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Report to the Test Director

Test of Scintillator Optical-Path Technique

E. H. Krause and Staff
Naval Research Laboratory
Washington, DC

June 1953

NOTICE:
This is an extract of WT-567, Operation TUMBLER SNAPPER.

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Experiments were conducted to determine the feasibility of a technique employing scintillators near the device in conjunction with remote photosensitive detectors for measurements of reaction history to be conducted on Mike Shot of Operation Ivy, and to determine the maximum gamma-ray intensity and total dosage at which scintillators could be employed. The principal objectives of these tests were to: (1) determine the maximum gamma-ray intensity and total dosage at which scintillators could be employed; and (2) determine the feasibility of and obtain field experience in the employment of a scintillator-remote photosensitive detector technique with the optical-patch problems involved. This included the test of new types of equipment proposed for use on Ivy.

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FOREWORD

Classified material has been removed in order to make the information available on an unclassified, open publication basis, to any interested parties. The effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is either currently classified as Restricted Data or Formerly Restricted Data under the provisions of the Atomic Energy Act of 1954 (as amended), or is National Security Information, or has been determined to be critical military information which could reveal system or equipment vulnerabilities and is, therefore, not appropriate for open publication.

The Defense Nuclear Agency (DNA) believes that though all classified material has been deleted, the report accurately portrays the contents of the original. DNA also believes that the deleted material is of little or no significance to studies into the amounts, or types, of radiation received by [redacted]

Report to the Test Director

TEST OF SCINTILLATOR OPTICAL-PATH TECHNIQUE

Operation Snapper

By

E. H. Krause and Staff

Originally Issued as Report NRL-4158

Radiation Division
Naval Research Laboratory
Washington, D. C.
June 1953

ABSTRACT

Experiments were conducted to determine the feasibility of a technique employing scintillators near the device in conjunction with remote photosensitive detectors for measurements of reaction history to be conducted on Mike shot of Operation Ivy and to determine the maximum gamma-ray intensity and total dosage at which scintillators could be employed.

Insufficient data were obtained to predict accurately the behavior of scintillators at high gamma intensities; however, it was unequivocally determined that the technique would not be suitable for Ivy measurements. For the technique to be acceptable a sufficient signal was required from the detectors to cover a wide dynamic range (four orders) of measurements. Since the Teller light was down in magnitude from the scintillator light by not more than about two orders, it would have been necessary to shield the optical path to have sufficient dynamic range. This shielding would have been prohibitively expensive. The signal obtainable at the recording station would have required the use of high-gain photomultipliers and amplifiers throughout the system. In addition, the signal, was unpredictable, with unknown spurious background signals. It was highly improbable that the minimum required data could have been obtained for the Ivy Mike shot.

PREFACE

This report contains the scintillator optical-path experiments report, in which a proposed technique for use on the Mike phase of forthcoming Operation Ivy was tested and found unsatisfactory. These experiments were performed during the Tumbler-Snapper series of tests in the spring of 1952 by the Radiation Division of the Naval Research Laboratory (NRL).

In addition to the people having general supervisory responsibilities,* the following individuals were primarily responsible for the accomplishment of these experiments.

T. A. Bergstralh	Scintillator test project leader
L. A. Beach	Experimental analysis
S. E. Golian D. V. Miller B. R. Moskowitz A. E. McCoy K. W. Marlow H. I. Robison	Optical path and components
F. H. Trogdon	Recording system and scintillator report
N. M. Campbell	Recording system
J. M. Frame G. L. McCroskey	Mechanical phases

Strong support was given by other members and groups of NRL and by the Los Alamos Scientific Laboratory group.* The NRL group headed by D. C. Cook, who carried out the Tumbler-Snapper alpha measurements, was especially helpful during these hurried tests.

*E. H. Krause and Staff, Ivy Report, Measurement of Reaction History, Vol. I, WT-620, 1953.

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CHAPTER 1

INTRODUCTION

1.1 HISTORICAL BACKGROUND

In planning some of the experiments for Mike shot of Operation Ivy, consideration was given to the use of a system with scintillators near the weapon. This system would replace the long runs of transmission lines by utilizing optical-path transmission of the scintillator light to a distant photosensitive detector. If such a system were feasible without extensive optical-path shielding, it would provide a simpler and cheaper approach to the problem.

The system required that the scintillators be used at gamma-radiation levels about 10^6 to 10^8 times higher than that at which they had previously been used. There was no method to determine experimentally the characteristics of scintillators under such high radiation levels except by performing tests involving a nuclear weapon. This type of measurement was considered for the Greenhouse tests, but the stringent time requirements prevented it from being attempted. Arrangements were therefore made to perform feasibility tests during the Tumbler-Snapper Operation at Nevada Proving Grounds (NPG) during May 1952.

Initial tests were conducted which was detonated on a 300-ft tower. It was believed that the results would be sufficient for experimental planning on Operation Ivy; however, the results were inconclusive. Greatly accelerated planning and buildup of experimental parts were then undertaken to perform a modified experiment and still further experiments The results of these tests indicated that the proposed method of measurements would be extremely costly and the results would be dubious. Hence the technique was abandoned as far as the forthcoming Ivy tests were concerned.

1.2 AIMS OF THE EXPERIMENT

The principal objectives of the Snapper-Ivy tests were to:

1. Determine the maximum gamma-ray intensity and total dosage at which scintillators could be employed.
2. Determine the feasibility of and obtain field experience in the employment of a scintillator–remote photosensitive detector technique with the optical-path problems involved. This included the tests of new types of equipment proposed for use on Ivy.

1.3 NATURE OF THE EXPERIMENT

1.3.1 Scintillators

Organic scintillators had been tested at low radiation levels over a fairly large temperature range.[1] These tests indicated that the scintillator would continue to function properly up to a temperature of 80°C or higher. The measurements were stopped at 80°C because of difficulties with vaporization of toluene. As shown in Table 1.1 the number of 2-Mev gammas required to raise the temperature of toluene at the surface 1°C is approximately $1.45 \times 10^{14}/cm^2$. From this value and the expected gamma output of the weapon, a location was chosen for the scintillators where the heating effect of the radiation was expected to exceed the known safe figure in order to test scintillator behavior under intensity conditions that would result in a large temperature change. At more distant locations and by gamma shielding, the behavior of the scintillators under conditions of high radiation rates but safe temperatures were studied.

Table 1.1—CHARACTERISTICS OF SCINTILLATOR

Composition: 0.5 per cent by weight of terphenyl in toluene
Chemical composition of toluene: C_7H_8
Density of toluene: 0.862 g/ml at 25/4
Boiling point of toluene: 110.8°C
Specific heat of toluene: 0.386 cal/g °C = 1.01×10^{13} Mev/g °C
Terphenyl emission spectrum: 3300 to 4000 A with peak at 3450 A (3.6 ev)
Absorption of terphenyl emission spectrum in toluene: $\bar{\alpha} = 0.03$ cm^{-1}, where $dI/dx = -\bar{\alpha}I$
Fraction of energy loss in scintillator converted to light: 2.4×10^{-2}*
Number of 2-Mev gammas required to raise temperature of toluene 1°C: $\sim 1.45 \times 10^{14}$ gammas/cm^2

Gamma-ray Absorption Coefficients for Toluene (cm^{-1})

Gamma-ray energy Mev	Gamma-ray energy mc^2	Total, μ_t	Compton, μ_c	Pair production, μ_p	Fraction of energy given to electron in Compton process, $E_{e/h\nu}$
0.51	1.0	0.0806	0.0806		0.344
1.02	2.0	0.0587	0.0587		0.443
1.53	3.0	0.0477	0.0477		0.498
2.04	4.0	0.0406	0.0406		0.534
3.06	6.0	0.0327	0.032	0.0007	0.560
4.08	8.0	0.0288	0.0266	0.0012	0.609
5.10	10.0	0.0247	0.023	0.0017	0.630
6.12	12.0	0.0225	0.0203	0.0020	0.650
7.14	14.0	0.0206	0.0186	0.0024	0.660
8.16	16.0	0.0193	0.0166	0.0027	0.670

*This value is in question. It may be as low as 1.4×10^{-2}.

1.3.2 General

The first objective was attempted by placing scintillators at different distances from the bomb and by using gamma-ray attenuators in combination with scintillators, comparing the light output vs time. Differences in the form of curves from any two of the scintillators would indicate that the light output of one of the scintillators was not proportional to the incident gamma radiation, that the approximate inverse-square relation of the gamma radiations changes with time, or that a time-varying differential optical attenuation was present in the light paths between scintillators and detectors. Except for a position very close to the weapon, it is believed that the inverse-square law can be trusted. By using two scintillators at the same distance from the bomb and a gamma-ray attenuator between the bomb and one of the scintillators, the effect of a light-path absorption can be eliminated. In this case, however, the effect of the lead filter on the gamma spectrum introduces some uncertainty. For this reason the thickness of the attenuator was limited by the need to ensure that the spectrum effects did not overshadow any possible saturation effect. In an ideal experiment the optical attenuation in the various light paths would be measured as a function of time so that information could be obtained on the scintillator efficiency as a function of the incident gamma intensity, separated out completely from other effects. On the assumption that the optical transmission could not be determined, it was believed that the experiment would still answer the second objective of how the near scintillator–distant detector technique would work. This would improve the experimental design for Ivy as a result of these Snapper measurements, even if it were not possible to fully distinguish between scintillator failure and attenuation in the optical path.

1.4 THEORY

1.4.1 Gamma Intensity and Intensity Relations

Figure 1.1 shows a predicted curve of the gamma radiation From the gamma intensity based on the assumed bomb characteristics and the following derived expressions, the anticipated current expected from a photocell placed at the focus of a collecting mirror can be calculated. For these calculations the following symbols are used:

$\mathring{I}$ = source strength in gammas per second outside the bomb

F_γ = gamma transmission of material between the bomb case and scintillator

Ω_s = fractional solid angle subtended by the scintillator*

Ω_0 = fractional solid angle subtended by the photocathode at the focus of the collecting mirror

B = joules of terphenyl light emitted in the direction of the detector per 4π steradians per incident gamma

T = optical transmission, including the efficiency of the collecting mirror and photocell system

θ and ϕ = angles shown in Fig. 1.2

μ_t = absorption coefficient for gamma rays

μ_a = μ_t times the fraction of gamma-ray energy transferred to Compton electrons or pairs (on the average)

β = absorption coefficient for the emitted light

l = thickness of scintillator

ϵ = efficiency of conversion of beta-particle energy to light

E_γ = gamma-ray energy

1.6×10^{-13} = the conversion factor from million electron volts to joules

The gammas per second incident on the scintillator are

$$\mathring{I}F_\gamma \Omega_s \tag{1.1}$$

and the current in amperes expected from a photocell placed at the focus of a collecting mirror is

$$C = \mathring{I}F_\gamma \Omega_s B T \Omega_0 K \tag{1.2}$$

Considering only the first gamma-ray processes,

$$B = \frac{\mu_a \sec\theta\, e^{-\mu_t \sec\theta l - \beta \sec\phi l}}{\sec\phi - \mu_t \sec\theta} \quad \epsilon E_\gamma \; 1.6 \times 10^{-13} \tag{1.3}$$

*$\Omega_s = A_s/4\pi r_s^2$, in which A_s is the projected area of the scintillator and r_s is the distance from source to scintillator.

