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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*

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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 time 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 time spread. Little experimental data pertaining to the time spread is available from tube manufacturers. The investigation described in this report 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.

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

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. time spread due to the 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 (EG and G) traveling-wave oscilloscope and photographic records of these pulses were made for later anlaysis.

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

In order to make 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 serve 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

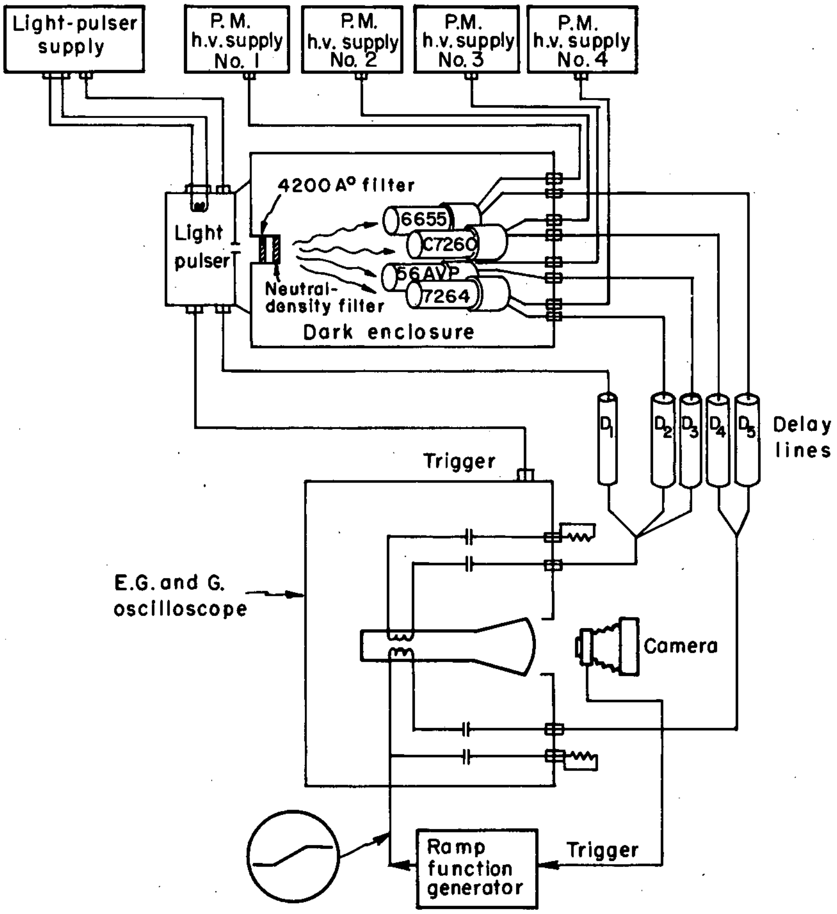

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Fig. 1. Block diagram of test setup.

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 such that maximum collection efficiency is achieved and tube gains were set within the useful ranges. The tests were carried out at a light level that produced an average of one photoelectron per pulse.

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-cycle periods (corresponding to 2 nanosec) were then linearly divided. About 120 traces were treated in that way, and the conclusions 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 shall be read by the flying spot scanner fitted to the computer at UCRL Livermore by a program designed by Hans Bruijnes. Then the digitalized information will be processed further by a special program on the computer at the U.C. Berkeley campus.

