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FINAL TECHNICAL REPORT ON BALLOON EXPERIMENTS WITH THE STL FLIGHT PROTOTYPE LUMINESCENT CHAMBER

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INTRODUCTION

The STL Flight Prototype Luminescent Chamber was developed under NASA contract NASw-285 and the final report on this program was submitted 30 September 1963. The current follow-on program, to fly the instrument is a series of high altitude balloon flights, was proposed 27 July, 1962. Due to a delay in the delivery schedule of the image intensifier tubes from RCA work did not commence on this program until January 1964.

The luminescent chamber affords a means of obtaining a visual record of the track produced by a charged particle traversing a scintillation crystal. Unlike scintillation counting, a fraction of the fluorescent light produced along the path of a charged particle as it loses energy in a scintillatior is optically coupled and focused onto the photocathode of an image intensifier tube. The photoelectrons thus liberated are accelerated within the tube through a potential difference of the order of 10 kilovolts before impinging upon a fluorescent phosphor screen. A one to one spacial correspondence is maintaned between the electron's point of departure at the cathode and its arrival at the phosphor. This is accomplished by appropriate electron-optical focusing which in our case is provided by an external axial magnetic field. In practice, several such "stages" are built into a single envelope with a corresponding increase in the overall quantum gain. However, an entirely satisfactory tube of this type with more than three stages has not, as far as we know, been built successfully. Unfortunately, three stages of light gain coupled with the kinds of resolution currently available are not quite sufficient to enable one to record, on photographic film, the image of a single photoelectron released from the first photocathode. This, of course, is the ultimate criterion which must be realized in order to have the most sensitive type of instrument.

The present instrument uses two 3-stage magnetically focused image tubes (RCA C-70021) with specially constructed grid electrodes in the second stage of each tube. The first tube in the system is built with a fiber optic output and the second tube has a fiber optic input and output. In practice the two tubes are mounted inside a cylindrical permanent focusing magnet with a coil spring to maintain positive optical contact of the fiber optic elements between the tubes.

A special film camera was built for experiments to be performed aboard the recoverable high altitude balloons. This magazine is mounted at the output fiber faceplate of the second image intensifier tube. A pressure plate is used to maintain the film in optical contact with the fiber faceplate preparatory to being exposed. After each exposure the pressure is released using a Geneva movement arrangement while the film is being advanced to the next frame. The magazine automatically advances and meters each frame on demand via a pulse from the triggering system. Provision was made in the camera design to record pulse height as well as track data on the film. The light from any of twelve tiny argon bulbs is focused on the film. These provide two independent 64 bit channels of pulse height information. In addition, each frame includes an identifying number and a clock picture so that the time of each event is known.

The basic triggering system for the luminescent chamber is a fast three-fold coincidence circuit. The geometric arrangement of the guard or triggering counters around the track forming detector is dictated by the requirements of the particular experiment being performed.

The coincidence circuit output triggers the film advance and also a 10 microsecond and a 1 millisecond univibrator. The univibrators each drive separate 500 volt pulse generators which turn on the second stage of each image intensifier tube via the special gating grids provided for this purpose. Thus the first tube is on for several microseconds, and the second tube for several milliseconds each time the coincidence circuit indicates that an event has occurred in the chamber. The coincidence circuit also triggers a delay generator which prevents retriggering of the image tubes during the one second interval required for the film to advance. All the electronics are transistorized and packaged.

1. SELECTION OF BALLOON EXPERIMENT

The choice of an initial experiment was based on the following considerations: a) that the experiment be relatively simple and straighforward, b) that it provide a good test of the luminescent chamber as an important instrument for future space physics investigations, c) that the fundamental results of the experiment be easily verified by comparison with data obtained from previous similar measurements, d) that the use of the luminescent chamber in the particular experiment be unique and e) that the results obtained contribute to a better understanding of the phenomena involved.

As a result of these considerations the decision was made to investigate in detail the charge and energy spectra of primary cosmic rays from charge $Z = 2$ through $Z = 8$, i.e., from helium nuclei through oxygen nuclei. The track picture of each event is supplemented by pulse height information from counters surrounding the chamber. For each primary nucleus traversing the track forming and counter assembly, the pulse height from an energy loss (dE/dx) counter and from a Cerenkov counter is recorded along with the track picture. This "simultaneous" pulse height analysis will suffice to resolve the charge of the incident particle. (see Fig. 1). Since the charged primary high energy cosmic rays consist primarily of bare nuclei, a measure of the net charge serves to identify the mass as well. Isotopic effects are ignored in the present experiment. From a knowledge of the charge, mass, and energy loss it is then a simple matter to calculate the energy. The geometrical arrangement of the counter and track forming assembly is described in more detail in the following section.

2. THE TRACK FORMING SCINTILLATOR AND COUNTER ASSEMBLY

The track forming scintillator and associated crystals were fabricated as an integral, hermetically sealed, unit. The configuration of the assembly in shown in Fig. 2. The unit is divided into 5 optically insulated slabs with a sealed glass faceplate on the front surface. Crystals A, C, and E are track forming sections of NaI(Tl) scintillator material. Crystal B is made of ultraviolet transmitting grade lucite. It is packaged in dry contact with Al_2O_3 spray on 5 mil foil and serves as the Cerenkov radiator. Crystal D serves as the energy loss detector and is made of NaI(Tl) but with a graded reflector to maximize uniformity of response.

The walls of the track forming sections, with the exception of those coupled to the front glass window, are polished and painted with RB13 compound and carbon black. This technique minimizes scattered and reflected light in the crystal which could result in unwanted background in the track pictures. Light pipes are brought out of the crystal housing from crystals B and D to be coupled to photomultiplier tubes. The anode pulse height from these tubes is recorded for each event. In addition, a light pipe is also brought out from a side face of crystal A. The dynode pulses from this counter along with t e dynode pulses from counters B and D are fed to a three-fold coincidence circuit whose output defines an event. The counter/track assembly, less the photomultiplier tubes, was fabricated by the Harshaw Chemical Company. It is packaged in a ruggedized aluminum mount filled with 10^6 centistoke silicon oil. Fig. 3 is a photograph of this assembly including the photomultiplier tubes.

The geometrical arrangement, as described above, enables one to observe the particle before it enters the Cerenkov counter and again as it leaves. Similarly, the same particle is observed prior to entering and after emerging from the dE/dx counter. In this fashion, if the track segments fall on a straight line, it can be stated with a high degree of reliability that no local nuclear interactions have occurred in the counters themselves. Therefore, the pulse height, as measured, should represent "good" information and the interaction background is eliminated. A schematic representation of an event is shown in Fig. 4. Secondly, each event contains directional information in the track picture. This fact enables one to afford a relaivelv large solid angle since the path length of the particle through the crystal is known. The pulse height which one measures in such a case is proportional to the particles' path length through the medium. A block diagram of the entire system is presented in Fig. 5 and the electronic details are discussed in Section 4.

3. THE FLIGHT FILM MAGAZINE

Since the image tubes have a fiber optic output and exposures are made by having the film in direct optical contact with the fiber bundle, it was necessary to include a mechanism for releasing the film from the fiber during each film advance cycle. This was accomplished by a cam arrangement which retracts a longitudinally spring loaded platen prior to advancing the film. The platen is mounted in such a way that, except during the advance cycle, it insures positive seating of the film against the fiber optic. As explained in Section 1, the two photomultiplier tube anode pulses are fed into two 64 channel pulse height analyzers which in turn drive separate binary scalers. The final state of these scalers for each event is then read out into a sequence of six argon lamps. The appropriate lamps are pulsed on for about 30 milliseconds and recorded as dots on the same film that records the track information. This is accomplished by a special housing on the rear of the platen that accomodates the 12 argon lamps. (see Fig. 6). The light is piped through 12 small holes to the front of the platen so that the exposure is actually made through the back of the film. The position of the pulse height light display coincides on the film with the position of the Cerenkov counter so that there is no overlap with the track information.

At a different place within the camera, and an integral number of frames from the track and pulse height information, an optical system projects the image of a clock and a frame counter onto the emulsion side of the film. Thus a number is assigned to each event and the time history is also known. This information appears on the film in the same position as the dE/dx counter so that again there is no overlap of information (see Figs. 4 and 6).

The time required for the film to advance one frame is from 0.3 of a second to 1 second depending on the camera motor voltage. An electrical interlock, to be described later, inhibits triggering of the entire system until completion of the camera wind cycle. The wind cycle is initiated by an electrical pulse from the coincidence circuit and master pulse logic, after which a cam actuated microswitch takes over for the remainder of the cycle. A Geneva movement action accurately measures a one-inch advance of the film per event. Dynamic electrical braking is applied to the camera motor at the completion of the cycle to prevent recycling in the case of inertial overshoot. Another microswitch is actuated when the film is exhausted and was used to signal the release of the balloon and initiate the payload recovery sequence. The film magazine is mated to the image tubes and magnet by a dovetail assembly and sliding shutter so that it can easily be removed from the rest of the system without exposing the film.

4. ELECTRONICS DESIGN

The image intensifier tubes are designed to be "cut-off" by applying to the gating grids a negative D.C. bias of several hundred volts with respect to the second stage cathodes. This D.C. potential is supplied through a 20 megohm resistor. The appropriate "on" and "in focus" voltage requires that the grids be several hundred volts positive with respect to the second stage cathodes. Thus, ideally, a square positive pulse of about 500 volts must be developed across the 20 megohm resistor in order to bring the tubes from a cut-off condition to an operating condition. The optimum pulse characteristics for the image tube grids were determined experimentally. The pulse lengths are generated by appropriate univibrators which drive 50 volt transistors. The 50 volt pulses are then applied to pulse transformers with a 10:1 step-up ratio to obtain the required 500 volt pulses. The complete image intensifier tube high voltage supply divider and pulsing electronics is shown in Figs. 7 and 8.

It should be noted that two pulse transformers are necessary to generate the correct pulse shape for the first tube. These were designed and wound in our laboratory on ferrite cores. The first transformer (T1) produces a rise time at the secondary of less than one microsecond and saturates at about 10 microseconds. The pulse at the secondary of the second transformer rises in about 5 microseconds and saturates at about 200 microseconds. By connecting the secondaries of the pulse transformers in parallel through steering diodes 1N547, the required output pulse shape is generated. A flat topped pulse is obtained by overdriving the primaries and clipping the secondary pulse height with zener diodes of the required voltage.

The 2 millisecond pulse width and 30 microsecond rise time required for the second tube is generated in a similar fashion. Here, however, a commercial power transformer (UTC H-198) is used as the pulse transformer.

The operation of the electronics which control the camera and image tube gating is described below. Referring to Fig. 9, a negative pulse is applied to the base of T-16. This transistor along with T-17 generates a fast rising master pulse of 100 microseconds duration. The positive pulse from the collector of T-17 is allowed to procede through T-18 only if T-19 is conducting. At the end of the 100 microsecond interval T-20 and T-21 generate a positive pulse which is applied to the base of T-19 and turns this transistor off. It is kept off so that no signal appears at emitter follower T-35 for a time determined by C and other circuit parameters. This "dead time" is built in so that there is sufficient time for the pulse height analysis and the film advance. A safety feature is provided by routing the 15 volt positive signal from the camera motor to point "A" which keeps T-19 turned off for the duration of the camera wind. The pulse at "C" is fed directly to emitter follower T-36, shown on Fig. 8, which in turn drives the high voltage transistor T-37 and pulse transformers for the first image tube, The pulse at "D" is fed to univibrator T-22 and T-23 which generates the 2 millisecond pulse for the second image tube. Points "E" and "F" drive the grids of the respective image intensifier tubes as shown in Fig. 7. Point "B" is fed to the collector of T-41 as shown on the camera control circuit diagram, Fig. 10. T-41 and T-42 generate a 30 millisecond pulse which turns on T-45 ar ights argon lamps A1 and A2. These lamps supply the illumination the clock and message register whose image then appears on the film. At the end of the 30 millisecond interval univibrator T-43 and T-44 applies a pulse to T-46 which closes the relay. One pair of relay contacts supplies D.C. power to the camera motor while another pair enables a pulse to be applied to the message register, advancing it one unit. The time constant of T-43, T-44 is chosen to be greater than that time required for the cam operated microswitch, S1, to be actuated but less than the camera wind cycle. When S1 opens and removes power from the camera motor, both poles of the motor are simultaneously grounded which quickly brings the motor to a complete stop. It should be emphasized that the film advance is accurately controlled by the Geneva movement action and not by the time during which the camera motor armature is turning.

