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Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant

Dispersion Analysis for Postulated Accidents

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DISPERSION ANALYSIS FOR POSTULATED ACCIDENTS

by

J. M. Dewart, B. M. Bowen, and J. C. Elder

ABSTRACT

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy (DOE) Pantex Plant near Amarillo, Texas. The report covers the calculation of atmospheric dispersion and deposition of plutonium following postulated nonnuclear detonations of nuclear weapons. Downwind total integrated air concentrations and ground deposition values for each postulated accident are presented. The model used to perform these calculations is the DIFOUT model, developed at Sandia National Laboratories in conjunction with Operation Roller Coaster, a field experiment involving sampling and measurements of nuclear material dispersed by four detonations. The DIFOUT model is described along with the detonation cloud sizes, aerosol parameters, and meteorological data used as input data. A verification study of the DIFOUT model has also been performed; the results are presented in Appendix C.

I. INTRODUCTION

This report documents work performed in support of preparation of an Environmental Impact Statement (EIS) regarding the Department of Energy (DOE) Pantex Plant near Amarillo, Texas. The EIS addresses continuing nuclear weapons operations at Pantex and the construction of additional facilities to house those operations. The EIS was prepared in accordance with current regulations under the National Environmental Policy Act. Regulations of the

Council on Environmental Quality (40 CFR 1500) require agencies to prepare concise EISs with less than 300 pages for complex projects. This report was prepared by the Los Alamos National Laboratory to document details of work performed and supplementary information considered during preparation of the Draft EIS.

The Pantex Plant is a nuclear weapons assembly/disassembly facility located 25 km to the east-northeast of Amarillo, Texas. The EIS covers the existing Pantex Plant facilities; new facilities and/or upgrading facilities at the Pantex Plant; moving a portion of the Pantex facilities to the Iowa Army Ammunition Plant (IAAP) at Burlington, Iowa; and building a new plant at the IAAP or on the Hanford Site in eastern Washington.

As part of the Pantex EIS, several accidents involving the detonation of high explosives in the presence of plutonium have been postulated (Chamberlin 1982). Several initiating events have been assumed to cause a detonation of high explosives: these include a tornado, an aircraft crash, and an operational accident (such as dropping high explosives during assembly/disassembly). A complete description of the postulated accidents is by necessity classified and is presented in Chamberlin (1982). The accidents have been assigned letter designations (A, B, C, etc.) (Chamberlin 1982) and are presented in this manner for this report.

To estimate the health consequences and cleanup costs from these accidents at each of the three sites considered in the EIS, atmospheric dispersion and deposition modeling have been performed. This report presents the results of the dispersion and deposition calculations, which are used by Elder (1982B) and Wenzel (1982B, 1982E) to assess these health and monetary impacts. A description of the DIFOUT model, used to perform the calculations, and the data used as input to the model are also presented.

A verification study was performed on the DIFOUT model to assess its predictive capabilities for this study. The model verification is presented in Appendix C of this report, and a summary of specific verification results that were employed in this study is presented in Section II.E.

II. THE DIFOUT MODEL

This section of the report focuses on aspects of the DIFOUT model most important to this study: the background of the model, dispersion and deposition assumptions, source characterization, and the required meteorological data. The actual data used in the DIFOUT model calculations are presented in Sec. III. For a complete description of all DIFOUT model features, including the model equations, the reader is referred to Luna (1969).

A. Background

The DIFOUT model (Luna 1969) was designed to assess the dispersion and deposition from an accidental nonnuclear detonation of a nuclear weapon during transport or storage. Therefore, it is ideally suited for use in the assessment of accidents at a nuclear weapons assembly/disassembly facility.

DIFOUT was originally developed as one of the objectives of Operation Roller Coaster (Shreve 1965), a field experiment at the Nevada Test Site in 1963. It involved the sampling and measurement of nuclear material dispersed by four separate test detonations. The detonations were triggered so as to simulate accidental detonation of the high explosives. The experiment consisted of four separate detonations that simulated accidents involving different amounts of high explosives and different storage facilities (earth-covered structures, unbunkered buildings, open pads, or transportation vehicles). This experiment provided data over a range of cloud heights (a function of the amount of high explosives) and assessed the effect of plutonium-soil attachment (bunkered tests) on the fallout of particles near the detonation site. The amount of high explosives and the type of earth cover for each test are presented in Table I. DIFOUT was designed to predict the pattern of dispersion and deposition measured in these Roller Coaster tests.

TABLE I

ROLLER COASTER TEST SHOTS

Event	High Explosives (lb)	Placement	Cover
Double Tracks	118	8-ft by 8-ft steel plate	None
Clean Slate 1	1062	20-ft by 20-ft concrete pad	None
Clean Slate 2	2242	Storage structure	2 ft earth
Clean Slate 3	2242	Storage structure	8 ft earth

Source: Shreve (1965), Church (1969).

The verification study performed with the DIFOUT model (Appendix C) indicates that DIFOUT is an acceptable model for use in this study.

B. Dispersion and Deposition Assumptions

DIFOUT is a tilting plume Gaussian dispersion model. It includes aerosol depletion through particle fallout and the effects on dispersion of wind speed and direction variation with height. The aerosol cloud produced by the detonation is divided into several horizontal cylindrical layers, each containing a specified amount of the total aerosol of the cloud. The aerosol is dispersed from a vertical line source in each layer; the downwind integrated air concentrations ($\mu g\text{-}s/m^3$) and ground deposition ($\mu g/m^2$) are a sum of the contributions from the line source in each layer.

The DIFOUT model allows two alternative methods for determining dispersion coefficients required in the Gaussian equation: Sutton's power law relation or the turbulence intensity formulation of Smith and Hay (Slade 1968). The Smith and Hay method, which was chosen for this study, calculates horizontal and vertical dispersion coefficients (σ_y, σ_z) as a function of downwind distance and turbulence intensities. Turbulence intensity values (I_y, I_z) are a measure of the horizontal and vertical fluctuations of the wind, proportional to the standard deviation of the horizontal and vertical wind velocities divided by the horizontal wind speed.

The initial size of the cloud is also taken into account in calculating horizontal dispersion coefficients. A virtual source distance is added to all downwind ranges such that, at the initial location of the cloud, σ_y has a finite value proportional to the cloud diameter.

Deposition values are calculated in DIFOUT as the product of the integrated air concentration and the deposition velocity. For a given particle size, the deposition velocity is a function of the gravitational fall velocity, wind speed, turbulence intensity, and reflection coefficient. The reflection coefficient varies from zero to one for a completely depositing aerosol to a nondepositing aerosol. It is calculated as a function of the particle fall velocity, wind speed, downwind distance, and initial height of the particle.

C. Source Characterization

The DIFOUT model requires, as input data, a detailed description of the initial stabilized detonation cloud (that is, no further cloud rise due to the initial detonation). The cloud shape, including height and diameter, and aerosol characteristics, including mass distribution with height and size distribution, must be specified.

1. Cloud Shape. For each detonation cloud modeled with DIFOUT, the cloud height must first be determined. This cloud height is then divided into 10 layers of equal thickness; the height of each layer is input data for the model. The diameter of each layer must also be specified.

2. Aerosol Parameters. The DIFOUT model provides a method for completely describing the aerosol as it exists in the detonation cloud. DIFOUT input parameters include the distribution of aerosol mass with height and the aerosol size distribution. For each of the 10 layers of the cloud, the fraction of the total aerosol and the aerosol size distribution must be specified. The model also allows the user to select the size range of aerosol to be considered when summing the different vertical line source contributions to the integrated air concentrations and the ground deposition.

The aerosol size distribution may vary from layer to layer or be constant over as many layers as desired. The distributions may be specified in two different manners for input to the model. The manual method requires that the specific particle diameters and the percentage of aerosol of each size be entered as input data for each layer. In the alternate method used in this study, the distribution is approximated by line segments from a log probability plot. This method requires the geometric standard deviation, activity (mass) median aerodynamic diameter (amad), and the upper and lower limits of particle diameter for each line segment; the model computes the mass in each size fraction.

D. Meteorology

The meteorological parameters required by DIFOUT for dispersion of the detonation cloud are wind speed, wind direction, and turbulence intensity. All these parameters may be varied with height so that the cloud can be modeled realistically.

E. Model Verification

Based on the results of the model verification (Appendix C), the following assumptions have been applied to the modeling of postulated accidents for this study.

1. The respirable fraction of plutonium aerosol was not modeled using DIFOUT. Air concentrations of the total aerosol were calculated, and the respirable fraction was assumed to be 20% of these values.

2. Data from the Roller Coaster, Double Tracks, and Clean Slate 2 tests were determined to be appropriate for the description of the initial detonation clouds. These data include the distribution of aerosol with height, aerosol size distribution, and cloud diameter. Data from the Clean

Slate 1 test were judged to be inappropriate for describing the initial detonation clouds.

III. DATA BASE FOR DIFOUT MODEL CALCULATIONS

The actual data used as input to the model for the calculation of dispersion and deposition of plutonium from each of the postulated accidents (Table II) are presented in this section. These data include the parameters that characterize the initial detonation cloud and the meteorological conditions that were used for calculating downwind air concentrations and ground deposition.

A. Cloud Parameters

Measurements from the Roller Coaster test shots provide the best available data for the initial stabilized cloud description required for this study. These data include aerosol size distribution, distribution of plutonium with height, and cloud diameter. Some Roller Coaster data have been used directly in this study. Other data were modified because of differences between the postulated accidents and the Roller Coaster test shots. Each of the accidents postulated (Chamberlin 1982) has been compared to the Roller Coaster test detonations. Data from the test most closely resembling the accidents considered in this study were used in the DIFOUT model. Roller Coaster test data were applied to each accident as shown in Table III.

For most of the accidents, the Double Tracks test (an unbunkered test) was the appropriate choice. Clean Slate 2 data (a bunkered test) were chosen for the other accidents. Clean Slate 1 data were not selected even though the test involved more comparable amounts of high explosives for some of the accidents than did Double Tracks. (The Clean Slate 1 distribution of plutonium with height was not considered representative.) Also, the DIFOUT model verification study (Appendix C) indicated inconsistencies between modeling results and measurements for Clean Slate 1.

Cloud parameters specific to clouds resulting from all accidents are discussed in the following sections.

1. Cloud Height. For each postulated accident, the height of the cloud top was calculated as a function of the amount of high explosives involved in the detonation (Church 1969):

$$H = 76 \, (HE)^{0.25} \quad , \tag{1}$$

where H is the height of the cloud in meters and HE is the amount of high explosives in pounds. When the cloud reaches this height, no further rise

TABLE II

POSTULATED ACCIDENTS: HIGH EXPLOSIVES DETONATED AND PLUTONIUM RELEASED

	High Explosives*** (lb)	Plutonium Released (kg)	Cloud Height (m)
Pantex Plant			
A	500	50	359
B	1000	100	427
C	1000	100	427
D	300	25	316
E	183	12	280
F	183	12	280
G*	114	8	248
H	2000	30	508
I	420	120	344
J	1.3	0.056	67**
K	19.6	0.625	135**
IAAP			
L	183	12	280
M+	6	0.460	119
N*	114	8	248
O*	114	8	248
P	300	25	316
Q	2000	30	508
R	420	120	344
S	19.6	0.625	135**
Hanford Site			
T	19.6	0.625	135**

---

*Dispersion and deposition values will not be calculated for these accidents. Considering the amount of high explosives and plutonium, the impact of these accidents will be no greater than the impact from accidents E or F (Pantex) or L (IAAP).

**The cloud height has been calculated based upon one-half of the high explosive involved because the cloud was released through two separate points (Chamberlin 1982).

***These are the effective amounts of high explosives detonated, representing the amount of energy available for the initial cloud rise (Chamberlin 1982).

+Dispersion and deposition values will not be calculated for this accident. Considering the amount of high explosives and plutonium, the impact of this accident will be no greater than was accident S.

TABLE III

ROLLER COASTER DATA FOR POSTULATED ACCIDENTS

Accident*	Applicable Roller Coaster Test Shot
H, I, Q, R	Clean Slate 2
J, K, S, T	Modified Double Tracks
A, B, C, D, E, F, G, L, M, N, O, P	Double Tracks

---

*Independent of location and initiating event (tornado, aircraft crash, etc.).

TABLE IV

CLOUD DIAMETERS (m) FOR POSTULATED ACCIDENTS

Cloud Top	Accidents A-G, J-P, S, T	Accidents H, I, Q, R
Layer 10*	67	122
Layer 9	78	189
Layer 8	71	250
Layer 7	34	209
Layer 6	91	81
Layer 5	128	81
Layer 4	115	68
Layer 3	71	135
Layer 2	91	162
Layer 1	121	155
Surface		

---

*Each layer is of equal thickness.

occurs as a result of the initial detonation. The cloud heights for each of the postulated accidents are presented in Table II.

2. Cloud Diameter. For each accident analyzed, cloud diameters either were taken directly from Double Tracks or Clean Slate 2 measurements (Table IV) or were a modification of the Double Tracks measurements. Using the

Double Tracks diameters is a conservative assumption: each of the detonation clouds is taller than is the Double Tracks cloud (220 m); therefore, the detonation clouds would probably have larger diameters. Thus, the estimated aerosol concentration in the initial cloud is higher than might realistically occur. This initial overestimate of aerosol concentration also occurs for several of the accidents modeled with Clean Slate 2 data.

The estimated clouds produced from accidents J, K, S, and T are lower in height than the Double Tracks cloud. Using the diameters from Double Tracks would be a nonconservative assumption in this case as the initial aerosol would be distributed through too great a volume. Thus, the Double Tracks diameters were modified based on the amount of high explosives (Taylor 1981):

$$\text{Modified Diameter} = (\text{Double Tracks Diameter}) \times \left[\frac{\text{Accident J, K, S, or T HE amount}}{\text{Double Tracks HE amount}}\right]^{3/8} . \qquad (2)$$

The cloud diameters for these four accidents are listed in Table V.

TABLE V

CLOUD DIAMETERS (m) FOR ACCIDENTS J, K, S, and T

Layer*	Accident J	Accidents K, S, T
Layer 10	5	14
Layer 9	5	14
Layer 8	6	17
Layer 7	8	23
Layer 6	11	31
Layer 5	14	39
Layer 4	14	39
Layer 3	12	34
Layer 2	10	28
Layer 1	7	20
Surface		

---

*Layer 1 is 18 m deep in both cases to account for building wake effects. The other nine layers of each cloud are of equal thickness (Accident J--5.5 m, accidents K, S, and T--13 m).

Unlike the other accident cases, however, only 9 of the 10 layers are of equal depth. The bottom layer for these four accidents has been modified to take into account the effect of the building wake. As the cloud moves away from the accident, the lower part of the cloud will be entrained into the building wake. For accident J, the lowest cloud layer was estimated to be 7 m in diameter to an elevation of 18 m. For accidents K, S, and T, the diameter of the first layer was scaled up from 7 m (accident J) according to Eq. (2), and the depth of this first layer was set to 18 m.

3. Plutonium Distribution with Height. For each accident, the plutonium distribution with height was taken from Double Tracks or Clean Slate 2 measurements. The Roller Coaster distributions are presented in Table VI. Note that a somewhat greater amount of mass is located closer to the ground for the Clean Slate 2 test. This occurrence is a result of the interaction between the plutonium and the earth cover. The distribution for accidents J, K, S, and T again required modification to account for building wake effects (Taylor 1981). A much greater fraction of plutonium is close to the ground resulting from entrainment of the cloud down to the ground in the wake of the building. The plutonium distribution for the other accidents was taken directly from the Roller Coaster tests.

4. Aerosol Size Distribution. For each accident, the aerosol size distribution for the detonation cloud was taken from Double Tracks or Clean Slate 2 distributions. Although DIFOUT allows separate distributions for each layer of the cloud, only one distribution was used for each cloud.

TABLE VI

PLUTONIUM DISTRIBUTION WITH HEIGHT (percentages)

Layer	Accidents A-G, L-P (Double Tracks Data)	Accidents H, I, Q, R (Clean Slate 2 Data)	Accidents J, K, S, T (Modified Double Tracks Data)
Layer 10	9	3	1
Layer 9	14	10	4
Layer 8	17	16	0
Layer 7	17	17	3
Layer 6	14	15	23
Layer 5	12	11	13
Layer 4	8.5	11	13
Layer 3	6.5	8	9
Layer 2	0.8	6	10
Layer 1	0.2	2	24
Surface			

As described in Section II.C.2., the aerosol size distribution is estimated in DIFOUT by specifying several straight line segments of a log probability plot, each covering an interval of particle size. These line segments are described by the activity median aerodynamic diameter (amad) and the geometric standard deviation (σ_g) of the particles. The line segments for each of the Roller Coaster tests are displayed in Figure C-3. The amad and σ_g values for accidents modeled with Double Tracks and Clean Slate 2 data are presented in Table VII. Note that only two line segments were required to adequately describe the Clean Slate 2 distribution, whereas three were required for the Double Tracks distribution.

Based on the results of the DIFOUT verification study, presented in Appendix C, all particle sizes up to 1000 μm were considered for calculation of ground deposition. Twenty per cent of the total aerosol to 1000 μm was considered to be the respirable fraction.

