UCRL-9200 Rev.

# University of California

# Ernest O. Lawrence Radiation Laboratory

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545*

Berkeley, California

9200/Rev. Cy 2.

## DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

UCRL-9200 Rev
Limited Distribution

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

# A PRELIMINARY INVESTIGATION OF THE SYSTEM TIME SPREAD FOR SOME TYPES OF MULTIPLIER PHOTOTUBES

Yahia El Hakim

October 1960

# A PRELIMINARY INVESTIGATION OF THE SYSTEM TIME SPREAD FOR SOME TYPES OF MULTIPLIER PHOTOTUBES

Yahia El Hakim

Lawrence Radiation Laboratory
University of California
Berkeley, California

October 1960

## ABSTRACT

A preliminary investigation of four types of multiplier phototubes under conditions simulating their use in scintillation and Čerenkov nuclear detectors is described. The investigation involves time-spread and rise-time measurements at different reference points on the output pulses, as well as observations of some special characteristics of these tubes.

# A PRELIMINARY INVESTIGATION OF THE SYSTEM TIME SPREAD FOR SOME TYPES OF MULTIPLIER PHOTOTUBES*

Yahia El Hakim†

Lawrence Radiation Laboratory
University of California
Berkeley, California

October 1960

## INTRODUCTION

In high-energy nuclear research, the multiplier phototube is an important part of some of the detectors used. However, output pulses from these tubes exhibit a time spread which is in some instances detrimental to the results sought. When controllable factors affecting this spread are optimized, experimental statistical studies of the time spread of different points of the output pulses will indicate the method that should be used to extract time information from these pulses to obtain minimum error due to this spread. Little experimental data pertaining to the time spread is available from tube manufacturers. The investigation described here was therefore carried out on four types of photomultiplier tubes as a preliminary step towards an investigation on a wider scale. Time spread and rise time of the output pulses as well as the sensibility of the tubes were observed, and deductions were based upon these observations.

---

*This work was done under the auspices of the U. S. Atomic Energy Commission.

†Present address: United Arob Republic Atomic Energy Establishment, Inchas, Egypt, U.A.R.

## METHODS OF MEASUREMENT

### A. General Description

Time spread of the output pulses from multiplier phototubes used in scintillation and Čerenkov counters is due to many reasons, of which the more obvious are:

a. time spread of light pulses reaching the photocathode

b. photocathode time spread caused by differences of the transit time of photoelectrons emitted at and (or) away from the center of the photocathode

c. re-excitation of the photocathode due to light pulses reflected from the inner surfaces

d. photoelectrons leaving the photocathode with different initial velocities

e. different electron paths and initial velocities in the multiplier section of the tube.

Except for the first cause listed above, time spread is due to differences occurring inside the tube and therefore is not easily controllable. Almost perfect simulation of the conditions met by the tubes in nuclear counters can be achieved in the system described below.

All four tubes were simultaneously exposed to light pulses from a UCRL-type mercury-capsule light pulser.[1] The output pulses were observed on a type-3343 Edgerton, Germeshausen, and Grier (E. G. and G.) traveling-wave oscilloscope, and photographic records of these pulses were made for later analysis.

B. Illumination of the Tubes

Four tubes (RCA types 6655A, 7264, and developmental type C7260 as well as La Radiotechnique of Paris type 56AVP) were placed in a dark enclosure[1] such that the centers of their photocathodes lay at equal distances from a UCRL-type mercury-capsule light pulser affixed outside the enclosure opposite an aperture of suitable diameter. The light pulser was tested for light output in different directions, and it was ascertained that the output is constant within a cone of about 30 deg perpendicular to the plane of the pulser base plate. This ensured that all tubes received equal light inputs with every pulse. To bring the test nearer actual conditions met in counting roles, a narrow-band filter of about 4200 A was placed at the aperture, thus simulating light from a plastic scintillator. In addition to the polaroid light attenuator integral with the UCRL light pulser, neutral density filters (Kodak No. 96) were used for light attenuation.

C. Oscilloscope Display and Photographic Recording

For efficient and full use of the system, pulses from all four tubes, as well as a fiducial mark derived from the light pulser were displayed on every sweep. Successive sweeps were displaced at regular intervals on the screen by a voltage ramp impressed on the Y deflecting helixes of the traveling-wave oscilloscope.

Output pulses from the tubes were connected to a mixing junction by delay lines (Fig. 1) which served the double purpose of providing the necessary delay required between the trigger and the signal to be observed, as well as delaying the reflections resulting from impedance discontinuities at the mixing points and at the anodes of the tubes beyond the range of the time-base

sweep. Delay lines for each tube were adjusted so that the pulses appeared successively on each trace. The output trigger pulse from the light pulser was used to trigger the oscilloscope sweep circuit, while a delayed trigger pulse from the light pulser was displayed as a time reference on each trace. Because of the relatively low gain and therefore small output-pulse amplitudes that could be obtained from tubes type 6655 and C7260, the delayed trigger pulse was mixed with the outputs of the 7264 and 56AVP tubes, while the outputs of the C7260 and 6655A were mixed alone at another mixing point. Each set of mixed signals was impressed on a terminated Y deflecting helix of the traveling-wave oscilloscope.

