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OPERATION GREENHOUSE

SCIENTIFIC DIRECTOR'S REPORT

ANNEX 5.2, EVALUATION OF AIR-BORNE RADIAC EQUIPMENT

NUCLEAR EXPLOSIONS
1951

~~FORMERLY RESTRICTED DATA~~

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Annex 5.2

Evaluation of Air-borne Radiac Equipment

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EVALUATION OF AIR-BORNE RADIAC EQUIPMENT

by

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and

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Bureau of Aeronautics

Department of the Navy

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Scientific Director

[redacted]

Bureau of Aeronautics
Washington, D. C.

Air Research and Development Command
Wright Air Development Center
Wright-Patterson Air Force Base
~~Dayton, Ohio~~

August 1951

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Abstract

The Bureau of Aeronautics and the Air Force have, in a coordinated developmental program, developed techniques and air-borne radiac equipment to meet specific military requirements. However, before initiating a full-scale program of supplying Navy fleet organizations and Air Force operating organizations with air-borne radiac equipment, it was necessary to evaluate, as fully as possible, the developmental prototypes under conditions made possible only by an atomic bomb detonation.

To carry out this evaluation program, a joint Bureau of Aeronautics–Air Force project was initiated in which a Navy P2V-2 type aircraft and an Air Force B-17 aircraft were, in general, identically instrumented with radiac equipment developed by both services. In this manner, maximum insurance against equipment or aircraft failure during Operation Greenhouse was obtained as well as an interchangeability of data.

In general, the types of air-borne radiac equipment evaluated in this project can be classified under the following operational functions:

1. Radioactive-cloud tracking
2. Air-borne surface-radioactivity mapping
3. Ground-to-air gamma-radiation-data telemetering
4. Air-borne radiation detection and measurement

As a result of tests made on the radioactive cloud itself, the surface area within and surrounding the crater, and the air above the crater and surrounding area, the shortcomings as well as the advantages of the equipment and techniques were demonstrated. Detailed data, conclusions, and recommendations are presented for each piece of equipment.

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Chapter 1

Aircraft Installations

1.1 INTRODUCTION

With the exception of a few variations which are discussed in this chapter, the P2V-2 and B-17 aircraft were identically equipped and contained the following types of radiac equipment and systems:

1. AN/ADR-1 automatic gamma-radiation monitoring equipment
2. AN/ADR-2 electronic dosimeter and dose-rate meter
3. AN/ADR-3 radioactive-cloud detector and tracker
4. Type D-1 radioactive-cloud detector and tracker
5. AN/ADR-4 air-borne surface-gamma-radiation survey equipment
6. Type F-1 air-borne surface-radiation survey equipment
7. AN/USQ-1 and AN/ARR-29 gamma-radiation telemetering system
8. Type E-1 air-borne air beta monitor

By employing identical equipment and similar installation methods in both aircraft, it is possible to interchange data. This might become necessary in the event that one aircraft is forced out of the test operation because of radiac equipment or aircraft failure.

Although in most individual major radiac equipment is incorporated a recorder to make a permanent record of the results, the technical operating personnel aboard these test aircraft were provided with wire recorders to enable them to make a running commentary to supplement the individual equipment recordings.

In addition to the radiac equipment listed, both aircraft were provided with all the normal navigational, radio, intercommunication, and radar equipment. Also provided were oxygen breathing systems which are used in all high-altitude flying as well as in those instances where a danger of inhalation of radioactive particles exists.

Inasmuch as the number of technical personnel available to operate and observe the radiac equipment aboard the aircraft during the test operation was extremely limited, great care was taken to locate the equipment in such a manner as to enable each technician to operate several pieces of equipment at the same time.

1.2 P2V-2 AIRCRAFT INSTALLATION

Figure 1.1 is a pictorial representation of the P2V-2 radiac equipment installation showing the relative locations of the various parts of the equipment. As can be seen from Fig. 1.1, a dual installation of the AN/ADR-1 equipment is used. The detector units for both these installations are located in the nose section of the P2V-2. An indicator and a control box for one AN/ADR-1 are placed in the pilot's compartment for the pilot's use. The indicator unit and control box for the second AN/ADR-1 are placed in the navigator's compartment. The amplifier power-supply unit, as well as the recorder RD-77/ADR-1, for the pilot's AN/ADR-1 is located in the nose section. The amplifier power-supply unit and the recorder unit for the second equipment are located in the navigator's position. Also located in the nose section of the aircraft is the type D-1 radioactive-cloud detector and tracker. The type D-1 equipment indicator unit is located in the radar compartment. The AN/ADR-2 electronic dosimeter—rate recorder is located in the nose section of the P2V-2.

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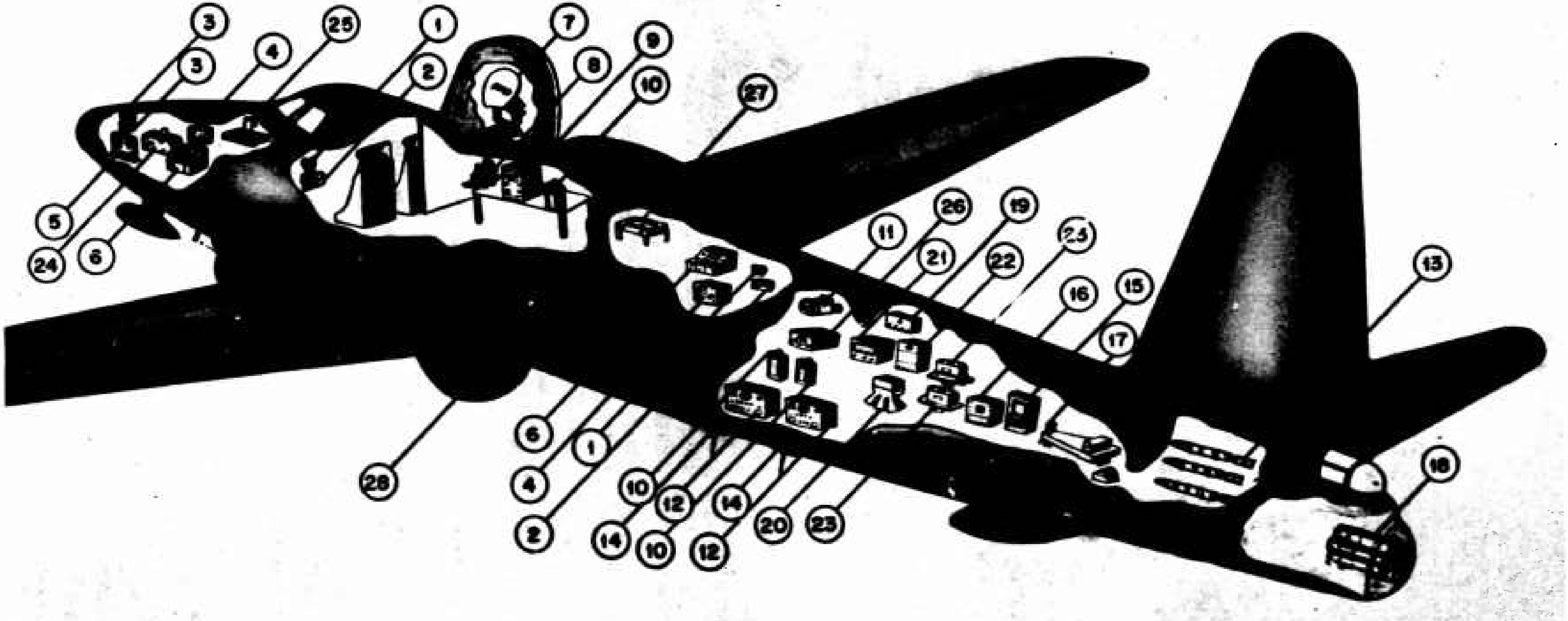

Fig. 1.1 P2V-2 Radiac Equipment Installation

1. AN/ADR-1, indicator
2. AN/ADR-1, control box
3. AN/ADR-1, detector unit
4. AN/ADR-1, amplifier and power unit
5. AN/ADR-2, electronic dosimeter and rate meter and recorder
6. RD-77/ADR-1 radiac recorder
7. AN/ADR-3, antenna assembly
8. AN/ADR-3, scope indicator and camera
9. AN/ADR-3, control console
10. Recorder
11. AN/ADR-3, remote scope indicator
12. AN/ARR-29 gamma-telemetering system, receiver
13. AN/USQ-1 gamma-telemetering unit
14. Vhf (iff) antenna
15. AN/ADR-4, recorder unit
16. AN/ADR-4, computer unit
17. AN/ADR-4, directional unit
18. AN/USQ-1 telemetering unit, dispenser
19. Type E-1 air-borne air beta monitor equipment
20. Type F-1 air-borne surface-radiation survey equipment, directional unit
21. Type F-1 air-borne surface-radiation survey equipment, recorder unit
22. Type F-1 air-borne surface-radiation survey equipment, amplifier power-supply unit
23. Strip-camera and film-speed synchronizer
24. Type B-1 air-borne gamma dosimeter
25. Type D-1 radioactive-cloud detector and tracker equipment, directional head and amplifier
26. Type D-1 radioactive-cloud detector and tracker equipment, indicator
27. Odograph, ground-position tracer
28. AN/APS-33, radar radome

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As indicated in Fig. 1.1, the AN/ADR-3 antenna assembly is housed in a radome which is located on the top surface of the aircraft, directly over the radio compartment. The AN/ADR-3 control console, recorder, and cathode-ray-scope indicator which is equipped with a camera, are also located in the radio compartment. A remote scope indicator for the AN/ADR-3 equipment is located in the radar compartment.

An odograph, which continuously plots the position of the aircraft, is located in a compartment built into the navigator's table, which has a transparent top. By feeding wind-direction and -velocity information into the odograph, a ground-position track is obtained. If no wind information is fed into the equipment, an air-position track is obtained. This position plotter, with wind information fed in, is used with the AN/ADR-4 surface-survey equipment to give ground positions to correlate with the computed ground-radiation intensities. This odograph equipment, with no wind information fed in, is used to plot continuously the position of the aircraft with respect to the radioactive cloud. Since both the aircraft and the radioactive cloud are similarly affected by the wind, a relative aircraft-cloud position can be obtained. As an added feature on the odograph, the pen assembly used is provided with a means of varying the width of traceline in accordance with the radiation measured by the AN/ADR-1 equipment. The higher the intensity of radiation, the wider is the odograph traceline. The use of this variable-width traceline is optional; and the traceline can be made a consistent width by merely throwing a toggle switch located on the navigator's table, in which case the odograph will plot the aircraft position with a very thin unmodulated line.

Placed in a rack in the radar compartment are two complete AN/ARR-29 gamma-telemetering receiving and recording systems. The two required vhf receiving antennas are located on the bottom of the aircraft under the radar compartment. These receivers are interconnected with the normally furnished AN/APS-33 radar so as to indicate, on the radar scope, the locations of the dropped AN/USQ-1 telemetering units.

Because of the required directional characteristics of both the AN/ADR-4 and type F-1 air-borne surface-gamma-radiation survey systems, special attention must be paid to prevent surface-emanated radiations from being reflected or scattered into the directional detectors by large metallic masses such as the aircraft engines. In view of this installation requirement the AN/ADR-4 system, complete with the directional unit, computer unit, recorder unit, and strip camera, was placed in the waist section of the aircraft immediately behind the radar compartment. The complete type F-1 equipment, which includes a directional unit, amplifier-integrator unit, power unit, recorder unit, and strip camera, is also placed in the waist section.

Adjacent to the type F-1 equipment is the type E-1 beta air monitor.

Facilities for storing AN/USQ-1 telemetering units are placed in the tail section of the aircraft. Approximately ten units can be stored.

After considerable study and experimentation on methods of ejecting the AN/USQ-1 units from an aircraft, it was determined that by employing a dispenser, as shown in Fig. 1.1, the units can be launched reliably and quickly. In the P2V-2, eight individual launching tubes are used. Each tube is equipped with a plunger which forces the telemetering units out the tail section first. Since a negative pressure exists at this point of the aircraft in level flight, the units leave the launching tubes very readily. This launching system is so designed and constructed that all eight tubes can be loaded either prior to take-off or during flight. When it is desired to launch the telemetering units, it is only necessary to pull the trigger on each tube.

A photograph of the actual installation of the equipment in the P2V-2 aircraft is given in Fig. 1.2.

1.3 B-17 AIRCRAFT INSTALLATION

The relative positions of the various radiac equipment in the B-17 installation are shown in Fig. 1.3.

As in the case of the P2V-2, the pilot of the B-17 has an AN/ADR-1 at his disposal. The indicator and control box are in the pilot's compartment; the detector unit and amplifier power-supply unit are in the nose of the aircraft. The detector unit for a second AN/ADR-1 is also in

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Fig. 1.2 P2V-2 with Radiac Equipment Installed for Evaluation Tests in Operation Greenhouse

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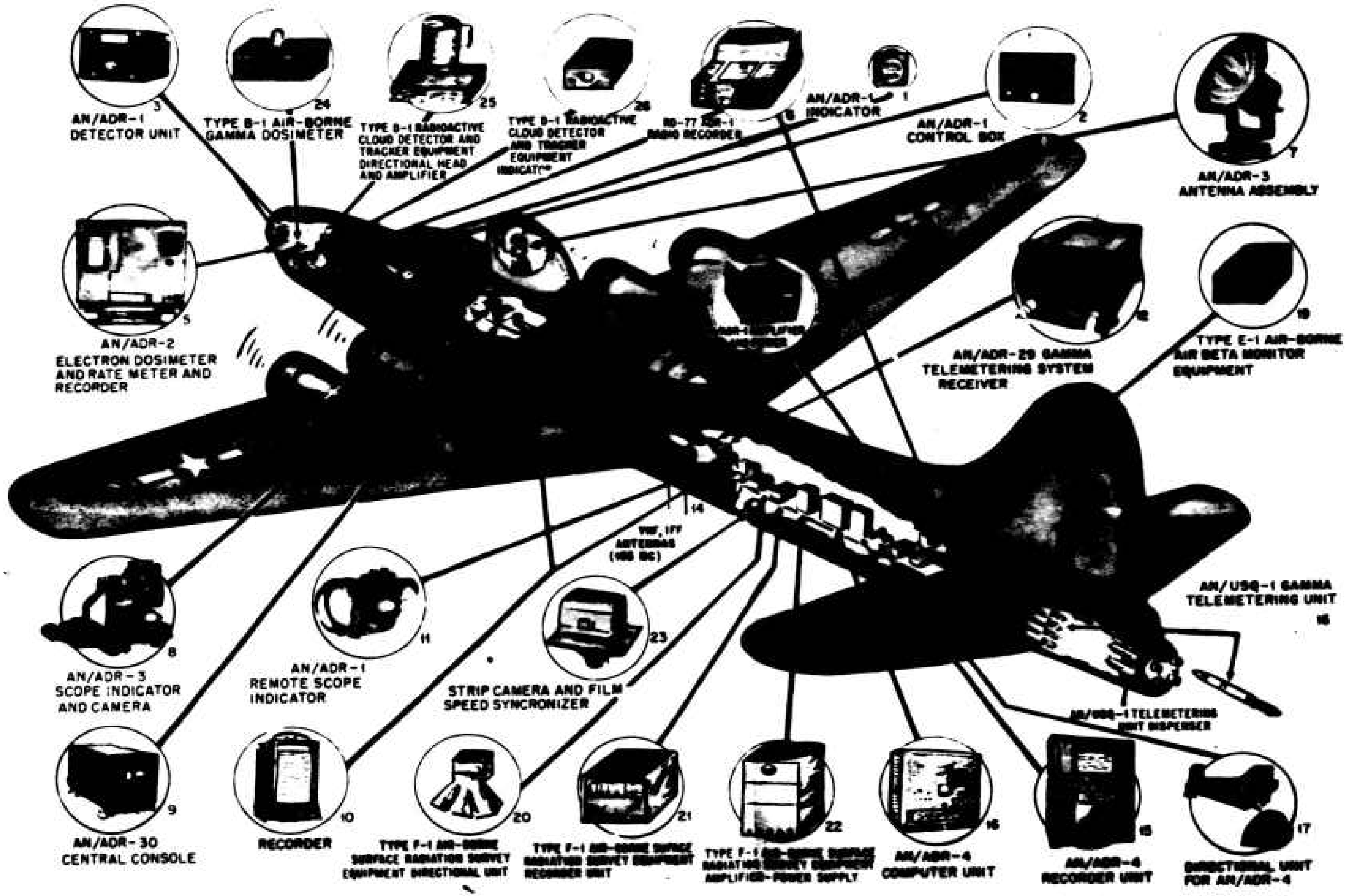

Fig. 1.3a B-17 Radiac Equipment Installation

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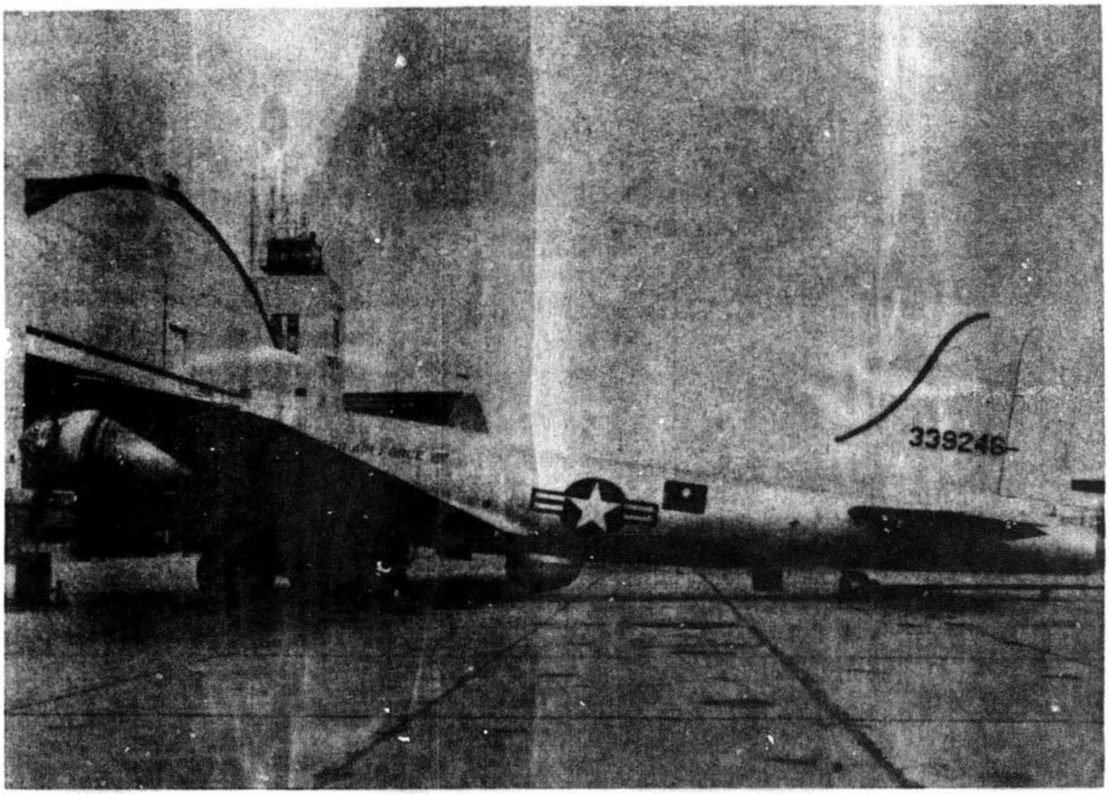

Fig. 1.3b Air Force B-17 with Radiac Equipment Installed for Evaluation Tests in Operation Greenhouse. Note the AN/ADR-3 cloud tracker in radome on top, the USQ-1 launching tubes protruding from the tail, and the type F-1 surface-survey dome on bottom.

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the nose of the B-17. The remainder of the second AN/ADR-1, namely, the indicator, recorder, control box, and amplifier power-supply unit, is placed on a table in the waist of the aircraft.

The entire type D-1 equipment, including the indicator, is placed in the bombardier's compartment.

The AN/ADR-3 equipment is located directly behind the pilot's compartment. As in the case of the P2V-2 installation, the AN/ADR-3 antenna assembly is housed in a radome placed on the top of the aircraft directly above the other AN/ADR-3 components.

The AN/ARR-29 telemetering receivers are located in the radio compartment, and the associated telemetering recorders are located directly behind the radio compartment. The vhf antennas for the AN/ARR-29 receivers are mounted on the bottom of the aircraft below the radio compartment as shown in Fig. 1.3.

Located in the waist of the B-17 are the AN/ADR-4 and type F-1 surface-survey equipment. As indicated in Fig. 1.3, the AN/ADR-4 is not equipped with a strip camera as was the case in the P2V-2 installation. The type F-1 system, however, does include a strip camera.

Also a type E-1 air beta monitor is placed in the waist of the aircraft, adjacent to the AN/ADR-4 equipment.

Unlike the P2V-2 installation, the B-17 installation does not include an odograph.

As in the P2V-2, the B-17 has storage and dispensing provisions for the AN/USQ-1 telemetering units in the tail section. Storage racks for ten AN/USQ-1 units are provided. As shown in Fig. 1.3, five dispensing tubes are placed in the B-17 tail. The dispensing tubes are identical with those installed in the P2V-2.

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Chapter 2

Description of Radiac Equipment

2.1 INTRODUCTION

Some of the equipment being evaluated in this project was designed and constructed in accordance with military electronic-equipment specifications in order to permit operation under conditions such as extreme temperatures, high altitude, vibration, high humidity, and other extreme conditions encountered in military operations. Other equipment was in an experimental stage which was suitable for evaluation of techniques and special circuitry.

In this chapter every type of radiac equipment installed and tested in both aircraft is described. Sufficient design and construction details are given to enable intelligent use and interpretation of the data obtained and the conclusions reached.

2.2 AN/ADR-1 AUTOMATIC GAMMA-RADIATION MONITORING EQUIPMENT

2.2.1 Purpose

This air-borne equipment has been designed and constructed to perform three principal functions: (1) to indicate, by means of warning lights, the presence of various levels of gamma radiation to which the aircraft crew is being subjected, (2) to measure continuously the dose rate of the incident gamma radiation, and (3) to actuate automatically auxiliary apparatus such as aircraft air-intake filters and oxygen supplies, upon reaching predetermined and preset levels of gamma radiation.

This particular equipment operates over an intensity range of approximately 0.1 to 2000 mr/hr in two scales which change automatically.

It is intended that the AN/ADR-1 will be used for general-purpose gamma-radiation monitoring and measuring in all aircraft that may be involved in any phase of atomic warfare.

2.2.2 Principle of Operation

In Fig. 2.1, the basic principle of operation employed in the AN/ADR-1 is illustrated diagrammatically.

As shown in Fig. 2.1, two ionization-chamber—d-c amplifier channels are employed. Both the low-range and high-range channels are fed to the indicator. However, only one channel is connected to the indicator at a time. This switching between channels is completely automatic and is accomplished by the switching and control circuit. The switching and control circuit also activates warning lights as well as external circuits (such as oxygen sources and air filters) upon reaching preset values of radiation intensities.

The ionization chambers employed are of a high-pressure type and are filled with 50 atm of argon.

As shown in Fig. 2.1, both the high-range and low-range channels are employed to detect and measure radiation. However, only the low-range channel is used for switching and control. By the use of two separate channels, instead of merely changing the high-ionization resistors in one channel to obtain two ranges, increased stability and more positive switching and control operations were made possible.

2.2.3 Description

This entire AN/ADR-1 system consists of five interconnected units: (1) the detector unit containing the ionization chambers and d-c

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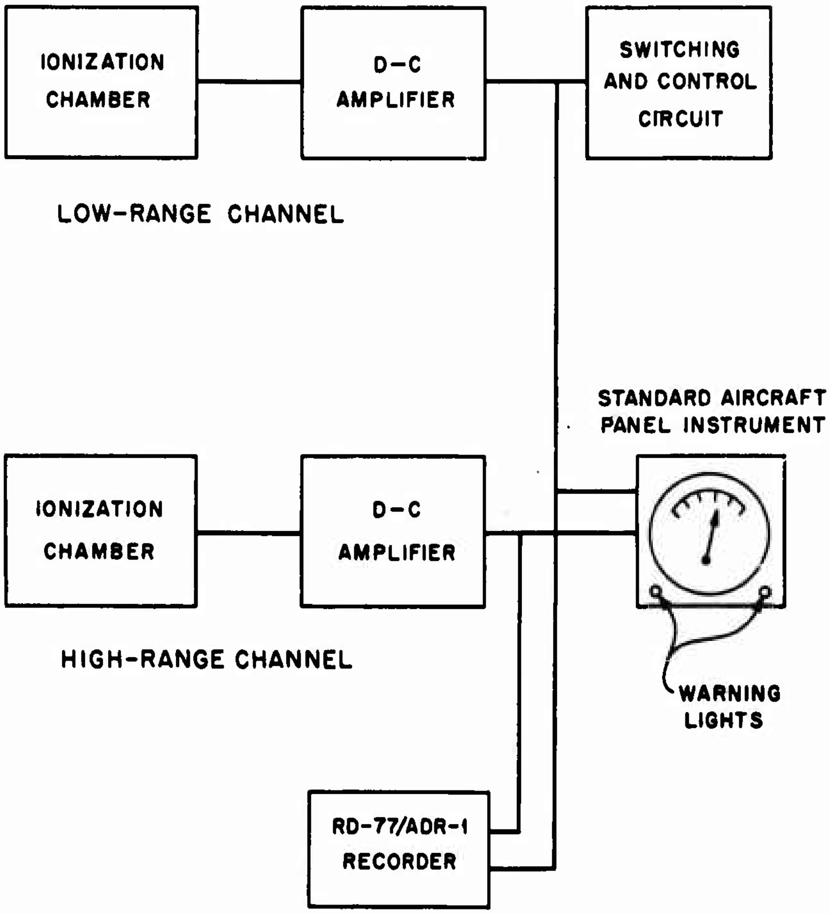

Fig. 2.1 Diagram of AN/ADR-1 Automatic Gamma-radiation Monitoring Equipment

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TABLE 2.1 DATA FOR AN/ADR-1 EQUIPMENT*

Physical Data

Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Detector	10	$6\frac{3}{4}$	$8\frac{1}{4}$	$12\frac{1}{4}$
Power amplifier	28	$10\frac{1}{8}$	$11\frac{1}{4}$	19
Indicator	1	$2\frac{3}{8}$	$2\frac{3}{8}$	$4\frac{3}{4}$
Control	1	$3\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{8}$
Recorder	30	12	11	19

Power requirements	
AN/ADR-1 radiac set	
115 volts, 320–1760 cps	200 va
24 volts, d.c.	50 watts
RD-77/ADR-1 recorder	
115 volts, 320–1760 cps	
24 volts, d.c.	
Indicator scales (mr/hr)	
No. 1	0–20
No. 2	20–2000
Recorder scales	
No. 1 (mr/hr)	0–20
No. 2 (mr/hr)	20–2000
Dosimeter (r)	100

*Gamma-radiation monitoring.

amplifiers, (2) the amplifier power-supply unit housing a regulated power supply and the switching and control circuits, (3) the indicator containing a meter, two warning lights, and the automatic scale-changing mechanism, (4) the control unit which has the on-off switch as well as the zeroing and test controls, and (5) the recorder unit which provides a continuous record of gamma intensity and integrates these data to give a total-dosage reading. Although zeroing controls are available, only very infrequent use of these controls is necessary.

By operating the test switch on the control box, a small self-contained radium source is placed close enough to the ionization chambers to obtain a predetermined reading on the meter, thus providing a means for determining if the complete system is in operating condition. Upon release of this test switch the small radium source is removed from the ionization chamber, and the indicator reads zero.

The AN/ADR-1 equipment data are listed in Table 2.1.

2.3 AN/ADR-2 ELECTRONIC DOSIMETER AND DOSE-RATE METER

2.3.1 Purpose

The purpose of this equipment is twofold: (1) to determine and indicate instantaneously the gamma-radiation dosage that the aircraft crew has been exposed to and (2) to indicate the manner in which this dosage was accumulated by continuously measuring and recording the dose rate. This equipment can indicate continuously and instantaneously a dosage up to 100 r and can measure and record a maximum dose rate of approximately 50 r/hr.

2.3.2 Principle of Operation

A block diagram illustrating the basic operating principle of the AN/ADR-2 is given in Fig. 2.2.

As can be seen from this figure, this equipment consists of two completely separate basic circuits, one for the dose-rate recorder and the other for the dosage indicator.

Inasmuch as the dose-rate meter must operate over three logarithmic cycles (i.e., from 0.05 to 50 r/hr), ionization chamber 1 is of a saturable type. It is filled with nitrogen under 10 atm pressure. By operating this ionization chamber under conditions such as to give partial saturation, clearly discernible readings are obtained over the entire range from 50 to 50,000 mr/hr.

After amplification in the d-c amplifier, the signal voltage is introduced into the balancing circuit, where it is balanced against a d-c voltage from the rotating balancing potentiometer. The sliding arm of the rotating balancing potentiometer is mechanically connected to the rotating recorder drum. Since the drum rotates at approximately 90 rpm, the d-c balancing voltage fed into the balancing amplifier by the rotating balancing potentiometer also goes through 90 cpm, each cycle going from a minimum to a maximum voltage. At the point where the signal voltage equals the rotating-potentiometer balancing voltage a trigger tube in the balancing circuit actuates the recorder solenoid, which in turn causes the clapper to

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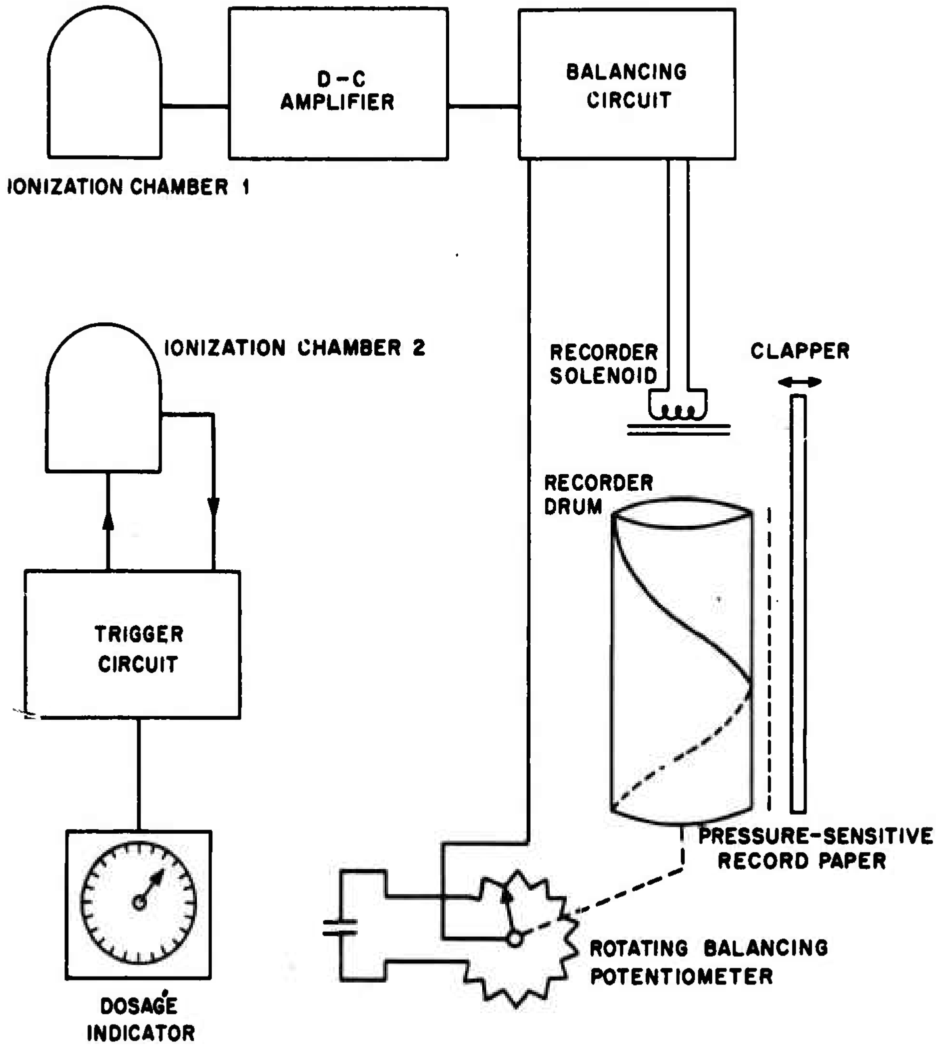

Fig. 2.2 Diagram of AN/ADR-2 Electronic Dosimeter and Dose-rate Meter

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strike down on the recorder drum, thus making a mark on the recorder paper. Since the recorder drum has a helical ridge which is struck by the clapper, the distance from the edge of the pressure-sensitive paper at which the mark appears can be calibrated in terms of the radiation incident on the instrument. The type of trace obtained is clearly shown in Fig. 2.3.

The dosage-indicator part of the equipment consists of ionization chamber 2 (see Fig. 2.2), which is filled with air under atmospheric pressure. After a charge is placed on the ionization chamber, the charging voltage is removed. In the presence of gamma radiation, the ionization

TABLE 2.2 DATA FOR AN/ADR-2 EQUIPMENT*

Physical data	
Total weight (lb)	~30
Length (in.)	17
Width (in.)	$6\frac{5}{8}$
Height (in.)	$15\frac{3}{8}$
Power requirements	200 watts, 320–1760 cps
	50 watts; 24 volts, d.c.
Scales	
Dosage† (r)	100
Dose rate (r/hr)	0.05–40

*Gamma-radiation monitoring.

†In 10-mr steps. Greater dosages can be measured by noting the number of revolutions of the main counter indicator.

in the chamber causes it to discharge. Since the chamber is effectively a condenser, the discharge is an accumulative phenomenon, as is a dosage. This particular ionization chamber and its associated circuitry are so designed that 10 mr will discharge it to the point at which the voltage between the chamber-center electrode and shell is small enough to cause a vacuum tube in the trigger circuit to actuate a mechanical counter indicator. At the same instant that the mechanical counter is actuated by the trigger circuit, a full charge is again placed on the ionization chamber and the cycle is repeated. Thus the process is continuous, and each time that the counter moves one step, it is known that the instrument has been exposed to a gamma-radiation dosage of 10 mr. Therefore by calibrating the mechanical counter in roentgens, a continuous and instantaneously read dosimeter is obtained.

2.3.3 Description

Both portions of this equipment are enclosed in a single case and are operated from the same regulated power supply. Figure 2.3 is a photograph of the entire unit. Provisions for checking the operation and calibration of this equipment have been made on the front panel.

Data pertaining to AN/ADR-2 equipment are presented in Table 2.2.