A. Electronics Design for Pulse Height Analysis

As outlined in Section 1, the pulse height from a Cerenkov radiator and energy loss scintillator is recorded for each event. Since the electronics is nearly identical for both counters, only the Cerenkov channel will be described. The pulse height from the Cerenkov counter is a monotonically increasing function of the particle velocity from the

Cerenkov theshold velocity (determined by the index of refraction) up to extreme relativistic velocities. It also varies directly with the square of the charge. This means that for the primary particles (Z = 2 through 8) and velocities, to be investigated in this experiment, the pulse heights to be expected will have a dynamic range of about 160 to 1. In order to keep the electronics as simple as possible and still maintain a linear response in the analyzer over this range, it was decided to introduce a nonlinear amplification of the pulses to compress the range before the actual analysis. Since the statistical fluctuation in the pulse height for any given event is expected to be Poissonian, a standard deviation of plus or minus the square root of the average pulse height must be assigned to each event. For this reason a circuit was designed which would generate an output pulse proportional to the square root of the Cerenkov counter input pulse. In this way the dynamical range is compressed and in addition, each channel of the 64 channel pulse height analyzer will present information of equal statistical weight. The following description refers to Fig. 11. The square root response is approximated, after current amplification, by four appropriately loaded and biased diodes at the base of T-4. A zero D.C. level is maintained at this point by D.C. feedback amplifiers T-33 and T-34. The pulse then proceeds through emitter follower T-5 to a signal gate. This gate is opened through T-27 by the master pulse from T-35 in Fig. 9. The gate can be accurately balanced so that no pedestal appears on the output signal which then is stretched by T-6. The following circuit performs the height to time conversion resulting in a pulse across tunnel diode D-1 at the collector of T-10 whose length is proportional to the incoming pulse height. This pulse starts a frequency stabilized 100 kilocycle clock, comprised of oscillator T-13, which runs for the duration of the input pulse length. Before the clock pulses can proceed to the six binary scaler stages shown in Fig. 12, transistor T-15 must be turned on by the scaler gate T-24 and T-25. This gate is also opened by the master pulse from T-35. The scaler gate serves a two-fold purpose. First, the pulse length can be accurately set so that a maximum of 64 cycles of the clock are counted by the scalers. This is to prevent a large pulse that might correspond to say, channel 65, from being counted further by the scalers and registering in channel 1. Thus all pulses whose heights correspond to channel 64 or larger (up to channel 128) are recorded in channel 64. Second, it also prevents large pulses from the counters, which could override the signal gate, in the absence of a master pulse, from actuating the scalers. The final state of the scalers is then displayed on the appropriate argon lamps for a time determined by the reset generator T-31 and T-32. The reset generator is also triggered through T-30 by the master pulse from T-35. The output of the reset generator is differentiated and the positive pulse at the end of this predetermined time resets the scalers to their initial state with all lamps off.

The coincidence circuit, whose output triggers the master pulse generator at the base of T-16, is shown in Fig. 13. The emitter followers T-47, T-49 and T-52 are built directly into the bases of the respective photomultiplier tubes. The emitter signals are fed out through shielded cables as shown. D-3 is a one milliampere tunnel diode which is biased in such a way that it does not change its state unless a signal appears simultaneously at all three collectors of limiters T-48, T-51, and T-54. The channel for counter A is straightforward. The channel for counter B (Cerenkov counter) includes a stage of amplification (T-50) since it is desirable to trigger on and investigate particles whose velocity is close to the Cerenkov threshold. The third channel, which looks at the dynode pulses from the NaI (dE/dx) counter D, requires further explanation. Since the primary proton spectrum is not to be investigated in this experiment, a bias must be established in the coincidence circuit which prevents triggering on singly charged particles. This is accomplished by tunnel diode D-2 whose bias is set by proper adjustment of the current in T-53.

The entire electronic circuitry, for both channels of pulse height analysis and the image tube, camera, and argon lamp triggering, is built on a total of eleven 3-1/8" x 6-3/4" epoxy circuit boards. Each board has a pair of plug-in connectors for signal and power distribution and all boards when mounted and plugged in occupy an electronic package measuring 3-1/2" x 7-1/2" x 10". All the electronics is designed to operate from standard voltages of +10, -10, +20, and -20 volts to be supplied by Yardney silvercels and each board contains its own RC filter network for each voltage. In order to conserve power, regulated voltages are supplied only to those parts of the circuit that require well regulated voltages, and separate power connections are brought to each board when required for this purpose. These voltages are regulated with respect to input voltage variations of $\pm$ 20%. All critical elements were also temperature compensated to insure accurate and reliable operation over the anticipated temperature range of 20°-70°F.

5. CALIBRATION PROCEDURES

The response of the photomultipler tubes, which view the Cerenkov and dE/dx counters, were carefully determined with a light pulser, calibrated optical filters, and a commercial 400 channel pulse height analyzer. With the photomultiplier tubes mounted in their flight geometry, sea level mu-meson spectra were first taken in order to normalize the calibration to singly charged particles. An argon lamp fast rise light pulser was developed so as to simulate the light from either the Cerenkov radiator or the NaI scintillator. By means of the optical filters the number of photoelectrons corresponding to those expected in the experiment were measured as a function of pulse height. Several such runs were made for both photomultiplier tubes operating at various gains. The log-log display of these data indicated not only that the photomiltiplier tubes response was linear over the anticipated dynamic range of the experiment but that when operating at the gain selected for this experiment the largest pulses were still well below the region of anode saturation.

Immediately after the light pulser calibration described above, the photomultiplier tubes were once again mounted in their flight geometry and a secondary gain calibration was taken using a thorium C" radioactive source and the 400 channel pulse height analyzer. A readily identifiable peak from the dE/dx counter was recorded and final trimming of the photomultiplier tube high voltage for this counter was accomplished by observing this spectrum just prior to the flight. The secondary calibration procedure for the Cerenkov counter was slightly different since one does not obtain a peak in the differential spectrum from this source for the Cerenkov radiator. In this case a standard position was defined for the source relative to the radiator and, with specified gain settings, the total number of counts with heights greater than channel 40 were recorded for a one minute run. This figure had to be periodically revised to account for the decay of the source.

The flight analyzers themselves were carefully calibrated by instroducing an electrical pulse which was shaped to simulate the photomultiplier tube anode pulses, and calibration curves of channel number versus the square root of the pulser voltage were recorded. These curves were very nearly linear. A final curve of this type for each flight analyzer was run just prior to the flight.

6. MECHANICAL ASSEMBLY

The flight gondola consists of two spun aluminum hemispheres 41 inches in diameter. These bolt from above and below to a central reinforced aluminum platform on which the equipment is mounted. A flange, at the equator of each hemisphere is sealed to the platform with a circular rubber gasket and 96 steel bolts, equally spaced around the equator. The gondola less the equipment platform is shown in its shipping cradle in Fig. 14. A rollover assembly was fabricated to fit around the upper hemisphere as shown. This member was designed to minimize any tendency of the gondola to roll after landing.

Passive thermal control was accomplished by painting the upper hemisphere with black and white stripes of the appropriate area to achieve the required temperature equilibrium. Since the crush pad, to be described below, covers the lower hemisphere painting was not necessary.

Strip heaters capable of supplying 30 watts of heat were installed on the equipment platform and were thermostatically controlled to provide the proper thermal environment for the equipment.

Pressure tests were conducted which indicated a change from 14.7 pounds per square inch gauge pressure to 14.5 psi in 10 hours when the bolts were tightened to 30 inch-pound of torque. The bolts themselves were independently tested to determine their yield point, which turned out to be 80 inch-pounds. To determine the effect on loading due to the low temperatures that will be encountered during the flight, another test was made. Sections of aluminum, simulating the hemisphere flange and platform mating surface, were bolted together with a section of gasket material. The bolts were instrumented with strain gauges, torqued to 45 inch-pounds and cooled to -65°F. This test indicated a loss in loading of 10 inch-pounds which was due entirely to the difference in thermal contraction between the aluminum flange and the steel bolts. No deterioration or shrinkage of the rubber gasket was observed. For the flight the gondola was sealed with 45 inch-pounds of torque on the bolts, which was completely adequate.

A landing gear assembly of crushable corrugated aluminum was designed and fabricated. The aluminum members were attached to a molded fiberglass hemispherical shell which fits over the lower hemisphere. This crush pad was designed to limit the landing impact to less than 10g.

Fig. 15 is a photograph of the complete instrument mounted on the gondola platform. The "front end" assembly is bolted to the dovetail plate at the opposite end of the magnet by means of the four rods as shown. The track forming and counter stack as well as the lens is mounted on this assembly. The Nikkor f/1.1 lens is positioned so that the 3"x3" front face of the crystal stack is demagnified by a factor of 3.4 and focused onto the 1-1/2" diameter photocathode of the first image intensifier tube. Provisions were made to enable both the lens and crystal stack to be independently moved parallel to the axis of the system in order to achieve the best optical focus.

Each of the photomultiplier tubes is located within a cylindrical netic - conetic magnetic shield. The shields are rigidly bolted to the crystal stack assembly. The front windows of the photomultiplier tubes are held in optical contact with their respective light pipes by means of beryllium-copper wave washers mounted under an end cap at the tubes' base. . Compression is then applied between the end cap and the magnetic shield mount.

The image intensifier tubes are kept under constant logitudinal compression between the end plates of the magnet by a large coil spring mounted inside the magnet. The magnet itself is made up of two semi-cylindrical sections. These are clamped together by two circular bands which are in turn attached to the two base supports for the entire system. The film magazine is cantilevered from the dovetail plate to assure positive mating at the dovetail interface.

In order to minimize the weight of the gondola structure, it was designed to be as small a sphere as possible, that would still enclose the equipment. Unfortunately, due to a small but necessary correction made in the overall dimension of the instrument after gondola design and fabrication, an immediate integration of the equipment to the gondola platform was not possible. These difficulties were overcome, however, by the following measures. The film magazine and crystal stack-phototube assemblies were both rotated 180° about the image tube axis. It was ascertained that the film transport mechanism and other mechanical features associated with the magazine, performed with no difficulty in this configuration. The possibility of affecting the nature of the experiment by inverting the crystal stack assembly was investigated and found to be negligible. In fact, an actual advantage resulted from these changes. It was now possible to rotate the film magazine and crystal-stack an additional 10°, thereby bringing the crystal stack in line with the vertical direction.

In the original instrument a 10° rotation of the optical image occurred electrically within the image intensifier tubes themselves. This had been compensated for by rotating the crystal stack assembly through 10° in the opposite direction with respect to the camera. It had then been planned to rig the gondola to the balloon with its equator making a 10° angle with the horizontal, and thereby bringing the crystal stack assembly into an upright orientation. This, of course, was no longer necessary.

To facilitate operation and electrical checkout of the system after the gondola was sealed up, a central power and signal distribution box was installed on the platform. This box contains a number of DC latching relays which when energized, apply the proper DC battery voltages to the various components of the system. The relay coil leads pass through a vacuum tight electrical connector to the outside of the gondola. Monitoring networks were built into the electronics at points which when observed on an oscilloscope, can completely check out the proper functioning of the system. Signal leads from these points also tie in to the electrical feed through connectors. A separate box was built containing batteries, on-off push buttons, and signal cable connectors, so that by means of a cable from this box to the gondola connector, all equipment can be turned on and monitored remotely after seal off and just prior to lift-off.

