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CORNING GLASS WORKS
CORNING
CORNING, NEW YORK

RESEARCH AND DEVELOPMENT LABORATORY

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Technical Report No. 12

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ABSTRACT:

This report summarizes the light scattering properties of some Corning Glass Works' materials along with those of some commercial rear projection screens. These data are discussed with reference to our theoretical studies of light scattering.

We have found good agreement between the experimental and theoretical data on the fraction of incident energy scattered into the forward hemisphere by volume scattering materials as a function of axial gain. The predicted wavelength dependence of the scattering cross-section has been observed and possesses some problems, which are discussed.

Three of the samples of Corning Glass Works' materials that were measured meet the necessary optical requirements for application in rear projection screens.

KEY WORDS: Light Scattering, Rear Projection Screens, Glass-Ceramics

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[redacted] 25X1

CORNING GLASS WORKS

ELECTRO-OPTICS LABORATORY

RALEIGH, NORTH CAROLINA

IMPROVED SCREEN FOR REAR PROJECTION VIEWERS

Technical Report No. - 12

Date - August 24, 1966

Period Covered - July 11, 1966
to
August 24, 1966

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This report summarizes the light scattering properties of some Corning Glass Works' materials along with those of some commercial rear projection screens. These data are discussed with reference to our theoretical studies of light scattering.

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Three of the samples of Corning Glass Works' materials that were measured meet the necessary optical requirements for application in rear projection screens.

A. Materials

This report summarizes the light scattering properties of some Corning Glass Works' materials together with those of some commercial rear projection screens. Although we do not as yet have the physical data on particle size and density of the Corning materials measured, we can make some inferences as to approximate particle size, and correlate some of the experimental data with theoretical predictions.

Light scattering data have been obtained on 34 different samples of Corning Glass Works' materials and on 23 commercial rear projection screen materials. These data include the angular gain function, axial gain, diffuse transmittance, specular transmittance, spectral properties of the specularly transmitted component, and the fraction of power within a viewing angle of $\pm 45^{\circ}$.

The angular gain function, Gain (θ), is defined as the ratio of the brightness of any material to that of an isotropic scatterer as a function of the angle (θ), assuming the same amount of incident energy

$$\text{Gain}(\theta) = \frac{4\pi I(\theta)}{I_o}, \qquad (1)$$

where $I(\theta)$ is the scattered intensity as a function of the angle θ. One may define the gain function as the ratio of the intensity at any angle to the average intensity,

$$\text{Gain}'(\theta) = \frac{4\pi\ I(\theta)}{\int_o^{2\pi}\int_o^{\pi} I(\theta)\cdot \sin\theta\ d\theta\ d\phi}. \qquad (2)$$

However, the one difference between these two expressions is that Equation (2) assumes no absorption, and for rear projection screens this is generally not true. In fact, the difference between Equations (1) and (2) provides a measure of the fraction of the power absorbed, A,

$$A = 1 - \frac{1}{I_o} \int_o^{2\pi} \int_o^{\pi} I(\theta) \cdot \sin\theta \, d\theta \, d\phi \quad . \tag{3}$$

By definition the diffuse transmittance, T_d, is the ratio of the sum of the scattered light, I_s, and the specularly transmitted light I_{spec}, to the incident light, I_o,

$$T_d = \frac{I_s + I_{spec}}{I_o} = \frac{\int_o^{2\pi} \int_o^{\pi/2} I(\theta) \cdot \sin\theta \, d\theta \, d\phi}{I_o} + \frac{I_{spec}}{I_o} \; . \tag{4}$$

The specular component represents the fraction of light directly transmitted through a material, i.e., not scattered, and where $I(\theta)$ denotes only the intensity of the scattered light. For convenience we shall denote I_s/I_o by T_s and the specular transmittance by T_{spec}. Thus, by measuring T_s in addition to $I(\theta)$, the angular gain function can be obtained,

$$\text{Gain } (\theta) = \frac{4\pi \; T_s \; I(\theta)}{\int_o^{2\pi} \int_o^{\pi/2} I(\theta) \cdot \sin\theta \, d\theta \, d\phi} \quad . \tag{5}$$

This can be simplified somewhat by performing the integration over ϕ, which gives

$$\text{Gain } (\theta) = \frac{2 \; T_s \; I(\theta)}{\int_o^{\pi/2} I(\theta) \cdot \sin\theta \, d\theta} \quad . \tag{6}$$

Besides T_s, it is important to know the fraction of power scattered inside ±45° since the primary viewing angles lie within ±45° of the optical axis. The fraction of the power inside 45°, T_{45}, is

$$T_{45} = \frac{2\pi \int_o^{\pi/4} I(\theta) \cdot \sin\theta \, d\theta}{I_o} \tag{7}$$

which after reduction becomes

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$$T_{45} = \frac{T_d \int_0^{\pi/4} I(\theta) \cdot \sin\theta \, d\theta}{\int_0^{\pi/2} I(\theta) \cdot \sin\theta \, d\theta} . \qquad (8)$$

The function $I(\theta)$ is measured directly with our goniophotometer, and the diffuse transmittance is measured by a scheme shown in Figure 1.

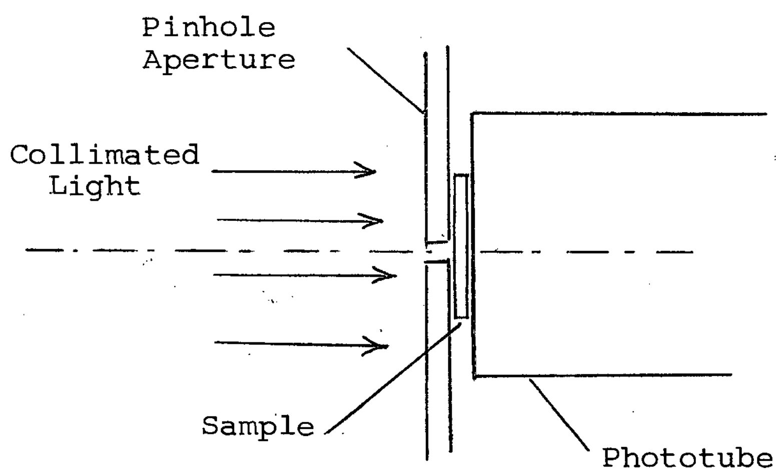


Figure 1. The Measurement of T_s

Collimated light passing through the pinhole is scattered by the sample, which is physically so close to the phototube that all of the light scattered through the material is detected along with the specular component. All of the backscattered light is absorbed by a dull black coating on the pinhole aperture. Thus, the ratio of the phototube signals, with and without the sample, gives the diffuse transmittance. To obtain only the scattered component T_s, we must measure T_{spec} and subtract this from T_d. To measure T_{spec} we use the arrangement shown in Figure 2.

The relatively large distance between the sample and the succeeding lens ensures that only the specularly transmitted component is intercepted by the lens and focused through the

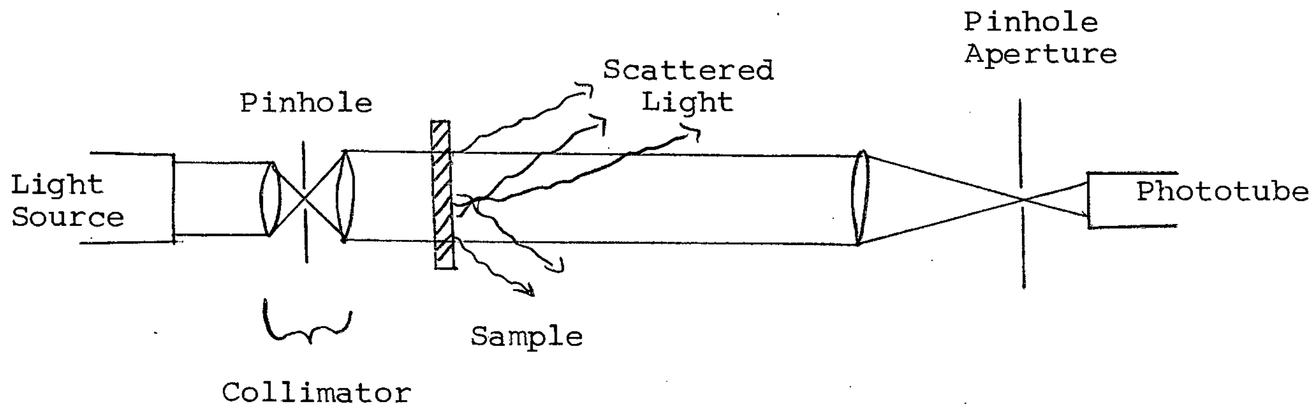


Figure 2. The Measurement of T_{spec}

pinhole aperture onto the detector. Having T_s, we can compute Gain (θ) and T_{45} using Equations (6) and (8) respectively. A computer program which computes Gain (θ) and T_{45} from values of I(θ) and T_s has been written, and is being used regularly to summarize the light scattering properties of the materials measured. These summaries, along with angular gain curves of the different materials measured, constitute Appendices A and B. For brevity, TSP and ABS represent the specular transmittance and the fraction of energy absorbed, respectively. Absorption, not yet measured, has been left blank.

Tables I and II summarize the viewing properties of the Corning Glass Works' materials and the commercial rear projection screen materials, respectively. The manufacturer and his designation of the commercial materials is given in Table III. Included among the Corning materials is the first set of samples made to have the desired physical properties as determined by our previous theoretical investigations. These samples have the Prefix "AF".

Table I

Summary of the Optical Properties of Some Corning Glass Works' Materials

Sample Code	T_s %	T_{45} %	T_{spec} %	Axial Gain	Half Gain Point (°)	Thickness mm
AC-1A	37.	15.	36.	1.2	75.	.534
AC-1B	40.	17.	19.	1.3	75.	.915
AC-3A	64.	25.	10.	8.3	5.8	.483
AC-3B	60.	26.	4.8	2.4	70.	.787
AC-10A	69.	27.	4.8	1.9	77.	.534
AC-10B	55.	23.	7.2	1.6	74.	1.287
AC-11A	25.	16.	57.	11.	5.6	.368
AC-11B	79.	39.	19.	17.	2.8	.825
AC-12A	38.	14.	3.6	0.98	81.	.610
AC-12B	39.	15.	4.8	1.0	81.	.623
AC-15B	53.	21.	14.	1.5	79.	.991
AC-16A	59.	24.	24.	1.8	77.	.376
AC-16C	52.	20.	7.2	1.4	80.	.864
AC-17A	46.	17.	14.	1.2	80.	.534
AC-17B	35.	13.	12.	0.88	83.	.929
AC-18A	61.	23.	3.6	1.6	80.	.864 ✓
AC-18B	76.	30.	2.4	2.5	77.	.356 ✓
AC-19A	59.	22.	4.8	1.5	81.	.850
AC-19B	73.	27.	3.6	1.9	82.	.330
AC-20A	52.	20.	3.6	1.4	80.	.623
AC-20B	48.	20.	2.4	1.4	75.	.864
AC-21A	55.	21.	26.	1.5	80.	.457
AC-21B	56.	21.	19.	1.6	80.	.965
AC-24A	46.	18.	29.	1.5	77.	.521
AC-24B	53.	20.	12.	1.4	80.	.940 ✓
AC-26B	67.	27.	7.2	2.1	77.	.864 ✓
AF-1A	28.	11.	43.	1.1	66.	.534
AF-1B	41.	15.	24.	1.3	80.	.991
AF-2A	46.	22.	19.	1.9	63.	.521
AF-2B	36.	12.	4.8	0.93	85.	.965
AF-3A	42.	20.	14.	1.9	56.	.534
AF-3B	40.	14.	4.7	1.1	84.	.991
AF-4A	37.	20.	4.7	1.9	53.	.534
AF-4B	27.	10.	2.4	0.8	82.	.991

Table II

Summary of the Optical Properties of Some Commercial Rear Projection Screen Materials

Sample Code	T_s %	T_{45} %	Axial Gain	Half Gain Point (degrees)
DA-TEX	53.	34.	8.2	15.
SN-2148*	64.	62.	65.	7.
SN-2149*	43.	17.	1.2	77.
HITRANS	78.	44.	25.	8.
S50R	70.	31.	3.7	35.
LS 40FM	48.	30.	5.8	20.
OC 50FM	83.	51.	10.	18.
LS 60FM	59.	33.	4.9	26.
LS 60BFM	68.	42.	11.	14.
LS 60G	38.	25.	3.8	26.
LS 60NG	48.	34.	5.5	25.
LS 60PL	55.	40.	6.0	26.
LS 60STG	35.	27.	5.8	18.
LS 60VR	59.	43.	8.8	20.
LS 75G	61.	52.	29.	10.
LS 85PL	75.	67.	77.	6.
LUX-50	54.	39.	10.	16.
LUX-70	60.	37.	6.2	22.
RAVEN	56.	33.	5.0	25.
TR-50PL	60.	27.	2.4	60.
TYPE 1	82.	70.	23.	14.
TYPE 4	28.	24.	6.7	15.
VCA 3606*	78.	37.	37.	4.

