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(1) Report on OPERATION REDWING, PROJECT 2.66b [U].

(6) CONTACT RADIATION HAZARD ASSOCIATED WITH AIRCRAFT CONTAMINATION BY EARLY CLOUD PENETRATIONS (U). (8)

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ABSTRACT

The contact hazard which personnel experience when working on radioactively contamina aircraft was investigated. Measurements of the contact hazard are approximated by surveying the aircraft with a gamma survey instrument (T1B) and applying a correction factor to the readings obtained; 110 times the T1B reading (r/hr) will give the approximate contact dose ep/hr) to the skin in areas of direct impingement of the contaminant, i.e leading edge of the wing, nose, etc., whereas 40 times the T1B reading is applicable to the sliding surfaces, i.e., sides of the fuselage.

The protection to an individual from the contact hazard realized by wearing gloves was also investigated. All gloves tested reduced the radiation intensity to the hands by at least 50 percent in addition to preventing the contaminant from coming in direct conta with the skin. Wearing of gloves in radiation fields of 0.1 r/hr or more is recommended.

It is recommended that Air Force publications be revised to indicate the lack of nece sity for the decontamination of radioactively contaminated aircraft by Air Force operational organizations.

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Chapter I

INTRODUCTION

1.1 OBJECTIVES

The operations with which this report is concerned were carried out as part of Project 2.66. The objectives were to: (1) determine whether any correlation exists between the contact radiation hazard on aircraft that have recently flown through nuclear clouds and the dose rate measured on the surface by an AN/PDR-39 (T1B) survey meter; (2) study the distribution, intensity, and decay of the contamination that causes the contact hazard; and (3) evaluate the amount of protection offered by each of a number of different types of gloves.

1.2 BACKGROUND AND THEORY

During recent years concern has grown over the potentially serious contact radiation hazard that might be encountered by personnel who come in contact with aircraft recently contaminated by flight through nuclear clouds. This concern has been prompted in large part by theoretical considerations as typified by analyses such as those in References 1 and 2.

For the purpose of their theoretical analysis of the problem of beta intensities, the authors of Reference 1 assumed an idealized geometry in which the contamination was considered to be distributed uniformly over an infinite plane. Based on this assumption, the ratio of the beta intensity to that of the gamma was calculated to be about 130 to 1. It was concluded that the beta hazard was of sufficient magnitude to warrant special instrumentation for measurement of the hazard in all areas of fission fragment contamination.

Similarly, it was shown in Reference 2 that in air or tissue the ion track density of moderately energetic beta particles is about 75 times that of the photon of comparable energy; hence, if two betas are emitted for each photon, the ratio of these ionization intensities would be 150 to 1.

As a result of analyses of this kind, experiments were undertaken to measure the relative ionization intensities of beta and gamma radiation under conditions that might be encountered in the field. Reference 3 is an example of such a field experiment. In this particular instance, the measurement of the beta-gamma ratio was undertaken in desert fallout regions. While this was an experiment of primary interest to ground troops, some of the results can be applied to the aircraft problem. Of particular interest is the finding that a somewhat-high ratio of beta to gamma ionization intensities could, in some instances, be changed to a field of almost pure gamma by removal of one relatively large particle in the vicinity of the area of measurement. Such a particle may contribute most of the beta radiation for that particular measurement. This demonstrates the fact that the effects of beta radiation will be experienced only in close proximity to actual radioactive material. Of more importance is the indication that in fallout areas, and perhaps under other conditions as well, one may be dealing with individual point sources rather than uniform areas of contamination. This experiment concluded that the total radiation hazard to the sensitive layer of the skin was less than six times the gamma hazard at heights of $\frac{1}{2}$ inch to 6 feet above a desert surface contaminated with fallout fission fragments and neutron-induced activity.

Another undertaking of considerable importance was carried out during Operation Greenhouse and extended during Operation Buster-Jangle (References 4 and 5). Measurements of both gamma energies and so-called beta-gamma ratios were made on fission fragments collected on plaques that had been flown through nuclear clouds or placed in fallout areas. During Buster-Jangle, the beta-gamma ratio in fallout areas was found to be a maximum of 14 for a surface shot and 24 for an underground shot. During Greenhouse this ratio was found to be 156 at times of 72 to 168 hours following detonation. It is apparent that a wide variation exists in the results of experimental measurements of the ratio of beta to gamma ionization intensities from fission fragments, depending on the history of the radiation source and the experimental arrangement.

One may not infer from these results that the beta-gamma ratios obtained from mathematical considerations are not correct. Instead, it should be emphasized that the experimental ratios depart from theory because the experimental conditions differ from those assumed in the calculations. The distribution of the contamination appears to be the most-critical variable.

In any study of the contact radiation hazard on aircraft, the distribution of the contamination must be determined. Certainly, the contamination consists of discrete particles of matter. The flux of fission products, as seen by an aircraft flying through a nuclear cloud, could be such as to result in surface contamination ranging from widely spaced particles to a condition approximating a uniform radiation field. Insight into just how much separation the particles may have and still be treated as a uniformly distributed source may be had by considering that the thinnest layer of inert skin is about 0.1 mm thick. This inert layer will always intervene (except in the case of open wounds) between the particles and the papillary, or sensitive, layer of the skin. Consequently, uniform particles separation not exceeding 0.1 mm will appear to the living tissues as essentially uniform contamination. The problem of determining the ratio of effective surface radiation to gamma field radiation becomes greatly simplified if uniform contamination exists on the surface.

On the other hand, departure from uniform contamination might result in intense radiation at a discrete particle that registers as a low dose rate on a standard survey meter, such as the T1B. This apparent lack of intensity results from the fact that an ion-chamber survey meter suitable for field use must, of necessity, have a rather large ionization chamber. As a result of this large size, the intense ionization in a small volume of the chamber near a highly active particle appears to be moderate when averaged throughout a volume of several hundred cubic centimeters.

Nevertheless, if one touches this highly active particle, the sensitive tissues nearest the particle receive the full impact of the intense radiation, and a burn hazard exists.

Other important considerations in evaluating a skin radiation hazard are the effect of scattering, filtration of beta and low-energy gamma radiation by instrument walls, and the penetrating characteristics of the radiation. To make an absolute measurement of the dose rate near a surface contaminated with fission fragments and to translate this to a personnel hazard is difficult. However, a few practical approaches developed in previous studies (References 3 and 6) permit one to make empirical measurements that are directly applicable to the determination of dose.

It has been shown (References 2, 3, and 7) that the papillary layer of skin where young skin cells grow is the area where the greatest hazard exists and is approximately 0.1 mm beneath an outside layer of dead, inert skin, except on the palms and soles (where the thickness of the dead skin may be 0.5 mm or more). By devising instrumentation with a covering of no more than the thickness of this inert layer of skin (approximately 10 mg/cm^2) over the detecting element, one eliminates from his measurements only the radiation that would not be seen by the sensitive tissue of the body anyway. Difficulties engendered by scattering are likewise minimized by instrumentation that limits its measurements to a very-thin layer and is surrounded by tissue-like material. Such a measurement gives the highest dose rate one could expect for the most sensitive layer, that is, the maximum hazard. With respect to the relative biological effectiveness (RBE) of betas as compared with gammas in the irradiation of skin, it was concluded in Reference 3 that in dealing with unknown proportions of betas and gammas mixed together, it is reasonable to accept the net ionization per unit volume as the total beta-plus-gamma dose. Consequently, it is not necessary to differentiate between the two types of radiation in the empirical measurements.

The work reported in Reference 6 undertook to determine the ratio between the greatest total dose rate reaching the sensitive tissues of the skin if contact is made with a contaminated aircraft surface and the dose rate indicated by standard field survey instruments. No attempt was made to differentiate between betas and gammas in determining this ratio, and the ratios so determined are not beta-gamma ratios. The ratio was found to be about 90 to 1 on aircraft impact surfaces and less than 40 to 1 on aircraft surfaces other than impact surfaces. Some absorption studies were made from which an apparent beta-gamma ratio could be inferred. These ratios agreed with those determined by the former technique.

All of the measurements reported in Reference 6 were made on aircraft whose contamination resulted from flying through the cloud of a detonation in the kiloton range. The present project has undertaken to continue this work and to extend it to contamination resulting from detonations in the megaton range.

Chapter 2

PROCEDURE

2.1 OPERATIONS

On each shot of the test series, jet aircraft departed from Eniwetok Atoll, flew through the cloud, and returned to base. It was on these aircraft that measurements were made. During Shots Erie and Inca the F-84 aircraft used for sampling by the Test Aircraft Unit were studied. During Shots Zuni, Flathead, Dakota, and Apache measurements were made on B-57B aircraft assigned to Project 2.66 from Tactical Air Command. The latter were flown through the cloud at somewhat earlier times than those employed by the sampling aircraft.

Studies were made on aircraft which flew through the cloud at times varying from 41 to 81 minutes after detonation. The aircraft were on the ground within an hour after the cloud penetration. Contamination studies were begun immediately and extended for about 9 hours. Decay studies continued for an additional 12 hours.

When the planes landed, a survey was made at predetermined spots using a T1B. The areas were clearly marked and the average dose rate was used to calculate the exposure time for the photographic film.

Radioautographs were made at intervals continuing up to 9 hours after time of detonation. These were intended to measure the amount and distribution of the contamination. Additional exposures were made in the evaluation of protective gloves.

2.1.1 Instrument Survey. The survey of the aircraft was made with a T1B. These readings were made at a distance of ¼ to ½ inch from the surface. In addition to the surface survey, several decay studies were made for times up to 24 hours after detonation. The T1B was used for these studies, and measurements were made at several locations on the contaminated aircraft.

2.1.2 Radioautographic Techniques. As soon as the surface dose rates on the aircraft had been established by the T1B survey, exposure of the photographic film was begun. The areas selected for the exposure were protected with a thin covering of polyvinylacetate sheet plastic. This covering protected the contamination from rainfall and other physical disturbance.

