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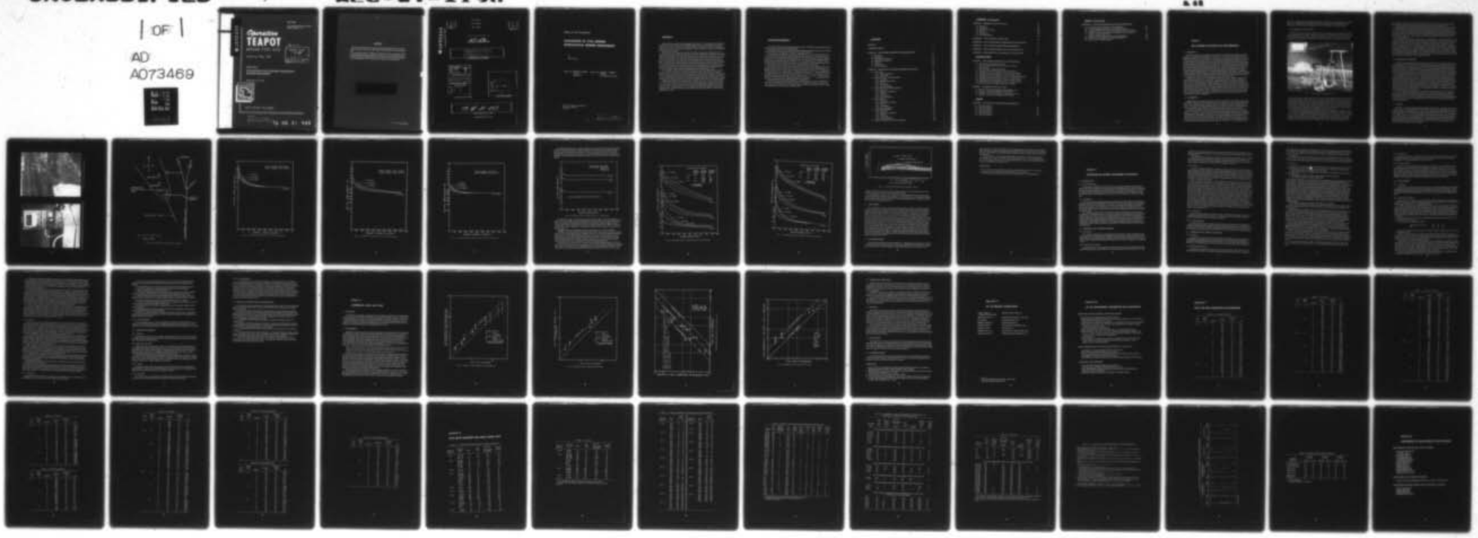

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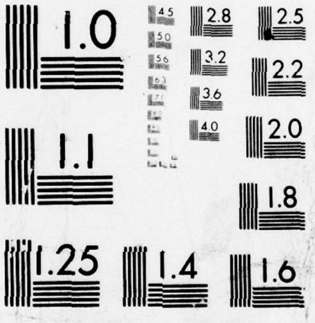

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AEC Category: HEALTH AND SAFETY
Military Category: 5-70

Operation TEAPOT

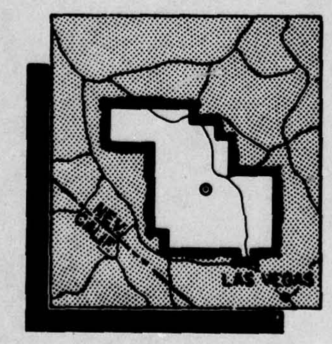
NEVADA TEST SITE

February – May 1955

Project 38.3

EVALUATION OF CIVIL DEFENSE RADIOLOGICAL DEFENSE INSTRUMENTS

Issuance Date: May 12, 1958



CIVIL EFFECTS TEST GROUP

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Report to the Test Director

EVALUATION OF CIVIL DEFENSE RADIOLOGICAL DEFENSE INSTRUMENTS

By

John H. Tolan

Approved by: ROSCOE H. GOEKE
Director
Program 38

Approved by: ROBERT L. CORSBIE
Director
Civil Effects Test Group

Federal Civil Defense Administration
Battle Creek, Michigan
April 1957

ABSTRACT

Experiments were performed during Operation Teapot (1) to investigate the beta-gamma exposure-rate ratio from fall-out to establish design criteria for high-range survey instruments, (2) to evaluate commercial radiological defense instruments, and (3) to investigate the feasibility of the use of commercial and amateur roll film and dental X-ray film as indicators of prompt gamma radiation.

The results of the beta-gamma exposure-rate ratio measurements indicate that, for an instrument having a beta window of the order of 50 mg/cm^2 thickness, the quantity of hazardous radiation not indicated by the instrument will not exceed a factor of 2. This factor is not constant with time postshot, nor would it be expected to be constant with fall-out over different types of ground surface, but it does indicate a magnitude to be expected and will serve as a basis for comparison of data collected in future test operations. An analysis of the absorption data of fission-product radiation indicates the presence of high-energy beta radiation, low-energy gamma radiation, and secondary X-radiation in large quantities immediately postshot. The soft component tends to diminish rapidly, and the high-energy gamma radiation of the longer-lived fission products becomes predominant after approximately 2 days.

The evaluation of commercial radiological defense instruments indicated that (1) satisfactory calibration facilities for this type of instrument must be developed, (2) ionization-chamber survey meters must have sealed chambers to avoid change in sensitivity with altitude, (3) an operational check rather than a simple battery check must be provided for all survey meters, and (4) dosimeters intended for monitoring applications must not demonstrate leakage resulting from high initial exposure and must be relatively insensitive to beta contamination.

Experiments performed to investigate the feasibility of the use of commercial and amateur roll film and dental X-ray film as indicators of prompt gamma radiation indicated that (1) commercial and amateur roll film can be used as prompt radiation dosimeters provided that the accuracy requirements are not too rigid and (2) dental film exposed to the prompt radiation gives a roughly satisfactory result whether or not special filters to reduce energy dependence are used.

ACKNOWLEDGMENTS

The author wishes to express appreciation to the many individuals and organizations whose help and cooperation made these studies possible.

The Georgia Institute of Technology Engineering Experiment Station and Emory University made available the time spent by the author at the Nevada Test Site.

Contributions to the planning of the beta-absorption phase of the project were made by J. C. Greene, Federal Civil Defense Administration (FCDA), and by Dr. J. B. H. Kuper and Dr. F. P. Cowan of the Brookhaven National Laboratory. The instrument used in the beta-gamma exposure-rate ratio experiment was proposed by Greene and the author and designed and fabricated by the Brookhaven National Laboratory. Dr. J. O. Buchanan and R. Boutelle, Project 38.2 participants, directly assisted the author in establishing an experimental procedure and in performing the measurements for the beta-absorption phase of the project.

Instruments to be used in the evaluation project were contributed by Admiral Corp.; Anton Electronic Laboratories; Bendix Aviation Corp., Cincinnati Div.; Cambridge Instrument Co.; Chatham Electronics Div., Gera Corp.; Corning Glass Works; El-Tronics, Inc.; Goldak Corp.; Jordan Electronics, Inc.; Keleket Mfg. Co.; Landsverk Electrometer Co.; Nassau Distributing Co.; NRD Instrument Co.; and Victoreen Instrument Co. The commercial instrument evaluation phase of this project was under the direct supervision of D. L. Collins, Assistant Project Officer and Chairman, RETMA Nuclear Instrument Subcommittee G-1, who performed all the necessary organizational and coordinating aspects of this phase.

The National Bureau of Standards (NBS), U. S. Department of Commerce, conducted the laboratory measurements of the exposed commercial and amateur roll film and dental film under contract with the FCDA. Dr. Margarete Ehrlich, Radiological Equipment Section, NBS, was responsible for these laboratory measurements.

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

CHAPTER 1 BETA-GAMMA EXPOSURE-RATE MEASUREMENTS

CHAPTER 3 COMMERCIAL AND X-RAY FILM

TABLES

APPENDIX C DATA FOR BETA-ABSORPTION MEASUREMENTS

TABLES (Continued)

APPENDIX D DATA FROM DOSIMETER AND SURVEY-METER TESTS

Chapter 1

BETA-GAMMA EXPOSURE-RATE MEASUREMENTS

1.1 OBJECTIVES

The primary objective of this phase of the project was to determine the optimum window thickness for a high-range beta-gamma survey meter. For such an instrument to give a true indication of exposure to beta radiation, it must have (1) a fairly shallow ionization chamber so that the aperture of the chamber can "see" all potentially hazardous beta radiation; (2) a thin window, which will admit essentially all the hazardous beta radiation and yet be strong enough to withstand physical shock; and (3) a shield that is thick enough to discriminate effectively between the total of beta and gamma and the gamma only. A beta window thickness of 50 mg/cm^2 was the preliminary specification applied to this unit. This window thickness was considered thin enough to admit all beta radiation that might be hazardous to personnel and yet thick enough to withstand physical shock. The beta shield thickness of 1000 mg/cm^2 recommended in the preliminary specifications was considered thick enough to discriminate effectively against the beta radiation. The beta-absorption measurements performed in this phase of the project were intended to confirm or provide evidence to reject these dimensions.

Another item of interest to be investigated was the time-rate of change of energy of the beta radiation emitted by fall-out materials. Considering that a beta window of 50 mg/cm^2 would not admit all the hazardous radiation and that the instrument reading would tend to be low, it would be helpful if a factor could be assigned to correct the instrument reading. If the external hazard to beta radiation is taken to be the total quantity of beta particles having energies sufficient to penetrate 7 mg/cm^2 (average thickness of human skin), this correction factor will be the ratio of the sum of all beta radiation having a range in excess of 7 mg/cm^2 to the sum of beta radiation having a range of 50 mg/cm^2 or more. If the ratio of these two magnitudes remains relatively constant for all postshot times for all types of ground surface, the correction factor would be applicable.

1.2 BACKGROUND

Experiments were conducted by Jack C. Greene of the Federal Civil Defense Administration (FCDA) during Operation Upshot-Knothole[1] "to investigate the effect of beta window thickness on the amount of residual radiation indicated by a portable ionization-chamber survey meter." The results of these experiments were not conclusive, and the recommendation was made that follow-up experiments be performed during future weapons-test programs.

Following the 1953 test series, Greene discussed this problem with Dr. J. B. H. Kuper and Dr. F. P. Cowan of the Brookhaven National Laboratory (BNL), emphasizing measurement techniques that might improve the data. Shortly after being assigned to this project in January 1955, the author visited BNL to participate in discussions leading to the specifications for a special instrument for these measurements. Since Operation Teapot was to begin in a very short time and since the author could not provide close liaison, the general specifications for the instrument were established before the author left Brookhaven. J. S. Handloser was assigned the responsibility of coordinating the design, construction, and calibration of the instrument. W. A. Higinbotham designed the instrument and supervised its construction. After calibration, the instrument was shipped directly to the test site for the measurements.

1.3 DESCRIPTION OF INSTRUMENT

The beta-absorption instrument shown in Fig. 1.1 consisted of an aluminum block containing seven identical parallel-plate ionization chambers, 1.5 cm deep by 15 cm in diameter, with aluminum absorbers increasing in thickness by factors of 2 from 7 to 440 mg/cm^2. An additional absorber of 440 mg/cm^2 thickness was inserted under the ionization-chamber block to increase the absorber range to 880 mg/cm^2. A separate electrometer input circuit was wired in a Lubrifilm-covered Lucite block at the collector of each chamber. A remote unit contained a single final amplifier stage for all the electrometer stages, sensitivity switch, absorber-chamber selection switch, and zero-adjustment potentiometers for each of the seven chamber electrometers. The input resistors of the six chambers not in use were shorted out by Victoreen remote-control switches, and the input resistor of the unit being used could be shorted out by the push-button switch for zero adjustment of that electrometer.

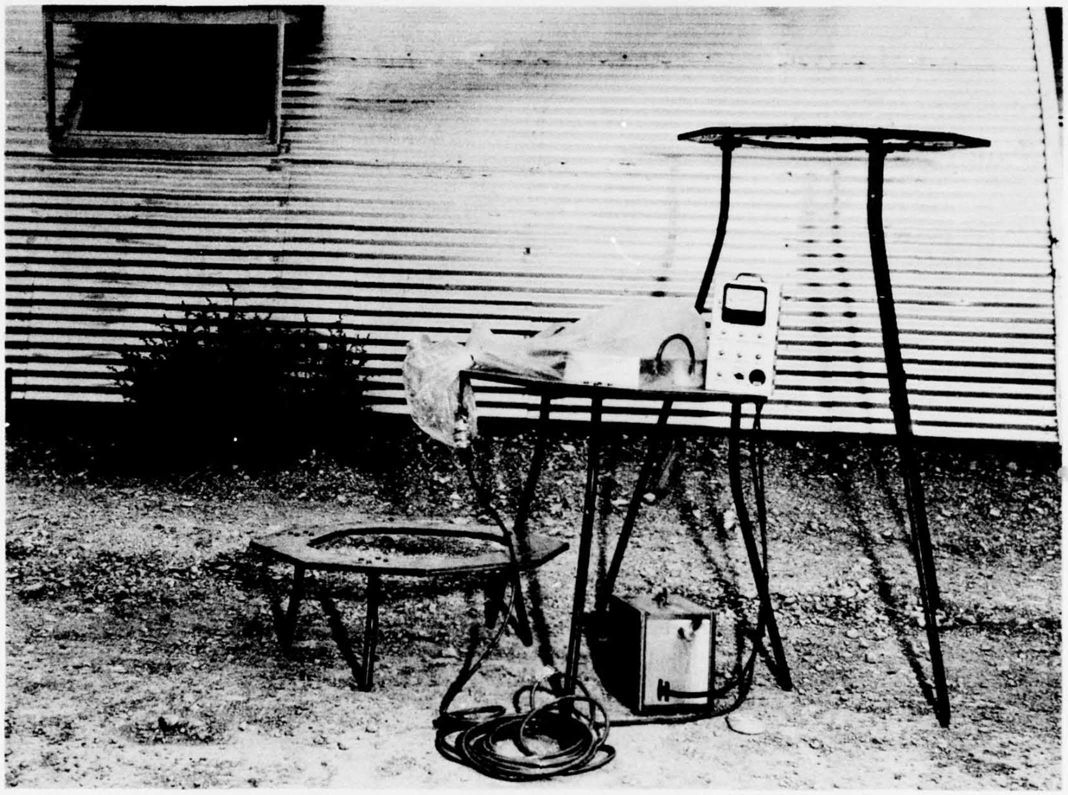


Fig. 1.1 — Complete beta-absorption instrument.

In order to cover the range of sensitivities required, the resistors at the input-electrometer tube grids were staggered and four voltage ranges were provided in the amplifier (×100, ×10, ×1, ×0.5). A negative feedback amplifier having a gain of 1 was used in each electrometer circuit. The Lucite block at each chamber contained the input electrometer, a second subminiature tube, the Victoreen switch VX-10, an input resistor, and a grid-current-limiting resistor for the input electrometer. The feedback line was common to all stages, and the place of the second amplifier tube was switched at the remote unit into a single third amplifier. Figure 1.2 shows the remote-control unit and a portion of the detector head.

In operation the unit was placed successively on three tables, which were 12, 30, and 60 in. above the surface of the ground. These three tables are shown with the instrument in Fig. 1.1. A 40-ft cable was used to connect the detection head with the control and metering box as shown in Fig. 1.3. A disposable polyethylene bag completely enclosed the detector assembly to prevent contamination of the instrument. This polyethylene bag encloses the detector assembly shown in Fig. 1.1. A similar bag could have been used for the control unit but, fortunately, was not necessary.