7. FAILURE OF ONE OF THE IMAGE INTENSIFIER TUBES

All equipment was functioning properly and a final mu-meson cosmic ray run was being taken in July, 1964 just before shipping the equipment to Sioux Falls, S.D., for the flight. During this run one of the image intensifier tubes (second one in system) broke down internally and ceased to operate. The inoperative tube was temporarily returned to the subcontractor (RCA) for failure analysis and any possible salvage of parts. A visual inspection of the tube after failure clearly indicated that the aluminized backing on the first stage phosphor has disintegrated. The purpose of this aluminum film is to prevent any light, which is normally generated in the phosphor, from being "seen" by the photocathode of that stage. The subcontractor has concurred with our analysis that once a small region of the aluminum is no longer opaque a regenerative feedback condition can set in which is accompanied by excessively large electron currents in that stage and can quickly destroy the remaining aluminum screen. A thorough analysis, both by us and the subcontractor, has failed to uncover the specific initial malfunction that led to this condition although they note it may have been due to poor bonding between the aluminum and the phosphor during fabrication. As a safety precaution we redesigned our high voltage image tube pulsing circuits so that, as far as our operation of the tubes is concerned, no possibility exists for such a failure in the future.

This failure necessitated a postponement in the program until a new tube could be ordered and delivered. In addition, it also became necessary to limit the scope of the program to one balloon flight rather than four as originally proposed. The new tube was finally received by us in April 1965 and the following four months were spent in integrating the new tube into the system. This operation involved a number of minor modifications. Additional high voltage potting was required to prevent voltage breakdown between the tube and the permanent magnet. The new tube also required very unequal voltage division between dynodes for optimum performance. This necessitated rebuilding the high voltage divider for this tube. Since both the gain and noise figures are different for the new tube than those for the old tube, adjustments had to be made on the overall operating voltage for both the new tube and the remaining first tube in the system as well as readjustment of the amplitude and duration of the image tube gate pulses. Cosmic ray mu-meson tracks were photographed with the system while adjusting various parameters to optimize gain, resolution, and signal-to-noise ratio.

It was also determined that a large number of the silver cells, that had been purchased originally for the balloon flight had deteriorated in storage and new cells had to be ordered. The new cells were received 2 September 1965 and delivered to our power system laboratory for conditioning and charging .

8. THE BALLOON FLIGHT

Special containers and crates were fabricated to facilitate the shipment of the equipment from our laboratory to the launch site at Sioux Falls, South Dakota. The instrument was partially disassembled from the gondola platform and the image intensifier tubes and magnet were hand carried aboard a passenger airliner to minimize any possible damage in shipment. The remaining equipment was transported via air freight. The shipment took place on September 13, 1965. The instrument was reassembled at the Raven Industries facilities and all preflight calibrations and adjustments were made while operating from laboratory power supplies. These included checking the photomultiplier tube gains with the throium source and external pulse height analyzer. Also a channel by channel electrical check of the flight analyzer circuits was performed with a modified pulse generator as described in Section 5. These curves checked with those taken just before shipment and indicated that all the electronic circuits were functioning properly. The Yardney silvercel batteries were also tested under load and all measured voltages were correct.

All electrical and mechanical tests were completed and the equipment was ready for flight on September 19, 1965. Inclement weather however, forced a postponement of the flight until the morning of 24 September 1965. The gondola was then sealed and flushed with five volumes of dry nitrogen to remove most of the water vapor. This was followed by a few percent by volume of Freon to minimize possible high voltage electrical breakdown. The payload was then transported by truck to the nearby launch site at the Sioux Falls airport. All internal power was turned on five minutes prior to launch and all voltage and signal monitor points were checked, as described in Section 5, and found to be functioning properly. Launch occurred at 5:35 a.m. CST, on September 24, 1965. Fig. 16 is a photograph of the gondola and balloon just prior to launch and Fig. 17 is a photograph of the descent. The flight proceeded smoothly, and the payload reached its floating altitude of about 105,000 feet at 7:00 a.m. An automatic timer had been set to release the balloon at 5:15 p.m. on the same date. Prior to this time, however, a radio signal was received indicating that the 1100 ft of recording film had been expended and the flight was terminated by radio command at 3:15 p.m. The payload descended by parachute and impacted in a cornfield near Livermore, Iowa, at 3:55 p.m. on September 24. The landing was very soft and later inspection revealed no damage to either the equipment or the gondola. The post-flight calibration of the photomultiplier tubes and pulse height analyzers, operating from laboratory power, reproduced nearly identically the pre-flight calibration curves.

9. EXPERIMENTAL RESULTS

The first indication that there had been a malfunction was upon inspection of the silver cell battery pack after recovery. This inspection revealed that two of the 1.5 volt cells in a 20 cell pack measured zero volts open circuit and that the polarity of one of these had actually reversed. When the flight film record was developed and inspected it revealed that the voltage of the cell in question had dropped to zero and actually had been driven to about 2 volts in the opposite direction. This occurred only 1/2 hour after launch when the balloon was at 25,000 ft. Thus, a tap from the 20 cell pack that was supposed to supply +10 volts to the transistorized logic circuits was providing only 6-1/2 volts. This voltage drop was outside the 20% tolerance for which the input was regulated. As a result, the entire triggering logic functioned improperly. In addition to the malfunction of the triggering circuits, these incorrect voltages also adversely affected the image tube pulse lengths and rise times as well as the pulse height analysis. Consequently, no useful data resulted from the flight.

A failure analysis by our power systems laboratory of the entire battery pack, including the bad cells, indicated that all the cells had been very poorly formed. In particular, the cells that failed during the flight exhibited the following abnormalities:

a) All the zinc electrode separators were punctured by the electrode collector wires

b) Discolored pressure indentations were present on all the silver separators on the sides facing the zinc electrode collector wires

c) All the zinc electrodes were thicker in the lower third of the plates than the top third

d) The paper separators were frayed or torn on the sides and bottoms of the thickened electrode area

e) Pieces of zinc had crumbled from the plates and migrated through the separator holes leaving a deposit in the electrolyte about 1/2 inch deep on the bottom of the cells.

Fig. 18 shows a photograph of the collector wire protruding from one of the zinc plates through the separator and the corresponding indentations on the silver separator and plate.

A third cell failed completely a few days after the flight and during the battery analysis. This cell was also examined and found to have a protrusion at the top of one of the zinc electrodes which had punctured both the zinc separator and all layers of silver separator.

All cells had been charged about ten days before the launch and had exhibited a normal charging curve of voltage vs time. In addition, as mentioned earlier in this report, all voltages were measured under load a few hours before launch and no discrepancies were noted. The external monitor points were checked just prior to lift-off and indicated that all the equipment was functioning normally.

It is the opinion of our power systems laboratory as a result of their analysis, that the abnormal condition of the batteries did not result from our handling and use, but rather from poor quality control on the part of the vendor.