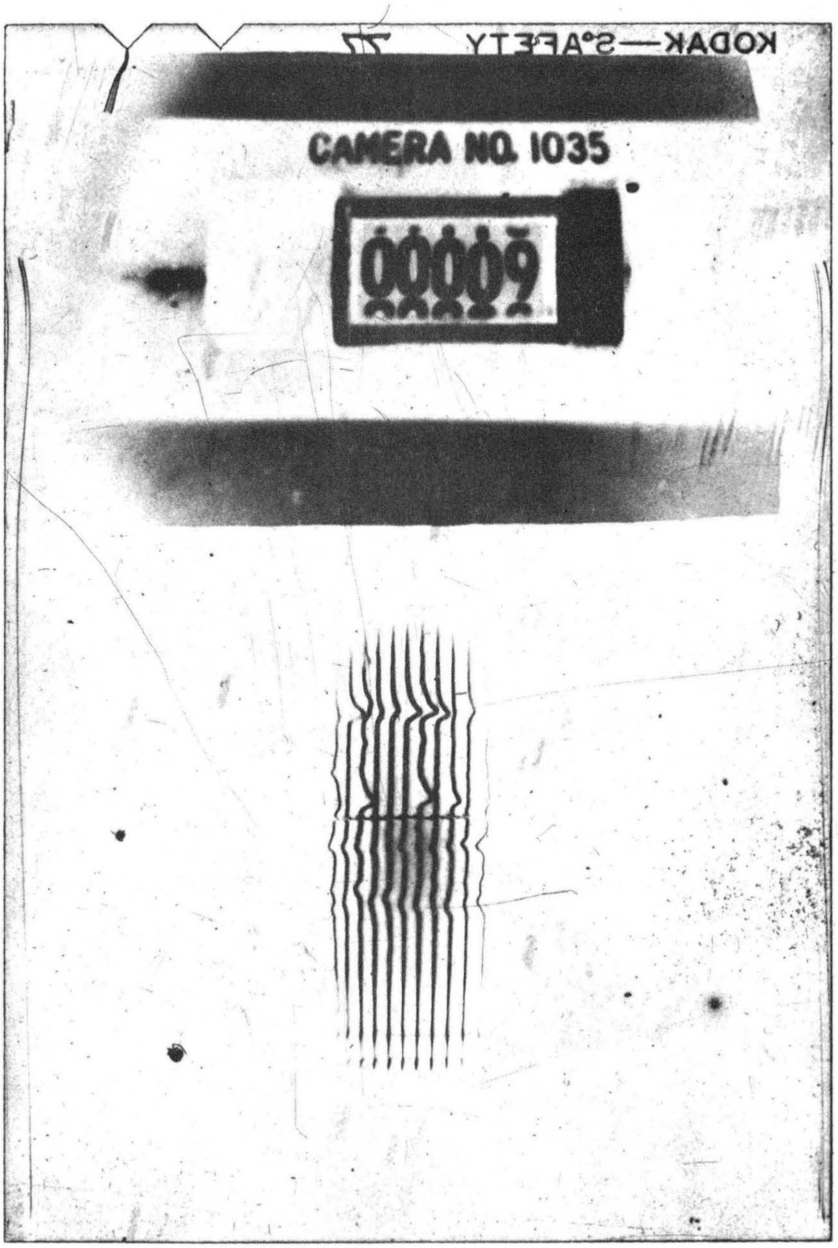

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Fig. 2. A typical photographic record of a raster of traces.

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 are 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 enumerated below.

Table I

Time spread, sensibility, and average rise time for the photomultipliers tested

Tube Type	Pulse time spread (nanoseconds)						Average rise time[a] (nanosec)	Output pulses per 120 light-pulse inputs
	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		
6655	3.3	1.2	3.7	1.2	4.4	1.3	2.9	110
C7260	1.5	0.5	2.1	0.7	1.9	0.7	2.1	111
56AVP	2.5	0.8	2.7	1.0	2.7	0.8	1.8	72[b]
7264	2.7	0.9	3.6	1.1	3.2	1.0	2.7	108