The beta sensitivity of each chamber was not established for the instrument before it was shipped to Nevada, nor was there a determination of beta sensitivity made after the instrument arrived in Nevada. This was the result of a shortage of time in the first case and a lack of facilities in the second case. Consequently, the results indicated below represent readings made in roentgens per hour for a mixed radiation of beta plus gamma. Thus, the roentgen used in these measurements is not a true roentgen but an artificial one, in which the total reading represents a contribution in roentgens from the gamma radiation plus a contribution in equivalent-roentgens from the beta radiation. The equivalent-roentgen, in this case, is that quantity of beta radiation producing the same ionization in air as 1 r of Co^{60} gamma radiation. A similar equivalence was assumed for the soft-gamma component.

1.4 OPERATIONAL PROCEDURE

In order for personnel to become familiar with the operation of the unit and to proof-test it for subsequent use immediately after a detonation, the instrument was taken to several contaminated test areas. In each of these a site was selected in which the radiation intensity was low enough to permit prolonged occupancy of the area but high enough to provide significant instrument readings. Each of these sites also provided beta-absorption data for the radiation emitted by fall-out that had been on the ground several days. These data were all remarkably uniform and indicated the constancy of the beta-gamma exposure-rate ratio after several days.

For the May 5, 1955, "open shot," five stations were selected for a series of measurements beginning soon after test-area access was permitted. The operational procedure indicated above was followed except that the radiation-intensity levels were substantially higher and a leisurely collection of data was not permitted. Working as rapidly as possible, the three members of the team, each having a separate function, successively set up each of the three tables and recorded the response of each chamber in each position to the radiation coming from the ground. It was expected that contamination of the equipment would prove an annoying problem. This was not the case, however, since subsequent checks of the equipment failed to indicate the presence of contamination.

A marker was placed at each of the five stations, and these locations were revisited at a later time. Analysis of the data made on the first run showed that the first three stations selected gave identical information; consequently reruns at two of these sites were discontinued. Stations 4 and 5, on the other hand, were located well within the fall-out path as shown in Fig. 1.4, and a new series of measurements was made at each of these sites at three different times postshot.

1.5 RESULTS

The results of the beta-absorption measurements in test areas several days old are shown in Figs. 1.5 to 1.7. These absorption curves indicate a uniformity of composition of beta and gamma radiation. The indicated ratio of the sum of all radiations having a range in excess of 7 mg/cm^2 to the sum of all radiations having a range in excess of 50 mg/cm^2 is of the order of 2 at a distance of 12 in. from the ground surface. This ratio decreases to a value of about 1.4 at a distance of 60 in. from the ground surface. These results are in agreement with those reported in WT-805 for the 1953 test series. The significant difference in the data is that the 1953 measurements were made at a distance of only 0.75 in. from the ground surface, and hence the ratio of exposure rates was higher.

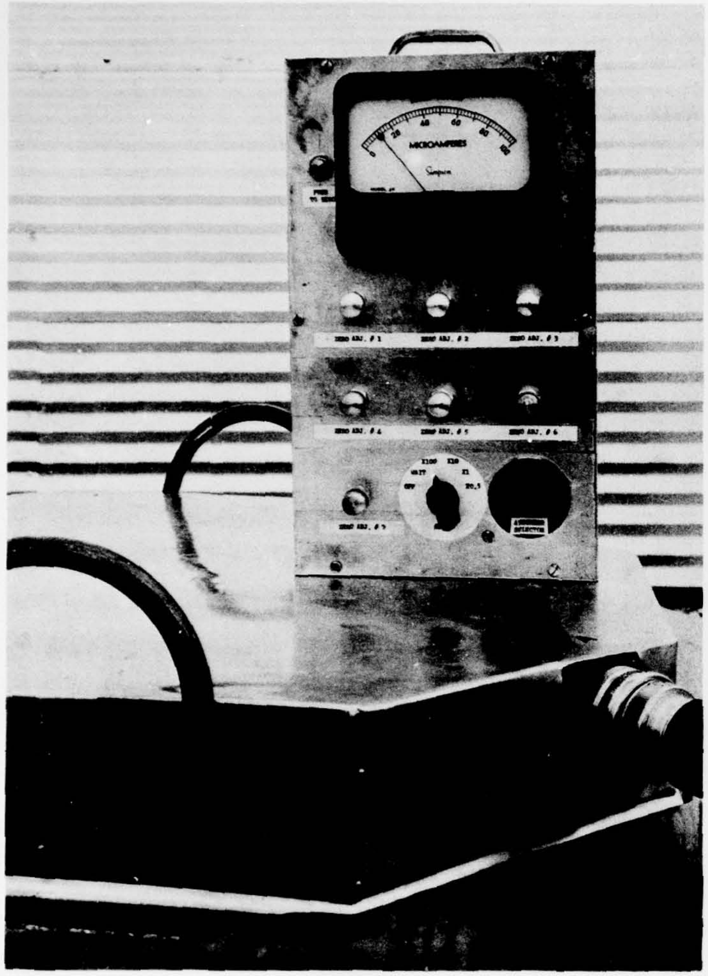


Fig. 1.2—Beta-instrument remote-control unit and a portion of detector head.

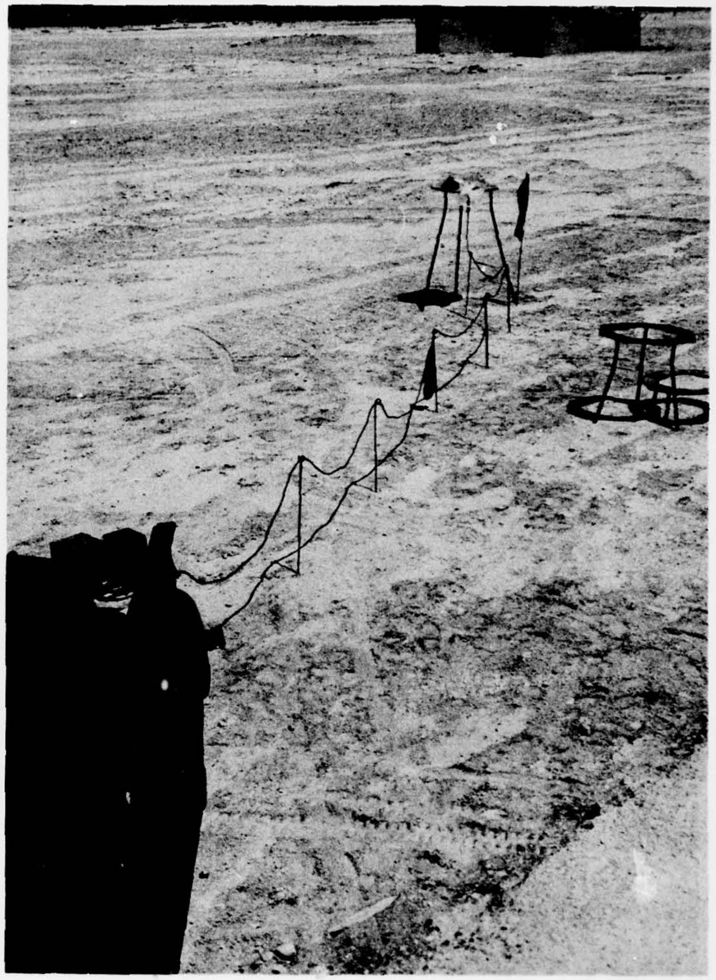


Fig. 1.3—Beta instrument in operating position.

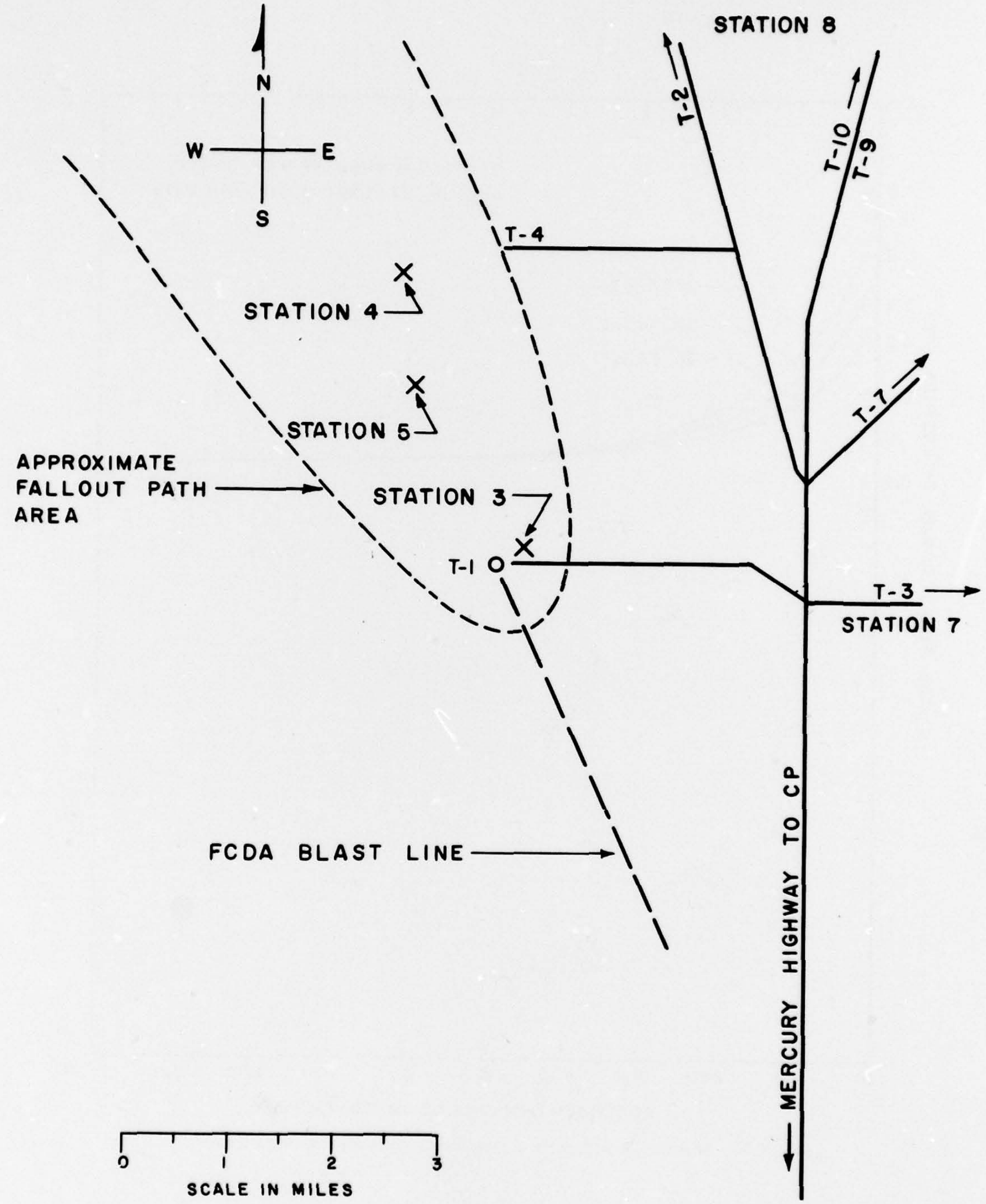


Fig. 1.4—Map of portion of test area with location of stations.

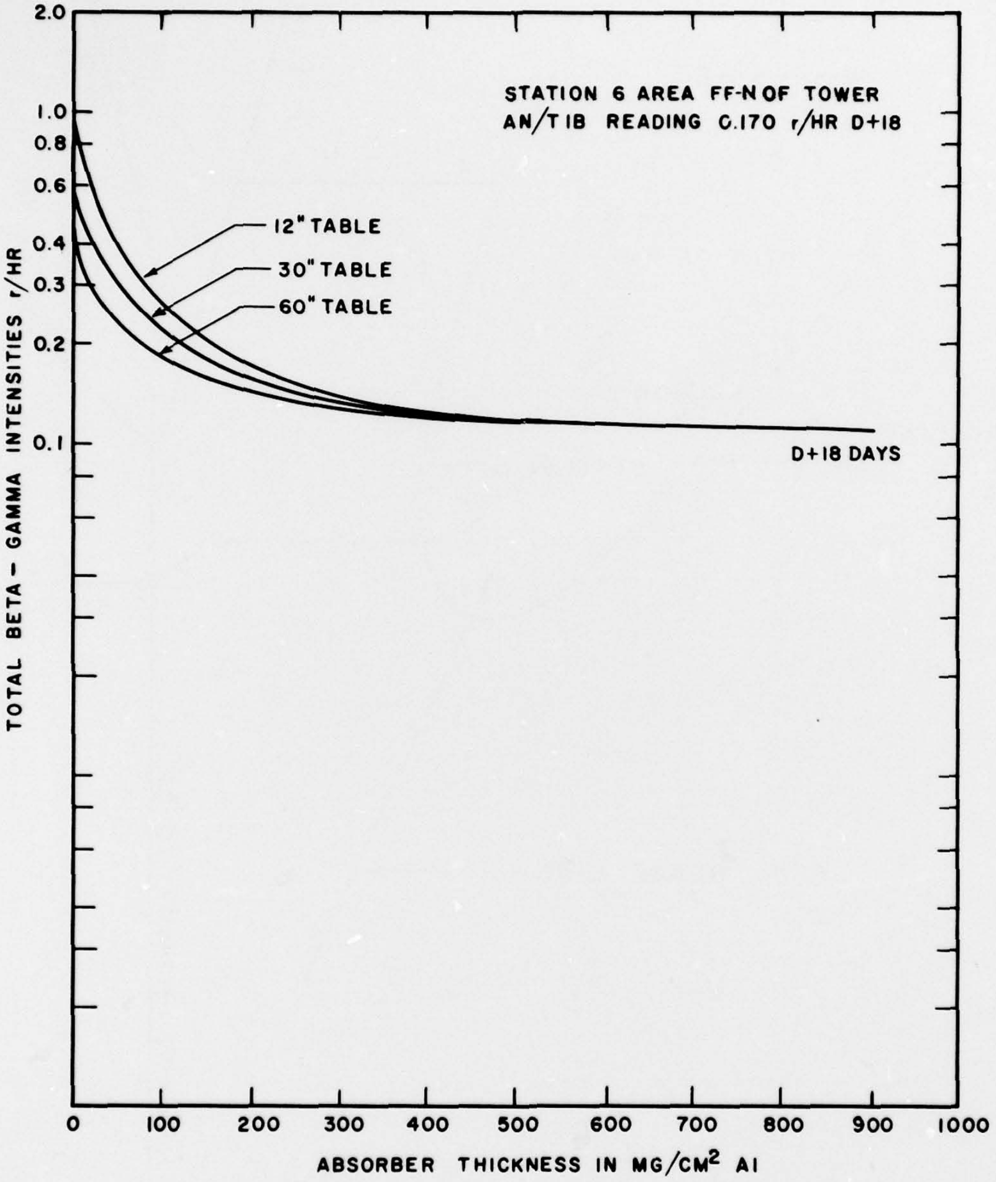


Fig. 1.5 — Absorption curves from Station 6, Area FF, north of tower.