TABLE VII

AEROSOL SIZE DISTRIBUTION PARAMETERS

	Amad (μm)	σ_g (μm)	Range of Particle Size (μm) From	Range of Particle Size (μm) To
Accidents A-G, J-P, S, T	9000*	90	0.1	4.0
	38	3.8	4.0	60
	48	1.8	60	1000
Accidents H, I, Q, R	39	7.8	0.1	42
	41	2.3	42	1000

*Although the 9000-μm activity median aerodynamic diameter (amad) appears to be an artificial value, it is the median extrapolated at a 50% probability by the line segment best fitting the distribution between 0.1 and 4.0 μm.

B. Meteorological Data

1. STAR Data. As noted in Section II.D., the meteorological data required for using the DIFOUT model include wind speed, wind direction, and turbulent intensity. Each of these variables may vary with height.

For each site, stability - wind rose (STAR) data have been used to select the wind parameters and the stability class for determining the turbulence intensities. Data from the Amarillo Airport (1955-64) have been used for the Pantex Plant, Burlington Airport data (1967-71) for the IAAP, and onsite data (Area 200) for the Hanford Site (1973-75). Wind roses for each site are presented in Figs. 1 through 3.

Each of the stations where STAR data are available is located within 16 km of the facilities analyzed in this study and in similar terrain. Thus, the STAR data are considered representative of conditions at each site. Fifteen years of data (two separate periods) are available for Amarillo and five years for Burlington. The STAR data for each site are presented in Appendix B.

The data from the Hanford Site are available in a somewhat different format than are the data from Burlington and Amarillo. Instead of the six standard Pasquill-Gifford stability classes A-F (Turner 1970), the Hanford data have been classified by four categories (USERDA 1976C): B, D, moderately stable (ms), and very stable (vs). Categories B and D approximately correspond to the B and D Pasquill-Gifford categories. Moderately stable and very stable correspond roughly to the Pasquill-Gifford classes E and F.

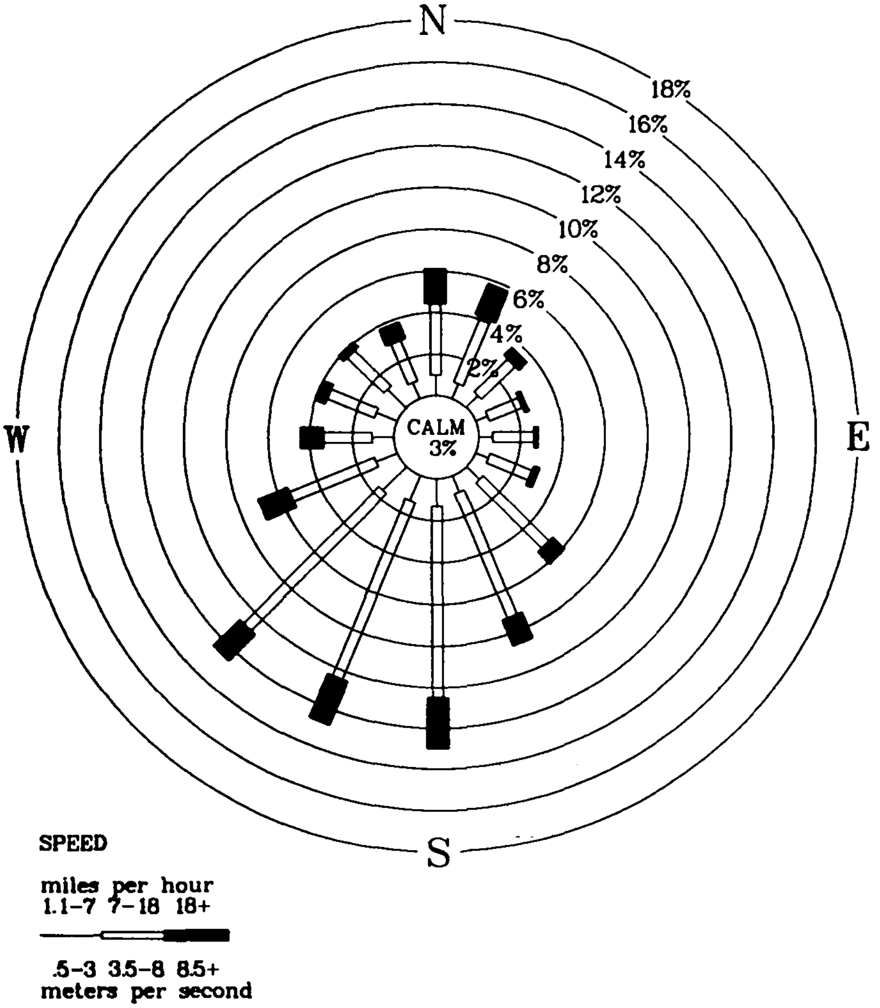

Fig. 1. Wind rose for Amarillo, Texas, 1955-1964.

The length of record of the Hanford data is also somewhat shorter than that of the other stations. Stability and wind data were available for only 3 years for Hanford, whereas 5 or more years of data are available for the other sites. However, a comparison of wind roses from the 3-year period (Fig. 3) and a 15-year period (1955-70) showed little variation. Therefore, the 3-year record at Hanford is regarded as adequate for this study.

2. Meteorological Data Used as DIFOUT Model Input. Two sets of meteorological conditions were selected for each site for each accident (excluding the tornado accident) to model the dispersion and deposition of the detonation cloud. The two sets of conditions were chosen to provide a range of possible downwind plutonium air concentrations that could occur as a result of the variability of the weather. They represent an "unfavorable" and a "median" (most likely) dispersion condition. Note that only the meteorology changes between the two cases, while the amount of plutonium or high explosives involved does not change.

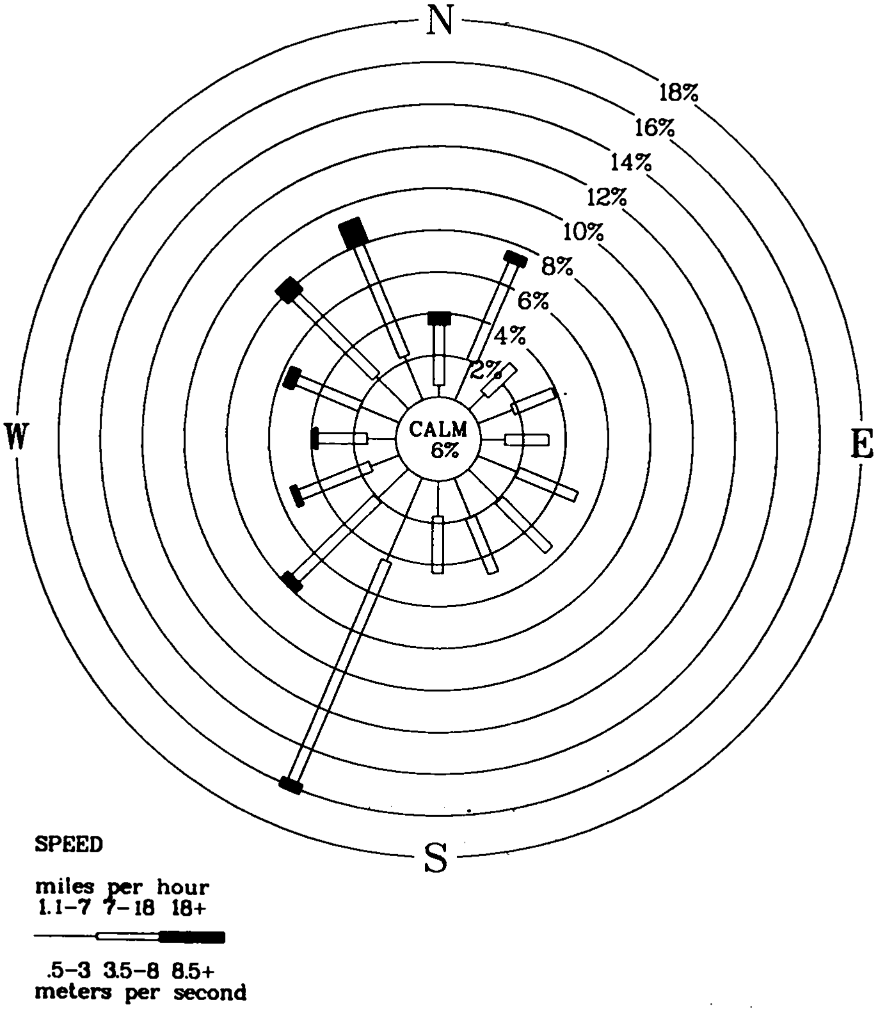

Fig. 2. Wind rose for Burlington, Iowa, 1967-1971.

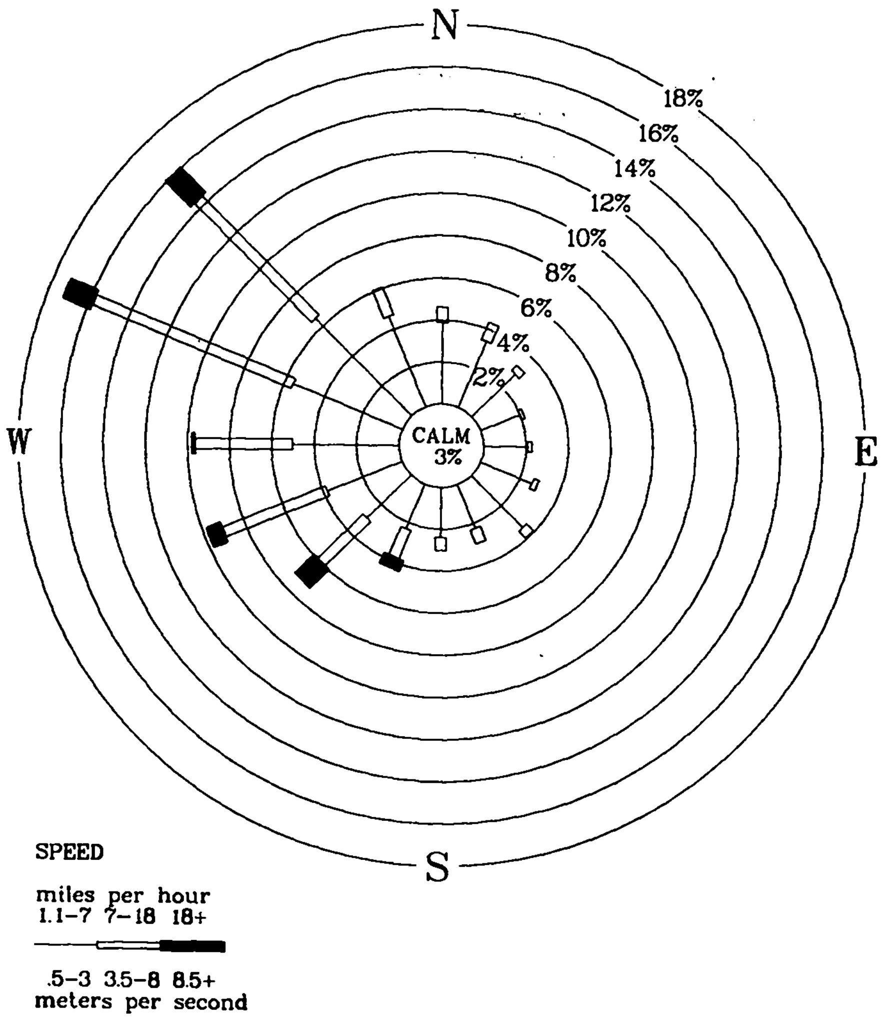

Fig. 3. Wind rose for the Hanford Site, Washington, 1973-1975.

The wind direction was chosen first for each case. For the unfavorable case, the wind direction was chosen so that release would affect the largest nearby population center. The median case wind direction was chosen so that the released cloud is carried in the prevailing wind direction (Table VIII).

To select the wind speed and stability appropriate to be used in DIFOUT for each accident scenario, preliminary dispersion factors (χ/Q) were calculated for each site with the STAR data using the following dispersion equation (Slade 1968):

$$\frac{\chi}{Q} = \frac{1}{\pi\sigma_y\sigma_z u}\left[\exp \frac{-H^2}{2\sigma_z^2}\right] , \qquad (3)$$

where χ/Q is the ground-level centerline integrated puff concentration, normalized by the source strength, Q,

u is the midpoint of the wind speed class, adjusted to the release height,

σ_y, σ_z are horizontal and vertical puff dispersion coefficients (Slade 1968), and

H is the release height.

Although this dispersion equation is not the same formulation as that used in the DIFOUT model, the effect of different wind speeds and stabilities on the dispersion of the detonation clouds can be assessed more quickly and inexpensively with this equation than with DIFOUT.

Because initially the detonation cloud has plutonium distributed through its entire depth, the release height is set equal to one-half the cloud top height. The wind speed was adjusted to reflect this height as discussed below. This release height is held constant for all downwind distances and all meteorological conditions. The initial σ_y and σ_z were assigned values equal to one-fourth the cloud top height. This value was chosen because 95.5% of the aerosol in a Gaussian cloud is within 2σ of the cloud center.

TABLE VIII

WIND DIRECTIONS* FOR DISPERSION CASES

	Median Dispersion Case	Unfavorable Dispersion Case	Largest Nearby Population Center (Distance from Site)
Pantex Plant**	SSW	ENE	Amarillo (25 km west-southwest)
Iowa Army Ammunition Plant**	SSW	W	Burlington (8 km east)
Hanford Site***	NW	NNW	Richland (43 km south-southeast)

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*Wind direction is defined as the direction from which the wind is blowing.

**Wind direction at 7 m.

***Wind direction at 16 m.

The preliminary dispersion factors were calculated at 10 distances for each combination of six windspeeds and six stability classes from the site boundary to 80 km in two selected directions: the wind direction blowing toward the closest nearby population center (unfavorable case) and the prevailing wind direction (median case). Each of these dispersion factors has a probability of occurrence based on the frequency of occurrence of the particular wind speed and direction and the stability class used to calculate it. From these probabilities, a cumulative probability distribution of dispersion factors was constructed for each distance in the two directions. The unfavorable case dispersion factor selected was the one exceeded during only 0.5% of the total hours at the distance of the largest nearby population center. The 0.5% χ/Q is chosen to be consistent with other accident analysis guidelines (USNRC 1979). The median dispersion factor selected was the median χ/Q in the prevailing wind direction at the same distance as the unfavorable case.

The meteorological data producing these dispersion factors for each accident (Table IX) are used as input for running the DIFOUT model. The wind speed and stability can vary between accidents because of different heights of the initial detonation clouds.

The variation of wind speed and direction with height was calculated for eight heights from 7 to 300 m and held constant above 250 m. The change of wind speed with height is determined by (USEPA 1977)

$$U_{Z2} = U_{Z1} \quad (Z2/Z1)^{p} \ , \qquad (4)$$

where U_{Z1} is the wind speed at height Z1, U_{Z2} is the wind speed at height Z2, and p is a stability dependent coefficient. The value of p varies with stability class as presented in Table X.

The variation of wind direction with height through the first few hundred meters of the atmosphere has been estimated (Smith 1968) to be a veering (turning clockwise with increasing height) of the direction by 15° during the day and 30° at night over smooth surfaces. For model input, a veering of 20° was assumed for neutral conditions and 25° for stable conditions.

The selection of horizontal and vertical turbulent intensities was based on stability class. The values for each stability class were taken from Luna (1972) and are presented in Table X. Turbulence intensities were assumed to be constant with height for DIFOUT model input.

The initiating event for Accident C is a tornado. This accident was modeled for only one set of meteorological conditions. Plutonium particles produced by the tornado-induced detonation could be spread by uptake in the funnel cloud or by winds behind the funnel cloud. Although the former case

TABLE IX

METEOROLOGICAL DATA FOR UNFAVORABLE AND MEDIAN DISPERSION CASES

	Median	Unfavorable
Pantex Plant*		
Accidents A-I, K	SSW wind (202.5°) 6.75 m/s D stability	ENE wind (67.5°) 4.25 m/s E stability
Accident J	SSW wind (202.5°) 6.75 m/s D stability	ENE wind (67.5°) 2.5 m/s F stability
Iowa Army Ammunition Plant*		
Accidents L-S	SSW wind (202.5°) 4.75 m/s D stability	W wind (270.0°) 2.5 m/s D stability
Hanford Site**		
Accident T	NW wind (315°) 6.9 m/s MS stability	NNW wind (337.5°) 0.78 m/s MS stability

---

*Wind speed and direction at 7 m.
**Wind speed and direction at 16 m.

TABLE X

WIND SPEED EXPONENT* AND TURBULENCE INTENSITY VALUES**

Stability Class	p	Turbulence Intensity I_y (horizontal)	Turbulence Intensity I_z (vertical)
A	0.10	0.17	0.25
B	0.15	0.14	0.21
C	0.20	0.12	0.14
D	0.25	0.067	0.065
E	0.30	0.025	0.025
F	0.40	0.017	0.017

---

*USEPA 1977.
**Luna 1972.

may occur, the resulting radiological consequences are expected to be much lower because of greater dispersion and dilution. As a conceivable and more conservative case, the winds behind the tornado were used in modeling the dispersion of plutonium following a tornado-produced detonation.

The data selected as representative of the meteorological conditions in the vicinity of a tornado are presented in Table XI. Based on a summary of directions of tornado paths (Fujita 1976), it is unlikely that the wind direction behind a tornado would be toward Amarillo (east-northeast wind). Thus, the wind direction from the south-southwest was selected for this postulated accident. The Borger area, north-northeast of the Pantex Plant, would be the largest population center affected.

