University of California

PROGRESS REPORT FOR NASA CONTRACT SC-NSR-05-003-100

December 31, 1965

Enclosed is the November 17, 1965 progress report prepared by ITTIL.

The ten ITT tubes available to Lick have been extensively tested in the laboratory. In general our feeling is that the pulse height distribution of these tubes is quite good. This has been adequately documented in the ITT portion of this report; our findings are in good agreement with theirs. The dark current is still rather high (ten counts/sec when the tube is cooled to dry ice temperatures) but we have not yet received prototypes of the final version of the tubes and until we do it will be impossible to estimate the dark current to be expected from the delivered tubes.

We have extensively investigated the gain in quantum efficiency as a function of wavelength that can be realized if the input illumination that is reflected rather than absorbed at the photocathode is returned to the photocathode. This is accomplished (as shown in Figure 1) by placing a right angle prism with one aluminized face in optical contact with the faceplate of the photomultiplier tube; the incident light then strikes the cathode at 45° incidence. The increase in electron yield when the tube is illuminated in this manner rather than by normal incidence as is the usual practice averages about 20% at $\lambda = 4200$ Å and about 80% at $\lambda = 7000$ Å. The increased yield in the red is almost certainly due to the greater transparency of the photocathode in the red. When the prism is used, 50% of the ITT photocells that we now have show a peak quantum efficiency greater than 23% and the most sensitive one has a peak quantum efficiency of 26%. This is satisfactory although one may expect that higher electron yield in the blue can be obtained if the photocathode is made somewhat thinner.

We have still not received the prisms we need for testing the tubes at the telescope. When the prisms arrive we will proceed with the telescope tests.

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(THRU)
None
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FACILITY FORM 602

E. J. Wampler

E. J. Wampler

[redacted]

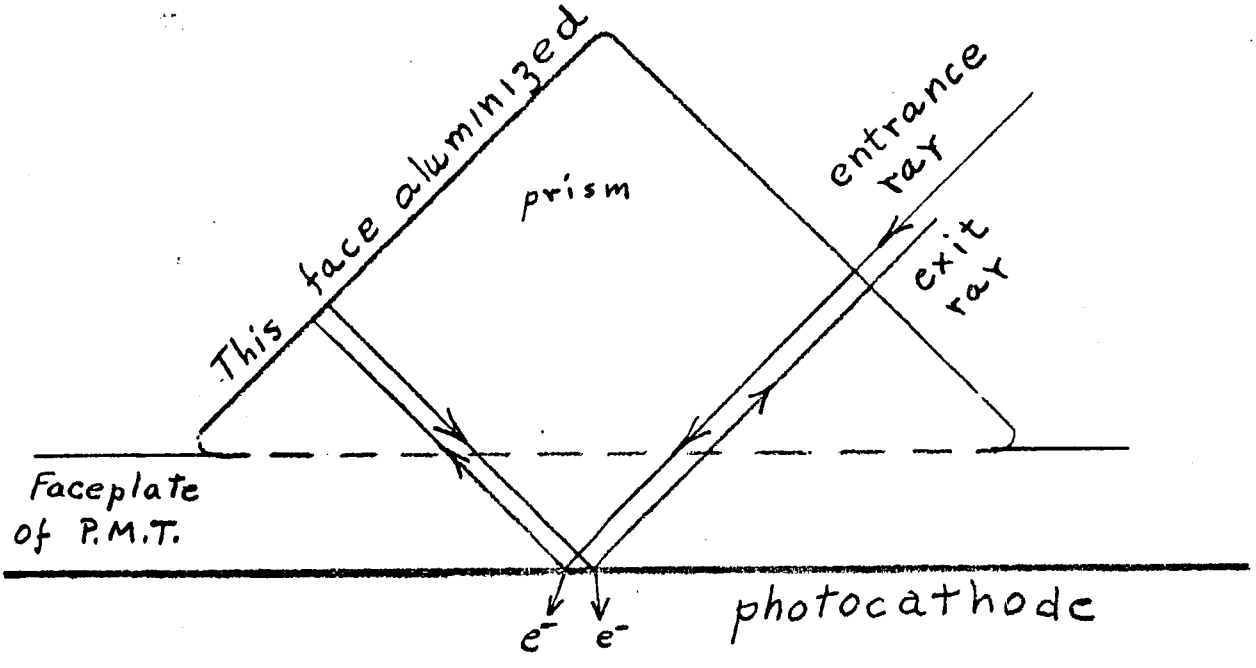

Fig. 1.--Method of returning unabsorbed light to the photocathode in order to increase electron yield.

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UNIVERSITY OF CALIFORNIA
LICK OBSERVATORY

Contract #G607170
ITTIL Project #14-90300

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RESEARCH CONTRACTS

IMPROVED QUANTUM EFFICIENCY DETECTOR

Progress Report

November 17, 1965

Prepared by
A. Knight

PROJECT REPORT

1.0 INTRODUCTION

1.1 During this period the effort has been directed toward solving the problems of optimizing the electron-optical input section and experimenting with entrance window materials; i.e., quartz and sapphire. The use of an extra aperture between the defining aperture and dynode #1 has been evaluated in F64-974-2 X-18 while the addition of a circular field shaping electrode located in the annular space between the aperture and focus electrodes has been tested in F64-974-2 X-21. Special test tubes IC-6 X-19 and X-20 in which a willemite phosphor screen replaced the defining aperture have been built to provide visual discernment of results from modification in the image section geometry. A description of tubes built and test results are contained in the following paragraphs.

2.0 TUBES CONSTRUCTED AND TEST RESULTS:

2.1 F64-974-2 X12(S20, 450R) is a modification of the ITTKL FW130 having a .21 magnification image section, 16 stage multiplier and flat-flat quartz window. See drawing 4711064. It is similar to F64-974-2, X20 described in the previous August report. Tube characteristics are found in figures 1, 2, 3 and 4.

2.2 F64-974-1 X-13 has a 12 stage multiplier and the unfocused electron-optical image section. This tube is similar to F64-974-1 X-9 described in the August report. (See drawing 4711032). The S20 cathode sensitivity was 60 ua/lu (2870°K source), 712 ua/lu (4113 blue filter) and 3.2 ua/lu. The effective cathode diameter was approximately .950" and a gain of 10^6 was obtained at 2300 volts overall. However, the pulse height distribution was exponential,,with many small pulses noted, similar in this respect to the X-9.

2.3 F64-974-2 X-14 (S-20, 450R) is constructed according to drawing 4711064 except for a change in the entrance window which is 7056 glass, of plano-concave surfaces. Figures 1, 2, 3, 4, 5, and 6 give the measured values of the responsivity, equivalent noise input, anode dark current, cathode spectral response, pulse height distribution and IEPD(instantaneous effective photocathode dimension)respectively

2.4 F64-974-2 X-15 (S-20, 450R) is similar to X-14 in design. See figures 1, 2, 3, 4, 7 and 8, for measured tube characteristics.

2.5 IC-6 X-16 and 16-6 X-17 - are S20 test tubes having plano-concave quartz windows sealed to a 7052 glass envelope with a silver chloride seal and having an external appendage to contain the bialkali generators. Cathode sensitivities of 60 and 67 ua/lu respectively, were measured on the exhaust system before tipoff. Both tubes developed leaks from the Kovar pinch-off.

2.6 F 64-974-2 X-18 (S-20, 450R) is similar in design to drawing 4711064 with the following modifications:

a. The entrance window is 7056 glass, with both surfaces flat and parallel.
b. An extra aperture has been included between the defining aperture and dynode 1, see figure 9 below:

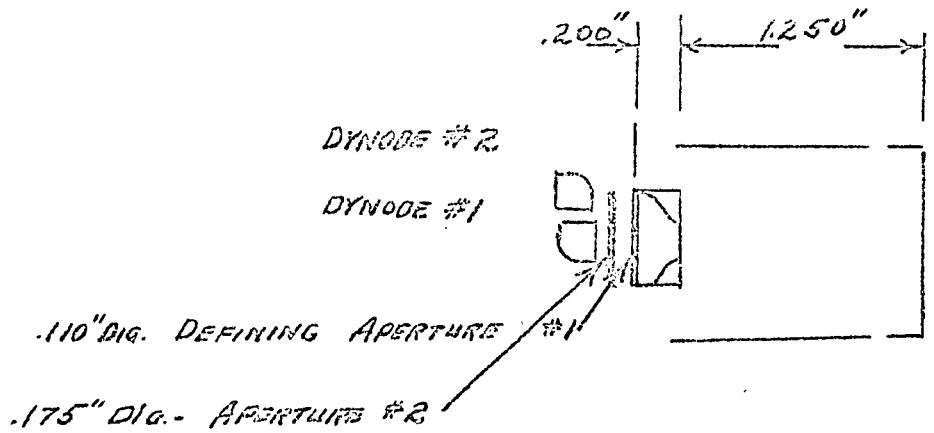


Figure 9.