A film of appropriate speed was selected and placed over the chosen area. Masking tape was used to hold the film in close contact with the surface. At least two exposures were made on each area. Exposure times differed by a factor of two or three. This was done in order to ensure that films of readable density would be obtained. To reduce darkening by the gamma field surrounding the aircraft to a minimum, the film was kept at a distance of about 100 feet from the aircraft, both before and after the controlled contact exposure. Since this could not eliminate gamma exposure entirely, control films were kept in a similar environment. The density of these control films was subtracted from that of the exposed films.

The exposed film was developed with uniform agitation in Kodak liquid X-ray developer (4 quarts of developer, 4 gallons of water) for 5 minutes at 67.45 ± 0.02 F, immersed in an acetic acid stop bath for 2 minutes, fixed for 7 minutes in Kodak liquid X-ray fixer, washed briefly, treated with Kodak HE-1 hypo eliminator, washed for 5 minutes in running water, rinsed in a wetting agent, and dried in a Fisher anhydrator for 10 to 15 minutes.

A set of calibration films was processed with each batch of film. These films had been exposed to a standard $Sr^{90}-Y^{90}$ source for predetermined lengths of time. A density-versus-exposure curve was plotted from these films. The curve was then used to determine the radiation dose received by the films that had been exposed to the surface contamination.

Density measurements on the processed film were made with two densitometers. One of these was a Macbeth-Ansco Color Densitometer equipped with a 0.1-mm-diameter aperture and the other was a Los Alamos Film Densitometer, manufactured by the Eberline Instrument Division of the Reynolds Electrical and Engineering Company, Inc.

Depth-dose measurements were made on the leading edge of the aircraft just inboard of the engine and, also, on the tip tank. These two positions were chosen in order to allow a comparison between the apparent beta-gamma ratios near and at a greater distance from the stronger gamma field that exists at or near the jet engine.

TABLE 2.1 CHARACTERISTICS OF FILMS USED

Film Type	Range	Emulsion	Total Thickness*
	rep		mg/cm^2
5135	0.02–2.0	Double	34.0
0523	0.4 4.0	Single	28.4
DF-19	4.0 70.0	Single	27.0

*Includes both emulsion and film support or backing.

As a practical application of the absorption measurements, an attempt was made to evaluate the protection offered by various types of gloves. This involved cutting a representative swatch from each type of glove and interposing the material between the film and the contaminated surface. By comparing these films with similar films exposed to the same area without the interposed swatch, the reduction in dose caused by the glove could be determined.

2.2 INSTRUMENTATION

2.2.1 Military Issue Instrument. The T1B is a standard Air Force instrument used for gamma survey. Since detailed specifications are readily available through Air Force channels, it will not be described here.

2.2.2 Densitometers. The densities of the exposed films were measured by two densitometers. One was the Ansco color densitometer. It has a usable range of from 0 to 6 density units. For the purpose of this study, it was fitted with an aperture having a diameter of 0.1 mm. It was used primarily for determining the density of the small areas of film darkened by exposure to particulate contamination. The other densitometer was the Los Alamos film densitometer, Model FD-2, manufactured by the Eberline Instrument Division of the Reynolds Electrical and Engineering Company, Inc. This in-

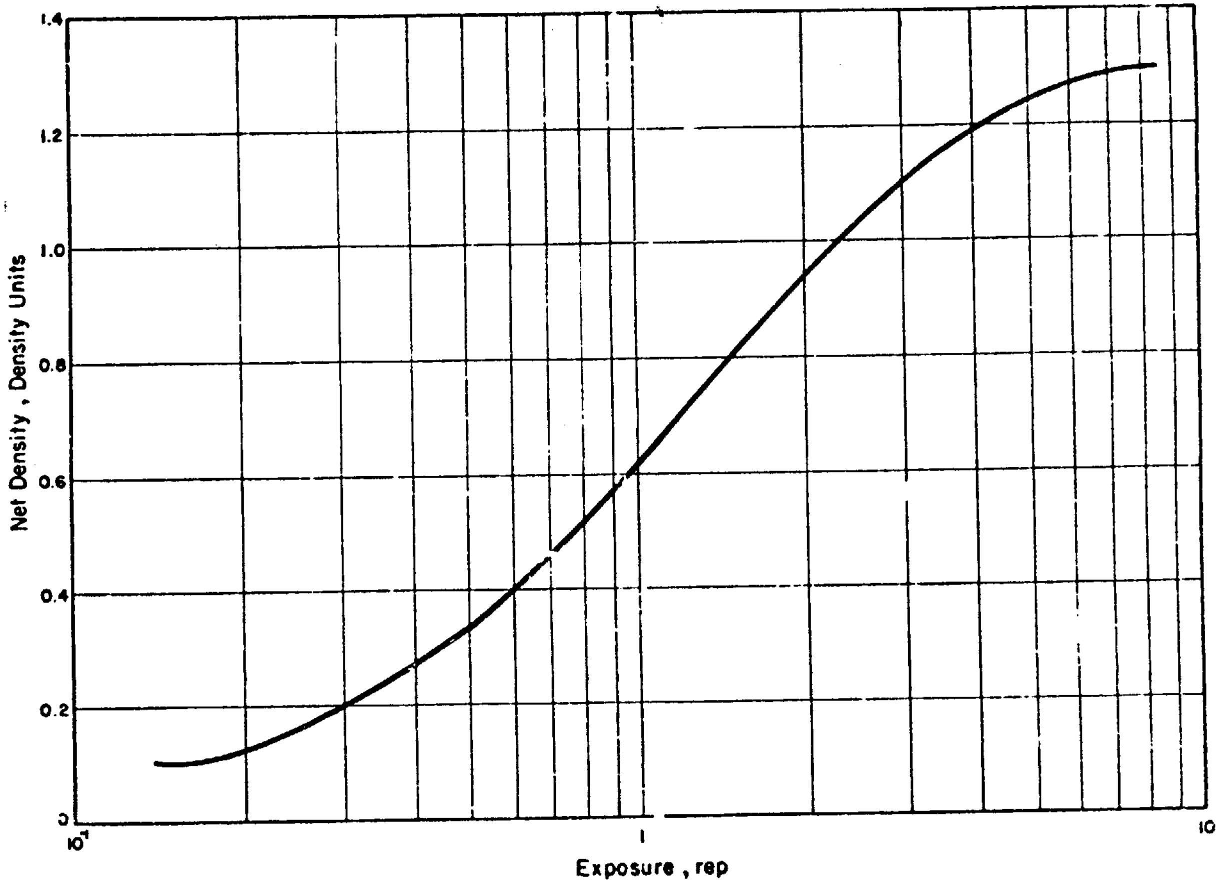


Figure 2.1 Exposure-density curve for 0523 film exposed to Sr^{90}-Y^{90}.

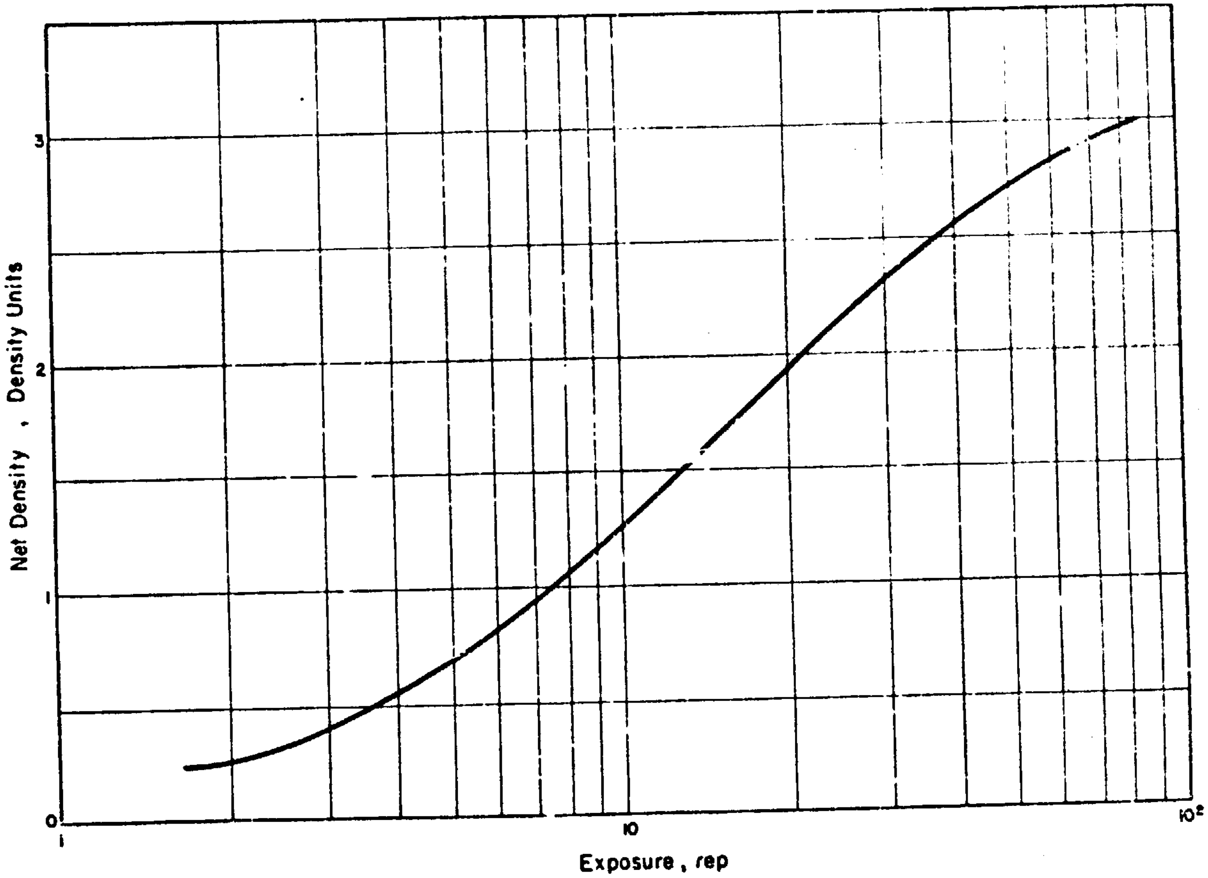


Figure 2.2 Exposure-density curve for DF-19 film exposed to Sr^{90}-Y^{90}.

strument has the capability of measuring the average density of areas of film as large as $\frac{3}{4}$ by $\frac{1}{8}$ inch, even though the density is nonuniform.