C. Site Data

The location of each site with respect to the communities within 80 km is presented in Figs. 4, 5, and 6. Distances to the site boundary and nearby population centers for each dispersion case are presented in Table XII. Note that for some accidents the nearest site boundary is closer to the accident site in the median dispersion case than it is in the unfavorable dispersion case. For these accidents, site boundary air concentrations for the median case are higher than are those for the unfavorable dispersion case.

IV. RESULTS AND DISCUSSION

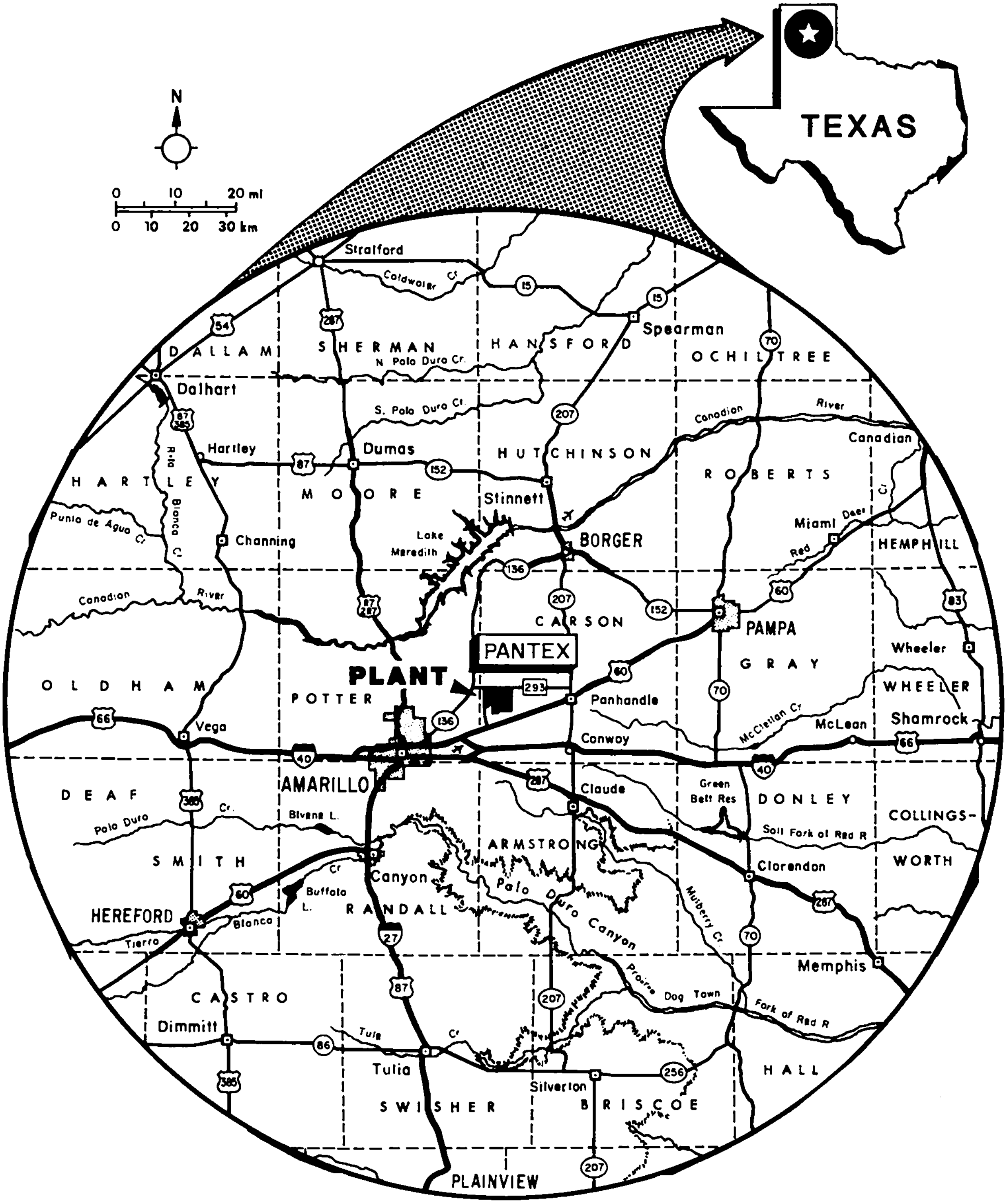
Integrated air concentrations in μg-s/m^3 and deposition values in μg/m^2 were calculated for each accident out to a distance of 80 km. For each downwind distance, air concentrations and deposition were calculated every 1° of azimuth across the path of the cloud. The data presented in Appendix A are the maximum concentration or ground deposition at each downwind distance. The tables are arranged by site (Pantex Plant, IAAP, Hanford Site) and in

TABLE XI

METEOROLOGICAL DATA FOR TORNADO ACCIDENT

Pantex Plant	
Accident C	SSW wind (202.5°) 10.0 m/s D stability

Note: Wind speed and direction at 7 m above ground.



80-MILE RADIUS

Fig. 4. Location of the Pantex Plant and surrounding communities.

Fig. 5. Location of the Iowa Army Ammunition Plant and surrounding communities.

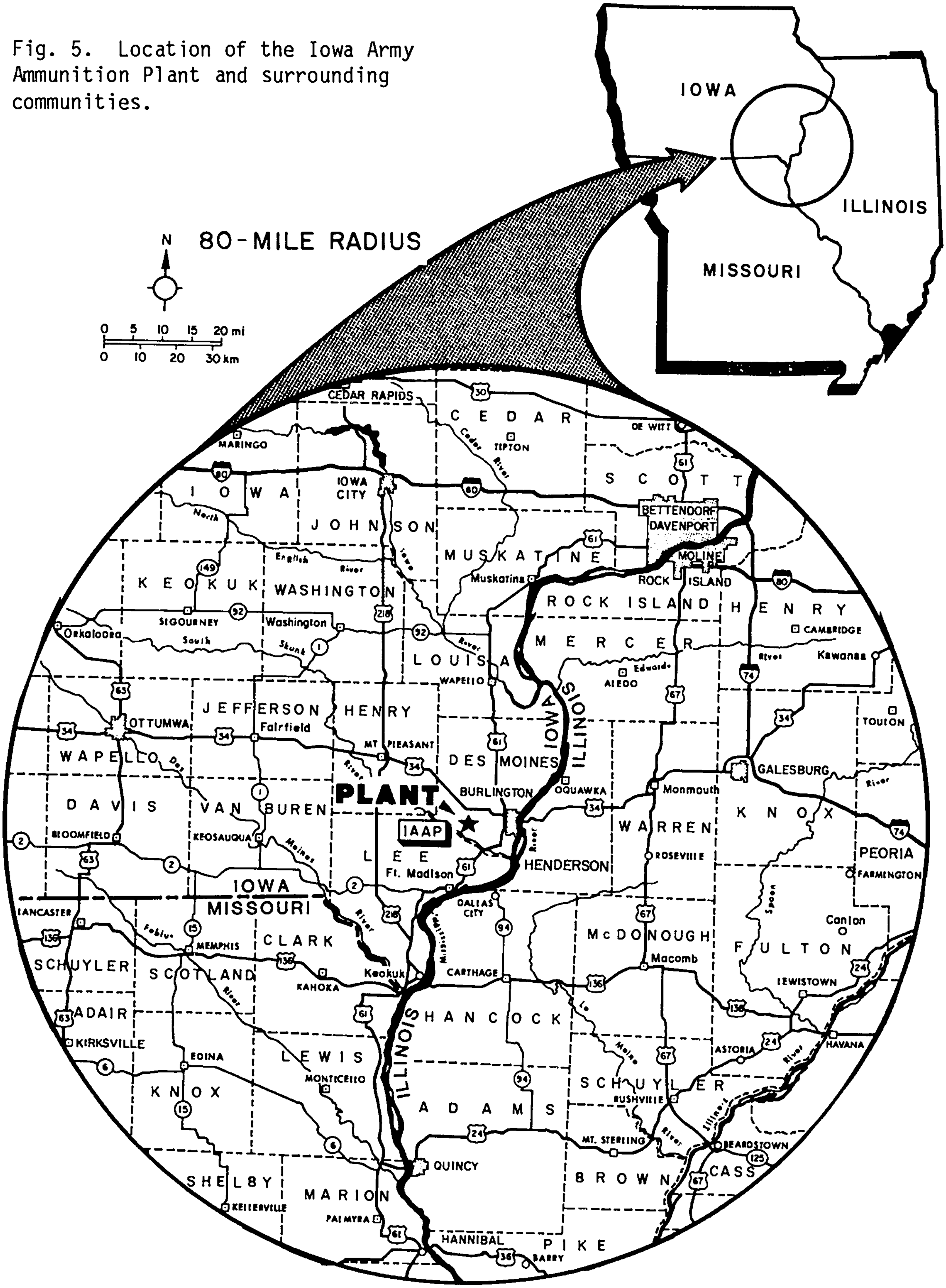


Fig. 6. Location of the Hanford Site and surrounding communities.

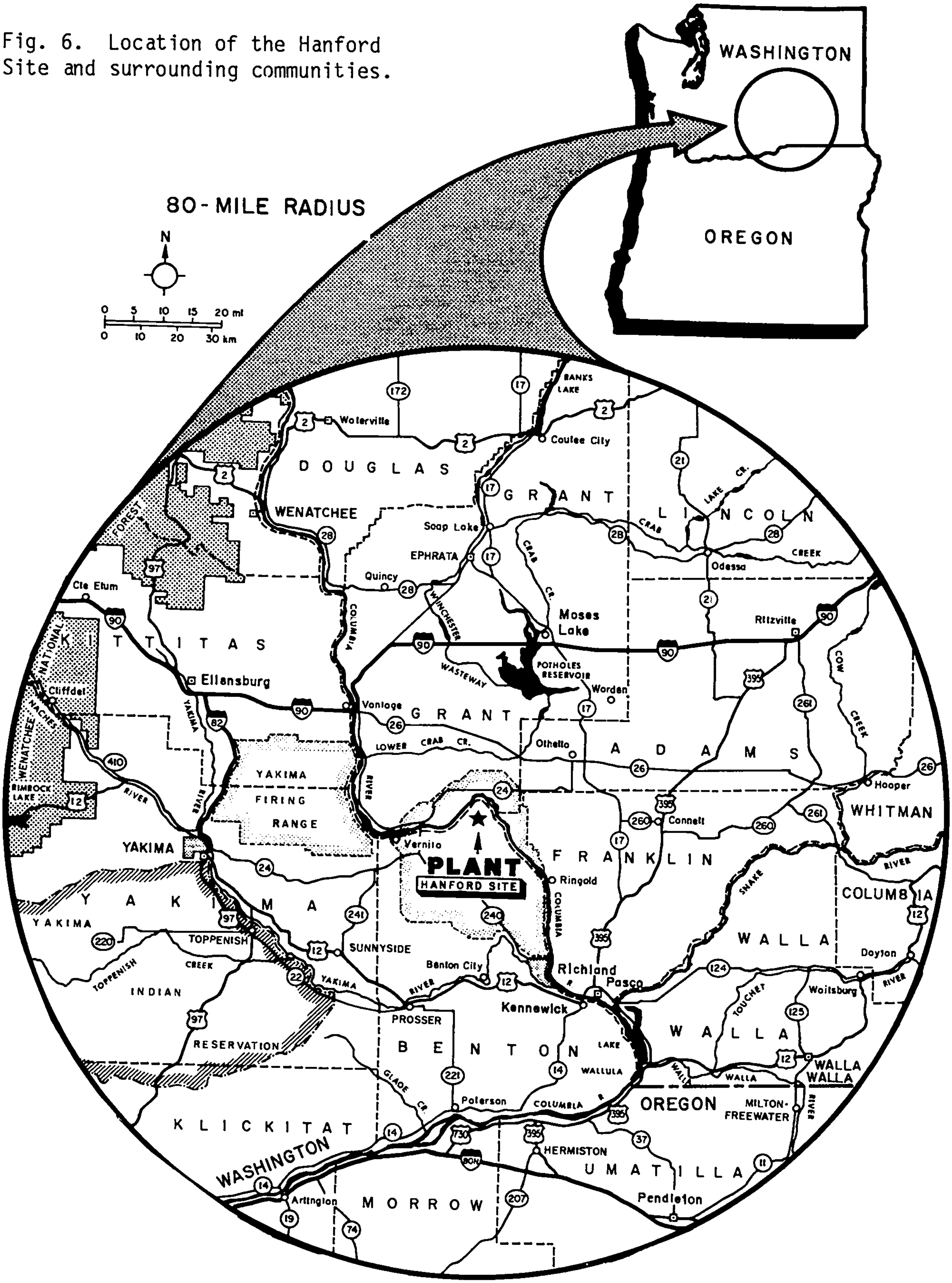


TABLE XII

DISTANCES TO SITE BOUNDARY, NEAREST RESIDENCE, AND MAJOR POPULATION CENTER

	Dispersion Case	Site Boundary (km)	Nearest Residence (km)	Major Population Center (km)
Pantex Plant				
Accidents A, B, C, D, E, F, G, J, K	Median	5.0	5.2	42
	Unfavorable	5.5	6.5	25
Accidents H and I	Median	2.2	2.4	42
	Unfavorable	4.0	5.0	25
IAAP				
Accidents L, M, N, O, P	Median	1.5	1.5	None
	Unfavorable	3.9	3.9	8.6
Accidents Q and R	Median	2.45	2.5	None
	Unfavorable	1.8	1.8	6.6
Hanford Site				
Accident T	Median	35	35	42
	Unfavorable	35	35	42

order of greatest air concentration or deposition by site. Values of peak air concentration and deposition by accident are presented in Table XIII for the Pantex Plant, Table XIV for the IAAP, and Table XV for the Hanford Site.

The data show that the accidents involving the largest amounts of plutonium produce the largest downwind integrated air concentrations and ground deposition. Thus, the accidents with the largest offsite consequences are accident I at the Pantex Plant and accident R at the IAAP. The only exceptions to this trend are accident C (Pantex Plant), a tornado-produced detonation, and accidents J, K (Pantex Plant), and S (IAAP). Downwind air concentrations and ground deposition from accident C are smaller than are values for accidents involving less plutonium because of the much higher wind speeds dispersing the aerosol. Air concentrations close to the detonation

TABLE XIII

HIGHEST OFFSITE INTEGRATED AIR CONCENTRATION AND GROUND DEPOSITION FOR PANTEX PLANT ACCIDENTS

		Concentrations ($\mu g\text{-}s/m^3$)		Ground Deposition ($\mu g/m^2$)	
Accident	Pu Released (kg)	Unfavorable Meteorology	Median Meteorology	Unfavorable Meteorology	Median Meteorology
I	120	3.38×10^4 (4)	4.25×10^4 (2.2)	1.37×10^4 (4)	8.60×10^3 (2.2)
B	100	9.60×10^3 (5.5)	9.40×10^3 (5)	3.45×10^3 (5.5)	1.80×10^3 (5)
A	50	8.20×10^3 (5.5)	7.00×10^3 (5)	2.15×10^3 (5.5)	1.38×10^3 (5)
H	30	4.80×10^3 (4)	5.90×10^3 (2.2)	2.07×10^3 (4)	1.10×10^3 (2.2)
C	100	NA	5.13×10^3 (8)	NA	1.18×10^3 (5)
D	25	4.90×10^3 (5.5)	5.00×10^3 (5)	1.15×10^3 (5.5)	8.30×10^2 (5)
E, F	12	3.00×10^3 (5.5)	2.92×10^3 (5)	6.60×10^2 (5.5)	4.65×10^2 (5)
K	0.625	1.05×10^3 (5.5)	4.40×10^2 (5)	3.80×10^1 (5.5)	4.60×10^1 (5)
J	0.056	2.30×10^2 (5.5)	6.00×10^1 (5)	5.02×10^0 (5.5)	5.59×10^0 (5)

( ) Distance from accident location to maximum value, km.
NA Not Applicable.

TABLE XIV

HIGHEST OFFSITE INTEGRATED AIR CONCENTRATION AND GROUND DEPOSITION FOR IAAP ACCIDENTS

		Integrated Air Concentrations ($\mu g\text{-}s/m^3$)		Ground Deposition ($\mu g/m^3$)	
Accident	Pu Released (kg)	Unfavorable Meteorology	Median Meteorology	Unfavorable Meteorology	Median Meteorology
R	120	1.73×10^{5} (1.8)	6.30×10^{4} (2.45)	2.25×10^{4} (1.8)	1.48×10^{4} (2.45)
P	25	1.65×10^{4} (3.9)	9.80×10^{3} (2.45)	2.92×10^{3} (3.9)	2.29×10^{3} (2)
Q	30	1.60×10^{4} (1.8)	7.30×10^{3} (2.45)	5.75×10^{3} (1.8)	1.85×10^{3} (2.45)
L	12	9.55×10^{3} (3.9)	5.41×10^{3} (2)	1.50×10^{3} (3.9)	1.28×10^{3} (2)
S	0.625	1.45×10^{3} (3.9)	6.00×10^{3} (1.5)	6.25×10^{1} (3.9)	4.75×10^{2} (1.5)

( ) Distance from accident location to maximum value, km.