2.4 AN/ADR-3 RADIOACTIVE-CLOUD DETECTOR AND TRACKER

2.4.1 Purpose

The purpose of this equipment is to detect and track a radioactive cloud produced by the detonation of an atomic bomb without actually coming into contact with the cloud itself. It is also necessary for this equipment to differentiate between a radioactive and a normal cloud. It is required that this equipment have sufficient angular resolution at long range to permit a high-speed aircraft to avoid the radioactive cloud.

2.4.2 Principle of Operation

The AN/ADR-3 air-borne radioactive-cloud detector and tracker is a microwave radiometric type of equipment that is based on the reception of the microwave radiation from the cloud. Since the field of microwave radiometry is relatively new and consequently the principle of operation and the limitations of a radiometer are not generally understood, a brief description of the theory of operation of the radiometer is given.

It is well known that a hot object gives off infrared radiation and will, if hot enough, radiate visible light. This type of radiation is known as "thermal" radiation. If the intensity of radiation is a continuous function of the wavelength so that energy is radiated over a very wide continuous-frequency spectrum, it is referred to as "black-body" radiation. Black-body radiation does exist in the radio-frequency

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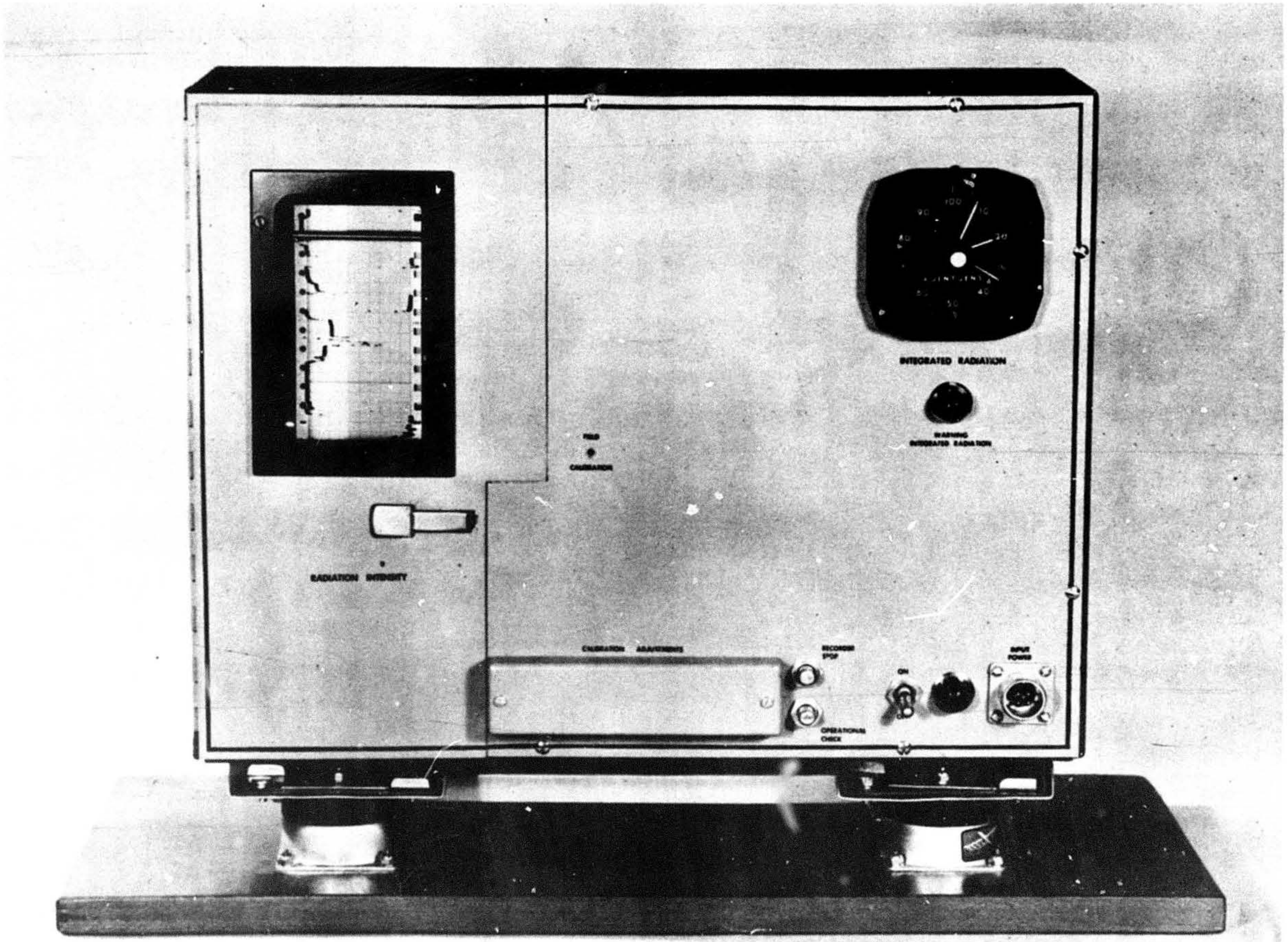

Fig. 2.3 Electronic Dosimeter and Dose-rate Meter AN/ADR-2

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range of the electromagnetic spectrum. From black-body theory it can also be shown that the ability of a body to radiate energy is directly related to its ability to absorb energy. The radiation from an object equals the value predicted by the common formula for black-body radiation only if it is a complete absorber (assuming reflections are zero) at the frequency in question. In fact this is the interpretation of the term "black." If the body is not a complete absorber, the radiation is reduced to a value equal to the product of the black-body radiation at the temperature of the body and its absorption coefficient. Thus if a body possesses high absorption to microwave energy, it will also be a good radiator of microwave energy.

At microwave frequencies there is some absorption, which is due to the water vapor and oxygen content in the atmosphere. At wavelengths of 2 cm and less, such absorption is appreciable. At these wavelengths there will also be added absorption and scattering if there is rain or snow present. However, at a wavelength of 10 cm there is only a small amount of atmospheric absorption (discounting weather containing electrical disturbances) except when the path length through the atmosphere is very long, as would be the case when the antenna is directed toward the horizon. Thus an ordinary cloud of water vapor would appear to be essentially transparent to radiation at 10 cm and consequently would radiate only a small amount of energy. However, if there are a large number of ions and electrons present in a cloud, such as would be the case in a radioactive cloud, there would be an associated absorption at these wavelengths. It then follows that a cloud of charged particles becomes an approximate black-body radiator. If a cloud radiates more energy than its surroundings, it should be possible to detect its presence by means of a suitable directive receiving device adapted to scan the general region in which the cloud is located. In the microwave-frequency range, a device known as the microwave radiometer will perform this function.

From radiometry theory the power received by an antenna which is surrounded by a black body at a uniform temperature is proportional to the absolute temperature of the body. If the medium surrounding the radioactive cloud is only the sky, which exhibits an equivalent black-body temperature close to absolute zero, and if the cloud does not fill the antenna beam, then the received radiation will be the integrated energy from both sources and will be lower than that received when the cloud completely fills the beam. Consequently, since radiation is directly associated with absorption, it is necessary to have some knowledge of the absorption of the atmosphere forming the background of the cloud, the absorption of the cloud itself, and the absorption of the medium between the antenna and cloud. It is also necessary to know the characteristics of the antenna before the magnitude of the radiation received by the antenna can be predicted.

The Dicke type radiometer is by far the most sensitive device for this purpose. This technique involves modulation of the input to an ordinary superheterodyne receiver. This is accomplished in a microwave receiver by the periodic insertion of an attenuating disk in the input wave guide. Consequently the receiver input is alternately transferred from the antenna to a reference termination and then back. The output of the detector following the i-f amplifier is therefore random "noise" that has been amplitude-modulated by the attenuating disk.

When the modulating or reference disk is out of the wave guide, the output of the second detector is determined by the sum of the equivalent input noise of the receiver and the energy being received by the antenna. When the attenuating disk is inserted in the wave guide, the output of the second detector is determined by the sum of the equivalent input noise of the receiver and the energy radiated by the attenuating disk. The resulting modulation is the difference between these two quantities and is equal to the difference between the energy received by the antenna and the energy being radiated by the attenuating disk. Since the energy radiated by the attenuating disk is proportional to its own temperature, the resulting modulation is a measure of the difference between the temperature of the attenuating disk and the equivalent temperature of the energy being received by the antenna. The temperature of the attenuating disk is therefore the reference to which the unknown received energy is compared. By synchronously demodulating the output modulation against the output of a

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reference generator that is driven by the same motor that drives the reference attenuator, a very narrow-band rectification process is obtained. The output of the synchronous demodulator is then fed through a low-pass filter to provide smoothing of the output signal. It can be seen from this discussion that the threshold sensitivity of the receiver is determined primarily by the time constant of the low-pass filter.

Figure 2.4 is a block diagram of the AN/ADR-3, showing the basic circuits employed.

From the standpoint of atmospheric attenuation, antenna size, and antenna-beam width, an operating wavelength of approximately 8.5 cm was selected as the best compromise for this equipment. The 8.5-cm wavelength signal intercepted by the antenna system is transferred to the reference modulator by a wave guide. The reference modulator consists of a slotted-wave-guide section provided with an attenuator which is alternately inserted and withdrawn from the wave guide, thus modulating the incoming signal. This modulated signal is then fed into the converter which consists of a local oscillator with automatic-frequency-control circuits and a mixer. The output of the converter is a modulated 30 Mc/sec i-f signal and is connected to the i-f amplifier and second detector. It is in this i-f amplifier that a considerable portion of the system gain is achieved. The second detector output runs at 30 cps, which is amplified in the 30-cps selective amplifier. (The 30-cps frequency of this voltage was determined by the insertion frequency of the attenuator in the reference modulator.) The synchronous demodulator combines the voltage from the reference generator (which is driven by the same motor that drives the attenuator in the reference modulator) and the voltage from the 30-cps selective amplifier, and it yields a d-c voltage which still contains some a-c component. This unwanted ripple is smoothed out by the low-pass filter. The resulting d-c voltage is then fed to a recorder through a d-c amplifier and also to the deflection circuits of a cathode-ray indicator.

As indicated in Fig. 2.4, antenna controls are provided to permit the operator to sector-scan continuously and to tilt the antenna.

2.4.3 Description

The entire AN/ADR-3 system consists of six separate units: antenna assembly, which includes a portion of the receiving circuits; control console; power supply; cathode-ray-scope indicator; scope camera; and d-c recorder.

Included in the AN/ADR-3 system is an audio monitor amplifier which permits the operator to monitor continuously the input signal and discount any false signals. Such false signals might result from radar interference, communications equipment, or other electrical or electronic equipment.

To avoid the use of rotating microwave connectors, all the high-frequency circuits are mounted directly on the antenna-dish assembly. In this manner all the necessary commutating is done at very low frequencies. To prevent moisture condensation in the wave-guide system and other microwave portions of the circuit which is due to altitude, humidity, and temperature variations, the wave-guide assembly and other critical microwave circuits are pressurized. Inasmuch as the accuracy of the measurements depends a great deal on the knowledge of the reference-modulator temperature, localized temperature control of the reference modulator is provided. The local-oscillator tube is relatively frequency-sensitive to temperature variations, and, since optimum radiometer response is critical to r-f impedance variations, it was deemed desirable to incorporate automatic frequency control in order to maintain the local-oscillator frequency within a small range around the frequency for which the r-f components are best matched.

In addition to continuous 360° azimuth scanning, two types of antenna sector scanning are employed, manual and automatic. The manual control serves to position the antenna in azimuth and to make selective observations of any section of the cloud if desired. The automatic scan provides a variable scan rate and variable sector-scan width around any selected target bearing. The variable scan rate must, of necessity, be interlocked with the variable low-pass filter. The reason for this is as follows: If an antenna beam of a receiver is swept past a signal source, the receiver output signal may be smaller (depending on the circuit parame-

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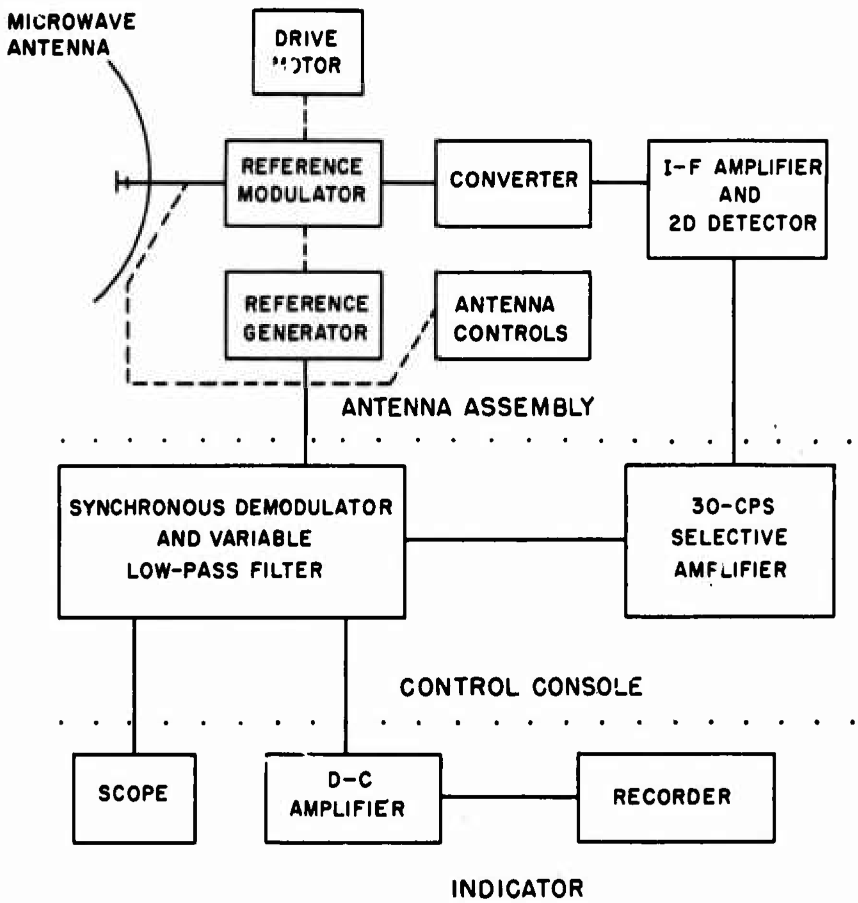

Fig. 2.4 Diagram of Radioactive-cloud Detector and Tracker AN/ADR-3

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ters) than that which would be obtained if the antenna was swept past the signal source more slowly. This diminution of the signal is termed the "scanning loss." Since there is a very definite relation existing between the charging time and the output voltage of the low-pass filter under scanning conditions, it is necessary to interlock the variable low-pass-filter time constant and the variable scan-rate control to prevent excessive scanning loss. Because the magnitude of the signal expected from the radioactive cloud cannot be accurately predicted, a choice of several scan speeds has been provided.

The control console incorporates all controls necessary to operate the equipment, including the scope camera. Meters and switches for monitoring various circuits of the entire equipment are also provided in the control console.

TABLE 2.3 DATA FOR AN/ADR-3 EQUIPMENT

Physical Data

Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Antenna assembly	55	38	30	30
Control console	20	11 1/8	12 3/8	23 3/8
Power supply	30	11 1/8	12 3/8	23 3/8
Scope	10	14 1/4*		7
Scope camera	15	14 1/2	10	24
Recorder	30	14 1/2	8 5/8	9 1/2
Total	160			

Miscellaneous Data

Operating signal wavelength (cm)	8.5
Antenna beam width (°)	~6
Type of scan	Continuous 360°; automatic variable sector; manual
Antenna tilt (°)	±30
Total power requirement	~700 va, 400 cps
Type of presentation	Azimuth scope and paper-ink recorder

* Length.

The AN/ADR-3 includes provisions for the use of two scope indicators. Each scope has individual intensity controls.

The recorder used is a standard Esterline-Angus type of ink recorder, equipped with suitable shock mounts.

The receiving circuits mounted on the antenna assembly are so designed and constructed that maintenance and repair work can be accomplished by removing and replacing subassemblies such as the reference modulator and i-f amplifier.

Data pertaining to AN/ADR-3 equipment are presented in Table 2.3.

2.5 TYPE D-1 RADIOACTIVE-CLOUD DETECTOR AND TRACKER

2.5.1 Purpose

As in the case of the Navy developed AN/ADR-3, the purpose of this Air Force developed equipment is to indicate the presence and direction of a radioactive cloud for avoidance purposes. Although the intended goal of these two types of equipment is similar, the techniques employed in obtaining the results are entirely different.

2.5.2 Principle of Operation

This equipment provides two salient features for the indication of the presence and direction of gamma radioactivity. The first feature is an early warning system which produces single-sweep lines on a polar-coordinate oscilloscope screen for each detected gamma ray. The angular position of the sweep trace on the scope is correlated with the position of a slit opening in the rotating lead shield through which the rays pass to a scintillation crystal. Cosmic rays penetrating the lead shield will produce randomly oriented traces; however, small levels of gamma radiation emanating from a radioactive cloud may be detected and the source direction determined by noting the angular direction in which the sweep traces appear most frequently. It is realized that multiple scattering of the gamma rays in the air between the detector and the radioactive cloud will tend to diffuse the radiation and thus decrease the directivity; however, it is felt that

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enough directivity will still exist to make the equipment useful. As the equipment moves closer to the source of radiation, more radial sweep traces are noted on the oscilloscope screen, the direction of the source of radioactivity still being indicated by a preponderance of pulses on the screen in a fixed direction. As the radiation intensity approaches a level of approximately 10 mr/hr, the scope screen becomes filled with traces of the radial sweeps which produce a brightly lighted section on the scope. At the 10 mr/hr level the second feature of this system begins to function. A darkened lobe is a polar-coordinate graph of the radiation field and its intensity. A logarithmic intensity scale on the scope provides reference lines for comparing the relative intensities being received from different directions. As the intensity of the radiation increases, the magnitude of the darkened lobe increases, and the direction of maximum intensity shifts as the direction of the radioactivity source changes with respect to the position of the detector head.

As can be seen from Fig. 2.5, a scintillation counter is employed as the basic detector of radioactivity. Two selected 1P21 photomultiplier tubes simultaneously pick up the gamma-ray scintillations in a stilbene phosphor crystal. A quartz light "pipe" is employed to transmit the light emerging from the phosphor (located in the center of the lead shield) to the photomultiplier tube which is located in a lead-shielded housing below the rotating lead-shielding head. The outputs of each photomultiplier are fed into two individual amplifiers. These two amplifiers are located in a single housing at the side of the head unit.

To distinguish true radiation counts from noise pulses inherent in photomultipliers, a two-channel coincidence amplifier is employed. Basically, this coincidence amplifier consists of a duogrid vacuum tube that is normally biased beyond cutoff. These two grids are separately actuated by the outputs of the two photomultiplier-tube amplifiers. Only when the two grids of this tube are lifted simultaneously from below the plate-current cutoff value can there be an output pulse from this coincidence tube. Phosphor pulses detected by the photomultipliers coincide to give an output, whereas the coincidence of two randomly spaced noise pulses in the photomultipliers has a very low probability of occurrence, and hence the noise pulses are discriminated against.

The pulse output of the coincidence amplifier is connected to the computer unit, where each scintillation pulse is made to trigger the radial oscilloscope sweep and produce an intensified sweep trace. The darkening lobe and logarithmic intensity indications have their origins in one of the two photomultiplier tubes. By the use of a logarithmic diode placed in the photomultiplier-tube circuit, a voltage proportional to the logarithm of the radiation intensity is obtained. After this voltage passes through a suitable a-c amplifier (see Fig. 2.5), a voltage is obtained which decreases as the radiation intensity increases. This voltage is then applied to the scope-sweep circuits in such a manner as to cause a blanking of a portion of the radial intensified sweeps. This blanking action extends from the center of the scope screen to a point corresponding to the radiation level at the detector and is at a particular angular direction.

To obtain the necessary high voltages to operate the cathode-ray-oscilloscope indicator, a conventional tuned-plate tuned-grid type of r-f oscillator is employed. The regulated high voltage necessary for proper operation of the photomultiplier tubes is obtained by a high-gain degenerative amplifier which controls the screen of the r-f oscillator tube.

2.5.3 Description

Physically, the D-1 radioactive-cloud tracker consists of four units: the detector head, the computer, the indicator, and the power supply.

Data pertaining to this equipment are presented in Table 2.4.

2.6 AN/ADR-4 AIR-BORNE SURFACE-GAMMA-RADIATION SURVEY EQUIPMENT

2.6.1 Purpose

The purpose of this equipment is to obtain, in flight, enough information to make a surface-radioactivity contour map indicating the gamma-radiation intensities that would be encountered by a man walking over the area.

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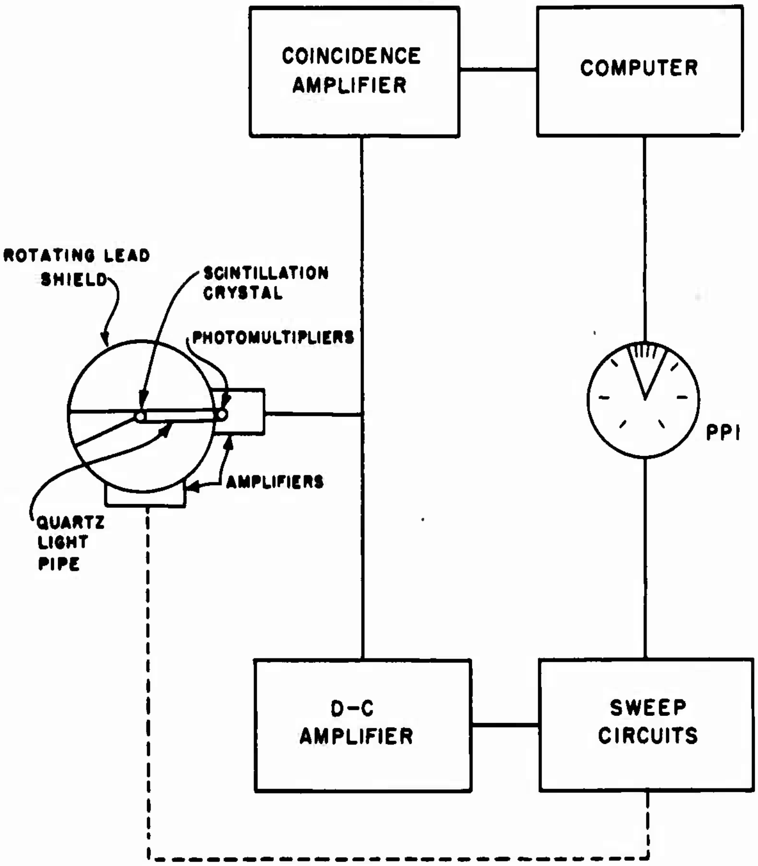

Fig. 2.5 Diagram of Type D-1 Radioactive-cloud Detector and Tracker

TABLE 2.4 DATA FOR TYPE D-1 RADIOACTIVE-CLOUD TRACKER*

	Physical Data			
Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Detector head†	150 or 300	16	16	18
Computer	25	22	10	10
Indicator	10	12	6	12
Power supply	25	22	10	10
Power Requirements				
115 volts, a.c.; 400 cps	200 va			
28 volts, d.c.	300 watts			

*Type of presentation, PPI.

†The unit weighing 300 lb has greater directivity than the 150-lb unit. The detector heads in both units are mechanically interchangeable.

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The radioactivity contour maps so obtained are to be used to determine the extent of the radioactivity and the best routes of entry to or exit from contaminated areas.

2.6.2 Principle of Operation

Basically, the general type of equipment necessary to accomplish the purpose outlined in Sec. 2.6.1 is a directional gamma-radiation detector with appropriate computers for converting intensity readings taken at any altitude to values that would actually be measured on the surface. After careful consideration of pertinent factors such as possible military operating conditions, sensitivity requirements, serviceability, and ease of maintenance and operation, a directive ionization-chamber system was designed and constructed. The directivity of the detecting and measuring unit was chosen as 30°; thus, when flying at an altitude of 500 ft, the directive detector "looks" at and measures the average intensity over an area approximately 300 by 300 ft. By continuously measuring and recording the radiations of this area as the aircraft proceeds, a strip 300 ft wide (when flying at an altitude of 500 ft) is surveyed. To reduce to a minimum the number of passes over the contaminated area, three such detecting elements and their associated circuitry are employed. This enables the surveyor to cover a strip approximately 900 ft wide in a single pass at a 500-ft altitude.

Because of the scattering of the gamma rays in the air, it becomes more and more difficult to determine their point of origin as the distance becomes greater. Up to approximately 2000 ft a fairly good estimate can be made of the total amount of radiation coming from a given source on the ground. However, as the height increases, the sources of radiation, as seen from the air, become more and more diffused until, ultimately, the scattering becomes so great that very little directivity, if any at all, can be obtained. For this reason, all flights should be confined to below approximately 2000 ft, if reasonably accurate results are desired. However, if only rough estimates are required, altitudes in excess of 2000 ft may be used.

In general, two types of corrections must be applied to the intensity readings obtained with the directional detector in the aircraft in order to convert them to ground readings. The first correction is for distance from the source. In considering this correction it must be borne in mind that an extended source and not a point source is being dealt with. The second correction concerns the actual attenuation of the gamma rays in the air between the aircraft and the sources on the ground. In determining and applying this latter correction, the energy level of the radiation is considered. The techniques and methods employed in making these corrections are outlined in the following discussion.

In Fig. 2.6 a simplified block diagram of the complete AN/ADR-4 equipment is given.

In order to make the ionization-chamber detector directive, the normally expected procedure would be to enclose it in a long lead tube, in order to cut out radiation from all directions other than that desired. This is impractical in this case because the amount of lead required to shield the chamber properly would weigh much more than can be profitably carried in an aircraft. Instead, two ionization chambers are used for each channel; one of the chambers looks at the entire landscape, and the other looks at all the landscape with the exception of the 30° portion in question. When the outputs of the two chambers are subtracted, the resultant is the output from the desired 30° area. As can be seen from Fig. 2.6, the shadowed chamber requires a relatively small amount of lead. The output of this chamber is fed into the differential d-c amplifier as is the output of the associated unobstructed chamber. The differential d-c amplifier output, which is actually the difference between these two chambers, is fed into the computer unit. As indicated in Fig. 2.6, three such differential d-c amplifiers and associated shielded and unshielded chambers are used, each covering 30° and so arranged that a total angle of 90° is obtained. This entire assembly is referred to as the "directional unit."

Included in the computer unit is a logarithmic counter which takes the voltage from the differential d-c amplifiers and produces voltage pulses which are separated in time by an amount proportional to the logarithm of the input voltage. These logarithmically spaced voltage pulses are then fed into a conventional facsimile recorder which translates these spaced pulses into a line on electrolytic paper. Thus the distance from the left edge of the recording paper to the recorded line is pro-

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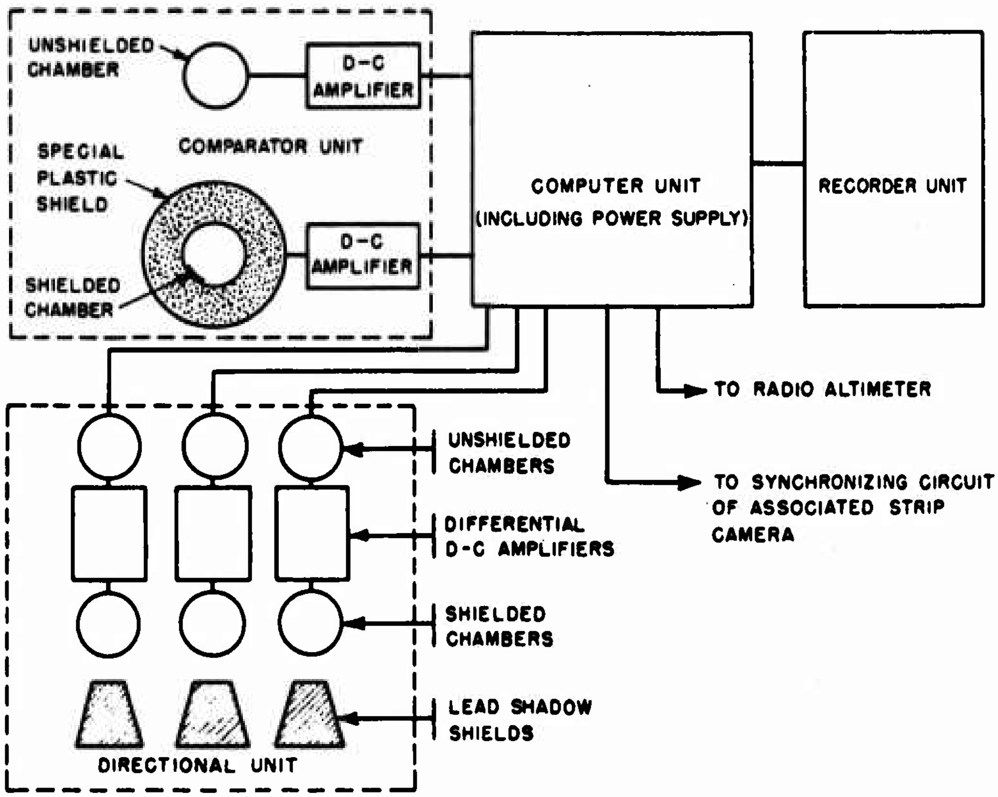

Fig. 2.6 Diagram of Air-borne Surface-radioactivity Monitor AN/ADR-4

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portional to the logarithm of the radiation intensity in the desired 30° field of view.

It is in the logarithmic counter that the correction for altitude is made. This is done by merely introducing a bias-voltage change in the counter circuit. This bias-voltage change can be made manually at a central location on the front panel of the computer unit, or it can be done automatically by utilizing the output voltage of a normal radio altimeter.

To accommodate the three directional detector systems, three such logarithmic counters and recorder channels are used.

In determining the attenuation factor to be applied, two nondirective ionization chambers are used as shown in Fig. 2.6. One of these chambers is entirely unshielded, whereas the other is completely enclosed in a spherical plastic shield. The composition of this plastic shield is such that it reduces the intensity at the chamber in its center to an amount which is the same as if the chamber had passed through an additional 500 ft of air. The outputs of both the plastic-shielded chamber and the unshielded chamber are connected to individual d-c amplifiers. The d-c output voltages of these amplifiers are fed into the computer unit, where they are introduced into a logarithmic counter, the output of which is a logarithmic function of the ratio of the two chamber outputs. This counter output is the attenuation coefficient and is in the form of spaced pulses which are recorded by the facsimile recorder in the same manner as were the three directional channels. In this case, however, the distance from the recorded attenuation-coefficient curve to the right edge of the recorder paper represents the logarithm of the attenuation correction.

To determine the radiation intensity on the ground at any given time for a particular channel, it is merely necessary to determine the number whose logarithm is the sum of the logarithmic intensity curve and the logarithmic attenuation-correction curve.

The AN/ADR-4 can be used in conjunction with a type S-7 strip camera which photographs the ground areas that emanate the recorded radiation. To coordinate the photographic data and radiation data, provisions have been made to place a marker on the facsimile-recorder paper by voltage pulses which are normally furnished by the strip-camera film-counter circuits. In addition to the S-7 camera, an odograph, which plots ground position at all times, is used. Thus additional correlation between ground radiation and position is obtained.

2.6.3 Description

As indicated in Fig. 2.6, the shadow shielding of the three chambers in the directional unit is accomplished by placing a mass of lead in front of each one. However, rather than employing three separate slabs of lead shielding, one piece is used for all three shielded chambers. This single shadow shield is so shaped and spaced with respect to all three shielded chambers that each has a shadow zone of 30°, the same as would be obtained with three individual shields.

Eight ionization chambers are used in the AN/ADR-4. Each chamber contains argon gas under a pressure of 50 atm. By employing such high-pressure ionization chambers it is possible to obtain high sensitivities and at the same time small size.

A computer unit contains all the controls to operate this equipment. Push-button switches are provided in this unit to test each of the three directional channels as well as the comparator unit. When these test buttons are used, appropriate readings appear on the recorder paper as well as on the meter located on the computer-unit print panel.

The recorder is essentially a conventional facsimile recorder with a few minor modifications. Time markers are placed automatically on the recorder paper.

Data pertaining to the AN/ADR-4 are found in Table 2.5.

2.7 TYPE F-1 AIR-BORNE SURFACE-RADIATION SURVEY EQUIPMENT

2.7.1 Purpose

Although considerably different techniques are employed, the general purpose of this equipment as developed by the Air Force and of the Navy developed AN/ADR-4 is the same. While in flight, they both measure, in roentgens per hour, the intensity of the gamma radiation existing over a radioactively contaminated surface area.

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2.7.2 Principle of Operation

This equipment instantaneously surveys a rectangular area of ground surface which subtends an angle of 70° in a direction perpendicular to the path of flight and an angle of 12° in a direction along the path of flight. The width is divided into three sections, each of which has its radiation measured in the aircraft, and, through an altitude correction, this radiation-intensity value is used to compute the equivalent ground-radiation intensity. The instantaneous intensity for each section of ground surface can be read visually on a meter and is also continuously recorded on a paper-strip recorder. To correlate the recorded intensity with the area in which it was measured, a photograph of the area surveyed is simultaneously made with a type S-11 strip camera. The paper tape and the photographic film are synchronized to travel at the same speed. The film and recording can then be superimposed and viewed together for exact correlation.

As can be seen from Fig. 2.7, this equipment consists of three individual channels, one for each of the three directional detection systems. Since the three channels are identical, only one is discussed here. Gamma radiation from a rectangular area of ground enters the pyramidal directional shield of the directional head and produces scintillations in a calcium fluoride crystal. These scintillations are observed by two photomultiplier tubes, and the resulting voltage pulses are fed to the detector-integrator unit. This detector-integrator unit consists of several stages of amplification to raise the scintillation-voltage pulses to approximately 20 volts. These pulses are applied to a pulse-height discriminator stage where only pulses of over 20-volt peak amplitude will produce an output pulse. After some amplification these pulses, two from each scintillation crystal detector, are applied to a coincidence circuit which has an output pulse only when two input pulses occur simultaneously. These coincidence pulses trigger a monostable multivibrator which produces uniform output pulses of 15-μsec duration and 100-volt amplitude for each input pulse. These uniform pulses are integrated to give a direct voltage proportional to the rate at which these pulses occur.

TABLE 2.5 DATA FOR AN/ADR-4 EQUIPMENT

Physical Data

Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Directional	40	20	20	40
Computer	70	20	21	12
Recorder	40	30	20	12
Lead shadow shield	170	12	8	6
Comparator	50	20	20	12

Miscellaneous Data

Total power requirement	500 va 400 cps Single phase
Recorded gamma-radiation intensity (radiation intensity on ground)	~0.5–500 r/hr
Directivity	3 channels; each channel 30°, arranged to give total angle of 90°

This direct voltage is then applied to an exponentially tapered potentiometer in the computer unit. The slider of this potentiometer is positioned by a servomotor so that the angular position is a linear function of the altitude of the aircraft. This is accomplished by establishing equality between the output voltage of an AN/APN-1 radio altimeter and a standard voltage obtained from an electronic standard cell.

