A Facsimile Report

NUCLEAR AIRCRAFT SAFETY ANALYSIS PROGRAM

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INTRODUCTION

The information presented here is a summary - prepared for the Ad Hoc Committee - of the current status of continuing studies on the hazards associated with nuclear powered aircraft. The results of previous studies have been reported in FZM-25-015, FZM-25-018, and FZM-25-019. These earlier studies were less detailed and therefore included large factors of uncertainty in areas which were not treated in detail. The results presented here differ from the earlier ones principally as a consequence of more exhaustive analysis of the factors involved. The first part of the presentation, "Nuclear Hazards Analysis", gives descriptions of the nuclear consequences of a typical and an extreme reactor accident. The assumptions used in this study have been made so as to evidence a readily discernable degree of conservatism, so that the results for both can be considered to be pessimistic.

In the second part, "Operation Studies", these data are used, first, in a statistical prediction of the probable average number of bystanders affected by nuclear aircraft accidents. This prediction is based on the SAC jet bomber accident statistics. Second, the effect of the worst credible accident is analysed. Finally, a description is given of what would have happened if the B-47 bombers had been nuclear-powered between 1952 and 1955.

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NUCLEAR HAZARDS ANALYSIS

304-4

NPC 5813A

MAJOR HAZARD FACTORS

The prediction of nuclear hazards associated with the release of fission products from a reactor has been organized as shown on this chart. First, the fission product inventory in the reactor at the time of release must be established - both the total activity and the activity of specific isotopes of major importance to the biological hazards must be determined. Next, release models must be established to define the relative amounts and physical chracteristics of the fission products released. In this connection, the relative probability of occurrence of each release model should be established.

At this point the fission product inventory in the cloud has been defined. The next problem is to establish the degree of dispersal downwind from the point of release. This involves a prediction of both the concentration of the fission products in the cloud as a function of position downwind from the source and the extent to which they fall out of the cloud and contaminate the ground.

Finally, the degree of biological damage to humans by irradiation from the cloud and the ground, and from matter inhaled and ingested must be estimated. The next series of charts will specify the assumptions and methods used in making these predictions.

MAJOR HAZARD FACTORS

FISSION PRODUCT:

- INVENTORY
- RELEASE PROBABILITY
- RELEASE MODELS
- DISPERSAL
- BIOLOGICAL EFFECTS

NPC 5810

FISSION PRODUCT INVENTORY - ASSUMPTIONS

This chart lists the reactor operating history which was assumed to predict the fission product inventory at the time of release. Two cases were chosen; one an average (release occurring at approximately the mid-point of normal core life) and the other leading to the maximum inventory expected (release occurring at the end of the useful life of a reactor core).

FISSION PRODUCT INVENTORY–ASSUMPTIONS

- ONE 150-Mw REACTOR
- 24-HOUR FLIGHTS EVERY TWO WEEKS
- FIVE MINUTE RUNUP PRIOR TO TAKEOFF
- AVERAGE CASE – RELEASE ON 10th FLIGHT
- MAXIMUM CASE – RELEASE ON 21st FLIGHT

NPC 5960

FISSION PRODUCT INVENTORY

This chart shows the fission product inventory for the average and maximum cases described previously. Both the total activity and the activity of important mixtures of isotopes are shown.

In the first two rows it can be seen that, due to the reduced inventory on take-off, an accident at that time would be roughly an order of magnitude less hazardous than an accident on landing. It should be pointed out that the statistical study which follows this presentation was based on the assumption that all aircraft crashes occurred on landing. This leads to a considerable overestimate of the hazard.

The second and third rows demonstrate that, with the exception of Sr^{90}, the inventory on landing is essentially the same for the 10th and 21st flights. The maximum Sr^{90} inventory is equivalent to the amount released in the explosion of a 76 KT fission weapon.

The values presented here have been calculated independently by several different agencies and the results are in good agreement.

FISSION PRODUCT INVENTORY

- CURIES AT SHUTDOWN

	CORE TOTAL	IODINES	NOBLE GASES	BONE SEEKERS	Sr^{90}-Y^{90}
TAKE OFF 10th FLIGHT	6.7×10^8	1.0×10^6	0.50×10^6	3.5×10^6	5.0×10^3
LANDING 10th FLIGHT	11.2×10^8	29×10^6	15×10^6	22×10^6	5.5×10^3
LANDING 21st FLIGHT	11.2×10^8	29×10^6	15×10^6	27×10^6	1.16×10^4 (76 KT EQUIV.)

NPC 5963

070 502

It has been estimated that if the reactor core were compacted into a minimum size sphere, the excess reactivity could be as much as 30%; overriding the control rods and causing a runaway. A rough calculation indicates that a 500 g deceleration load applied at right angles to the centerline would collapse an appreciable part of the core due to its own inertial. It is not clear whether a similar load applied at other angles would cause internal failures to lead to sufficient compaction to cause a runaway. With this in mind, aircraft crash statistics have been reviewed to ascertain the relative number which might lead to deceleration loads greater than 500 g. Five percent appears to be a reasonable estimate of the number of crashes to be expected in this category. This is based on the fact that (1) loads approaching 500 g do not occur in crashes where the impact angle and speed of the aircraft are typical of those for landing and take-off and (2) even for high angle and speed impacts the effects of angular motion and cratering in the soil will, in many cases, keep the loads under the critical value.

In considering the 5% cases which are expected to exceed the critical load it is important to realize that not all of them will necessarily lead to a runaway. This is due to the fact that critical loads, applied at different angles will lead to (1) different patterns of fracture some of which may tend to split the core rather than compacting it and (2) different degrees of mixing the reactor materials as opposed to compacting the core. For these reasons, it is expected that (1) the numbers of runaways will be appreciably less than 5% and (2) the ones which do occur will cover the entire range of severity above meltdown and below the maximum possible runaway.

CRASH INDUCED REACTOR RUNAWAY

100 CRASHES

TYPE OF CRASH	REACTOR CORE EXPECTED LOAD FACTOR <500g	REACTOR CORE EXPECTED LOAD FACTOR >500g*
TAKE OFF	13	0
PATTERN AND IN FLIGHT		
LANDING ATTITUDE AND SPEED	7	0
HIGH SPEED AND/OR STEEP IMPACT	21	5**
LANDING	54	0

*LOAD FACTOR >500g MAY INDUCE RUNAWAY DUE TO CORE COLLAPSE
** LOAD FACTOR >500g FOR VERTICAL VELOCITY >450 ft/sec.

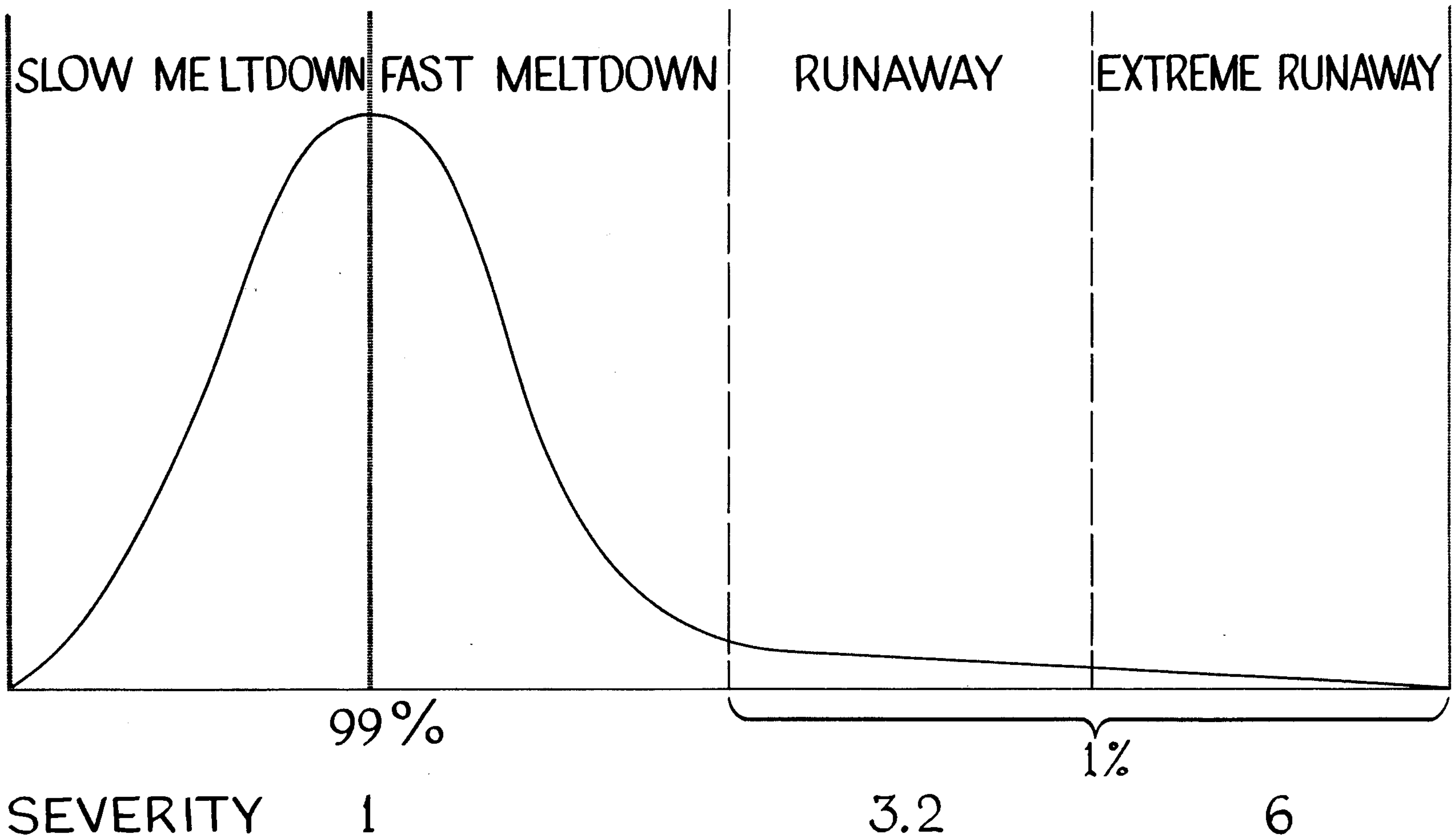
NPC 5986A

RELEASE PROBABILITIES

The preceding GE presentation has served to define four major categories of release incidents: a slow and a fast meltdown which differ largely in the length of time over which the release occurs; and two runaway incidents which differ largely in the magnitude of the release because one postulates the introduction of a ramp increase and the other a step increase in excess reactivity. Two models, a meltdown and an extreme runaway have been considered in this study. It is believed that the meltdown release model described in the next chart adequately represents the broad range of both the slow and fast meltdown. It is further believed that the extreme runaway model represents an upper limit of the release expected due to a step function increase in excess reactivity.

In view of the discussion on crash induced reactor runaway, and with due consideration for the possibility of reactor control system failure, it is believed that not more than one in a 100 reactor incidents will be a runaway. These conclusions, together with a consideration of the relative severity of the various incidents (measured in terms of average numbers of people affected), led to the conclusion that the statistical study should be based on the results of the meltdown model, whereas the extreme runaway is appropriate for the analysis of the worst credible accident.

RELEASE PROBABILITIES



NPC 5954A

FISSION PRODUCT RELEASE

Two release models have been used in this study. The first is applicable to the meltdown case. The volatile materials are released in higher percentages than the non-volatile materials. The volatiles are all aerosol and the non-volatiles are in aerosol and particulate form. The aerosol fraction includes all particles less than 10μ in diameter.

The second model is non-selective in nature, i.e., the assumption is made that all fission product are released in the same proportions in which they exist in the reactor, and the fraction of the released material which is in aerosol form is taken to be the same for all nuclides. This model is representative of an extreme reactor runaway.

The distribution of activity between the aerosol and particulate fractions is based on a log-normal distribution of particle size and on an activity distribution versus particle size obtained from bomb data. Although the applicability of bomb data is questionable, this assumption tends to yield higher activities in small particles than would an assumption of direct proportionality between activity and mass. Therefore, the bomb data were used.

FISSION PRODUCT RELEASE

- MELTDOWN ACCIDENT - AVERAGE CASE

  PREFERENTIAL RELEASE OF ISOTOPES
  VOLATILE ISOTOPES IN AEROSOL FORM ONLY
  NON-VOLATILE ISOTOPES IN AEROSOL AND PARTICLES

- EXTREME RUNAWAY ACCIDENT - MAXIMUM CASE

  UNIFORM RELEASE OF ALL ISOTOPES
  EACH ISOTOPE IN AEROSOL AND PARTICLE FORM

- PARTICLE SIZE DISTRIBUTION: LOG NORMAL ($\sigma_g = 2.75$)

- RELATIVE PARTICLE ACTIVITY FROM BOMB DATA

- AEROSOL: ALL PARTICLES $< 10\,\mu$

NPC-5809

RELEASE MODELS

These data show the relationship between the fission product inventory in the reactor and in the cloud, and the assumed distribution between aerosol and particulate matter for the two release models.

Previous studies using Stokes' Law have shown that large particles should fall out of the cloud in relatively short distances. For this reason, only the aerosol was assumed to stay in the cloud, and no further depletion of the cloud was assumed due to dry deposition or rainout.

The release model for the meltdown case follows very closely the experimental results obtained by Parker and Creek at ORNL.

RELEASE MODELS

	EXTREME RUNAWAY	MELTDOWN			
	ALL ISOTOPES	IODINE	NOBLE GASES	BONE SEEKERS	CESIUM
AEROSOL (%)	35	50	100	0.23	2.3
PARTICULATE (%)	40	0	0	0.77	7.7
RELEASED (%)	75	50	100	1.00	10.0

NPC 5898

FISSION WEAPON YIELD EQUIVALENCE (Sr^{90}) OF AIRCRAFT REACTOR ACCIDENTS

The release of Sr^{90} is shown here in units of KT equivalence. (One KT equivalent of Sr^{90} is the amount of Sr^{90} produced by a 1 KT equivalent fission weapon.) Three cases are shown:

1. The burnout of a fuel element in the 10th flight.
2. A meltdown of the reactor during the 10th flight.
3. The runaway of a reactor in the 21st flight.

FISSION WEAPON YIELD EQUIVALENCE (Sr-90) OF AIRCRAFT REACTOR ACCIDENTS

(1KT = 158 CURIES Sr-90)

INCIDENT	KT EQUIVALENCE
INFLIGHT LOSS OF ONE FUEL ELEMENT (10th flight)	0.24
MELTDOWN	0.36
EXTREME RUNAWAY	57

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NPC 5955

FISSION PRODUCT DISPERSAL

Generally accepted methods have been used to predict the dispersal of fission products. A particular assumption which is possibly unique to aircraft accidents is a choice of 150 feet for the effective release height. This choice is based on observations of the height to which clouds rise in an aircraft crash fire. In cases where large amounts of chemical fuel burn initial cloud rise will be several times this figure especially if the wind speed is low. However, 150 feet is considered to be a conservative average value for use in the present study.

FISSION PRODUCT DISPERSAL

- DIFFUSION: SUTTON THEORY
- DIFFUSION PARAMETERS: U.S. WEATHER BUREAU AND BROOKHAVEN
- DRY DEPOSITION AND RAINOUT: CHAMBERLAIN
- EFFECTIVE RELEASE HEIGHT: FIXED

NPC 5894

The equations used for predicting the cloud concentration and the ground contamination are given here. It has long been recognized that Sutton's diffusion equation (χ) is strictly applicable for short distances only ($\sim$5 miles). In spite of this limitation, it is used here to predict concentrations at larger distances since it is the best theory available and since recent experimental data give guidance in the proper choice of parameters.

$\chi(x,y,o)$, the cloud concentration at ground level, is strongly affected by the choice of the horizontal and vertical diffusion coefficients (C_y, C_z) and the parameter n. The first term in the equation expresses the concentration on the cloud centerline, with a factor of 2 included to account for the reflection of the cloud by the ground. The exponential is a multiplication factor for cloud concentration off the centerline at ground level.

The ground contamination is assumed to be proportional to the cloud concentration at ground level, the proportionality constant being termed "deposition velocity" (v_g). The choice of v_g strongly affects the extent of ground contamination at large distances downwind through its effect on the exponential which is a cloud depletion factor.

The form of the equation for rainout is the same as for dry deposition where the proportionality constant Λ is the fraction of the cloud deposited per second, and

$$\chi(x,y) = \int_0^\infty \chi(x,y,z)\,dz,$$

DISPERSAL EQUATIONS

CLOUD CONCENTRATION

$$\chi_{(x,y,o)} = \frac{2Q_o}{\pi C_y C_z \bar{u} x^{(2-n)}} \exp\left[-\frac{1}{x^{(2-n)}}\left(\frac{y^2}{C_y^2} + \frac{h^2}{C_z^2}\right)\right]$$

DRY DEPOSITION

$$\omega_{(x,y,o)} = \chi_{(x,y,o)} v_g \exp\left[-\frac{4 V_g X_1^{n/2}}{n \pi^{1/2} \bar{u} C_z}\right]$$

RAIN-OUT

$$\omega_{(x,y,o)} = \chi_{(x,y)} \Lambda \exp\left[-\frac{\Lambda x}{\bar{u}}\right]$$

NPC 5895A

METEOROLOGICAL ASSUMPTIONS

The study has been made for two sets of meteorological conditions, typical lapse and typical inversion. The values for the parameters are typical of those which have been used in many other studies with one notable exception. The crosswind (or horizontal) diffusion coefficient (C_y) for typical inversion conditions has been chosen as 0.4, roughly a factor of 8 larger than that which has generally been used in the past. This choice still leads to significant overestimates of the cloud concentration compared to recent experiments on diffusion over long distances.

METEOROLOGICAL ASSUMPTIONS

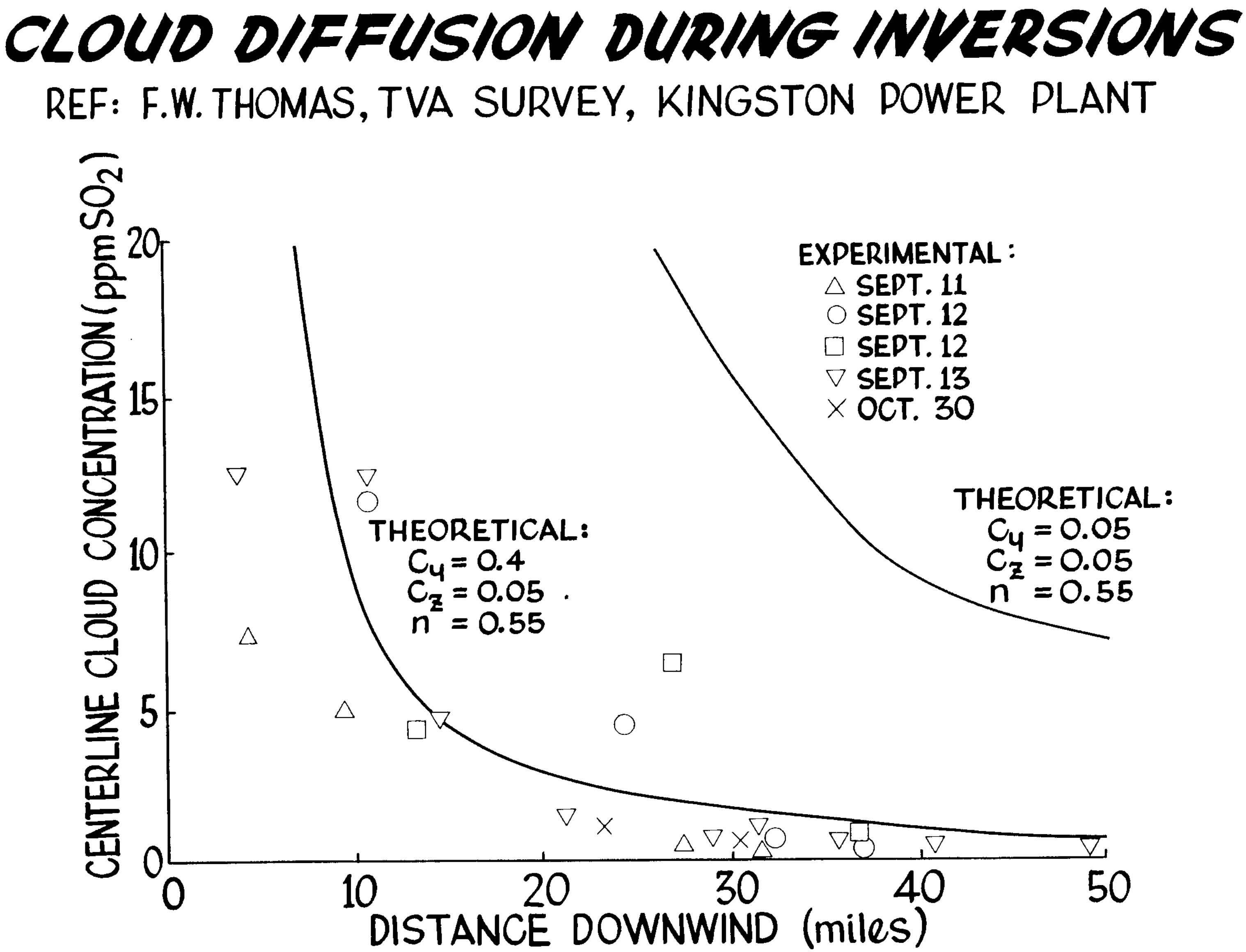
	TYPICAL LAPSE	TYPICAL INVERSION
STABILITY PARAMETER (n)	0.25	0.55
VIRTUAL SOURCE HEIGHT (Feet)(h)	150	150
MEAN WIND SPEED (MPH)($\bar{u}$)	11	6.7
VERTICAL DIFFUSION COEFFICIENT (C_z)	0.4	0.05
CROSSWIND DIFFUSION COEFFICIENT (C_y)	0.4	0.4

NPC 5884

CLOUD DIFFUSION DURING INVERSIONS

F. W. Thomas* in recent surveys made for TVA has measured the concentration of SO_2 in a cloud plume emitted from the Kingston Power Plant. The data were obtained for the centerline of the cloud by traversing the plume in a helicopter. The data, taken over a period of months for various degrees of inversion conditions, demonstrate that with the exception of local variations, all of the concentrations lie below the theoretical predictions made in this study. It can further be seen that for Cy = 0.05, generally used in earlier studies, the predictions are roughly an order of magnitude too high.