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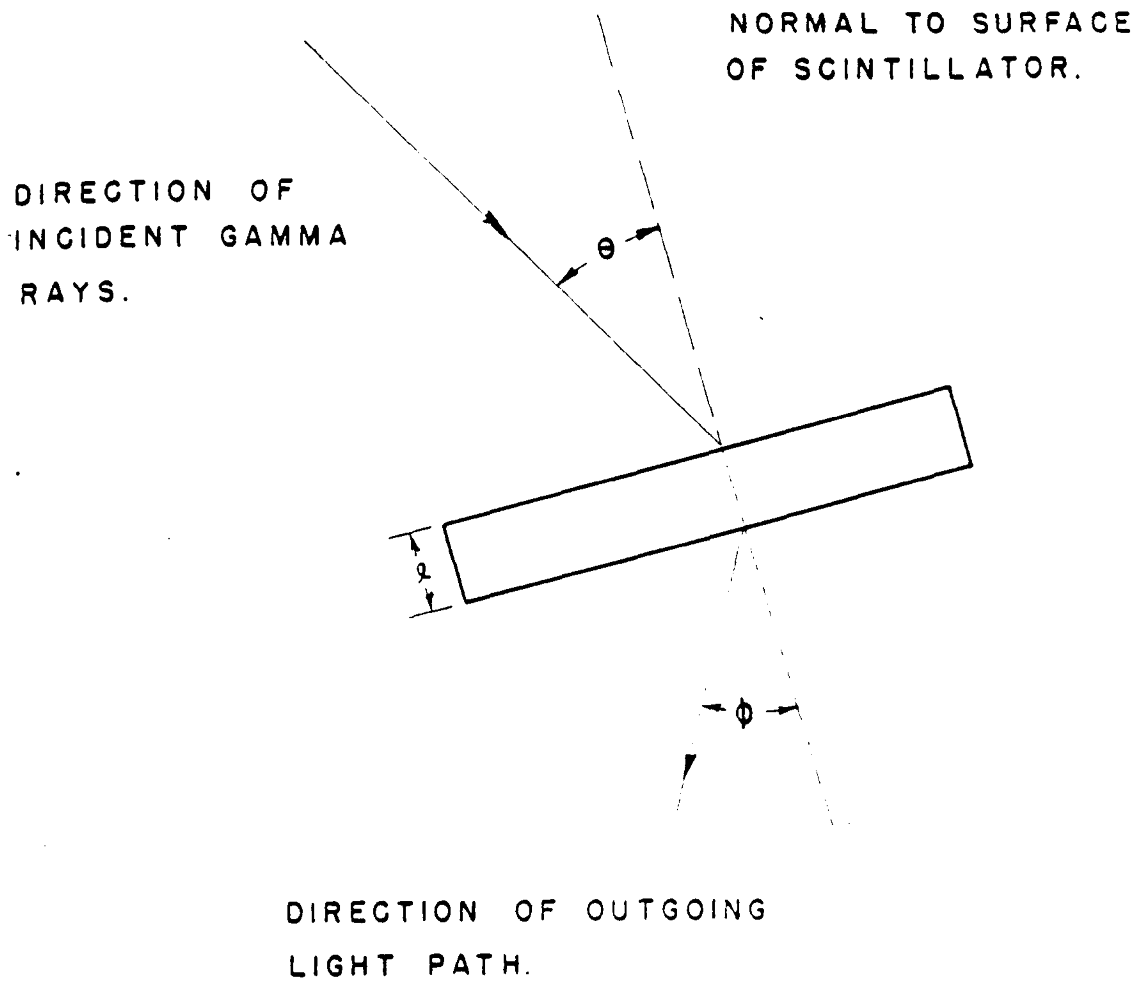

Fig. 1.2—Nomenclature for scintillator calculations.

Scintillator characteristics are shown in Table 1.1, and curves of B for various scintillator depths are shown in Fig. 1.3. These values of B were calculated from Eq. 1.3 using the constants from Table 1.1 and assuming that the incident gammas and the emergent terphenyl light were directed normal to the surface of the scintillator; i.e., $\theta = \phi = 0$. These assumptions were correct for the but for the later tests a calculation of B was necessary for each scintillator.

The fluorescence spectrum of the terphenyl in toluene scintillator is shown in Fig. 1.4.

1.4.2 Predicted Background and Related Effects

(a) Teller Light. The incidence of gamma rays on the air leads to a fluorescence referred to as "Teller light." This is caused by simple excitations and decreases as gamma intensity decreases. Harold S. Stewart, Naval Research Laboratory (NRL) Optics Division, had verified that Teller light exists in the air surrounding a nuclear detonation.[2] The intensity was not known, but the effect of the mirror system was to baffle the optical path and minimize the region from which this light could enter the system.

(b) Gamma-ray Heating. Gamma rays falling on solid material near the weapon, such as the cab walls and structural members of the tower, were expected to raise them to incandescent temperatures. This is borne out by photographs obtained by Edgerton, Germeshausen & Grier (EG&G),[3] during Operation Greenhouse, which show that the cab walls glow prior to the time they are fractured by the shock wave. Preliminary analysis indicated that such incandescence would not yield as much light as a scintillator at the same position, provided the scintillator efficiency remained constant. Cab incandescence should also occur a little later than the period of greatest interest. Hence it was believed that this source of background would not prevent the testing of a scintillator placed a few meters from the bomb. It was also possible to use a filter in the optical system to discriminate against the longer wavelengths from such background sources, and the photocell also acts as such a filter owing to its spectral sensitivity. To increase the reliability of data, a background monitor viewing an area adjacent to the 10-meter scintillator was used.

(c) Optical Attenuation Due to Gamma Rays. The gamma rays incident on the air in the optical path between a near scintillator and a distant detector cause dense ionization and leave the air highly excited; however, Stewart has made tests that show the light attenuation to be less than 10 per cent in the region of interest. Photographs of the cabs taken by EG&G on previous tests showed two corners of the cab approximately along the line of sight glowing with apparently the same intensity. Since the optical path for the two points differed by several feet in the region close to the bomb, this indicated that no profound attenuation takes place, at least in the visible spectrum, within the time of the proposed scintillator tests.

If two scintillators are placed at the same distance from the bomb in a manner such that their associated optical paths are similar and if the gamma radiation incident upon one of the scintillators is attenuated by means of a lead absorber, it should be possible, in this case, to eliminate the effects of a differential optical absorption. A more direct measurement of optical transmission effects would be of interest, but the outlined measurements were considered adequate to obtain the information concerning the behavior of a near scintillator.

(d) Other Optical-path Problems. Problems not introduced by the bomb include twinkle effect and the presence of dust in the atmosphere. Measurements reported by Stewart indicated that, if optical paths 3 ft in diameter were used, the transmission would remain constant to within 10 per cent. From his measurements the twinkle effect, which is caused by localized density variations in the air, acts to increase or decrease the light received in patches approximately 6 in. in size. Hence using optical paths that are 2 to 3 ft in diameter should make the average transmission remain reasonably constant.

The presence of dust in the air at NPG was expected to prove a source of difficulty during the installation and testing phases by causing attenuation during tests and by making it difficult to keep optical surfaces clean. However, no such difficulties were expected at shot time because the wind conditions necessary for firing include low surface wind velocity and no vehicles would be in the area to stir up the dust. It was proposed to run the optical paths from the tower