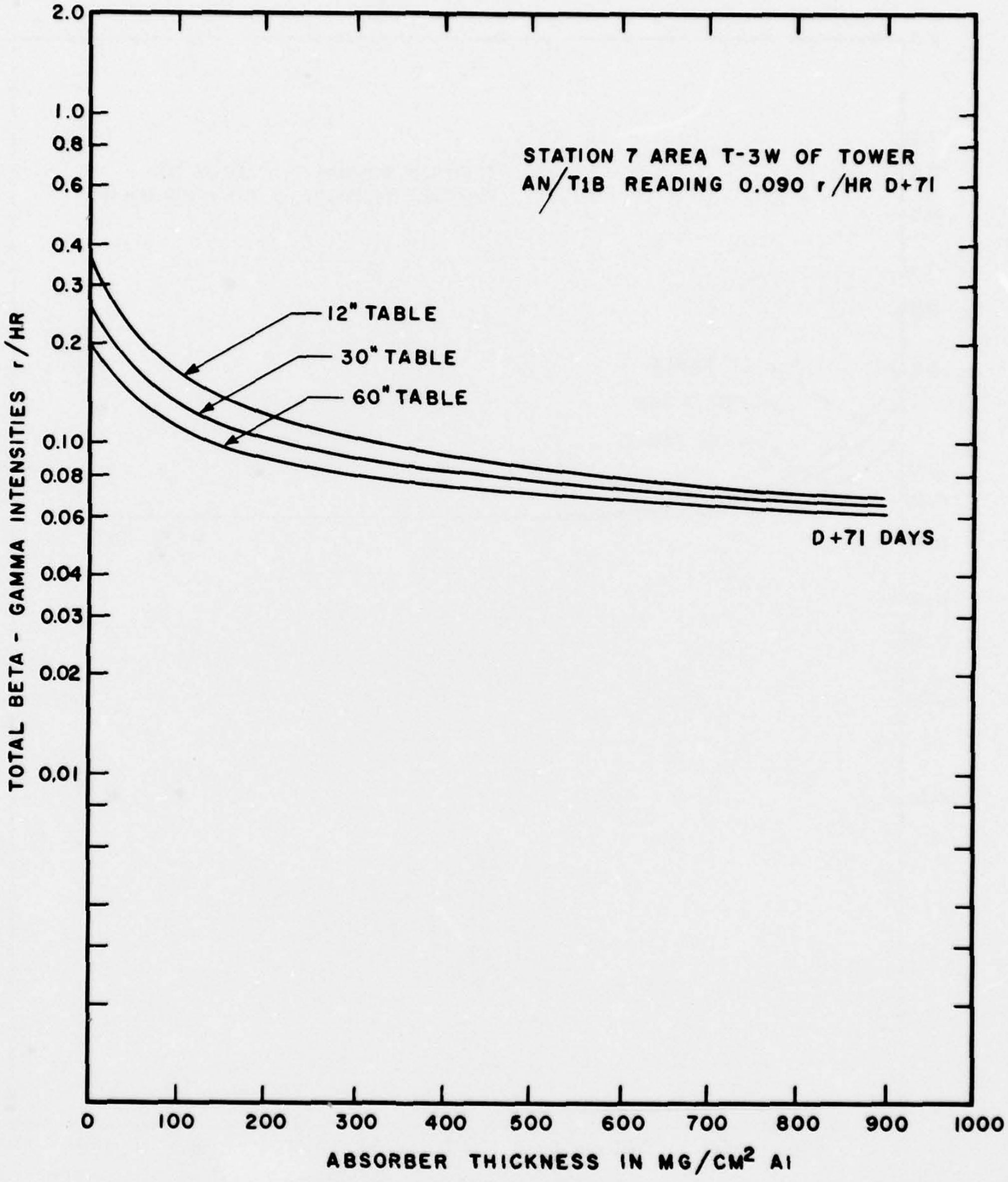


Fig. 1.6—Absorption curves from Station 7, Area T-3, west of tower.

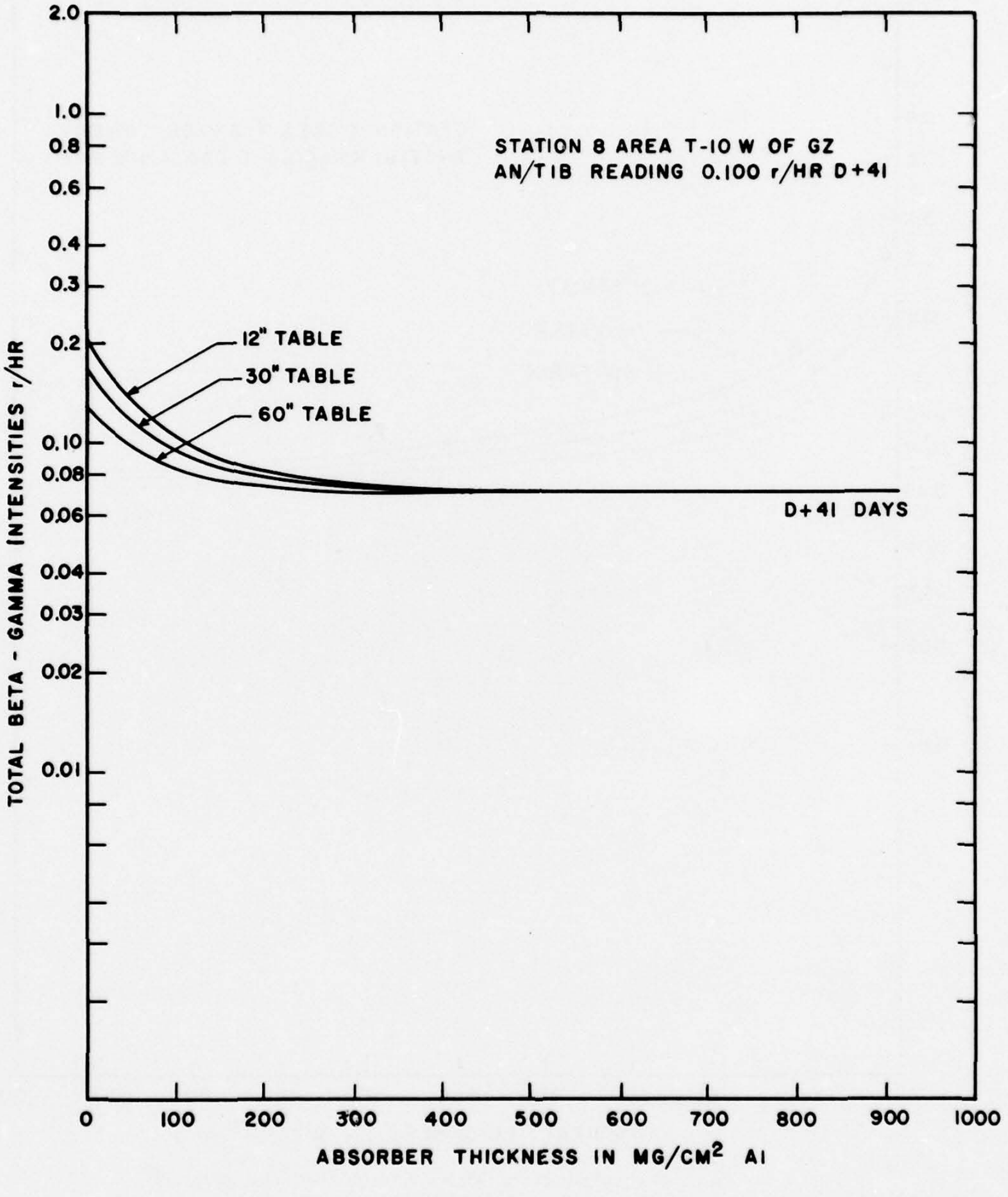


Fig. 1.7—Absorption curves from Station 8, Area T-10, west of Ground Zero.

The absorption data in Fig. 1.8 show an almost complete absence of beta and soft-gamma radiation. It was assumed that the induced radioactivity created by neutron capture would lie below the surface of the ground; consequently the soft component of the radiation would be filtered before it escaped from the surface. In these measurements there was no significant difference in detected radiation intensities between the 12- and 60-inch levels from the ground surface.

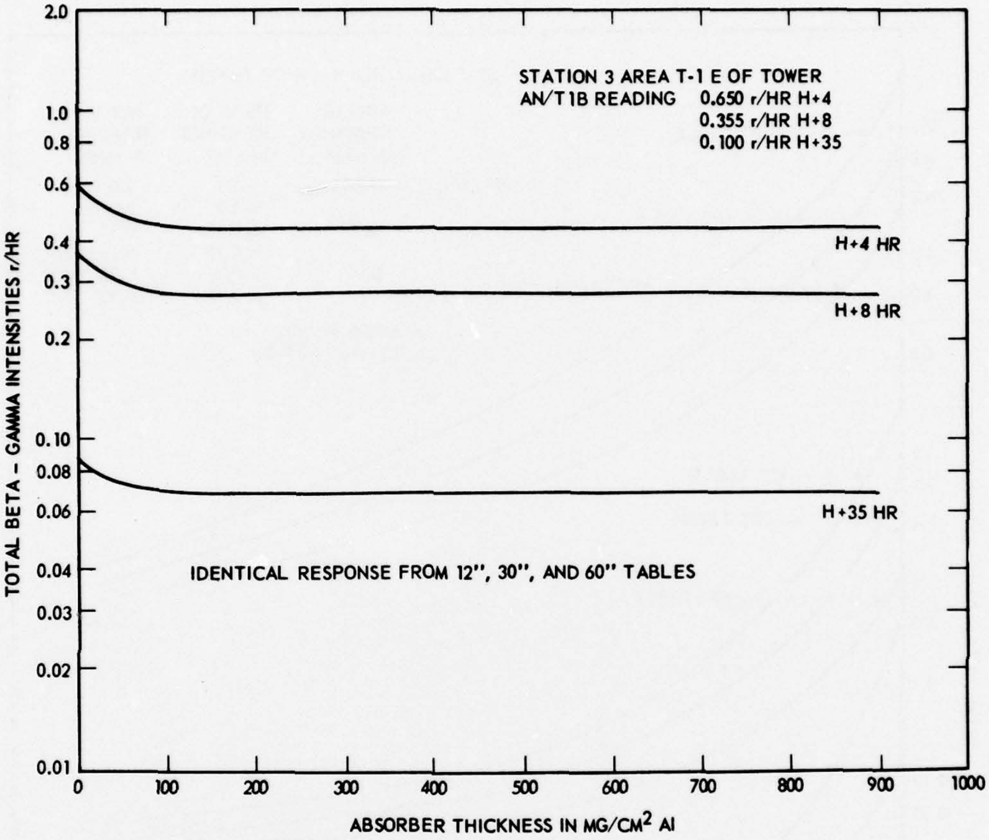


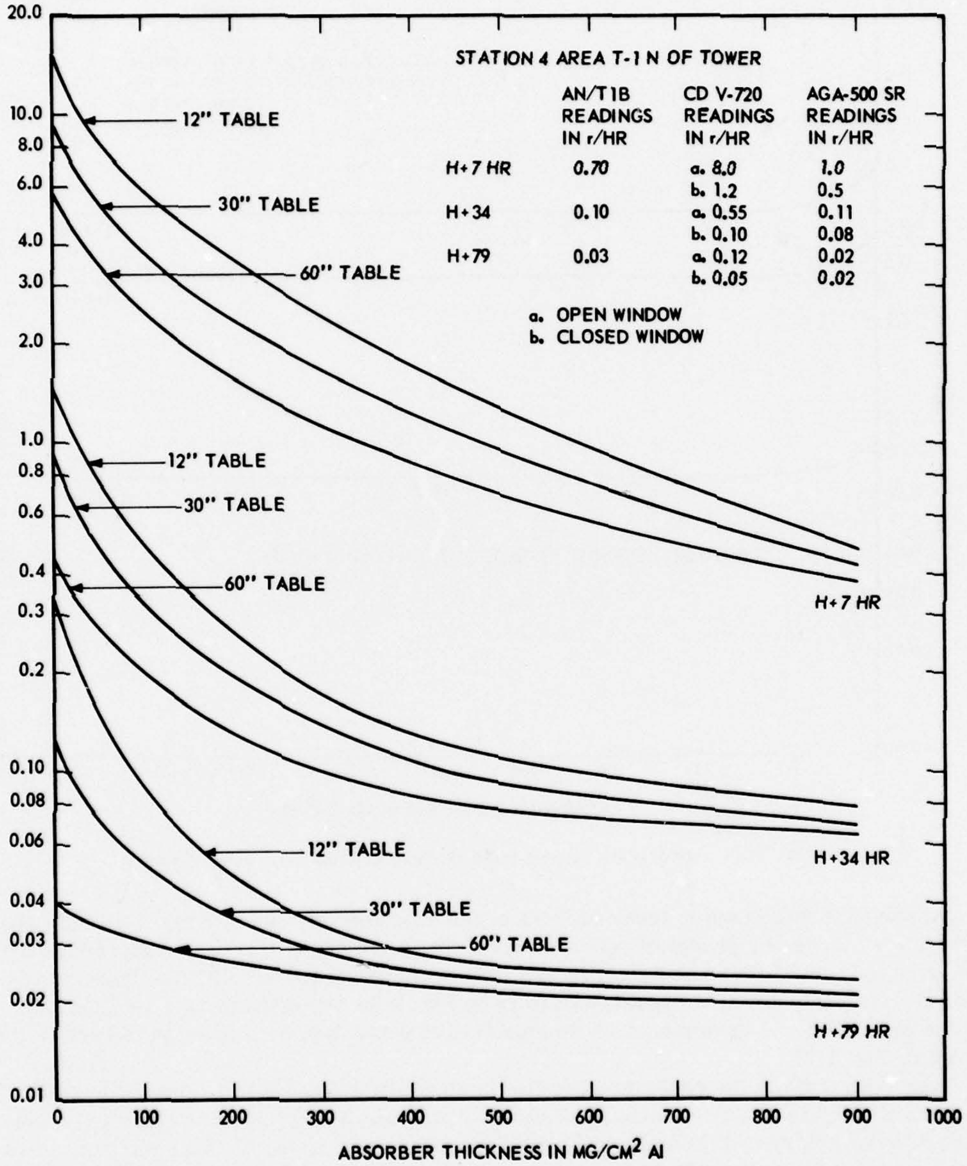
Fig. 1.8—Absorption curves from Station 3, Area T-1, east of tower.

Absorption data taken in fresh fall-out areas as shown in Figs. 1.9 and 1.10 indicate initially a very large component of soft radiation. The intensity of this soft component diminishes with time, so that at 79 hr postshot the absorption curves begin to look like those obtained several days postshot. The exposure-rate ratio for these two stations lies between 1.2 and 2.0 for the period 7 to 79 hr postshot. A compilation of these data as a function of time postshot is shown in Fig. 1.11.

Appendix C gives the experimental data from which Figs. 1.5 to 1.10 were plotted.

In addition to the beta-absorption measurements made at each station, a measurement was made with an AN/PDR-T1B ionization-chamber survey meter to establish the gamma-radiation exposure rate. The AN/PDR-T1B instrument has a steel cover over its ionization chamber which effectively discriminates against all incident beta radiation. This measurement established the approximate level of gamma-radiation intensity as a reference for the absorption measurements as well as for establishing the hazard to operating personnel.

A prototype CD V-720 survey meter and a Jordan AGA-500-SR high-range (0 to 500 r/hr) survey meter were available to use in conjunction with the beta-absorption instrument. Readings were made at each station with the AN/PDR-T1B, the CD V-720, and the AGA-500-SR. In the case of the CD V-720 and the AGA-500-SR instruments, an open-window, as well as a closed-



STATION 4 AREA T-1 N OF TOWER

	AN/T1B READINGS IN r/HR	CD V-720 READINGS IN r/HR	AGA-500 SR READINGS IN r/HR
H+7 HR	0.70	a. 8.0 b. 1.2	1.0 0.5
H+34	0.10	a. 0.55 b. 0.10	0.11 0.08
H+79	0.03	a. 0.12 b. 0.05	0.02 0.02

a. OPEN WINDOW
b. CLOSED WINDOW

Fig. 1.9—Absorption curves from Station 4, Area T-1, north of tower.