*Private Communication

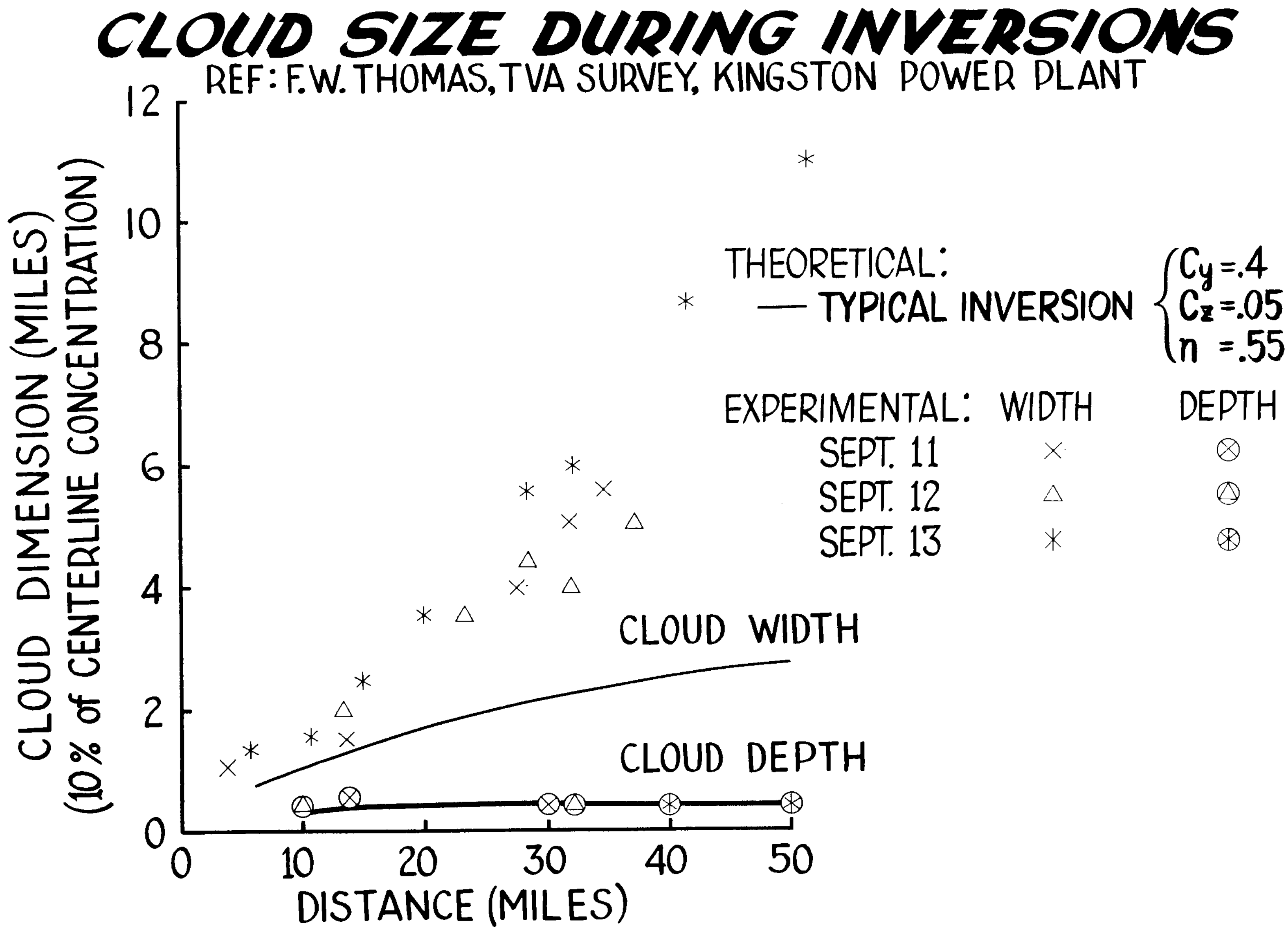


CLOUD DIFFUSION DURING INVERSIONS
REF: F.W. THOMAS, TVA SURVEY, KINGSTON POWER PLANT
CENTERLINE CLOUD CONCENTRATION (ppm SO_2)
0
5
10
15
20
0
10
20
30
40
50
DISTANCE DOWNWIND (miles)
EXPERIMENTAL:
SEPT. 11
SEPT. 12
SEPT. 12
SEPT. 13
OCT. 30
THEORETICAL:
$C_y = 0.4$
$C_z = 0.05$
$n = 0.55$
THEORETICAL:
$C_y = 0.05$
$C_z = 0.05$
$n = 0.55$

NPC 5958AB

CLOUD SIZE DURING INVERSIONS

In addition to centerline measurements, Thomas estimated the physical dimensions of the cloud plume. A comparison of experimental data and theory is shown here. The comparison demonstrates very graphically that the conservatism in the predictions is due to a considerable underestimate of the width of the cloud. In fact, the width of the cloud is significantly larger than that predicted for typical lapse conditions. Thomas' work shows clearly that cloud concentrations under inversion conditions have been grossly overestimated in the past and that the concentration estimates used in this study are clearly conservative.


CLOUD SIZE DURING INVERSIONS
REF: F.W. THOMAS, TVA SURVEY, KINGSTON POWER PLANT
CLOUD DIMENSION (MILES)
(10% of CENTERLINE CONCENTRATION)
12
10
8
6
4
2
0
THEORETICAL:
— TYPICAL INVERSION
Cy =.4
Cz =.05
n =.55
EXPERIMENTAL: WIDTH DEPTH
SEPT. 11
SEPT. 12
SEPT. 13
CLOUD WIDTH
CLOUD DEPTH
0
10
20
30
40
50
DISTANCE (MILES)

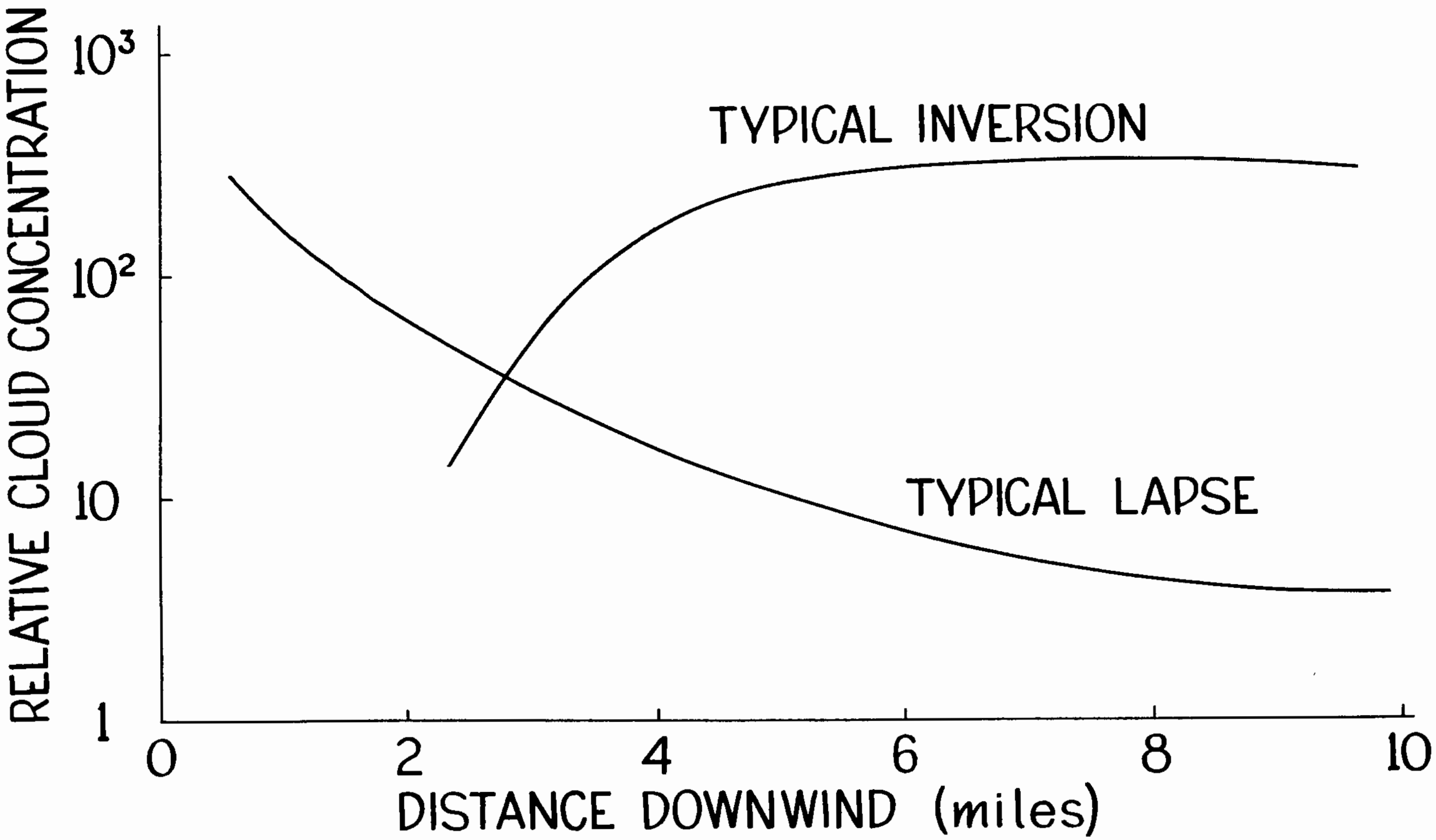
NPC 5959 A

EFFECT OF DIFFUSION CONDITION ON DOWNWIND CONCENTRATIONS

Lapse conditions lead to much larger diffusion in the vertical direction than do inversions. This fact, together with the assumption of 150-foot initial cloud height, leads to much larger ground level cloud concentrations near the release point for the typical lapse case. At large distances where the cloud has diffused to the ground, the poorer diffusion under inversion conditions leads to considerably larger cloud concentrations.

EFFECT OF DIFFUSION CONDITION ON DOWNWIND CONCENTRATIONS

GROUND LEVEL

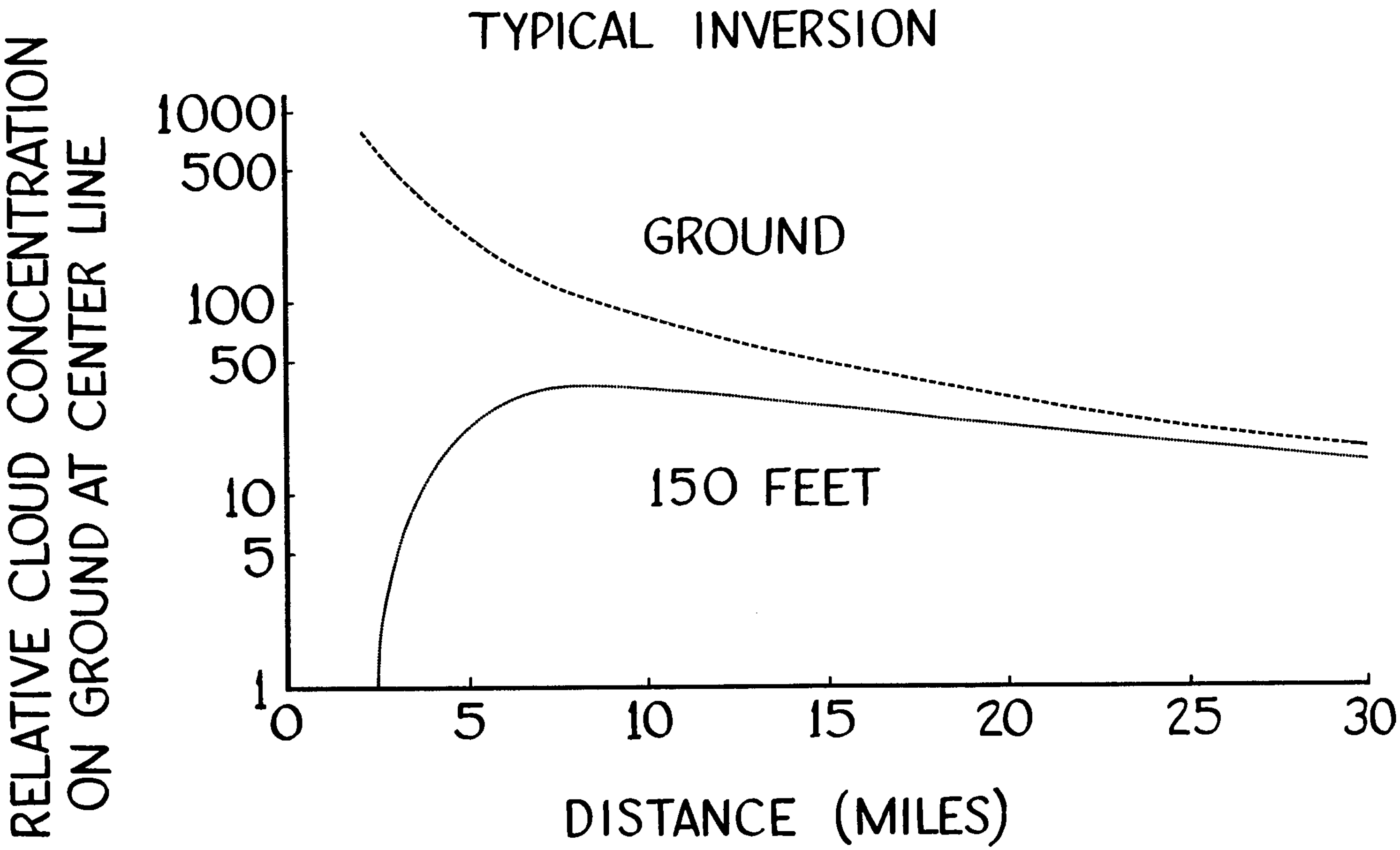


NPC 5900A

EFFECT OF SOURCE HEIGHT ON CLOUD CONCENTRATION

The effect of the initial rise of the cloud is relatively unimportant in the case of typical lapse because of the large vertical diffusion. In the case of an inversion the difference in ground level cloud concentration between an initial height of 150 feet and ground level release can be appreciable at distances up to 10 miles. From the curves it can be seen that the concentrations differ by about a factor of 5 at six miles.

EFFECT OF SOURCE HEIGHT ON CLOUD CONCENTRATION



NPC 5945

EXPERIMENTAL RESULTS ON VELOCITY OF DEPOSITION

A study of the diffusion and dry deposition theories leads to the conclusion that, for small particles, the deposition velocity (v_g) has essentially no relation to the terminal velocity of the particles in still air. This conclusion results largely from two considerations:

1. For particles whose terminal velocities are small as compared to the wind velocities encountered in the cloud, the particle position in the cloud will be governed almost totally by the wind velocity.
2. The proportionality constant v_g is at best a pseudo velocity, since it includes the probability that a particle will adhere to the surface it contacts.

The experimental data bear out these conclusions by demonstrating a dependence on the deposition surface. That iodine vapor has the largest value of v_g undoubtedly is due to its propensity to adhere to other matter.

In view of these facts, no attempt was made to predict fallout for different particle sizes. With the exception of iodine, the entire cloud inventory (aerosol and particles) was taken together and assigned the values 0.1 and 1.0 (typical of the range of experimental data). Iodine was assigned the values 0.25 and 2.5. The smaller value was considered in the belief that considerable portions of the iodine might adhere to particles in the cloud, rendering its v_g more typical of other matter.

EXPERIMENTAL RESULTS ON VELOCITY OF DEPOSITION

REF.: CHAMBERLAIN AND MEGAW U.K.A.E.A. RHM (56) 116

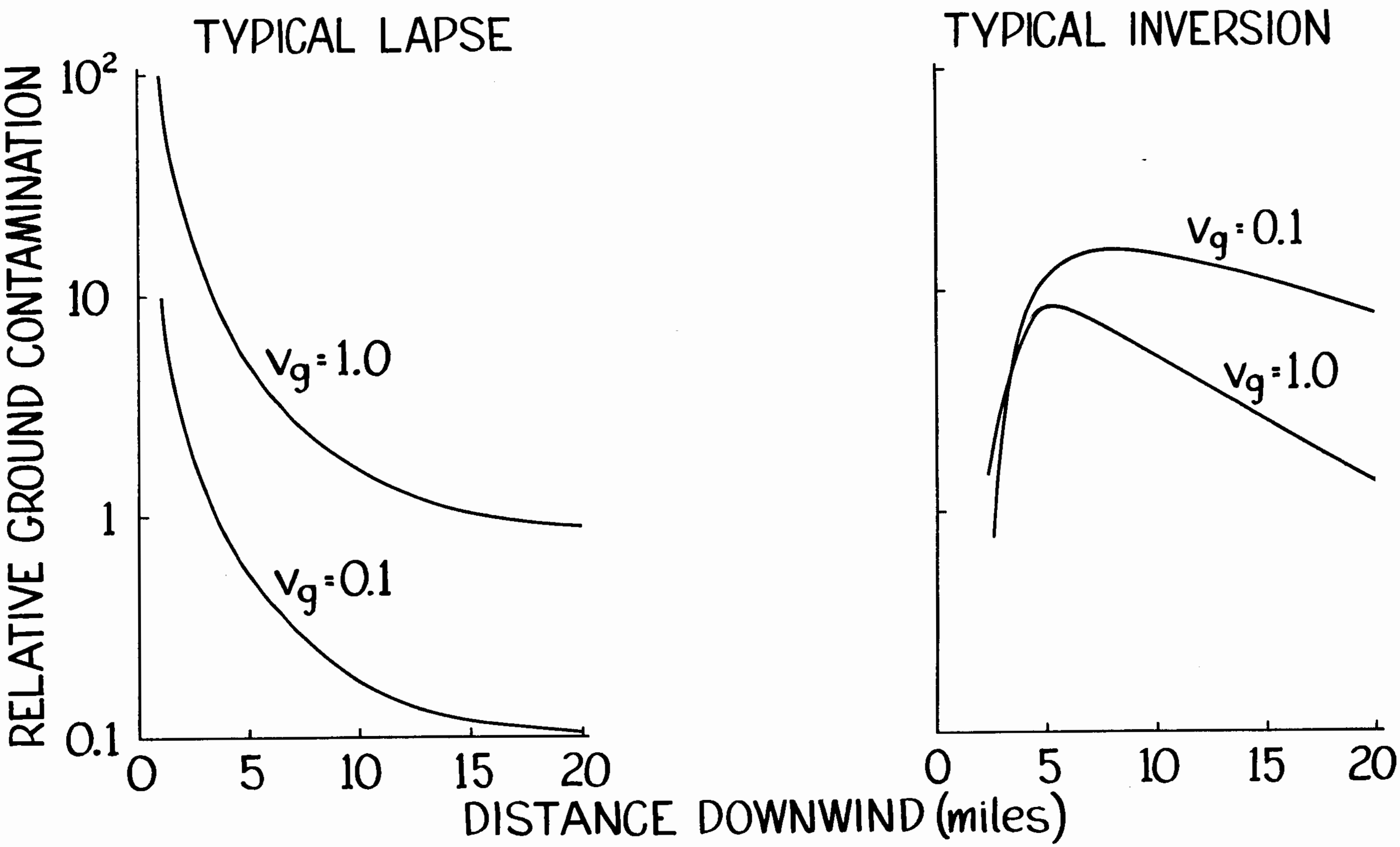
AEROSOL OR VAPOR	SURFACE	VELOCITY OF DEPOSITION V_g-CM/SEC
LYCOPODIUM SPORES (32 μ DIAM.)	GRASS AIRFIELD	1.2
I^{131} VAPOR	" "	2.5
FISSION PRODUCT AEROSOL	" "	0.1
NUCLEAR EXPLOSION DUST	GUMMED PAPER	1.0
SMOKE (AVERAGE OVER COUNTRY)	DEPOSIT GAUGE	0.8
SMOKE (LEICESTER)	" "	1.0
SMOKE (LONDON, IN FOG)	STREETS, ETC.	0.3
SO_2 (LONDON, IN FOG)	" "	0.7
SO_2 (AVERAGE OVER COUNTRY)	DEPOSIT GAUGE	0.3
SO_2 (LEICESTER)	" "	0.12

NPC 5983

EFFECT OF DEPOSITION VELOCITY ON GROUND CONTAMINATION

The predictions shown here demonstrate an interesting phenomenon. To choose values of deposition velocity which lead to conservative estimates of the extent of ground contaminations, 1.0 should be used for typical lapse conditions and 0.1 for typical inversion conditions. The reason for this lies in the fact that dry deposition depletes the cloud in the vicinity of the ground. This leads to appreciable reductions in ground level cloud concentrations for the typical inversion case, which are not present under lapse conditions due to the large vertical diffusion. The ground contamination data shown later in this presentation are, in every case, taken for the most pessimistic assumptions for the value of deposition velocity.