The recording camera was arranged so that when the shutter mechanism was operated it triggered the ramp-producing circuit, whose slope was adjusted to produce a raster of about 10 traces. Fast, fine-grain film (Kodak Tri-X film) was used to allow sharp focusing of the beam as well as an accurate record of each event. An example of such a record is shown in Fig. 2.

## D. Experimental Procedure

Optimum operating conditions were sought for the four tubes under test. Thus divider chains were adjusted so that maximum collection efficiency was achieved and tube gains were set within the useful ranges. The tests were carried out at a light level that produced a few photoelectrons per pulse. Estimates of the average number of photoelectrons per pulse striking the first dynode of each tube are also given in Table I.

Table I

| Tube Type | Time spread, sensibility, and average rise time for the photomultipliers tested | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pulse time spread (nanoseconds) | | | | | | | | | |
| | At 50% point | | At threshold point | | At intercept point | | | | | |
| | For 95% of pulses | For 50% of pulses | For 95% of pulses | For 50% of pulses | For 95% of pulses | For 50% of pulses | Average rise time[a] (nanosec) | Output pulses per 120 light-pulse inputs | Average No. of photoelectrons per pulse | Average peak amplitude of output pulses |
| 6655 | 3.3 | 1.2 | 3.7 | 1.2 | 4.4 | 1.3 | 2.9 | 110 | 2.5 | 30 |
| C7260 | 1.5 | 0.5 | 2.1 | 0.7 | 1.9 | 0.7 | 2.1 | 111 | 2.6 | 30 |
| 56AVP | 2.5 | 0.8 | 2.7 | 1.0 | 2.7 | 0.8 | 1.8 | 72[b] | 0.9 | 100 |
| 7264 | 2.7 | 0.9 | 3.6 | 1.1 | 3.2 | 1.0 | 2.7 | 108 | 2.3 | 100 |

[a] Measured between 10% and 90% of pulse amplitude.

[b] See text

The photographically recorded trace images were linearly enlarged about 35 times in two stages to allow accurate manual processing. Because of the nonlinearity of the oscilloscope sweep, a time scale was obtained by recording a raster of traces of the output of a 250-Mc oscillator. Half-cyle periods (corresponding to 2 nanosec) were then linearly divided. About 120 traces were treated in this way, and the conclusions given below are based on the information extracted from these traces.

Because of the impracticability of treating a large batch of recorded traces manually, mechanization of this process has been attempted with reasonable success and accuracy.[2] In the future, such records will be read by the flying-spot scanner fitted to the IBM-709 computer at the Lawrence Radiation Laboratory in Livermore by a program designed by Hans Bruijnes. Then the digitalized information will be processed further by a special program on the IBM-704 computer at the University of California, Berkeley.

## RESULTS AND CONCLUSIONS

Histograms of the time spread of output pulses from each of the four tubes were obtained from measurements made at three different reference points. These are:

a. the point on the leading edge of the pulse where the pulse rises to 50% of the peak value (referred to as the 50% point)

b. the point on the leading edge where the pulse rises to a fixed threshold chosen such that about 90% of the total number of pulses observed reach or exceed this threshold (referred to as the threshold point)

c. the point on the base line where a straight line representing the mean slope of the leading edge of the pulse intersected the base line (referred to as the intercept point).

A fourth reference point at which these measurements would have been desirable is the centroid of the pulse or a portion of the pulse. The location of this point manually would have been prohibitively time-consuming; however, the program prepared for the analysis of the results by means of a computer includes the production of a histogram for the time spread at the centroid.

Time spread for the different tubes as well as sensibility and average rise-time figures are summarized in Table I. Histograms of the time spread as shown in Figs. 3 to 5.

The best reference point cannot be decided conclusively now with this amount of information. However, Table I indicates that the 50% point seems to be the best of the three measured reference points because of the indicated small time spread.

Interesting observations made on the C7260 and the 56AVP tubes are given below.