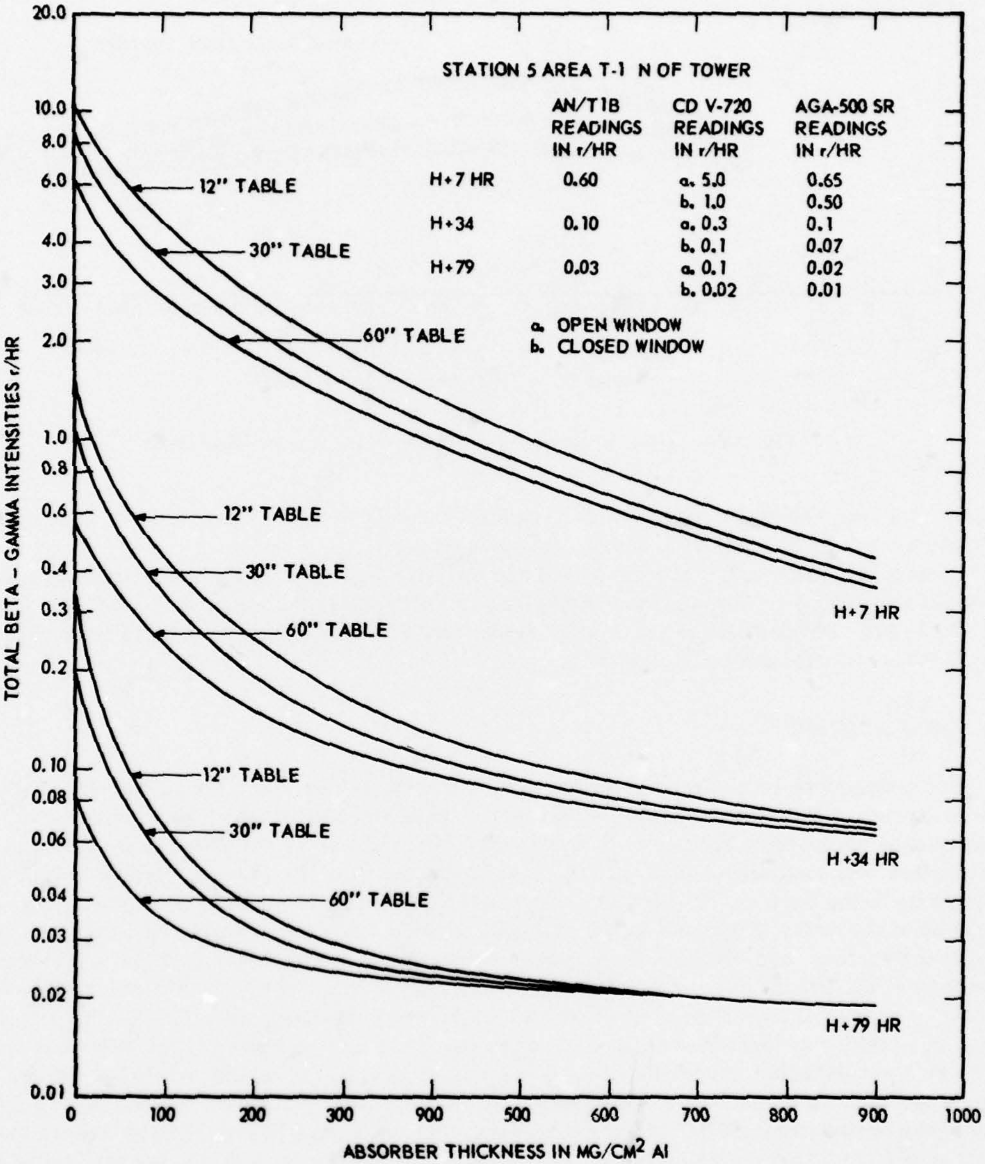


Fig. 1.10 — Absorption curves from Station 5, Area T-1, north of tower.

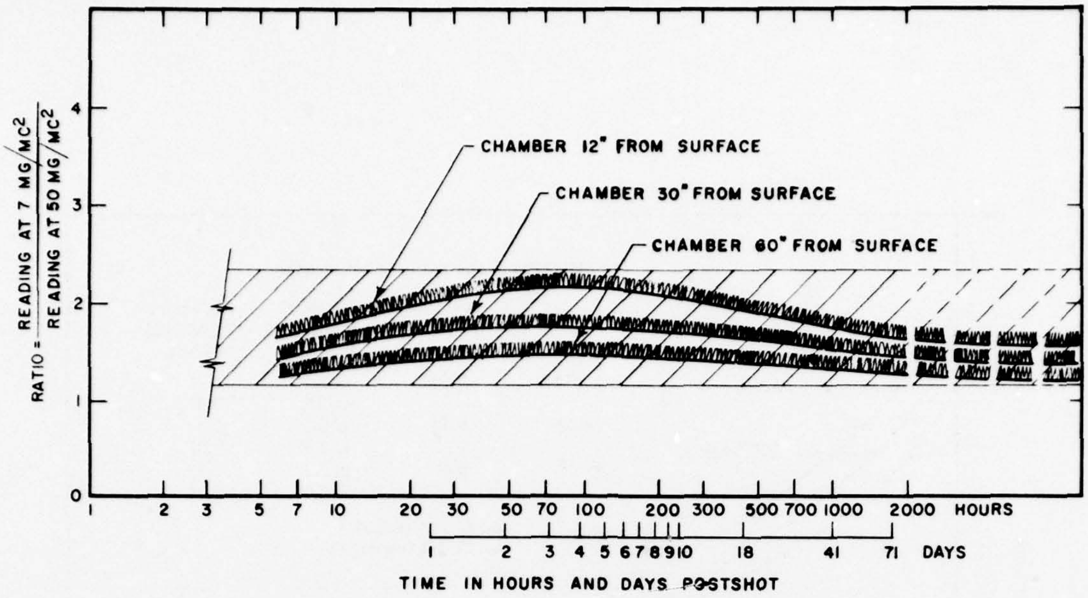


Fig. 1.11 — Effect of 50 mg/cm^2 window on instrument reading.

window, reading was made. Where these readings contribute to the interpretation of the absorption data, they are reported on the appropriate figure.

Considering that neither the CD V-720 nor the AGA-500-SR had a sensitivity adjustment made for operations in Nevada, they both gave a reasonable indication of the gamma intensity. The CD V-720, having a thinner beta window than the AGA-500-SR, gave a much better indication of the total beta-gamma intensity.

1.6 CONCLUSIONS

The conclusions to be drawn from these measurements are that (1) a 50 mg/cm^2 window admits enough of the beta radiation so that the ionization produced will provide a reasonable indication of whole-body exposure, (2) a shield of 1000 mg/cm^2 is sufficient to discriminate against this beta radiation except for times within hours after the explosion and at distances quite close to the surface, (3) correction factors to be applied to the beta window reading would be of the order of 2 in the worst case and close to 1.5 if the chamber is held 30 in. from the ground surface, and (4) these factors may be neglected in the practical situation, since the tolerance of the human body to external beta radiation is higher than for external gamma radiation by at least a factor of 2.[2] It is not to be inferred from these data that similar results would be obtained in measurements of fall-out intensities over different types of ground surface. Fall-out deposited on hard surfaces, such as asphalt and concrete, would not diffuse into the surface as it would in a sandy soil or broken surface. Furthermore, the ground surface at the Nevada Test Site (NTS) is not subjected to weathering agents such as rain to the same extent that other areas might be. Weathering agents and artificial agents that might be used for decontamination should be expected to change materially the quantity of the soft component of radiation from fall-out.

1.7 RECOMMENDATIONS

The successful development of instrumentation for radiological defense depends critically on a knowledge of the type of radiation to be measured. Studies of this type should be continued to increase the store of basic knowledge on which instrument design can be based. In this particular project it was not possible to obtain enough information to document the conclusions fully. In future test programs an opportunity to participate in several shots should be presented. This was, unfortunately, not possible during the Operation Teapot series because of long delays between shots.

Another difficulty in the successful performance of this phase of the project was that it was necessary for the Project Officer to take the field data as well as fulfill responsibilities for the other phases of the project. If such measurements are continued, consideration should be given to establishing a separate project.

REFERENCES

1. Jack C. Greene, Various Aspects of Nuclear Radiation Measurements for Civil Defense Radiological Defense Purposes, Upshot-Knothole Report, WT-805.
2. "Permissible Dose from External Sources of Ionizing Radiation," NBS Handbook 59.

Chapter 2

RADIOLOGICAL DEFENSE INSTRUMENT EVALUATION

2.1 INTRODUCTION

2.1.1 General Objectives

The objectives of this phase of the project were to evaluate radiological defense instruments in field use to establish (1) conformance with FCDA specifications, (2) general suitability as radiation-measuring devices, and (3) convenience in operation and maintenance in field use. The types of instruments selected for these field tests were survey meters similar in range to FCDA Standard Item Specifications CD V-710 and V-720, dosimeters, and laboratory equipment.

2.1.2 Background

On 23 March 1954 the Nuclear Instrument Committee of the Radio-Electronic-Television Manufacturers Association (RETMA) was invited by the FCDA to participate in the spring 1955 (Operation Teapot) test series at NTS. The committee accepted the invitation and, after preliminary discussions, met in Cleveland, Ohio, on 7 January 1955 to formulate plans for the participation. The meeting was attended by members of the RETMA committee and representatives of the FCDA.

The conclusions derived from the meeting were that (1) instruments in the class of the low-range CD V-700 Geiger counter would not be evaluated, (2) instruments in the class of the medium-range CD V-710 (0 to 50 r/hr) and high-range CD V-720 (0 to 500 r/hr) ionization-chamber meters would be evaluated as a single group of survey meters, (3) instruments in the class of self-reading dosimeters CD V-730 and CD V-740 (0 to 20 r and 0 to 100 r) would be evaluated as a single group of dosimeters, (4) laboratory equipment would be evaluated as a single group, and (5) project consultants representing each instrument group would be selected by drawing lots.

2.2 DOSIMETER TESTS: PROMPT RADIATION

2.2.1 Objectives

The objective of this portion of the project was to determine accuracy of dosimeters and dosimetric systems exposed to gamma radiation associated with a nuclear detonation. (It was assumed that neutron intensities were negligible at the points where exposures were made.) A National Bureau of Standards (NBS) type film pack was to be used as a standard for comparison of data.

2.2.2 Operational Procedure

The dosimeters were each externally marked to denote the range of the instrument. This facilitated the placement of the dosimeters at the proper distance from Ground Zero. At least two but no more than five dosimeters of a given type were utilized in this experiment. The ranges of instruments tested were not less than 10 r full scale, and the upper range limit was 600 r full scale.

The instruments were located at distances from Ground Zero calculated to give a $^2/_3$ full-scale reading from the prompt gamma radiation. As soon as possible after exposure, the meters were read and zeroed so that subsequent leakage could be determined. A similar determination was made prior to the shot to have a basis for comparison.

2.2.3 Results

Table D.1 in Appendix D gives the ionization-chamber readings observed for the instruments (column 4). These readings were taken immediately upon removal from the field at the data collecting station located at the Control Point. Included in Table D.1 is a Co^{60} calibration factor (sensitivity) obtained using the source at the Rad-Safe Building. The Rad-Safe calibration data were used to determine true dose, and the corrected readings are given in column 6 of Table D.1. Table D.3 gives the preexposure and postexposure electrical leakage characteristics of the individual instruments.

There is little to discuss relative to the response of the instruments to the prompt radiation since the NBS type film data were not complete for many stations. However, an examination of the data for a group of instruments located at the same station indicates disagreement between these ionization-chamber devices. More valid data are given in column 6 of Table D.1 (corrected readings). The wide variation in sensitivity factors may indicate that no special efforts were made by the manufacturers to provide calibrated instruments. Furthermore, since the trend is toward a decrease in sensitivity rather than an increase, this implies either that the instruments were not hermetically sealed or that the Rad-Safe calibration constants were in error. The source used for calibration was suspected by Rad-Safe personnel of having discontinuities in an intensity vs azimuth plot, but a check with survey instruments failed to reveal such a discontinuity. Little more can be said about Tables D.1 and D.2 because of the lack of comparison standards and the possibility of errors discussed above. With regard to electrical leakage, Table D.3 reveals that (1) although electrical leakage prior to exposure was present in some of the instruments tested, it was for the most part less than 2 per cent of full scale per 24 hr, and (2) electrical leakage was induced by exposure in all ranges of instruments of some manufacturers.

2.2.4 Conclusions

Induced electrical leakage is a problem in some of the instruments tested. The lack of a comparison standard that does not require intricate and precision reading procedures has rendered the tests performed, to a degree, inconclusive.

2.2.5 Recommendations

This experiment should be repeated as part of future test programs. The development of a suitable ionization-chamber standard for this work should be undertaken by the FCDA. A reliable calibration facility should be established at the NTS under the control and supervision of the FCDA. These facilities should be located close to the storage point of the instruments.

2.3 DOSIMETER TESTS: RESIDUAL RADIATION

2.3.1 Objective

The objective of this portion of the project was to determine the accuracy and precision of dosimeters and dosimetric systems when exposed to the residual gamma radiation associated with a fission-product field. The Victoreen r-meter was used as the standard for these tests. Test conditions were such that the effects of beta particles could be determined.

2.3.2 Operational Procedure

The ranges of the dosimeters tested were no less than 200 mr to 600 r full scale. The instruments were exposed to the radiation field emanating from fission products. Exposures were made on a test stand that was approximately 2 ft away from the ground. Test conditions were established to approximate as closely as possible the expected field conditions. A Victoreen r-meter was exposed concurrently whenever range, availability, and dosage considerations permitted.

The instruments were checked for beta contamination immediately upon removal from the field. An electrical leakage test was performed on each instrument prior to and after exposure to the residual field. This was done to determine the effects of the radiation upon the insulators.

2.3.3 Results

The data given in Table D.4 apply to this experiment. The response, as given in Table D.4, of the individual types of instruments of various manufacturers may indicate the following:

1. Beta contamination on the surface of the instrument
2. Electronic equilibrium, or lack thereof, in the walls surrounding the sensitive volume of the instruments
3. The nonuniform spectral response characteristics of the instruments
4. The nonuniform spectrum of the residual field

It is known that radiations from residual fields are heterogeneous from the standpoint of energy of the radiation. Furthermore, this condition is continuously changing with time. For this reason, when a comparison is made between instruments of various manufacture, constructional details that may influence performance must be considered. For instance, the Victoreen r-meter chambers must be fitted with plastic equilibrium caps approximately $1/8$ in. thick so that their response will be relatively uniform between Co^{60} energies and, say, 100 kev. For energies below 100 kev, there may be a gradual cutoff present. In addition to this, the equilibrium cap prevents the instrument from responding to any beta contamination present on the surface of the chamber element. These considerations apply even more strongly to the test instruments. It is a reasonable assumption that instruments of different manufacture varied in the materials of construction and thickness of walls of barrel, chamber, etc. Because of these variations, the test instruments differed in their response to the heterogeneous beta and gamma radiations present.

The results of Tests A to G indicated in Table D.4, are as follows:

Test A, Instruments Exposed on 090° Line in Radiation Field of 10 r/hr for 4.5 Hr: There was no beta contamination present on the instruments. Corrected instrument readings show close agreement.

Test B, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 1.5 Hr: In this test both the test stand and the tape that secured the instruments were contaminated with a beta emitter. The heavier walled Bendix instruments, as may be expected, gave a lower response on the average than the r-meter or the Keleket instruments simultaneously exposed. Here one may expect instrument response to be a function of the degree of localization of beta contamination. It may be noteworthy that r-meters V-VN-1 and V-VN-2 were not fitted with equilibrium shells. Therefore the effect of beta radiation on response was increased.

Test C, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 3.5 Hr; Test D, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 4.5 Hr; and Test E, Instruments Exposed on 290° Line in Radiation Field of 2 r/hr for 1 Hr: Here again beta contamination was present on the wrappings. The wide variation in response in these tests might be attributed to severe beta exposure or to electrical leakage.