EFFECT OF DEPOSITION VELOCITY ON GROUND CONTAMINATION



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DEPOSITION OF AEROSOLS AND VAPORS IN RAIN

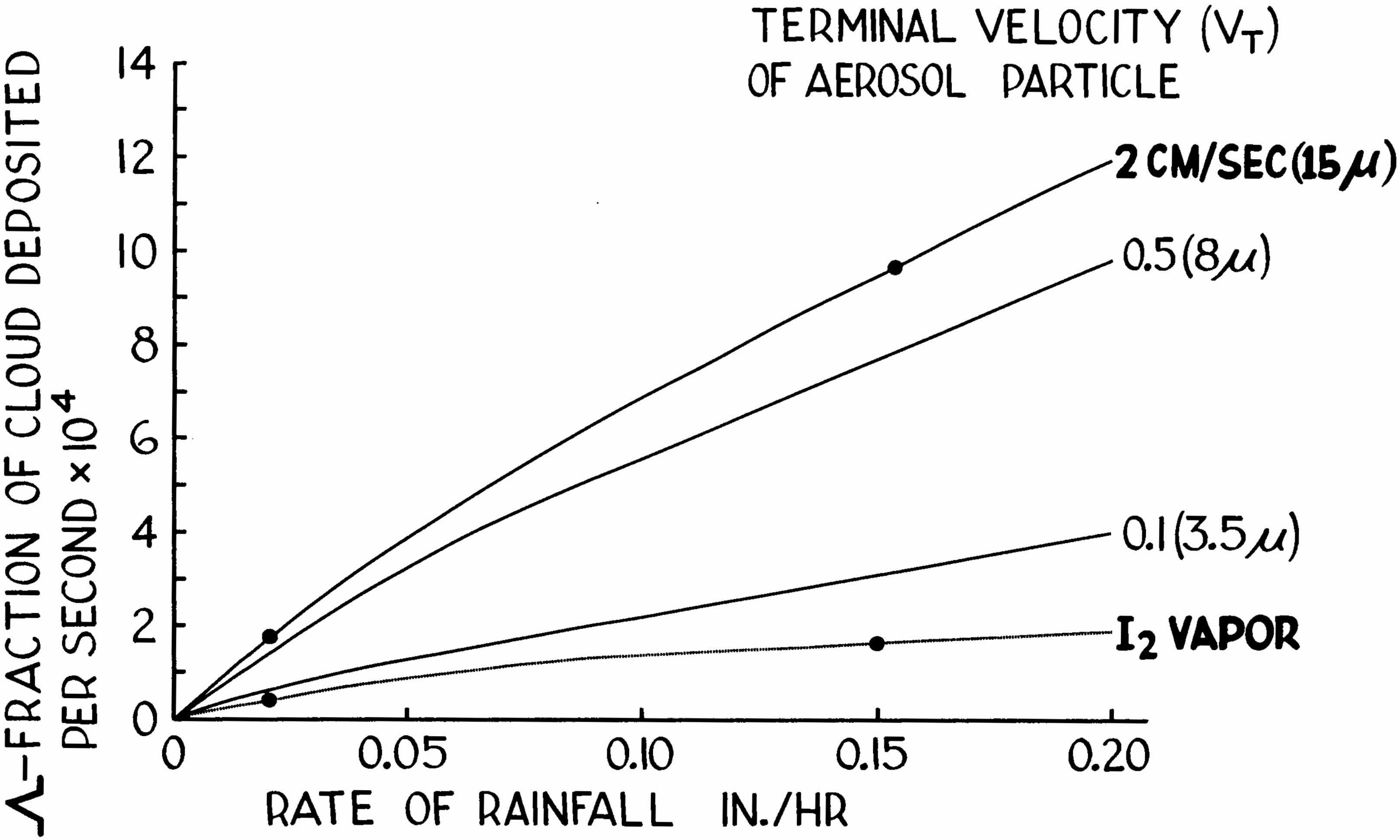
The rate of removal of particles from a cloud by rain drops is strongly dependent on the terminal velocity of the particles as well as the rate of rain fall. The information presented here shows the relation between the rate of cloud deposition (Λ), the particle terminal velocity, and the rain fall rate. Two values of Λ, 10^{-3} and 2×10^{-4}, were used for all fission products other than iodine. By the nature of the curves these values are representative of either

1. 15μ particles in rain rates of 0.15 and 0.02 in/hr, or
2. a rain rate of 0.15 in/hr for particles of 15μ and 3μ diameter.

From the curve, it can be seen that the deposition rate for iodine is expected to be roughly a factor of 2 to 4 less than the smallest value chosen for other fission products.

DEPOSITION OF AEROSOLS AND VAPORS IN RAIN

REF: CHAMBERLAIN, A.E.R.E. HP/R 1261



NPC 5912

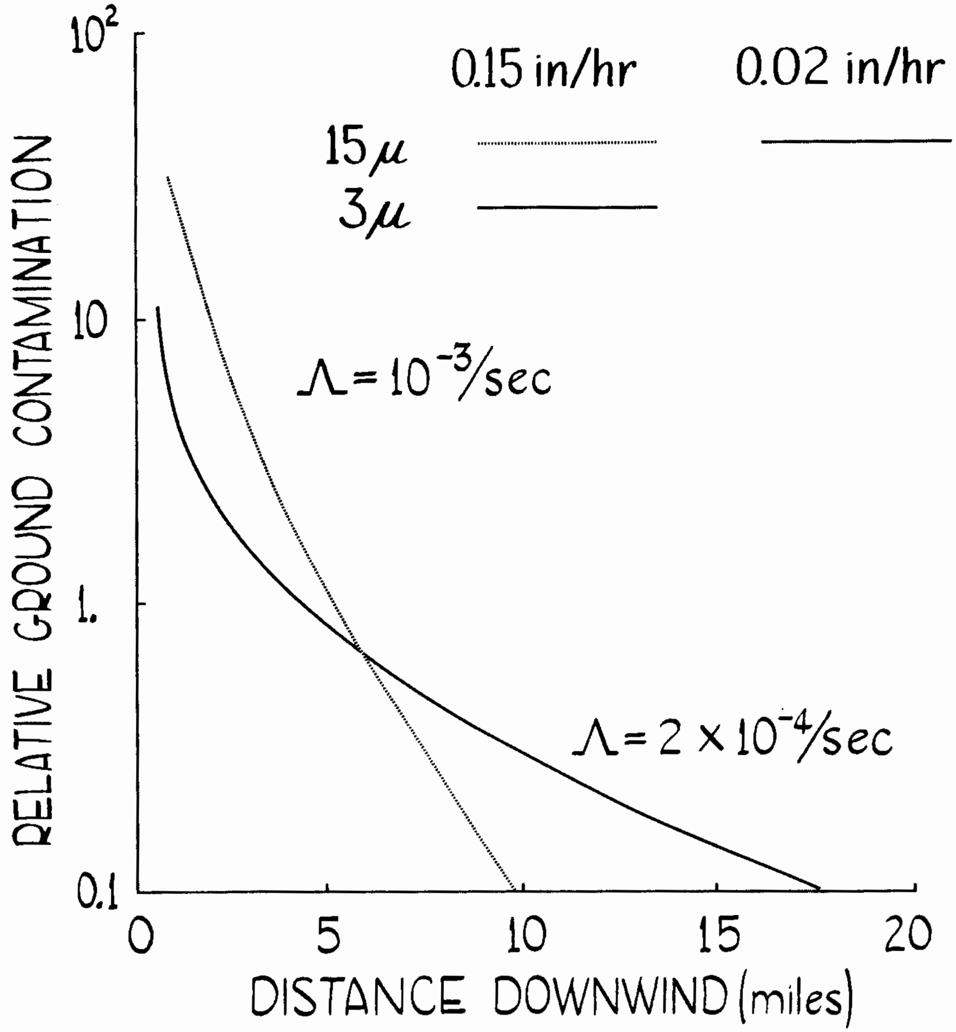
EFFECT OF WASHOUT RATE ON GROUND CONTAMINATION

The data presented here demonstrate clearly that the higher deposition rate causes less extensive ground contamination due to greater depletion of the cloud. For this reason, the smaller value has been chosen for all ground contamination data shown later in this presentation.

It should be noted here that the strong dependence on meteorological conditions of dry deposition is not present in washout, because the entire cloud is depleted rather than only that portion near the ground.

EFFECT OF WASHOUT RATE ON GROUND CONTAMINATION

TYPICAL LAPSE



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BIOLOGICAL EFFECTS

The predictions of biological effects are based on the assumption that the person stays in and breathes the cloud during its full passage. Only gamma rays are considered for external doses, and internal doses are calculated for each isotope using the methods from NBS Handbook 52. In order to estimate the total biological damage, it is assumed that the external dose and the largest single organ dose (in units of maximum permissible exposures) are additive.

BIOLOGICAL EFFECTS

- RECIPIENT IMMERSED IN CLOUD DURING FULL PASSAGE
- EXTERNAL DOSE FROM CLOUD GAMMAS
- INHALATION AND INGESTION DOSES ANALYZED BY ISOTOPES
- INHALATION DOSE CALCULATED PER NBS HANDBOOK 52 FORMULAS
- TOTAL DOSE EQUALS EXTERNAL DOSE PLUS LARGEST SINGLE ORGAN DOSE

NPC 5812

INHALATION DOSE EQUATION

In the equation shown here, the product $\chi(x,y,o)$ (BR)t f_a is the number of microcuries of a specific isotope deposited in the organ under consideration. The other factor is the dose per microcurie to the organ.

Perhaps the greatest uncertainties in the biological factors lie in the quantity f_a, the fraction of inhaled activity which is deposited in the organ of interest. Direct measurements of f_a have not been found in the literature, but meager data bearing on this problem indicate that the values of f_a currently in use may be significantly conservative.

INHALATION DOSE EQUATION

$$D = \chi_{(x,y,o)} (BR)\, t \; f_a \, \frac{\Sigma Ei\,(RBE)\,T}{m}$$

NPC 5944

DOSAGE CRITERIA

The maximum permissible exposures (MPE) and lethal exposures chosen for this study are shown here. Only in the case of whole body and bone irradiations were the predicted doses sufficiently large to approach lethal exposures.

DOSAGE CRITERIA

ORGAN	MAXIMUM PERMISSIBLE EXPOSURE (MPE)	LETHAL EXPOSURE
WHOLE BODY	25 rem	500 rem
BONE	25	500
THYROID	1500	NOT LETHAL
KIDNEY	25	——
MUSCLE	25	——
LUNG	50	——

NPC 5885

RELATIVE INTERNAL DOSES (MPE'S)

The relative internal doses in units of MPE's are shown here for the meltdown and extreme runaway cases. It can be seen that for the meltdown case and nonlethal doses, the dose to the thyroid controls (it will be shown later that no doses approaching lethality are predicted for the meltdown case). In the case of the runaway, the doses to the bone and the lung might become comparable if the fission products were extremely insoluble. Inasmuch as the extreme runaway results in a broad mixture of isotopes, it is believed that the portion of activity in soluble form will be such that the bone dose will be higher than that for the lung. It has therefore been assumed that the bone dose will control for the extreme runaway case.

RELATIVE INTERNAL DOSE (MPE's)*

	MELTDOWN	EXTREME RUNAWAY
THYROID	1.0	0.19
BONE	0.019	1.0
KIDNEY	0.0026	0.13
MUSCLE	0.00004	0.0004
LUNG	0.2	0.1

* FISSION PRODUCTS SOLUBLE

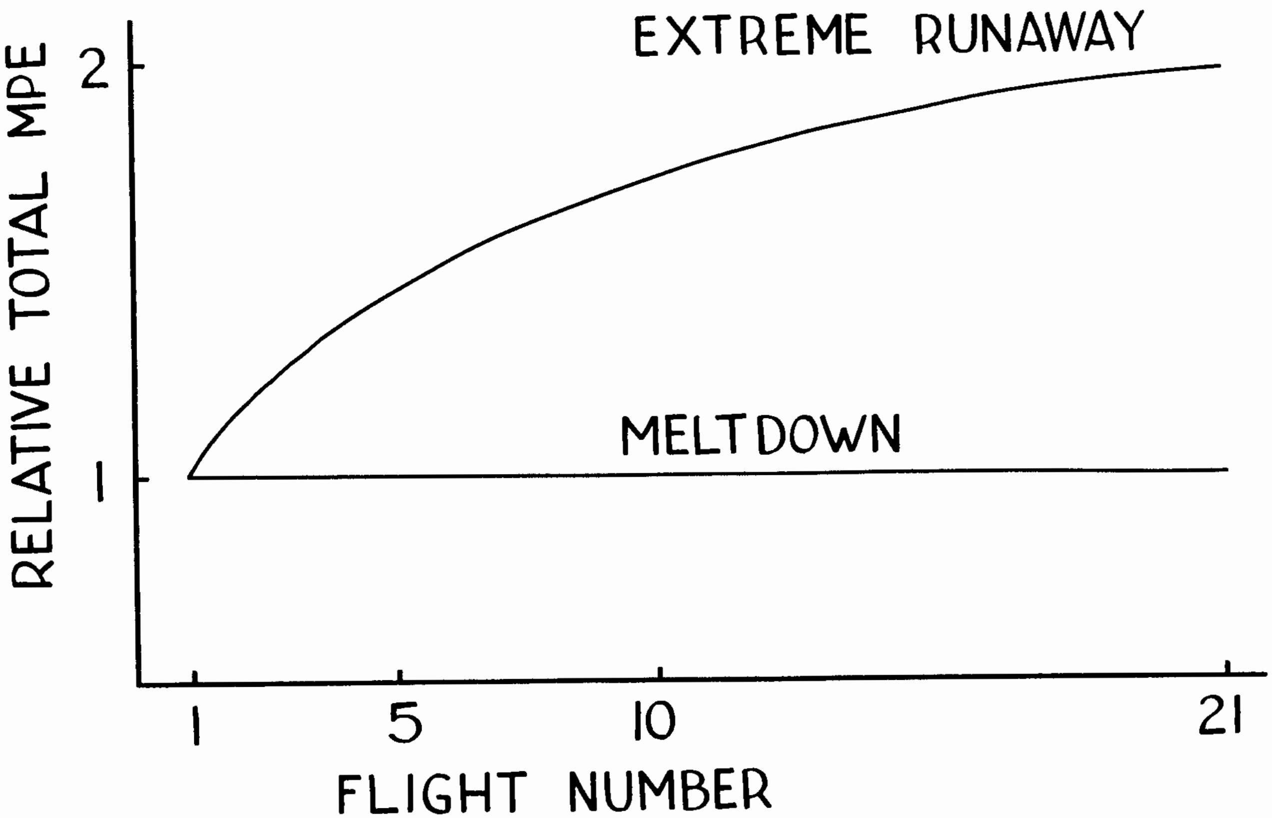
NPC 5893AB

EFFECT OF REACTOR HISTORY ON CLOUD HAZARD

The total nuclear hazard from the cloud (external plus controlling internal dose) has been considered as a function of the flight number in which the incident occurs. Both the meltdown and the extreme runaway cases have been normalized to one at the first flight. Therefore, quantitative comparison between the two curves is not meaningful. Since the total activity in the core is essentially the same at the end of each flight (shown previously), the external dose does not change. In the case of meltdown, the iodines control for the internal dose. Because of the short half-life of the iodines, the total hazard from the cloud is the same for each flight. In the runaway case, the bone dose controls. Since some of the bone seekers have long half lives, the total MPE's do increase with flight number. The somewhat surprising result that the total dose does not change more than a factor of 2 between the first and twenty-first flight is caused by two factors:

1. More than half of the bone dose is due to relatively short half-life isotopes.
2. The external dose, which does not change with flight number, is of about the same magnitude as the internal bone dose.