TABLE XV

HIGHEST OFFSITE INTEGRATED AIR CONCENTRATION AND GROUND DEPOSITION FOR HANFORD SITE ACCIDENTS

		Integrated Air Concentrations ($\mu g\text{-}s/m^3$)		Ground Deposition ($\mu g/m^2$)	
Accident	Pu Released (kg)	Unfavorable Meteorology	Median Meteorology	Unfavorable Meteorology	Median Meteorology
T	0.625	6.30×10^{1} (35)	1.70×10^{1} (35)	2.20×10^{-1} (32)	5.00×10^{-1} (32)

( ) Distance from accident location to maximum values, km.

for accidents J, K, and S are larger than are concentrations for accidents involving more plutonium because of the small cloud height (Table II) and the large initial concentration of plutonium in the lowest layer of the detonation cloud (Table VI). Further downwind, air concentrations from accidents J, K, and S become much smaller than are concentrations from the other accidents, more in proportion to the initial plutonium release.

For each accident at similar downwind distances, air concentrations under unfavorable dispersion conditions are greater than are concentrations under median dispersion conditions. Depending on the cloud height and meteorological conditions, the unfavorable case concentrations are as much as four times higher than are median case concentrations. For plutonium ground deposition, unfavorable case values are greater than are median case values for most downwind distances. Because of this greater deposition near the detonation in the unfavorable case, the unfavorable case cloud is more quickly depleted of plutonium. Thus, beyond 50 km, ground deposition for many of the accidents is greater for the median dispersion case.

No results have been presented for accident G at the Pantex Plant or accidents M, N, and O at IAAP. Considering the amounts of high explosives and plutonium, the accident G impact would be similar to but no worse than that for accidents E or F. Also, the impact of accidents N and O would be similar to but no greater than the impact of accident L; the accident M impact would be no greater than that of accident S.

V. SUMMARY

As part of the Pantex EIS, the dispersion and deposition of plutonium, released from postulated detonations of nuclear weapons, have been calculated using the DIFOUT model. Experimental data were used to describe the initial characteristics of the detonation clouds as realistically as possible. Meteorological data from each of the three sites considered for the EIS were analyzed to select dispersion parameters for each postulated accident.

Results show that the postulated accidents involving the greatest amounts of plutonium generally produce the highest offsite air concentrations and ground deposition. Air concentrations and ground deposition values calculated for unfavorable meteorological dispersion conditions were as much as four times greater than those for median dispersion conditions, depending upon the specific accident and the downwind distance.

ACKNOWLEDGMENTS

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APPENDIX A

CALCULATION RESULTS

Integrated Air Concentrations

Pantex	Tables A-I through A-IX
IAAP	Tables A-X through A-XIV
Hanford	Table A-XV

Ground Deposition

Pantex	Tables A-XVI through A-XXIV
IAAP	Tables A-XXV through A-XXIX
Hanford	Table A-XXX

Downwind air concentrations and deposition values were not calculated for the distances indicated (----).

TABLE A-I

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: I
Pu Released: 120 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations ($\mu g\text{-}s/m^3$) Unfavorable Meteorology	Median Meteorology
1.0	---	6.23×10^4
2.0	---	4.58×10^4
4.0	3.38×10^4	2.62×10^4
8.0	1.66×10^4	1.56×10^4
16.0	9.87×10^3	7.30×10^3
20.0	7.73×10^3	---
25.0	5.58×10^3	3.06×10^3
32.0	3.82×10^3	1.74×10^3
36.0	3.15×10^3	---
50.0	1.74×10^3	5.78×10^2
64.0	1.05×10^3	3.04×10^2
80.0	6.42×10^2	1.67×10^2

TABLE A-II

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: B
Pu Released: 100 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations ($\mu g\text{-}s/m^3$) Unfavorable Meteorology	Median Meteorology
1.0	---	5.54×10^3
2.0	---	3.62×10^3
4.0	1.15×10^4	9.68×10^3
8.0	8.35×10^3	8.47×10^3
16.0	5.85×10^3	6.13×10^3
20.0	5.26×10^3	---
25.0	4.13×10^3	3.04×10^3
32.0	3.12×10^3	1.82×10^3
36.0	2.74×10^3	---
50.0	1.78×10^3	6.34×10^2
64.0	1.17×10^3	3.39×10^2
80.0	7.51×10^2	1.89×10^2

TABLE A-III

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: A
Pu Released: 50 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations ($\mu g\text{-}s/m^3$) Unfavorable Meteorology	Median Meteorology
1.0	---	3.17×10^3
2.0	---	2.85×10^3
4.0	1.01×10^4	7.74×10^3
8.0	6.30×10^3	6.17×10^3
16.0	3.67×10^3	3.37×10^3
20.0	2.70×10^3	---
25.0	2.13×10^3	1.44×10^3
32.0	1.57×10^3	8.25×10^2
36.0	1.32×10^3	---
50.0	7.59×10^2	2.75×10^2
64.0	4.77×10^2	1.45×10^2
80.0	2.98×10^2	7.99×10^1

TABLE A-IV

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: H
Pu Released: 30 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations ($\mu g\text{-}s/m^3$) Unfavorable Meteorology	Median Meteorology
1.0	---	1.14×10^4
2.0	---	6.46×10^3
4.0	5.14×10^3	3.37×10^3
8.0	3.11×10^3	2.02×10^3
16.0	1.10×10^3	1.41×10^3
20.0	1.10×10^3	---
25.0	1.10×10^3	7.77×10^2
32.0	9.70×10^2	4.97×10^2
36.0	8.44×10^2	---
50.0	5.15×10^2	1.88×10^2
64.0	3.31×10^2	1.04×10^2
80.0	2.12×10^2	5.91×10^1

TABLE A-V

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: C
Pu Released: 100 kg
Wind Direction: N/A* Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m³) Unfavorable Meteorology	Median Meteorology
1.0	Not applicable for this accident	0
2.0		2.22×10^3
4.0		4.53×10^3
8.0		5.13×10^3
16.0		4.15×10^3
25.0		2.19×10^3
32.0		1.33×10^3
50.0		4.71×10^2
64.0		2.53×10^3
80.0		1.42×10^2

---

*N/A not applicaable.

TABLE A-VI

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: D
Pu Released: 25 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m³) Unfavorable Meteorology	Median Meteorology
1.0	---	1.74×10^3
2.0	---	2.13×10^3
4.0	5.89×10^3	5.13×10^3
8.0	3.79×10^3	3.90×10^3
16.0	2.01×10^3	1.89×10^3
20.0	1.54×10^3	---
25.0	1.23×10^3	7.51×10^2
32.0	8.81×10^2	4.19×10^2
36.0	7.27×10^2	---
50.0	3.96×10^2	1.36×10^2
64.0	2.34×10^2	7.07×10^1
80.0	1.40×10^2	3.87×10^1

TABLE A-VII

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accidents: E, F
Pu Released: 12 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance	Concentrations (μg-s/m^3)	
(km)	Unfavorable Meteorology	Median Meteorology
1.0	---	9.38×10^2
2.0	---	1.74×10^3
4.0	3.48×10^3	3.21×10^3
8.0	2.40×10^3	2.37×10^3
16.0	1.07×10^3	9.10×10^2
20.0	8.24×10^2	---
25.0	6.23×10^2	3.43×10^2
32.0	4.49×10^2	1.88×10^2
36.0	3.70×10^2	---
50.0	1.96×10^2	6.00×10^1
64.0	1.14×10^2	3.10×10^1
80.0	6.71×10^1	1.69×10^1

TABLE A-VIII

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: K
Pu Released: 0.625 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance	Concentrations (μg-s/m^3)	
(km)	Unfavorable Meteorology	Median Meteorology
1.0	---	9.07×10^3
2.0	---	2.50×10^3
4.0	1.90×10^3	7.02×10^2
8.0	4.77×10^2	1.65×10^2
16.0	1.06×10^2	2.93×10^1
20.0	6.44×10^1	---
25.0	3.81×10^1	8.83×10^0
32.0	2.08×10^1	4.46×10^0
36.0	1.55×10^1	---
50.0	6.56×10^0	1.27×10^0
64.0	3.38×10^0	6.23×10^{-1}
80.0	1.83×10^0	3.27×10^{-1}

TABLE A-IX

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Pantex Plant
Accident: J
Pu Released: 0.056 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3)	
	Unfavorable Meteorology	Median Meteorology
1.0	---	1.25×10^{3}
2.0	---	4.98×10^{2}
4.0	3.59×10^{2}	1.11×10^{2}
8.0	1.53×10^{2}	1.85×10^{1}
16.0	4.02×10^{1}	2.77×10^{0}
25.0	1.34×10^{1}	7.82×10^{-1}
32.0	7.05×10^{0}	3.84×10^{-1}
50.0	2.11×10^{0}	1.05×10^{-1}
64.0	1.06×10^{0}	5.07×10^{-2}
80.0	5.66×10^{-1}	2.63×10^{-2}

TABLE A-X

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: IAAP
Accident: R
Pu Released: 120 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3)	
	Unfavorable Meteorology	Median Meteorology
1.0	1.73×10^{5}	1.05×10^{5}
2.0	---	7.31×10^{4}
4.0	7.07×10^{4}	3.83×10^{4}
8.0	4.27×10^{4}	2.38×10^{4}
10.0	3.25×10^{4}	---
12.0	2.54×10^{4}	---
16.0	1.54×10^{4}	1.04×10^{4}
20.0	9.82×10^{3}	---
25.0	6.02×10^{3}	4.31×10^{3}
32.0	3.37×10^{3}	2.44×10^{3}
50.0	1.11×10^{3}	8.05×10^{2}
64.0	---	4.22×10^{2}
80.0	---	2.32×10^{2}

TABLE A-XI

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: IAAP
Accident: P
Pu Released: 25 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3) Unfavorable Meteorology	Concentrations (μg-s/m^3) Median Meteorology
1.0	1.77×10^4	3.93×10^3
2.0	---	9.32×10^3
4.0	1.65×10^4	9.30×10^3
8.0	1.07×10^4	6.94×10^3
10.0	8.12×10^3	---
12.0	6.23×10^3	---
16.0	3.74×10^3	2.57×10^3
20.0	2.37×10^3	---
25.0	1.44×10^3	1.00×10^3
32.0	7.96×10^2	5.59×10^2
50.0	2.56×10^2	1.81×10^2
64.0	---	9.43×10^1
80.0	---	5.16×10^1

TABLE A-XII

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: IAAP
Accident: Q
Pu Released: 30 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3) Unfavorable Meteorology	Concentrations (μg-s/m^3) Median Meteorology
1.0	2.71×10^4	1.61×10^4
2.0	---	---
4.0	8.14×10^3	4.76×10^3
8.0	5.35×10^3	2.97×10^3
10.0	5.03×10^3	2.69×10^3
12.0	4.67×10^3	2.55×10^3
16.0	3.50×10^3	2.11×10^3
20.0	2.56×10^3	1.62×10^3
25.0	1.73×10^3	1.14×10^3
32.0	1.05×10^3	7.14×10^2
50.0	3.76×10^2	2.65×10^2
64.0	---	---
80.0	---	---

TABLE A-XIII

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: IAAP
Accident: L
Pu Released: 12 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3) Unfavorable Meteorology	Median Meteorology
1.0	1.04×10^4	2.04×10^3
2.0	---	5.41×10^3
4.0	9.52×10^3	4.87×10^3
8.0	5.57×10^3	3.71×10^3
10.0	4.08×10^3	---
12.0	3.01×10^3	---
16.0	1.75×10^3	1.28×10^3
20.0	1.11×10^3	---
25.0	6.72×10^2	4.77×10^2
32.0	3.73×10^2	2.61×10^2
50.0	1.20×10^2	8.25×10^1
64.0	---	4.26×10^1
80.0	---	2.32×10^1

TABLE A-XIV

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: IAAP
Accident: S
Pu Released: 0.625 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3) Unfavorable Meteorology	Median Meteorology
1.0	---	1.30×10^4
2.0	5.09×10^3	3.55×10^3
4.0	1.39×10^3	9.90×10^2
8.0	3.30×10^2	2.26×10^2
16.0	---	4.00×10^1
20.0	3.15×10^1	---
25.0	1.71×10^1	1.20×10^1
32.0	8.61×10^0	6.06×10^0
36.0	6.18×10^0	---
50.0	2.43×10^0	1.72×10^0
64.0	1.19×10^0	8.45×10^{-1}
80.0	6.25×10^{-1}	4.43×10^{-1}

TABLE A-XV

GROUND-LEVEL PLUTONIUM INTEGRATED AIR CONCENTRATIONS (TOTAL AEROSOL)

Location: Hanford Site
Accident: T
Pu Released: 0.625 kg
Wind Direction: NW Unfavorable Meteorology
NW Median Meteorology

Distance (km)	Concentrations (μg-s/m^3) Unfavorable Meteorology	Concentrations (μg-s/m^3) Median Meteorology
1.0	1.14×10^4	2.75×10^4
2.0	---	---
4.0	6.34×10^3	1.68×10^3
8.0	---	---
16.0	4.29×10^2	1.08×10^2
25.0	1.16×10^2	3.98×10^1
32.0	8.08×10^1	2.17×10^1
42.0	3.96×10^1	1.08×10^1
50.0	2.48×10^1	6.81×10^0
60.0	1.51×10^1	4.18×10^0
64.0	---	---
80.0	---	---

TABLE A-XVI

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: I
Pu Released: 120 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition (μg/m^2) Unfavorable Meteorology	Ground Deposition (μg/m^2) Median Meteorology
1.0	---	9.78×10^3
2.0	---	8.99×10^3
4.0	1.37×10^4	5.61×10^3
8.0	2.34×10^3	2.89×10^3
16.0	9.82×10^2	8.56×10^2
20.0	6.79×10^2	---
25.0	4.08×10^2	3.20×10^2
32.0	2.08×10^2	1.77×10^2
36.0	1.49×10^2	---
50.0	6.09×10^1	5.65×10^1
64.0	3.18×10^1	2.93×10^1
80.0	1.78×10^1	1.60×10^1

TABLE A-XVII

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: B
Pu Released: 100 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Median Meteorology
1.0	---	7.78×10^3
2.0	---	9.58×10^3
4.0	3.72×10^3	1.88×10^3
8.0	2.91×10^3	1.68×10^3
16.0	8.77×10^2	8.92×10^2
20.0	7.19×10^2	---
25.0	5.07×10^2	3.77×10^2
32.0	2.64×10^2	2.14×10^2
36.0	1.91×10^2	---
50.0	8.24×10^1	7.04×10^1
64.0	4.53×10^1	3.69×10^1
80.0	2.63×10^1	2.03×10^1

TABLE A-XVIII

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: A
Pu Released: 50 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Median Meteorology
1.0	---	4.31×10^2
2.0	---	9.93×10^2
4.0	2.70×10^3	1.41×10^3
8.0	1.56×10^3	1.16×10^3
16.0	4.84×10^2	4.41×10^2
20.0	3.23×10^2	---
25.0	1.83×10^2	1.68×10^2
32.0	9.13×10^1	9.20×10^1
36.0	6.70×10^1	---
50.0	3.00×10^1	2.91×10^1
64.0	1.66×10^1	1.51×10^1
80.0	9.57×10^0	8.20×10^0

TABLE A-XIX

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: H
Pu Released: 30 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0	---	1.92×10^3
2.0	---	1.20×10^3
4.0	2.07×10^3	6.78×10^2
8.0	1.33×10^3	4.59×10^2
16.0	1.11×10^2	2.21×10^2
20.0	1.16×10^2	---
25.0	1.11×10^2	9.90×10^1
32.0	8.35×10^1	5.87×10^1
36.0	6.53×10^1	---
50.0	2.82×10^1	2.06×10^1
64.0	1.49×10^1	1.11×10^1
80.0	8.26×10^0	6.23×10^0

TABLE A-XX

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: C
Pu Released: 100 kg
Wind Direction: N/A* Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0		---
2.0		4.14×10^2
4.0	Not applicable for this accident	1.18×10^3
8.0		1.11×10^3
16.0		7.74×10^2
25.0		3.65×10^2
32.0		2.14×10^2
50.0		7.26×10^1
64.0		3.85×10^1
80.0		2.13×10^1

---

*N/A not applicable.