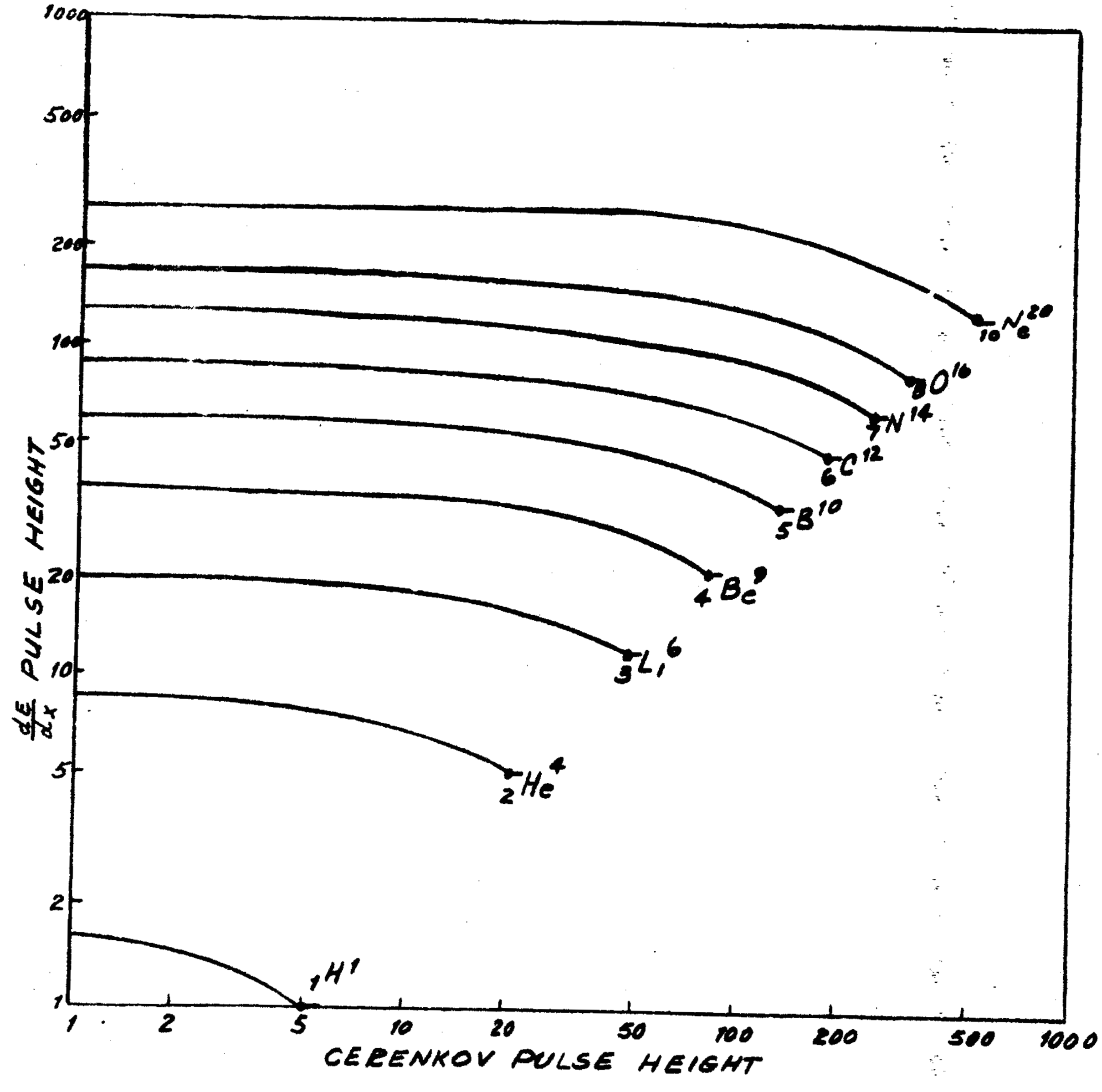

Figure 1. dE/dx vs Cerenkov Pulse Height

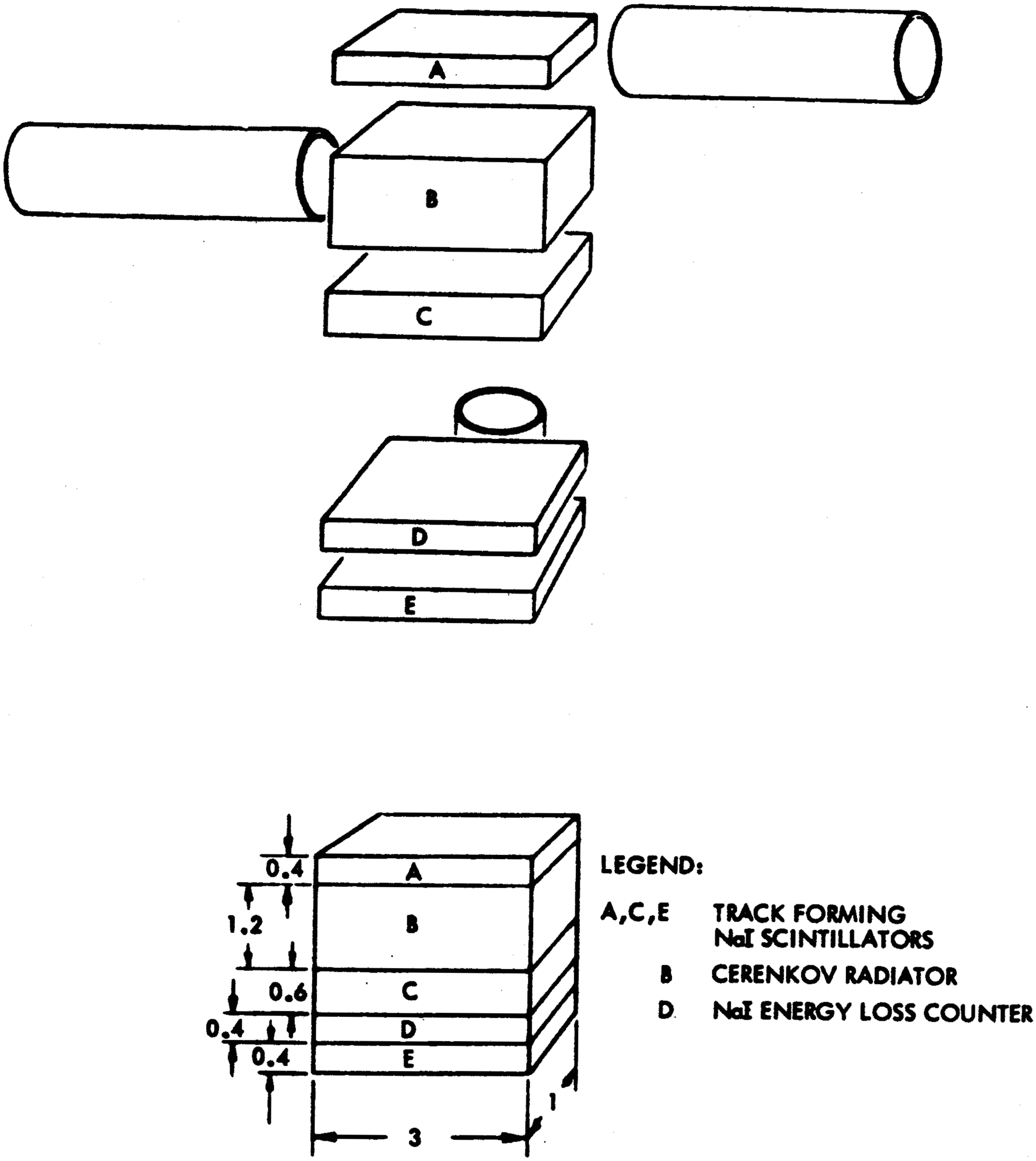

Figure 2. Schematic Drawing of Chamber/Counter Assembly

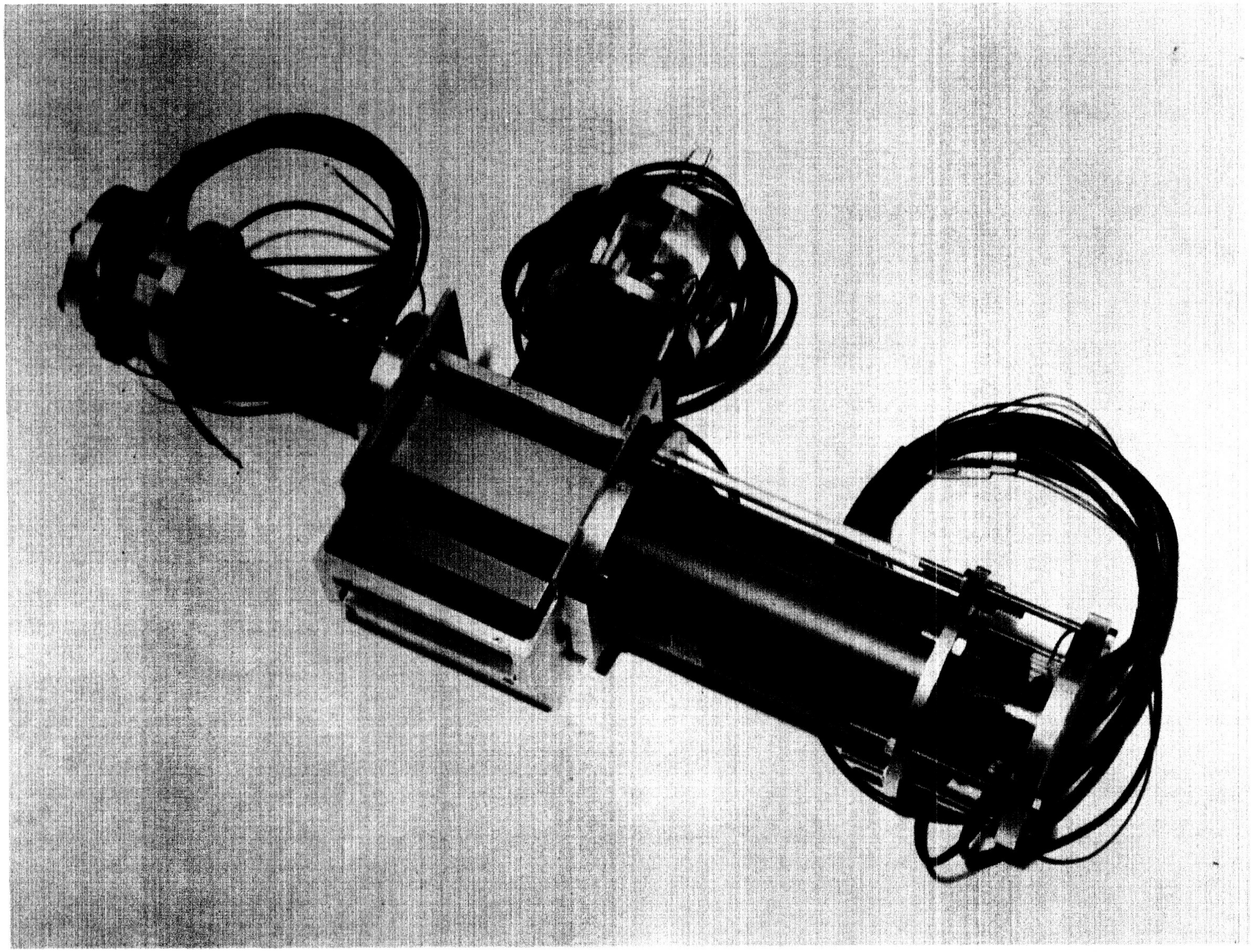

Figure 3. Photograph of Chamber/Counter Assembly Including Photomultiplier Tube

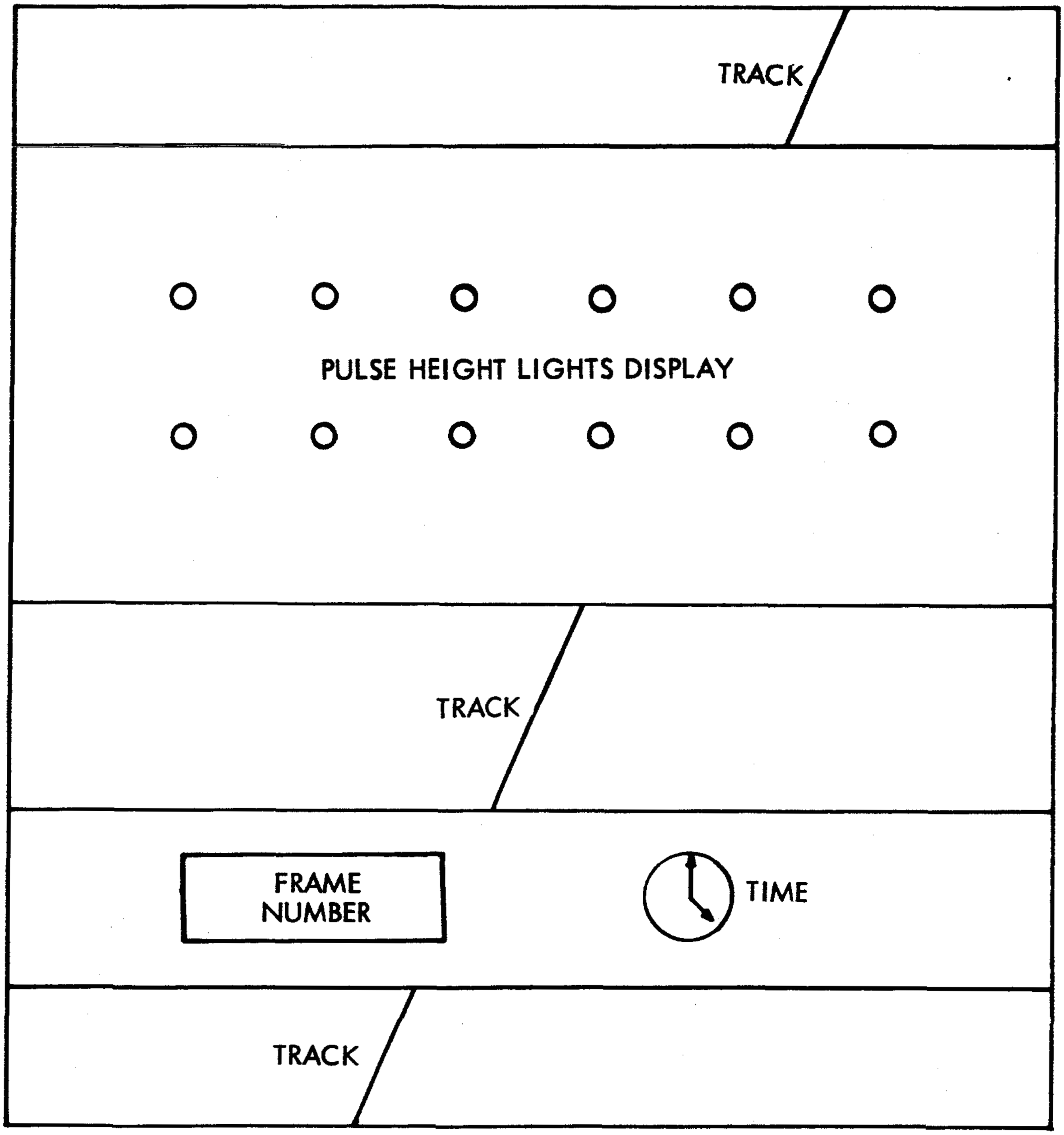

Figure 4. Schematic Representation of an Event on Film.