The output from the potentiometer is applied to a direct-voltage amplifier which drives a modulator stage. This modulator circuit is part of the computer unit shown in Fig. 2.7. The modulator varies the output of a 25-cps oscillator so that the peak amplitude is proportional to the modulator input voltage. The output is then a 25-cps carrier with the peak amplitude proportional to the actual ground intensity.

This modulated signal is fed to the indicating voltmeters on the control panel and to the recording pen on the recorder unit. As indicated in Fig. 2.7, three such recorder pens are used, one for each channel. The recording pens vibrate with a sinusoidal motion at 25 cps, the peak amplitudes of which are proportional to

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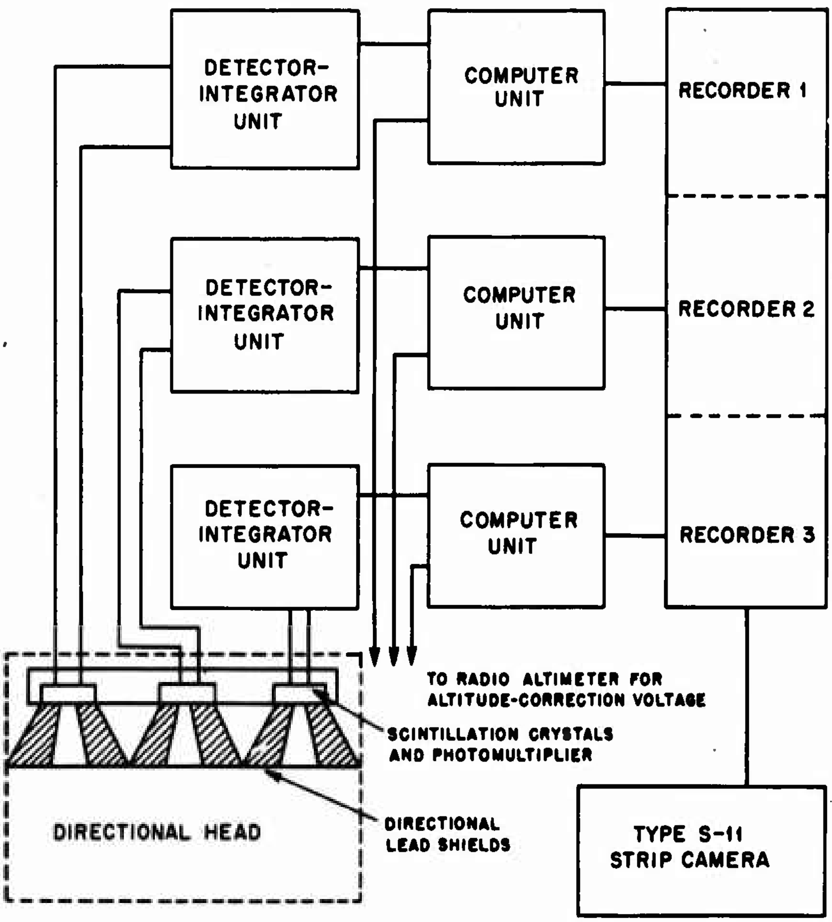

Fig. 2.7 Diagram of Type F-1 Air-borne Surface-radiation Survey Equipment

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the ground intensities. These recorded indications are then calibrated in roentgens per hour. As shown in Fig. 2.7, the recording unit is supplied by the camera with a voltage which is proportional to the film speed. This voltage is used to synchronize the paper-drive mechanism so that the film and paper speeds are the same.

The camera used is a shutterless standard S-11 type, slightly modified to operate with this equipment. A lens with a 6-in. focal length is used. With this lens the S-11 camera photographs the same strip of ground surveyed by the surface-radiation survey equipment.

The AN/APN-1 radio altimeter is used to supply an altitude-proportional voltage which controls the servosystem driving the potentiometers in the computer unit.

2.7.3 Description

This equipment consists of six units and a complete S-11 camera assembly. These units include a directional head, an amplifier-integrator, a computer, the power-supply unit, the control unit, and a recorder unit. The amplifiers, integrators, computers, and power supply are all placed in a single rack.

Data pertaining to this equipment are found in Table 2.6.

TABLE 2.6 DATA FOR AIR-BORNE SURFACE-RADIATION SURVEY EQUIPMENT

Physical Data

Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Directional head	500	16	25	13
Amplifier-integrator	30	10	20	19
Computer	30	12	20	19
Power supply	60	10	20	19
Control	20	11	20	14
Recorder	60	8	23	22

Miscellaneous Data

Power requirements	
115 volts, a.c.; 400 cps	700 va
28 volts, d.c.	100 watts
Gamma-intensity range (radiation intensity on ground)	~0.5–500 r/hr
Directivity	70 by 12°, divided into 3 equal sections

2.8 AN/USQ-1 AND AN/ARR-29 GAMMA-RADIATION-DATA TELEMETERING SYSTEM

2.8.1 Purpose

The purpose of this system is to provide a means of measuring, by remote control, gamma radiation present in locations inaccessible because of geographic, military, or radiological safety reasons. It is also necessary to be able to determine the relation between radiation intensity in various areas and time so as to make it possible to plan in advance military operations such as amphibious landings and entrance into highly contaminated areas.

There are several very important conditions these machines must fulfill. They must be designed so that they can be dropped from high-speed aircraft anywhere on water or land. After dropping, they must continue to work for at least 48 hr. It must be possible to locate these machines, after dropping, using the standard aircraft radar equipment in conjunction with the AN/ARR-29 receiver, and it must be possible to monitor these units by remote control from the aircraft. If all the foregoing conditions are met, it should be possible to detect, measure, and telemeter the gamma radiation over an intensity range 0.4 to 400 r/hr. The surface-to-air telemetering range should be about 20 miles.

2.8.2 Principle of Operation

Owing to the necessity for placing these remote units accurately and also because of the difficulties arising from the possibility of the spent parachute fouling the antenna structure, the design of the AN/USQ-1 remote units, rather than depending on a parachute, was based on the use of small air brakes, which are jettisoned upon landing. To protect the electronic equipment from damage caused by the shock of landing on a hard surface without a parachute, the entire electronic assembly was specially constructed and encased in plastic.

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(The acceleration experienced by the unit upon landing on concrete is approximately 2500 *g*.) The construction and encasing techniques used were similar to those employed with the proximity fuse. Another method used to help the unit absorb some of the shock upon landing was to attach a nose made of cellular cellulose acetate to the front of the unit. On striking the surface, the nose crushes in an approximately exponential manner and is automatically removed.

The complete system consists of the expendable AN/USQ-1 unit, which is ejected from the aircraft, and an AN/ARR-29 receiver-recorder unit, which remains in the aircraft.

As can be seen in Fig. 2.8, the AN/USQ-1 is basically an f-m vhf transmitter and a microwave beacon receiver.

The oscillator generates a voltage at approximately 20 Mc. After passing through several stages of frequency multiplication, it is applied to a power amplifier operating at approximately 160 Mc. (Actually, each AN/USQ-1 is fixed-tuned to one of five frequencies, namely, 162, 164, 166, 168, and 170 Mc/sec.) From the r-f power amplifier the signal is fed to a quarter-wave whip antenna.

As indicated by Fig. 2.8, this vhf transmitter can be modulated by either the beacon channel or the gamma-data channel.

The gamma-data channel consists merely of an ionization chamber and its associated d-c amplifier. The d-c voltage out of the gamma-data channel is proportional to the gamma radiation incident on the AN/USQ-1 unit.

The beacon channel consists of a small microwave antenna, capable of receiving radar signals in the 8.5- to 3-cm wavelength region, a crystal detector, and a pulse amplifier to amplify the detected radar pulses. For every radar pulse impressed on the antenna, a voltage pulse of sufficient magnitude to frequency-modulate the transmitter is procured across the output terminals of the beacon channel.

It is thus seen that the transmitter can be frequency-modulated by either the gamma-data channel or the beacon channel, depending on which of the two channels is connected to the reactance modulator by switch S.

To conserve battery power, each AN/USQ-1 is turned on automatically by a clock mechanism for only 5 min out of every hour over a period of 48 hr. This 5-min interval of operation is, in turn, divided into four alternate periods of beacon operation and gamma-data operation. During the periods of beacon operation the ionization chamber in the gamma-data channel is shorted out. The circuit constants are so selected that, when an AN/USQ-1 unit is subjected to a gamma-radiation intensity of 500 r/hr, the frequency of the transmitter is caused to deviate or shift 500 kc/sec. For example, when the unit is not subjected to any gamma radiation (or when the ionization chamber is shorted out during beacon operation), the frequency will be one of the preset frequencies, for example, 162 Mc/sec. If the unit is in a field of 500 r/hr, at the instant the automatic clock mechanism in the unit switches to gamma-data operation the frequency will immediately change to 162.5 Mc/sec. If the gamma-radiation field is only 250 r/hr, the frequency will change to 162.25 Mc/sec. If no gamma-radiation field is present, the frequencies will remain at 162 Mc/sec. These changes or deviations in frequency, when received by the the air-borne AN/ARR-29 receiving and recording equipment, are converted back to a direct current. They are then fed into a recorder calibrated in terms of roentgens per hour (gamma-radiation intensity) being experienced by the remote AN/USQ-1 units. It can be seen that it may be possible for the frequency of the transmitter to change because of reasons other than the presence of gamma radiation. To eliminate this source of error, the AN/ARR-29 is designed and constructed so that it is possible to zero-beat the received frequency during the beacon-operation part of the cycle (when the ionization chamber is shorted out). In this manner any change in frequency detected by the AN/ARR-29 when the remote unit is switched to gamma-data operation can be considered as having been caused by incident gamma radiation.

As for the beacon operation, the interrogating radar pulse received by the microwave receiving antenna is rectified, amplified, and retransmitted via an f-m vhf signal to the AN/ARR-29 receiver. This receiver is interconnected with the aircraft radar that originally interrogated the remote unit. This interconnection is made in such a manner that the returning pulse received via vhf is impressed on the radar scope,

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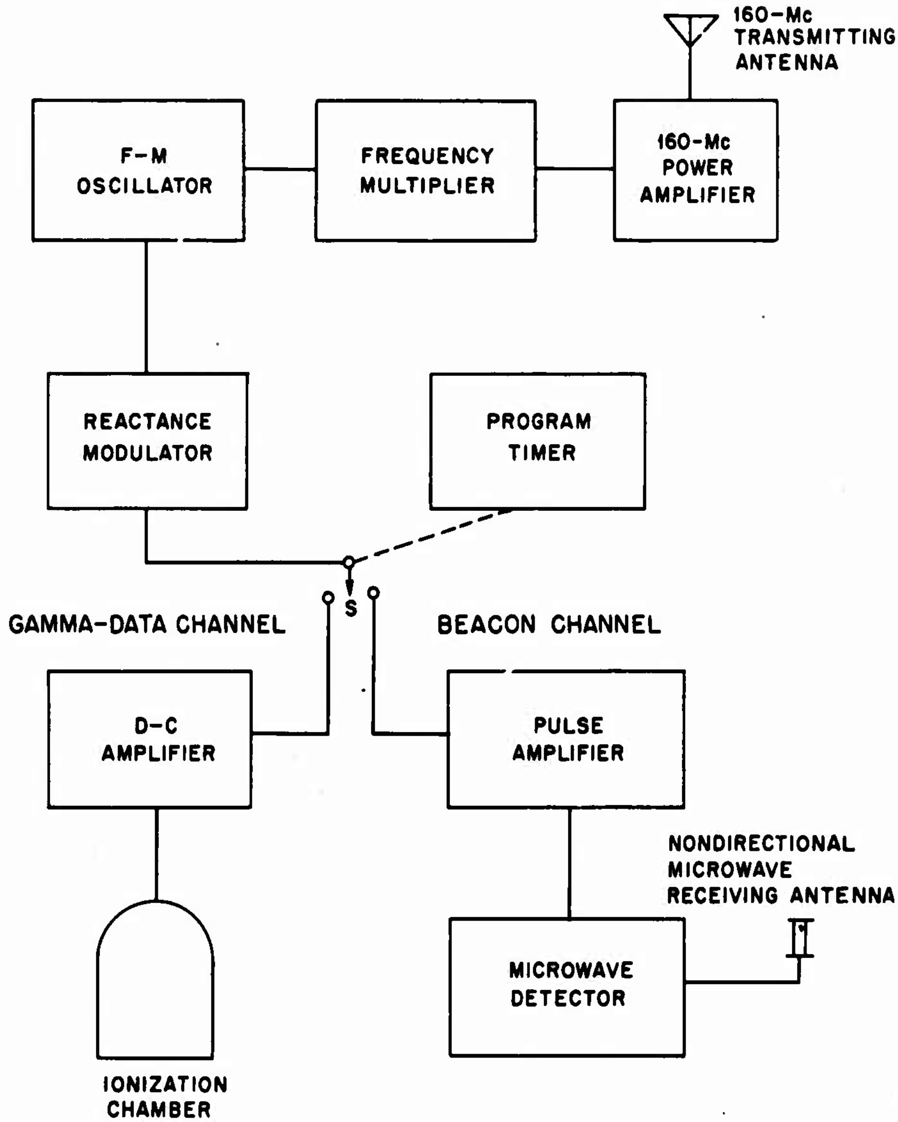

Fig. 2.8 Diagram of Transmitter Unit AN/USQ-1 of Gamma-radiation-data Telemetering System

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thus locating the remote unit. In so far as the radar indicating scope is concerned, the presentation will be normal in spite of the fact that the radar pulse is returned via vhf radio rather than via the microwave path.

As can be seen from Fig. 2.9, the AN/ARR-29 receiving and recording equipment is basically a conventional f-m receiver equipped with an Esterline-Angus ink recorder. The receiver incorporates push-button tuning for five channels. Each channel is provided with a fine tuning control which is used in conjunction with a tuning meter to tune in accurately the incoming frequency during the periods that the remote units are on beacon operation. As discussed previously, this procedure affords a method of zeroing the remote units.

The channel push buttons and associated circuits have been so designed and constructed that, on depressing a button, not only does the channel change but indications are made on the right edge of the recorder paper indicating which channel is being recorded.

Timing markers appear on the left edge of the recorder paper. These are to be used to determine the necessary relation between radiation intensity and time.

The output circuit of the pulse amplifier (Fig. 2.9) is so designed that it can be plugged into any low-impedance radar video circuit normally available, such as i-f circuits and radar bombing circuits.

2.8.3 Description

To ensure optimum operation of the AN/USQ-1 units, it is necessary that the antenna structure, which consists of the vhf whip type transmitting antenna with the microwave receiving antenna mounted on top, always be in a vertical position. This is accomplished by the use of orienting springs and sensing switches in such a manner that, regardless of the position of the unit itself, the antenna is in a vertical position. Figure 2.10 is a photograph of an AN/USQ-1 after landing.

On the top deck of the AN/USQ-1 unit a knob is located which is used to set the automatic clock mechanism discussed previously. A calibrated time scale is visible through a small window near the adjusting knob. By the use of this clock-mechanism adjustment it is possible to preset the unit as far as 48 hr in advance of the drop. This is the starting time of the 5-min-every-hour operating cycle previously discussed.

The case of the AN/USQ-1 has two separate watertight compartments, one for the timer and encased electronic assemblies and the other for the battery pack. All the necessary batteries to operate the unit are contained in one battery pack which is inserted before the nose is attached.

The AN/USQ-1 will operate for approximately 48 hr after landing on land or water. Data pertaining to this unit are presented in Table 2.7.

TABLE 2.7 DATA FOR AN/USQ-1 EQUIPMENT*

Physical data	
Length (in.)	~40
Diameter (in.)	$4\frac{7}{8}$
Weight (lb)	~14
Transmitting frequency,† (Mc/sec)	
Type A	162
Type B	164
Type C	166
Type D	168
Type E	170
Beacon receiving frequency (cm)	8.5; 3
Maximum recommended launching speed (knots)	200
Range (r/hr)	0.5–500‡
Low-range unit	0.5–17
High-range unit	13–500

*Gamma-radiation monitoring.
†Each AN/USQ-1 unit is preset at the factory.
‡In two ranges.

Figure 2.11 is a photograph of the AN/ARR-29 receiver that is installed in the aircraft. The recorder used is a standard Esterline-Angus Model AW. Data for the AN/ARR-29 equipment are found in Table 2.8.

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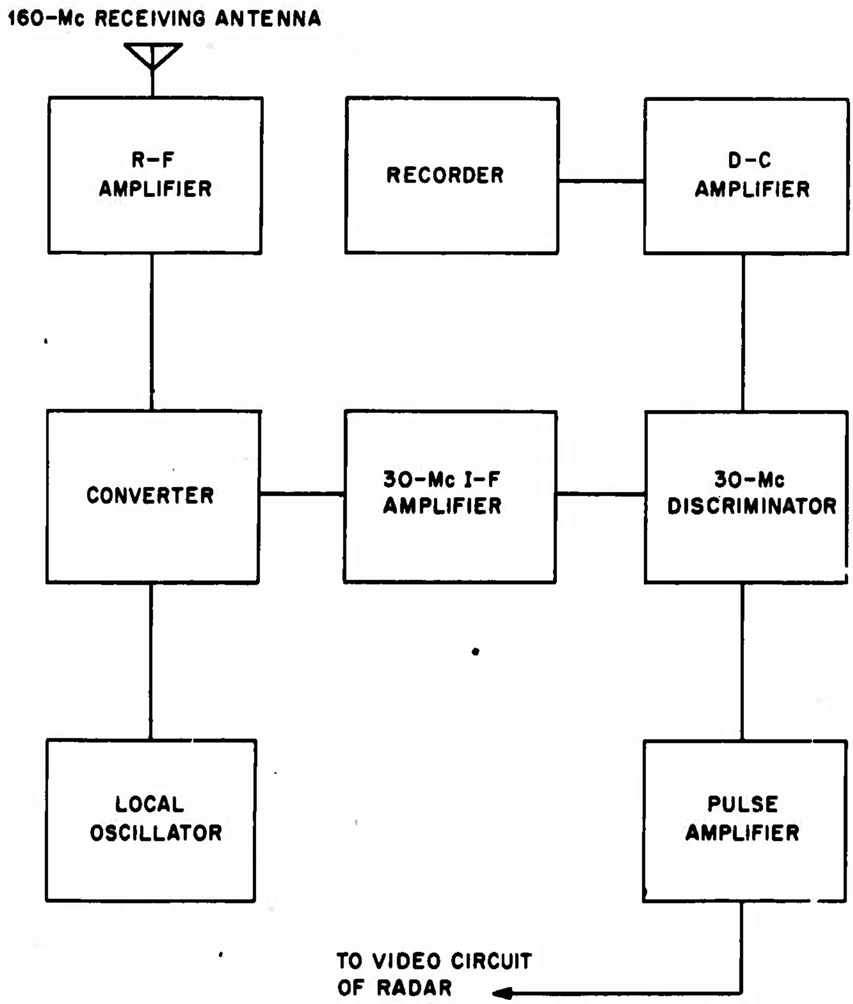

Fig. 2.9 Diagram of Receiver Unit AN/ARR-29 of Gamma-radiation-data Telemetering System

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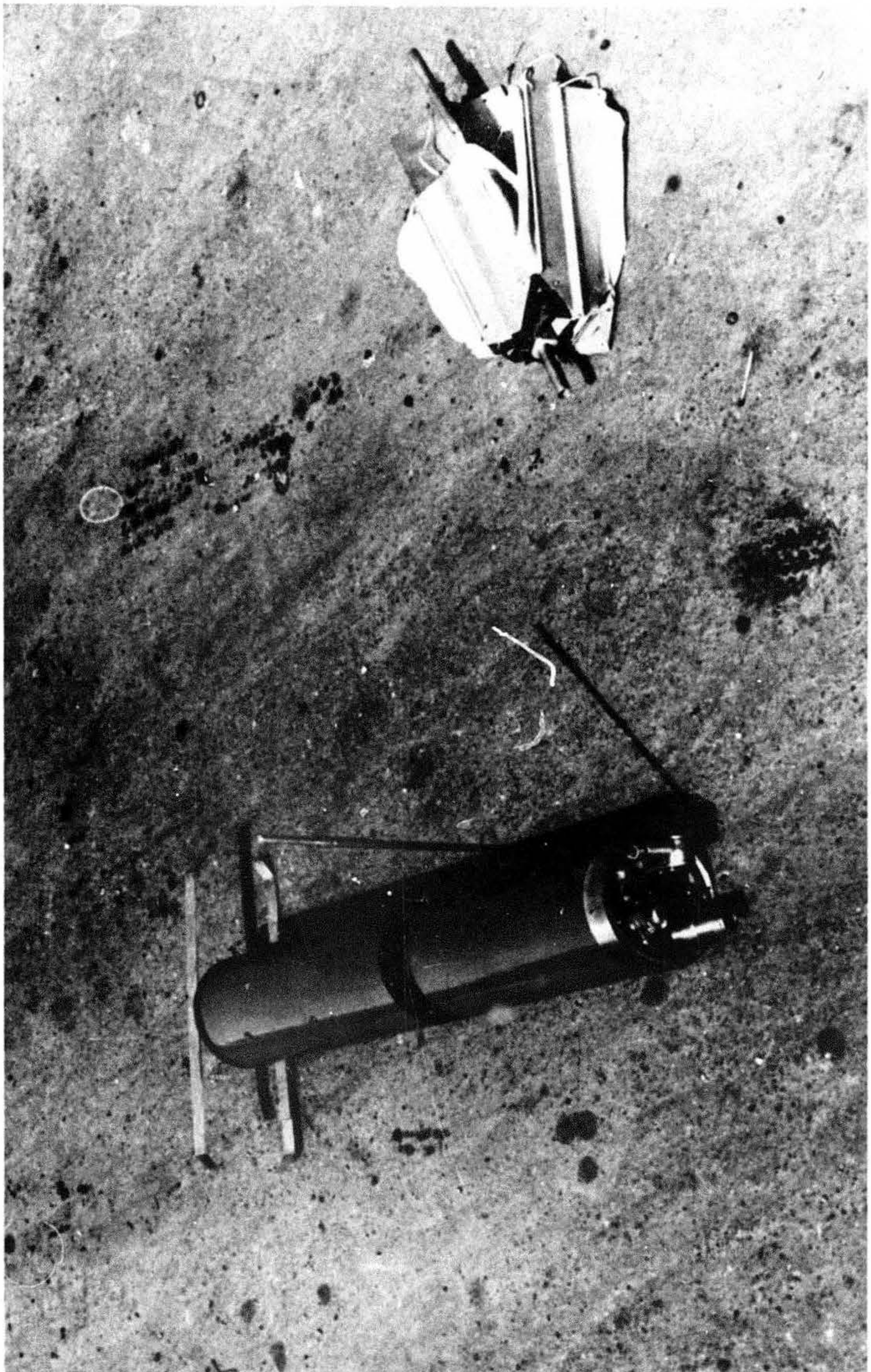

Fig. 2.10 Radiation-data Transmitter AN/USQ-1

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Fig. 2.11 Receiver Unit AN/ARR-29 of Gamma-radiation-data Telemetering System

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TABLE 2.8 DATA FOR AN/ARR-29 EQUIPMENT

Physical data	
Receiver	
Weight (lb)	25
Length (in.)	$21\frac{1}{4}$
Width (in.)	10
Height (in.)	$7\frac{5}{8}$
Recorder	
Weight (lb)	30
Length (in.)	10
Width (in.)	$9\frac{1}{2}$
Height (in.)	13
Receiver power requirement*	100 va; 320–1760 cps; single phase
Radar video pulse-output impedance (ohms)	~2000
Receiver frequency band (Mc/sec)	160–172

*The recorder requires no power.

2.9 TYPE E-1 AIR-BORNE AIR BETA MONITOR

2.9.1 Purpose

The type E-1 air-borne cabin-air monitor is an alarm device used to indicate an unsafe condition in the cabin of an aircraft caused by the presence of radioactive particles.

The type E-1 monitor is designed so that it responds only to the presence of radioactive particles suspended in the air being tested and will not respond to strong gamma radiations from sources outside the aircraft. It gives an alarm when the concentration of radioactive material in the air reaches a level which would present an inhalation hazard to personnel in the aircraft.

2.9.2 Principle of Operation

Indication of air contamination is given by lights. A green light glows steadily when the equipment is operating properly and the concentration of radioactive material is below the danger level. Dangerous conditions are indicated by the alternate flashing of the green light and a red light. The length of the red flash increases as the contamination increases.

The air-sampling assembly consists of a constant-displacement pump, a filtering device (sniffer), a detector unit, and a preamplifier unit. A recorder, installed for test purposes only, is also housed in the air-sampling assembly. The amplifier assembly consists of two linear and two nonlinear amplifiers and their associated power supply. The indicator assembly consists of a power supply, discriminator, scaler, comparator circuits, rate meter, alarm circuit, and red and green indicating lights. A block diagram of this equipment is shown in Fig. 2.12.

In operation, air is drawn in at a constant rate and passed through a filter tape which is moving past the air-pump orifice. Radioactive particles collected on the filter tape are transported to the detector unit which consists of two cadmium sulfide crystal conduction detectors separated by a strip of aluminum. The detector nearest the tape responds both to beta radiation from radioactive particles on the tape and to the ambient gamma radiation. The second detector responds only to the ambient gamma radiation since the aluminum strip is of sufficient thickness to stop beta radiations. The outputs from the two detectors are amplified separately by two channels of the preamplifier unit and are then passed on to the amplifier assembly.

The amplifier assembly also has two channels. The signal first enters a two-stage linear amplifier which raises the pulse-amplitude level in order to obtain optimum performance during the operation time of the nonlinear amplifiers which follow. These amplifiers are biased beyond cutoff and greatly increase the effective signal-to-noise ratio by having extremely high gain at amplitudes above a critical value (slightly above the noise level) but very low gain for all amplitudes under that value. A final amplifier stage and a cathode follower in each channel then transmit the signals on to the indicator assembly.

The function of the indicator assembly is to process the information received from both channels, reject that caused by gamma activity alone, and indicate, by a flashing red light on the front panel, whenever the beta level on the tape is above a value corresponding to maximum safe air contamination. This function is accomplished by feeding the signals from the

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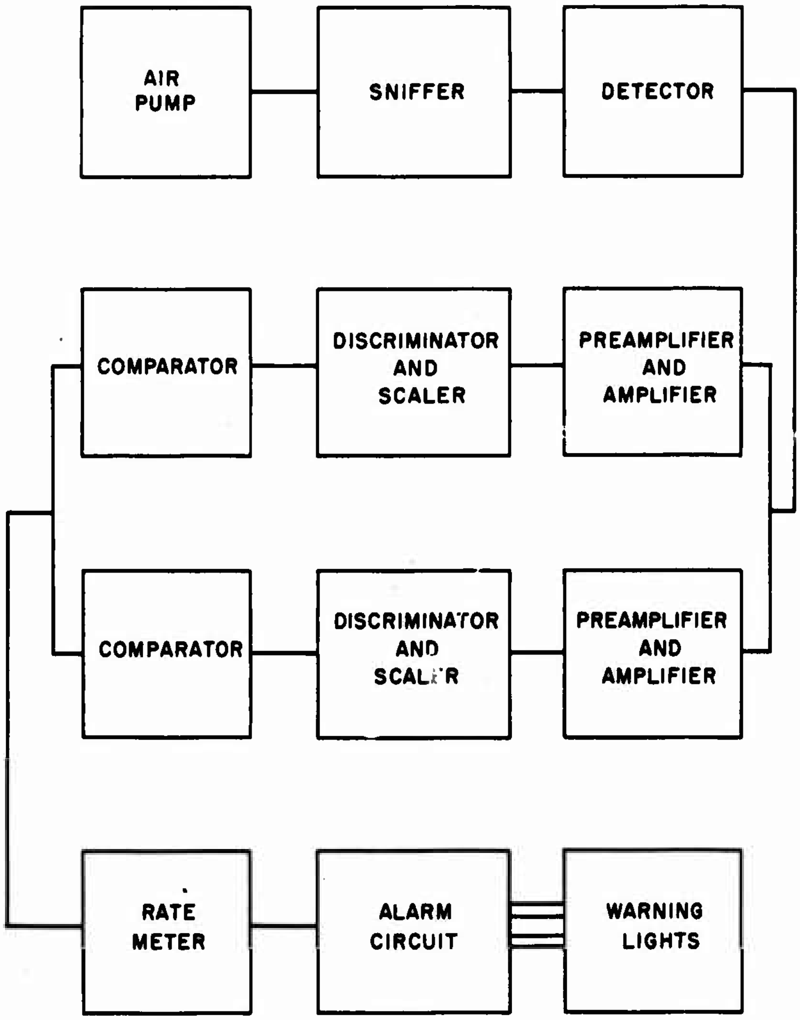

Fig. 2.12 Diagram of Type E-1 Air-borne Air Beta Monitor

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amplifier assembly into an adjustable pulse-height discriminator which feeds an equalizer–cathode-follower combination. The equalizer generates a pulse of fixed amplitude, width, and waveform for every input pulse which is passed by the discriminator. These standardized pulses pass through a scale-of-two scaler whose function is to increase the regularity of the random pulse discrimination from the detector. The scaler output pulses are fed to a four-stage comparator section which cancels pulses appearing simultaneously in both channels. The remaining pulses are then fed into a pulse-rate meter, the output of which is a direct current proportional to the difference in the pulse repetition rate of the two channels. This output is therefore proportional to the beta activity of the material collected on the tape. When this beta count reaches a preset tolerance level, the alarm system is activated.

2.9.3 Description

The E-1 air monitor consists of three units: the air-sampling assembly, the amplifier assembly, and the indicator assembly. Dimensions and weights of these units are shown in Table 2.9.

TABLE 2.9 DATA FOR E-1 AIR BETA MONITOR*

Physical Data

Unit	Weight (lb)	Height (in.)	Width (in.)	Depth (in.)
Air-sampling assembly	60	10	15	20
Amplifier assembly	30	7	10	20
Indicator assembly	30	7	10	20

Power Requirements

28 volts, d.c.	300 watts
115 volts, a.c.	400 cps, 400 va

*Operates alarm system at 1700 ± 10 per cent beta disintegrations per cubic centimeter of air per second in gamma-radiation fields up to 50 r/hr.

2.10 TEST-UNIT MARK 7 MOD 3 INFRARED DETECTOR

This equipment is a standard Navy infrared measuring device.

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Chapter 3

Operational and Test Procedure

3.1 INTRODUCTION

Although both the P2V-2 and the B-17 were practically indentically equipped and capable of carrying out all operations, the operations carried out by the two aircraft were somewhat different on shot days. On subsequent days both aircraft carried out identical missions.

3.2 P2V-2 OPERATION PLAN

The operations of the P2V-2 consisted generally of three phases. The first phase commenced immediately after zero time. Prior to zero time the aircraft maintained station at an approximate altitude of 8000 ft and at approximately 20 miles from the detonation point. Immediately after the detonation, the P2V-2 started a gradually closing course toward the radioactive cloud (see Fig. 3.1). During this first phase, measurements were made on the radioactive cloud with the AN/ADR-1, AN/ADR-3, and the type D-1 cloud tracker. The aircraft was flown as close as safety permitted. This distance varied with the different shots. Extreme care had to be exercised in maneuvering the aircraft during this portion of the test in order to avoid contaminating the aircraft and endangering the crew. Shifting winds at various altitudes made this flight operation very difficult. This first phase continued until the atomic cloud became diffused to the point where good measurements could not be taken. Generally this phase ended approximately 2 hr after detonation time.

Upon completing the first phase, the second phase began. The latter consisted in measurements of altitude vs gamma intensity. These measurements were made with the AN/ADR-1 and AN/ADR-2 equipment directly over the zero point from altitudes at 500-ft intervals, starting at approximately 6000 ft and ending at approximately 500 ft.

The third phase consisted in conducting the surface-survey runs. During this phase of the operation the AN/ADR-1 and the type F-1 surface-survey units were used. It was also during this phase that the AN/USQ-1 telemetering equipment was dropped and monitored. An average of eight telemetering units were dropped on each shot. On Dog and Easy shots this phase of operation was started approximately 4 hr after detonation and was continued on succeeding days. On George shot, however, this phase was not started until the day following the detonation. In conducting these ground-survey runs, the aircraft made four passes, each approximately 45° apart and all intersecting over zero point (Fig. 3.2). This type of pattern was flown at both 500 and 1000 ft.

3.3 B-17 OPERATION PLAN

While awaiting zero time, the B-17 maintained station at an altitude of approximately 18,000 ft and at a distance approximately 20 miles from the detonation point. Immediately after the detonation the B-17 started its first phase of the operation by flying a gradually closing course on the radioactive cloud (Fig. 3.1). The B-17 concentrated on detecting and tracking the cloud on shot day. In conducting these cloud runs, the AN/ADR-3 and type D-1 cloud tracker and the Farrand Mark 7 infrared equipment were employed. These runs on the cloud were continued until the cloud dissipated itself to the point where the instruments failed

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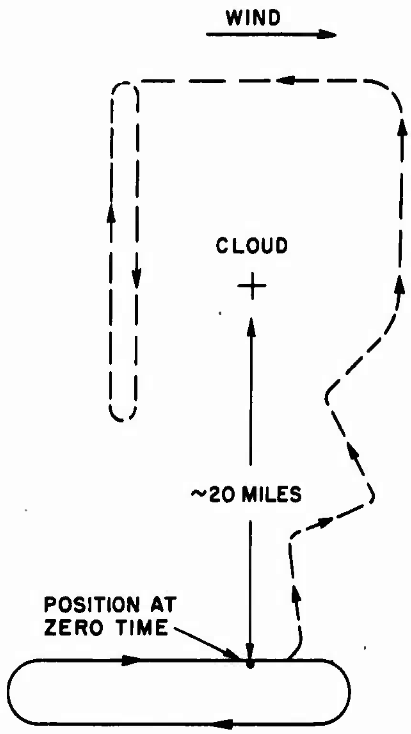

Fig. 3.1 Typical Cloud-tracking Flight Pattern

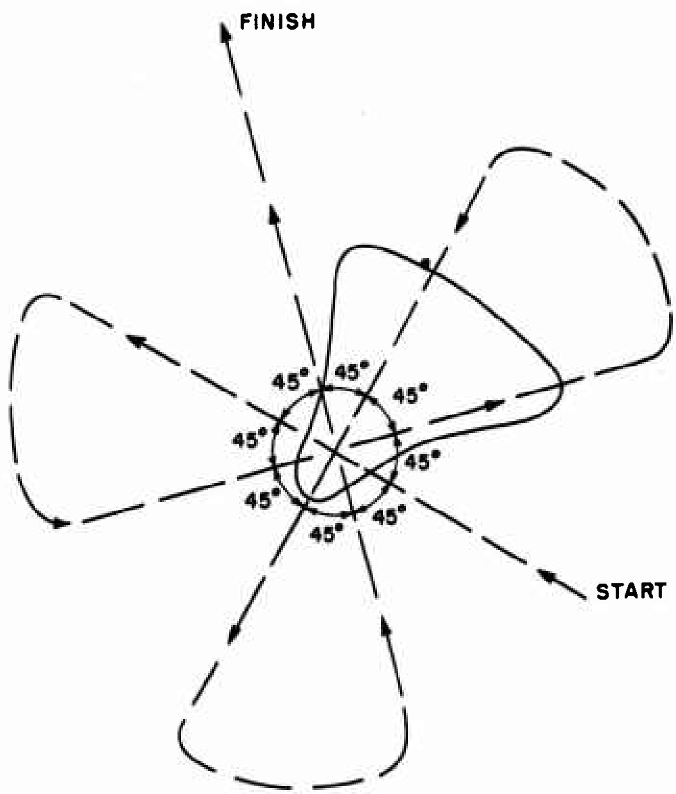

Fig. 3.2 Typical Surface-survey Flight Pattern

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to give good measurements. The B-17 then returned to base.

