AD NUMBER

AD842573

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; Jul 1968. Other requests shall be referred to the Office of the Secretary of the Army, Washington, DC 20310.

AUTHORITY

DCPA ltr, 7 Oct 1976

IIT RESEARCH INSTITUTE
Technology Center
Chicago, Illinois 60616

IITRI Project No. J6067
Final Report

PERSONNEL CASUALTY STUDY

by

D. I. Feinstein
W. F. Heugel
M. L. Kardatzke
A. Weinstock

This document is subject to special export controls and each transmittal to foreign governments or foreign national may be made only with prior approval of THE OFFICE OF THE SECRETARY OF THE ARMY, OFFICE OF CIVIL DEFENSE RESEARCH, the Pentagon, Washington, D. C. 20310.

Contract No. OCD-PS-64-201
Work Unit No. 1125-A
Subcontract No. B-10923(4949A-24)-US

OCD Review Notice

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of The Office of Civil Defense.

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D. C.

July 1968

SUMMARY
PERSONNEL CASUALTY STUDY

A computer simulation model for evaluating the effectiveness of shelter systems was developed under Office of Civil Defense (OCD) Contract OCD-PS-64-50 Subtasks 1614-A and 1125-A. The Shelter Evaluation Program (SEP) permits shelter evaluation in terms of the casualties produced from initial effects of nuclear weapons. The model was divided into the following components:

- The propagation of nuclear weapon effects through the free-field.
- The attenuation of the free-field effects as they interact with local obstructions.
- The effects of the shelter on the transmission of the weapon effects to the personnel within the shelter.
- The response of the personnel to each of the effects.
- Test of personnel response against casualty of injury or death.

This is the final report on Subtask 1125-A and deals primarily with establishing quantitative data for use as casualty criteria. The following casualty mechanisms were considered:

- Primary Blast - Experimental data collected from animal experiments were extrapolated based upon weight of the species and resulted in an estimate for LD50 of an overpressure equal to 62-64 psi. Detailed overpressure wave forms were found to be relatively unimportant.

- Debris Effects - Three debris mechanisms which cause casualties were identified: impulse loading related to debris momentum (MV); crushing or tearing related to debris energy (MV^2); and cutting or penetration related to energy times the square of velocity (MV^4). Wound data for human cadavers and animals were reviewed, and casualty criteria were developed as a function of mass and velocity of the debris fragment.
- Blast Displacement - The mean velocity of impact for 50 percent lethality of small rodents was 36.4 feet/sec. This did not show a significant variation with weight, as a result, this criteria was applied to humans.
- Thermal Radiation - Second and third degree burns resulting from direct exposure of the skin, reradiation from clothing heated by the thermal energy, and ignition of the clothing and subsequent burning of the skin were considered. Percentage of mortality was then related to percentage of the body area burned. (See Fig. S-1.)
- Initial Radiation - Radiation casualty criteria were determined by extrapolating animal data based upon Hiroshima-Nagasaki results. The LD50 for illness and death were set at 150 and 500 REM respectively with a standard deviation of 20 percent.

The SEP code is described and sample application of the code presented. The following conclusions can be made based on the results of the computer code and the information gained in conducting this study:

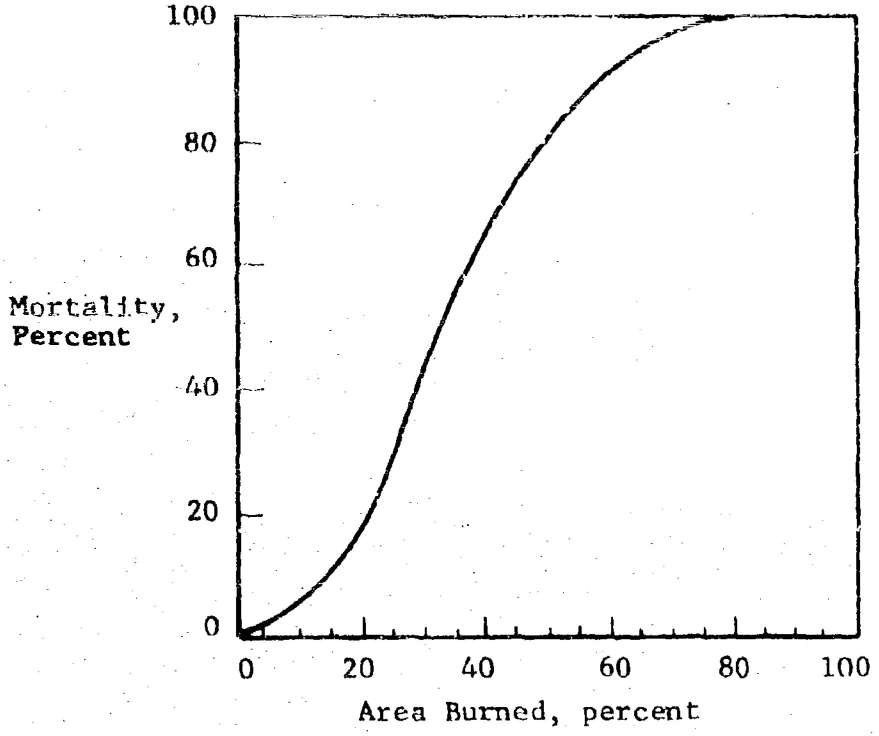


Fig. S-1 BURN MORTALITY

- The computer code provides a means of evaluating the protective capability of various shelters, provided adequate information describing the shelter is available.
- Many of the casualty criteria are studied estimates and require further refinement.
- The interaction of free-field blast effects and structures is an important link in the prediction of casualties. The present information on this subject is insufficient.
- The posture of personnel in relation to blast-wave affects their survival probability. This is shown by the differences in casualties for personnel standing and lying when under blast wind translation. The response during the translation may also be an important factor in lowering casualties.

FOREWORD

This is the Final Report to be submitted on Subtask 1125-A, "Personnel Casualty Study" (IITRI Project J6067), which is under Contract OCD-PS-64-201, Subcontract No. B-70923 (4949A-24)-US. Contributors to this report include D. I. Feinstein, W. F. Heugel, M. L. Kardatzke and A. Weinstock.

Respectfully submitted,
[redacted]
IIT RESEARCH INSTITUTE

W. Heugel
W. F. Heugel, Manager
Systems and Facilities
Engineering Section

APPROVED:

C. A. Miller
Assistant Director
Mechanics Research Division

ABSTRACT

This investigation has resulted in the development of a computer code (SEP - Shelter Evaluation Program) which predicts casualties of personnel when subjected to the initial effects of a nuclear weapon. Conditions for both sheltered and unsheltered personnel were considered. Available casualty data were analyzed and functional relationships between casualty and appropriate weapon effects were approximated. Analytic models relating the weapon effects to these casualty functions were also developed for SEP Code. A validation of the code was performed using existing Hiroshima data. Finally, results are presented for a range of construction and weapon parameters to illustrate how SEP Code may be easily utilized to study shelter effectiveness in terms of added survivors.

CONTENTS

CONTENTS (Contd)

ILLUSTRATIONS

ILLUSTRATIONS (Contd)

ILLUSTRATIONS (Contd)

TABLES

TABLES (Contd)

SECTION I
INTRODUCTION

The rational development of a nationwide shelter system must be based upon a tradeoff between the effectiveness of the shelter system, as measured in terms of increased survivors, and the cost of the system. Estimates of survivors in urban areas subjected to a specified nuclear attack have been based upon empirical casualty models which have been developed from Hiroshima data. Even accepting the large extrapolations of this data from the yield of the Hiroshima device to yields of current interest, one still cannot reasonably alter the data to incorporate structural mixes which vary from Hiroshima. Certainly "slanted" construction and designed shelters will differ in their response and protection level from the Hiroshima buildings.

The objective of this study has been to develop a casualty model which admits a broad range of shelter configurations and attack conditions (i.e., yield and height of burst). The approach taken was to develop an analytical model which was then to be validated with specific data points from the Hiroshima detaonation. The development of such a model can be conveniently divided into the following components:

- The propagation of weapon effects (air blast, dynamic pressure, thermal radiation, and ionizing radiation) through the free-field (i.e., over an idealized plane surface).
- The attenuation of these free-field effects as they interact with the local obstructions (buildings and/or natural topology) of the urban area.
- The effects of the shelter on the transmission of the weapon effects to the personnel housed within the shelter.

- The response of the personnel to each of the effects.
- Test of personnel response against casualty criteria to determine the probability of injury or death.

It should be noted that the term shelter is used in its broadest sense in this text. The description of a given type of shelter as used in this program defines the degree to which the free-field nuclear environment is attenuated in passing through the shelter. The types of shelters considered include conventional construction where there is some attenuation of the free-field effects, and shelters designed to resist given overpressures, with effects on unshielded personnel being included for comparisons. The interaction and attenuation of the free-field environment with a range of conventional buildings is automatically handled within the computer code prepared during this study. The code has also been prepared in a format so that other shelter configurations may be considered by processing the attenuation afforded by these shelters as input to the code.

A product of this study is a computer code organized according to the above five components. While it is recognized that interactions may well occur between each of the above phenomena, they are assumed to be uncoupled for this "first order" model. If a better understanding of the interrelationships become available, then the code may be easily modified to include these higher order effects. During the development of this code it has been our objective to produce an operable code which could be checked against available data and used for sensitivity studies. These applications hopefully will point to specific facets of the code requiring further improvement. The code has been so prepared that such modification may be easily added as they become available.

This study was performed in parallel with a companion study, "Parametric Study of Shelter Vulnerability" (Subtask 1614-A) Ref. 45. The gross characteristics of the model were developed during that study while this effort was concentrated on the development of casualty criteria. As such the discussion of casualty criteria is given a prominent place in the report (Section II).

SECTION II

CASUALTY CRITERIA

Rather extensive experimental data are available describing the susceptibility of animals to the effects of a nuclear detonation. The purpose of this study was to construct a computer model based upon these data for predicting the percentage of casualties resulting from a nuclear detonation depending on the shelter configuration housing the populus. Two interpretations of the data were required to achieve this objective. First, the animal data had to be extended to encompass the human. Second, the condition inside a shelter had to be related to the experimental configuration. It should be noted that casualty criteria define levels of blast, shock, thermal, debris and radiation exposure required to cause death or injury to personnel. The propagation and attenuation of these weapon effects over the free field and interacting with shelters are not considered as a part of the definition of casualty criteria.

2.1 PRIMARY BLAST

The response of personnel to primary blast involves many complex interactions of the free-field blast with the shelter. While these interactions are not per se of concern to the casualty criteria they are significant in that they affect the form of the criteria. For example, consider the problem of a man sitting in the center of the room with a small opening to the outside environment. The following event occurs:

- The free-field pressure pulse reflects off of the exterior of the shelter resulting in an increase in pressure. The duration of which is related to the clearing time of the wave around the structure.

- The blast energy begins to bleed into the room through the opening with the particle velocity and rate of pressure rise dependent on the size of opening, volume of the room, and outside pressure.
- Complex reflections occur within the room as the pressure rises.

The man in the room is therefore subjected to a pressure pulse which rises in steps to a peak and then decays slowly in time. The size of the steps depend on the room geometry, position of the man in the room and size of window opening; the peak pressure depends on these same parameters plus the external environment. The treatment of all these factors is clearly impractical for the first order model being developed, and a simpler formulation has been devised.

Much of the work reported in the literature on blast effects of nuclear detonations on animals and people has been conducted by Dr. C. S. White and his co-workers at the Lovelace Research Foundation in New Mexico. Unless otherwise indicated, the information reported in this section was obtained from Lovelace publications and at a meeting with Dr. White.

Four experimental variables were examined in the Lovelace sutdies of primary blast: (1) species of the animal; (2) duration of the pressure pulse; (3) orientation of the animal to the wave front; and (4) onset of the pressure wave. Data for eight different species of small mammals were used to extrapolate results to the weight range of man. Pressure pulse durations ranged from 3 msec to 20 sec in the various experiments. One experiment had animals placed in four different positions with respect to the onset wave. The onset of the blast was instantaneous, gradual (several milliseconds), stepwise, or instantaneous (preceded by increased initial pressure) in different experiments. Only instantaneous onset was used with all eight species.

Extrapolation to the human weight range was performed. Where basic mortality data were available, probit analyses were computed and estimates of overpressure for 50 percent mortality (LD50) made. The pulse duration effect was correlated with respect to body linear dimension (cube root of weight). Experiments with stepped onset of the pressure pulse were reexamined to determine the importance of reflected pressure on the LD50.

Pressure adjustments over short time intervals are analyzed in detail. This bridges the gap between instantaneous onset and pulses preceded by gradual or stepwise pressure increases.

2.1.1 Instantaneous Blast Onset

Table 1 shows mean body weight and LD50 for the following experimental animals: mouse, hamster, rat, guinea pig, rabbit, cat, dog, and goat. Estimates for humans were extrapolated on the basis of linear dimension (i.e., cube root of weight) because this scaling technique provided the best fit to the experimental data. Other scaling parameters considered were log weight, two-thirds root of weight, and the weight itself. There were no significant differences between the data fits for other extrapolations.

All values shown in this table correspond to 12 psi ambient air pressure and 24 hr mortality. Extrapolation of the LD50 based on linear dimension is shown graphically in Fig. 1.

2.1.2 Blast Pulse Duration

Duration of the pressure pulse is not a significant variable in the range of body weights relevant for humans and megaton range weapons. Although short durations (1 to 10 msec) result in reduced mortality in human weight ranges, no great reduction occurs in longer durations (in excess of 20 msec).

Table 1

EXTRAPOLATION OF MAMMAL LD50 TO HUMAN RANGE OF SIZES*

Species	Mean Body Weight (kg)	LD50 (psi)	Standard Deviation (psi)
Mouse	0.022	30.7	± 0.56
Hamster	0.089	28.6	
Rat	0.192	36.6	± 0.61
Guinea Pig	0.455	34.5	± 0.64
Rabbit	1.97	29.6	± 0.90
Cat	2.48	43.6	
Dog	15.1	47.8	± 1.06
Goat	20.5	53.0	± 2.79
Estimated Mammal**	70.0	63.2	± 5.8
Child	20.0	50.9	± 4.4
Average Woman	50.0	59.4	± 5.4
Large Man	90.0	67.7	± 6.1

* 12 psi ambient pressure, 24 hr. mortality.

** LD50 for 70 kg mammal at sea level (14.7 psi) would be 62-64 psi based on data from Ref. 1.

The short duration reduction is inconsequential since applicable peak overpressures (less than 200 psi) have durations considerably in excess of 20 msec. Even within shelters pressure change will occur within a few reverberation times. Therefore for a 10 ft room and shock velocity of 1,000 ft per second duration of at least 20 msec are to be expected.

2.1.3 Orientation to the Blast

The orientation of the animal to the shock wave was found to be of minor importance. No significant differences resulted in an experiment with guinea pigs in four different positions with respect to a shock wave (Ref. 3). Orientation does not seem to be an important factor when the position of

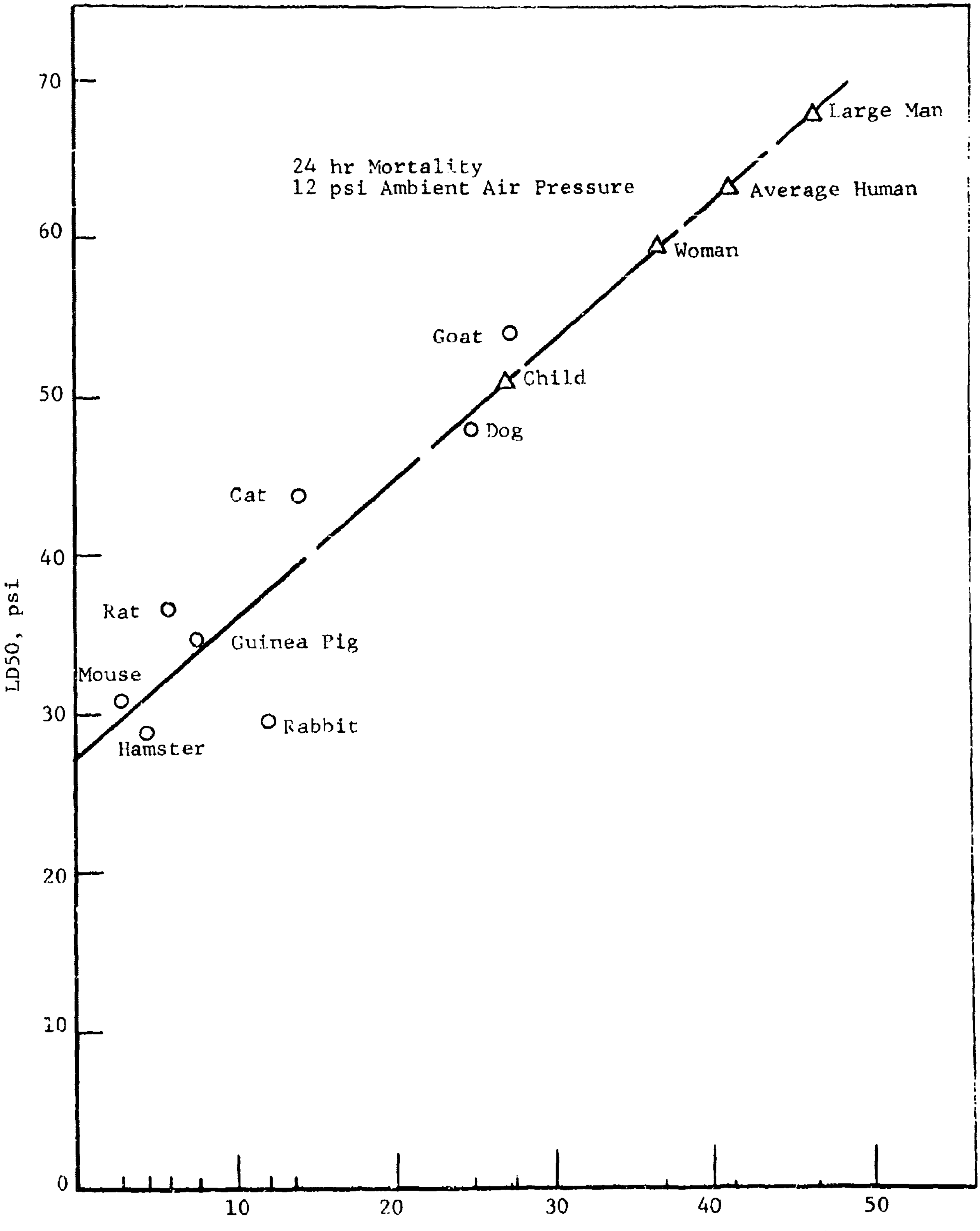


Fig. 1 EXTRAPOLATION OF INSTANTANEOUS BLAST ONSET LD50 TO HUMANS

the animal does not change the waveform to which it is exposed, or when the pressure does not significantly change over the length of the animal's body.

2.1.4 Stepped Pressure Pulse Effects

Variation in pressure time history introduced by a complex structural environment may result in wide deviations in probability of kill for persons. The reflection and diffusion of shock waves so that the peak overpressure is reached gradually in a series of steps or pulses can appreciably change the LD50 point from that of instantaneous onset. Specifically, the latter probability of mortality is altered when the overpressure onset is gradual, stepped, or instantaneous preceded by a gradual pressure increased.

Tests were conducted on dogs (Ref. 4) using gradual pressure onsets to 170 psi over 30 to 150 msec (rate of rise restricted to 4,000 psi/sec). The results are shown in Fig. 2. No dogs died as a result of these tests. This is a large decrease in mortality compared to the 47.8 psi LD50 of Table 1. Applying this to the human range, it is expected that if the pressure rise is gradual the LD50 pressure of people will be significantly increased over that shown in Fig. 1 and Table 1. The dog lung pathology shows that pulmonary hemorrhage occurred at the higher pressure levels. This correlates with the results of previous tests with lethal doses of overpressure in which pulmonary hemorrhage was identified as the mechanism of death.

More quantitative results are shown in Fig. 3 which shows mouse LD50 for 1 hr mortality with different preblast initial pressures (Ref. 5). In this case the mice were initially subjected to gradually increased pressure, held at that pressure 2 min, and then subjected to an instantaneous increase. Two regression lines are shown: (1) for the case of mice held at prepressure for 1 hr after the blast; and (2) for that of mice dropped back to ambient after the instantaneous pressure rise.

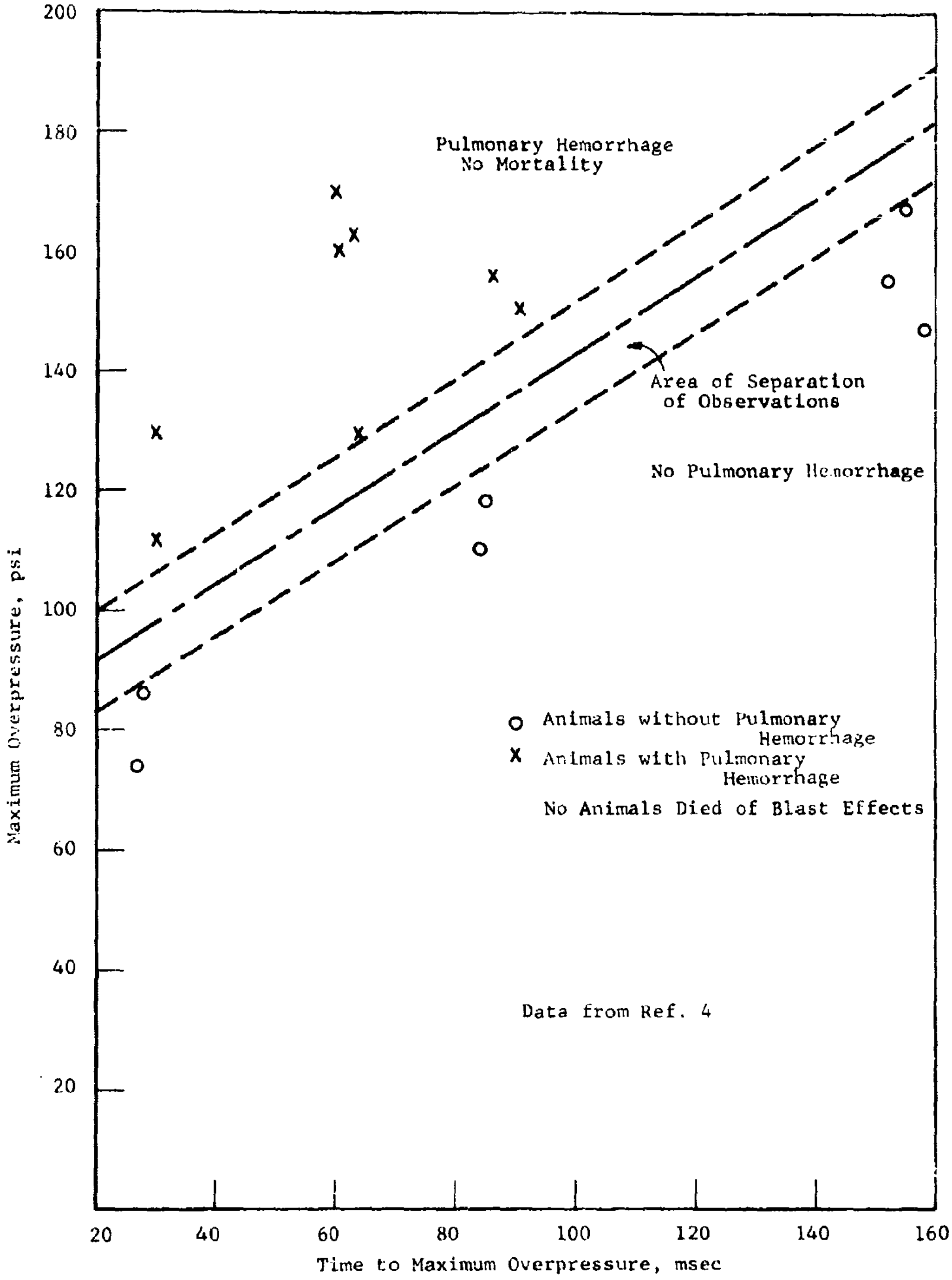


Fig. 2 EFFECTS OF LONG DURATION OVERPRESSURE APPLIED AT DIFFERENT RATES ON DOGS

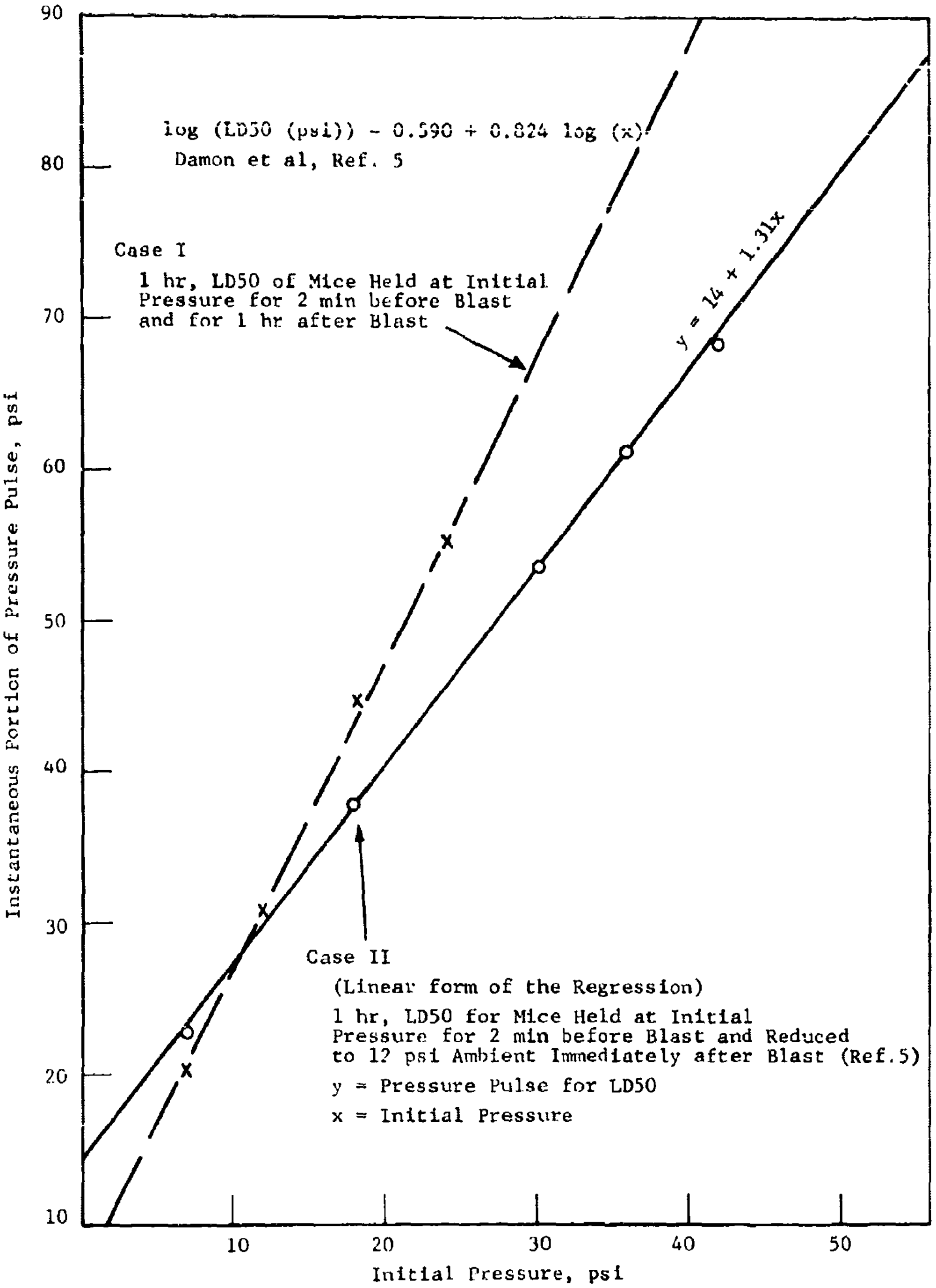


Fig. 3 MICE IN PREPRESSURED ENVIRONMENT

Neither case is a precise simulation of the nuclear weapon produced blast environment.

The first case allows the mouse to recover in a pressured environment which may aid recovery; the second subjects the mouse to an unnatural drop from a pressured state to which he has had 2 min to adjust (refer to Fig. 3).

The weapon produced blast onset would be more of an instantaneous one, even within a shelter. Therefore, embolism (the bends) as a result of the ensuing decompression would be less likely than for Case II. (The regression in Case I of Fig. 3 will be used below for stepped pressure pulses to calculate maximum possible adjustment to initial steps of blast waves.) Case I in Fig. 3 is representative of the effect of different ambient pressures because the pressure is held at a preset value before and after the blast. Using the LD50 regression equation in Fig. 3, the effect of different ambient pressures on human LD50 rates can be estimated. Taking the value of human LD50 from Fig. 1 and Table 1, and applying the regression equation for Case I, the LD50 for a 70 kg human is found to be 75 psi at 14.7 psi ambient pressure. From Ref. 5,

$$\log(\text{LD50, psi}) = 0.590 + 0.842 \log(\text{ambient pressure, psi}).$$

For human LD50 = 63.2 at 12 psi, we get

$$\log(\text{LD50}) = \log 63.2 + 0.842(\log(14.7) - \log(12.0))$$
$$= 1.801 + 0.842(0.088) = 1.875.$$

Thus LD50 = 75.0 at 14.7 psi ambient pressure.

2.1.5 Probability of Mortality by Instantaneous Blast

The slope for log dose response to overpressure on a probit scale for percent mortality varies in the experiments reviewed from 13.0 to 30.0 for small experimental animals. The slope in this case is that of a straight line as a probit scale through the experimental points establishing the relationship between the dose (in this case instantaneous pressure) and the response percent mortality. The homogeneity of these test animals compared with the heterogeneity of the human population would suggest that a broader difference (from 1 to 99 percent mortality) i.e., less slope, would be expected for humans. A slope of 8.0 was chosen to represent the human relation. This establishes the rate of change of the mortality for humans to overpressure. Figure 4 illustrates this estimated mortality by blast with instantaneous onset as a function of the peak overpressure for 14.7 psi ambient pressure.

2.2 MORTALITY AS A FUNCTION OF TIME

Probit analyses for guinea pig mortality at 1 hr, 2 hr, 24 hr and 30 days were given in Ref. 3. Human LD50 is taken proportionally to these values as shown in Table 2. Figure 5 shows the resultant probit curves for mortality for various times after exposure. The experimental guinea pig curves are shown for convenient comparison.

Table 2

LD50 AS A FUNCTION OF TIME AFTER EXPOSURE TO BLAST

Time After Exposure	Guinea Pig LD50* (psi)	Human LD50 (psi)
1 hr	40.3	83.5**
2 hr	39.2	81.2**
24 hr	36.2	75.0
30 day	34.3	71.1**

* Ref. 3,

** These values are derived proportionally to guinea pig mortality relative to the 75.0 psi peak overpressure which was the 24 hr LD50 derived for man. That is

$$\frac{\text{Human} \quad \text{LD50(24 hr)}}{\text{Guinea Pig LD50(24 hr)}} = \frac{75.0}{36.2} = \frac{\text{Human} \quad \text{LD50(1 hr)}}{\text{Guinea Pig LD50(1 hr)}} = \frac{83.5}{50.3}$$

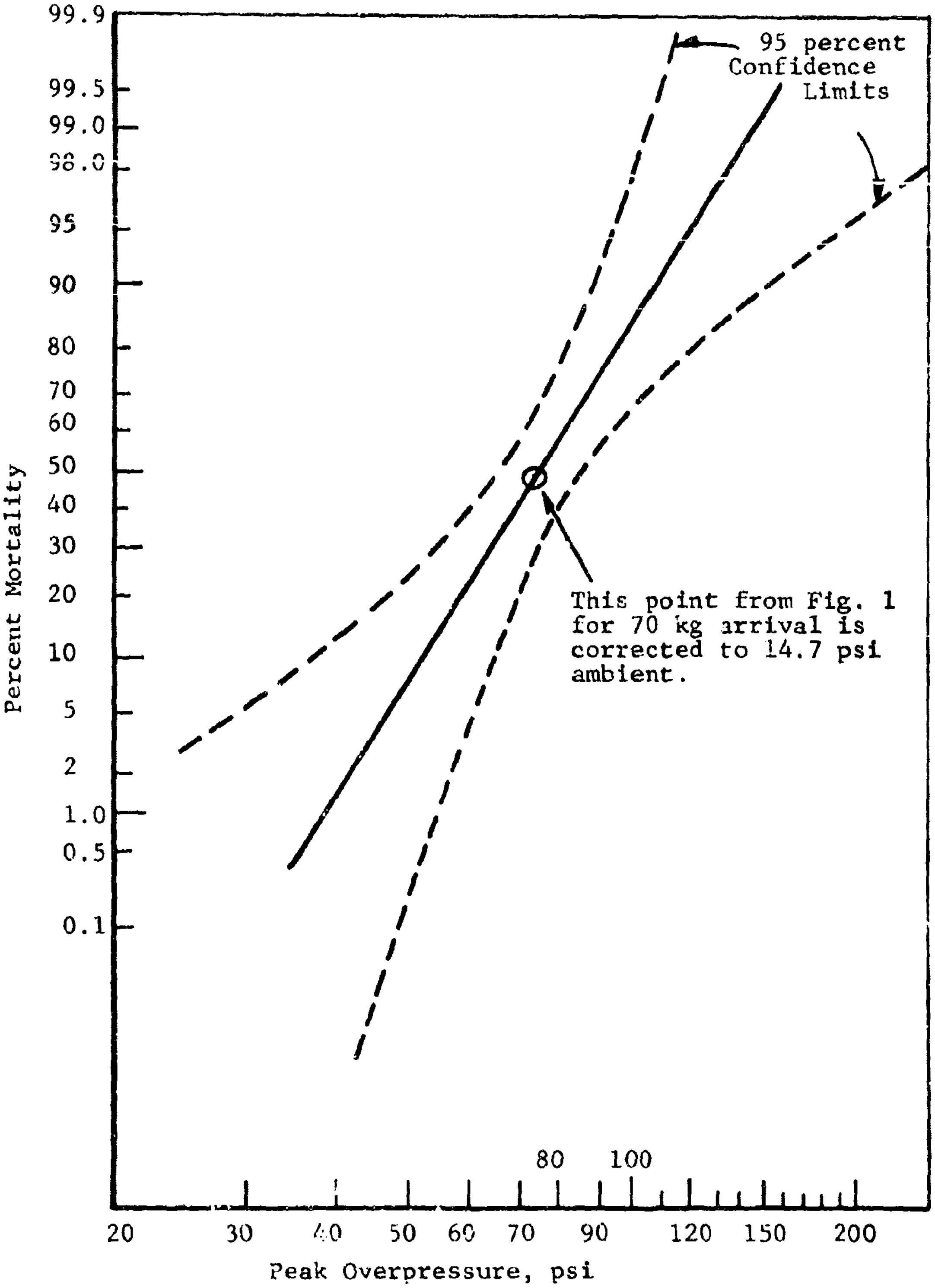


Fig. 4 ESTIMATED HUMAN 24 HR MORTALITY BY INSTANTANEOUS BLAST

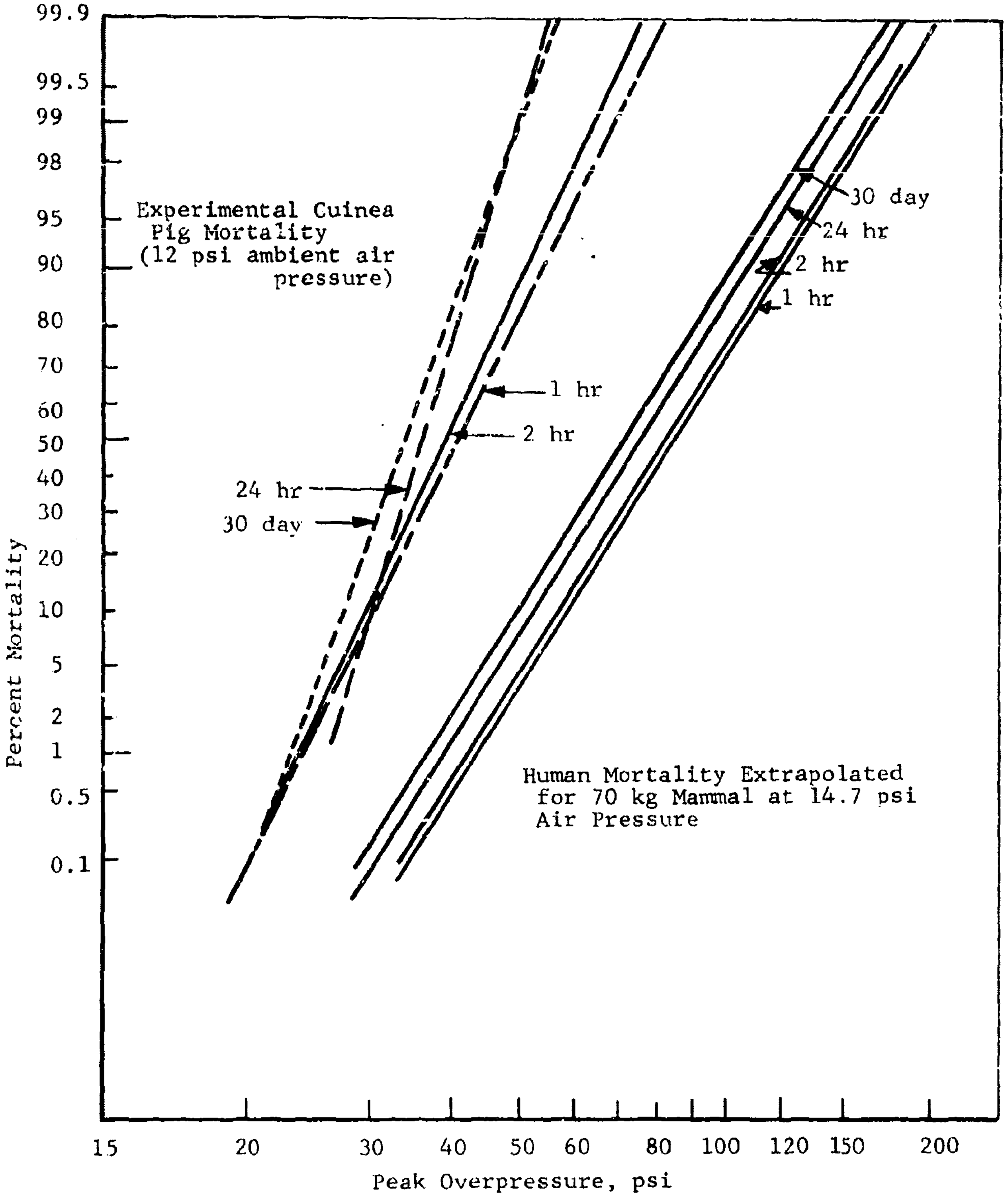


Fig. 5 HUMAN MORTALITY FOR VARIOUS TIMES AFTER EXPOSURE TO PRIMARY BLAST

Table 3 showing cumulative percent mortality is taken from the graph showing mortality as a function of time. This table illustrates that time to death changes radically with level of blast exposure. It should be emphasized that cumulative mortality over all levels of exposure is irrelant and misleading. Those further away from the center of the blast and thus expose to lower overpressures can be expected to take longer to die and thus may possibly be treated. Death requiring 24 hr may be averted by treatment such as bed rest which is not available to laboratory animals. However data on hospital treatment of blast injury is not available.

Table 3

CUMULATIVE PERCENT MORTALITY
(For Humans at 14.7 Ambient Pressure)

Blast Overpressure (psi)	Time After Exposure			
	1 hr	2 hr	24 hr	30 days
40	0.5	0.7	1.4	2.4
50	4.0	5.0	8.0	12.0
60	13.0	15.0	23.0	28.0
70	27.0	31.0	42.0	49.0
80	45.0	49.0	60.0	67.0
100	74.0	77.0	85.0	89.0
120	90.0	92.0	95.0	97.0
150	98.0	98.3	99.2	99.5

2.3 SUMMARY OF PRIMARY BLAST

Animal body weight was related to the level of mortality. Specie to specie variation was rather large compared to the experimental error estimate within each specie tested. Extrapolation of these results to 70 kg mammals gave 63-64 psi as the point for 50 percent mortality. Extrapolation was made on the basis of a linear dimension scale and the result was adjusted to correspond to sea level ambinet air pressure. The pressure rise in a shelter space will occur increments (depending on the size of the opening) at times equal to the reverberation time of the room. When the "gradual" rise is included, the LD50 value is raised to 75 psi. It is recognized that the occupant may be exposed to reflected pressure greater than the incident but this will occur near walls. This phenomena is neglected but could be included in the model when reliable experimental data became available. It should be noted that since the LD50 corresponds to the 62-64 psi overpressure point, it may be concluded that primary blast is not important in that other casualty mechanisms will take effect before blast.

Duration of the pressure pulse is not a significant variable in the study of survival of humans in a multimegaton weapon environment. The orientation of the animal has not been shown to be important where the form of the wave is not affected by the animal's position.

The estimates for instantaneous onset for 30 day (total) mortality from Table 3 were used to generate Fig. 6. Time to death (Fig. 7) was handled in a way that shows how different distributions of time to death occur at different levels of overpressure.

Figure 7 was also obtained from Table 3 by forming the ratio of the difference in mortality between specific time intervals at a specific pressure level and the total mortality for that same pressure level. Figures 6 and 7 are used in the computer code with the overpressure to determine primary blast mortality as a function of time.

2.4 DEBRIS EFFECTS

Blast generated debris from buildings, furniture, etc., will be accelerated by the blast winds and may cause casualties to people within the path of the debris. This subsection is concerned with relating the effect of debris size and impact

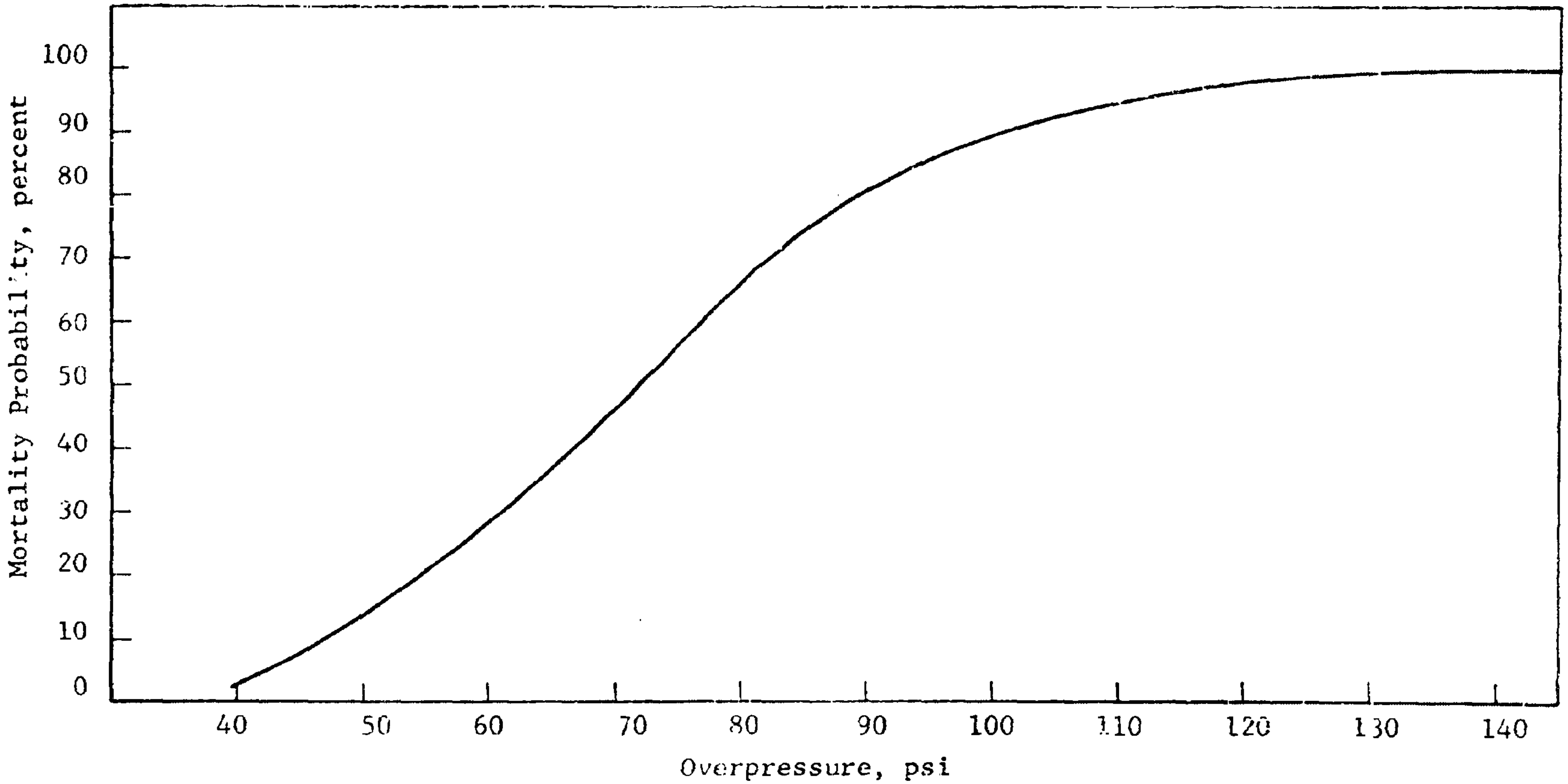


Fig. 6 KILL PROBABILITY FROM PRIMARY BLAST

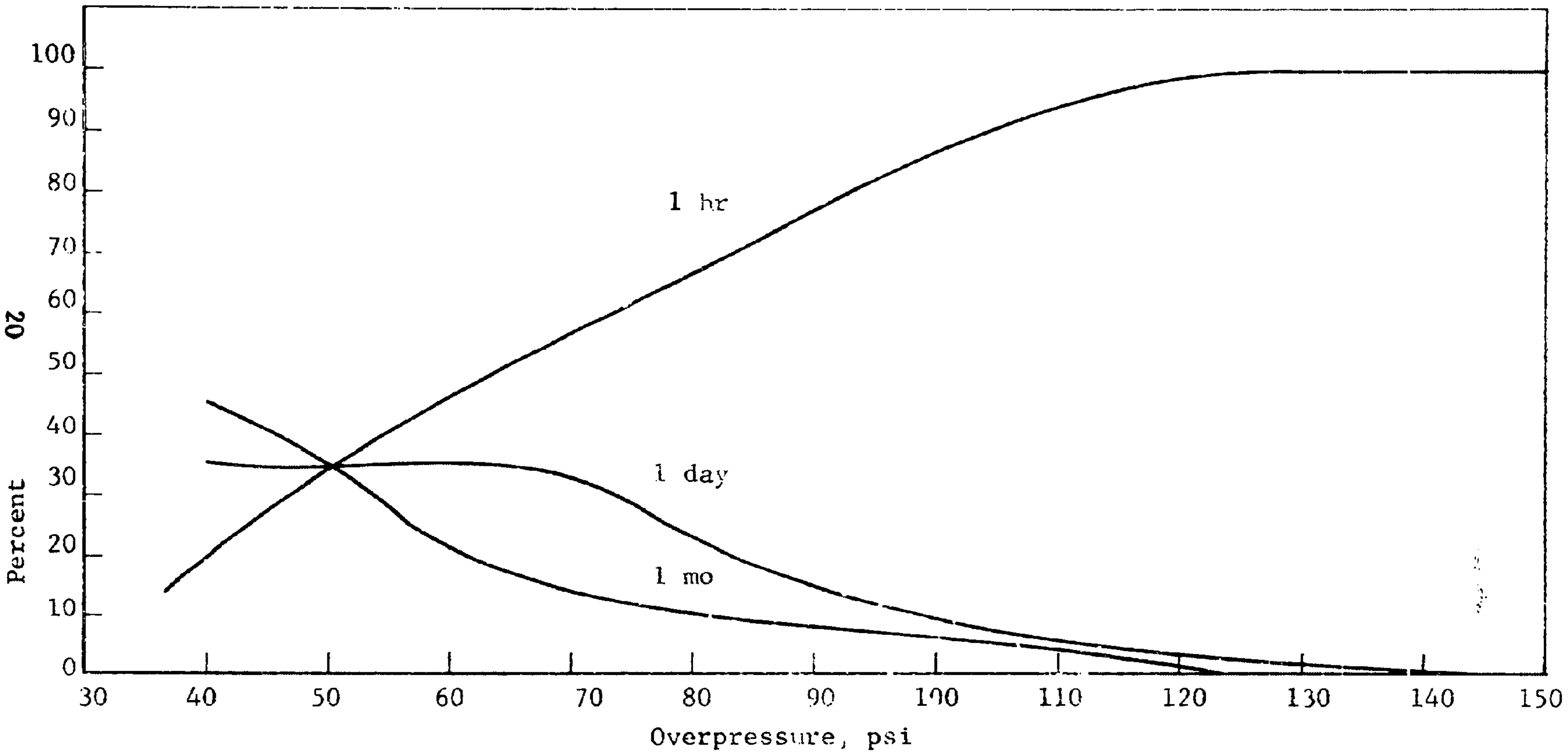


Fig.7 TIME TO DEATH FROM PRIMARY BLAST

velocity (within a range of body regions) to mortality and injury. The actual impact velocity, or debris velocity displacement history is estimated and described in Section III.

The effects of missiles on biological tissues were reviewed using available experimental evidence and including superficial, incapacitating, and near lethal categories of injury. Missiles consisted of glass, bullets, balls, and blunt objects. The parts of the body used were: skin, lower abdomen, thorax, limbs, and skull.

Unfortunately, very little information was available relating specifically to mortality. Consequently, many judgments were made, rendering the results qualitative. It is the author's opinion that a logical means of relating missile mass velocity and mortality has been proposed. The task for future experimenters will be to gather the types of data required for casualty estimating. The method devised to integrate evidence concerning effects under differing conditions and make possible extensive extrapolation and interpolation of experimental results was to develop dose functions consisting of mass M and velocity V of missiles. Momentum MV, energy MV^2, and energy times velocity square MV^4, depending upon the mechanism of injury were assigned as the dose functions. The three functions applied to injuries were primarily in the nature of: (1) impulse loading for momentum; (2) crushing or tearing for energy; and (3) cutting or penetrating for energy times velocity square.

This method makes possible digital computation of probable biological effects in a diverse missile environment interrelating the various kinds of experimental evidence available. The values estimated and formulas proposed may serve as a hypothesis for further experimental validation. Application of these formulas will reveal which mechanism of injury and missile environments are of greatest importance. How critical the assumptions may be can be revealed by variations of the parameters.