EFFECT OF REACTOR HISTORY ON CLOUD HAZARD



NPC 5866

RELATIVE IMPORTANCE OF GROUND CONTAMINANTS

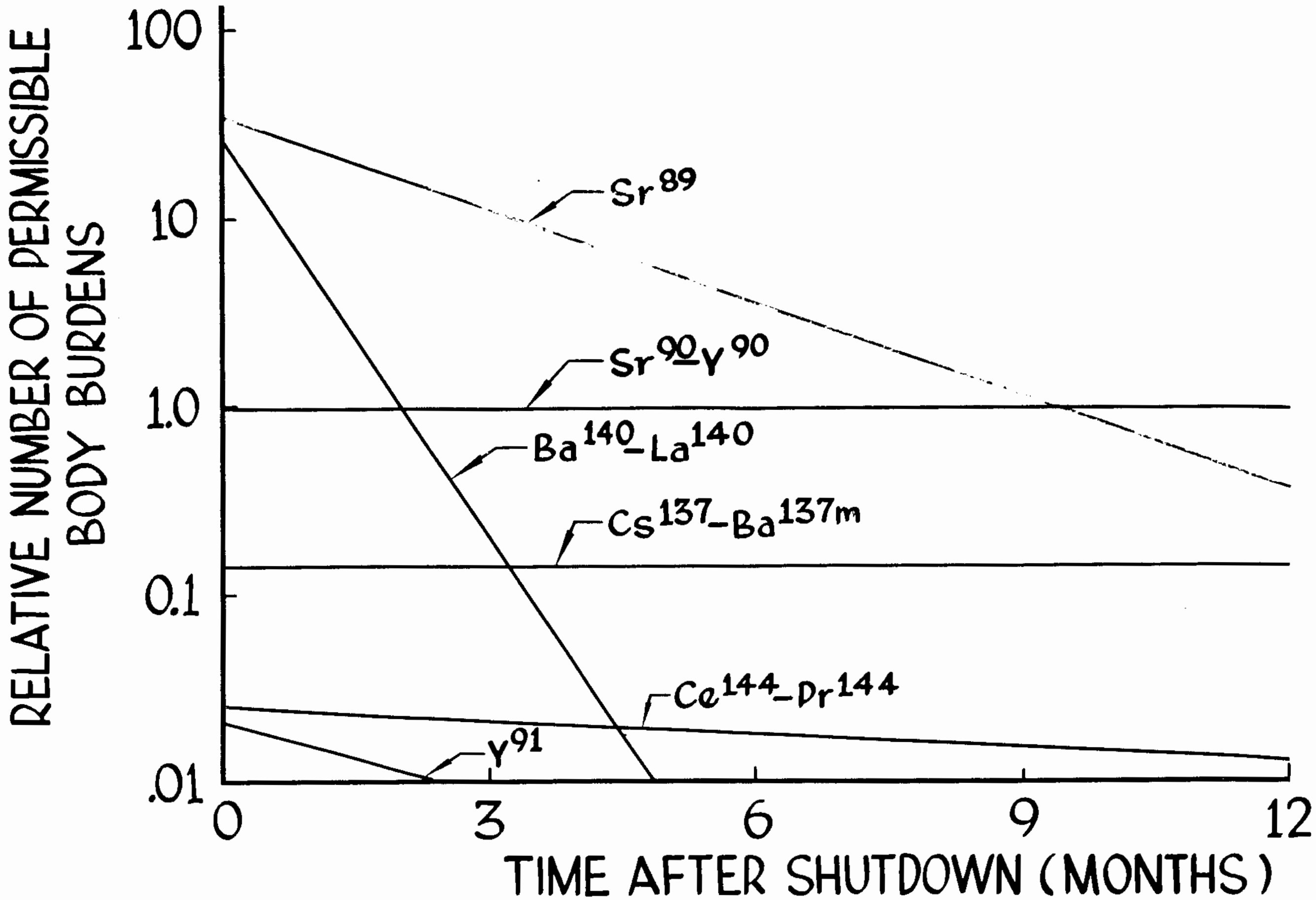
Since the reactor under consideration is not saturated, it appeared important to consider all of the bone seekers in investigating the ground contamination problem. To do this, the relative number of permissible body burdens for each isotope were calculated assuming:

1. The same proportions initially as would exist in the reactor at the end of the tenth flight.
2. Ingestion takes place at various times after shutdown.

The results, presented here, show that initially Sr^{89} and Ba^{140}-La^{140} control. But, since Sr^{90}-Y^{90} controls from nine months on and since crops would certainly be destroyed in the event of serious contamination, the contamination problem has been presented in terms of Sr^{90}-Y^{90} only.

RELATIVE IMPORTANCE OF GROUND CONTAMINANTS

MELTDOWN



NPC - 5896

EFFECTS OF GROUND CONTAMINATION

In considering the effects of ground contamination resulting from fallout of Sr^{90}, it is important to differentiate between the two mechanisms by which plants may become contaminated:

1. Sr^{90} falling directly onto the foliage of the plant
2. Uptake of Sr^{90} from the soil.

It appears that, in the case of fallout from bombs, the first mechanism is by far the most important, leading to a ratio ranging from 2 to 5 for vegetation-to-soil contamination. Direct experimental evidence leads to an average value of about 0.36 for the ratio where uptake from the soil is the only mechanism. This fact, together with additional experimental evidence for equilibrium conditions among vegetation, the milk of cows, and human bones, leads to the conclusion that the choice of an upper limit of 1 MPC in the soil is clearly conservative. After destruction of the first crop, a person could live wholly off the contaminated land for several years without reaching the recommended upper limit of 0.1 microcuries for the body burden.

EFFECTS OF GROUND CONTAMINATION

REF.: LIBBY, PROCEEDINGS OF NATIONAL ACADEMY OF SCIENCES (1956)

1MPC=1μC Sr^{90}/KG CALCIUM

	FALLOUT	UPTAKE FROM SOIL
SOIL	1 MPC	1 MPC
VEGETATION	2 to 5	0.36
MILK	0.7	0.05
HUMANS	0.7	0.05

NPC 5950

CLOUD HAZARD AND GROUND CONTAMINATION

• Meltdown

The next series of charts summarizes the best estimates of the nuclear hazards expected in the event of a meltdown of the reactor. Since this occurrence is by far the most probable serious incident, the results shown here are those used in the statistical study, which follows this presentation. The dose maps shown do not include predictions of the direct radiation from the reactor in the immediate vicinity of the crash. The danger distance for the direct radiation is comparable to that resulting from non-nuclear hazards of an aircraft crash.

CLOUD HAZARD AND GROUND CONTAMINATION

- MELTDOWN -

NPC 5925

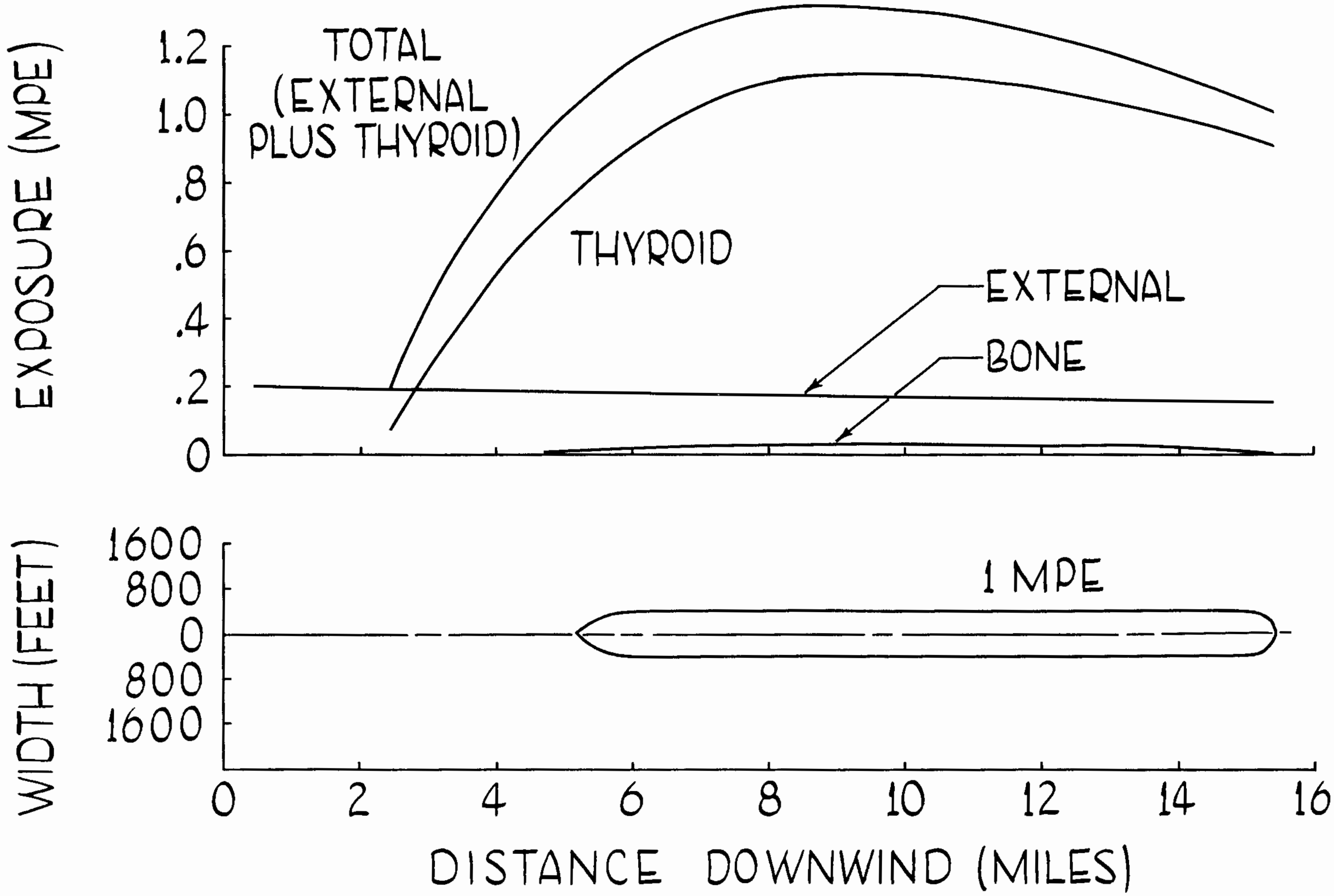
EXTENT OF CLOUD HAZARD

Meltdown · Typical Inversion

The extent of the hazard from the cloud for a meltdown incident under inversion conditions is shown here. It can be seen that the total dose (external + Thyroid) curve peaks at slightly over 1 MPE at about eight miles from the release point. Thus, inside a very narrow strip from about 5 to 15 miles the dose received from the cloud as it passed would be 1 MPE or slightly greater. The smaller doses close in to the release point are caused by the initial rise of the cloud and the poor vertical diffusion in the case of an inversion. Clearly, no lethal or near lethal doses exist anywhere for this case.

EXTENT OF CLOUD HAZARD

MELTDOWN TYPICAL INVERSION



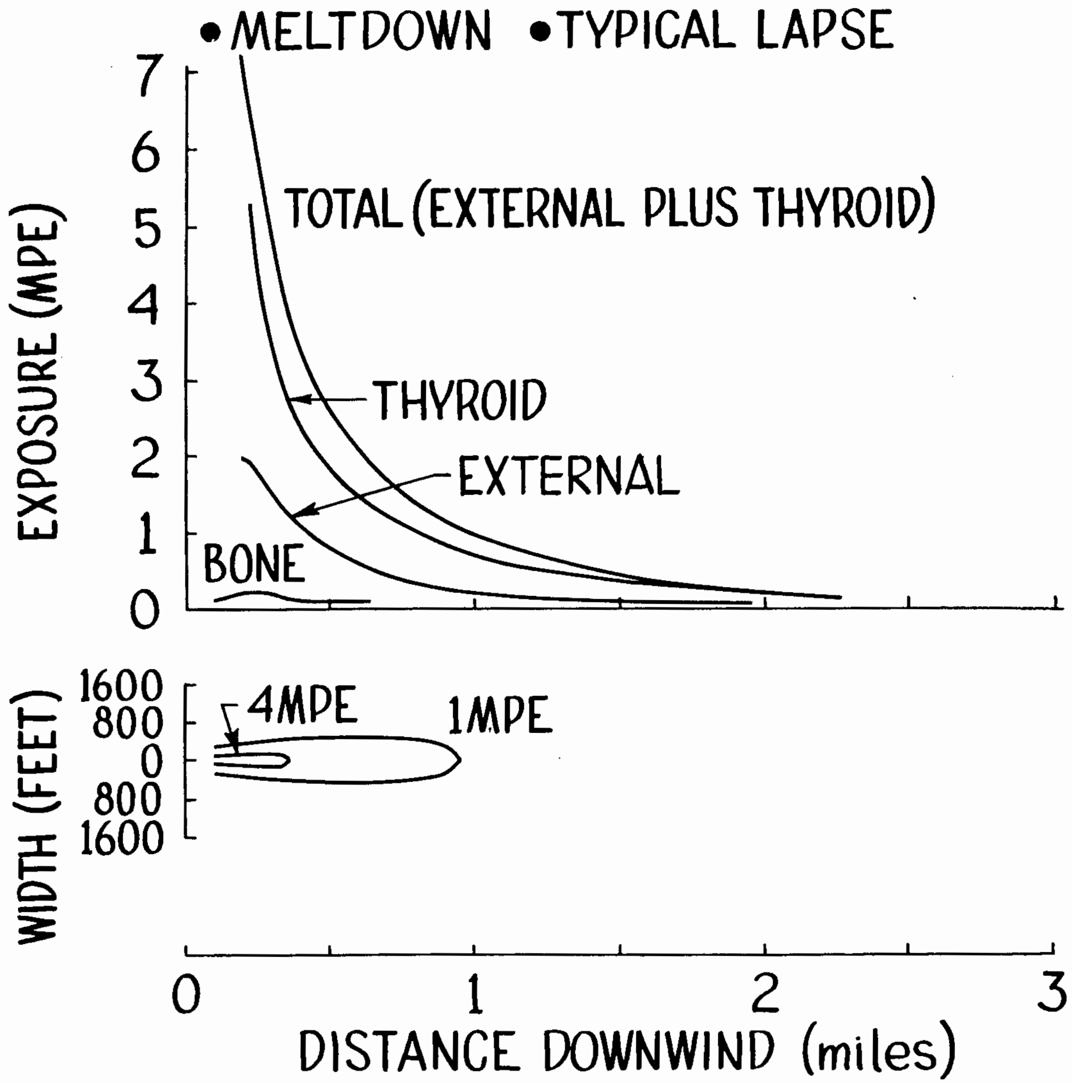
NPC-5961

EXTENT OF CLOUD HAZARD

• Meltdown • Typical Lapse

In this case, as in the case of typical inversion, the dose received by the bone is small as compared to the thyroid. Therefore, the total dose is taken to be the external plus the thyroid dose. In the case of typical lapse, the rapid vertical diffusion takes the cloud to the ground rapidly in spite of the initial rise. This situation leads to small areas within a mile from the release point inside of which a person would receive 1 MPE or greater and an even smaller area of 4 MPE or greater (a person receiving 4 MPE might possibly suffer some radiation sickness). No doses approaching lethality would occur anywhere and the good diffusion conditions would rapidly dissipate the cloud to unimportant concentrations at two miles.

EXTENT OF CLOUD HAZARD



NPC 5962

GROUND CONTAMINATION FROM DRY DEPOSITION

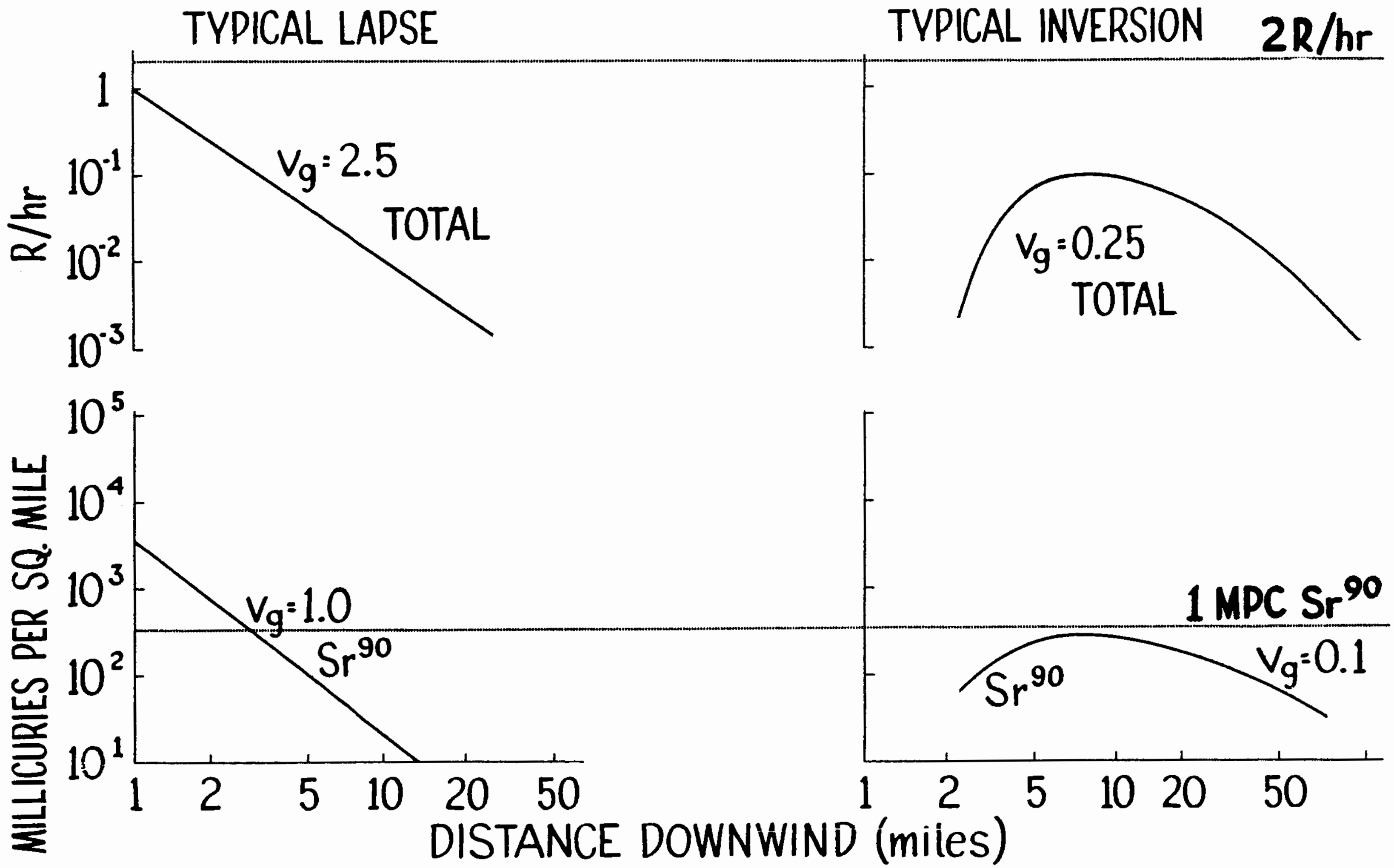
• Meltdown • 24 Hours after Release

The extent of ground contamination in dry weather is shown here. In every case, the most pessimistic value of deposition velocity has been chosen. For external gamma radiation, deposition velocities for iodine have been used since no other isotope contributes significantly. For either weather condition, the external radiation levels never reach a value which implies evacuation within 12 hours (2 R/hr). In fact, in the region from 2 to 50 miles, the values range from 1 to 3 orders of magnitude lower than 2 R/hr. This fact, together with the short half lives of the iodines, leads to relatively small hazards from external radiation.

Contamination of the ground by Sr^{90} would exceed the 1 MPC line only under typical lapse conditions and then only within 2 miles of the release point. In considering the ground contamination data, it should be remembered that these conditions exist only on narrow strips of ground downwind of the release point. More will be said of these areas later.

GROUND CONTAMINATION FROM DRY DEPOSITION

• MELTDOWN • 24 HRS AFTER RELEASE



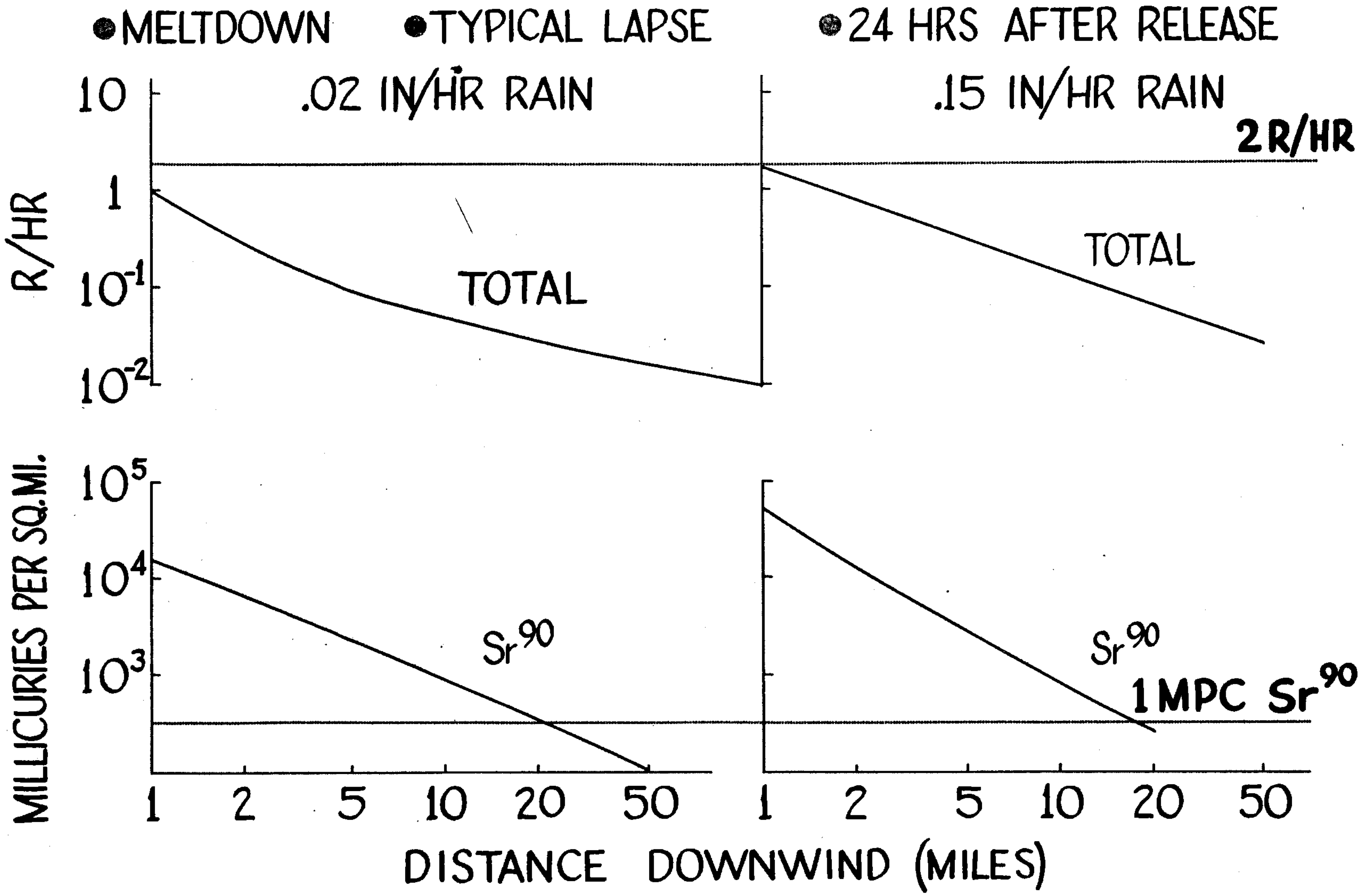
NPC 5956

GROUND CONTAMINATION FROM RAINOUT

• Meltdown • Typical Lapse • 24 Hours After Release

If the release should occur during a rain, the extent of ground contamination would be magnified. The iodines would be deposited on the ground in somewhat larger quantities than in dry weather, but the radiation levels would not exceed 2 R/hr at any point. The Sr^{90} contamination in rain would be greater than 1 MPC for distances up to 20 miles. By comparison, the heavier rain would lead to higher concentrations in close and lower concentrations past 20 miles due to cloud depletion. Results for rainout and typical inversion have not been shown here due to the relative infrequency of their simultaneous occurrence.