TABLE A-XXI

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: D
Pu Released: 25 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$)	
	Unfavorable Meteorology	Median Meteorology
1.0	---	2.31×10^2
2.0	---	7.57×10^2
4.0	1.67×10^3	8.69×10^2
8.0	7.13×10^2	6.80×10^2
16.0	2.57×10^2	2.32×10^2
20.0	1.35×10^2	---
25.0	7.04×10^1	8.30×10^1
32.0	3.77×10^1	4.47×10^1
36.0	2.86×10^1	---
50.0	1.32×10^1	1.38×10^1
64.0	7.20×10^0	7.09×10^0
80.0	4.09×10^0	3.84×10^0

TABLE A-XXII

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accidents: E, F
Pu Released: 12 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$)	
	Unfavorable Meteorology	Median Meteorology
1.0	---	1.24×10^2
2.0	---	5.47×10^2
4.0	1.14×10^3	5.04×10^2
8.0	3.48×10^2	3.69×10^2
16.0	1.12×10^2	1.04×10^2
20.0	5.65×10^1	---
25.0	3.10×10^1	3.59×10^1
32.0	1.73×10^1	1.91×10^1
36.0	1.32×10^1	---
50.0	6.04×10^0	5.86×10^0
64.0	3.27×10^0	2.99×10^0
80.0	1.85×10^0	1.61×10^0

TABLE A-XXIII

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: K
Pu Released: 0.625 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0	---	9.94×10^{2}
2.0	---	2.75×10^{2}
4.0	9.31×10^{1}	7.68×10^{1}
8.0	1.25×10^{1}	1.59×10^{1}
16.0	2.85×10^{0}	2.62×10^{0}
20.0	1.65×10^{0}	---
25.0	9.39×10^{-1}	7.69×10^{-1}
32.0	4.92×10^{-1}	3.85×10^{-1}
36.0	3.60×10^{-1}	---
50.0	1.48×10^{-1}	1.08×10^{-1}
64.0	7.47×10^{-2}	5.28×10^{-2}
80.0	4.00×10^{-2}	2.76×10^{-2}

TABLE A-XXIV

PLUTONIUM GROUND DEPOSITION

Location: Pantex Plant
Accident: J
Pu Released: 0.056 kg
Wind Direction: ENE Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0	---	1.77×10^{2}
2.0	---	5.22×10^{1}
4.0	9.27×10^{0}	1.01×10^{1}
8.0	1.79×10^{0}	1.61×10^{0}
16.0	4.00×10^{-1}	2.34×10^{-1}
25.0	1.27×10^{-1}	6.21×10^{-2}
32.0	6.52×10^{-2}	3.18×10^{-2}
50.0	1.89×10^{-2}	8.62×10^{-3}
64.0	9.43×10^{-3}	4.17×10^{-3}
80.0	4.99×10^{-3}	2.15×10^{-3}

TABLE A-XXV

PLUTONIUM GROUND DEPOSITION

Location: IAAP
Accident: R
Pu Released: 120 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

	Ground Deposition ($\mu g/m^2$)	
Distance (km)	Unfavorable Meteorology	Median Meteorology
1.0	5.22×10^4	2.16×10^4
2.0	---	1.64×10^4
4.0	7.50×10^3	9.76×10^3
8.0	3.45×10^3	2.56×10^3
10.0	2.43×10^3	---
12.0	1.68×10^3	---
16.0	8.51×10^2	8.22×10^2
20.0	4.85×10^2	---
25.0	2.72×10^2	3.09×10^2
32.0	1.42×10^2	1.69×10^2
50.0	4.29×10^1	5.32×10^1
64.0	---	2.74×10^1
80.0	---	1.49×10^1

TABLE A-XXVI

PLUTONIUM GROUND DEPOSITION

Location: IAAP
Accident: Q
Pu Released: 30 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

	Ground Deposition ($\mu g/m^2$)	
Distance (km)	Unfavorable Meteorology	Median Meteorology
1.0	8.48×10^3	2.89×10^3
2.0	---	---
4.0	3.14×10^3	1.26×10^3
8.0	5.07×10^2	7.26×10^2
10.0	4.61×10^2	4.62×10^2
12.0	3.87×10^2	3.19×10^2
16.0	2.63×10^2	2.02×10^2
20.0	1.96×10^2	1.14×10^2
25.0	1.02×10^2	9.34×10^1
32.0	5.53×10^1	5.57×10^1
50.0	1.74×10^1	1.95×10^1
64.0	---	---
80.0	---	---

TABLE A-XXVII

PLUTONIUM GROUND DEPOSITION

Location: IAAP
Accident: P
Pu Released: 25 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$)	
	Unfavorable Meteorology	Median Meteorology
1.0	5.76×10^3	8.44×10^2
2.0	---	2.29×10^3
4.0	2.86×10^3	1.75×10^3
8.0	1.02×10^3	8.87×10^2
10.0	6.08×10^2	---
12.0	3.89×10^2	---
16.0	1.90×10^2	2.19×10^2
20.0	1.08×10^2	---
25.0	6.11×10^1	7.44×10^1
32.0	3.21×10^1	3.94×10^1
50.0	9.73×10^0	1.20×10^1
64.0	---	6.12×10^0
80.0	---	3.30×10^0

TABLE A-XXVIII

PLUTONIUM GROUND DEPOSITION

Location: IAAP
Accident: L
Pu Released: 12 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$)	
	Unfavorable Meteorology	Median Meteorology
1.0	3.43×10^3	6.61×10^2
2.0	---	1.28×10^3
4.0	1.45×10^3	1.01×10^3
8.0	4.64×10^2	4.37×10^2
10.0	2.76×10^2	---
12.0	1.77×10^2	---
16.0	8.67×10^1	1.03×10^2
20.0	4.95×10^1	---
25.0	2.80×10^1	3.37×10^1
32.0	1.48×10^1	1.76×10^1
50.0	4.49×10^0	5.29×10^0
64.0	---	2.68×10^0
80.0	---	1.44×10^0

TABLE A-XXIX

PLUTONIUM GROUND DEPOSITION

Location: IAAP
Accident: S
Pu Released: 0.625 kg
Wind Direction: W Unfavorable Meteorology
SSW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0	---	1.02×10^{3}
2.0	3.36×10^{2}	2.93×10^{2}
4.0	6.12×10^{1}	7.60×10^{1}
8.0	1.17×10^{1}	1.44×10^{1}
16.0	---	2.29×10^{0}
20.0	1.02×10^{0}	---
25.0	5.49×10^{-1}	6.69×10^{-1}
32.0	2.74×10^{-1}	3.34×10^{-1}
36.0	1.96×10^{-1}	---
50.0	7.63×10^{-2}	9.33×10^{-2}
64.0	3.73×10^{-2}	4.57×10^{-2}
80.0	1.95×10^{-2}	2.38×10^{-2}

TABLE A-XXX

PLUTONIUM GROUND DEPOSITION

Location: Hanford Site
Accident: T
Pu Released: 0.625 kg
Wind Direction: NW Unfavorable Meteorology
NW Median Meteorology

Distance (km)	Ground Deposition ($\mu g/m^2$) Unfavorable Meteorology	Ground Deposition ($\mu g/m^2$) Median Meteorology
1.0	---	1.00×10^{3}
2.0	---	---
4.0	---	1.12×10^{2}
8.0	---	---
16.0	---	3.61×10^{0}
25.0	---	1.20×10^{0}
32.0	2.81×10^{-1}	6.33×10^{-1}
42.0	1.34×10^{-1}	3.07×10^{-1}
50.0	8.30×10^{-2}	1.91×10^{-1}
60.0	4.99×10^{-2}	1.16×10^{-1}
64.0	---	---
80.0	---	---

APPENDIX B

STABILITY - WIND ROSE (STAR) DATA

Amarillo	1955-1964
Burlington	1967-1971
Hanford	1973-1975

AMARILLD 1955-1964

STABILITY A

WIND SPEED. KNDTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TDTAL
N	.01	.02	0.00	0.00	0.00	0.00	.03
NNE	.01	.02	0.00	0.00	0.00	0.00	.03
NE	.02	.02	0.00	0.00	0.00	0.00	.04
ENE	.01	.02	0.00	0.00	0.00	0.00	.02
E	.01	.02	0.00	0.00	0.00	0.00	.03
ESE	.00	.01	0.00	0.00	0.00	0.00	.01
SE	.01	.02	0.00	0.00	0.00	0.00	.03
SSE	.01	.01	0.00	0.00	0.00	0.00	.03
S	.01	.03	0.00	0.00	0.00	0.00	.04
SSW	.02	.03	0.00	0.00	0.00	0.00	.05
SW	.02	.03	0.00	0.00	0.00	0.00	.05
WSW	.02	.03	0.00	0.00	0.00	0.00	.04
W	.01	.01	0.00	0.00	0.00	0.00	.02
WNW	.01	.02	0.00	0.00	0.00	0.00	.03
NW	.01	.02	0.00	0.00	0.00	0.00	.04
NNW	.01	.02	0.00	0.00	0.00	0.00	.02
TDTAL	.19	.32	0.00	0.00	0.00	0.00	.51

AMARILLD 1955-1964

STABILITY B

WIND SPEED. KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.03	.08	.06	0.00	0.00	0.00	.17
NNE	.02	.07	.05	0.00	0.00	0.00	.13
NE	.03	.07	.05	0.00	0.00	0.00	.14
ENE	.02	.04	.05	0.00	0.00	0.00	.11
E	.03	.06	.06	0.00	0.00	0.00	.14
ESE	.03	.06	.05	0.00	0.00	0.00	.14
SE	.03	.09	.06	0.00	0.00	0.00	.19
SSE	.03	.07	.07	0.00	0.00	0.00	.17
S	.05	.13	.11	0.00	0.00	0.00	.28
SSW	.03	.10	.15	0.00	0.00	0.00	.27
SW	.06	.15	.22	0.00	0.00	0.00	.43
WSW	.03	.11	.09	0.00	0.00	0.00	.23
W	.04	.10	.07	0.00	0.00	0.00	.21
WNW	.04	.10	.07	0.00	0.00	0.00	.20
NW	.06	.10	.06	0.00	0.00	0.00	.22
NNW	.03	.06	.05	0.00	0.00	0.00	.14
TOTAL	.55	1.35	1.28	0.00	0.00	0.00	3.18

AMARILLO 1955-1964

STABILITY C

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.02	.09	.26	.05	.02	.00	.43
NNE	.01	.05	.24	.09	.03	.01	.41
NE	.01	.05	.20	.06	.00	.00	.32
ENE	.01	.06	.16	.04	.00	0.00	.28
E	.01	.06	.15	.03	.00	0.00	.25
ESE	.02	.05	.15	.04	.01	0.00	.27
SE	.01	.07	.20	.06	.02	.00	.36
SSE	.01	.06	.28	.12	.04	.01	.52
S	.01	.12	.49	.33	.14	.03	1.13
SSW	.01	.12	.65	.48	.20	.03	1.48
SW	.02	.17	.78	.39	.12	.03	1.51
WSW	.02	.10	.43	.22	.07	.04	.87
W	.02	.10	.28	.07	.03	.02	.52
WNW	.03	.15	.37	.05	.01	.01	.61
NW	.02	.15	.30	.04	.00	.00	.51
NNW	.01	.08	.25	.04	.01	.01	.40
TOTAL	.24	1.48	5.17	2.10	.68	.19	9.86

AMARILLO 1955-1964

STABILITY D

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.04	.18	.75	1.85	1.00	.64	4.45
NNE	.03	.16	.81	1.83	1.03	.55	4.41
NE	.03	.18	.64	1.04	.39	.14	2.41
ENE	.01	.12	.51	.71	.18	.04	1.56
E	.03	.13	.57	.77	.14	.03	1.67
ESE	.02	.12	.61	.91	.21	.06	1.93
SE	.02	.15	1.03	2.06	.62	.14	4.02
SSE	.02	.13	1.15	3.31	1.01	.26	5.87
S	.03	.13	1.34	4.89	1.83	.48	8.70
SSW	.02	.14	1.24	4.60	1.66	.42	8.08
SW	.03	.16	1.27	4.40	1.30	.32	7.47
WSW	.02	.10	.57	2.13	.95	.45	4.22
W	.02	.07	.36	1.00	.61	.40	2.46
WNW	.02	.10	.39	.89	.27	.13	1.79
NW	.02	.13	.48	.94	.21	.11	1.89
NNW	.04	.13	.45	.91	.45	.36	2.33
TOTAL	.38	2.12	12.15	32.24	11.85	4.53	63.26

AMARILLD 1955·1964

STABILITY E

WIND SPEED. KNOTS

DIR	0·3	4·6	7·10	11-16	17·22	22+	TDTAL
N	0.00	.17	.48	0.00	0.00	0.00	.65
NNE	0.00	.14	.35	0.00	0.00	0.00	.49
NE	0.00	.12	.28	0.00	0.00	0.00	.41
ENE	0.00	.10	.24	0.00	0.00	0.00	.35
E	0.00	.10	.38	0.00	0.00	0.00	.48
ESE	0.00	.11	.40	0.00	0.00	0.00	.50
SE	0.00	.17	.97	0.00	0.00	0.00	1.14
SSE	0.00	.17	1.49	0.00	0.00	0.00	1.66
S	0.00	.22	2.01	0.00	0.00	0.00	2.23
SSW	0.00	.20	2.01	0.00	0.00	0.00	2.21
SW	0.00	.19	2.11	0.00	0.00	0.00	2.30
WSW	0.00	.12	.92	0.00	0.00	0.00	1.04
W	0.00	.11	.54	0.00	0.00	0.00	.65
WNW	0.00	.11	.65	0.00	0.00	0.00	.77
NW	0.00	.14	.66	0.00	0.00	0.00	.80
NNW	0.00	.10	.44	0.00	0.00	0.00	.54
TDTAL	0.00	2.27	13.93	0.00	0.00	0.00	16.19

AMARILLD 1955·1964

STABILITY F

WIND SPEED. KNDTS

DIR	0-3	4-6	7-10	11·16	17·22	22+	TDTAL
N	.11	.28	0.00	0.00	0.00	0.00	.39
NNE	.10	.21	0.00	0.00	0.00	0.00	.30
NE	.08	.21	0.00	0.00	0.00	0.00	.29
ENE	.06	.16	0.00	0.00	0.00	0.00	.22
E	.07	.16	0.00	0.00	0.00	0.00	.23
ESE	.07	.17	0.00	0.00	0.00	0.00	.24
SE	.08	.24	0.00	0.00	0.00	0.00	.32
SSE	.07	.27	0.00	0.00	0.00	0.00	.33
S	.15	.44	0.00	0.00	0.00	0.00	.59
SSW	.13	.50	0.00	0.00	0.00	0.00	.63
SW	.17	.61	0.00	0.00	0.00	0.00	.78
WSW	.13	.43	0.00	0.00	0.00	0.00	.55
W	.13	.44	0.00	0.00	0.00	0.00	.58
WNW	.13	.41	0.00	0.00	0.00	0.00	.53
NW	.15	.46	0.00	0.00	0.00	0.00	.61
NNW	.10	.28	0.00	0.00	0.00	0.00	.38
TDTAL	1.72	5.27	0.00	0.00	0.00	0.00	6.99

BURLINGTDN 1967-1971

STABILITY A

WIND SPEED. KNDTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TDTAL
N	.01	.01	0.00	0.00	0.00	0.00	.02
NNE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NE	.00	.01	0.00	0.00	0.00	0.00	.01
ENE	.01	.01	0.00	0.00	0.00	0.00	.02
E	.02	.05	0.00	0.00	0.00	0.00	.07
ESE	.01	.01	0.00	0.00	0.00	0.00	.02
SE	.01	.02	0.00	0.00	0.00	0.00	.03
SSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S	.01	.02	0.00	0.00	0.00	0.00	.03
SSW	.01	.01	0.00	0.00	0.00	0.00	.02
SW	.01	.01	0.00	0.00	0.00	0.00	.02
WSW	.02	.03	0.00	0.00	0.00	0.00	.05
W	.01	.02	0.00	0.00	0.00	0.00	.03
WNW	.02	.01	0.00	0.00	0.00	0.00	.03
NW	.01	.02	0.00	0.00	0.00	0.00	.03
NNW	.01	.01	0.00	0.00	0.00	0.00	.02
TDTAL	.14	.26	0.00	0.00	0.00	0.00	.40

BURLINGTDN 1967-1971

STABILITY B

WIND SPEED, KNDTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TDTAL
N	.04	.14	.08	0.00	0.00	0.00	.25
NNE	.02	.09	.06	0.00	0.00	0.00	.17
NE	.04	.19	.09	0.00	0.00	0.00	.31
ENE	.00	.04	.06	0.00	0.00	0.00	.10
E	.01	.07	.08	0.00	0.00	0.00	.16
ESE	.04	.14	.07	0.00	0.00	0.00	.25
SE	.02	.18	.06	0.00	0.00	0.00	.26
SSE	.03	.08	.10	0.00	0.00	0.00	.21
S	.05	.29	.18	0.00	0.00	0.00	.52
SSW	.02	.12	.05	0.00	0.00	0.00	.18
SW	.06	.11	.09	0.00	0.00	0.00	.26
WSW	.02	.10	.08	0.00	0.00	0.00	.20
W	.03	.15	.06	0.00	0.00	0.00	.24
WNW	.01	.14	.03	0.00	0.00	0.00	.18
NW	.01	.09	.08	0.00	0.00	0.00	.18
NNW	.01	.06	.01	0.00	0.00	0.00	.08
TDTAL	.41	1.98	1.16	0.00	0.00	0.00	3.54

BURLINGTON 1967-1971

STABILITY C

WIND SPEED. KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.05	.08	.32	.08	.01	0.00	.53
NNE	.01	.05	.21	.02	0.00	0.00	.29
NE	.03	.09	.31	.01	0.00	0.00	.44
ENE	.01	.07	.23	.02	0.00	0.00	.34
E	.03	.09	.25	.01	0.00	0.00	.38
ESE	.07	.13	.24	.03	0.00	0.00	.48
SE	.04	.12	.32	.01	.01	0.00	.48
SSE	.01	.05	.23	.03	0.00	0.00	.32
S	.05	.24	1.03	.32	.01	0.00	1.66
SSW	.06	.12	.62	.20	.01	0.00	1.02
SW	.04	.07	.46	.23	.01	0.00	.81
WSW	.01	.04	.34	.10	0.00	0.00	.49
W	.04	.10	.43	.10	.01	0.00	.68
WNW	.04	.12	.47	.06	0.00	0.00	.68
NW	.03	.10	.36	.03	.03	0.00	.56
NNW	.04	.10	.16	.06	.01	0.00	.37
TOTAL	.55	1.56	5.98	1.31	.10	0.00	9.50