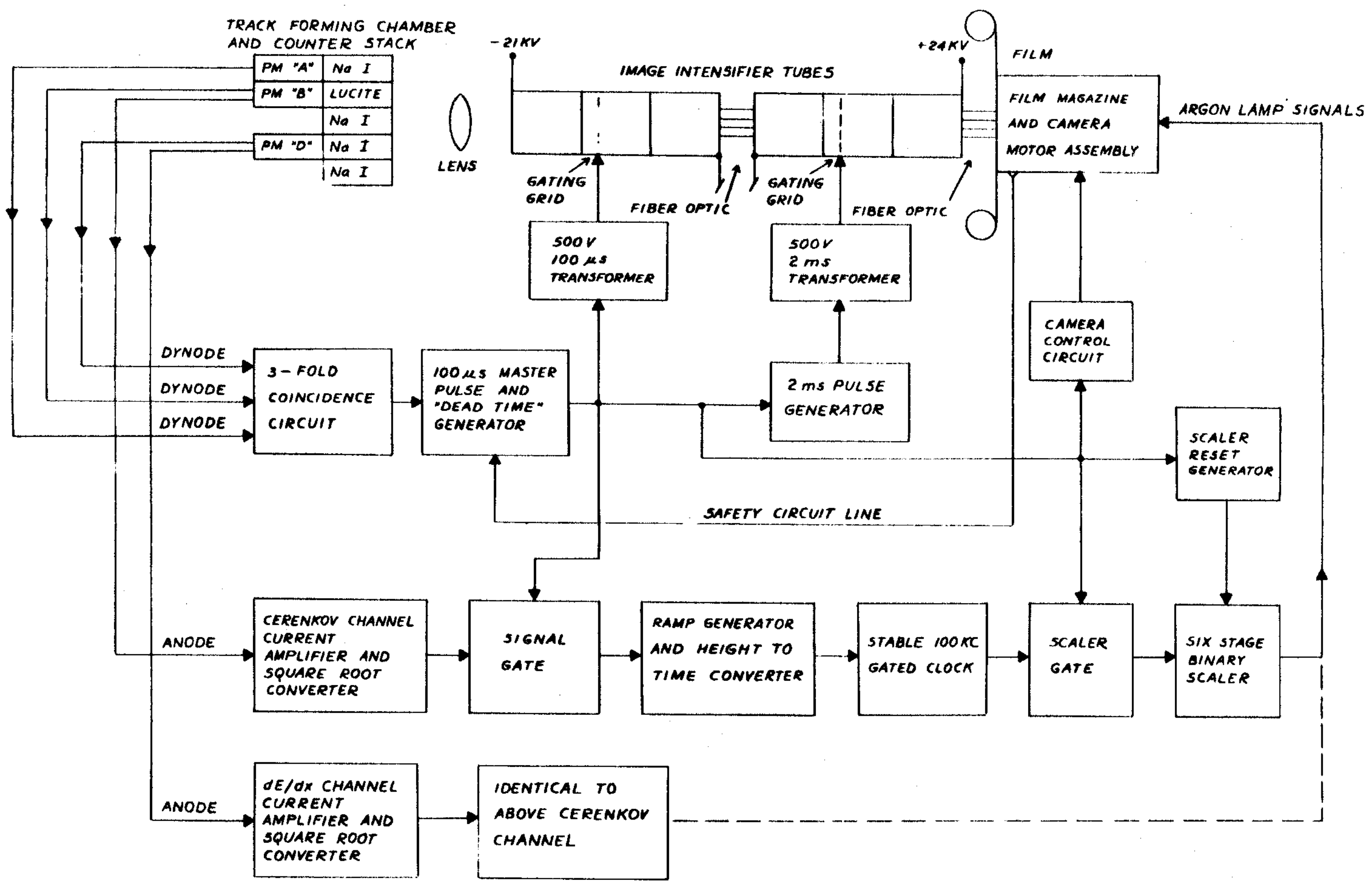

Figure 5. Block Diagram of Complete Luminescent Chamber Experiment

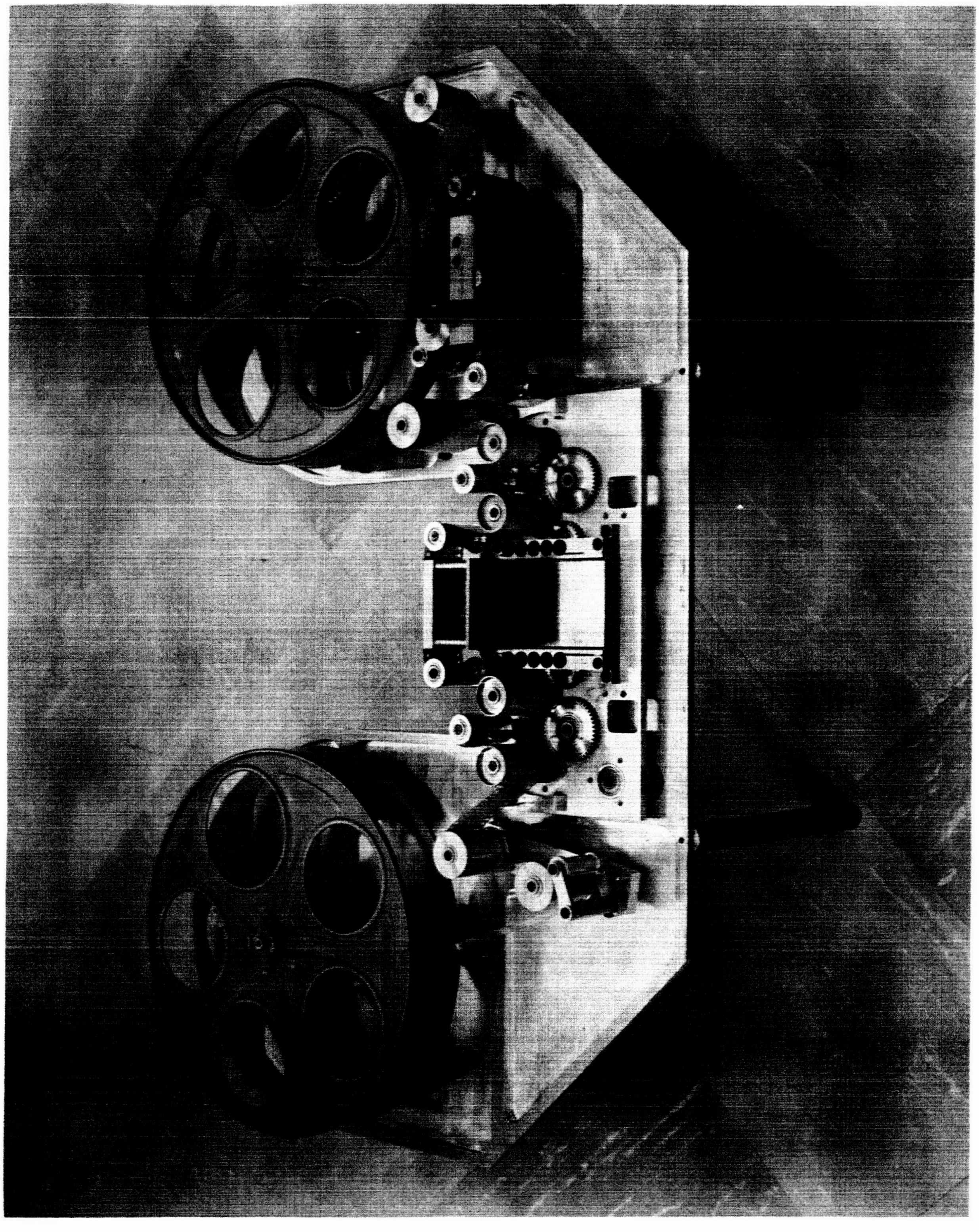

Figure 6. Film Magazine Mechanism

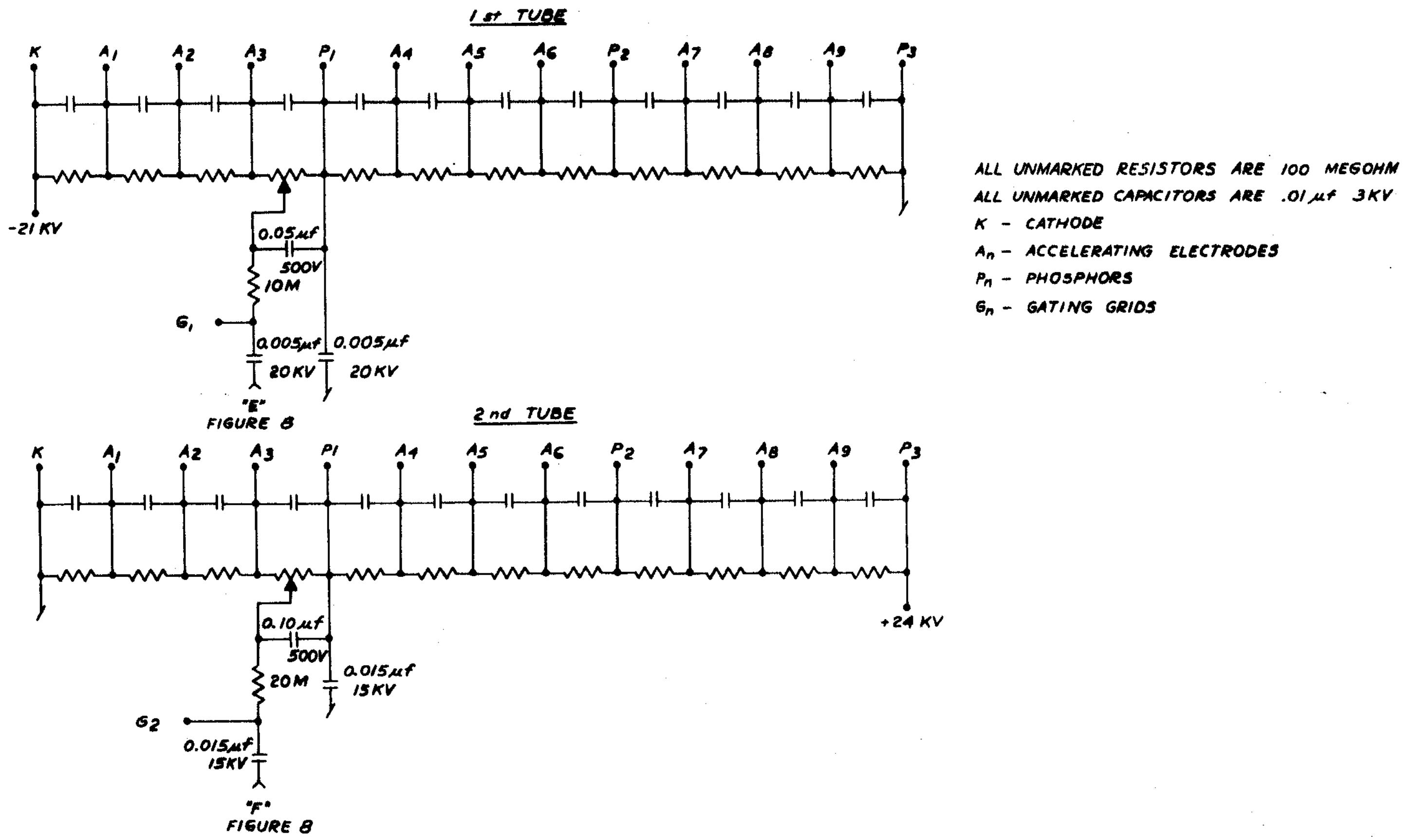

Figure 7. High Voltage Divider Showing Image Intensifier Tube Connections