GROUND CONTAMINATION FROM RAINOUT



NPC 5951A

CLOUD HAZARD AND GROUND CONTAMINATION

• Extreme Runaway

The nuclear hazards in the event of an extreme runaway are presented here. In considering these results it should be borne in mind that the assumptions are so extreme that the results are clearly an upper limit of the hazards to be expected in any single accident and are not applicable to the statistical analysis.

CLOUD HAZARD
AND
GROUND CONTAMINATION
-EXTREME RUNAWAY-

NPC 5924

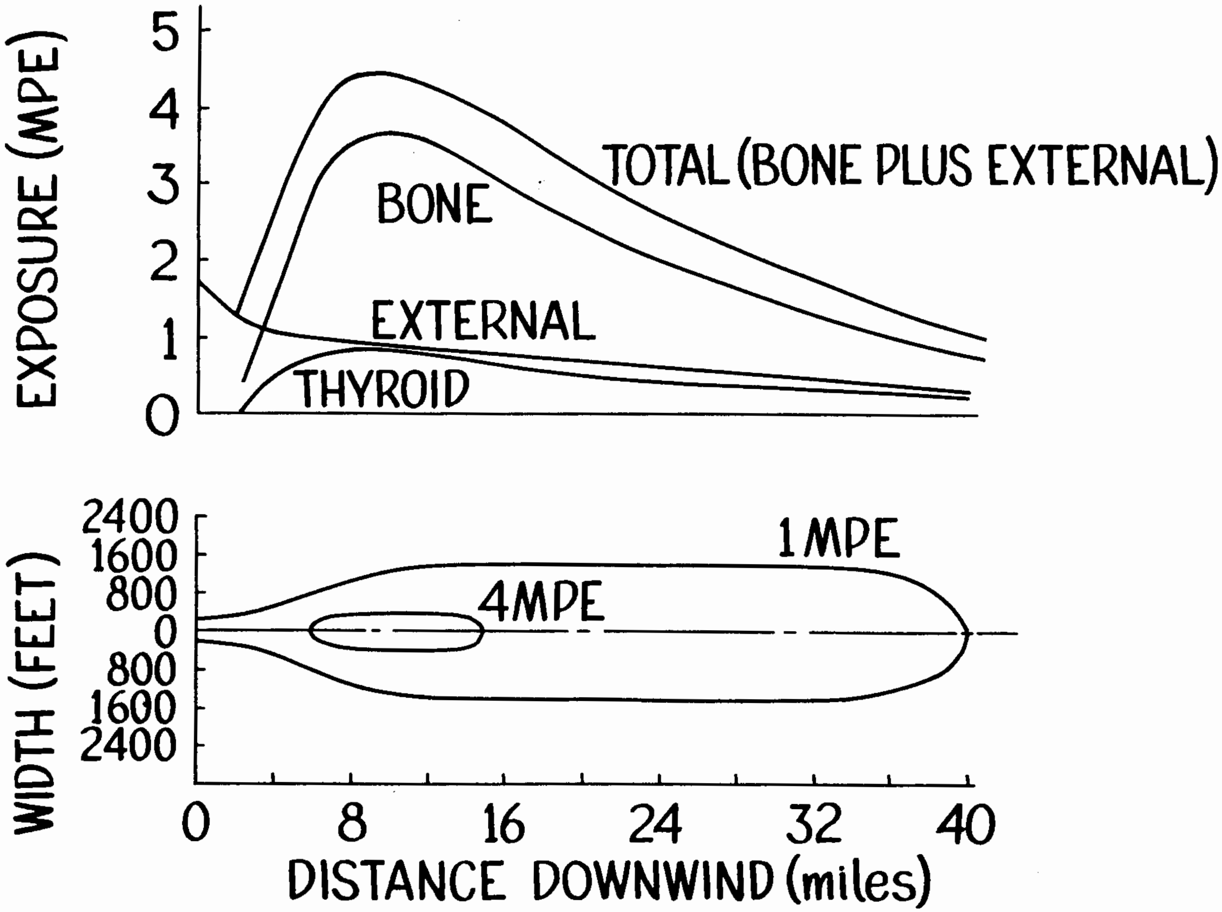
EXTENT OF CLOUD HAZARD

• Extreme Runaway • Typical Inversion

In the case of the extreme runaway the internal dose to the bone controls. Therefore, the total MPE is the sum of the external and bone doses. The extent of the hazards shown here are the greatest obtained in the study. In the case of inversions, the area in which a person would receive 1 MPE or greater extends to just under 40 miles from the release point. It should be stressed, however, that the width of the strip is only slightly more than one-half mile. Inside a considerably narrower and shorter strip, extending from about 6 to 14 miles, a dose of 4 MPE or greater would be received. At no point do the doses approach the lethal level.

EXTENT OF CLOUD HAZARD

- EXTREME RUNAWAY
- TYPICAL INVERSION

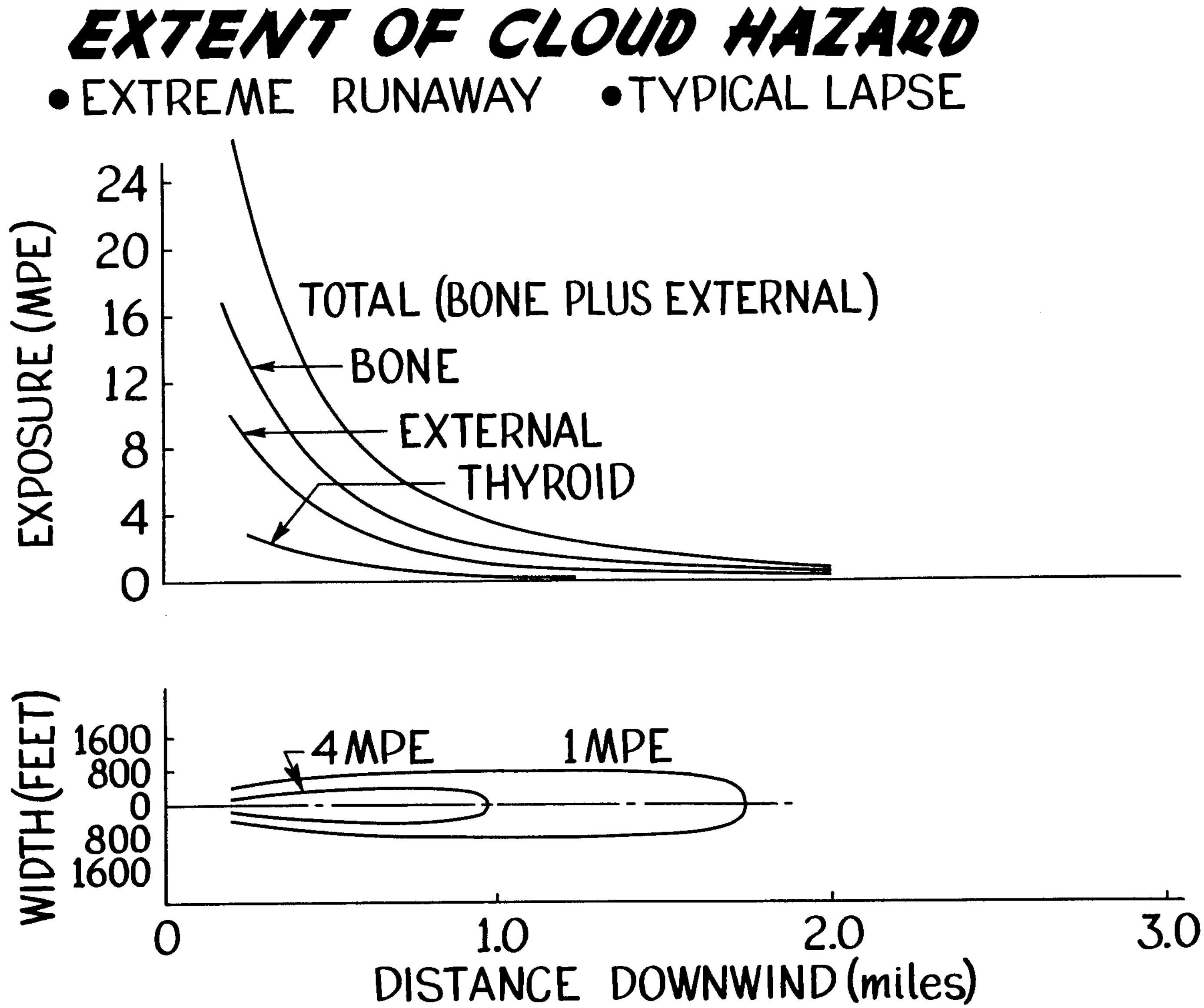


NPC 5964

EXTENT OF CLOUD HAZARD

• Extreme Runaway • Typical Lapse

In the case of typical lapse conditions for the extreme runaway case, the 4 MPE and 1 MPE isopleths do not extend past one and two miles, respectively. The large vertical diffusion in the lapse conditions imply relatively large doses at distances less than one-half mile from the point of release. No attempt has been made to specify doses precisely within less than 1/4-mile since the predictive methods tend to overestimate the doses close to the release point. This overestimate results from assuming the cloud to be a point source at zero distance.


EXTENT OF CLOUD HAZARD
• EXTREME RUNAWAY • TYPICAL LAPSE
EXPOSURE (MPE)
24
20
16
12
8
4
0
TOTAL (BONE PLUS EXTERNAL)
BONE
EXTERNAL
THYROID
WIDTH (FEET)
1600
800
0
800
1600
4 MPE
1 MPE
0
1.0
2.0
3.0
DISTANCE DOWNWIND (miles)

NPC 5965

GROUND CONTAMINATION FROM DRY DEPOSITION

Extreme Runaway • 24 Hours after Release

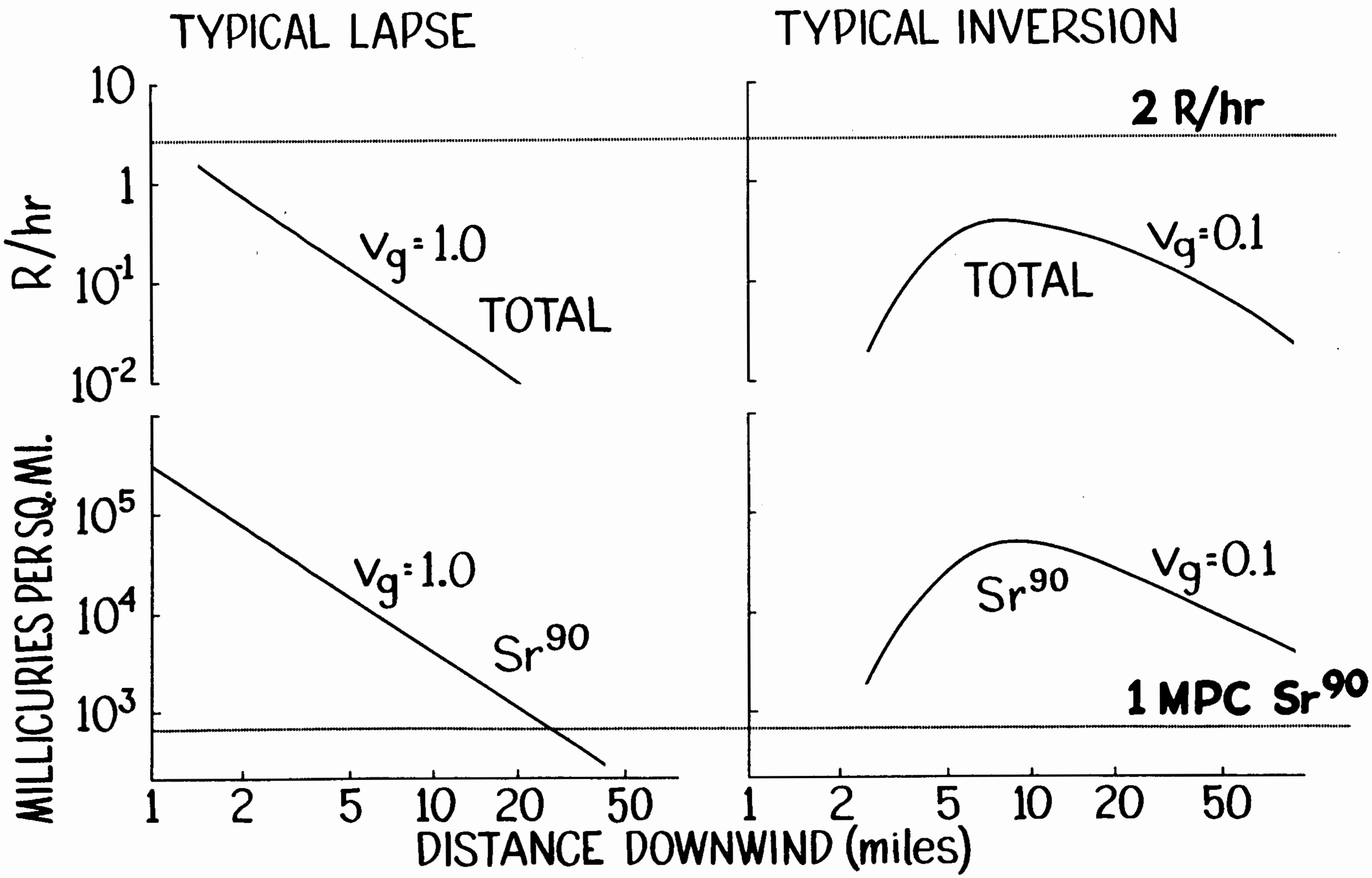
The ground contamination predicted in the case of an extreme runaway leads to the following conclusions:

1. Evacuation within 12 hours in any area due to external whole body radiation would not be required.
2. The extent of ground contamination due to fallout of Sr^{90} would be appreciable, the 1 MPE level extending to distances of 50 to 100 miles.

Apparently, in regions from 2 to 10 miles from the point of release, the ground contamination might be 1 to 2 orders of magnitude greater than 1 MPC.

GROUND CONTAMINATION FROM DRY DEPOSITION

- EXTREME RUNAWAY
- 24 HOURS AFTER RELEASE



NPC 5949

GROUND CONTAMINATION FROM RAINOUT

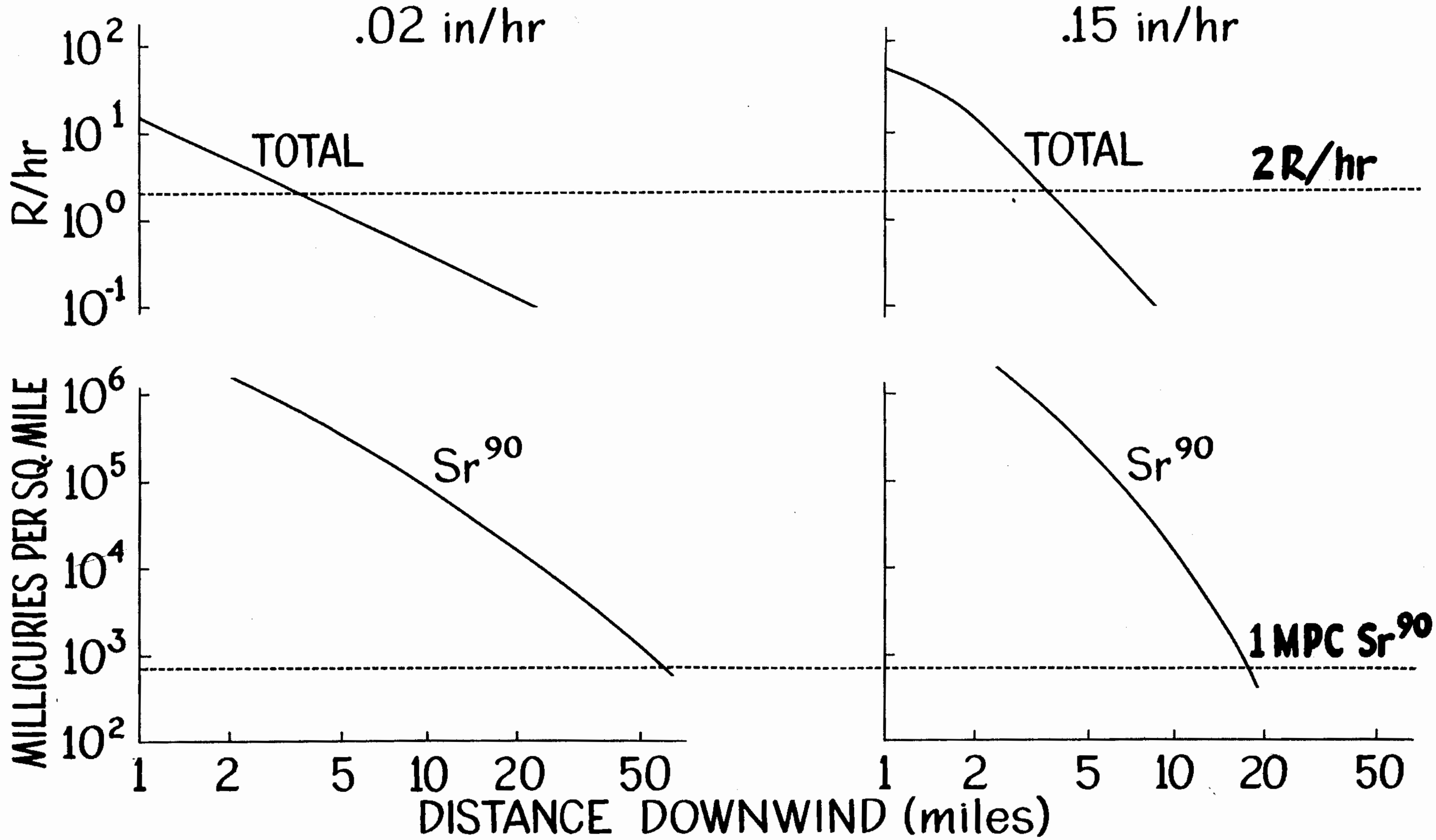
• Extreme Runaway • Typical Lapse • 24 Hours after Release

Should rain occur under extreme runaway conditions, the levels of contamination with 20 miles from the release point would be materially greater than those expected under dry conditions. However, the distances of significant contamination would, in general, be reduced because of cloud depletion. Rain conditions would lead to ground contamination which would:

1. Imply evacuation from contaminated areas as far as five miles from the release point within 12 hours.
2. Result in Sr^{90} concentrations ranging from 1 to 3 orders of magnitude greater than 1 MPE to distances of 20 to 50 miles.