The function of the second aperture as determined on Contract NASw 1038 is to repel low energy electrons which may be emitted from the aperture electrode under the impact of high energy primary electrons emitted from the cathode and accelerated by the potential between the cathode and aperture electrode. This requires a small negative potential on the second aperture with respect to the defining aperture.

In actual measurements, best results were obtained when aperture #2 was 90 volts negative with respect to the defining aperture and, in this mode of operation, the combination of aperture and dynode #1 possibly acted as a type of Einsel lens tending to converge the electron beam in the area between the defining aperture and dynode #1.

Figures 1, 2, 3, 4, 10 and 11 contain the measured tube characteristics.

2.7 16-6 X-19 is an image test tube having an S-1 cathode, a willemite phosphor screen in the plane of the defining aperture and replacing it, an annular ring electrode and modified spacing as shown in figure 12.

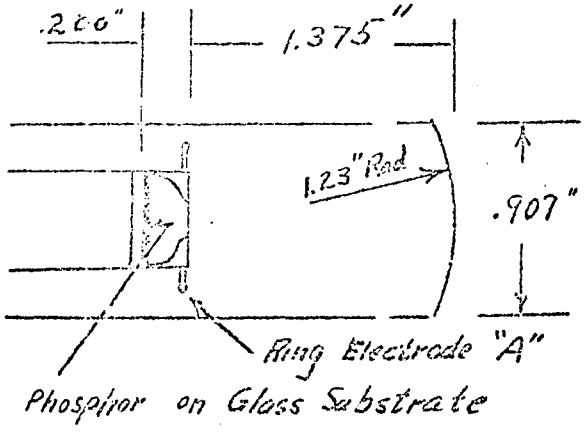


Figure 12.

This tube was built to determine the effect of increased spacing between the aperture electrode and cathode and also the result of applying a potential to an electrode, designated as electrode "A" located as shown in figure 12.

The results observed so far have been as follows:

a. With 1900 volts between the cathode and aperture electrode, a focus voltage 22 volts positive with respect to the cathode and electrode "A" at the aperture electrode potential, an image .144" diameter was measured on the phosphor corresponding to an IEPD of .7" giving a magnification of approximately .21.
b. Under the same operating conditions as in a, but with electrode "A" at the cathode potential, an image .120" diameter on the phosphor corresponded to an IEPD of .7" for a .17 magnification.

2.8 XC-6 - X-20 is an image test tube, similar in construction to X-19, built to note the effect of combining the standard FW130 image section spacing of .850" between the cathode and aperture electrode with the .2 spacing between the aperture cone and defining aperture as used in the F64-974-2 tubes. See figure 13.

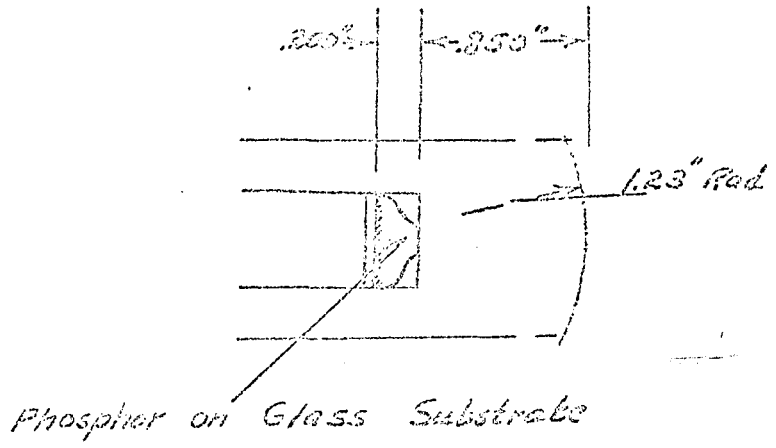


Figure 13.

The test results observed were:

a. With 1900 volts overall and the focus electrode 200 volts positive with respect to the cathode, an area of about .5/16" diameter on the cathode corresponded to an area of 1/32" diameter on the phosphor for a mag of .1.
b. With the same overall voltage, but with the focus electrode at cathode potential .076" diameter on the phosphor corresponded to .4" on the cathode and .148" diameter on the phosphor to .625" diameter on the cathode for magnifications of .19 and .24 respectively.

2.9 F64-974-2 X21 (S-20, 420R) is constructed according to drawing 4711064, but with the image section modified to include an electrode similar to the electrode A in figure 12. The cathode sensitivity was very low, 19 ua/lu, but sufficient to test the tube. The results of these tests are shown in figures 1, 2, 3, 4, 14 and 15. Apparently no siginficant advantage has been gained in this instance. A slight increase in the IEPD from .420 to .435 is obtained by changing the electrode A from aperture electrode to cathode potential. However, this is accompanied by an increase in the dark counting rate from 114/sec. to 145/sec.

Overall tube performance is optimum with electrode A at aperture electrode potential.

The difference in the amplitude of the signal spectra in figure 14 is not readily explainable, but may have been caused by a change in the signal light intensity during test.

3.0 PARTS AND MATERIAL PROCUREMENT

3.1 A copper tipoff assembly has been developed and will be incorporated in future tubes.

3.2 Sapphire windows sealed to a Kovar heliarc weld ring have been obtained from Entel-McCullough, Inc., San Carlo, California. These will be evaluated as soon as an additional glass working fixture is obtained to permit a heliarc seal at each end of the cathode section of the tube envelope.

3.3 Two one liter/sec. Varian Vac Ion pump and magnets have been purchased for use in off system ion pumping of multiplier phototubes built on this project.

4.0 FUTURE EFFORT.

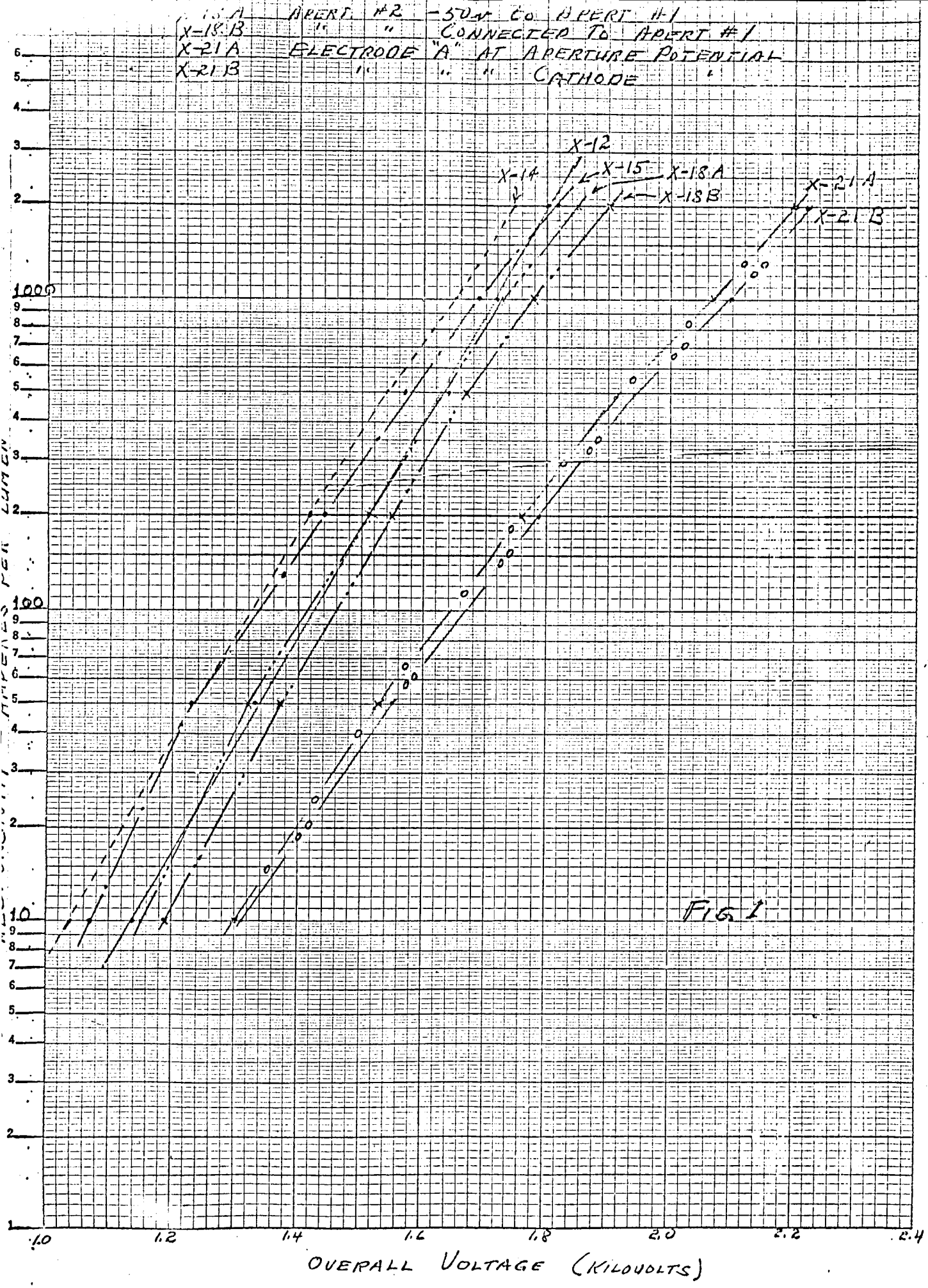
4.1 At the present level of effort, development funds will be expended by December 31, at which time tube fabrication for delivery of six contractual tubes will begin. During this period it is planned to build the F64-974-3 type tube for evaluation of image and multiplier section modifications in all cases except where it is clearly advantageous to build a standard type.