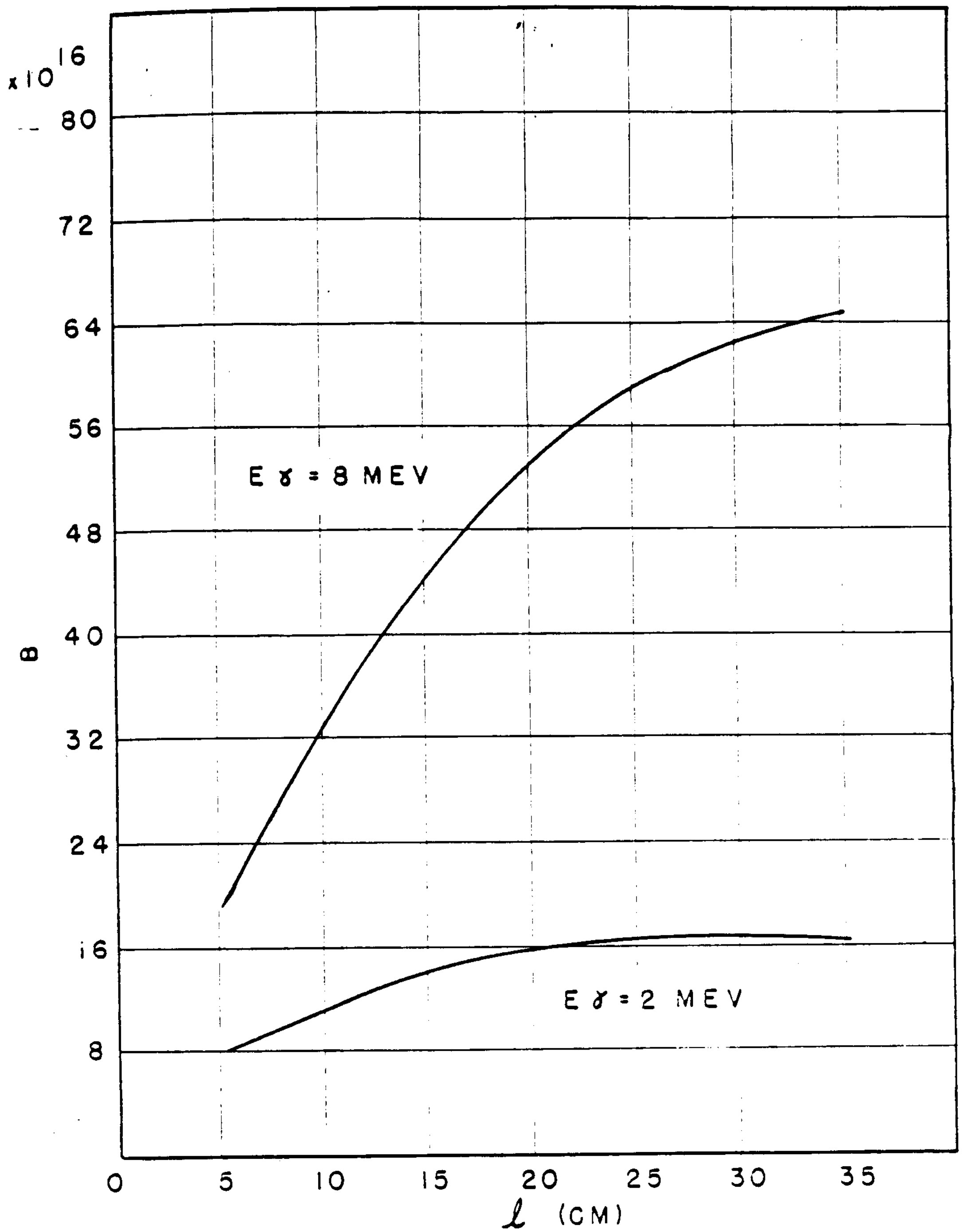

Fig. 1.3—Effect of scintillator thickness.

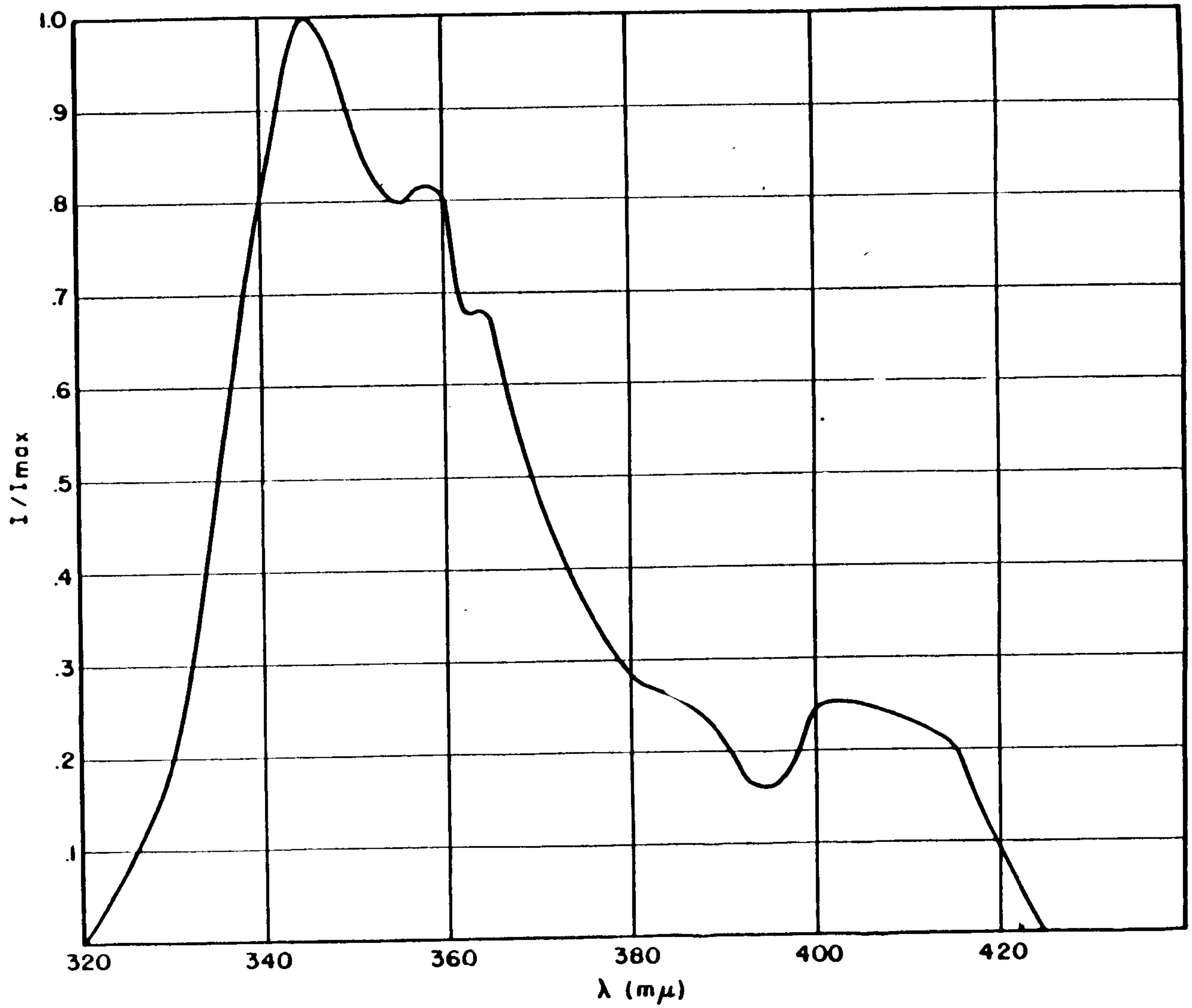

Fig. 1.4—Fluorescence spectrum of 0.5 per cent terphenyl in toluene.

to the recording station about 15 ft above the ground to decrease both dust and twinkle effects.

(e) Gamma Rays on Detectors and Cables. The gamma rays per square centimeter per second at a distance r are given by

$$\mathring{J} = \frac{\mathring{I}\, e^{-r/\lambda}}{4\pi r^2} \tag{1.4}$$

in which λ is the effective mean free path for gammas in air. The expected peak gamma-flux density at the photocell position near the recording station (r = 1000 yd) was roughly 10^{17} gammas/cm^2/sec.

Preliminary analysis indicated that shielding of photocell detector circuits and cables would be required. In order to facilitate this shielding, a second bend in the optical paths by the use of plane mirrors at the recording station was included. This made it possible to place the photocells and cables at ground level behind an earth shield.

REFERENCES

1. Wayne Hall, Prompt Gamma Rays Used in Measurement of Alpha, Greenhouse Report, Annex 1.1, Part I, WT-66, Sec. 6.4.1, December 1951.
2. Harold S. Stewart, private communication prior to Tumbler-Snapper tests.
3. B. E. Watt, LASL, private communication prior to Tumbler-Snapper tests.

CHAPTER 2

2.1 DESCRIPTION OF EXPERIMENTS

2.1.1 Scintillator Measurements

The main scintillator test was aimed at determining the amplitude range over which the combination of a near scintillator and a distant photosensitive detector would operate successfully. This was to be accomplished by operating three scintillators under different gamma-intensity conditions in observing logarithmically vs time the current from a distant photocell, viewing each scintillator. In addition, the output of a photocell viewing a monitoring path adjacent to the scintillator nearest the bomb was recorded. One of the scintillators was placed approximately 3 meters from the bomb and was partially shielded from fission-neutron radiation by means of paraffin placed between the bomb and the scintillator. The second and third scintillators were both placed 10 meters from the bomb and also had paraffin shielding. In addition, one of them had sufficient lead to introduce approximately a fivefold attenuation of the gamma radiation from the bomb. This arrangement of the second and third scintillators was proposed to eliminate the effects of a differential optical absorption and make possible a direct comparison of the two scintillators with regard to saturation. A linear time sweep of 1.6 μs duration was used for these displays (see Table 2.1). The expected time resolution ranged from about 0.12 μs at the lowest level recorded to about 0.01 μs for the region of the peak of the gamma-ray curve limited mainly by the time constants of the log circuit.

Table 2.1 — EXPERIMENTAL ARRANGEMENT,*

	Distance from weapon, meters	Neutron attenuation†	Gamma-ray attenuation‡
Monitor	3		
Scintillator 1	3	100	2.7
Scintillator 2a	10	20	2
Scintillator 2b	10	20	10
Gamma detector	915 (Recording sta.)		

*Sweep time for all oscilloscopes was 1.6 μs.

†Attenuation for fission neutrons in paraffin between source and scintillator.

‡Attenuation in lead and in neutron shield.

The experimental layout, optical efficiencies, and intensity calculations are shown in Tables 2.2 to 2.4.

Table 2.2 — EXPERIMENTAL LAYOUT,

	Scintillator 1	Scintillators 2 and 3	Monitor
Distance from weapon to scintillator, meters	3	10	3
Projected area of scintillator in per cent of physical area			
For gammas	100	100	100
For light path	94	100	100
Diameters of optical path in per cent of scintillator diameter			
For gammas	100	100	100
For light path	94	100	100
Mirror diameters in per cent of scintillator diameter			
Tower, for gammas	100	100	100
Tower, for light path	150	162	160
Receiver, for gammas	150	150	150
Receiver, for light path	165	174	174
Total optical-path length, meters	962.34	962.58	962.34

Table 2.3 — OPTICAL EFFICIENCY,

	Scintillator 1	Scintillators 2 and 3	Monitor
Transmission of scintillator window	0.36*	0.36*	
Reflectivity of 1st plane mirror	0.80	0.80	0.80
Reflectivity of 2d plane mirror	0.80	0.80	0.80
Transmission of optical path	0.88	0.88	0.88
Reflectivity of collecting mirror	0.55	0.55	0.55
Fraction of light from collecting mirror focused into photocell	0.75	0.75	0.75
Total optical efficiency	0.083	0.083	0.232

*These values are based on data given by Pittsburgh Plate Glass Co. The validity of these data for terphenyl radiation is uncertain.

2.1.2 *Measurement of* Gamma Rays *as a Function of Time*

An attempt was made to measure the gamma rays independently by use of a gamma-ray detector placed near the recording station. In order to obtain a reasonably complete record on one oscilloscope, a photocell was immersed in its own scintillator, with a logarithmic circuit identical to those used in the scintillator test. Due to the differential absorption of the gamma radiation over the spectrum resulting from the long air path, difficulties were anticipated in comparing the curve from the far scintillator and the one near the weapon.