## A. RCA Developmental Type C7260

This tube exhibited a rise time as well as a total time spread for the output pulse which were much smaller than those of the other tubes. However, a glow was observed at the final electrodes of the multiplier, which increased in intensity with increasing average anode current in the tube.[3] This glow appeared to be causing some feedback by exciting the photocathode through the translucent side plates of the multiplier section. In later models of the C7260 these plates have been replaced by opaque side plates,[4] which should greatly reduce this effect.[4]

## B. Type 56AVP

Output pulses from the 56AVP exhibited a consistent output-pulse shape which featured a relatively fast rise and a sharp peak, followed by a nearly perfect exponential decay. This effect explains the close values of time spread measured at three different reference points on the pulse. It was observed for two different samples of this type that the collection efficiency seemed to be lower than for the other tubes. On investigation, two main points to be observed with this tube were found:

a. The tube is highly sensitive to magnetic fields. When four samples were tested on a flying-spot scanner, the collection efficiency could only be adjusted to a uniform pattern when the tube was demagnetized and a magnetic shield was placed around the tube. It is believed that a better collection efficiency than that obtained with the statistical measurements can be obtained when this precaution is followed; however it is not known whether a collection efficiency comparable to that of the other tubes can be reached.

b. As suggested by the tube designer, G. Pietri, at least 350 v should be applied between the cathode and first dynode, and a potential distribution such as that shown in Fig. 6 should be used. Adjustment of the potential of dynode 3 is necessary, as it affects the electrostatic field at the front end of the tube because of its position (see Fig. 7).

More work is needed to reach more definite conclusions than those indicated by the results given here. At least we know that much is to be gained by pursuing this investigation further. It is hoped that results of the future investigations will be published.

## ACKNOWLEDGMENTS

This work was done as part of the program of the counting research group under the direction of Quentin A. Kerns. Thanks are due Fredrick Kirsten for permission to publish Figs. 6 and 7. I am indebted to Dr. Clyde Wiegand for his helpful suggestions.

## REFERENCES

1. Q. A. Kerns, F. A. Kirsten, and G. C. Cox, Generation of Nanosecond Light Pulses for Phototube Testing. Rev. Sci. Instr. 30, No. 1, 31 (1959).

2. Yahia El Hakim, Digital Processing of Photographically Recorded C. R. O. Traces, Lawrence Radiation Laboratory Report UCID-965, March 4, 1960.

3. Fred Kirsten, Multiplier Phototube Special Characteristics, in Lawrence Radiation Laboratory Counting Handbook, Lawrence Radiation Laboratory Report UCRL-3307 Rev., January 1, 1959, File No. CC8-4. See also Q. A. Kerns and F. A. Kirsten, Voltage Glow in the 7046 Phototube, Lawrence Radiation Laboratory Report, UCID-357, February 21, 1958.

4. RCA developmental-type C7260 has been superseded by commercial-type 7746.

## LEGANDS

Fig. 1. Block diagram of test setup.

Fig. 2. A typical photographic record of a raster of traces.

Fig. 3. Histograms of the time spread at the 50% point.

Fig. 4. Histograms of the time spread at the threshold point.

Fig. 5. Histograms of the time spread at the intercept point.

Fig. 6. Divider for type-56AVP tube suggested by the tube's designer.

Fig. 7. Schematic diagram of the electrode structure of the type-56AVP tube.