2.4.1 Discussion

Four groups of data based upon experiments were considered: penetration of the lower abdomen of dogs by glass (Ref. 8), effects of missiles on human cadavers (Ref. 9), data on skull fracture (Ref. 10), and effects of missile impact on the chest (Ref. 11). There were considerable differences in the scope of these data groups and in the availability of raw observations for independent estimations of parameters. The probability of penetration or laceration by glass was related to the mass and velocity of the missile by MV^4. This statistic was then used to attempt to consistently account for other biological effects of missiles regarding injuries which primarily involve penetrating wounds. Some results using larger missiles with biological effects primarily involving bones did not fit this pattern. Especially the data on skull fracture proved the necessity of another statistic. Mass times velocity square, satisfied the requirements to explain crushing or tearing wounds such as most bone injuries or passage through regions of tissue. These injuries could be incurred with or without penetration of intervening tissues as in the case of skull fracture, bone breakage, or rib fracture complicated by internal lacerations. When the tissue has been penetrated, energy is the determining factor for estimating the probability of complete passage through a limb. It was found that even these two statistics did not correlated well for unilateral lung hemorrhage and simple rib fractures. It appeared from the data available that mass times velocity alone could be used to predict the occurrence of these injuries.

The data and the resultant mass, velocity, and probability of each effect occurring are provided in Appendix V. It is again called to the attention of the reader that the values shown are indications of levels of injury and not mortality.

Table 4 summarizes the mass-velocity relationships obtained for the data from Appendix V. The dose relationship column indicates the criteria employed to relate biological response with missile characteristics at the time of impact. The last three columns in Table 4 present the value of the missile-velocity dose for 10, 50 and 90 percent probability of the specific effect occurring. For optimistic and pessimistic estimates of the 50 percent probability values indicated in Table 4, 70 and 140 percent of the values provided are suggested, based on the uncertainty of the data for the MV^4 doses, and 80 and 125 percent for the MV and MV^2 doses. Different probability values can be determined from Table 4 by the following relation

$$S^2 = \left(\frac{\log P90 - \log P50}{1.282}\right)^2$$

$$P_i \{x\} = \frac{1}{2\pi S} \int_{-\infty}^{x} e^{-(t - \log P(50)^2/2S^2)} dt$$

where P_i is the probability of the effect occurring.

Figure 8 is a graph of 50 percent probability thresholds for each effect in Table 4. The curves of Fig. 8 are obtained by applying the specific relationship of Table 4 between M and V to obtain the 50 percent probability of the effect occurring. For example, for rib fracture (MV relationship) the 50 percent probability is 31 x 10^3 gm ft/sec. Therefore, for a 1,000 gm mass, the missile velocity must be about 31 fps for 50 percent probability of rib fracture. If the mass of the missile is 100 gm, the velocity must be 310 fps. In a similar manner, the 50 percent values of the other effects at various velocities and ranges were determined.

Table 4

SUMMARY OF BIOLOGICAL EFFECTS OF MISSILE DATA

No.	Effect	Part of Body Tested	Type of Missile Used	Part of Body for Application	Target Area % Body	Target Area ft^2	Dose Relationship	Units	Probability of Effect Occurring, percent: 10 (Dose Required)	50 (Dose Required)	90* (Dose Required)	Severity
1	Laceration	Skin	Glass	General	100.0	4.20	MV^4	$gm\ \frac{ft^4}{sec^4}$	0.108×10^9	0.902×10^9	7.50×10^9	Superficial
2	Penetration	Abdomen	Glass	Abdomen and limbs	25.0	1.01	MV^4	$gm\ \frac{ft^4}{sec^4}$	0.569×10^9	3.83×10^9	25.9×10^9	Incapacitating
3	Laceration	Skin	Spherical Bullets	General	100.0	4.20	MV^4	$gm\ \frac{ft^4}{sec^4}$	4×10^9	11×10^9	30×10^9	Superficial
4	Penetration	Limb	Spherical Bullets	Abdomen (lower) and limbs	25.0	1.01	MV^4	$gm\ \frac{ft^4}{sec^4}$	9×10^9	24×10^9	64×10^9	Incapacitating
5	Bilateral Hemorrhage	Lung	Balls	Thorax	15.5	0.65	MV^4	$gm\ \frac{ft^4}{sec^4}$	65×10^9	175×10^9	475×10^9	Near Lethal
6	Fatality within 1 hr	Thorax	Balls	General	43.0	1.81	MV^4	$gm\ \frac{ft^4}{sec^4}$	225×10^9	625×10^9	1625×10^9	Lethal
7	Fracture	Skull	Blunt Objects	Head	8.0	0.33	MV^2	$gm\ \frac{ft^2}{sec^2}$	0.974×10^6	1.37×10^6	1.93×10^6	Near Lethal
8	Bone Abrasion and Cracking	Limbs	Spherical Bullets	Not including ribs	35.0	1.47	MV^2	$gm\ \frac{ft^2}{sec^2}$	0.6×10^6	0.9×10^6	1.3×10^6	Incapacitating
9	Passage	Thigh	Spherical Bullets	Abdomen and limbs	25.0	1.01	MV^2	$gm\ \frac{ft^2}{sec^2}$	1.4×10^6	2.0×10^6	2.8×10^6	Near Lethal
10	Fractures Large Bones	Limbs	Bullets	Not including ribs	35.0	1.47	MV^2	$gm\ \frac{ft^2}{sec^2}$	2.3×10^6	3.4×10^6	5.0×10^6	Near Lethal
11	Internal Lacerations on Fractured Ribs	Thorax	Balls	Thorax	15.5	0.65	MV^2	$gm\ \frac{ft^2}{sec^2}$	3.1×10^6	4.5×10^6	6.6×10^6	Incapacitating
12	Unilateral Hemorrhage	Lung	Balls	Thorax	15.5	0.65	MV	$gm\ \frac{ft}{sec}$	16×10^3	22×10^3	29×10^3	Superficial
13	Rib Fractures	Thorax	Balls	Thorax	15.5	0.65	MV	$gm\ \frac{ft}{sec}$	24×10^3	31×10^3	40×10^3	Superficial

* Thus for a glass missile imparting skin with $7.5 \times 10^9 gm\ ft^4/sec^4$ the probability of laceration occurring is 90 percent.

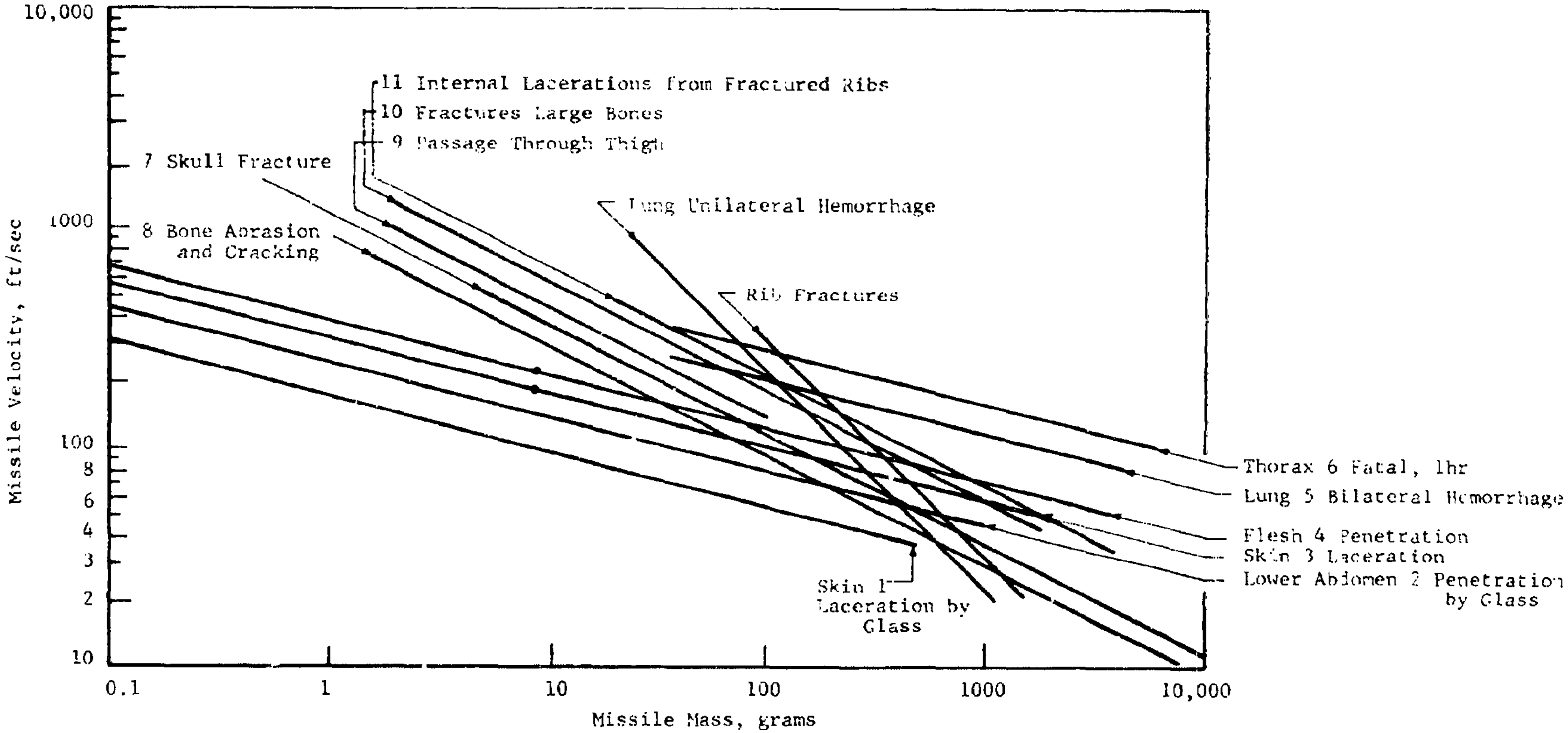


Fig. 8 VARIOUS BIOLOGICAL EFFECTS OF MISSILES

Table 5 provides an estimate of total body projected areas, as well as vulnerable areas of various body regions. This data will be useful at a later date when complete consideration of debris areas and characteristics and body areas are used in making casualty descriptions. However, for this report it was used in making qualitative estimates of mortality based on the injuries reported in the data of Appendix V and summarized in Table 4. Of course the type and size of missiles has a definite effect on vulnerable areas. Future research on missile casualties might consider some of these effects when reporting data.

Table 5

BODY TARGET AND VULNERABLE AREAS (REF. 6 AND 7)

Region	Area ft^2	% of Total	Vulnerable Area		
			Area ft^2	% of Region	% of Body
Head and Neck	0.5	12	0.15	30	3.5
Thorax	0.67	16	0.65	97	15.5
Abdomen	0.46	11	0.45	97	10.5
Upper Limbs	0.92	22	0.19	20	4.5
Lower Limbs	1.65	39	0.38	23	9.0

Kneeling presents approx. 55% of field projected area
Sidewise presents approx. 45-50% of field projected area
End of prone presents 25% of field projected area.

2.4.2 Probability of Mortality and Time to Death

Only limited data were available concerning mortality and time to death relative to mass and velocity of missiles. To make use of the injury data which were available, estimates of mortality based on severity of the wound were made. In addition, time to death based on the mortality probability was estimated. These estimates are judgements of the scientists involved in the study, and are based upon general considerations of the types of injuries and estimation of the environment which might be available for recovery. They are shown in Table 6.

2.4.3 Incorporating Mass-Velocity Relations

The goal of this study was to isolate casualty criteria which could be used to analyze the effectiveness of shelters. A series of functions have been developed relating missile characteristics to probability of injury. The severity of injuries and associated probability of mortality based on severity have also been estimated. However, even at this stage functions are of limited value. Therefore, the effects of severity and probability of occurrence for each effect have been combined, averaged and extrapolated as necessary to obtain one continuous relationship covering the complete range of missile masses and velocities which might be of interest where data were available. For example, in Case 1 of Table 4 the effect of penetrating glass is classified as a superficial wound, these are estimated at 10 percent mortality. The probability of a glass fragment missile mass-velocity combination producing mortality can subsequently be determined by multiplying the probability of its producing the effect by the mortality probability. If the probability of producing a superficial wound is 10 percent, then the probability of producing mortality from the same missile mass-velocity combination is only 1 percent. In a similar manner, each of the effect relationships was changed to mortality and plotted on one graph for each applicable body region (head, thorax, abdomen and limbs). Those relations marked "general" were applied to each graph, while those indicated for a specific region were only used when that region applied. An example of the former is the category of skin laceration, which can be used for each region. Three graphs resulted similar to Fig. 8 with almost as many lines. Effects requiring the least velocity were selected in each mass region, and then various relations were averaged visually (at this point it hardly seemed worth the effort to do more).

Table 6

ESTIMATES OF PROBABILITY OF MORTALITY AND TIME TO DEATH

Severity	Representing	Mortality Rate percent
Superficial	Glass and other lacerations Unilateral lung hemorrhage Rib fractures	10
Incapacitating	Glass and other missile penetrations Bone abrasions and cracking Internal lacerations from fractured ribs	30
Near Lethal	Bilateral hemorrhage Skull fracture Passage through abdomen or other lethal areas Fractures large bones	70
Lethal	Fatality within 1 hr	100

Probability of Mortality percent	Time to Death
0 - 10.0	1 mo
10.1 - 50.0	1 wk
50.1 - 90.0	1 day
90.1 - 100.0	1 hr

Three sets of curves emerged, one (each) for MV, MV^2 and MV^4, and separate ones for 10, 50 and 90 percent mortality probability. These were made continuous by using the lowest velocity curves for each mass and cutting off the curves at the intersection points. The only remaining problem was the low end of the velocity scale for high mass objects. It was decided that this point should be determined by the results of the translation casualty criteria, discussed in the next section. The results of these inquiries are shown in Fig. 9, 10 and 11. As an afterthought, the casualty criteria employed in World War II was plotted on each of these figures, and the similarity was gratifying. It is highly recommended that future research in the areas of casualty criteria and mortality be aimed at covering the full range of mass and velocity of interest to civil defense problems, and further that an attempt be made to verify the estimates made in conducting this study.

Figures 12, 13 and 14 represent the debris impact casualty criteria as it is employed in the computer code. Specific sizes of debris were selected and the corresponding impact velocity--kill probabilities were estimated from Fig. 9, 10 and 11.

2.5 BLAST DISPLACEMENT

Overall blast displacement effects for small rodents were available. This data did not show a significant effect with respect to weight. The overall mean velocity of impact for 50 percent lethality of small rodents was 36.4 ft/sec, and 90 and 10 percent mortality point averages are approximately 41 and 31 ft/sec respectively. Time to death was based on mortality probability, the same technique employed for debris impacts.

The blast displacement data for small rodents was extrapolated in Ref. 1 to humans and an LD50 value of 26.2 ft/sec recommended. It was cautioned however that there was little

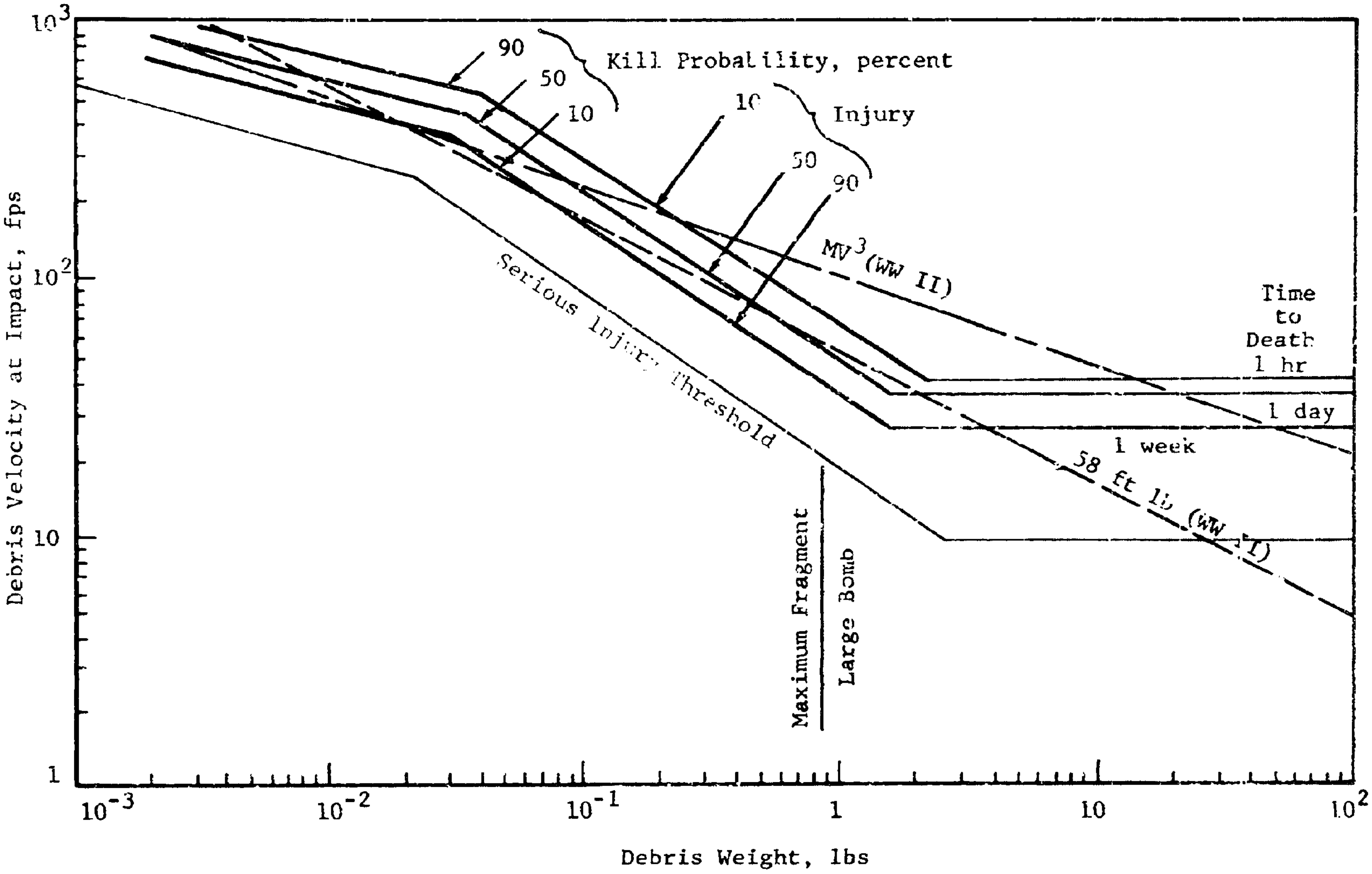


Fig. 9 KILL PROBABILITY FROM DEBRIS IMPACTS (Thorax)

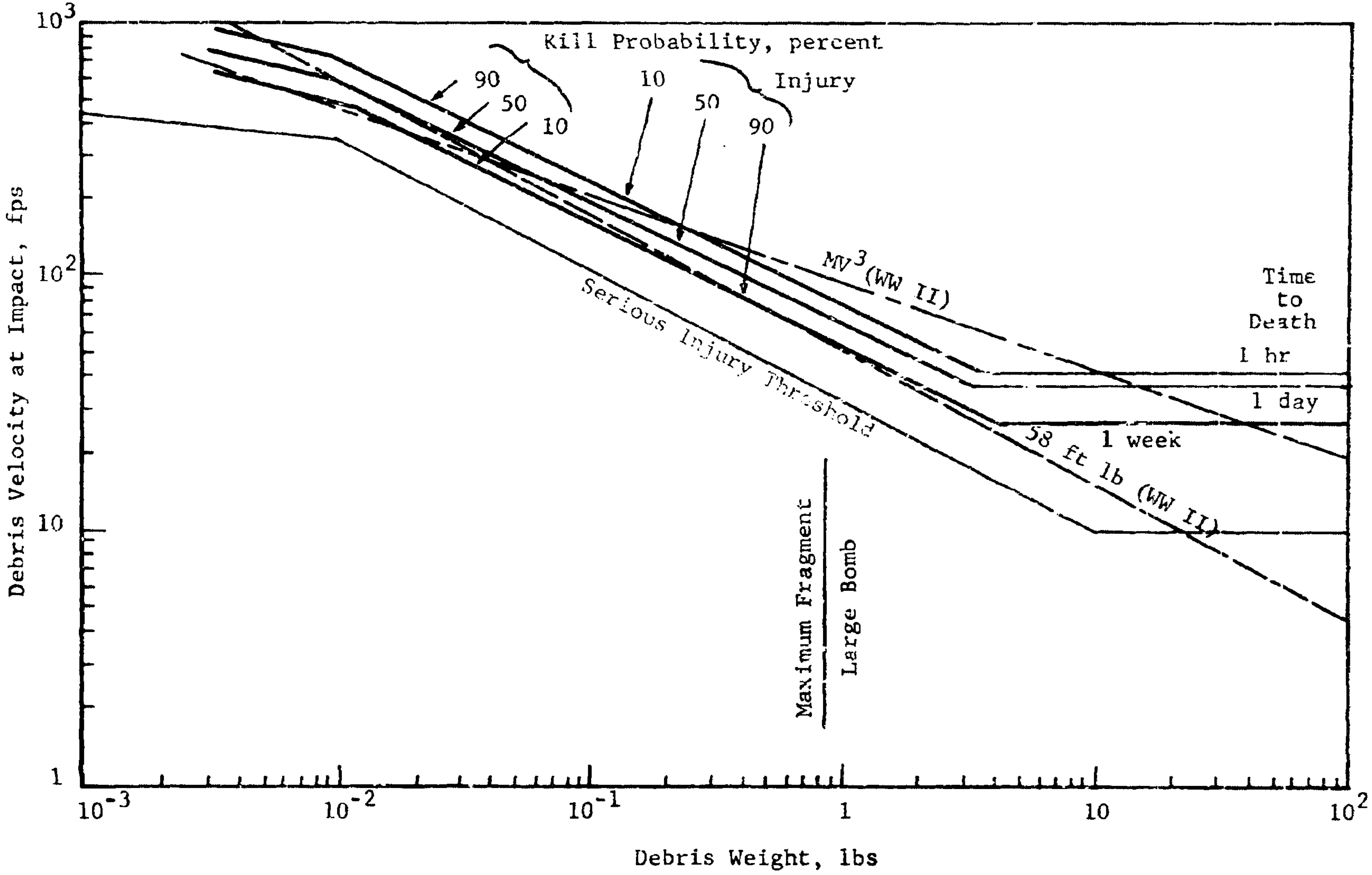


Fig. 10 KILL PROBABILITY FROM DEBRIS IMPACTS (Head)

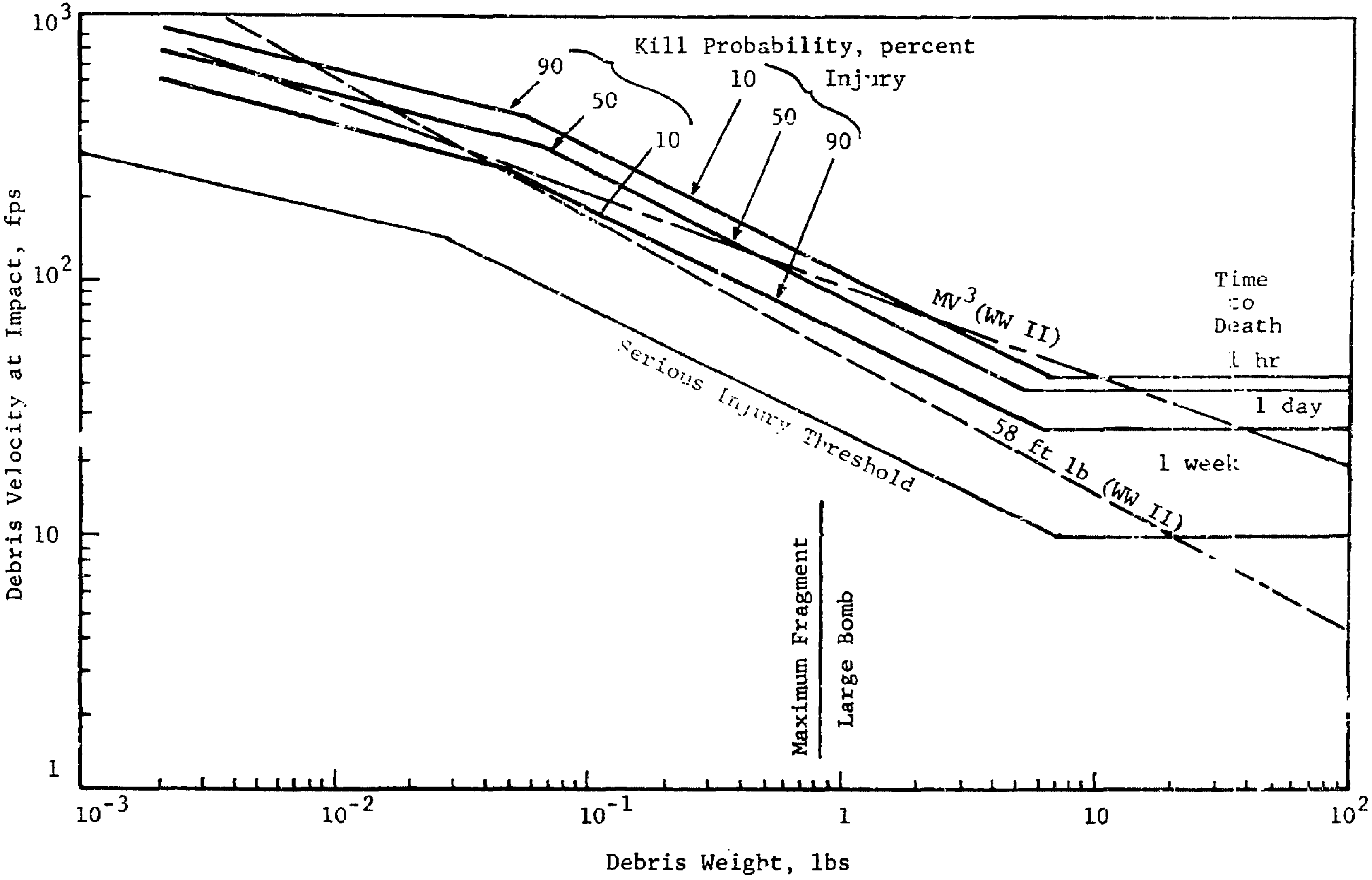


Fig. 11 KILL PROBABILITY FROM DEBRIS IMPACTS (Abdomen and Limbs)

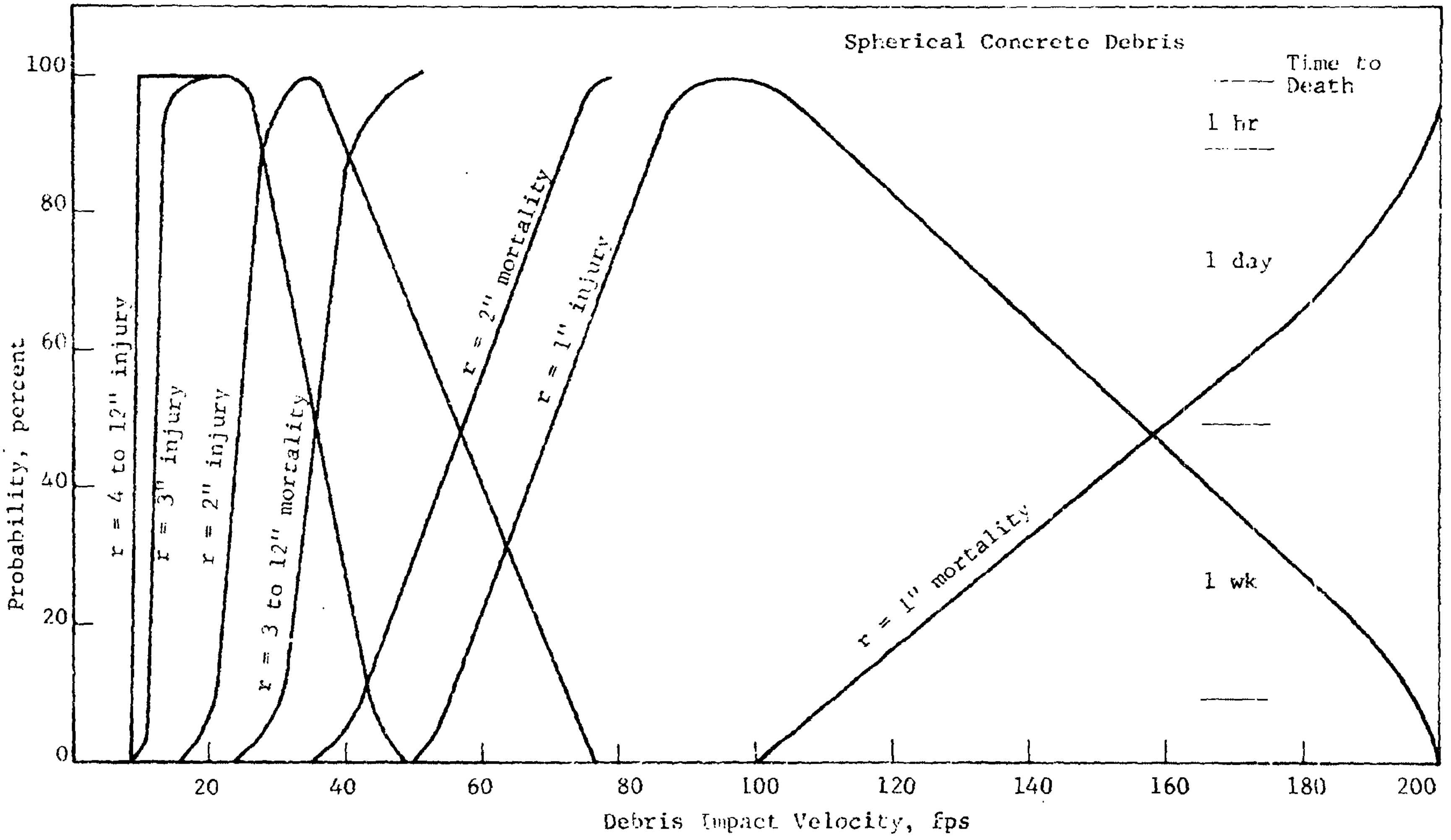


Fig. 12 KILL PROBABILITY FROM DEBRIS IMPACTS (Abdomen and Limbs)

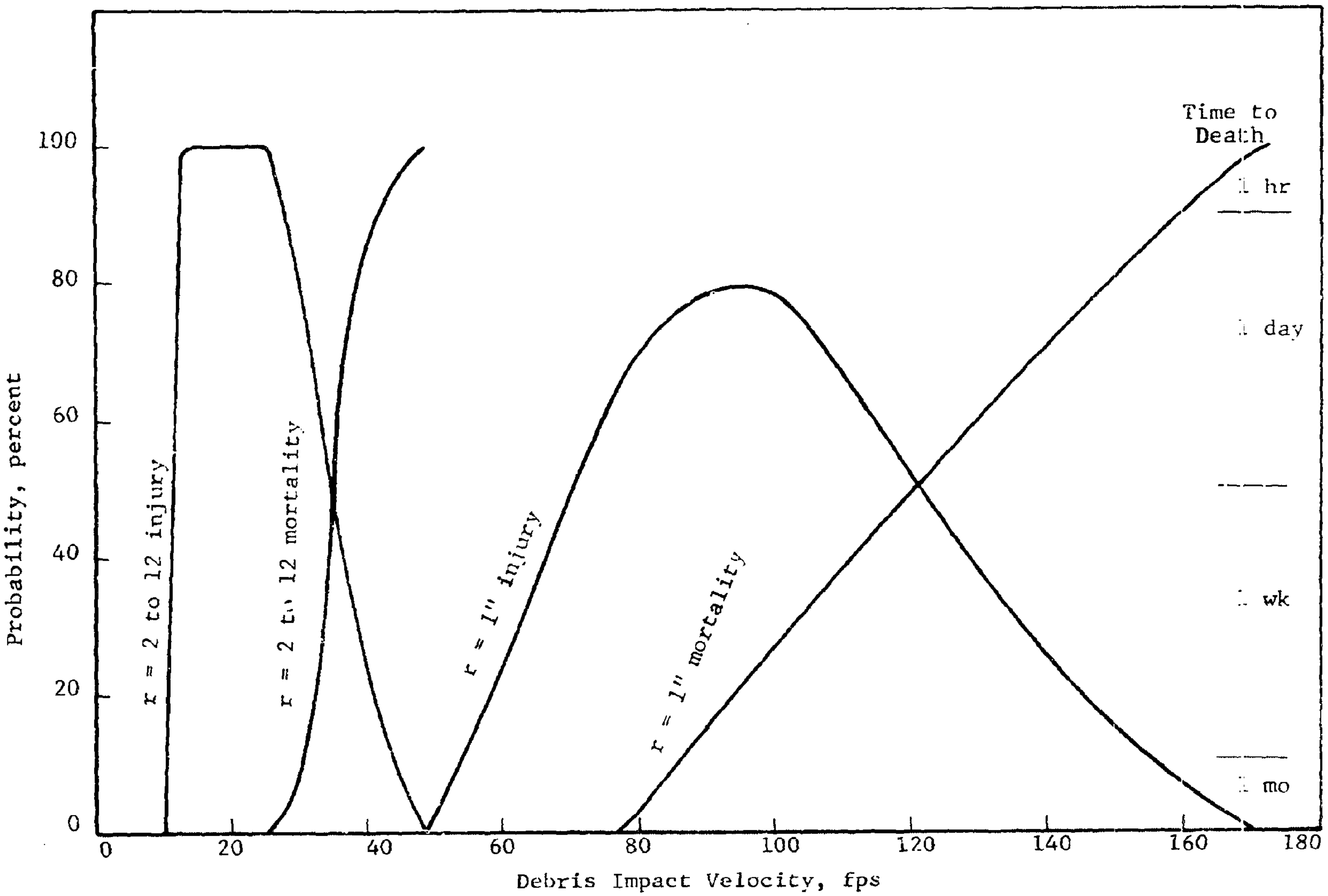


Fig. 13 KILL PROBABILITY FROM DEBRIS IMPACTS (Thorax)

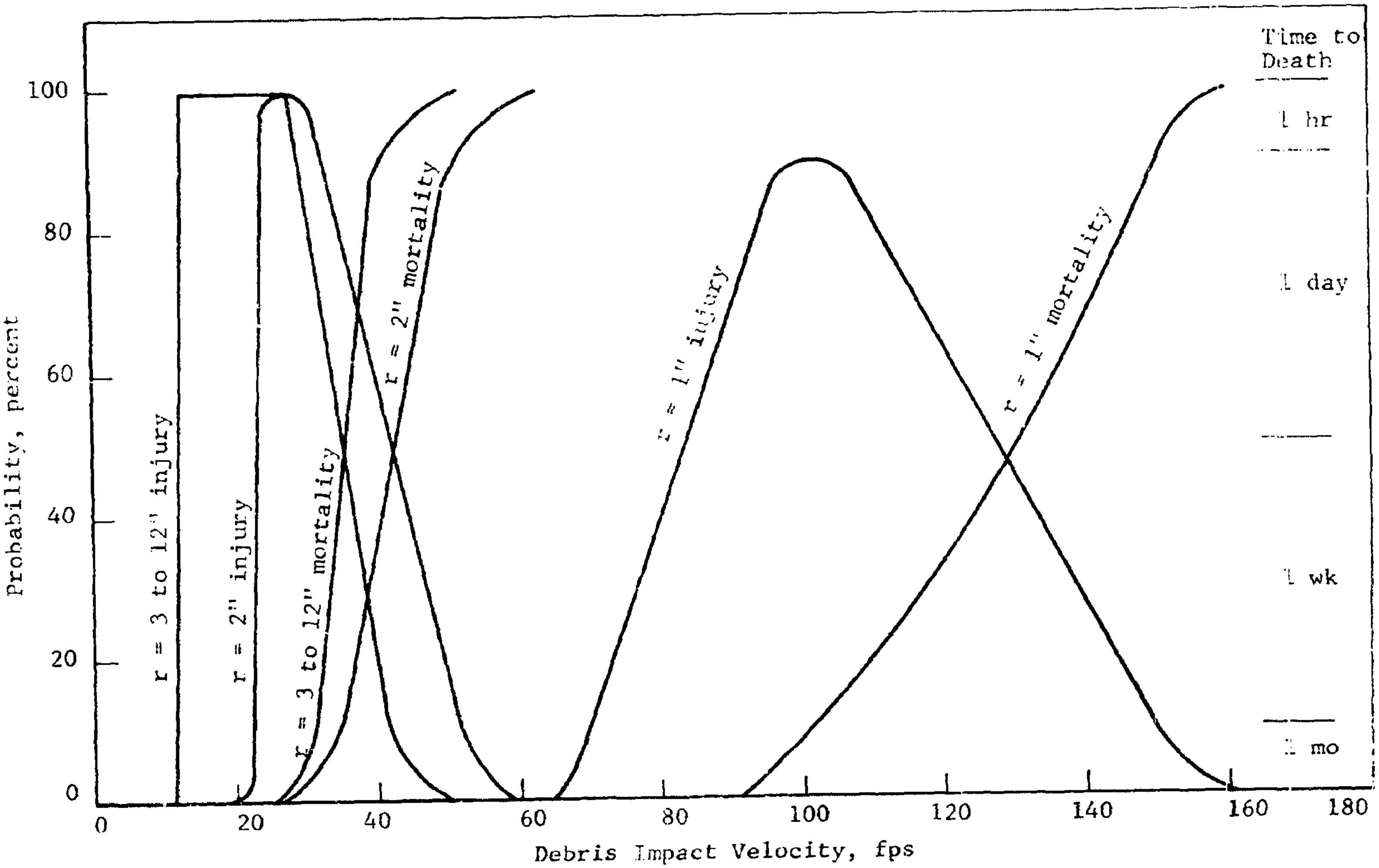


Fig. 14 KILL PROBABILITY FROM DEBRIS IMPACTS (Head)

basis for such an extrapolation in view of the limited data. For this reason automobile accident data were reviewed Based upon fatalities in urban auto accidents 50 percent mortality was placed at approximately 33.8 ft/sec. While this refers to the velocity of the crash, not the body impact velocity, it is interpreted as lending support for an LD50 impact velocity greater than 26.2 ft/sec. The rodent data were therefore taken to apply to humans giving and LD50 impact velocity of 36.4 ft/sec. This certainly is an area requiring further study.

The injury probabilities were taken directly from Ref. 12 since no adequate contrary or supporting data were found. However the results of accidents and falls where people survive, and everyone has found such instances, make one question the validity of these numbers. It is because of these effects that a program of data gathering and tests is suggested to determine the actual initial impact velocities. The data of Fig. 15 were included in the computer code for estimating the effects of blast translation.

2.6 THERMAL EFFECTS

Thermal energy burns of concern for casualty considerations are second and third degree burns. These burns may be inflicted by direct exposure of the skin to radiation, by the reradiation of clothing heated by the thermal energy, or by the ignition of clothing and subsequent burning of the skin.

2.6.1 Effect of Thermal Radiation on Personnel

It is estimated that 20 to 30 percent of the fatal casualties of Hiroshima and Nagasaki were caused by flash burns. Most, if not all, of the survivors exposed in the open at Hiroshima, had much less than 50 percent of the body surface burned. Even the lightest clothing gave protection by a factor of 2 and in a few cases by a factor of 4. It was determined that thermal radiation is capable of causing skin

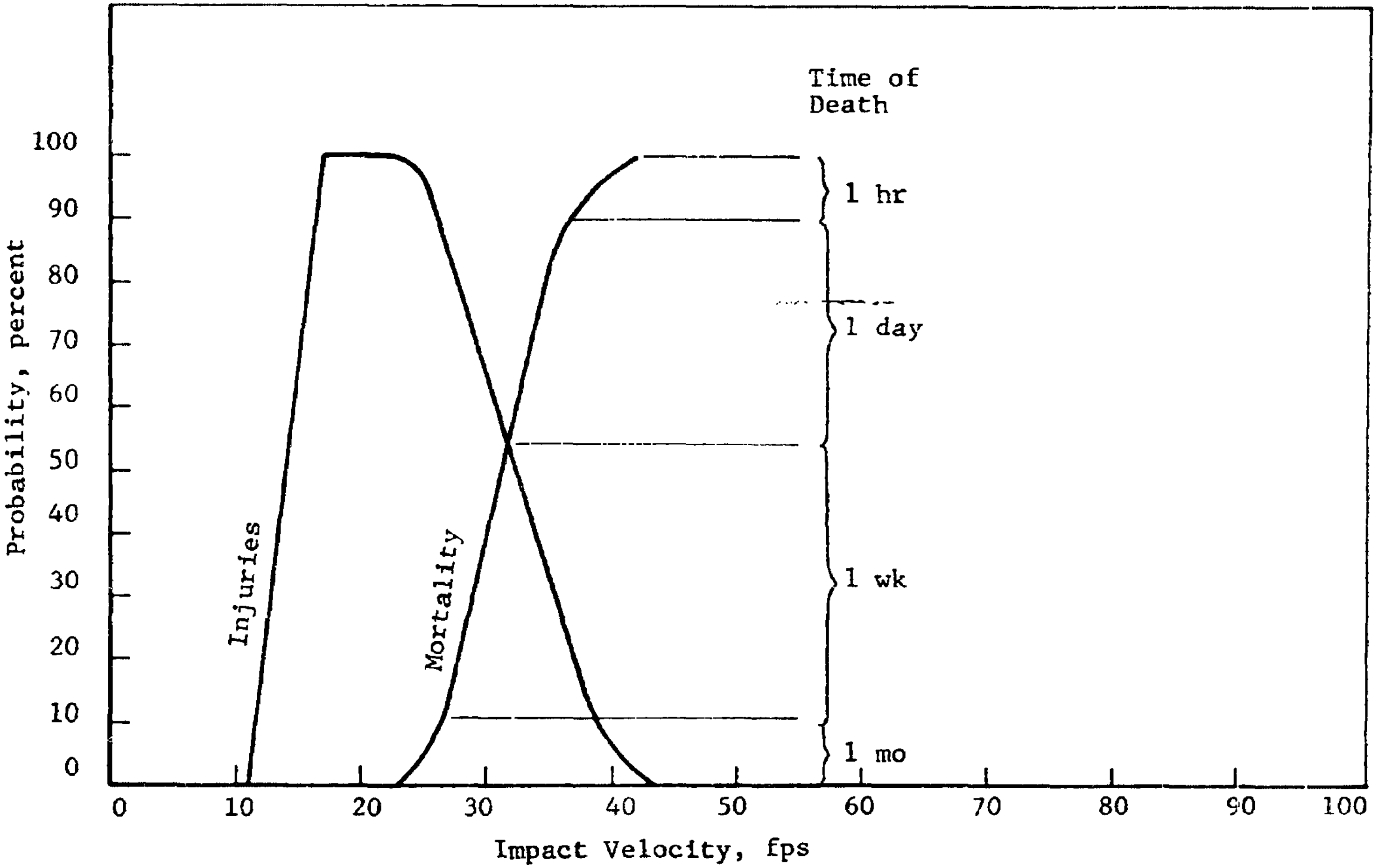


Fig. 15 KILL AND INJURY PROBABILITY FROM BLAST TRANSLATION

burns and eye injuries in exposed individuals at such distances from the nuclear explosion that the consequences of blast and of the initial nuclear radiation were not significant.

2.6.2 Burn Mortality

Since second and third degree burns for all practical purposes involve infection, early therapy is essential. Clean second degree burns usually heal by epithelization, but if infection ensues, healing may take up to 6 weeks. Healing time and symptomology for various burn situations is shown in Table 7.

Table 7

ESTIMATED HEALING TIME AND SYMPTOMOLOGY FOR BURNS

Degree of Burn	Healing Time, days	Symptomology
1	8	Burning pain 24 hr, soreness and redness 8 days.
2	8-16 (uninfected)	Burning pain 24 hr, swelling.
	up to 42 (infected)	Blistering 2 to 30 hr; ooze serum 3 to 4 days; scar (scabbing) 6 to 10 days, aching and tenderness 8 to 14 days.
3	20-30 (uninfected small burns)	Brief intense pain; swelling up to 2 days; blistering 24 to 36 hr, soreness 7 to 10 days.
	20-40 (larger burns scar formation)	Separation of destroyed skin 3 to 4 wk; ulceration; epithelization 4 wk.
	Many months (skin grafting)	Scale formation 6 wk; plastic surgery required for burnt areas 0.8 in.

Figure 16 from Ref. 44 illustrates the relationship in which the percent of total body burned is related with mortality based on over 1,800 treated burn cases. This figure represents the most up to date data on burn mortality. The effect of untreated burn cases has not been determined. However, the important of treatment on mortality in the case of burns as well as in the other casualties is of great concern for civil defense purposes. Another effect not illustrated in Fig. 16 is the relationship between burn area, mortality and age as shown in Fig. 17. Figure 18 presents the relationship between the energy deposited on the skin and the weapon yield for first, second, and third degree burns. This variation occurs because of the relative rates of release of energy by various size weapons. Large weapons require more energy to be delivered to cause the equivalent burn because the delivery rate is lower. Small weapons release energy over a short period of time and have a higher delivery rate, thus requiring less total energy to affect the same injury.

2.6.3 Determining Burn Areas

Thermal radiation from a nuclear explosion, like ordinary light, can be shielded by opaque material placed between a given object and the fireball. The opaque material will absorb the energy and act as a shield providing protection from thermal radiation, unless reradiation or ignition occur. Transparent materials such as glass allow some thermal radiation to pass through.

Some of the most extensive and destructive burns result from burning clothing; such burns are usually deep and circumferential in extent. Reflectance and transmittance generally play a more important role than the absorption which ultimately leads to ignition. Obviously, dark materials with a low ignition temperature are hazardous during nuclear attack. Transmittance depends both on the color and weight of the fabric.

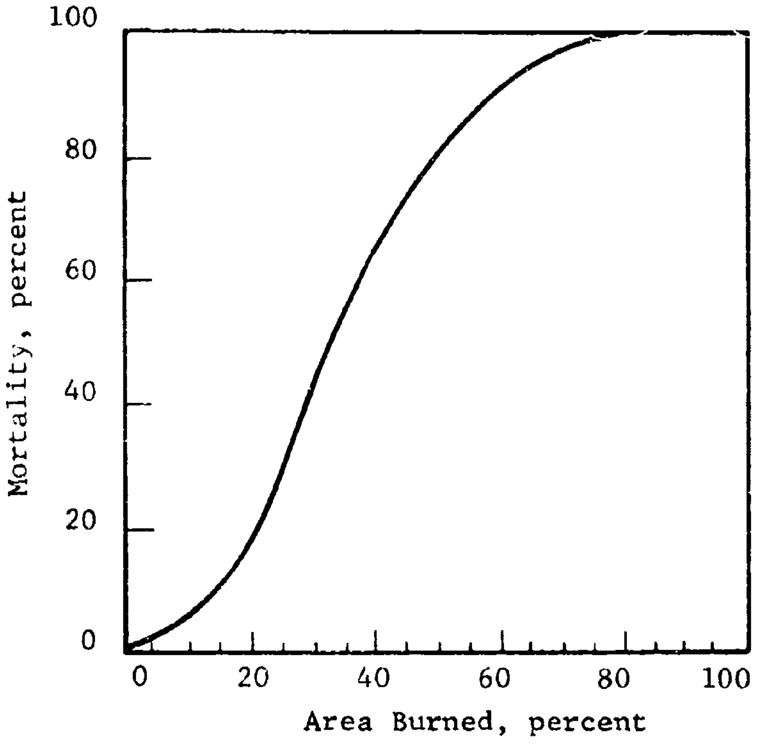


Fig. 16 BURN MORTALITY

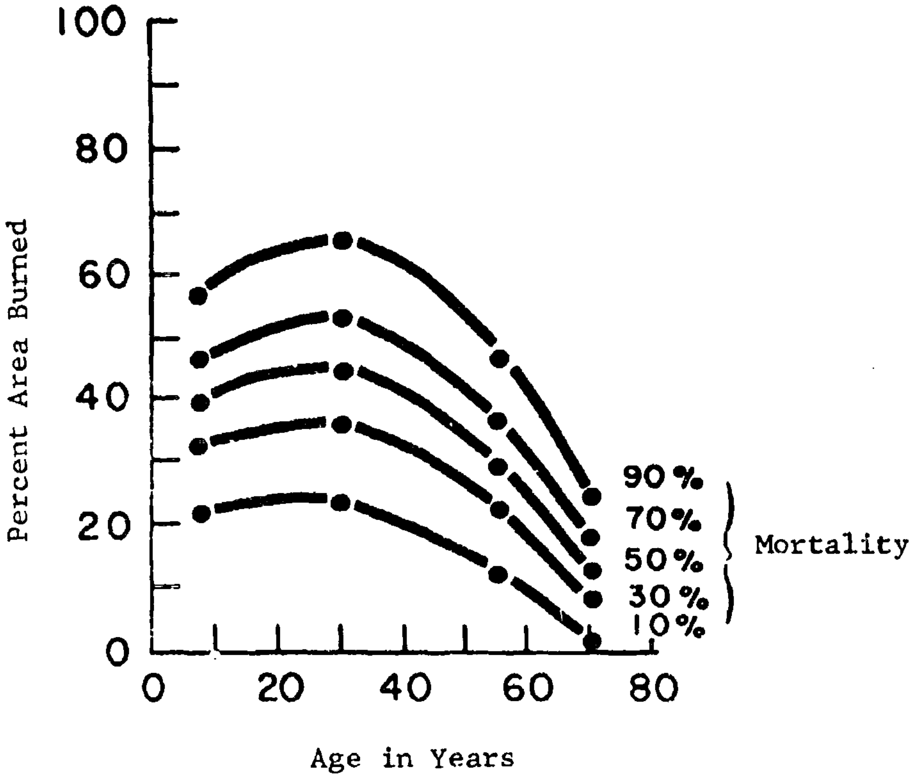


Fig. 17 MORTALITY FOR DIFFERENT AGES AND BURN AREAS

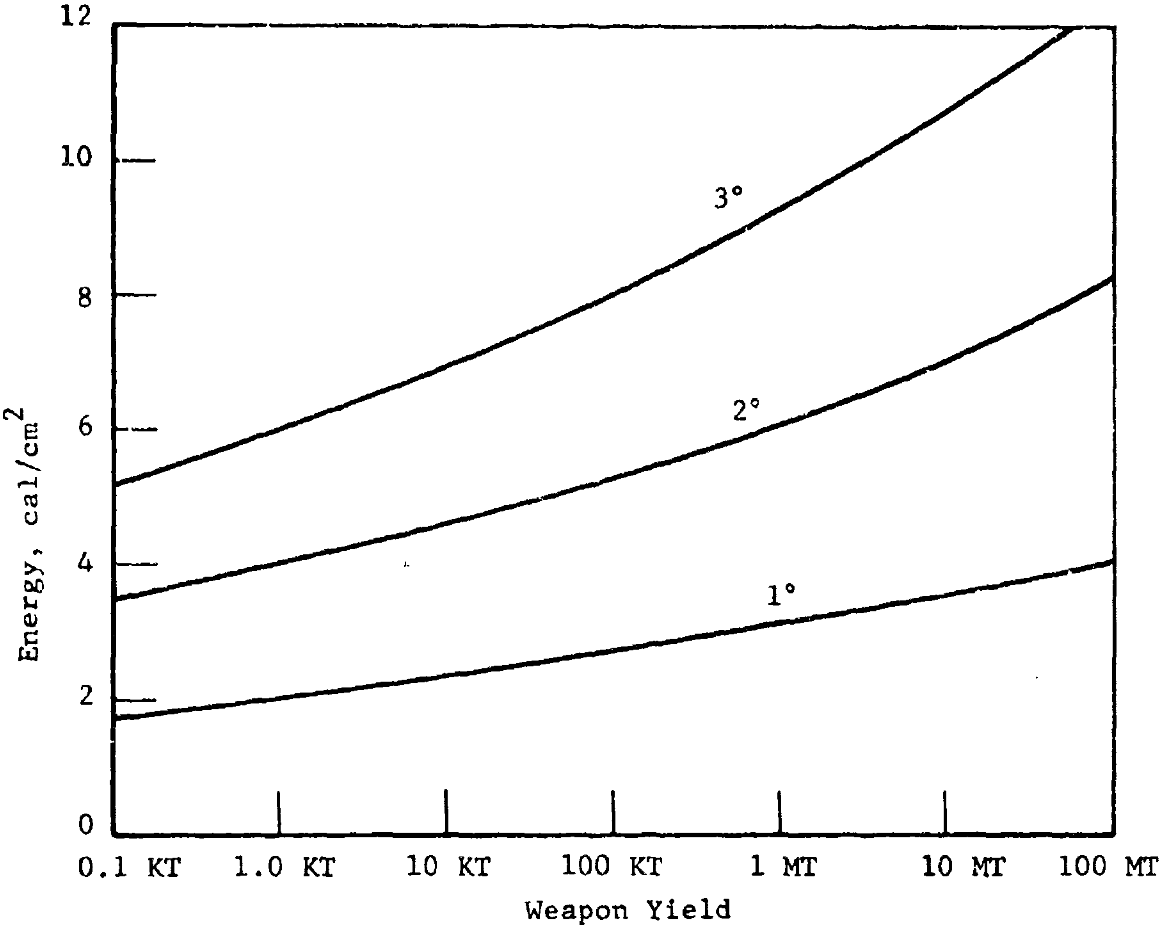


Fig. 18 THRESHOLD EXPOSURES FOR HUMANS EXPOSED TO WHOLE THERMAL PULSE (Ref. 31)

Table 8 relates the estimated energy to cause ignition of various materials. The results can be scaled to other yields. Figure 19 illustrates the relationship between the thermal energy delivered and the percent of the skin burned for a 1 MT weapon. These curves were estimated from explosed skin areas, thermal radiation energies necessary to cause burns, and the thermal energies necessary to ignite clothing. The curve was extrapolated to 100 percent based on Hiroshima data.