On the days following each detonation, the B-17 commenced its second phase by conducting surface-survey runs. The flight pattern for making these runs consisted of four passes, each 45° apart and all intersecting at the zero point (Fig. 3.2). These runs were made at various altitudes. It was during these surface-survey runs that the AN/USQ-1 units, which were previously dropped by the P2V-2, were monitored.

Although minor changes in the operational plans were made from time to time, the overall plan of operation was essentially as outlined in the preceding paragraphs.

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Chapter 4

Test Results

4.1 AN/ADR-1

The AN/ADR-1 equipment performed very well. There were instances where it became necessary to change tubes and to make other minor adjustments; however, the over-all operation of this equipment came up to expectations. During the radioactive-cloud tracking operation on Dog shot, it was possible to detect the cloud at a distance of approximately 3 miles within approximately 30 min after the detonation.

While the aircraft were flying upwind of the cloud at approximately 5000 ft, evidences of radioactivity were found in normal cumulus clouds. These cumulus clouds gave readings of approximately 20 mr/hr on the AN/ADR-1. In some instances large cloud banks, also upwind of the atomic cloud, gave long and persistent indications of radioactivity. These cumulus clouds probably captured some fall-out from the radioactive cloud which was overhead at higher altitudes. The wind conditions over the test area were such that there were several shearing points with winds blowing in different directions at different altitudes. These unstable wind conditions resulted in extensive shearing and general dissipation of the radioactive cloud.

After all three shots the AN/ADR-1 equipment was used to measure altitude vs gamma intensity over the zero point. The results of these measurements are shown graphically in Figs. 4.1 to 4.3. It will be noted that the curve representing the measured values for +53 hr deviates considerably from the curve obtained by correcting the +3-hr measured values to 53 hr by applying the normally accepted 1.2 decay factor. This is explained by the fact that a decrease in energy level occurs during the period from 3 to 53 hr, and this change in energy level gives rise to an increase in the attenuation between the ground and the various altitudes. This being the case, it would be expected that the computed values at the higher altitudes would be higher than the measured values. This fact is borne out in Fig. 4.1.

During the surface-survey runs the nondirective AN/ADR-1 was used to obtain data to correlate with the readings obtained with the directive AN/ADR-4 equipment. As was expected, the AN/ADR-1 gave extremely good indications of radiation and also gave decreasing indications as the aircraft left the islands. However, it was very clearly indicated that, for obtaining detailed radiological contour data, a nondirectional system such as the AN/ADR-1 cannot be used. Figures 4.4 to 4.19 indicate the intensity readings made in flying the surface-survey flight pattern. The tracks flown and the altitude are indicated for each curve. To compare the nondirective AN/ADR-1 readings with the directive AN/ADR-4 readings, the proper curves must be matched by shot track and altitude.

It was found, during the operation of the equipment, that an unusually long time was required before the equipment stabilized itself satisfactorily. The required time for stable operation varied from 15 min to as long as $1\frac{1}{2}$ hr. This equipment incorporates a thermostatically controlled heater which maintains the temperature of some of the critical circuits at approximately 80°C. This shortens the warm-up time to some extent. It is also the function of this heater to dry out any moisture that may be present in the critical circuits. Under the extremely adverse humidity conditions present during this operation, the time necessary to remove the moisture probably was very greatly increased. By properly sealing the enclosing

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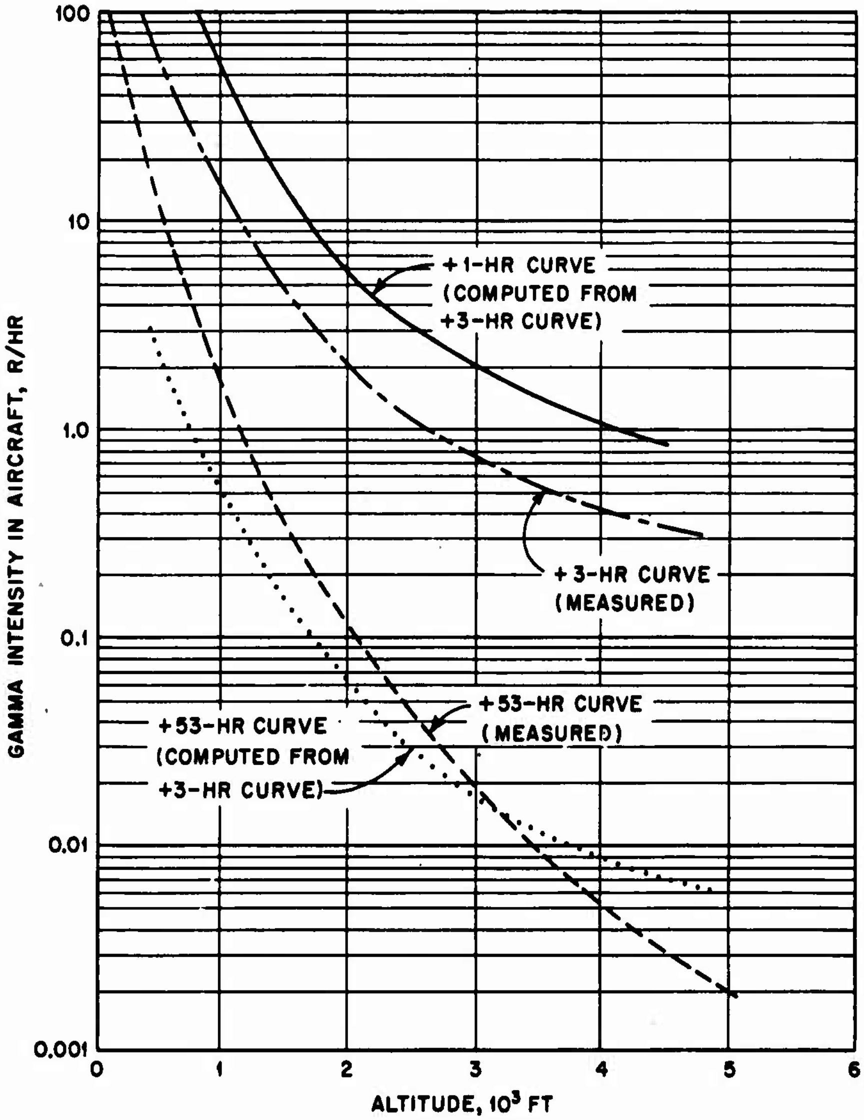

Fig. 4.1 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-1, Dog Shot

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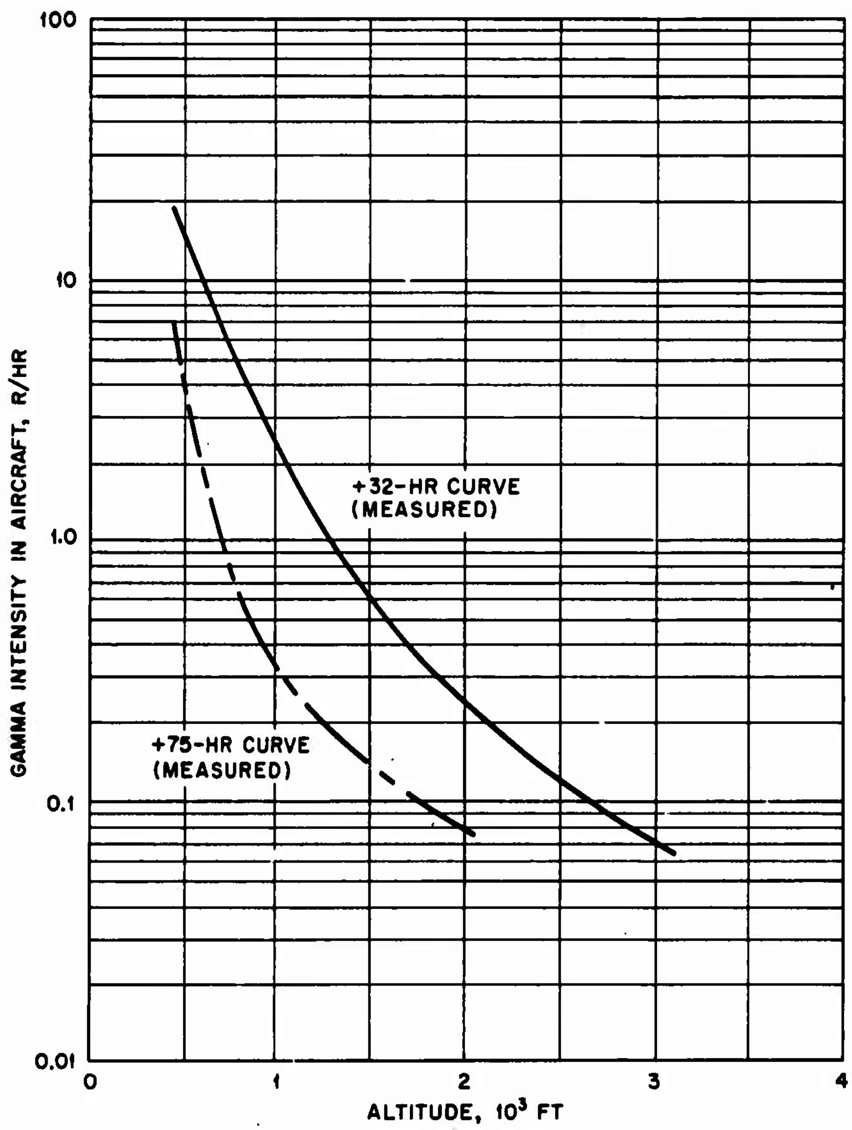

Fig. 4.2 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-1, Easy Shot

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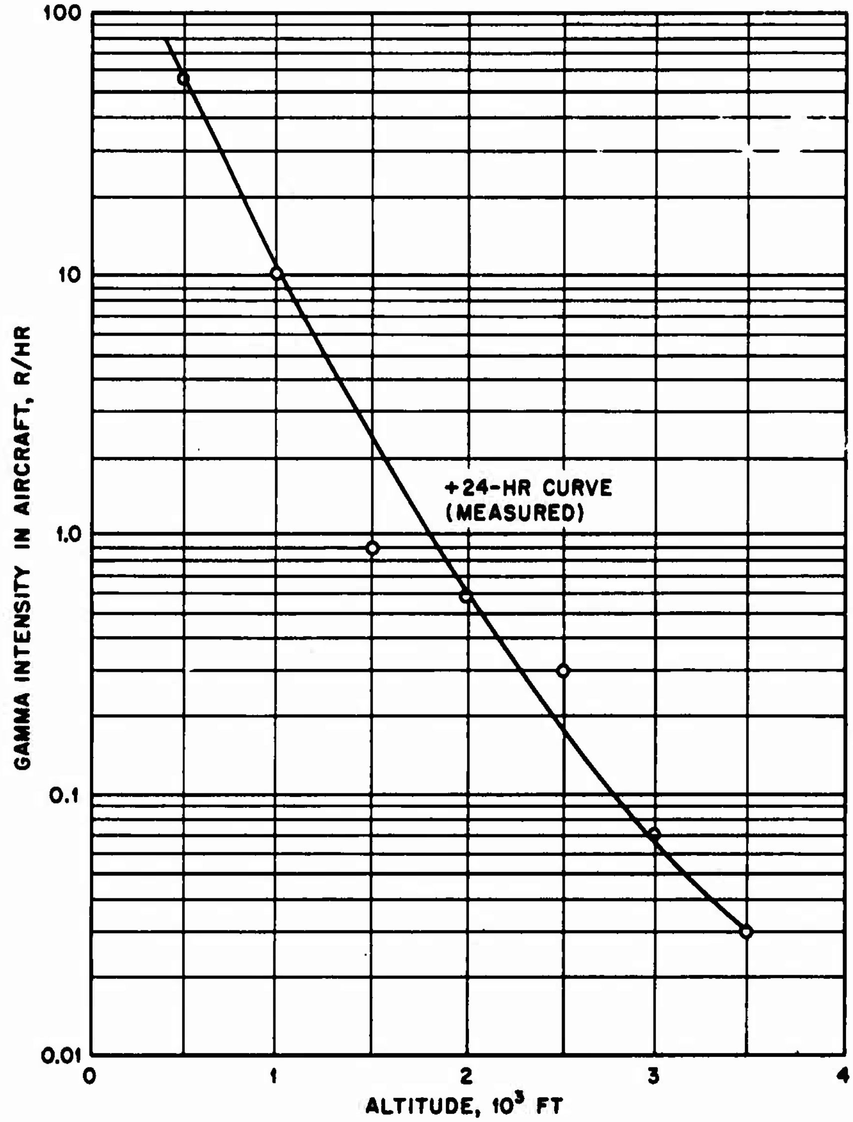

Fig. 4.3 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-1, George Shot

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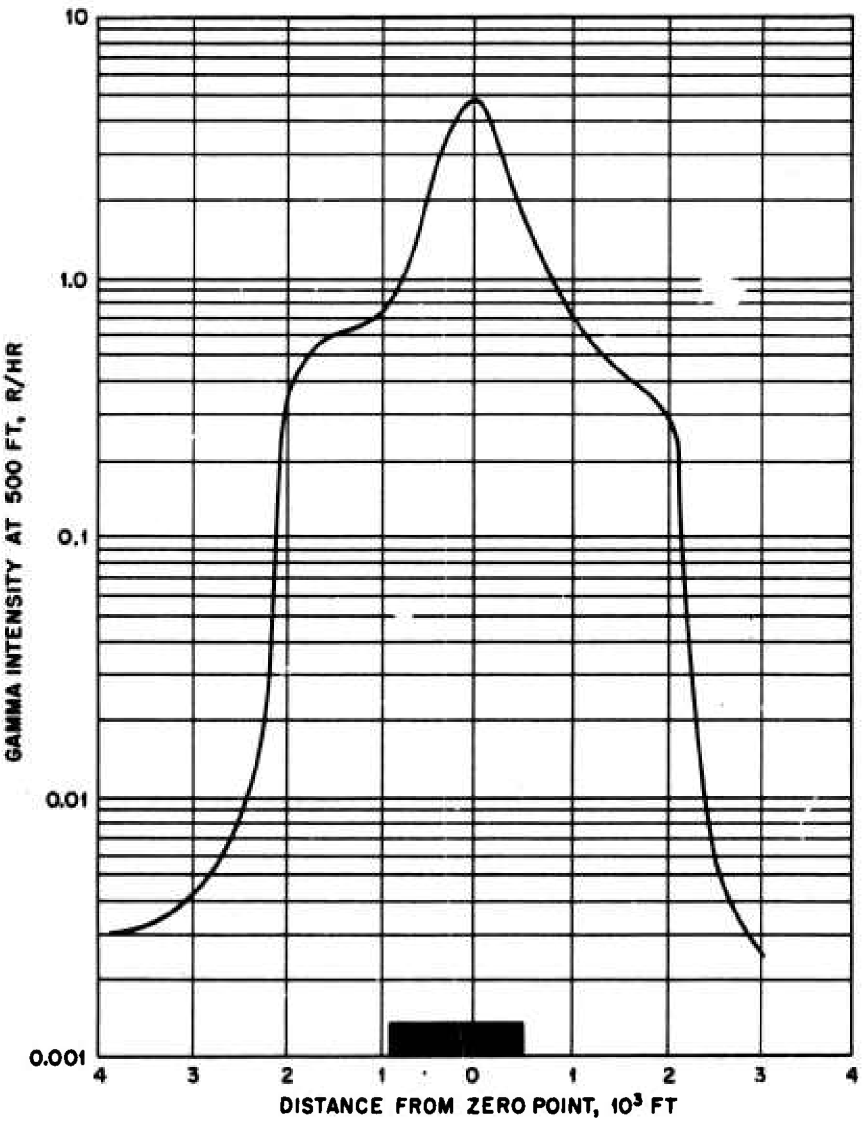

Fig. 4.4 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 55°, Ground Speed 135 Mph, Dog Shot

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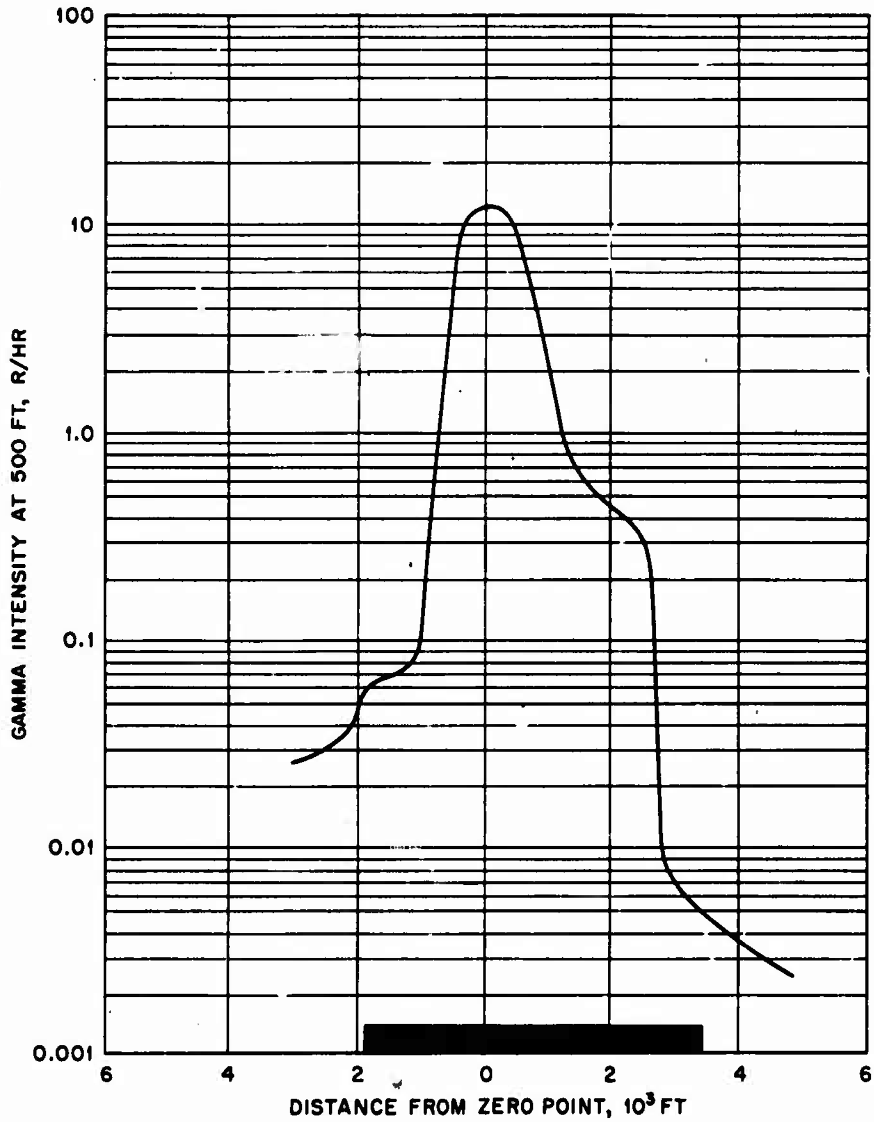

Fig. 4.5 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 145°, Ground Speed 153 Mph, Dog Shot

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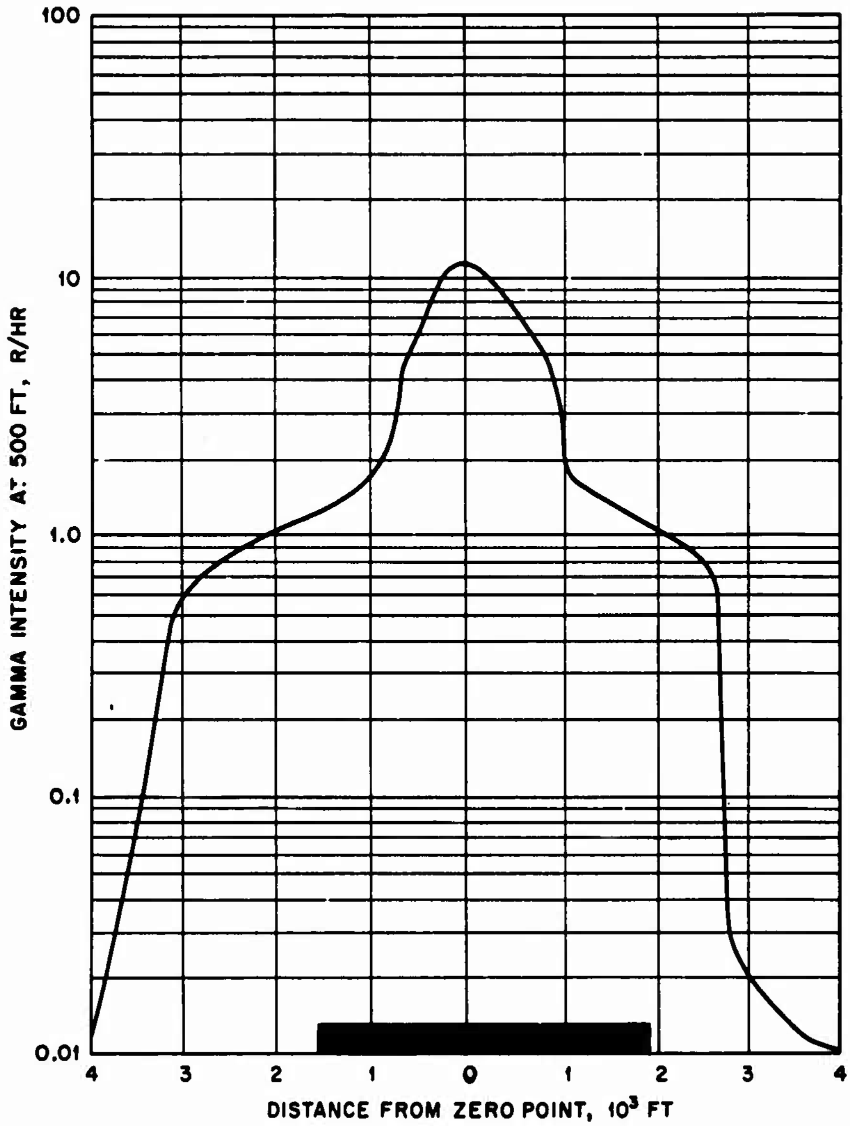

Fig. 4.6 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 190°, Ground Speed 175 Mph, Dog Shot

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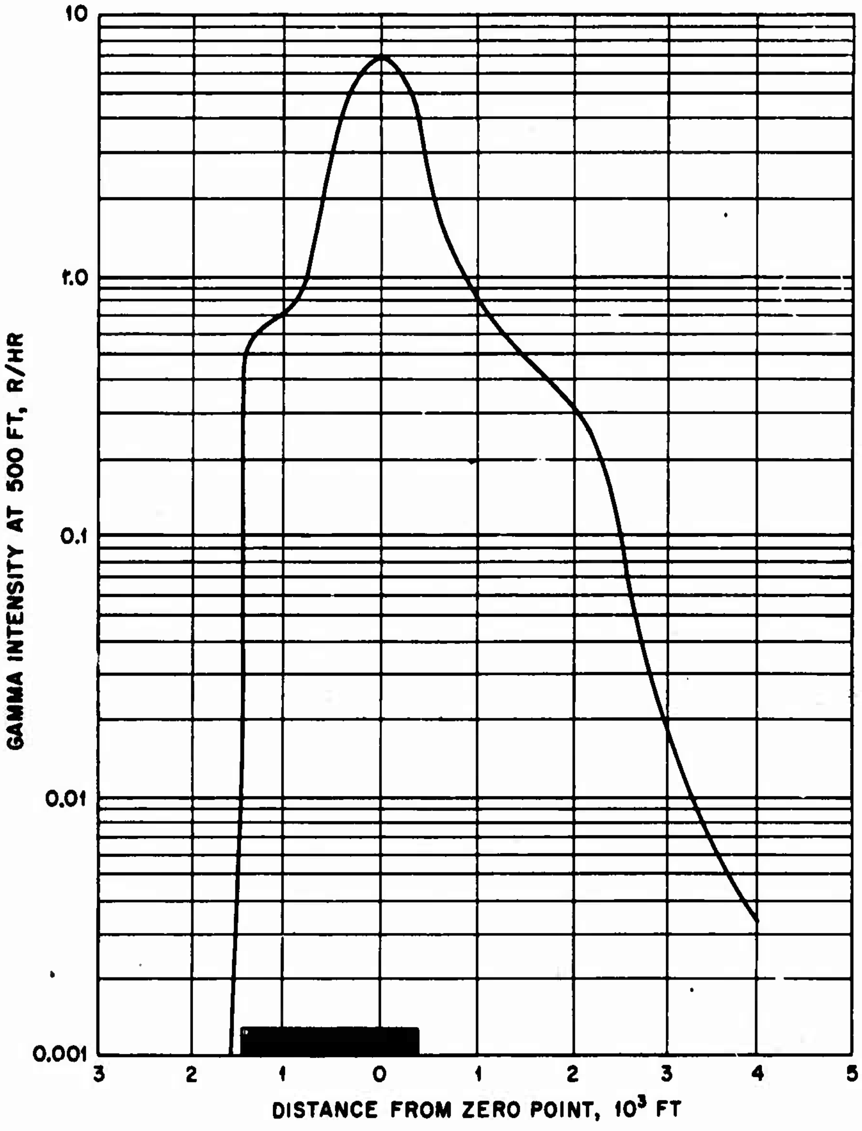

Fig. 4.7 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 280°, Ground Speed 184 Mph, Dog Shot

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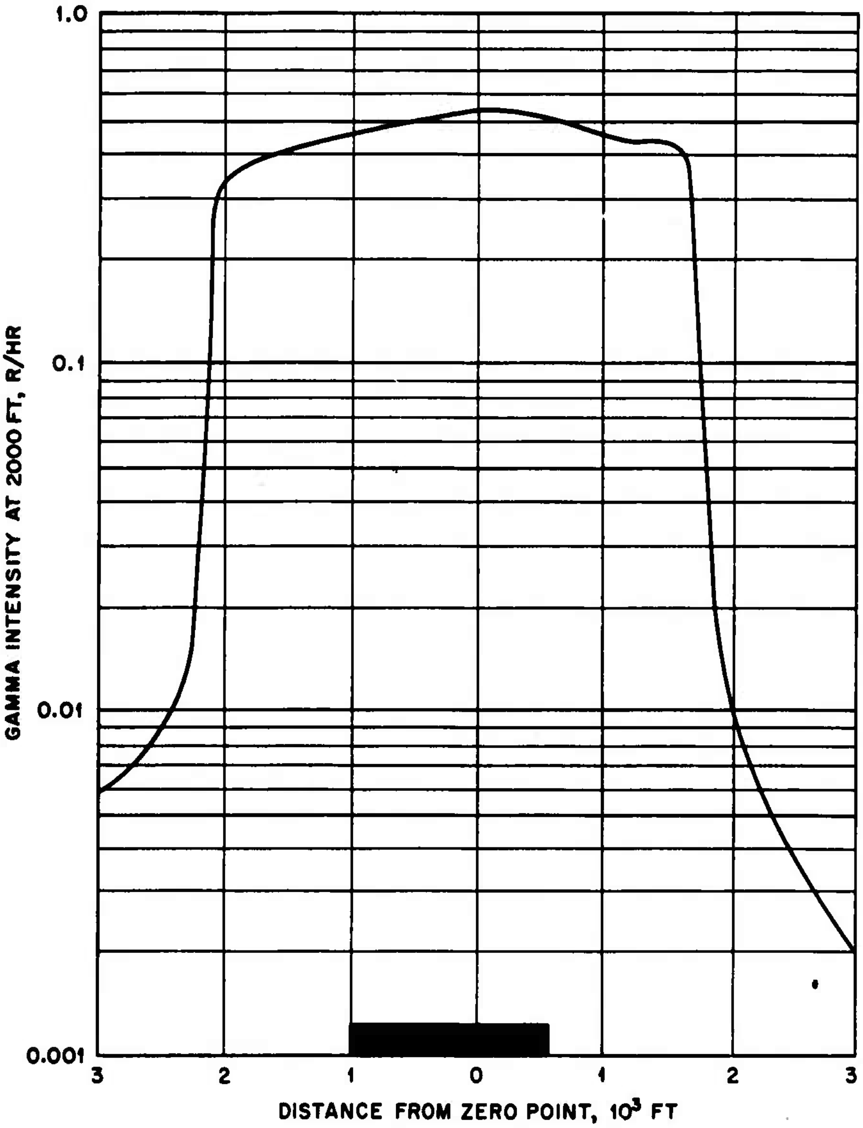

Fig. 4.8 Variation of Gamma Intensity in Aircraft at 2000-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 55°, Ground Speed 153 Mph, Dog Shot

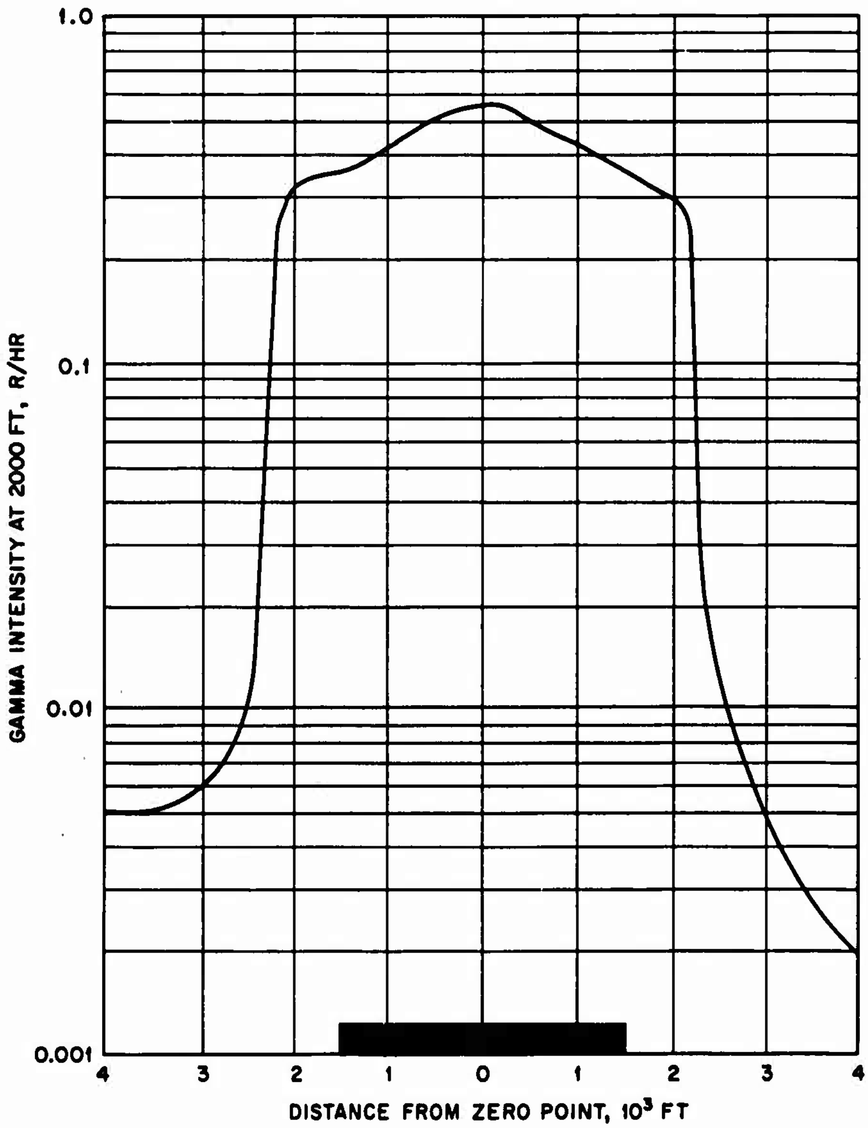

Fig. 4.9 Variation of Gamma Intensity in Aircraft at 2000-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 190°, Ground Speed 175 Mph, Dog Shot