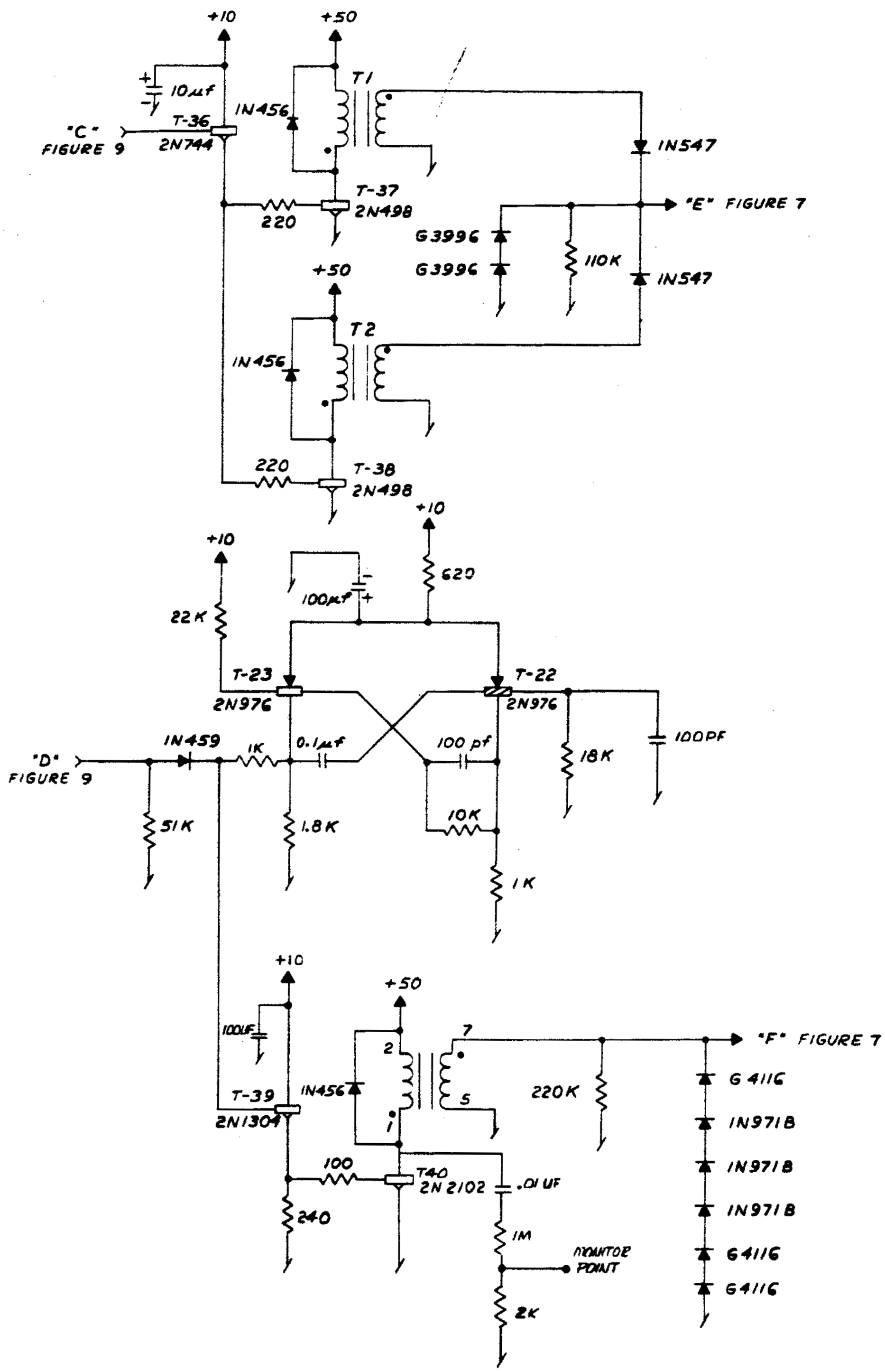

Figure 8. Image Intensifier Tube Pulse Transformer Network

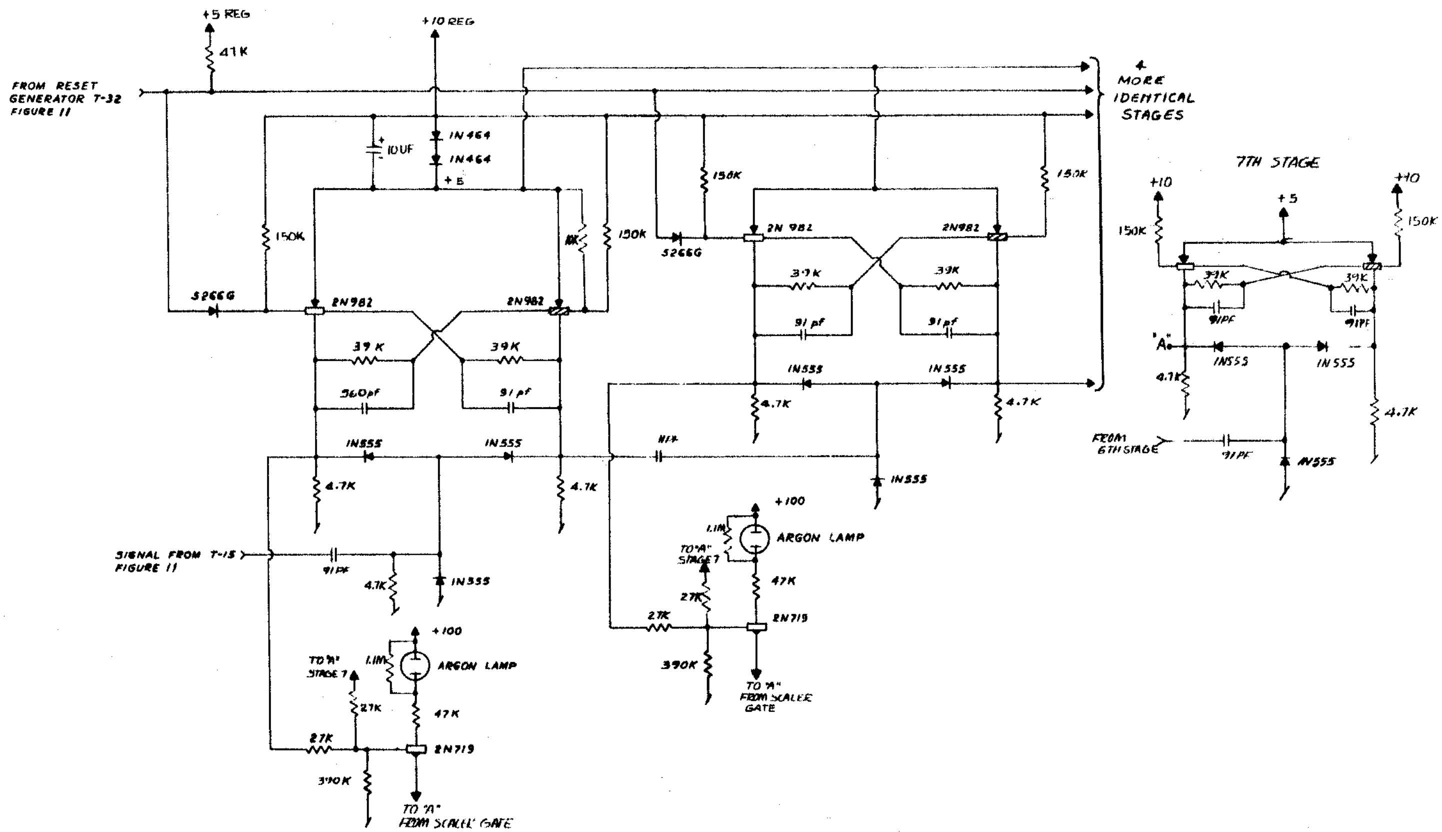

Figure 9. Master Pulse and "Dead Time" Generator

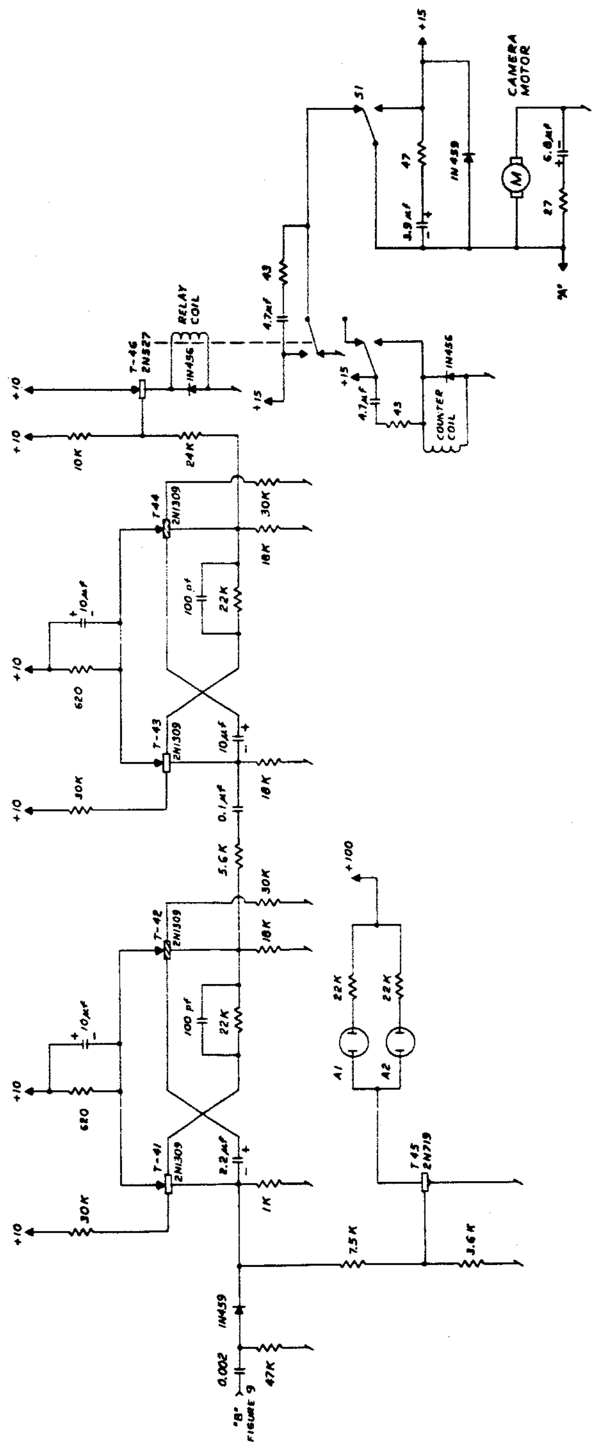

Figure 10. Camera Control Circuit

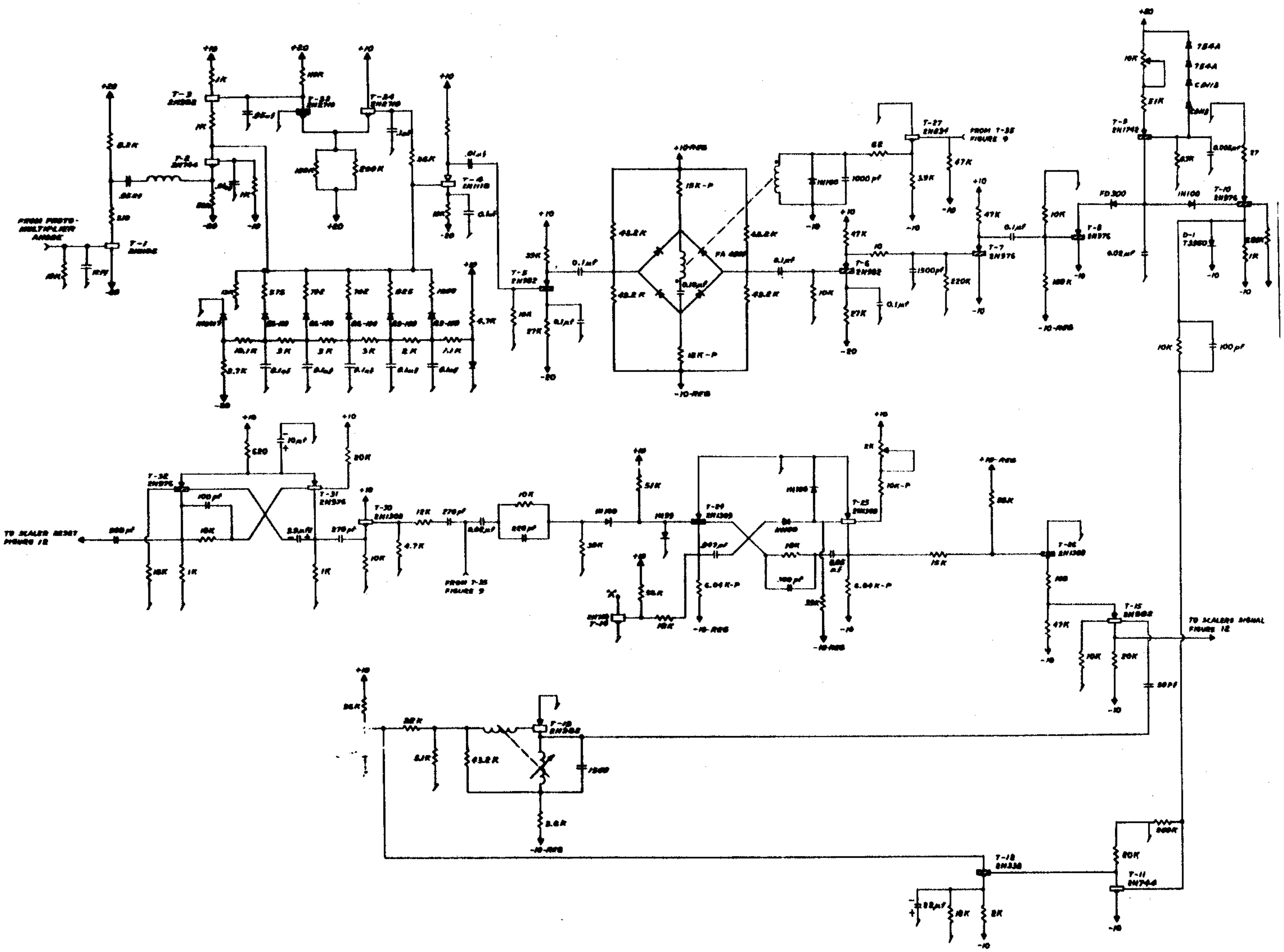