GROUND CONTAMINATION FROM RAINOUT

EXTREME RUNAWAY TYPICAL LAPSE 24 HRS. AFTER RELEASE



NPC 5948AB

SUMMARY

It appears that a good criterion for evaluating the extent of hazard from a nuclear incident is a comparison of areas affected. This is particularly true in the case of ground contamination. The next two charts summarize the results of this study in terms of areas affected.

SUMMARY

NDC 5957

COMPARISON OF RELEASE MODELS

• Areas Affected • Typical Inversions

In comparing the final results of the two release models, the most important point to be made is that in no case do the predictions imply lethal doses to civilian population. Even under the worst meteorological conditions assumed, the areas in which people would receive 1 MPE or greater are small, 1.5 and 14.5 square miles for the meltdown and extreme runaway cases, respectively. The greatest area affected under the worst combination of circumstances considered is 150 square miles. This area represents the Sr^{90} contamination for the extreme runaway case under inversion conditions.

COMPARISON OF RELEASE MODELS

• AREAS AFFECTED • TYPICAL INVERSION

	MELTDOWN	EXTREME RUNAWAY
CLOUD EXPOSURE		
LETHAL	0 SQ. MI.	0 SQ. MI.
1 MPE	1.5	14.5
GROUND CONTAMINATION		
2 R/hr	0	0
1 MPC Sr^{90}	0	150

NPC 5946

COMPARISON OF MOST PROBABLE INCIDENTS

• Areas Affected • Meltdown

This chart shows the final results for the most probable nuclear accidents - meltdown under typical lapse and inversion conditions. Nowhere do lethal or near-lethal doses occur. One MPE can be expected in areas no larger than two square miles. No areas exist in which evacuation would have to occur within the first 12 hours, and the areas affected by Sr^{90} contamination range from only one to five square miles.

In conclusion it is believed that the results from this study are considerably more realistic than those which have been obtained in the past. Yet a very careful attempt to retain a degree of conservatism in each phase of the assumptions and predictions has probably led to a very considerable overestimate of the hazards.

COMPARISON OF MOST PROBABLE INCIDENTS

• AREAS AFFECTED • MELTDOWN

	TYPICAL LAPSE	TYPICAL INVERSION
CLOUD EXPOSURE		
LETHAL	0 SQ. MI.	0 SQ. MI.
1 MPE	0.1	1.5
DRY DEPOSITION		
2 R/hr	0	0
1 MPC Sr^{90}	1.2	0
RAINOUT		
2 R/hr	0	—
1 MPC Sr^{90}	4.5	—

NPC 5947

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PD-3526

SAFETY OF NUCLEAR POWERED AIRCRAFT OPERATIONS

Scope:

- AIRCRAFT ACCIDENT MODEL
- OPERATIONAL CONCEPT FOR NUCLEAR AIRCRAFT
- PROBABLE NUMBERS OF PEOPLE AFFECTED BY NEAR OR ON BASE ACCIDENTS.
- PROBABLE NUMBERS OF PEOPLE AFFECTED BY IN-FLIGHT ACCIDENTS.
- NUMBER OF PEOPLE AFFECTED BY WORST CREDIBLE ACCIDENT.
- NUMBER OF PEOPLE AFFECTED ASSUMING THE ACTUAL ACCIDENT HISTORY OF FOUR JET BOMBER WINGS.

JET BOMBER ACCIDENT MODEL

The statistics of existing jet bomber accident experience are used to develop statistical models for nuclear aircraft accidents.

Accidents are divided into four categories:

- Landing - those accidents concerned with approach (three miles from runway), flare-out, and roll.
- Take-Off - those accidents from beginning to roll to three miles beyond end of runway.
- Pattern - those accidents occurring within 15 miles of the base that are not included in the first two categories.
- In-Flight - accidents occurring beyond 15 miles from the base.

This model includes accidents including training, testing, and operation of the first three jet bomber models in the USAF. This covers a period when bomber pilot transitioned from propeller to jet aircraft.

PD-2726

JET BOMBER ACCIDENT RATES

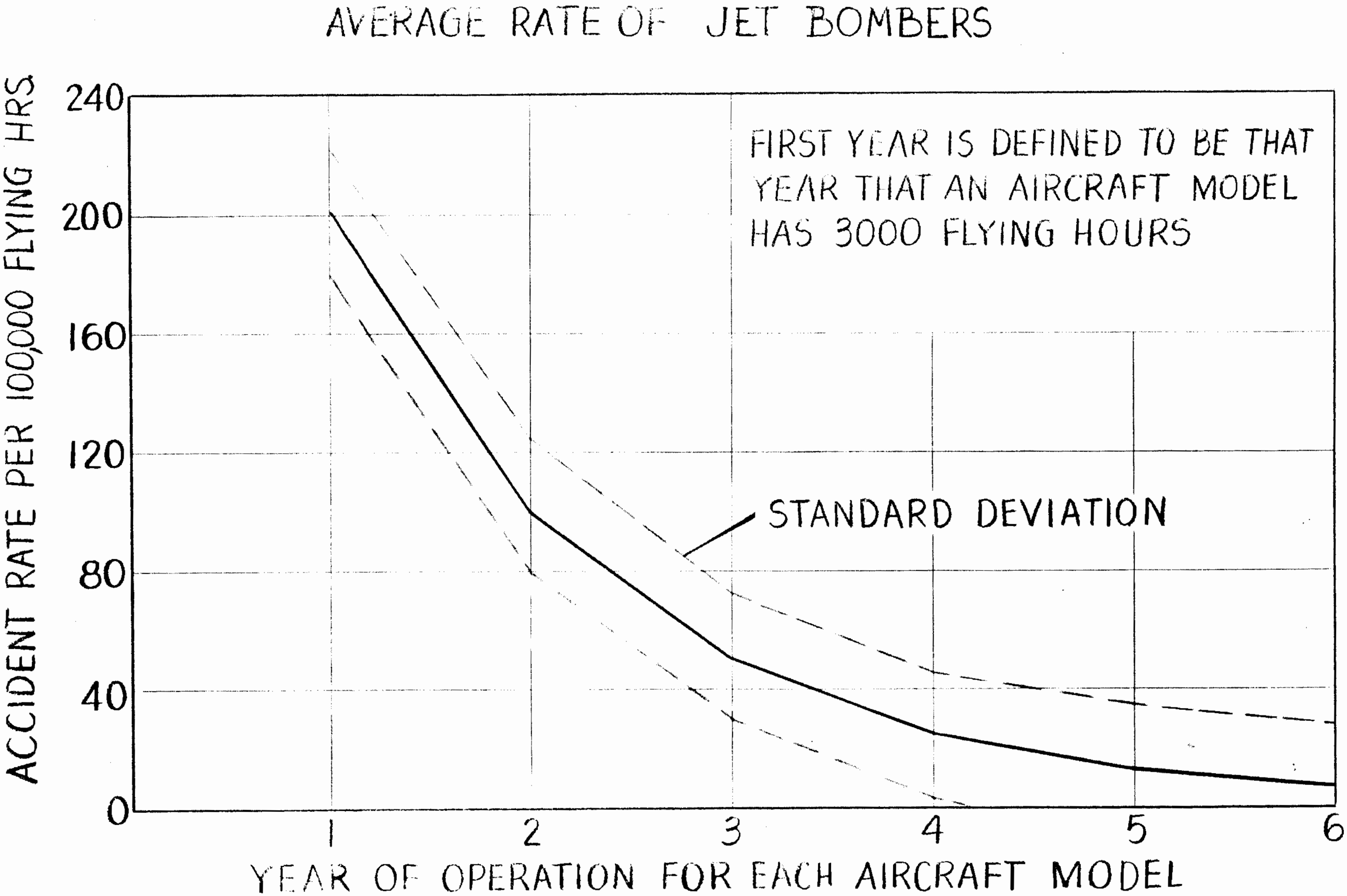
1952 - 1956

PHASE OF OPERATION	AVERAGE PER YEAR	STD'D. DEVIATION BY YEAR
Landing	1.831/10,000 Landings	0.878
Take-offs	0.700/10,000 Take-offs	0.126
Pattern	0.180/10,000 Landings	0.050
In-Flight*	2.650/100,000 Flying Hrs.	1.460

* The in flight rate does not include formation in-flight refueling, and out-of-fuel type accidents. (Reference 4)

The accident rates of the early years of aircraft operation include testing, transition, and initial training of combat organizations. Thus, the rates decrease with aircraft maturity and the numbers of operational aircraft usually increase. The rate chosen for this model was an average rate which coincided with the third year of operation shown in the maturity chart.

AVERAGE ACCIDENT RATE VS YEAR OF OPERATION

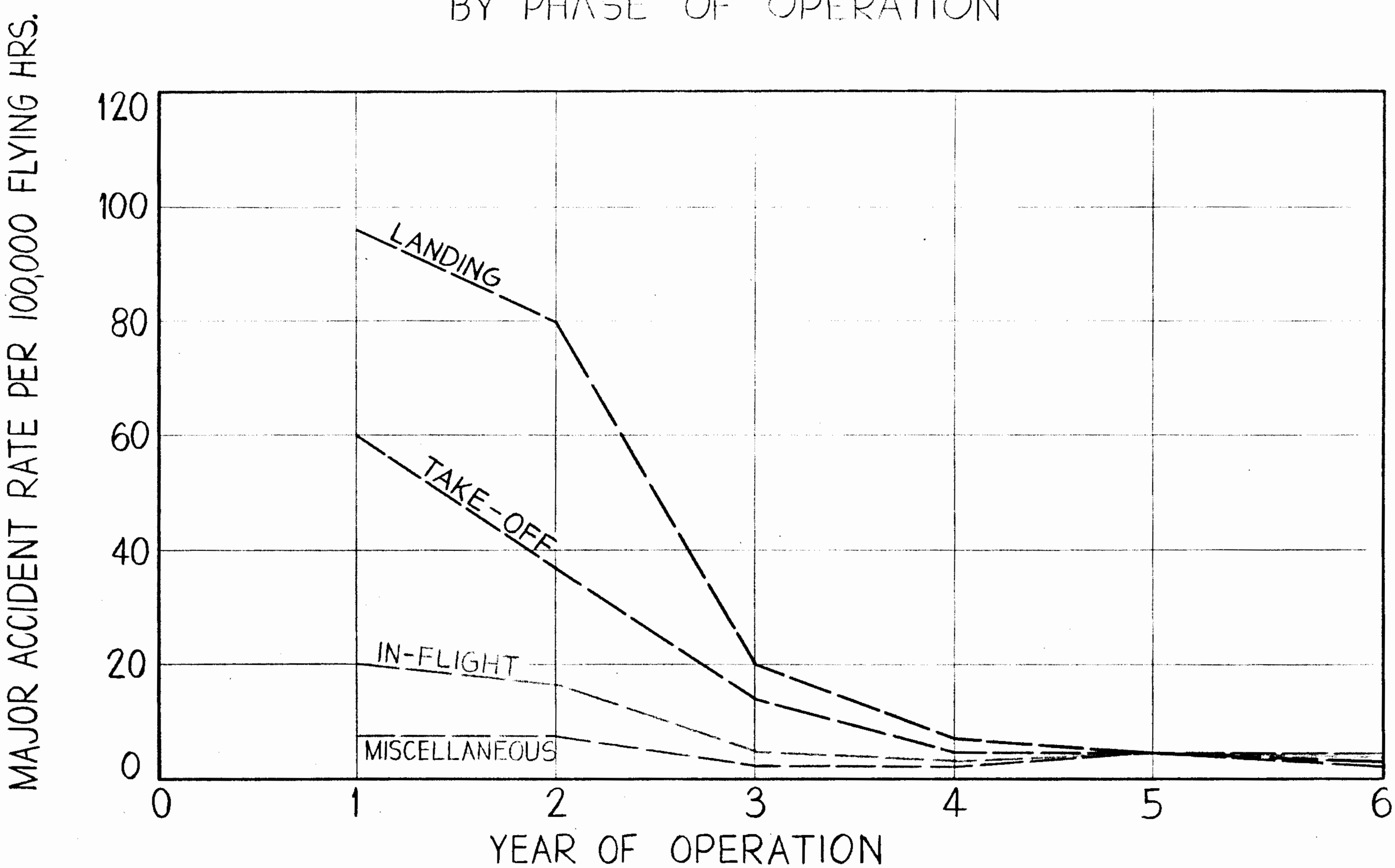


The accident rate by phase of operation decreases with the maturity of the aircraft.

PD 2961

AVERAGE ACCIDENT RATE VS YEAR OF OPERATION

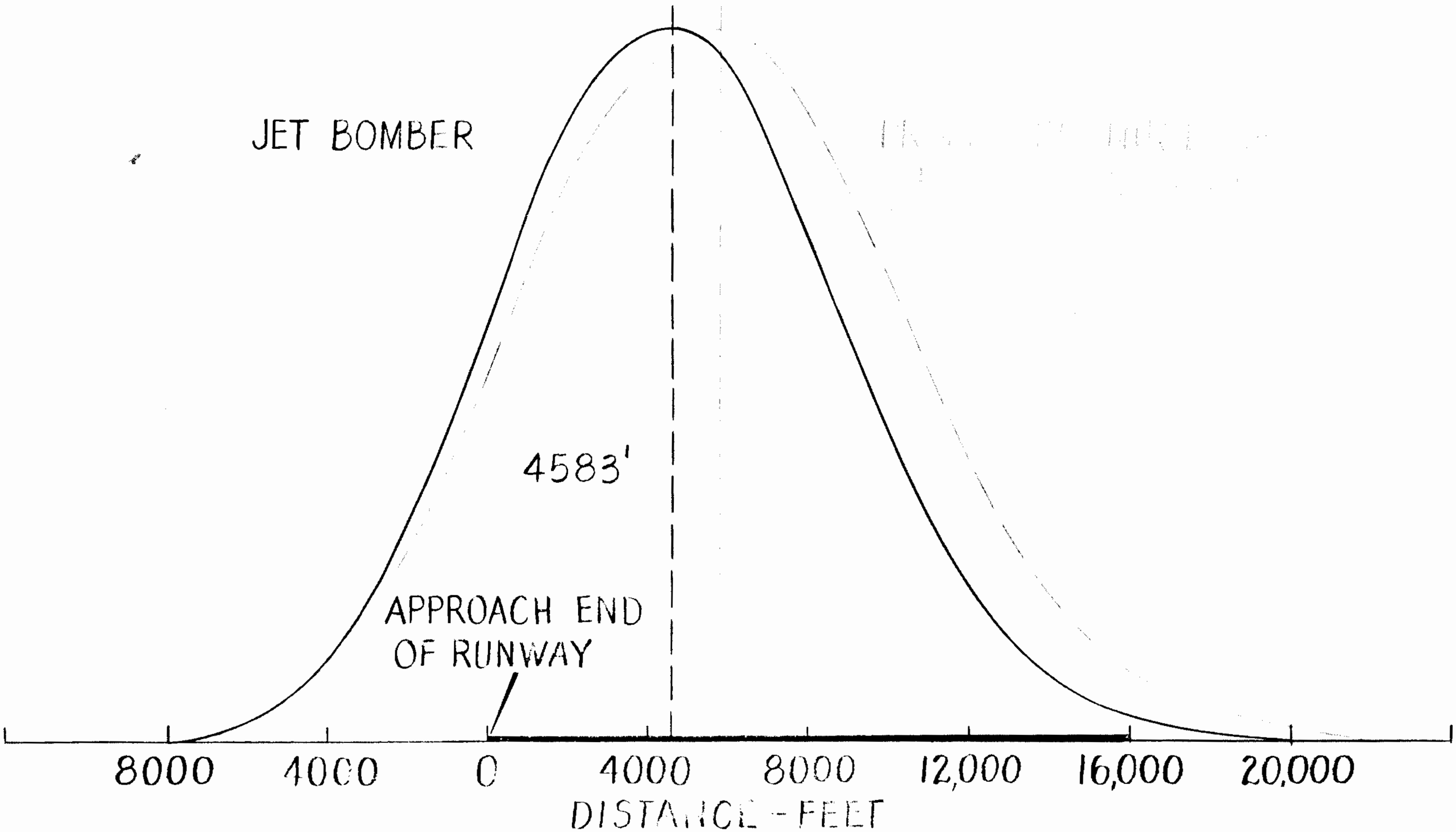
BY PHASE OF OPERATION



The solid line represents the placement distribution of present jet bomber landing accidents on the runway. The dashed line is the projected distribution for nuclear powered aircraft based on placements vs landing speeds of various bombers.

PD-3396

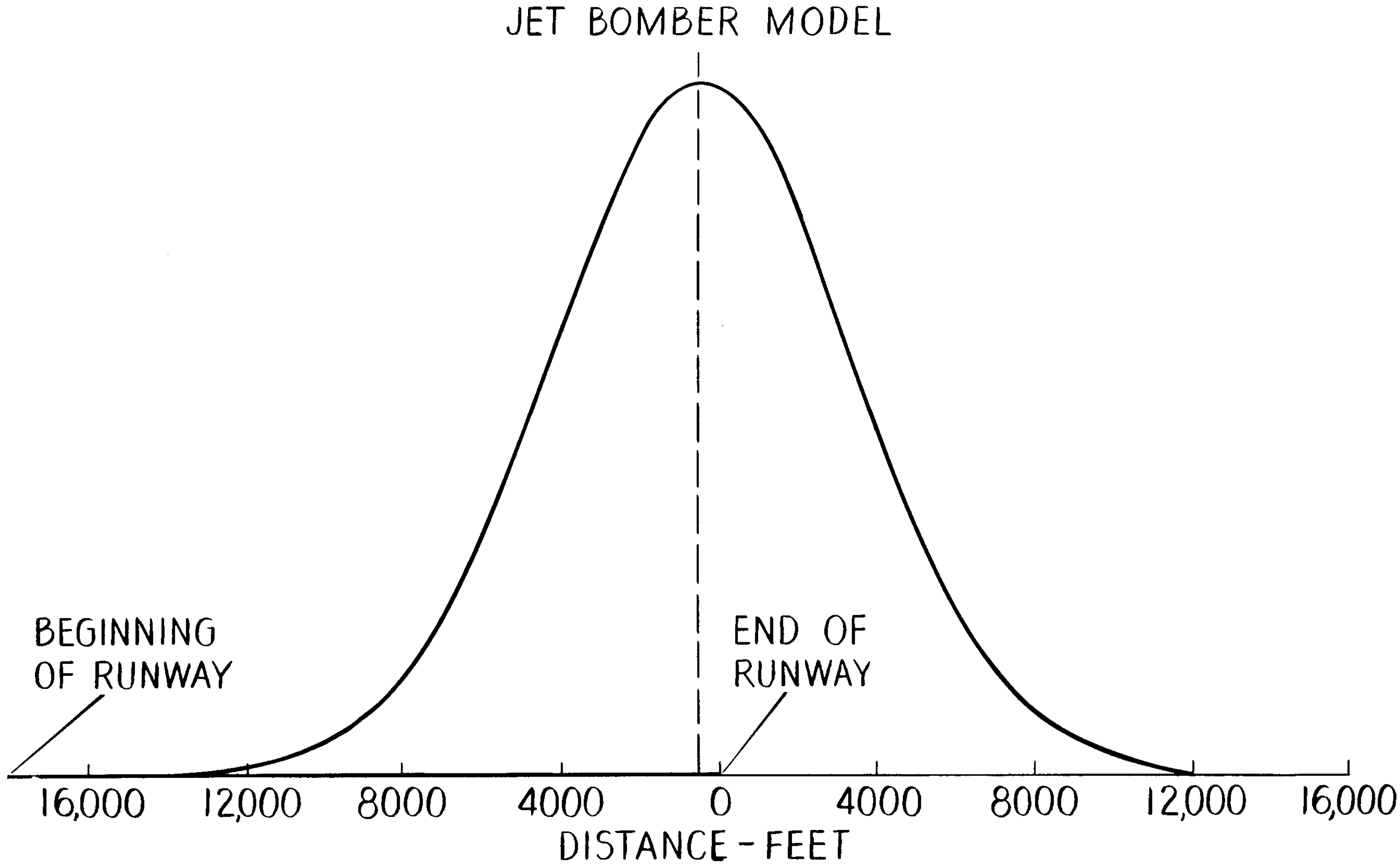
PROBABLE DISTRIBUTION OF LANDING ACCIDENTS



The distribution of take-off accidents is Gaussian with the mean point at the opposite end of the runway from which the take-off roll is begun.