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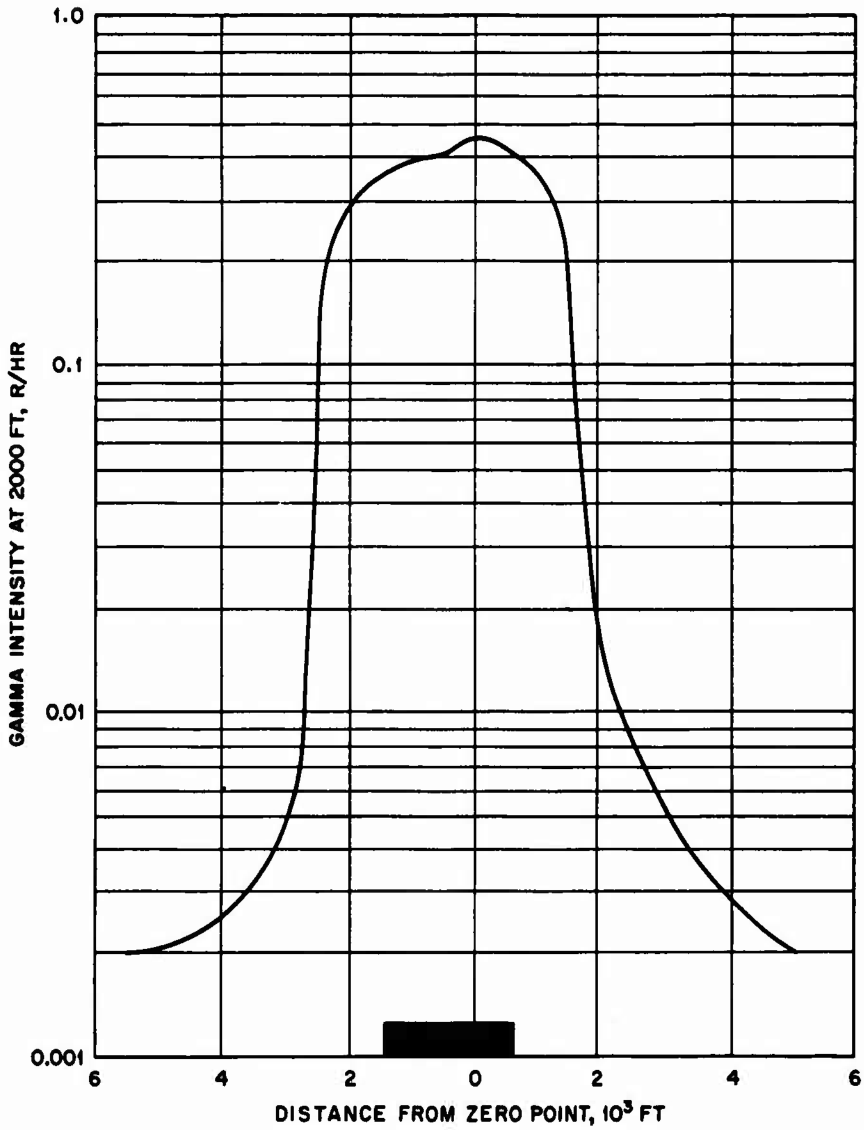

Fig. 4.10 Variation of Gamma Intensity in Aircraft at 2000-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 280°, Ground Speed 184 Mph, Dog Shot

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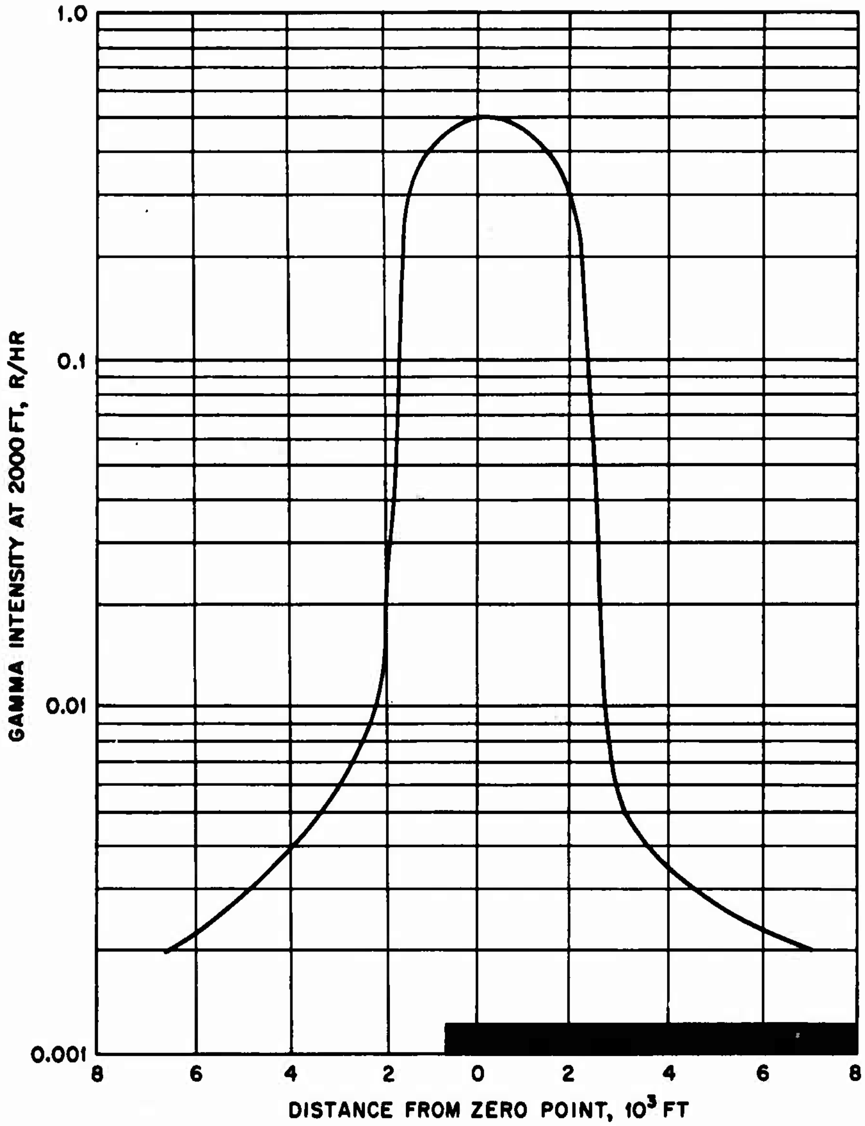

Fig. 4.11 **Variation of Gamma Intensity in Aircraft at 2000-ft Altitude, Measured with Radiac Set AN/ADR-1, +55 Hr, Track 145°, Ground Speed 153 Mph, Dog Shot**

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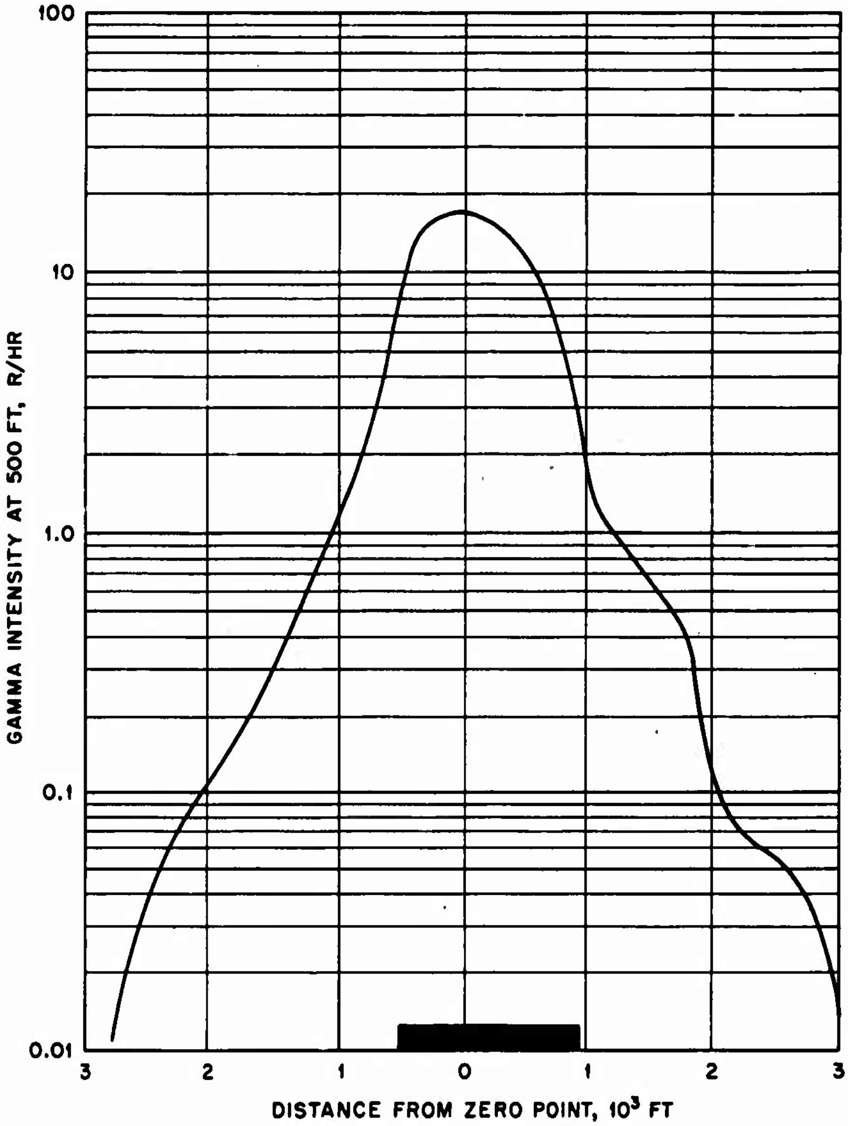

Fig. 4.12 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 59°, Ground Speed 144 Mph, Easy Sho.

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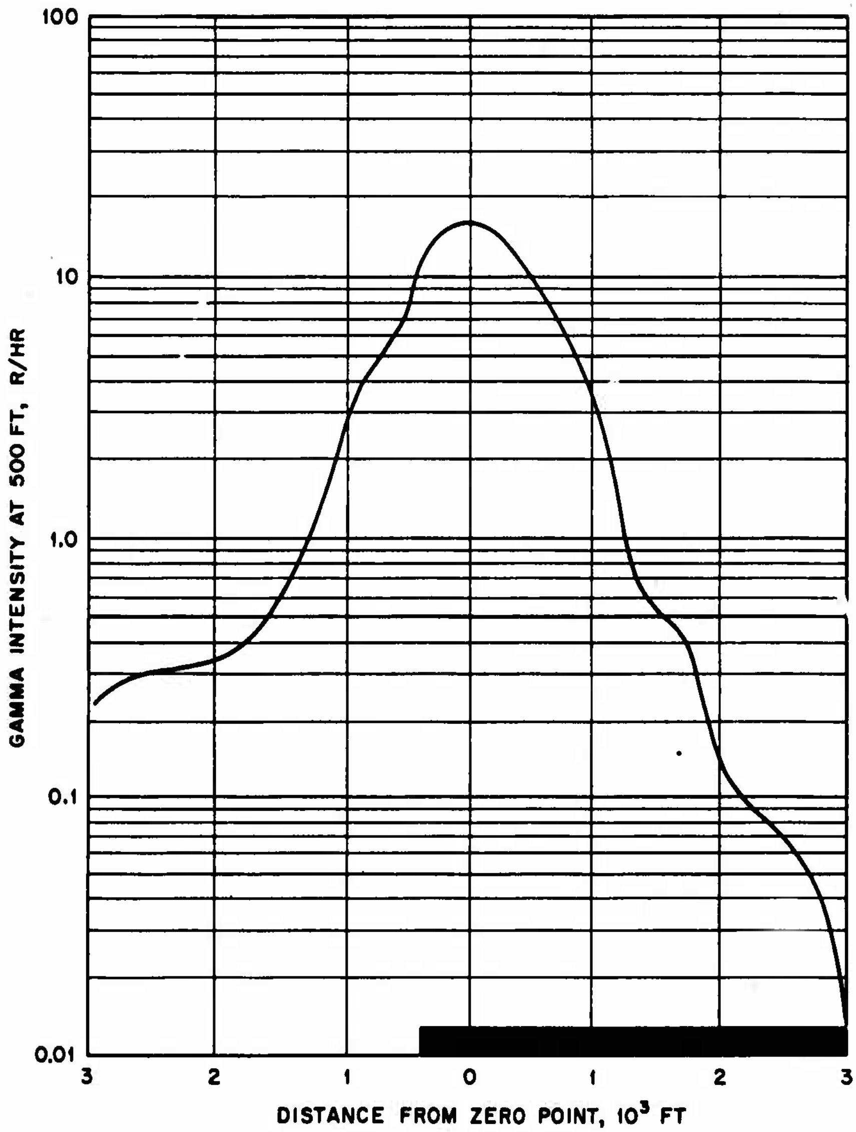

Fig. 4.13 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 78°, Ground Speed 146 Mph, Easy Shot

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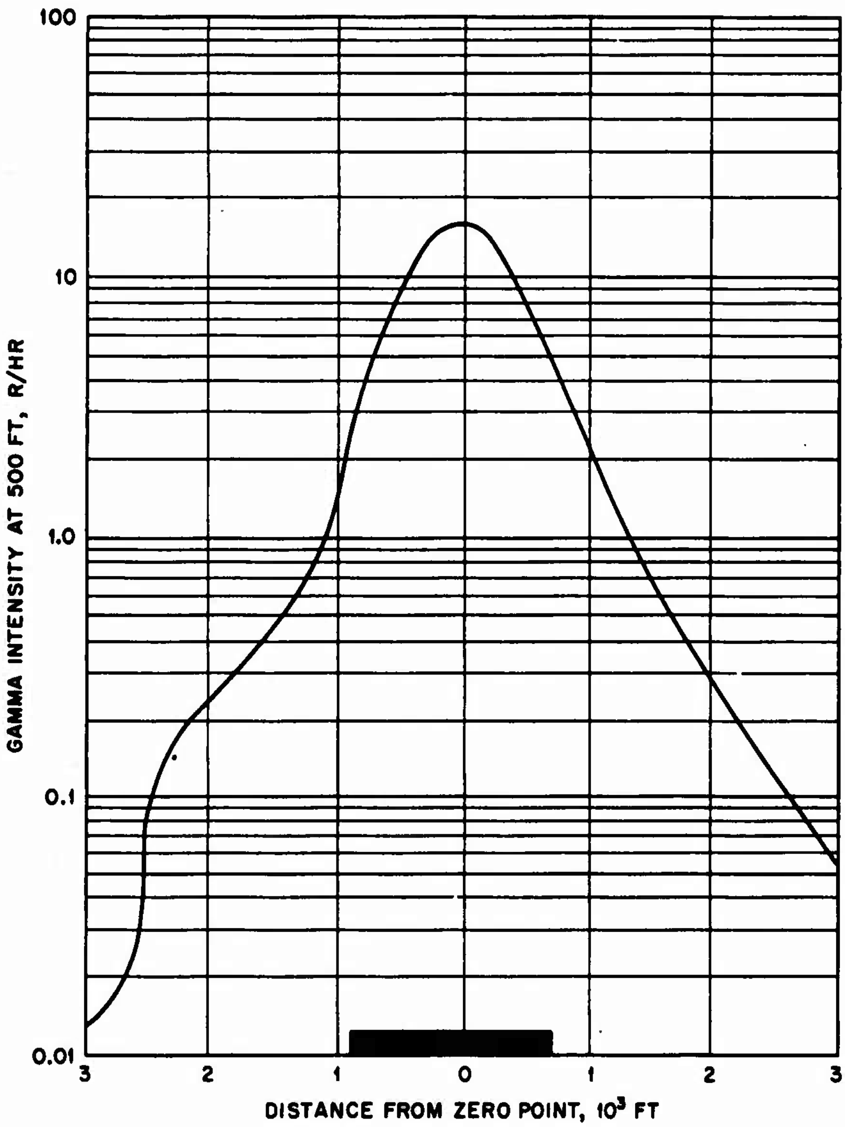

Fig. 4.14 Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 153°, Ground Speed 158 Mph, Easy Shot

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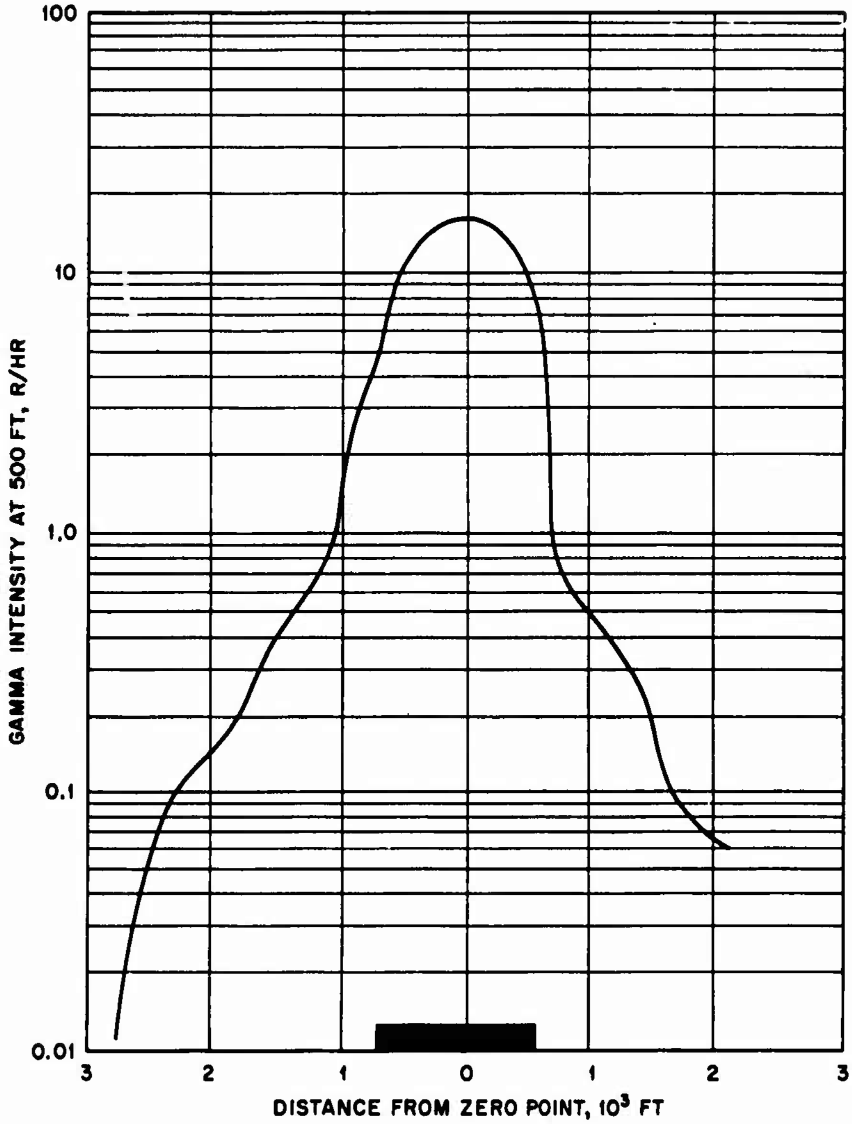

Fig. 4.15 **Variation of Gamma Intensity in Aircraft at 500-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 355°, Ground Speed 153 Mph, Easy Shot**

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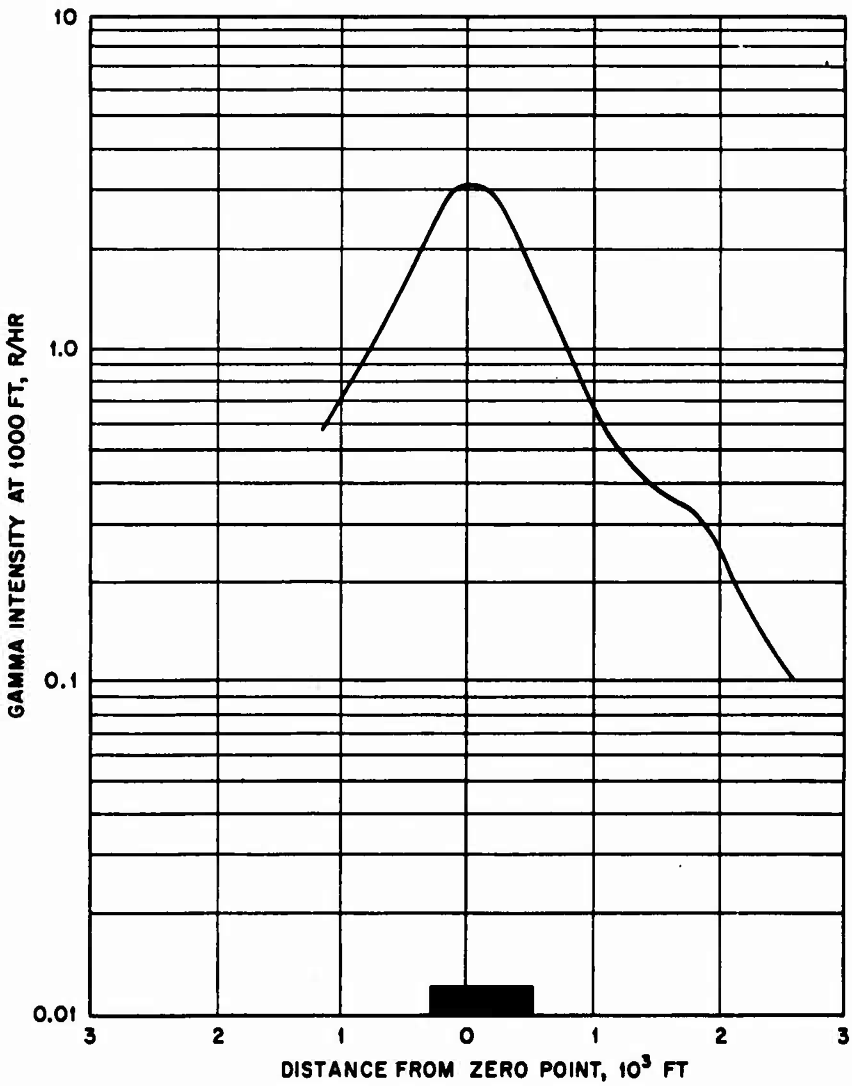

Fig. 4.16 Variation of Gamma Intensity in Aircraft at 1000-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 45°, Ground Speed 144 Mph, Easy Shot

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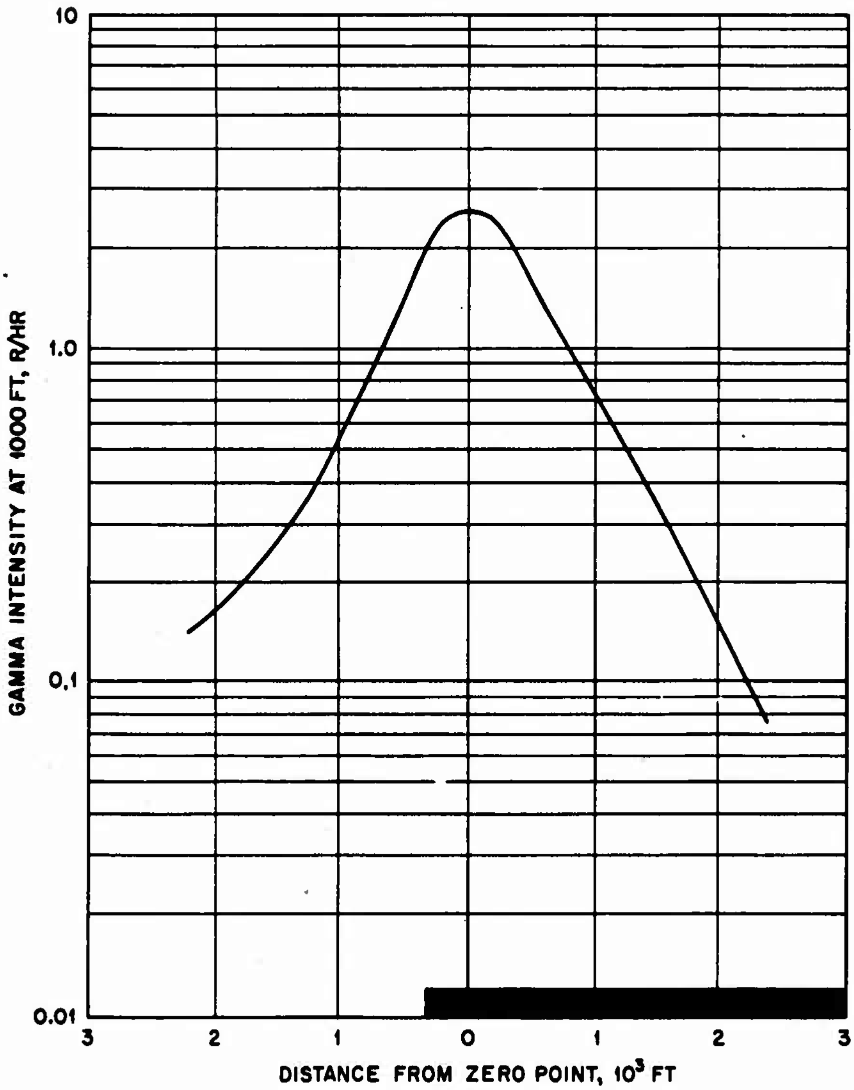

Fig. 4.17 Variation of Gamma Intensity in Aircraft at 1000-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 91°, Ground Speed 146 Mph, Easy Shot

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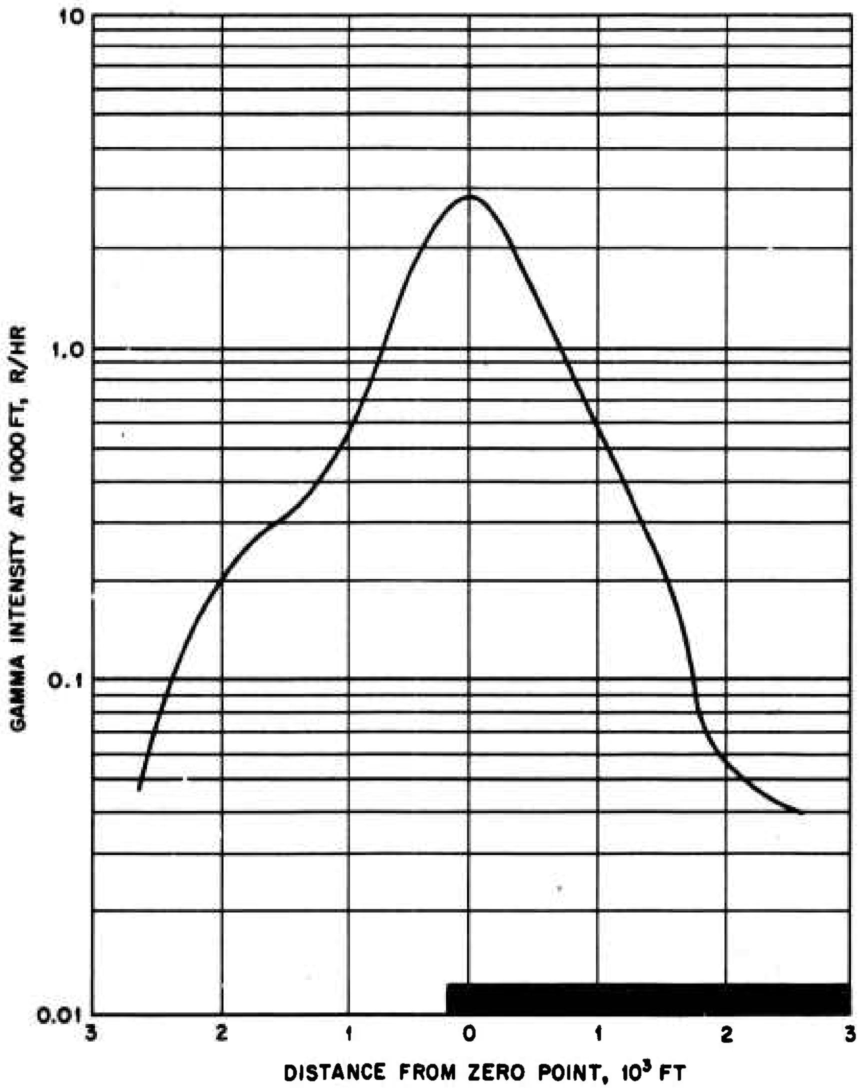

Fig. 4.18 Variation of Gamma Intensity in Aircraft at 1000-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 135°, Ground Speed 158 Mph. Easy Shot

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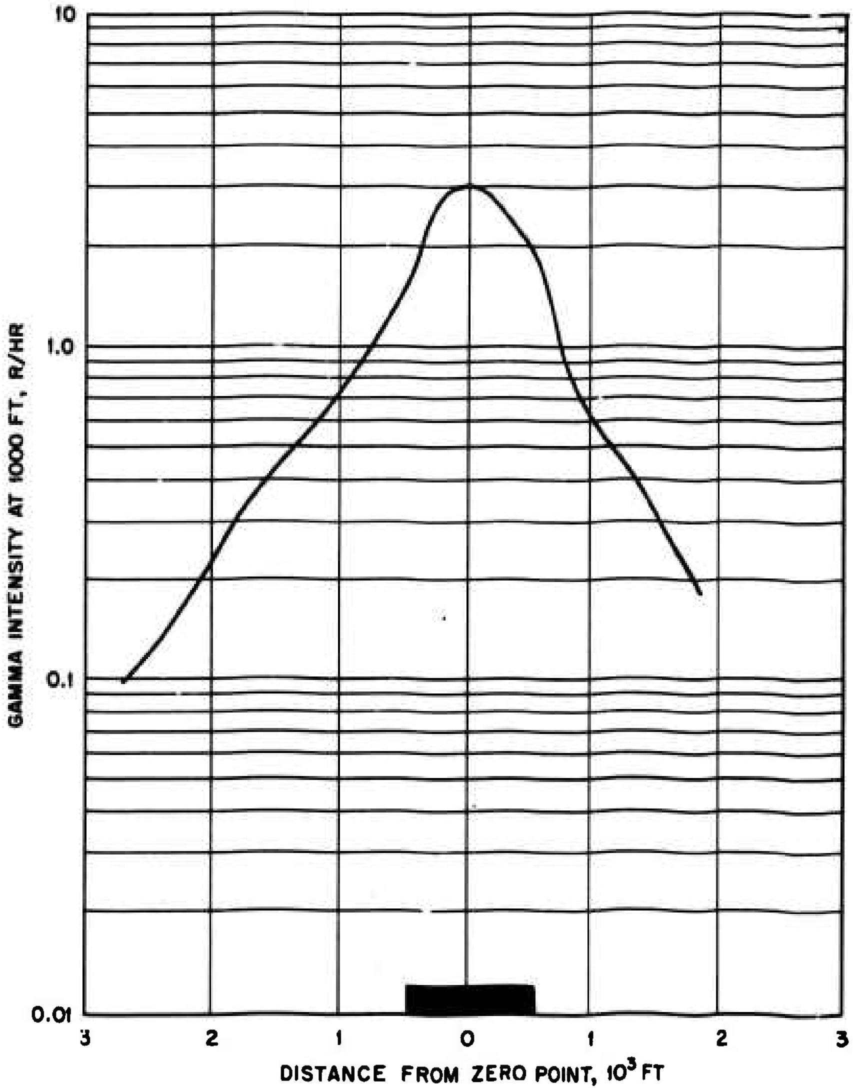

Fig. 4.19 Variation of Gamma Intensity in Aircraft at 1000-ft Altitude, Measured with Radiac Set AN/ADR-1, +33 Hr, Track 355°, Ground Speed 154 Mph, Easy Shot

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plastic around the critical circuitry, this warm-up period can be very greatly reduced.

The speed of response of the instrument was found to be very adequate for operation in high-speed aircraft.

Several instances of erratic operation of the automatic scale-changing circuitry were experienced; however, in all but one case the changing of a tube corrected the difficulty. The erratic operation in the one exception cited was caused by a critical resistor changing its value.

The operation of the equipment throughout the entire operation was considered to be satisfactory.

4.2 AN/ADR-2

This equipment was used to obtain data on dose rate vs altitude during the second phase of the P2V-2 operation. In addition, the integrated dosage indicator of this equipment was used to indicate the dosage to which the crew had been exposed. The dosages so determined were within 20 per cent of the values measured by the radiological safety officer.

The dose-rate values vs altitude readings are presented graphically in Figs. 4.20 to 4.22.

During high aircraft speeds it became evident that the type of recorder used in the dose-rate recording portion of the equipment was too slow to follow rapid changes in radiation intensity.

Except for the inadequate speed of response, this equipment functioned very satisfactorily.

4.3 AN/ADR-3

The AN/ADR-3 installation in the P2V-2 yielded good results in two of the three shots. On Dog shot the radioactive cloud was detected and tracked at a distance of approximately 10 miles when the cloud was approximately 30 min old. During George shot the atomic cloud was located and tracked from a distance of approximately 24 miles when the cloud was approximately $1\frac{1}{2}$ hr old.

In the B-17, because of serious misadjustment and misalignment of the AN/ADR-3 equipment, no definite signals could be attributed to the radioactive cloud.

During Dog and George shots, which yielded positive indications, as well as Easy shot, which did not produce positive indications, many indications were received which could not be directly attributed to the visual portion of the atomic cloud. It is quite possible that these indications were bona fide signals caused by the invisible portion of the radioactive cloud; there was, however, no means for verifying this. Inasmuch as the AN/ADR-3 is a very sensitive S-band (approximately 10 cm) receiver, some of the S-band energy employed by the drone-tracking radar equipment may have been received.

Although positive results were obtained with the AN/ADR-3 installed in the P2V-2, the equipment was not at optimum operating condition. Normally the equipment has a sensitivity measurement of approximately 10° per milliampere output. The equipment used had a sensitivity value of approximately 50° per milliampere output.

Although provisions were made for variable scan speeds, the fastest speed did not seem to be adequate.

On Dog and Easy shots the relatively fast and widespread diffusion of the radioactive cloud, the result of erratic wind conditions, made the operation of the AN/ADR-3 extremely difficult.

4.4 TYPE D-1 CLOUD TRACKER

This equipment detected and tracked the radioactive cloud from Easy shot from a distance of approximately 12 miles when the cloud was approximately 20 min old. The similar unit in the B-17 was inoperative during Dog and George shots because of power-supply difficulties.

The P2V-2 installation of this equipment did not yield any definite target signals. This was probably the result of misadjustment and low sensitivity of the particular equipment.

4.5 TYPE E-1 AIR BETA MONITOR

Inadequate electronic engineering caused a great deal of difficulty in keeping this equipment in working order. Of the original six units, only two remained in working condition by the end of the operation.