2.2 EXPERIMENTAL ARRANGEMENT

2.2.1 General

The four-path layout shown in Fig. 2.1 was chosen after consideration of the necessity to shield against optical and gamma-ray disturbances in the photocell detectors and the various problems outlined above. The arrangement of the optical paths running down the tower to the plane mirrors, then horizontally through a slit to the turning mirrors, and thence to the collecting system seemed adequate. The collecting system, with its earth bunker between it and the tower cab, and the lead shielding for the photocells seemed adequate for gamma-ray shielding. A photograph of the over-all experimental layout taken from the weapon tower is shown in Fig. 2.2.

2.2.2 Components

(a) Scintillators. The optimum choice of the scintillator appeared to be a toluene-terphenyl mixture previously used in photocell-scintillator detectors. It has a short decay time of 2.5 ns (1 nenosecond = 10^{-9} sec), can be obtained in quantity, and, being a liquid, can be formed into any shape. Its characteristics are shown in Table 1.1. To use the liquid scintillator conveniently, it was necessary to have a window which would transmit the terphenyl radiation and would not darken under 10^7 r of gamma radiation. An investigation of glasses showed that the types that will not darken under intense fluxes of radiation will not transmit well in the ultraviolet (the region of interest). In the time available best results were anticipated by the use of $^1/_{32}$-in. plate glass (see Table 2.3). The installed scintillators are shown in Figs. 2.3 and 2.4.

(b) Baffles. The purpose of the baffling system was to reduce crosstalk between the individual optical paths and to prevent extraneous light (from the bomb-cab area) from entering the turning mirrors. Originally it was planned to use only a center pinhole baffle (see Fig. 2.5) through which the light paths would be transposed for cancellation of crosstalk; however, in the field additional baffles were placed near the scintillators and in front of the collecting-system mound to help prevent crosstalk (see Figs. 2.2 and 2.6).

(c) Plane Mirrors. Plane mirrors were used to allow changes in direction of the optical paths so that better collimation of the light and shielding components could be obtained. Plate glass of adequate quality was obtained. At Fort Belvoir Research Center the glass was coated with aluminum, and this surface was protected by a thin layer of silicon monoxide. This combination resulted in a fairly durable surface with high reflectivity (about 80 per cent) for the terphenyl light. The 24- by 30-in. mirrors at the base of the tower are shown in Fig. 2.7, and the stand for the 48-in.-diameter turning mirrors at the receiving end is shown in Fig. 2.6.

(d) Light-collecting System. Three-foot-diameter Navy searchlight mirrors (Fig. 2.8) made of stellite were used as collecting mirrors. The polished stellite surface was extremely durable and had a reflectivity of approximately 55 per cent for terphenyl radiation. An RCA 935 vacuum phototube was mounted on an adjustable arm out from the center of the stellite mirror. Between the mirror and the photocell was mounted a fisheye lens to collect the light and focus it into the 935 photocathode for homogeneous illumination (see Fig. 2.9). Aluminum-coated filters were used between the lens and the phototube, providing a means to cover a wide dynamic range in recording the signal. These filters were nonselective to wavelength and were made for transmissions ranging from 5 to 90 per cent of the incident light.

2.3 OPTICAL ALIGNMENT

The optical alignment was accomplished by using a d-c light source mounted on an adjustable arm in a 2-ft stellite searchlight mirror (Fig. 2.10) similar to the collecting mirrors. The assembly was mounted in the scintillator yokes and during the hours of darkness was directed onto the respective plane mirrors at the base of the tower. The mirrors were adjusted to direct the beam through the baffle slit and onto the plane turning mirrors on the stand

(Text continues on page 34.)

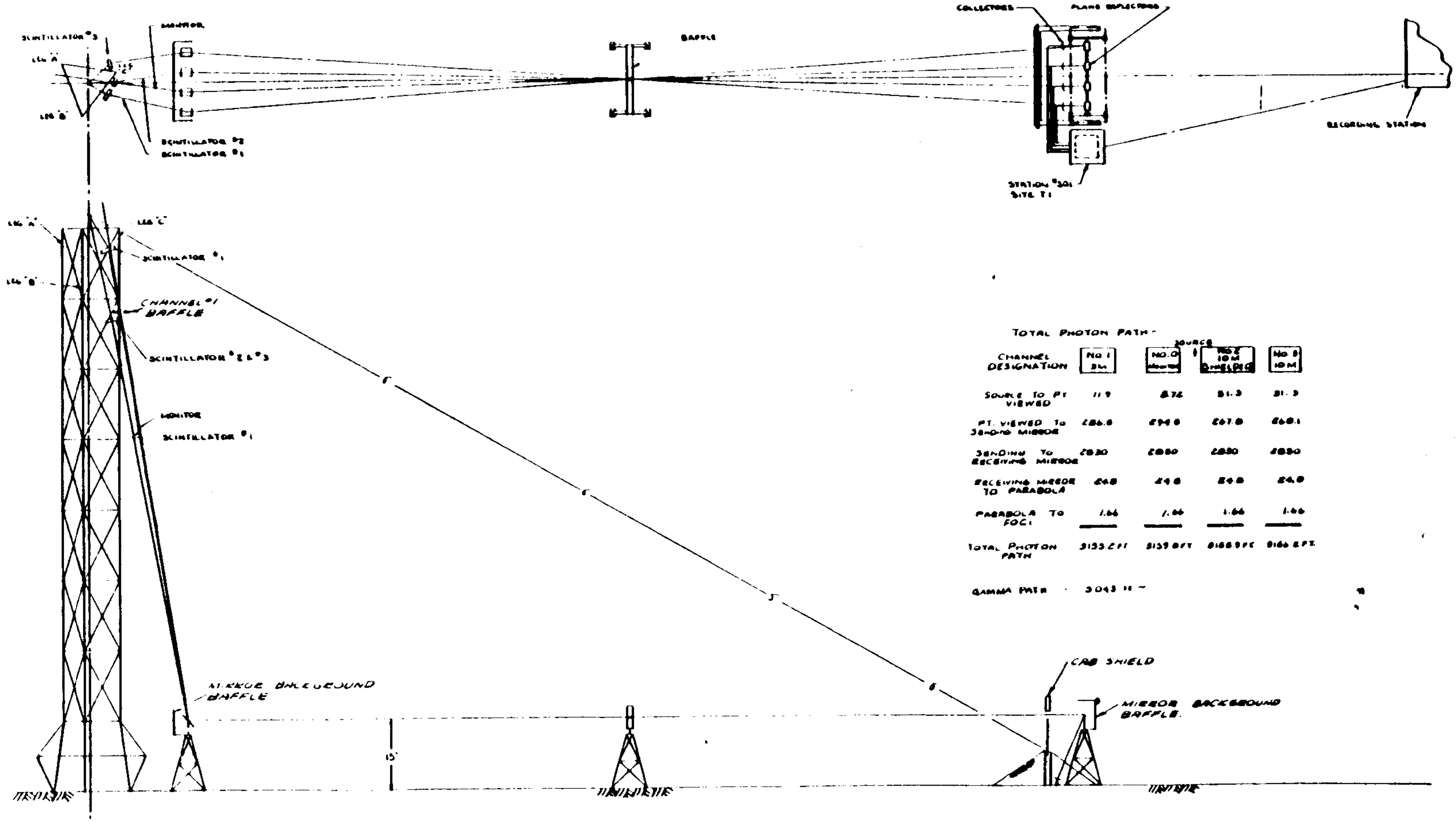

Fig. 2.1—Over-all schematic,

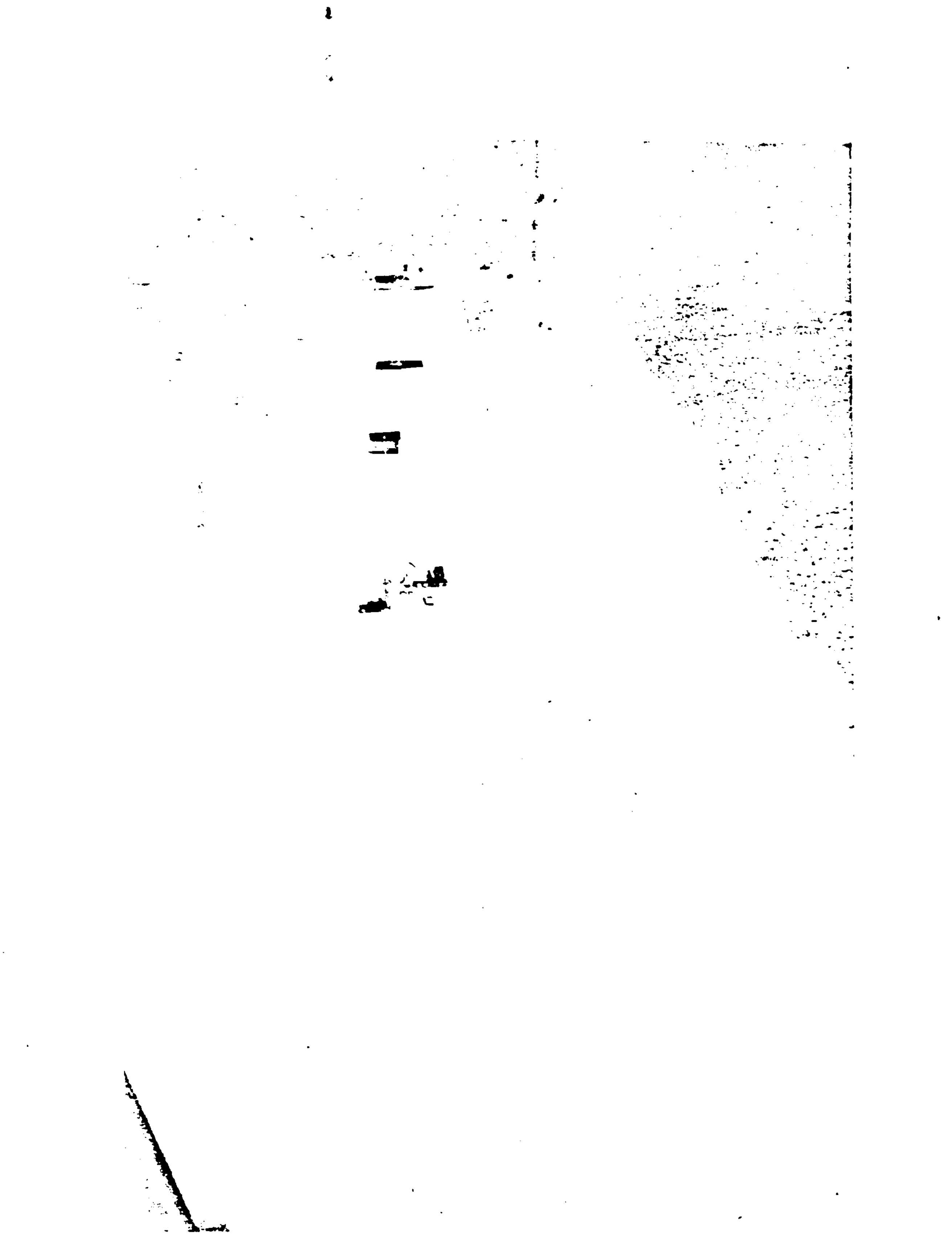

Fig. 2.2—View of propagation path from tower.