Table 8

VALUES OF ENERGY REQUIRED FOR IGNITION OF CERTAIN MATERIALS FOR A 1 KT WEAPON

Materials (Ref. 24)	(cal/cm^2)
Newspapers, dry	2.6
Dry, rotted wood	3.0
Dry deciduous leaves	4.5
Brown Kraft paper, dry pin needles	5.7
Trees, not ignited	5.6
Colored fabrics, not wool	5.8
Many combustible materials, weathered wood siding (new wood charred)	8.9
White cotton, colored wool	11.8
Painted (white) wood siding, charred only	18.5

2.6.4 Time to Death

Figure 20 from Ref. 20 is an estimate of time to death based on animal tests. The figure shows the probable time to death as a function of the skin area burned. By no means is this data significant to the problem since it represents only one test. However, results of this type were necessary for completeness of the analysis. Figures 16, 19 and 20 are incorporated in the computer code for determining mortalities, injuries, and time to death. The area burned is determined from

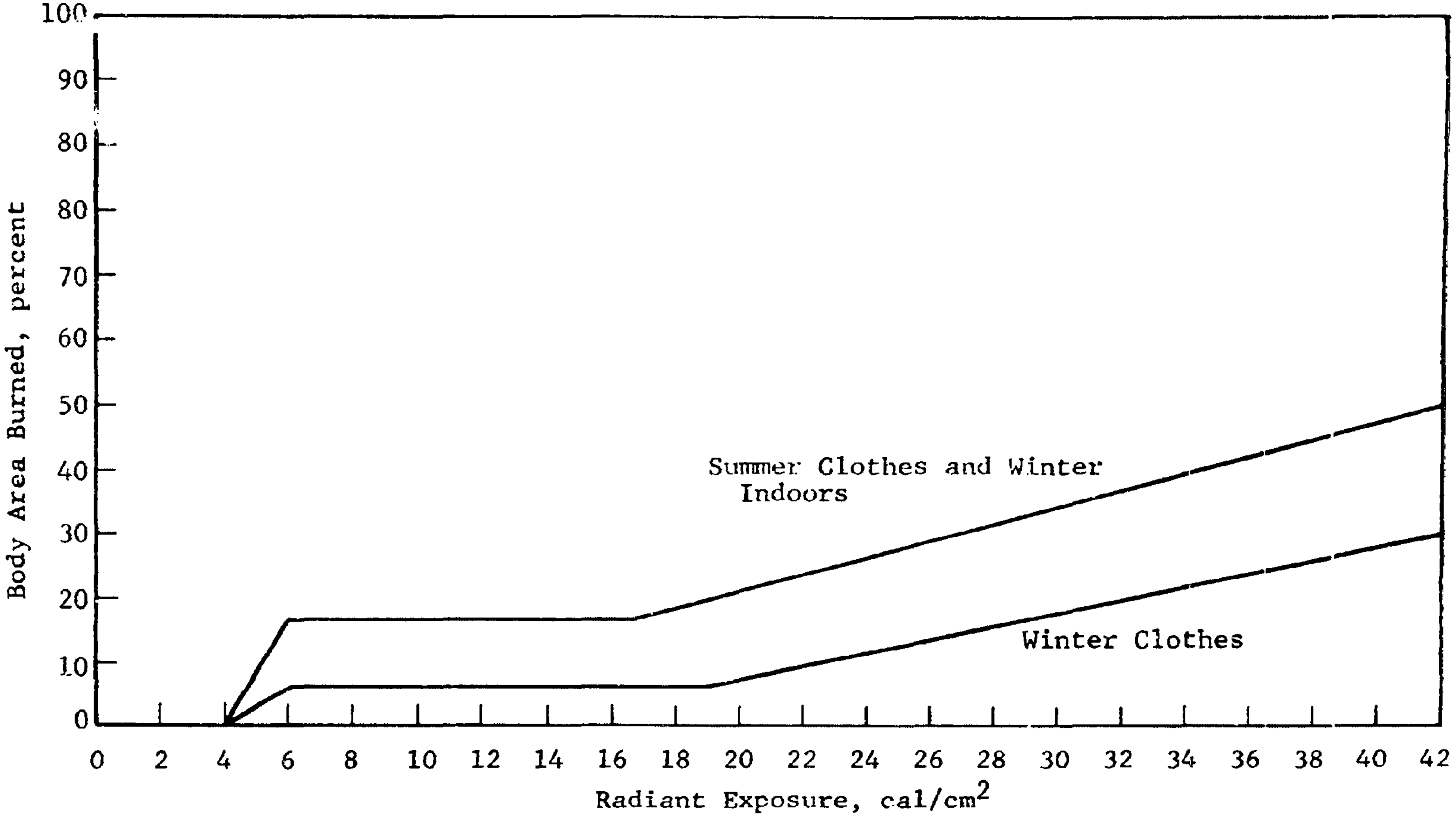


Fig. 19 BODY AREA BURNED BY THERMAL RADIATION, 1 MT

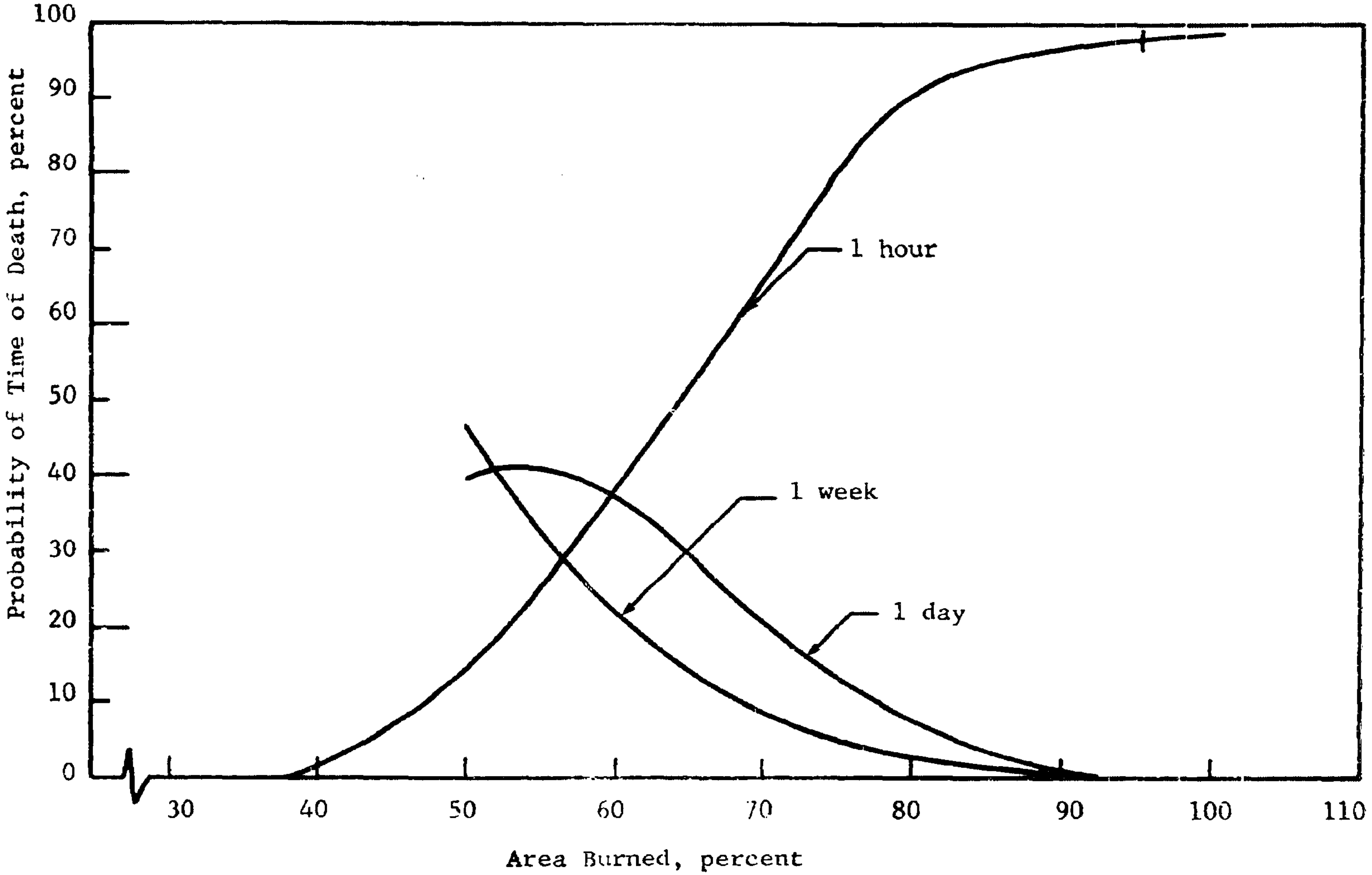


Fig. 20 TIME TO DEATH THERMAL RADIATION

Fig. 19 and the incident energy, which is scaled to 1 MT. This is used with Fig. 17 and 20 to determine the probability of death and time to death. Any burns indicated are counted as injuries, therefore the number of burn injuries is the difference between the number of people burned, and those dying.

2.6.5 Eye Injury

Results from the detonations over Japan indicate that eye injuries directly attributable to thermal radiation appeared to be relatively unimportant. There were many instances of temporary blindness occasionally lasting up to 2 or 3 hrs. In no case, among 1,400 persons examined, was the thermal radiation exposure of the eyes sufficient to produce permanent opacity of the cornea.

Neither flash blindness nor retinal damage constitute major hazards during the daytime because of the restricted pupillary diameter which limits the amount of light entering the eye. Furthermore, the blink reflex, 100 to 150 msec, protects the eye from undue amounts of radiation, except in those cases where the thermal impulse is delivered within extremely short times. This is the case for low yield weapons on the ground and for weapons of any yield exploded at very high altitudes. Permanent eye injury would be expected only in those persons who were looking directly at the fireball.

Indicated Areas of Research on Thermal Effects

- No effort appears to have been directed to the evaluation of thermal damage for more than one weapon on target.
- Configuration of the thermal-time pulse and variations due to burst height and transmissivity of the atmosphere should be determined.
- More needs to be learned about biological and physical effect of hot gases entering underground shelters.

- Extent of protection afforded by various types of clothing and shielding should be further explored.
- Synergistic effects of thermal and radiation energies are not fully known.

2.7 BIOLOGICAL EFFECTS OF INITIAL RADIATION

The primary damage which causes radiation death is damage to the hematopoietic system which consists of the bone marrow, lymphatic system, and the spleen. Comparable patterns of hematopoietic response are shown by small animals and man but the response is at an accelerated rate in the animals because of their shorter life span. Each species tested, and possibly man, can tolerate a chronic dosage of only five times the acute LD50 dosage.

Blair (Ref. 15) stated that radiation injury is proportional to the dose rate. A part of this injury is repaired spontaneously at a rate proportional to the magnitude of injury, and an irreparable fraction is present which is proportional to the total accumulated dose. Death following an acute dose is due primarily to excessive reparable injury (injury for which there has not been enough time or the proper conditions to recover); whereas life-shortening following chronic radiation is due to irreparable injury.

There is essentially no difference in effect of a given dose delivered over a few seconds, a few minutes or a few hours. However, a comparable dose delivered over several days or weeks would be much less effective for some effects. The lethal dose for a mouse given over 4 wks is five times the single acute dose, whereas for the dog it is only 1.5 times. However, Blair postulates that extrapolation to another species may be made on the basis of the normal median survival time for that species.

2.7.1 General Effects of Radiation Doses on Humans

As with biological effects, the shape of the mortality versus dose curve is not know for man. Reliable information on man has been obtained for radiation doses up to 200 rem. As the dose increases from 200 to 600 rem, available data from exposed humans decreases rapidly and must be supplemented more and more by extrapolations based on animal studies. However, the conclusions drawn can be accepted with a reasonable degree of confidence. Beyond 600 rem, relationships between dose and biological effects on man must be translated almost entirely from observations made on animals exposed to ionizing radiations. Figure 21 presents representative quantitative values postulated for humans (Ref. 18).

The effect of nuclear radiation on living organisms depends not only on the total absorbed dose but also on the rate of absorption and on the region and extent of the body exposed. Different portions of the body show different sensitivities to ionizing radiations, also, there are variations in degree of sensitivity among individuals. In general, the most radiosensitive parts include the lymphoid tissue, bone marrow, spleen, organs of reproduction, and gastrointestinal tract.

Gerstner (Ref. 16) notes that in the dose range from 150 to 200 rem the acute radiation syndrome becomes noticeable in the majority of an exposed population, and it may reach clinical significance in a few highly radiosensitive persons. Approximately 200 rem will be the clinical tolerance dose, or the threshold dose, beyond which an appreciable number of persons can be expected to develop significant complications requiring hospitalization and intensive medical treatment. At these levels the physical fitness and work capacity of the patient will return to normal about three to four months following exposure. Up to about 500 rem the clinical course of the acute radiation syndrome is largely determined by radiation

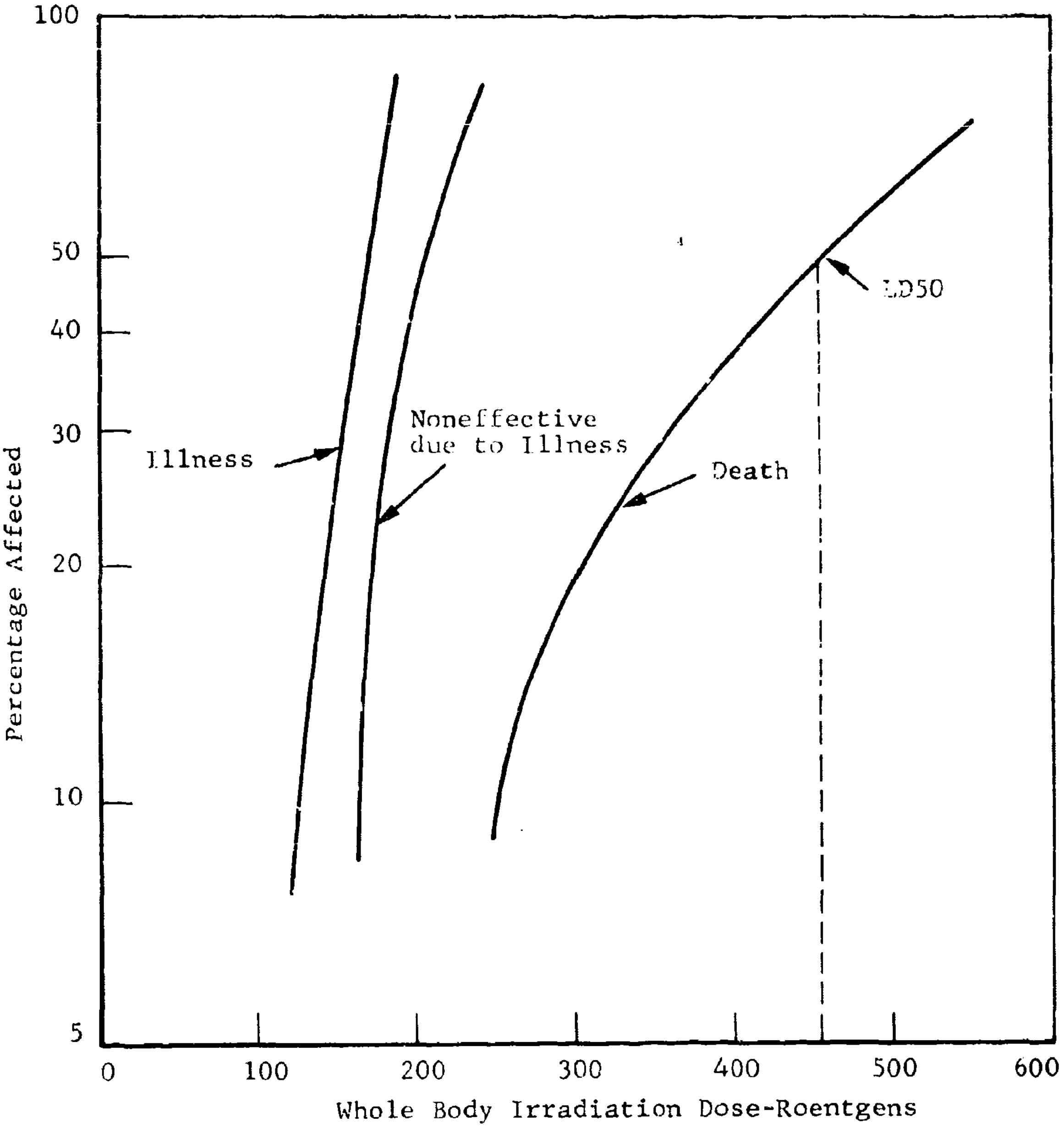


Fig. 21 ESTIMATED EFFECTS OF IRRADIATION (Ref. 18)

effects on the lymphoid tissue and the bone marrow. At doses greater than 500 rem, direct radiation damage to the epithelium of the gastrointestinal mucosa becomes a decisive factor. Thus, in a wide dose range (up to 500 rem) those individuals who survive can overcome the acute radiation syndrome and return to a useful life. With doses larger than 700 rem, death usually occurs in a few hours to a week. Table 9 illustrates the predicted clinical course for humans exposed to acute dosages of penetrating radiation. In general a median lethal dose of 450 rem is postulated for man. The 39 percent fatalities given for a dose of 400 to 500 rem would appear to be low in light of subsequent information.

Another study (Ref. 17) provided related data based on the assumption that human populations behave in the same way as animal populations, and the fatality versus dose curve is a normal distribution with a standard deviation of about 20 percent of the LD50 value. With 500 rem as the LD50 dose, the standard deviation is then 100 rem. The percent fatalities versus dose curve in this case is shown in Fig. 22. The time to death and incapacitating illness curves are shown in Fig. 23 from Ref. 15. These two cases represent the data employed in the computer simulation. Actually, the LD50 for man still is a matter of speculation and the estimates made in Fig. 22 must be regarded as tentative. However, the radiation casualty criterion constitutes one of the better defined criteria in the author's opinion.

2.7.2 Effects of Acute Radiation Doses

Table 10 (Ref. 15) is presented as the best available summary of the effects of various whole-body dose ranges of ionizing radiation on human beings. Below 100 rem, the response is almost subclinical, although changes may be occurring in the blood. Between 100 and 1,000 rem is the range in which therapy will be successful at the lower end and may be successful at the upper end. The earliest symptoms of radiation injury are nausea

Table 9

ESTIMATED CLINICAL COURSE AND HOSPITALIZATION REQUIREMENTS FOR HUMANS EXPOSED TO VARIOUS ACUTE DOSAGES OF PENETRATING RADIATION (Ref. 17)

Dose, rem	Clinical Symptoms, percent						Individuals Needing Hospitalization, percent	Maximum Time of Hospitalization, wk
	Trivial	Light	Moderate	Serious	Grave	Fatal		
200-300	1	23	64	2			2	6
300-400			6	68	26		94	7
400-500				3	58	39	100	9
500-600					6	94	100	11
600						100	100	11

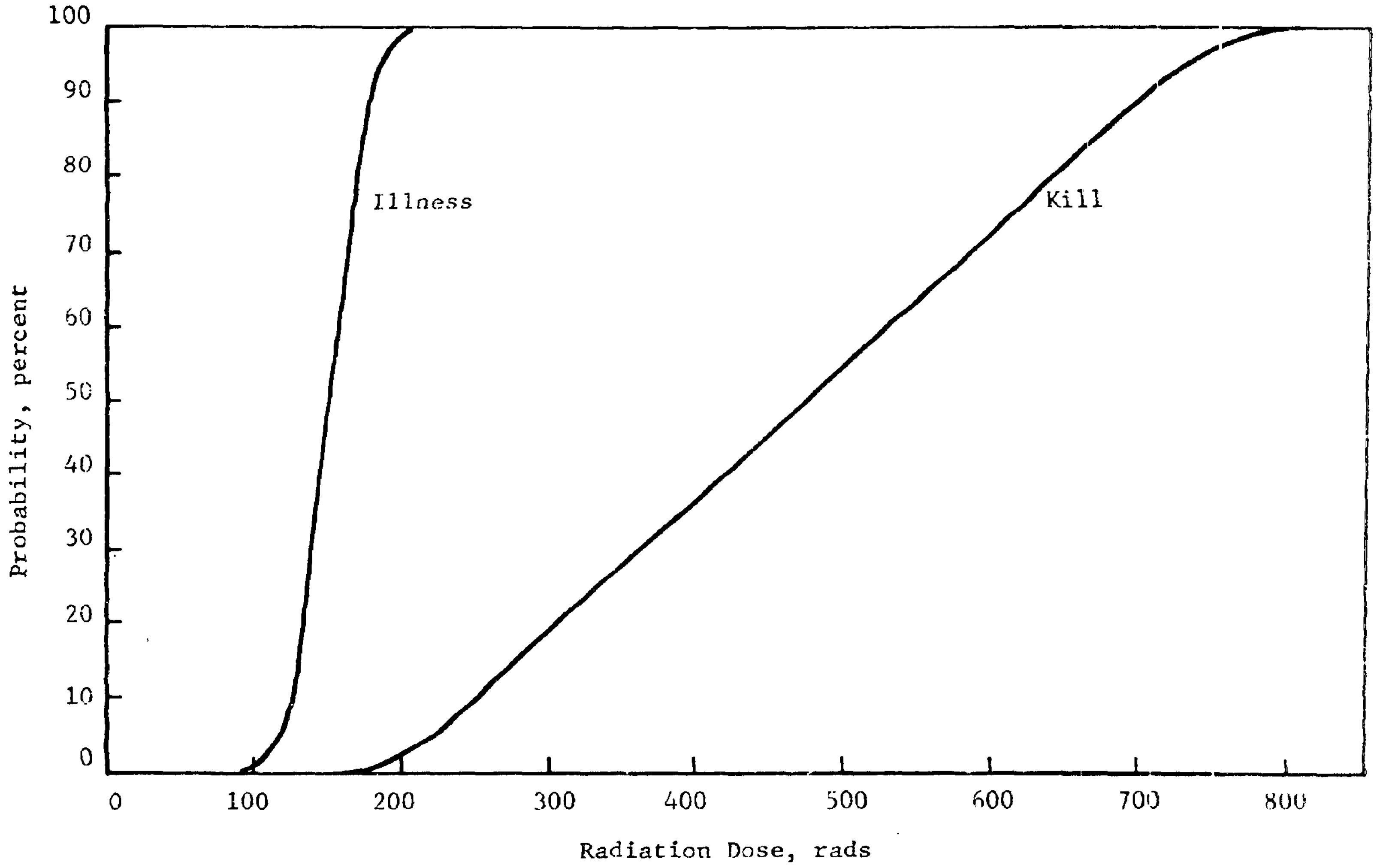


Fig. 22 KILL AND ILLNESS PROBABILITY FROM IONIZING RADIATION

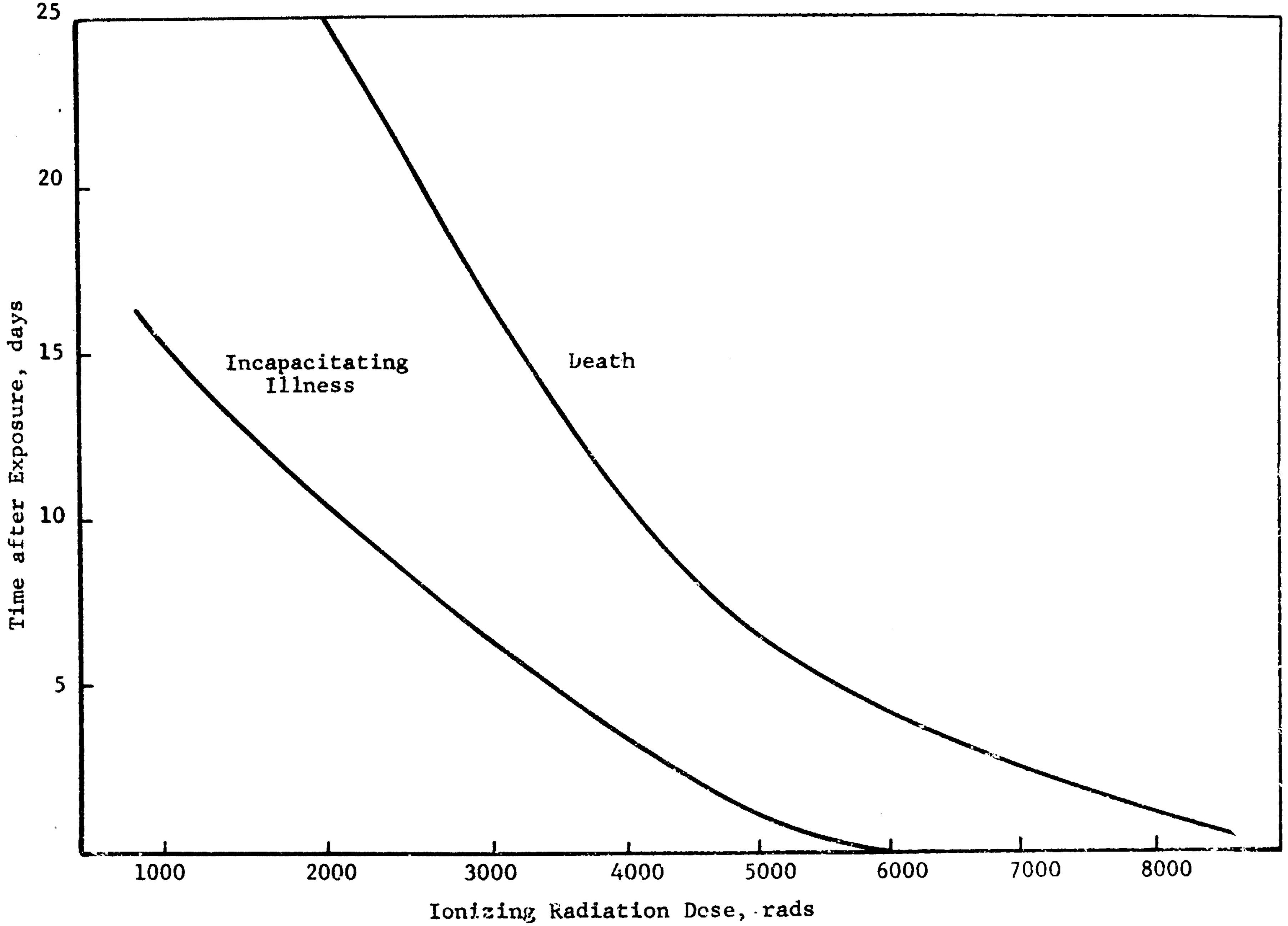


Fig. 23 TIME TO DEATH AND ILLNESS FROM IONIZING RADIATION

Table 10

SUMMARY OF CLINICAL EFFECTS OF ACUTE IONIZING RADIATION DOSES (Ref. 16)

		100 to 1000 rems Therapeutic Range			Over 1000 rems Lethal Range	
Range	0 to 100 rems Subclinical Range	100 to 200 rems	200 to 600 rems	600 to 1000 rems	1000 to 5000 rems	Over 500 rems
		Clinical Surveillance	Therapy Effective	Therapy Promising	Therapy Palliative	
Incidence of vomiting	None	100 rems: 5% 200 rems: 50%	300 rems: 100%	100%	100%	
Delay time	--	3 hr	2 hr	1 hr	30 min	
Leading organ	None		Hematopoietic tissue		Gastrointestinal tract	Central nervous system
Characteristic signs	None	Moderate leucopenia	Severe leucopenia; purpura; hemorrhage; infection. Epilation above 300 rems		Diarrhea; fever; disturbance of electrolyte balance.	Convulsions; tremor; ataxia; lethargy.
Critical period post-exposure	--	--	4 to 6 weeks		5 to 14 days	1 to 48 hr
Therapy	Reassurance	Reassurance; hematologic surveillance.	Blood transfusion; antiobotics.	Consider bone marrow transplantation.	Maintenance of electrolyte balance.	Sedative
Prognosis	Excellent	Excellent	Good	Guarded	Hopeless	
Convalescent period	None	Several weeks	1 to 12 months	Long		
Incidence of death	None	None	0 to 80% (variable)	80 to 100% (variable)	90 to 100%	
Death occurs within	--	--	2 mo		2 wk	2 days
Cause of death	--	--	Hemorrhage; infection		Circulatory collapse	Respiratory failure; brain edema.

and vomiting accompanied by discomfort, loss of appetite, and fatigue. The most significant effect is on the hematopoietic tissue. An important manifestation of the changes in the functioning of these organs is leukopenia, that is, a decline in the number of luekocytes (white blood cells). Beyond 1,000 rem, the prospects of recovery are so poor that therapy may be restricted largely to palliative measures. In the range from 1,000 to approximately 5,000 rem, the pathological changes are most marked in the gastrointestinal tract; above 5,000 rem it is the central nervous system which exhibits the major injury.

Individuals exposed in the lethal range can be divided according to symptoms and signs into groups having different prognosis. These may be condensed into three groups in which survival is, respectively, probable, possible, and improbable (Ref. 18).

Group 1 - Survival Probable

This group consists of individuals who may or may not have had fleeting nausea and vomiting on the day of exposure. There is no further evidence of effects of exposure except for hematologic changes. The lumphocytes reach low levels early, within 48 hr, and may show little evidence of recovery for many months afer exposure. The granulocytes may show some depression during the second and third week. Platelet counts reach the lowest level on approximately the 30th day, at the time when maximum bleeding was observed following the Japanese explosions. It is well known that all defenses against infection are lowered even by sublethal doses of radiation and thus, patients with severe hematological depression should be kept under close observation and administered appropriate therapy as indicated.

Group 2 - Survival Possible

Vomiting may occur early but will be of short duration followed by a period of well-being. However, marked changes are taking place in the hemopoietic tissues. Lymphocytes are profoundly depressed within hours and remain so for months. Signs of infection may be seen when the total neutrophile count has reached virtually zero (7 to 9 days). The platelet cound may reach very low levels after 2 wk. External evidence of bleeding may occur within 2 to 4 wk. In the higher exposure groups of this category the latent period lasts from 1 to 3 wk with little evidence of injuries other than slight fatigue. At the termination of the latent period, the patient may develop purpura, epilation, oral and eutaneous lesions, infections of wounds or burns, diarrhea, and melena. The mortality will be significant. With therapy the survival time can be expected to be [illegible]

Group 3 - Survival Improbable

If vomiting occurs promptly or within a few hours and continues and is followed in rapid succession by prostration, diarrhea, anoreria, fever, the prognosis is grave; death will almost definitely occur in 100 percent of the individuals within 1 wk. There is no known therapy for these individuals.

2.7.3 Special Shielding Considerations

Shielding of the spleen has been found to afford protection against radiation. The LD50 for mice exposed to total body X-radiation with lead shielded spleen is nearly twice that for mice with spleen exposed (Ref. 19). The data shown in Table 11 emphasizes the importance of shielding as a protective measure. Data obtained subsequent to that shown in the table indicates that with the spleen protected, about 78 percent of the mice exposed to 1,025 rem survived.

Table 11

INCREASED RADIATION TOLERANCE BY
LEAD SHIELDING OF THE SPLEEN

Dosage (rem)	Spleen Shielded	Number of Mice	Number of Survivors	Survivors (percent)
700	Yes	27	26	96.3
	No	11	0	0.0
900	Yes	60	41	68.3
	No	44	3	6.8

2.8 COMBINED EFFECTS

An examination of the comparative weapons effects data confirms that it is not possible to realistically dissociate the integrated input effects for other than empirical considerations. However, for purposes of studying combined effects a situation can be conceived in which no single type injury is lethal or seriously incapacitating, but where a combination of two or more may be so, or where survival probability is reduced because of an exposure to two or more effects. Combined ionizing radiation effects are particularly important because those exposed to fallout radiation may have many types of injuries. In addition, combined thermal-ionizing radiation effects are of particular interest because of the wide range of thermal radiation and burn injuries which might be experienced.

Alpen (Ref. 20) reported that for each level of X-irradiation the death rate is higher when a burn is also applied. Conversely, for every burn level studied, mortality increased with increasing X-irradiation. He concluded:

1. Thermal trauma increased the lethality of the ionizing radiation.

2. The protective devices of animals against infection are so depressed by irradiation that the animal is unable to cope with the infectious processes arising as a result of the burn.
3. Combined trauma may unmask or accentuate lesions which, although present in the animal receiving either burn or X-irradiation alone, are usually of less consequence.

Valeriote and Baker (Ref. 21) working with rats found that a primary "shock" from thermal trauma potentiates the effect of X-irradiation. One series of rats were given second degree burns from which 100 percnet survival was observed for the first 30 days after trauma. Another series were exposed to 650 rem and 700 rem X-irradiation from which 94 percent survival was noted by 8 days following irradiation. The most significant increase in mortality occurred when the thermal trauma was superimposed on the series that received 700 rem of X-irradiation. A decrease in survival from 94 to approximately 40 percent was obtained in the 0 to 8 days period after combined injury. This period coincides with injury to the gastrointestinal tract. During days 8 to 20, which is the "bone marrow" phase of radiant injury, superposition of the thermal trauma on X-irradiation was found not to produce any statistically significant decrease in survival. A slight increase in mortality was found between days 20 to 30. This effect was attributed to infection of the animals from the burn area where a marked sepsis was seen to occur.

In all the X-irradiation groups, exposure to increasing severity of burn trauma resulted in increased mortality. Antibiotic therapy was found to be ineffective in combating the synergistic effect of combined burn and X-irradiation injury.

Bond (Ref. 22) reported a synergistic effect between a pulmonary infection and X-irradiation. An otherwise nonlethal pulmonary infection combined with doses of X-irradiation produced a markedly increased incidence of the pulmonary disease and a sharply increased mortality rate above that expected from the radiation alone. Working on the combined effect of burns and X-irradiation, Bond reported that 31 to 35 percent burns combined with the radiation levels shown in Table 12 increased mortality.

Table 12

EFFECT OF COMBINED BURNS AND X-IRRADIATION
(31 to 35 percent burns)

X-Irradiation (rem)	Mortality (percent)
0	50
100	65
250	100

When 16 to 30 percent burns, which are not normally lethal, were combined with 500 rem X-irradiation, mortality was 75 percent. Since 500 rem exceeds the LD50 value (450 rem) and therefore may be itself cause about 60 to 65 percnet mortality, the specific increase due to combined thermal (16 to 20 percent) and 500 rem X-irradiation is apparently about 10 to 15 percent.

Figure 24 relates the data reported herein on thermal and radiation effects. This effect has not been incorporated in the computer code. The entire relation between radiation, thermal, and blast injuries requires further investigation. In particular, the relation between ionizing radiation and each other effect should be examined because of the fallout environment which may exist after an attack, as well as the effect of a multiple attack.

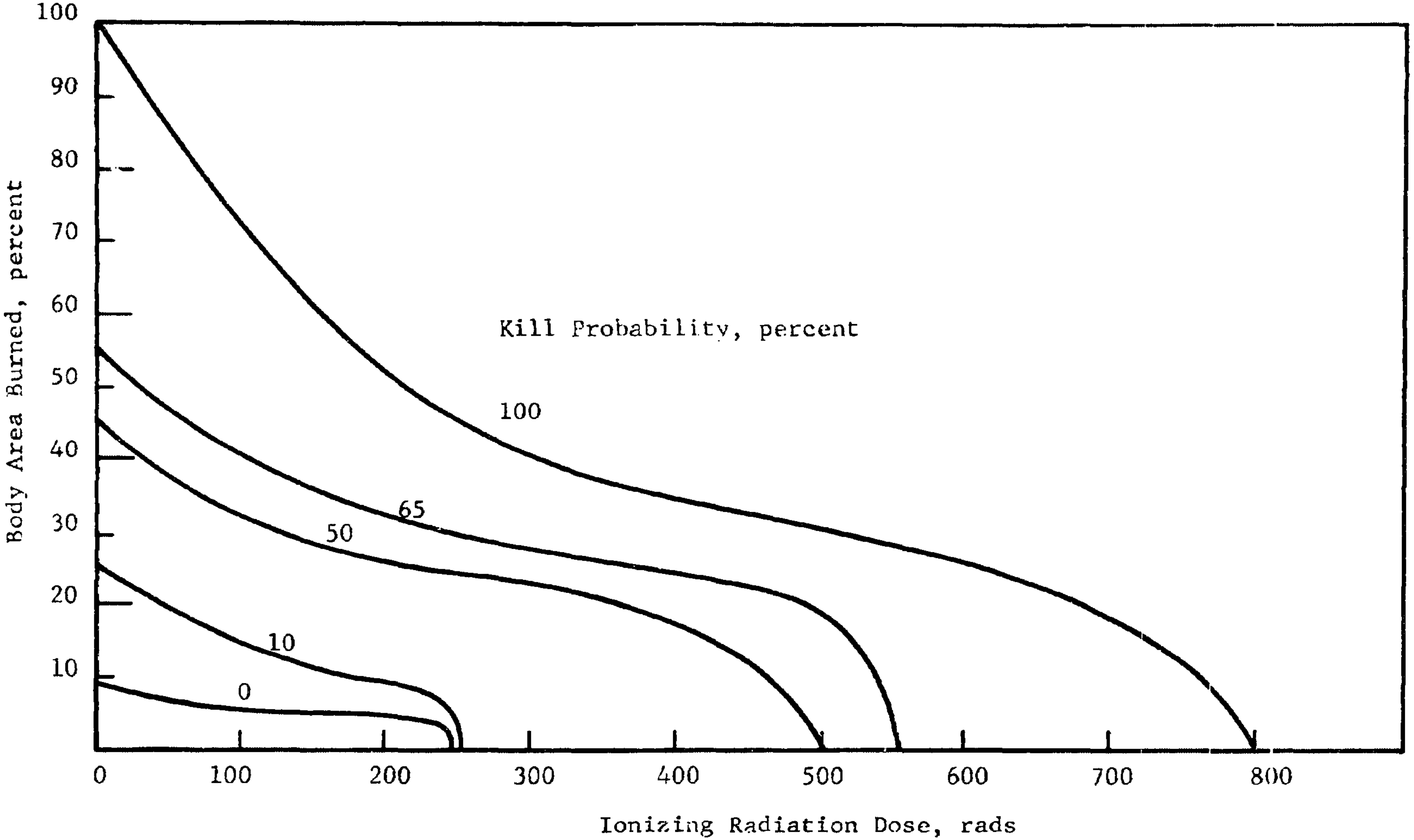


Fig. 24 KILL PROBABILITY FROM COMBINED THERMAL AND IONIZING RADIATION

SECTION III

MODEL DESCRIPTION

This section describes the various models developed for the overall computer simulation of casualties resulting from the initial effects of a nuclear detonation. The specific casualty mechanisms included in this model were:

(1) Primary Blast,
(2) Blast Translation,
(3) Debris,
(4) Thermal Radiation, and
(5) Initial Ionizing Radiation.

This first attempt at a model specifically excludes other important casualty mechanisms such as:

(1) Fallout Radiation,
(2) Fire, and
(3) Ground Shock,

and also indirectly excludes such important effects as scattering effects of gamma and neutron radiation and being "buried alive" by debris. The model also is only operative in the mach region inasmuch as only horizontal blast loading of people and structures are considered.

It was the overall intention in developing this model to provide a modular framework which could be easily updated when appropriate additions and changes were warranted. It may be noted that where parts of the model were uncertain provision has been provided to treat these parts parametrically. For example, in evaluating casualties from debris, the model requires a mix of particle sizes. Here, one can get into the problem of predicting structural collapse mechanisms and the fragmentation of frangible plates. Instead of letting the model compute these mixes directly, the mix is specified parametrically by particle size distribution or more generally by acceleration coefficient. There are, however, two areas in which the model utilizes questionable techniques and assumptions in order to deal with problems which are the subject of current research. These areas are in describing the geometry of the shelter system and the interaction of the blast wave with that geometry and also within a specific shelter. Although special techniques, which will be described below, were developed to treat both these areas in an analytic fashion, they could also be treated parametrically as input data as discussed above.

Detailed description of the casualty criteria and the way it was developed for each casualty mechanism was provided in the previous section of this report.

3.1 CHARACTERISTICS OF NODE GEOMETRY

Most of the casualty mechanisms which develop on the exterior of structures are highly dependent on geometric properties associated with the structure's length, width, height, spacing between contiguous structures and the orientation of the structure to ground zero. A general representation of the typical node geometry is illustrated in Figure 25. A particular structure located at the node is considered to have three structures contiguous to it. This results, in general, in affecting five particular ground areas with respect to the reference structure where personnel may be present. In special instances, which deviate from the general representation, these five areas may be both inconsistent and inapplicable. These special cases may best be shown by developing expressions for each of the five regular areas. These are:

$$\begin{aligned} A_1 &= S_1 (\ell - S_1 \cot \varphi) \\ A_2 &= S_1 S_2 + 1/2\ S_2 S_2 \cot \varphi \\ A_3 &= S_1 (S_1 \cot \varphi - S_2) \\ A_4 &= S_1 S_2 + 1/2\ S_2 \tan \varphi \\ A_5 &= S_2 (w - S_2 \tan \varphi) \end{aligned} \qquad (1)$$

S_1 and S_2 are Spaces between Buildings

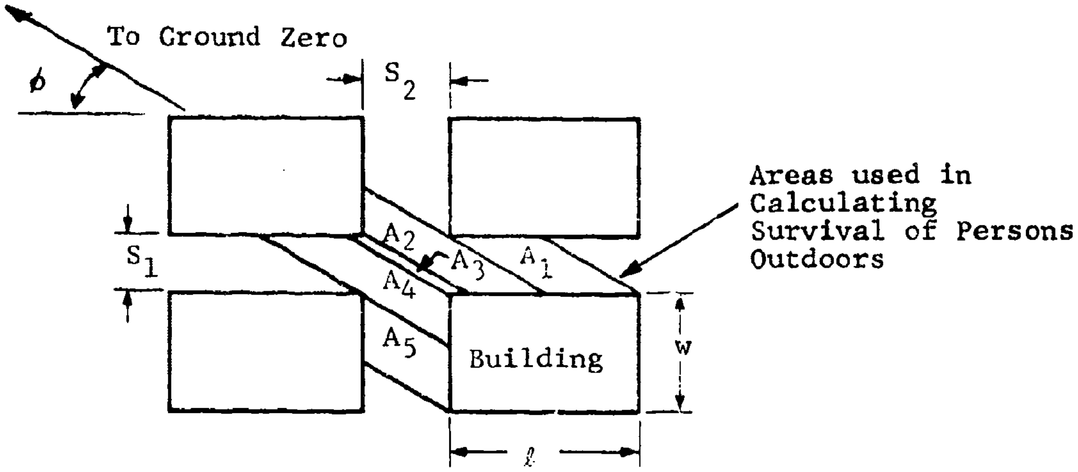


Fig. 25 NORMAL NODE GEOMETRY

where S_1 and S_2 are distances between structures as shown in Figure 25 and φ is the angle of incidence from the reference to ground zero, ℓ and w are structural dimensions. Corresponding distances associated with the areas are:

$$D_1 = S_1/\sin\varphi$$

$$D_2 = D_1 + S_2/\cos\varphi$$

$$D_3 = D_1$$

$$D_4 = D_2$$

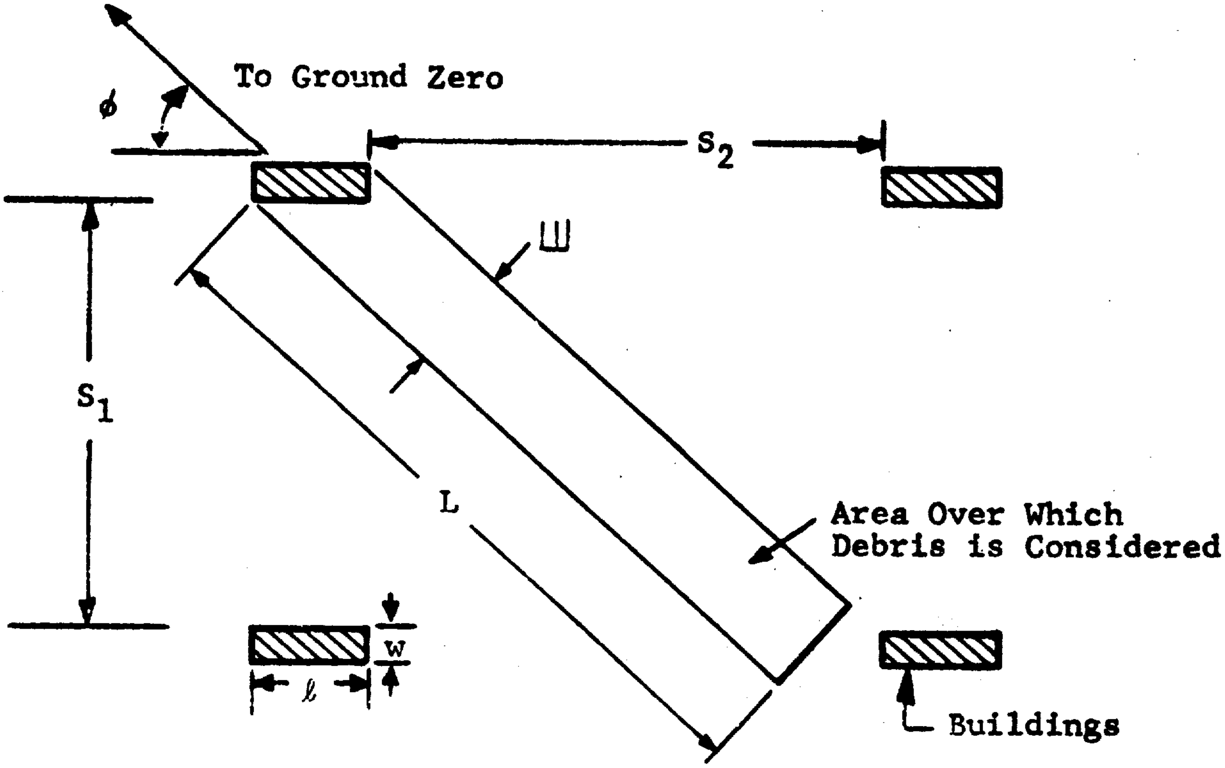
$$D_5 = D_2 - D_1$$

When $\varphi = 0$ or $\pi/2$, the five areas degenerate into a two area representation consisting only of the area of the two streets. These two areas are simply

$$\begin{aligned} A_1 &= S_1 S_2 + 2\, S_1 \ell \\ A_2 &= 2\, S_2\, w \end{aligned} \qquad (2)$$

When $0 < \varphi < \pi/2$, the area representation is developed differently for each of the appropriate casualty mechanisms (i.e., translation, debris, thermal radiation and ionization radiation).

Equation (2) is utilized directly in cases of translation and ionizing radiation with no regard to the angle of incidence, φ. The rationale here is that these effects are not influenced substantially by the angle of incidence because they take place over the entire exterior area. Exterior debris, however, is highly dependent upon the angle of incidence with the structure generating debris. Exterior debris is distributed over the area shown in Figure 26. This area is only a part of the entire exterior area which consists of the sum of the two areas of Equation (2). Thermal radiation is represented by a proportion of each of the two areas. This proportion is dependent on the shading which a neighboring structure affords another structure. Equations (3) below outline the altered Equation (2).



$$Ш = \ell \sin \phi + w \cos \phi$$
$$L = S_1 \sin \phi + S_2 \cos \phi$$
$$A = Ш L$$

Fig. 26 SPECIAL GEOMETRY FOR OUTSIDE DEBRIS CALCULATIONS

$$\begin{aligned} A_1^* &= \frac{D^*}{D_1} A_1 \\ A_2^* &= \frac{D^{**}}{D_2} A_2 \end{aligned} \qquad (3)$$

where

$$D_1 = (2\bar{l} + S_2)/2$$

$$D_2 = (2\bar{w} + S_1)/2$$

$\bar{l}, \bar{w}$ = average length and width of a particular class of structures at the node

$$D^* = D_1 - \frac{\bar{h}\, x_o}{h_{ob}} \sin \varphi$$

and

$$D^{**} = D_1 + S_1 - \frac{\bar{h}\, x_o}{h_{ob}} \cos \varphi$$

where

$\bar{h}$ = the height of the structure

h_{ob} = the height of burst

x_o = the distance from ground zero

3.2 WEAPON EFFECTS

The purpose of the weapon model is to provide the free field weapon effects which occur as a function of weapon yield, height of burst, distance from ground zero and in the case of thermal energy, visibility. Weapon effects parameters which are predicted include peak incident overpressure, positive phase duration, time of arrival of the blast wave, thermal energy, and the radiation dose due to the presence of initial gamma rays and neutron flux. In addition to these parameters, other blast parameters are developed utilizing the Rankine-Hugoniot relationships. These include peak dynamic overpressure, peak particle velocity, and the shock velocity. The approach in developing the weapon effects parameters is to utilize Effects of Nuclear Weapons (ENW) (Ref. 15) data as much as possible. However, other sources are utilized where applicable. The computer code, which employs this model, has been developed on a modular principle allowing for ease of updating weapon effects prediction.