2.2.3 Photographic Film for Radioautographic Studies. One method of studying the surface contamination and relating it to the contact hazard is that of photographic film dosimetry. To obtain accurate measurements of dose rates of all tissue-damaging radiation and the distribution of this radiation, special film packs were developed. These had the following characteristics:

1. **Size:** Dental pack size of $1\frac{7}{32}$ by $1\frac{5}{8}$ inches.

2. **Emulsion:** Single emulsion of about 5 mg/cm^2 in thickness. A thin single emulsion eliminates the necessity for the use of corrections to account for the absorption of the beta radiation in the material of the film itself.

3. **Wrapping:** (1) Individually wrapped by hand in a light-tight covering 8.6 mg/cm^2 thick consisting of red cellophane and thin aluminum foil. (2) Film stacks for depth-dose measurements wrapped [illegible] described above. A stack consisted of 30 films with 8-mg/cm^2 paper spacers between adjacent films. Two types of films were used. The composition of each stack was as follows: (1) six to ten of the less sensitive film; (2) five of each film type placed alternately; and (3) sufficient of the more sensitive film to bring the total number of pieces of film to thirty.

4. **Range of Sensitivity:** Several types of film with varying sensitivities were obtained in order to assure that all anticipated dose rates could be measured. Table 2.1 lists these films, along with their respective characteristics. In actual practice only the 0523 and DF-19 types were used inasmuch as they covered the entire range of exposures that was encountered.

2.2.4 Calibration Standards. Since densities of film are relative measurements, the accuracy of dose measurements made with film is no better than the standard to which the densities refer. The standards used by the authors of Reference 6 were used for the present study. They were Sr^{90}-Y^{90} and tuballoy.

Through exposure of a particular type of film to one of these standards, a characteristic exposure-versus-density curve was obtained. Figures 2.1 and 2.2 show typical curves obtained for 0523 and DF-19 film. These curves were used to convert density measurements to dosage for those films that had been exposed to fission-fragment contamination. In order to eliminate any variation that might have resulted from variations in processing conditions, control films were exposed and processed with each batch of film. The densities of these control films were averaged, and a characteristic exposure-versus-density curve was drawn for each shot. The variation in these curves from one shot to another was never more than 10 percent and usually was less than 5 percent.

2.3 DATA REQUIRED

The data required to accomplish the objectives of this project included: (1) radiation dose rate surrounding a contaminated aircraft as measured by a standard survey instrument; (2) actual radiation dose rates on the surface of the aircraft and the distribution of the activity; (3) a measure of the absorption characteristics of this contamination; and (4) measurements of the rate of decay of the contamination as a function of elapsed time after detonation.

Chapter 3
RESULTS

The aircraft that were surveyed had surface gamma dose rates at the same location of from 1 r/hr to 10 r/hr. The aircraft had penetrated the cloud at an early time and were highly contaminated. The detailed instrument survey and radioautographic studies required three of the project personnel to remain in the vicinity of the aircraft for 8 to 12 hours immediately after the aircraft landed. The radiation doses received under these circumstances were of the order of 0.5 to 1 r for the day. The total radiation dose after participation in seven shots did not exceed the maximum permissible exposure of 3.9 r established for the operation by the Commander of Joint Task Force Seven. The experimental plan and procedure proved to be satisfactory. Considerable data which are directly applicable to operations in the field were collected.

3.1 DISTRIBUTION OF CONTAMINATION

The radioautographs obtained showed generally a uniform field of radiation on which were superimposed small areas of relatively more intense radiation. The uniform field was the gamma field that surrounded the aircraft. The number of intense regions varied from less than ten to several hundred per square centimeter. These areas of greatest intensity showed up on the film as dark spots ranging in diameter from 0.1 mm to as much as 1 or 2 mm. The radioautographs of the contamination showed no difference between kiloton-range and megaton-range shots nor between F-84 and B-57 aircraft. Figure 3.1 shows two typical radioautographs. The areas of contamination appear as darkened portions of the film.

The contamination was most prominent in crevices on the aircraft, in cracks, and around rivet heads or other irregularities in the surface. In these cases the radioautograph was a sharp outline of the object beneath the film with the crevices showing collections of relatively intense contamination. This is illustrated by Figure 3.2, which is the radioautograph of the canopy release button on an F-84. For the purposes of extensive study, relatively smooth surfaces were chosen, since such surfaces predominate in the total surface area of the aircraft. As might be expected, the leading edge of the wing, nose, or any other surface at which a sharp change in the direction of the air flow occurred, exhibited greater contamination than those surfaces where a smooth flow prevailed. These will be referred to as impingement and sliding surfaces, respectively. Examples of sliding surfaces are the top and bottom surfaces of the wing and the side of the fuselage. Figure 3.1 shows examples of the contamination pattern on both impingement and sliding surfaces. Table 3.1 shows values for the intensities measured on F-84 aircraft contaminated by flights through the clouds from kiloton-range bursts. Table 3.2 shows similar values for B-57 aircraft contaminated by flights through clouds from multimegaton detonations. The values shown are the average of a number of measurements made during the period from 2 to 4 hours after detonation. More complete tables can be found in Appendixes A.1 and A.2.

3.2 INTENSITY OF RADIATION

A wide range of dose rates was measured. The dose rates varied from shot to shot and from location to location on the aircraft. The variations are indicated in Tables 3.1 and 3.2, which show the surface dose rates as measured by the T1B and by photographic film. For the film the maximum, average, and minimum dose rates are given. The maxima and minima were measured through a densitometer aperture 0.1 mm in diameter. The average value was derived from a densitometer aperture that encompassed nearly the whole area of the film. The intensity of radiation showed wide variations over very small areas. For example, one film placed on the nose of a B-57 about 2 hours after

Side of fuselage of B-57B just below canopy. (Blurring near edges due to poor contact with aircraft surface.)

Leading edge of wing of B-57B just outboard of engine

Figure 3.1 Typical radioautographs, showing distribution of contamination on smooth surfaces.

detonation showed a maximum of 400 rep/hr and a minimum of 15 rep/hr. The latter value is only 4 percent of the former.

As might be expected, the variation in dose rates from one shot to another was greatest on impingement surfaces. This holds true for both T1B and film measurements.

3.2 COMPARISON OF MEASUREMENT METHODS

Dose-rate measurements with a T1B and photographic film were made over as nearly the same area as possible. (It should be remembered that the sensitive area of the T1B is approximately ten times that of the film.) Care was taken not to disturb the contamination. The ratios between the two methods of measurement are shown in Tables 3.3 and 3.4. The values shown are the average of a number of measurements. More comprehensive tables are given in Appendix A (A.3 and A.4).

The values shown in the columns headed "Film Max/T1B" and "Film Ave/T1B" are the ratios of the maximum and average dose rates measured by the film to the T1B measurement. These ratios are not beta-gamma ratios nor are they ratios of beta plus gamma to gamma. They are ratios of the total surface dose rates as measured by two entirely

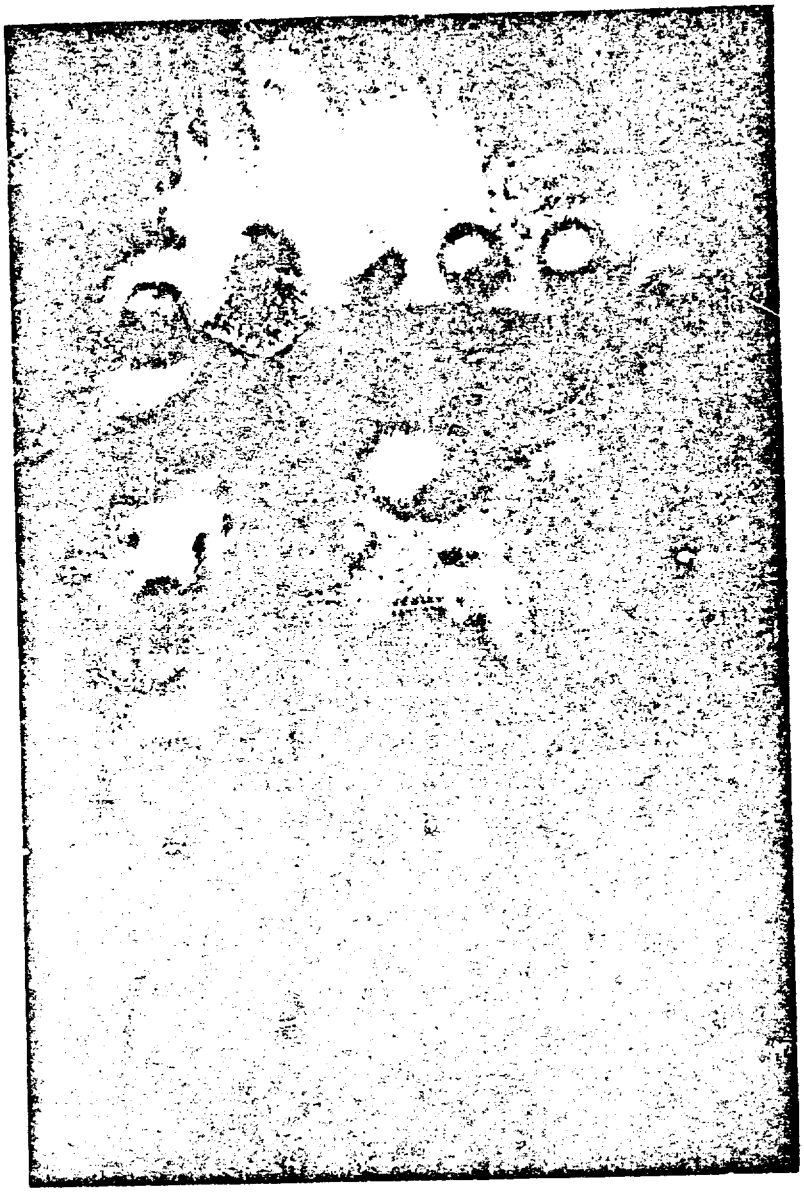


Figure 3.2 Radioautograph of canopy-release button on F-84.

different methods. The ratio of the maximum dose rate on "hot spots," i.e., small areas of intense radiation, measured by film to that indicated by the T1B varied from 650 to 6. Mean values of 110 for impingement surfaces and 40 for sliding surfaces were found. The comparable variation in the ratio of average film dose rates to T1B dose rates was from 300 to 3 with mean values of 55 and 20 for impingement and sliding surfaces, respectively. It is also apparent from the tables that a wider variation exists on impingement surfaces than on sliding surfaces.