Test F, Instruments Exposed on 290° Line in Radiation Field of 1 r/hr for Time Calculated To Give On-scale Reading: The 200-mr instruments having low preexposure leakage were in good agreement. There was no beta contamination present on either the instrument wrappings or test stand upon removal of these instruments from the field. The Victoreen pocket chambers were omitted from this test because no a-c supply was available for charging and reading purposes.

Test G, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 27 Hr: The 600-r instruments, when corrected, were in close agreement despite severe beta contamination.

2.3.4 Conclusions

With some exceptions it is possible to employ commercial instruments for the evaluation of residual radiation fields. Residual fields of even low intensity are sufficient to produce postexposure electrical degradation in some instruments.

2.3.5 Recommendations

The lack of a reliable standard of comparison in all ranges is a decided obstacle in performing such tests. It is unfair to expect a laboratory instrument such as the Victoreen r-meter to perform under the rigorous field conditions applicable to these experiments. The instruments were subject to vibration and shock since they were carried to and removed from the exposure sites by means of trucks traveling over rough terrain. It is recommended that a rugged and reliable secondary standard be sought for future tests. In addition, the standards should be used in quantities and ranges commensurate with the test instruments.

2.4 SURVEY METERS

2.4.1 Objectives

The objectives of this portion of the project were to evaluate the radiation, environmental, and operational characteristics of portable radiological survey instruments similar in range to FCDA Standard Item Specifications CD V-710 (medium range) and CD V-720 (high range) instruments under actual field conditions to determine their compliance with FCDA specifications.

2.4.2 Operational Procedure

Survey meters were received from five different manufacturers as listed in Appendix B. The instruments were checked for calibration accuracy using the UDM-1, 7-curie cobalt source and the 1-curie cobalt source at the Rad-Safe Building.

The UDM-1 test set was a complete installation, with track, movable instrument stand, safety plug, and attenuation plug. The calibration for the test set was provided by the Rad-Safe group. This calibration was obtained with a Victoreen r-meter and associated condenser ionization chambers. The chambers were equipped with plastic caps to ensure electron equilibrium for gamma radiation emanating from Co^{60}. The system had been checked at NBS, and the corrections given by NBS were used as well as the necessary temperature and pressure corrections.

The attenuation plug was calibrated by NBS and was found to reduce the intensity of the Co^{60} beam by a factor of 140.0.

The calibration for the UDM-1 points is:

Distance from source, cm	130	47	42
r/hr	3.5	28	35

The point 47 cm distant from the source was used to obtain an intensity of 0.2 r/hr by use of the attenuation plug.

At 42 cm, the nearest point to the source used, the beam size was 8.6 in. in diameter. Therefore the size of the beam was large enough to ensure a uniform field for all instruments tested. At this distance, 42 cm, any small placement error would produce a negligible error in reading because of the inverse-square function.

To familiarize a group of Project 38.2 participants with calibration procedures of FCDA portable survey meters and those submitted by industry, the calibration range outside the Rad-Safe Building was used. This range consisted of a 1-curie Co^{60} source in a plastic holder mounted 3 ft from the ground. Branching out from the Co^{60} source were long boards 45° apart mounted 3 ft from the ground. These boards were 12 in. wide and approximately 100 ft long. They served as test stands for the instruments under calibration.

The source strength was determined by the calibration certificate from NBS dated July 1954 and was checked by using a Landsverk r-chamber and reader.

In order to avoid excessive exposure to personnel, all instruments with multiple scales were calibrated in the lowest range at the 400 mr/hr point. For instruments with calibration controls inside and not accessible externally, a longer time was required for calibration than for those in which controls were available from outside the case. It would have been desirable to calibrate other points, but to do so would have exposed the Project 38.2 participants to larger quantities of radiation.

Prior to "shot day" the Project 38.2 participants were taken to the Military Effects Test area to use and evaluate portable instruments under field conditions. The instruments were distributed from a vehicle outside the contaminated area, and the participants were instructed to make a survey toward Ground Zero using two instruments simultaneously. The highest indicated level of contamination was 7 r/hr, permitting the use of the highest range on each of the instruments. To avoid excessive exposure, each trainee limited his tests to instruments that he had not previously used and evaluated on this project. Each party made two trips toward Ground Zero, and their individual accumulated exposures ranged from 0.06 to 0.2 r. The results of these and other evaluation tests are discussed in Sec. 2.4.3.

In order to evaluate the results of this program, two questionnaires were prepared. The first concerned equipment evaluation, and the second, the test operator. Owing to the many postponements and the busy schedule of the trainees, only a small number of questionnaires were submitted. Under the conditions encountered in these tests, it was the opinion of the project consultants that only a few of the questions could be properly answered by the trainees. These questions are listed in Table D.5, and the respective answers received are given in Table D.6. The test operator questionnaire was not used.

2.4.3 Results

The first survey meters tested for calibration accuracy were two CD V-710 "Rad-tek" instruments (Serial Nos. 418 and 228) manufactured by the El-Tronics Corp. Both instruments were subjected to the preliminary operational checks specified by the manufacturer in the instruction book, i.e., "battery check" and "zero." These checks were accomplished by means of the controls on the top panel, with satisfactory results for both instruments. Therefore the instruments were assumed to be operating properly. They were then placed in the radiation fields, and readings were taken. These readings are given in Table D.7.

Two Anton Model 11 instruments (Serial Nos. 205 and 206) were tested following the same general procedure. The preliminary checks and adjustments specified by the manufacturer were performed satisfactorily, and the instruments were assumed to be in proper operating condition. These checks were accomplished by the "calibration check" and "calibration adjust" controls provided on the case shell of the instrument. They were then placed in the radiation fields, and the results are shown in Table D.7.

At the conclusion of the calibration tests, the instrument having Serial No. 205 was accidentally dropped onto the concrete floor from a height of $4\frac{1}{2}$ ft. As a result the case shell and top cover were damaged. The manufacturer had supplied a spare case and cover, and the instrument was repaired. The instrument was replaced in the radiation field, and it was found that the instrument was in calibration and functioning properly.

The Jordan Model AG-50-SR survey meter (Serial No. 82) was then tested using the same general procedure. The preliminary checks and adjustments were made according to the manufacturer's specifications, and the calibration results shown in Table D.7 were obtained with no further adjustments.

The Chatham Electronics Model CH-50 survey meter (Serial No. 3) was tested next, and the results are given in Table D.7.

Because of the lack of time and the availability of suitable test facilities, it was not possible to test more instruments in the CD V-710 range or to test any instruments in the CD V-720 range. Therefore any conclusions to be drawn are based on tests on a small number of instruments. However, the results will serve as a guide for further evaluation studies.

2.4.4 Conclusions

Although only a small number of instruments were evaluated and only a small number of questionnaires were returned, some valid conclusions can be drawn:

1. In the case of ionization-chamber detectors, a true hermetic seal should be used. Chambers not hermetically sealed produced low readings because of the high altitude in Nevada.

2. An operational check or circuit check rather than a battery check should be used.

3. The size and weight of all instruments were suitable for their intended use.

4. The carrying straps were not easily adjusted.

5. The battery replacement should not entail removing nuts and lock washers. Captive screws or captive holders should be used to prevent loss of small parts in the field.

6. Battery replacement should be accomplished without exposing circuitry. Either a separate battery compartment or a separate compartment for circuitry should be provided.

Concerning the evaluation program, the following conclusions can be drawn:

1. The use of calibration facilities assigned to other programs is not satisfactory. Separate test facilities should be provided for this project.

2. The time spent with the Project 38.2 participants was not adequate because of their crowded program.

3. Housing should be provided at Mercury for the Project Consultants so that valuable time would not be wasted in commuting to NTS.

4. Results were generally good in all aspects of this portion of the project. Experience gained by all participants in this project will be of invaluable assistance in the preparation of similar programs in the future.

2.4.5 Recommendations

It is recommended that every effort be expended to continue the field evaluation of instruments in future weapons test programs. Preoperational planning and coordination are most important in such an evaluation project, and close supervision must be provided in its execution.

2.5 LABORATORY EQUIPMENT

2.5.1 Objective

The objective of this portion of the project was to evaluate the use of commercial, laboratory type measuring instruments to be used to quantitatively establish the extent of contamination of food, drug, and water samples.

2.5.2 Operational Procedure

Program 32, under the supervision of Dr. E. P. Laug of the Food and Drug Administration, Department of Health, Education, and Welfare, was concerned with the problem of contamination of food, drug, and water supplies. Laboratory type equipment to be evaluated was loaned to Program 32 for use in establishing contamination on their test samples. These instruments were supplementary to those provided by Program 32.

Food and other test samples were exposed by Program 32 personnel, and, after recovery, measurements were made to establish the extent of induced radioactivity and surface contamination. All the measurements performed after recovery were done in the Quonset area where laboratory space and a-c supply voltages were available.

2.5.3 Results

The quantity of laboratory type instruments available was quite small; consequently no relative figure-of-merit could be established for the instrument types. All the equipment submitted for this evaluation functioned in an acceptable manner.

2.5.4 Conclusions

The results of use of the laboratory type equipment did not provide sufficient information on which to base an evaluation; therefore no general conclusions can be drawn.

2.5.5 Recommendations

It is recommended that an evaluation of laboratory type equipment not be attempted in future test operations. To perform a good evaluation, several instrument types and several units of each type would have to be provided. To perform a systematic evaluation of this large number of different instruments would place a severe personnel burden on an instrument evaluation project. To ask another program, having itself a large number of problems to undertake, to use and evaluate these instruments would be an unreasonable request. Furthermore, this type of evaluation is essentially a laboratory function and one that can be performed to a much more favorable degree in laboratories designated by the FCDA. Test programs selected for NTS should be those that cannot be performed under any other experimental conditions except those available at NTS.

2.6 GENERAL CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations listed separately under each of the three preceding sections need not be repeated here, but some general statements touching on these specific items can be made.

Any project involving a large number of people and an even larger number of separate items of equipment must be very well planned. The experience gained from this project indicated that, despite the efforts of many interested persons, this project was not planned as well as it should have been. For the benefit of anyone responsible for a similar project in the future, the following recommendations are made:

1. Consideration should be given to setting up an instrument evaluation project as a separate entity.
2. Instrument consultants assigned to the project could work more efficiently if housing accommodations were provided at Mercury. Security clearances that would permit them convenient access to suitable working areas would be helpful.
3. An instrument calibration range for the exclusive use of this project would increase efficiency.
4. The assignments made for the participants of the radiological defense training program should be such that each of them will have an opportunity to become completely familiar with all the radiological defense instruments and their maintenance and calibration.
5. It is very strongly urged that a project of this type be continued within the FCDA participation in future test programs so that a continuing field evaluation of new operational and developmental instruments can be made.

Chapter 3

COMMERCIAL AND X-RAY FILM

3.1 OBJECTIVE

The objective of this phase of the project was to evaluate the possible use of commercial roll film and dental X-ray film as indicators of the quantity of prompt radiation resulting from a nuclear detonation. Such film collected from drugstores and dentists' offices in the vicinity of the detonation may contribute to a determination of the location and approximate yield of detonation. The data from these film exposures will also help define the areas of critical exposure from the prompt radiation to the inhabitants of the areas.

3.2 BACKGROUND

Exploratory experiments were performed during Operation Upshot-Knothole[1] to determine the feasibility of using commercial roll film as detectors of prompt radiation resulting from a nuclear detonation. The results of these experiments were promising and encouraged the FCDA to schedule experiments for Operation Teapot. In preparation for the field tests scheduled for Operation Teapot, the FCDA sponsored a laboratory study by NBS to determine energy dependence, directional dependence, and latent-image stability of commercial roll film. The results of this study were reported[2] as favorable to continuing the investigation with field tests. Briefly, the conclusions reported in NBS-3662 were that:

> The errors introduced due to batch-to-batch and processing variations as well as to the latent-image stability would be comparatively small. The main drawback and greatest source of error of the procedure would stem from the energy dependence, which in this case could not very well be counteracted by metallic filters or other devices usually employed in film dosimeters.

In addition to the commercial roll film normally stocked in drugstores, another source of indicators of prompt radiation is the dental X-ray film stored in dentists' offices. Normally, this film is kept in cartons until used. Each carton contains 150 individual packets, each of which has a thin lead backing. Consequently, considerable attenuation of radiation would occur from one end to the other end of the carton. Thus film taken at random from the carton would not yield a reasonable measure of the exposure to the carton. For this reason it was determined that such film should be exposed two at a time with the sensitive sides facing. This exposure would eliminate directional response of the film resulting from the position of the lead foil with respect to the direction of the radiation.

The energy dependence of dental X-ray film is quite marked, but it can be eliminated by the use of appropriate metallic filters.[3] It was considered advisable, therefore, to recommend NBS type film holders for film dentists set aside in their offices as radiation detectors. The same NBS type film holders were to be used in the field tests during Operation Teapot.

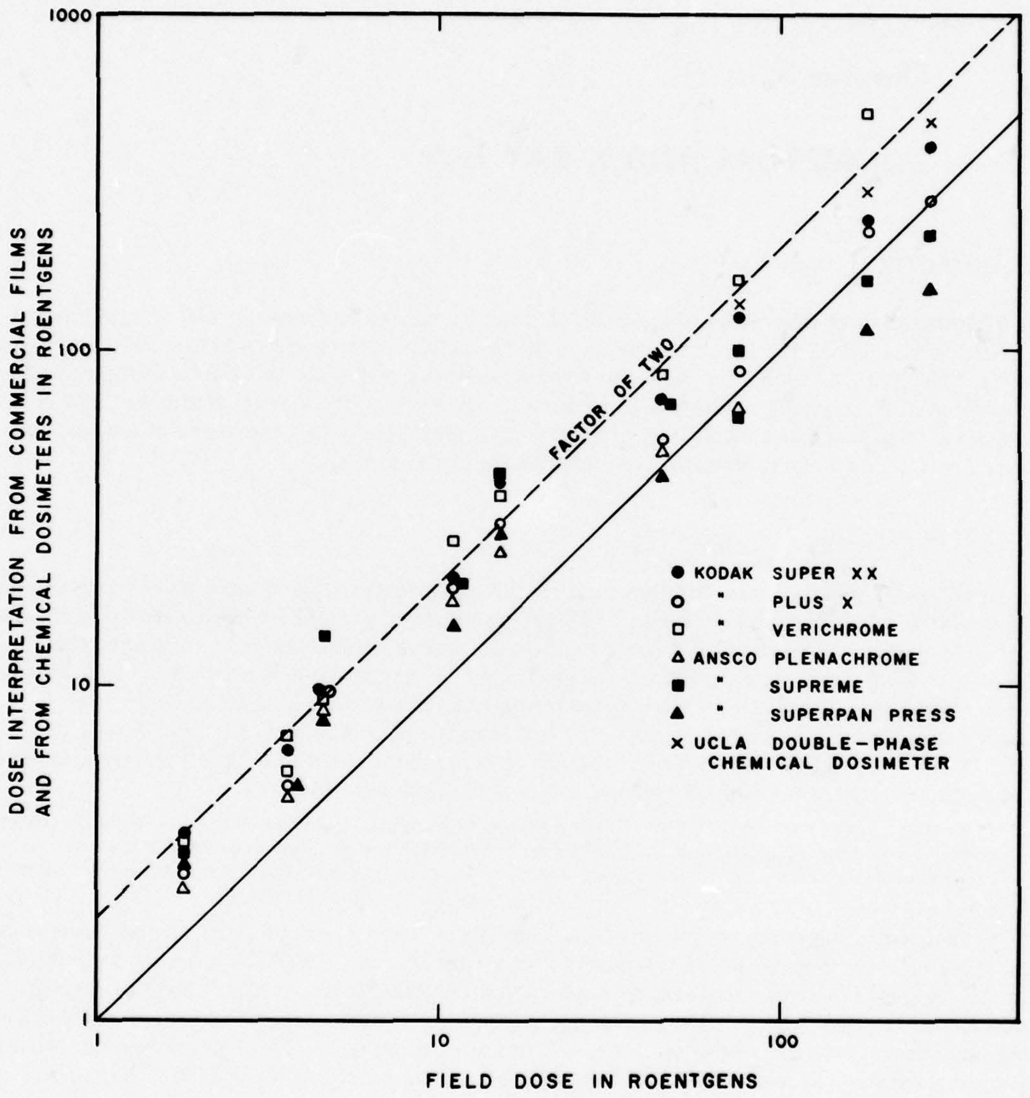


Fig. 3.1—Response of roll film exposed on dose-distance line.