BURLINGTON 1967-1971

STABILITY D

WIND SPEED. KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.07	.45	1.67	2.16	.40	.02	4.77
NNE	.05	.36	.76	.64	.05	.01	1.86
NE	.07	.47	.98	.51	.02	.01	2.05
ENE	.04	.34	1.07	.47	.03	.01	1.95
E	.06	.62	1.57	.73	.02	0.00	3.00
ESE	.05	.42	1.72	.84	.08	.01	3.11
SE	.06	.50	1.43	.78	.08	0.00	2.85
SSE	.05	.36	1.23	.86	.08	0.00	2.59
S	.12	.92	3.68	4.33	.43	.02	9.49
SSW	.04	.55	1.56	2.04	.36	.04	4.59
SW	.04	.35	1.01	1.35	.25	.03	3.02
WSW	.04	.32	.76	.69	.14	.01	1.97
W	.06	.34	1.01	1.16	.40	.08	3.05
WNW	.07	.49	1.40	2.48	.71	.12	5.27
NW	.04	.36	1.51	2.93	1.02	.12	5.98
NNW	.04	.28	.92	1.77	.50	.07	3.59
TOTAL	.90	7.12	22.26	23.73	4.57	.55	59.13

BURLINGTON 1967·1971

STABILITY E

WIND SPEED. KNOTS

DIR	0-3	4-6	7·10	11-16	17·22	22+	TOTAL
N	.29	.88	.83	0.00	0.00	0.00	2.00
NNE	.13	.35	.20	0.00	0.00	0.00	.68
NE	.24	.66	.19	0.00	0.00	0.00	1.09
ENE	.15	.47	.19	0.00	0.00	0.00	.81
E	.28	.82	.36	0.00	0.00	0.00	1.46
ESE	.28	.92	.43	0.00	0.00	0.00	1.63
SE	.22	.84	.28	0.00	0.00	0.00	1.34
SSE	.24	.86	.27	0.00	0.00	0.00	1.37
S	.59	2.02	1.88	0.00	0.00	0.00	4.50
SSW	.27	.86	.98	0.00	0.00	0.00	2.11
SW	.17	.60	.48	0.00	0.00	0.00	1.25
WSW	.16	.63	.37	0.00	0.00	0.00	1.16
W	.28	.98	.50	0.00	0.00	0.00	1.76
WNW	.38	.93	.97	0.00	0.00	0.00	2.27
NW	.36	1.25	.88	0.00	0.00	0.00	2.50
NNW	.22	.85	.46	0.00	0.00	0.00	1.53
TOTAL	4.25	13.93	9.26	0.00	0.00	0.00	27.44

HANFORD 1973-1975

STABILITY B

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.55	1.16	.34	.06	.03	0.00	2.14
NNE	.79	1.12	.46	.16	.01	0.00	2.54
NE	.74	.78	.18	.06	0.00	0.00	1.76
ENE	.33	.53	.08	0.00	0.00	0.00	.94
E	.28	.54	.09	0.00	0.00	0.00	.91
ESE	.44	.60	.06	0.00	0.00	0.00	1.10
SE	.39	.66	.08	0.00	0.00	0.00	1.13
SSE	.17	.34	.08	.03	0.00	0.00	.62
S	.20	.35	.08	.02	0.00	0.00	.65
SSW	.15	.50	.27	.15	.06	.02	1.15
SW	.15	.52	.50	.48	.32	.17	2.14
WSW	.21	.48	.76	.67	.29	.08	2.49
W	.18	.43	.30	.25	.05	.01	1.22
WNW	.15	.65	.75	.64	.32	.11	2.62
NW	.30	1.25	1.33	.80	.57	.21	4.46
NNW	.39	1.33	.42	.07	.01	.01	2.23
TOTAL	5.42	11.24	5.78	3.39	1.66	.61	28.10

HANFORD 1973-1975

STABILITY D

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.54	.39	.14	.06	.01	0.00	1.14
NNE	.55	.28	.16	.04	.01	0.00	1.04
NE	.54	.21	.05	.05	.02	0.00	.87
ENE	.41	.16	.03	.01	0.00	0.00	.61
E	.42	.20	.04	0.00	0.00	0.00	.66
ESE	.36	.34	.08	.01	0.00	0.00	.79
SE	.48	.28	.10	.01	0.00	0.00	.87
SSE	.27	.17	.11	.04	0.00	0.00	.59
S	.25	.20	.09	.08	.05	.01	.68
SSW	.20	.21	.27	.30	.17	.11	1.26
SW	.27	.25	.32	.60	.35	.13	1.92
WSW	.24	.30	.53	.52	.17	.06	1.82
W	.25	.45	.65	.38	.05	.01	1.79
WNW	.33	.81	1.23	1.33	.62	.08	4.40
NW	.41	.96	1.02	.86	.65	.11	4.01
NNW	.50	.63	.32	.09	.02	0.00	1.56
TOTAL	6.02	5.84	5.14	4.38	2.12	.51	24.01

HANFORD 1973-1975

STABILITY MS

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.79	.36	.11	.01	.01	0.00	1.28
NNE	.33	.24	.07	.01	0.00	0.00	.65
NE	.27	.26	.02	.01	.02	0.00	.58
ENE	.32	.20	.03	0.00	0.00	0.00	.55
E	.30	.26	.06	0.00	0.00	0.00	.62
ESE	.36	.44	.11	0.00	0.00	0.00	.91
SE	.72	.68	.21	.03	.01	0.00	1.65
SSE	.45	.62	.39	.04	.03	.01	1.54
S	.54	.63	.25	.11	.04	0.00	1.57
SSW	.44	.56	.28	.17	.11	.06	1.62
SW	.59	.90	.62	.43	.19	.09	2.82
WSW	.54	1.70	1.74	.65	.09	.02	4.74
W	.67	2.48	2.48	.34	.02	0.00	5.99
WNW	.68	2.45	4.06	1.42	.25	.02	8.88
NW	.77	2.29	2.50	.93	.14	0.00	6.63
NNW	.63	.93	.46	.04	0.00	0.00	2.06
TOTAL	8.40	15.00	13.39	4.19	.91	.20	42.09

HANFORD 1973-1975

STABILITY VS

WIND SPEED, KNOTS

DIR	0-3	4-6	7-10	11-16	17-22	22+	TOTAL
N	.08	.04	0.00	0.00	0.00	0.00	.12
NNE	.07	.04	0.00	0.00	0.00	0.00	.11
NE	.05	.03	0.00	0.00	0.00	0.00	.08
ENE	.06	.01	0.00	0.00	0.00	0.00	.07
E	.06	.02	0.00	0.00	0.00	0.00	.08
ESE	.07	.02	0.00	0.00	0.00	0.00	.09
SE	.11	.14	.02	0.00	0.00	0.00	.27
SSE	.07	.15	.03	0.00	0.00	0.00	.25
S	.11	.10	.01	0.00	0.00	0.00	.22
SSW	.08	.17	.02	0.00	0.00	0.00	.27
SW	.08	.18	.05	0.00	0.00	0.00	.31
WSW	.07	.26	.39	.01	0.00	0.00	.73
W	.10	.47	.21	0.00	0.00	0.00	.78
WNW	.09	.44	.78	.01	0.00	0.00	1.32
NW	.14	.39	.43	0.00	0.00	0.00	.96
NNW	.10	.15	.01	0.00	0.00	0.00	.26
TOTAL	1.34	2.61	1.95	.02	0.00	0.00	5.92

APPENDIX C

DIFOUT MODEL VERIFICATION STUDY

I. INTRODUCTION

DIFOUT (Luna 1969) was designed to simulate the dispersion of a cloud of particulate material, as opposed to other dispersion models that treat all dispersed material as gas. The accidental releases postulated here deal strictly with a particle cloud in which fission products are negligible. Since many particles produced in the accident would be quite large (up to 1000 μm), they would fall out near the source. For example a 500-μm particle thrown 300 m into the air would reach the ground in only 150 s. If a 5 m/s wind were blowing at the time, the particle would be carried only 750 m downwind from its starting point. Since weapons operations (excluding transportation) are conducted at locations well inside the site fence, this particle would fall onsite. The ultimate use of this analysis is investigation of offsite consequences of airborne plutonium inhaled by the population or plutonium deposited on soil and buildings; therefore, it is important to use a realistic model that accounts for both fallout of larger particles and dispersion of particles small enough to be inhaled.

Usefulness of the DIFOUT model depended on its ability to predict airborne concentrations and disposition with reasonable accuracy over the desired range. The best way to verify its ability to calculate these values was to prepare input from experimental data obtained in the four Project Roller Coaster tests and compare the calculated results with the experimental results. The success or shortcomings detected in these comparisons allowed determination of applicability of the model to each postulated accident (that is, virtually unrestricted release versus partial restriction by earth bunkering).

II. ROLLER COASTER SUMMARY

The Roller Coaster test series was conducted over the period May 15 to June 9, 1963 (Shreve 1965). Table C-I summarizes the major features of these tests. The four tests were entitled Double Tracks, Clean Slate 1, Clean Slate 2, and Clean Slate 3. Double Tracks and Clean Slate 1 were unbunkered tests performed on open pads. Although there was some uptake of soil with these tests, fallout was not enhanced to the extent observed in the bunkered tests, Clean Slate 2 and 3. Each test was conducted to simulate a storage or transport detonation accident. One plutonium-containing device was included in each array to permit radiometric tracing of the dispersed material. When more than one device was used, the additional assemblies were identical in configuration and HE amounts but with the plutonium replaced with depleted

TABLE C-I

SUMMARY OF ROLLER COASTER TEST FEATURES

Test	Placement	Approximate Cloud Height (m)	High Explosive Amount (lb)	Mean Wind Speed (m/s)
Double Tracks	8-ft by 8-ft steel plate	220	118	8
Clean Slate 1	20-ft by 20-ft concrete pad	710	1062	7
Clean Slate 2	Storage bunker 2-ft roof	440	2242	4
Clean Slate 3	Storage bunker 8-ft roof	520	2242	2.5

uranium. Therefore, clouds produced were of representative height without spreading unnecessary quantities of plutonium. It should be noted, however, that the activity-height distribution may be significantly affected by the use of one plutonium-bearing device in a multidevice array.

The early morning (predawn) hours were selected to yield more predictable wind direction, air turbulence, and wind speed. Downwind instrument arrays, including air samplers supported by a balloon curtain, obtained airborne particle concentrations in terms of time-integrated dosage ($\mu g\text{-}s/m^3$). Dosages in this form allow calculation of plutonium mass taken in by a person or animal breathing at a specific rate.

The Roller Coaster tests were reasonably well instrumented to provide (1) the meteorological conditions existing at the time of the test, (2) the aerosol concentrations at points of interest downrange, (3) the deposited activity at points of interest downrange, (4) the particle size distribution of the aerosol at various heights, and (5) the cloud shape and activity distribution in the cloud. This supporting information, input into the DIFOUT model, allowed calculation of time-integrated aerosol concentration (or airborne dosage in $\mu g\text{-}s/m^3$) and deposition ($\mu g/m^2$) at desired distances downwind. Cases where agreement was best between experimental (measured) results and calculated results provided a basis for choosing appropriate input for the accident case calculations. No other source of verification of DIFOUT was available.

Applicability of Roller Coaster input data was enhanced by the experimenter's choice of early morning to perform the tests at a time when meteorological conditions would be neutral or stable (D, E, or F stability class by Pasquill category) (Slade 1968). These same stability categories were chosen as representative of the median and unfavorable dispersion conditions under which all of the accident cases were analyzed.

The most noteworthy findings of the Roller Coaster tests were the following.

(1) Increasing the amount of HE reduces the radiological hazards by increasing the cloud height.

(2) Plutonium particle size distribution indicated that the respirable fraction (fraction of total aerosol mass associated with particles less than 10-μm D_{ae}) was approximately 0.20 for plutonium.

(3) The activity median aerodynamic diameter of the respirable fraction appeared to be approximately 5 μm. Geometric standard deviation was approximately 2.5.

(4) Most of the plutonium mass in the weapon-like assembly was aerosolized.

(5) Soil overburden provided both a cloud height suppression and scavenging of plutonium particles, causing particles to deposit nearer to the detonation site than for the unbunkered shots. Overburden 2 ft thick was almost as effective as overburden 8 ft thick, partially because a major portion of the material vented through the door.

III. UNBUNKERED DETONATIONS

The unbunkered shots from Roller Coaster (Double Tracks and Clean Slate 1) offered experimental data for use in verification of the DIFOUT model as applied to postulated accidents in unbunkered locations. The cloud heights covered the range of interest (220 m for Double Tracks and 710 m for Clean Slate 1). Although the actual plutonium amounts involved in the tests remain classified, normalized airborne and deposited plutonium dosages have been presented as dosage per kilogram dispersed under measured conditions. From these normalized dosages, scaling to higher plutonium amounts in the postulated accident cases can be done with reasonable accuracy if (1) the DIFOUT model can be shown to approximate the Roller Coaster experimental results and (2) the dispersion conditions of the accident cases are close enough to the Roller Coaster conditions to be considered applicable. The analyses described briefly in the next two sections were performed to determine whether the DIFOUT model using either Double Tracks or Clean Slate dispersion conditions would adequately describe dispersion and deposition for the postulated accidents occurring in unbunkered locations.

A. Double Tracks

In this analysis and in Clean Slate 1 and 2 analyses, the cloud was divided into 10 horizontal layers of equal thickness. Each layer was assigned an activity concentration fraction, diameter, particle size distribution, and meteorological parameters, all obtained from Roller Coaster data.

1. Cloud Description. The Double Tracks test produced a cloud 220 m high, the lowest of the Roller Coaster series. The general outline of the cloud after growth from thermal buoyancy had ceased is shown in Fig. C-1 (Beasley 1965). This outline derived from photographic reproduction permitted scaling of the cloud diameters with height (see Table V for cloud diameters).

2. Meteorological Conditions. The meteorological conditions existing during the test were summarized completely in a classified report (Stewart 1969) and partially in an unclassified report (Church 1969). The parameters of interest were wind speed, wind direction, vertical turbulence intensity, and horizontal turbulence intensity at several elevations up to ultimate

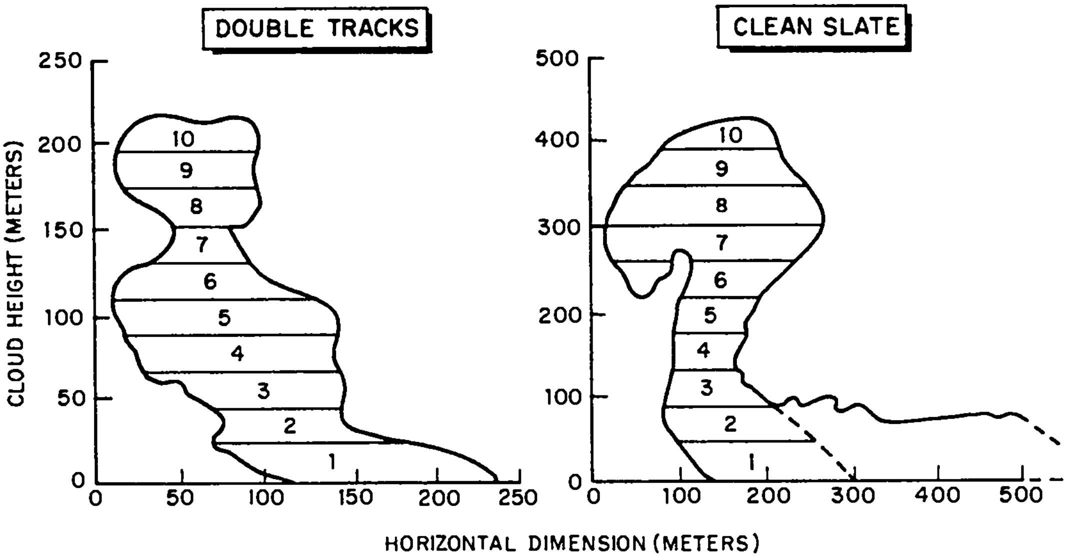

Fig. C-1. Outline of debris cloud (Double Tracks at 105 s after detonation; Clean Slate 2, 120 s).

TABLE C-II

DOUBLE TRACKS METEOROLOGICAL PARAMETERS

Height (m)	Wind Direction (degrees E of N)	Wind Speed (m/s)	Vertical Turbulence Intensity	Horizontal Turbulence Intensity
2	350	5.2	0.038	0.079
20	370	5.6	0.038	0.079
50	350	6.4	0.038	0.079
100	345	7.0	0.038	0.079
200	340	7.8	0.038	0.079

cloud height and measured near enough to the cloud path to be representative. Table C-II lists the meteorological parameters used in modeling Double Tracks. Horizontal and vertical turbulence intensities are measures of the crosswind and vertical fluctuations of the wind, respectively.