Figure 27 illustrates the overpressure-height of burst-range relationship for a 1 KT burst (Ref. 15). Figures 28 and 29 illustrate a similar relationship for positive phase duration and arrival time respectively for a 1 KT weapon. The cube root scaling law makes these curves applicable to higher yield weapons. A linear interpolation scheme was utilized in obtaining intermediate values from these contour curves.

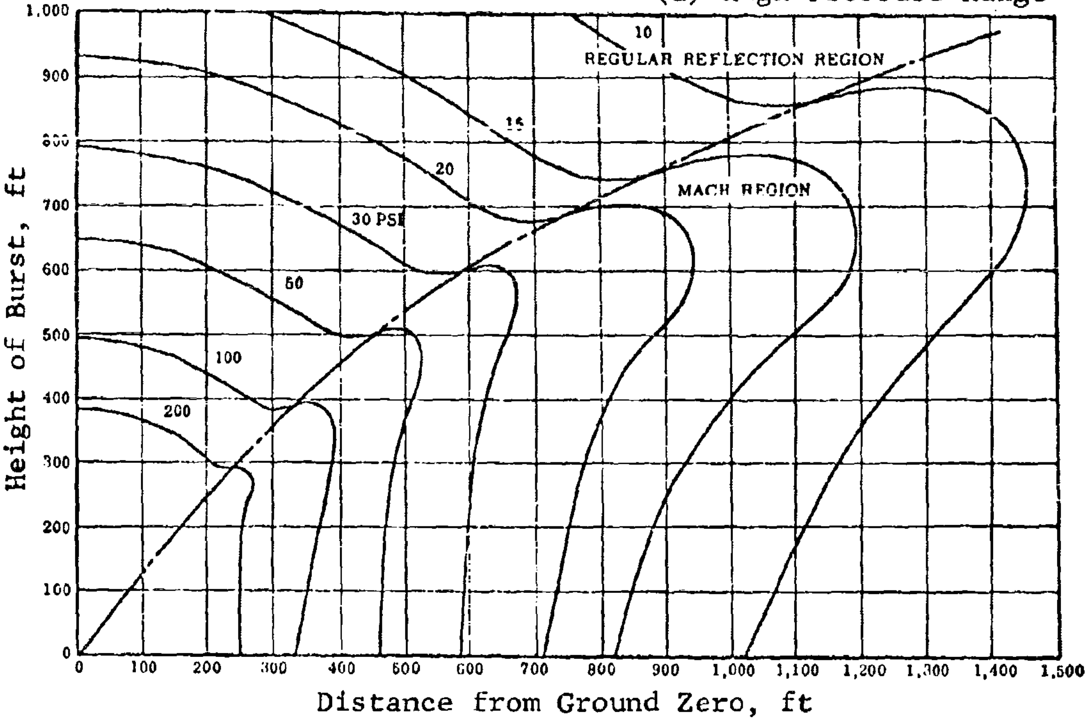
Development and usage of this interpolative routine is diagrammed in Figure 30 and consists of the following steps:

- Scaled heights of bursts and corresponding scaled ground ranges for 25-ft increments in h_{ob} along each constant overpressure curve are stored in the interpolative program.

  To obtain peak overpressure, given scaled h_{ob} and scaled ground range·

- Each constant overpressure curve is followed from $h_{ob} = 0$ upwards until the interval is found on each overpressure curve, which contains the given scaled h_{ob}.
- Linear interpolation is made within the chosen intervals to obtain the ground range on each constant overpressure curve corresponding to the the given scaled h_{ob}.
- Interpolated ground ranges corresponding to given scaled h_{ob} are read for each constant overpressure curve.

(a) High-Pressure Range



(b) Low-Pressure Range

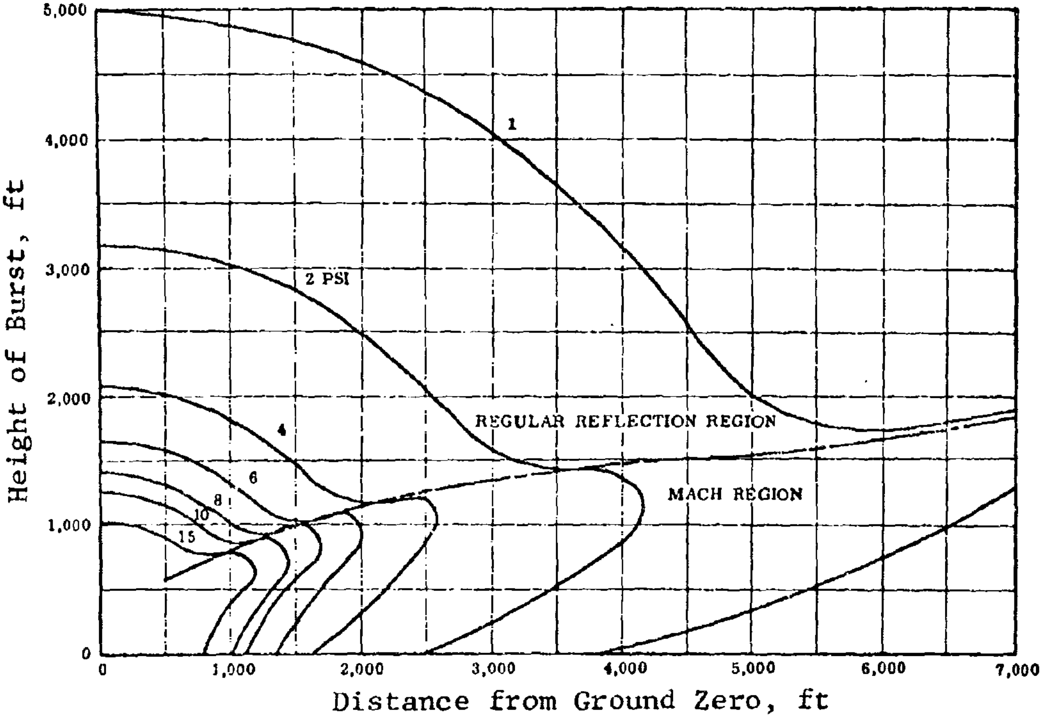
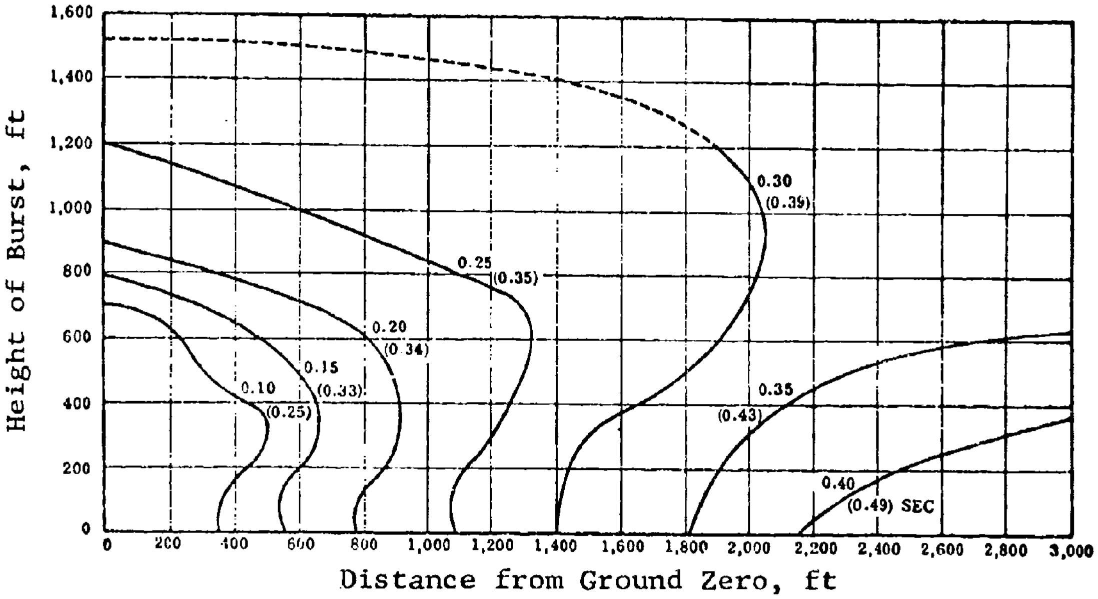


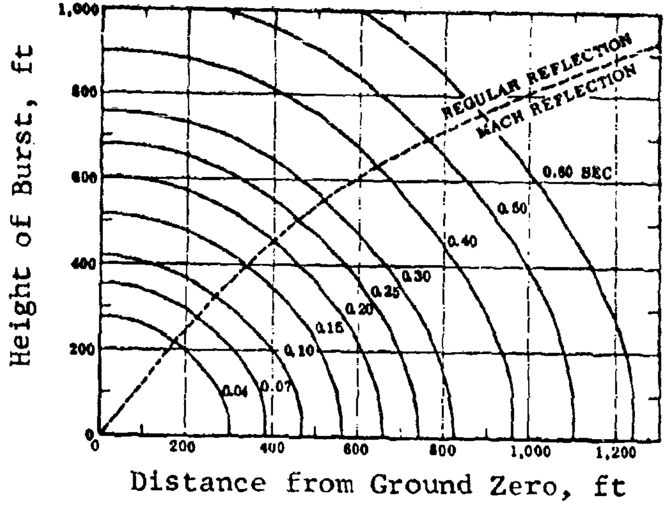
Fig. 27 PEAK OVERPRESSURES ON THE GROUND FOR 1 KT BURST



Note: Dynamic pressure is given in parenthesis

Fig. 28 POSITIVE PHASE DURATION ON THE GROUND OF OVER-PRESSURE AND DYNAMIC PRESSURE FOR 1 KT BURST

(a) Early Times



(b) Late Times

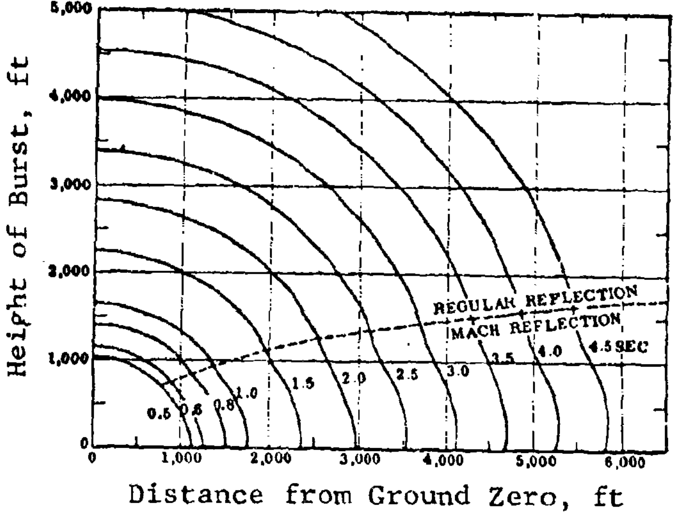


Fig. 29 ARRIVAL TIMES ON THE GROUND OF BLAST WAVE FOR 1 KT BURST

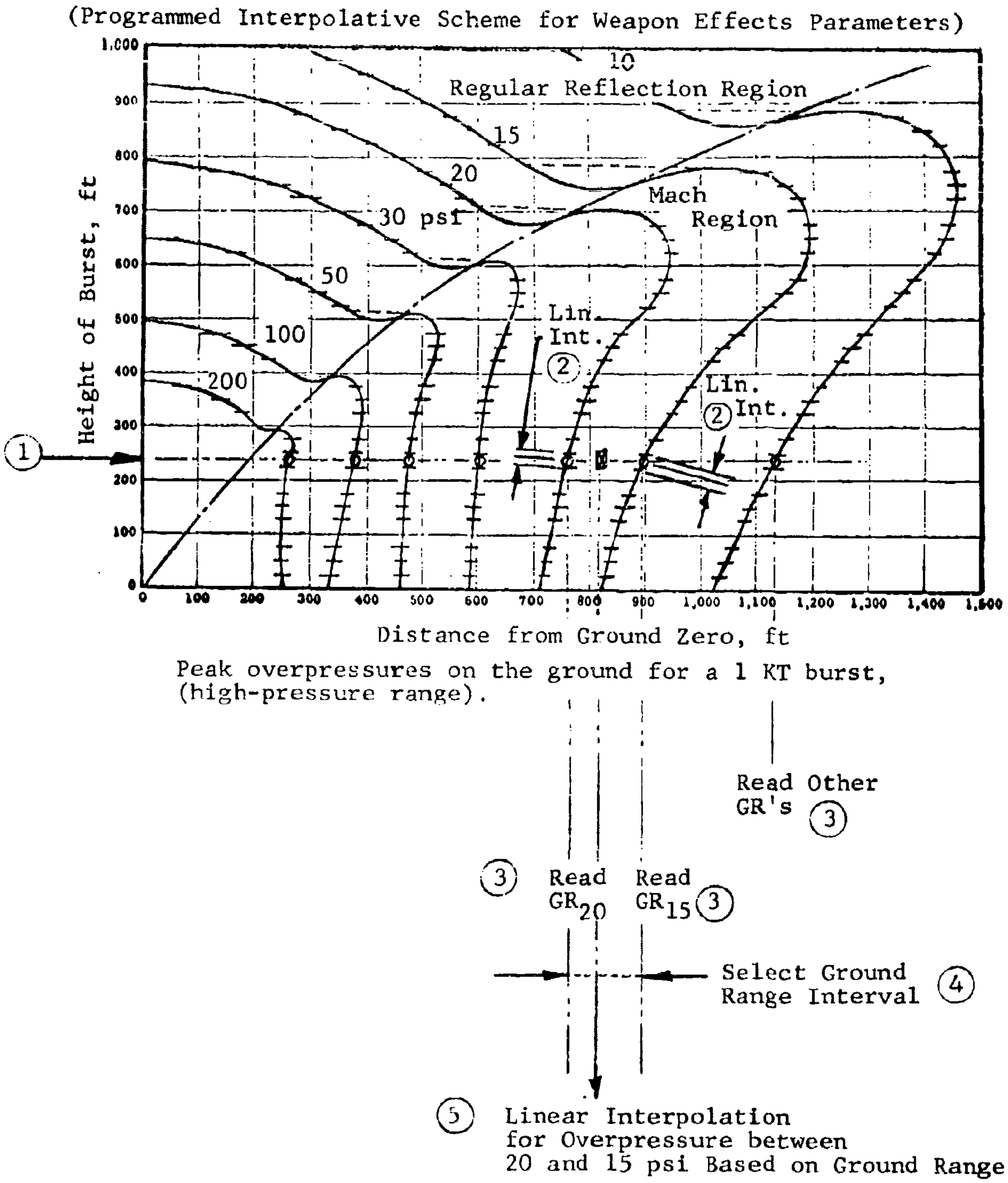


Fig. 30 HEIGHT-OF-BURST CHART FOR PEAK OVERPRESSURE
(High Range)

- Overpressure interval containing given scaled ground range is selected.
- Peak overpressure is finally obtained by linear interpolation, based on given ground range and interpolated ground ranges corresponding to given scaled h_{ob} on constant overpressure curves.

The thermal energy from the weapon may be expressed in the following functional form:

$$Q = \frac{1.04\ WT}{R^2}\ (\mathrm{cal/cm^2})\ \text{(Ref. 15)} \qquad (4)$$

where

W = weapon yield (KT)
R = slant range (mi)
T = transmissibility of the energy in air.

The transmissibility factor T was expressed in functional form utilizing

$$T = e^{-3.912\ R/V}\ \text{(Ref.23)} \qquad (5)$$

where

V = visibility (mi).

Figure 31 illustrates how this total energy Q is delivered as a function of scaled time. Scaled time, in this case, is the ratio of the time to the second thermal peak to the actual delivery time. The time to the second thermal peak is approximated by

$$t_{max} = 0.032\ W^{1/2}\ \text{(Ref. 15)}$$

Utilizing Figure 31, the thermal energy may be determined as a function of selected discrete time intervals. This is useful in evaluating the effect of evasive actions on reducing the kill expectancy associated with initial thermal radiation.

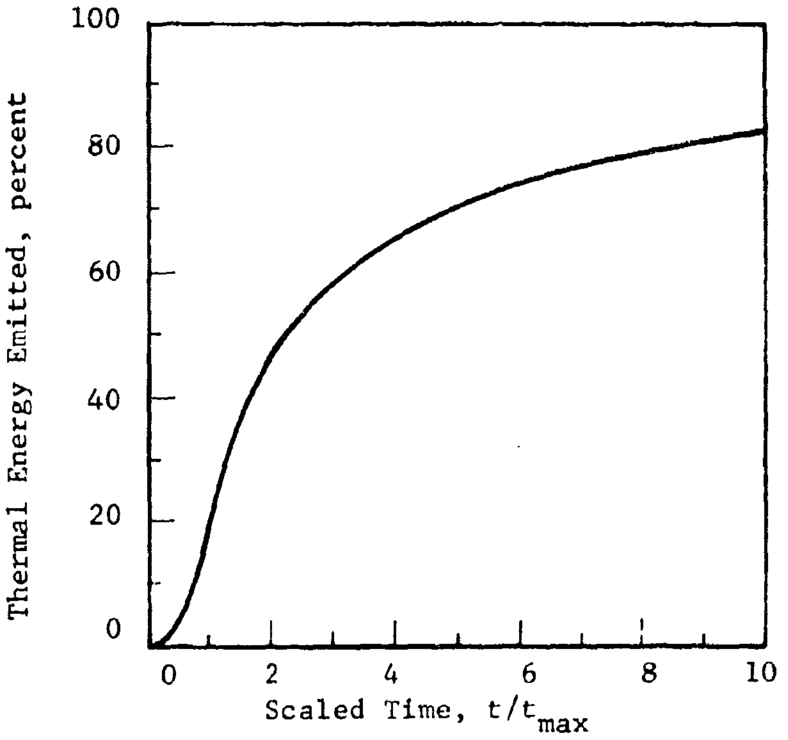


Fig. 31 FRACTION OF THERMAL ENERGY DELIVERED (Ref. 16)

Equations (6) and (7) express the dose of ionizing radiation in rads due to gamma rays and the integrated neutron flux respectively.

$$R_\gamma = \frac{10^9 K}{R^2} 3.2 W' e^{-R/360} \qquad (6)$$

$$R_N = \frac{10^9 K}{R^2} 15.5 W e^{-R/210} \qquad (7)$$

with

$W' = W$ for $1 \leq W \leq 20$

$W' = 0.614\ W^{1.163}$ for $20 < W \leq 100$

$W' = 0.485\ W^{1.214}$ for $100 < W \leq 5000$

$W' = 0.005\ W^{1.740}$ for $5000 < W \leq 1000$

and

$K = 1$ for $h_{ob} \geq 180\ W^{0.4}$

$K = 0.67 + 0.33\ h_{ob}/(180 W^{0.4})$ for $h_{ob} < 180\ W^{0.4}$

where

R_γ and R_N are the gamma ray and neutron flux doses (rad)

W is the yield (KT)

R is the slant range (yds)

h_{ob} is the height of burst (ft)

These relationships are not applicable for slant ranges below 3600 ft and for weapon yields below 1 KT. Within the specified ranges, Equations (6) and (7) are piecewise linear approximations of the appropriate curves in Ref. 15 and have been previously utilized in Ref. 24. They also seem to conform to the relationships set out by Brode (Ref. 25).

3.3 INTERACTION EFFECTS

When free-field weapon parameters are developed for some range of interest, height of burst and weapon yield, the results must be interfaced with the structural environment that exists at the point of interest. This interaction of weapon parameters and structural environment results in a most complicated effect often referred to as "shielding." The most important interaction effects include:

- Alteration of overpressure due to close proximity structures. This alteration may be either positive or negative depending on the particular situation.
- Alteration of overpressure within structures due to apertures.
- Reduction of thermal energy by shading caused by other structures and window coverings.
- Reduction of ionizing radiation by the effects of surrounding structures and the material within the structure itself.

3.3.1 Blast Casualties Due to the Blast Alone

Review of the literature indicates that only a small effort has been made to determine the overpressure reduction due to the structural shielding. At Nagaskai it was first observed that certain groups of buildings which were closely spaced survived overpressure damage, while others of the same construction and at further ranges failed. This unorthodox observation led to a few shock tube and HE tests (Ref. 26 and 27). Figure 32 (from Ref. 26) illustrates how shielding and protection of buildings occurs. It may be observed that for a constant separation ratio the shielding effect increases with increasing positive phase duration. Once the separation ratio (i.e., the ratio of structure spacing to structure height) is determined, the overpressure may be reduced by the shielding factor, μ_s.

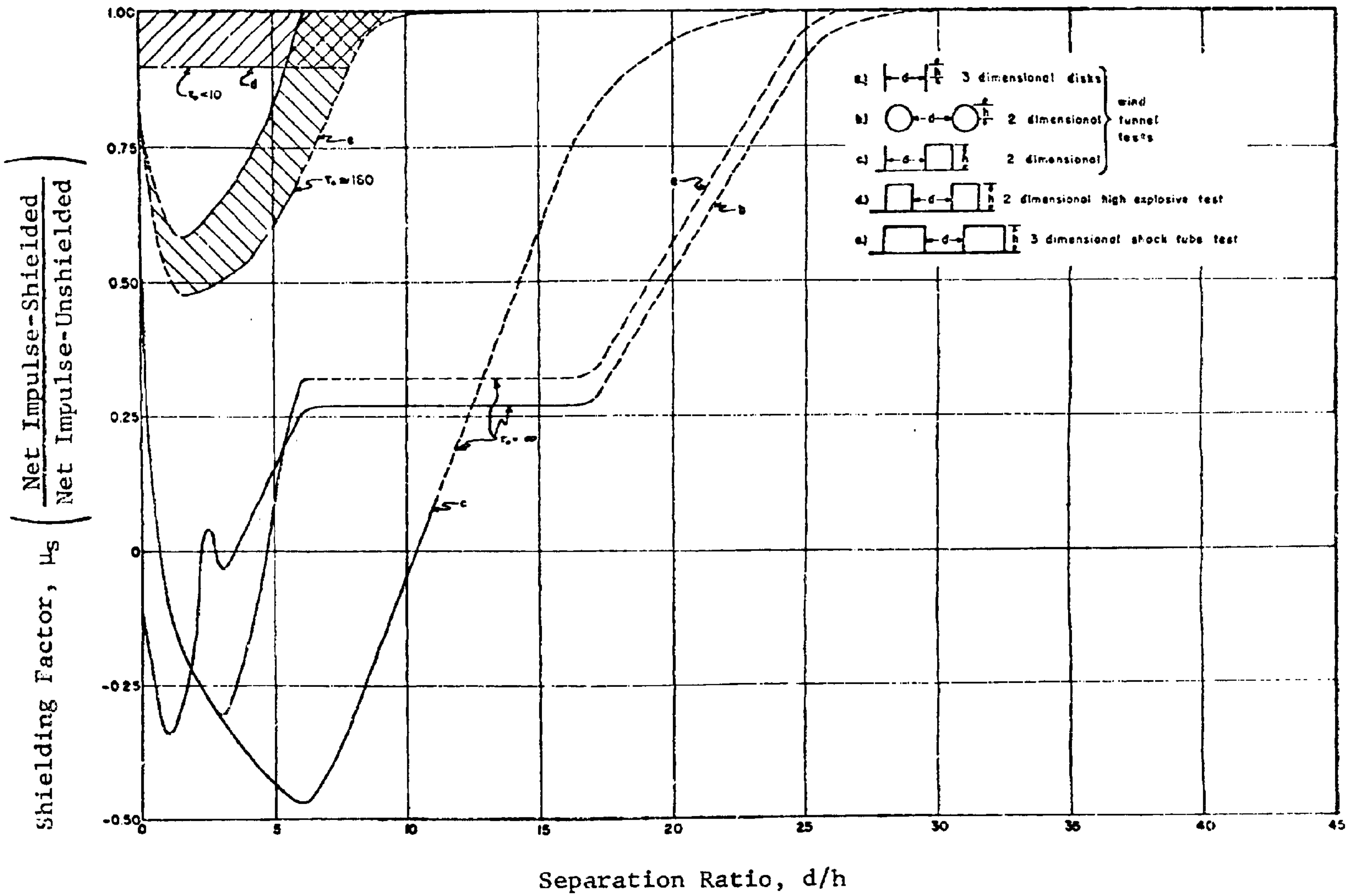


Fig. 32 SHIELDING FACTOR VERSUS SEPARATION RATIO
(Comparison of Wind Tunnel and Shock Tube Results)

Additional reductions in overpressure might be due to the orientation of the structure to the blast but this is not considered herein.

The attenuated overpressure stemming from contiguous structures may be further reduced due to apertures on the structure. Figure 33 illustrates the results of a shock tube study (Refs. 28 and 29) of the effect of window openings on overpressure reduction. Summarizing, the free field overpressure p_o is first obtained. This is attenuated to p_o' by proximity to contiguous buildings; p_o' is further attenuated to p_o'' within the structure due to the presence of apertures. Percent of blast casualties for each time to death on the outside is calculated directly by utilizing p_o' and Figures 6 and 7. These percentages are reduced by the percent of people outside. In a similar manner casualties sustained indoors and attributed to blast effects alone are determined from p_o'' and Figures 6 and 7. These qualities are modified further by the percent of building type and the percent of population indoors.

3.3.2 Whole Body Translation

High velocity winds, both inside and outside of structures, cause persons to translate into surrounding rigid surfaces (including the ground) resulting in casualties due to the associated impact. The translation analysis considers a standing, sitting or lying man as a rigid body that can pivot at one point on the ground. Simultaneously this point can also translate horizontally as in a slot. The associated equations are summarized: (Ref. 42)

$$\ddot{\theta} = (BC-E)/(AC-D)$$

$$\ddot{x} = (BD-EA)/D-AC) \qquad (8)$$

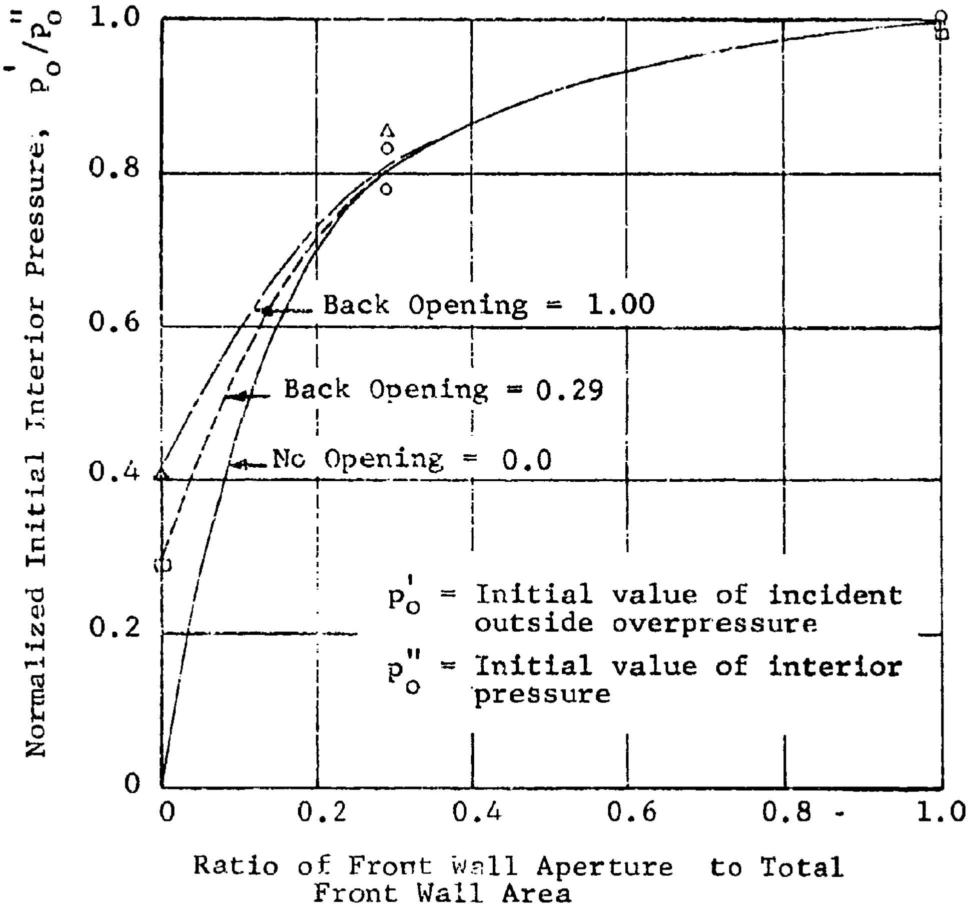


Fig. 33 NORMALIZED INITIAL INTERIOR PRESSURE VERSUS FRONT OPENING SIZE FOR MODELS WITH FRONT AND BACK OPENINGS ONLY

where

$A = r \cos\beta + \mu r \sin\beta$

$B = (F(t) - \mu W)/m + r\dot{\theta}^2 \, (\mu\cos\beta - \sin\beta)$

$C = r \cos$

$D = J/m$

$E = (F(t)d - Wr \sin\beta)/m$

where

μ = coefficient of friction

W = weight of the rigid body

J = moment of inertia of the rigid body

m = mass of the rigid body

and

$\beta = \varphi - \theta(t)$

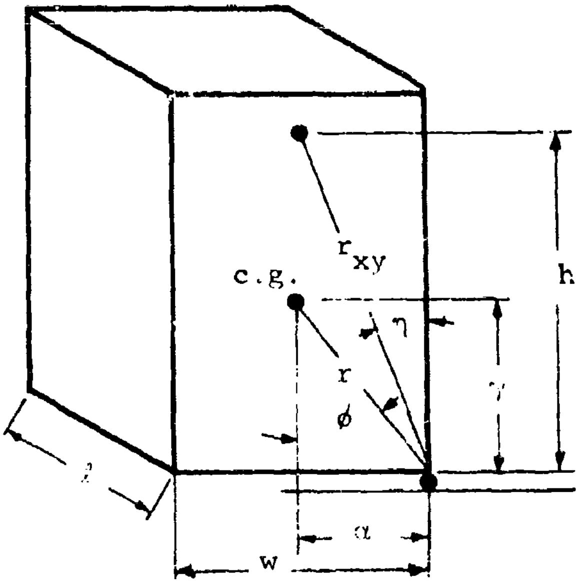
$r = (\alpha^2 + \gamma^2)^{1/2}$

$F(t) = 144 \, h\ell \, (p_f(t) - p_b(t))$

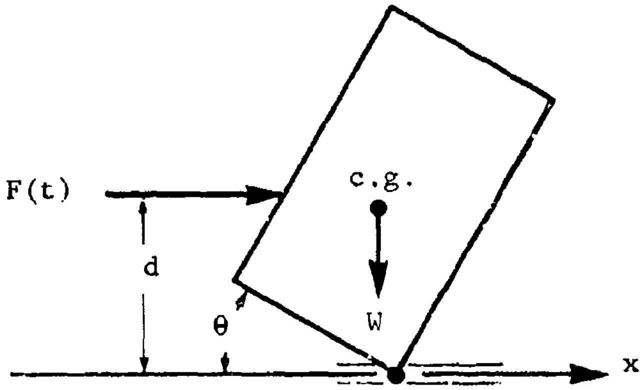
$d = h/2 \cos\theta + w \sin\theta$

The parameters φ, θ, α, γ, h, ℓ, w, η, r_{xy} and W are as illustrated in Figure 34. Table 13 shows the value of these parameters used in the analysis. The pressure on the front and back face of the man models $p_f(t)$ and $p_o(t)$ is illustrated in Figure 35. Equations (8) are numerically integrated as a function of time to yield the velocity/displacement time-history for both rotation and translation at the pivot point

To facilitate applications of the casualty criteria, and minimize computer running times, the distance that a body may translate is broken down into 10 subdivisions of a basic unit of length. This unit is dependent on whether translation takes place inside or outside On the inside, the unit of length is the average room length. The outside unit of length is the longest distance associated with the outside area of interest (see Subsection 3.1). As the equations are integrated one of three things may develop:



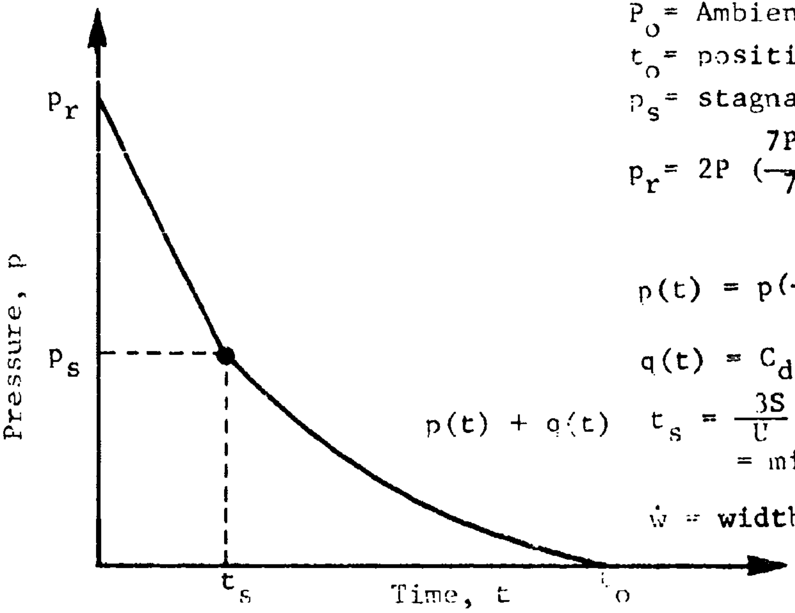
a) Geometry



b) Force Diagram

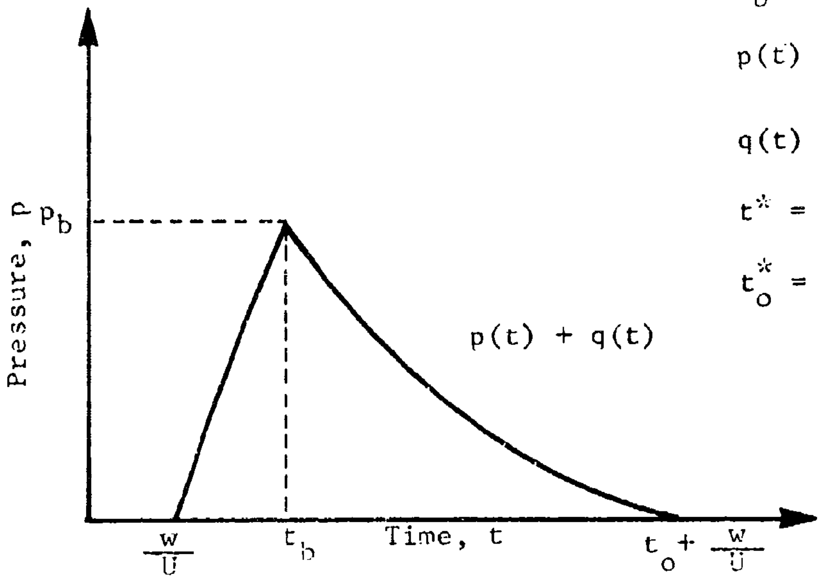
Fig. 34 SLIDING-OVERTURNING MODEL

U = Shock Velocity, 1132 ft/sec
p = peak overpressure
P_o = Ambient Pressure, 14.7 psi
t_o = positive phase duration
p_s = stagnation pressure
$p_r = 2P\left(\frac{7P_o+4p}{7P_o+p}\right)$ - reflected overpressure
$p(t) = p(\frac{t}{t_o})e^{-t/t_o}$ - overpressure
$q(t) = C_{df}q\left(1-\frac{t}{t_o}\right)^2 e^{-\frac{2t}{t_o}}$ - drag pressure
$t_s = \frac{3S}{U}$ where S = min(h,w/2) - stagnation time
w = width



(a) Front Loading

$t_b = \frac{w + 4S}{U}$
$p(t) = p\left[1-\frac{t^*}{t_o^*}\right]e^{-t^*/t_o^*}$
$q(t) = C_{db}q\left[1 - \frac{t^*}{t_o^*} e\right]^{-\frac{2t^*}{t_o^*}}$
$t^* = t - \frac{w}{U}$
$t_o^* = t_o - \frac{w}{U}$



(b) Back Loading

Fig. 35 TRANSLATION LOADING

Table 13
TRANSLATION PARAMETERS

Parameter (Ref.30)	Standing	Sitting	Lying
Man Height (h), ft	5.76	3.0	0.833
Man Depth (ℓ), ft	1.33	1.33	1.33
Man Width (w), ft	1.0	1.58	5.76
c.g. x distance (α), ft	0.28	0.667	2.63
c.g. moment of inertia (J), slug ft^2	8.57	5.32	8.57
c.g. Y distance (γ), ft	3.14	0.833	0.55
Buildup Coefficient**	8.0	3.0	2.5

Note: Weight of Man, W, = 160 lb in all cases.
Coefficient of friction, μ, = 0.5 in all cases.

**See Capabilities, Ref. 31 (Classified).

(1) The body may translate horizontally a distance corresponding to a multiple of one-tenth the basic unit of length.
(2) The body may rotate into the ground.
(3) The body may neither translate nor rotate

If case (1) applies, the velocity at each of the 10 stages is recorded as the body translates through each of the stages. If no translation or rotation occurs or if translation stops before translating the full unit length, the velocities corresponding to the remaining stages are set equal to zero. When the body rotates into the ground (90 deg) the total velocity (i.e., translation and rotation) is applied for all remaining stages. When the body starts from a lying position, only translational motion is considered. Having determined the velocity of the body at each stage, and the position at each stage with respect to a down wind rigid wall, the translation velocities are assumed equal to the impact velocities which can be directly related to mortality, injury and time to death.

A matrix of head velocities corresponding to each of the three initial body positions, (i.e., standing, sitting, lying) in each of the 10 subdivisions of the basic unit of length is transformed into a corresponding kill probability matrix by relating to Figure 15. An injury matrix is also formed utilizing Figure 15 in a similar manner. The above matrices are post-multiplied by a column vector of position percentages to form a vector of kill and injury percentages. Each element of those vectors corresponds to the percent of people killed and injured in each of the 10 subdivisions or stages of the basic unit of length. It remains to relate the actual areas to the basic unit of length. Each of the actual areas, as determined by one of the methods outlined in Subsection 3.1, has a representative unit of length associated with it. This unit of length is then associated with that stage of the basic unit of length which is nearest in size to it. The percentages killed and injured in that stage are then applied to the percent population in the actual area under consideration. The percent killed is further broken down by time of death as determined by the probability of kill in the area.

The procedure described is applied on the outside of the structure and to each individual building type at the node under consideration. Consider, for example, the five-area outside geometric case developed in Figure 25. Suppose A_3 has the longest distance, D_3, associated with it. Then D_3 would be considered the basic unit of length and divided into 10 stages. After the probability of kill and injury have been determined for each stages of D_3, the percent of people killed and injured in A_3 is discovered simply for forming the product of the ratio A_3 to the total area (i.e., $A_1 + A_2 + A_3 + A_4 + A_5$), the probability number, and the outside population percent. To find the probabilities of kill and injury in another area, say A_1, it is laid over the basic area, A_3, and the attributes of the stages which correspond to D_1 are assigned to it. This might be the attributes of five stages if D_1 is half the length of D_3. The process of finding the percent killed and injured in A_1 when the probabilities of kill and injury are known is similar to that outlined for A_3.

3.3.3 Structural Debris

The analysis to compute debris trajectories has been developed previously and is outlined in another report (Ref. 32). That analysis has been utilized to develop displacement-velocity-time relations as a function of debris characteristics and weapon parameters. The computation of casualties due to debris takes place in particular subset areas of the total area. The total outside debris area of interest is computed as shown in Figure 26.

On the inside of a structure the area of interest depends on the type of interior walls. Two types of interior walls are assumed to exist, plaster and masonry. Plaster walls are considered to have no effect on casualty production and thus only the outside walls of the building in this case act to cause debris within the structure. Plaster walls is a term used in the computer code to indicate no casualty production due to debris from interior wall failure. Such conditions as lath and plaster, wood stud and other type interior walls which might produce casualties may be included as masonry and their actual acceleration coefficient entered explicitly into the code. The items of interest in the plaster wall case are the entire building area and either its width or length depending on which is the larger. When the building has masonry interior walls there are two possible areas of interest depending on wall failure: 1) the area associated with exterior room (i.e., rooms adjacent to exterior walls); and 2) the area of the remaining inner portion of the structure. Each of these areas has a characteristic length associated with it. When the interior masonry walls fail, they are assumed to be the only walls acting on the interior portion of the building; outside wall failure is assumed to act only on exterior rooms in this case. The following four cases of debris action are thus possible within a structure:

- outside walls fail - plaster walls
- outside walls fail - interior masonry walls fail
- outside walls fail - interior masonry walls do not fail
- outside walls do not fail - interior masonry walls fail.

After a characteristic length is chosen, it is broken down into 10 subdivision (sectors) in the same manner as discussed in Subsection 3.3.2 for translation. Depending upon which of the four assumed debris action is under consideration, either a masonry interior or exterior wall is considered to be failed at one end of the characteristic length. An investigation is undertaken within each sector to determine whether particles from the wall can strike a man in each of three body positions (standing, sitting or lying) in any of three places on the body (head, thorax, or abdomen). This investigation is accomplished in the following manner. For a given sector, a starting distance and ending distance from the wall under consideration is known. Also known are the displacement-velocity-time relationships for all particles assumed to make up the wall. There are nine possible heights considered, corresponding to nine combinations of body position and body region of damage. Gravity forces are assumed to be the only vertical forces acting on debris particles and thus, time of flight may be directly related to initial particle position on the wall as shown below:

$$t_i = \sqrt{\Delta h_i/16}$$

where

h_i represents the vertical difference in height between the initial particle position on the wall and the nine impacted positions of interest on the body.

t_i are time of flights corresponding to each Δh_i.

Consequently, given the distance bounds on a sector and average velocity in the sector, the initial wall height of a specific particle size that may pass through the sector at some height of interest may be determined. It may be impossible to find an actual wall position to exist for some size particles. If this is the case, it is assured that that size particle does not pass through the section at the height of interest. If a particle size exists in a sector its lethality and injury are determined by using Figures 12 through 14, the particle weight. and average final velocity in the sector.

It is assumed that the effect of one particle striking a person is independent of the effects of other particles. Therefore, only the maximum effect over all particle sizes, all body positions and body regions of damage is considered in each of the 10 sectors. This effect is further assumed to be constant in any one of the ten sectors. The lethality in each sector is reduced by the body position probability, construction percentage, window percentage and probability of particle size. It remains to determine an average over the 10 sectors of the area under investigation, and then to divide the mortality figures into time-to-death categories. This division is accomplished in the same manner as was done in the translation model. Finally, a weighted average total over all areas of interest is obtained by considering both inside and outdoor populations to be uniformly distributed over the total inside and outside areas.

3.3.4 Thermal Radiation Model

The thermal energy reported as free-field actually includes attentuation due to the interaction of the atmosphere and the light source path to the ground. The thermal radiation energy, Q, as expressed in Eq. (4), is further attenuated by whatever shielding is available between the radiation source and the recipient. The attenuation caused by full shielding as the result of interaction with another structure is 100 percent. The percent of radiation transmitted through window glass and screens as reported in Ref. 23 is given in Table 14.

Table 14

THERMAL ATTENTUATION FACTORS, η_t

Single Glass (%)	Double Glass (%)	Screens (%)
56	31	67

The above quantities may be combined in series for various combinations of window cover. (In the case of open windows no attenuation takes place.) The termal energy within a structure is then

$$Q' = \eta_t Q$$

where η_t represents an attenuation factor developed from Table 14 taking each material placed between the interior and the exterior of the building into consideration.

The thermal radiation energy in the street outside, is represented by the total Q, provided the street is not shaded by another building as shown in Figure 36. No thermal injury is assumed to occur in the shaded portion of the outside area. In order to compute casualties on the outside, the curves in the radiant exposure as predicted are scaled to 1 MT. The curves in Figure 19, with the known value of radiant exposure

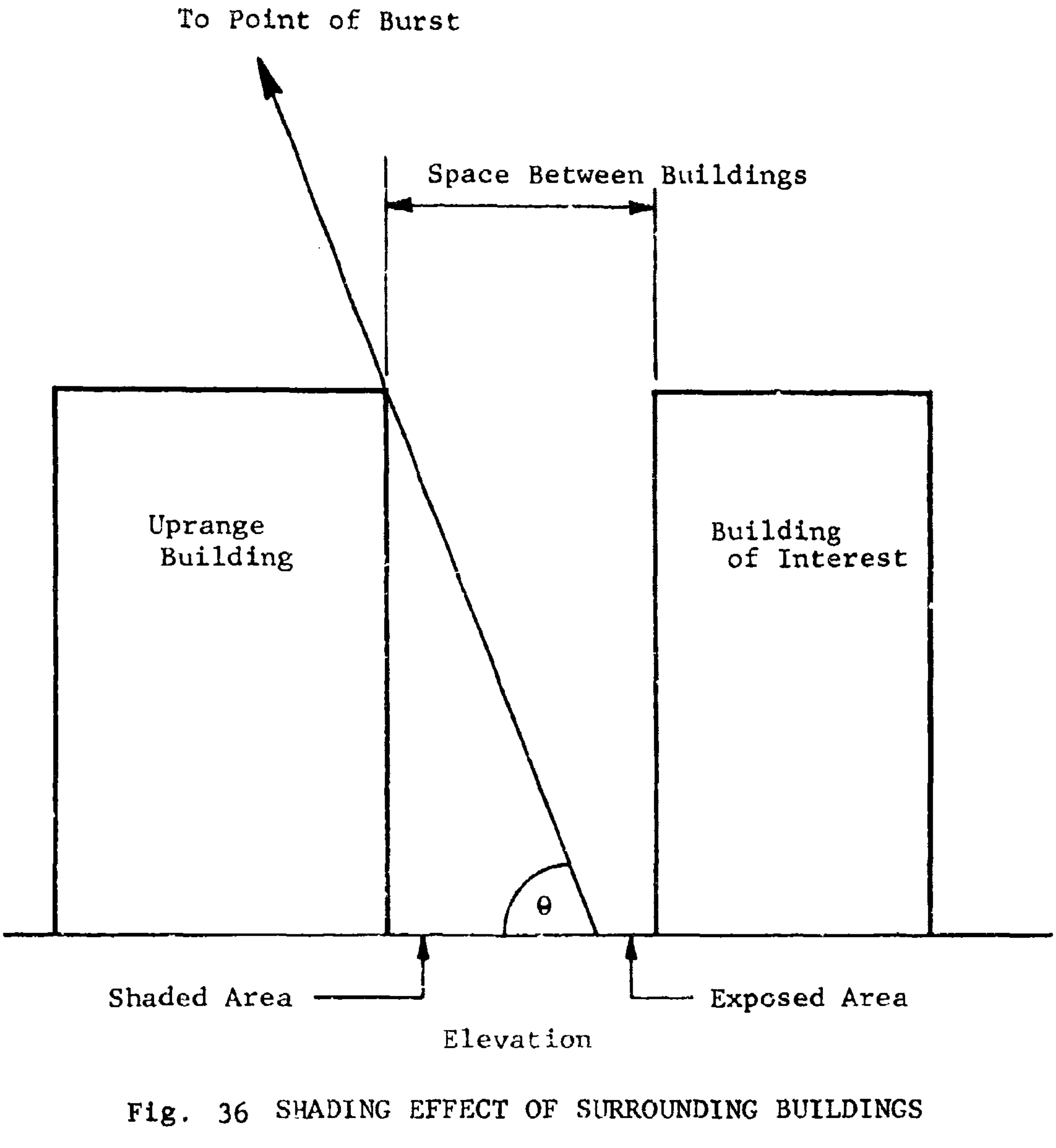


Fig. 36 SHADING EFFECT OF SURROUNDING BUILDINGS

and season of the year are used to determine the percent of body area burned. After the latter is known the corresponding kill and injury probabilities may be found by using Figure 16. Figure 20 utilizes the information obtained from Figure 16 in order to break down the kill probabilities by time to death. The final probabilities are adjusted for the percent of population on the outside and the ratio of the unshaded area to total area.

In order to determine the effect of thermal energy within structures, both attenuated energy exposure areas within the structures and shielding from adjacent structures must be determined. The exposure area within the structure is computed using window dimensions, the angle of incidence of the thermal energy, θ, and the building orientation to the blast ϕ. Three floor areas are determined:

a. area for people standing,
b. area for people sitting,
c. area for people lying on the floor.

An example of the linear dimension into the room is illustrated in Figure 37. An attenuated Q is determined within each of these three areas and kill and injury probabilities computed as in the outdoor case discussed previously. The probabilities are then combined based on the percent of the total building area involved to determine the total kill and injury probabilities for the building. Computations are repeated for each building at the point of interest. If uprange shielding by a contiguous building occurs, the total irradiated area within the building is reduced by the percent of the building being shielded.

