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UNITED STATES ATOMIC ENERGY COMMISSION

DEVELOPMENT OF DUMONT PHOTOMULTIPLIER TUBES

Report No. 19 for September 1, 1955 to December 1, 1955

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Development of DuMont Photomultiplier Tubes

Report No. 19

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DEVELOPMENT OF PHOTOMULTIPLIER TUBES

A. Large Area Multiplier Phototubes

Development of the K1328 has neared its completion point. As mentioned in the last quarterly report, the problem of the regenerative dark current was being attacked in two ways. The first way was to increase the size of the focusing electrode to get more shielding of the cathode from ions created in and about the multiplier structure. The second way was to enclose the multiplier structure within a metallic shield for the same purpose. Both these improvements have been incorporated in the tubes. They have virtually eliminated the problem of regenerative dark current so that it is possible to run the tubes at relatively high voltage per stage without running into excessive noise. This is a very important improvement since it allows use of relatively high gain in the tube when detecting low energy gamma rays with a liquid phosphor.

An experiment has been conducted using a 16" phototube to determine the proper positioning of the first dynode with respect to the photocathode for the K1328. A special 16" tube was constructed containing a movable shield and first dynode with a small plate placed over the dynode which was electrically independent of the shield. On the far ends of the ceramics, used to support the dynode and shield, were fastened two magnets, the purpose of which was to offer a means of moving the entire system with respect to the cathode with the aid of an external magnet. The entire system was positioned to give considerable maneuverability. Both the shield and the first dynode were coated with P1 phosphor in order that the focal point of the electron optical system might be visually determined.

The experiment was conducted in a dark room with the tube exposed to a point source of light. A microammeter was connected to the first dynode and a specific collection current measured, then an external magnet was employed to move the dynode and shield to various positions with respect to the cathode until a maximum indication is obtained on the meter. With the low light intensity used, it was necessary to use a voltage between dynode 1 and cathode of about 800 volts in order to see the focal spot. This enables the observer to get a better view of what occurs in the system. Fig. 1 gives a sketch of the experimental tube. The experimental results indicated that the present position of the multiplier structure is just about at the optimum point. However, a slight repositioning of the structure toward the cathode may give better collection efficiency. There are three tubes now in process to check out this possibility.

The same experiment was conducted for the 12½" split cone tube. The optimum position of the multiplier structure was determined as described above. This position has been incorporated into the first models of the 12½" tube. This tube is the first of the split cone tubes to be constructed and several such tubes are now in process. Fortunately, this tube is just small enough to fit into the flying spot scanner apparatus and this will allow an estimate of the cathode uniformity and uniformity of the photoelectron collection.

Because of the desirability of investigating the photoelectron collection for the larger size tubes (16" and 22" tubes) a special addition has been constructed for the flying spot scanner which will allow testing these tubes. It is anticipated that data on such tubes will be available within a short time.

B. 3/4" Diameter, Cs-Sb Dynode Tubes (K1382)

Since the last quarterly report, a number of 3/4" diameter 10 stage tubes have been constructed. The data is summarized in the following table. All data was taken at 105 volts/stage with 210 volts between cathode and dynode 1.

Tube No.	PC Sensitivity(uA/l)	Gain	Anode Leakage(uA)
8559EJ	38.4	352,000	0.082
8085EJ	25.6	10,500	0.12
6630EJ	49.6	300,500	0.052
6853EJ	41.6	30,000	0.088
6635EJ	41.6	36,000	0.005
6852EJ	51.2	61,000	12.0
6634EJ	30.4	23,800	0.01

Tube No.	PC Sensitivity(uA/l)	Gain	Anode Leakage(uA)
6137EJ	32	217,000	0.003
6139EJ	33.6	30,000	0.007
5746EJ	22.4	640,000 (unstable)	0.22
7445EG	24 (24.0)	87,000 (14,420)	0.008
3326EG	17.6 (7.6)	355,000 (287,800)	0.48

The last two tubes were reported in the last quarterly report. The values reported then are given in parentheses. Through various means, such as baking and reflashing the cesium pellets in these two tubes, efforts have been made to improve their characteristics. While some success has been achieved, the tubes are still not satisfactory. Of this group of tubes, numbers 8559EJ, 6630EJ, and 6137EJ are passable. Another group of tubes is now in process.