The values shown in the columns headed "Hot Spot β/γ" and "Area β/γ" are apparent beta-gamma ratios as determined by depth dose studies with photographic film. Details of this study will be given in a later section. In almost all cases there is fair agreement between these ratios and the film-to-T1B ratios.

3.4 OTHER FACTORS AFFECTING THE NATURE OF THE CONTAMINATION

From an examination of Tables 3.1 and 3.2, it can be seen that there is considerable variation from one shot to another in the general level of contamination picked up by the aircraft. A number of variables can be suggested that might account for this. Among them are time and altitude of penetration, total time in cloud, type and yield of nuclear device, type of burst, prevailing weather conditions, condition of aircraft, and airspeed. No doubt there are others. The data collected are not sufficiently complete to allow inferences concerning the effects of these variables. All that can be said is that the surfaces of some of the aircraft became more heavily contaminated than others.

TABLE 3.1 SUMMARY OF INSTRUMENT SURVEY AND FILM MEASUREMENTS ON F-84 AIRCRAFT DURING PERIOD 2-4 HOURS AFTER DETONATION

Location of Film on F-84 Aircraft	Erie Time of Penetration H + 57 min; H + 62 min				Inca Time of Penetration H + 81 min; H + 85 min			
	T1B r/hr	Film rep/hr			T1B r/hr	Film rep/hr		
		Max	Ave	Min		Max	Ave	Min
Side of Air Intake	6.5	3,300	1,500	1,300	0.8	60	8	5
Side of Fuselage Below Compt.	0.7	55	12	7	0.9	55	14	12
Wing Low Edge, Halfway Out	5.4	3,800	1,600	900	1.0	50	15	6
Side of Tip Tank	1.2	90	30	15	0.8	50	14	10

3.5 DEPTH DOSE STUDIES

Approximately fifty depth dose studies were made by means of stacks of photographic film. Two representative examples of the results are shown in Figures 3.3 and 3.4. They show the dose experienced at various depths in stacks of film exposed to the leading edge of the wing at a point just inboard of the engine and to the inboard side of the tip tank. The dashed lines represent average values over the total area of the film, whereas the solid lines represent a single "hot spot," or area of intense radiation.

The film stacks consisted of Eastman DF-19 and 0523 film. In the analysis of the data, the film nearest the surface was considered to have received 100 percent of the dose. This is justified for the purposes of this study, inasmuch as the 8.6-mg/cm^2 wrapper

TABLE 3.2 SUMMARY OF INSTRUMENT SURVEY AND FILM MEASUREMENTS ON B-57B AIRCRAFT DURING PERIOD 2-4 HOURS AFTER DETONATION

Location of Film on B-57B Aircraft	Time of Penetration H + 52 min				Time of Penetration H + 65 min; H + 78 min				Time of Penetration H + 41 min			
	T1B r/hr	Film rep/hr			T1B r/hr	Film rep/hr			T1B r/hr	Film rep/hr		
		Max	Ave	Min		Max	Ave	Min		Max	Ave	Min
Top of Nose	2.0	400	30	15	0.5	65	64	36	0.8	65	11	8
Side of Fuselage Below Canopy	0.2	20	4	1	0.5	12	5	3	0.6	27	4	1
Unpainted Gun Cover, Leading Edge	3.0	300	100	60	1.6	410	96	69	2.8	96	22	18
Painted Leading Edge, Inboard	3.0	190	40	20	3.5	—	270	145	6.0	35	15	8
Side of Tip Tank	1.5	50	15	4	0.8	215	36	30	1.0	30	12	7

TABLE 3.3 SUMMARY OF FILM/T1B AND APPARENT BETA/GAMMA RATIOS FOR F-84 AIRCRAFT AS MEASURED FROM 2 TO 4 HOURS AFTER DETONATION

Location of Film on F-84 Aircraft	Shot Erie Time of Penetration H + 52 min				Shot Inca Time of Penetration H + 81 min; H + 88 min			
	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ
Side of air intake	510	—	230	—	75	—	10	—
Side of fuselage below canopy	80	—	17	—	61	—	16	—
Wing lower edge, half way out	650	70	300	35	50	60	15	14
Side of tip tank	75	—	25	—	62	65	18	20

TABLE 3.4 SUMMARY OF FILM/T1B AND APPARENT BETA/GAMMA RATIOS FOR B-57B AIRCRAFT AS MEASURED 2 TO 4 HOURS AFTER DETONATION

Location of Film on B-57B Aircraft	Shot Zuni Time of Penetration H + 52 min				Shot Flathead Time of Penetration H + 65 min; H + 78 min				Shot Dakota Time of Penetration H + 41 min			
	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ
Top of nose	200	—	15	—	220	—	215	—	130	—	22	—
Side of fuselage below canopy	100	—	20	—	24	—	10	—	45	—	7	—
Unpainted gun cover	100	—	33	—	260	—	60	—	34	—	8	—
Painted leading edge, inboard	63	—	13	—	—	100	70	45	6	—	2	3
Side of tip tank	33	—	10	—	145	90	48	30	3	30	12	16

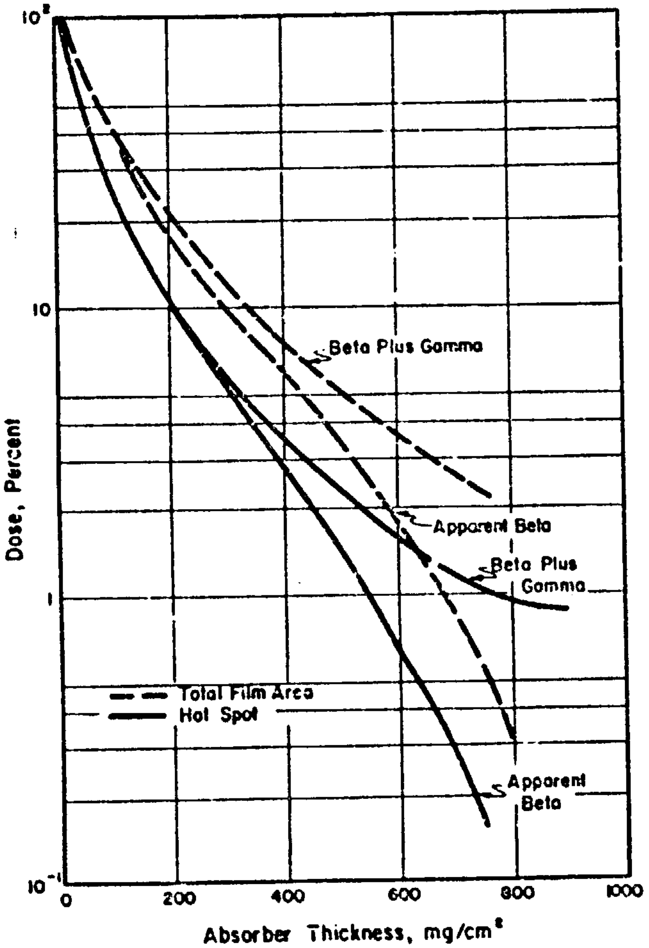


Figure 3.3 Depth-dose measurements on leading edge of B-57B.

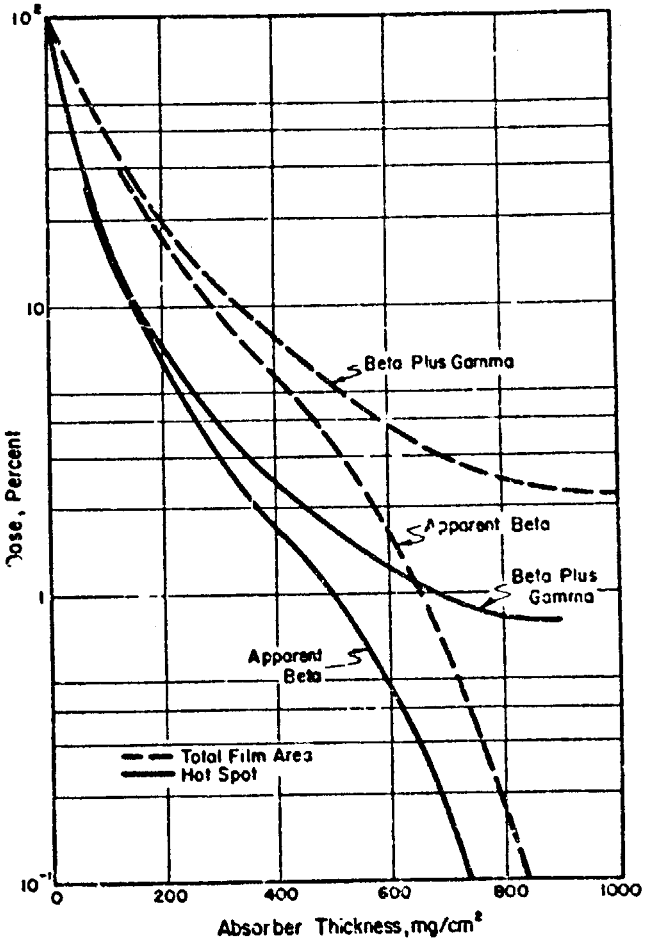


Figure 3.4 Depth-dose measurements on tip tank of B-57B.

plus the polyvinylacetate surface covering is very nearly equal to the thickness of the inert layer of the skin.