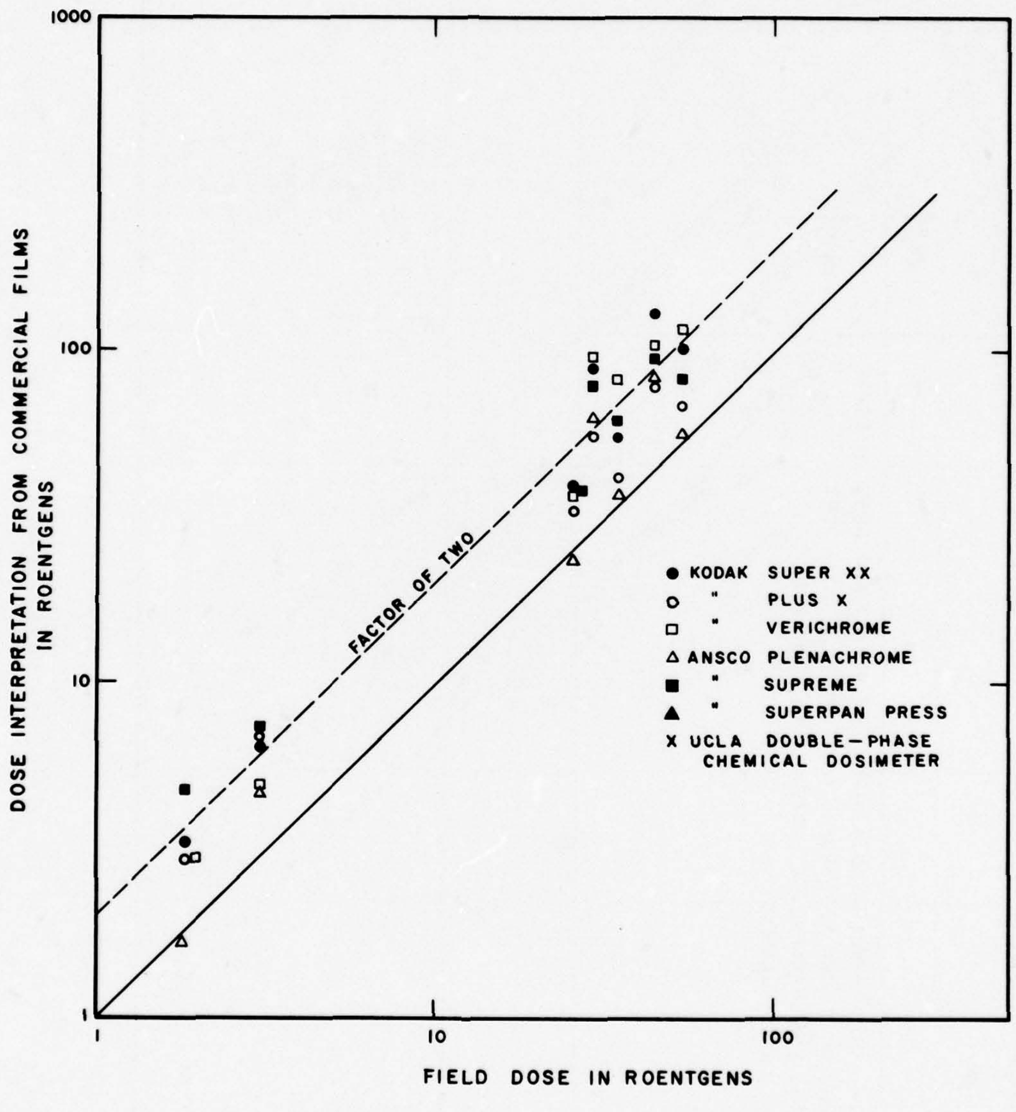


Fig. 3.2—Response of roll film exposed in FCDA houses.

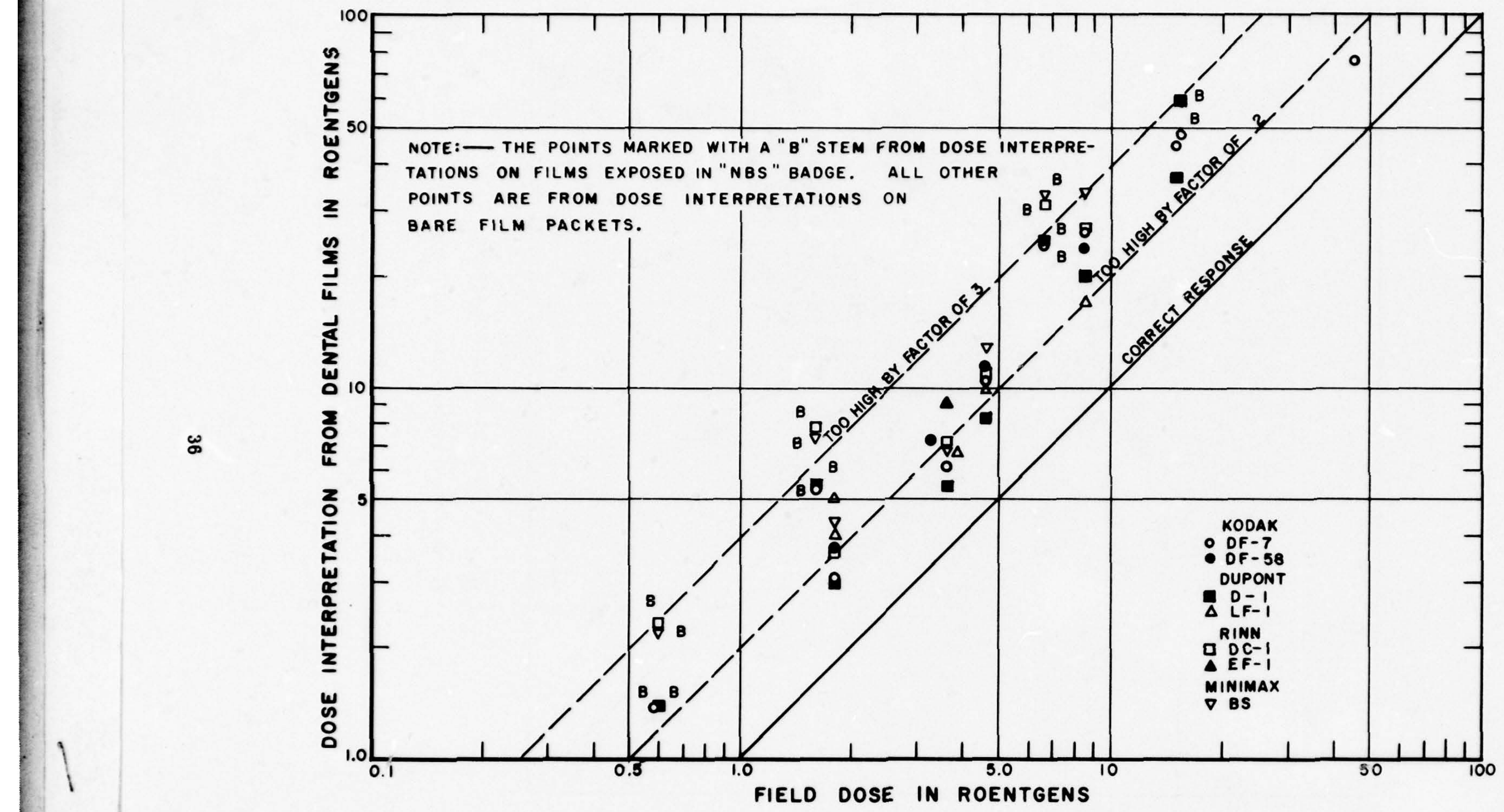

NOTE:—— THE POINTS MARKED WITH A "B" STEM FROM DOSE INTERPRETATIONS ON FILMS EXPOSED IN "NBS" BADGE. ALL OTHER POINTS ARE FROM DOSE INTERPRETATIONS ON BARE FILM PACKETS.

Fig. 3.3—Response of dental film exposed on dose-distance line.

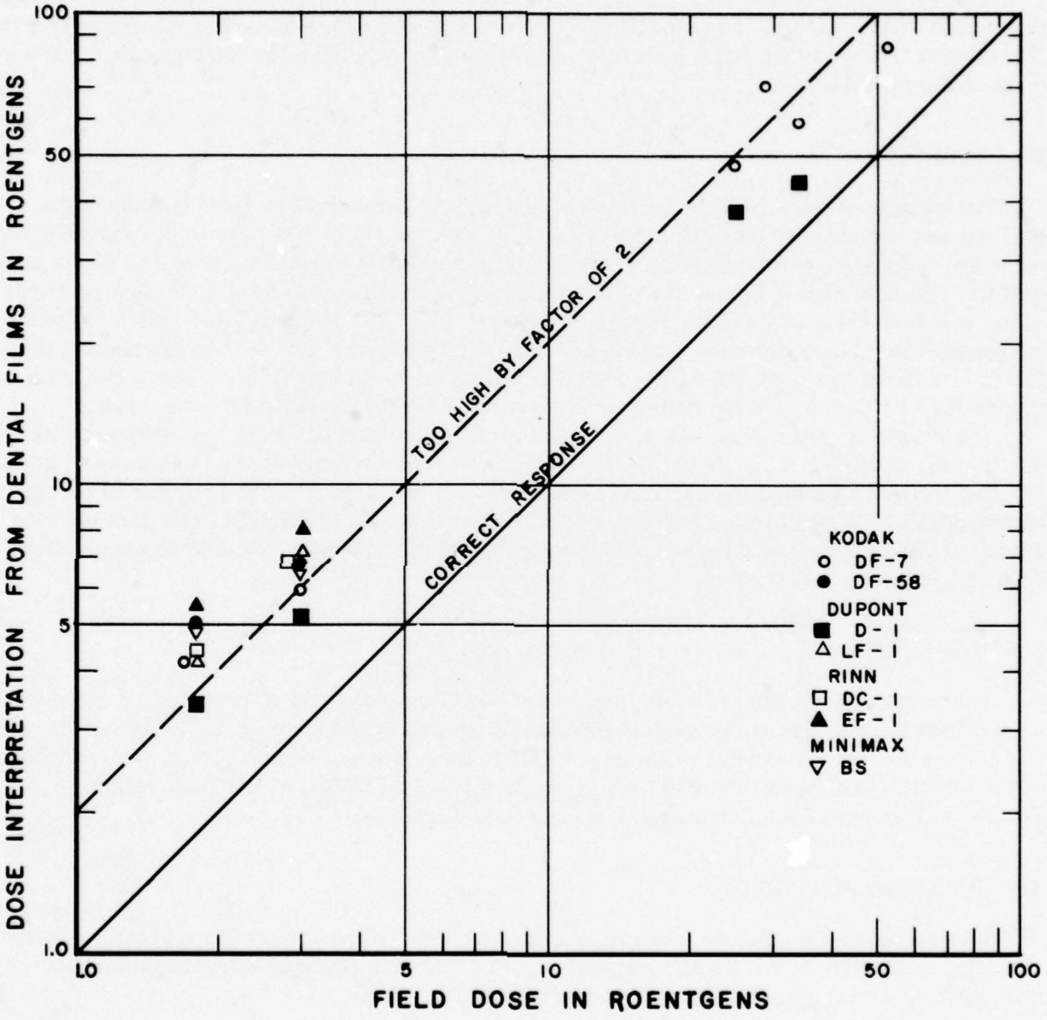


Fig. 3.4—Response of dental film exposed in FCDA houses.

3.3 OPERATIONAL PROCEDURE

Packages containing the roll film and dental film to be evaluated were placed on the dosimeter line set up by Project 39.6 to cover the range of exposures required. Additional packages were placed in some of the FCDA houses in an effort to approximate the exposure expected in the Civil Defense situation. The complement of film exposed at each station is given in Appendix E.

The dental X-ray film was exposed to one detonation without the NBS type film holder as a result of error rather than by design. Additional dental film was exposed in the special holders to a second shot and shipped with the other film to NBS for dose interpretation.

A batch of control film was maintained for each film type exposed and shipped to NBS with the exposed film. All film was stored in refrigerators until it was placed in the exposure area. The control film was then stored at room temperature to resemble the temperature environment of the exposed film.

3.4 RESULTS

The results of the exposed-film dose interpretation performed by NBS[4] supported the original assumption that these film types could be used as indicators of prompt radiation from a nuclear detonation provided that a high accuracy is not demanded. The response of the commercial roll film exposed along the dose-distance line is shown in Fig. 3.1, and the response of the roll film exposed in FCDA houses is shown in Fig. 3.2. The solid line indicates the response of the AEC instruments which are used for reference. The dashed line indicates a factor of 2 more than this reference line. The response of the roll film is generally within this factor of 2 with somewhat better agreement for higher doses than for lower doses.

The response of the dental X-ray film exposed on the dose-distance line is shown in Fig. 3.3, and the response of the dental film exposed in FCDA houses is shown in Fig. 3.4. Figure 3.3 also indicates the response of film exposed in NBS type film holders (marked B) as well as the response of dental film exposed without holders. It is interesting to note that the response of film not enclosed in the special holders was more nearly like the reference response than that in the special holders.

3.5 CONCLUSIONS

The results of the field test of commercial roll film and dental X-ray film indicated that such detectors will give a reasonable measure of the prompt exposure from a nuclear detonation. Since no exposures were made in residual fields and since no measurements were made of the effect of contamination of the film carton by residual fields, no conclusions can be stated about the response of the film to other than prompt radiation.

3.6 RECOMMENDATIONS

It is recommended that residual field measurements be made to determine the effect of radiation from fall-out on the roll and dental film. Film can be exposed during some future weapons test series at NTS to provide this information.

REFERENCES

1. Jack C. Greene, Various Aspects of Nuclear Radiation Measurements for Civil Defense Radiological Defense Purposes, Upshot-Knothole Report, WT-805.
2. Photographic Roll Film from Local Drugstores for Radiation Surveys in the Case of Atomic Disaster, Report NBS-3662, Oct. 12, 1954.
3. M. Ehrlich and S. H. Fitch, Nucleonics, 9(3): 5 (1951).
4. Field Performance of Photographic Roll Fills Used as Radiation Dosimeters, supplement to Report NBS-3662, Sept. 26, 1955; The Use of Dental X-ray Film in Atomic Disaster Surveys, Report NBS-4302, Oct. 1, 1955.

Appendix A

LIST OF PROJECT CONSULTANTS

Collins, Donald L., Assistant Project Officer	Landsverk Electrometer Co.
Anderson, Carl G., Jr.	Chatham Electronics Div., Gera Corp.
Bell, John M.	Jordan Electronics, Inc.
McKnight, William H.	Corning Glass Works
Minowitz, Wilbert*	Anton Electronics Laboratory, Inc.
Pollock, Earl M.†	El-Tronics, Inc.
Siebentritt, Carl, Jr.	Cincinnati Div., Bendix Aviation Corp.
Wakefield, Ernest H.	Radiation Counter Laboratories, Inc.

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* Now with Chatham Electronics Div., Gera Corp.

† Now with Victoreen Instrument Co.