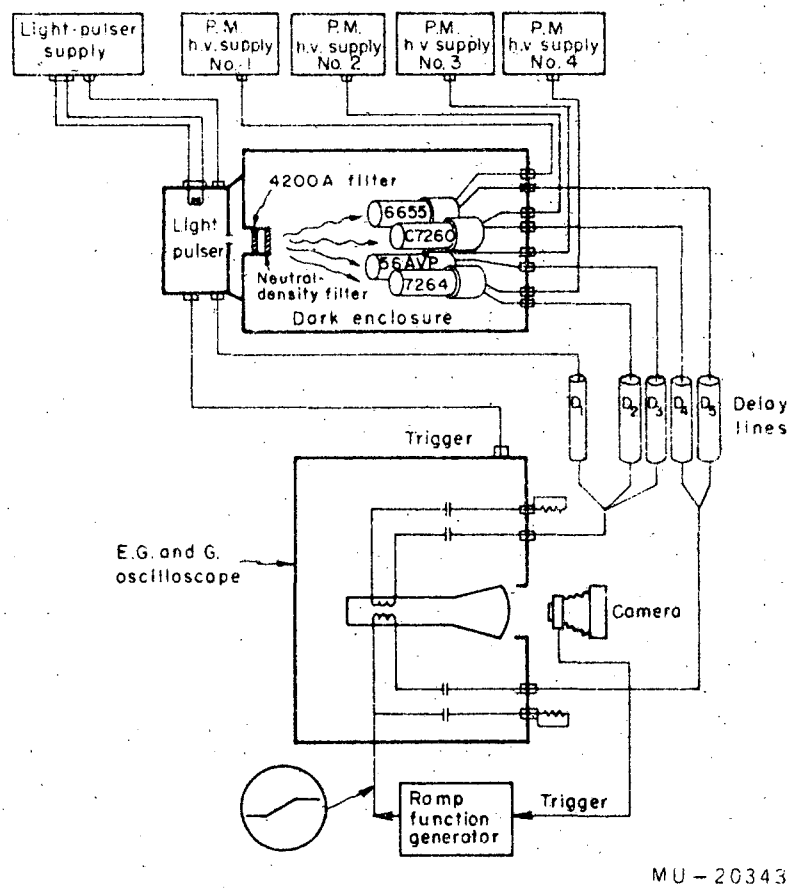
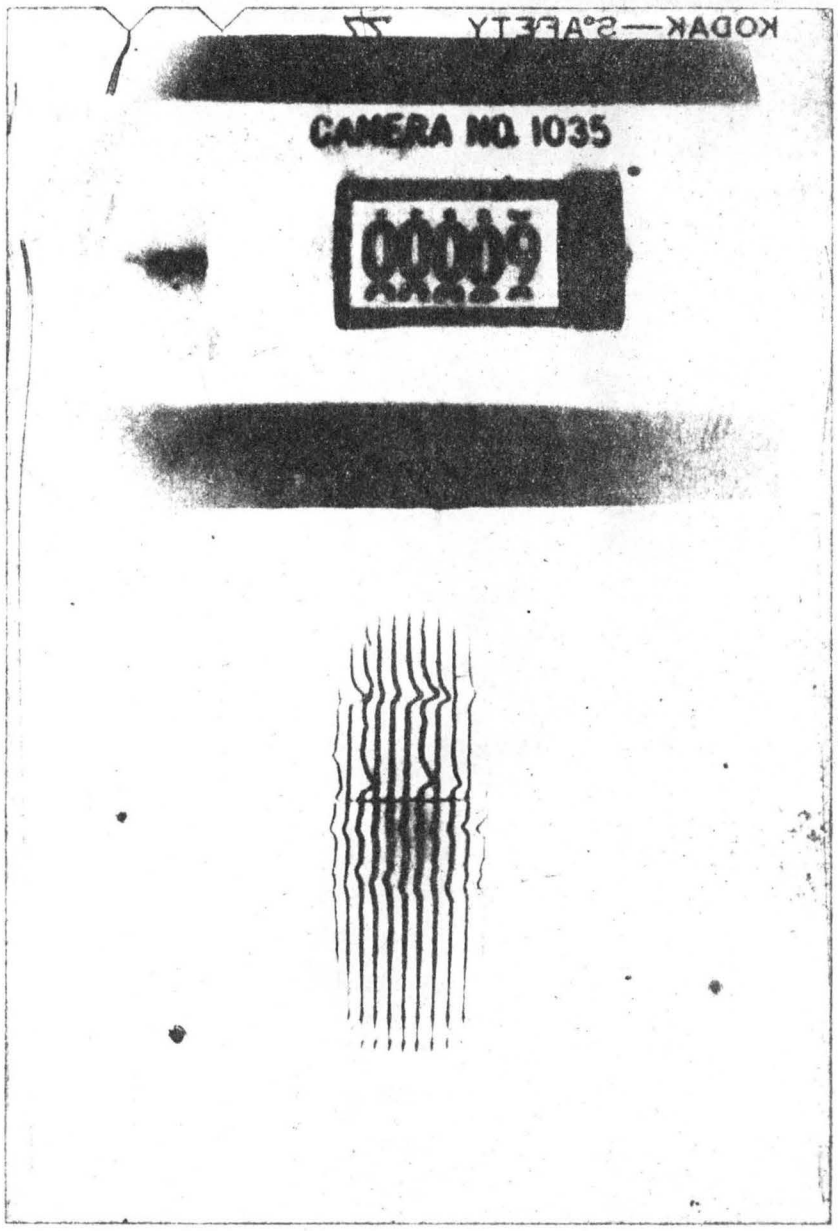



Fig. 1. Block diagram of test setup.




ZN-2483

Fig. 2. A typical photographic record of a raster of traces.