*

Table III

Identification of Materials Codes with the Respective Manufacturers of Commercial Rear Projection Screens

Sample Code	Manufacturer	Manufacturers' Codes
DA-TEX	Da-Lite Screen Company, Inc.	DA-TEX (Da-Lite Translucent Fabric)
SN-2148 *	Edmund Scientific Company	SN-2148 Ground Glass - Satin Finish
SN-2149 *	Edmund Scientific Company	SN-2149 Opal Glass
LS-40FM	Polacoat Incorporated	LS 40FM
LS-60BFM	"	LS 60BFM (Blue)
LS-60FM	"	LS 60FM
LS-60G	"	LS 60G 1/8"
LS-60NG	"	LS 60NG 1/8"
LS-60PL	"	LS 60PL 1/16"
LS 60STG	"	LS 60STG 1/8"
LS-60VR	"	LS 60VR 025
LS-75G	"	LS 75G 1/8"
LS-85PL	"	LS 85PL 1/16"
OC-50FM	"	OC 50FM (white)
TR-50PL	"	TR 50PL 1/16"
RAVEN	Raven Screen Corporation	Lenscreen-Rear Projection
HITRANS	Trans-Lux News-Sign Corp.	HI-TRANS
S-50R	"	S-50R
LUX-50	"	Luxchrome "50"
LUX-70	"	Luxchrome "70"
TYPE 1	[illegible] Kodak Corporation	Day-View Screen White Type 1
TYPE 4	Kodak Corporation	Day-View Screen Black Type 4
VCA 3606*	Union Carbide Corporation Plastics Division-Films Dept.	VCA-3606 White

*These materials are not sold as Rear projection screens.

The fraction of incident energy scattered into the forward hemisphere, i.e., the efficiency, is plotted against axial gain in Figure 3. The theoretical curve in the figure is based on single volume scattering. The data from the Corning Glass Works' materials behaved as predicted: they showed a rapid increase in efficiency with increasing gain*.

The commercial materials showed little correlation between efficiency and gain, indicating that they have less than optimum viewing properties. Many of the commercial materials have some neutral density, which in part is responsible for their lower than optimum efficiency.

In the theoretical summary, some calculations were made showing the effects of variations in the scattering cross-section with wavelength for particles of different relative refractive indices. This work indicated that for refractive indices near unity, i.e., $.8 \leq n \leq 1.2$, there would be large differences between the scattering coefficients for red and blue light. As more of the blue light would be scattered than the red, a red colored specular component would be transmitted through the screen. Although the relative refractive indices of the particles in the samples measured are not exactly known, they are believed to be near unity, and the size parameter α, ($\alpha = \pi D/\lambda$ where D is the particle diameter), to be less than 5.

Experimentally we have measured the spectral characteristics of the specular component of many CGW samples. As predicted, many of these have a strong excess of red, Figure 4. Because different samples have different physical properties, no two samples have the same light scattering characteristics or the same spectral properties of the specularly transmitted component.

There is little doubt that the variations in scattering with wavelength are produced by particles about the same size as the incident wavelength, not by very small particles. This

* Report No. P-19-9, "Improved Screen for Rear Projection Viewers", Phase II. Theoretical Studies, April 26, 1966. 25X1

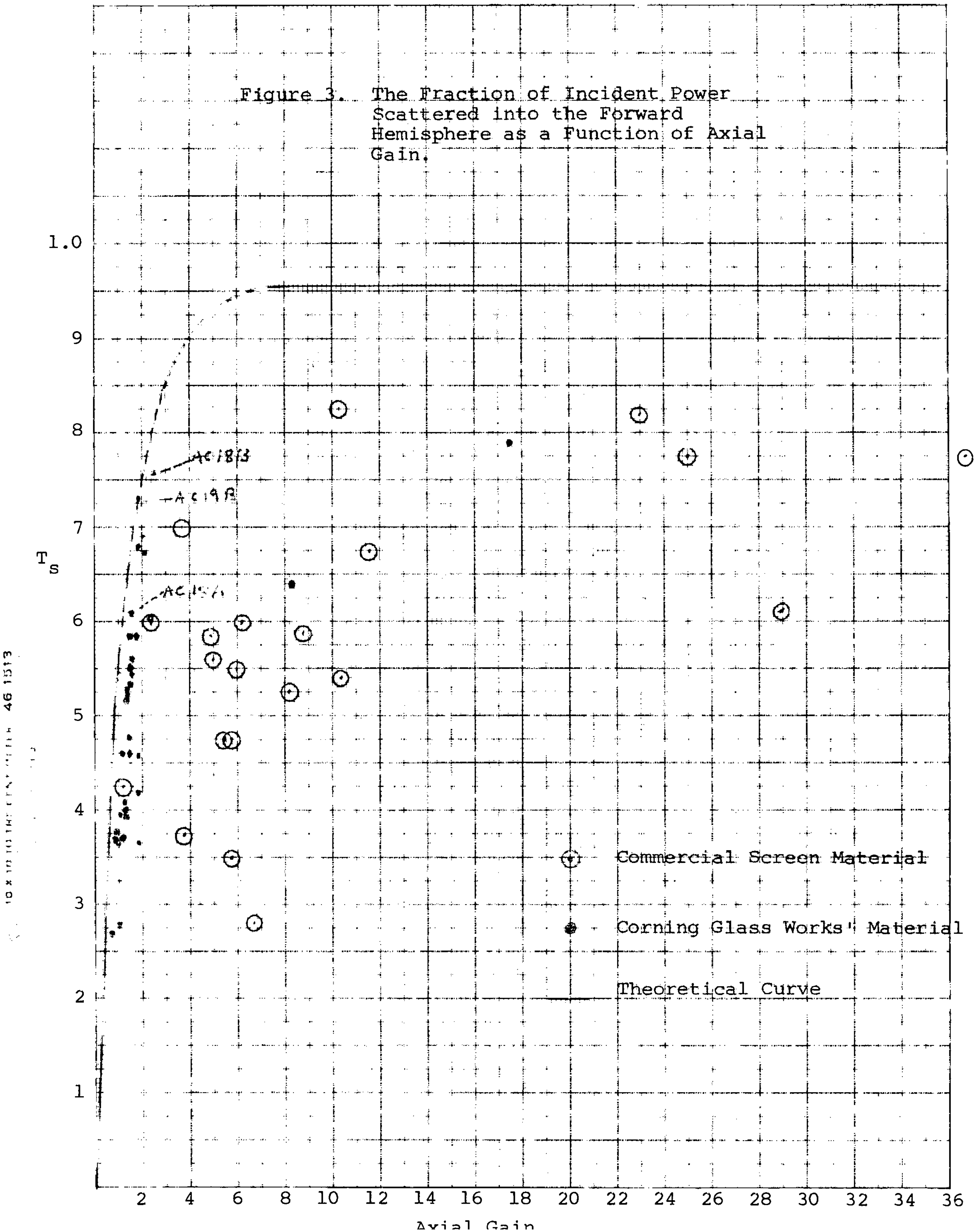
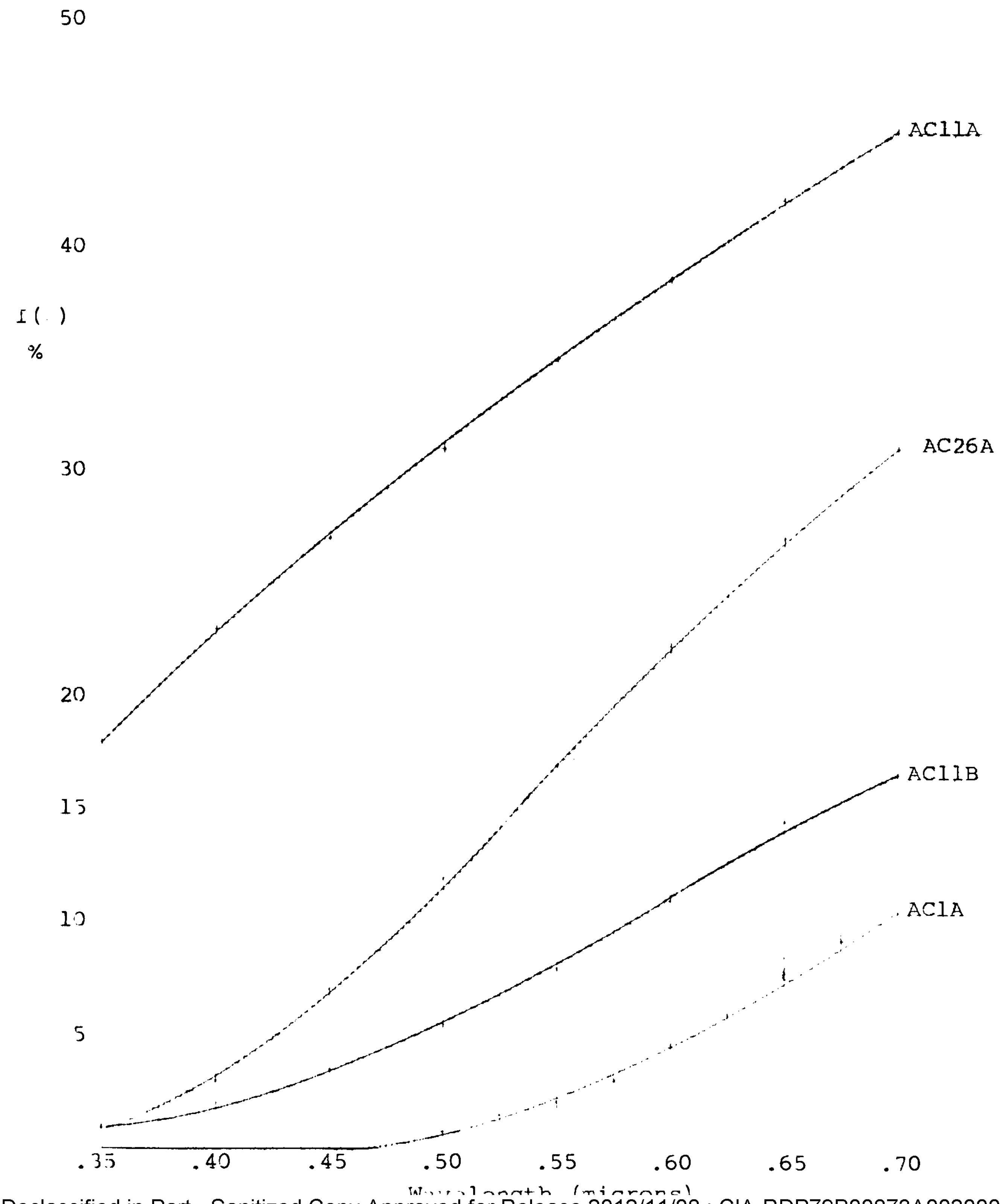


Figure 3. The Fraction of Incident Power Scattered into the Forward Hemisphere as a Function of Axial Gain.
1.0
9
8
7
6
5
4
3
2
1
T_s
AC 18B
AC 19B
AC 15A
Commercial Screen Material
Corning Glass Works' Material
Theoretical Curve
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
Axial Gain

Figure 4. Spectral Properties of the Specularly Transmitted Component for Some Corning Glass Works' Materials



is shown in Figure 5 by the large differences between these data, and a curve of $1/\lambda^4$ which represents Rayleigh scattering produced by very small particles. Such curves are a good measure of the approximate size of the particles producing the scattering. Here the size parameter α is thought to lie between .5 and 5, and probably between .9 and 2.. The absolute values are not as important as the relative shapes of the curves. If any absorption occurs, it is relatively independent of wavelength, only lowering the curves given and having no effect on their shape. The presence of the colored spectral component in almost all of the glass-ceramic materials measured suggests we should consider only systems where large relative refractive indices can be obtained. No specular transmission can be tolerated, not only because of efficiency considerations, but because one would be able to see the projector through the screen. This analysis implies we should also seriously consider materials containing metallic particles, which for the most part would circumvent this problem at some loss of efficiency.

The three best Corning Glass Works' materials thus far measured are AC18A, AC18B, and AC19B, Figure 3. These materials are considered best because they are more efficient, have higher gains, show little or no specular transmission, and give the necessary uniformity of screen brightness.

B. Instrumentation

The contrast computer for the modulation transfer function analyzer is progressing on schedule. Construction is over 90 percent complete and initial checkout has started; completion is expected by the first of September.

We have made six sine-wave masks which are to be used with the modulation transfer function analyzer. Some difficulties in making these have been encountered; however, we will be able to use the masks we have, and expect to make more when the present difficulty has been corrected. These difficulties are due to minute variations of the film transport speed and produce slight variations in the density of the mask pattern.