3. Activity Fraction with Height. Relatively minor amounts of plutonium were detected in the bottom two or three layers of the cloud, that is, in the stem up to 0.2 to 0.3 of the cloud height. Figure C-2 shows cumulative fractions of total plutonium activity versus fraction of cloud height from the Double Tracks test. This relationship is considered applicable to low-to-intermediate cloud heights (say 150 to 450 m) from unbunkered locations. The actual activity fractions used in the Double Tracks analysis are listed in Table VII in the body of this report.

4. Aerosol Size Distribution. Size distributions of plutonium-bearing particles produced in Roller Coaster tests were treated in detail in an unclassified report (Friend 1965); variability in air sampler data was treated in greater detail by Luna (1971).

The particle size distribution in a newly formed cloud is subject to change with time as (1) larger particles settle out and (2) agglomeration depletes the cloud of smaller particles. With the passage of time, a more physically stable aerosol forms as most of the large particles have settled out and dispersion of the cloud has reduced particle concentration to the point where agglomeration becomes negligible. If aerosol size measurements were made after that time interval, they would be representative of the stabilized cloud. These would be of interest in determining airborne dosages offsite but would not necessarily provide representative deposition amounts near the detonation site. The Roller Coaster particle size measurements were

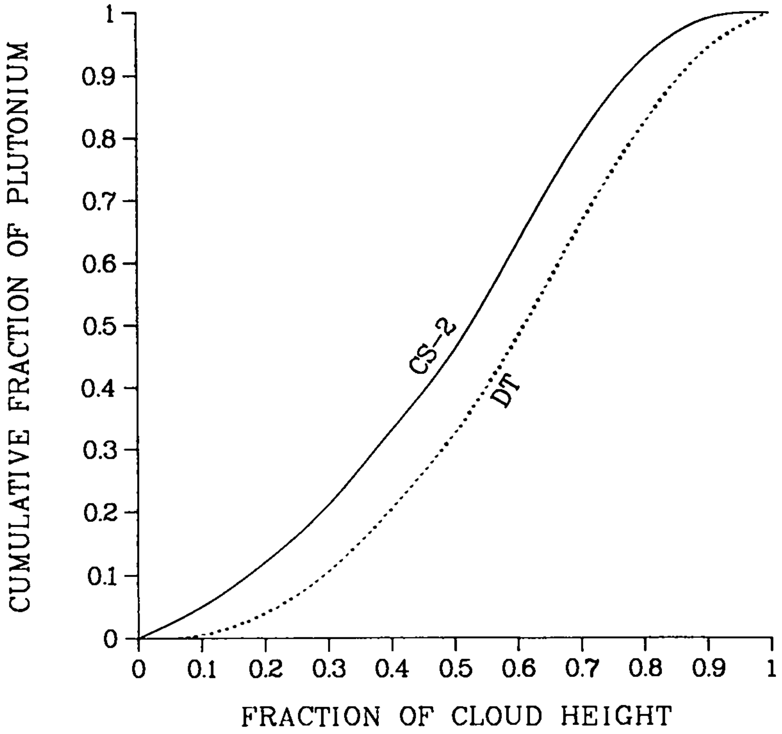

Fig. C-2. Distribution of plutonium with height for Double Tracks and Clean Slate 2 tests.

made at 750 m and beyond, which provided the desired information for both offsite airborne dosage and offsite deposition calculations.

Active particles in each cloud were composed of plutonium alone or plutonium attached to inert particles. The Roller Coaster data were based on aerosols collected inertially, analyzed radiometrically for activity (mass) of plutonium, and reported in terms of activity associated with particles of aerodynamically equivalent diameter. Although particles behaving aerodynamically alike might not contain like amounts of plutonium, the particle size distribution can be described most usefully in terms of an activity (plutonium activity) aerodynamic equivalent diameter (D_{ae}). The inertial techniques for determining D_{ae} were appropriate, without need to know microscopic diameters, shapes, or actual densities of particles. The size characteristics of a log normally distributed aerosol of mixed particles can then be described in terms of the activity median aerodynamic diameter (amad) and geometric standard deviation (σ_g). As noted in the ICRP Task Group on Lung Dynamics report, regional deposition in the lungs is relatively insensitive to changes in σ_g, making it unnecessary to include σ_g in the model (ICRP 1966).

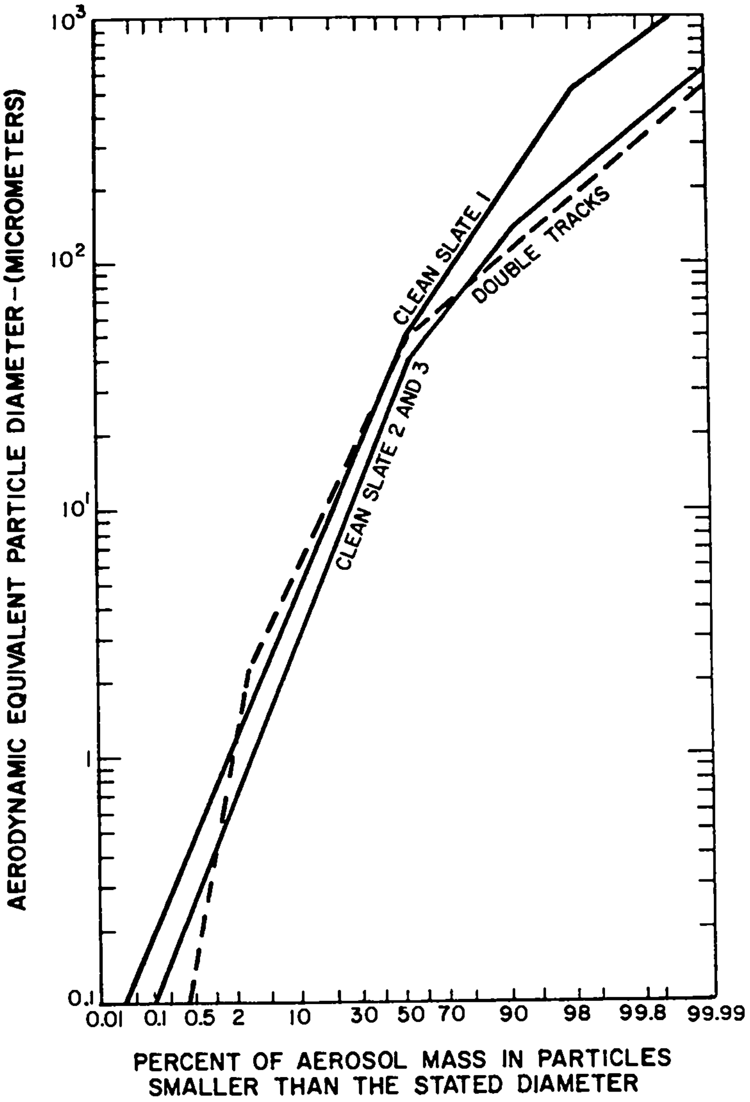

Fig. C-3. Aerosol size distribution for Roller Coaster experiments (Luna 1971).

Curves expressing the distribution of mass associated with particles with diameters ranging from 0.1 to 1000 µm are shown in Fig. C-3. None of the size distributions in the Roller Coaster series were log normally distributed; that is, the natural logarithms of particle diameters were not normally distributed. However, each size distribution, when plotted on a log probability scale as used in Fig. C-3, could be approximated by several straight line segments, each covering an interval of particle size. The DIFOUT model could accommodate a composite distribution expressed in this manner. The particle size characteristics of these composite distributions (taken from more detailed curves than Fig. C-3) were as follows.

amad (µm)	σ_g	Range (µm) From	To
9000	90	0.1	4.0
38	3.8	4.0	60
48	1.8	60	1000

[Although the 9000-µm activity median aerodynamic diameter (amad) appears to be an artificial value, it is the median extrapolated at a 50% probability by the line segment best fitting the distribution between 0.1 and 4.0 µm.] These characteristics were used as input to verify the DIFOUT model. As noted earlier, these composite distributions represent the continuum of particle sizes from 0.1- to 1000-µm D_{ae}. The model used this particle size range to calculate the total airborne dosage, the respirable airborne dosage, and the deposited dosage.

A complete input file for each of the Roller Coaster tests is provided in Appendix C, DIFOUT Input Files.

5. Selection of Median Respirable Diameter. For the purpose of selecting an amad as input to the ICRP Task Group lung model (ICRP 1966), the Roller Coaster particle size distribution data were reviewed for consistency of the respirable fraction. The referenced Roller Coaster reports stated 19 to 26% of the total aerosol mass was under 10-µm D_{ae}; therefore, 19 to 26% was respirable by nose breathing. Because 20% has been commonly stated as the respirable fraction, 20% was used throughout this analysis. To construct an assumed log normal distribution of the under 10-µm D_{ae} particles, percentage values by mass corresponding to several sizes (2, 5, and 8 µm) were normalized as though they were percentages of the mass of the under 10-µm distribution. From these data, the characteristics of the log normal distribution under 10 µm were derived. The amad of this distribution was approximately 5 µm. Although 5 µm is the probable diameter of interest, it yields a comparatively low pulmonary deposition by the ICRP lung model calculation. Although submicron particles yield highest pulmonary deposition, it was considered overly conservative to choose a submicron particle size. Consequently, an intermediate size of 2 µm was selected upon which to base organ dose calculations. Friend (1965) indicated diminishing particle size (Fig. C-4) with distance. At 5 km, a distance very likely to be offsite, the amad was projected to be approximately 2 µm. Particle size information to allow projection of amad beyond 5 km was not available. Some further reduction in amad (and possibly in respirable fraction) at greater distances could be expected as the last of the larger particles fall out of the cloud. However, deposition data presented later show over 90% of ground deposition will have occurred by the time the cloud moved 5 km.

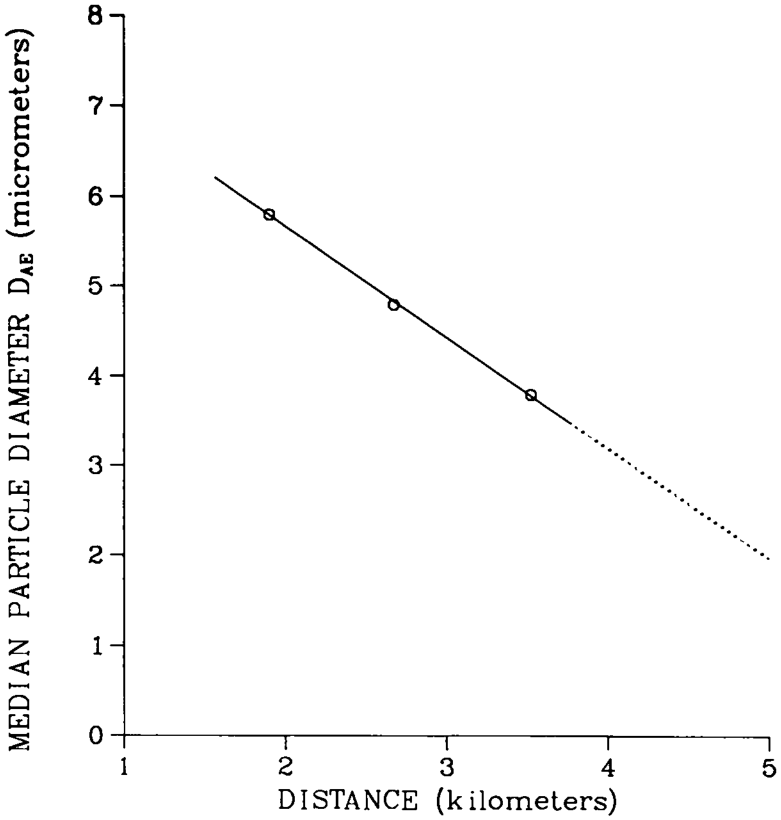

Fig. C-4. Variation of median particle diameter with distance (Friend 1965).

Derivations of organ dose factors applied to the integrated concentrations obtained from DIFOUT are described by Elder (1982B).

6. Calculated Versus Measured Dosages. Peak dosages of total aerosol and respirable aerosol from Double Tracks calculated by DIFOUT model are shown as functions of distance in Fig. C-5.

Agreement between the calculated and measured amounts of total aerosol was reasonably good. The dosage was underestimated no more than a factor of 2 (this under 1000 m); beyond 2000 m the dosage was overestimated by no more than a factor of 2.

Calculated values of peak respirable dosage were gross underestimates of the measured dosage out to 7000 to 8000 m. At 1000 m the difference was a factor of 10 to 20. This underestimation of respirable dosage made the respirable calculation of dubious value.

Deposited dosages, shown in Fig. C-6, were in reasonable agreement over the range of interest. The dip in measured dosage from 400 to 2000 m was not

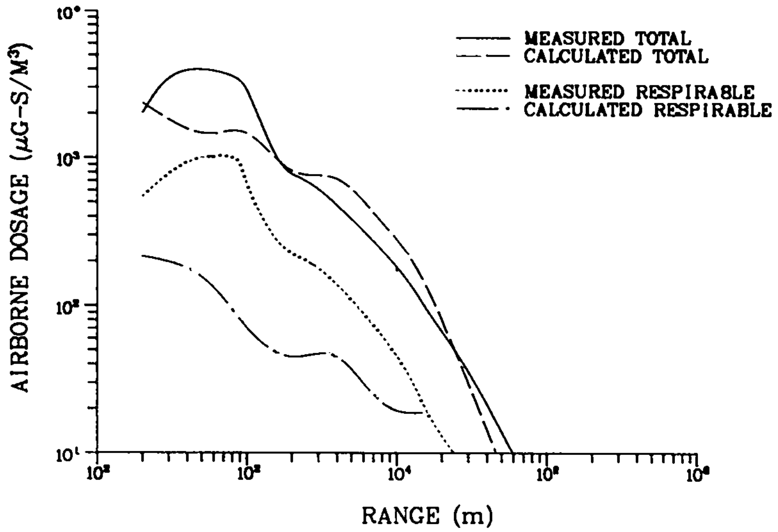

Fig. C-5. Peak airborne dosage - Double Tracks.

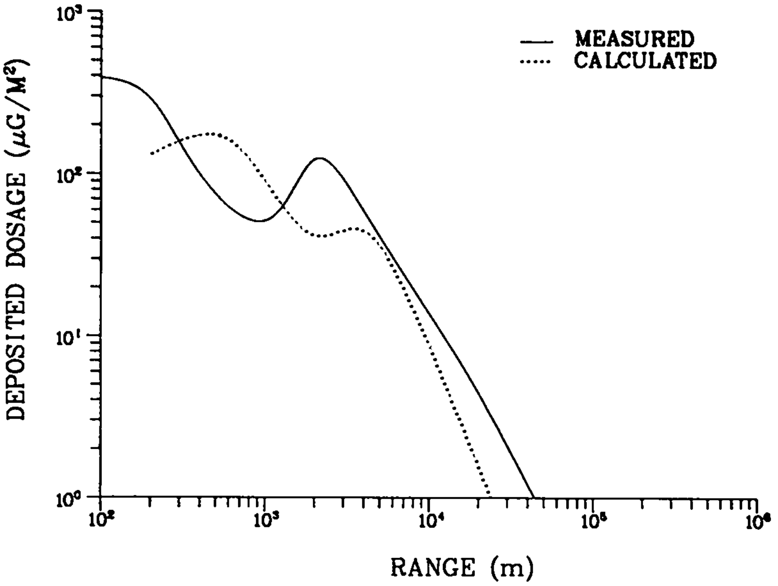

Fig. C-6. Peak deposited dosage - Double Tracks.

reflected by the model; however, the calculated values provided a conservative overestimate of the deposited dosage through this range.

An empirical check of DIFOUT's ability to calculate area bounded by dosage contours or isopleths was performed by comparing calculated values with summed areas graphically determined from computer-generated contour maps. The agreement was ±20%, adequate for our purposes.

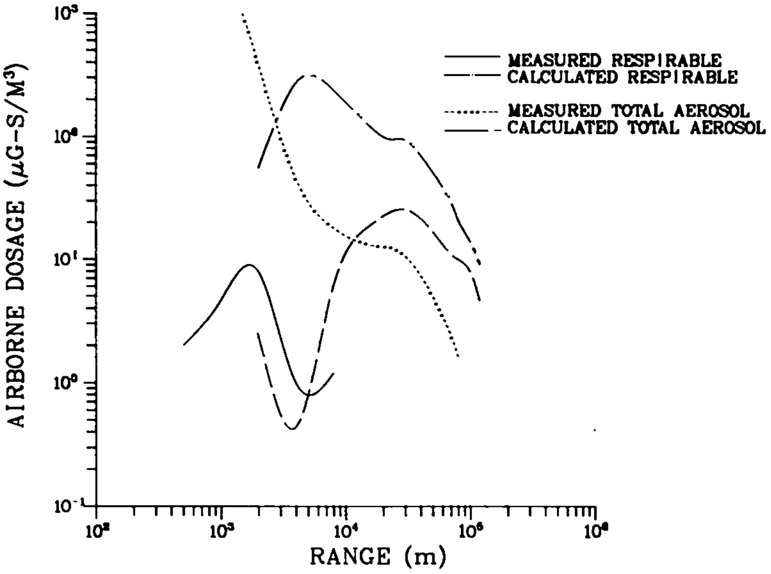

Fig. C-7. Peak airborne dosage - Clean Slate 1.