C. Linear Photomultiplier Structures

The construction of a linear type photomultiplier has been under consideration and steps have been taken to determine the various characteristics of such structures. Field plots have been made employing dynode arrangements of various configurations both with and without accelerating electrodes. From these plots it is evident that the insertion of accelerators into the dynode structure tends to form the electric field in such a manner so as to focus the majority of the electrons onto a useful portion of the dynode surface.

However, for reduced transit time spread it appears necessary to place the dynodes closer together and thereby shortening the electron paths. At present, work is being conducted to further determine the best possible dynode configuration for optimum conditions and ease of construction. One structure has been worked out using short arcs of a circle for the dynode configuration as shown in Figure 2. This structure has the shortest estimated transit time spread of any structure investigated by these laboratories. The final details are still to be worked out and it is expected that the use of accelerator electrodes in the structure will improve both the transit time spread and the space charge saturation condition. It is expected to include such a structure in one of the transit time spread tubes as are described in Section D of this report.

D. Transit Time Spread

The experimental tube as shown in Fig. 3 has been constructed and tested. Some difficulties were encountered in focusing the electron beam emitted from the dynode structure into a small spot. It is believed that since a curved surface secondary emitter is being used as a potential cathode for the following gun, the emitted electrons are entering the electron optical system at some skew angle. Since these electrons are at a velocity of approximately 100 volts up on entering the gun, the focusing problem becomes a more difficult one. Therefore, it is deemed necessary that several limiting apertures be placed within the gun in order to form the beam. A 3/16" aperture was cut into the 10th dynode so that the electrons emitted from the 9th dynode may pass through into the secondary gun of the tube.

The only difficulty appears to be with the secondary gun system. The spot size as obtained on the screen of the tube is of the order of magnitude of a half dollar. At present, a new tube is under construction employing a new secondary gun design, which is expected to properly curb the beam size by employing several limiting apertures. The new design will also incorporate another modification, that being, to mount the 10th dynode of the dynode structure under examination onto the secondary gun. This will enable us to secure more perfect alignment of the entire system. No useful data could be obtained from the tube, due to the enormous spot size.