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

[b] See text

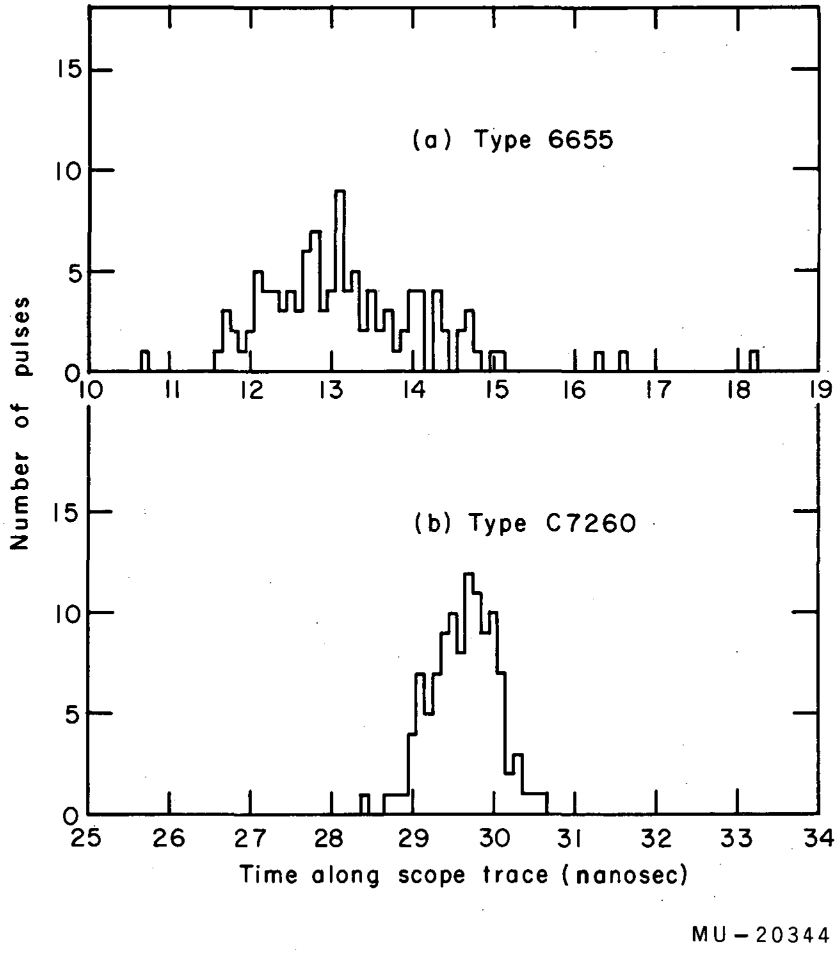
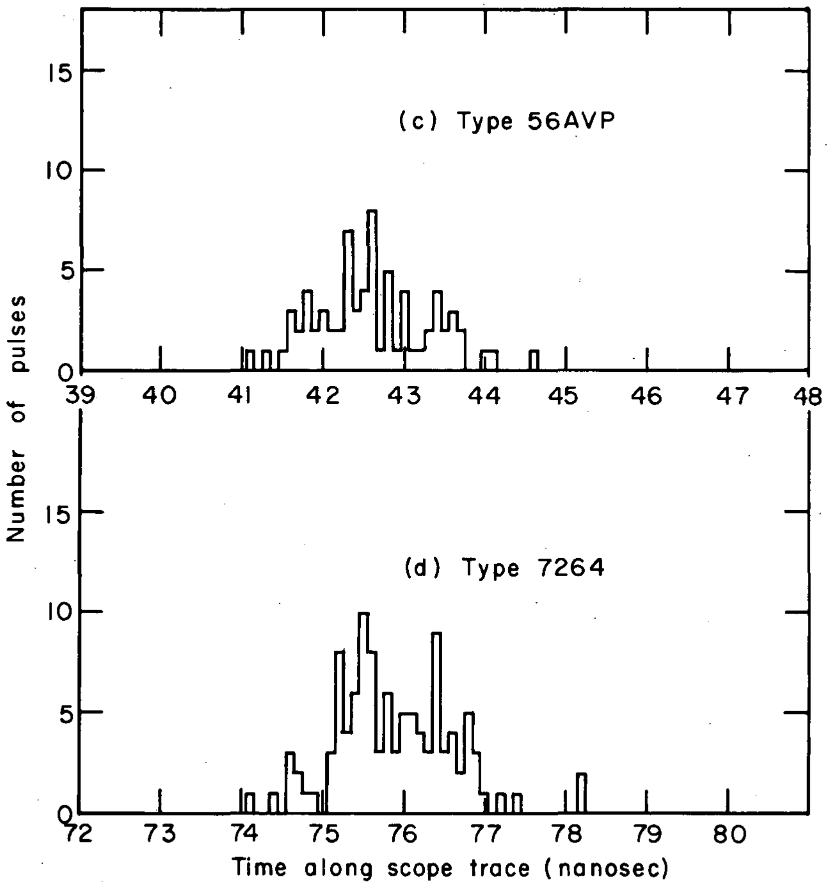