The apparent total dose (Figures 3.3 and 3.4) decreases smoothly as the absorber thickness is increased and finally reaches a constant value. If this constant value is taken to be the gamma dose to which the stack was exposed, the apparent beta dose can be calculated by subtracting this amount from the apparent total dose. A curve that represents the absorption characteristics of the beta contamination alone can then be drawn. This was done in Figures 3.3 and 3.4.

The results of this method of analysis are summarized for all of the film stacks in Tables 3.3 and 3.4 under columns headed "Hot Spot β/γ" and "Area β/γ." In general, these ratios agree rather well, especially for the average dose rates measured by the individual films and the T1B.

3.6 ABSORPTION BY STANDARD GLOVES

An attempt was made to evaluate the extent to which various types of gloves would reduce the contact hazard to which the wearer would be subjected. A complete description of each of the thirteen different gloves is given in Appendix B.

A preliminary evaluation was obtained by interposing the glove swatches between film and the Sr^{90}-Y^{90} standard source. The column headed "Absorption Sr^{90}-Y^{90}" in Table 3.5 shows the percentage of the incident radiation which was absorbed by the glove in question. Each percentage is the average from at least eight exposures ranging from 0.5 to 60 rep. The average deviation for each percentage value was less than 5 percent.

A series of exposures was made in which films were exposed to a contaminated surface, both with and without the interposition of a glove swatch. The area chosen was the leading edge of the wing of a B-57B that had penetrated the cloud from a megaton-range burst. The fourth column of Table 3.5, headed "Reduction of Average Dose Rate To Hand," shows the percentage by which the dose reaching the film from the aircraft is reduced by the glove. The film densities were read through the large aperture on the densitometer. This column, then, represents the percentage by which the dose to the hand as a whole would be reduced. Repeat measurements for some of the gloves were made on subsequent shots. These are indicated on the table.

It will be noted that the percentage absorption on the aircraft exposures is greater than that on the Sr^{90}-Y^{90} calibration source. This is an indication that the average energy of the contamination is less than that of the radiation from Sr^{90}-Y^{90}.

Since the primary contact hazard is caused by the small "hot spots" of intense radiation, it is instructive to compare the maximum dose rates observed on a surface with and without the interposition of a glove swatch. The percentage by which the maximum dose rate is reduced is shown in the last column of Table 3.5. It is observed that all gloves reduce the maximum at least 50 percent. This is due in part to actual absorption by the glove material and in part to the scattering caused by the increased linear separation between the contamination and the film. In addition, no residual contamination was observed on the hands of personnel who wore leather, rubber, or vinyl-coated gloves Figure 3.5 shows a number of radioautographs made with and without the interposition of several different glove swatches.

From the standpoint of ease of movement and comfort to the wearer, as well as from the standpoint of the protection provided, the vinyl coated cotton glove (No. 13) or a combination of a jersey liner and leather flying glove was found to be more satisfactory. Any of the gloves not containing leather could be decontaminated by laundering. The vinyl-coated glove had the advantage that the wearer could remove most of the contami-

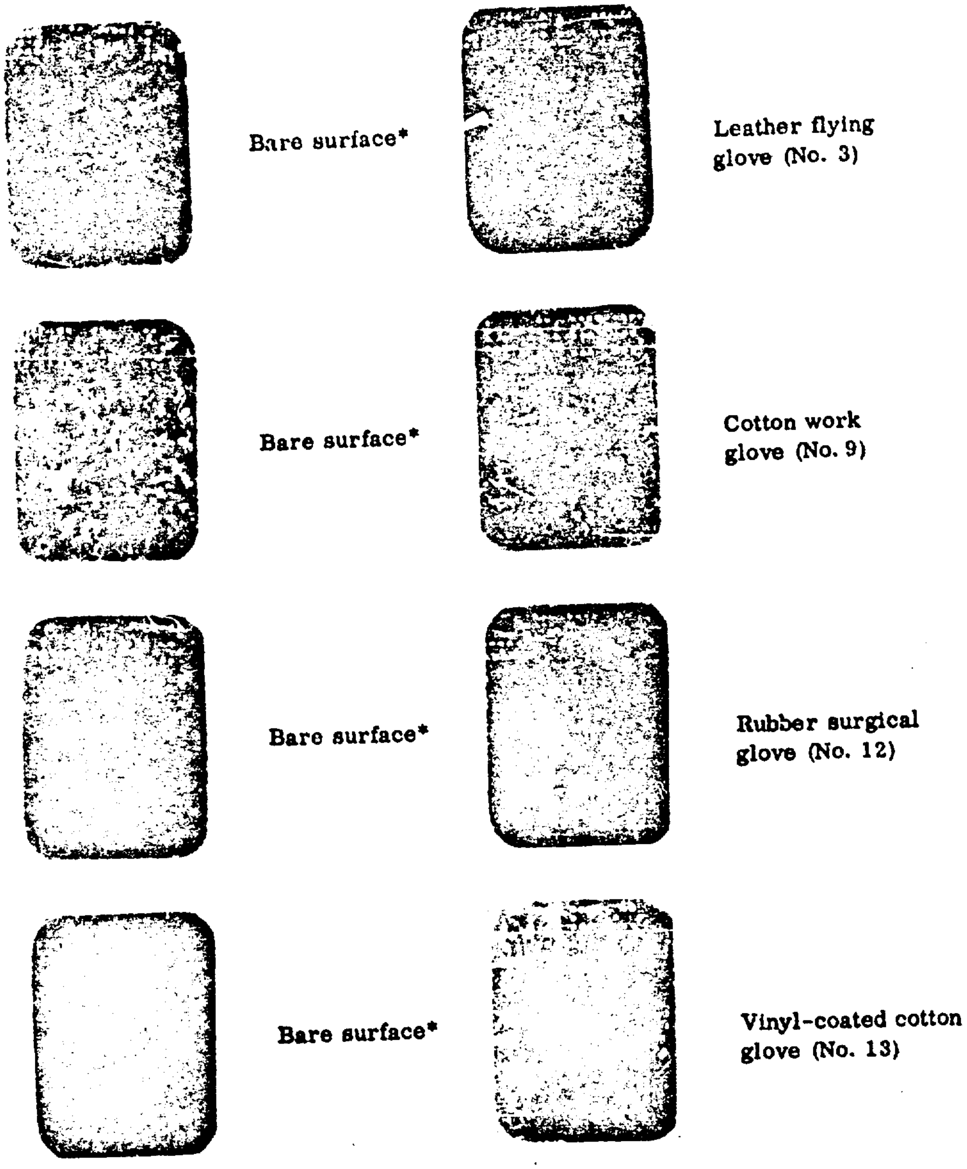
TABLE 3.5 ABSORPTION BY GLOVES

Number and Brief Description of Glove	Weight of Glove	Absorption $Sr^{90} - Y^{90}$	Reduction of Average Dose Rate to Hand	Reduction of Maximum Dose Rate to Hand
	mg/cm²	pct	pct	pct
1 Synthetic rubber	27	23	50	69
2A Lightweight flying	39	41	56•	60
2B Mosquito bar f 2A	18	18	48	65
3 Standard Flying	36	33	49•	85•
4 Neoprene-coated cotton	90	56	78	92
5 Cotton work	36	35	40	86
6 Cotton liner	27	25	38	63
7 Rayon liner	14	17	19	71
8 Rayon liner	12	16	22	71
9 Heavy cotton work	36	46	45•	80•
10 Light work	22	21	41	81
11 Nylon liner	18	17	30	51
12 Surgical rubber	26	21	42	81
13 Vinyl-coated cotton	77	49	74•	90•

• Tested on two or more shots.

TABLE 3.6 COMPARATIVE RADIATION EXPOSURES, HAND TO WHOLE BODY

Location	Dose, r Outside Glove	Dose, r Inside Glove	Percent Reduction by Glove	Ratio to Whole Body Outside Glove	Ratio to Whole Body Inside Glove
Breast pocket	1.0				
Right wrist	2.0	1.1	45	2.0	1.1
Right palm	3.0	1.9	37	3.0	1.9
Left palm	2.1	1.2	43	2.1	1.2
Right finger	4.3	3.6	16	4.3	3.6
Left finger	5.1	1.8	65	5.1	1.8
	Average		41	3.3	1.9


Bare surface*

Leather flying glove (No. 3)

Bare surface*

Cotton work glove (No. 9)

Bare surface*

Rubber surgical glove (No. 12)

Bare surface*

Vinyl-coated cotton glove (No. 13)

Figure 3.5 Radioautographs of leading edge of the wing of a B-57B with and without interposition of glove swatches.

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* Slight blurring at edge due to incomplete contact with surface.

