W. Hopkins Bldg 6

JOINT ELECTRON DEVICE ENGINEERING COUNCIL

Please reply to:
650 SALMON TOWER
11 WEST FORTY-SECOND STREET
NEW YORK 36, N.Y.
TELEPHONE: LONGACRE 5-3450

May 8, 1959

Subject: Laboratory X-Radiation Report on Cathode Ray Tubes

To: Members of JT-6 and JT-6.4

Gentlemen:

Attached is a set of detailed reports dated June 19, 1958, February 4, 1959, and February 20, 1959, prepared by Dr. Carl Braestrup, covering X-radiation measurements conducted on Television Picture Tubes.

These tests, which were sponsored by the Cathode Ray and Allied Tube Section of EIA, were felt to be of sufficient interest to you to warrant reprinting and distribution.

The results of the tests indicated that all standard glass cathode ray television tubes tested would comply with the proposed limit of 0.5 mr. per hour at 5 cm. from the surface of the set, under normal operating conditions.

Yours very truly,

J. A. Cailliaux, Secretary
JEDEC Electron Tube Council

JAC:cjk

6062:1-12:5/59(JEDEC)

ASSOCIATES:
G. H. CAMERON
R. MOONEY

C. B. BRAESTRUP, F.A.C.R. (Assoc.)
REGISTERED X-RAY PHYSICIST
630 WEST 168TH STREET
NEW YORK 32, NEW YORK

WADSWORTH 3-2500
EXT. 7534

June 19, 1958

Cathode Ray Committee
Electronics Industries Association
Engineering Offices
1721 De Sales Street, N. W.
Washington 6, D. C.

Re: Report on X-Radiation Measurements on Television Tubes

Gentlemen:

The enclosed results of my recent x-radiation measurements on various types of black and white television tubes confirm my preliminary report of May 16, 1958. The tests were carried out in accordance with arrangements made by Dr. John L. Sheldon, who also participated in the investigation, and by Mr. C. W. Crockett. The measurements were made at the Industry Service Laboratory in Newark from May 5th to 8th, inclusive, with the collaboration of Mr. J. P. Foltz and Mr. R. Wechsler.

The objective of the tests was to determine the operating conditions under which the tubes meet the proposed maximum exposure level of 0.5 mr per hour.

General Considerations:

Until recent years the basic objective in providing protection against over-exposure to x-rays was to safeguard the health of the individual. For this purpose the American Standards Association Code Z-54.1 of 1946 set an exposure limit of 12.5 mr per hour for Class A installations to meet the prevailing maximum permissible dose of 100 mr per day, as then recommended by the National Committee on Radiation Protection. Tests made since 1949 of representative types of television tubes used in home sets show that these meet the above requirements with a high factor of safety, under normal operating conditions.

The maximum permissible dose has since been reduced to an average of 100 mr per week for radiation workers and 0.5 r per year for persons not occupationally exposed. In addition, further limits have been set on the exposure of large population groups in order to minimize the genetic effects. Since any significant x-ray emission from television

(continued next page)

(continued--)

sets would affect a large percentage of the population, special limitations have been recommended for this type of equipment.

According to the recently proposed recommendations, not yet official, the x-ray emission from television sets should not exceed 0.5 mr per hour when measured 5 cm. from any accessible surface of the set. It should be emphasized that this limitation is for the protection of future generations; it does not necessarily follow that a higher level will cause radiation injuries to any individual.

It has been estimated that if the value of 0.5 mr per hour is not exceeded, the average dose to the population due to television will be less than 2 per cent of the normal background radiation; this is based on assumed average viewing hours and distance.

This increase is insignificant when compared with the normal variation in background. For instance, the background radiation in Denver is about 100 per cent higher than in New York; a person living in a stone house receives of the order of three times as much radiation as one living in a wooden house.

Experimental Set-Up:

No commercial instruments are available for the accurate determination of the x-ray emission from television tubes. It requires sensitive instruments with a minimum wave length dependence in the 15 to 25 K.V. region. Special thin-walled condenser ionization chambers were constructed for this purpose.

The x-radiation was measured in mr per hour by means of these ionization chambers after preliminary scanning with a G-M survey meter. The chambers had previously been calibrated against a standard open-air chamber. No ionization measurements were made where the G-M survey meter showed a level of less than 0.05 mr per hour (five times normal background). Spherical chambers were used where it was desirable to have minimum directional variation in sensitivity.

The chambers were located at positions of maximum radiation level, as determined by the G-M meter, taking into account the nearest possible approach to the tube with the cabinet in place. The description of measuring instruments and test positions of the chambers are shown in the appendix.

(continued next page)

(continued--)

Relation between radiation level and panel distance:

Routine radiation surveys were made with the center of the ionization chamber 5 to 7.5 cm. from the surface of the set. This permits the use of a flat chamber 10 to 15 cm. thick, or a spherical chamber 10 to 15 cm. in diameter, in contact with the set. These short distances are used in order to get sufficiently high readings to eliminate errors due to the normal variations in background radiation. At the usual viewing distances the level of the x-ray field is normally only a small fraction of the background radiation. Since the radiation level at the viewing distance is the one of greatest genetic significance, it is necessary to establish the relationship between the radiation level and distance. This was done with a metal tube having a thin panel and, therefore, abnormally high x-ray emission. The results are shown in Figure 1. The results indicate:

a) there is no significant variation in mr per hour for short distances, between 5 and 8 cm.; this might be expected due to the large area of the x-ray source.

b) the radiation is reduced by a factor of about 12 from 5 cm. to 100 cm. and about 50 from 5 cm. to 200 cm. These factors have been found to be somewhat higher for smaller raster sizes.

c) beyond 100 cm. the radiation is reduced slightly more than by the inverse square law; this may be explained by the air absorption.