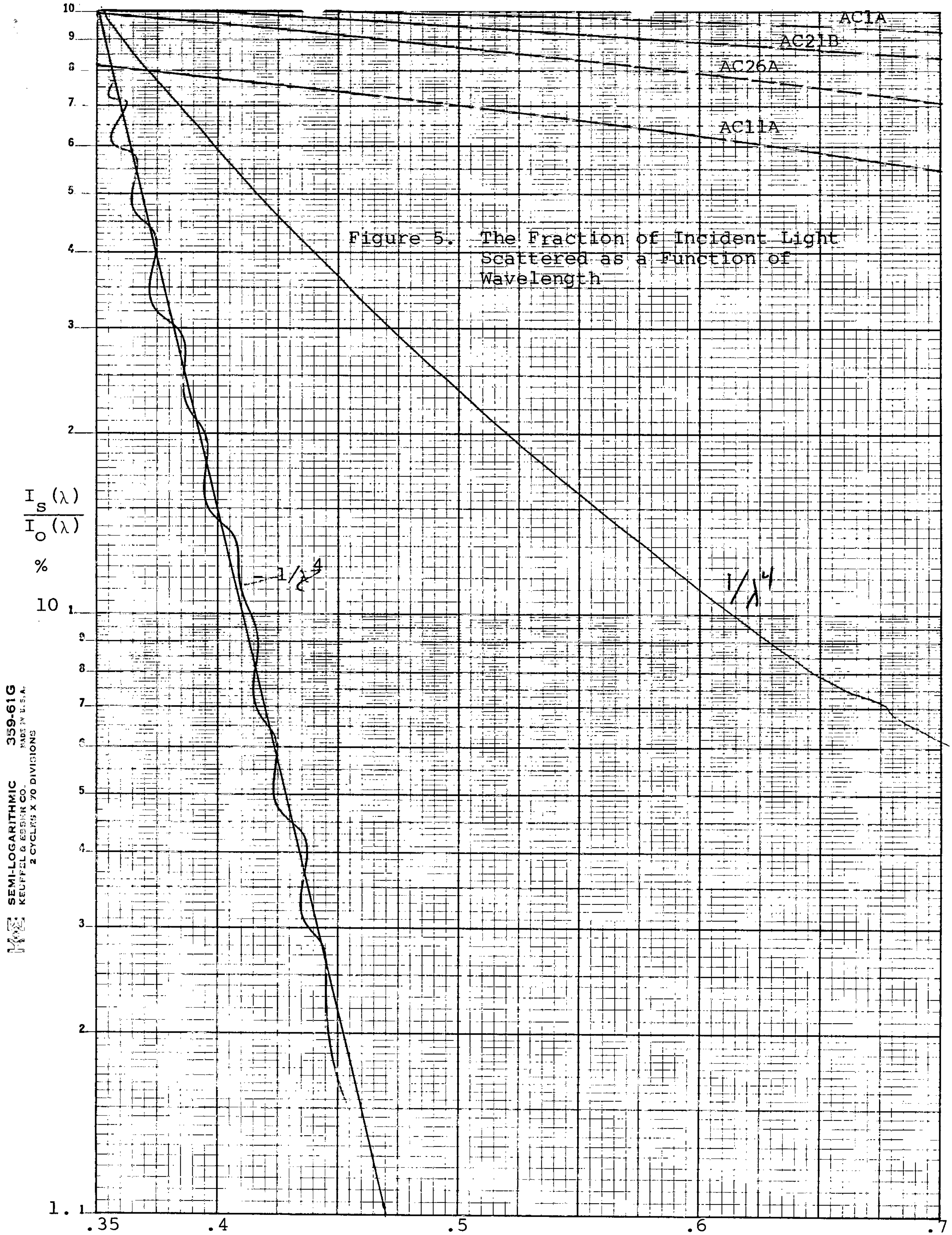
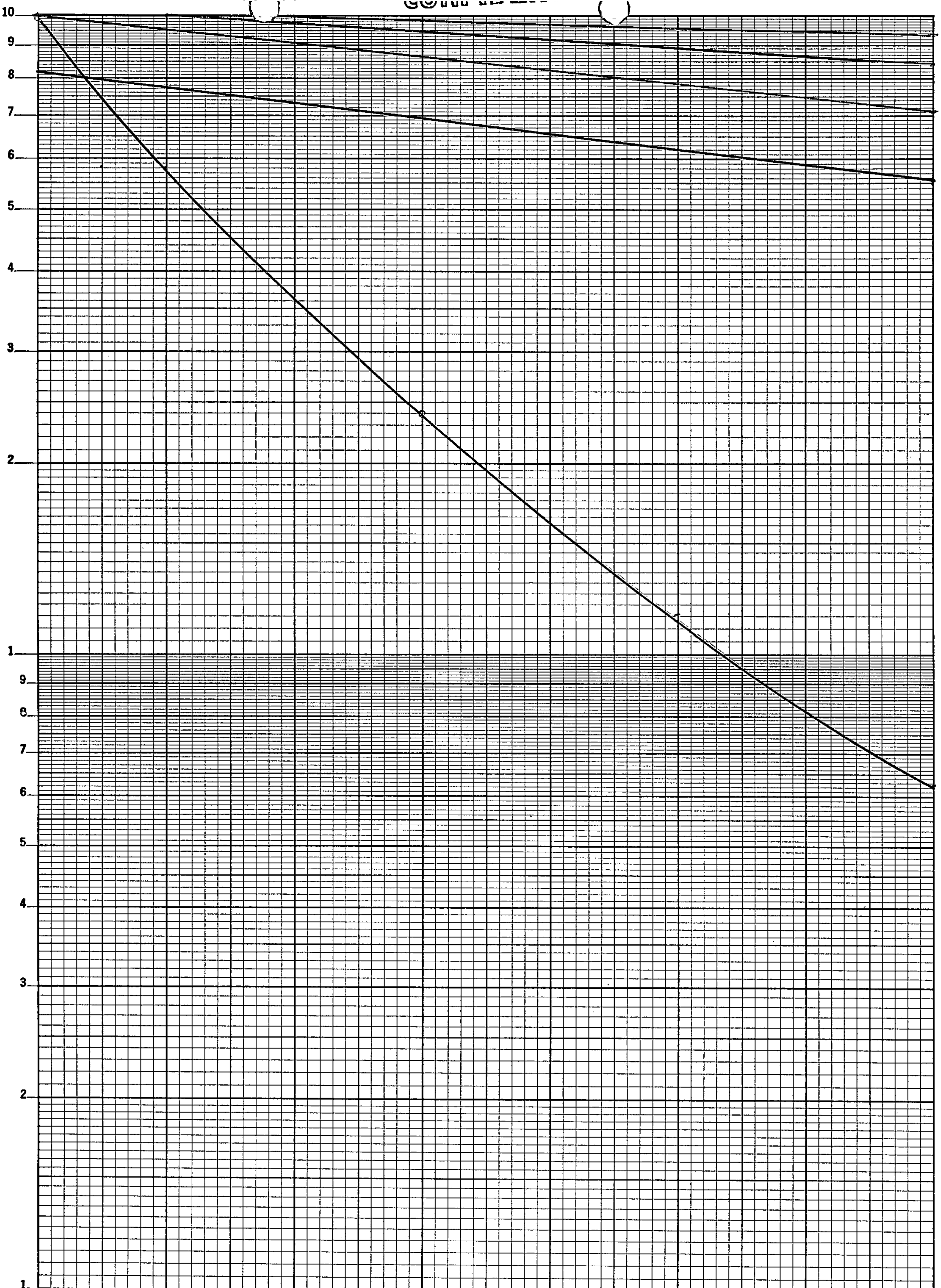


Figure 5. The Fraction of Incident Light Scattered as a Function of Wavelength


10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
1

APPENDIX A

SUMMARY OF LIGHT SCATTERING DATA OF CORNING GLASS WORKS' MATERIALS

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	AC-1A	AC-1B	AC-3A	AC-3B	AC-10A	AC-10B
	SAMPLE CODES					
0	1.245	1.320	8.302	2.368	1.934	1.587
5	1.220	1.240	5.977	1.902	1.896	1.746
10	1.164	1.207	1.826	1.860	1.876	1.746
15	1.164	1.201	1.652	1.839	1.876	1.667
20	1.133	1.188	1.635	1.807	1.867	1.587
25	1.071	1.161	1.627	1.797	1.838	1.572
30	1.009	1.135	1.618	1.786	1.828	1.572
35	.971	1.108	1.602	1.765	1.809	1.564
40	.934	1.089	1.585	1.754	1.780	1.548
45	.909	1.069	1.569	1.733	1.760	1.540
50	.884	1.049	1.544	1.680	1.731	1.524
55	.853	1.016	1.502	1.638	1.712	1.476
60	.822	.983	1.461	1.564	1.654	1.429
65	.784	.924	1.403	1.448	1.547	1.341
70	.716	.844	1.303	1.226	1.451	1.143
75	.629	.666	1.162	.655	1.267	.698
80	.498	.277	.880	.031	.832	.063
85	.199	.013	.132	.010	.038	.007
90	.000	.000	.000	.000	.000	.000
TS	.372	.403	.640	.599	.687	.546
T45	.149	.166	.253	.261	.266	.232
TSP	.363	.186	.095	.048	.048	.072
ABS						

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	AC-11A	AC-11B	AC-12A	AC-12B	AC-15B	AC-16A
	SAMPLE CODES					
0	11.040	17.462	.984	1.025	1.492	1.798
5	6.127	6.984	1.033	1.025	1.462	1.816
10	2.870	4.755	.984	1.015	1.462	1.906
15	1.913	3.715	.969	1.015	1.455	1.942
20	1.352	3.120	.964	1.025	1.440	1.879
25	1.002	2.675	.964	1.025	1.432	1.762
30	.772	2.377	.934	1.000	1.410	1.690
35	.634	2.154	.934	.984	1.402	1.582
40	.542	1.932	.934	.984	1.380	1.510
45	.469	1.783	.915	.974	1.358	1.438
50	.404	1.709	.915	.943	1.335	1.366
55	.377	1.560	.885	.933	1.298	1.303
60	.349	1.486	.846	.902	1.253	1.222
65	.322	1.367	.826	.871	1.193	1.150
70	.290	1.263	.782	.810	1.104	1.061
75	.248	1.070	.688	.707	.955	.935
80	.187	.817	.580	.574	.701	.755
85	.018	.445	.236	.256	.119	.449
90	.000	.000	.000	.000	.000	.000
TS	.252	.790	.376	.394	.534	.586
T45	.160	.387	.138	.146	.206	.244
TSP	.572	.190	.036	.048	.143	.238
ABS						

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SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	SAMPLE CODES AC-16C	AC-17A	AC-17B	AC-18A	AC-18B	AC-19A
0	1.388	1.224	.883	1.585	2.462	1.505
5	1.388	1.224	.883	1.585	2.425	1.520
10	1.402	1.224	.892	1.585	2.339	1.520
15	1.388	1.218	.883	1.577	2.277	1.513
20	1.374	1.212	.874	1.577	2.216	1.513
25	1.374	1.193	.874	1.569	2.142	1.505
30	1.354	1.181	.870	1.569	2.056	1.505
35	1.340	1.175	.865	1.561	1.994	1.498
40	1.333	1.175	.856	1.553	1.920	1.490
45	1.306	1.175	.847	1.537	1.846	1.483
50	1.292	1.151	.843	1.521	1.797	1.475
55	1.264	1.126	.829	1.497	1.723	1.430
60	1.209	1.095	.784	1.458	1.662	1.385
65	1.161	1.065	.757	1.394	1.600	1.324
70	1.072	.998	.712	1.299	1.480	1.234
75	.934	.881	.631	1.141	1.305	1.084
80	.673	.600	.541	.824	.985	.767
85	.192	.036	.351	.158	.443	.180
90	.000	.000	.000	.000	.000	.000
TS	.519	.460	.352	.611	.756	.585
T45	.198	.174	.127	.228	.302	.219
TSP	.072	.143	.119	.036	.024	.048
ABS						

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SUMMARY OF ANGULAR GAIN FUNCTIONS