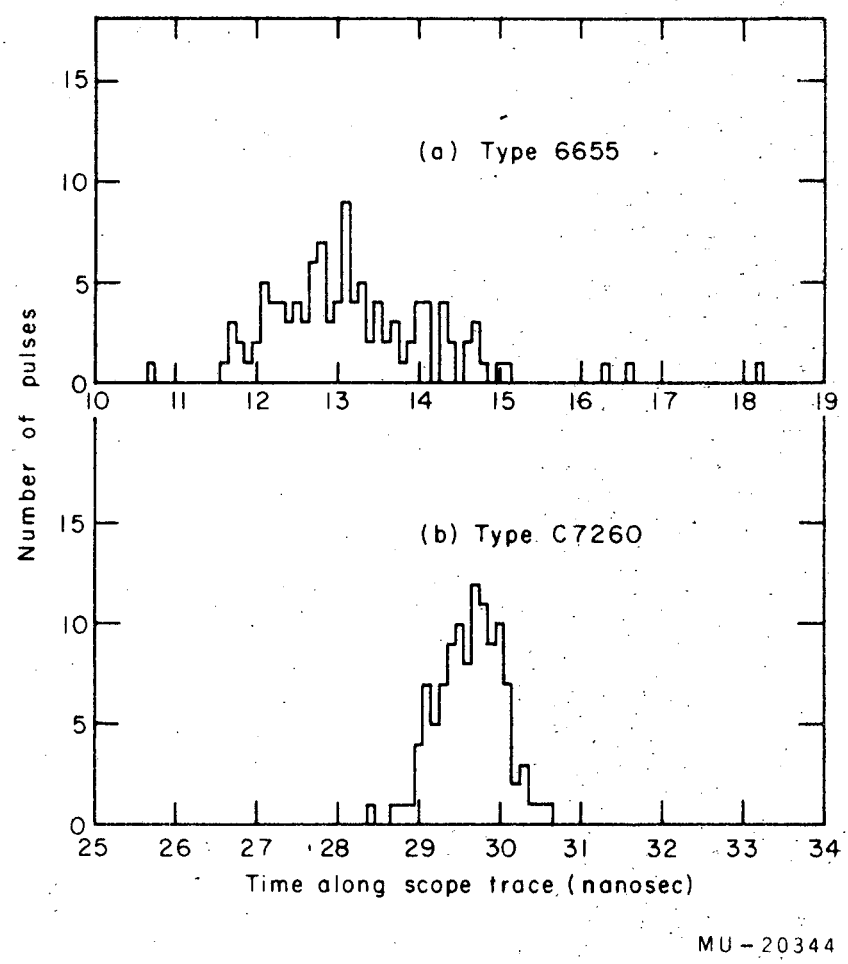



Fig. 3. Histograms of the time spread at the 50% point.

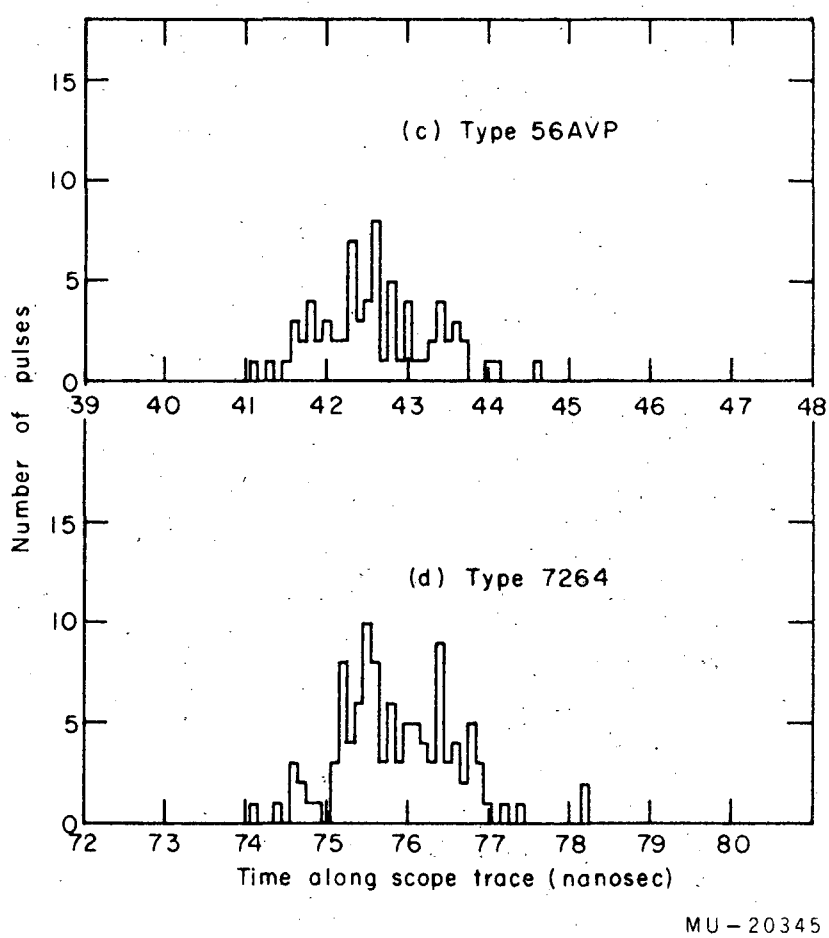

(c) Type 56AVP
(d) Type 7264
Number of pulses
Time along scope trace (nanosec)
0
5
10
15
39
40
41
42
43
44
45
46
47
48
72
73
74
75
76
77
78
79
80
MU-20345

Fig. 3.