Fig. 3. Histograms of the time spread at the 50% point.


(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

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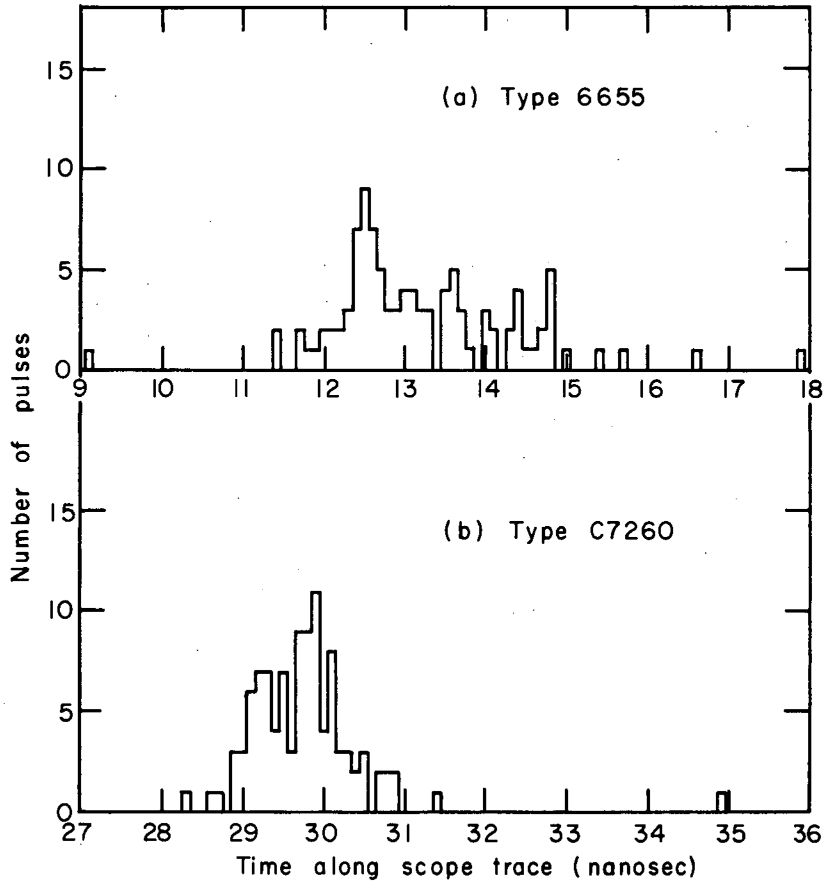