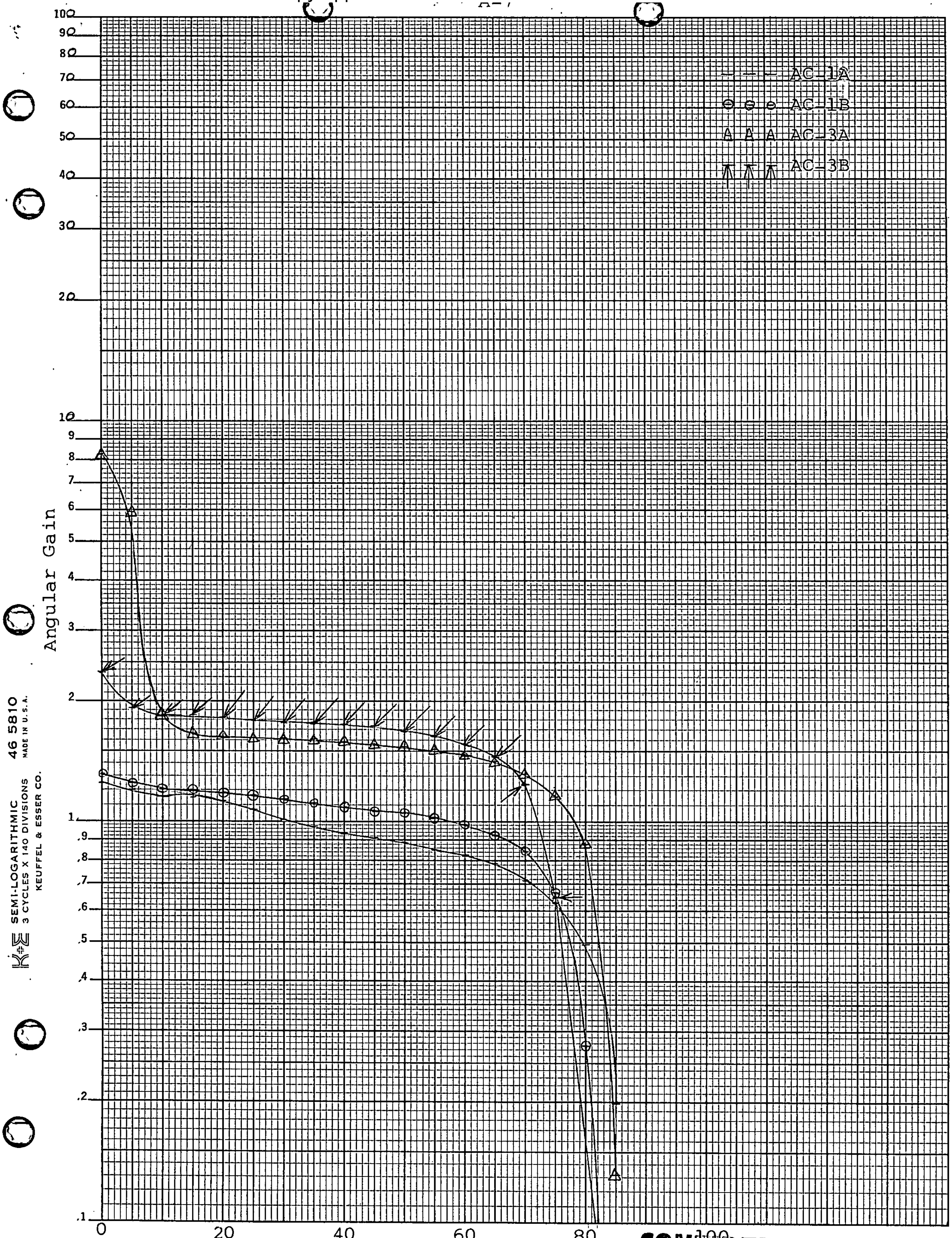
ANGLE K	SAMPLE CODES AC-19B	AC-20A	AC-20B	AC-21A	AC-21B	AC-24A
0	1.897	1.431	1.447	1.508	1.578	1.467
5	1.887	1.416	1.447	1.390	1.499	1.248
10	1.887	1.416	1.433	1.404	1.484	1.241
15	1.878	1.402	1.418	1.412	1.477	1.241
20	1.868	1.388	1.404	1.419	1.460	1.234
25	1.849	1.388	1.389	1.419	1.460	1.227
30	1.840	1.345	1.375	1.419	1.436	1.220
35	1.821	1.330	1.346	1.419	1.436	1.220
40	1.811	1.316	1.332	1.412	1.421	1.200
45	1.792	1.330	1.317	1.397	1.405	1.193
50	1.754	1.288	1.303	1.375	1.373	1.172
55	1.716	1.273	1.245	1.345	1.357	1.131
60	1.659	1.202	1.187	1.301	1.326	1.083
65	1.582	1.166	1.129	1.249	1.255	1.028
70	1.487	1.059	.999	1.168	1.184	.925
75	1.334	.930	.709	1.027	1.026	.795
80	1.087	.744	.159	.739	.773	.603
85	.533	.214	.000	.088	.157	.192
90	.000	.000	.000	.000	.000	.000
TS	.729	.523	.476	.548	.559	.464
T45	.268	.198	.200	.206	.211	.178
TSP	.036	.036	.024	.206	.186	.286
ABS						

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	AC-24B	AC-26B	AF-1A	AF-1B	AF-2A	AF-2B
	SAMPLE CODES					
0	1.402	2.140	1.134	1.260	1.901	.925
5	1.388	2.119	.954	1.118	1.799	.883
10	1.374	2.087	.850	1.089	1.735	.879
15	1.367	2.034	.831	1.071	1.679	.869
20	1.381	1.971	.803	1.059	1.642	.865
25	1.374	1.907	.779	1.036	1.587	.851
30	1.360	1.865	.765	1.012	1.513	.846
35	1.318	1.801	.746	1.006	1.449	.832
40	1.346	1.748	.727	.989	1.393	.823
45	1.325	1.695	.699	.971	1.329	.814
50	1.297	1.642	.680	.959	1.236	.805
55	1.262	1.579	.652	.930	1.144	.795
60	1.206	1.515	.614	.900	1.070	.791
65	1.164	1.420	.576	.871	.904	.786
70	1.052	1.314	.524	.818	.710	.763
75	.925	1.144	.453	.741	.452	.740
80	.715	.847	.340	.618	.184	.675
85	.378	.254	.170	.441	.005	.462
90	.000	.000	.000	.000	.000	.000
TS	.528	.673	.278	.409	.457	.364
T45	.198	.272	.112	.149	.221	.123
TSP	.119	.072	.428	.238	.190	.048
ABS						

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	AF-3A	AF-3B	AF-4A	AF-4B		
	SAMPLE CODES					
0	1.898	1.053	1.878	.678	.000	.000
5	1.788	1.001	1.803	.678	.000	.000
10	1.659	.990	1.737	.678	.000	.000
15	1.548	.969	1.615	.678	.000	.000
20	1.465	.969	1.568	.671	.000	.000
25	1.391	.937	1.474	.678	.000	.000
30	1.308	.927	1.399	.674	.000	.000
35	1.262	.927	1.286	.657	.000	.000
40	1.179	.916	1.183	.671	.000	.000
45	1.124	.906	1.089	.644	.000	.000
50	1.041	.895	.995	.650	.000	.000
55	.958	.874	.901	.630	.000	.000
60	.884	.858	.751	.623	.000	.000
65	.746	.843	.563	.589	.000	.000
70	.663	.821	.460	.545	.000	.000
75	.534	.769	.216	.494	.000	.000
80	.368	.679	.037	.393	.000	.000
85	.184	.495	.018	.250	.000	.000
90	.000	.000	.000	.000	.000	.000
TS	.418	.395	.365	.270	.000	.000
T45	.195	.137	.201	.097	.000	.000
TSP	.142	.047	.047	.024		
ABS						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AC-3B
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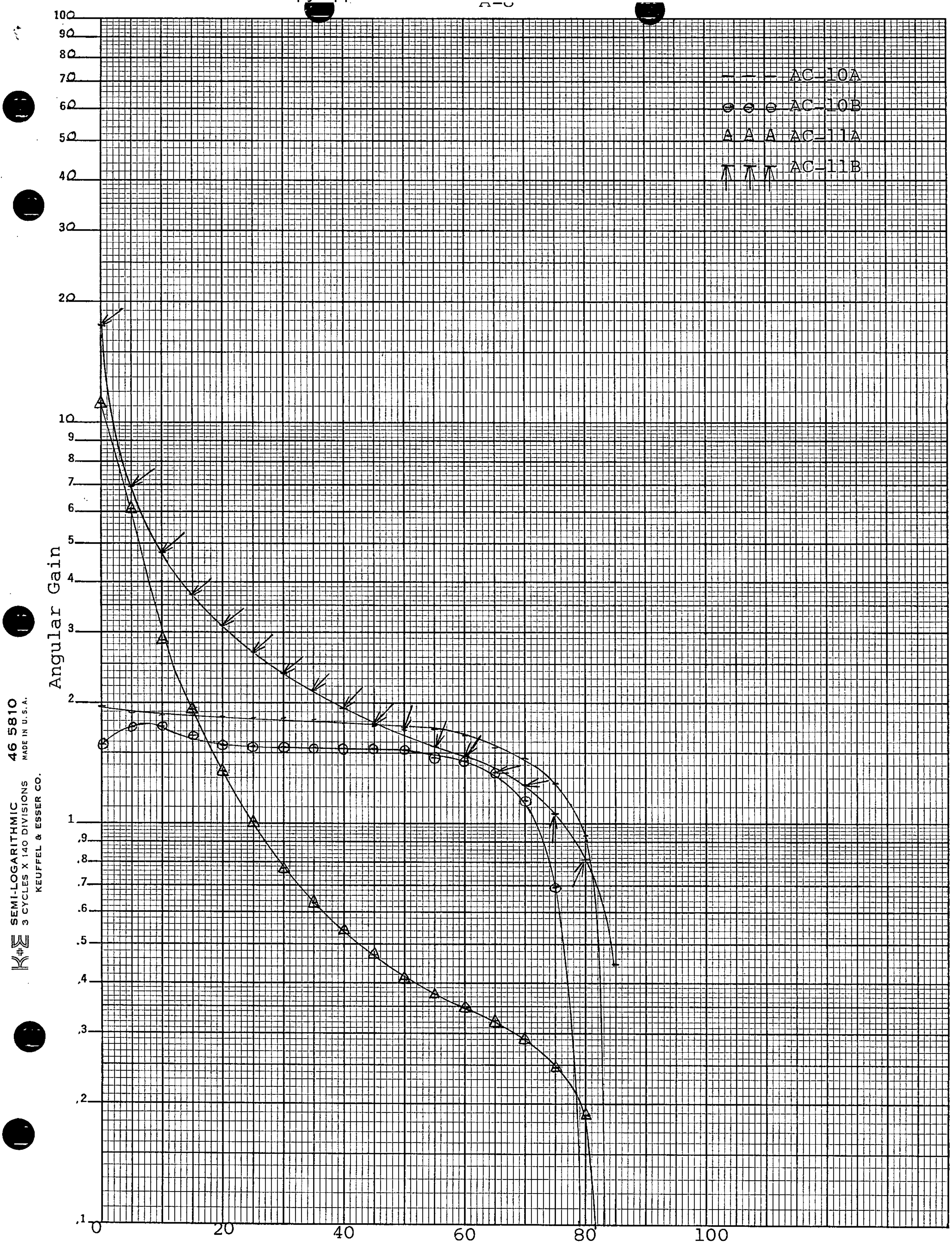
46 5810
MADE IN U.S.A.
SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.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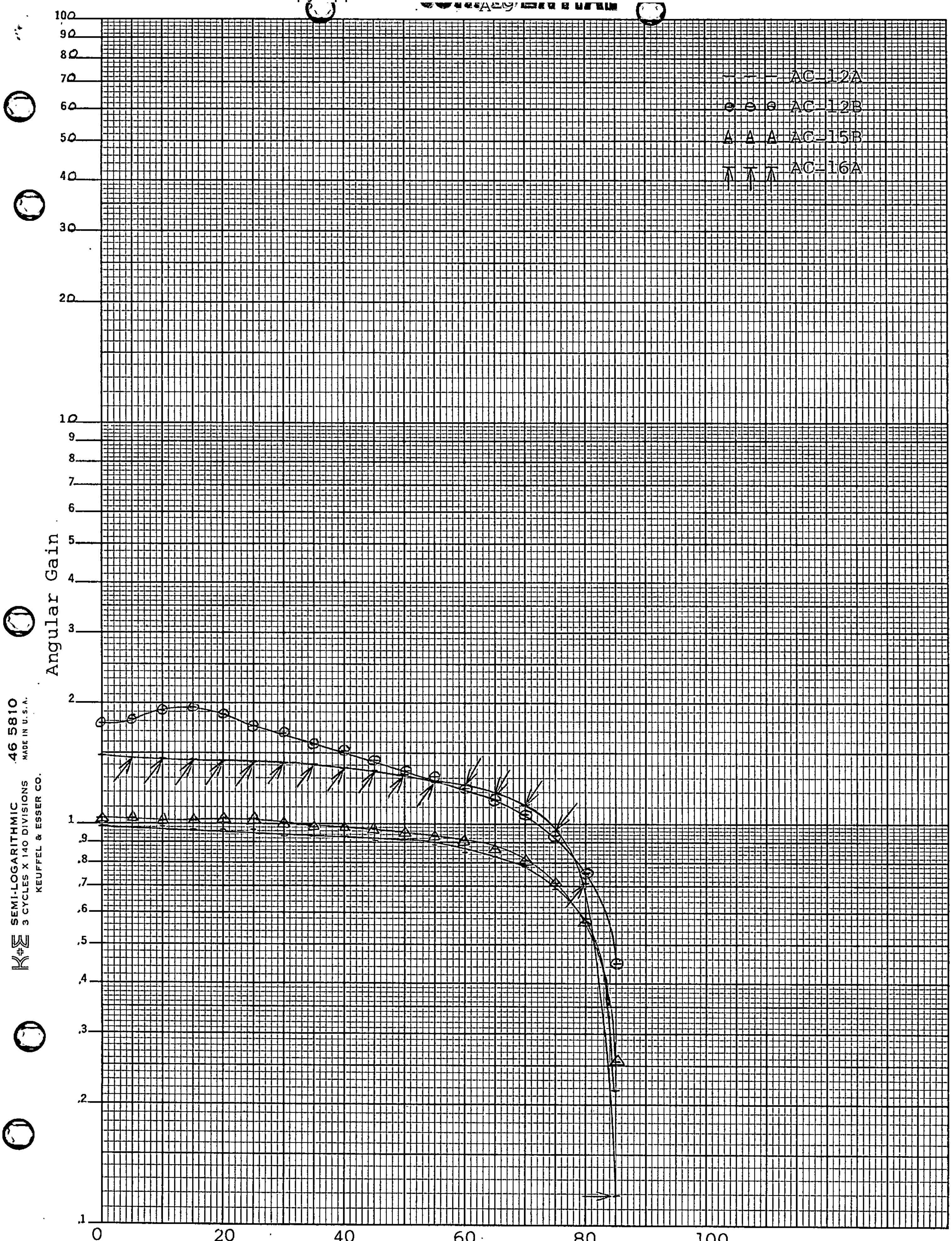
MADE IN U.S.A.
SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.