3.3.5 Ionizing Radiation Model

Ionizing radiation dose determined by using Equation (4) and (5) includes atmospheric attenuation between the burst point and the node point. Unlike thermal radiation, however, ionizing radiation is not completely attenuated by the presence

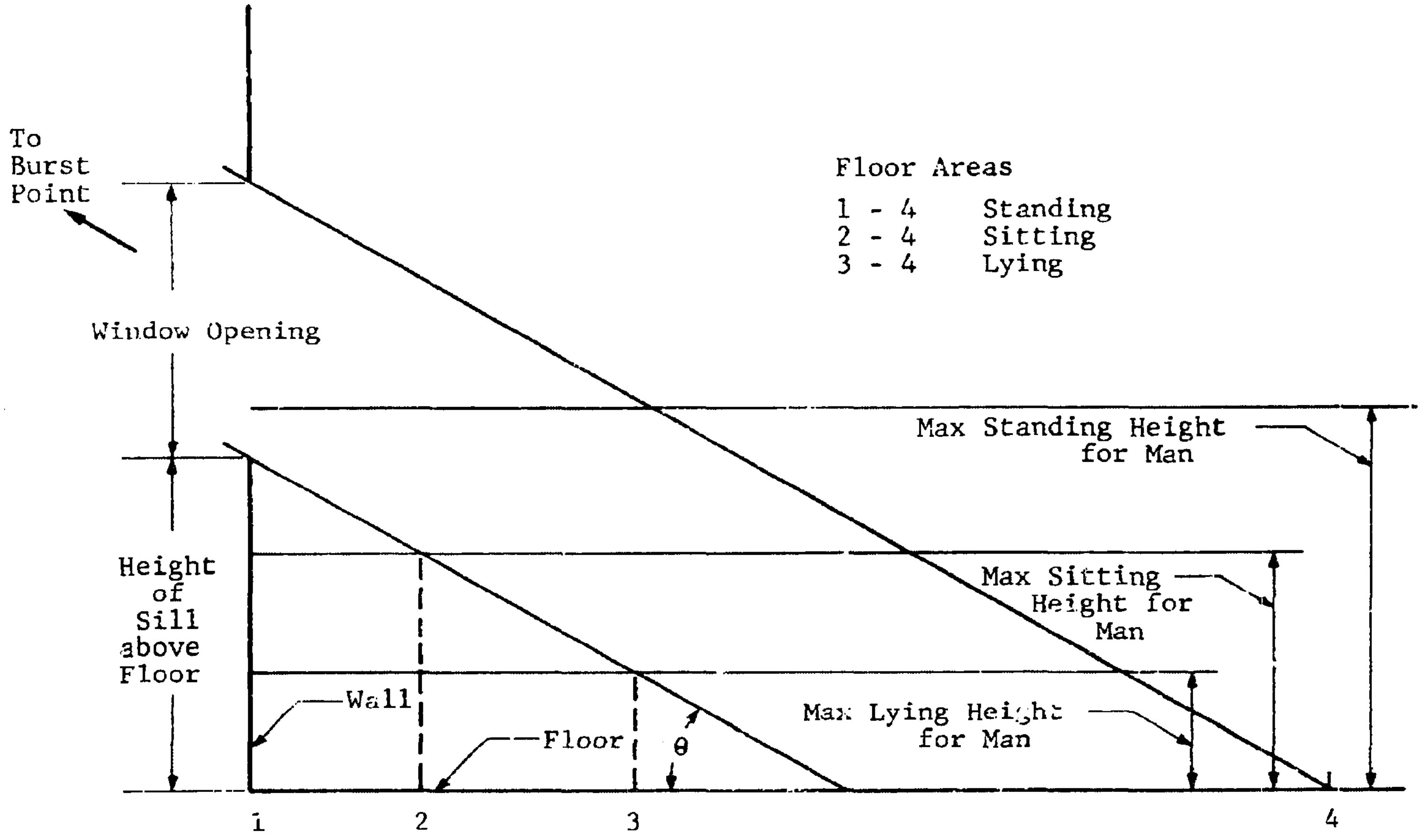


Fig. 37 EXAMPLE OF FLOOR AREAS WHERE PEOPLE WOULD BE SUBJECTED TO THERMAL RADIATION

of structural components (e.g., buildings, walls, etc). Gamma rays are attenuated in the following manner:

$$I = R_{\gamma} e^{-0.0113 \rho x} \text{(rad)}$$

where ρ is the density of the shielding material (pcf) and x represents the path length through the shielding material. Figure 38 illustrates the relationship between the shielding thickness and the attenuation factor applied to the integrated neutron flux (Ref. 33) for several common building materials. Here the attenuation factor is much more sensitive to the type of material employed as shielding then in the case of gamma radiation attenuation where only the mass thickness is important. The effects of scattered radiation and buildup factors have been neglected. The accuracy of the above radiation computations seems to be consistent with the effect of ionizing radiation as a kill mechanism for high yield weapons.

In the case of outdoor population, shielding is approximated by a building having the average characteristics of all the buildings at the node. Furthermore, outdoor population is considered surrounded by this shielding. Once the computations have been made to determine the average shielding of outdoor population, the actual doses may be found, and using Figure 22 the probabilities of death and injury determined. The time to death relationship is shown in Figure 23. Here, as in thermal radiation, the minimum time to death was selected as one day.

The indoor population is exposed to a dosage which is dependent upon attenuation factors which vary within the building. These attenuation factors are computed using the thickness of material placed between the interior and exterior of a building. This is determined by computing the shielding of the floors and walls of the building for individual cells within the building as illustrated in Figure 39. The ionizing radiation dose in each cell is computed and the corresponding probabilities

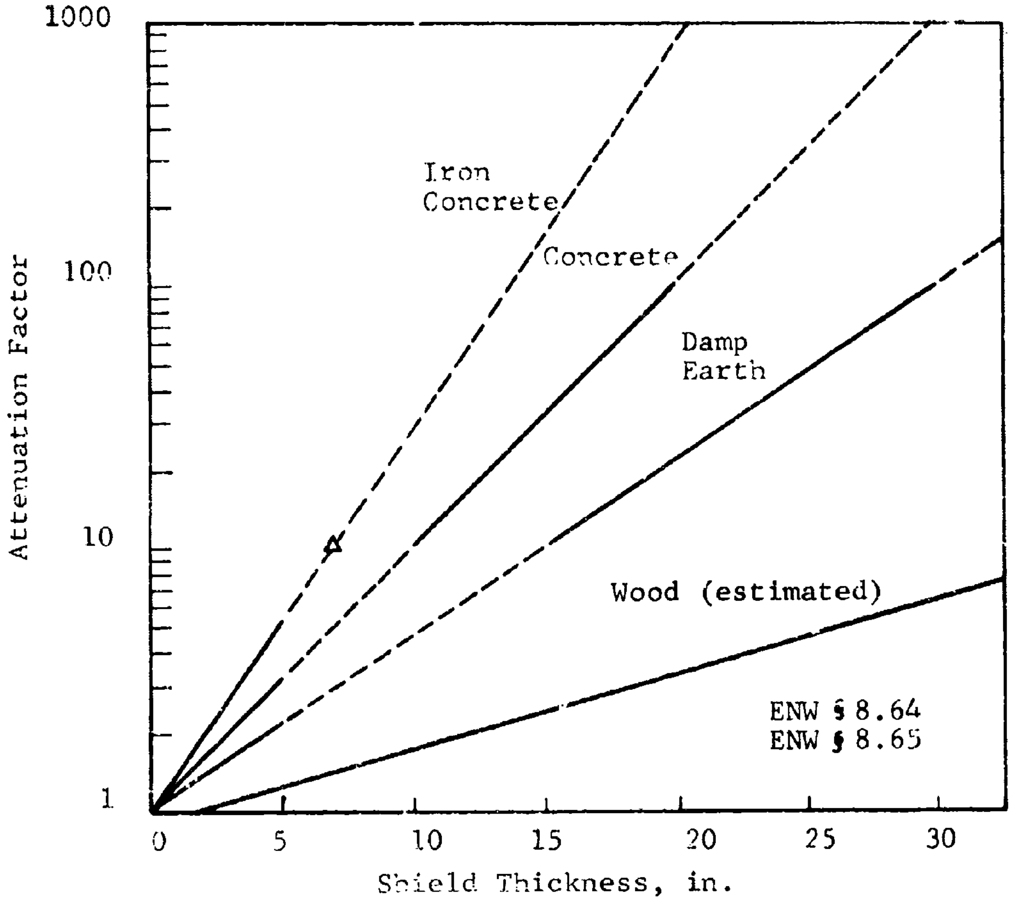
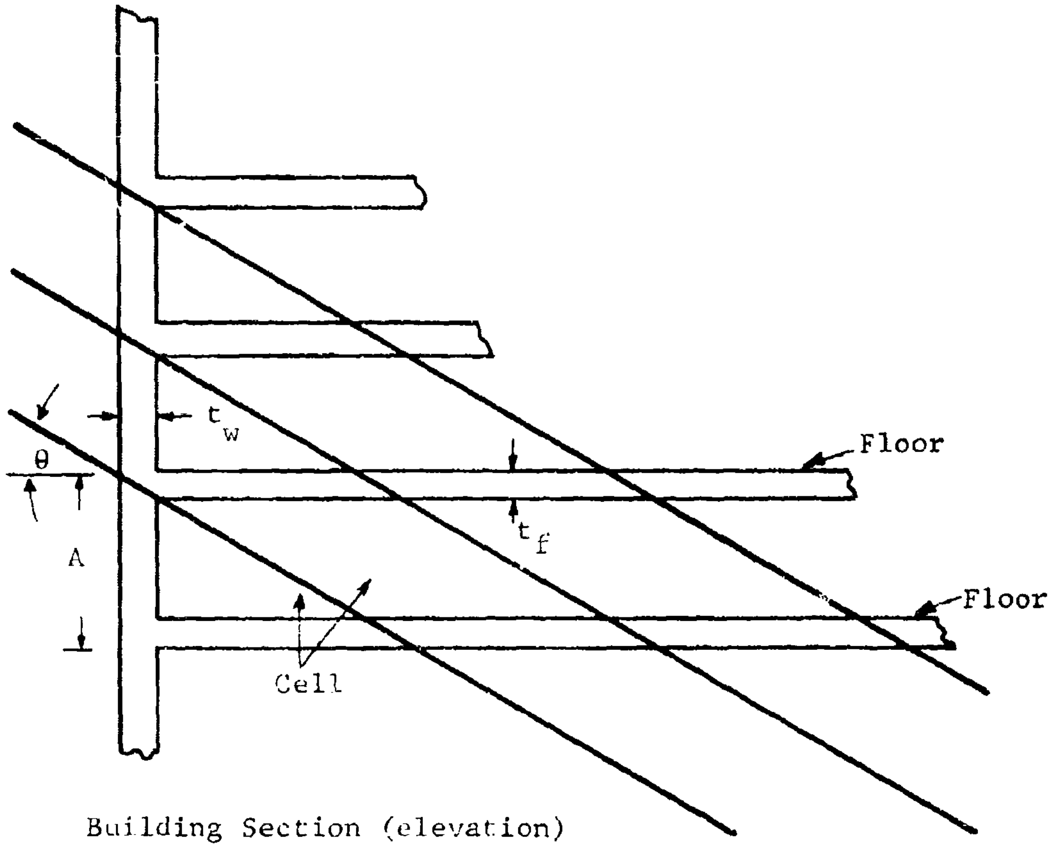


Fig. 38 ATTENUATION OF INTEGRATED NEUTRON FLUX (Ref. 33)



Building Section (elevation)

cell floor area = (ℓ or w)·A cos θ

$$\tan\theta = \frac{\text{burst height}}{\text{range}}$$

$$\text{shielding thickness at a cell} = \frac{t_w}{\cos\theta} + N\frac{t_f}{\sin\theta}$$

N = number of floor thicknesses the energy must pass through to reach the cell of interest

ℓ = building length

w = building width

Fig. 39 METHOD OF DETERMINING SHIELDING IN BUILDINGS of death and injury again determined for each cell from Figure 22. The population within any building is considered uniformly distributed, therefore, a weighted average, based on cell area and probability of kill and injury can be determined. This process is repeated for each building type at the node and adjusted for percent of buildings of a particular type of construction.

3.4 FACTORS NOT INCLUDED IN SEP CODE

Topography obviously plays a significant role in the interaction of weapon parameters with the structural environment. The free field overpressure, for example, has been shown to increase on the up slopes and decrease on the down slopes of hilly terrain (Ref. 34). Also buildings on the reverse side of hills are protected from thermal and direct ionizing radiation (for low height of burst). These effects, however, were too ill-defined at present to be included in the analysis.

The effect of ground shock on the production of casualties has been reviewed in this study. Although this effect was considered, it was not included in the analysis for two reasons:

- At lower overpressures (i.e., below 20 psi), which are of primary interest, the ground shock effects are negligible in relation to other effects, and
- One-dimensional ground shock information (Ref. 35) which can easily be implemented shows little correlation with the latest two-dimensional ground shock analyses now being employed (Ref. 36).

The new analyses are too expensive and time consuming to include in this effort.

3.5 COMBINATION OF INDEPENDENT CASUALTY EFFECTS

Two matrices in the output of the SEP code provide the percent killed and survived respectively for individual casualty effects and within specific time periods. These individual effects are first combined with the specific time periods (i.e., hour, day, week, month) and finally transformed into total survivors, mortalities and injuries.

The first of the two matrices, percent of population killed by each individual effect (e.g., blast, debris, thermal, etc.) in each time period (e.g., hour, week, one day, etc.) is transformed into the second. This is accomplished by sequentiallly subtracting the percent affected in the present time period from those remaining in the previous time period. Initially the percent of people inside or outside is used as in the previous time period depending upon where the specific event takes place. As an example of this technique, suppose that 50 percent of the population are indoors and that 10 percent of the indoor population die from blast in an hour. Then, the percent which will survive indoors from blast for an hour is 50 - 10 = 40 percent. Suppose also that 20 percent die from 1 hour to a day, 5 percent die from 1 week to a month and 2 percent are injured. Then 40 - 20 = 20 percent survive between a day and a week, and 20 - 5 = 15 percent survive a month. Finally, 15 - 2 = 13 percent are uninjured from blast indoors.

After the survival matrix has been generated, total survival from all effects may be determined within each time to death for inside and outside populations. This is done by obtaining the products of surviving each individual effect. As an example, suppose that 20 percent of the population survive a week from blast indoors and 15 percent survive a week from translation indoors. Then 20 x 15 = 3 percent is the probability of surviving the combined effects of indoor blast and translation.

The total uninjured persons, injured and dead may be calculated by applying the population, indoor and outdoor, to the appropriate total percent surviving from all effects. Total survivors are those injured plus those uninjured, the total dead are 100 percent minus the survivors.

SECTION IV

RESULTS

In order to illustrate the prediction of casualties, the computer code developed in the previous section was utilized in a variation of parameter study for the evaluation of shelter systems. It should be emphasized that the results obtained from these parameter variations were picked to show up the sensitivity of the computer model. When parameters are varied in this computer model a complicated set of interactions takes place. As an example, when all parameters were varied for buildings not surrounded by any contiguous structure debris results were insignificant. However, when structures were introduced debris results were significant. To further illustrate, consider the problem of building debris which effects people outside the building. With large spacing between buildings, no effect of debris shows up in the model, but as space between buildings is reduced the importance of debris on outside mortalities and injuries is increased.

4.1 Primary Buildings

The parameters of the basic structures which were employed in the parameter variations are presented in Table 15. (Table 15 is in the actual computer input format, see Appendix 1 for a more complete explanation of this format). Whenever parameter variations were made they were made one at a time while holding the rest of the parameters in Table 15 constant.

4.2 Range Variations

Figure 40 illustrates the mortality effects inside the reinforced concrete frame building (R/C) for a 1 MT, 7,000 ft height of burst. The probability of being a mortality from translation effects, debris effects and thermal effects within the reinforced concrete building are displayed as a function of distance out from ground zero. Corresponding overpressures are displayed below the appropriate ground range and

Table 15

PARAMETER VARIATIONS

Reinforced Concrete Structures

```
NODE AND BUILDING PARAMETERS
AREA OF NODE 1, SQ. MILE
NUMBER OF BUILDINGS AT NODE 1
LOCATION OF NODE X=20000, Y=0.0
CONSTRUCTION PERCENTAGE 100.
HEIGHT  90. FT
WIDTH  65. FT
LENGTH  65. FT
AVERAGE SPACE SOUTH 1000, NORTH 1000, EAST 1000, WEST 1000,
DENSITY OF WALL MATERIAL(CONCRETE) 135. LBS./FT.**3
WALL PANEL THICKNESS  8 IN.
ROOF THICKNESS 10. IN. ROOF DENSITY(CONCRETE) 135. LB./FT.**3
FLOOR THICKNESS  8 IN.
MATERIAL DENSITY OF FLOOR(CONCRETE) 135. LBS/FT**3
BASEMENT WALL THICKNESS 10. IN. BASEMENT DENSITY 135. LB./FT.**3
SOIL DENSITY 75. LB./FT.**3
STORIES  9
WINDOW PERCENTAGE   30.
SILL HEIGHT ABOVE FLOOR 2.5 FT.
NO SHIELDING PERCENTAGE 0.0
SCREEN PERCENTAGE 0.0
SINGLE GLASS PERCENTAGE  50.
COMBINED SINGLE GLASS AND SCREEN PERCENTAGE 0.0
DOUBLE GLASS PERCENTAGE 0.0
SHIELDING FROM DOUBLE GLASS AND SCREEN PERCENTAGE 0.0
DRAPERY BLIND AND SHADE PERCENTAGE 50.
DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL  5.0 FT.
INNER ROOM LENGTH  20.  FT.
NEXT
CHARACTERISTICS OF WALL FRAGMENTATION
NUMBER OF PARTICLES   9
INSIDE  PERCENT   0.0.100.,0.0.0.0.0.0.0.0.0.0.0.0.0.0
MASONRY FAILURE PRESSURE  1. PSI
OVERPRESSURE AT FAILURE  1.  PSI
NUMBER OF PARTICLES   9
OUTSIDE PERCENT  100.,0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0
WALL TYPE 1
```

*   MASONRY INTERIOR WALLS

Table 15 (Contd)

People

```
DESCRIPTION OF PERSONNEL
POPULATION DENSITY 100. PEOPLE PER SQ. MILE
INDOOR PERCENTAGE OF POPULATION  50.
OUTDOOR  POSITION PERCENTAGES STANDING 100. SITTING 0.0 LYING 0.0
INTERIOR POSITION PERCENTAGES STANDING 25. SITTING 75. LYING 0.0
NEXT
SKIP COMMANDS
ACCUMULATION
IONIZING
NEXT
SOLVE
```

Wood Buildings

```
HEIGHT  20. FT

WIDTH  35. FT

LENGTH  45. FT

AVERAGE SPACE SOUTH 1000. NORTH 1000. EAST 1000. WEST 1000.

DENSITY OF WALL MATERIAL  (Wood)   30. LBS./FT.**3

WALL PANEL THICKNESS  4 IN.

ROOF THICKNESS  1  IN. ROOF DENSITY    (WOOD) 30. LB./FT.**3

FLOOR THICKNESS  2 IN.

MATERIAL DENSITY OF FLOOR(WOOD) 30. LBS./CU. FT.

BASEMENT WALL THICKNESS 10. IN. BASEMENT DENSITY 30.0 LB./FT.**3

SOIL DENSITY 75. LB./FT.**3

STORIES  2
```

Table 15 (Contd)

```
WINDOW PERCENTAGE   30.
SILL HEIGHT ABOVE FLOOR 2.5 FT.
NO SHIELDING PERCENTAGE 0.0
SCREEN PERCENTAGE 0.0
SINGLE GLASS PERCENTAGE  50.
COMBINED SINGLE GLASS AND SCREEN PERCENTAGE 0.0
DOUBLE GLASS PERCENTAGE 0.0
SHIELDING FROM DOUBLE GLASS AND SCREEN PERCENTAGE 0.0
DRAPERY BLIND AND SHADE PERCENTAGE 50.
DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL  16. FT.
INNER ROOM LENGTH 16. FT.
NEXT
CHARACTERISTICS OF WALL FRAGMENTATION
ACCELERATION COEFFICIENT 10.
NUMBER OF PARTICLES   9
INSIDE PERCENT   100.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
MASONRY FAILURE PRESSURE  1. PSI
OVERPRESSURE AT FAILURE  1.  PSI
NUMBER OF PARTICLES   9
OUTSIDE PERCENT  100.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
WALL TYPE 0
*     PLASTER INTERIOR WALLS
```

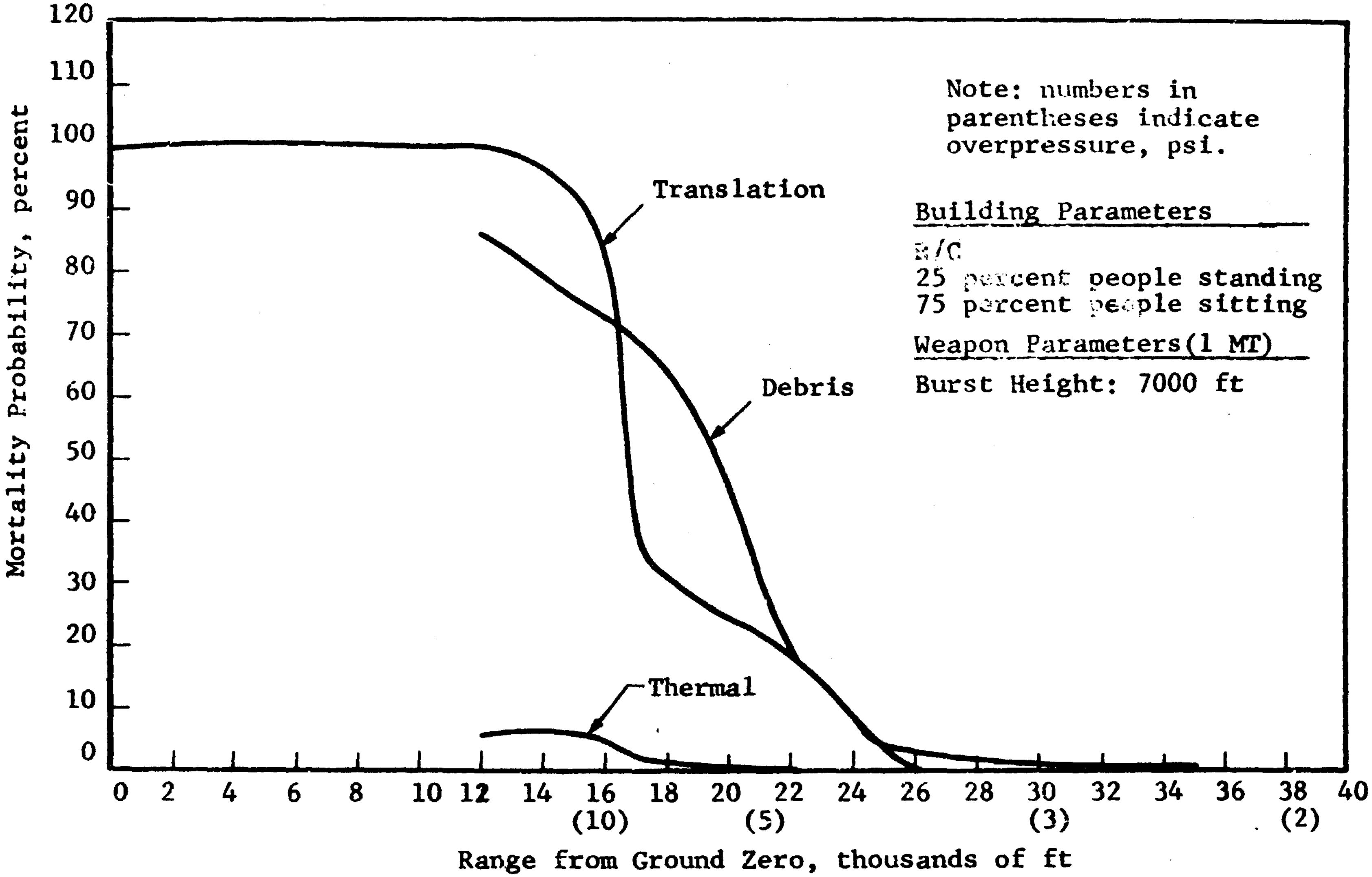


Fig.40 RANGE EFFECTS ON MORTALITIES (Indoor)

are in parenthesis In order to observe the full effect of debris, the failure pressure for the nonload bearing outside panel wall was set at 1 psi. In reality, the failure pressure may be well above 1 psi and this will reduce both the mortality and injury due to debris. In Fig. 40, for example, if the exterior wall did not fail until 10 psi was reached, there would be no debris casualties beyond a 16,000 ft range. The apparent step in the translation curve in Fig. 40 is due to the assumed personnel posture within the concrete building.

Figure 41 illustrates the injuries associated with the people indoors. At the lower ranges, the probability of injury is low due to the corresponding high probability of mortality. As the ranges increase the various injuries become more important and then begin to decrease and finally the curves go to zero. Here again, the effect of sitting as illustrated in the translation injuries would be eliminated at about 39,000 ft. Here too, if the 1 psi failure pressure of the outside walls was assumed to be a more realistic higher value, injuries due to debris would be eliminated in a much smaller range.

Figures 42 and 43 illustrate the mortality and injury relationships for persons outside of shelters. Because of the large spacing (i.e., 1000ft between structures) the effect of thermal radiation is prominent and debris is negligible. In Fig. 42 the flat slope of the curve starting at about 25,000 ft is due to burning of exposed skin areas. Only below 25,000 ft does clothing ignite and a greater kill probability result. Assuming a winter condition reduces casualties resulting from thermal radiation outdoors due to an appropriate increase in the amount of clothing worn. Personnel on the outside were considered to be standing, and translation mortalities are indicated out to a range of 41,000 ft with injuries due to translation extending to about a range of 65,000 ft.

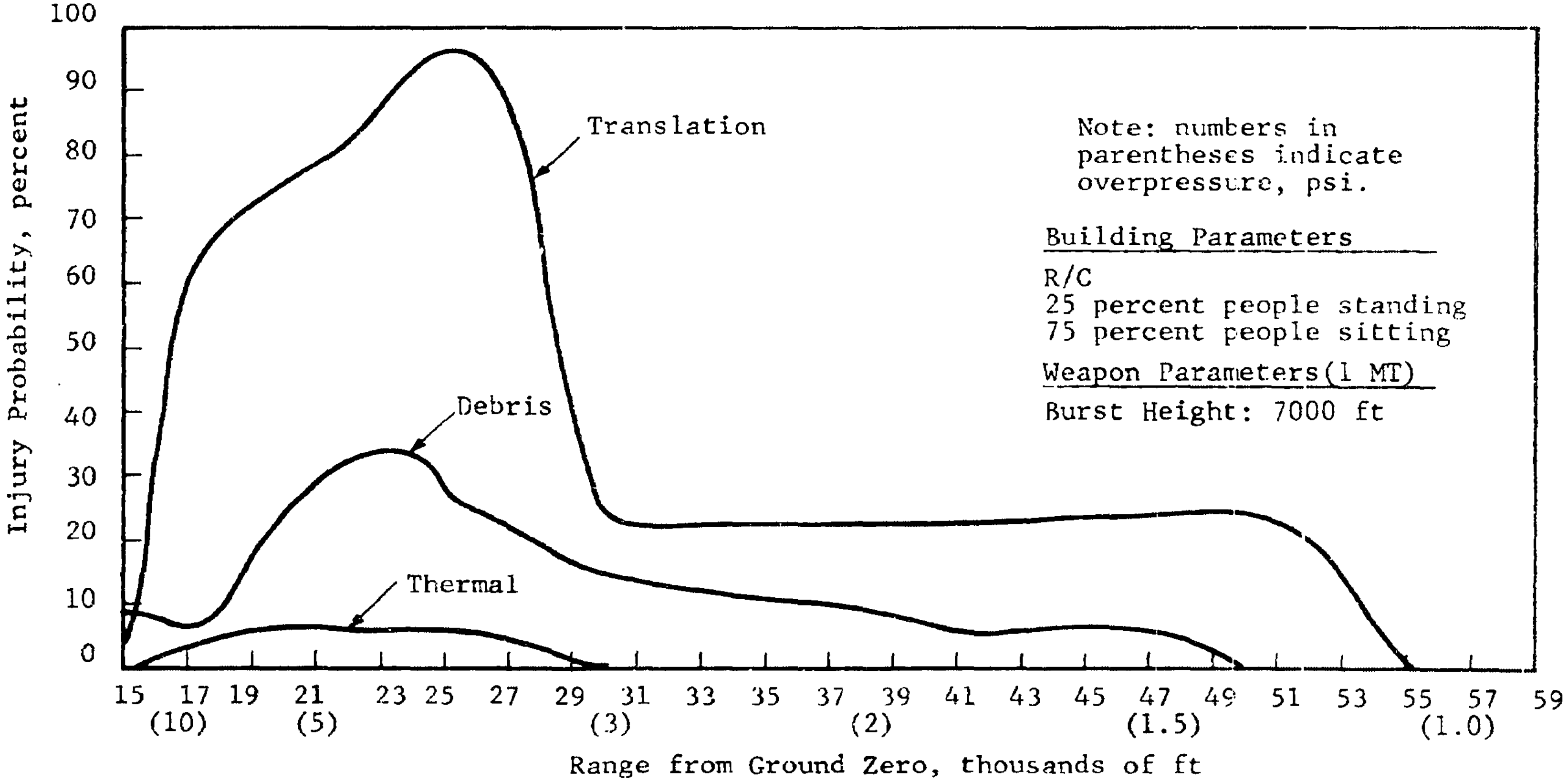


Fig. 41 RANGE EFFECTS ON INJURIES (Indoor)

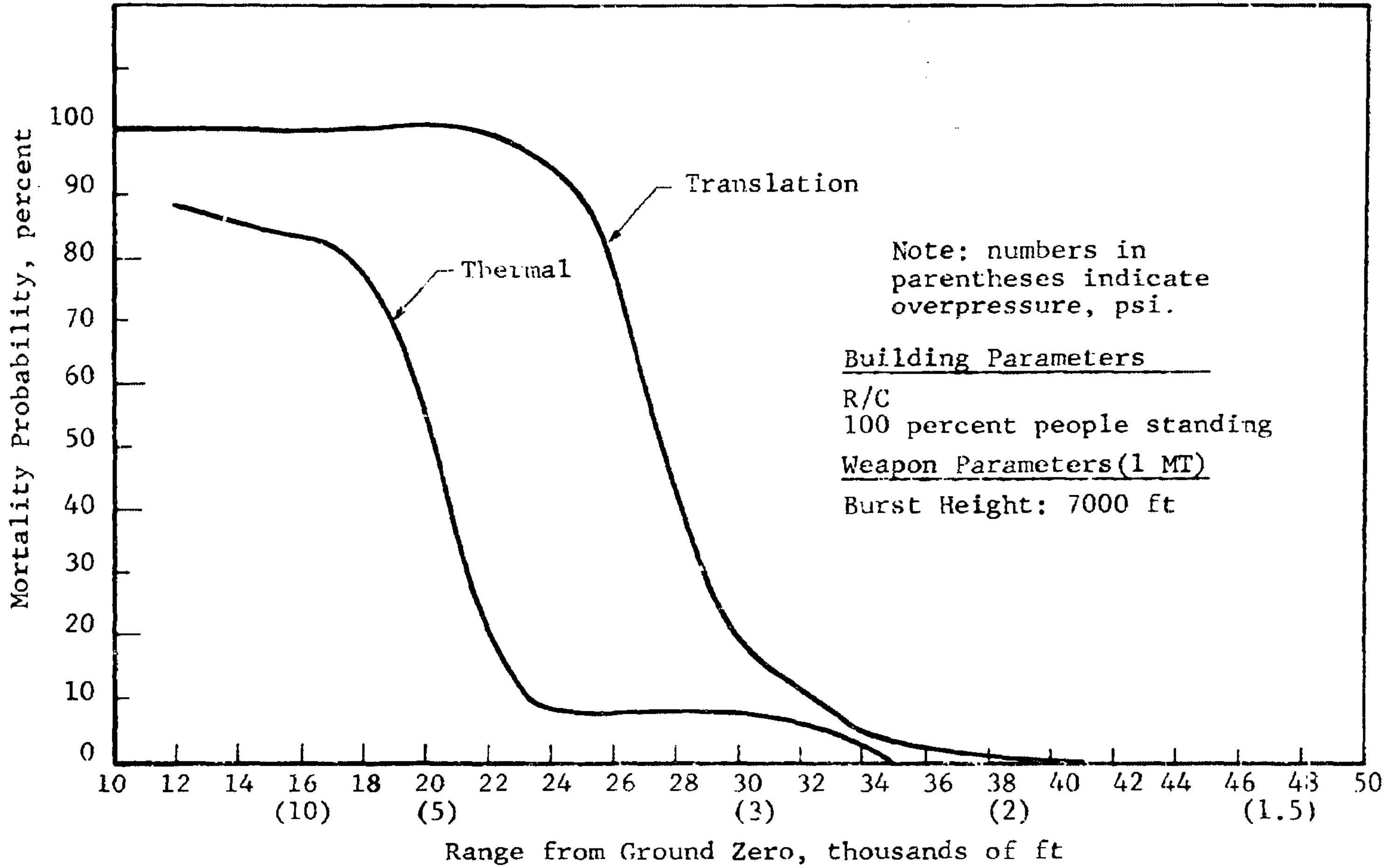


Fig. 42 RANGE EFFECTS ON MORTALITIES (Outdoor)

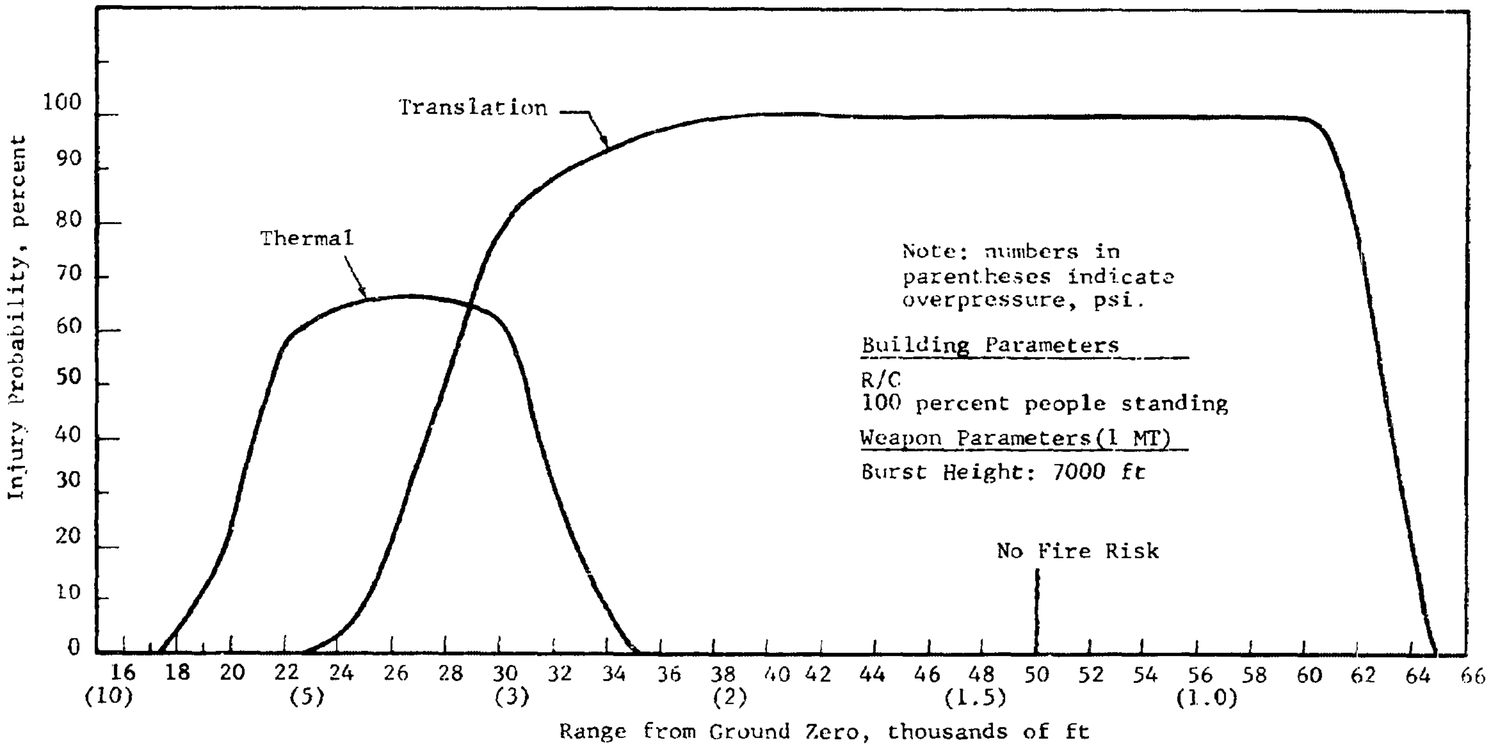


Fig. 43 RANGE EFFECTS ON INJURIES (Outdoor)

4.2.1 Effect of Positions

As was previously described, Fig. 40, the effect of personnel posture within a shelter was seen to vary as to whether people were standing or sitting. Figure 44 illustrates the indoor mortality for personnel lying on the floor. Translation effects are dramatically reduced in this case over those standing. No indoor mortality is seen to occur beyond a range of 22,000 ft. However, the debris mortalities are slightly increased with personnel lying on the ground because their more vulnerable parts, that is, their chest and head are exposed to a greater assortment of debris. Here, all debris strikes the ground, but not all debris passes through a point 4 ft above the ground. Debris mortalities result out to a range of 30,000 ft for personnel lying, however, for personnel standing or sitting, it predominates out to a range of about 26,000 ft. Comparing the sitting portion of the translation curve of Fig. 41 with the translation curve of Fig. 44, it becomes apparent that in some instances sitting appears to result in lower casualties than lying. This peculiarity is the result of the assumptions employed in the translation model. The sitting person is assumed to slide and rotate about his feet. Rotation is the predominate form of motion. Whenever rotation attains 90 degrees, the problem is stopped and the current motion information is used to determine the mortality. For a person lying, it is assumed that no rotation takes place and the body slides until impact with a wall occurs. A person sitting who rotates through 90 degrees will in actuality continue to tumble and slide during and after the rotation until he strikes a wall or friction overcomes exterior loading of inertia. During this period he will actually achieve the same or a greater velocity than the lying person. However, analysis of this sliding-rotating man is a much more difficult problem and beyond scope of the present program. The reader must therefore be wary of this anamoly. The effects of personnel posture on thermal radiation mortalities was not significant as illustrated in Fig. 44.

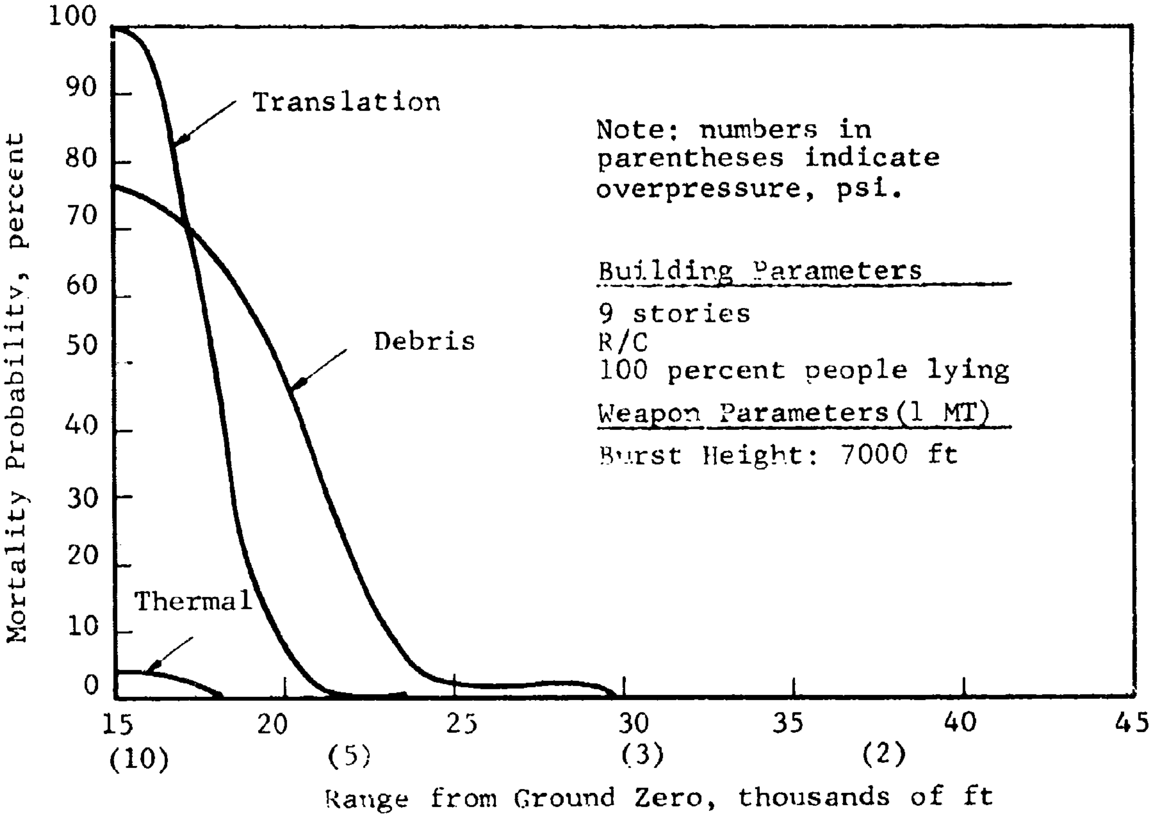


Fig. 44 MORTALITIES FOR A LYING POPULATION (Indoor)

Figure 45 illustrates the mortality probability as a function of range for personnel lying on the ground outdoors. As would be expected, from the previous effects indoors, thermal calualties are not reduced by lying down, and again the translation effects are significantly reduced from a range of 40,000 ft as per Fig. 42, to less than 25,000 ft here. These illustrations give the implication that the response of people may be a very important factor in saving their lives in a nuclear attack.

4.2.2 Evasive Action to Thermal Radiation

Figure 46 illustrates the advantages of taking evasive action from the thermal effects of a nuclear weapon. Three curves are shown for no evasion, two second evasion and ten second evasion respectively. These represent the times from the initial exposure until the people are completely shielded. For the case selected, it appears that evasion does not help when the range is between ground zero and less than 10,000 ft or beyond about 24,000 ft. Evasion is not a very important parameter beyond the 24,000 ft range because only exposed skin areas are effected and the total kill probability is low. However, in the range between 10,000 and 24,000 ft, the effective evasive action is quite significant. Even the rather slow time of 10 seconds can represent 100 ft (i.e., an average street width) if people run at 10 ft per second. It is difficult to imagine people responding in less than 2 seconds, unless they are inside a room where they can jump to a shaded area. Even so they would have to know both what to expect and what to do.

4.3 Building Types

Obvious variations in building type may include the description of the debris which occurs, and the failure pressure associated with it. As an example of the effect of the building type, a two story, one family wood frame building was assumed. Here again, the building failure pressure was specified low enough to insure that a complete picture of debris effects

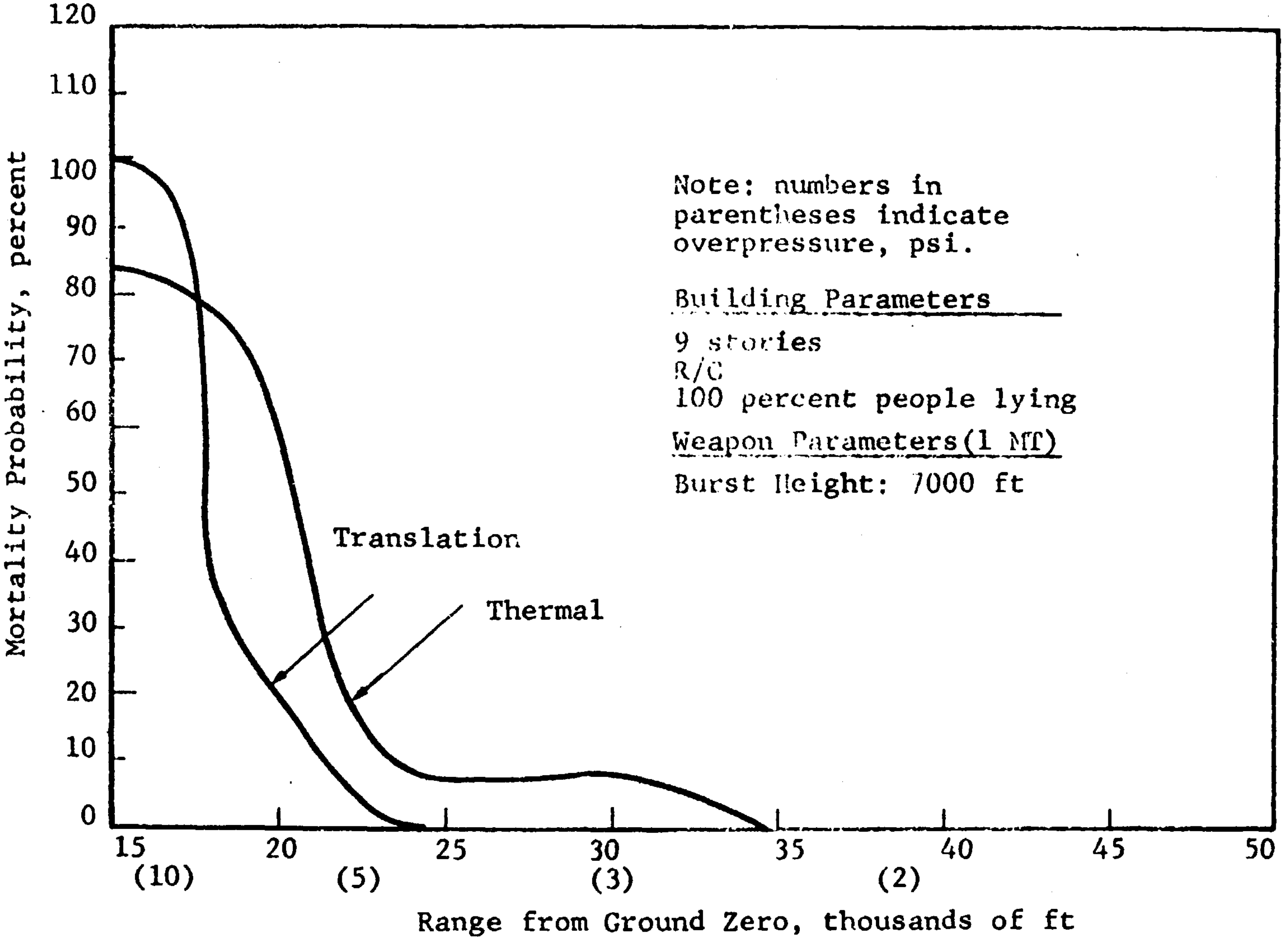


Fig. 45 MORTALITIES FOR A LYING POPULATION (Outdoor)

100 percent people standing

Weapon Parameters (1 MT)

Burst Height: 7000 ft

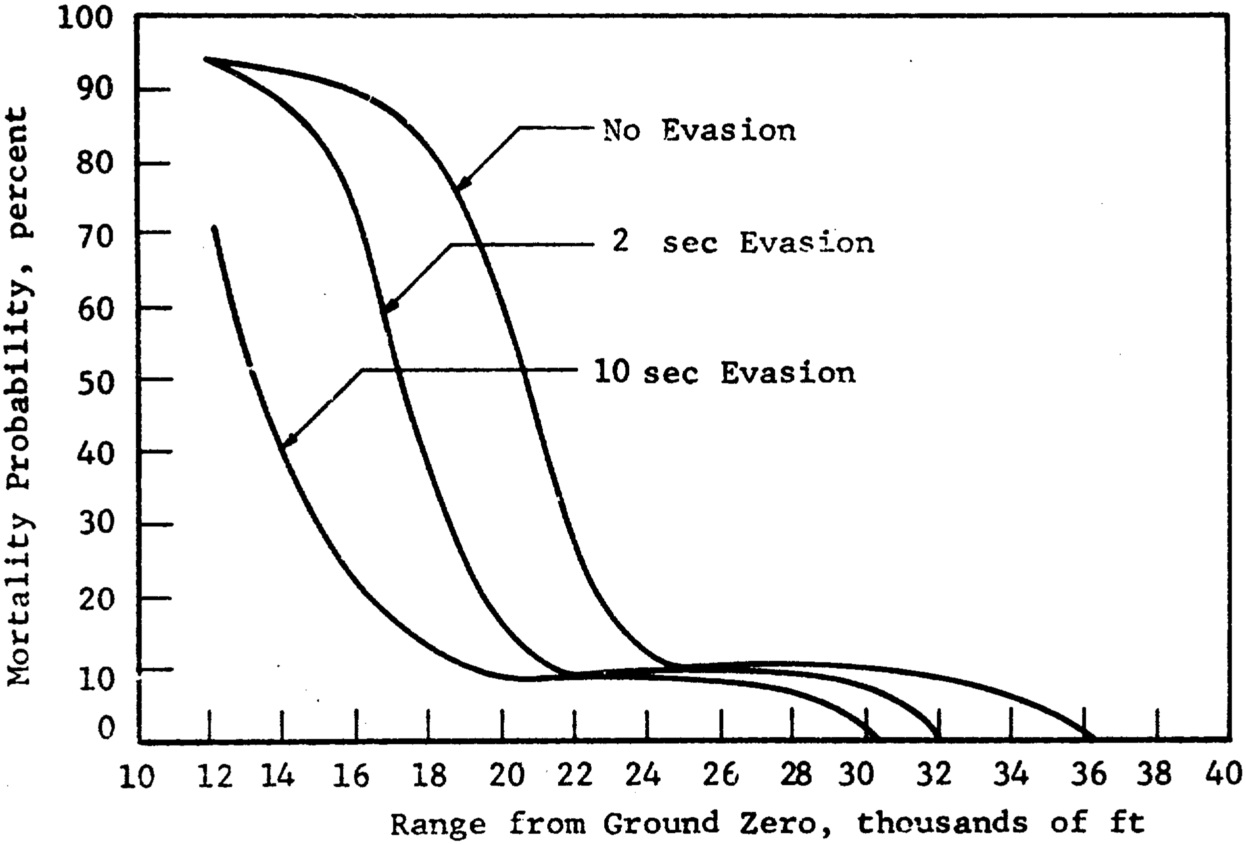


Fig. 46 EFFECT OF EVASIVE ACTION ON OUTDOOR THERMAL MORTALITIES

would evolve. Figure 47 illustrates a relationship between range and mortality inside the wooden building. In comparison with Fig. 40 for the reinforced concrete building, the translation mortalities did not change because translation effects for people standing inside buildings are not effected by building type but rather by the window opening percentages. Thermal effects are seen to increase somewhat because the greater ratio of exposed interior area to the total interior area of the building. Debris effects are far more interesting. At 15,000 ft range the mortality probability due to debris in the wood house is about 58 percent while in the concrete structure in Fig. 40 it was seen to be about 75 percent. In the woodframe house debris mortalities extended to about 26,000 ft.

It is obvious that care must be exercised in evaluating these results. First, the debris assumed for the concrete structure was heavier than that assumed for the wood structure. For the wood structure it was assumed that the 1 x 6 in. wood siding failed in 2 ft lengths for all overpressures. The result was a fragment weighing less than 1 lb, which according to the casualty criteria illustrated in Fig. 10, must be accelerated to nearly 100 ft per second before it is lethal. On the other hand the concrete building in Fig. 40, was assumed to fail in debris sizes of about 2 in. radius which require much lower ballistic coefficients (w/AC_d, for lethality), than the wooden debris. In the short distance of travel involved, this difference in ballistic parameters was apparently not enough to overcome the increased velocity requirements due to the low weight of the wooden debris involved.