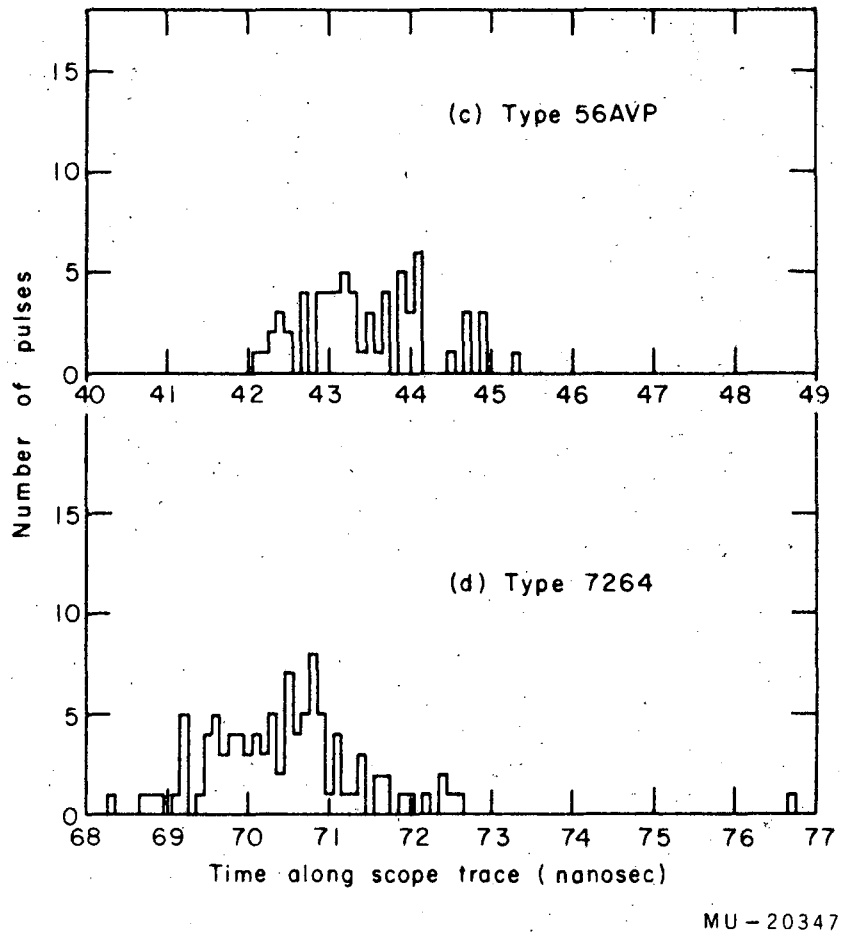



Fig. 4. Histograms of the time spread at the threshold point.

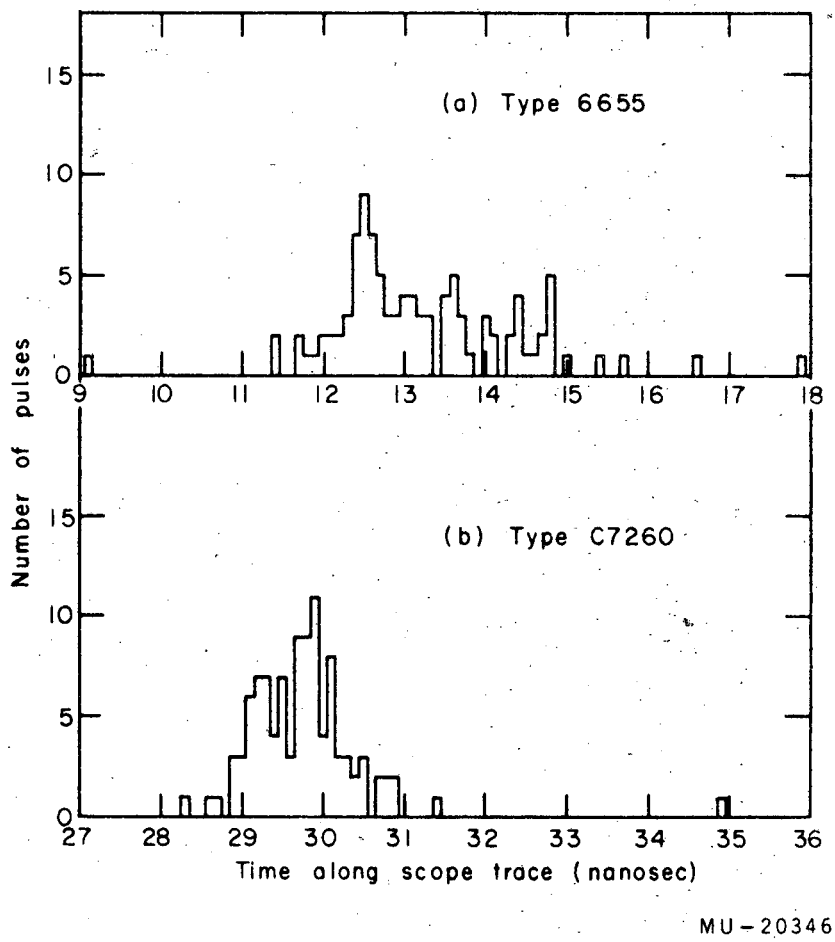

(a) Type 6655
(b) Type C7260
Number of pulses
Time along scope trace (nanosec)
MU-20346