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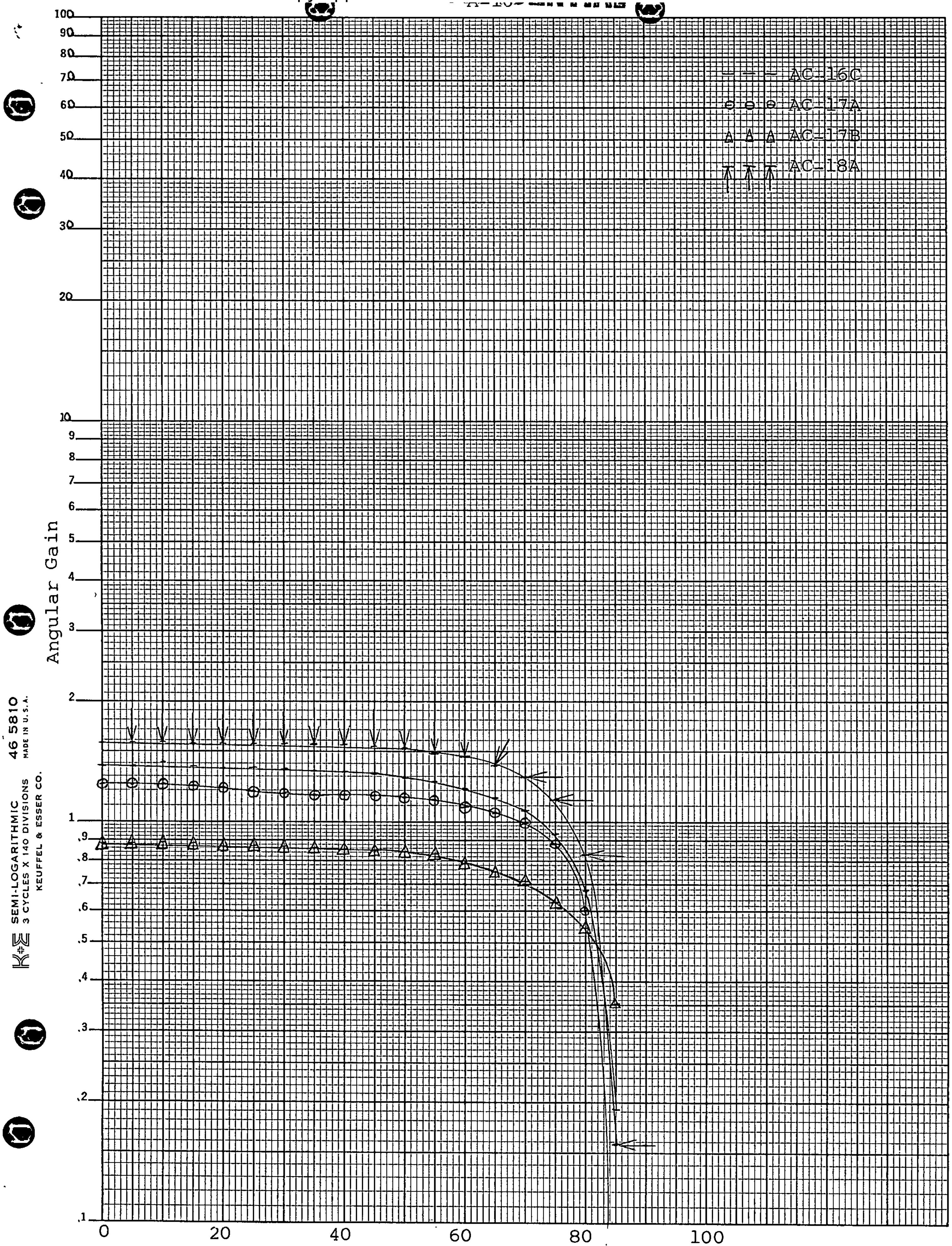
SEMI-LOGARITHMIC 46 5810
3 CYCLES X 140 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.



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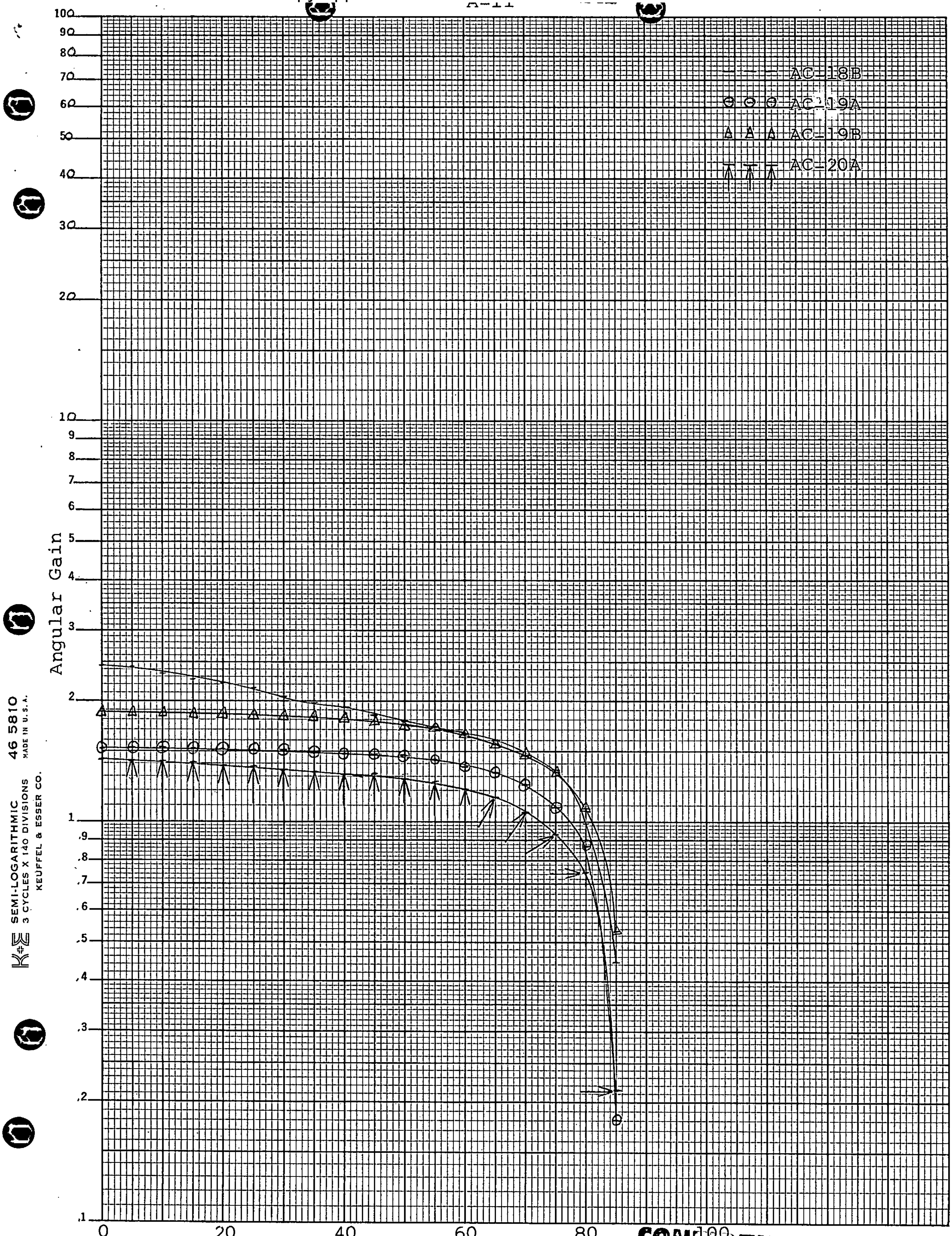
SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.
46 5810
MADE IN U.S.A.