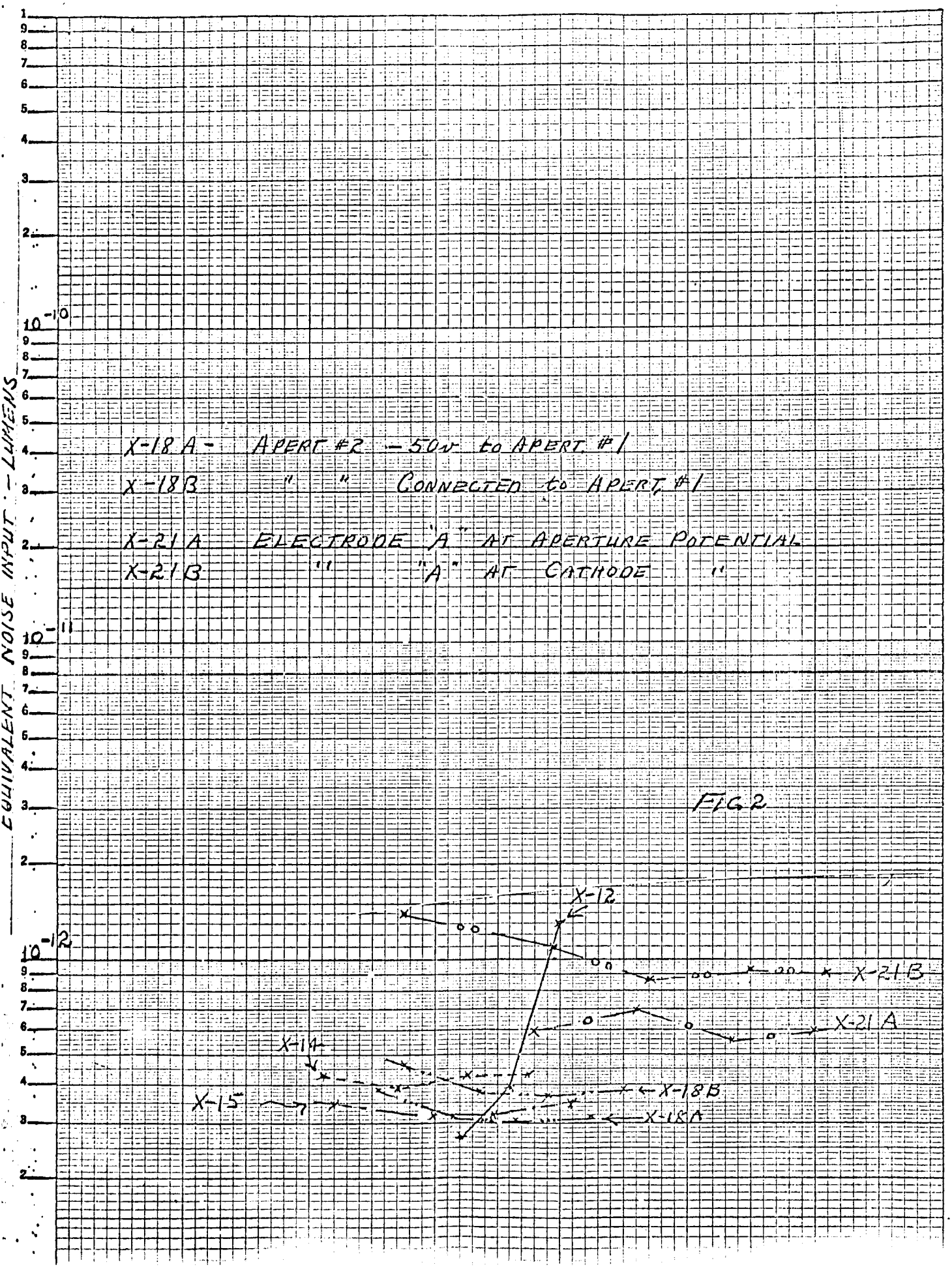
4.2 The following decisions have yet to be finalized:

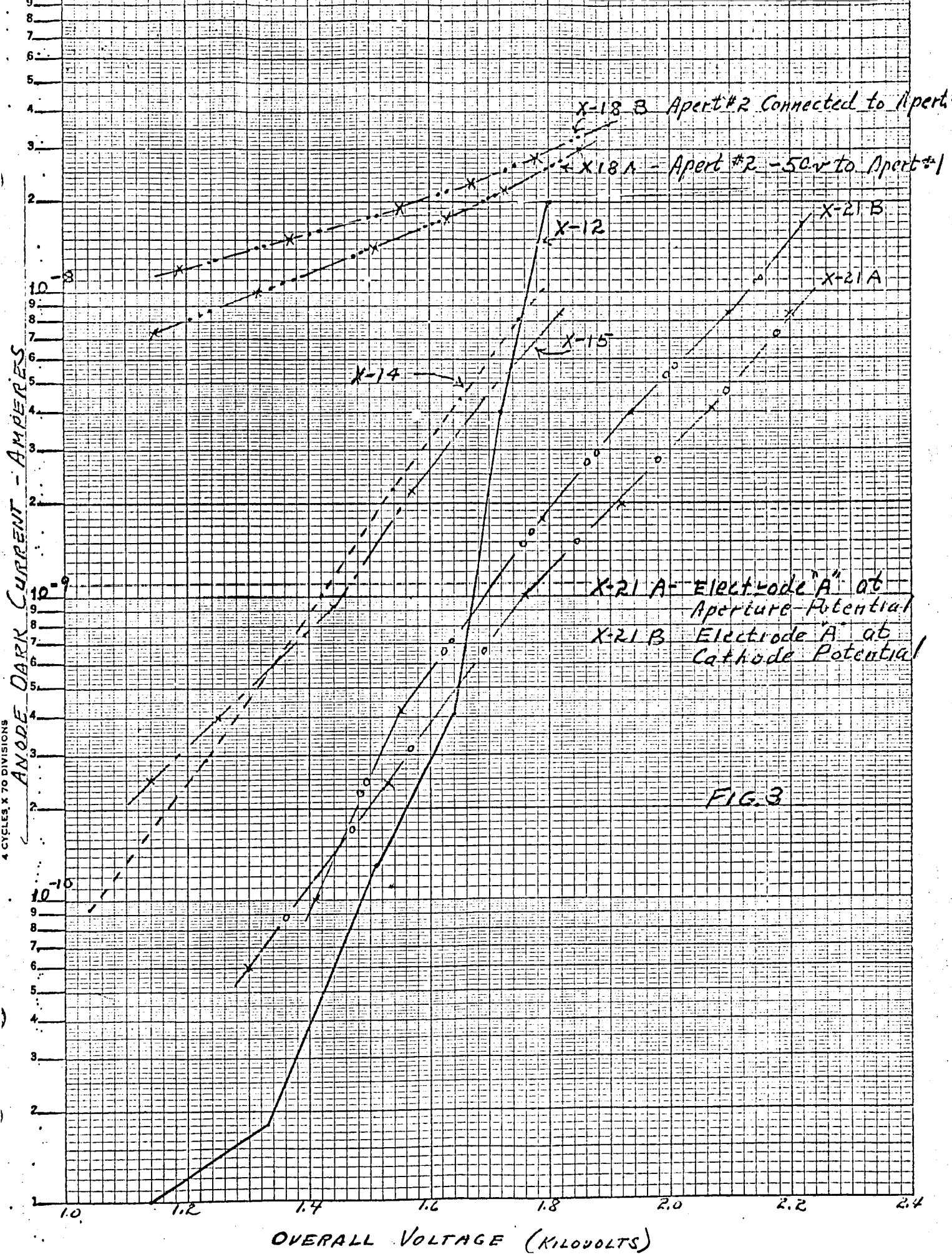
a. Exact electron optical input geometry. Two modifications, tested in image tubes, have yet to be fully evaluated in a multiplier phototube.
b. Type of entrance window. - Tests to date indicate either flat or curved inner surface will provide the necessary IEPD when the .21 image electron optics are used.