This example serves to focus the obvious requirement for knowing the character of the debris formed, as well as the associated casualty criteria. Both of these are areas in which more information is required. A further point concerning the debris casualties of the wood and concrete structures must be made. If the failure threshold of the concrete building had

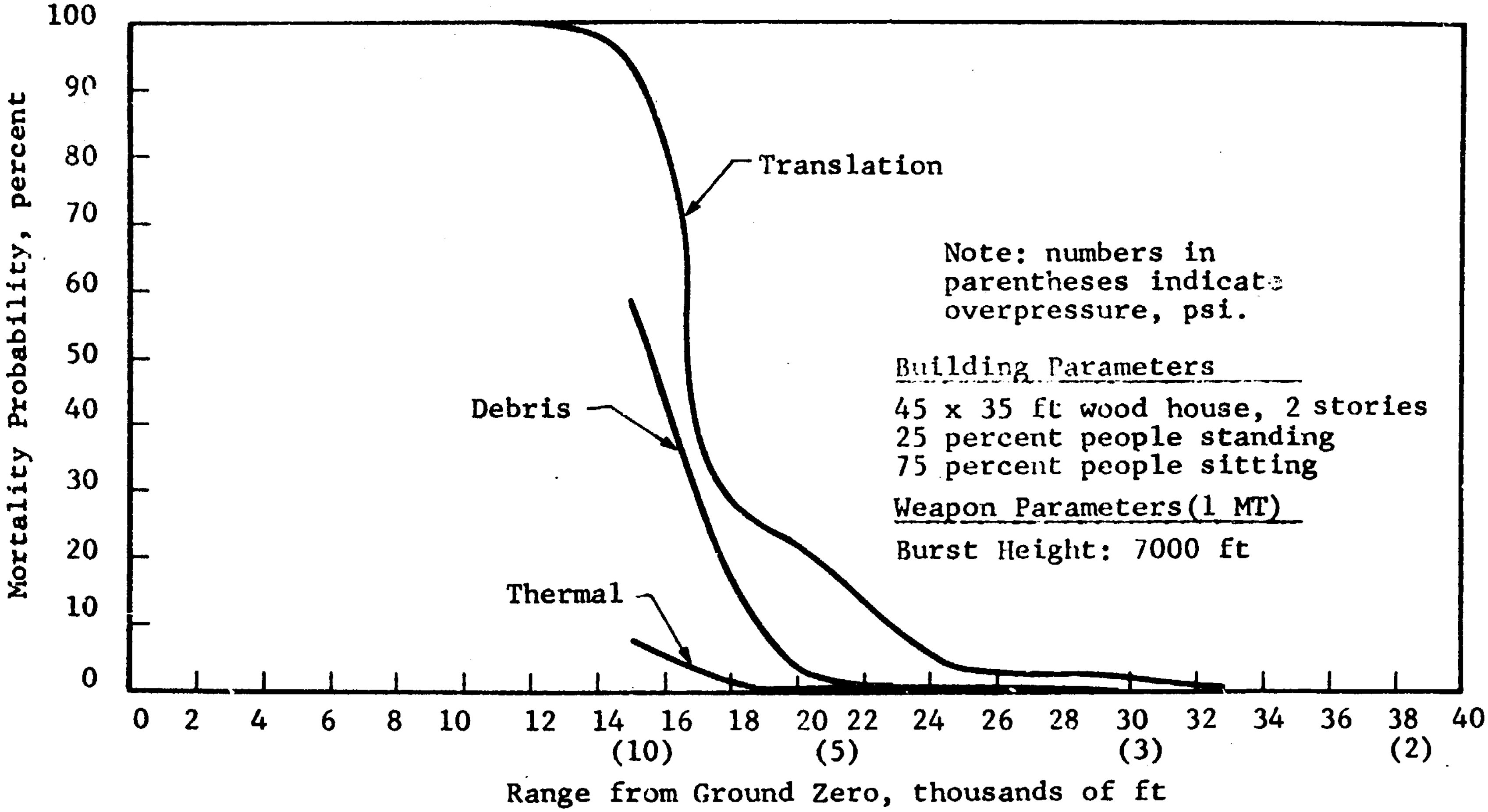


Fig. 47 RANGE EFFECTS ON MORTALITY FOR WOODEN BUILDINGS (Indoor Casualties)

occured at a higher level, the effect of the difference in debris would obviously not occur, and the wood building would appear to be more hazardous than the reinforced concrete building at these ranges.

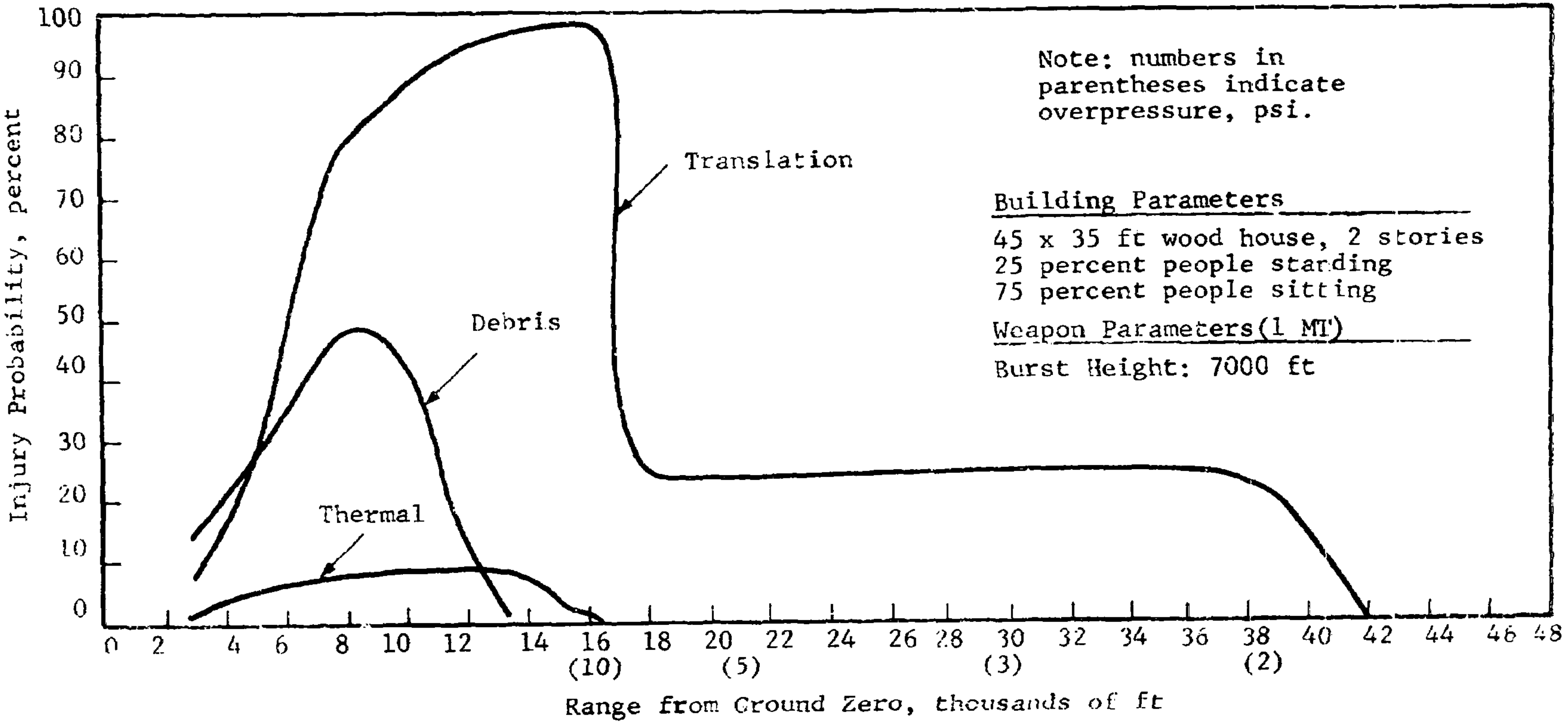
Figure 48 illustrates the injury probability for each effect for the wood building. Again the effects of debris and translation injuries are more prevalent as in the mortality case above.

4.3.1 Building Configuration Variations

In this investigation the building parameters that were varied included the story height and the building width. The effect of varying the external and interior room lengths were also investigated and provided interesting results. All variations were conducted at 20,000 ft fange for the 1 MT, 7,000 ft height of burst conditions.

4.3.2 Building Story Height Variations

Figure 49 illustrates the effect on indoor mortality due to varying the height of the structure, while maintaining a constant total floor area. Mortalities due to thermal radiation decrease slightly with increasing building height due to the reduction in the ratio of exterior room area where exposure takes place to total floor areas as the height of the structure is reduced. Translation mortality essentially remains constant since it is based on an overpressure level which in this model does not depend on the building parameters being varied. The mortality due to debris effects are increased with decreasing building height because the interior area exposed to debris from the failure of interior walls becomes a greater part of a total area which is held constant. Two debris sizes were selected, one for exterior and one for interior walls. The debris from exterior walls does not produce a significant amount of casualties, so a reduction of the area exposed to the exterior wall debris causes an increase in mortality because the area



Note: numbers in
parentheses indicate
overpressure, psi.

Building Parameters

45 x 35 ft wood house, 2 stories
25 percent people standing
75 percent people sitting

Weapon Parameters (1 MT)

Burst Height: 7000 ft

Fig. 48 RANGE EFFECTS ON INJURIES FOR WOODEN BUILDINGS (Indoor)

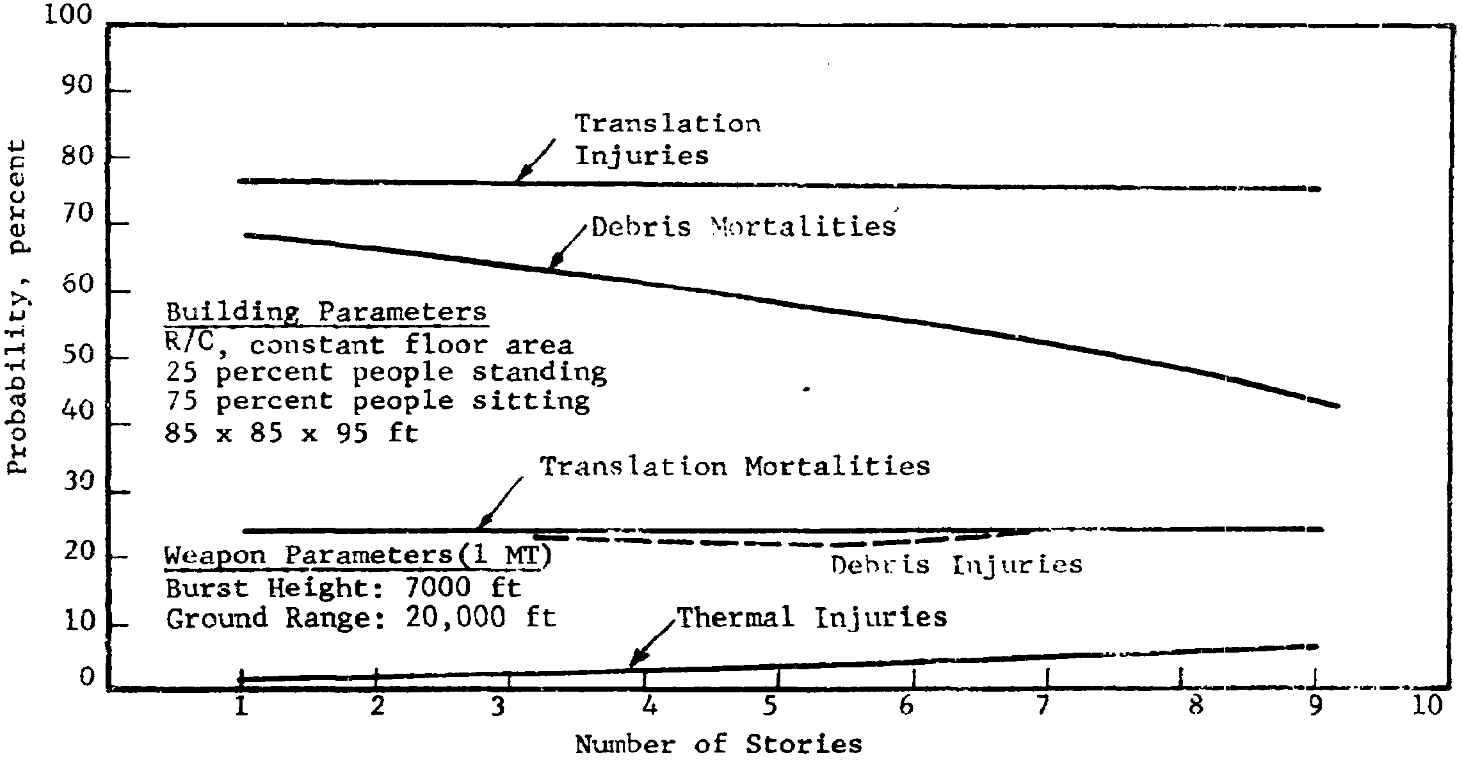


Fig. 49 EFFECT OF STORY HEIGHT ON CASUALTIES FOR R/C BUILDINGS (Indoor)

exposed to interior debris is increased.

Figure 50 illustrates the effects of story height on outdoor thermal injuries. Only a slight increase in mortalities is caused by decreasing the building height and increasing the exposed exterior areas.

4.3.3 Plan Dimension Variations

The effect of varying the plan dimensions of a nine-story building is shown in Fig. 51 for indoor casualties. The primary effect occurs in the case of thermal radiation casualties As the building width is increased, the illuminated area becomes a greater percentage of a total floor area and more casualties result.

4.3.4 External Room Length

The effect on casualties due to a variation in the external room length is shown in Fig. 52. Only debris casualties have been shown since translation and thermal effects remain essentially constant over the region of variation. The difference in the exterior and interior wall debris size assumed is the reason for the reduction in the casualties with an increase in the external room size. Practically no injuries or mortalities are generated in the external room. Therefore, an increase in the exterior room size increases the total area associated with the exterior wall debris size and the result is a decrease in total casualties.

4.3.5 Internal Room Length

Figure 53 illustrates the effect of varying the interior room length and is perhaps the most informative of the building parameter variations. With very small interior room lengths, there are no debris mortalities but about 55 percent injury. This is explained by the insufficient acceleration of the debris particle to a lethal velocity. At very close distances to the wall the debris particles do not have time to accelerate to a

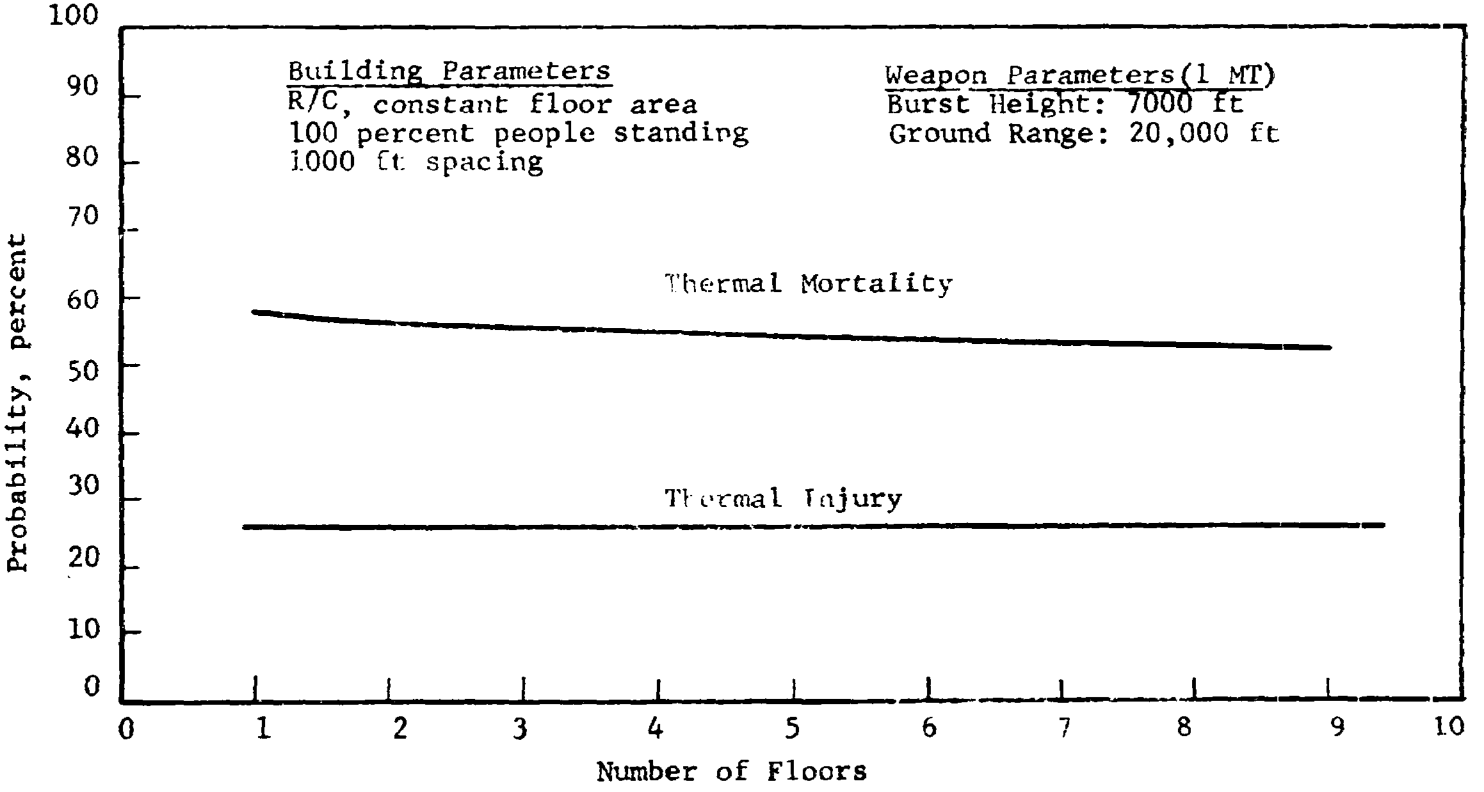


Fig. 50 EFFECT OF STORY HEIGHT ON CASUALTIES (Outside)

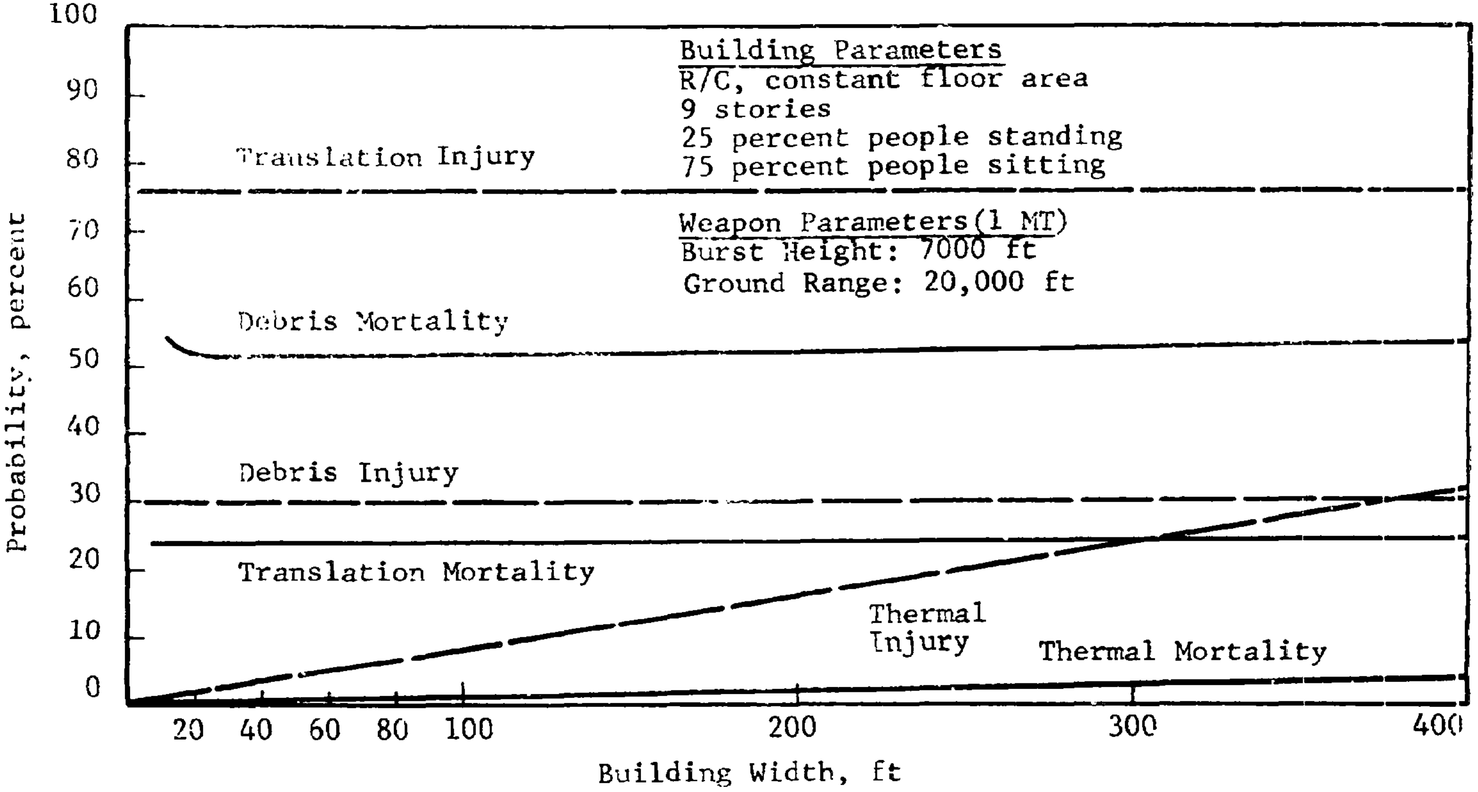


Fig. 51 EFFECT OF BUILDING SHAPE ON CASUALTIES (Indoor)

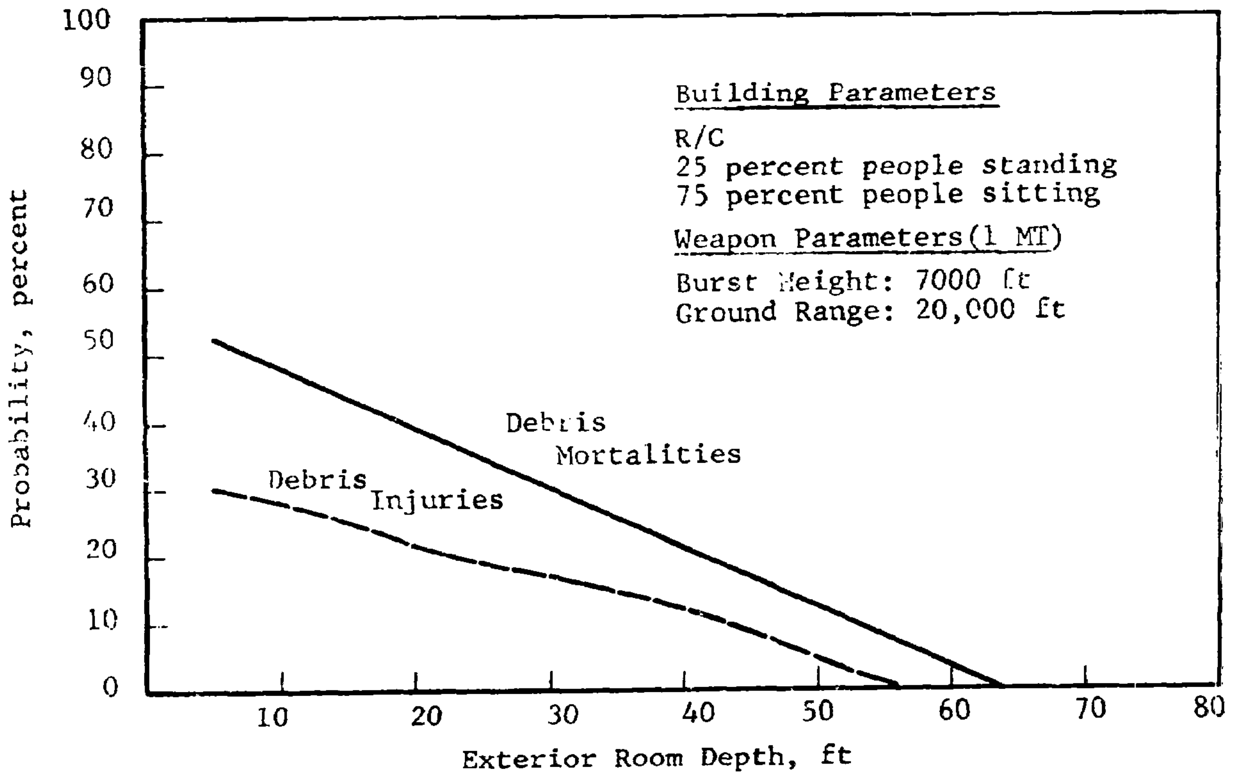


Fig. 52 EFFECT OF EXTERIOR ROOM DEPTH ON DEBRIS CASUALTIES

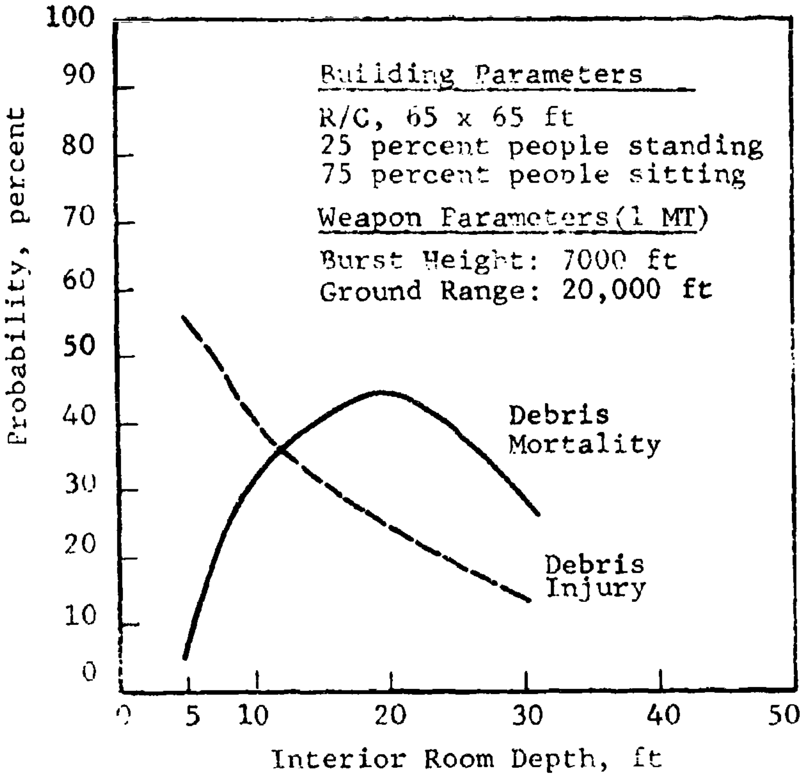


Fig. 53 EFFECT OF INTERIOR ROOM DEPTH ON DEBRIS CASUALTIES

lethal velocity before they impact. However, the velocity is adequate to cause injury. As the interior room length is increased, lethal particle velocity is achieved and mortality increased. Injuries are reduced because the low velocity region now represents a small part of the total area. As the room length is increased further, the mortalities drop off and the injuries continue to decline. This is caused by the particles impacting with the ground before they are able to reach the people at the far end of the room.

4.4 Translation

As can be seen from the figures presented previously in this section, the overall computer code is highly sensitive to the translation phenomena. As a result of this, further results and discussing of translation problems are provided.

Figure 54 illustrates impact velocity as a function of the overpressure that was taken from the various runs performed in generating the other curves. The overpressure plotted is that which was applied to the model, both interior and exterior velocities are shown. The first observation to be made is that there is a significant difference between the sitting and standing cases. The second observation is that the results are a smooth function of the overpressure, with only minor dependence on the positive phase duration, as shown by interior and exterior velocities with the same overpressure. The inside cases correspond to shorter positive phase durations.

This dependence on overpressure requires some additional explanation. The values illustrated in Fig. 54 are for rotation of the body only. This rotation to 90 degrees occurs in a very short time after the arrival of the blast wave. For the yields involved, the time for the rotation to occur is only a small part of the total positive phase duration, however, as will be shown later translation is dependent on the positive phase duration.

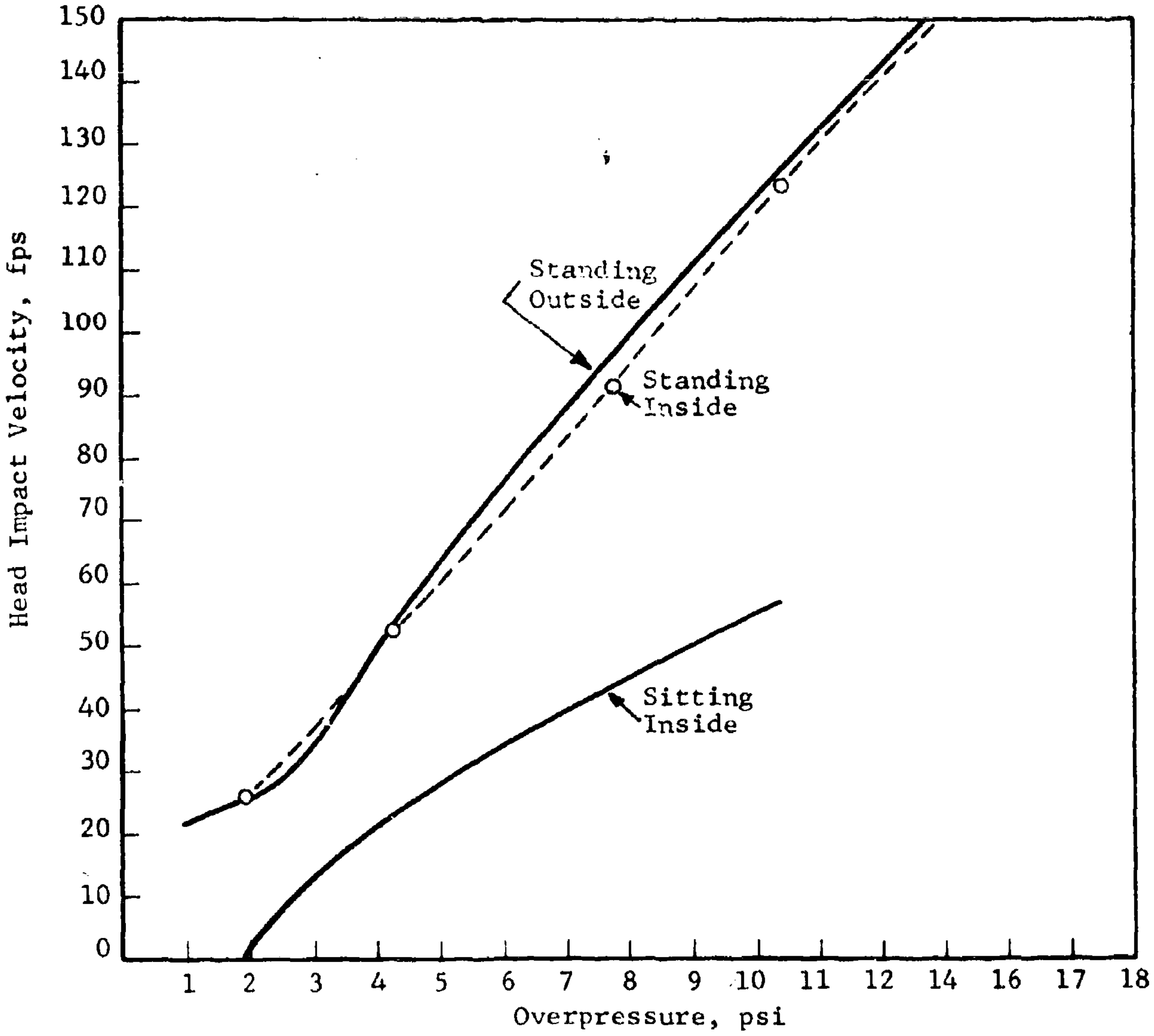


Fig. 54 TRANSLATION IMPACT VELOCITY FOR STANDING AND SITTING PEOPLE

Returning to Fig. 54, the most interesting part of the curve is below 3 psi for the standing cases. In this region the slope flattens out. Of primary importance is the fact that in this region, when the slope is quite flat, the translation velocity thresholds occur. This is also shown as the region where the overpresure range relationship, Fig. 55, flattens out. This means that a small variation in casualty criteria can cause significant variations in the ground regions over which these variations occur. Therefore, in order to predict casualties with reasonable assurance, one must be able to make reasonable predictions of the impact velocities. Similarly, casualty criteria must also be well defined. It is further obvious from the velocity differences between a sitting and standing posture that the reactions of people will play an important part in whether they will or will not be injured during this first phase of the translation problem. During the second phase of the translation in which people are knocked down, roll and tumble, their reactions will likely be of even greater importance.

Figure 56 is an illustration of the velocity displacement relationships for several overpressures from the 1 MT, 7,000 ft height-of-burst case for a man lying parallel to the direction of the blast wave motion. The translation distances reveal the importance of considering what people will do and how they will react if blown these distances by the blast wave. Obviously the problem is not over when people rotate 90 degrees and strike the ground.

This selected discussion of the blast translation effect has been an attempt to illustrate the importance of both the casualty criteria and the response of people in the prediction of casualties associated with a nuclear weapon.

4.5 Fire Mortalities

Up to this point only direct effects have been considered. This subsection discusses the relationship between blast

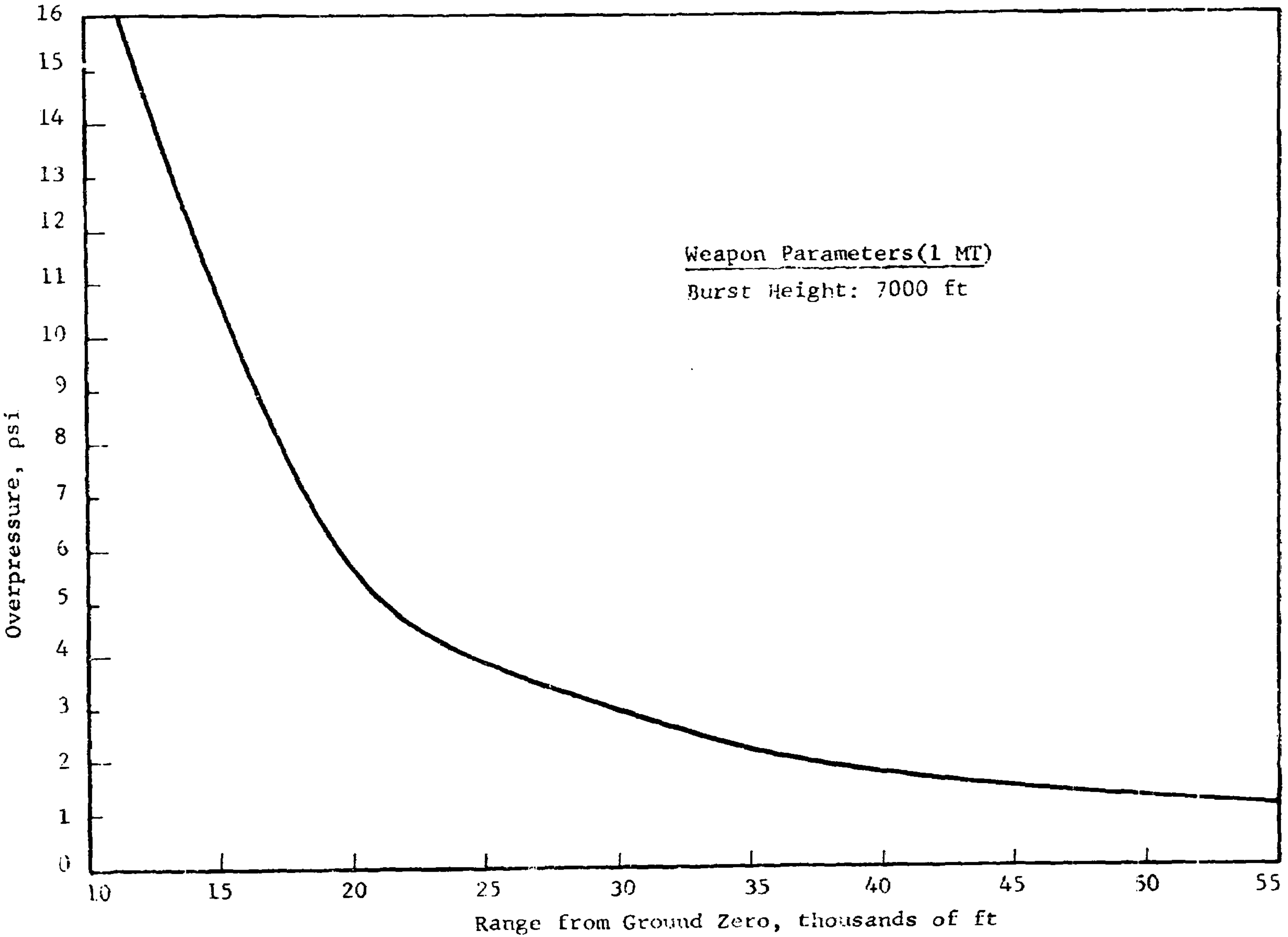


Fig. 55 OVERPRESSURE RANGE RELATIONSHIP FOR 1 MT AT 7000 FT HEIGHT OF BURST

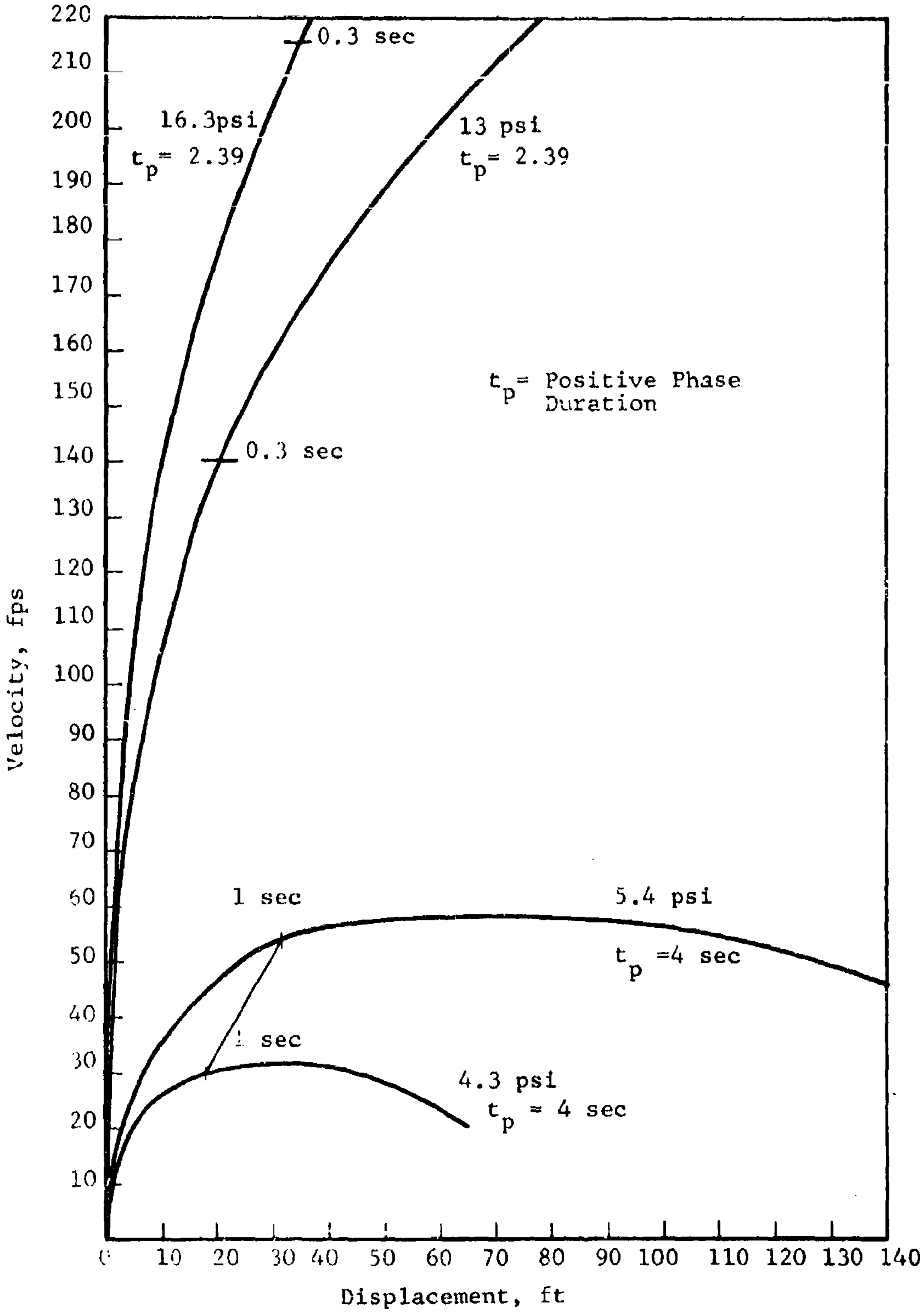


Fig. 56 TRANSLATION VELOCITY-DISPLACEMENT FOR LYING POPULATION AND DIFFERENT OVERPRESSURES

mortalities and fire mortalities for blast injured people trapped within burning buildings. (i.e., as predicted by the model). The model predicts a range in which persons indoors will be seriously injured and unable to move unless outside assistance is provided. This immobile period may last for as much as several hours after detonation of the weapon. The types of unjuries incurred are serious head injuries and broken limbs. In some cases self mobility will never occur. However, for this example, it is assumed that no persons may move and that no assistance is provided. It is then possible to estimate the additional casualties which may occur as a result of fires started within buildings where injured persons are trapped.

Figure 57 illustrates translation injury probability for the sample problem. Translation injury only was assumed, because it is the primary contributor to injuries. The second curve is the probability of ignition in a room for a clear day obtained from Ref. 23. With these two curves, estimates of the fire mortalities can be made. First, the blast translation casualties occur in the area represented by πr_b^2. For the problem at hand r_b is 15,000 ft.

Fire casualties will occur out to the range where there is a meaningful number of uninjured translation survivors, or approximately 29,000 ft from Fig. 57. Beyond this range most of the people are uninjured and they are assumed to assist injured persons prior to complete fire development, or they put out fires before the spread occurs. Therefore, the area subjected to fire is $\pi r_i^2 - \pi r_b^2$ where r_i is 29,000 ft.

Two possibilities exist: (1) to assume that 30 percent of exposed rooms in each building ignite; or (2) that 30 percent of the buildings ignite. If the latter is assumed, fire spread from building to building must account for a complete kill to 29,000 ft. The blast mortality area is 2640 x 10^6 ft squared; the ratio of the fire mortality to the blast mortality

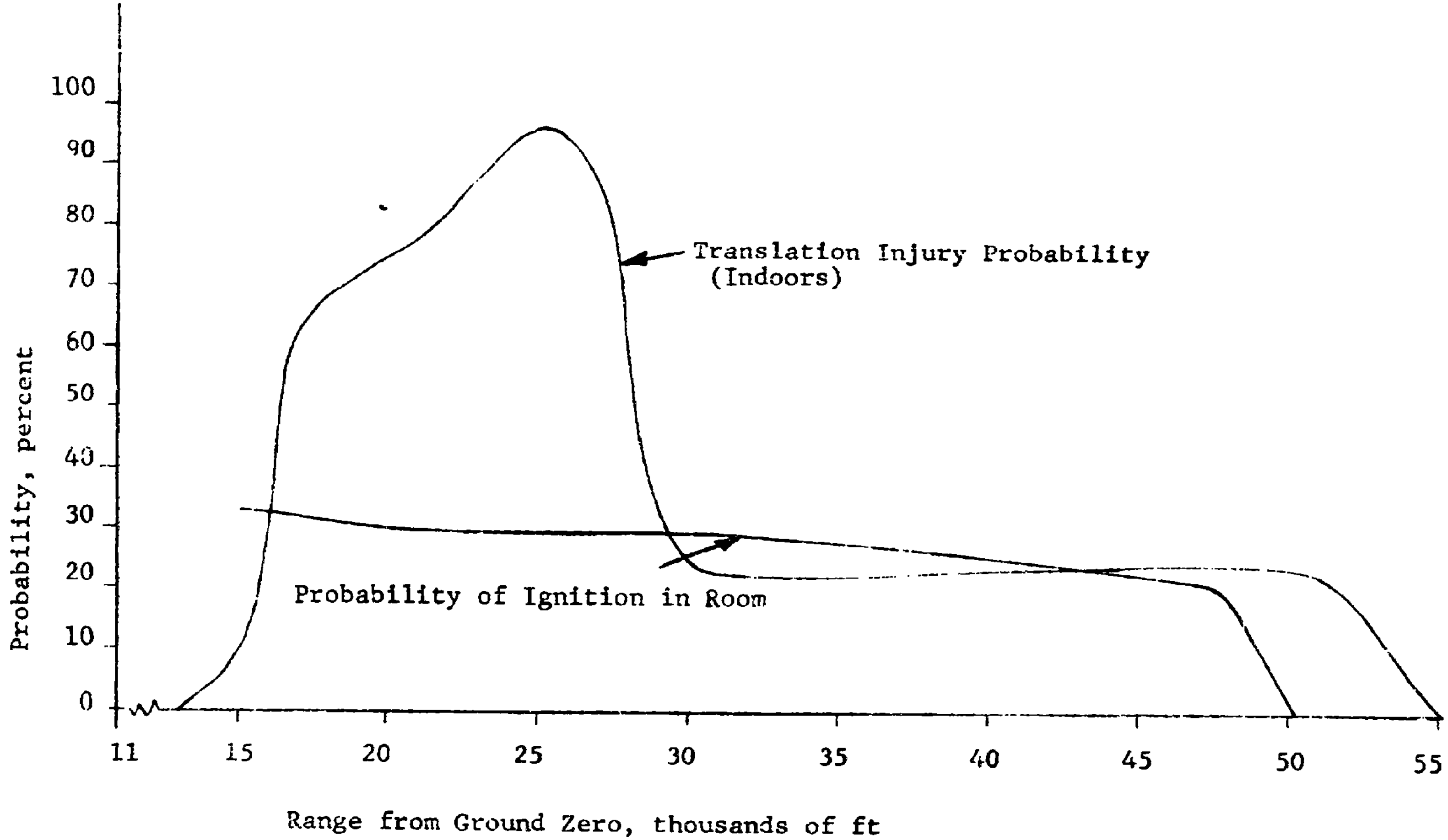


Fig. 57 RELATION BETWEEN INJURIES AND FIRE SUSCEPTIBILITY

area is then 2640: 710 or 3.7; an almost 400 percent greater area is involved.

Assuming Case (i) above holds, that is only 30 percent of the exposed rooms of each building are effected, the building area still represents more than 100 percent of the blast area. Considering the population density, which is an obviously important number in determining the mortalities, (e.g., Chicago in the daytime has a average population density of 50,000 people per square mile out to 15,000 ft. From 15,000 to 30,000 ft the average population density is 30,000 people per square mile.), a 3:5 ratio is established. The ratio of fire to blast mortalities becomes approximately 220 percent, if all within the total injury region become mortalities, and 67 percent if only even 30 percent are affected. Two further things must be kept in mind at this point:

- The population density figures are for daytime; a nighttime figure would reduce the population in the center of the city, the assumed ground zero, and raise the level in the outer ring where fire is more important.
- The percentage of people indoors and outdoors will be different for the two regions considered, and this would certainly influence the ratio of mortalities.

Although the above discussion is very qualitative, it does indicate that fire mortalities would probably be on the order of the blast-caused mortalities for people indoors. The incident of fire spread may well extend casualties well beyond the range of primary ignition. Of course, secondary ignition, (i.e., fire starting due to blast or ground shock and not thermal pulse) will be a contributor, but no information is presently well established on this subject.

However, secondary fires did occur in some of the weapon tests, but at a range where people inside may not be severely injured. They may be assumed to be putting out the fires or helping those outside who are seriously injured.

SECTION V

VALIDATION

Validation of models for predicting casualities to personnel from the effects of nuclear weapons poses obvious difficulties. Although data from Hiroshima and Nakisaki weapons tests can be employed, the sources of this data report only partial information, and in many cases only sample data is available. The best data found on these two cities comes from Ref. 37 and 38, but even with this, questions of accuracy arise when a sample group must represent the total population within a building. Where available, weapons test data of dummies and animal translations were gathered for comparison (Ref. 39 and 40).

Table 16 lists several cases from Hiroshima which were selected for comparison purposes. Structural information on the specific buildings was obtained from Ref. 38. All comparisons were made assuming a 13 KT weapon at 2000 ft height of burst with a visibility of 10 miles. Table 16 presents the information for the buildings checked and the corresponding results. Models both with and without translation are presented because the model determines all results as if they were in the mock region, while for Hiroshima the regular reflection region ran to about 2000 ft from ground zero. This is not to say that it is more likely that blast translation takes place in the mock region than in the regular reflection region. The loading in the regular region, however, is too complicated to include in the present model.

Figure 58 illustrates the mortalities as predicted for people within the Hiroshima telephone office, as if it had been located at various ranges from ground zero. The total mortality with and without translation is provided as a function of range from ground zero. Individual mortalities for each kill mechanism and the effects of yield and heights of burst changes at 2000 ft range are also shown. It becomes quite obvious that kill probabilities can be greatly influenced by these parameters.