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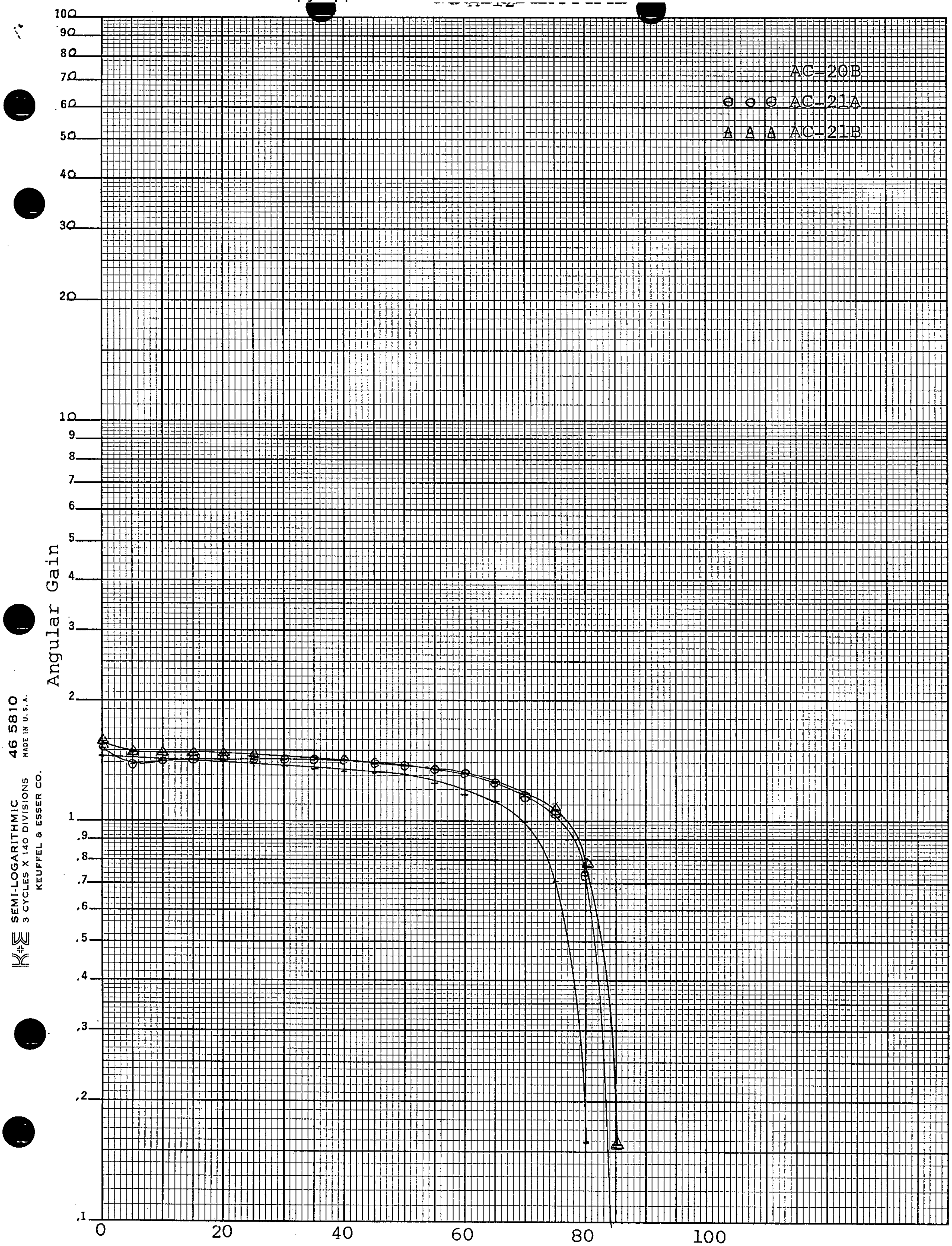
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AC-21B
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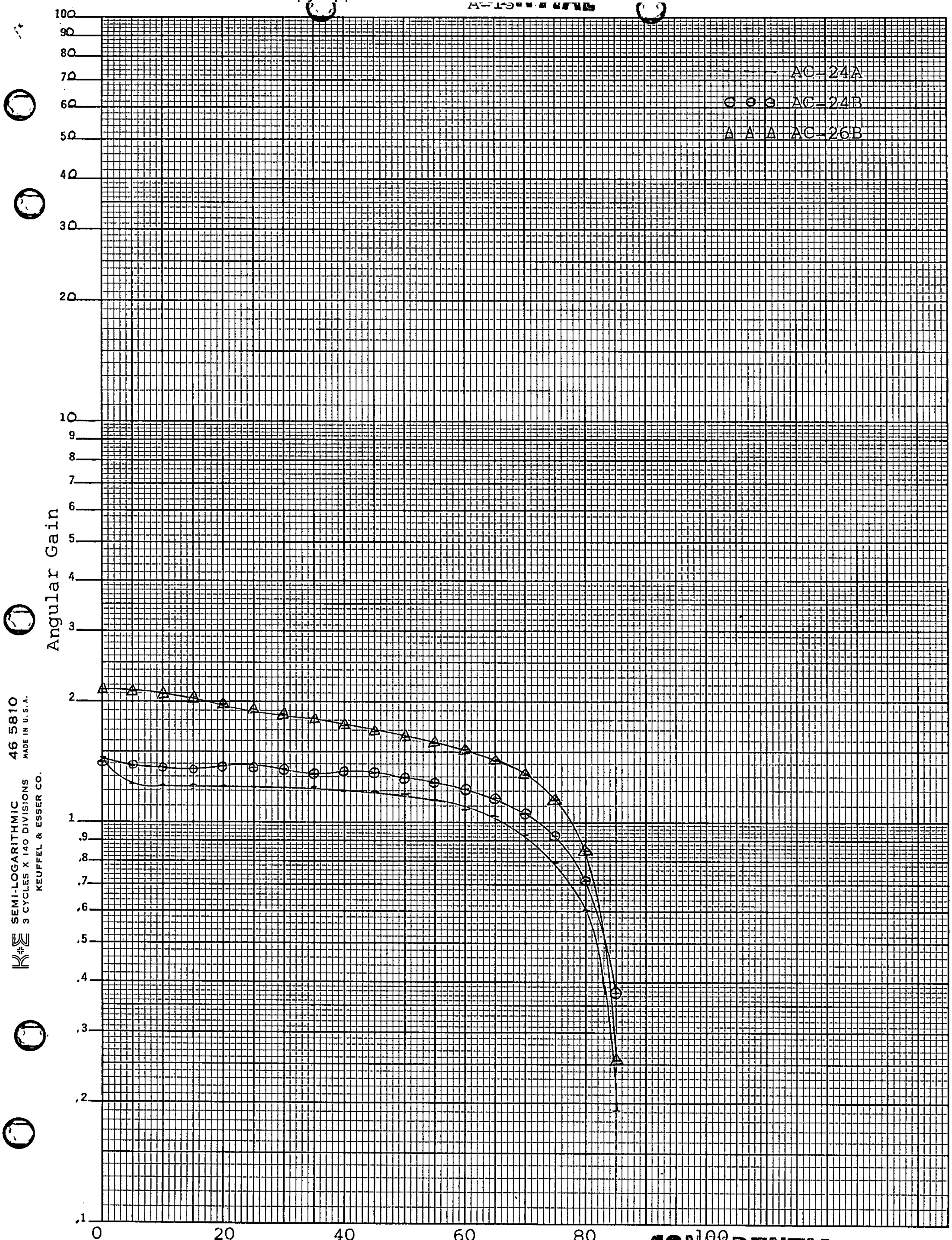
SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.
46 5810
MADE IN U.S.A.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AC-24B
AC-26B
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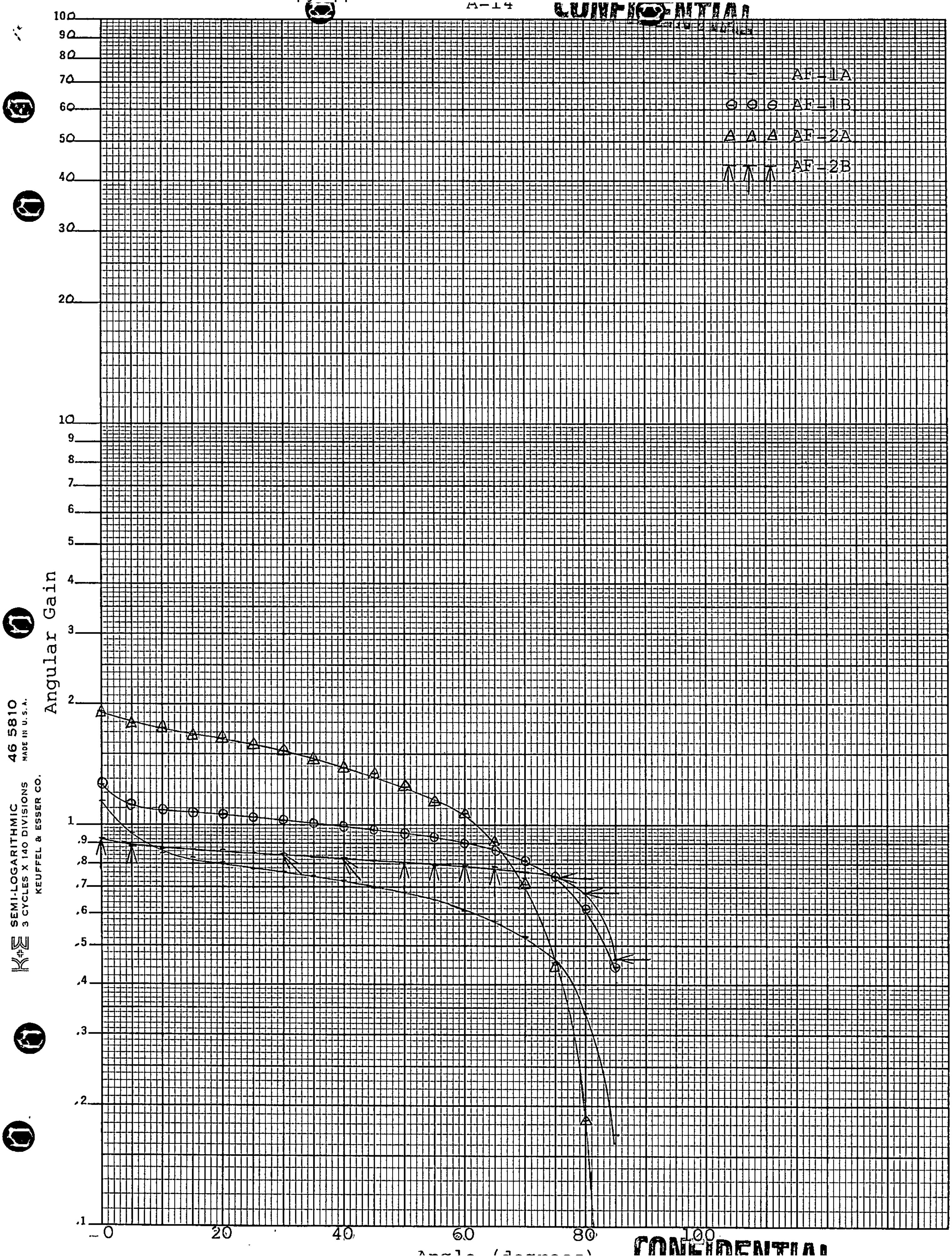
K&E SEMI-LOGARITHMIC 46 5810
3 CYCLES X 140 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.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AF-1B
AF-2A
AF-2B
Angular Gain
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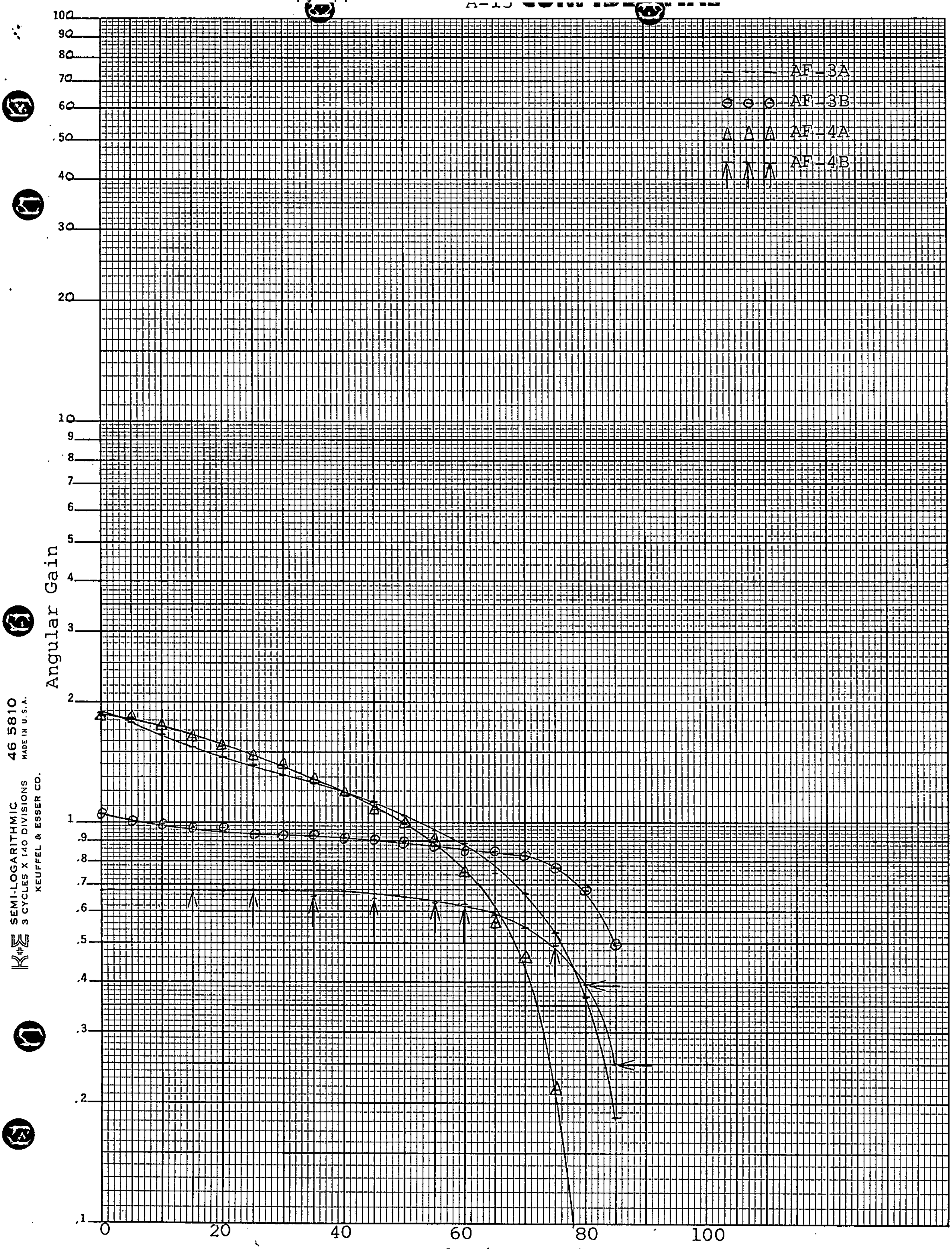
K&E SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.
46 5810
MADE IN U.S.A.



AF-3A
AF-3B
AF-4A
AF-4B
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K&E SEMI-LOGARITHMIC 46 5810
3 CYCLES X 140 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

APPENDIX B

SUMMARY OF LIGHT SCATTERING DATA ON COMMERCIAL REAR PROJECTION SCREENS

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SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE K	DA-TEX	SN-2148	SN-2149	HITRANS	S-50R	LS-40FM
	SAMPLE CODES					
0	8.220	64.451	1.209	25.059	3.696	5.789
5	6.740	47.049	1.185	17.416	3.548	5.123
10	5.507	22.557	1.197	10.274	3.142	4.382
15	4.192	10.312	1.185	5.638	2.809	3.473
20	3.164	4.511	1.179	3.508	2.476	2.865
25	2.507	1.933	1.148	2.505	2.236	2.258
30	1.972	.966	1.160	1.854	2.033	1.852
35	1.602	.644	1.148	1.503	1.848	1.459
40	1.315	.322	1.124	1.303	1.681	1.215
45	1.068	.257	1.118	1.227	1.552	1.013
50	.904	.193	1.112	1.052	1.423	.839
55	.739	.128	1.076	1.027	1.330	.694
60	.657	.064	1.027	1.002	1.256	.607
65	.534	.000	.991	1.002	1.182	.521
70	.493	.000	.919	1.002	1.127	.463
75	.411	.000	.761	1.002	1.072	.347
80	.328	.000	.362	.977	1.035	.318
85	.287	.000	.024	.952	.961	.289
90	.000	.000	.000	.000	.000	.000
TS	.528	.637	.426	.775	.700	.475
T45	.344	.619	.168	.439	.308	.302
TSP	.000	.000	.000	.000	.000	.000
ABS						

CONFIDENTIAL

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE	SAMPLE CODES					
K	OC-50FM	LS-60FM	LS60BFM	LS-60G	LS-60NG	LS-60PL
0	10.340	4.873	10.596	3.823	5.491	6.026
5	8.685	4.532	9.166	3.670	5.656	5.935
10	7.445	4.020	6.993	3.364	5.162	5.544
15	5.945	3.435	5.192	2.867	4.366	4.700
20	4.756	2.924	3.963	2.408	3.459	3.856
25	3.722	2.534	3.020	1.949	2.636	3.103
30	3.060	2.144	2.384	1.605	2.086	2.470
35	2.481	1.754	1.907	1.280	1.537	1.928
40	2.026	1.540	1.536	1.032	1.208	1.506
45	1.706	1.315	1.292	.841	.961	1.205
50	1.447	1.169	1.102	.688	.768	.934
55	1.240	.999	.964	.573	.604	.705
60	1.075	.877	.858	.458	.466	.542
65	.982	.779	.794	.305	.356	.397
70	.827	.682	.688	.248	.302	.301
75	.620	.609	.635	.229	.247	.271
80	.620	.536	.529	.229	.192	.241
85	.723	.487	.413	.152	.164	.210
90	.000	.000	.000	.000	.000	.000
TS	.825	.588	.675	.375	.475	.550
T45	.508	.331	.424	.252	.342	.395
TSP	.000	.000	.000	.000	.000	.000
ABS						

SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE	SAMPLE CODES					
K	LS60STG	LS-60VR	LS-75G	LS-85PL	LUX-50	LUX-70
0	5.803	8.769	29.135	76.821	10.374	6.186
5	5.223	8.418	21.559	43.020	9.544	5.691
10	4.642	7.366	14.276	21.510	7.366	5.103
15	3.540	5.814	8.157	9.218	5.446	4.206
20	2.698	4.472	4.661	4.993	3.942	3.371
25	2.060	3.358	2.913	3.072	2.801	2.814
30	1.508	2.455	1.893	1.920	2.074	2.289
35	1.102	1.771	1.340	1.152	1.452	1.825
40	.812	1.359	1.019	.921	1.141	1.515
45	.620	1.052	.699	.768	.881	1.237
50	.487	.833	.640	.614	.726	1.082
55	.377	.631	.582	.384	.601	.897
60	.313	.526	.437	.307	.497	.804
65	.237	.420	.291	.230	.414	.711
70	.203	.350	.174	.153	.394	.649
75	.145	.333	.087	.076	.363	.606
80	.116	.263	.029	.076	.331	.556
85	.087	.245	.000	.000	.145	.247
90	.000	.000	.000	.000	.000	.000
TS	.350	.588	.613	.750	.538	.600
T45	.266	.434	.519	.670	.391	.367
TSP	.000	.000	.000	.000	.000	.000
ABS						

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SUMMARY OF ANGULAR GAIN FUNCTIONS

ANGLE	SAMPLE CODES					
K	RAVEN	TYPE 1	TYPE-4	VCA3606	TR-50PL	
0	4.965	23.094	6.730	36.758	2.412	.000
5	4.320	19.399	5.922	16.357	2.412	.000
10	3.972	14.780	4.643	6.432	2.340	.000
15	3.376	10.392	3.365	3.675	2.219	.000
20	2.979	7.043	2.355	2.462	2.087	.000
25	2.507	4.849	1.749	2.021	1.978	.000
30	2.085	3.348	1.211	1.837	1.833	.000
35	1.787	2.309	.874	1.543	1.713	.000
40	1.489	1.732	.639	1.470	1.592	.000
45	1.291	1.270	.471	1.396	1.483	.000
50	1.092	1.039	.403	1.360	1.387	.000
55	.918	.808	.269	1.323	1.278	.000
60	.819	.577	.201	1.286	1.201	.000
65	.720	.461	.134	1.249	1.134	.000
70	.645	.000	.000	1.213	1.025	.000
75	.571	.000	.000	1.176	1.013	.000
80	.496	.000	.000	1.102	.880	.000
85	.347	.000	.000	1.102	.048	.000
90	.000	.000	.000	.000	.000	.000
TS	.563	.820	.280	.775	.600	.000
T45	.327	.696	.236	.368	.270	.000
TSP	.000	.000	.000	.000	.000	.000
ABS						

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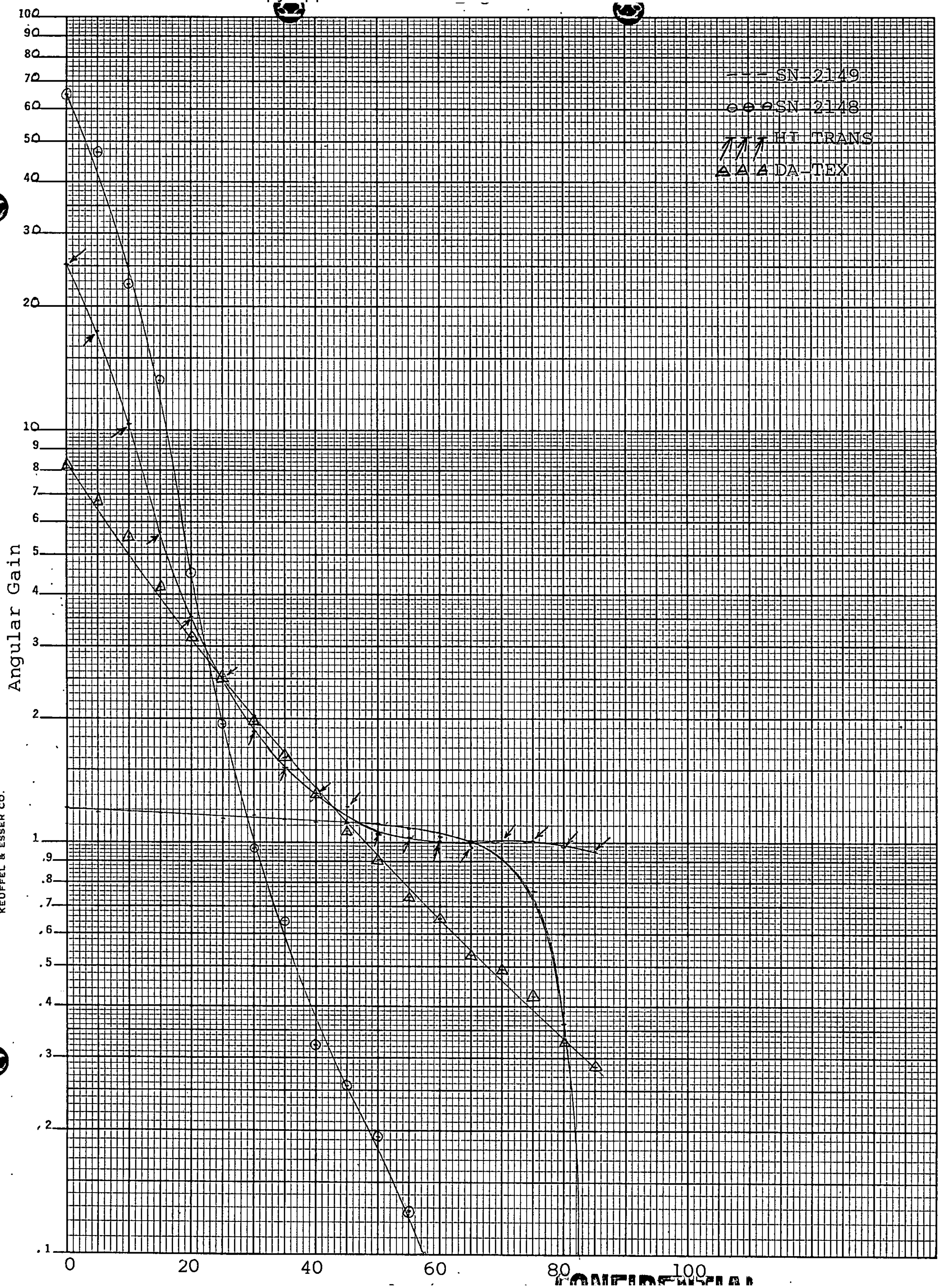

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SN-2149
SN-2148
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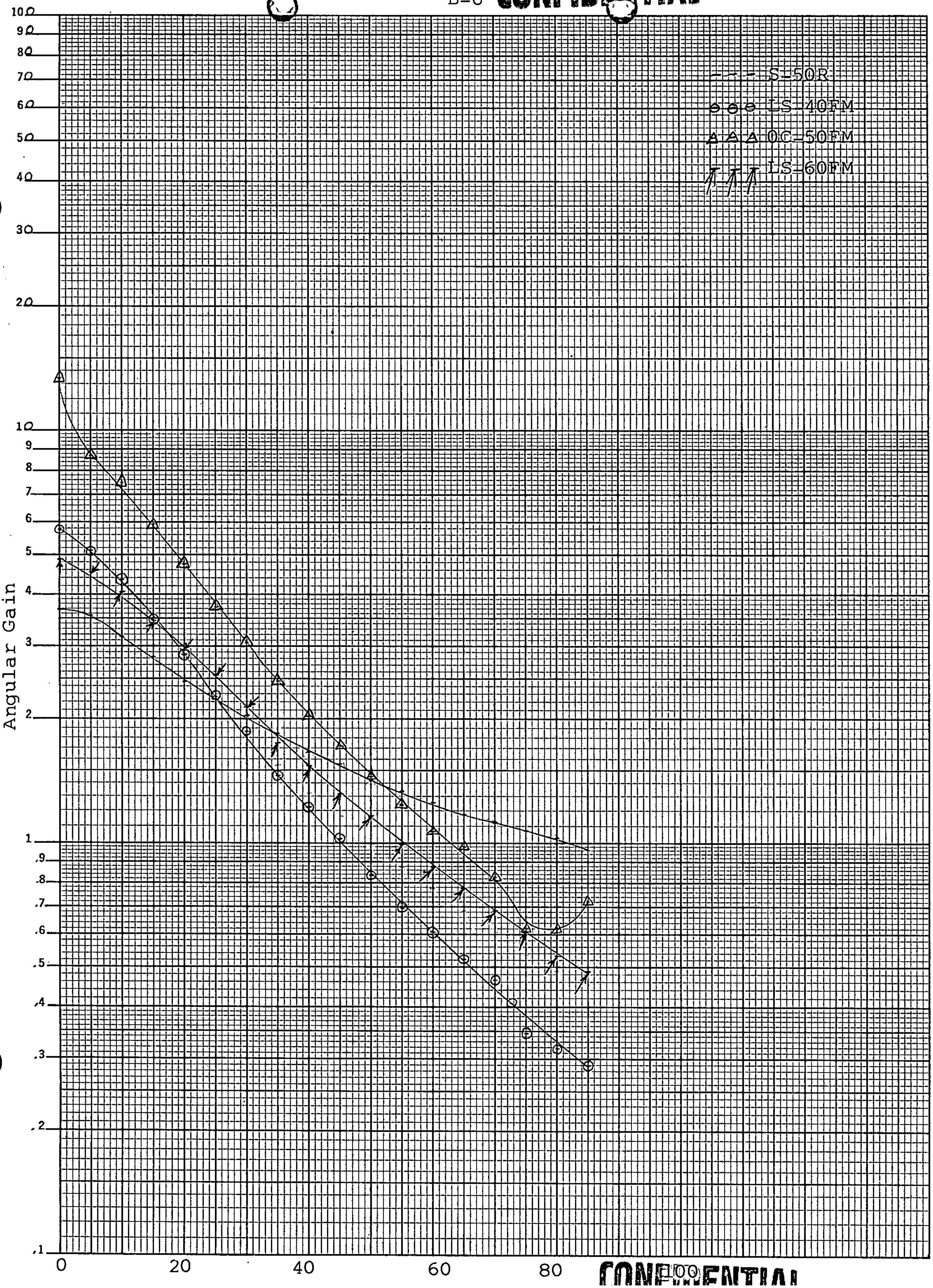
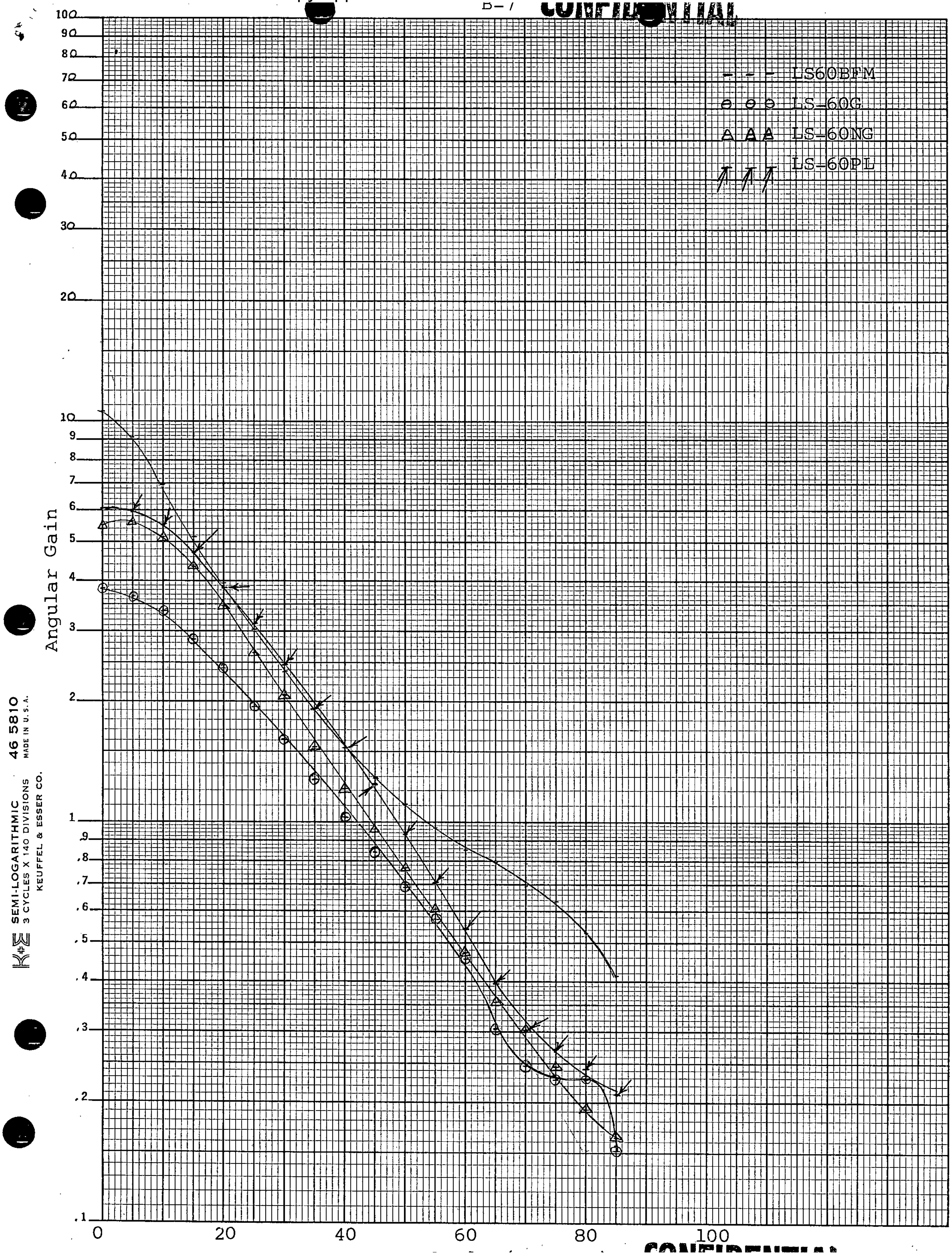