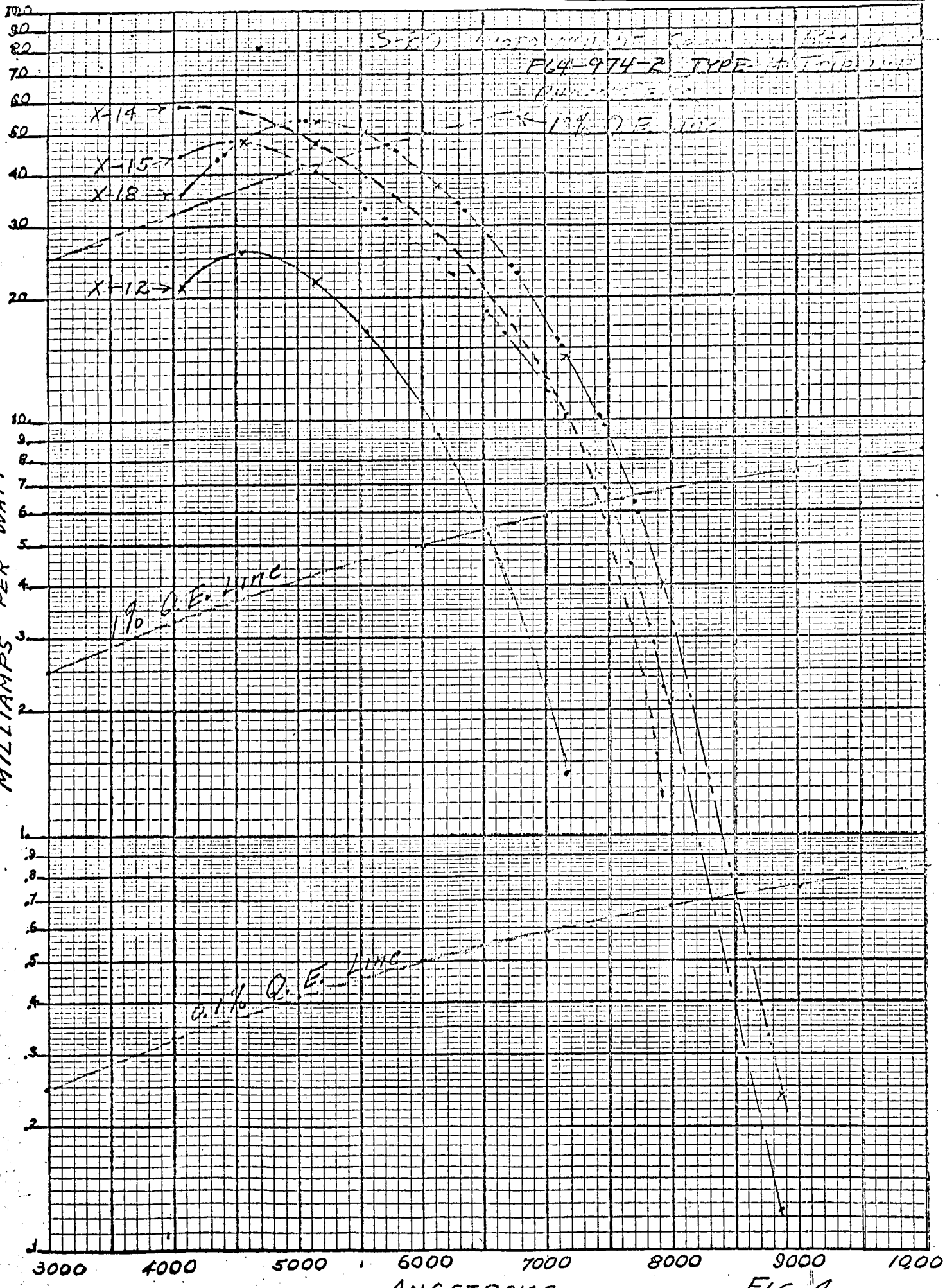
The .450 max. diameter reported to date can probably be increased by the use of a larger diameter defining aperture. Whether "dynasil" fused silica or sapphire are used must also be decided and this decision will be based on window sealing and cathode formation problems encountered.

4.3 It is expected that the geometry of the F64-974-3 type will be retained with perhaps a modification in the cathode assembly if a sapphire window (See drawing 4711049) is used. The multiplier will be our standard box and grid type with twelve stages and an anode supported in a manner to provide complete isolation from any internal leakage currents.


X-18 A APERT #2 -50μ Co APERT #1
X-18 B " " CONNECTED TO APERT #1
X-21 A ELECTRODE "A" AT APERTURE POTENTIAL
X-21 B " " " " CATHODE
X-12
X-14
X-15
X-18 A
X-18 B
X-21 A
X-21 B
1000
100
10
1
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
OVERALL VOLTAGE (KILOVOLTS)
FIG 1


EQUIVALENT NOISE INPUT - LUMENS
X-18 A - APERT #2 - 50v to APERT #1
X-18B " " CONNECTED to APERT #1
X-21 A ELECTRODE "A" AT APERTURE POTENTIAL
X-21 B " "A" AT CATHODE "
FIG 2
X-12
X-21 B
X-21 A
X-1A
X-18 B
X-15
X-18 A

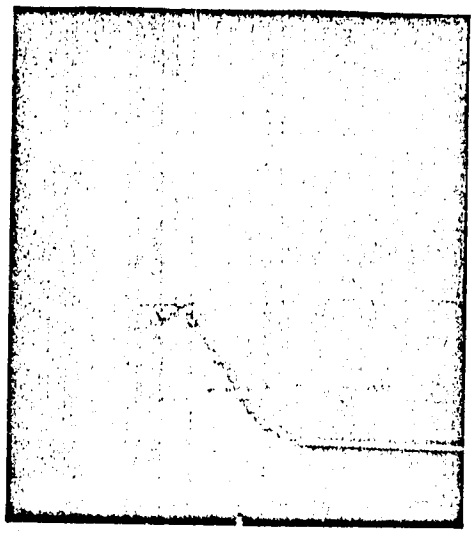

X-18 B Apert #2 Connected to Apert
X-18 A - Apert #2 -50v to Apert #1
X-12
X-21 B
X-21 A
X-15
X-14
X-21 A - Electrode "A" at Aperture Potential
X-21 B Electrode "A" at Cathode Potential
FIG. 3
ANODE DARK CURRENT - AMPERES
OVERALL VOLTAGE (KILOVOLTS)
4 CYCLES X 70 DIVISIONS
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
10^{-8}
10^{-9}
10^{-10}



F64-974-2 TYPE
X-14
X-15
X-18
X-12
1% Q.E. Line
0.1% Q.E. Line
MILLIAMPS PER WATT
3000
4000
5000
6000
7000
8000
9000
10,000
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