Since no attempt was made to fly the manned aircraft into areas of beta activity, no positive

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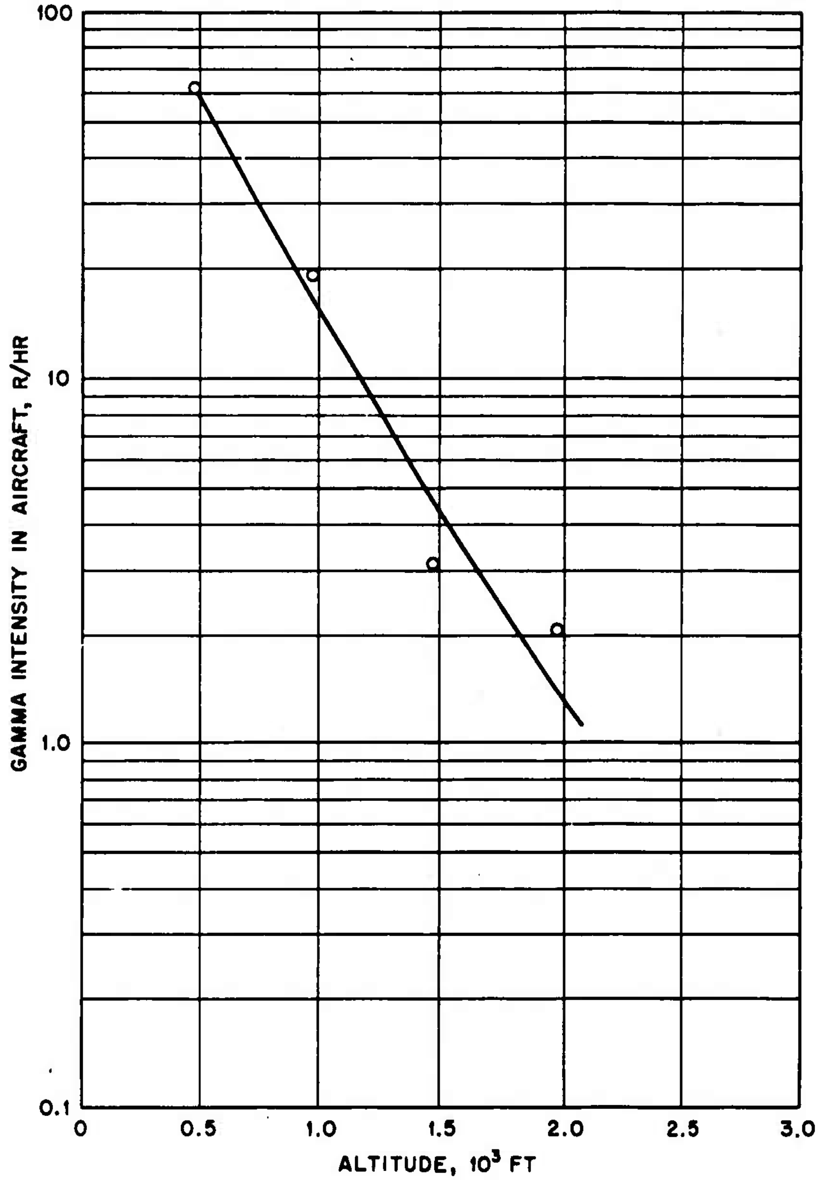

Fig. 4.20 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-2, +3 Hr, Dog Shot

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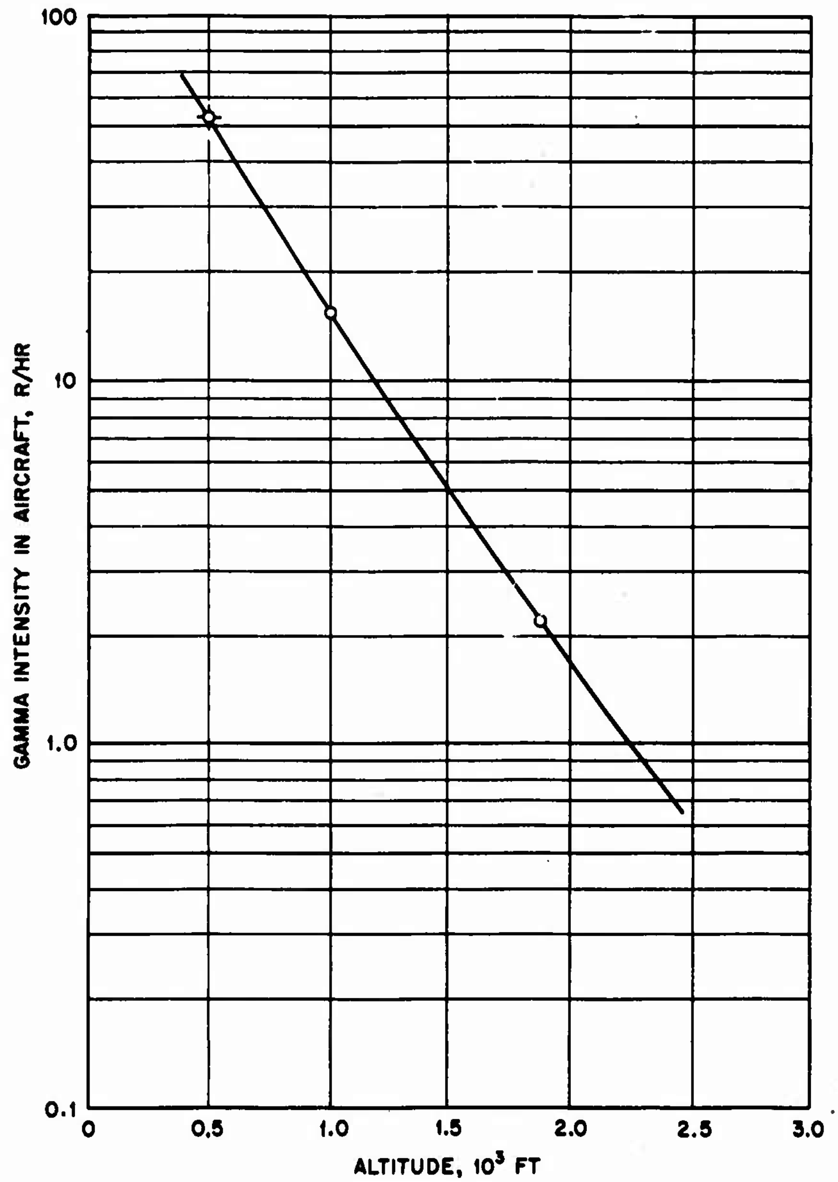

Fig. 4.21 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-2, +3 Hr, Easy Shot

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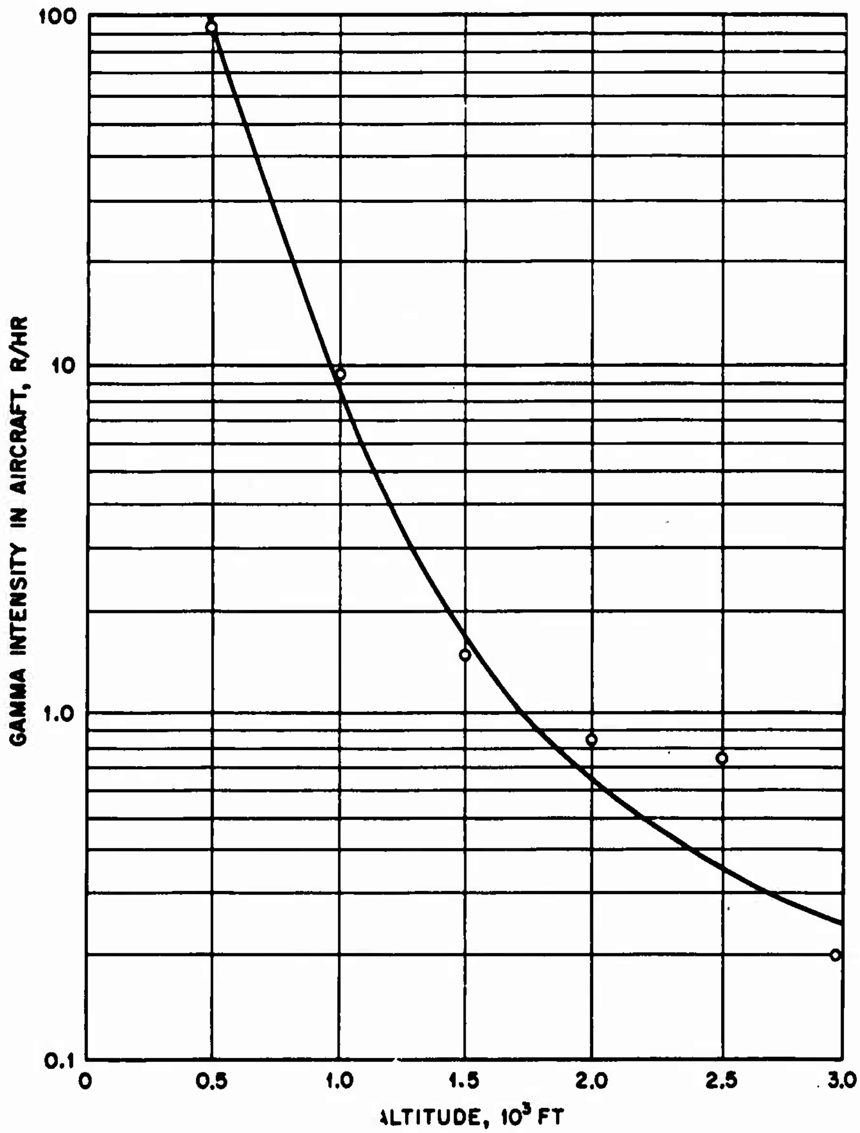

Fig. 4.22 Variation of Gamma Intensity in Aircraft with Altitude, Measured with Radiac Set AN/ADR-2, +24 Hr, George Shot

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indications of beta activity were noticed. However, the equipment seemed to operate satisfactorily even though it continuously indicated "Safe."

The fact that this equipment can be made to function properly if engineered properly was borne out by the fact that it functioned satisfactorily when installed in a drone which flew through the radioactive cloud immediately after the detonation.

It must be borne in mind that this equipment was constructed to test a technique of measuring beta intensity in a high-gamma field and not as a prototype instrument to withstand the extremely adverse conditions of this operation. It appears that this purpose was satisfied.

4.6 AN/ADR-4

Although there were instances of circuit instabilities in this equipment, these were corrected, and the unit performed satisfactorily. The purpose of this equipment was to test techniques and not to provide a prototype equipment. The techniques that were to be tested were the effectiveness of shadow shielding for the directive detector, a "comparator" method of determining the energy-level effect on attenuation between the ground and the aircraft, and special electronic computing circuitry.

In carrying out the ground survey, the general flight pattern described in Chap. 3 was followed. The actual tracks flown and ground-intensity values obtained for Dog and Easy shots are indicated in Figs. 4.23 to 4.36. Altitude time, aircraft speed, and other pertinent data are included for each graph. By correlating the data included in these figures, the radiological contour lines on Runit and Engebi islands after Dog and Easy shots, respectively, are obtained (see Figs. 4.27 and 4.32). It must be borne in mind, however, that the values given are average values and may not be identical to the values obtained at isolated points.

By employing the comparator readings, rough estimates of the energy levels at the aircraft altitude for various positions over the ground were determined. These data are given in Figs. 4.37 to 4.40. Because these measurements were made from a 500-ft altitude and because the skin of the aircraft will stop some of the low-energy radiation, the average energy level indicated in the curves will be higher than the average energy level found on the ground beneath the aircraft.

To correlate the ground intensities measured by this equipment with position on the ground and structures on the ground, strip-camera pictures of the ground areas were taken. Many of the peaks in ground intensity can be correlated with the location of debris and test structures shown in the photographs.

The directive properties of this equipment were found to be excellent. Narrow reefs that were contaminated gave definite and distinct indications on the recorder. In fact it became quite evident that, in order to take full advantage of the directivity available, the recorder circuit should be speeded up so as to increase the recording speed from six recorded pieces of information per second to approximately ten. This can be accomplished by making some minor modifications.

The computing circuits employed, on the whole, operated satisfactorily. However, in a few intermittent cases some of the microswitches failed to make contact rapidly enough. This resulted in an occasional loss of recorder indication for approximately ½ sec. This was not considered to be serious.

4.7 TYPE F-1 SURFACE-SURVEY EQUIPMENT

Because of extreme circuit instabilities it was not possible to obtain measurements of ground intensities. There were, however, indications that the equipment had sufficient directive properties. Figures 4.41 and 4.42 illustrate the results obtained from a ground survey of Runit after Dog shot; Figs. 4.43 and 4.44 give the results from the ground survey of Eberiru after George shot.

4.8 AN/USQ-1 AND AN/ARR-29 TELEMETERING SYSTEM

The operation of these telemetering units fell short of expectation. Approximately 25 AN/USQ-1 units were dropped. Of these approximately 40 per cent were considered to have operated properly. The remaining equipment failed to operate because of mechanical

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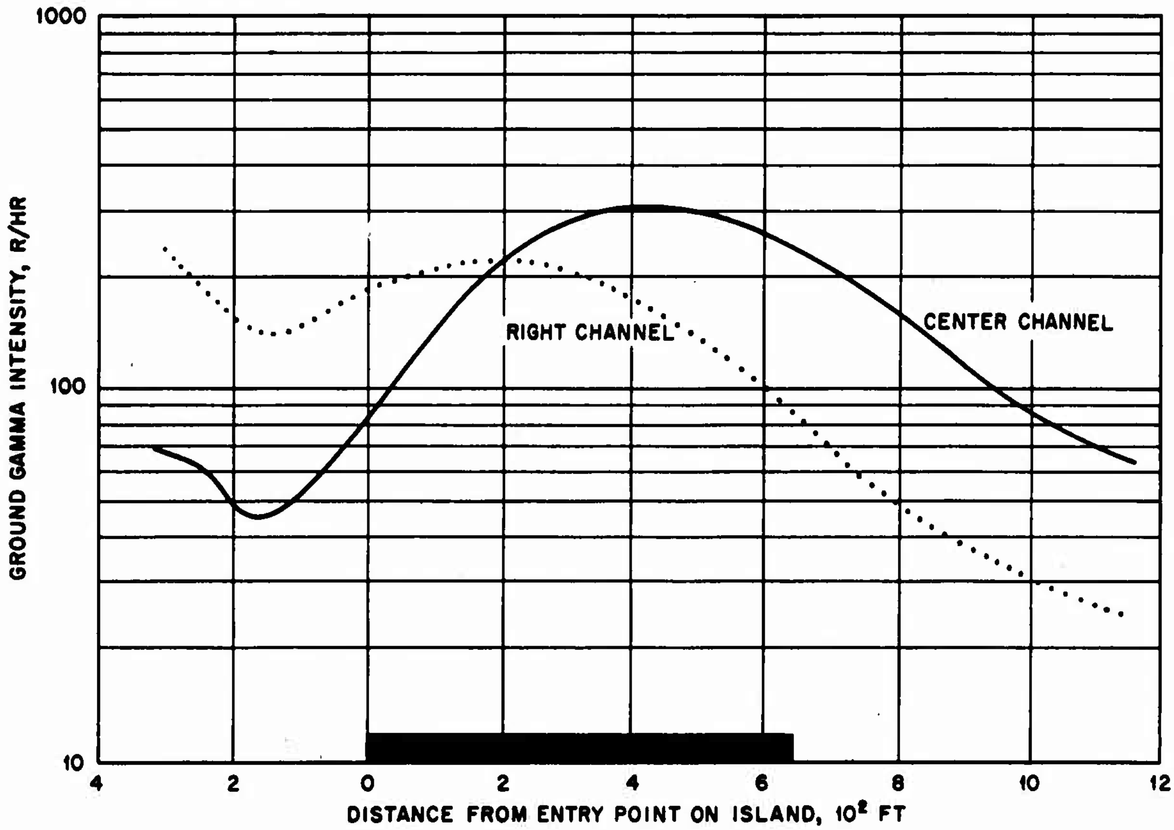

Fig. 4.23 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, + 32 Hr, Track 40°, Ground Speed 173 Mph, Aircraft Altitude 1000 Ft, Dog Shot. Aircraft passed slightly to the left of zero point.

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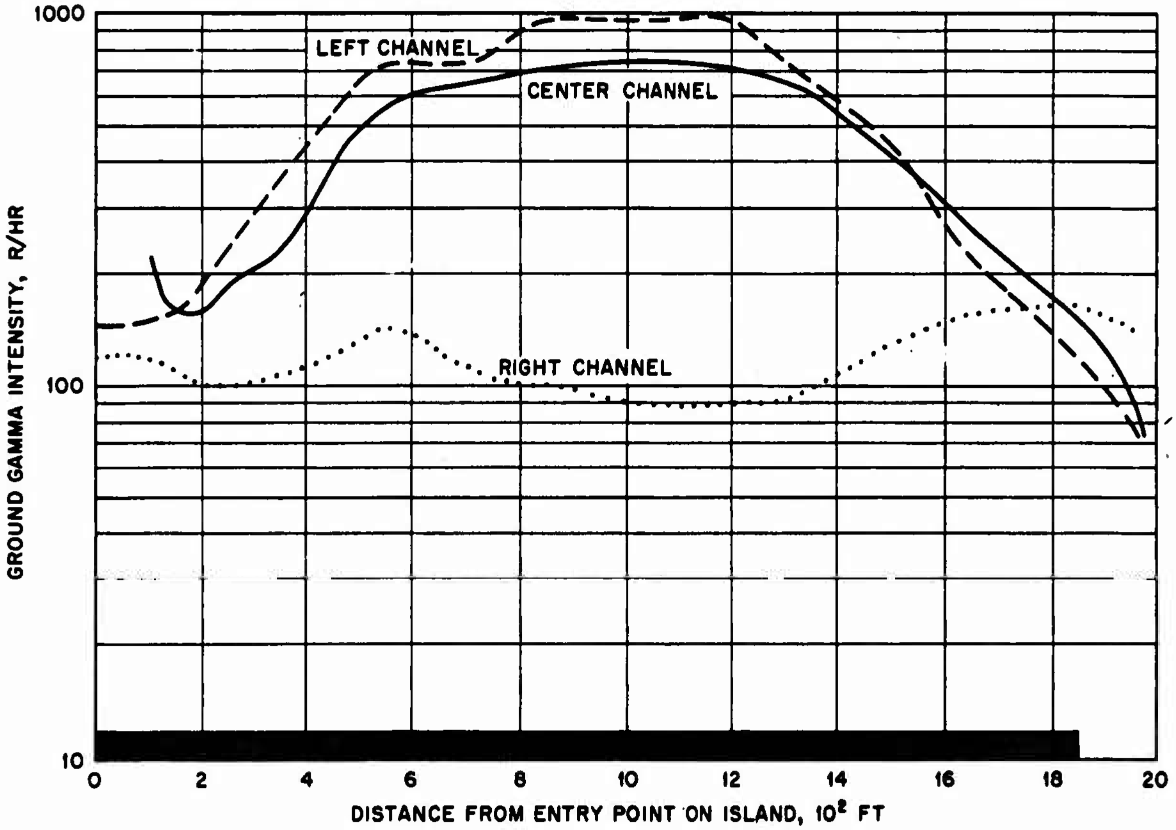

Fig. 4.24 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +32 Hr, Track 127°, Ground Speed 157 Mph, Aircraft Altitude 1000 Ft, Dog Shot

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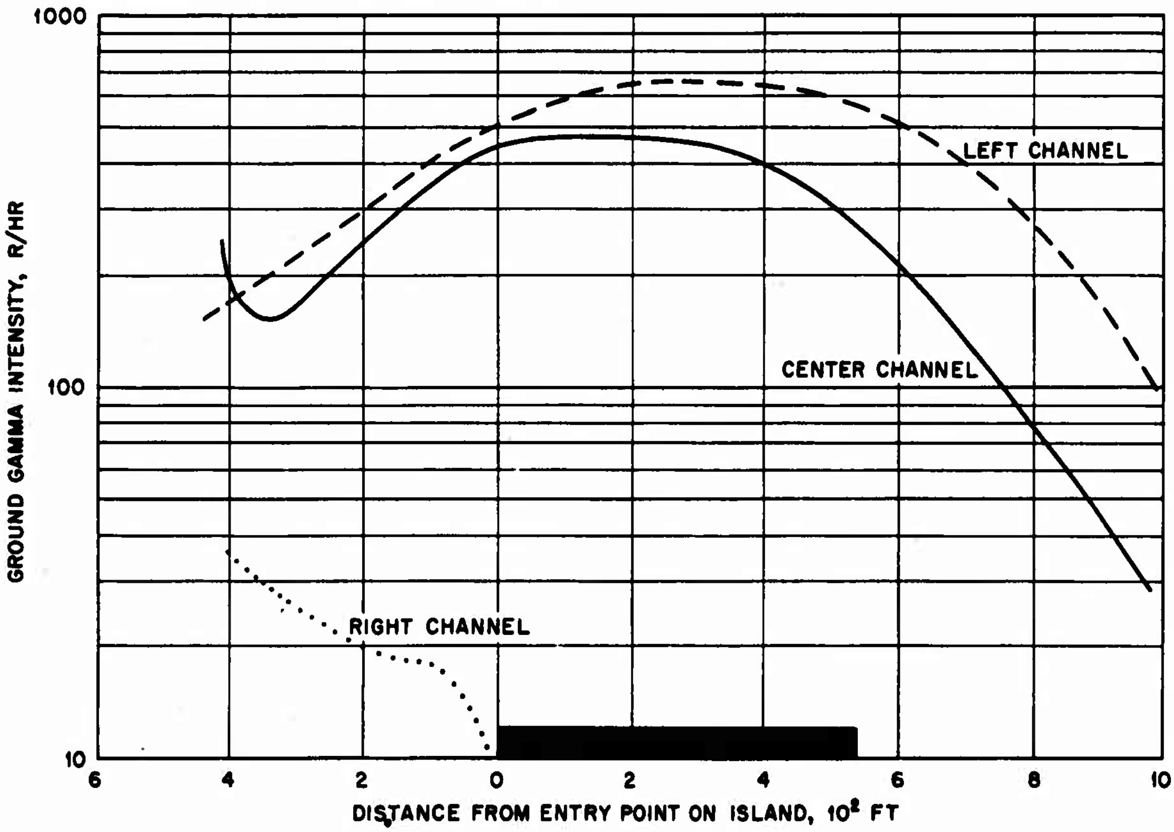

Fig. 4.25 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +32 Hr, Track 210°, Ground Speed 186 Mph, Aircraft Altitude 1000 Ft, Dog Shot

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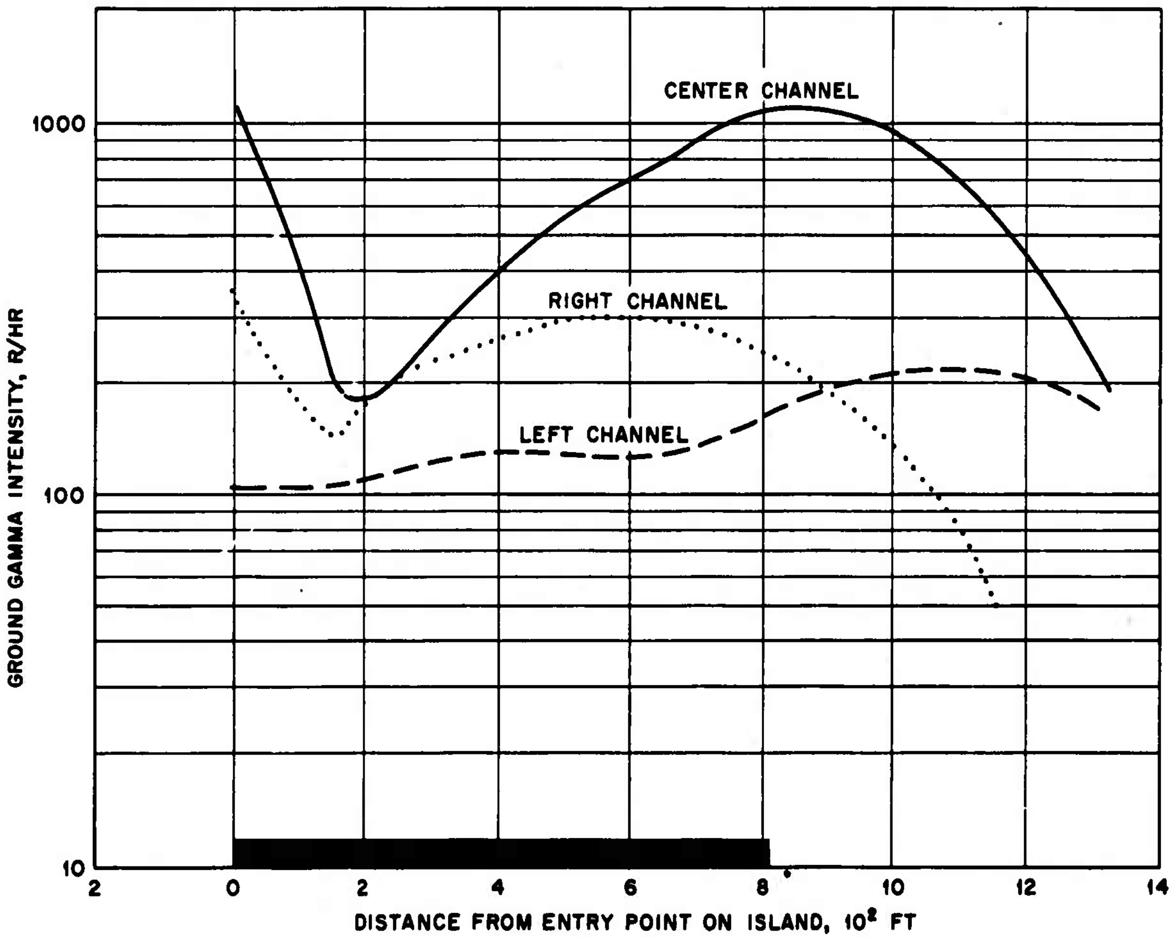

Fig. 4.26 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +32 Hr, Track 351°. Ground Speed 174 Mph, Aircraft Altitude 1000 Ft, Dog Shot

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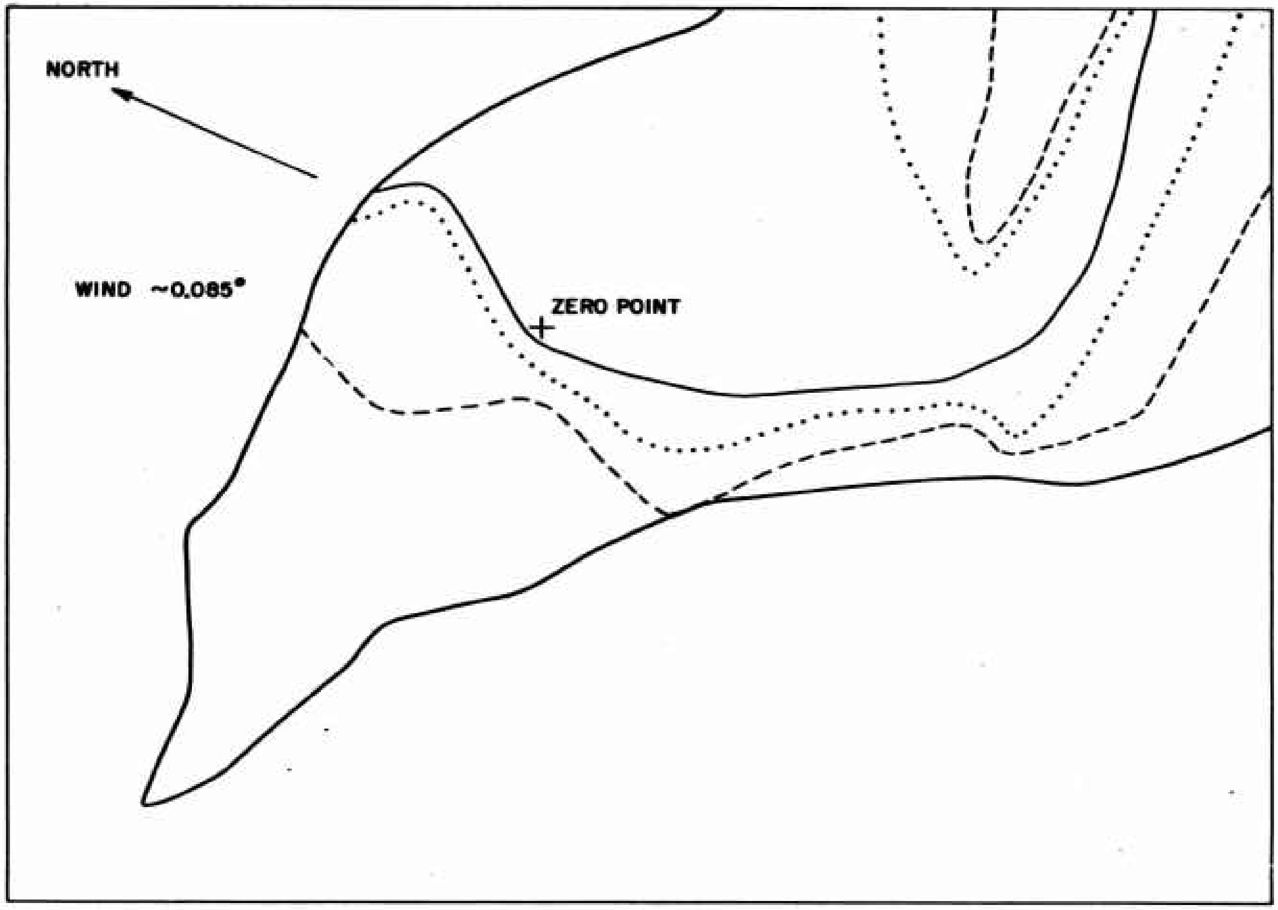

Fig. 4.27 Radioactivity Contours of Runit Obtained with Radiac Set AN/ADR-4, Dog Shot. Time +32 hr, aircraft altitude 1000 ft, distance scale 1 in. = 200 ft. ——, 470 r/hr. ····, 300 r/hr. ----, 200 r/hr.

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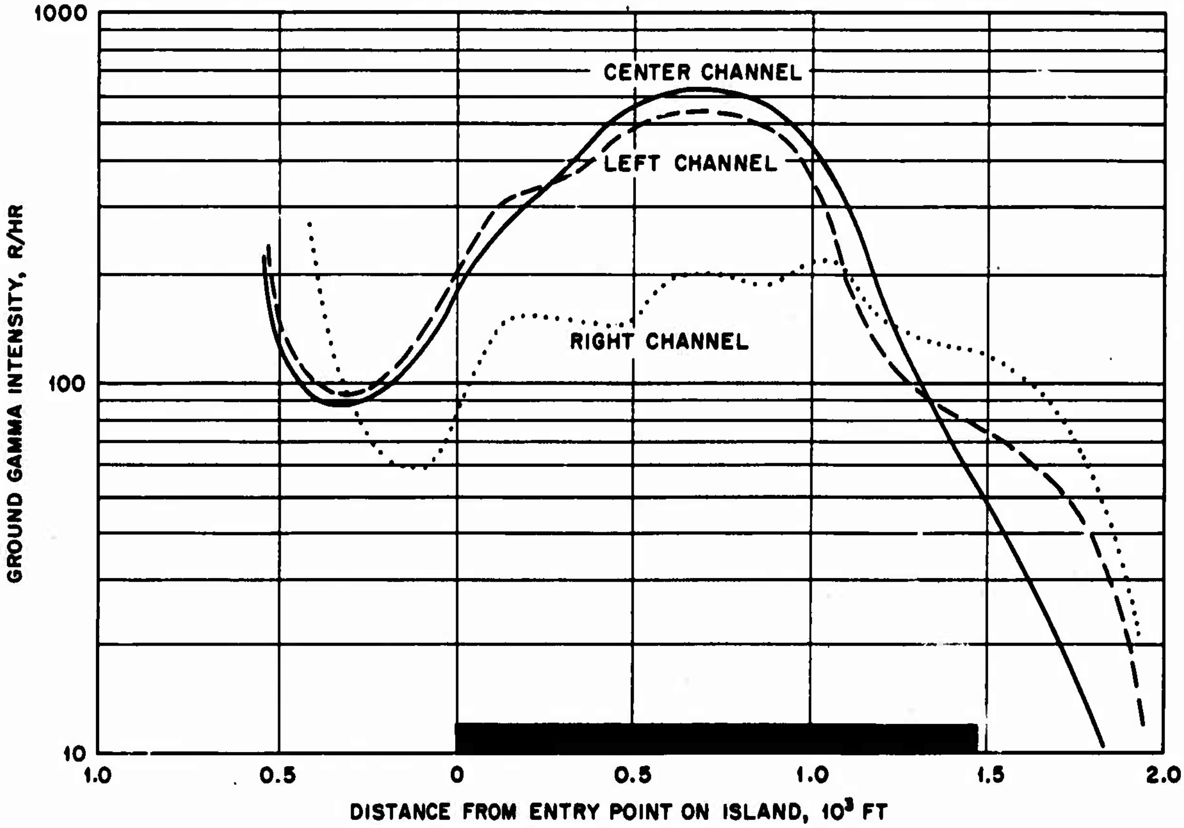

Fig. 4.28 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 59°, Ground Speed 144 Mph, Aircraft Altitude 500 Ft, Easy Shot

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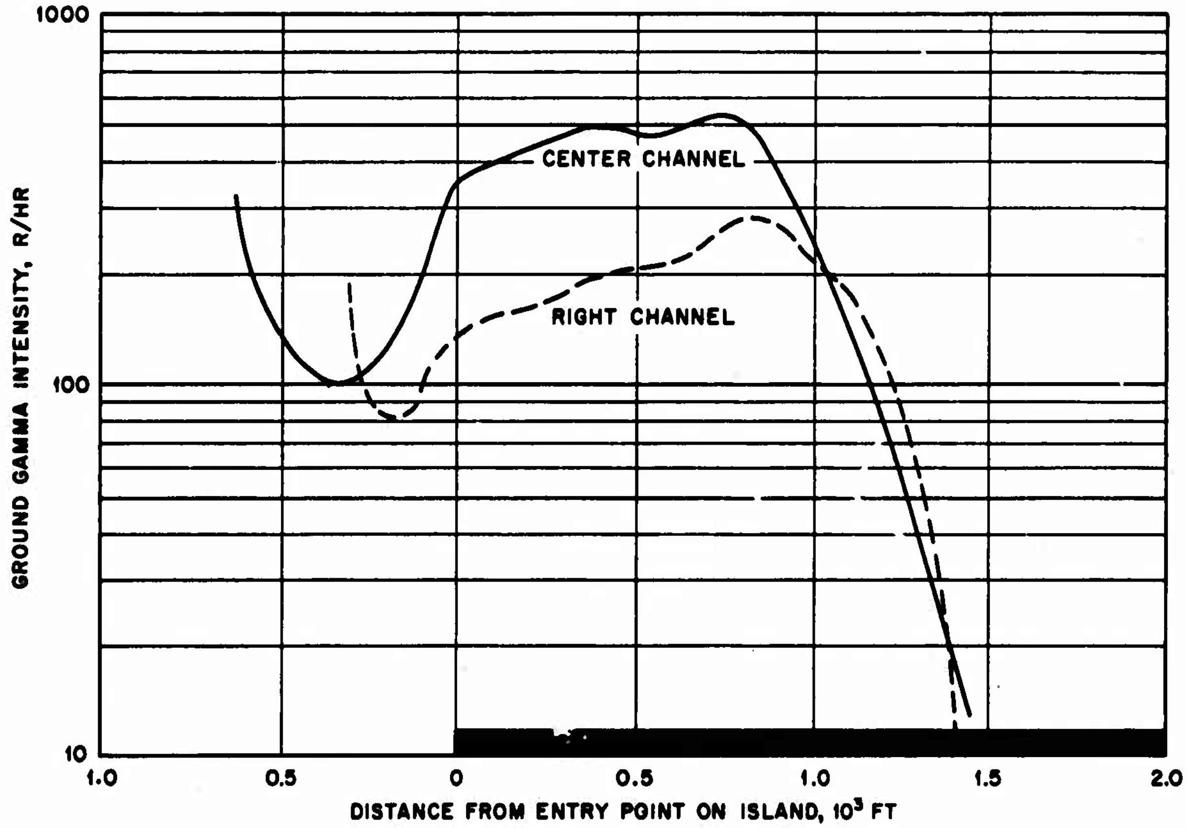

Fig. 4.29 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 78°, Ground Speed 146 Mph. Aircraft Altitude 500 Ft, Easy Shot. Aircraft passed 100 ft right of target.