(continued--)

Attenuation of the Radiation:

The absorption of the radiation by various materials was determined by placing the absorber between the panel of the 19AP4 tube and an ionization chamber located at 15 cm. distance from the panel. This tube was chosen for this purpose due to its high x-ray emission caused by its thin panel. The thickness of the panel was adequate, however, to ensure essentially monochromatic radiation. Similar attenuation may be expected, therefore, with other tubes. The tabulated results are shown below and the aluminum absorption curves on Figure 2.

KV	Thickness	Weight gm	Material	trans. %	approximate HVL mm	approximate U_{-1} cm
24	.142 in.	599	masonite	83.2		
24	.233 in.	935	masonite	75.4		
24	.250 in.	645	plywood	79.0		
24	.117 in.		L. F. window glass	12.5		
24	.215 in.		safety glass	2.44		
24	0.49 mm.	218	aluminum	67.2		
24	1.02 mm.	458	aluminum	40.7	0.8	8.67
24	1.51 mm.	676	aluminum	26.7		
24	.67 mm.		black iron	.2		
20	1.02 mm.		aluminum	24.4	0.5	13.9

X-ray emission versus current:

Measurements made at 24 KV in contact with the panel of the 19 AP-4 tube showed that the mr per hour was almost directly proportional to the μA, as might be expected from theoretical considerations. The results were:

μA	mr/hr	mr/μA hr
50	21	.42
100	44	.44
200	87	.435
400	167	.418
800	310	.388

(continued--)

X-Ray Emission Versus Voltage:

Figures 3, 4, 5 and 6 show this relationship for different types of tubes. Measurements were made at various locations, as shown on Figure 8, 5 cm. from the surface of the cabinet, without the cabinet in place.

It will be noted that the slope of the graphs is almost the same, irrespective of the tube and the position of measurements. This, of course, might be expected as the radiation is nearly monochromatic. The x-ray emission is very nearly proportional to the twentieth power of kilovoltage.

In addition, measurements were made also at the front in contact with the panel; the readings obtained there were less than 0.1 mr per hour.

In Figure 7 and Table I is shown the current which gives 0.5 mr per hour at the position of maximum radiation level for different voltages.

Table I Maximum Permissible Operating Conditions

for a maximum radiation level of 0.5 mr/hr

tube	21 DEP-4	21 DEP-4	24 AMP-4	21 DQP-6	17 BW P-4	17 BJP-4	ST 1937	19" Metal
KV	#3 μA	#6 μA	#6 μA	#6 μA	#6 μA	#1 μA	#1 μA	μA
19		400				870		
20	760	154			492	523	257	161
21	286	68	455	364	182	180		
22	118	30	190	148				37
23	54	16	85	74				
24		8	40	37				
25			21					11
position of maximum	A	A	A-1	A-1111	A-11	A-11	A-1111	panel
refers to Figure	3	4	5	6				

(continued--)

Conclusions:

The measurements indicate clearly that all the standard glass cathode ray television tubes tested would comply with the proposed limit, 0.5 mr per hour at 5 cm. from the surface of the set, under normal operating conditions.

The highest radiation level was at the sides rather than at the front, where it was found to be less than 0.1 mr per hour. The radiation dose received by the viewer is only a small fraction of the normal background radiation at the usual viewing distance.

Since the measurements were made without cabinet and safety glass in front of the panel, there is an additional significant factor of safety.

Very truly yours,

Carl B. Braestrup

CBB:hr
enclosures

6062:4a-11

FEB 9 1959

ASSOCIATES:
G. H. CAMERON
R. MOONEY

C. B. BRAESTRUP. F.A.C.R. (ASSOC.)
REGISTERED X-RAY PHYSICIST
630 WEST 168TH STREET
NEW YORK 32, NEW YORK

WADSWORTH 3-2500
EXT. 7534

February 4, 1959

Cathode Ray Committee
Electronics Industries Association
Engineering Offices
1721 De Sales Street, N. W.
Washington 6, D. C.

Re: Report on X-Radiation Measurements on Television Tubes Part II

Gentlemen:

Enclosed are the results of the additional measurements of the black and white television tubes. These tests were made at the EIA Standards Laboratory with the collaboration of Dr. John L. Sheldon of Corning Glass, Mr. C. B. Brookover of Kimble Glass and Mr. J. P. Foltz of E.I.A.

The experimental set-up and instruments used were the same as those described in my report of June 19, 1958.

The results of the measurements indicate that all five tubes comply with the proposed limit, 0.5 mr per hour at 5 cm. from the surface of the set, under normal operating conditions. It will be noted that repeat measurements of earlier tests checked very closely.

Please let me know if you should require any additional information.

Very truly yours,

Carl B. Braestrup

CBB:hr

6062:5-12

E.I.A.

Date of Test: Jan. 10, 1959

ASSOCIATES:
G. H. CAMERON
R. MOONEY

C. B. BRAESTRUP, F.A.C.R. (ASSOC.)
REGISTERED X-RAY PHYSICIST
630 WEST 168TH STREET
NEW YORK 32, NEW YORK

WADSWORTH 3-2500
EXT. 7534

TABLE I

SUMMARY OF RESULTS OF RADIATION

MEASUREMENTS

KV (800 uA)	Pos.	CORNING 21 DEP-4			KIMBLE 21 CEP-4		
		#1	#3	#8	#2	#17	#17 Repeat
		mr/hr	mr/hr	mr/hr	mr/hr	mr/hr	mr/hr
21.5	A						0.96
	B'						0.36
	C						0.33
22	A		3.22			1.56	
	B'					0.57	
	C		0.74			0.51	
	C'						
	F						
22.5	A	0.92			1.07		
	B'	0.36			0.41		
	C	0.55			0.29		
23	A	1.49	7.10	0.73	1.67	3.64	
	B'	0.57		0.34	0.66		
	C	0.78	2.26	0.55	0.58	1.2	
	C'		3.16				
	F					0.1	
24	A	3.37	15.1	1.74	3.76	8.10	8.10
	B'	1.24		0.75	1.46	2.98	3.12
	C	1.79		1.26	1.12	2.74	2.78
	F	0.11	0.47			0.14	
25	A	6.95		3.74	8.10		15.6
	B'	2.70		1.74	2.91		6.04
	C	3.80		2.62	2.83		5.52
	F	0.28	0.336	0.15	0.17		0.16

E.I.A.