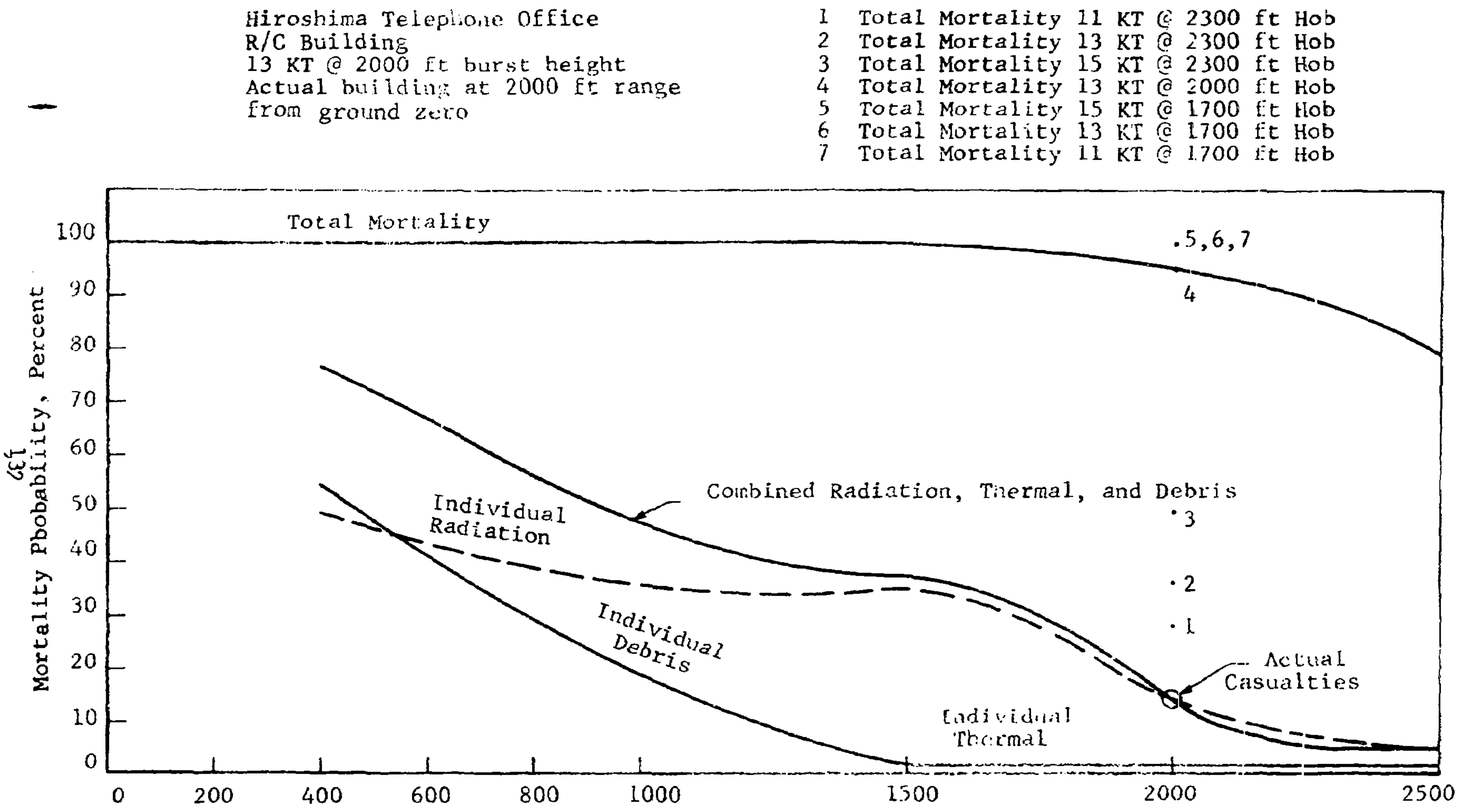


Fig. 58 HIROSHIMA TELEPHONE OFFICE RANGE VARIATIONS

Table 16
COMPARISON OF ACTUAL AND PREDICTED HIROSHIMA CASUALTY RESULTS

Building	Actual percent	Model with Translation percent	Model without Translation percent
Central telegraph	15	100	13.5
Central telephone office	14	93	14
Outside unshielded at 3000 ft	96	100	100
Outside shielded:			
a. Railroad Post Office R/C	3.6	0	0
b. Postal Office R/C	4	0	0

Neglecting translation from the model, the check on the results is gratifying; however, several things must be realized. First, all buildings must be modeled at the present time by rectangular structures. Most of the actual buildings were not simple, rectangular structures, and some had openings in the center. Second, the people are assumed to be uniformly distributed throughout the building; actually, they may have been bunched in specific regions of the building. Therefore; actual verification of the model is impossible with the data available, however, gross inconsistencies can be indicated.

Except for blast translation, the gross comparisons are quite good. There were no primary blast mortalities reported for Hiroshima, and the model predicted none. There were very few thermal injuries within buildings, which was also a model prediction. There was mainly ionizing radiation kill and injury in the region from 1000 to 3000 ft, and the code predicted a significant portion of the injuries in this region to be due to radiation. The greatest disparity occurred in the blast displacement mechanism. Although cases of blast displacement were recorded, no one was reported killed by this effect.

However, as noted before for the Hiroshima burst, the regular reflection region extended to approximately 2000 ft and the computer model considers all cases to be in the Mach region where winds are parallel to the surface and blast displacement is more likely.

To check at least the translation portion of blast displacement, anthropomorphic dummy data gathered from weapon tests was used. The comparisons are based on displacement of body parts and on rotation of the body at these displacements. Table 17 compares the actual and predicted maximum displacements and velocities. The maximum velocities for the standing dummy seem quite accurate, however, the displacements are considerably different. The major cause for difference is that the computer code stops computing when the dummy has rotated 90 deg in either direction, while in the actual case the body continues to slide and tumble until it comes to rest.

In the case of the prone dummies, no actual velocities were determined and only displacements can be used. Where displacements are recorded, they vary considerably from the predirected results. This may be due to local ground interaction effects which occur in actual tests and are not reflected in the model. When one compares the early stages of motion for each weapon test, the results indicate a much more satisfactory prediction capability than the total displacements indicate. Figures 59, 60 and 61 illustrate the velocity displacement history for the early stages of the actual and predicted tests. It should be noted that the predicted results are based on the actual overpressure and positive phase duration. In addition to the c.g. velocity, head velocity displacement curves are shown. Based on these, it can be seen that the predictions are quite reasonable. Figure 62 illustrates the predicted and actual body rotations for the 37 KT Plumbbob and 1/2 KT Snowball tests.

Table 17

COMPARISON OF ACTUAL AND PREDICTED TRANSLATION RESULTS

Weapon Test	Yield	Positive Phase Duration sec	OP psi		Maximum Velocity fps		Maximum Displacement	
					Actual	Predicted	Actual	Predicted
Plumbbob	37 KT	0.964	5.3	Stand	21	27	21.9	17.9
				Prone	-	16.5	-	9.9
Snowball	1/2 KT	(0.23)	10.0	Stand	30.4	38	59.8	8.3
				Prone	-	21	1.3	11.2
Plumbbob	44 KT	0.844	6.9	Stand	-	>44	255	11.1
				Prone	-	27.5	124	29.6

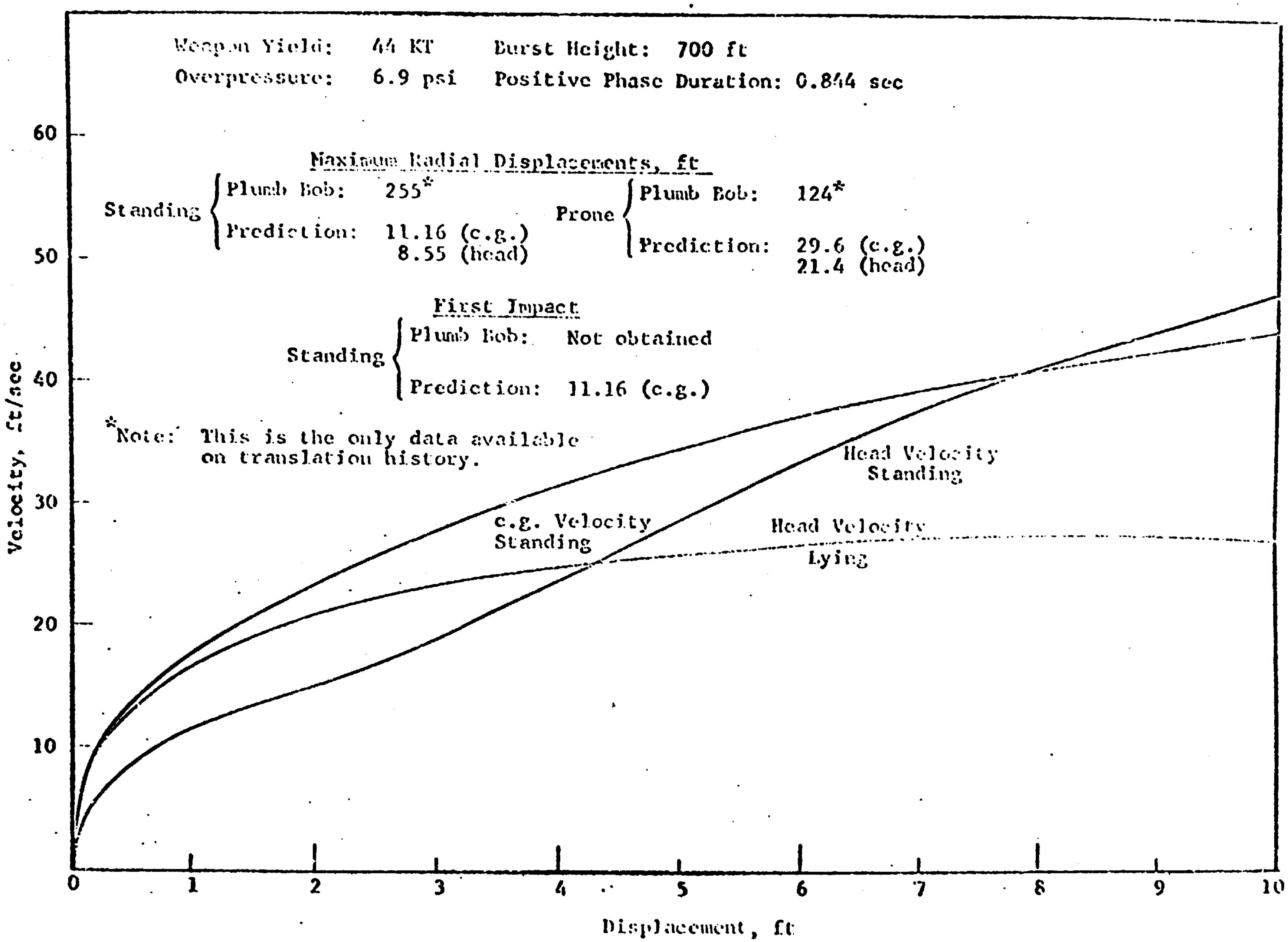


Fig. 59 TRANSLATION HISTORY OF ANTHROPOMETRIC DUMMY (5 ft - 9 in. - 169 lb)

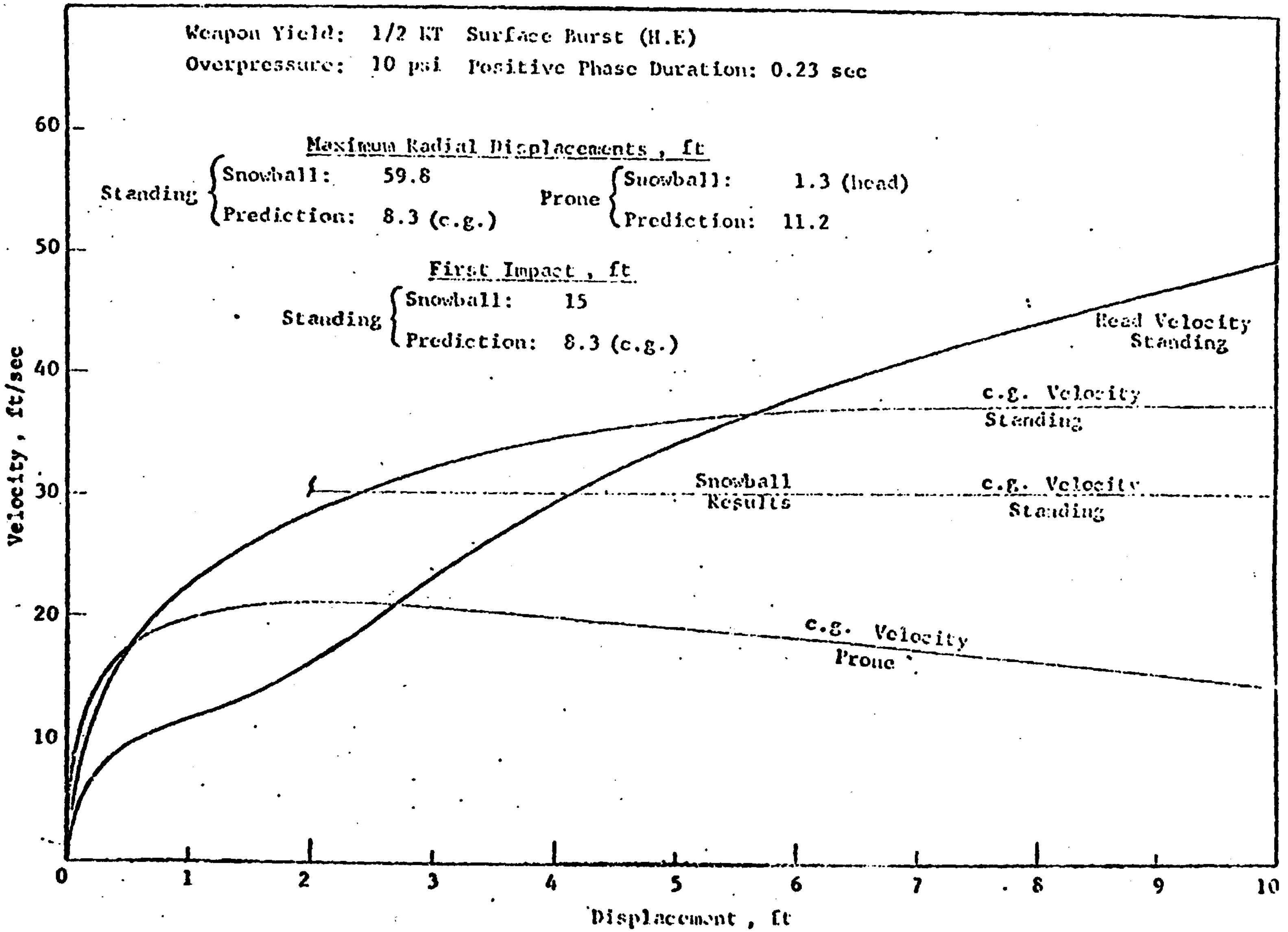


Fig. 60 TRANSLATION HISTORY OF ANTHROPOMETRIC DUMMY (5 ft - 9 in. - 165 lb)

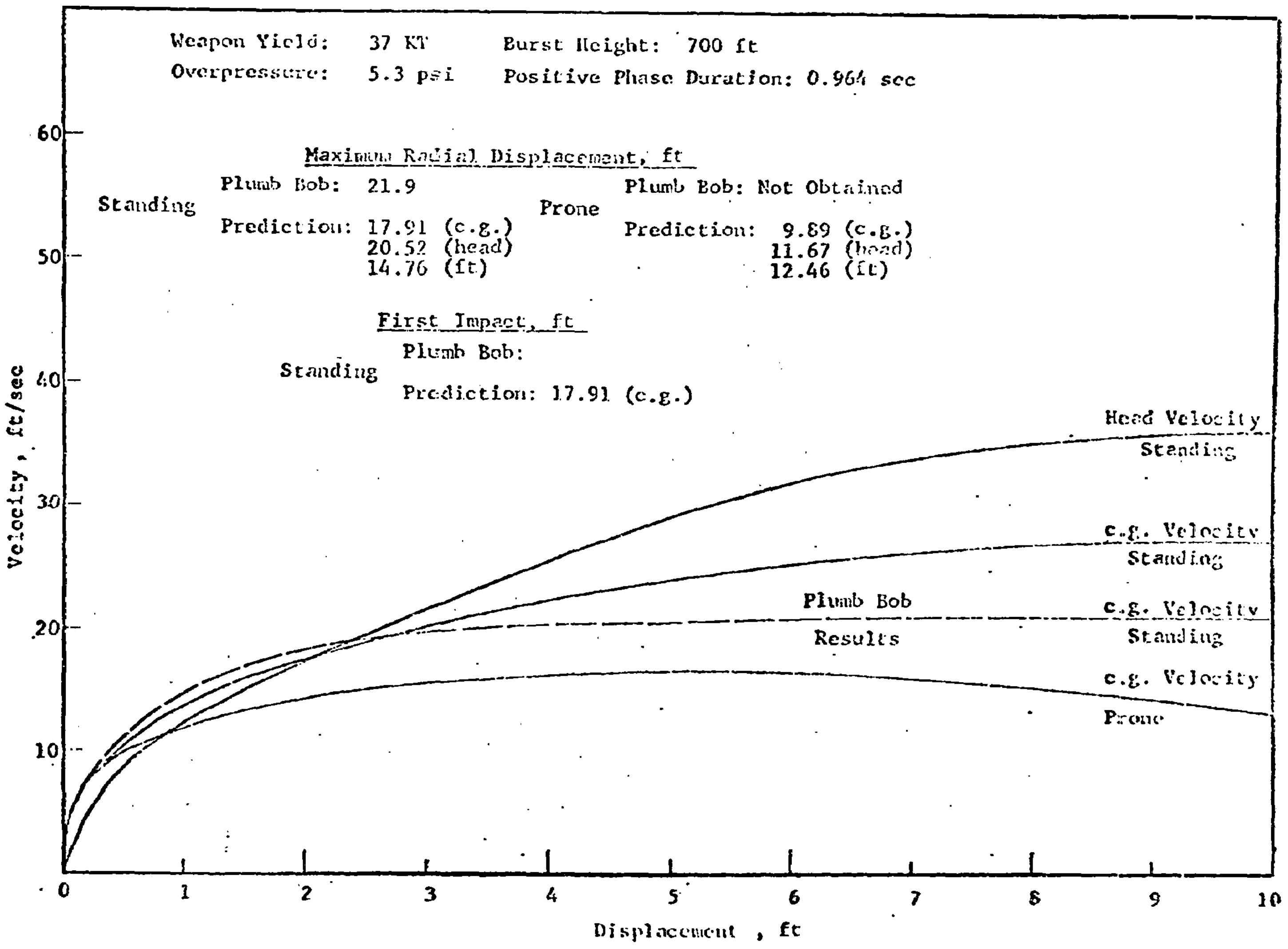


Fig. 61 TRANSLATION HISTORY OF ANTHROPOMETRIC DUMMY (5 ft - 9 in. - 169 lb)

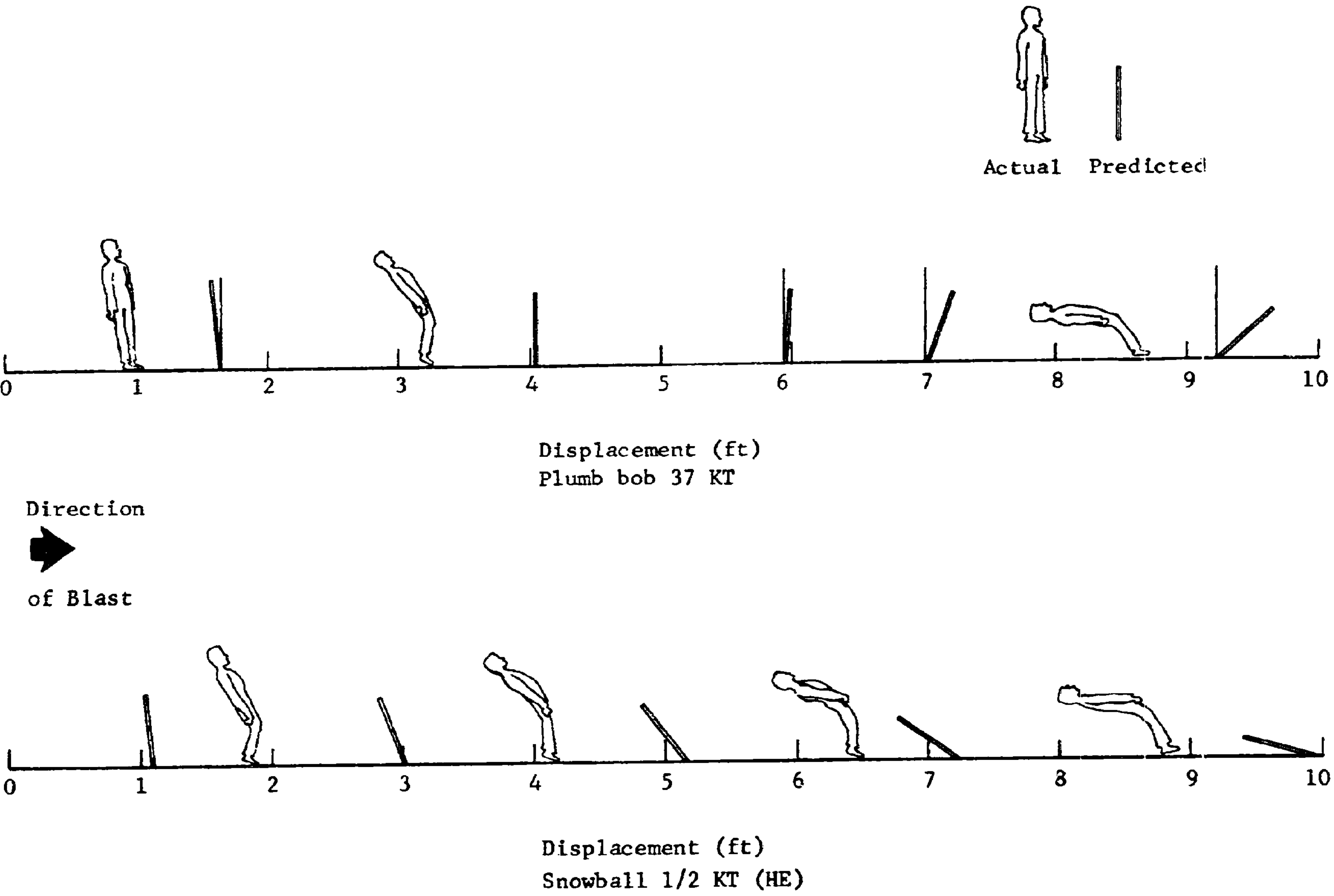


Fig. 62 PREDICTED AND ACTUAL ROTATIONS OF ANTHROMORPHIC DUMMIES

The model only allows rotation of the body to occur about the feet, while in the actual case, the feet are free to leave the ground, and rotation occurs about the center of gravity. However, as can be seen from the figure, the actual rotations for the Snowball test are quite similar to those predicted. In the Plumbbob test, the model predicts backward rotation initially, but because of the friction force on the feet, final rotation and impact is in the forward direction. Had the feet of the model been removed from the ground, rotation would have been negative as in the actual case. However, it can be concluded that the translation prediction techniques are reasonable.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

The result of this effort, along with Subtask 1614A, has been the development of a deterministic tool in estimating shelter effectiveness in terms of protection, when exposed to conditions more severe than design criteria. This evaluation of effectiveness is only possible provided detailed knowledge of specific shelter failure criteria is available. Furthermore, models for individual casualty mechanisms depend on a knowledge of appropriate biological damage functions. The present state-of-the-art is such as to limit the practicability of developing a statistical representation of shelter effectiveness. There are many detailed problems which can be investigated to refine the SEP code output. These problems are associated with structural interactions, debris prediction, translation prediction and casualty criteria for many of the initial effects. The primary effort in future work should be to remove the qualitative aspects that now surround the casualty data. Development of statistical measures for both structural and casualty data would enable statistical bounds on the SEP code output to be established.

The following conclusions can be made based on the results of the computer code and the information gained in conducting this study:

- The computer code provides a means of evaluating the protective capability of various shelters, provided adequate information describing the shelter is available.
- Many of the casualty criteria are studied estimates and require further refinement.

- The interaction of free-field blast effects and structures is an important link in the prediction of casualties. The present information on this subject is insufficient.
- The physical posture of personnel in relation to blast-waves affects their survival probability. This is shown by the differences in casualties for personnel standing and lying when under blast wind translation. The response during the translation may also be an important factor in lowering casualties.
- Fire mortalities are of the same order of magnitude as blast casualties.

The following are recommendations:

- More adequate casualty criteria should be developed for debris, translation and combined effects. Experimental programs to relate debris mass and velocity to injury and mortality should be undertaken. Further studies and experiments of combined affects should be encouraged. Particular attention should be paid to the effect of medical treatment and the time to death.
- A joint experimental and analytical study should be undertaken to determine the relationship between physical response during translation and reduction of casualties. In addition the effect of the rigidity of the impacted material should be studied.

- Debris size, initial velocity and drag characteristics are necessary to adequately predict debris casualties inside and outside structures. Presently, the only available estimate of the failure sizes is given in Ref. 43 for hydrostone panels. Full-scale tests at various overpressures and simulated weapon yields should be conducted on a variety of panels. These tests should be related to analytical results and/or a reliable empirical relation should be developed. Various types of bearing and nonbearing panels with and without windows should be included in this study. Orientation effects should be studied in these panel tests.
- Basements are an important area for further study. Failure criteria should be established for basements and suitable analysis developed to apply these criteria.

REFERENCES

1. White, C. S., Bowen, G. I. and Richmond, D. R., Biological Tolerance to Air Blast and Related Biomedical Criteria, Lovelace Foundation, April 1965, U. S. Atomic Energy Commission, CEX-65.4.
2. Richmond, D. R. and White, C. S., A Tentative Estimation of Man's Tolerance to Overpressures from Air Blast, Tech. Progress Report DASA 1335, 1962.
3. Close, Richmond, Goldizen, Fischer, Pratt, Gaylord and White; The Effects of Shock Tube Generated Step-Rising Overpressures on Guinea Pigs Located in Shallow Chambers Oriented Side-on and End-on to the Incident Shock, Tech. Progress Report, DASA 1312, 1962.
4. Journal of Aviation Medicine, Vol. 28, p. 454.
5. Damon, E. G., The Effects of Ambient Pressure on the Tolerance of Mice to Air Blast, Tech. Progress Report DASA 1483, 1964.
6. Black, A. N. and Zuckerman, S., British Medical Journal, 2, 1941. (Data taken from secondary sources.)
7. McMillen, J. H. and Gregg, J. R., National Research Council, Office of Scientific Research and Development, Missile Casualties, Report No. 12, Nov. 6, 1945.
8. Bowen, G. I., et al, Biological Effects of Blasts from Bombs, AECU-3350, June 18, 1956.
9. Journee Rev. D'Artillerie, May 1907.
10. Gurdjian, E. S., American J. Surg., 78:736-742, 1949.
11. Richmond, D. R. and White, C. S., Biological Effects of Blast and Shock, Tech. Progress Report, Lovelace Foundation, Albuquerque, N. M., Contract No. DA-49-146-XZ-055, April 1966.
12. Richmond, D. R., Bowen, G. I. and White, C. S. Tertiary Blast Effects: The Effects of Impact on Mice, etc., Aerospace Medicine, 32, 789, 1961.
13. Butterfield, W. J. H., Surg. Gunecol. Obstet. 103, pp 655-665, 1956.
14. Henriques, DASA 1555.

REFERENCES (Contd)

15. Glasstone, S., Ed., Effects of Nuclear Weapons, U. S. Government Printing Office, 1964.

16. Gerstner, H. B., Acute Radiation Syndrome in Man, U. S. Armed Forces Medical Journal, 9, pp 313-354, 1958.

17. Smith, E. H. and Company, Final Report, Contract AF 33(657)-9712, August 1963.

18. Cronkite, E. P., Dunham, C. L., Griffin, D., McPherson, S. D., and Woodward, K. T., 12 Month Post Exposure of the Marshallese Exposed to Fallout Radiation, Brookhaven National Lab., BNC-384(T-71), 1955.

19. Smith, E. H. and Company, Final Report, Contract AF 33(600)-39304, May 1961.

20. Alden, Annals of Surgery, 140, 1954.

21. Valeriote, F. A. and Baker, D. G., The Combined Effects of Thermal Trauma and X-Irradiation on Early Mortality, Radiation Research, 22, pp 693-702, 1964.

22. Bond, U. S. Naval Radiation Defense Laboratory Report AD-273(b), 1950.

23. Survey of the Thermal Threat of Nuclear Weapons, Contract OCD-OS-62-135 (IIT), Stanford Research Institute, No. I, MU-4021, May 1964

24. OCD Soft Target Study, FR-64-16-66, Contract OCD-OS-62-277, AD 601467, April 1964.

25. Brode, H., A Review of Nuclear Explosion Phenomena Pertinent to Protective Construction, Rand Corp. No. R-425-PR, May 1964.

26. Shielding of Three-Dimensional Blocks, Report No. 22, Final Test Report No. 2, for WADC Contract No. AF 33(616)-2644, Armour Research Foundation Report No. D-087, November 1955.

27. Willoughby, Kaplan and Wallace, Blast Shielding in Complexes, Broadview Research Corp., AFSWC-TR-57-29, AD 144535, August 1958.

28. Experimental Observation of Interior Pressures in Hollow Models - Blast Effects on Buildings and Structures Operation of Six Foot and Two Foot Shock Tubes, Final Test Report No. 5, Armour Res. Founda., No.D-087, Mar.12, 1956.

REFERENCES (Contd)

29. Experimental Observations of Interior Pressures in Hollow Models (Part II) - Blast Effects on Buildings and Structures Operation of the Six Foot and Two Foot Shock Tubes, Final Test Report No. 7, ARF No. D-087, July 1956.

30. Hanovan, F. P., Jr., A Mathematical Model of the Human Body, AMRL TR-64-102, October, 1964

31. Capabilities of Atomic Weapons, TM 23-200, November 1957, (Confidential)

32. Debris Clearance Study, IIT Research Institute No. M264, OCD-OS-62-202, Subtask 3322A, September 1963.

33. Design of Structures to Resist Nuclear Weapons Effects, ASCE Manual of Engineering practice No. 42, American Society of Civil Engineers, New York, N.Y., 1961

34. Keefer and Day, Terrain Effects on Blast Wave Parameters, BRL Report No. 1319, April 1966.

35. A Guide for the Design of Shock Isolation Systems for Under-Ground Protective Structures, AFSWC-TDR-62-64, December 1962.

36. Automated Design of Advanced Hardened Facilities Study, IIT Research Institute, BSD-TR-66-256, Vol. I, Sept. 1966.

37. Oughterson and Warren, Medical Effects of the Atomic Bomb in Japan, McGraw Hill Book Co., Inc., 1956

38. The Effects of the Atomic Bomb on Hiroshima, Japan, Reprint No. 92, (Vols. I-III) U. S. Strategic Bombing Survey, Physical Damage Division, May 1947.

39. Biomedical Program 500 Ton Explosives, Final Report, DASA 1656, AD468368, June 1965.

40. Operation Plumbbob Tertiary Effects of Blast Displacement, ITR-1469, December 1957.

41. Fenves, et al, STRESS: A Reference Manual, Cambridge, Mass: M.I.T. Press, 1965.

42. Ground Environment Complex Survivability, Third Quarterly Report, IITRI for U. S. Army Satellite Communications Agency under Contract No. DA 28-043 AMC-01478 (S), 1 January 1966 to 1 April 1966 (SECRET)

43. Barnett, R. L., et al Accumulation and Removal of Blast-Initiated Debris, Draft Final Report IITRI M6103, SRI.

44. Rittenbury, Maddox, Schmidt, Han, Haynes, Burn Mortality Study of 1831 Patients, DASA 1687, 22 November 1965.

APPENDIX I

PROGRAM USER'S MANUAL

A.1 INTRODUCTION

The code is a problem-oriented computer language which deals with the problem of defining casualties and injuries in a nuclear environment. Input to the computer code is a series of statements that describe the weapon parameters and the structural and personnel characteristics of a representative area. This area may consist of from a single building or open area to an area the size of which is consistent with a constant weapon effects assumption. The output of the code is normally the effects associated with each of five primary kill mechanisms. These five kill mechanisms are further broken down by indoor and outdoor occurrence, and treated by the time required to cause death (i.e., an hour, day, week or month). In addition, injuries are distinguished from mortalities and personnel completely uninjured. The individual effects are combined and totals are found first for each category of time, and then for the overall problem. A detailed description of the environment associated with each kill mechanism is also available to the user as optional information.

A.2 INPUT LANGUAGE

The form of the input to the processor differs significantly from most other computer programs. Format and ordering of card input have been almost eliminated and replaced by a set of commands consistent with civil defense terminology. The fact that a group of characters starts with a letter is sufficient to recognize a word. Similarly, a number indicates numerical data; a decimal point distinguishes a decimal number from an integer; and a blank or a comma after a group of characters indicates the end of that group.

The input commands may be data descriptors, data to be stored, or more generally information about the input process. A data descriptor (e.g., YIELD or HEIGHT OF BURST) communicates to the system that the number that follows is to be associated with that command. Data to be stored consists of the numerical data associated with data descriptors. Commands such as WEAPON PARAMETERS, WEATHER AND TOPOGRAPHY, NODE AND BUILDING PARAMETERS, CHARACTERISTICS OF WALL FRAGMENTATION, DESCRIPTION OF PERSONNEL, SKIP COMMANDS, INTERMEDIATE OUTPUT, and SOLVE actually control the internal flow of the program. Table 18 contains the dictionary of available commands. Each command occupies a separate input card in the data and a card may be continued by placing a dollar sign ($) in the first column of the following cards. Each input card is printed on the system output before the solution phase of the processor takes over. It is possible to put comment cards into the input phase simply by placing an asterisk (*) in Column 1 of the card. This card is simply echo printed, but otherwise ignored. Table 19 contains a typical set of commands which are sufficient to describe a full casualty problem for two buildings.

Once the problem has been initially described, any subsequent changes will involve only those parameters that are being changed. It may be noted that a full set of commands as specified in Table 19 is quite lengthy. In order to shorten this list all input parameters have been initialized to consistent values. Thus, unless a problem contains input data which differs from this initialized state, the input list of Table 19 is shortened considerably. Table 20 illustrates the initialized state of the code which specifies the value of all input parameters implicitly at the beginning of all problems initiated by a SOLVE statement. An explicit statement of an implicitly defined input value is often useful in order to obtain a record that this value has been utilized in the problem under consideration.

Table 18
A DICTIONARY OF AVAILABLE COMMANDS

Process Command	Data Descriptor*	Units
WEAPON PARAMETERS		
	YIELD	MT
	HEIGHT OF BURST	ft
	GROUND ZERO COORDINATES	ft
WEATHER AND TOPOGRAPHY		
	VISIBILITY	miles
	SEASON OF YEAR	
NODE AND BUILDING PARAMETERS		
	AREA OF NODE	sq miles
	NUMBER OF BUILDINGS AT NODE	
	LOCATION OF NODE	ft
	CONSTRUCTION PERCENTAGE	
	HEIGHT	ft
	WIDTH	ft
	LENGTH	ft
	WEIGHT	kips
	AVERAGE SPACE S__N__E__W__	ft
	DENSITY OF WALL MATERIAL	lb/cu ft
	WALL PANEL THICKNESS	in.
	ROOF THICKNESS/ROOF DENSITY	in.-lb/cu ft
	FLOOR THICKNESS	in.
	MATERIAL DENSITY OF FLOOR	lb/cu ft
	BASEMENT WALL THICKNESS/DENSITY	in.-lb/cu ft
	SOIL DENSITY	lb/cu ft
	STORIES	
	WINDOW PERCENTAGE	
	SILL HEIGHT ABOVE FLOOR	ft
	NO SHIELDING PERCENTAGE	
	SCREEN PERCENTAGE	
	SINGLE GLASS PERCENTAGE	
	COMBINED SINGLE GLASS AND SCREEN PERCENTAGE	
	DOUBLE GLASS PERCENTAGE	
	SHIELDING FROM DOUBLE GLASS AND SCREEN PERCENTAGE	

Table 18 (Contd)

Process Command	Data Descriptor*	Units
	DRAPERY BLIND AND SHADE PERCENTAGE	
	DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL	ft
	INNER ROOM LENGTH	ft
CHARACTERISTICS OF WALL FRAGMENTATION		
	NUMBER OF PARTICLES	
	INSIDE PERCENT	
	OUTSIDE PERCENT	
	MASONRY FAILURE PRESSURE	psi
	OVERPRESSURE AT FAILURE	psi
	WALL TYPE	
	ACCELERATION COEFFICIENT	lb/sq ft
DESCRIPTION OF PERSONNEL		
	POPULATION DENSITY	people/sq mi
	INDOOR PERCENTAGE OF POPULATION	
	INTERIOR POSITION PERCENTAGES STANDING___ SITTING___ LYING___	
	OUTDOOR POSITION PERCENTAGES STANDING___ SITTING___ LYING___	
SKIP COMMANDS		
	BLAST	
	TRANSLATION	
	DEBRIS	
	THERMAL	
	IONIZING	
	BUILDING DESCRIPTION	
	ACCUMULATION	
INTERMEDIATE RESULTS		
SOLVE		

*The descriptor NEXT indicates that the next command is a new process command. All commands and descriptors within them may be in any order and may be redefined any number of times prior to a SOLVE command.

Table 19

SAMPLE PROBLEM TO ILLUSTRATE TYPICAL INPUT AND OUTPUT

```
WEAPON PARAMETERS

      YIELD 1.0 MEGATONS

      HEIGHT OF BURST 7000. FT

      GROUND ZERO COORDINATES X 0.0 Y 0.0 FT.

   NEXT

WEATHER AND TOPOGRAPHY

      VISIBILITY 10. MILES

      SEASON OF YEAR 2 (SUMMER)

*     1 IS WINTER

    NEXT

NODE AND BUILDING PARAMETERS

      AREA OF NODE 1.0 SQ. MILES

      NUMBER OF BUILDINGS AT NODE 2

      LOCATION OF NODE X=7000. Y=0.0 FT.

      CONSTRUCTION PERCENTAGE 60. 40.

*     NOTE THAT THE TWO NUMBERS ABOVE ARE REPRESENTATIVE OF BUILDINGS

*     1 AND 2 RESPECTIVELY - THE SAME CONVENTION WILL HOLD BELOW

      HEIGHT  90. 60. FT.

     WIDTH 65. 100.  FT.

      LENGTH 100. 65. FT.

      STORIES 17  15

  AVERAGE SPACE SOUTH 60. NORTH 60. EAST 60. WEST 60.

      DENSITY OF WALL MATERIAL(CONCRETE) 135. 135. LBS./FT.**3

      WALL PANEL THICKNESS 8. 10. IN.

      ROOF THICKNESS 10. 8. IN. ROOF DENSITY(CONCRETE) 135. 135. LB/CUFT

      FLOOR THICKNESS 10. 8. IN.
```

Table 19 (Contd)

```
        MATERIAL DENSITY OF FLOOR(CONCRETE) 135. 135. LB./CU. FT.
        BASEMENT WALL THICKNESS 10. 12. IN. BASEMENT DENSITY 135. 135. LB.
*       /CU. FT. (NO NEED FOR CONTINUATION CARD AS NUMBERS ALL FIT CARD 1)
        SOIL DENSITY 75. 75. LBS./CU.FT.
        STORIES 9 6
*   NOTE THAT THE ABOVE COMMAND HAS THE EFFECT OF OVERRIDING PREVIOUS
*       DATA ABOVE
        WINDOW PERCENTAGE 30. 20.
        SILL HEIGHT ABOVE FLOOR 2.5 3.0 FT.
        NO SHIELDING PERCENTAGE 50. 40.
        SINGLE GLASS PERCENTAGE 50. 60.
*NOTE WINDOWS ARE EITHER OPEN OR COVERED BY A SINGLE GLASS - OTHER
*       POSSIBLE CONDITIONS ARE IMPLICITLY DEFINED AS A ZERO PERCENTAGE
  DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL 16. 14. FT.
INNER ROOM LENGTH 20. 16. FT.
   NEXT
CHARACTERISTICS  OF WALL FRAGMENTATION
NUMBER OF EXTERIOR WALL PARTICLES 1
OUTSIDE PERCENT 100. / 100.
  NUMBER OF INSIDE WALL PARTICLES 9
 INSIDE PERCENT 0.0,70.,0.0.0.0,0.0.0.0,0.0,0.0.30. / 0.0,100.,0.0,0.0,
$ 0.0,0.0,0.0,0.0,0.0
*
* THE ABOVE ILLUSTRATES A TYPICAL STATEMENT CONTINUATION USING $
*
 WALL TYPE 1 1
* WALL TYPE 1 IS MASONRY 0 IS PLASTER AND HAS NO CASUALTY EFFECT
```

Table 19 (Contd)

```
   NEXT
DESCRIPTION OF PERSONNEL
   POPULATION DENSITY 1000. PEOPLE PER SQ. MILE
INDOOR PERCENTAGE OF POPULATION 50.
  INTERIOR POSITION PERCENTAGES STANDING 30. SITTING 40. LYING 30.
   OUTDOOR POSITION PERCENTAGES STANDING 70. SITTING 30. LYING 0.0
NEXT
*     NOTE THAT ONE CAN SKIP ANY OF THE KILLING MECHANISMS WITH THE
*     FOLLOWING COMMAND SET
*  SKIP COMMANDS
*     BLAST
*     TRANSLATION
*     DEBRIS
*     THERMAL
*     IONIZING
*  ONE CAN ALSO SKIP THE BUILDING DESCRIPTION AND ACCUMULATING FEATURE
*     BY INCLUDING ALONG WITH THE ABOVE
*     BUILDING DESCRIPTION
*     ACCUMULATION
*     NEXT (THIS IS PUT AT COMPLETION OF SKIP COMMANDS)
*
*     IF INTERMEDIATE OUTPUT IS DESIRED SPECIFY
*     INTERMEDIATE RESULTS
*
*     THE FOLLOWING COMMAND INITIATES THE PROBLEM-BEFORE ITS ISSUE ANY
*  OF THE PRECEDING DATA MAY BE CHANGED.  ALSO NOTE ALL CARDS MAY START
* IN ANY ARBITRARY CARD COLUMN AND ARE FORMAT FREE
*                  SOLVE
```

Table 20

INITIALIZED STATE OF INPUT PARAMETERS

Parameter	Quantity of Parameters	Value
YIELD	1	1.0
HEIGHT OF BURST	1	0.0
GROUND ZERO COORDINATES	2	0.0, 0.0
VISIBILITY	1	10
SEASON OF YEAR	1	2 (summer)
AREA OF NODE	1	1.0
NUMBER OF BUILDINGS AT NODE	1	1
LOCATION OF NODE	2	3600, 0.0
CONSTRUCTION PERCENTAGE	10	100, Rest 0.0
HEIGHT	10	All 0.0
WIDTH	10	All 0.0
LENGTH	10	All 0.0
WEIGHT	10	All 0.0
AVERAGE SPACE S__N__E__W__	4	All 1000
DENSITY OF WALL MATERIAL	10	All 135
ROOF THICKNESS/ROOF DENSITY	10-10	All 12, All 135
FLOOR THICKNESS	10	All 12
MATERIAL DENSITY OF FLOOR	10	All 135
BASEMENT WALL THICKNESS/DENSITY	10-10	All 12, All 135
SOIL DENSITY	10	All 75
STORIES	10	1.0
WINDOW PERCENTAGE	10	All 0.0
SILL HEIGHT ABOVE FLOOR	10	All 0.0
NO SHIELDING PERCENTAGE	10	All 0.0
SCREEN PERCENTAGE	10	All 0.0
SINGLE GLASS PERCENTAGE	10	All 0.0
COMBINED SINGLE GLASS AND SCREEN PERCENTAGE	10	All 0.0
DOUBLE GLASS PERCENTAGE	10	All 0.0
SHIELDING FROM DOUBLE GLASS AND SCREEN PERCENTAGE	10	All 0.0

Table 20 (Contd)

Parameter	Quantity of Parameters	Value
DRAPERY BLIND AND SHADE PERCENTAGE	10	All 0.0
DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL	10	All 0.0
INNER ROOM LENGTH	10	All 0.0
NUMBER OF PARTICLES	1	1
INSIDE PERCENT	10, 9	All 0.0
OUTSIDE PERCENT	10, 9	All 0.0
MASONRY FAILURE PRESSURE	1	0.0
OVERPRESSURE AT FAILURE	1	0.0
WALL TYPE	10	All 0 (Plaster)
ACCELERATION COEFFICIENT	1	0 (Equiv. Spher. Rad.)
POPULATION DENSITY	1	1.0
INDOOR PERCENTAGE OF POPULATION	1	100
INTERIOR POSITION PERCENTAGES STANDING___, SITTING___, LYING___	3	0.0, 100, 0.0
OUTDOOR POSITION PERCENTAGES STANDING___, SITTING___, LYING___	3	100, 0.0, 0.0
SKIP COMMANDS	7	All off (0)
INTERMEDIATE RESULTS	1	Off (0)

An alternative to this, however, is to state in a comment statement implicitly defined values. The command SOLVE terminates the input phase of the processor and transfers control to the computational section. When the specified problem is solved and the answer printed, control is automatically returned to the input phase. Each of the data descriptors will now be discussed in detail.

The process command WEAPON PARAMETER has three data descriptors: YIELD, HEIGHT OF BURST, and GROUND ZERO COORDINATES. The YIELD is the weapon size in megatons. The HEIGHT OF BURST is specified in feet as are the GROUND ZERO COORDINATES. These coordinates are laid out on some two-dimensional map of the area under consideration and are utilized to find distances from ground zero to node points under study. The command NEXT signifies completion of specification of all data descriptors concerned with a process command. It is the means by which one gets from one process command set to another.

The WEATHER AND TOPOGRAPHY process command specifies the VISIBILITY in miles and the SEASON OF YEAR (i.e., 1 for winter or 2 for summer). These parameters are used to compute the thermal radiation effects. The NODE AND BUILDING PARAMETERS process command contains a great deal of data descriptors. A node is a finite area of the total area under consideration. It may be considered to represent one room within a building or a several mile square area in which many types of buildings exist. AREA OF NODE, in square miles, represents the associated area. NUMBER OF BUILDINGS AT NODE specifies the number of different types of representative buildings within the node under consideration. A maximum of 10 per node is allowed at present. CONSTRUCTION ERCENTAGE serves to break down the above types into the percentage represented by each of the total. LOCATION OF NODE is a set of coordinates which, together with the ground zero coordinates, is utilized to find the distance and orientation from ground zero to the node. These coordinates are specified in feet.

HEIGHT specifies the building height of each building type considered. Likewise WIDTH, LENGTH AND WEIGHT specify each building's width, length and weight. The next data descriptor specifies the AVERAGE SPACE SOUTH_____NORTH_____EAST_____WEST_____ between contiginous buildings in a single node. It perhaps is necessary here to explain that all buildings within a node are presumed to lie on a north-south-east-west orientation, however, the node itself lies on some less general orientation with respect to ground zero. This orientation is determined by the node coordinates with respect to ground zero. Ordinarily building width is on a north-south orientation while length is east-west.

The next set of commands describe the roof, wall, basement and surrounding soil characteristics. These include for each building type, WALL PANEL THICKNESS, DENSITY OF WALL MATERIAL, ROOF THICKNESS-ROOF DENSITY (same card), FLOOR THICKNESS, MATERIAL DENSITY OF FLOOR, BASEMENT WALL THICKNESS-BASEMENT WALL DENSITY (same card) and SOIL DENSITY. All thicknesses are in inches and densities in pounds per cubic foot. The data descriptor STORIES indicates the number of floors in each building type. At present there is a limit of 100 floors imposed on any one building type. The command WINDOW PERCENTAGE describes the percent of apertures in each building type, while the next set of command breaks this aperture percentage down by different types of shielding provided. This set of data descriptors include NO SHIELDING PERCENTAGE, SCREEN PERCENTAGE, SINGLE GLASS PERCENTAGE, COMBINED SINGLE GLASS AND SCREEN PERCENTAGE, DOUBLE GLASS PERCENTAGE, SHIELDING FROM DOUBLE GLASS AND SCREEN PERCENTAGE and DRAPERY BLIND AND SHADE PERCENTAGE. The final two data descriptors deal with the room lengths of typical exterior and interior rooms of each building type. They are DISTANCE FROM EXTERIOR WALL TO INTERIOR WALL and INNER ROOM LENGTH and are expressed in foot units.

The next process command CHARACTERISTICS OF WALL FRAGMENTATION indicates the overpressure associated with failure of both exterior and interior walls. Exterior wall failure pressure is indicated for each building type by the data descriptor OVERPRESSURE AT FAILURE. In a similar manner MASONRY FAILURE PRESSURE indicates interior wall failure pressure levels. The particle size description resulting from panel fragmentation is inputed separately for outside and inside walls. In either case the data descriptor NUMBER OF PARTICLE SIZES gives the number of particle sizes under consideration for each wall type. If a certain size particle is to be considered, the number of particle sizes must include all smaller sizes up to this size but not larger. There are nine possible sizes of equivalent spherical particles. These include 1, 2, 3, 4, 5, 6, 8, 10 and 12 in. radius particles. The commands OUTSIDE PERCENT and INSIDE PERCENT indicate the percentage of each size category, for exterior and interior walls respectively. There should be as many percentages listed for each building type as there are number of particles specified. The number of particles specified may be changed prior to specifying either inside or outside size distributions. If the user wishes to describe a projectile which is not represented by an equivalent sphere, he has the option of specifying the particle's acceleration coefficient. The data descriptor ACCELERATION COEFFICIENT describes the shape and orientation in flight of an individual debris projectile and is equal to 2x mass/projected area in units of pounds per square foot. This parameter should be used in conjunction with one of the above radii in order to specify the approximate weight of the projectile. Only one particle acceleration coefficient per building type is allowed and this parameter must be inputed explicitly for every subsequent case run. Each building is classified as having either masonry or nonmasonry interior wall panels by the data descriptor WALL TYPE. An entry of 0 indicates nonmasonry wall panels while an entry of 1 indicates masonry panels. Nonmasonry walls have no effect on interior personnel.

The process descriptor DESCRIPTION OF PERSONNEL identifies the number and deposition of personnel at the node.

POPULATION DENSITY is specified in units of people per square mile while INDOOR PERCENTAGE OF POPULATION specifies the percentage of people inside the previously defined structures. The personnel is broken down into the percent standing sitting and lying both inside and outside by the commands INTERIOR POSITION PERCENTAGES STANDING-SITTING-LYING, and OUTDOOR POSITION PERCENTAGES STANDING-SITTING-LYING.

The next process descriptor, SKIP COMMANDS, allows the analyst to skip some of the kill mechanisms and only use those he actually wishes to utilize. These commands skip around the parts of the program associated with blast, translation, debris, thermal radiation, ionizing radiation, description of post attack building condition and accumulation of casualty information. The data descriptors are respectively BLAST, TRANSLATION, DEBRIS, THERMAL, IONIZING, BUILDING and ACCUMULATION. These parameters, if used, must be specified for each node of a run of several nodes.

The user has a great deal of flexibility in analyzing many special cases because of the many commands available in the language. For instance, the user may wish to study the case of population in an unshielded area. He might do this by specifying the distance between contiginous buildings to be extremely large (e.g., 1000ft). If he is only interested in the effect of ionizing radiation he might set all the SKIP COMMANDS on except IONIZING. If it is desirable to study what is going on WITHIN one room of a structure, this may be simulated by a one story structure whose exterior walls do not fail. The interior wall properties of the structure correspond to the actual walls of the room. The exterior room length of the structure is set to zero. With this type of configuration, even one room within a building may be studied in detail.

Table 21 illustrates the output of the program and is self-explanatory. In the final analysis it is felt that the language is both flexible and readily usable by a noncomputer user.