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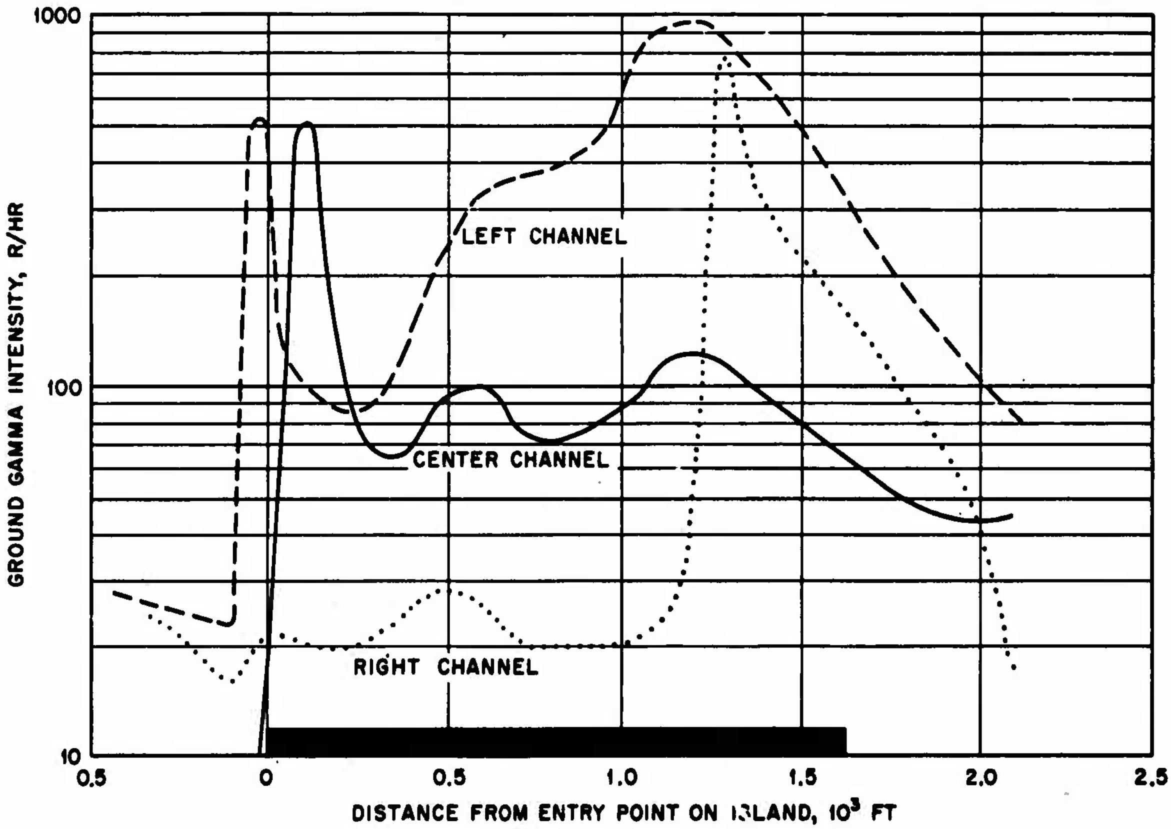

Fig. 4.30 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 153°, Ground Speed 158 Mph, Aircraft Altitude 500 Ft, Easy Shot. Aircraft passed 150 ft right of target.

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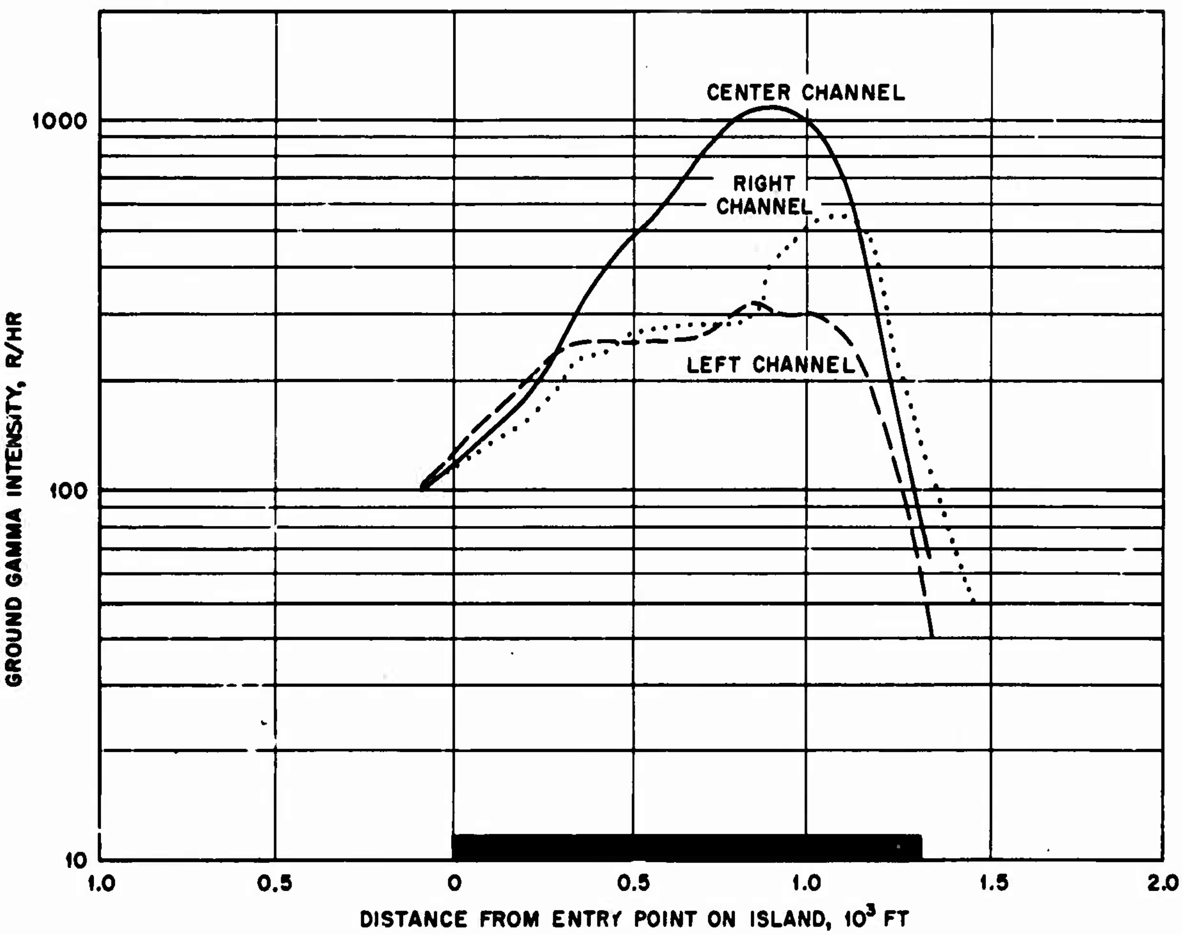

Fig. 4.31 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 355°, Ground Speed 153 Mph, Aircraft Altitude 500 Ft, Easy Shot

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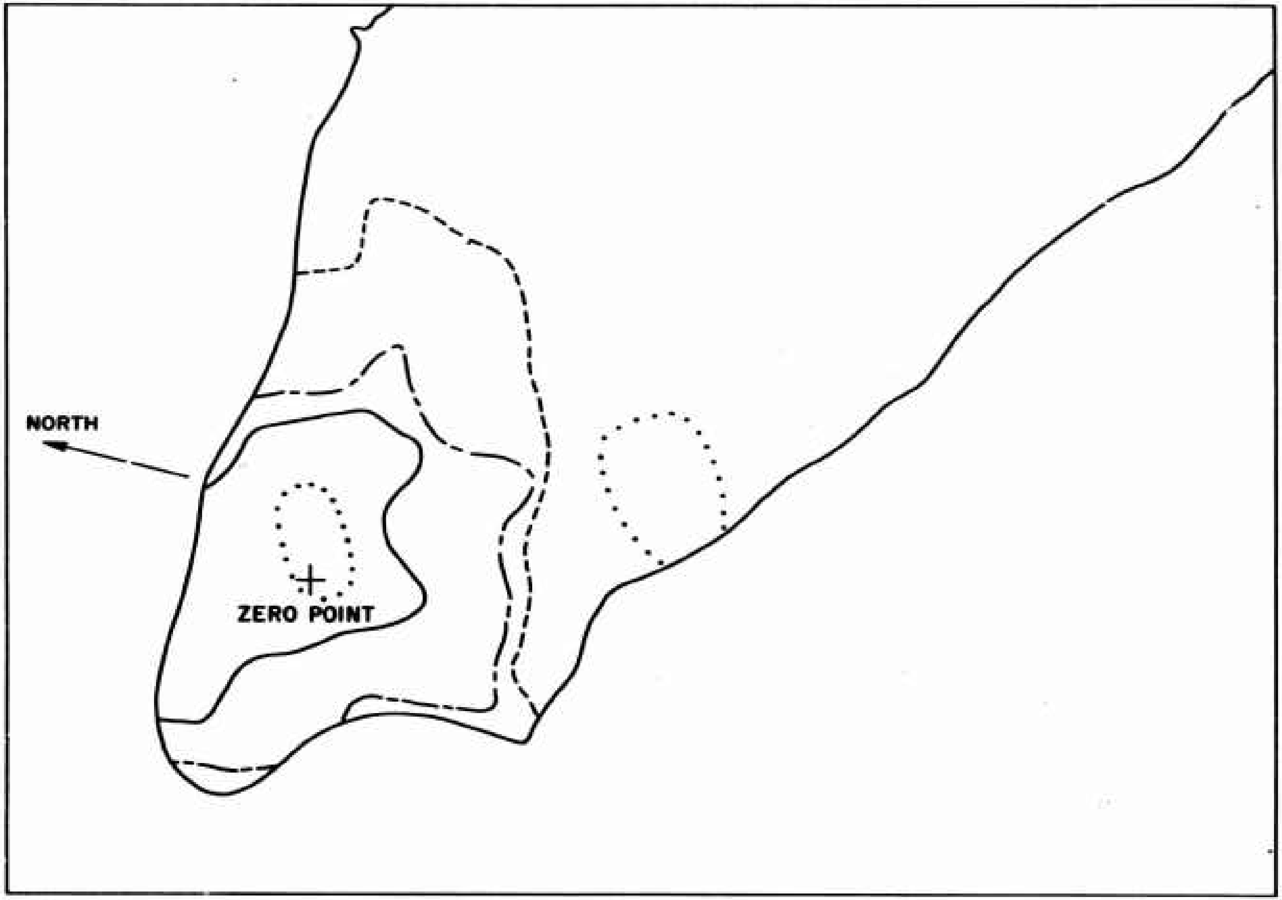

Fig. 4.32 Radioactivity Contours of Engebi Obtained with Radiac Set AN/ADR-4, Easy Shot. Time +33 hr, aircraft altitude 500 ft, distance scale 1 in. = 363 ft. ····, 600 r/hr. ——, 300 r/hr. —–-, 200 r/hr. ----, 100 r/hr.

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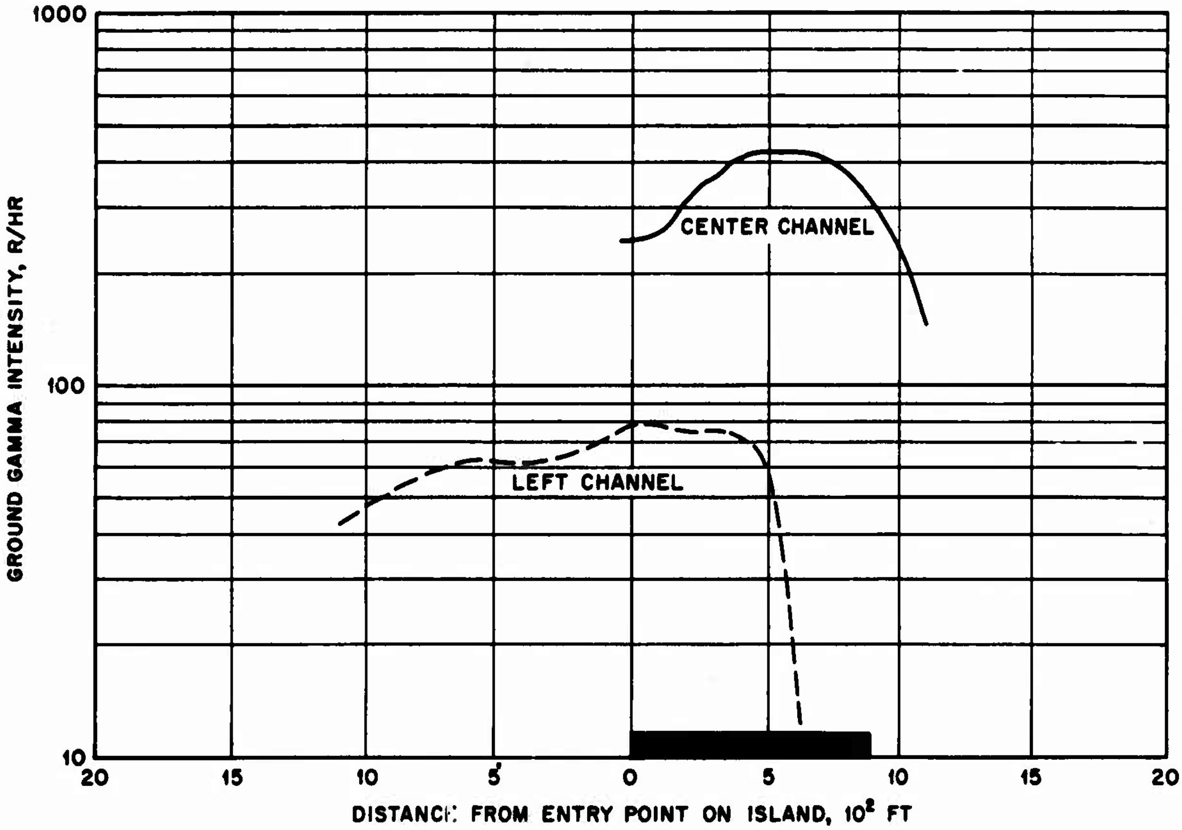

Fig. 4.33 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 45°, Ground Speed 144 Mph, Aircraft Altitude 1000 Ft, Easy Shot

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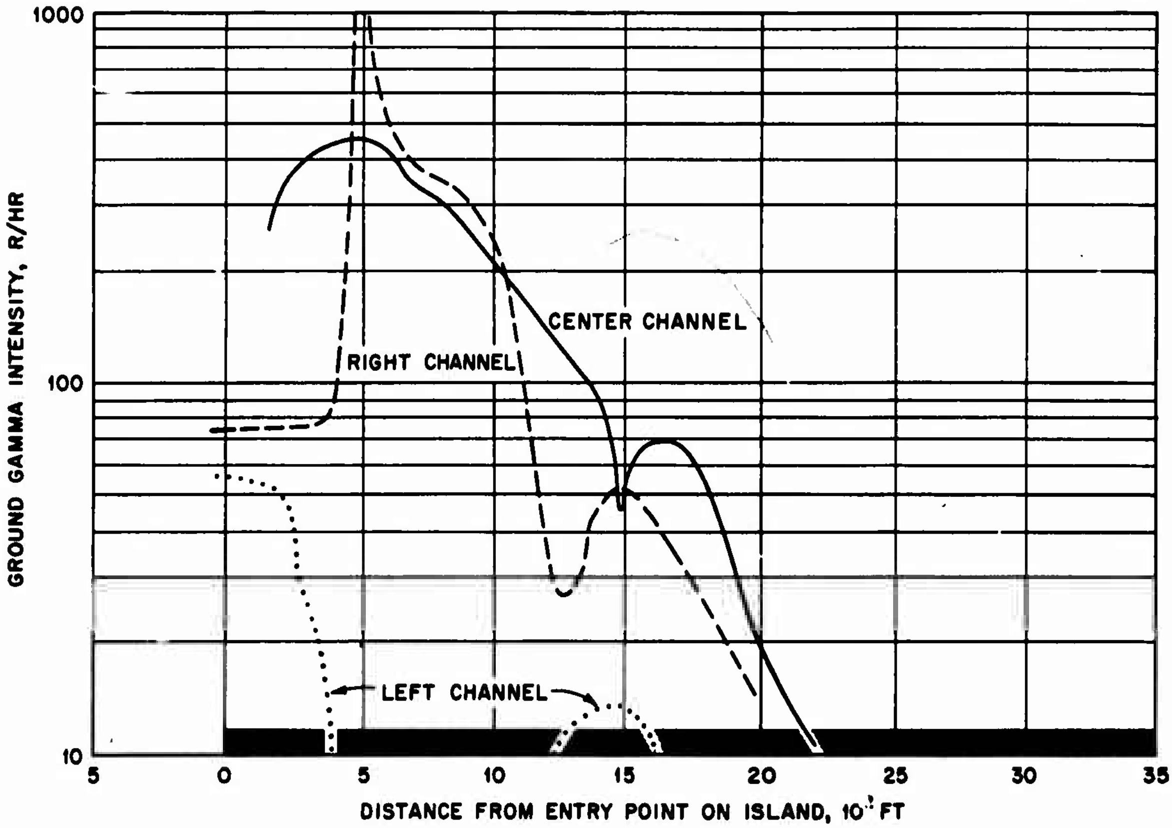

Fig. 4.34 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 91°, Ground Speed 146 Mph, Aircraft Altitude 1000 Ft, Easy Shot

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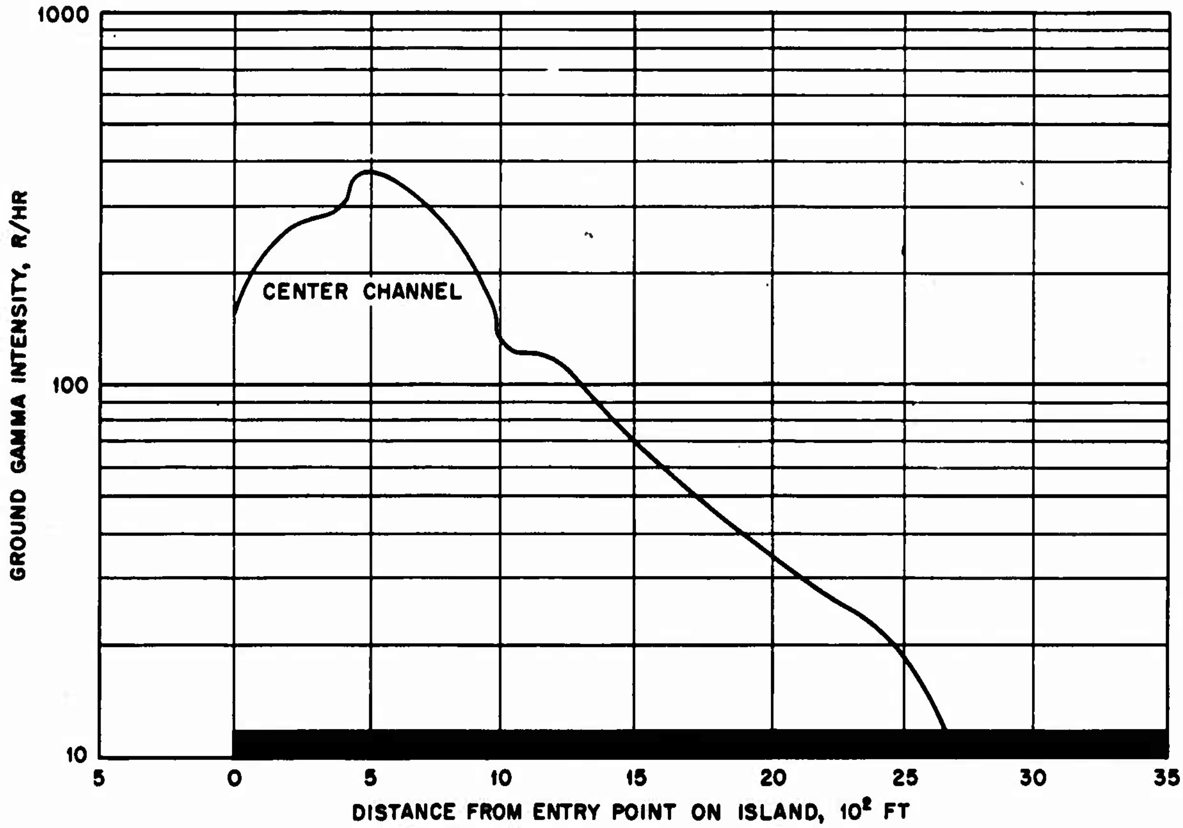

Fig. 4.35 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 135°, Ground Speed 158 Mph, Aircraft Altitude 1000 Ft, Easy Shot

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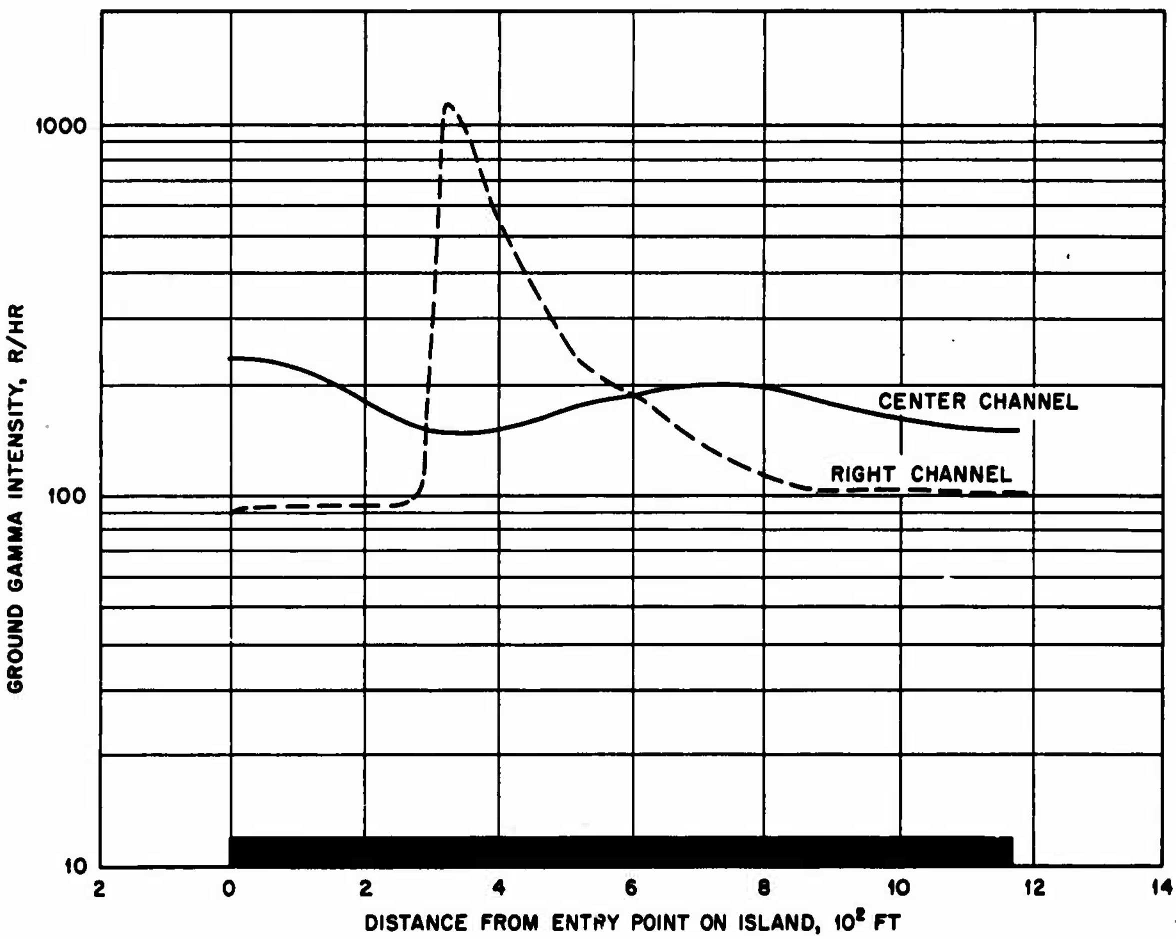

Fig. 4.36 Ground Gamma Intensity, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 355°, Ground Speed 153 Mph, Aircraft Altitude 1000 Ft, Easy Shot

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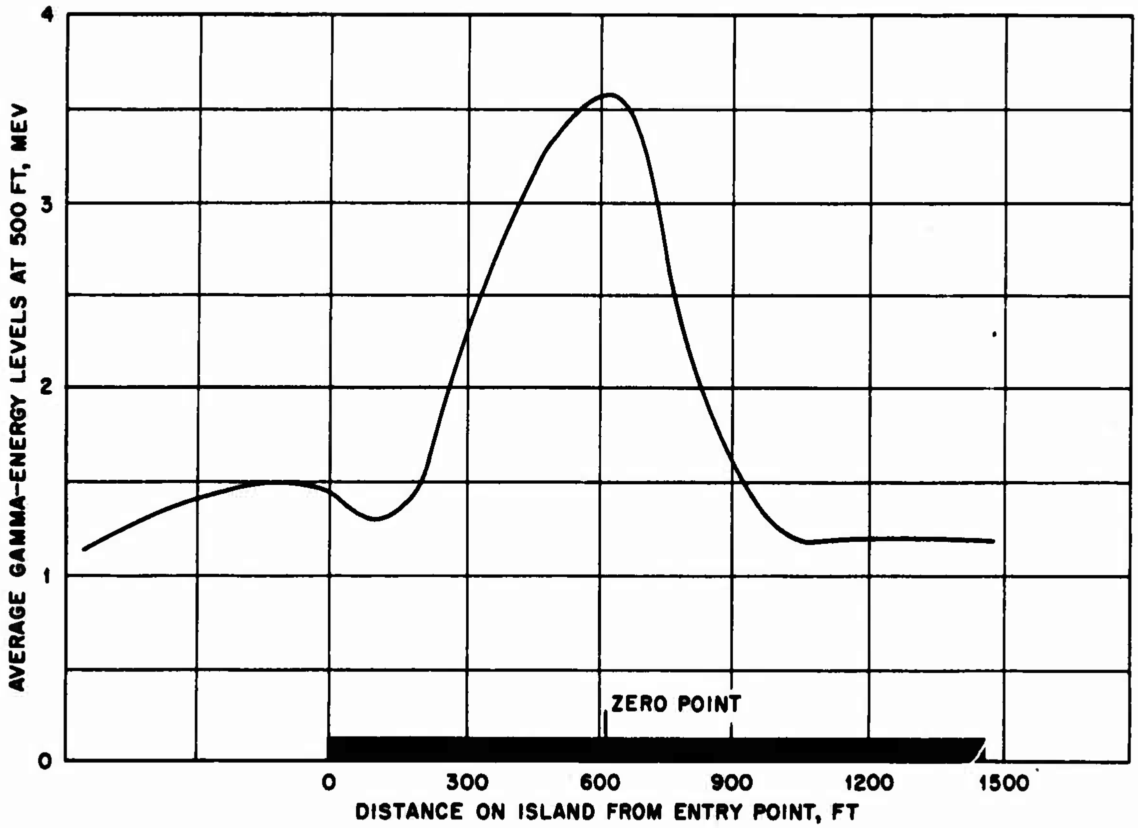

Fig. 4.37 Average Gamma-energy Levels at 500 Ft, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 59°, Easy Shot. Aircraft passed 200 ft right of zero point.

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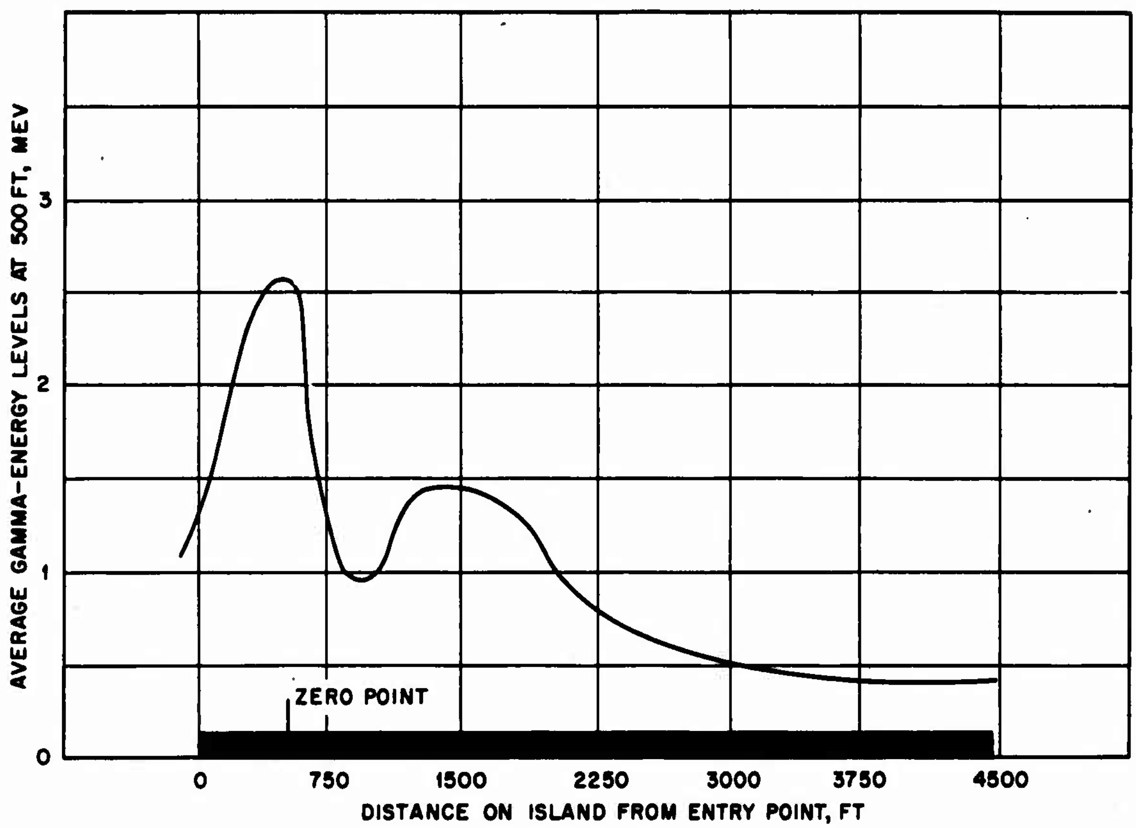

Fig. 4.38 Average Gamma-energy Levels at 500 Ft, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 78°, Easy Shot. Aircraft passed 100 ft right of zero point.

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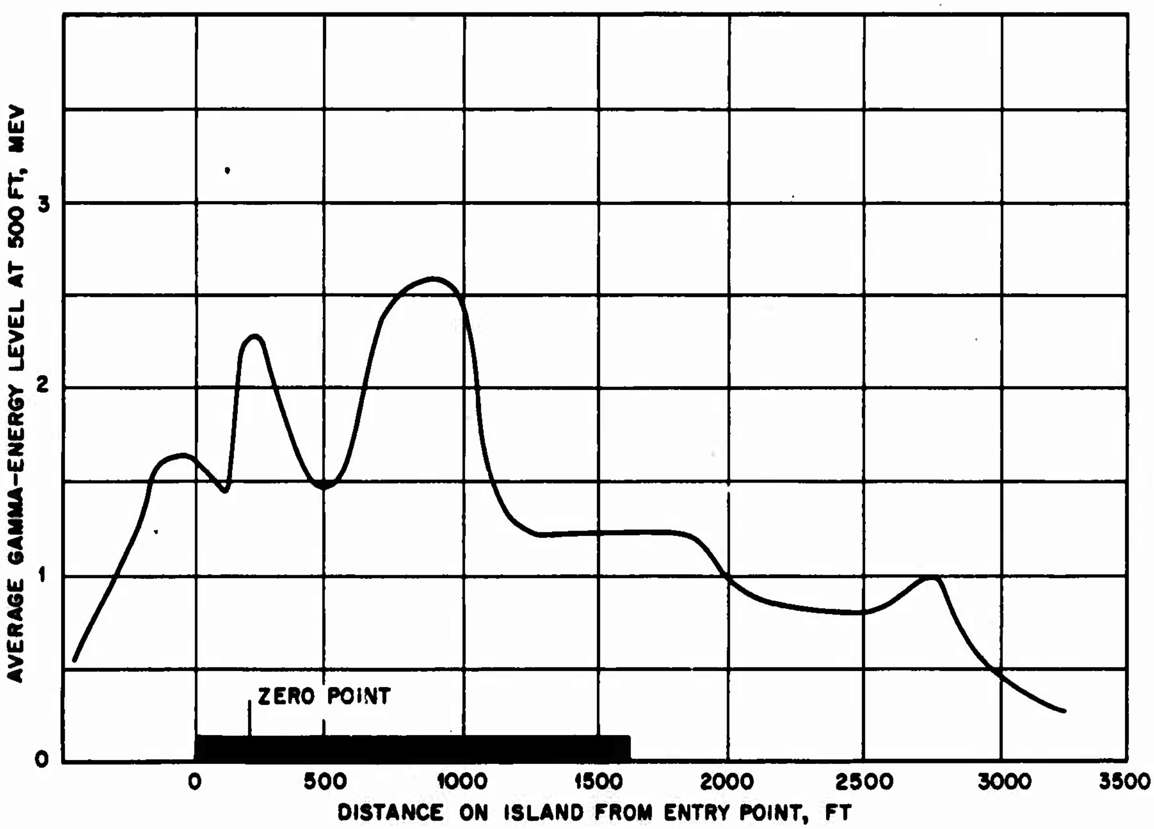

Fig. 4.39 Average Gamma-energy Levels at 500 Ft, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 153°, Easy Shot. Aircraft passed approximately 150 ft right of zero point.