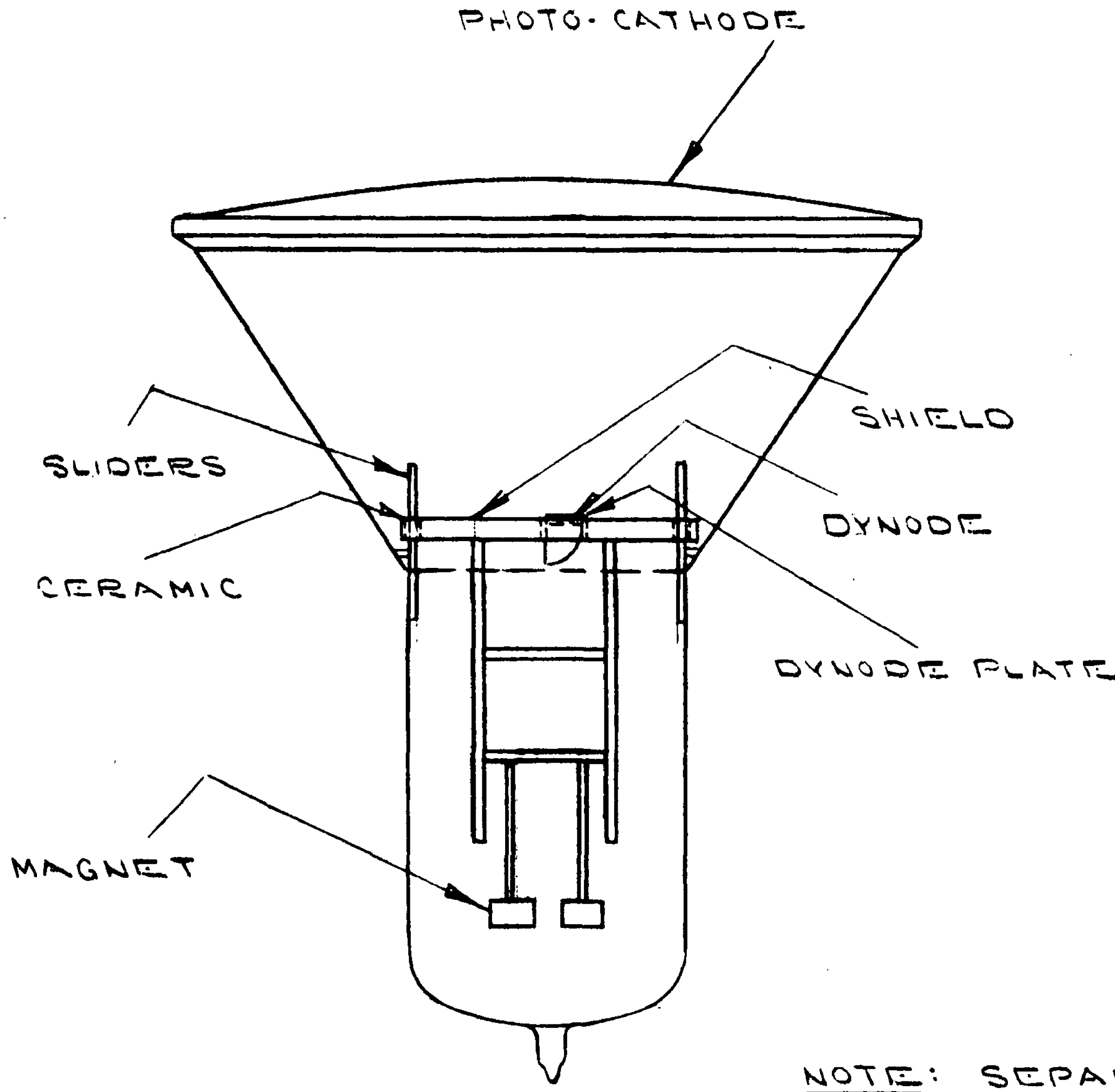
Various circuit difficulties were encountered as far as pickup is concerned. It appears that this difficulty is mainly due to power supply regulation. It was found necessary to shield the entire tube in order to eliminate interferring magnetic field effects. The first tube built has been useful from a trouble shooting point of view. Thus by operating the tube with the circuitry built for this experiment, it has been possible to pick up various difficulties which would be encountered and to correct those difficulties which arise from the circuitry.

Figure 4 is a block diagram of the transit time measurement system as presently set up.

E. Al-Be Dynodes

Two more tubes were constructed using Al-Be dynodes. These tubes use three dynodes. The gains are measured at each of these dynodes and the average of the individual gains is computed for a given voltage. The variation of this average with voltage is shown in Figure 5. Curve I is the first experiment and this data was presented in the last quarterly report. Curves II and III show the results of variation in the activation procedure of the Al-Be surfaces. The main difference is in the amount of oxidation to which the surface is subjected. The dip in curve III at the higher potentials has not been explained. It may be due to experimental error. It should be pointed out that the graphs represent the secondary emission ratio with cesium in the tubes. The secondary emission ratio of the Al-Be by itself has not been studied. Other tubes are under construction using Al-Be dynodes and enough material has been ordered to manufacture ten stage multiplier phototubes. As soon as these tubes are constructed they will be tested for such characteristics as variation of gain with voltage, variation of gain with output current, etc.