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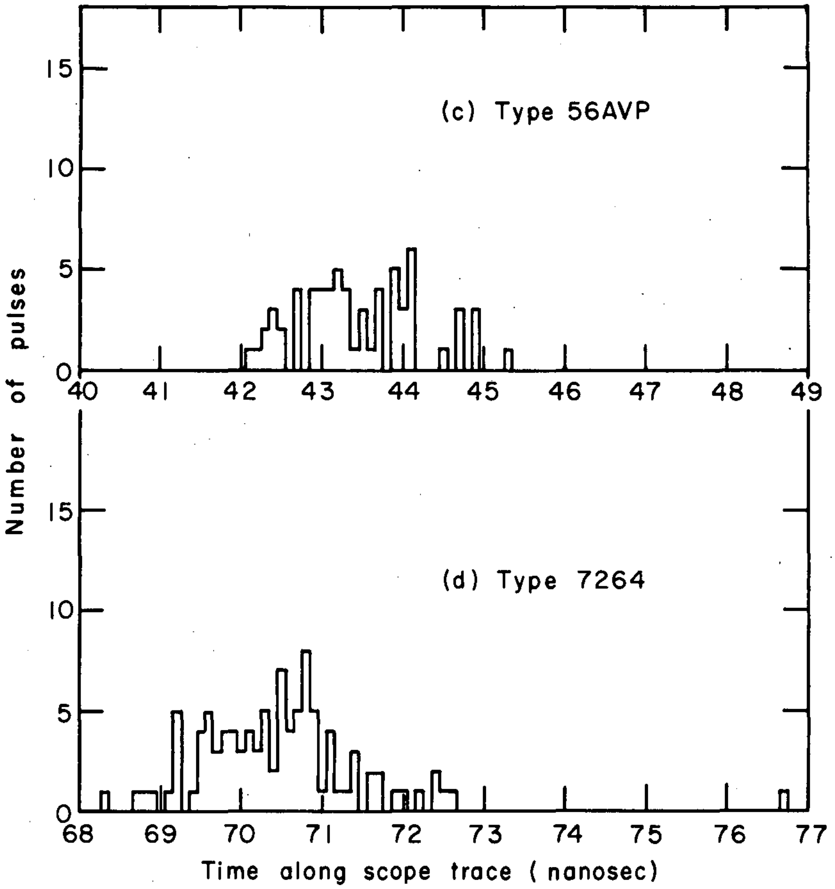
Fig. 4. Histograms of the time spread at the threshold point.


(c) Type 56AVP
(d) Type 7264
Number of pulses
0
5
10
15
40
41
42
43
44
45
46
47
48
49
68
69
70
71
72
73
74
75
76
77
Time along scope trace (nanosec)