Signal

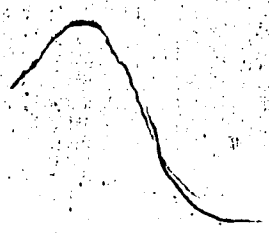
1071	3.01
492	1.02
339	7.03
359	2.04
344	5.05
318	9.06
326	5.07
322	8.08
322	0.09
332	0.10
341	2.11
349	1.12
341	5.13
371	1.14
401	6.15
386	0.16
395	9.17
402	7.18
403	7.19
418	9.20
428	4.21
443	7.22
431	1.23
432	0.24
438	7.25
434	8.26
432	9.27
434	3.28
413	0.29
396	7.30
400	1.31
406	4.32
387	8.33
371	0.34
378	7.35
361	6.36
339	2.37
327	8.38
302	1.39
294	1.40
305	7.41
281	1.42
264	7.43
246	4.44
241	2.45
222	9.46
212	4.47
201	7.48
191	7.49
173	2.50
164	0.51
150	8.52
145	9.53
132	0.54
131	6.55
112	7.56
106	1.57
91	0.58
89	3.59



DARK SPECTRUM

PARTIAL PRINT-OUT OF PULSE HEIGHT DISTRIBUTION
FL4-974-2 X-14

1900V OVERALL
τ = .5 MIN
GAIN = 50 & 3.0
CATHODE +4V w/respect to WALL



SIGNAL SPECTRUM

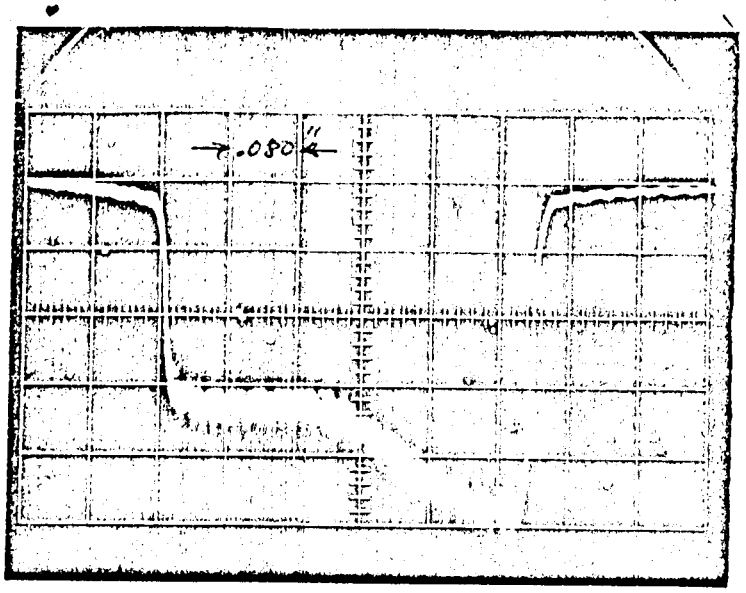
Fig 5

Dark

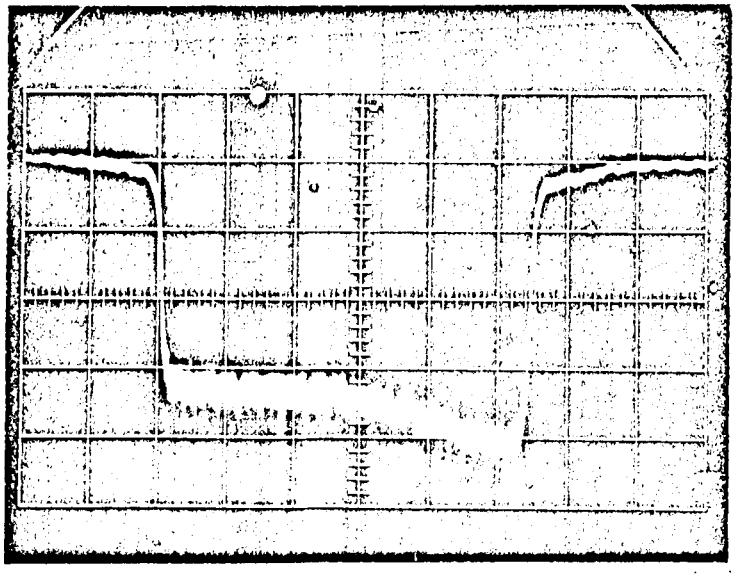
1098	0.01
345	6.02
205	7.03
221	1.04
218	0.05
216	8.06
220	3.07
223	8.08
231	0.09
232	3.10
222	0.11
222	6.12
209	0.13
212	1.14
208	4.15
189	8.16
175	5.17
159	8.18
164	1.19
145	0.20
147	1.21
130	8.22
125	8.23
115	2.24
105	4.25
88	4.26
83	0.27
77	5.28
66	5.29
60	2.30
54	0.31
47	5.32
36	4.33
38	8.34
36	0.35
24	9.36
22	9.37
18	5.38
16	6.39
15	2.40
11	5.41
10	7.42
7	7.43
6	0.44
6	3.45
5	9.46
4	4.47
2	6.48
1	5.49
1	3.50
2	1.51
1	1.52
1	1.53
	8.54
	3.55
	4.56
	5.57
	2.58
	1.59

400V cath to ground

4V + focus



E64-974-2, X-14 .100" DEFINING APERTURE
400 Volts K-Ap. Focus Elec. +3.5v
80 mil/cm scan D-1 Width



Scan D-1 Length

IEPD As Measured by Scanning the photo electron beam generated by a .001" dia spot of light centered on the cathode

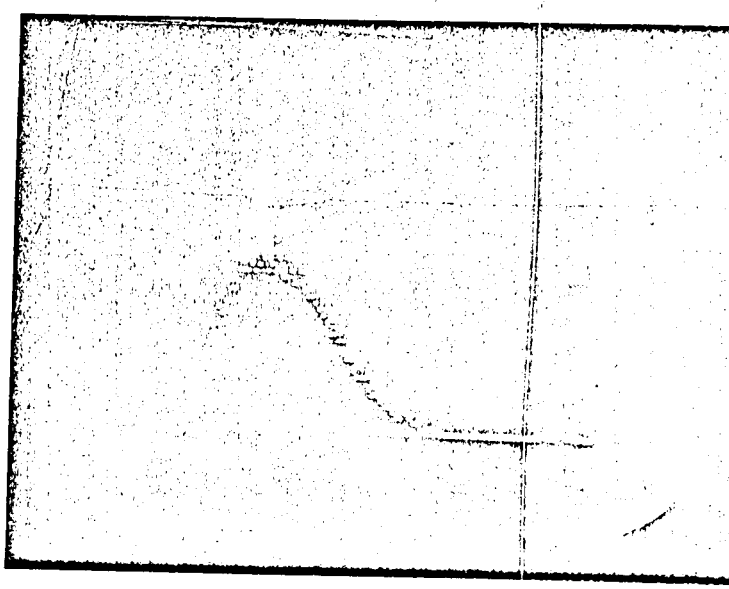
Fig. 6

2.651	01
1.726	02
1.518	03
1.870	04
2.132	05
2.084	06
2.350	07
2.400	08
2.487	09
2.736	10
2.721	11
2.786	12
2.873	13
2.731	14
2.839	15
2.907	16
2.733	17
2.806	18
3.235	19
2.929	20
2.650	21
2.862	22
2.717	23
2.592	24
2.790	25
2.479	26
2.368	27
2.395	28
2.229	29
2.195	30
2.074	31
1.928	32
1.778	33
1.721	34
1.667	35
1.682	36
1.363	37
1.350	38
1.138	39
1.026	40
1.086	41
1.094	42
.833	43
.733	44
.774	45
.698	46
.570	47
.506	48
.478	49
.384	50
.334	51
.423	52
.303	53
.256	54
.235	55
.160	56
.104	57

	.139
	.110
	.092
	.072
	.063
	.064
	.065
	.066
	.067
	.068
	.069
	.070
	.071
	.072
	.073
	.074
	.075
	.076
	.077
	.078
	.079
	.080
	.081
	.082
	.083
	.084
	.085
	.086
.9999	.087
	.088
	.089
	.090
.9999	.091
.9999	.092
	.093
	.094
	.095
	.096
	.097
	.098
	.099