PD-3397

PROBABLE DISTRIBUTION OF TAKE-OFF ACCIDENTS

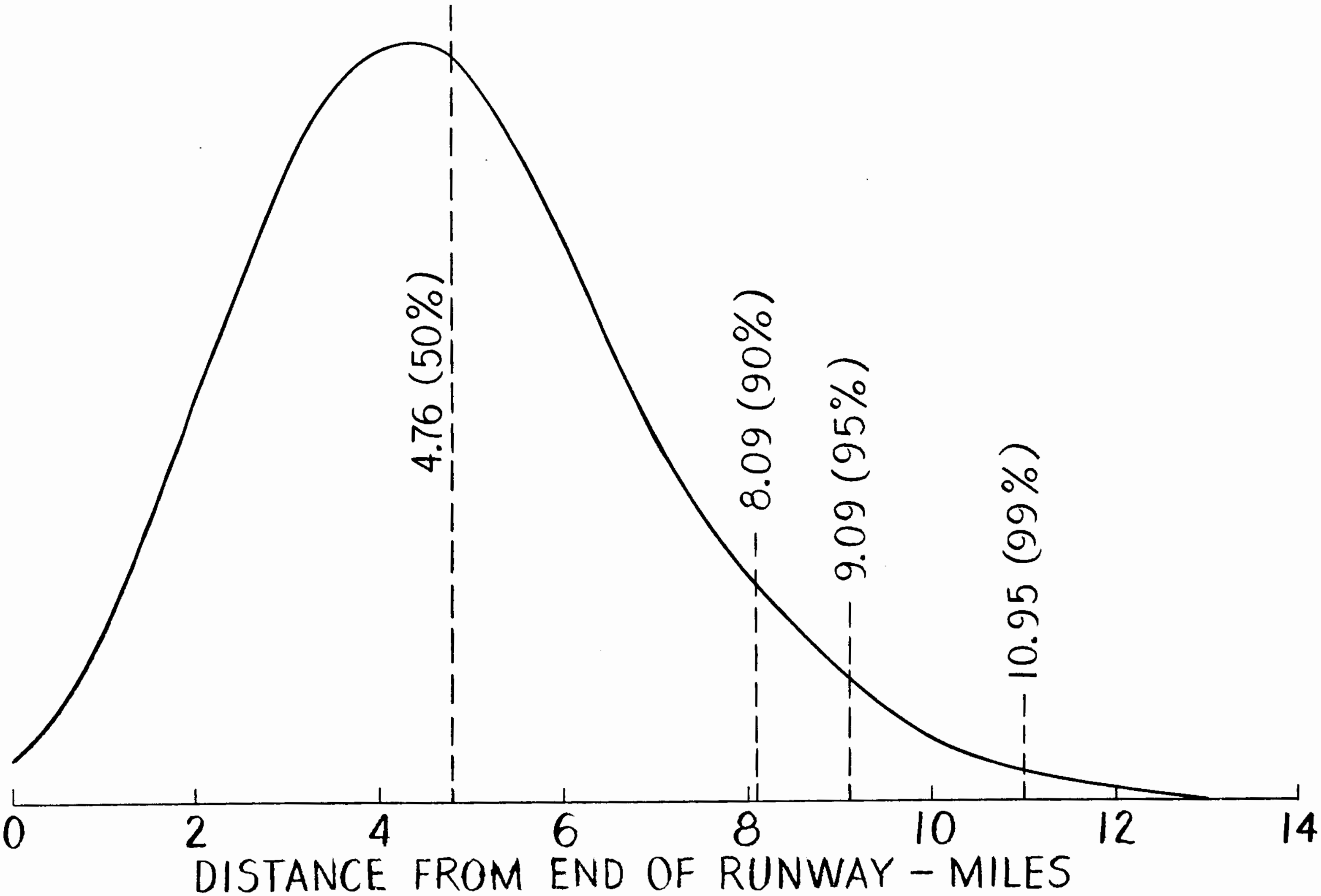


The mean placement of pattern accidents is about five miles from the end of the runway. A distance of 11 miles from the end of the runway contains 99% of the accidents.

PD 2779

PROBABLE DISTRIBUTION OF PATTERN ACCIDENTS

JET BOMBER MODEL



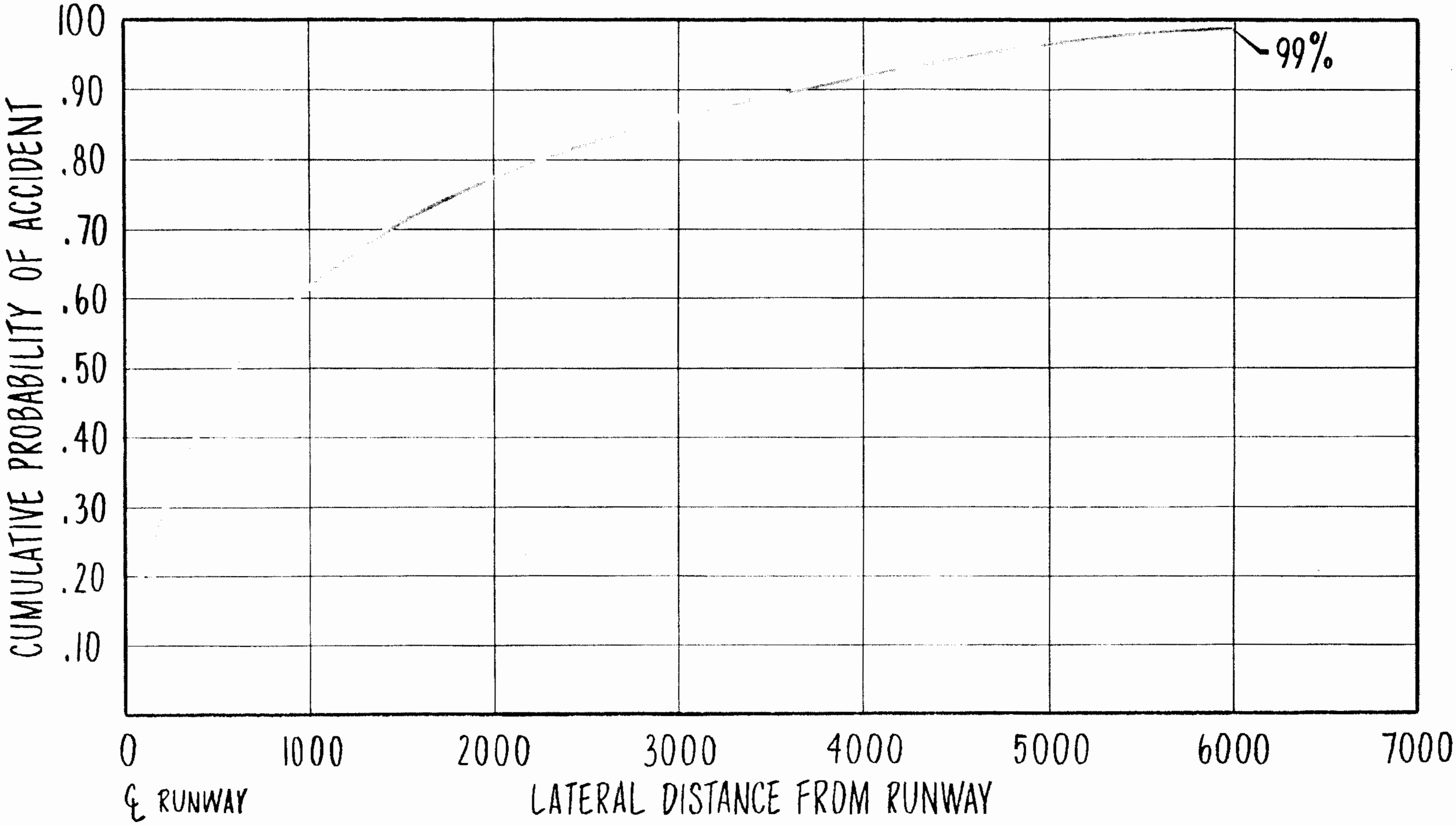
The lateral distribution represents the placement of aircraft accidents with respect to the centerline of the runway. This includes landing, take-off, and pattern accidents.

2778

PROBABLE LATERAL DISTRIBUTION OF ACCIDENTS

NEAR OR ON THE BASE

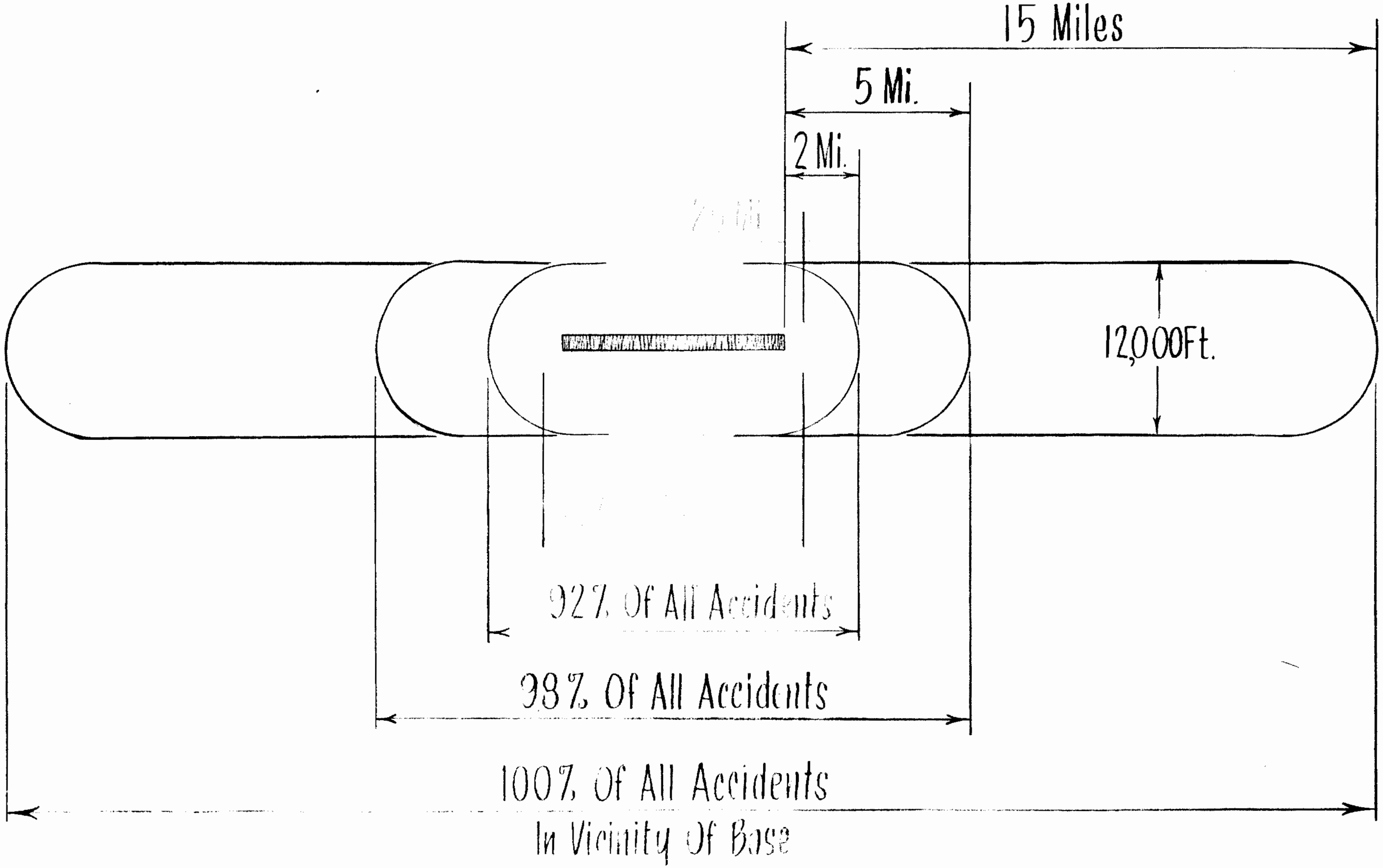
JET BOMBER MODEL



The distribution of all accidents near or on the base is represented by this summary of accident distribution. This includes landing, take-off, and pattern accidents.

PD-3424

WHERE ACCIDENTS OCCUR



In-flight accidents (away from base) exclude certain accidents peculiar to chemical powered aircraft. Allowance for accidents peculiar to nuclear powered aircraft are made as shown later in the presentation.

PD 2978

IN-FLIGHT ACCIDENTS OF JET BOMBERS 1953-1956

CATEGORY OF ACCIDENT	PERCENT OF TOTAL
*1. ACCIDENTS RESULTING IN NORMAL LANDING	10.00
*2. ACCIDENTS DUE TO SPECIFIC OPERATION (REFUELING ETC.)	34.00
*3. OUT OF FUEL	8.00
4. MID AIR COLLISIONS	10.00
5. OTHER MATERIAL FAILURES	6.00
6. IN-FLIGHT FIRES	10.00
7. LOST AT SEA	6.00
8. REASON UNKNOWN	16.00
TOTAL	100.00

(REFERENCE -5)

* EXCLUDED FROM HAZARD ANALYSIS

One concept of a nuclear powered aircraft would be a supersonic aluminum airplane with low altitude capability. For purposes of this study, it will be considered to incorporate a General Electric XMA-1 nuclear power package in conjunction with wing tip mounted conventional jet engines.

As such, the aircraft could maintain level cruise flight with the XMA-1 operating on either nuclear or chemical power (JP-4) or with the outboard chemical engines alone. It could also make complete flights of approximately four hours duration on chemical fuel alone.

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One of many general operational concepts for nuclear powered aircraft has been selected as a basis for this study. It consists, in general, of the following:

1. Aircraft carrying cold reactors (i.e. reactors with low fission product inventory) could be flown on chemical fuel out of most SAC bases in the U.S.
2. Training, dispersal, and readiness procedures would be similar to those of chemical bombers and would be conducted on chemical power from existing bases with cold reactors aboard. In the event of war, all aircraft could take off from these bases on nuclear powered missions.
3. For nuclear training, aircraft would be returned to one or more special nuclear bases.
4. All nuclear training flights would originate from the nuclear bases.
5. All nuclear training flights would leave and return to the nuclear bases through selected corridors.
6. Long endurance nuclear flights would be conducted over water or uninhabited areas.
7. For this study each aircraft will be considered to operate about 50% of the flying time on chemical power with cold reactor, and 50% on nuclear power.

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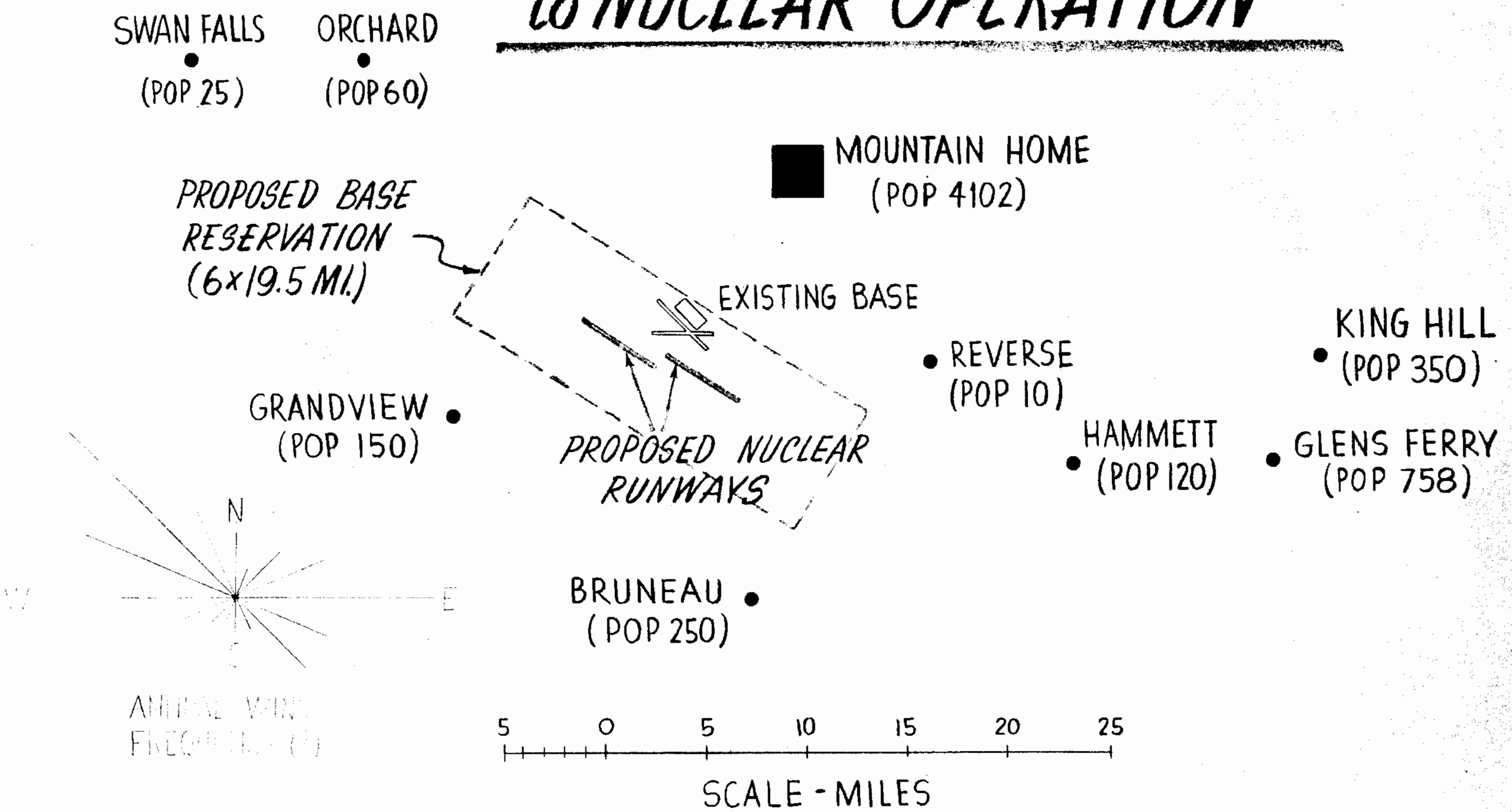
Base conversion criteria were developed (Ref. FZM 25-015), and an assumed converted base, Mountain Home, is used for this hazard analysis. Note should be made of the direction of the runways which are parallel to the surface winds of greatest frequency and velocity. Thus, the prevailing winds are perpendicular to a line running from the runway system through the base complex to the town of Mountain Home, Idaho.

2135

CONVERSION OF MOUNTAIN HOME AFB to NUCLEAR OPERATION



The probability of diffusion was developed from an analysis of meteorological conditions at the time of each accident in the model. The annual wind frequencies for 16 points of the wind rose at the selected base were used as the probability of wind direction.

PD-2960

ANALYSIS OF THE NUCLEAR HAZARD TO CIVILIAN AND MILITARY POPULATION

The singular events that lead to a crash and the number of people affected by the subsequent release of radiation is viewed as a series of independent probabilities:

P_1 TAKE-OFF OR LANDING CRASH
P_2 WIND DIRECTION
P_3 PROBABILITY OF DIFFUSION TYPE
P_4 PROBABILITY OF LOCATION OF ACCIDENT
P_5 FISSION PRODUCTS HITTING POPULACE

$P_1 \times P_2 \times P_3 \times P_4 = P_5$
$P_5 \times$ AREA AFFECTED $\times$ POPULATION DENSITY = PROBABLE NUMBER OF PEOPLE AFFECTED.

METHOD OF ANALYSIS

A graphical method was devised to solve the probability of a combination of events which could culminate in a crash accident. A scaled map of each base locality is used, with particular attention given to the placement and direction of the runway in reference to the base complex and off-base population centers.

If any of the accident placement distributions are superimposed on a scaled base map, with the abscissa of the curve placed on the runway, then the accident probability of any location on the runway can easily be determined.