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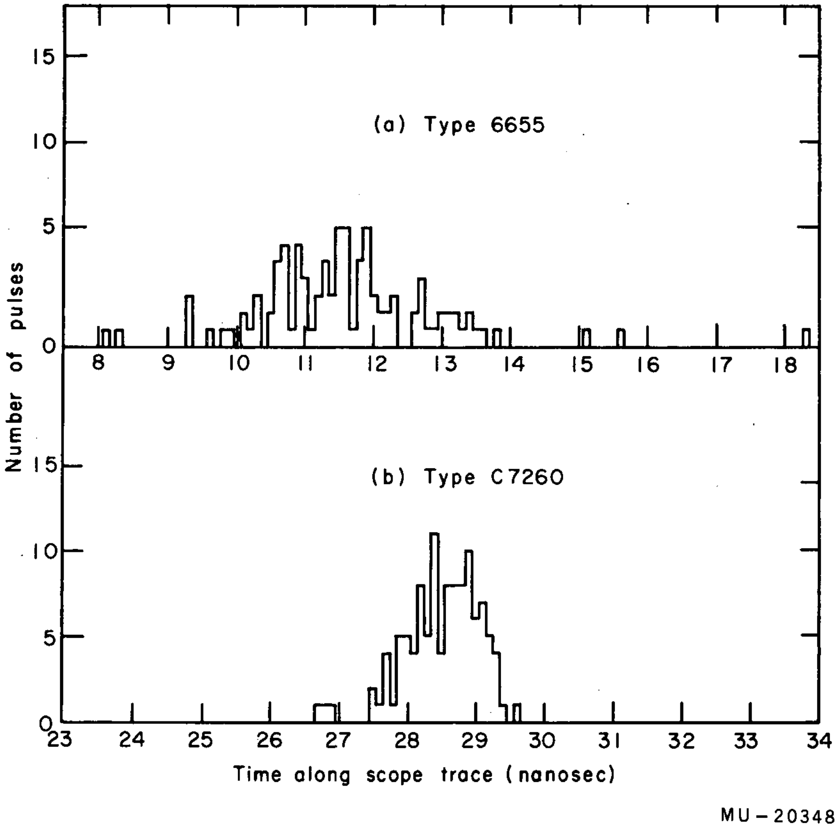
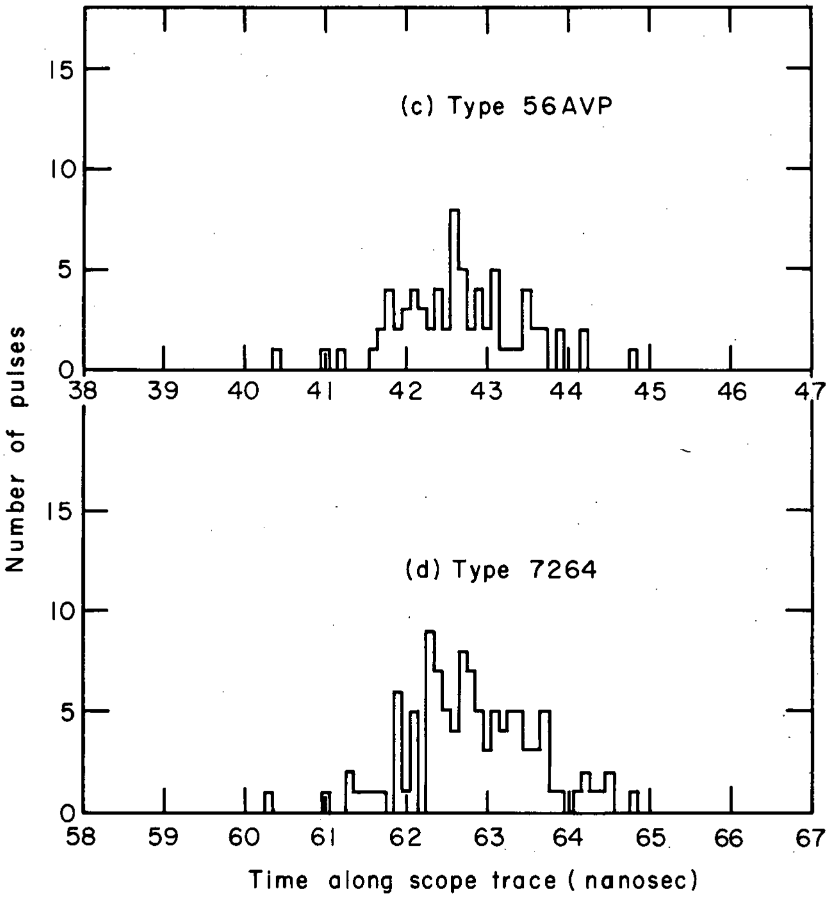


Fig. 5. Histograms of the time spread at the intercept point.


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

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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, which should greatly reduce this effect.

B. Type 56AVP

Output pulses from the 56AVP exhibited a consistent output-pulse shape which featured a relatively fast rise, 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 in another UCRL report.

ACKNOWLEDGMENTS

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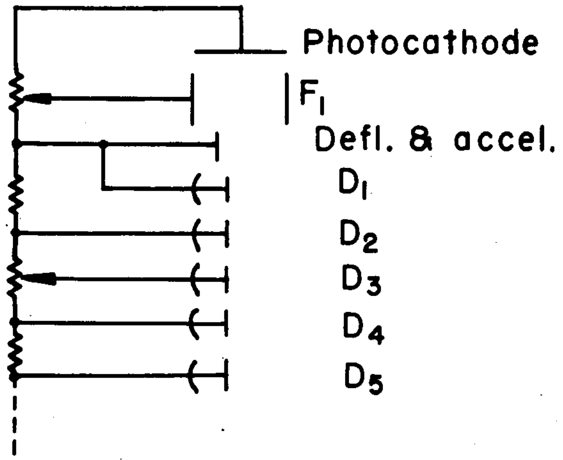

Electrode	Potential ratio
Photocathode	}adj. }3
Focussing elect. F_1	
Dyn. 1 + defl. + accel.	1
Dyn. 2	$1+\alpha^*$
Dyn. 3	$1-\alpha^*$
Dyn. 4	1
Dyn. 5	1
Dyn. 6	1
Dyn. 7	
etc.	etc.