Figure 11. Square Root and Pulse Height Analyzer Circuits

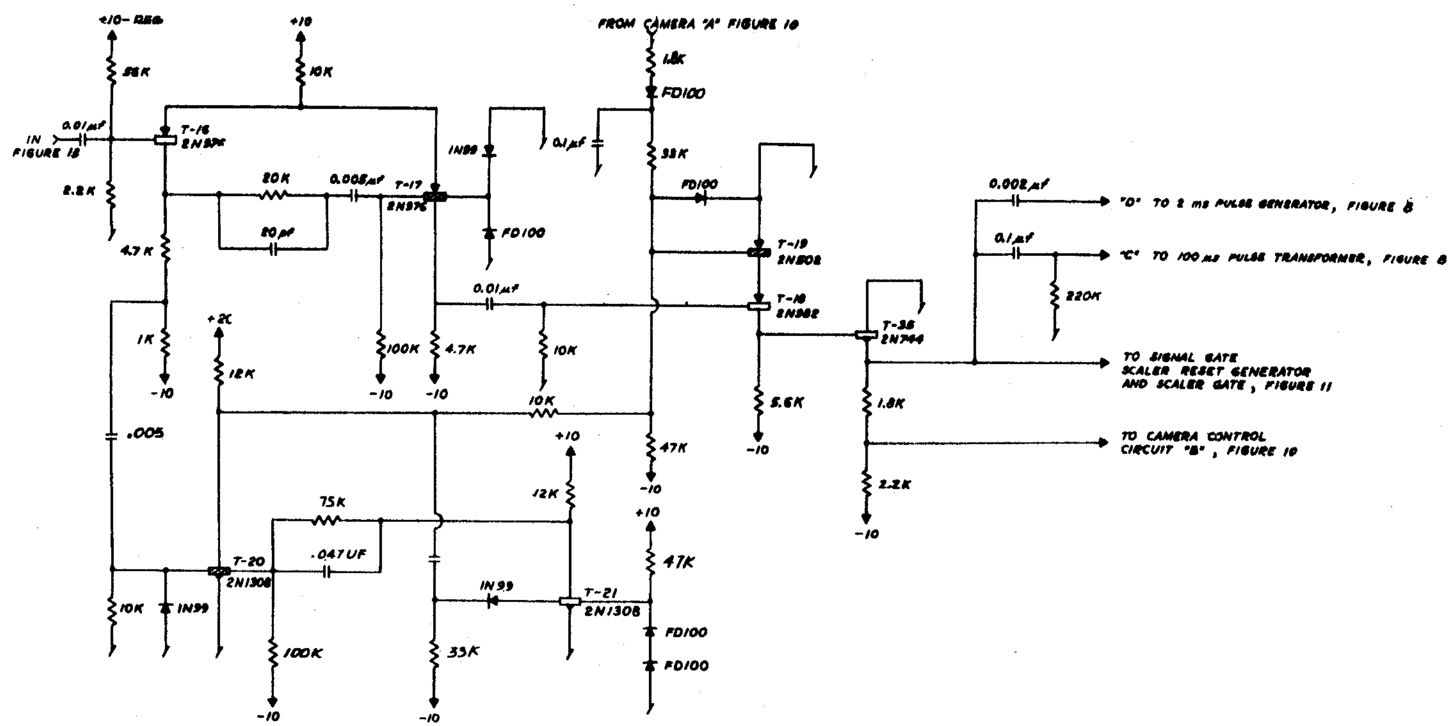

Figure 12. Binary Scaler Circuit

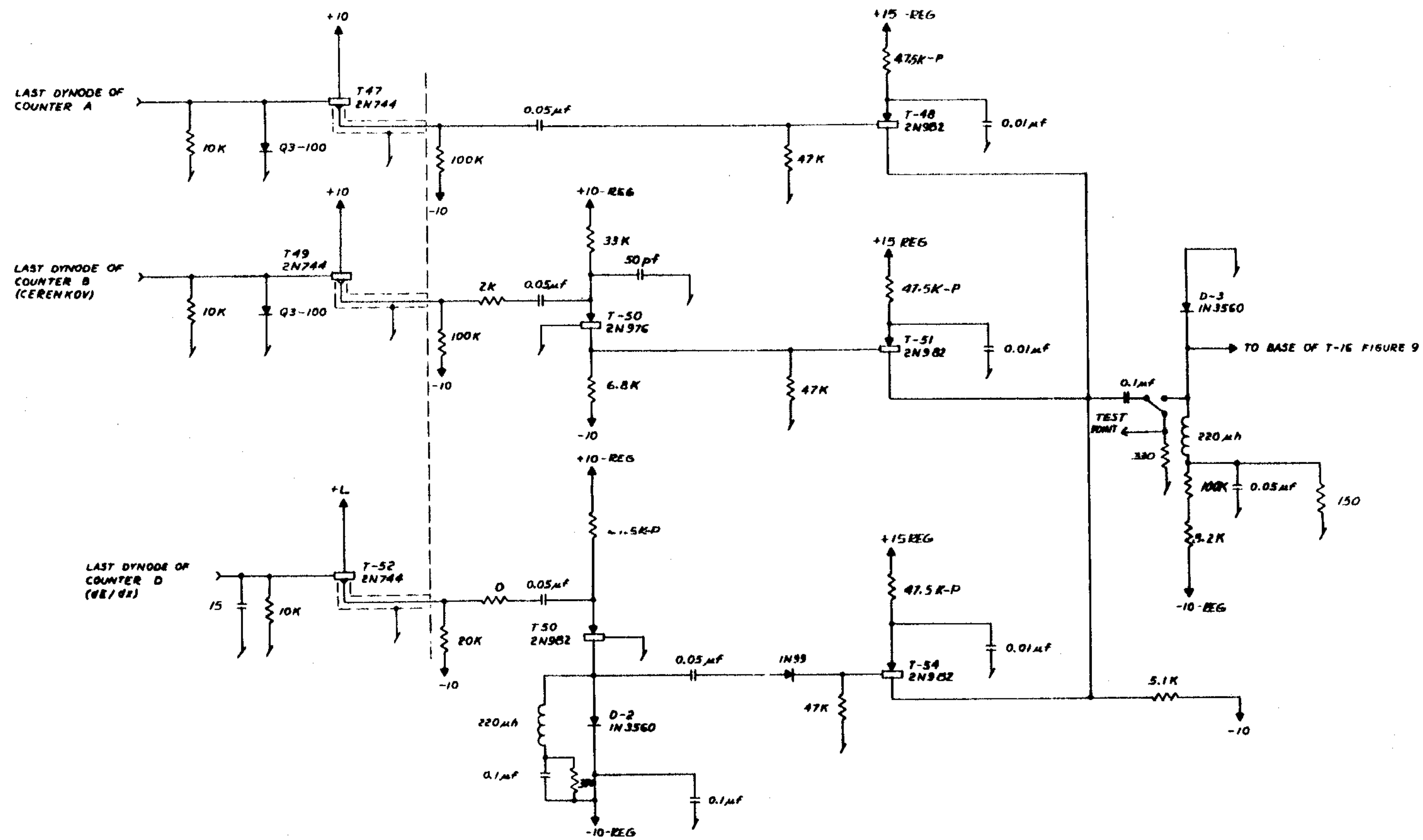

Figure 13. Coincidence Circuit with Threshold Descriminator

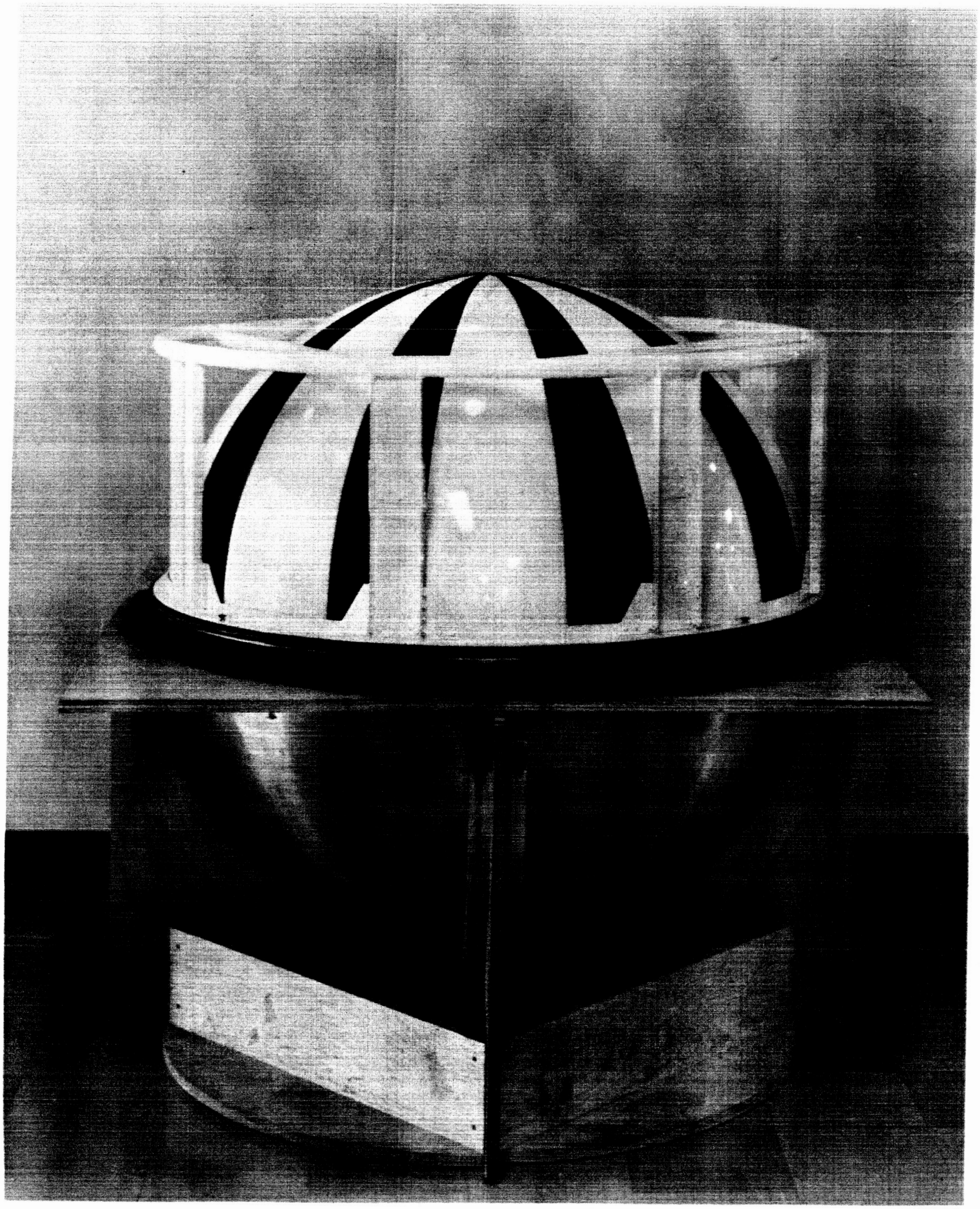

Figure 14. Gondola in Shipping Cradle

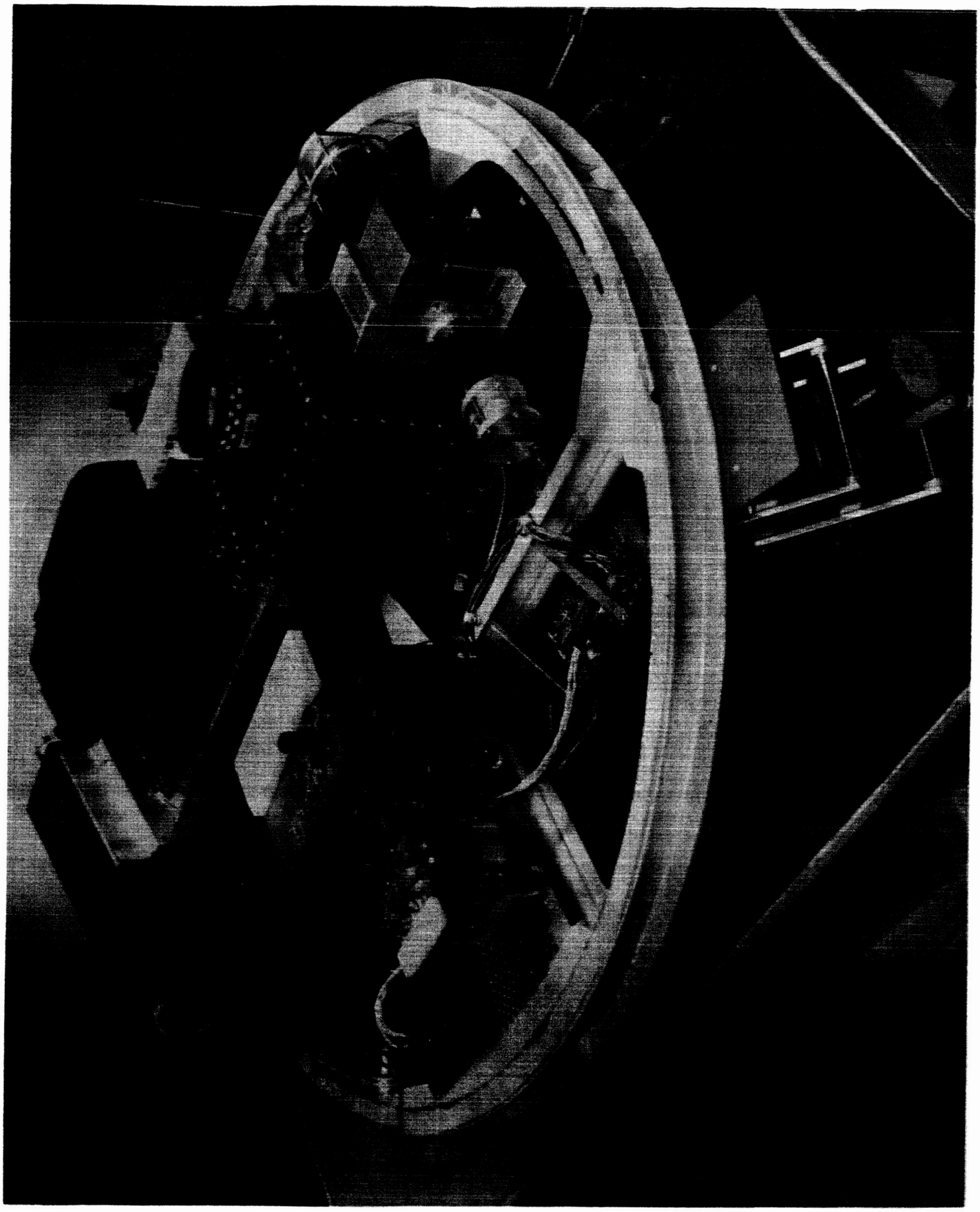