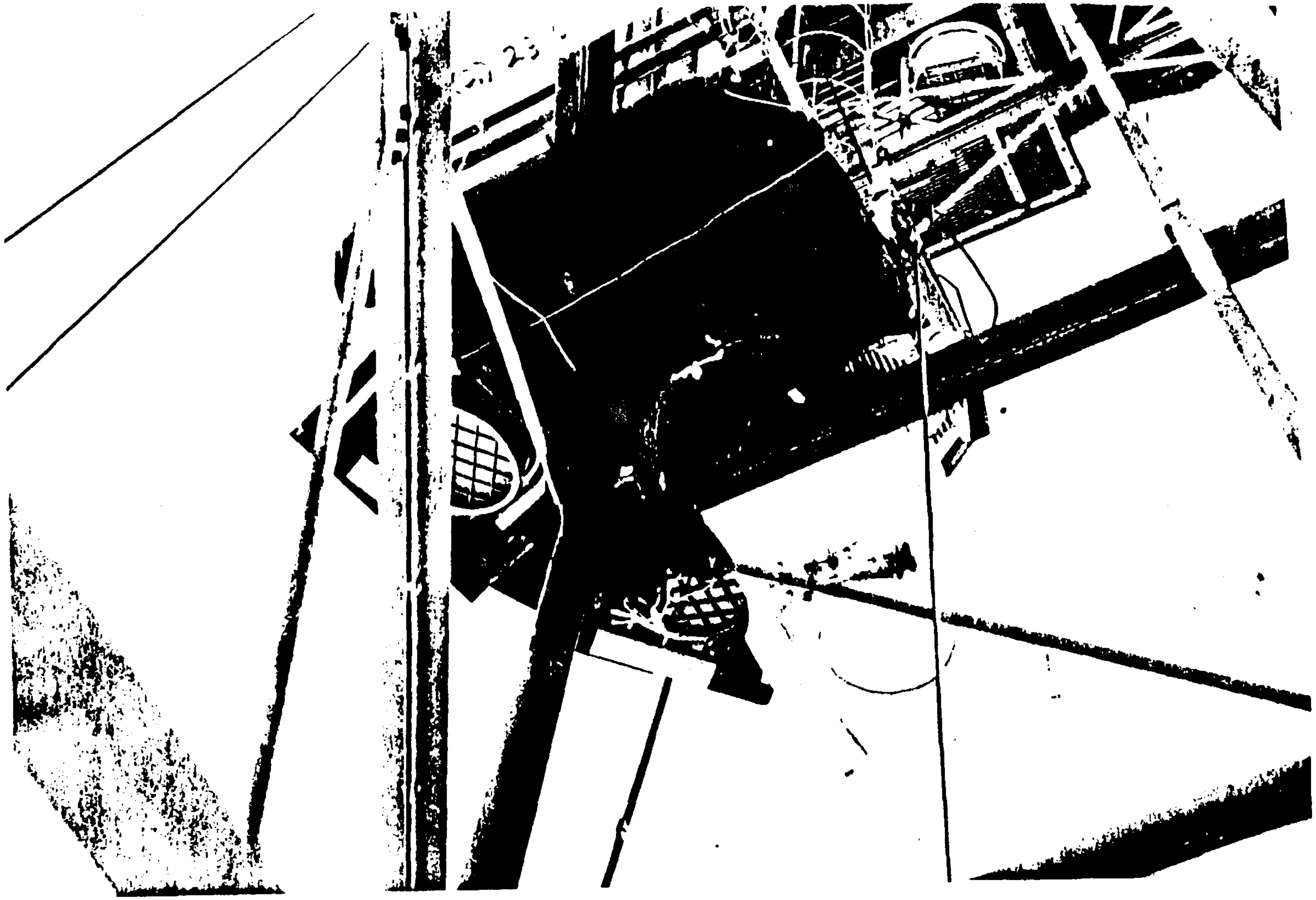

Fig. 2.3—Bottom view of scintillators.

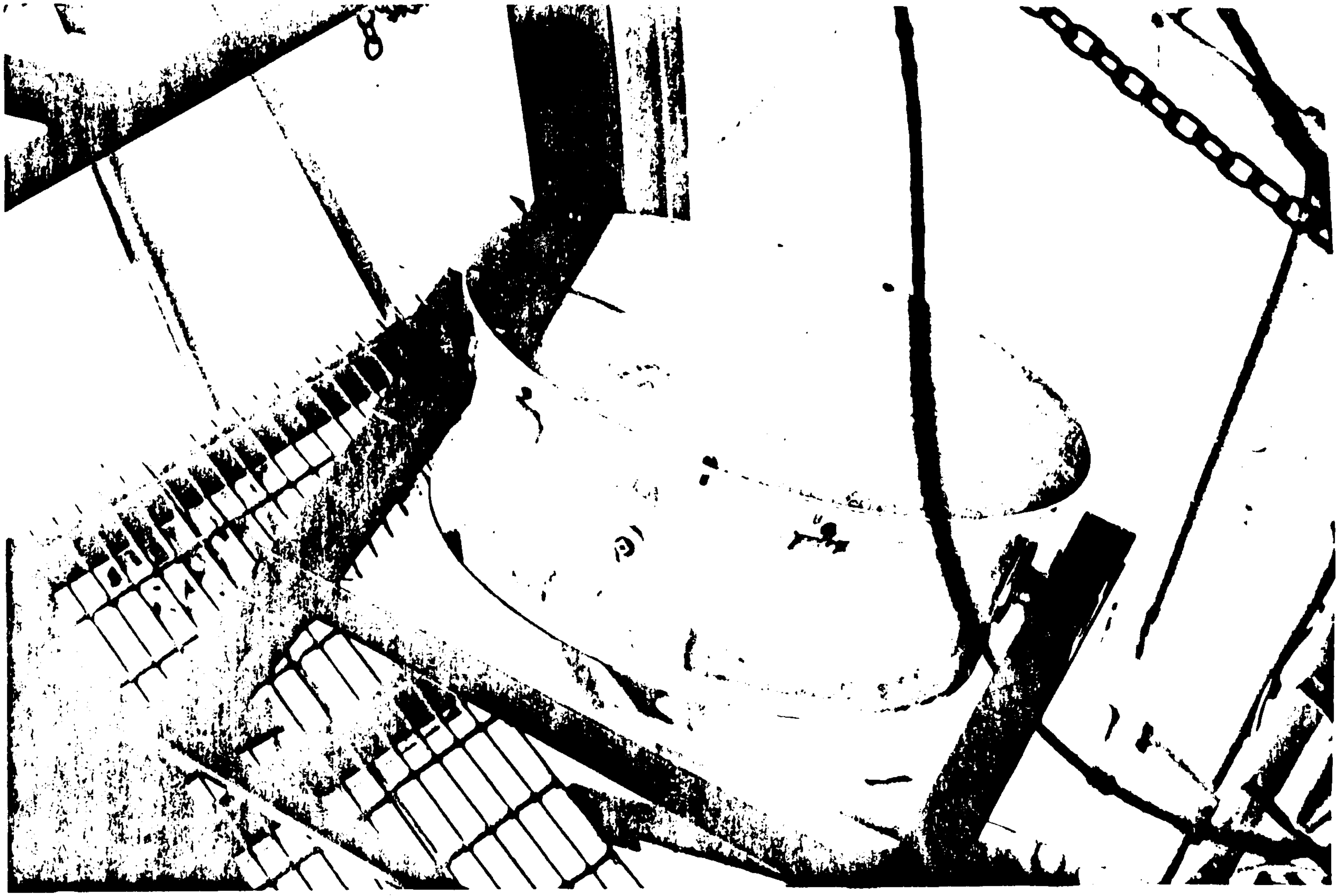

Fig. 2.4—3-meter scintillator.

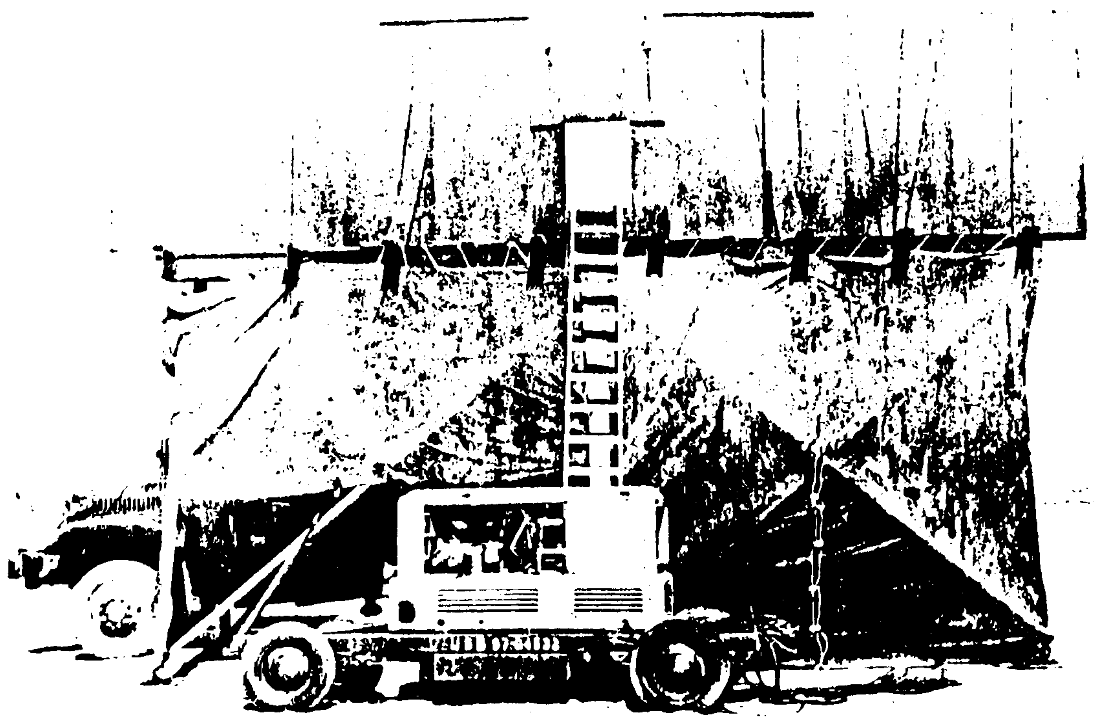

Fig. 2.5—Center baffle.