Date of Test: Jan. 10, 1959

ASSOCIATES:
J. H. CAMERON
R. MOONEY

C. B. BRAESTRUP. F.A.C.R. (ASSOC.)
REGISTERED X-RAY PHYSICIST
630 WEST 168TH STREET
NEW YORK 32, NEW YORK

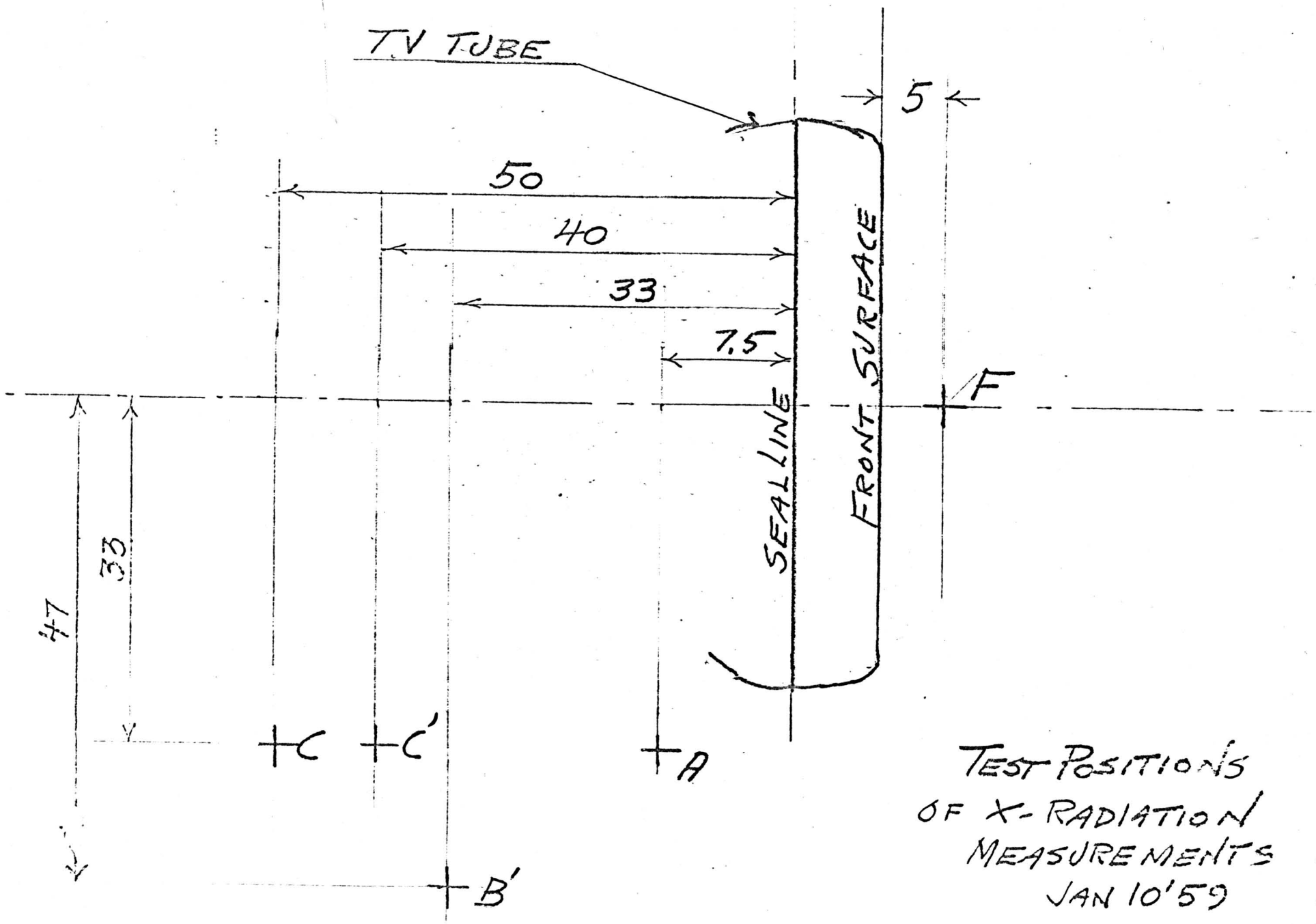
WADSWORTH 3-2500
EXT. 7534

TABLE II

MAXIMUM PERMISSIBLE OPERATING CONDITIONS

for a maximum radiation level of 0.5 mr/hr

	CORNING 21 DEP-4			KIMBLE 21 CEP-4	
KV	#1	#3	#8	#2	#17
21.5	μA	μA	μA	μA	417 μA
22		124			256
22.5	435			374	
23	268	56	550	240	110
24	119	27	230	107	49
25	58		107	49	26



TEST POSITIONS
OF X-RADIATION
MEASUREMENTS
JAN 10'59

6062:6a-12

ASSOCIATES:
G. H. CAMERON
R. MOONEY

C. B. BRAESTRUP, F.A.C.R. (ASSOC.)
REGISTERED X-RAY PHYSICIST
630 WEST 168TH STREET
NEW YORK 32, NEW YORK

WADSWORTH 3-2500
EXT. 7534

FEB 24 1959

February 20, 1959

Cathode Ray Committee
Electronics Industries Association
Engineering Offices
1721 De Sales Street, N W.
Washington 6, D. C.