Appendix B

LIST OF INSTRUMENTS CONTRIBUTED FOR EVALUATION

DOSIMETERS, POCKET CHAMBERS, AND READING DEVICES

Admiral CP-95/PD phosphate-glass dosimeter reader
Bendix Models 622 and 619 (CD V-730 and V-740) and Model 686 quartz-fiber dosimeters; Model 643 (CD V-750) dosimeter charger
Cambridge Models BM 20013/10, BM 20013/50, and BM 20013/100 quartz-fiber dosimeters
Chatham 200-r dosimeters; 100- and 600-r pocket chambers; 100- and 600-r charger readers; Model XA-100 charger
Corning DT-60 phosphate-glass dosimeter
Keleket Models K191 and K171 quartz-fiber dosimeters; Model K135C charger
Landsverk Models L-28, L-43, L-45, and L-46 quartz-fiber dosimeters; Models L-65, L-81, L-83, and L-85 pocket chambers; Models L-21K-12, L-24K-12, L-60, and L-61 chargers; Model L-61 RK r-meter and chambers
Nassau Ionometer
Victoreen Model 541/A quartz-fiber dosimeter and Model 561/A charger; Model 362 pocket chamber and Model 287 charger reader; Model 70 condenser r-meter; Models 130, 70-5, and 552 chambers

SURVEY METERS SIMILAR TO FCDA SPECIFICATIONS CD V-710 OR V-720

Anton Models 11, 32, and HR Geiger-Mueller survey meters
Chatham Model CH-50 Geiger-Mueller survey meter
El-Tronics Models SID-1 (CD V-710) and PR-50 ionization-chamber survey meters
Goldak Model CD-10 Geiger-Mueller survey meter
Jordan Models AG-50-SR, AGA-500-SR, and 10K-SR ionization-chamber survey meters

LABORATORY TYPE EQUIPMENT

Anton Model 203 Precision Radioactivity Comparator
El-Tronics Model LS-64SS scintillation detector and scaler
Jordan Model PRAM-5 ionization-chamber monitoring and recording instrument
Landsverk Model L-76K Radicond
NRD Model B-1800 automatic scaler and Model CS-5 sample changer

Appendix C

DATA FOR BETA-ABSORPTION MEASUREMENTS

TABLE C.1 — DATA FROM STATION 3

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 4	12	8	880	0.5	0.44
		1	920	0.5	0.46
		2	360	1.2	0.43
		3	380	1.2	0.46
		4	200	2.3	0.46
		5	190	2.7	0.51
		6	100	6.1	0.61
		7	92	6.1	0.56
	30	8	860	0.5	0.43
		1	910	0.5	0.45
		2	350	1.2	0.42
		3	380	1.2	0.46
		4	200	2.3	0.46
		5	180	2.7	0.49
		6	100	6.1	0.61
		7	86	6.1	0.52
	60	8	850	0.5	0.43
		1	900	0.5	0.45
		2	350	1.2	0.42
		3	360	1.2	0.43
		4	180	2.3	0.41
		5	180	2.7	0.49
		6	90	6.1	0.55
		7	83	6.1	0.57
H + 8	12	8	560	0.5	0.28
		1	580	0.5	0.29
		2	220	1.2	0.26
		3	240	1.2	0.29
		4	120	2.3	0.28
		5	120	2.7	0.32
		6	60	6.1	0.37
		7	60	6.1	0.37

TABLE C.1 — (Continued)

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 8	30	8	550	0.5	0.27
		1	560	0.5	0.28
		2	220	1.2	0.26
		3	240	1.2	0.29
		4	120	2.3	0.28
		5	120	2.7	0.32
		6	60	6.1	0.37
		7	60	6.1	0.37
	60	8	540	0.5	0.27
		1	560	0.5	0.28
		2	210	1.2	0.25
		3	230	1.2	0.28
		4	120	2.3	0.28
		5	100	2.7	0.27
		6	60	6.1	0.37
		7	55	6.1	0.34
H + 35	12	8	140	0.5	0.070
		1	140	0.5	0.070
		2	54	1.2	0.065
		3	58	1.2	0.070
		4	28	2.3	0.065
		5	28	2.7	0.075
		6	14	6.1	0.085
		7	14	6.1	0.085
	30	8	140	0.5	0.070
		1	140	0.5	0.070
		2	54	1.2	0.065
		3	56	1.2	0.065
		4	28	2.3	0.065
		5	28	2.7	0.075
		6	13	6.1	0.080
		7	13	6.1	0.080
	60	8	140	0.5	0.070
		1	140	0.5	0.070
		2	55	1.2	0.065
		3	56	1.2	0.065
		4	30	2.3	0.070
		5	26	2.7	0.070
		6	14	6.1	0.085
		7	14	6.1	0.085

TABLE C.2 — DATA FROM STATION 4

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 7	12	8	1000	0.5	0.5
		1	2900	0.5	1.5
		2	2800	1.2	3.4
		3	4500	1.2	5.4
		4	3400	2.3	7.8
		5	3700	2.7	10.0
		6	2000	6.1	12.0
		7	2200	6.1	13.0
	30	8	880	0.5	0.44
		1	2200	0.5	1.1
		2	1800	1.2	2.2
		3	3000	1.2	3.6
		4	2200	2.3	5.1
		5	2200	2.7	5.9
		6	1200	6.1	7.3
		7	1300	6.1	7.9
	60	8	770	0.5	0.39
		1	1600	0.5	0.80
		2	1200	1.2	1.4
		3	2000	1.2	2.4
		4	1400	2.3	3.2
		5	1400	2.7	3.8
		6	800	6.1	4.9
		7	780	6.1	4.8
H + 34	12	8	160	0.5	0.080
		1	240	0.5	0.12
		2	200	1.2	0.24
		3	380	1.2	0.46
		4	310	2.3	0.71
		5	300	2.7	0.81
		6	220	6.1	1.3
		7	220	6.1	1.3
	30	8	140	0.5	0.070
		1	200	0.5	0.10
		2	150	1.2	0.18
		3	250	1.2	0.30
		4	190	2.3	0.44
		5	200	2.7	0.54
		6	120	6.1	0.73
		7	130	6.1	0.79
	60	8	130	0.5	0.065
		1	160	0.5	0.080
		2	100	1.2	0.12
		3	160	1.2	0.19
		4	110	2.3	0.25
		5	120	2.7	0.32
		6	60	6.1	0.37
		7	67	6.1	0.41

TABLE C.2 — (Continued)

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 79	12	8	46	0.5	0.023
		1	54	0.5	0.027
		2	37	1.2	0.044
		3	69	1.2	0.083
		4	58	2.3	0.13
		5	70	2.7	0.19
		6	40	6.1	0.24
		7	50	6.1	0.31
	30	8	41	0.5	0.021
		1	48	0.5	0.024
		2	28	1.2	0.034
		3	39	1.2	0.047
		4	29	2.3	0.067
		5	32	2.7	0.086
		6	18	6.1	0.11
		7	18	6.1	0.11
	60	8	38	0.5	0.019
		1	44	0.5	0.022
		2	22	1.2	0.026
		3	24	1.2	0.029
		4	14	2.3	0.032
		5	15	2.7	0.040
		6	6	6.1	0.037
		7	6	6.1	0.037

TABLE C.3 — DATA FROM STATION 5

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 7	12	8	920	0.5	0.46
		1	2600	0.5	1.3
		2	1600	1.2	1.9
		3	4600	1.2	5.5
		4	2500	2.3	5.8
		5	2000	2.7	5.4
		6	1700	6.1	10.0
		7	1500	6.1	9.1
	30	8	800	0.5	0.40
		1	2000	0.5	1.0
		2	1500	1.2	1.8
		3	2900	1.2	3.5
		4	2000	2.3	4.6
		5	2000	2.7	5.4
		6	1200	6.1	7.3
		7	1300	6.1	7.9
	60	8	760	0.5	0.38
		1	1800	0.5	0.90
		2	1400	1.2	1.7

TABLE C.3 — (Continued)

Time, hr	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
H + 7	60	3	2200	1.2	2.6
		4	1500	2.3	3.5
		5	1600	2.7	4.3
		6	840	6.1	5.1
		7	880	6.1	5.4
H + 34	12	8	140	0.5	0.070
		1	240	0.5	0.12
		2	160	1.2	0.19
		3	450	1.2	0.54
		4	280	2.3	0.64
		5	250	2.7	0.68
		6	220	6.1	1.3
		7	200	6.1	1.2
	30	8	140	0.5	0.070
		1	200	0.5	0.10
		2	140	1.2	0.17
		3	300	1.2	0.36
		4	220	2.3	0.51
		5	220	2.7	0.59
		6	150	6.1	0.91
		7	150	6.1	0.91
	60	8	130	0.5	0.065
		1	180	0.5	0.090
		2	120	1.2	0.14
		3	190	1.2	0.23
		4	140	2.3	0.32
		5	140	2.7	0.38
		6	80	6.1	0.49
		7	80	6.1	0.49
H + 79	12	8	38	0.5	0.019
		1	49	0.5	0.025
		2	27	1.2	0.032
		3	80	1.2	0.096
		4	50	2.3	0.11
		5	34	2.7	0.092
		6	46	6.1	0.28
		7	34	6.1	0.21
	30	8	38	0.5	0.019
		1	45	0.5	0.023
		2	25	1.2	0.030
		3	43	1.2	0.052
		4	32	2.3	0.074
		5	35	2.7	0.095
		6	24	6.1	0.15
		7	25	6.1	0.15
	60	8	39	0.5	0.019
		1	44	0.5	0.022
		2	23	1.2	0.028
		3	26	1.2	0.031
		4	18	2.3	0.041
		5	20	2.7	0.054
		6	11	6.1	0.067
		7	12	6.1	0.073

TABLE C.4 — DATA FROM STATION 6

Time, days	Table height, in.	Chamber	Response μa	Conversion, r/hr/μa ×10⁻³	r/hr
D+18	12	8	210	0.5	0.11
		1	240	0.5	0.12
		2	120	1.2	0.14
		3	220	1.2	0.26
		4	160	2.3	0.37
		5	180	2.7	0.49
		6	120	6.1	0.73
		7	130	6.1	0.79
	30	8	220	0.5	0.11
		1	260	0.5	0.13
		2	130	1.2	0.16
		3	180	1.2	0.22
		4	120	2.3	0.28
		5	130	2.7	0.35
		6	80	6.1	0.49
		7	80	6.1	0.49
	60	8	240	0.5	0.12
		1	270	0.5	0.13
		2	120	1.2	0.14
		3	150	1.2	0.18
		4	90	2.3	0.21
		5	100	2.7	0.27
		6	50	6.1	0.31
		7	60	6.1	0.37

TABLE C.5—DATA FROM STATION 7

Time, days	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa ×10⁻³	r/hr
D+71	12	8	140	0.5	0.070
		1	180	0.5	0.090
		2	90	1.2	0.11
		3	150	1.2	0.18
		4	80	2.3	0.18
		5	80	2.7	0.22
		6	50	6.1	0.31
		7	50	6.1	0.31
	30	8	130	0.5	0.065
		1	160	0.5	0.080
		2	80	1.2	0.096
		3	110	1.2	0.13
		4	70	2.3	0.16
		5	70	2.7	0.19
		6	40	6.1	0.24
		7	40	6.1	0.24
	60	8	130	0.5	0.065
		1	150	0.5	0.075
		2	70	1.2	0.084
		3	90	1.2	0.11
		4	60	2.3	0.14
		5	60	2.7	0.16
		6	30	6.1	0.18
		7	30	6.1	0.18

TABLE C.6—DATA FROM STATION 8

Time, days	Table height, in.	Chamber	Response, μa	Conversion, r/hr/μa $\times 10^{-3}$	r/hr
D+41	12	8	130	0.5	0.065
		1	140	0.5	0.070
		2	70	1.2	0.084
		3	80	1.2	0.096
		4	60	2.3	0.14
		5	60	2.7	0.16
		6	30	6.1	0.18
		7	30	6.1	0.18
	30	8	140	0.5	0.070
		1	160	0.5	0.080
		2	70	1.2	0.085
		3	80	1.2	0.10
		4	50	2.3	0.11
		5	50	2.7	0.13
		6	20	6.1	0.12
		7	25	6.1	0.15
	60	8	140	0.5	0.070
		1	150	0.5	0.075
		2	60	1.2	0.070
		3	70	1.2	0.085
		4	40	2.3	0.090
		5	40	2.7	0.11
		6	20	6.1	0.12
		7	20	6.1	0.12

Appendix D

DATA FROM DOSIMETER AND SURVEY-METER TESTS

TABLE D.1 — IONIZATION-CHAMBER RESPONSE TO PROMPT RADIATION

Exposed at station No.	Mfr.* and dosimeter No.	Range, r	Final reading, r	Sensitivity, $\frac{\text{instr. reading}}{\text{true dose}}$	Corrected reading, r
AS-30	CE-1-10	10	2.7	0.77	3.5
	CE-2-10†	10	3.5	0.91	3.8
	CE-3-10	10	2.7	0.77	3.5
AS-26	BX-8337	20	9.4	0.83	11.3
	BX-8339	20	8.9	0.78	11.4
	KT-13†	20	8.9	0.82	10.8
	KT-15†	20	9.2	0.82	11.2
	L-1025†	20	7.9	1.0	7.9
AS-24	CE-1-50	50	15	0.80	19
	L-1221	50	17	0.78	22
AS-22	BX-8545	100	36	0.94	38
	BX-8546	100	36	0.91	40
	CE-2-100	100	30	0.84	36
	CH-103	100	40	1.23	33
	CH-104†	100	78	1.18	66
	KT-3	100	29	0.76	38
	KT-10	100	33	0.82	40
	L-1128†	100	38	1.09	35
AS-20	CH-13	200	53	0.80	66
	CH-22	200	55	0.86	64
AS-17	BX-8154	600	200	0.80	250
	L-1033†	500	160	0.93	170
AS-16	BX-8153	600	310	0.78	400
	CH-601	600	380	0.93	410
	CH-602	600	340	0.62	550
	CH-603	600	360	0.93	390
AU-27	BX-9884	20	12.1	0.93	13
	BX-10185	20	11.9	0.83	14
	KT-5	20	11.1	0.79	14
	KT-6	20	11.1	0.81	14
AU-25	CE-2-50	50	24	0.84	29
	L-1220†	50	21	0.75	28

TABLE D.1 — (Continued)

Exposed at station No.	Mfr.* and dosimeter No.	Range, r	Final reading, r	Sensitivity, instr. reading / true dose	Corrected reading, r
AU-23	CH-105	100	47	1.01	47
	CH-106	100	40	1.11	36
AU-21	BX-8548	100	77	0.99	78
	BX-8549	100	72	0.84	86
	CE-1-100	100	64	0.84	76
	CH-101	100	78	1.21	65
	CH-102	100	78	1.01	77
	KT-1	100	56	0.74	76
	KT-2	100	57	0.81	70
	L-1129†	100	74	1.12	66
AU-17	BX-8152	600	260	0.77	340
	CH-605	600	340	0.93	370
	CH-606†	600	360	0.93	390
	L-1034	500	230	0.93	250
AU-16	BX-8155	600	400	0.80	500
AU-15	BX-8156	600	600	0.80	750

*CE, Cambridge; BX, Bendix; KT, Keleket; L, Landsverk; CH, Chatham.

† These chambers exhibited high leakage rates both before and after the shot (see Table D.3).