16" EXPERIMENTAL TUBE



NOTE: SEPARATE ELECTRICAL CONTACTS ARE PROVIDED FOR BOTH DYNODE AND SHIELD.

Fig. 1

TD 4370- A

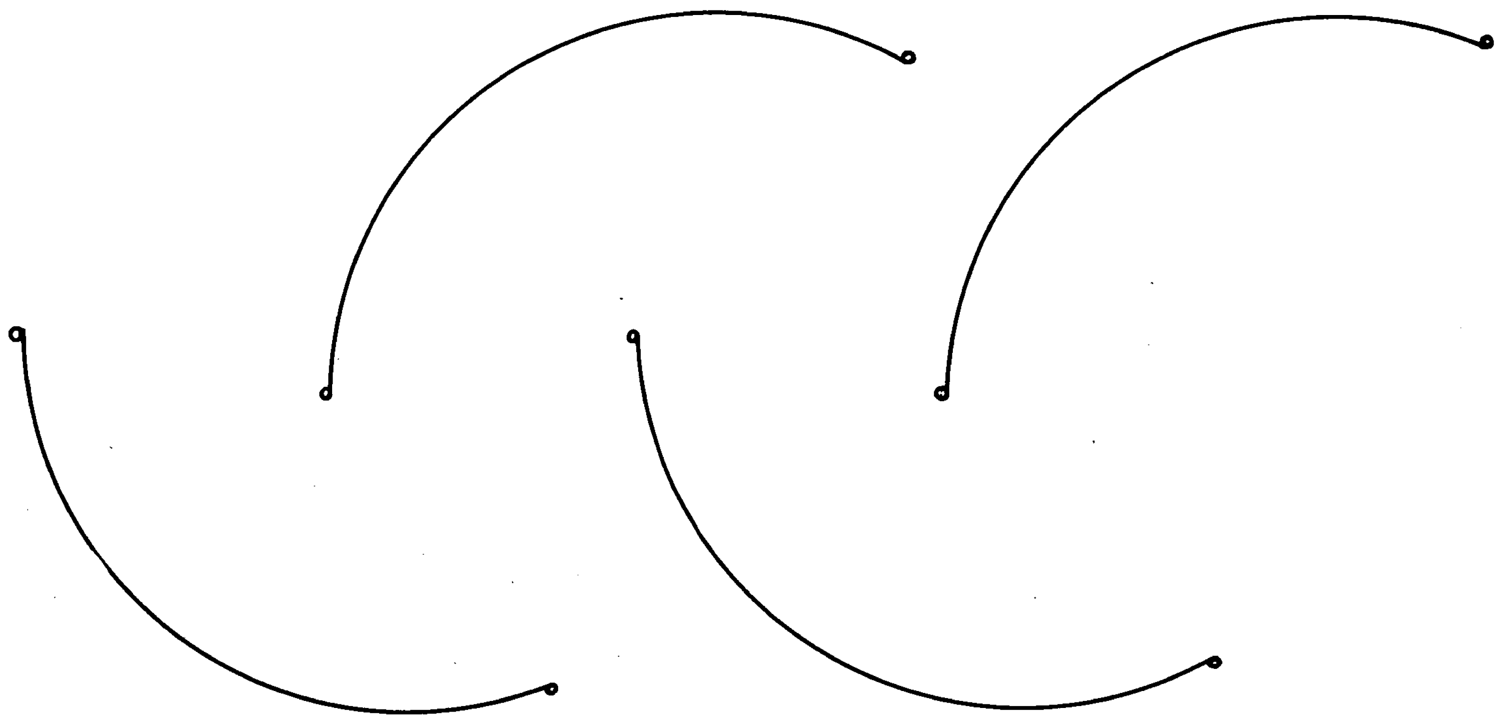


Fig. 2

Linear Type Dynode Structure

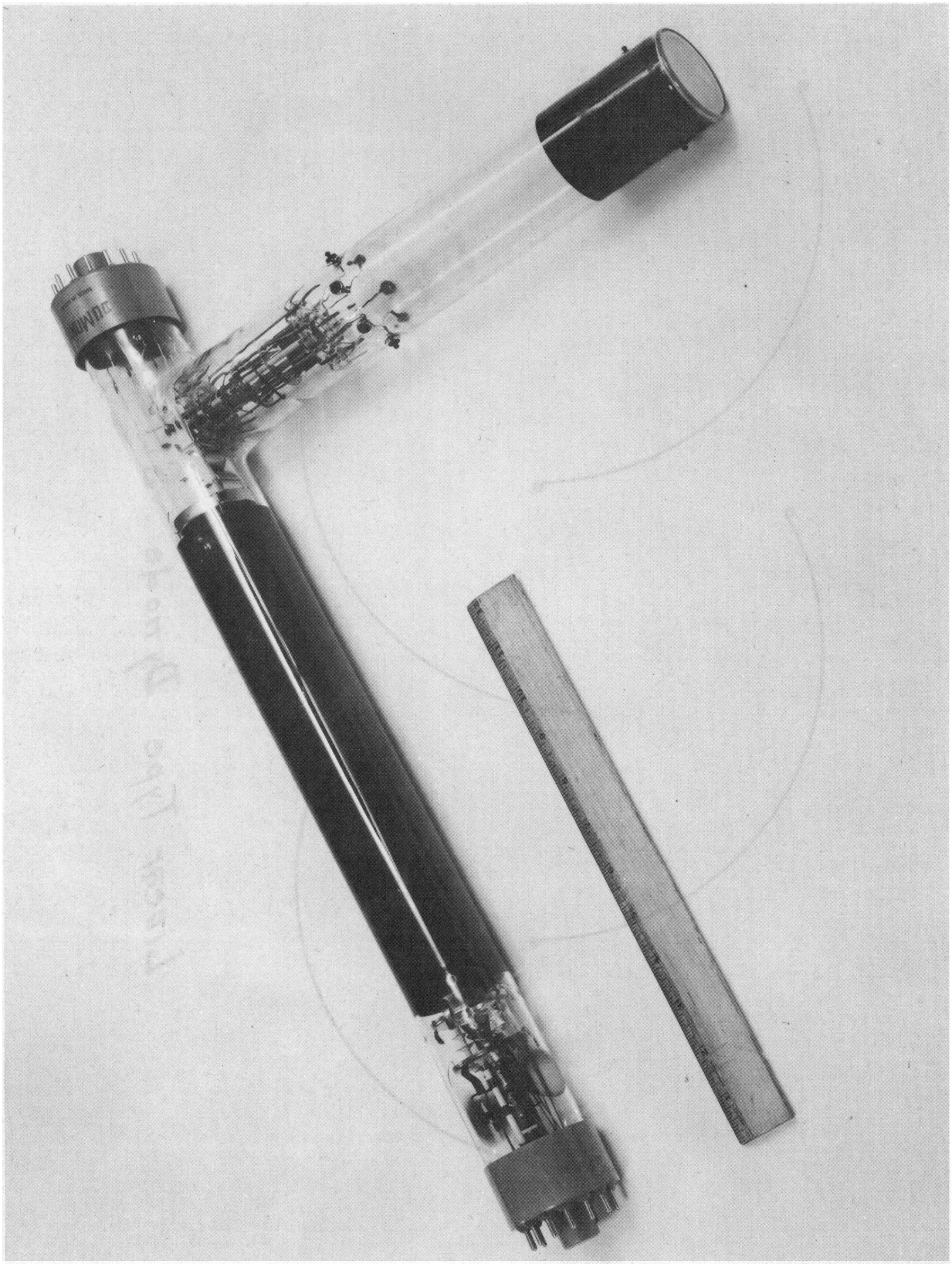