Re: Report on X-Radiation Measurements on Television Tubes Part II

Gentlemen:

This is in further reference to my report of February 4, 1959. Mr. G. B. Brookover of Kimble Glass Company has informed me that only their tube #2 is representative of their present production of T.V. bulbs. The higher radiation levels found on their #17 tube may therefore not be expected on present types.

Very truly yours,

Carl B. Braestrup

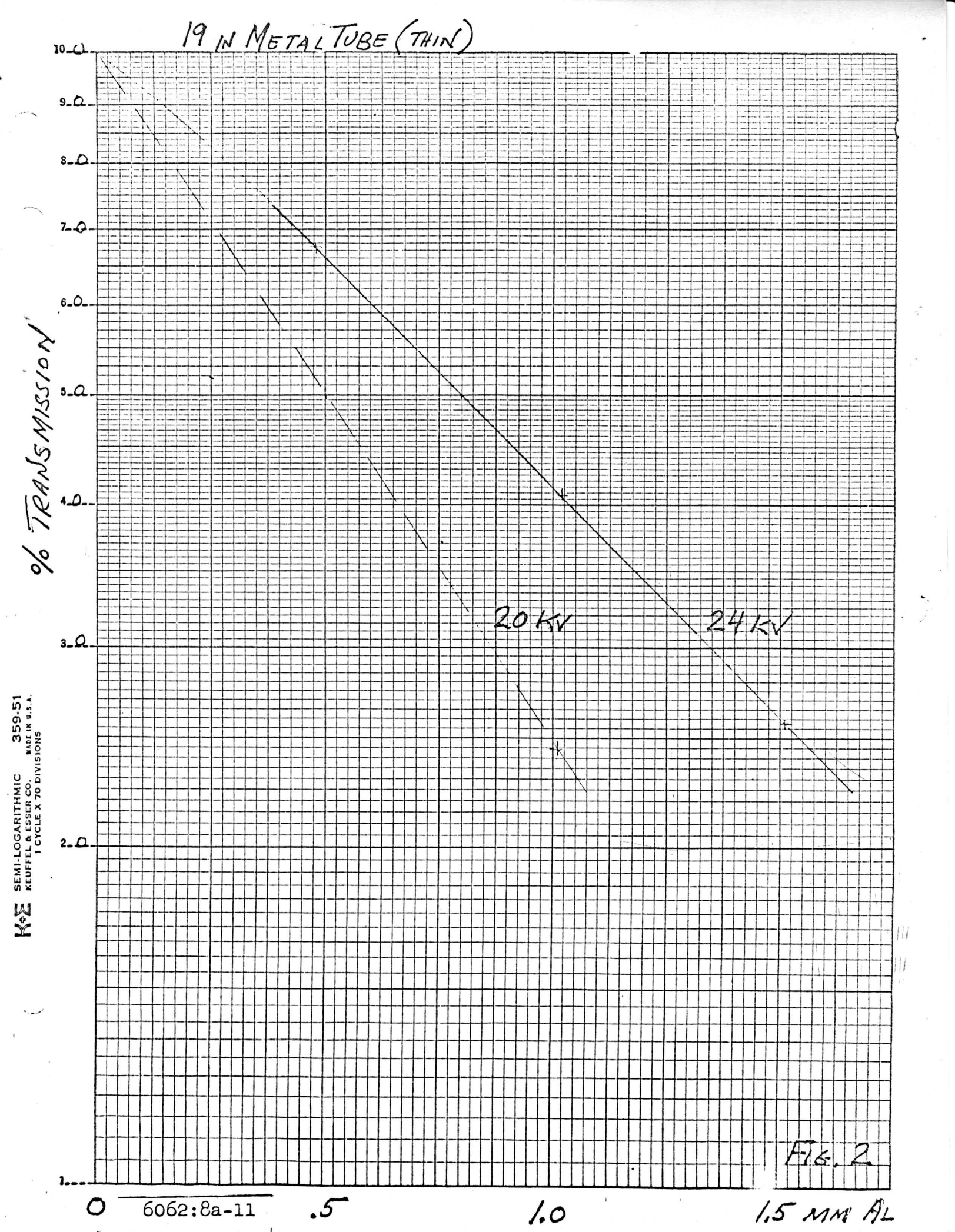