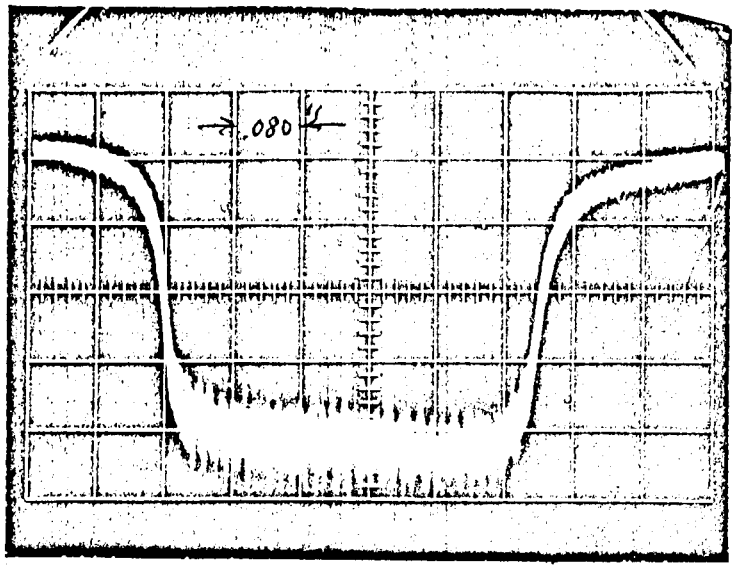
PRINT-OUT OF SIGNAL PULSE HEIGHT DISTRIBUTION DATA
FC4-974-2 X-15

CATHODE +6.3v w/respect to WAL

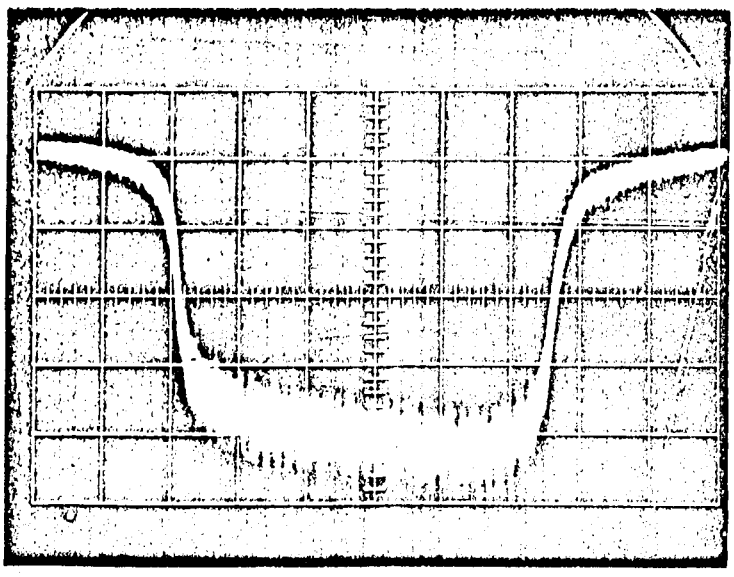


SIGNAL SPECTRUM

Fig. 7

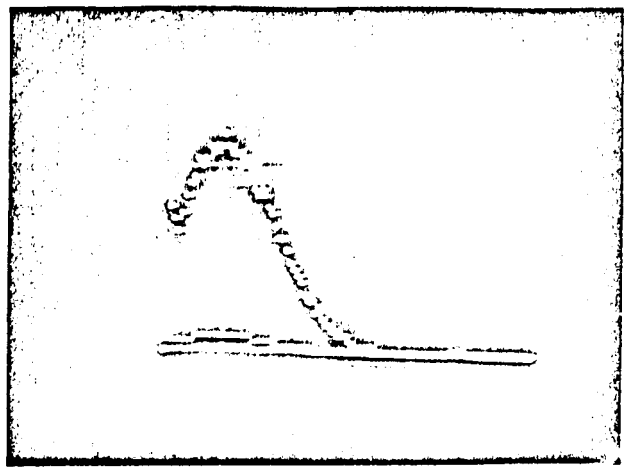


F64-974-2 X-15 .100" DEFINING APERTURE
150 v. K-Ap. Focus 0. volts
80 mil/cm Scan D-1 width



Scan D-1 Length

LEPD As Measured by Electro-Magnetic Scan.



SIGNAL SPECTRUM

PARTIAL PRINT-OUT OF
PULSE HEIGHT DISTRIBUTION

F64-974-2 X-18

1800 Volts Overall

T = .1 min.

GAIN = 50 & 1.0

Focus Electrode +25v w/res. to Cathode

$E_{Apert\#2}$ −90 w/res. to Apert #1 + Dynode #1

430v Cath to D-1 + Apert. #1

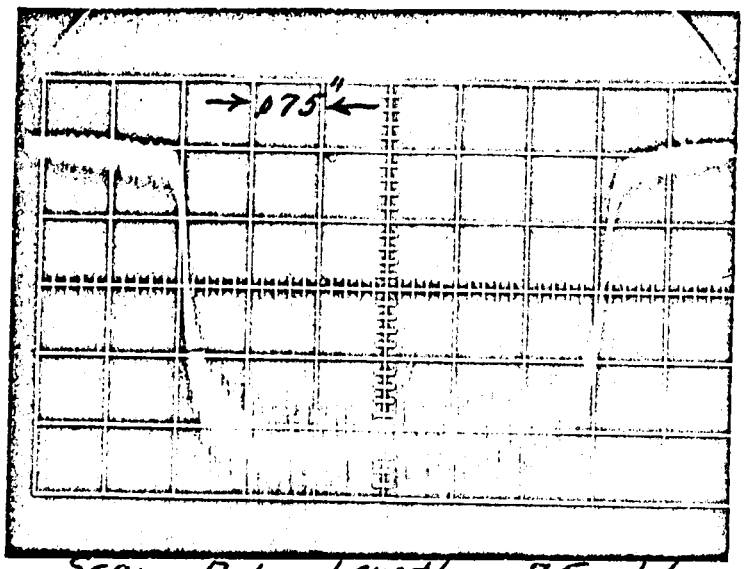
SIGNAL

2468	01
2274	02
2016	03
2364	04
2688	05
2801	06
2952	07
3206	08
3183	09
3295	10
3418	11
3340	12
3442	13
3470	14
3615	15
3434	16
3327	17
3361	18
3105	19
3203	20
3141	21
3170	22
2788	23
2660	24
2792	25
2623	26
2450	27
2327	28
2156	29
1963	30
1968	31
1777	32
1545	33
1484	34
1388	35
1241	36
1072	37
998	38
944	39
741	40
824	41
672	42
530	43
512	44
477	45
406	46
325	47
319	48
300	49
236	50
196	51
173	52
139	53
127	54
100	55
96	56
73	57
58	58

DARK

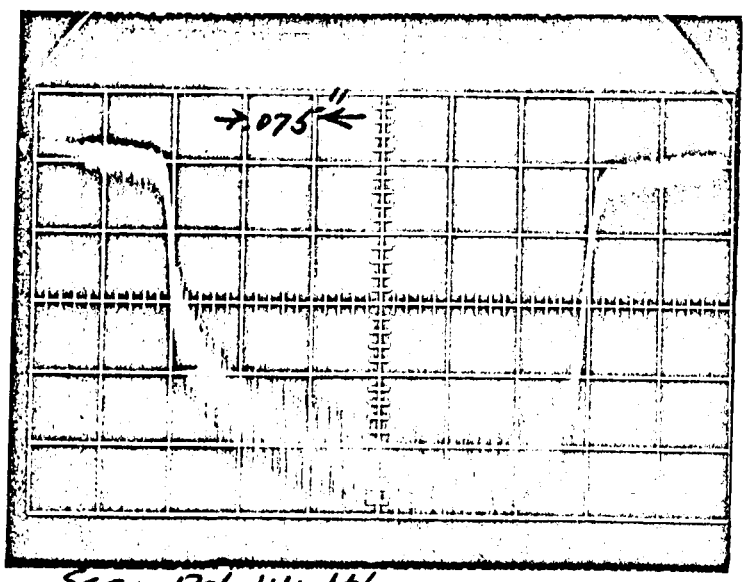
688	01
247	02
142	03
144	04
141	05
134	06
130	07
123	08
120	09
107	10
105	11
94	12
91	13
84	14
81	15
78	16
64	17
62	18
56	19
54	20
46	21
44	22
44	23
38	24
38	25
28	26
27	27
27	28
27	29
25	30
22	31
20	32
17	33
18	34
16	35
14	36
14	37
13	38
11	39
10	40
9	41
8	42
6	43
7	44
8	45
5	46
5	47
5	48
4	49
5	50