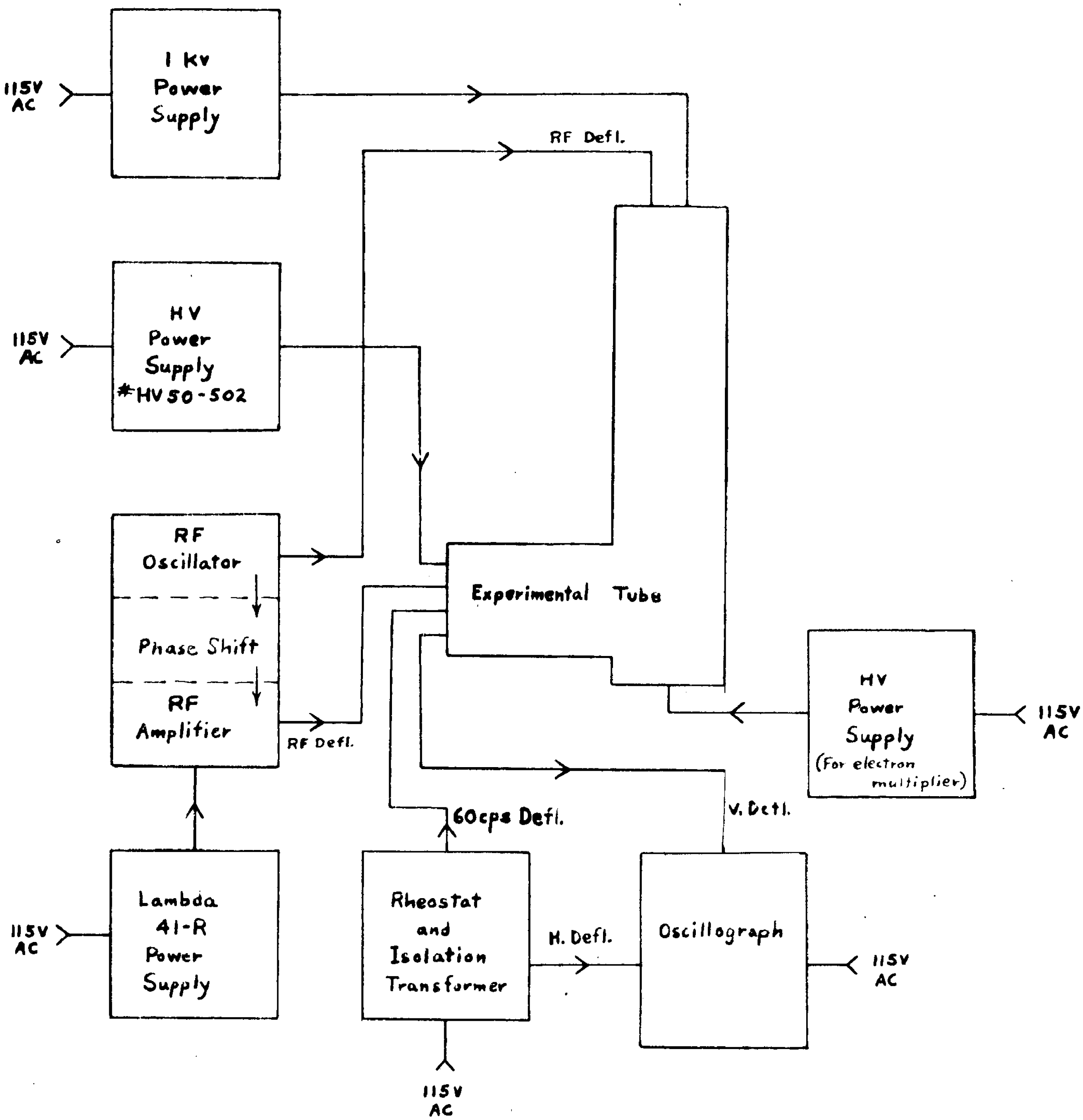
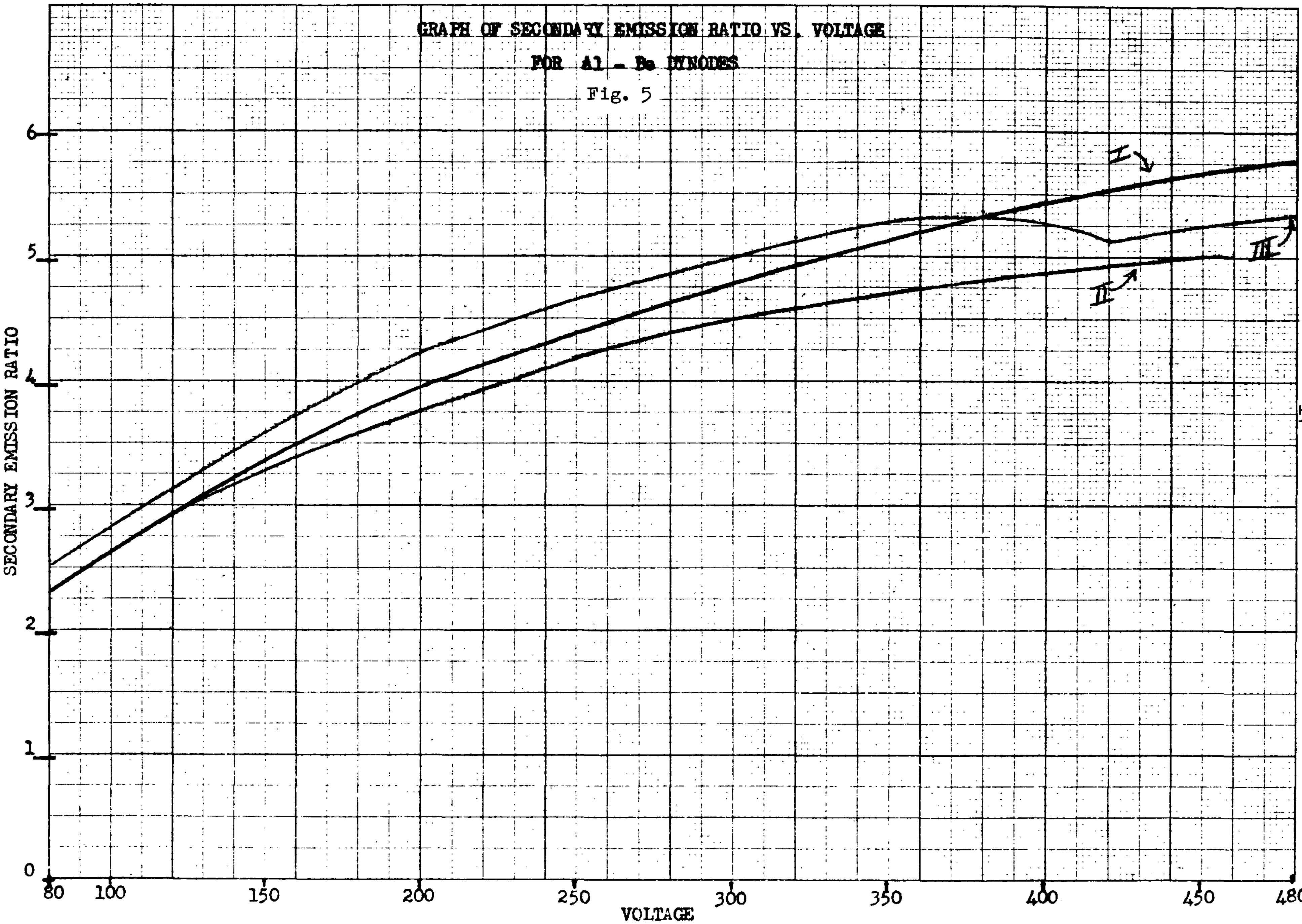


Fig. 3



Block Diagram, Transit Time Spread Measurement

Fig. 4



GRAPH OF SECONDARY EMISSION RATIO VS. VOLTAGE
FOR Al - Be DYNODES
Fig. 5