B. Clean Slate 1

Clean Slate 1, another unbunkered test, also offered the opportunity for input to the postulated accident cases, particularly where high clouds (more HE) were postulated. However, as shown in Fig. C-7, major disagreement exists between the measured and calculated values of total aerosol and respirable aerosol, particularly within 4000 m of the detonation site. Beyond 4000 m, the model overestimates total aerosol by a factor of 10. The overestimation of total aerosol by the model may not be caused by the model at all; rather, overestimation may be caused by a lower than expected aerosol concentration resulting from the Roller Coaster test arrangement. It is suspected that ringing the only plutonium-containing test device with other devices caused the plutonium in the Clean Slate 1 cloud to be lifted to a high elevation in the center of the cloud. Therefore, the distribution of plutonium with height probably would not be representative of the postulated accidents.

The respirable aerosol curve was in reasonable agreement over the short range where the measured and calculated values overlapped and both showed a dip at 4000 to 6000 m. However, the model indicated a respirable aerosol peak 60 000 to 80 000 m away which, if real, was missed by the downwind sampler array.

Figure C-8 shows that deposition is calculated in reasonable agreement with measured values 1000 m and beyond. Inside 1000 m, the dosage is grossly underestimated.

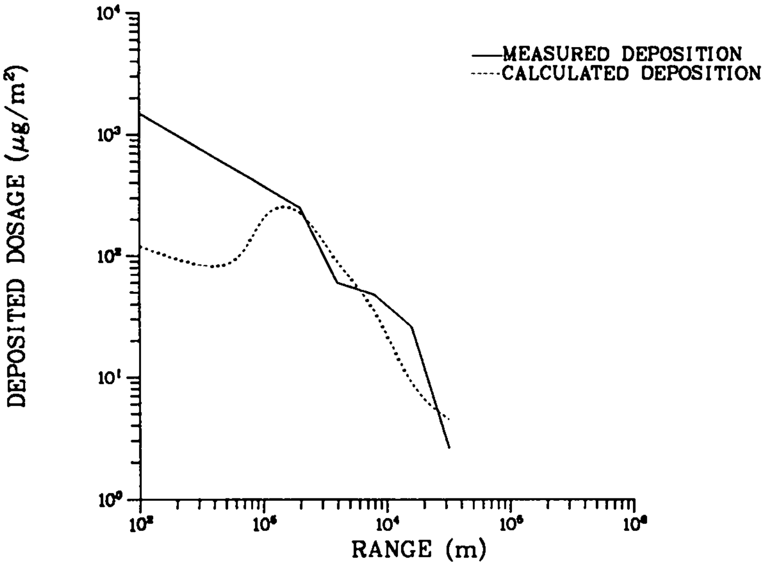

Fig. C-8. Peak deposited dosage - Clean Slate 1.

In general, the Clean Slate 1 test results were not consistent with the model, discouraging any use of these measured conditions as input to the model for accident analysis. Consequently, the meteorological data, particle size characteristics, and clouds are not described in detail here. However, a complete input file for each of the DIFOUT runs is provided in Appendix C, DIFOUT Input Files.

IV. BUNKERED DETONATIONS

The bunkered shots of Roller Coaster (Clean Slate 2 and 3) offered experimental data for use in verification of the DIFOUT model as applied to postulated accidents in bunkered locations. The only major difference between these two tests was the thickness of the overburden (2 ft for Clean Slate 2; 8 ft for Clean Slate 3). Since the results were similar for these tests, only Clean Slate 2 will be covered in detail in this Appendix. The additional overburden apparently had little effect.

Clean Slate 2

Cloud Description. The cloud height of Clean Slate 2 was 440 m. The general outline of the cloud after buoyant growth had ceased (Fig. C-1) differs from Double Tracks only in that Clean Slate 2 has a better defined stem and larger top.

Meteorological Conditions. Table C-III lists the meteorological conditions used in modeling Clean Slate 2 (Church 1969).

TABLE C-III

CLEAN SLATE 2 METEOROLOGICAL PARAMETERS

Height (m)	Wind Direction (degrees E of N)	Wind Speed (m/s)	Vertical Turbulence Intensity	Horizontal Turbulence Intensity
2	360	2.1	0.078	0.070
25	325	3.0	0.078	0.070
50	325	3.2	0.036	0.018
125	325	4.2	0.036	0.018
175	290	7.2	0.036	0.018
225	300	5.0	0.036	0.018
275	300	3.0	0.036	0.018
325	300	2.0	0.036	0.018
375	340	1.5	0.036	0.018
425	340	2.0	0.036	0.018

Activity Fraction with Height. Figure C-2 shows the relationship between cumulative plutonium activity and fractional cloud height for Clean Slate 2. Somewhat higher activity amounts were measured in the lower layers of the Clean Slate 2 cloud than were measured in the Double Tracks cloud, as would be expected where more soil particles were present to aid in scavenging the plutonium particles. Actual activity fractions used in the Clean Slate 2 analysis are listed in Table VI in the body of this report.

Aerosol Size Distribution. Analysis of Clean Slate 2 aerosol size distribution was similar to that described earlier for Double Tracks, except the particle size information (unclassified) was found in classified report AWRE T6/69 (Stewart 1969). Overall size distribution was shown earlier in Fig. C-3. The distribution was approximated by two line segments as follows.

amad (μm)	σ_g	Range (μm) From	Range (μm) To
39	7.8	0.1	42
41	2.3	42	1000

A complete input file for the Clean Slate 2 test is provided in Appendix C, DIFOUT Input Files.

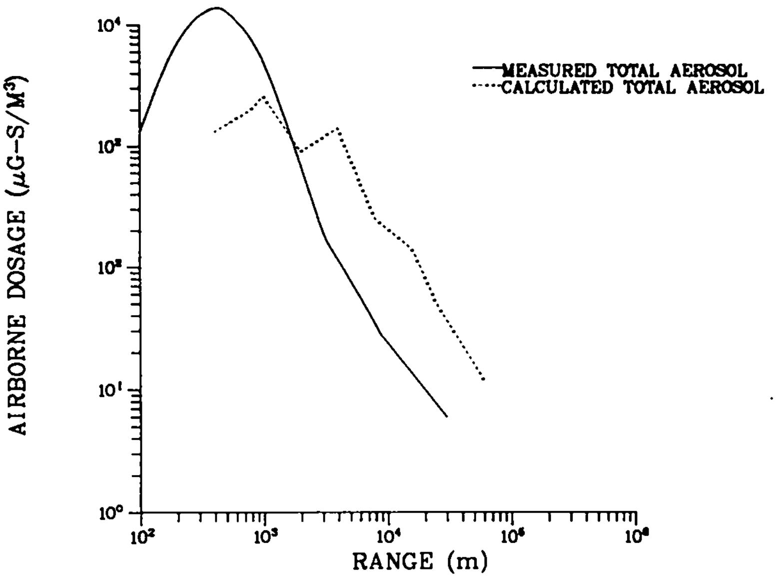

Fig. C-9. Peak airborne dosage - Clean Slate 2.

Calculated Versus Measured Dosages. Peak dosages of total aerosol from the Clean Slate 2 test data are shown as functions of distance in Fig. C-9. Agreement was not exceptionally good. However, beyond 600 m the model either predicted closely or overestimated the measured value. Beyond 4000 m, the dosage was consistently overestimated by a factor of 10. This discrepancy may have been caused by better scavenging processes than a simple sedimentation and turbulent dispersion depletion model would predict.

Peak deposition is shown as a function of distance in Fig. C-10. The model underestimated peak deposition over the entire range but only by a factor of 1.5 to 2.5 beyond 1500 m, the shortest distance to the site boundary for any of the accident cases. Therefore, for offsite dosage calculations, the model is considered to adequately estimate deposition.

V. SUMMARY AND CONCLUSIONS

Airborne and deposited plutonium dosages expected from the Roller Coaster test series of 1963 were calculated using the DIFOUT dispersion model. Meteorological parameters, cloud descriptions, and particle size characteristics from this series of four plutonium dispersion tests were used to model the tests as carefully as possible. The calculated values of total airborne dosage and deposition dosage adequately approximated or conservatively overestimated the measured values. Poor agreement between measured and calculated respirable airborne dosage suggests that an alternative method be used to estimate respirable airborne dosage, that is, the total airborne dosage multiplied by a respirable fraction of 20%.

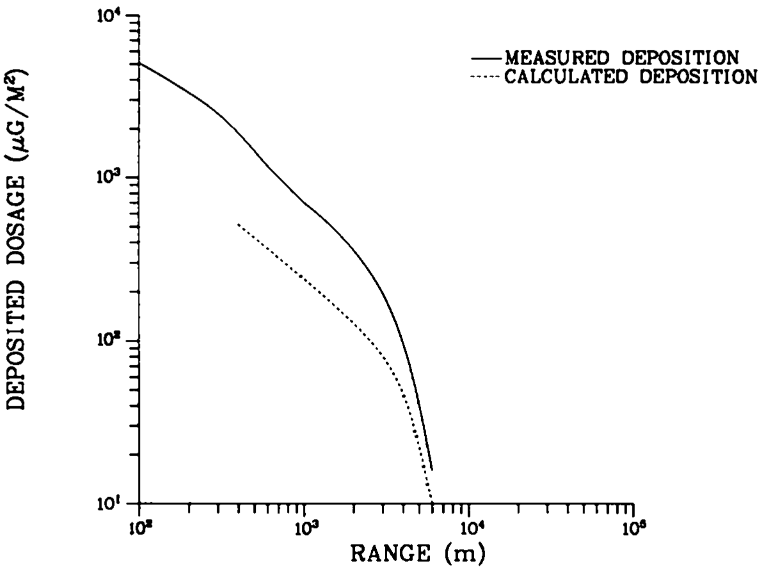

Fig. C-10. Peak deposition - Clean Slate 2.

The verification process indicated that parameters and conditions similar to those from the Double Tracks test performed in an unbunkered location would be suitable for estimating dosages from accidents in unbunkered assembly/disassembly areas. Parameters from the Clean Slate 2 test performed in an earth-covered bunker would be suitable for DIFOUT estimation of dosages from the accidents in earth-bunkered locations.

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Stewart 1969: K. Stewart, "Roller Coaster Summary Report," Atomic Weapons Research Establishment (UK) report, AWRE T6/69, Secret Restricted Data (1969).

DIFOUT INPUT FILES

```
1        3 VERIFICATIDN PRDBLEM FOR DIFDUT USING DT DATA
  6.25E+2    2.0E+1   1.0E+9MICROGRAMS
     2.       1.      216.
         1        11
        0.       10.       25.       50.       75.      100.      125.      150.
      175.      200.      216.
      121.       91.       71.      115.      128.       91.       34.       71.
       78.       67.         1
       .01       .01      .065      .085       .12       .14       .17       .17
       .14       .09         1
         2         5
        1.       20.       50.      100.      200.
       5.2       5.6       6.4       7.0       7.8
      350.      370.      350.      345.      340.
      .079      .038
      .079      .079      .079      .079      .079
      .038      .038      .038      .038      .038
         3        10
      200.      500.     1000.     2000.     4000.     8000.    16000.    32000.
    64000.    80000.
         9         3
         1        10         1   1.0E+06
    .1E-6    4.0E-6    9.0E-3    9.0E+1         4
    4.0E-6    60.E-6    38.E-6    3.8E+0         4
    60.E-6   400.E-6    48.E-6    1.8E+0         4
         5         3
    10.E-6  1000.E-6 -1000.E-6
         5
    3.0E+0    1.0E+1    3.0E+1    1.0E+2    3.0E+2
         5
    1.0E+1    3.0E+1    1.0E+2    3.0E+2    1.0E+3
         5
    1.0E+0    1.0E+1    1.0E+2    1.0E+3    1.0E+4
         1    5.0E-1         1         1
   1.70E+2    2.0E+4
        10
```

```
         3 VERIFICATION PROBLEM FOR DIFOUT USING CS1 DATA
   6.25E+2    2.0E+1    1.0E+9MICROGRAMS
        2.        1.      710.                           1500.      145.
         1        11
        0.       10.       30.      100.      200.      300.      400.      500.
      600.      700.      710.
      155.      154.      250.      340.      252.      300.      289.      291.
      141.       26.        1.
     .0018     .0027     .0045      .029      .102      .153      .194      .216
      .153      .045        1.
         2        10
        2.       25.       50.      100.      200.      300.      400.      500.
      600.      700.
       1.2       2.8       5.2       5.5       7.2       8.0       8.2       7.0
       7.0       7.0
       55.      350.      315.      325.      325.      325.      325.      325.
      325.      325.
       .14       .25
       .14      .061      .061      .061      .061      .061      .061      .061
      .061      .061
       .25      .044      .044      .044      .044      .044      .044      .044
      .044      .044
         3        10
     1000.     2000.     4000.     8000.    16000.    32000.    64000.    80000.
   100000.   120000.
         9         2
         1         1         1   1.0E+06
   1.E-07   200.E-6     2.E-1    38.E+0         4
  200.E-6  1500.E-6   350.E-6    1.4E+0         4
         9         2
         2         2         2    1.0E+6
   .05E-6   210.E-6    4.8E-2    48.E+0         4
  210.E-6   600.E-6   210.E-6    3.5E+0         4
         9         2
         3         3         3    1.0E+6
  .01E-06    80.E-6  4000.E-6    40.E+0         4
  80.E-06  1000.E-6   180.E-6    2.2E+0         4
         9         2
         4        10         4    1.0E+6
  .07E-06   120.E-6    38.E-6    5.4E+0         4
  120.E-6  1000.E-6    75.E-6    2.1E+0         4
         5         2
   10.E-6   600.E-6
         5
   1.0E-1    3.0E-1    1.0E+0    3.0E+0    1.0E+1
         5
   1.0E-1    1.0E+0    1.0E+1    1.0E+2    1.0E+3
         1    5.0E-1         1         1
  1.45E+2    2.0E+4
        10
```

```
1        4 VERIFICATION PRDBLEM FDR DIFDUT USING CS1 DATA
   6.25E+2    2.0E+1    1.0E+9MICRDGRAMS
      2.     1.         560.
         1        11
        0.       10.       30.      100.      176.      252.      328.      404.
      480.      556.      560.
      155.      154.      250.      340.      252.      300.      289.      291.
      141.       26.        1.
     .0018     .0027     .0045      .029      .102      .153      .194      .216
      .153      .045        1.
         2        10
        2.       25.       50.      100.      200.      300.      400.      500.
      600.      700.
       1.2       2.8       5.2       5.5       7.2       8.0       8.2       7.0
       7.0       7.0
       55.      350.      315.      325.      325.      325.      325.      325.
      325.      325.
       .14       .25
       .14      .061      .061      .061      .061      .061      .061      .061
      .061      .061
       .25      .044      .044      .044      .044      .044      .044      .044
      .044      .044
         3        10
      100.      500.     1000.     2000.     4000.     8000.    16000.    32000.
    64000.    80000.
         9         2
         1         1         1   1.0E+06
    1.E-07   200.E-6     2.E-1    38.E+0         4
   200.E-6  1500.E-6   350.E-6    1.4E+0         4
         9         2
         2         2         2    1.0E+6
    .05E-6   210.E-6    4.8E-2    48.E+0         4
   210.E-6   600.E-6   210.E-6    3.5E+0         4
         9         2
         3         3         3    1.0E+6
   .01E-06    80.E-6  4000.E-6    40.E+0         4
   80.E-06  1000.E-6   180.E-6    2.2E+0         4
         9         2
         4        10         4    1.0E+6
   .07E-06   120.E-6    38.E-6    5.4E+0         4
   120.E-6  1000.E-6    75.E-6    2.1E+0         4
         5         1
 -1000.E-6
         5
    1.0E-2    1.0E-1    1.0E+0    1.0E+1    1.0E+2
         3                   1         1
   1.45E+2    2.0E+4
        10
```

```
         4 VERIFICATION PROBLEM FOR DIFOUT USING CS2 DATA
   6.70E+2    2.0E+1    1.0E+9MICROGRAMS
        1.        1.      440.
         1        11
        0.       10.       30.      100.      149.      198.      247.      295.
      343.      391.      440.
      155.      162.      135.       68.       81.       81.      209.      250.
      189.      122.        1.
       .01       .01       .06       .11       .12       .15       .18       .19
       .12       .04        1.
         2        10
        2.       25.       50.      125.      175.      225.      275.      325.
      375.      425.
       2.1       3.0       3.2       4.2       7.2       5.0       3.0       2.0
       1.5       2.0
      360.      325.      325.      325.      290.      300.      300.      300.
      340.      340.
      .078       .07
      .078      .078      .036      .036      .036      .036      .036      .036
      .036      .036
       .07       .07      .018      .018      .018      .018      .018      .018
      .018      .018
         3        10
      400.      800.     1000.     2000.     4000.     8000.    16000.    32000.
    64000.    80000.
         9         2
         1        10         1   1.0E+06
     .1E-6    42.E-6    39.E-6    7.8E+0         4
    42.E-6  1000.E-6    41.E-6    2.3E+0         4
         5         2
   600.E-6 -1000.E-6
         5
    1.0E-3    1.0E-2    1.0E-1    1.0E+0    1.0E+1
         5
    1.0E+0    1.0E+1    1.0E+2    1.0E+3    1.0E+4
         1    5.0E-1         1         1
   1.50E+2    2.0E+4
        10
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