Fig. 4

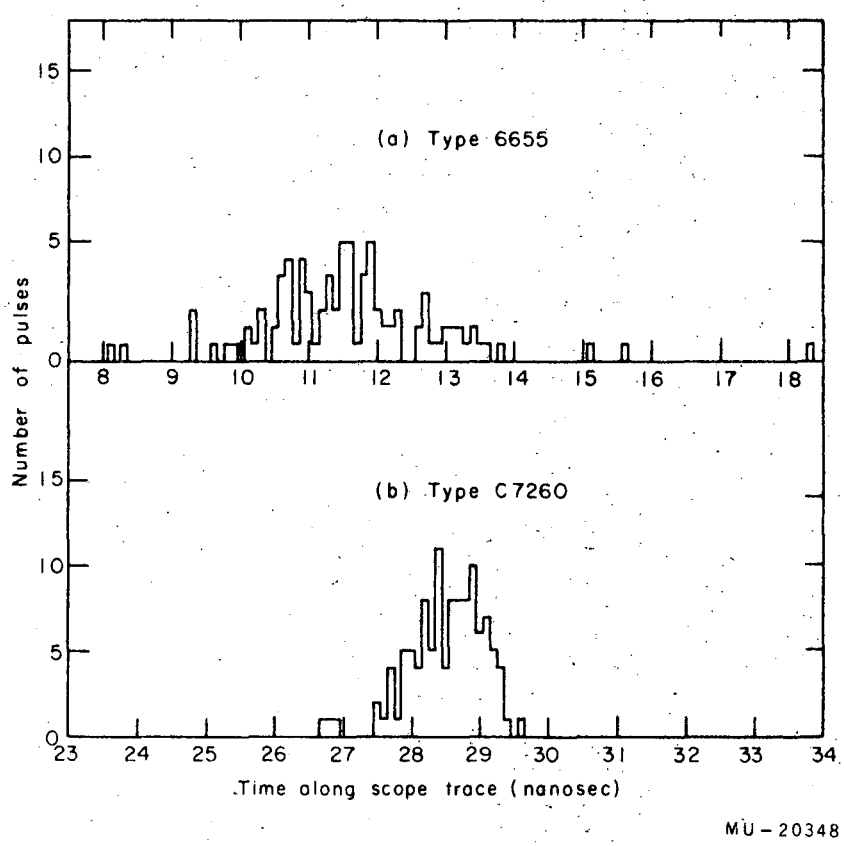



Fig. 5. Histograms of the time spread at the intercept point.

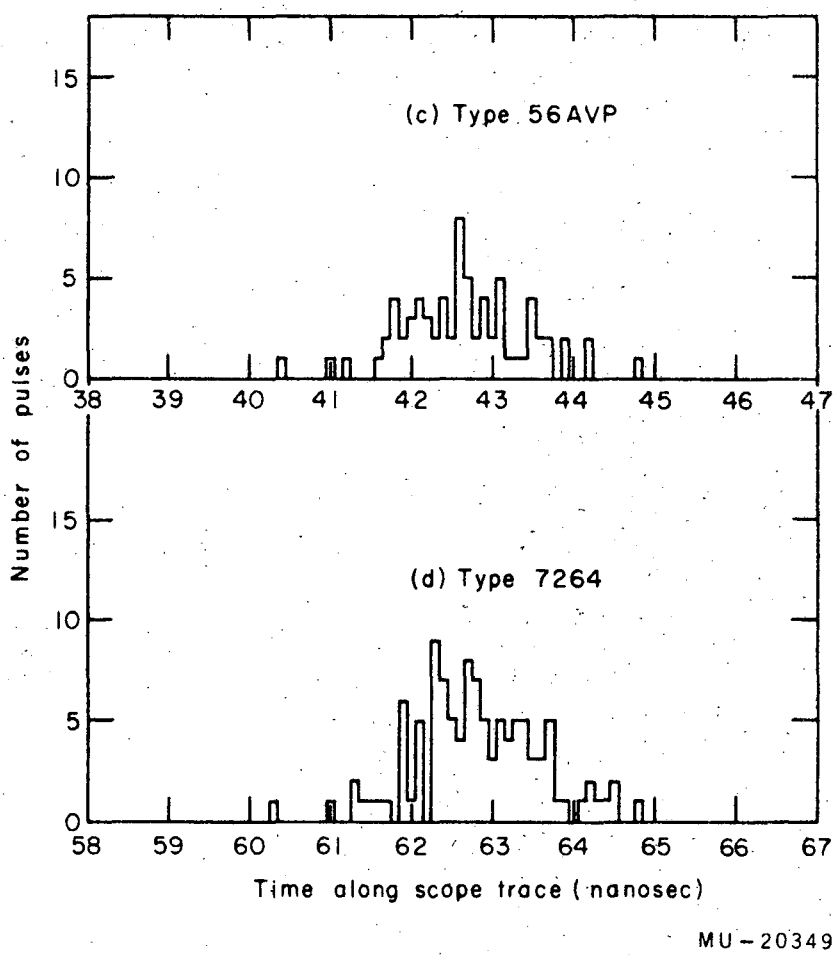
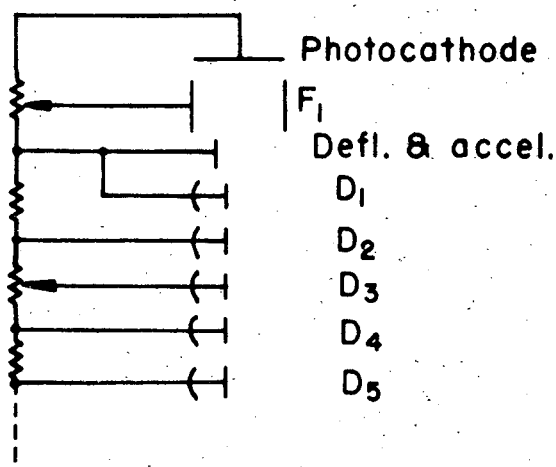