Figure 15. Equipment Mounted on Gondola Platform

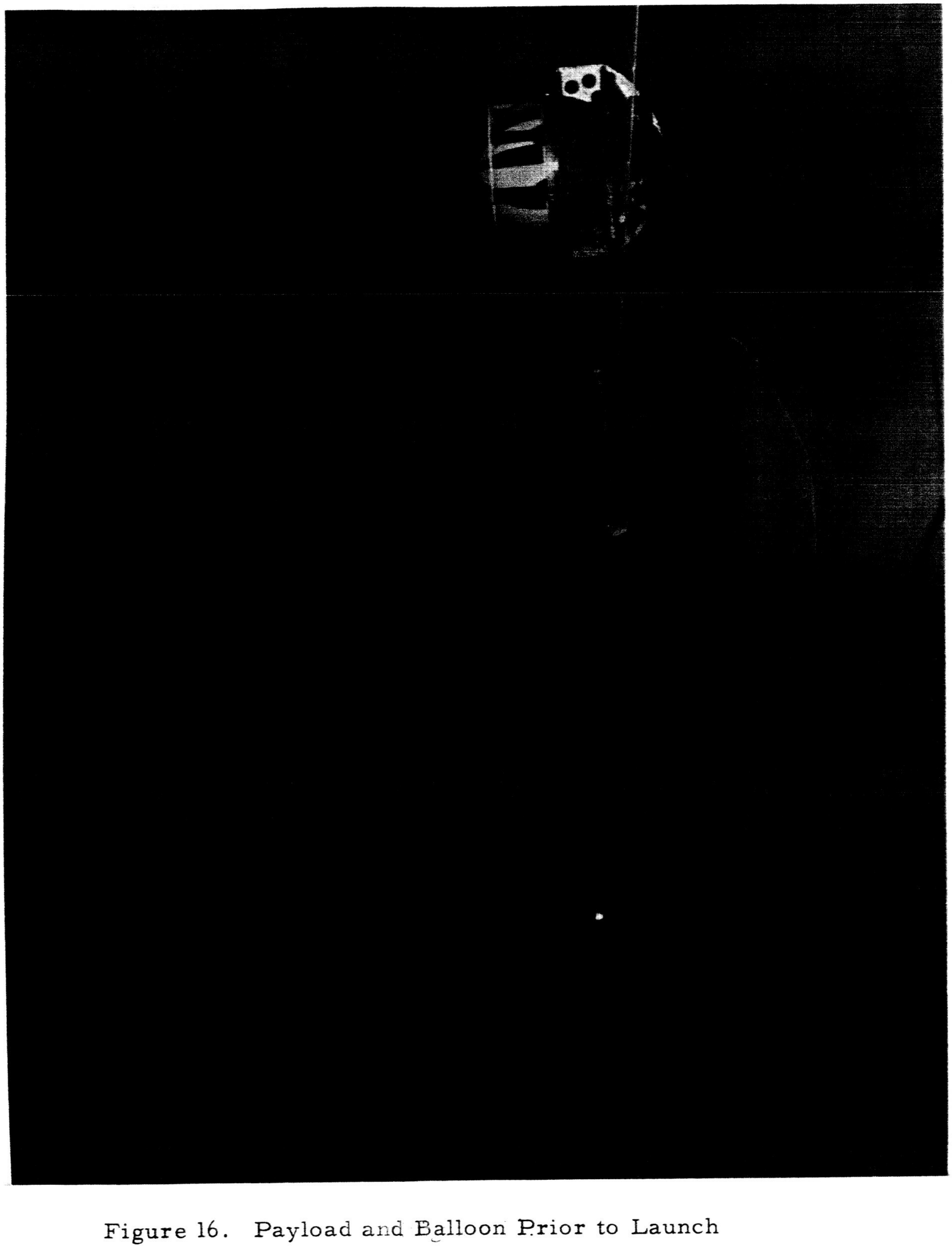

Figure 16. Payload and Balloon Prior to Launch

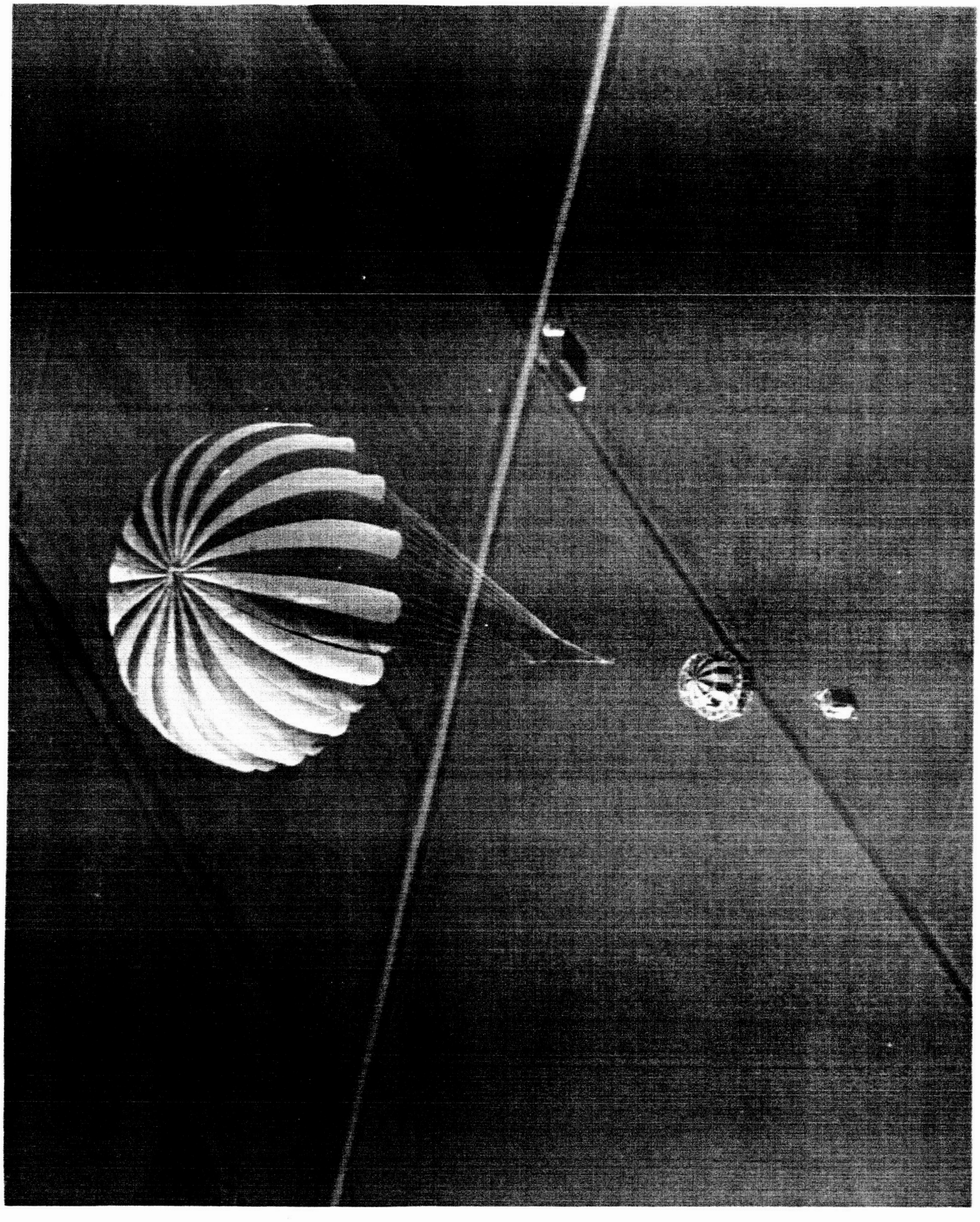

Figure 17. Payload Descending by Parachute

Zinc Plate

Silver Plate

Figure 18. Representative Plates from Damaged Cell