TABLE D.2 — CORNING PHOSPHATE-GLASS RESPONSE TO PROMPT RADIATION

Exposed at station No.	Serial No.	Final reading, r 8 hr	55 hr
AS-24	3116	8	8
	3117	8	9
	3118	7	5
	3119	9	11
	3120	8	8
AS-23	3111	16	16
	3112	19	18
	3113	10	11
	3114	16	16
	3115	19	19
AS-22	3106	28	30
	3107	31	35
	3108	32	32
	3109	38	42
	3110	31	34
AS-21	1041	50	49
	1042	54	55
	1043	50	51
	1044	52	55
	1045	51	52
AS-20	1036	79	85
	1037	80	82
	1038	82	85
	1039	79	80
	1040	79	85
AS-19	1031	116	124
	1032	112	115
	1033	119	125
	1034	120	126
	1035	115	120
AS-18	1026	172	
	1027	172	182
	1028	162	170
	1029		
	1030	175	185
AS-17	1021	250	260
	1022	255	270
	1023	265	285
	1024	245	253
	1025	260	280
AS-16	1016	400	410
	1017	380	395
	1018	380	395
	1019	382	392
	1020	380	395
AS-15	1011	585	600
	1012	570	585
	1013	595	600
	1014	570	580
	1015	575	585
AU-25	3103	16	17
	3104	18	19
	3105	10	13
AU-24	3101	21	21
	3102	21	24
AU-23	1046	25	26
	1047	30	32
	1048	32	32
	1049	29	31
	1050	28	35
AU-22	1051	45	42
	1052	44	55
	1053	46	48
	1054	48	58
	1055	51	55
AU-21	1056	78	82
	1057	79	85
	1058		
	1059	81	91
	1060	68	75
AU-20	1061	102	110
	1062	96	102
	1063	108	115
	1064	107	114
	1065	90	94
AU-19	1066	168	182
	1067	170	175
	1068	170	190
	1069	164	182
	1070	156	180
AU-18	1071	225	265
	1072	218	220
	1073	240	250
	1074	218	222
	1075	218	218
AU-17	1076	318	322
	1077	325	360
	1078	325	370
	1079	315	342
	1080	323	360
AU-16	1081	520	530
	1082	460	500
	1083	520	555
	1084	520	545
	1085	480	580

TABLE D.3 — LEAKAGE OF IONIZATION CHAMBERS AFTER EXPOSURE TO PROMPT RADIATION

Mfr.* and dosimeter No.	Range of dosimeter, r	Preshot exposure electrical leakage, % of full scale for 24 hr	Exposed at station No.	Total prompt radiation reading,† r	Start of electrical leakage test, hr postshot	Reading at end of 24 hr, r	% of full scale change after 24 hr	Reading at end of second 24 hr, r	% of full scale change after second 24 hr
BX-8153	600	0	AS-16	400	35	0	0		
BX-8154	600	0	AS-17	250	35	0	0		
BX-8155	600	0	AU-16	500	7	8	1.3	0	0
BX-8156	600	0	AU-15	750	35	0	0		
BX-8545	100	0	AS-22	38	7	1	1	2	0.3
BX-8546	100	0	AS-22	40	7	0	0	0	0
BX-8548	100	0	AU-21	78	7	1	1	1	1
BX-8549	100	0	AU-21	86	7	1	1	1	1
BX-8337	20	0.4	AS-26	11.3	7	0.2	1	0.4	2
BX-8339	20	0.4	AS-26	11.4	7	0.1	0.5	0.1	0.5
BX-9084	20	0	AU-27	13	7	0.2	1	0	0
BX-10185	20		AU-27	14	7	0.1	0.5	0.2	1
CE-1-100	100	0.2	AU-21	76	7	4	4	3.5	3.5
CE-2-100	100	0	AS-22	36	7	2	2	0	0
CE-1-50	50	0	AS-24	19	7	0	0	0	0
CE-2-50	50	0	AU-25	29	7	0	0	0	0
CE-1-10	10	0.5	AS-30	3.5	7	0	0	0.2	2
CE-2-10	10	1	AS-30	3.8	7	1.1	11	0.5	5
CE-3-10	10	0.5	AS-30	3.5	7	0	0	0	0
CH-601	600	0	AS-16	410	35	0	0		
CH-602	600	0	AS-16	550	7	0	0	0	0
CH-603	600	0	AS-16	390	35	0	0		
CH-605	600	0	AU-17	370	35	0	0		
CH-606	600	1.5	AU-17	390	7	150	25	45	7.5
CH-13	200	0	AS-20	66	7	0	0	0	0
CH-22	200	0	AS-20	64	7	8	1.3	0	0
CH-101	100	0	AU-21	65	7	0	0	11	11
CH-102	100	1	AU-21	77	7	0	0	2	2
CH-103	100	1	AS-22	33	7	1	1	3	3
CH-104	100	80	AS-22	66	7	65	65	76	76
CH-105	100	2	AU-23	47	7	5	5	3	3
CH-106	100	0	AU-23	36	7	5	5	3	3
KT-1	100	0.5	AU-21	76	7	7	7	0	0
KT-2	100	0	AU-21	70	7	8	8	1.5	1.5
KT-3	100	0	AS-22	38	7	2.2	2.2	2	2
KT-10	100	0	AS-22	40	7	5	5	3	3
KT-5	20	0.5	AU-27	14	7	0.8	4	0.5	2.5
KT-6	20	0	AU-27	14	7	1.6	8	0.7	3.5
KT-13	20	0.5	AS-26	10.8	7	4.3	21	2.5	13
KT-15	20	1.5	AS-26	11.2	7	5.3	27	3	15
L-1033	500	1.0	AS-17	170	35	28	5.5		
L-1128	100	5.4	AS-22	35	7	15	15	6	6
L-1129	100	1.5	AU-21	66	7	19	19	19	19
L-1220	50		AU-25	28	7	4	8	−3	−6
L-1221	50		AS-24	22	7	1	2	−3	−6
L-1025	20	1	AS-26	7.9	7	3.8	19	1.3	6.5

Note: The instruments were rezeroed after the first 24-hr postexposure leakage test.

* BX, Bendix; CE, Cambridge; CH, Chatham; KT, Keleket; L, Landsverk.

† Corrected value (see Table D.1).

TABLE D.4—RESPONSE OF IONIZATION-CHAMBER AND PHOSPHATE-GLASS DOSIMETERS TO RESIDUAL FISSION-PRODUCT FIELD

Mfr.* and instrument No.	Range of dosimeter, r	Electrical leakage, % of full scale for 24 hr	Sensitivity, $\frac{\text{instr. reading}}{\text{true dose}}$ for Co^{60} radiation	Dosimeter reading, r	Corrected reading, r	Additional reading after 24 hr, r	% of full scale change after 24 hr
Test A, Instruments Exposed on 090° Line in Radiation Field of 10 r/hr for 4.5 Hr							
BX-8542	100	0	0.91	41	45	2	2
BX-8543	100	0	0.92	41	45	0	0
CE-3-100	100	0.5	0.77	36	47	4	4
CH-107	100	0	0.94	36	38	5	5
CH-108	100	0.5	0.94	47	50	8	8
KT-11	100	1	0.81	39	48	8.5	8.5
KT-12	100	1	0.79	40	51	7.8	7.8
L-1127	100			40		4	4
Test B, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 1.5 Hr							
BX-8338	20	0	0.85	21	25	0.1	0.5
BX-10186	20	0	0.86	21	24	0.2	1.0
BX-221	20	0	0.91	21	23	0	0
KT-4	20	1.1	0.88	25	28	2.5	13
KT-14	20	3.5	0.73	0.8		3.5	17
NBS-V	25		0.68	15.5	23	1.8	7.2
V-VN-1	25	0	0.90	30	33	0	0
V-VN-2	25	0	0.92	30	33	0	0
Test C, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 3.5 Hr							
BX-8547	100	0.5	0.91	O.S.		0	0
CE-3-50	50	0.25	0.82	55	67	0.7	1.4
CH-109	100	20	1.94	88	45	28	28
CH-110	100	0	0.96	61	64	4	4
L-1051	50		0.81	48	59	0.7	1.4
Test D, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 4.5 Hr							
CH-607	600	0	0.94	140	150	0	0
CH-608	600	30	0.94	190	200	0	0
Test E, Instruments Exposed on 290° Line in Radiation Field of 2 r/hr for 1 Hr							
L-1282	5	0	0.75	O.S.		0.05	1
L-1283	5	0	0.75	O.S.		0.05	1
NBS-V	2.5		0.52	2.5	4.8	0.1	4
V-VN-1	2.5	0		2.6		0	0
Test F, Instruments Exposed on 290° Line in Radiation Field of 1 r/hr for Time Calculated To Give On-scale Reading							
KT-7	0.2	3	0.79	0.14	0.18	0.017	8.5
KT-8	0.2	3	0.80	0.13	0.16	0.014	7
KT-9	0.2	3	0.81	0.15	0.19	0.019	9.5
N-050	0.2	100	0.30	0.08	0.27	0.025	13
N-054	0.2	50	0.41	0.11	0.27	0.025	13
N-057	0.2	100	0.35	0.10	0.29	0.035	17
N-058	0.2	80	0.18	0.09	0.50	0.050	25
V-1	0.2	3	0.85	0.13	0.15	0.013	6.5

TABLE D.4 — (Continued)

Mfr.* and instrument No.	Range of dosimeter, r	Electrical leakage, % of full scale for 24 hr	Sensitivity, $\frac{\text{instr. reading}}{\text{true dose}}$ for Co^{60} radiation	Dosimeter reading, r	Corrected reading, r	Additional reading after 24 hr, r	% of full scale change after 24 hr
V-2	0.2	2.5	0.85	0.14	0.16	0.013	6.5
V-3	0.2	3	0.88	0.15	0.17	0.018	9
V-4	0.2	2.5		0.14		0.017	8.5
V-5	0.2	2	0.94	0.15	0.16	0.016	8
V-6	0.2	2.5	0.92	0.15	0.16	0.020	10
V-VN-1	0.25	0		0.12		0.007	2.8
V-VN-2	0.25	0		0.13		0.007	2.8
Test G, Instruments Exposed on 290° Line in Radiation Field of 10 r/hr for 27 Hr							
BX-8152†	600	0.4	0.77	310	400		
BX-8153†	600	0	0.78	340	440	0	0
BX-8154†	600	0	0.80	330	410	0	0
BX-8156†	600	0	0.80	330	410	0	0
CG-2001	600		0.89	380	430		
CG-2016	600		0.89	390	440		
CG-2031	600		0.89	380	430		
CG-2046	600		0.89	400	450		
CG-2061	600		0.89	380	430		
CG-2091	600		0.89	390	440		
CG-2092	600		0.89	390	440		
CG-2093	600		0.89	380	430		
CG-2094	600		0.89	390	440		
CG-2095	600		0.89	390	440		
CH-601†	600	0	0.93	370	400	0	0
CH-603†	600	0	0.93	370	400	0	0
CH-605†	600	0	0.93	360	390	0	0
L-1033†	500	1	0.93	390	420	28	5.5
L-1034†	500	2.5	0.93	380	410		

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* BX, Bendix; CE, Cambridge; CG, Corning Glass; CH, Chatham; KT, Keleket; L, Landsverk; N, Nassau; NBS-V, Victoreen r-meter with NBS calibration; V, Victoreen; VN, Victoreen r-meter.

† Instruments set in residual fission-product field upon removal from station for prompt radiation exposure.

TABLE D.5—QUESTIONS ASKED ON EQUIPMENT-EVALUATION QUESTIONNAIRE

1. Was equipment operative when you received it? ____Yes ___No
2. Does equipment have a means of indicating that it is operative?____ Yes___No If no, how did you determine that it was operative?______________________
3. If equipment would require no warm-up time, would you still have left equipment on for any period? ___Yes___No If no, explain. ______________________
4. Is the equipment of suitable size and weight for ease of handling and using in the field?____Yes___No If no, explain. ______________________
5. Could you use this equipment in the field and still have both hands free for other work?_____One hand free?____
6. Give comments on adequacy of the following after you have become familiar with the equipment in the field:
   a. Belt clip or carrying handle ______________________
   b. Carrying strap ______________________
   c. Zero stability. Does zero drift with time?____Yes ___No Is drift ___ up___down scale?
   d. Readibility. (If multiscale, did you have any difficulty in selecting scales, especially while walking and/or running in the field?) ______________________
   e. Can equipment be read in total darkness? ______________________
   f. Did meter needle fluctuate excessively? ______________________
   g. Controls (ease of use and identification): ______________________
7. Replace battery complement in the field with set of spares issued to you. How long did it require to make replacement?____ minutes. Was equipment operative after batteries were replaced?____Yes ___No Were you able to replace batteries with ease?____Yes____No If not, explain. ______________________
8. Did you have any malfunction of equipment?____Yes___No If yes, describe.______________________
9. Is your equipment directional?____Yes____ No Is this desirable? Explain.______________________

TABLE D.6 — RESULTS OF USE OF EQUIPMENT-EVALUATION QUESTIONNAIRE

	El-Tronics Rad-tek CD V-710				Jordan AGB-50-SR and AGB-500-SR				Chatham CH-50				Anton Model 11			
Question No.	No. of reports	Yes	No	Did not answer	No. of reports	Yes	No	Did not answer	No. of reports	Yes	No	Did not answer	No. of reports	Yes	No	Did not answer
1	11	11			5	5			2	2			7	7		
2	11	4	5	2	5	4		1	2		2		7	4		3
3	11	7	2	2	5	2	1	2	2	2			7	3		4
4	11	11			5	5			2	2			7	7		
5	11	4	7		5	3	2		2	2			7	7		
6a	11	7		4	5	5			2	2			7	4	1	2
6b	11	7	2	2	5	4		1	2	*	*		7	5		2
6c	11	6	3	2	5	1	4		2		2		7	4		3
6d	11	5	3	3	5		4	1	2	2			7	3	2	2
6e	11		11		5		5		2		2		7		7	
6f	11	1	10		5		5		2	1	1		7	2	4	1
6g	11	6	4	1	5	5			2	1		1	7	5	1	1
7	11		2	9	5	1		4	2	1	1		7	2		5
8	11	4	6	1	5	4		1	2		1	1	7		4	3
9	11	1	2	8	5	1		4	2			2	7	1		6

* Not answered.

TABLE D.7 — SURVEY-METER CALIBRATION RESULTS

Instrument designation	Calculated 0.2 r/hr		Calculated 3.5 r/hr		Calculated 35 r/hr	
	Reading	% error	Reading	% error	Reading	% error
El-Tronics No. 228	0.2	0	3.6	+3	29	−17
El-Tronics No. 418	0.15	−25	2.6	−26	27.5	−21
El-Tronics No. 418*	0.17	−15	3.0	−14	31	−14
Anton No. 205	0.17	−15	3.2	−9	38	+9
Anton No. 206	0.18	−10	3.2	−9	35	0
Jordan No. 82	0.19	−5	3.9	+11	40	+14
Chatham No. 3	0.28	+40	3.9	+11	34	−3
Chatham No. 3†	0.19	−5	3.9	+11	34	−3

* Batteries changed.

† Calibration adjustment on low scale.

Appendix E

COMPLEMENT OF FILM EXPOSED AT EACH STATION

FILM EXPOSED ON DOSE-DISTANCE LINE (10 STATIONS)

2 rolls Ansco Plenachrome
1 roll Ansco Press
2 rolls Ansco Supreme
2 rolls Kodak Plus-X
2 rolls Kodak Super-XX
2 rolls Kodak Verichrome
2 packets Minimax BS
2 packets Rinn EF-1
2 packets Rinn DC-1
2 packets Kodak DF-7
2 packets Kodak DF-58
2 packets Du Pont 150 D-1
2 packets Du Pont 150 LF-1

FILM EXPOSED IN FCDA HOUSES (7 STATIONS)

All films listed above except Ansco Press and 1 roll only of Ansco Supreme.

FILM EXPOSED IN SECOND EVENT IN NBS TYPE HOLDERS (4 STATIONS)

2 packets Minimax BS
2 packets Rinn DC-1
2 packets Kodak DF-7
2 packets Du Pont 150 D-1