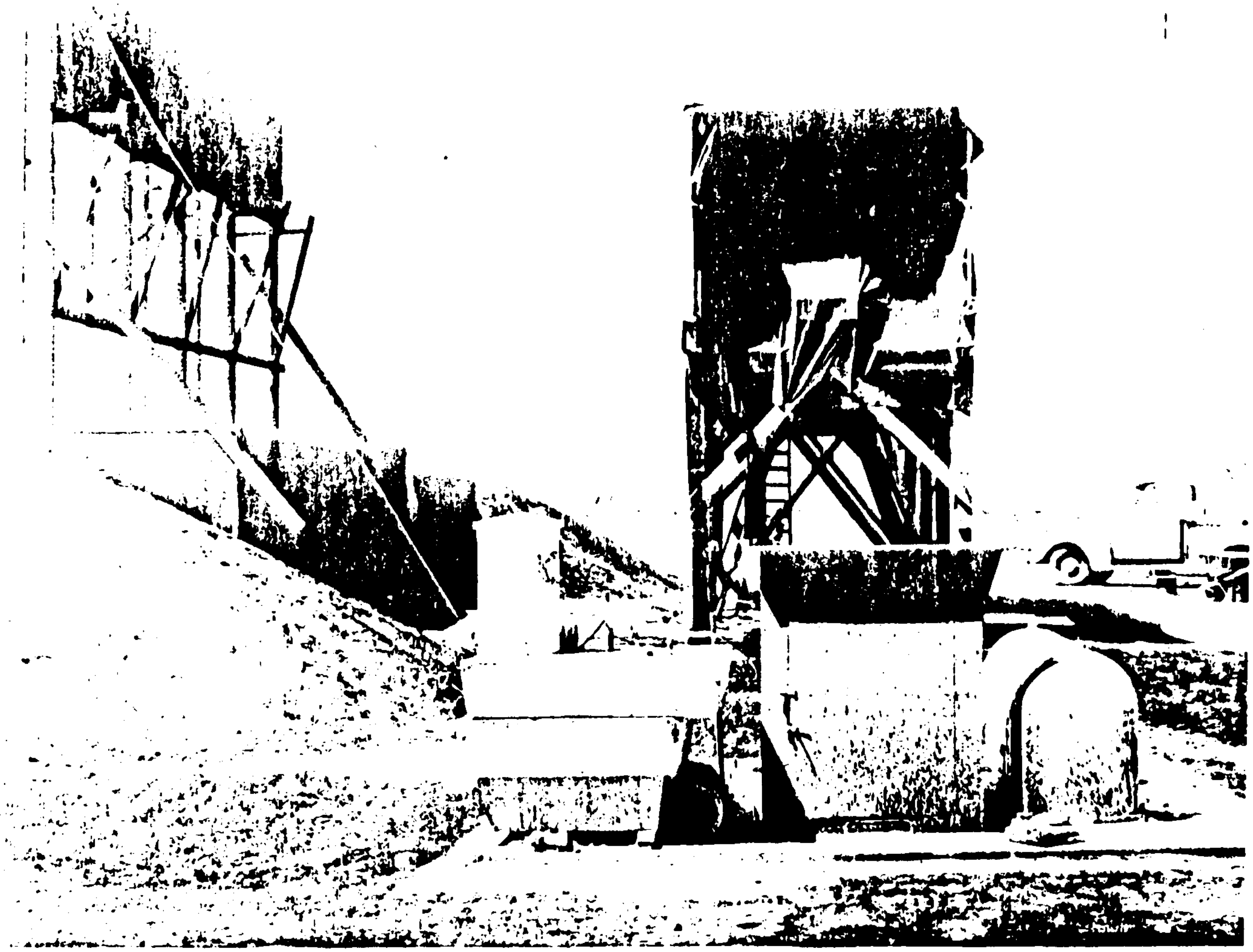

Fig. 2.6—Optical receiving-station installation.

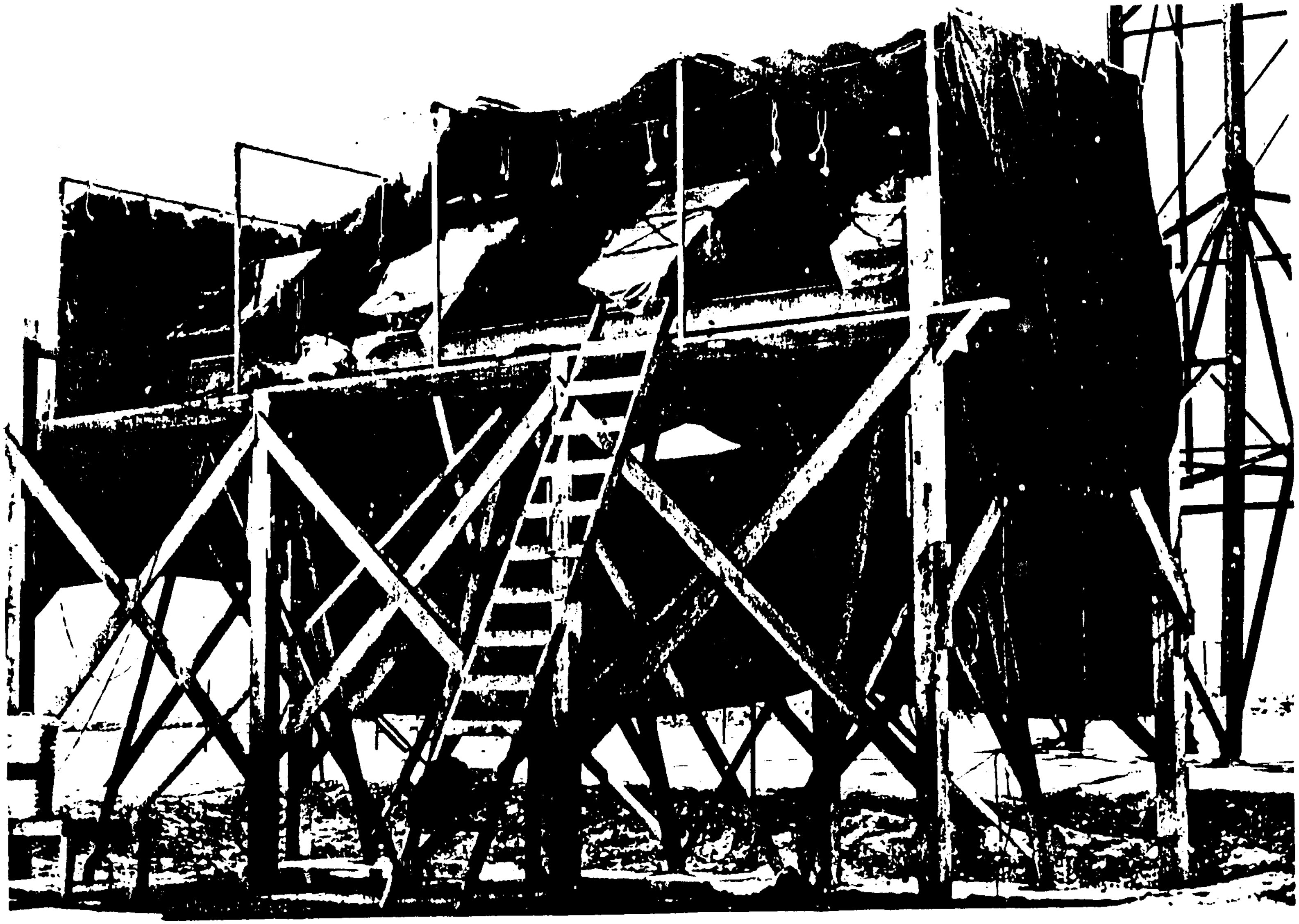

Fig. 2.7—Plane turning mirrors at tower base.

Fig. 2.8—Receiving-pit installation.