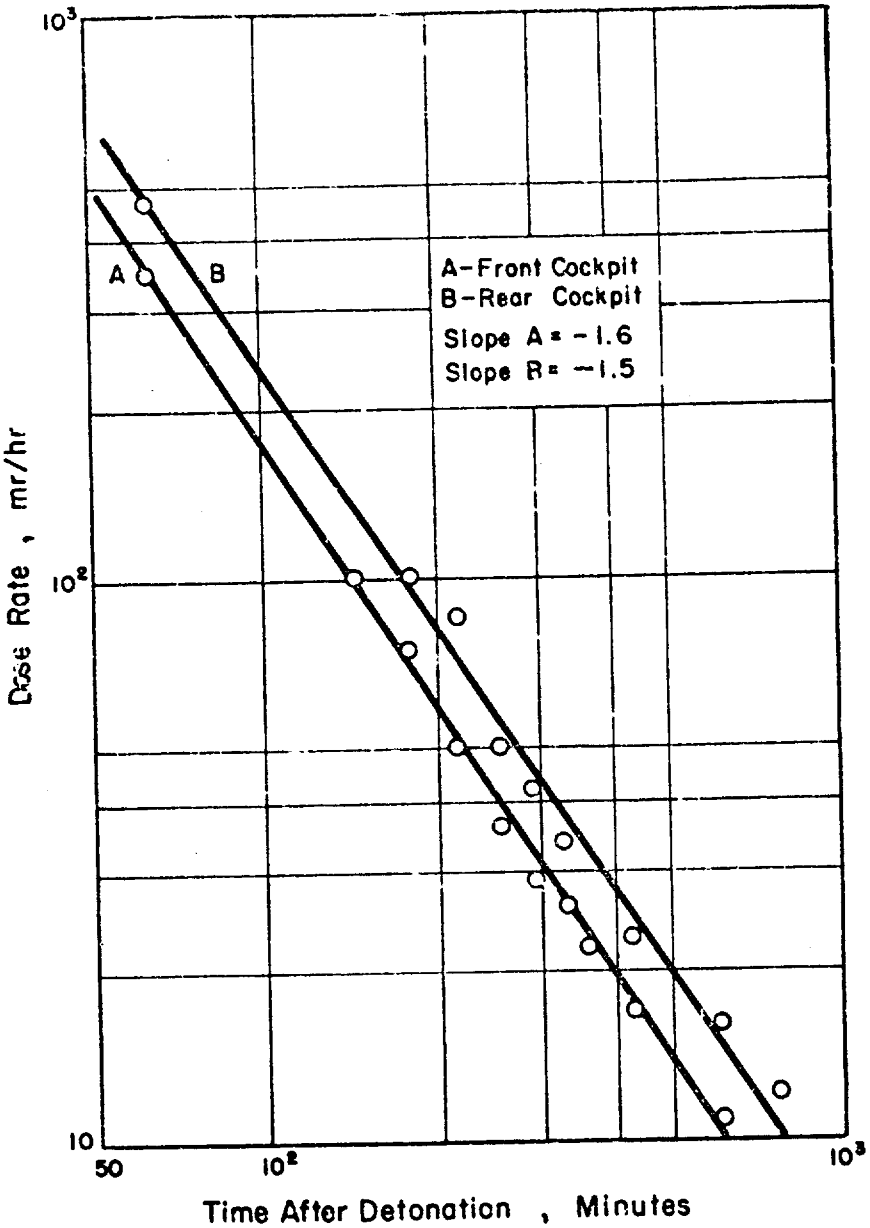

Figure 3.6 Decay of radiation dose rate in cockpit of contaminated aircraft, Shot Zuni, aircraft no. 527.

nation merely by scrubbing them while he still wore them. In this manner they could be used continually and decontaminated as needed. The foregoing statements refer to the gloves found to be most convenient by the personnel of this project. It can be seen from Table 3.5, however, that all of the gloves tested provide a reasonable degree of protection. Therefore, the ultimate choice can be left to the individual wearer.

3.7 RADIATION EXPOSURE OF PERSONNEL

Since it is the actual radiation exposure to personnel that is of importance, an experiment was carried out to compare the whole-body exposure to that received by the hands. Measurements were made on the four personnel who conducted the instrument survey and the radioautographic studies on approximately eighteen aircraft. The whole-body exposure was measured by a film badge worn on the breast pocket. Exposures to the hand were measured by film badges attached at various locations both inside and outside the protective rubber surgical glove. The results of this experiment are shown in Table 3.6. All of the films showed a uniform blackening. This indicates that the exposure conditions are such as to minimize the importance of the hot spots. The average percentage by which the gloves reduced that radiation dose was 41. The final column of Table 3.6 shows that the average ratio between the whole-body exposure and the dose to the hands of personnel wearing gloves is very close to two. This is true despite the large dose rates measured directly on the surface. This indicates that the hands of personnel who work on contaminated aircraft spend little time in close contact with the surface and relatively more time away from the surface in a position exposing them to essentially the same radiation field as the rest of the body

3.8 DECAY STUDIES ON CONTAMINATED AIRCRAFT

A record of the intensity of radiation in the crew compartments of the contaminated B-57's as measured by the T1B was kept. The measurements were begun as early as 90 minutes after detonation and continued for periods as long as 24 hours. The average slope of the decay curves was −1.6 with an average deviation of ±0.4. A typical decay curve is shown in Figure 3.6. These decay curves are discussed more thoroughly in Reference 8.

Chapter 4

DISCUSSION

The object of this study was to evaluate the contact hazard that exists for personnel who must come in contact with aircraft contaminated by flight through nuclear clouds. In achieving this goal, the apparent beta-gamma ratio of fission-fragment contamination was measured.

Measurement of the actual beta-gamma ratio was not attempted. The actual ratio would be extremely difficult to determine and would have some theoretical value, but little practical use. The requirement is for a means of determining a working ratio that can be expressed in terms of the intensity indicated by some standard survey instrument such as the T1B.

The ratio between the total contact dose rate and the T1B reading was found to vary between 6 and 650. Considering the lack of uniformity of the surfaces involved and the widely differing circumstances in which the aircraft became contaminated, this variation is not surprising.

The problem is to evaluate these measured ratios and to determine the importance that must be attached to them. Ratios less than ten may be regarded as unimportant, since the skin-tolerance dose is probably at least ten times greater than the tolerance for whole-body radiation. Under these conditions, the whole-body radiation dose would be the limiting factor, and the contact hazard would not hamper the activities of personnel in an operational situation. Obviously, the higher ratios are the ones that must be given consideration. From the limited experimental data shown in Table 3.6, it can be seen that the actual ratio of the contact dose to the whole-body exposure is approximately two for those personnel who wear gloves. Even though this is true, it is instructive to carry out a further theoretical analysis of the problem.

The highest contact-dose rate measured during the entire study was 3,500 rep/hr. The ratio between this dose rate and the T1B reading was 650. This dose rate was measured by means of a film tightly taped to an impingement surface. In order for a human being to sustain a beta burn, the bare surface of the skin would have to be held in equally close contact with the surface for an extended period. The mean ratios between the maximum contact dose rate and the T1B readings were found to be 110 for impingement surfaces and 40 for sliding surfaces. When an area of several square centimeters is considered, these mean values can be halved. For practical purposes, and without introducing a significant uncertainty, the contact radiation hazard can be evaluated by the use of these ratios in conjunction with a survey of the aircraft with a T1B.

An analysis of probable operational situations tends to minimize the significance of the highest ratios and focus attention on the intermediate values. Personnel who perform work on an aircraft do not grasp any one part (especially impingement surfaces) for long periods of time. Instead, the grip is changed constantly from one point to another, with the result that the exposure becomes nearly uniform and the hot spots of high activity are eliminated. This was shown by the uniform blackening of the films that were placed on the hands of the men who handled the survey film. If one considers the average dose rate over the entire film to be representative of the actual situation, the mean ratio of the total dose rate to T1B reading becomes 55 for impingement surfaces and 20 for sliding surfaces. These mean values can be applied to cases where personnel are wearing gloves. If no gloves are worn, the ratios of 110 and 40, measured over small areas, should be applied. The use of one of several types of gloves will reduce the radiation dose to the hands to about 60 percent of that which bare hands would receive under the same circumstances (see Table 3.6). Additionally, the hot spots of intense radiation are reduced to between 10 and 60 percent of the ungloved values. The vinyl-coated cotton glove, a combination of rubber surgical and broadcloth gloves, or a leather flying glove with liner were found to be satisfactory, since they were flexible but not too slippery for easy grasping. All three combinations suffer the disadvantage of increasing sweating of the hands. All three are impervious to the particulate contamination; thus, removal of the gloves leaves the hands free of contamination. There are undoubtedly other combinations that would prove more satisfactory to other individual users.

When all factors are taken into account, it becomes apparent that the whole-body gamma-radiation dose is the limiting factor in operational situations requiring work on aircraft contaminated by flight through the clouds from nuclear detonations, provided personnel wear gloves. Facts leading to this conclusion include: (1) personnel working on the aircraft are in the gamma field at all times; (2) high dose rates are encountered only by direct contact with impingement surfaces, an infrequent occurrence, and (3) the dose rate to the skin can be reduced appreciably by the wearing of gloves. The whole-body dose is measured by the standard Rad-Safe film badge and pencil dosimeters. It can be estimated with the dose rates measured by the T1B.

Since the whole-body gamma dose is the limiting factor, it is appropriate to consider what this dose will be under various conditions. If the dose rate at H + 1 hour, I_0, is known, the dose rate at any subsequent time can be computed from the relationship:

$$I_t = I_0 t^{-1.2} \tag{4.1}$$

Where: I_t = Dose rate at time t, r/hr

I_0 = Dose rate at H + 1 hours, r/hr

t = Time after detonation, hrs

The total dose received during any given interval of time is:

$$D = 5\,(I_1 t_1 - I_2 t_2) \tag{4.2}$$

Where: D = Total dose, r

I_1 = Dose rate at time t_1, r/hr

I_2 = Dose rate at time t_2, r/hr

t_1 = Time after detonation, hrs

t_2 = Time after detonation, hrs

This expression is derived in Reference 9.

The most-highly contaminated aircraft surveyed during this study was an F-84 that had penetrated the Shot Erie cloud. It had the following surface dose rates:

Location	Measured Rate	Time	Dose Rate at H + 1
Air Intake	9 r/hr	H + 2:18	25 r/hr
Side of Fuselage	0.9	2:21	2.5
Leading Edge	6.0	2:21	17.0
Tip Tank	1.5	2:25	4.2

Since the two highest values represent impingement surfaces, a value of 8 r/hr can be considered as a conservative value to represent the aircraft as a whole. (Note that 8 r/hr is more than three times the dose rate on a typical sliding surface, such as the side of the fuselage.) The effective center of the body will be at least a foot from the aircraft surface. Experiment has shown that the gamma dose rate at a distance of 1 foot from the surface is very near to half the surface dose rate. Hence, the whole-body dose rate can be taken to be half of the surface dose rate, or 4 r/hr at H + 1 hour.