FIG. 10



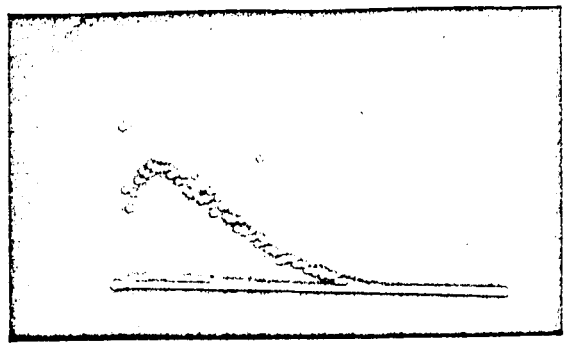
Scan D-1 Length 75 mil/cm

F64-974-2 X18
Cathode - D1 + Apert #1 260v
D-1 + Apert #1 to Ground 1700v
Focus -0.5v
Apert #2 -75v w/respect to Apert #1



Scan D-1 Width

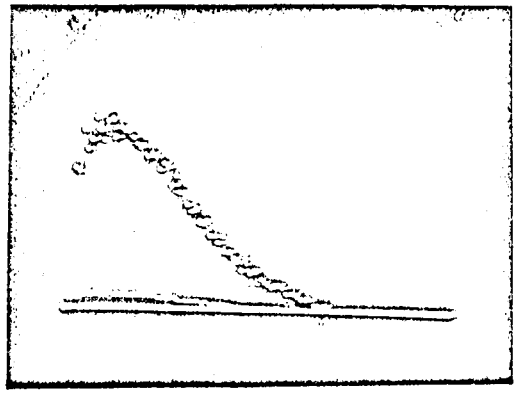
FIG. 11



RING ELECTRODE
AT APERTURE
POTENTIAL

NET SIGNAL SPECTRUM

TOT. DARK COUNTS . 114/sec.
1800 Volts Overall
Focus Electrode +20 v to cathode
400 Volts Cathode to Apert. + D-1

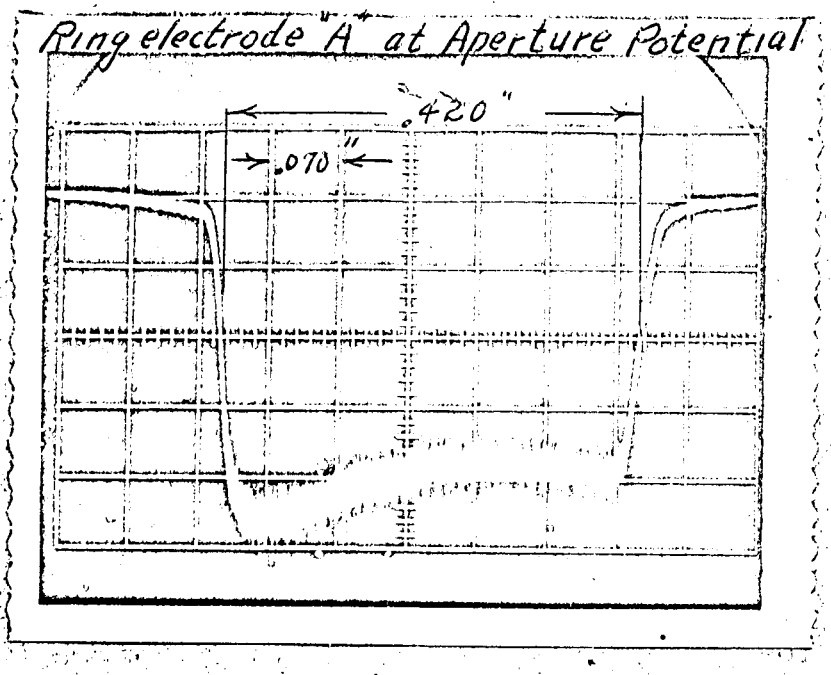


RING ELECTRODE
AT CATHODE
POTENTIAL

NET SIGNAL SPECTRUM

TOT. DARK COUNTS 145/sec.
1800 volts Overall
Focus Electrode +20v to cathode
400 Volts Cathode to Apert. + D-1

PULSE HEIGHT DISTRIBUTION
F64-974-2 X-21



F64-974-X21 .110" DIA. DEFINING APERTURE
400 Volts CATHODE - APERTURE ELECTRODE
FOCUS 0 volts

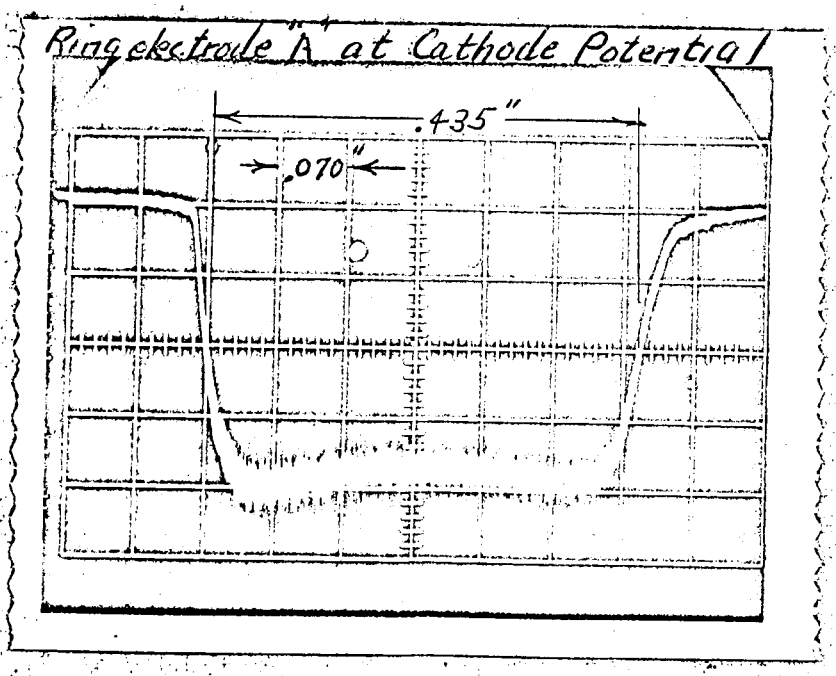
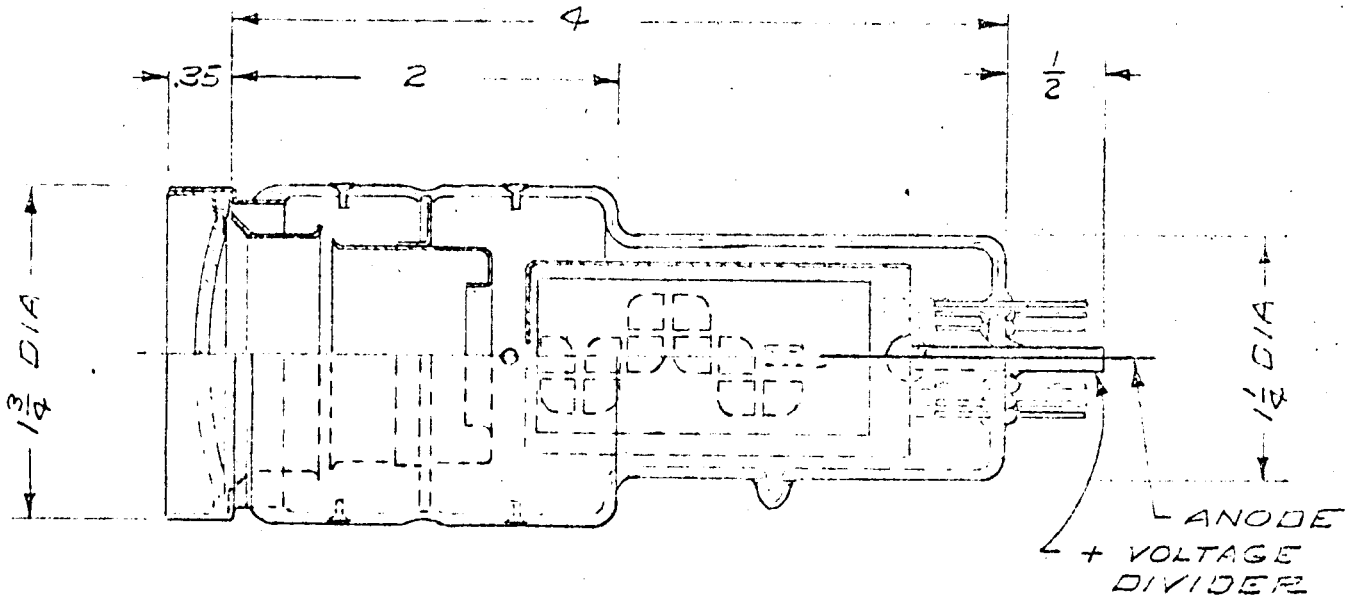


FIG. 15

4711032



PIN CONNECTIONS

PIN 1.	DYNODE	#1	8.	DYNODE	#10
2.	"	3	9.	"	8
3.	"	5	10.	"	6
4.	"	7	11.	"	4
5.	"	9	12.	"	2
6.	"	11	13.	SHIELD	
7.	NO CONNECTION		14.	KEY (CLIPPED PIN)	

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QTY	ITEM	DWG SIZE	PART NUMBER	DESCRIPTION

ATERIAL

ITT INDUSTRIAL LABORATORIES
A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
3700 PONTIAC ST. FORT WAYNE, IND.