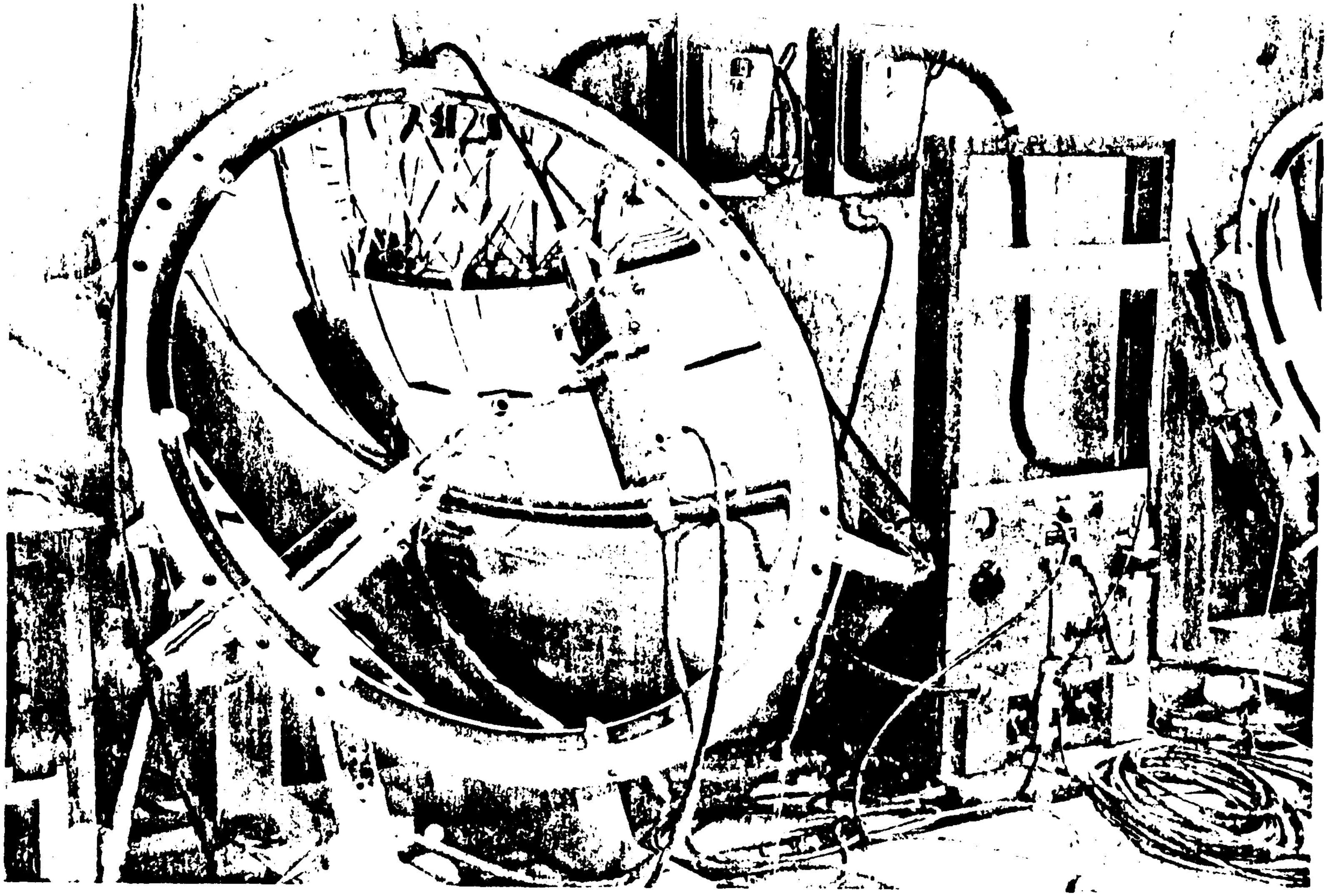

Fig. 2.9—Receiving mirrors and electronics.

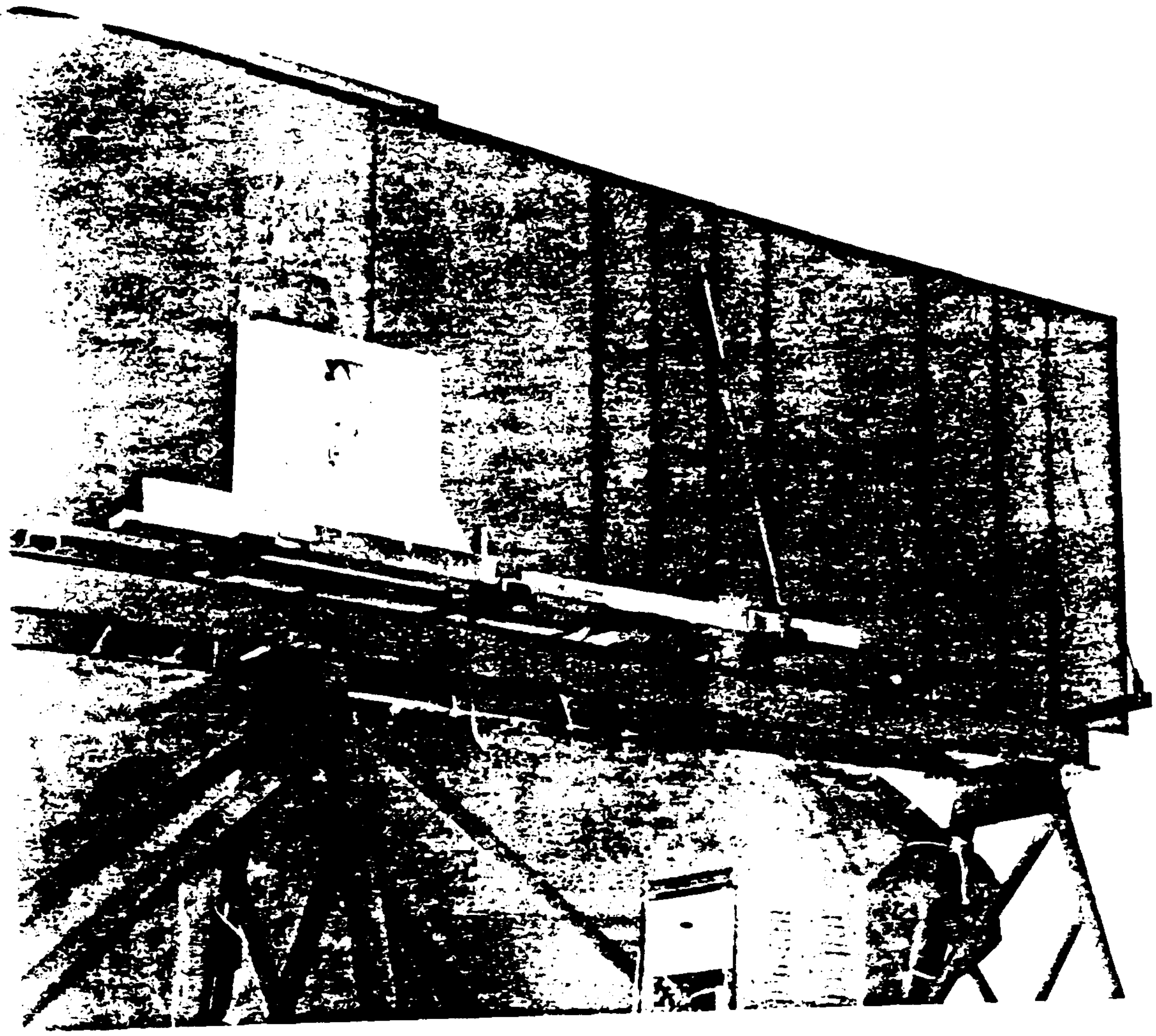

Fig. 2.10—Direct-current light source at center baffle.

shown in Fig. 2.6. The turning and collecting mirrors were then adjusted to give a maximum of light flux on the collecting lens and hence onto the photocathode.

2.4 RECORDING SYSTEM

2.4.1 Over-all System

The over-all recording system was similar in many ways to that used by D. C. Cook for the alpha measurement on Operation Snapper.[1] The signal from the scintillator, scintillator monitor, etc., was transmitted via the optical path to the 935 phototube. In the phototube the photon signal was converted to an electrical signal and transmitted through the log network via coaxial transmission lines to the recording system. The signal was amplified and displayed (utilizing a linear sweep) on cathode-ray tubes. The trace on the cathode-ray tube was photographed by special oscilloscope cameras which were actuated by EG&G timing signals. Time correlation of the signals was accomplished by having the two indicators associated with the 3- and 10-meter scintillators trigger the other indicators in the system. These two master indicators were time correlated by taking the trigger output from each (the initiating triggers for the other indicators in the system) and displaying them on a separate timing indicator.

Figure 2.11 is a schematic diagram of the over-all recording system. A photograph of the equipment in the recording station is shown in Fig. 2.12.

2.4.2 Detectors and Log-network Phototube

The conversion of terphenyl radiation into an electrical signal was accomplished by the phototube mounted near the focal point of the collecting mirror and adjusted so that the image of the light beam covered the photocathode. The spectral sensitivity of this tube (S-5) brackets the terphenyl radiation spectrum (see Fig. 2.13). The phototube was tested under overvoltage conditions, i.e., anode voltages from 500 to 6000 volts. At 3500 volts this tube delivered up to 1.5 amp linear with incident light. Therefore the use of this phototube with anode voltages of 1 to 6 kv ensured operation well above the knee of the saturation curve (beyond the region of space-charge limitation) but below the approximate 8-kv breakdown voltage. The rise time of the output current (as a function of input) is no greater than 1 ns (ns = 10^{-9} sec). Since the decay time of the scintillator is greater than this (2.5 ns), no rise-time distortion of the scintillator signal would occur in the phototube.*

(a) Gamma Detector. A gamma detector utilizing an RCA 935 vacuum phototube surrounded by scintillator solution was placed in a lighttight box on the mound in front of the receiving pit in direct view of the bomb. This detector, except for the added scintillator, was identical to the other detectors.

(b) Log Network. The current from the photocathode of each of the phototubes was fed into a log-network circuit (see Fig. 2.14). The log character of this network was obtained by decreasing the load on the phototube by approximately a factor of 10 whenever the current increased by the same factor. The load was decreased by parallel resistance, being switched in by the 1N56 diodes.

Rise-time response was an important consideration in the design of the log network. The final design was such that the following rise-time constants were realized: for photocell currents of 0.01 to 0.1 ma, RC = 125 ns; 0.1 to 1.0 ma, RC = 12.5 ns; 1.0 to 10.0 ma, RC = 1.25 ns, etc. Obviously for an exponential signal there is considerable time smear for low-current inputs; however, the smear becomes negligible in the region of interest.

*These results are essentially in agreement with other tests as reported by E. H. Krause and Staff, Diagnostic Neutron Experiments, Greenhouse Report Annex 1.5, Part I, WT-96 and WT-97, April 1952.