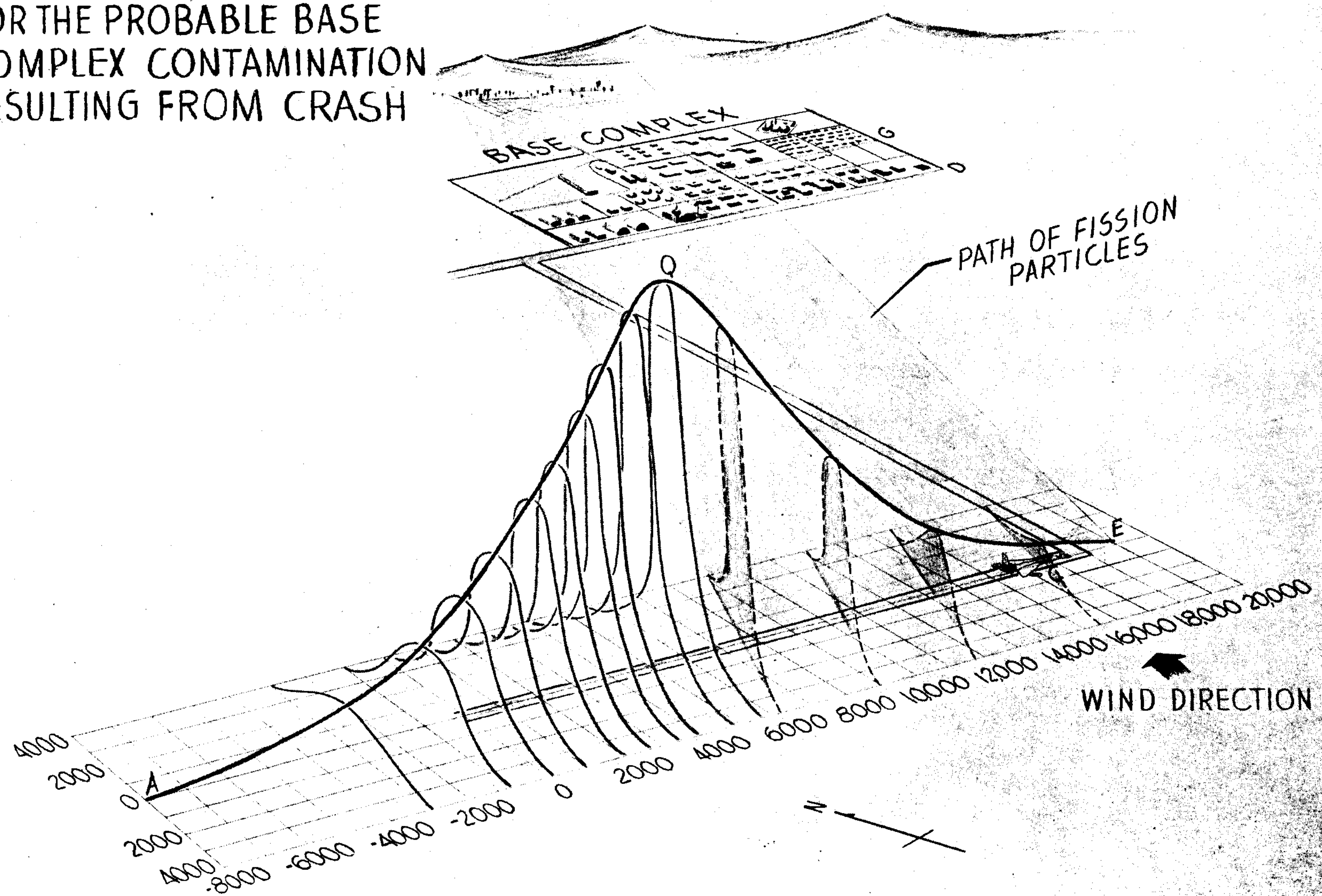
Assuming a particular wind direction, if projection lines are drawn from the runway to the base complex in the given wind direction, some portion (or all) of the base complex between the projection lines is the fraction considered to be affected by fission products release. This process was repeated for each wind direction for all bases and base localities.

For example, AQE represents the placement probability of a landing accident. Assuming a wind direction as shown, the shaded area of the base complex will be hit by released fission products with a placement probability represented by the volume under the shaded portion of the surface.

PD 2963

GRAPHICAL SOLUTION

FOR THE PROBABLE BASE COMPLEX CONTAMINATION RESULTING FROM CRASH



This study assumes the use of Mountain Home AFB only. Other bases or virgin sites can be evaluated in similar fashion. For example, the conversion criteria were applied to the three other possible basing sites shown here and the hazard was determined for each base. The hazards shown are for near and on-base accident.

PD-3445

PROBABLE NUMBER OF PEOPLE RECEIVING ONE OR MORE MAXIMUM PERMISSIBLE EXPOSURES OF RADIATION FROM OPERATION OF NUCLEAR AIRCRAFT PER WING PER YEAR

MELTDOWN

	WALKER AFB	GT. FALLS AFB	ELLSWORTH AFB	MT. HOME AFB	TOTAL ALL BASES
CIVILIANS	0.7	0.4	0.1	0.1	1.3
BASE	0.1	< 0.05	0.1	< 0.05	0.2
TOTAL	0.8	0.4	0.2	0.1	1.5
2σ VARIATION	1.5	0.6	0.2	0.1	2.1

The numbers on the preceding chart are built up predominantly from a few situations which affect large numbers of people. These are virtually the only hazardous cases at each assumed base of nuclear operations. Thus, the probable number of people receiving radiation from operation of nuclear powered aircraft are the compound probabilities of these cases.

It should be noted that the frequencies of the wind directions associated with these hazardous situations are quite low (e.g. 3.5% at Mountain Home).

This study is based on flight operations independent of weather conditions. The low frequency of unfavorable wind directions may permit control of flight operations to minimize the hazard further, as shown in the column at the far right, without materially affecting operational capability.

PC 3470A

HAZARDOUS SITUATIONS

OFF-BASE PERSONNEL
MELTDOWN

BASE	WIND	PEOPLE AFFECTED: TYPICAL LAPSE >1 MPE	TYPICAL INVERSION >20 MPE	TYPICAL INVERSION >4 MPE	TYPICAL INVERSION >1 MPE	CITY OR TOWN	AVERAGE DISTANCE (MI.)	PATTERN	TAKE-OFF	LAND-ING	PROBABILITY WITHOUT METEORLOGICAL ×10^-5	PROBABILITY WITH CONTROL ×10^-7
MT. HOME	WSW	0	0	0	120	MT. HOME	15.2		X		35.0	0
	NE	0	0	0	433		13.0			X	.5	.7
	ENE	0	0	0	956		14.0			X	2.4	3.1
ELLSWORTH	NE	0	0	0	642	RAPID CITY	14.0		X		3.2	0
	NE	0	0	0	657		15.0	T. O.			.1	0
	E	0	0	0	657		15.0	T. O.			1.5	0
	E	0	0	0	2095	GT. FALLS	6.7			X	8.7	11.3
	NW	0	0	0	148	ARMINGTON BELT	13.5			X	6.2	8.1
	ENE	0	0	0	629		7.5			X	11.0	14.3
	ENE	0	0	0	880	GT. FALLS	9.2		X		2.8	0
GT. FALLS	E	0	0	0	2095		8.0		X		1.8	0
	NW	0	0	0	148	ARMINGTON BELT	13.5		X		1.9	0
	ENE	0	0	0	1802		10.5	T. O.			1.7	0
	E	0	0	0	126	GT FALLS	6.1	T. O.			.1	0
	S	0	0	0	756		11.0			X	1.2	1.6
	SSW	0	0	0	850		10.5			X	34.0	44.2
	SW	0	0	0	511		9.0			X	25.0	32.5
	WSW	0	0	0	100		9.4			X	.6	.7
	S	0	0	0	754		11.0		X		.1	0
WALKER	SSW	0	0	0	527	ROSWELL	10.0		X		9.4	0
	SW	0	0	0	169		9.0		X		2.0	0
	SSW	0	0	0	267		10.5	L.			1.2	1.6
	S	0	0	0	456		14.0	T. O.			11.0	0
	SSW	0	0	0	534		11.0	T. O.			1.8	0
	W	0	0	0	649		11.0	T. O.			1.3	0
	WNW	0	0	0	156		10.0	T. O.			.1	0

PD-3421

OPERATION OF NUCLEAR POWERED AIRCRAFT IN RESTRICTED CORRIDORS

SCOPE:

- ANALYSIS OF CAPABILITY OF NUCLEAR AIRCRAFT TO REMAIN WITHIN THE DESIGNATED FLIGHT CORRIDORS.
- ESTIMATE OF THE PROBABLE HAZARD OF NUCLEAR FLIGHT WITHIN THE RESTRICTED CORRIDORS.

PD-3419A

ACCURACY AND RELIABILITY OF AVAILABLE MEANS OF NAVIGATION

EACH OF THREE INDEPENDENT SYSTEMS OF NAVIGATION CAN PROVIDE AN ACCURACY SUFFICIENT TO ENABLE AN AIRPLANE TO REMAIN WITHIN A 25 MI. CORRIDOR WITH THE FOLLOWING PROBABILITIES:

MILITARY NAV-BOMB SYSTEM	> 0.966
CIVIL NAVAIDS SYSTEM	> 0.900
GROUND SURVEILLANCE RADARS	> 0.800
AT LEAST ONE OPERATIVE SYSTEM	> 0.99932

IN THE EVENT OF SIMULTANEOUS FAILURES OF ALL THREE SYSTEMS, THE PILOT CAN STILL PROCEED BY MANUAL DEAD RECKONING AND PILOTAGE.

In this study the corridor from Mountain Home to the Pacific was considered for in-flight accidents. The in-flight accident rate was doubled to compensate for accidents that might be peculiar to the nuclear bomber.

PD-3446A

PROBABLE NUMBER OF PEOPLE RECEIVING RADIATION FROM OPERATION OF NUCLEAR AIRCRAFT IN FLIGHT CORRIDOR

ASSUMPTIONS

OPERATIONAL

- 30 AIRPLANES PER WING
- 360 NUCLEAR FLIGHTS PER WING PER YEAR
- MODEL : 2.65 ACCIDENTS/ 100,000 FLYING HOURS
- USED : 5.30 ACCIDENTS/100,000 FLYING HOURS

NUCLEAR

- ONE XMA-1 POWER PACKAGE
- ALL ACCIDENTS RESULTED IN MELTDOWN
- ACTUAL WEATHER CONDITIONS FOR EACH ACCIDENT
- PEOPLE AFFECTED ARE IN OPEN & FULLY EXPOSED TO ENTIRE CLOUD PASSAGE

RESULTS

(OPERATING FROM MOUNTAIN HOME

	$>$ 1 MPE	$>$ 4 MPE
CORRIDOR TO PACIFIC	0.3	$<$ 0.001

SUMMARY

PROBABLE NUMBER OF PEOPLE RECEIVING RADIATION FROM NUCLEAR AIRCRAFT OPERATIONS PER WING PER YEAR

MELTDOWN

	>1 MPE	>4 MPE
MOUNTAIN HOME AFB	0.1	0.01
CORRIDOR: MT. HOME TO PACIFIC	0.3	0.001
TOTAL	0.4	0.01

MAXIMUM NUMBER OF PEOPLE RECEIVING RADIATION FROM THE WORST CREDIBLE ACCIDENT WHILE OPERATING FROM MOUNTAIN HOME AND TO THE PACIFIC

Number of People Affected (Extreme Runaway)

	>20 MPE	>4 MPE	>1 MPE
1. Mountain Home, Idaho	0	0	641
2. Myrtle Creek, Oregon	Intermediate	103	351

BY COMPARISON: THE AVERAGE NUMBER OF INJURED OFF-BASE CIVILIANS FROM ALL USAF ACCIDENTS PER YEAR (1954 THRU 1956) ARE AS FOLLOWS:

INJURIES

FATAL	MAJOR	MINOR
18	13	14

HAZARDS BASED ON ACTUAL ACCIDENT HISTORY OF FOUR SAC MEDIUM BOMBER WINGS

1953 through 1955

HAZARDS BASED ON ACTUAL OPERATING HISTORY OF FOUR SAC BOMBER WINGS

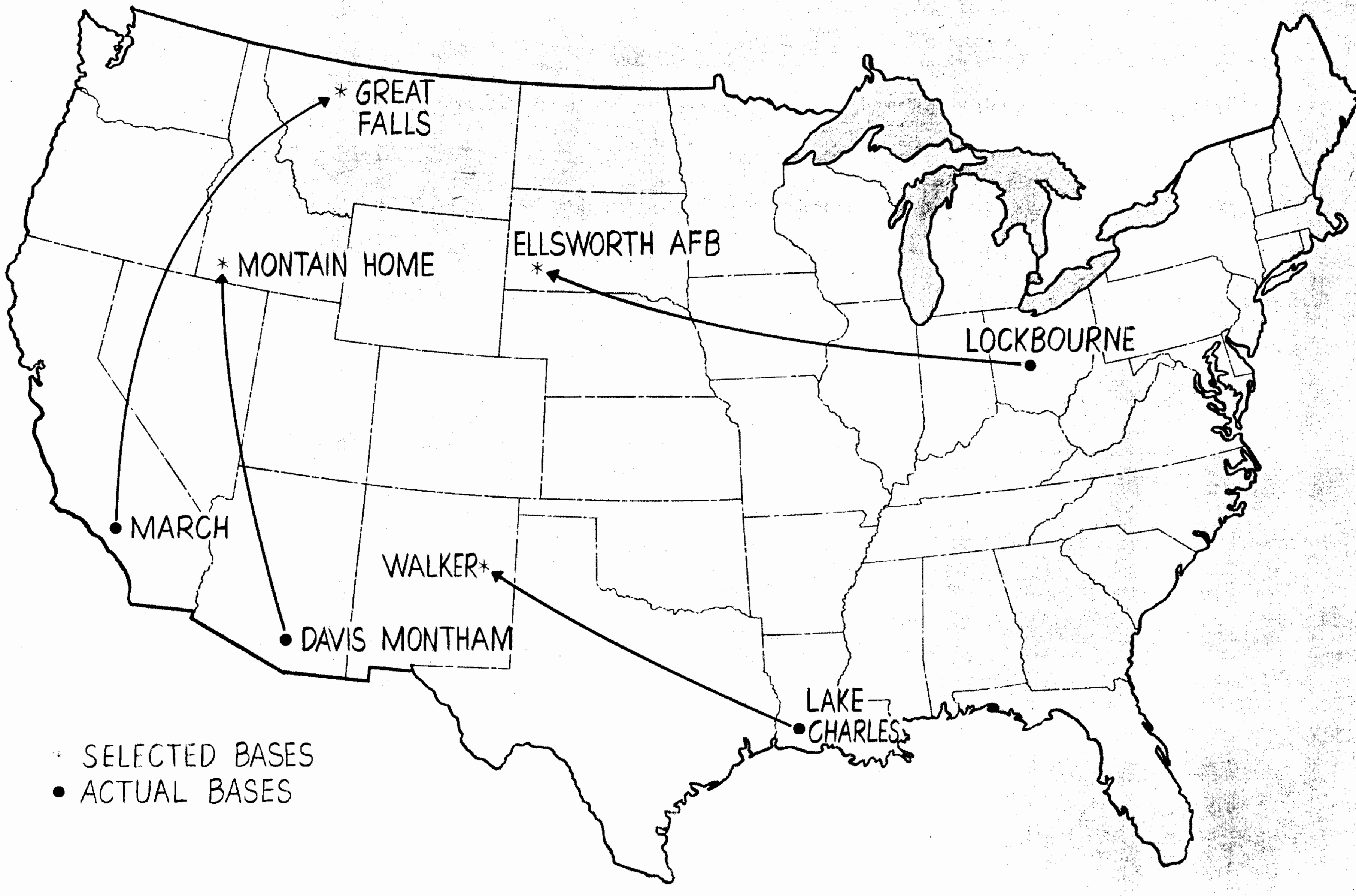
Case 1 Unrestricted Operation from Actual Bases

The aircraft of the four SAC medium bomber wings having the highest accident rates were assumed to be nuclear powered aircraft. The actual locations of each accident and the weather conditions at the time of accident were determined, and the resulting number of people that would have received greater than 1 MPE was calculated. Meltdown was assumed for each accident.

Case 2 Unrestricted Operation From Selected Bases

The four wings in Case 1 were then assumed to be operated from the four selected bases chosen for the probability model. The near or on-base accident pattern was then moved from the actual bases (Case 1) to the selected bases and rotated by an angle equal to the difference in the direction of the prevailing winds at the two bases. The in-flight accidents were assumed to be the same as in Case 1. With these assumptions the number of people receiving greater than 1 MPE was again calculated.

PD-3414


GREAT FALLS
MONTAIN HOME
ELLSWORTH AFB
LOCKBOURNE
MARCH
WALKER
DAVIS MONTHAM
LAKE CHARLES
SELECTED BASES
ACTUAL BASES

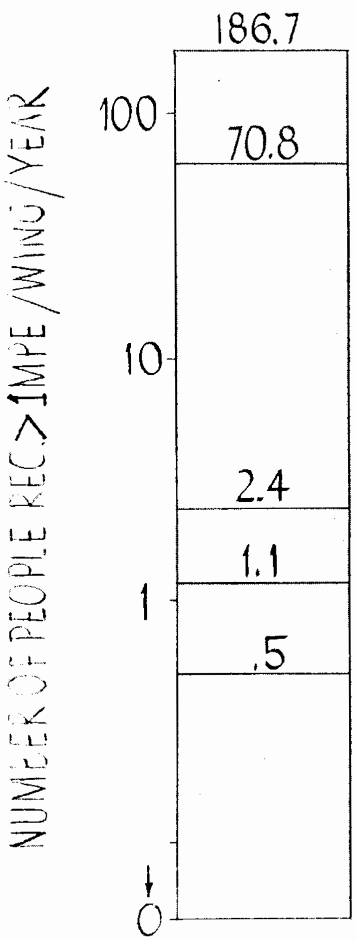
Case 3 Restricted Operation From Selected Bases

With the four wings at the selected bases it was then assumed that certain restrictions were placed on the operation such as restricted flight corridors, restricting pilot training to chemical power, etc. The resulting reduction in the number of people receiving greater than 1 MPE was determined. This case corresponds in general to the condition assumed for the Operational Hazards Study.

PD-3525

HAZARD BASED ON ACTUAL ACCIDENT HISTORY OF FOUR JET BOMBER WINGS

3 YEAR PERIOD MELT DOWN



1. UNRESTRICTED OPERATION FROM ACTUAL BASES.

2. UNRESTRICTED OPERATION FROM SELECTED BASES.

3. RESTRICTED FLIGHT OPERATION - CORRIDOR AND ETC.

4. RESTRICTED PILOT TRAINING TO CHEMICA OPERATION.

5. RESTRICTED TAKE-OFF TO CHEMICAL OPERATION.

PROBABILITY STUDY:
30 TIMES MORE FLIGHTS.
ASSUMED TO BE NUCLEAR. THUS
RESULTS = 2.1
PER YEAR AS COM
ACTUAL STUDY.

6 PROVIDE PROTECTION TO RURAL POPULATION.

This analysis may be used to illustrate the relative importance of factors affecting hazards.

Going from unrestricted operation from the actual bases (Case 1) to restricted operation from selected bases (Case 3) resulted in a reduction of the hazard by a ratio of 1:169.

In addition, the following comparative analyses were made:

Case 4 Typical Inversion versus Typical Lapse

The accidents in Case 2 were then assumed to occur, first under typical inversion, and then under typical lapse conditions, and the resulting number of people receiving greater than 1 MPE was determined and compared.

Case 5 Extreme Runaway versus Meltdown

The accidents in Case 1 (actual locations) were then assumed to have resulted first in extreme runaway and then in meltdown, and the resulting number of people receiving greater than 1 MPE was determined and compared.

It is apparent from the results that restricted operation and weather are primary factors, whereas the type of release is secondary for this example.

PO 3524

COMPARISON OF FACTORS AFFECTING HAZARD

		REDUCTION FACTOR
RESTRICTED OPERATIONS FROM SELECTED BASES	(Case 1 to Case 3)	$\frac{1}{169}$
TYPICAL INVERSION vs TYPICAL LAPSE	(Case 4)	134
EXTREME RUNAWAY vs MELTDOWN	(Case 5)	6