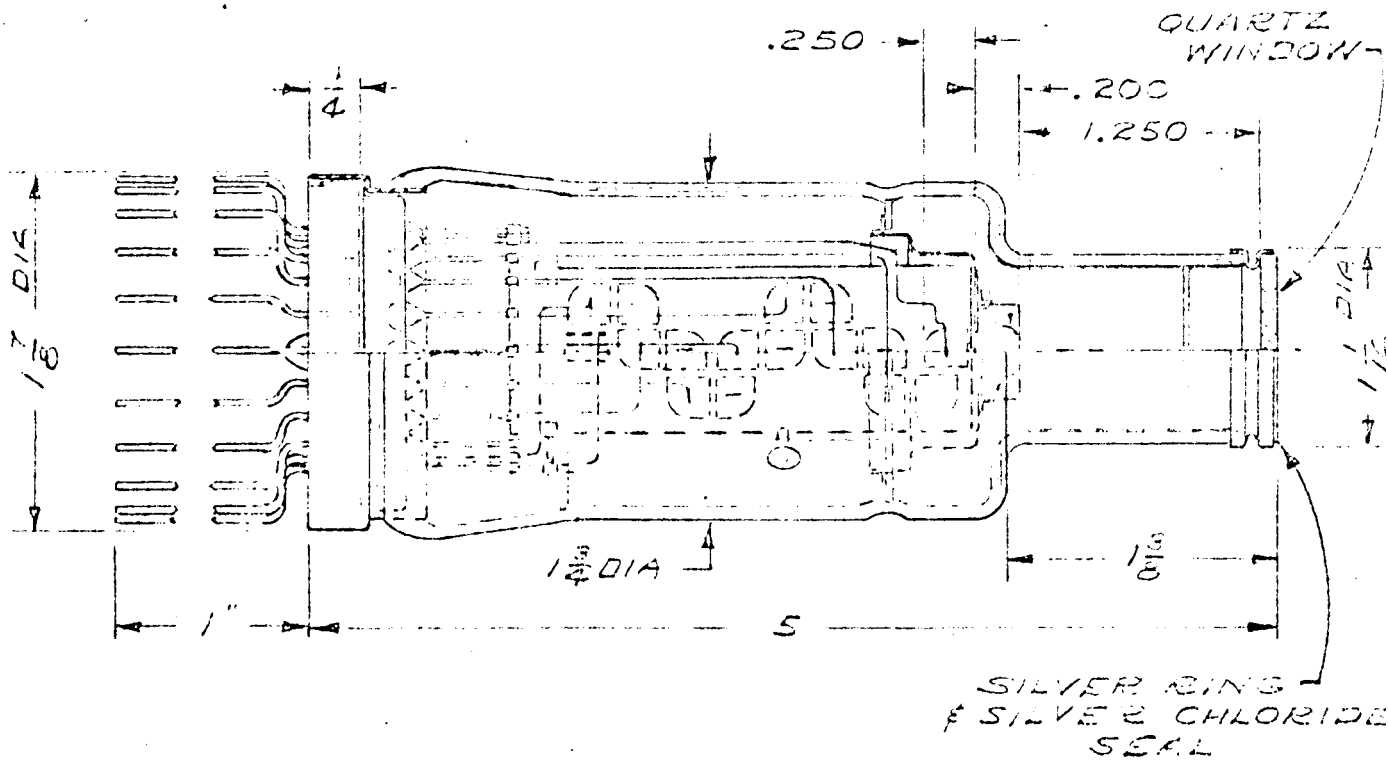
MULTIPLIER PHOTOTUBE F64-374-1

TOLERANCES UNLESS OTHERWISE SPECIFIED

ASIC DIM	2 PLACE	3 PLACE	ANGLES
UNDER 6	± .02	± .005	
[illegible]	[illegible]	[illegible]	[illegible]

DRAWN BY R.L. Connin DATE JULY 29 1965
USED ON
APPD. DATE
NEXT ASSY

4711[illegible]



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QTY	ITEM	DWG SIZE	PART NUMBER	DESCRIPTION

MATERIAL

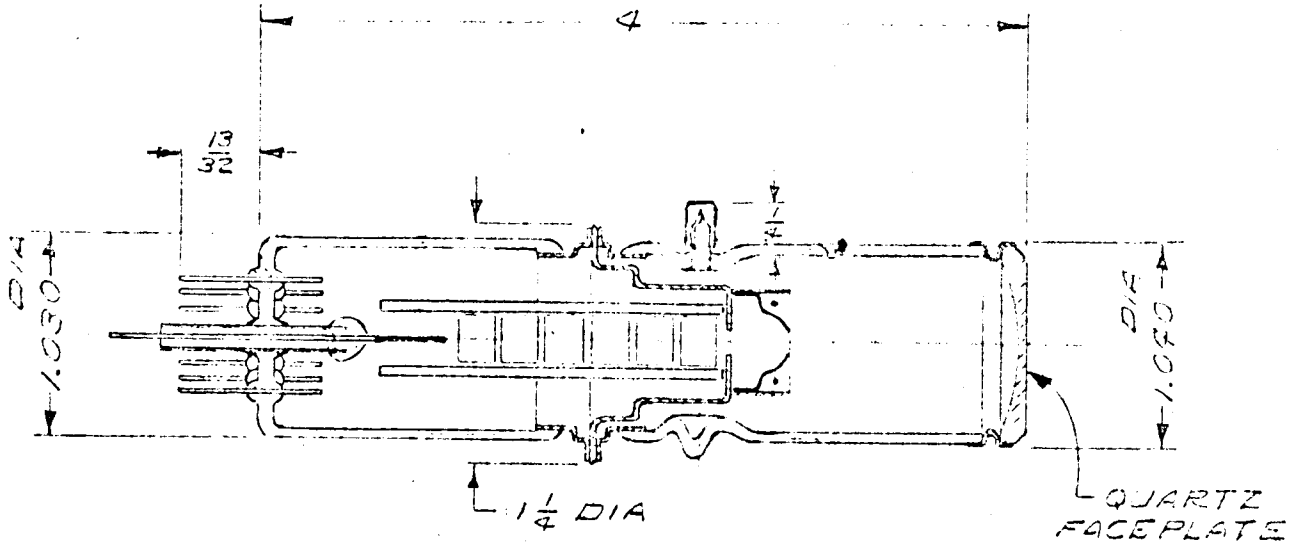
ITT INDUSTRIAL LABORATORIES
A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
3700 PONTIAC ST. FORT WAYNE, IND.

MULTIPLIER PHOTOTUBE
F64-974-2

TOLERANCES UNLESS OTHERWISE SPECIFIED			
BASIC DIM	2 PLACE	3 PLACE	ANGLES
UNDER 8	[illegible]	[illegible]	

DRAWN BY	DATE	USED ON
R. L. Connin	AUG 18 1965	
APPD.	DATE	NEXT ASSY

A471106



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QTY	ITEM	DWG SIZE	PART NUMBER	DESCRIPTION

TERIAL

INDUSTRIAL LABORATORIES
A DIVISION OF INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
3700 PONTIAC ST. FORT WAYNE, IND.

MULTIPLIER PHOTOTUBE
F64-974-3

TOLERANCES UNLESS OTHERWISE SPECIFIED

IC DIM	2 PLACE	3 PLACE	ANGLES

DRAWN BY R. L. Conner DATE AUG 10 1965 USED ON

DATE NEXT ASSY