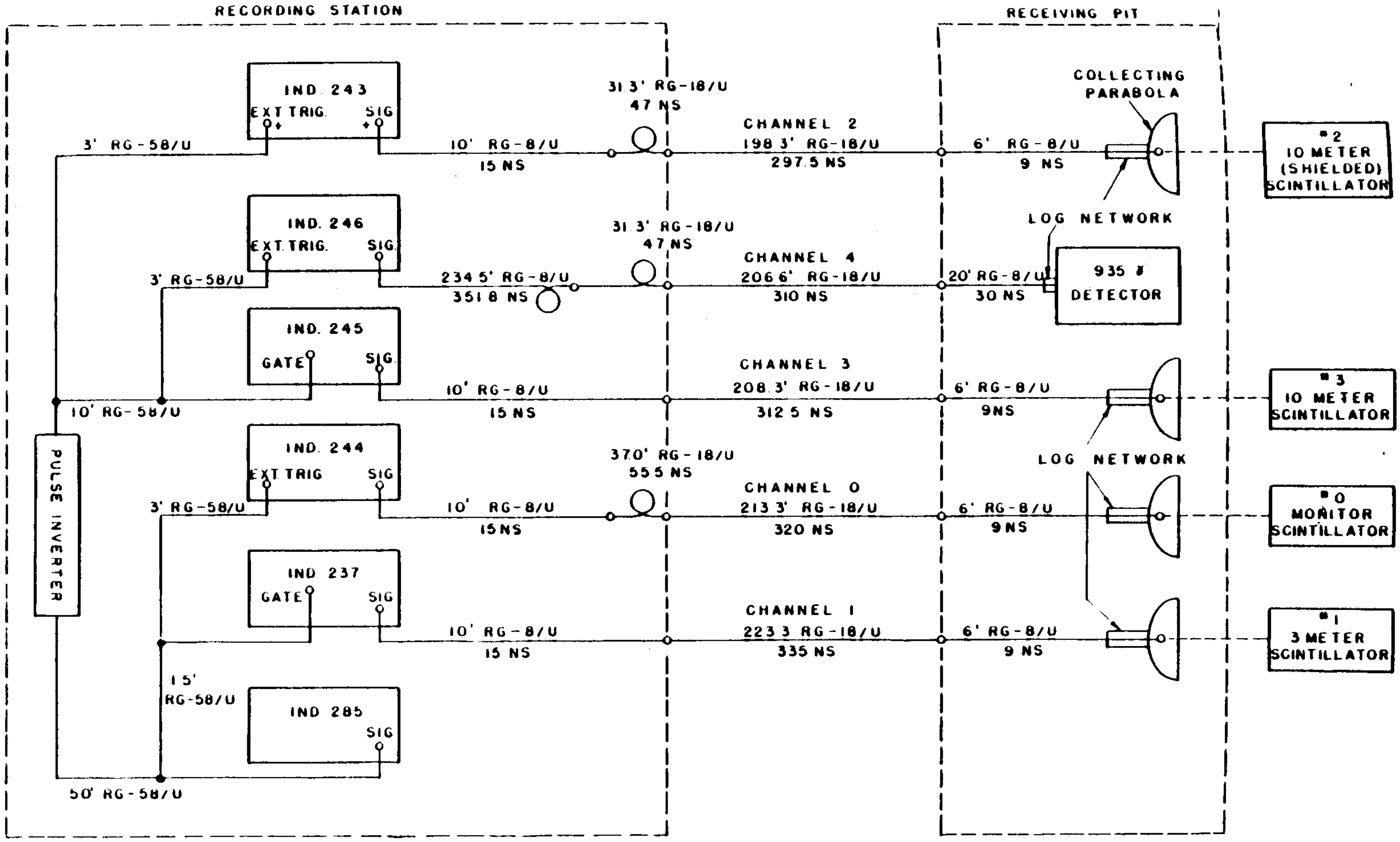

Fig. 2.11—Recording-system schematic.

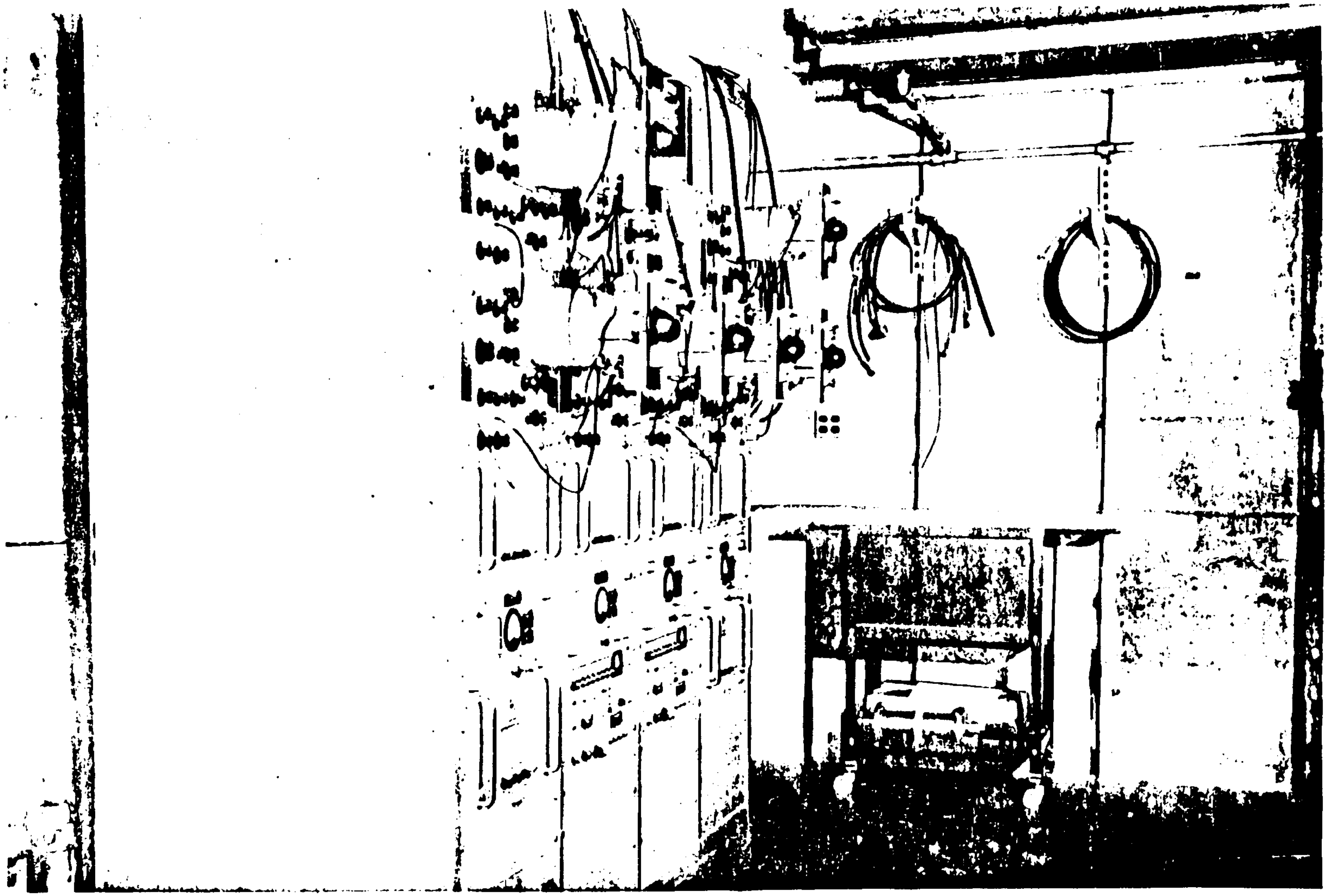

Fig. 2.12—Front view of recording station electronic bays.

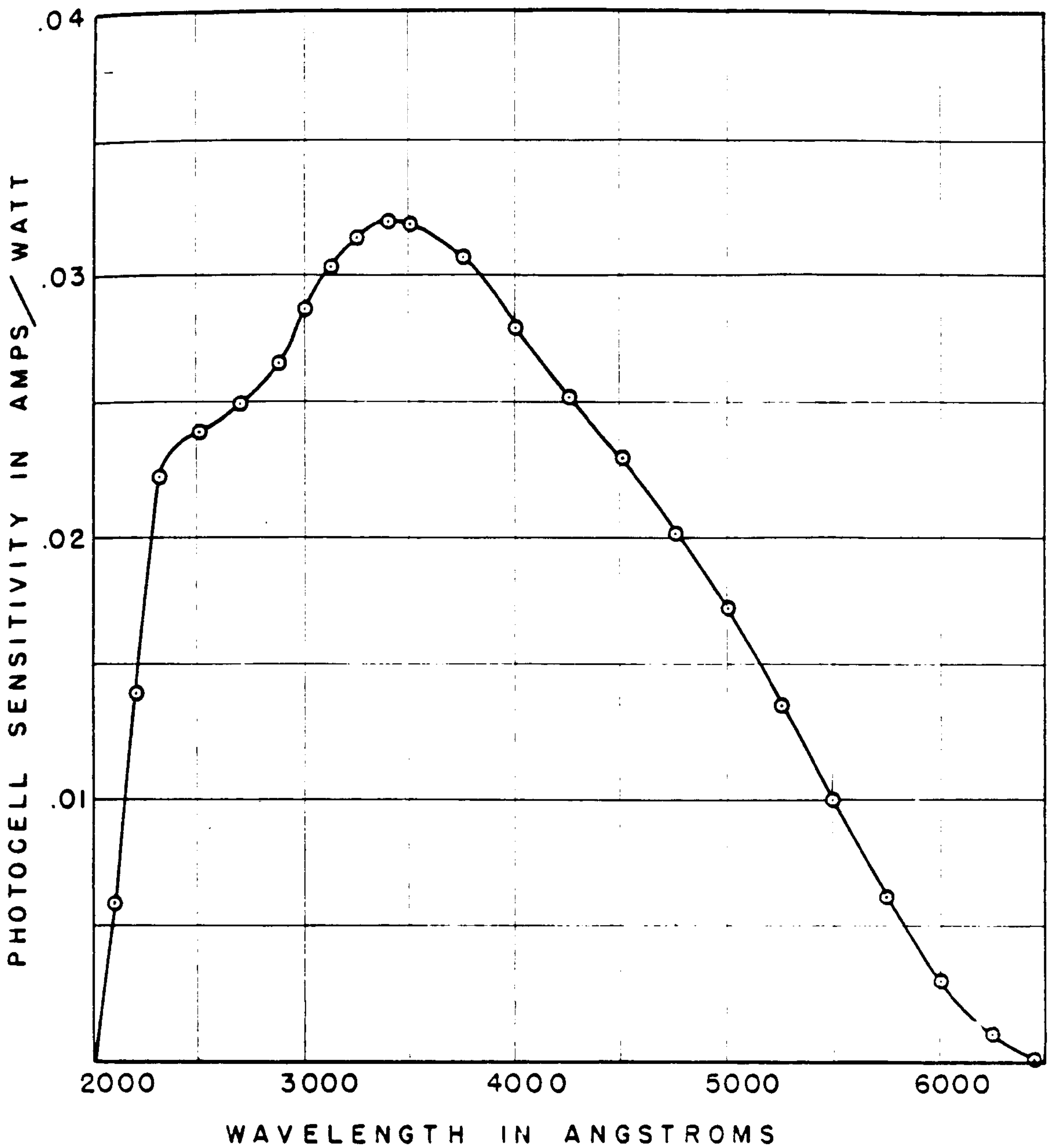

Fig. 2.13 — 935 phototube spectral sensitivity.