From this dose rate, the whole body radiation dose can be calculated for various situations through Equations 4.1 and 4.2.

If exposure began at H + 2 hours and continued for 8 hours, the dose rate at the end of the period would be 0.25 r/hr. The accumulated dose would be 5 r.

If exposure began at H + 24 hours and continued for 8 hours, the dose rate at the end of the period would be 0.06 r/hr. The accumulated dose would be 0.6 r.

If exposure began at H + 24 hours and continued at a rate of 8 hours per day for 10 consecutive days, the dose rate at the end of the tenth day would be 0.005 r/hr. The accumulated dose would be 1.2 r.

These calculations assume the extreme case, in which exposure is continuous and the center of the body is only a foot from the surface of the most-highly contaminated aircraft. In any actual situation the dose would undoubtedly be smaller. These calculations were performed using the value of -1.2 as the slope of the decay curve for fission products. It was pointed out in Section 3.8 that the contamination on the aircraft seems to decay with a slope of -1.6. If this value had been used in the computations made above, the accumulated dose would have been reduced by a factor of three.

Chapter 5

CONCLUSIONS and RECOMMENDATIONS

Although the results reported and discussed in this report do not have the precision of a carefully controlled laboratory experiment, they are adequate to support several conclusions.

5.1 CONCLUSIONS

1. The amount and distribution of contamination that aircraft incur during flights through nuclear clouds is fairly uniform, considering the widely varying circumstances under which the contamination is incurred. There do not seem to be any significant variations due to device yield or aircraft type.
2. The ratio between the surface intensity as measured by photographic film and the T1B was found to have a mean value of 110 for impingement surfaces and 40 for sliding surfaces. The measured values varied by a factor of five above and below the mean.
3. The total contact-radiation dose rate can be evaluated satisfactorily through the use of the T1B and these ratios.
4. There is no requirement for special field instrumentation for operational organizations to measure the total surface radiation intensity, provided that certain precautions are observed: (1) Personnel should avoid direct contact between the skin and the surface of highly contaminated aircraft and (2) the whole-body exposure should be monitored carefully. Skin-surface contact can be avoided through the use of disposable clothing, especially gloves. If the whole-body exposure is kept within permissible limits, there is little possibility of a serious contact exposure.
5. All of the gloves tested were found to reduce the intensity of radiation hot spots by at least 50 percent. Therefore, the important considerations are comfort, ease of movement, imperviousness to radioactive particles, and ease of laundering and cleaning.
6. Maintenance, refueling, and rearming personnel could begin work as early as H + 2 hours and continue to work for a period of 8 hours on the most-highly contaminated aircraft obtained in this project (without decontamination) at the expense of 5 r of whole-body gamma dose.
7. After (H + 24) hours, personnel could begin work and continue to work for 10 days, at a rate of 8 hours per day, on the most highly contaminated aircraft obtained in this project (without decontamination) at the expense of less than 1.5 r of whole-body gamma dose.

5.2 RECOMMENDATIONS

1. When working on contaminated aircraft on which the surface gamma radiation dose rate exceeds 0.1 r/hr, personnel should wear gloves, as well as adequate clothing, and exercise caution to prevent contact of bare skin with the aircraft surface.
2. Air Force Technical Orders and SOP's should be revised to reflect the lack of necessity for decontamination of aircraft by Air Force operational organizations.

Appendix A

ADDITIONAL TABLES

TABLE A.1 SUMMARY OF INSTRUMENT SURVEY AND FILM MEASUREMENTS ON F-84 AIRCRAFT

Location of Film on F-84 Aircraft	Time After Detonation	Shot Erie Time of Penetration H + 51 min; H + 62 min				Shot Inca Time of Penetration H + 81 min; H + 85 min			
			Film rep/hr				Film rep/hr		
	Hours	T1B	Max	Ave	Min	T1B	Max	Ave	Min
		r/hr				r/hr			
Side of air intake	2 to 4	6.5	3,300	1,500	1,300	0.8	60	8	5
	4 to 7	—	—	—	—	0.4	30	5	3
	7 to 9	—	—	—	—	0.1	20	2	1
Side of fuselage below canopy	2 to 4	0.7	55	12	7	0.9	55	14	12
	4 to 7	—	—	—	—	0.4	50	8	7
	7 to 9	—	—	—	—	0.2	12	4	3
Leading edge of wing, midway between root and tip	2 to 4	5.4	3,500	1,600	900	1.0	50	15	6
	4 to 7	3.1	700	330	70	0.5	18	6	3
	7 to 9	—	—	—	—	0.2	14	3	2
Side of tip tank	2 to 4	1.2	90	30	15	0.8	50	14	10
	4 to 7	0.5	50	8	4	0.5	30	8	6
	7 to 9	—	—	—	—	0.1	13	4	2

TABLE A.2 SUMMARY OF INSTRUMENT SURVEY AND FILM MEASUREMENTS ON B-57B AIRCRAFT

Location of Film on B-57B Aircraft	Time After Detonation	Shot Zuni Time of Penetration H + 52 min				Shot Flathead Time of Penetration H + 65 min; H + 78 min				Shot Dakota Time of Penetration H + 41 min			
			Film rep/hr				Film rep/hr				Film rep/hr		
	Hours	T1B	Max	Ave	Min	T1B	Max	Ave	Min	T1B	Max	Ave	Min
		r/hr				r/hr				r/hr			
Top of nose	2 to 4	2.0	400	30	15	0.3	65	64	36	0.5	63	11	8
	4 to 7	—	—	—	—	0.3	64	23	17	0.1	20	4	2
	7 to 9	—	—	—	—	0.2	26	14	11	0.1	15	3	2
Side of fuselage below canopy	2 to 4	0.2	20	4	<1	0.5	12	5	3	0.6	27	4	1
	4 to 7	—	—	—	—	0.1	6	3	2	0.1	8	1	<1
	7 to 9	—	—	—	—	0.1	5	2	1	0.05	10	1	<1
Unpainted gun cover on leading edge	2 to 4	3.0	300	100	60	1.6	410	96	69	2.8	95	32	18
	4 to 7	—	—	—	—	0.3	175	53	32	0.6	37	13	10
	7 to 9	—	—	—	—	0.4	190	38	25	0.4	21	8	6
Painted leading edge, inboard of engine	2 to 4	3.0	190	40	20	3.9	—	270	145	6.0	35	15	8
	4 to 7	0.3	80	15	10	1.5	190	80	35	1.2	14	4	3
	7 to 9	—	—	—	—	0.8	200	70	35	0.6	8	3	2
Side of tip tank	2 to 4	1.5	50	15	4	0.8	115	38	30	1.0	30	12	7
	4 to 7	0.2	30	10	4	0.3	25	12	10	0.2	17	4	3
	7 to 9	—	—	—	—	0.1	20	7	5	0.1	7	2	1

TABLE A.3 SUMMARY OF FILM/T1B AND APPARENT BETA/GAMMA RATIOS FOR F-84 AIRCRAFT

Location of Film on F-84 Aircraft	Time After Detonation	Shot Erie Time of Penetration H + 57 min; H + 62 min				Shot Inca Time of Penetration H + 81 min; H + 85 min			
	Hours	Film Max T1B	Hot Spot β/γ	Film Ave T1B	Area β/γ	Film Max T1B	Hot Spot β/γ	Film Ave T1B	Area β/γ
Side of air intake	2 to 4	310	—	220	—	75	—	10	—
	4 to 7	—	—	—	—	73	—	12	—
	7 to 9	—	—	—	—	155	—	15	—
Side of fuselage below canopy	2 to 4	80	—	17	—	61	—	16	—
	4 to 7	—	—	—	—	125	—	20	—
	7 to 9	—	—	—	—	60	—	20	—
Leading edge of wing, midway between root and tip	2 to 4	650	70	300	35	50	60	15	14
	4 to 7	225	80	100	50	36	60	12	21
	7 to 9	—	—	—	—	56	65	12	—
Side of tip tank	2 to 4	75	—	25	—	62	65	18	20
	4 to 7	100	—	16	—	69	100	16	25
	7 to 9	—	—	—	—	93	90	29	28

TABLE A.4 SUMMARY OF FILM/T1B AND APPARENT BETA/GAMMA RATIOS FOR B-57B AIRCRAFT

Location of Film on B-57B Aircraft	Time After Detonation	Shot Zuni Time of Penetration H + 52 min				Shot Flathead Time of Penetration H + 65 min; H + 78 min				Shot Dakota Time of Penetration H + 41 min			
	Hours	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ	Film Max / T1B	Hot Spot β/γ	Film Ave / T1B	Area β/γ
Top of nose	2 to 4	200	—	15	—	220	—	215	—	130	—	22	—
	4 to 7	120	—	40	—	215	—	75	—	200	—	40	—
	7 to 9	—	—	—	—	145	—	75	—	270	—	40	—
Side of fuselage below canopy	2 to 4	100	—	20	—	24	—	10	—	45	—	7	—
	4 to 7	—	—	—	—	43	—	21	—	80	—	10	—
	7 to 9	—	—	—	—	30	—	20	—	200	—	20	—
Unpainted gun cover on leading edge	2 to 4	100	—	33	—	260	—	60	—	34	—	8	—
	4 to 7	—	—	—	—	220	—	70	—	62	—	22	—
	7 to 9	—	—	—	—	450	—	85	—	55	—	21	—
Painted leading edge, inboard of engine	2 to 4	63	—	13	—	—	100	70	45	6	—	2	3
	4 to 7	270	—	30	—	125	150	55	70	12	—	3	—
	7 to 9	—	—	—	—	250	350	95	95	13	—	5	—
Side of tip tank	2 to 4	33	—	10	25	145	90	48	30	30	30	12	16
	4 to 7	125	—	42	—	80	120	38	45	85	90	20	30
	7 to 9	—	—	—	—	140	160	50	55	70	40	20	20

Appendix B

DESCRIPTION OF GLOVES

1. Glove, rubber, synthetic; Spec Mil-G-4197A, Grade C; AF Stock No. 8415-263-0533.

2. Glove, flying, very light, mosquito resistant, Type K-1, Spec No. 3261-A; AF Stock No. 8415-261-7014; leather palm and fingers designated 2-A; poplin upper designated 2-B.