CONFIDENTIAL

CONFIDENTIAL



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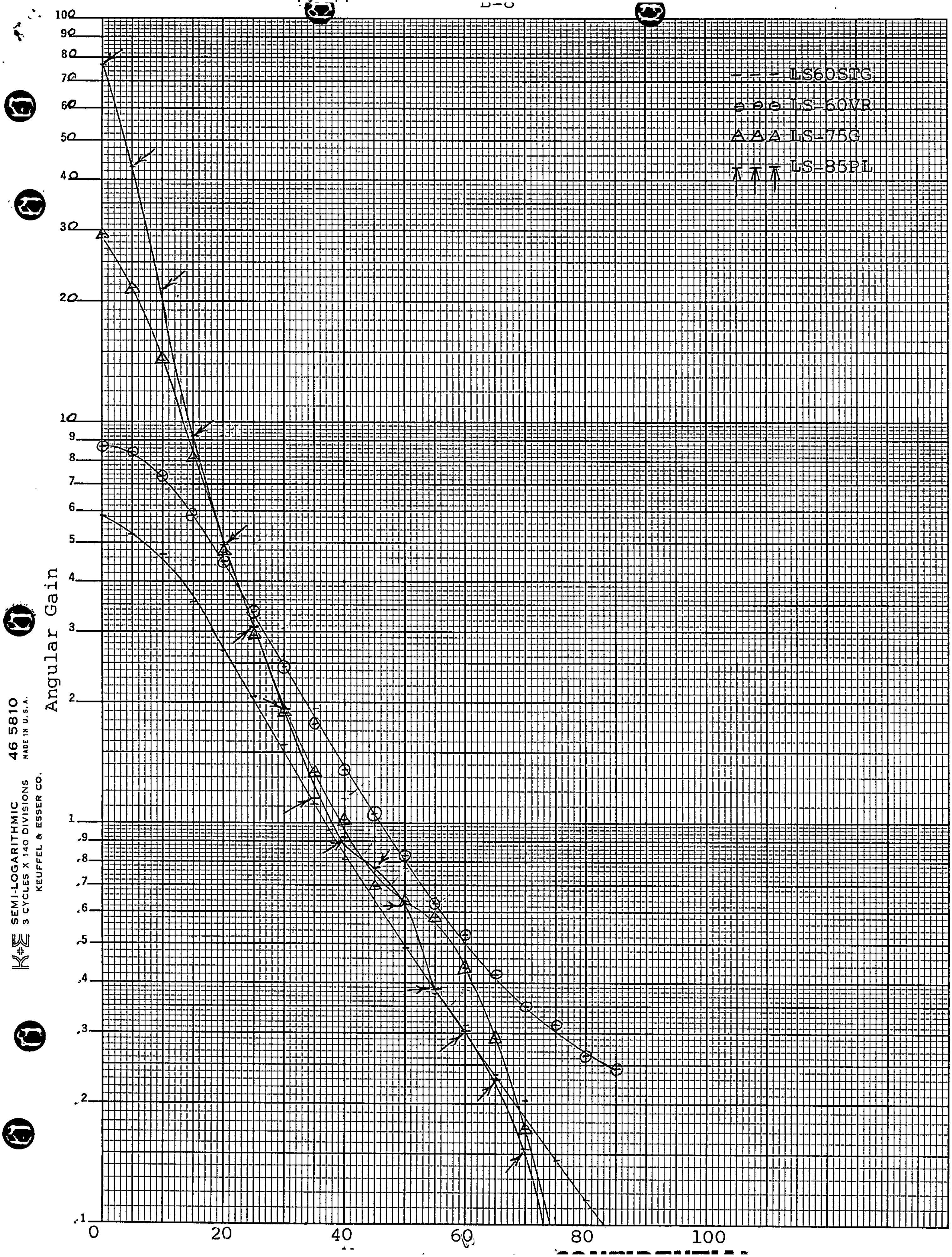
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LS-60VR
LS-75G
LS-85PL
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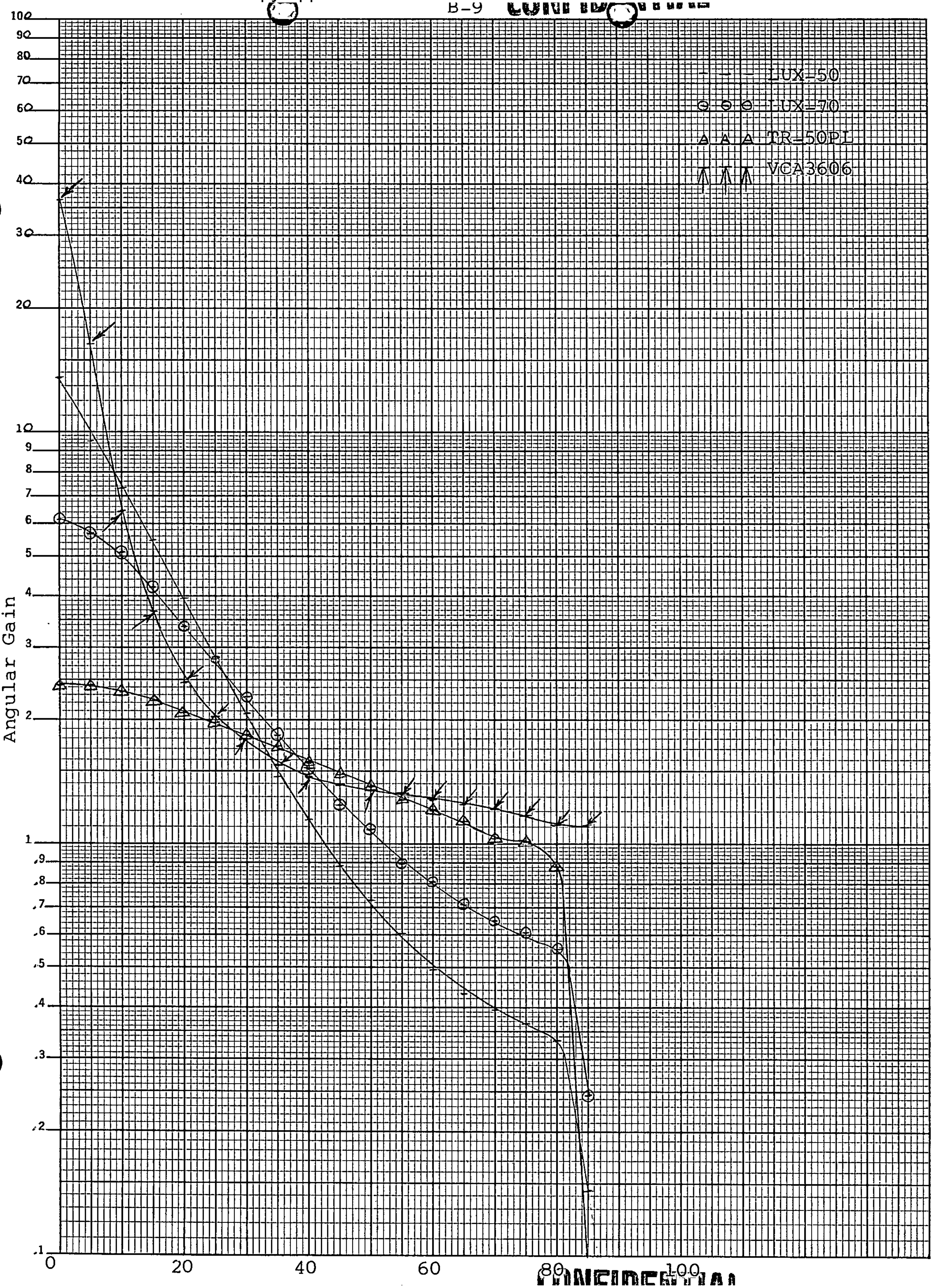
SEMI-LOGARITHMIC 46 5810
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.
MADE IN U.S.A.



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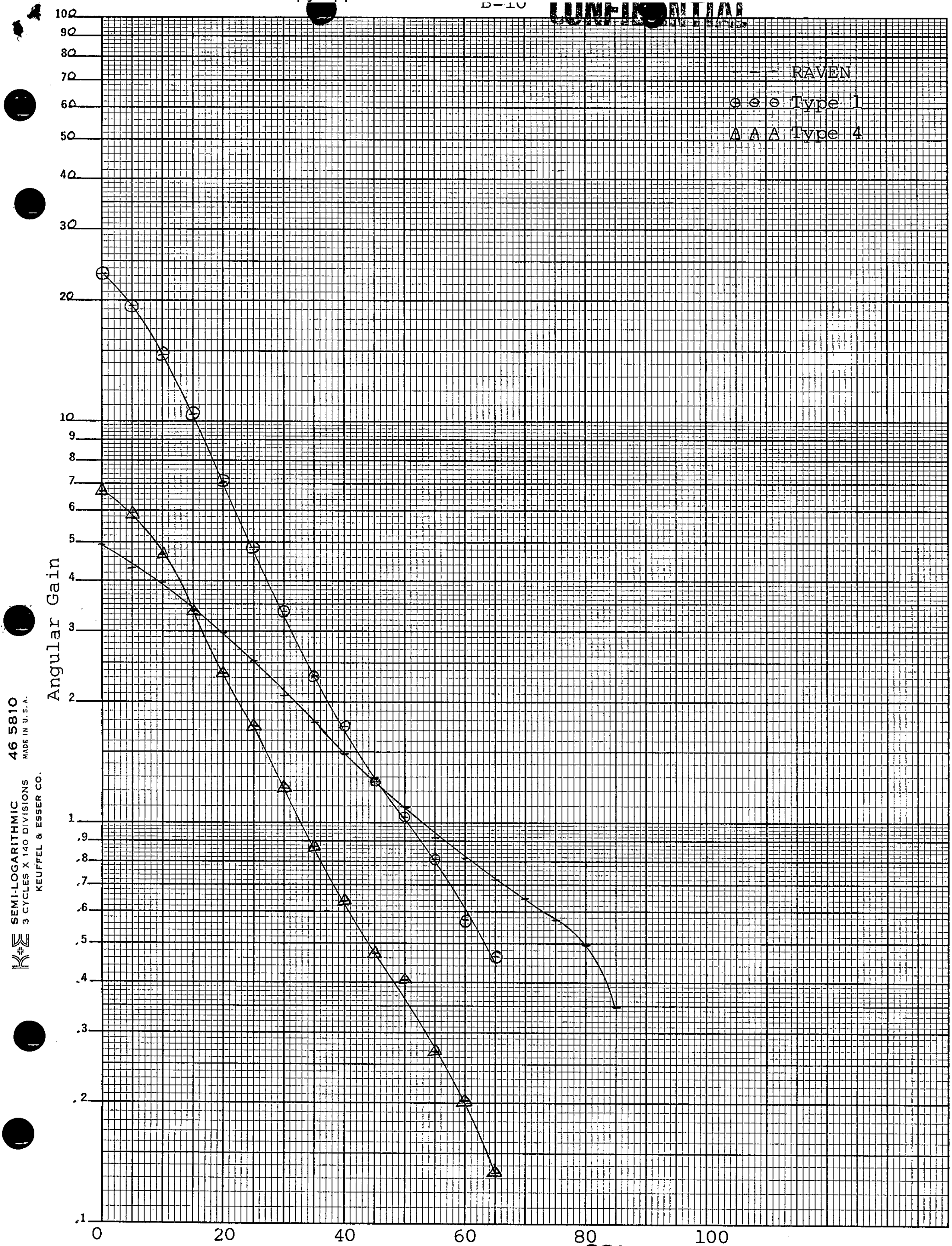

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SEMI-LOGARITHMIC
3 CYCLES X 140 DIVISIONS
KEUFFEL & ESSER CO.
46 5810
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