Carl B. Braestrup

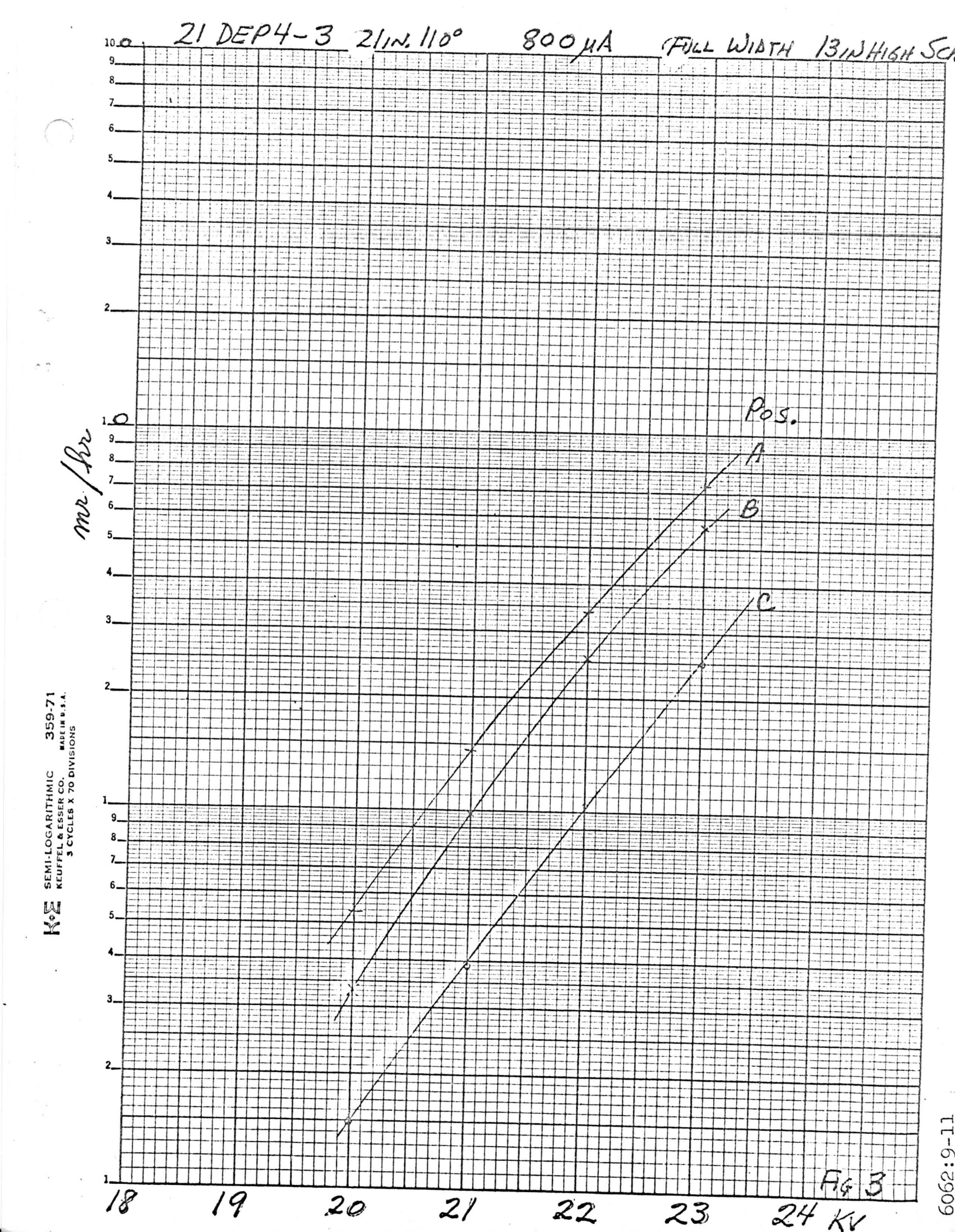
CBB:hr

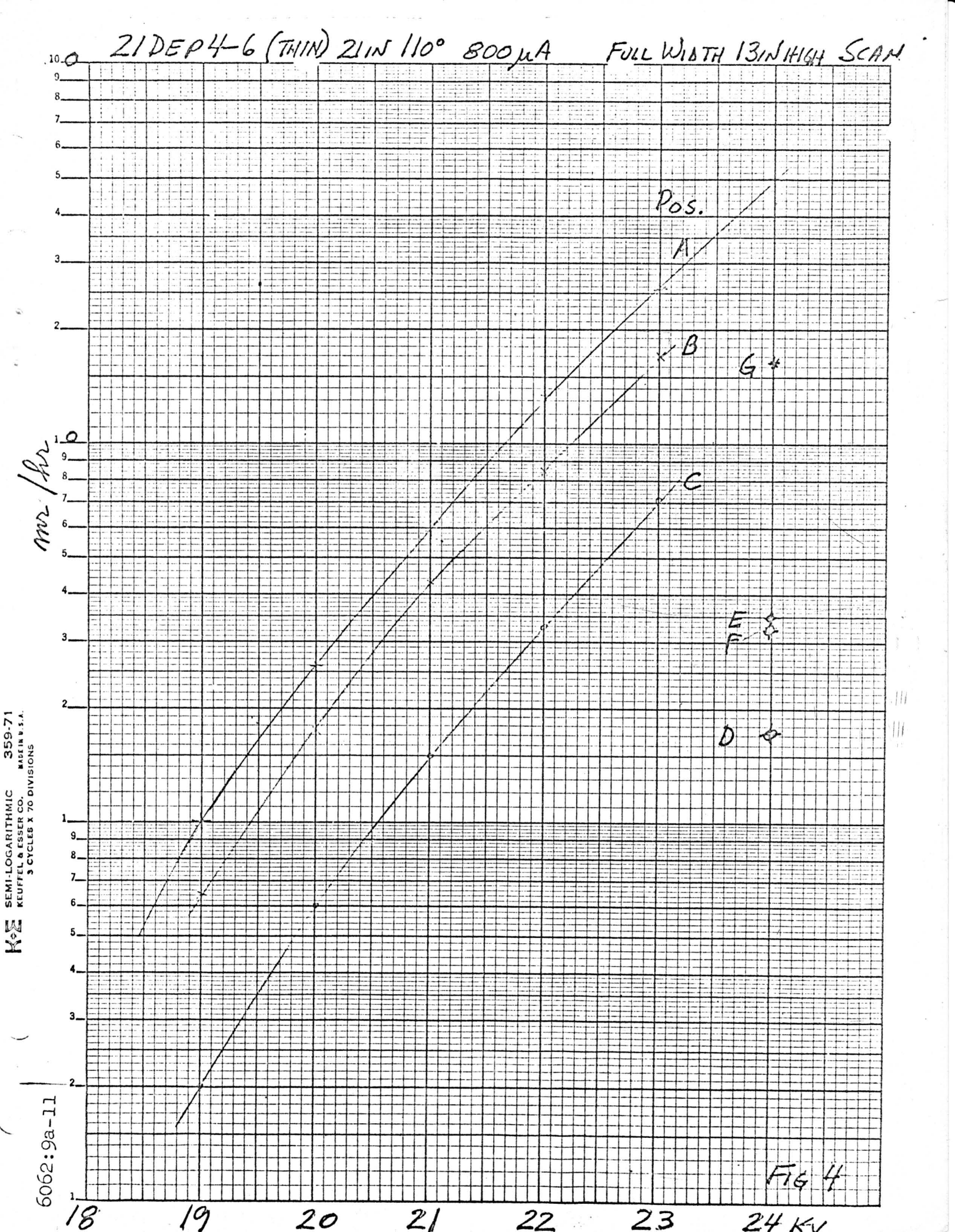
6062:7-11

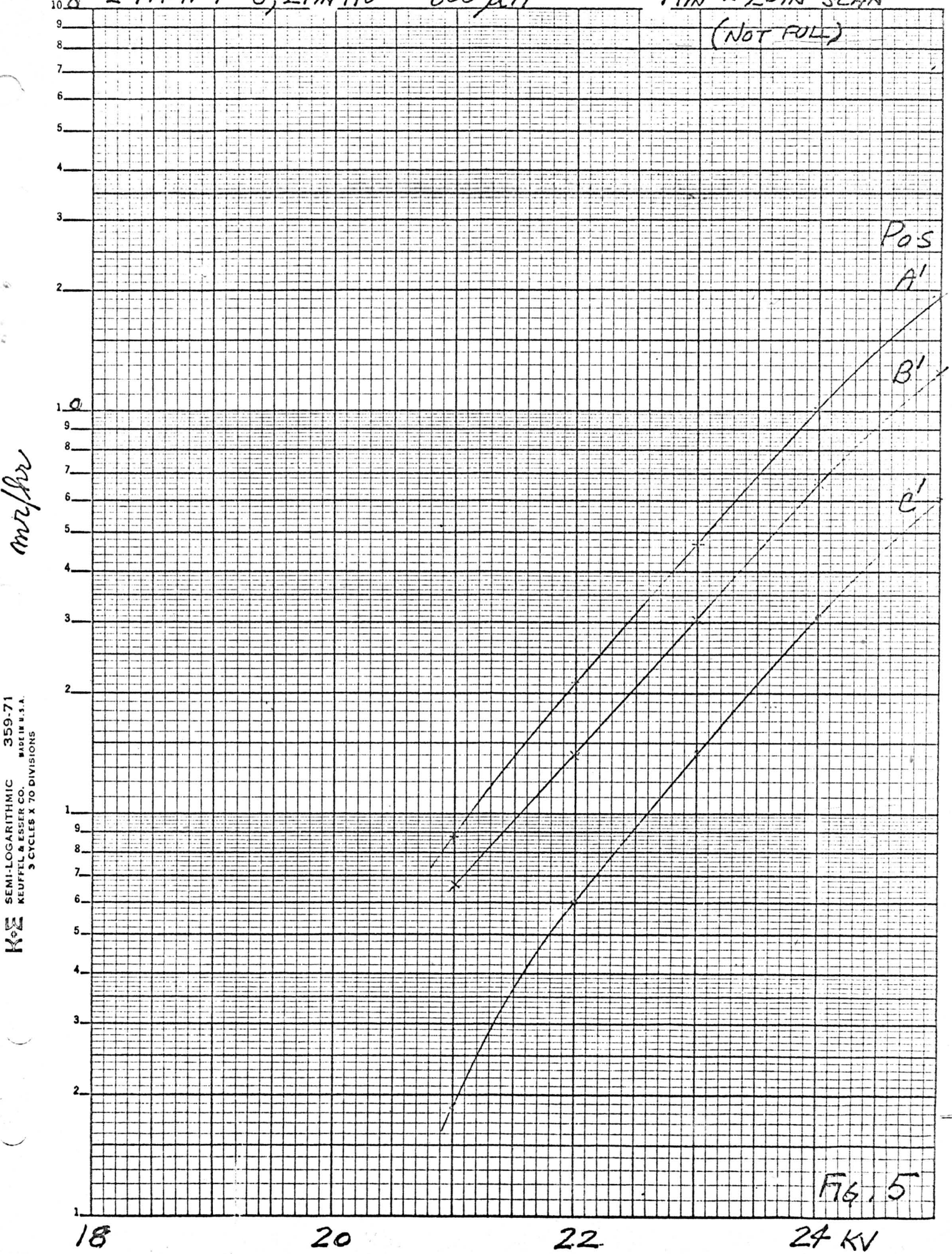
FIG 1

6062:8-11


19 IN METAL TUBE (THIN)
10
9
8
7
6
5
4
3
2
1
% TRANSMISSION
20 KV
24 KV
SEMI-LOGARITHMIC 359-51
KEUFFEL & ESSER CO. MADE IN U.S.A.
1 CYCLE X 70 DIVISIONS
K&E
FIG. 2
0
6062:8a-11
.5
1.0
1.5 MM AL


21 DEP4-3 21 IN. 110° 800 μA (FULL WIDTH 13 IN HIGH SC
mr/hr
Pos.
A
B
C
18
19
20
21
22
23
24 KV
Fig 3
SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
6062:9-11


21DEP4-6 (THIN) 21IN 110° 800μA FULL WIDTH 13IN HIGH SCAN
Pos.
A
B
C
D
E
F
G
mr/hr
10
9
8
7
6
5
4
3
2
1
18
19
20
21
22
23
24 KV
SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
6062:9a-11
FIG 4


24 AMP 4-6; 24 IN 110° 800 μA
14 IN × 20 IN SCAN
(NOT FULL)
Pos
A'
B'
C'
mr/hr
10
9
8
7
6
5
4
3
2
1
18
20
22
24 KV
SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
Fig. 5
6062:10-11

