-01	.787029E-01	51.295
18	85.	.803405E-01	.471549E-01	.637477E-01	26.028
19	90.	.456116E-01	.578467E-01	.517292E-01	-11.826
20	95.	.298057E-01	.715813E-01	.506935E-01	-41.204
21	100.	.542733E-01	.931781E-01	.737257E-01	-26.384
22	105.	.146814E 00	.133781E 00	.140298E 00	4.644
23	110.	.340693E 00	.213668E 00	.277181E 00	22.913
24	115.	.672400E 00	.364350E 00	.518375E 00	29.713
25	120.	.117806E 01	.628849E 00	.903456E 00	30.395
26	125.	.188863E 01	.105904E 01	.147383E 01	28.143
27	130.	.282424E 01	.170927E 01	.226676E 01	24.593
28	135.	.398846E 01	.262625E 01	.330735E 01	20.593
29	140.	.536335E 01	.383637E 01	.459986E 01	16.598
30	145.	.690638E 01	.533282E 01	.611960E 01	12.856
31	150.	.855019E 01	.706556E 01	.780788E 01	9.507
32	155.	.102058E 02	.893774E 01	.957178E 01	6.624
33	160.	.117693E 02	.108108E 02	.112900E 02	4.245
34	165.	.131320E 02	.125192E 02	.128256E 02	2.388
35	170.	.141913E 02	.138932E 02	.140423E 02	1.061
36	175.	.148637E 02	.147851E 02	.148244E 02	.265
37	180.	.150943E 02	.150943E 02	.150943E 02	.000

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6

SCATTERING FUNCTION FOR A = 3, M = 1.20

EFF. 1 = .9768 EFF. 2 = .9883 EFF. 3 = .9821

	ANGLE DEGREES	GAIN PARALLEL	GAIN NORMAL	GAIN UNPOLARIZED	PERCENT POLARIZATION
1	.	.03	.03	.03	.000
2	5.	.03	.03	.03	.647
3	10.	.03	.03	.03	2.622
4	15.	.03	.03	.03	6.012
5	20.	.03	.03	.03	10.905
6	25.	.03	.03	.03	17.320
7	30.	.04	.02	.03	25.123
8	35.	.04	.02	.03	33.977
9	40.	.05	.02	.03	43.350
10	45.	.05	.01	.03	52.581
11	50.	.05	.01	.03	60.967
12	55.	.06	.01	.04	67.827
13	60.	.06	.01	.04	72.512
14	65.	.06	.01	.03	74.337
15	70.	.05	.01	.03	72.446
16	75.	.05	.01	.03	65.527
17	80.	.04	.01	.02	51.295
18	85.	.02	.01	.02	26.028
19	90.	.01	.02	.01	-11.826
20	95.	.01	.02	.01	-41.204
21	100.	.01	.03	.02	-26.384
22	105.	.04	.05	.05	4.644
23	110.	.11	.08	.10	22.913
24	115.	.22	.14	.18	29.713
25	120.	.39	.24	.32	30.395
26	125.	.64	.41	.53	28.143
27	130.	.95	.66	.82	24.593
28	135.	1.35	1.01	1.19	20.593
29	140.	1.81	1.48	1.66	16.598
30	145.	2.34	2.07	2.21	12.856
31	150.	2.90	2.74	2.82	9.507
32	155.	3.46	3.46	3.46	6.624
33	160.	3.99	4.19	4.08	4.245
34	165.	4.45	4.85	4.64	2.388
35	170.	4.81	5.39	5.08	1.061
36	175.	5.04	5.73	5.36	.265
37	180.	5.11	5.85	5.46	.000

CONFIDENTIAL

CONFIDENTIAL

Declassified in Part - Sanitized Copy Approved for Release 2012/11/08 : CIA-RDP79B00873A002000010006-6