* Here α means adjust to obtain desired optimum

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Fig. 6. Divider for type-56AVP tube suggested by the tube's designer (from a private communication from G. Pietri to F. Kirsten).

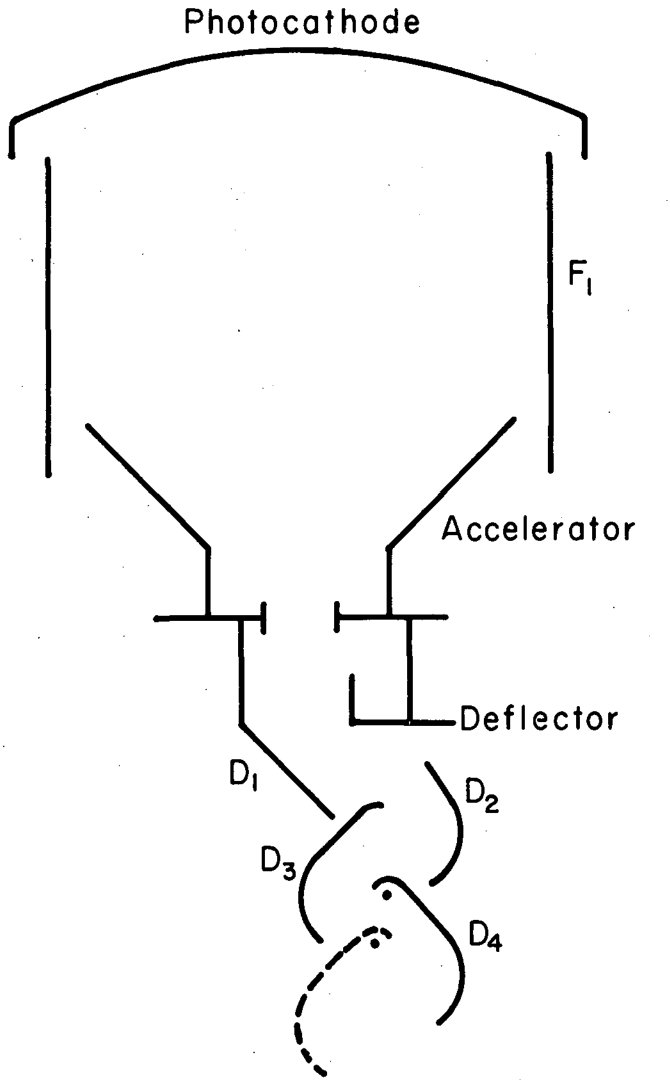

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Fig. 7. Schematic diagram of the electrode structure of the type-56AVP tube (from a private communication from G. Pietri to F. Kirsten).

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1. Q. A. Kerns, F. A. Kirsten, and G. C. Cox, Generation of Nanosecond Light Pulser for Phototube Testing. Rev. Sci. Instr. 30 No. 1, 31 (1959). See also Q. A. Kerns, F. A. Kirsten, and G. C. Cox, A Generator of Fast-Rising Light Pulses for Phototube Testing, UCRL-8227, March 24, 1958, and Counting Handbook file No. CC8-30.
2. Yahia El Hakim, Digital Processing of Photographically Recorded C.R.O. Traces, UCID-965, March 4, 1960.
3. Fred Kirsten, Multiplier Phototube Special Characteristics. Counting Note, UCRL Counting Handbook file No. CC8-4. See also Q. Kerns and F. Kirsten, Voltage Glow in the 7046 Phototube, UCID-357, February 21, 1958.