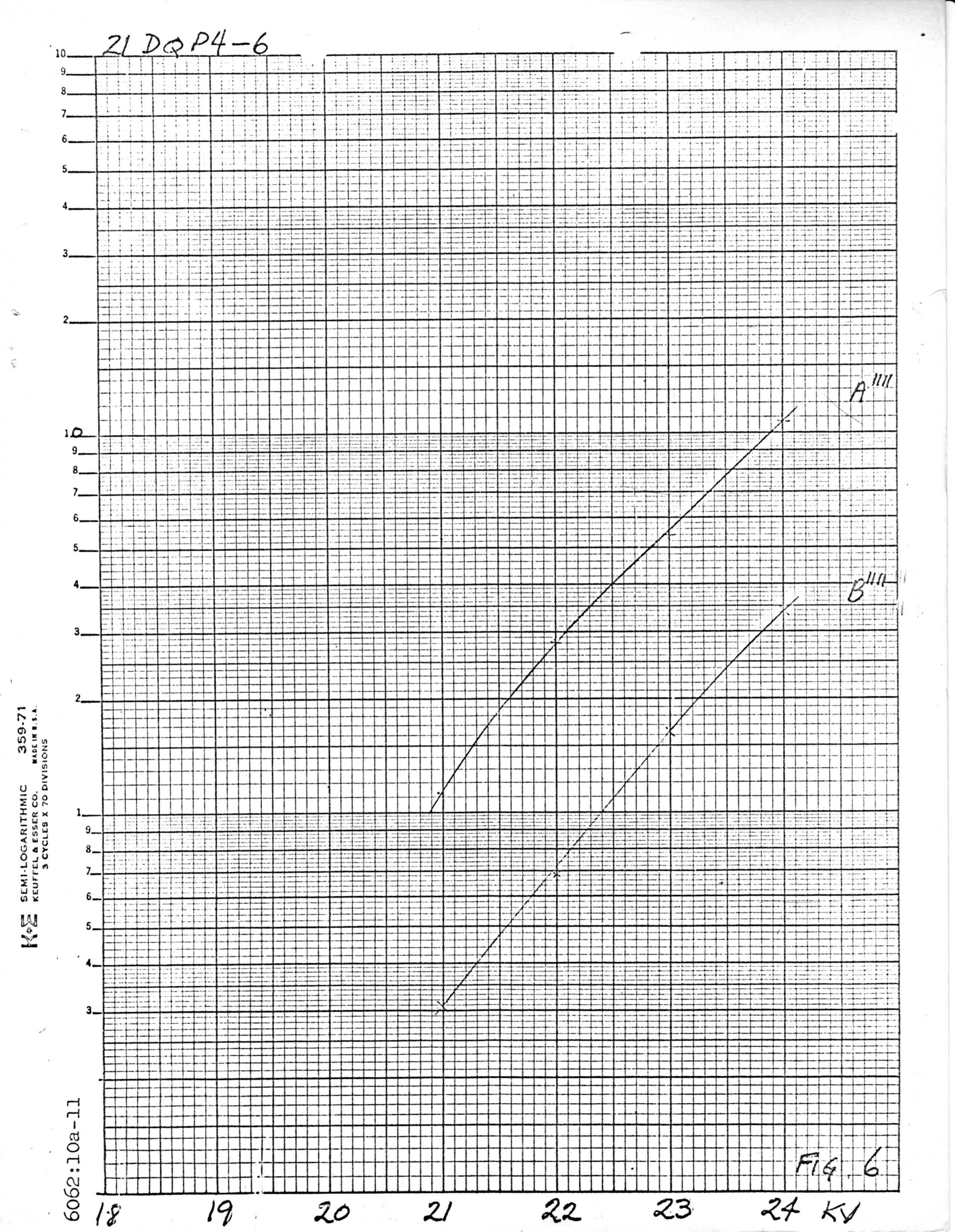
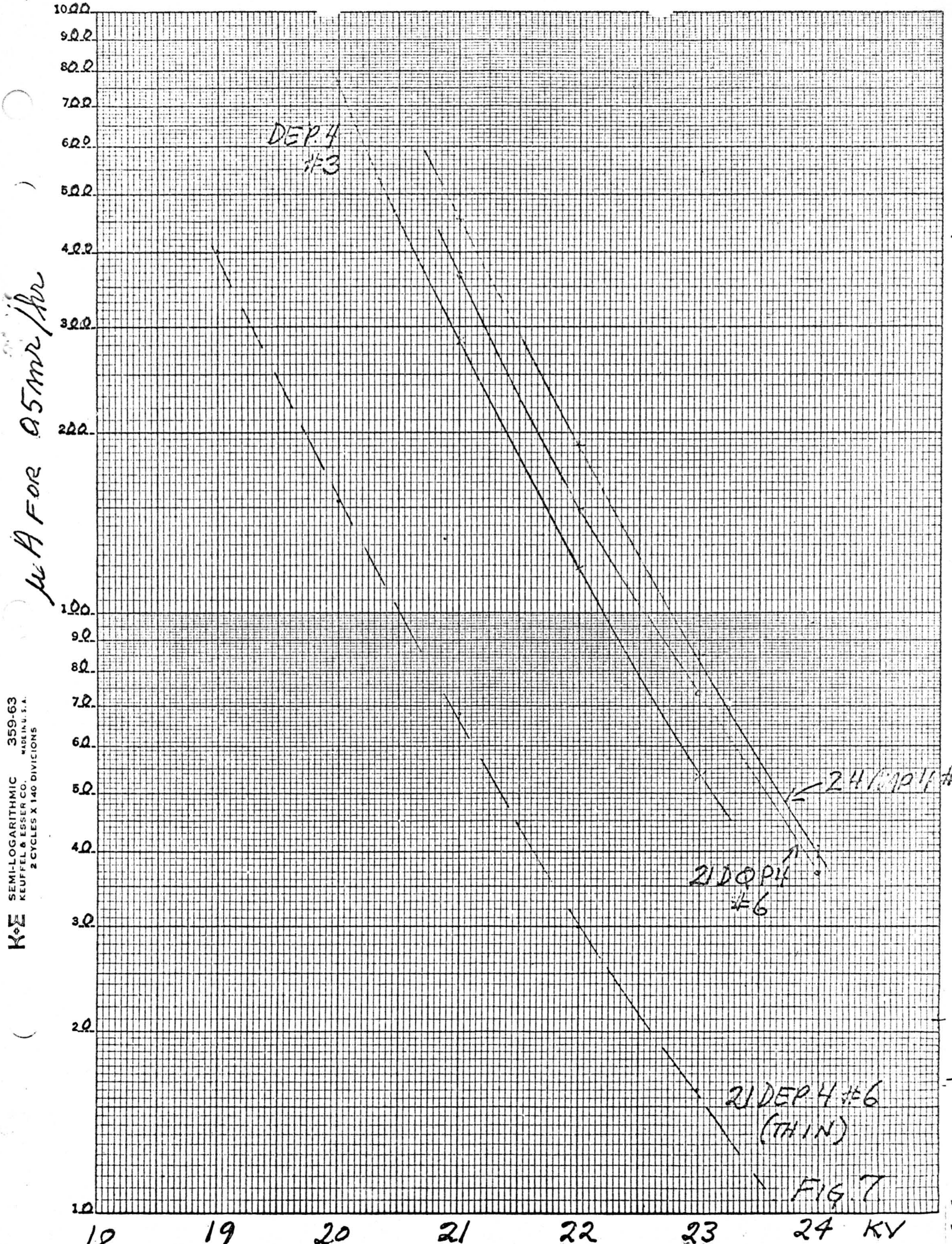
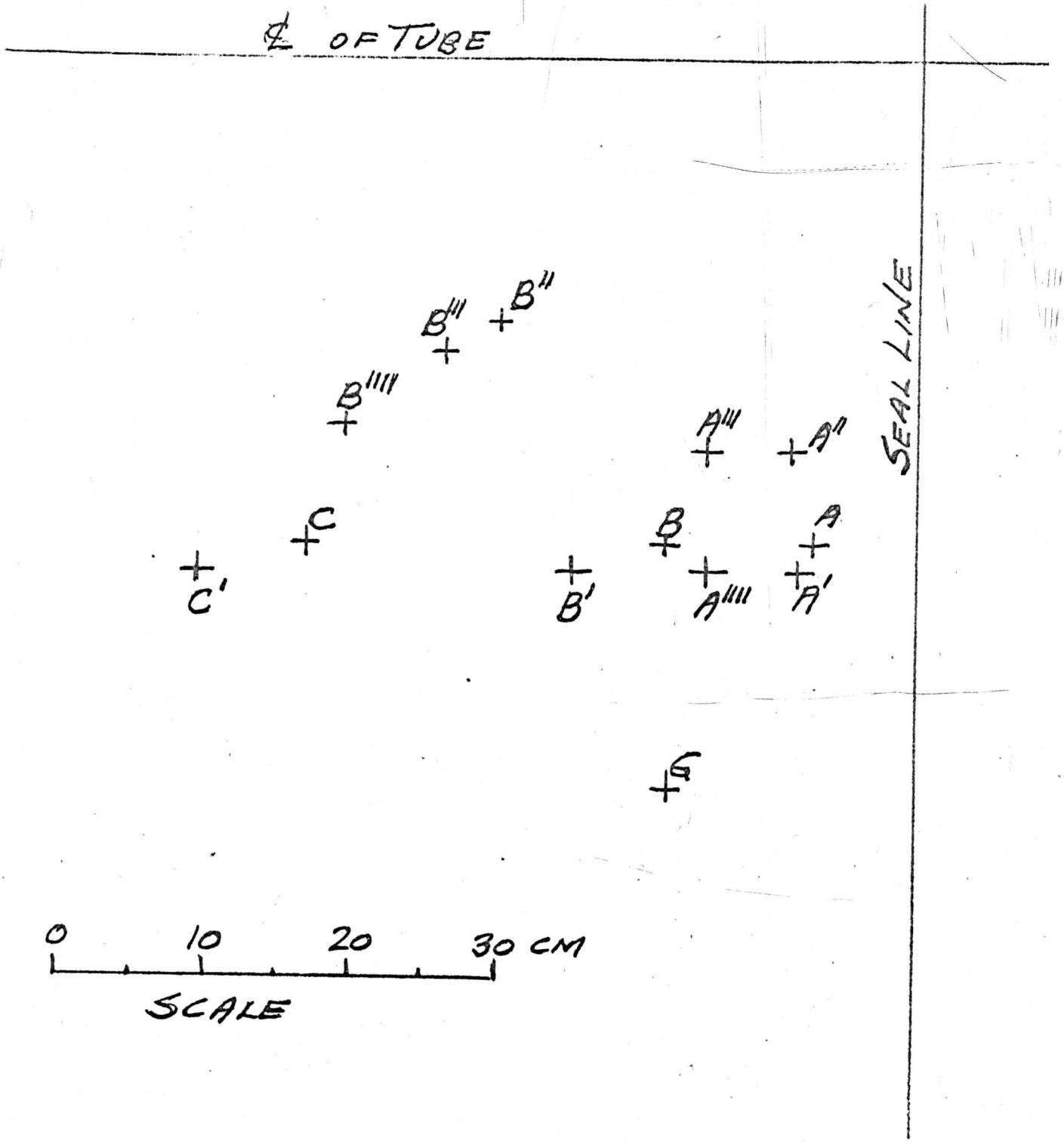

21 DQP4-6
A'''
B'''
10
9
8
7
6
5
4
3
2
1
18
19
20
21
22
23
24
KV
SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
6062:10a-11

Fig. 6


μA FOR .05mr/hr
DEP 4 #3
24 DEP 4 #6
21 DEP 4 #6
21 DEP 4 #6 (THIN)
FIG. 7
KV
18
19
20
21
22
23
24
SEMI-LOGARITHMIC 359-63
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 140 DIVISIONS
6062:11-11



POSITIONS OF MEASUREMENTS

F E D

FIG 8