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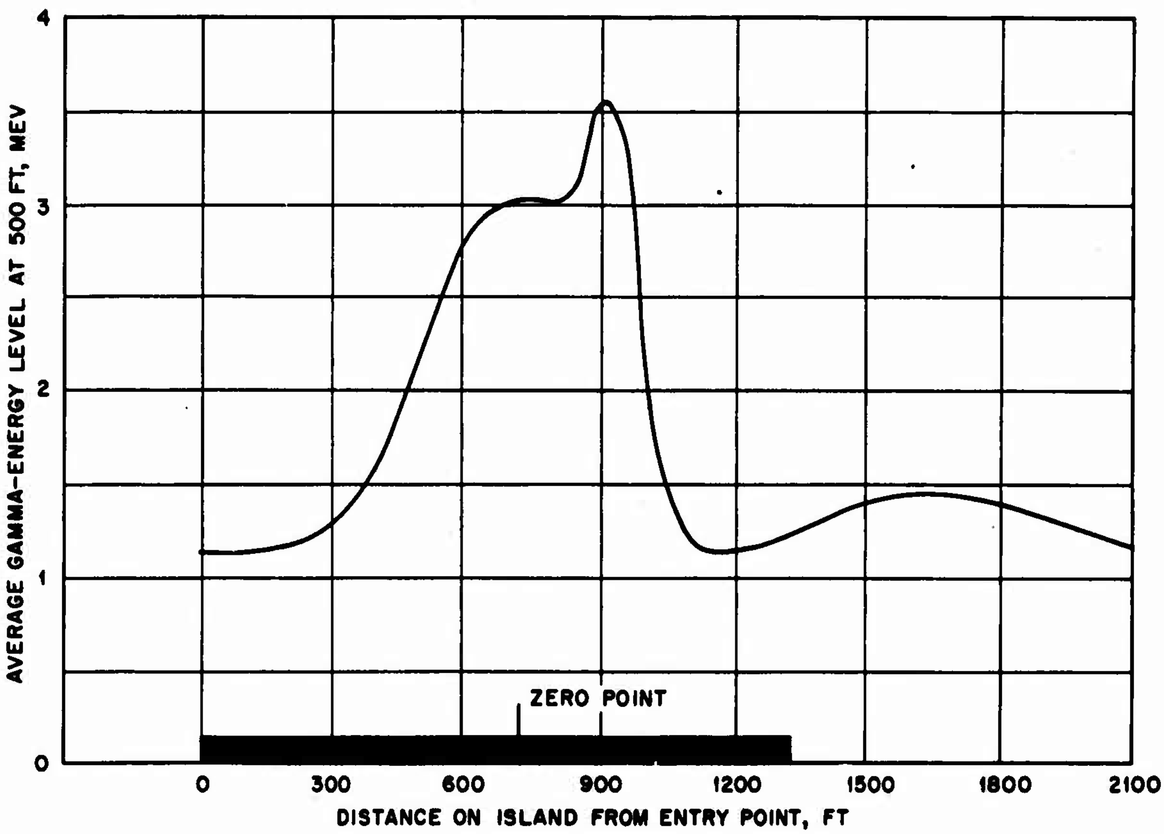

Fig. 4.40 Average Gamma-energy Levels at 500 Ft, Measured with Radiac Set AN/ADR-4, +33 Hr, Track 355°, Easy Shot

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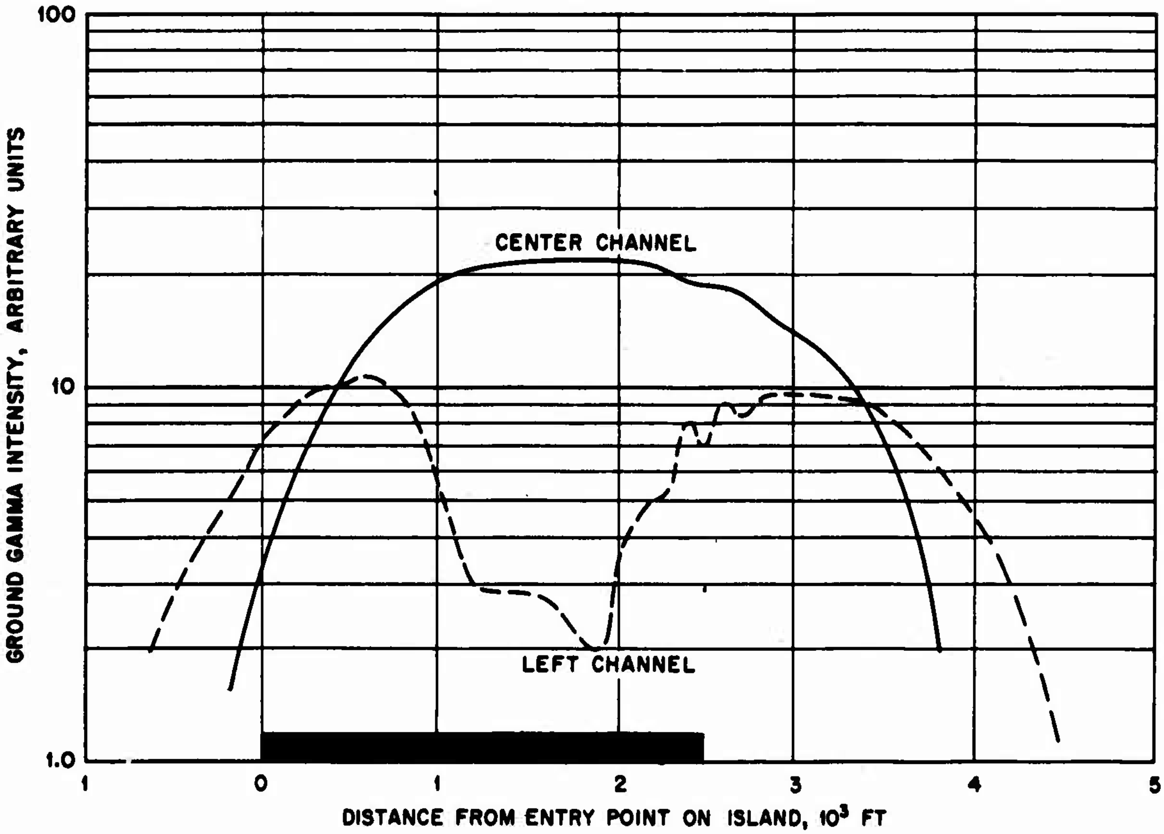

Fig. 4.41 Ground Gamma Intensity, Measured with Surface-survey Set Type F-1, +55 Hr, Track 55°, Ground Speed 135 Mph, Aircraft Altitude 500 Ft, Dog Shot

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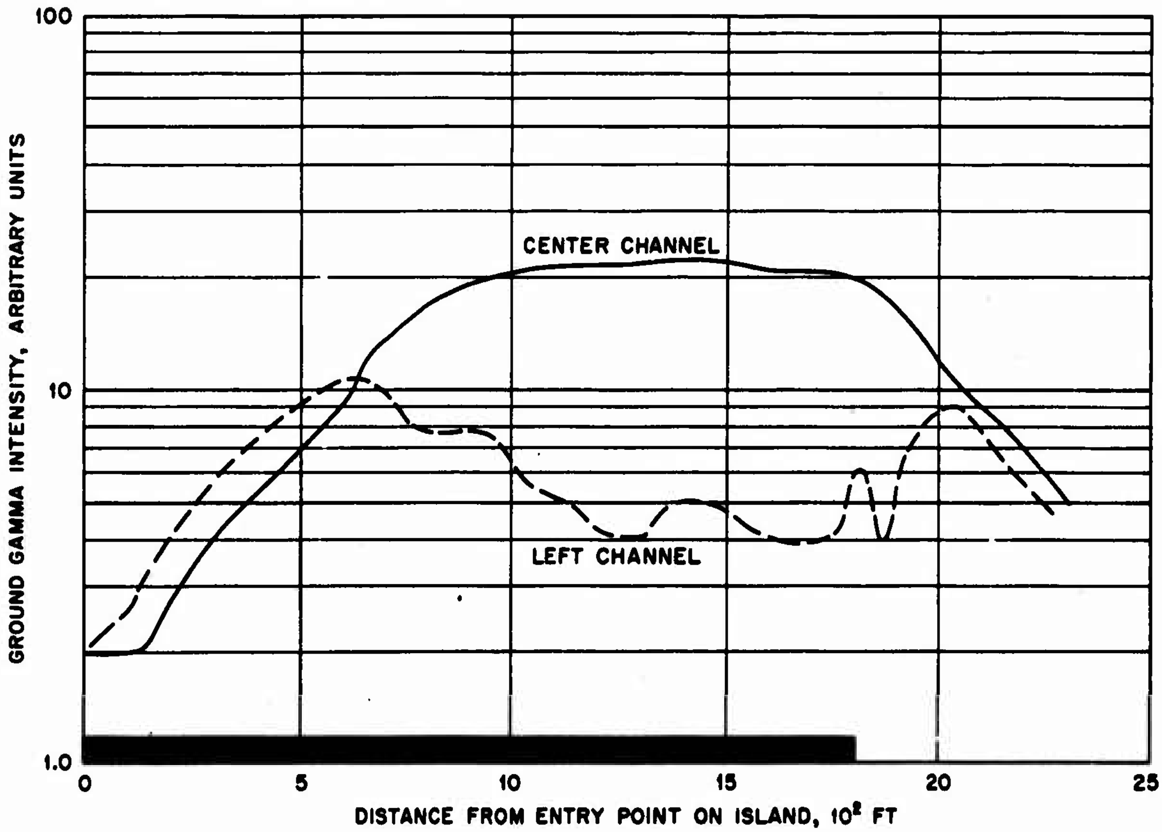

Fig. 4.42 Ground Gamma Intensity, Measured with Surface-survey Set Type F-1, +55 Hr, Track 280°, Ground Speed 184 Mph, Aircraft Altitude 500 Ft, Dog Shot

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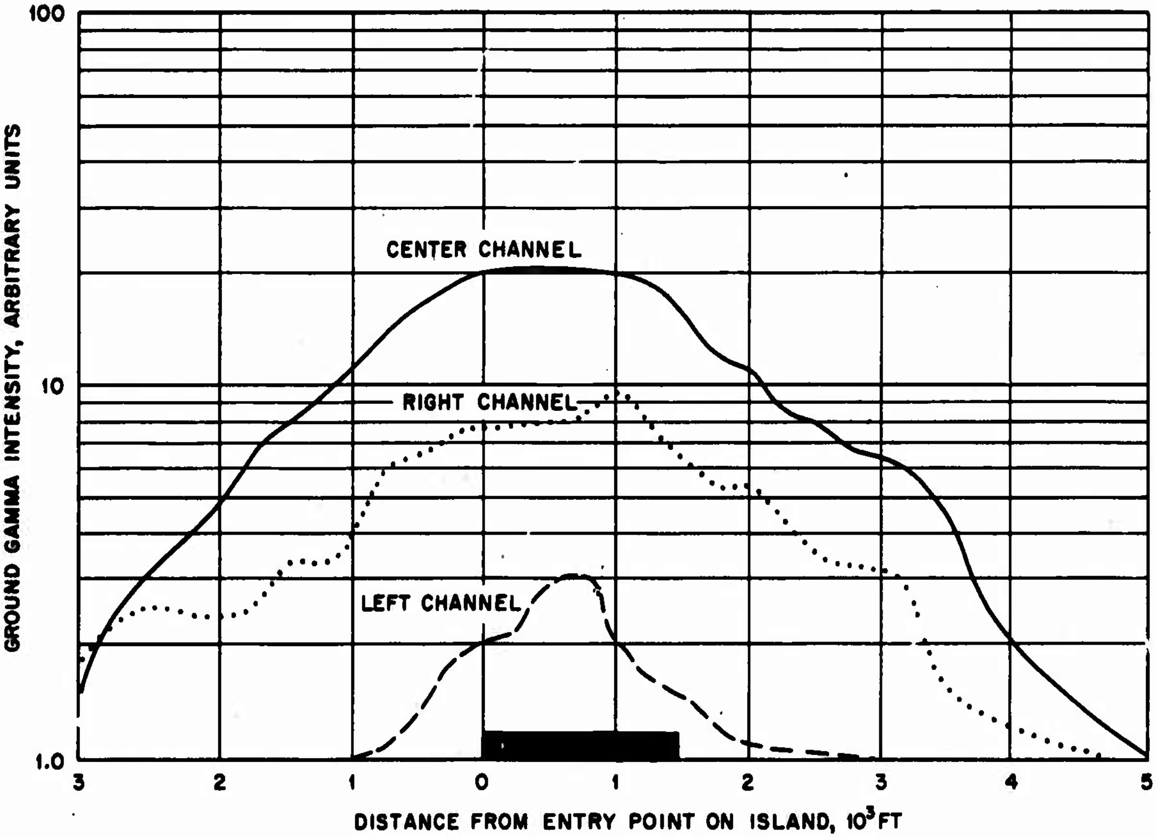

Fig. 4.43 Ground Gamma Intensity, Measured with Surface-survey Set Type F-1, +25 Hr, Track 120°, Ground Speed 142 Mph, Aircraft Altitude 1700 Ft, George Shot. Aircraft passed slightly to left of target.

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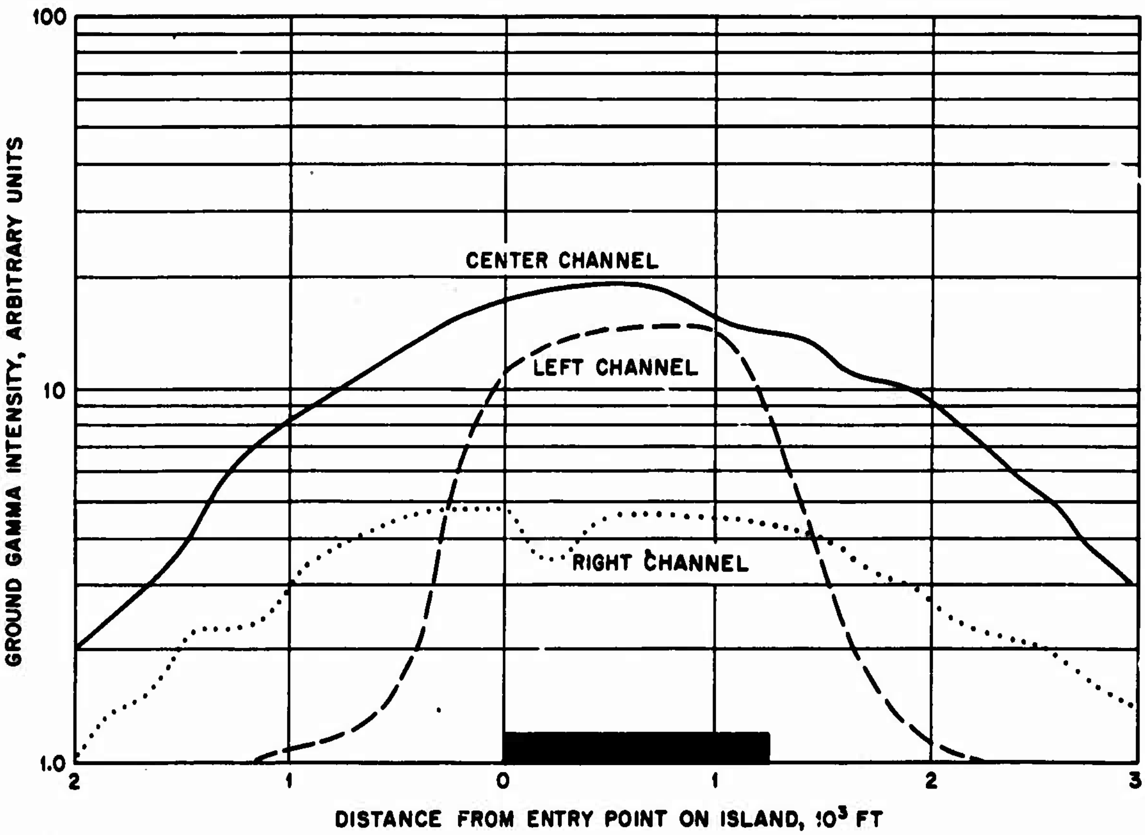

Fig. 4.44 Ground Gamma Intensity, Measured with Surface-survey Set Type F-1, +25 Hr, Track 360°, Ground Speed 187 Mph, Aircraft Altitude 1700 Ft, George Shot. Aircraft passed slightly to right of target.

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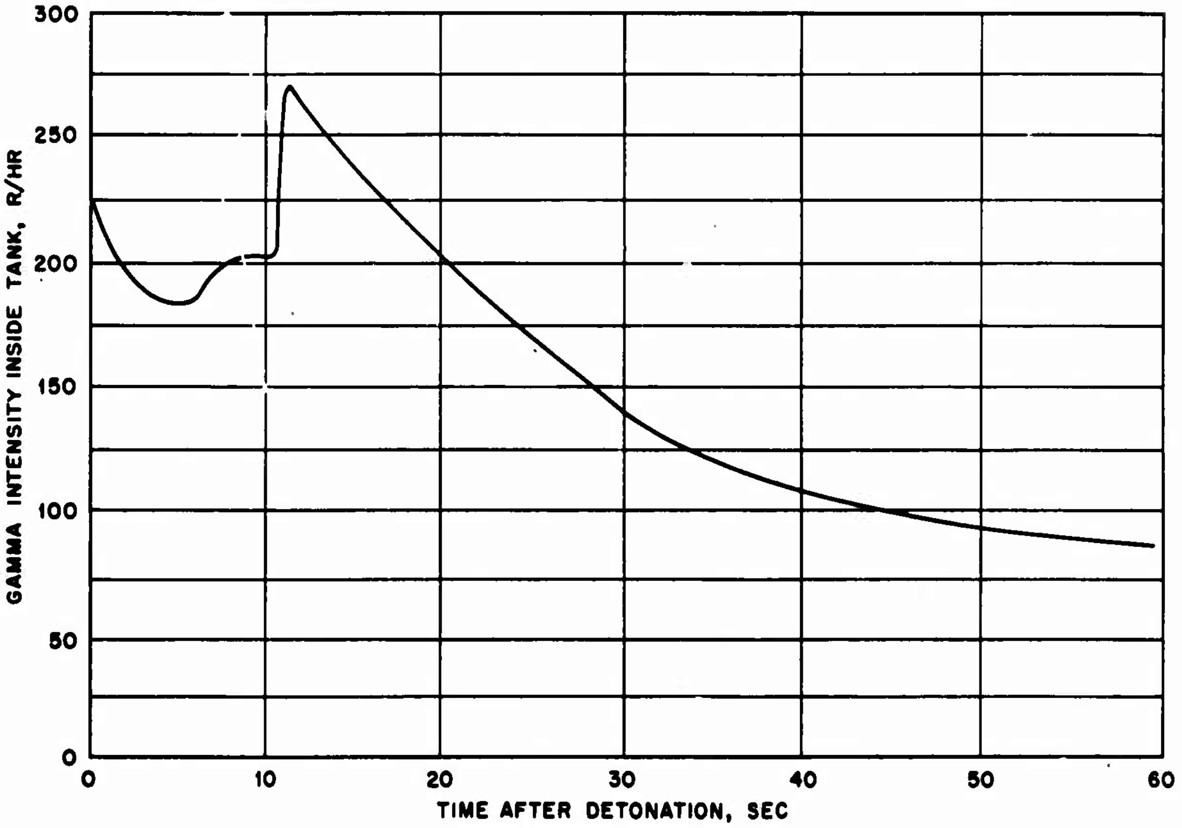

Fig. 4.45 Variation of Gamma Intensity Inside Tank, Measured with AN/USQ-1 and AN/ARR-29 Telemetering System, 0 to +60 Sec, Range to Tank 750 Yd, Easy Shot

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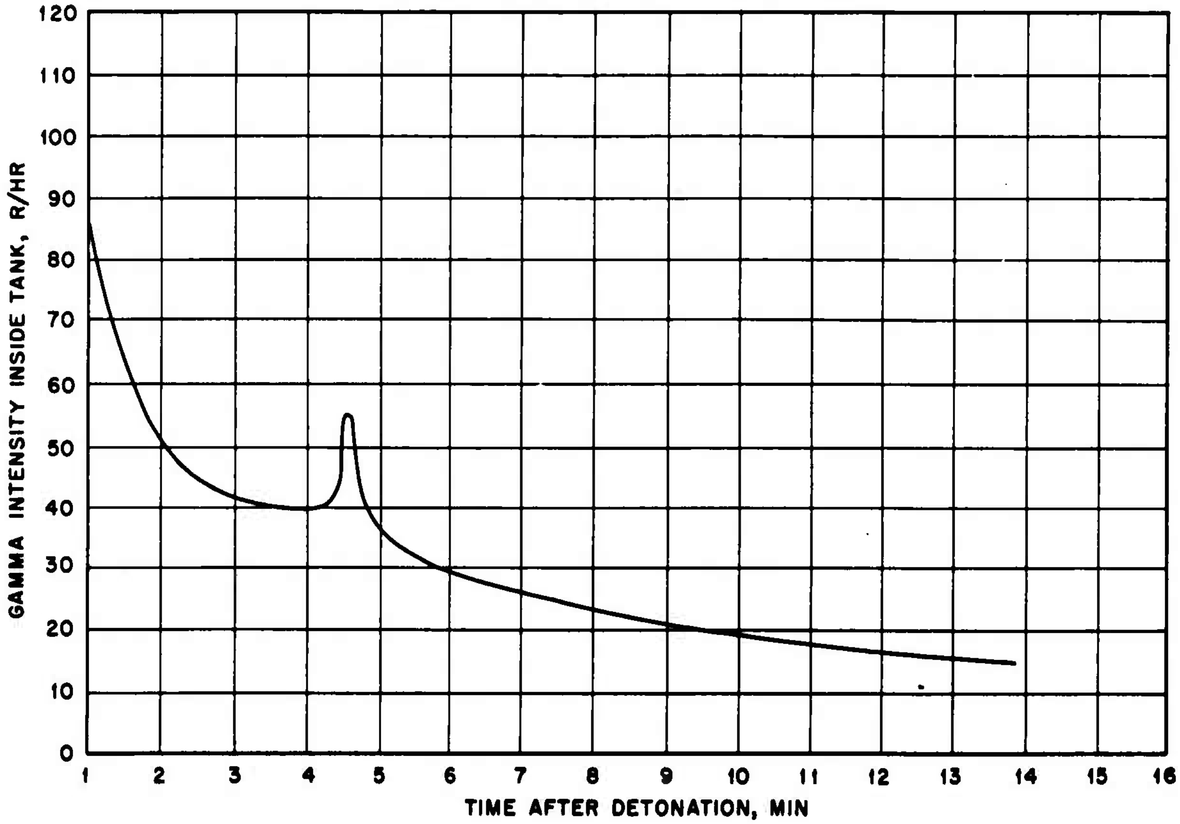

Fig. 4.46 Variation of Gamma Intensity Inside Tank, Measured with AN/USQ-1 and AN/ARR-29 Telemetering System, +1 to +14 Min, Range to Tank 750 Yd, Easy Shot

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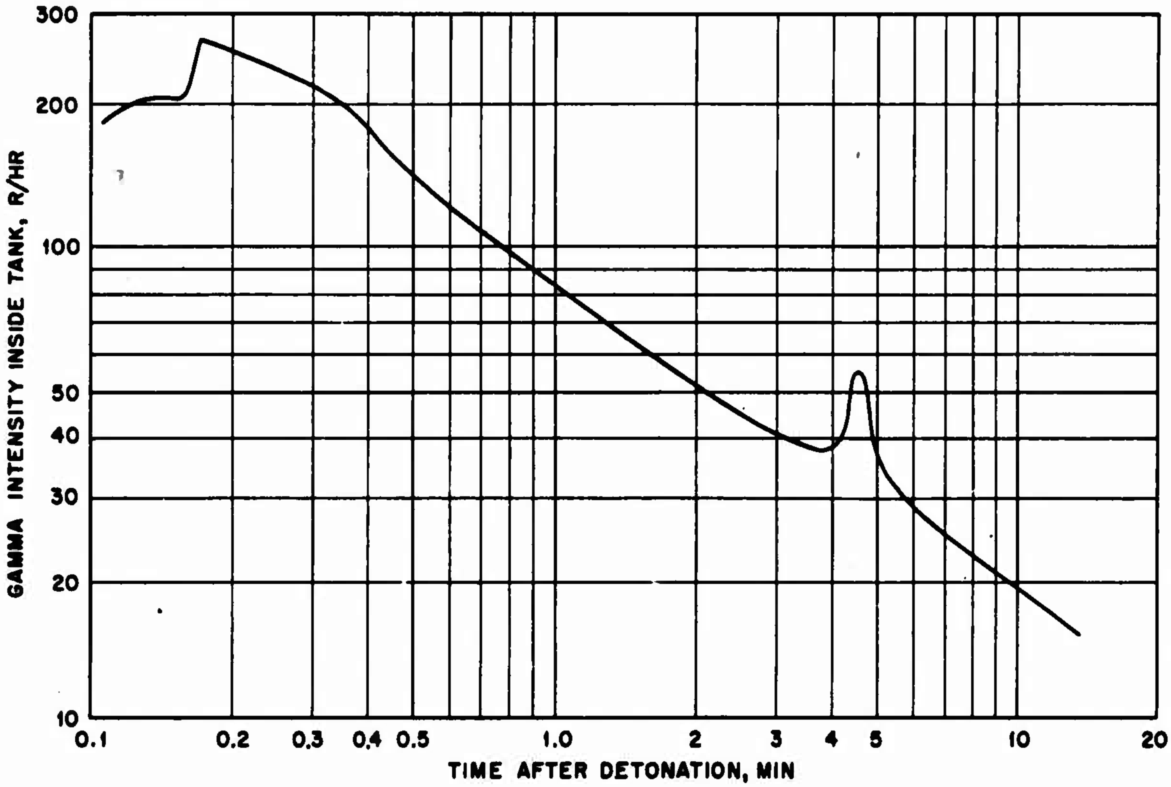

Fig. 4.47 Log-log Graph of Gamma Intensity Inside Tank, Measured with AN/USQ-1 and AN/ARR-29 Telemetering System, Range to Tank 750 Yd

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accessory failures. The mechanical devices in the AN/USQ-1 which caused all the difficulty were the mechanical timer, which activates the units after a preset time delay, and the antenna erection mechanism.

In approximately 25 per cent of the cases where the units failed to operate properly, it was found that, upon striking the ground, the units bounced and landed in such a manner as to bury the antenna partially, thus making transmission impossible. The correction of the mechanical deficiencies will involve some major changes.

On Dog shot approximately eight units were dropped into the crater and surrounding areas. Those dropped into the crater worked satisfactorily; however, the intensity in the crater at the time of drop was beyond the range of the equipment.

The AN/USQ-1 units were dropped into the crater area approximately 100 ft from zero point about 12 hr after Easy shot. These units indicated that the intensity was approximately 200 r/hr. Units dropped approximately 750 yd from zero point, about 3 hr after the Easy detonation, indicated that the intensity was approximately 20 r/hr.

One AN/USQ-1 unit was placed inside a medium tank. The antenna was placed on the top of the tank. This tank was stationed approximately 750 yd from zero point. Prior to leaving Engebi Island, a time-delay switch of $17\frac{1}{2}$ hr was inserted into the timer of the AN/USQ-1. Approximately 1 hr prior to shot time, the P2V-2, while circling at a 24-mile radius from zero point, received and monitored this unit. The AN/USQ-1 unit was continuously monitored from the P2V-2. At zero time the intensity indication rose extremely rapidly; however, because of the very slow-response Esterline-Angus recorder used with the AN/ARR-29 receiver in the aircraft, the prompt radiation could not be recorded. A fraction of a second later the recorder began recording the actual gamma radiation in the tank. When the shock wave reached it, the tank capsized. The capsizing of the tank apparently took several seconds in which it probably teetered and finally landed on its back. The underside of the tank apparently had slightly less shielding because the radiation intensity inside the tank increased slightly. This is shown in Fig. 4.45. Although the tank, with the antenna mounted on top, capsized, the transmission of data from it continued without any difficulty. The transmitted and recorded data indicated that, approximately $4\frac{1}{2}$ min after the detonation, a slight increase in the intensity occurred. This was probably caused by some fall-out or by a radioactive mist floating by. Figure 4.45 indicates the intensity present in the tank during the first minute. Figure 4.46 covers the period from +1 min to approximately 14 min, at which time the intensity inside the tank was approximately 16 r/hr. Figure 4.47 includes the same data as Figs. 4.45 and 4.46; however, these data are plotted on log-log graph paper to indicate the decay rates more clearly.

In so far as it was possible to determine, the electronic circuits of the AN/USQ-1 and AN/ARR-29 gamma-radiation telemetering system functioned exceedingly well. Practically all the difficulties experienced were concerned with the mechanical accessories.

4.9 FARRAND MARK 7 INFRARED DETECTION EQUIPMENT

The equipment detected and tracked the radioactive cloud for as long as $2\frac{1}{2}$ hr after the detonation. It also received signals from ordinary clouds.

This equipment was neither designed nor constructed for the purpose of detecting radioactive clouds but was thought of as a general infrared measuring device. This equipment has been used for infrared measuring purposes for many years.

The operation of this equipment was uneventful. It gave good results throughout the test and indicated that the radioactive cloud can be detected under the proper weather and atmospheric condition by the infrared radiation emanating from it.

Chapter 5

Conclusions and Recommendations

5.1 GENERAL EVALUATION

The tests made under this project demonstrated very clearly the shortcomings as well as the advantages of the various types of equipment and techniques used.

5.2 AN/ADR-1

This radiac equipment worked very satisfactorily during this operation. The test results indicate that this equipment would make a very good interim air-borne radiac instrument until such time as a lighter and smaller unit is developed. This smaller and lighter version of the AN/ADR-1 should also have a top range of 500 r/hr.

5.3 AN/ADR-2

Although this equipment worked satisfactorily throughout the entire test, it appears that, for general use, the functions that the AN/ADR-2 was originally intended to perform can be obtained more expeditiously by other instruments. The dose-rate vs time information can be obtained better on the AN/ADR-1, and the accumulated-dosage information can be obtained by an extremely small, light-weight, and simple instrument employing some circuitry developed in the AN/ADR-2. Accordingly, it is recommended that the AN/ADR-2, as such, be discontinued and that its functions be absorbed by the AN/ADR-1 and a small electronic dosimeter employing the AN/ADR-2 dosage-indicating circuitry.

5.4 TYPE E-1 BETA AIR MONITOR

As previously mentioned, this equipment was built to evaluate the detection technique employed and was not designed to withstand the extremes of environmental conditions encountered at Eniwetok. A great deal of difficulty was encountered in maintaining the electronic circuitry in an operating condition; however, good results were obtained in one drone installation, and it is felt that these results show that this detection technique is satisfactory for the selective detection of beta particles in a high-gamma field. It is inherent with this technique that some delay is encountered in the indication of a tolerance concentration of beta-emitting particles. However, no method is known at present which will detect and instantaneously indicate a tolerance concentration of these particles in a high-gamma field. Thus delay in indication is offset, to some extent, by the fact that the tolerance concentration, as used in this instrument, is the concentration that, in an 8-hr period, would give a tolerance dosage. Present equipment is heavy, bulky, and unreliable, and work is proceeding to reduce the size and weight and to improve operational reliability of the equipment. It is recommended that such work be continued and that some effort be expended to improve the response time of the instrument.

5.5 AN/USQ-1 AND AN/ARR-29 TELEMETERING SYSTEM

Approximately 40 per cent of the AN/USQ-1 telemetering units operated satisfactorily. The outstanding deficiencies in the equipment were the mechanical accessories. The electronics, as far as could be determined, worked very satisfactorily. The mechanical devices which gave practically all the trouble included the mechanical timer, which energized the equipment after a preset delay time, and the antenna erection mechanism. It is recommended that these units be revised so that the mechanical accessories are improved or completely removed. It is also recommended that the radio telemetering range be extended as far as is practical.

5.6 AN/ADR-4

These tests indicated that the AN/ADR-4, with a few minor improvements, will make very effective operational air-borne ground-surface survey equipment. It is recommended that the AN/ADR-4 be modified to include the following changes:

1. Employ one channel instead of the three now used.
2. Reduce the field of view of the one channel from 30° to approximately 10°.
3. Reduce the weight to approximately 250 lb.

These modifications, which are relatively simple to incorporate, will make this equipment a valuable asset to air-supported ground atomic warfare.

5.7 TYPE F-1 GROUND-SURVEY EQUIPMENT

Although this equipment suffered from extreme instability during the test, it was apparent that the detection head had some directivity; it was also apparent that the directivity was no better than the directivity obtained by the use of shadow shielding employed in the AN/ADR-4. Since it was not possible to obtain actual quantitative measurements because of the instability of the electronic circuitry, the effect of not correcting for energy levels could not be determined. From measurements made with the AN/ADR-4 and by other means, it would seem that some consideration should be given to the attenuation change caused by energy levels. In so far as this equipment is concerned, it is recommended that further development work be conducted to consider the possibility of employing a shadow type shield, or any other relatively light directive detecting systems, and to improve the stability of the electronic computing circuitry. It is further recommended that the effect of average energy level on attenuation corrections be considered.

5.8 AN/ADR-3

Although this cloud tracker operated satisfactorily during two of the three shots, it fell short of expectations. The most salient difficulty was the reception and detection of spurious and unaccounted for signals. Some of these signals which could not be directly related to the visible portion of the atomic cloud could very easily have emanated from the invisible part of the radioactive cloud. It is recommended that additional research and development work be carried on to increase the sensitivity and speed of response of the equipment. It is further recommended that a study and experimental project be initiated to investigate the background signals received and detected by the equipment. Because of the absence of scattering (such as was present when working with gamma-radiation detection) and the negligible effect of weather, the technique of employing a radiometric receiver, such as the AN/ADR-3, theoretically offers great promise for an operational radioactive-cloud tracker.

5.9 TYPE D-1 CLOUD TRACKER

These tests indicate that the type D-1 radioactive-cloud detector and tracker will satisfactorily determine and indicate the direction of the radioactive cloud and that it should be usable as an interim short-range instrument, provided that the high-voltage power supplies are modified to enable them to withstand high humidity and salt-spray conditions. Some of the disadvantages of the equipment are:

1. In bright sunlight, sweep lines are difficult to see, unless a hood is employed.
2. The equipment is quite heavy because of the lead shielding used to obtain directionality. (Study is under way to ascertain the degree of directionality obtainable with methods not using heavy shielding.)

3. A considerable period of time is required during the early warning period to determine the direction of cloud.

It is recommended that further development work be accomplished on this equipment as well as further study of the limitations imposed by multiple scattering.

5.10 MARK 7 INFRARED EQUIPMENT

Although this equipment detected the radioactive cloud, it also detected ordinary clouds. Furthermore, any detection system employing radiation in the infrared portion of the spectrum is extremely dependent on weather and atmospheric conditions. If an ordinary cloud or overcast area lies between the radioactive cloud and the detecting equipment, the atomic cloud will not be detected. Rain will very greatly reduce, or even completely eliminate, the signal received by the detector from the radioactive cloud. Because of these extremely limiting operating conditions, this technique does not appear to be practical. Therefore it is recommended that no further work be done toward developing an infrared atomic cloud detector.

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