3. Glove, flying, leather, Type B-3A; Spec No. 3176-B, Class P- pique sewn; AF Stock No. 8415-268-7850.

4. Glove, neoprene coated cotton, oil-proof; AF Stock No. 8415-268 8342.

5. Glove, cotton, olive drab; knit wrist, fuzzy finish inside; AF Stock No. 8415-268-8347.

6. Glove, flying, liner; light cotton jersey glove with knit wrist; AF Stock No. 8300-456030.

7. Glove, flying, liner; light rayon jersey glove with knit wrist; AF Stock No. 8415-242-2527.

8. Glove, flying, liner; much like No. 7, except no wristlet.

9. Glove, cotton, work; heavy cotton with long wristlet. This is the standard Rad-Safe glove.

10. Glove, work; light twill glove with knit wristlet.

11. Glove, flying, liner; light nylon jersey glove with knit wristlet; AF Stock No. 8415-269-0501.

12. Glove, surgical, rubber; manufactured by Wiltex Rubber Company.

13. Glove, cadet size, protective solvent resistant, vinyl coated; knitted cotton, Style No. 410; manufactured by Edmont Manufacturing Co., Coshocton, Ohio.

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17 President, U.S. Army Air Defense Board, U.S. Continental Army Command, Ft. Bliss, Tex.
18 President, U.S. Army Aviation Board, Ft. Rucker, Ala. ATTN: ATBG-DG
19 Commandant, U.S. Army Command & General Staff College, Ft. Leavenworth, Kansas. ATTN: ARCHIVES
20 Commandant, U.S. Army Air Defense School, Ft. Bliss, Tex. ATTN: Dept. of Tactics and Combined Arms
21 Commandant, U.S. Army Armored School, Ft. Knox, Ky.
22 Commandant, U.S. Army Artillery and Missile School, Ft. Sill, Okla. ATTN: Combat Development Department
23 Commandant, U.S. Army Aviation School, Ft. Rucker, Ala.
24 Commandant, U.S. Army Ordnance School, Aberdeen Proving Ground, Md.
25 Commandant, U.S. Army Ordnance and Guided Missile School, Redstone Arsenal, Ala.
26 Commanding General, Chemical Corps Training Comd., Ft. McClellan, Ala.
27 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Cmdt, Engr. School
28 Director, Armed Forces Institute of Pathology, Walter Reed Army Med. Center, 625 16th St., NW, Washington 25, D.C.
29 Commanding Officer, Army Medical Research Lab., Ft. Knox, Ky.
30 Commandant, Walter Reed Army Inst. of Res., Walter Reed Army Medical Center, Washington 25, D.C.
31- 32 Commanding General, QM R&D Comd., QM R&D Cntr., Natick, Mass. ATTN: CBR Liaison Officer
33 Commanding General, U.S. Army Chemical Corps, Research and Development Comd. Washington 25, D.C.
34 Commanding Officer, Chemical Warfare Lab., Army Chemical Center, Md. ATTN: Tech. Library
35 Commanding General, Engineer Research and Dev. Lab., Ft. Belvoir, Va. ATTN: Chief, Tech. Support Branch
36 Director, Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. ATTN: Library
37 Commanding Officer, Office of Ordnance Research Box CM, Duke Station, Durham, North Carolina
38 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
39 Commanding Officer, Diamond Ord. Fuze Labs., Washington 25, D.C. ATTN: Chief, Nuclear Vulnerability Br. (230)
40- 41 Commanding General, Aberdeen Proving Grounds, Md. ATTN: Director, Ballistics Research Laboratory
42 Commanding General, Frankford Arsenal, Bridge and Tacony St., Philadelphia, Pa.
43- 44 Commanding Officer Watervliet Arsenal, Watervliet, New York. ATTN: ORDBF-RR
45- 46 Commanding General, U.S. Army Ord. Missile Command, Redstone Arsenal, Ala.
47 Commander, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala. ATTN: Tech Library
48 Commanding General, White Sands Proving Ground, Las Cruces, N. Mex. ATTN: ORDBS-OM
49 Commander, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ATTN: ORDAB-HT
50 Commanding Officer, Ord. Materials Research Off., Watertown Arsenal, Watertown 72, Mass. ATTN: Dr. Foster
51 Commanding General, Ordnance Tank Automotive Command, Detroit Arsenal, Centerline, Mich. ATTN: ORDMC-RO
52 Commanding Officer, USA Signal R&D Laboratory, Ft. Monmouth, N.J.
53 Commanding General, U.S. Army Electronic Proving Ground, Ft. Huachuca, Ariz. ATTN: Tech. Library
54 Commanding General, USA Combat Surveillance Agency, 1124 N. Highland St., Arlington, Va.
55 Commanding Officer, USA, Signal R&D Laboratory, Ft. Monmouth, N.J. ATTN: Tech. Doc. Ctr., Evans Area
56 Director, Operations Research Office, Johns Hopkins University, 6935 Arlington Rd., Bethesda 14, Md.
57 Commander-in-Chief, U.S. Army Europe, APO 403, New York, N.Y. ATTN: Opot. Div., Weapons Br.
58 Commanding Officer, 9th Hospital Center, APO 180, New York, N.Y. ATTN: CO, US Army Nuclear Medicine Research Detachment, Europe

NAVY ACTIVITIES

59 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-0757
60 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-36
61 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-92202
62- 63 Chief of Naval Research, D/N, Washington 25, D.C. ATTN: Code 811
64- 65 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C.
66 Chief, Bureau of Medicine and Surgery, D/N, Washington 25, D.C. ATTN: Special Wpns. Def. Div.
67 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
68 Chief, Bureau of Ordnance, D/N, Washington 25, D.C. ATTN: S.P.
69 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 423
70 Chief, Bureau of Yards and Docks, D/N, Washington 25, D.C. ATTN: D-440
71 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Mrs. Katherine H. Cass
72- 73 Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.
74 Director, Material Lab. (Code 900), New York Naval Shipyard, Brooklyn, N.Y.
75 Commanding Officer and Director, Navy Electronics Laboratory, San Diego 52, Calif.
76- 79 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Tech. Info. Div.
80- 81 Officer-in-Charge, U.S. Naval Civil Engineering R&E Lab., U.S. Naval Construction Bn. Center, Port Hueneme, Calif. ATTN: Code 753
82 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.
83 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
84 Officer-in-Charge, U.S. Naval School, CEC Officers, U.S. Naval Construction Bn. Center, Port Hueneme, Calif.

85 Commanding Officer, Nuclear Weapons Training Center, Atlantic, U.S. Naval Base, Norfolk 11, Va. ATTN: Nuclear Warfare Dept.
86 Commanding Officer, Nuclear Weapons Training Center, Pacific, Naval Station, San Diego, Calif.
87 Commanding Officer, U.S. Naval Damage Control Tng. Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
88 Commanding Officer, Air Development Squadron 5, VX-5, China Lake, Calif.
89 Commander, Officer U.S. Naval Air Development Center, Johnsville, Pa. ATTN: NAS, Librarian
90 Commanding Officer, U.S. Naval Medical Research Institute, National Naval Medical Center, Bethesda, 14.
91-94 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H
95 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 372
96 Commanding Officer, U.S. Naval CIC School, U.S. Naval Air Station, Glynco, Brunswick, Ga.
97 Chief of Naval Operations Department of the Navy, Washington 25, D.C. ATTN: OP-25

AIR FORCE ACTIVITIES

98 Assistant for Atomic Energy, HQ, USAF, Washington 25, D.C. ATTN: DCS/O
99 Deputy Chief of Staff, Operations HQ. USAF, Washington 25, D.C. ATTN: Operations Analysis
00-101 Assistant Chief of Staff, Intelligence, HQ. USAF, Washington 25, D.C. ATTN: AFCIN-1B2
102 Director of Research and Development, DCS/D, HQ. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.
103 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division
104 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: OAWS
105 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch
106 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Atomic Energy Div., ADLAN-A
107 Commander, Hq. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDRWA
108 Commander, Air Force Ballistic Missile Div., Hq ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT
109-110 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2
111-115 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. and Intel. Div.
116-117 Director, Air University Library, Maxwell AFB, Ala.
118 Commander, Lowry AFB, Denver, Colorado. ATTN: Dept. of Sp. Wpns. Tng.
119 Commandant, School of Aviation Medicine, USAF, Randolph AFB, Tex. ATTN: Research Secretariat
120 Commander, 1009th Sp. Wpns. Squadron, HQ. USAF, Washington 25, D.C.
121-122 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCOSI
123-124 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.
125 Commander, Air Defense Systems Integration Div., L. G. Hanscom Field, Bedford, Mass. ATTN: SIDE-S
126 Chief, Ballistic Missile Early Warning Project Office, 120 Church St., New York 13, N.Y. ATTN: Col. Leo F. Skinner, USAF
127 Assistant Chief of Staff, Intelligence, HQ. USAFE, APO 633, New York, N.Y. ATTN: Directorate of Air Targets
128 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

129 Director of Defense Research and Engineering, Washington 25, D.C. ATTN: Tech. Library
130 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.
131-138 Chief, Armed Forces Special Weapons Project, Washington 25, D.C.
139 Commander, Field Command, AFSWP, Sandia Base, Albuquerque, N. Mex.
140 Commander, Field Command, AFSWP, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG
141-145 Commander, Field Command AFSWP, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT
146 Commander, JTF-7, Arlington Hall Station, Arlington 12, Va.
147 Administrator, National Aeronautics and Space Administration, 1520 "H" St., N.W., Washington 25, D.C. ATTN: Mr. R. V. Rhode
148 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N.Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

149-151 U.S. Atomic Energy Commission, Technical Library, Washington 25, D.C. ATTN: For DMA
152-153 Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
154-158 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.
159-161 University of California Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. ATTN: Clovis G. Craig
162 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.
163-195 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

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