(c) Type 56AVP
(d) Type 7264
Number of pulses
Time along scope trace (nanosec)
0
5
10
15
38
39
40
41
42
43
44
45
46
47
58
59
60
61
62
63
64
65
66
67
MU-20349

Fig. 5.




| Electrode | Potential ratio |
|---|---|
| Photocathode | adj. } 3 |
| Focussing elect. $F_1$ | |
| Dyn. 1 + defl. + accel. | 1 |
| Dyn. 2 | $1 + \alpha^*$ |
| Dyn. 3 | $1 - \alpha^*$ |
| Dyn. 4 | 1 |
| Dyn. 5 | 1 |
| Dyn. 6 | 1 |
| Dyn. 7 | etc. |
| etc. | |

* Here $\alpha$ means adjust to obtain desired optimum

MU-20350

Fig. 6. Divider for type-56AVP tube suggested by the tube's designer.

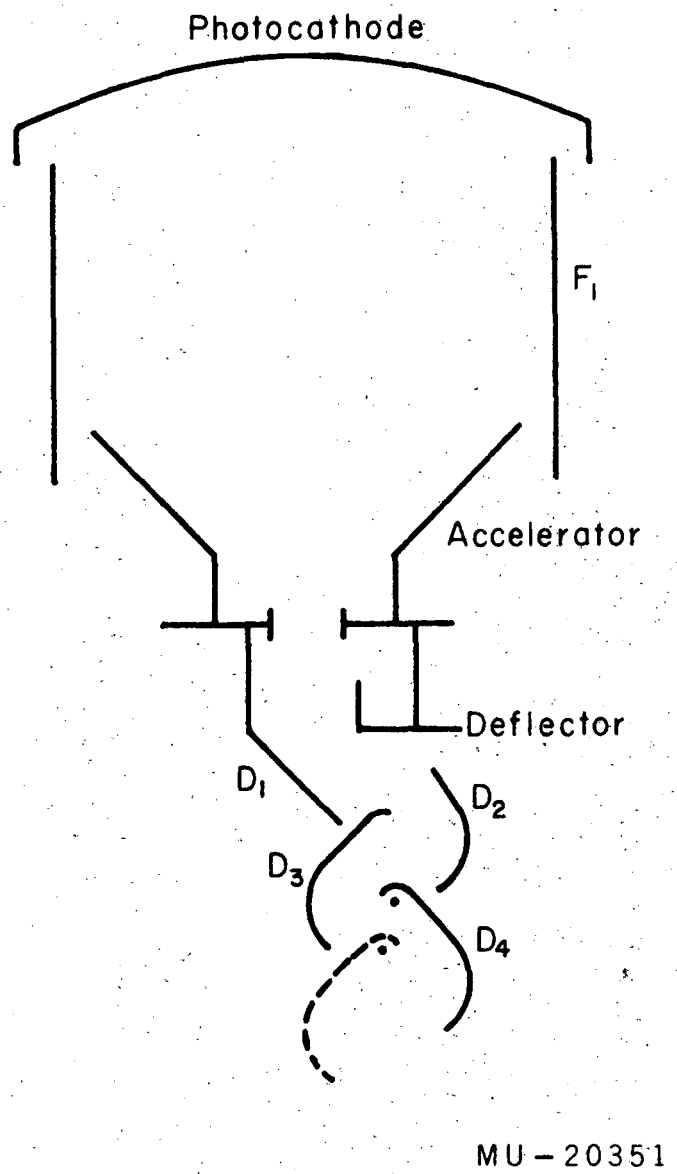



Fig. 7. Schematic diagram of the electrode structure of the type-56AVP tube.