TEXT NOT REPRODUCIBLE

Table 21

INDIVIDUAL EFFECT MATRIX FOR FATALITIES AND INJURIES

```
DISTANCE FROM GROUND ZERO TO NODE POINT IS     7000. FT.

FREE FIELD OVERPRESSURE AT NODE POINT IS  22.95 PSI

POSITIVE PHASE DURATION AT NODE POINT IS   2.050 SEC

ARRIVAL TIME AT NODE POINT IS   1.681 SEC

THERMAL ENERGY AT NODE POINT=    171.14 CAL/CM**2

IONIZING RADIATION IN(RAD) UNITS=     65.54 RADS

ATTENUATED NODE OVERPRESSURE=  13.4 PSI

   9.2 PSI WITHIN BUILDING TYPE  1

   8.0 PSI WITHIN BUILDING TYPE  2

SHOCK VELOCITY=   1721.64 FPS

PEAK WIND VELOCITY=    821.25 FPS

PEAK DYNAMIC PRESSURE=     10.47 PSI

REFLECTED PRESSURE=     59.09 PSI


INDIVIDUAL EFFECT MATRIX FOR FATALITIES AND INJURIES (FRACTION OF TOTAL)


+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+ EFFECT                       + DEAD HOUR + DEAD DAY + DEAD WEEK + DEAD MONTH + INJURED +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
+ INDOOR BLAST                 +    0.00   +   0.00   +           +    0.00    +         +
+                              +           +          +           +            +         +
+ OUTDOOR BLAST                +    0.00   +   0.00   +           +    0.00    +         +
+                              +           +          +           +            +         +
+ INDOOR TRANSLATION           +    0.49   +   0.00   +   0.00    +    0.00    +   0.01  +
+                              +           +          +           +            +         +
+ OUTDOOR TRANSLATION          +    0.50   +   0.00   +   0.00    +    0.00    +   0.00  +
+                              +           +          +           +            +         +
+ INDOOR DEBRIS                +    0.35   +   0.00   +   0.01    +    0.00    +   0.04  +
+                              +           +          +           +            +         +
+ OUTDOOR DEBRIS               +    0.00   +   0.01   +   0.02    +    0.00    +   0.05  +
+                              +           +          +           +            +         +
+ INDOOR THERMAL RADIATION     +           +   0.01   +   0.00    +    0.00    +   0.00  +
+                              +           +          +           +            +         +
+ OUTDOOR THERMAL RADIATION    +           +   0.40   +   0.00    +    0.00    +   0.00  +
+                              +           +          +           +            +         +
+ INDOOR IONIZING RADIATION    +           +   0.00   +   0.00    +    0.00    +   0.00  +
+                              +           +          +           +            +         +
+ OUTDOOR IONIZING RADIATION   +           +   0.00   +   0.00    +    0.00    +   0.00  +
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

POST ATTACK DESCRIPTION OF STRUCTURES

BUILDING TYPE  1

EXTERIOR WALLS HAVE FAILED
INTERIOR MASONRY WALLS HAVE FAILED

BUILDING TYPE  2

EXTERIOR WALLS HAVE FAILED
INTERIOR MASONRY WALLS HAVE FAILED
```

Table 21 (Contd)

```
INDIVIDUAL EFFECT MATRIX FOR SURVIVAL  (FRACTION OF TOTAL)

**************************************************************************************************************
* EFFECT                       * SURV. HOUR * SURV. DAY * SURV. WEEK * SURV. MONTH * UNINJURED *
**************************************************************************************************************
* INDOOR BLAST                 *    0.50    *    0.50   *    0.50    *    0.50     *    0.50   *
*                              *            *           *            *             *           *
* OUTDOOR BLAST                *    0.50    *    0.50   *    0.50    *    0.50     *    0.50   *
*                              *            *           *            *             *           *
* INDOOR TRANSLATION           *    0.01    *    0.01   *    0.01    *    0.01     *    0.00   *
*                              *            *           *            *             *           *
* OUTDOOR TRANSLATION          *    0.00    *    0.00   *    0.00    *    0.00     *    0.00   *
*                              *            *           *            *             *           *
* INDOOR DEBRIS                *    0.15    *    0.15   *    0.14    *    0.14     *    0.11   *
*                              *            *           *            *             *           *
* OUTDOOR DEBRIS               *    0.50    *    0.49   *    0.47    *    0.47     *    0.42   *
*                              *            *           *            *             *           *
* INDOOR THERMAL RADIATION     *    0.50    *    0.49   *    0.49    *    0.49     *    0.49   *
*                              *            *           *            *             *           *
* OUTDOOR THERMAL RADIATION    *    0.50    *    0.10   *    0.10    *    0.10     *    0.10   *
*                              *            *           *            *             *           *
* INDOOR IONIZING RADIATION    *    0.50    *    0.50   *    0.50    *    0.50     *    0.50   *
*                              *            *           *            *             *           *
* OUTDOOR IONIZING RADIATION   *    0.50    *    0.50   *    0.50    *    0.50     *    0.50   *
**************************************************************************************************************

SURVIVAL FROM  ALL EFFECTS (FRACTION OF TOTAL)

  LOCATION                        SURV. HOUR  SURV. DAY  SURV. WEEK  SURV. MONTH  UNINJURED

  INDOORS                            0.00       0.00       0.00        0.00        0.00

  OUTDOORS                           0.00       0.00       0.00        0.00        0.00

TOTALS FOR THIS NODE (PEOPLE)

NUMBER UNINJURED            0.

NUMBER OF FATALITIES     1000.

NUMBER OF INJURIES          0.

CUMULATIVE TOTALS FOR ALL NODES (PEOPLE)

NUMBER UNINJURED            0.

NUMBER OF FATALITIES     1000.

NUMBER OF INJURIES          0.
```

APPENDIX II

SEP CODE REFERENCE MANUAL

SEP code is a system designed to be run on the IBM 7094 IBSYS MONITOR SYSTEM. Furthermore, due to storage limitations it has been set in a overlay structure. All routines have been coded in FORTRAN IV with the exception of one FUNCTION SUBROUTINE MATCH. MATCH is written in MAP assembly code and is fully described in another publication (Ref. 41). All flow diagrams and program listings of SEP code, with the exception of MATCH, are included in Appendices III and IV respectfully. Figure 63 illustrates the general flow of the total system and Figure 64 indicates the overlay structure of SEP code. To facilitate card handling the system resides on an IEDIT tape, and only a small loder deck and the data are necessary to run the system. A diagram of the deck setup is illustrated in Figure 65. The IEDIT tape resides on physical unit B5 and an extra overlay tape unit A5, is also necessary for maximum execution efficiency. Table 22 illustrates the starter deck.

Running time is approximately 0.5 min per node point, however, this may fluctuate slightly depending on the structural complexity of the node point.

MAINLINE PROGRAM

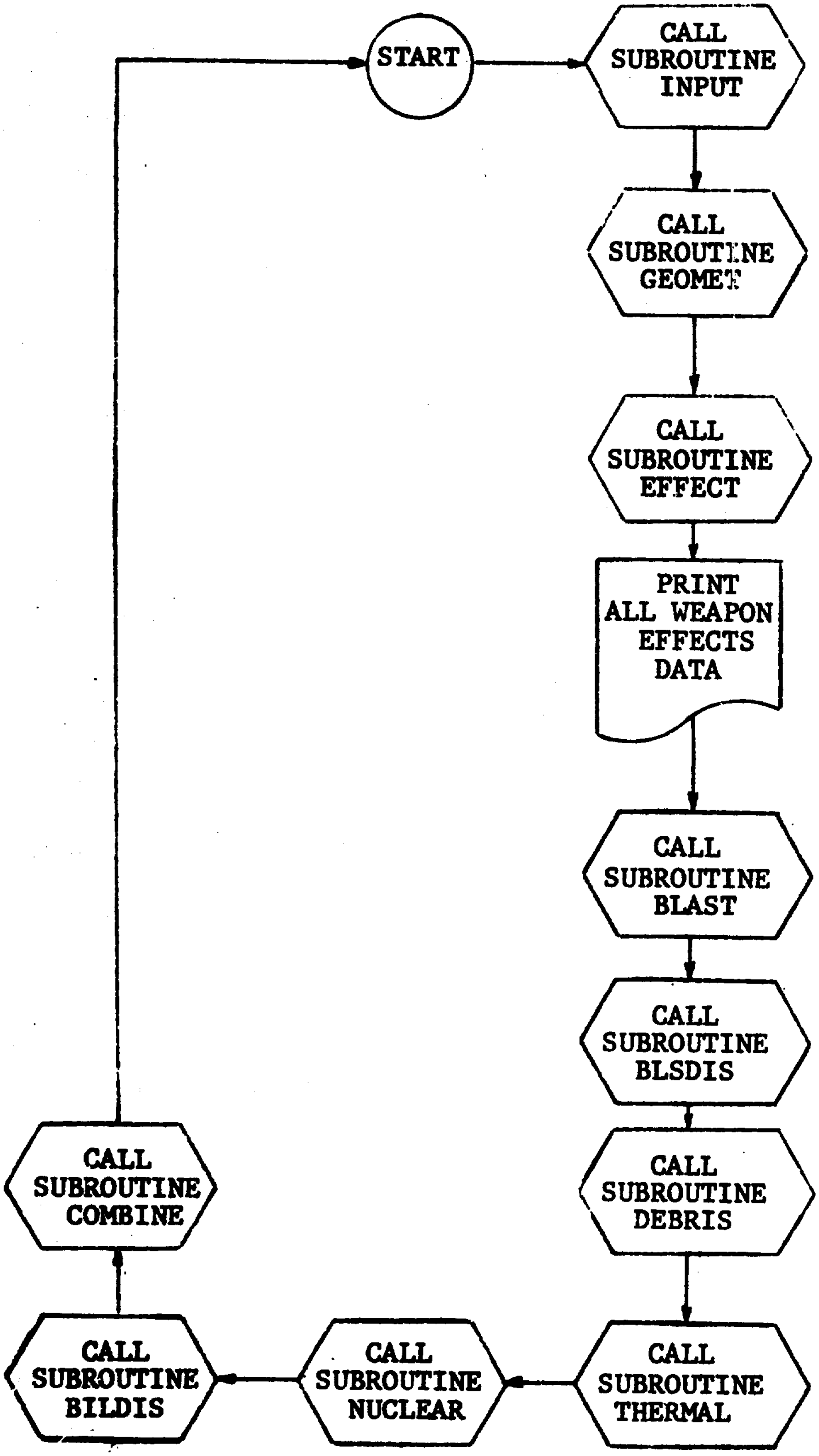


Fig. 63 SCHEMATIC FLOW CHART OF SEP CODE

MAIN PROGRAM
BLOCK DATA
SUBROUTINE CBINE
SUBROUTINE BILDS

LINK 0

BLOCK DATA 2
SUBRØUTINE INPUT
SUBRØUTINE EFFECT
SUBRØUTINE WEAPON
SUBRØUTINE FIND
SUBRØUTINE DELAY
SUBRØUTINE FINDAT
SUBROUTINE FINDTØ
SUBROUTINE FIREFR
SUBROUTINE PØNØDE
SUBROUTINE RADION
SUBROUTINE BLAST
SUBROUTINE BLASTH
SUBROUTINE BLASTD
SUBROUTINE BLASTM
SUBROUTINE BLSDIS
SUBROUTINE DISPLA
SUBROUTINE PFT
SUBROUTINE PBT
SUBROUTINE CHTIME
SUBROUTINE BTRANS
SUBROUTINE PCØNI
SUBROUTINE DEBRIS
SUBROUTINE TRAMAT
SUBROUTINE BDEBRE
SUBROUTINE BTRANI
SUBROUTINE TRAJ
SUBROUTINE THERM
SUBROUTINE PERCTH
SUBROUTINE FIRINJ
SUBROUTINE MATCH

LINK 1 (B1)

SUBROUTINE NUCLAC
SUBROUTINE AFFECT
SUBROUTINE ATTENU
SUBROUTINE RADINJ

LINK 2 (A5)

Fig. 64 SEP CODE OVERLAY STRUCTURE

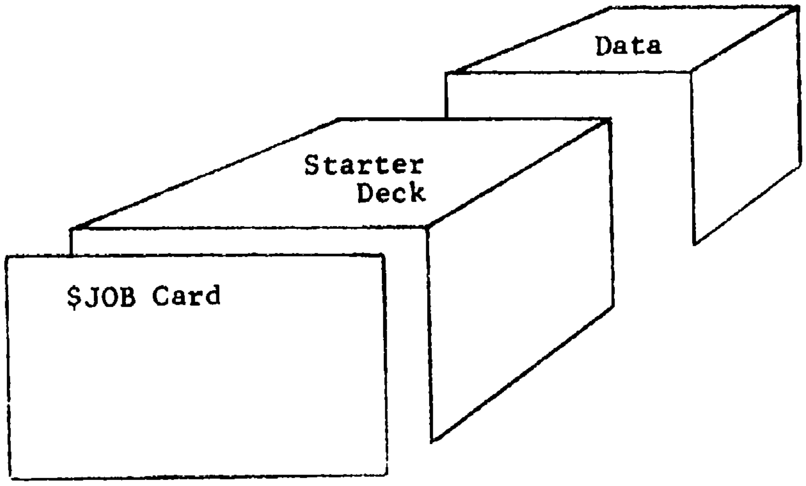


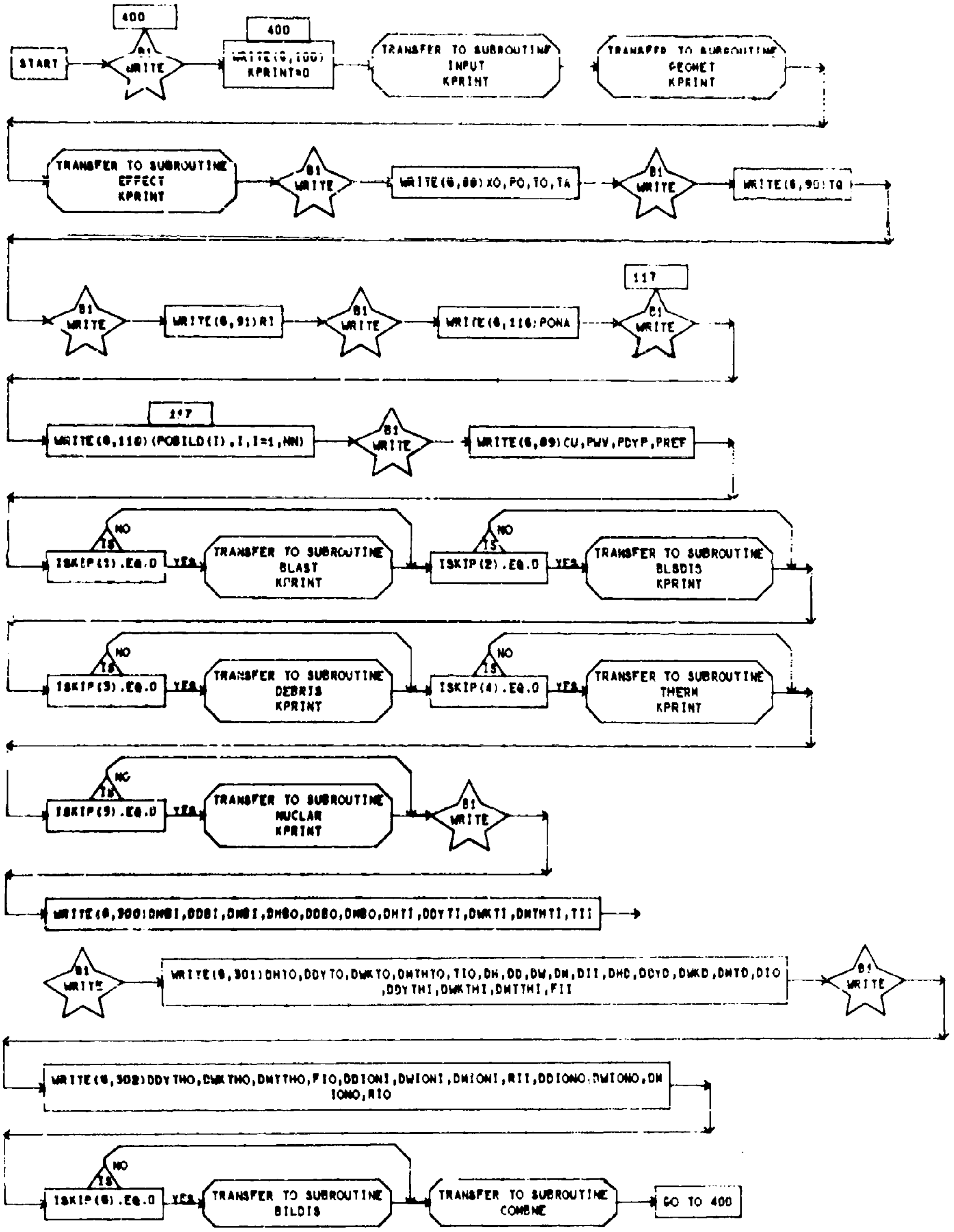
Fig. 65 SEP CODE DECK SETUP

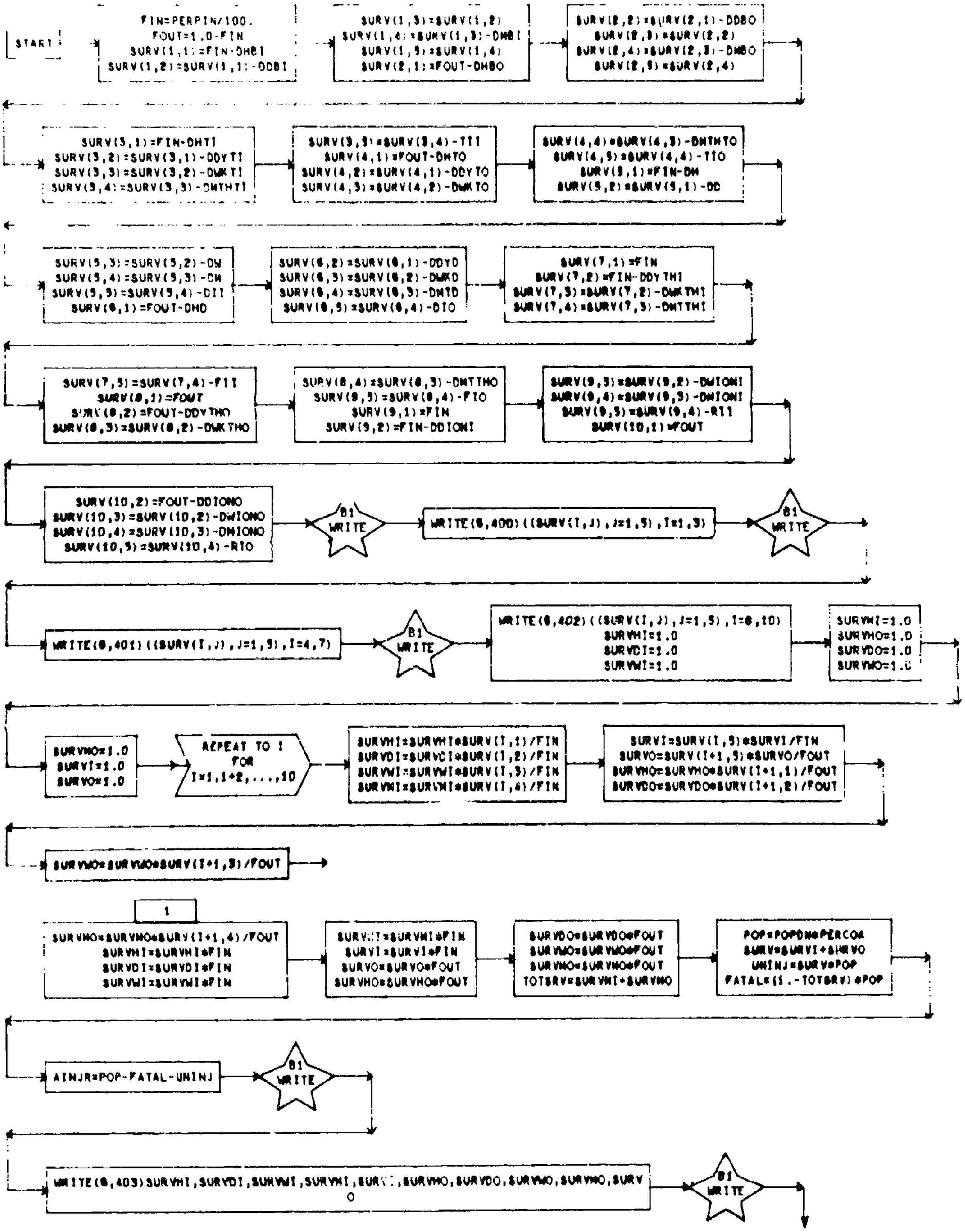
Table 22 STARTER DECK

```
$JOB  CASUALTY
$IBSYS
$ATTACH          A5
$AS              SYSLB4
$ATTACH          B5
$AS              SYSCK1
$EXECUTE         IBJOB
$IBJOB           GO,MAP,SOURCE,FIOCS
$IEDIT           SYSCK1,SCHF
$IBLDR MAIND
$IBLDR DAT
$IBLDR CBINE
$IBLDR BILDS
$IBLDR UNO9
$ORIGIN           ALPHA,SYSUT2,REW
$IBLDR DAT1
$IBLDR INPT
$IBLDR EFFEC
$IBLDR WEAP
$IBLDR DINT
$IBLDR DECA
$IBLDR FINDT
$IBLDR FINDP
$IBLDR FIREF
$IBLDR PONOD
$IBLDR POBRE
$IBLDR THERML
$IBLDR RADI
$IBLDR GEOM
$IBLDR BLAS
$IBLDR H
$IBLDR D
$IBLDR M
$IBLDR BLSDS
$IBLDR DISPL
$IBLDR PF
$IBLDR PB
$IBLDR CHTIM
$IBLDR BT
$IBLDR PCON
$IBLDR DEBR
$IBLDR TRAMA
$IBLDR BD
$IBLDR BTRI
$IBLDR TRAJE
$IBLDR THER
$IBLDR PERC
$IBLDR FIRIN
$IBLDR MATCH
$ORIGIN           ALPHA,SYSLB4,REW
$IBLDR NUCL
$IBLDR AFFE
$IBLDR ATTEN
$IBLDR RADIJ
$IEDIT
$DATA
```

APPENDIX III

FLOWCHART OF CASUALTY PROGRAM

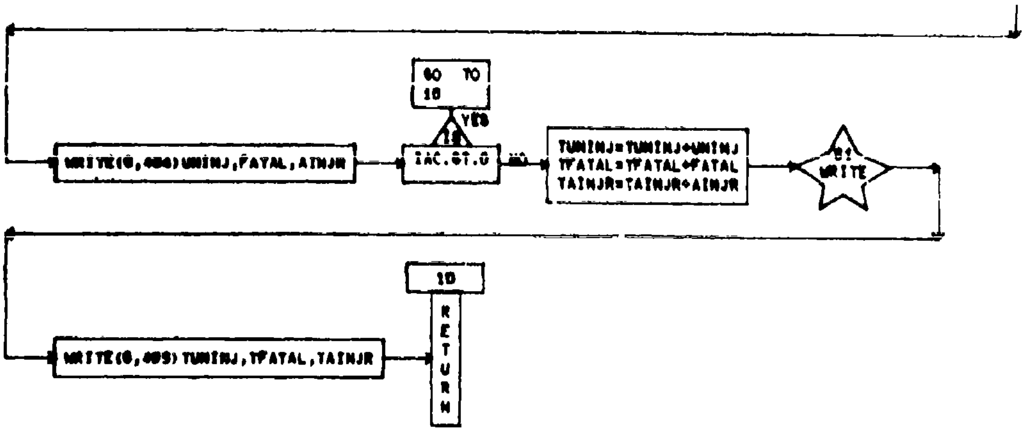

START
400
B1 WRITE
400
WRITE(6,100)
KPRINT=0
TRANSFER TO SUBROUTINE INPUT KPRINT
TRANSFER TO SUBROUTINE GEOMET KPRINT
TRANSFER TO SUBROUTINE EFFECT KPRINT
B1 WRITE
WRITE(6,88)XO,PO,TO,TA
B1 WRITE
WRITE(6,90)TQ
B1 WRITE
WRITE(6,91)RI
B1 WRITE
WRITE(6,116)PONA
117
B1 WRITE
117
WRITE(6,110)(POBILD(I),I,I=1,NN)
B1 WRITE
WRITE(6,89)CU,PWV,PDYP,PREF
ISKIP(1).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE BLAST KPRINT
ISKIP(2).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE BLSDIS KPRINT
ISKIP(3).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE DEBRIS KPRINT
ISKIP(4).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE THERM KPRINT
ISKIP(5).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE NUCLAR KPRINT
B1 WRITE
WRITE(6,300)DWBI,DDBI,DMBI,DWBO,DDBO,DMBO,DHTI,DDYTI,DWKTI,DMTHTI,TII
B1 WRITE
WRITE(6,301)DHTO,DDYTO,DWKTO,DMTHTO,TIO,DH,DD,DW,DM,DII,DHO,DDYO,DWKO,DMTO,DIO,DDYTHI,DWKTHI,DMTTHI,FII
B1 WRITE
WRITE(6,302)DDYTHO,DWKTHO,DMTTHO,FIO,DDIONI,DWIONI,DMIONI,RII,DDIONO,DWIONO,DMIONO,RIO
ISKIP(6).EQ.0
IS
NO
YES
TRANSFER TO SUBROUTINE BILDIS
TRANSFER TO SUBROUTINE COMBNE
GO TO 400



```
FIN=PERPIN/100.
FOUT=1.0-FIN
SURV(1,1)=FIN-DHBI
SURV(1,2)=SURV(1,1)-DDBI

SURV(1,3)=SURV(1,2)
SURV(1,4)=SURV(1,3)-DHBI
SURV(1,5)=SURV(1,4)
SURV(2,1)=FOUT-DHBO

SURV(2,2)=SURV(2,1)-DDBO
SURV(2,3)=SURV(2,2)
SURV(2,4)=SURV(2,3)-DHBO
SURV(2,5)=SURV(2,4)

SURV(3,1)=FIN-DHTI
SURV(3,2)=SURV(3,1)-DDYTI
SURV(3,3)=SURV(3,2)-DWKTI
SURV(3,4)=SURV(3,3)-DMTHTI

SURV(3,5)=SURV(3,4)-TII
SURV(4,1)=FOUT-DHTO
SURV(4,2)=SURV(4,1)-DDYTO
SURV(4,3)=SURV(4,2)-DWKTO

SURV(4,4)=SURV(4,3)-DMTHTO
SURV(4,5)=SURV(4,4)-TIO
SURV(5,1)=FIN-DH
SURV(5,2)=SURV(5,1)-DD

SURV(5,3)=SURV(5,2)-DW
SURV(5,4)=SURV(5,3)-DM
SURV(5,5)=SURV(5,4)-DII
SURV(6,1)=FOUT-DHO

SURV(6,2)=SURV(6,1)-DDYO
SURV(6,3)=SURV(6,2)-DWKO
SURV(6,4)=SURV(6,3)-DMTO
SURV(6,5)=SURV(6,4)-DIO

SURV(7,1)=FIN
SURV(7,2)=FIN-DDYTHI
SURV(7,3)=SURV(7,2)-DWKTHI
SURV(7,4)=SURV(7,3)-DMTTHI

SURV(7,5)=SURV(7,4)-FII
SURV(8,1)=FOUT
SURV(8,2)=FOUT-DDYTHO
SURV(8,3)=SURV(8,2)-DWKTHO

SURV(8,4)=SURV(8,3)-DMTTHO
SURV(8,5)=SURV(8,4)-FIO
SURV(9,1)=FIN
SURV(9,2)=FIN-DDIONI

SURV(9,3)=SURV(9,2)-DWIONI
SURV(9,4)=SURV(9,3)-DMIONI
SURV(9,5)=SURV(9,4)-RII
SURV(10,1)=FOUT

SURV(10,2)=FOUT-DDIONO
SURV(10,3)=SURV(10,2)-DWIONO
SURV(10,4)=SURV(10,3)-DMIONO
SURV(10,5)=SURV(10,4)-RIO

WRITE(6,400)((SURV(I,J),J=1,5),I=1,3)

WRITE(6,401)((SURV(I,J),J=1,5),I=4,7)

WRITE(6,402)((SURV(I,J),J=1,5),I=8,10)
SURVHI=1.0
SURVDI=1.0
SURVWI=1.0

SURVMI=1.0
SURVHO=1.0
SURVDO=1.0
SURVWO=1.0

SURVMO=1.0
SURVI=1.0
SURVO=1.0

I=1,1+2,...,10

SURVHI=SURVHI*SURV(I,1)/FIN
SURVDI=SURVCI*SURV(I,2)/FIN
SURVWI=SURVWI*SURV(I,3)/FIN
SURVMI=SURVMI*SURV(I,4)/FIN

SURVI=SURV(I,5)*SURVI/FIN
SURVO=SURV(I+1,5)*SURVO/FOUT
SURVHO=SURVHO*SURV(I+1,1)/FOUT
SURVDO=SURVDO*SURV(I+1,2)/FOUT

SURVWO=SURVWO*SURV(I+1,3)/FOUT

SURVMO=SURVMO*SURV(I+1,4)/FOUT
SURVHI=SURVHI*FIN
SURVDI=SURVDI*FIN
SURVWI=SURVWI*FIN

SURVMI=SURVMI*FIN
SURVI=SURVI*FIN
SURVO=SURVO*FOUT
SURVHO=SURVHO*FOUT

SURVDO=SURVDO*FOUT
SURVWO=SURVWO*FOUT
SURVMO=SURVMO*FOUT
TOTSRV=SURVMI+SURVMO

POP=POPDN*PERCOA
SURV=SURVI+SURVO
UNINJ=SURV*POP
FATAL=(1.-TOTSRV)*POP

AINJR=POP-FATAL-UNINJ

WRITE(6,403)SURVHI,SURVDI,SURVWI,SURVMI,SURVI,SURVHO,SURVDO,SURVWO,SURVMO,SURV
O
```

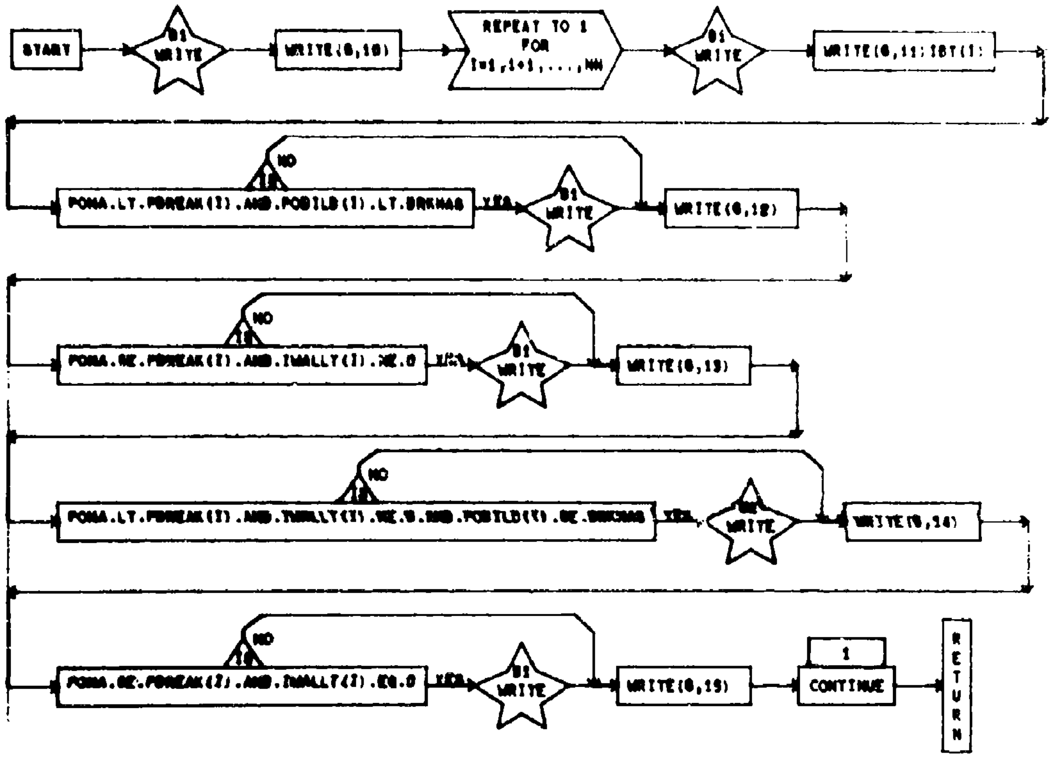
COMBINED EFFECTS SUBROUTINE

PAGE 2

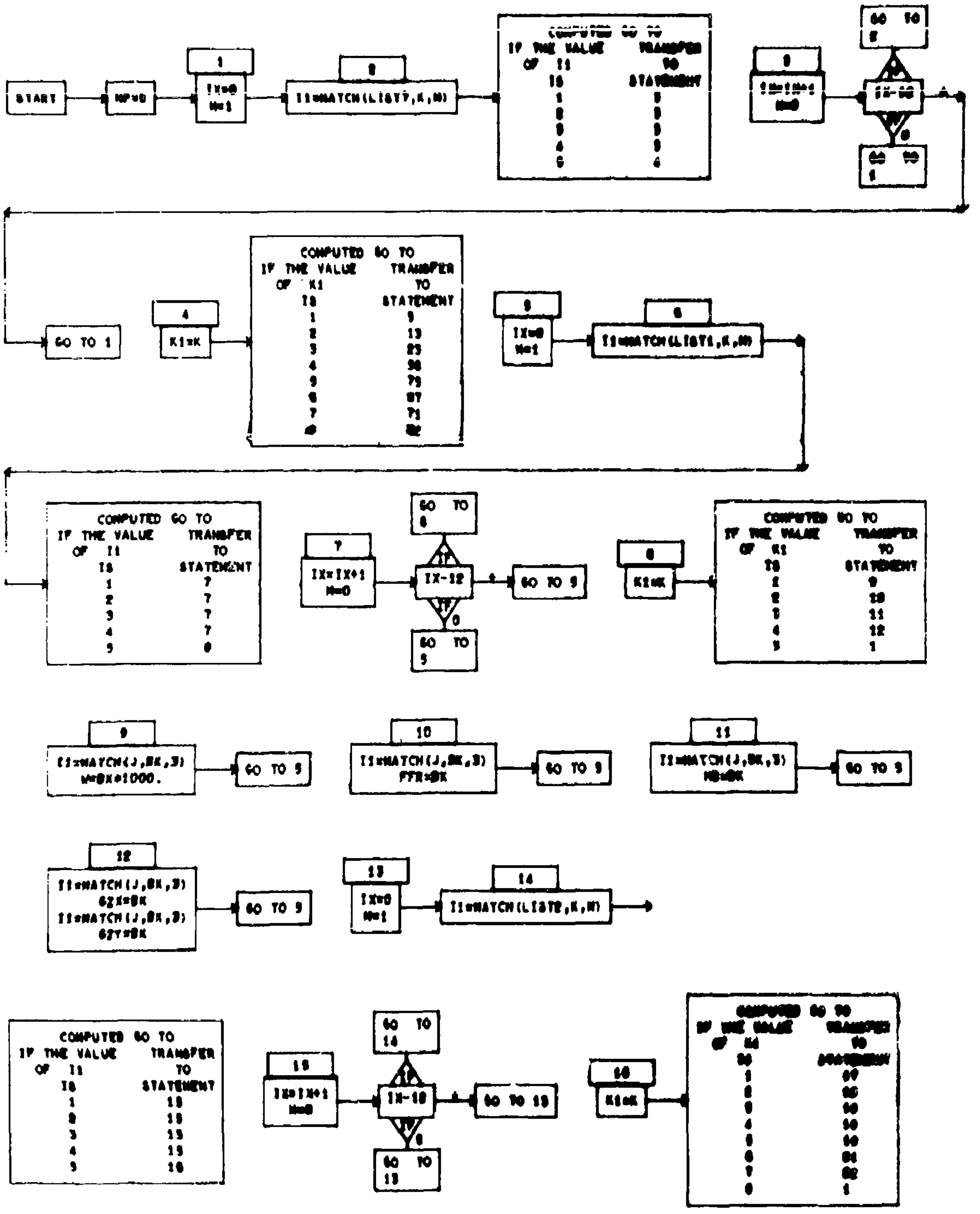


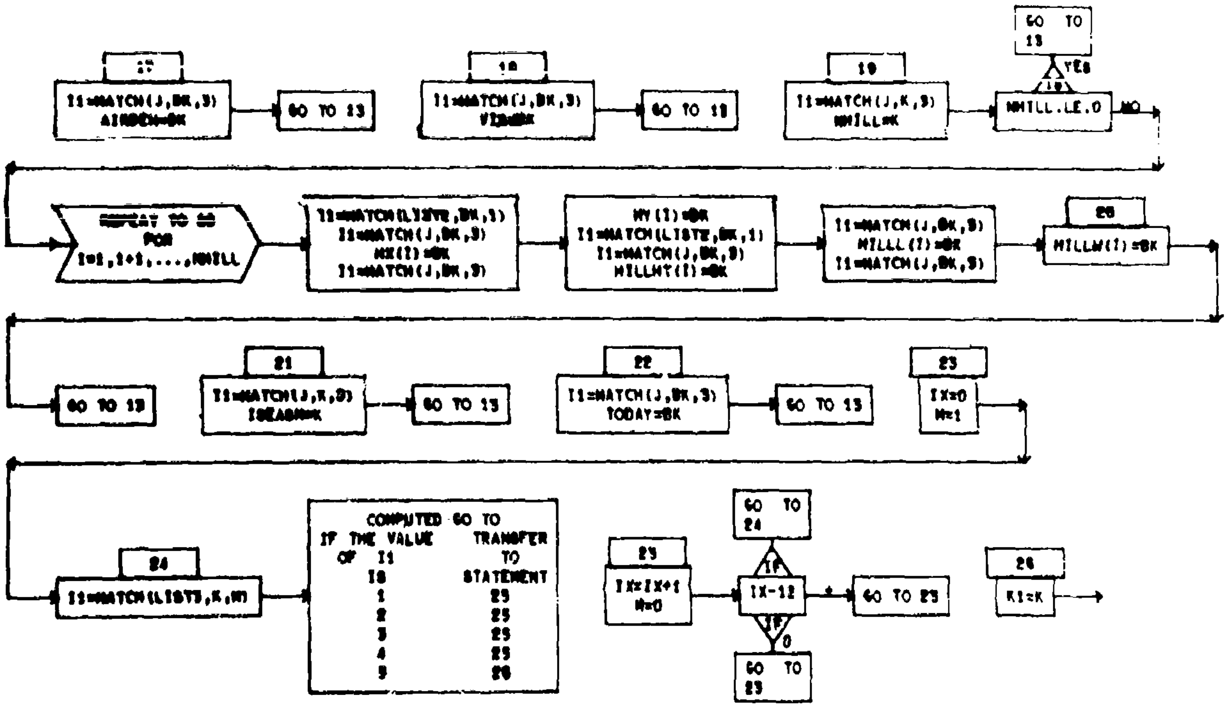
POST ATTACK BUILDING DESCRIPTION

PAGE 1

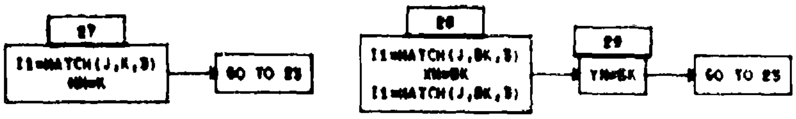


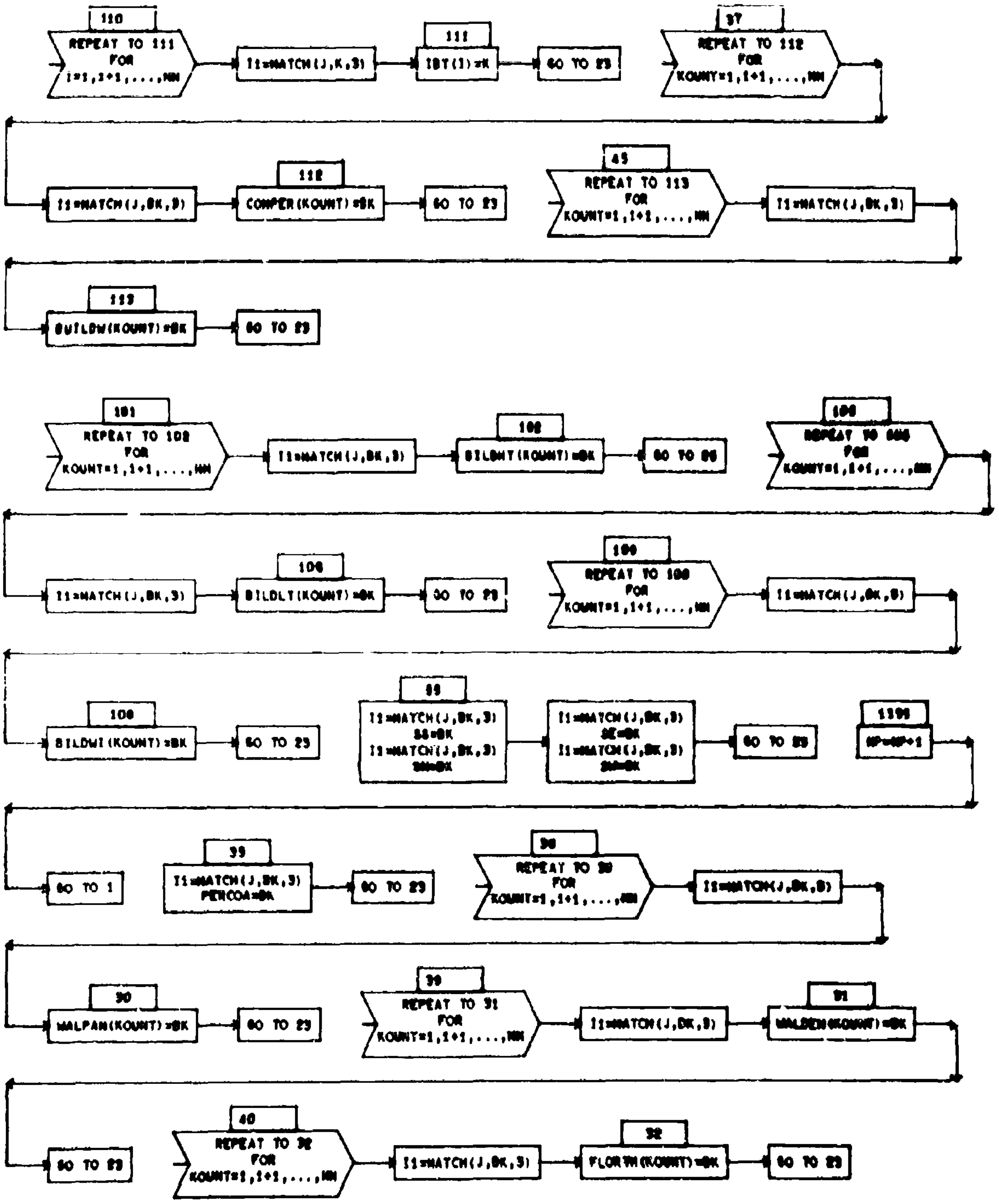
INPUT SUBROUTINE PAGE 1

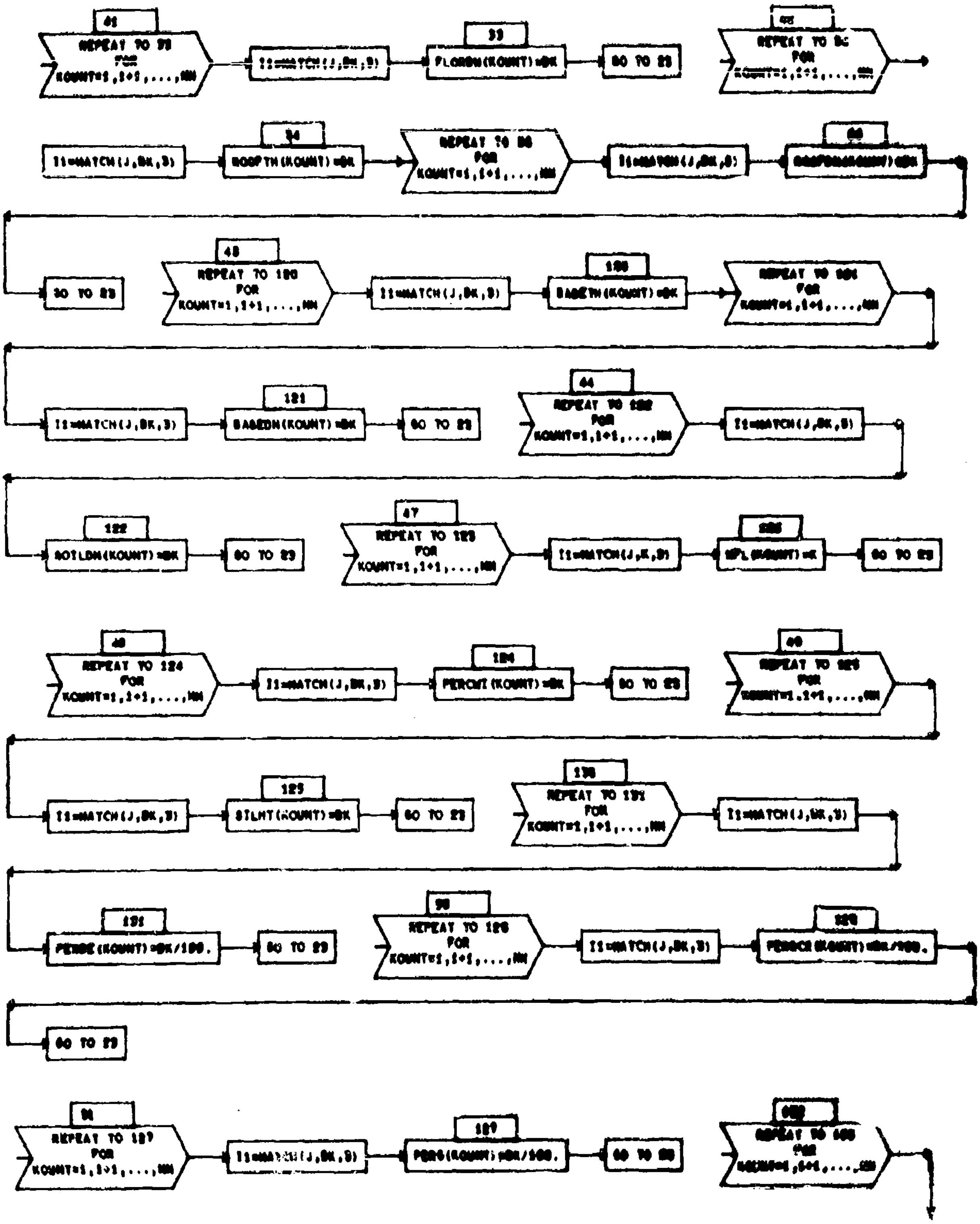


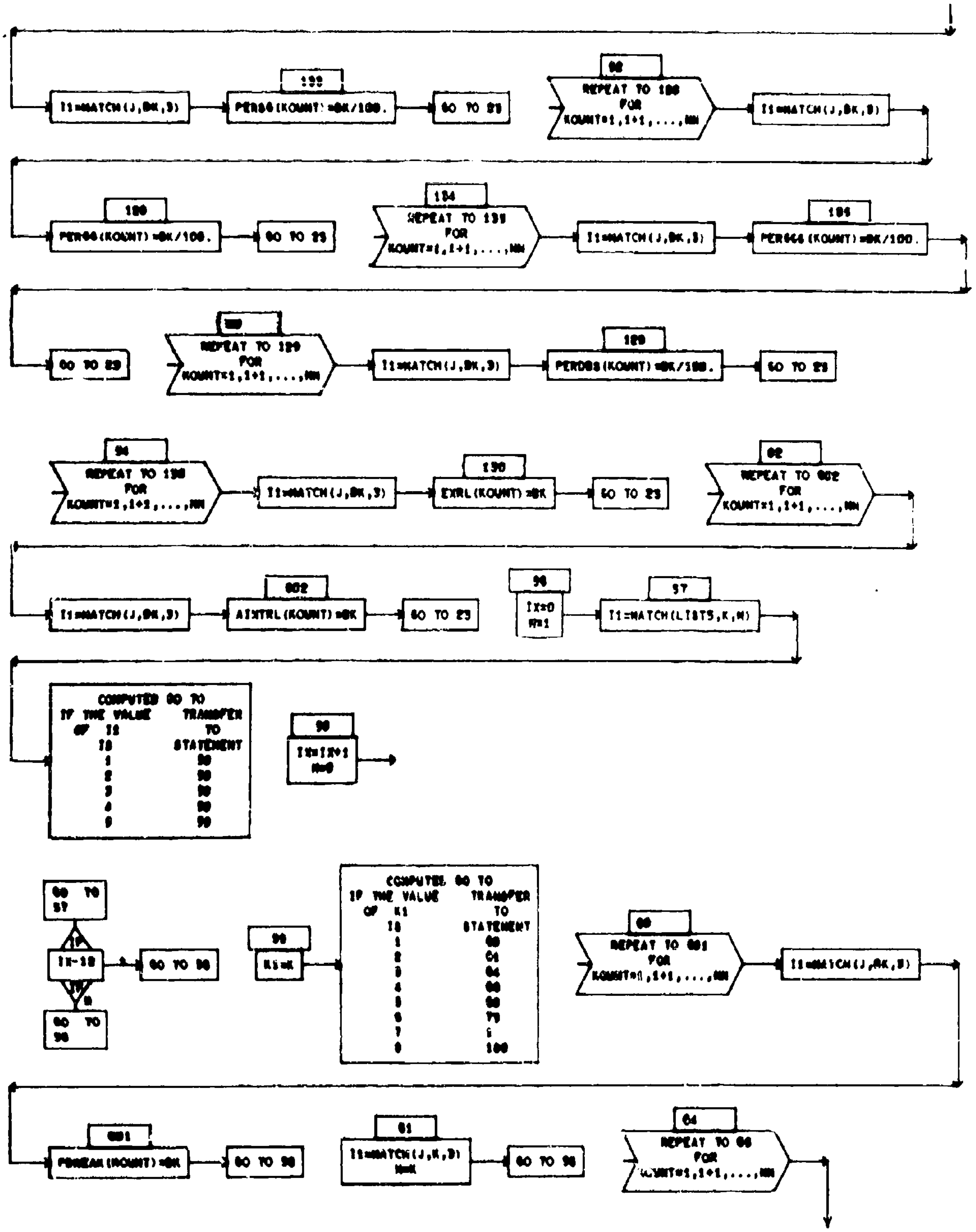


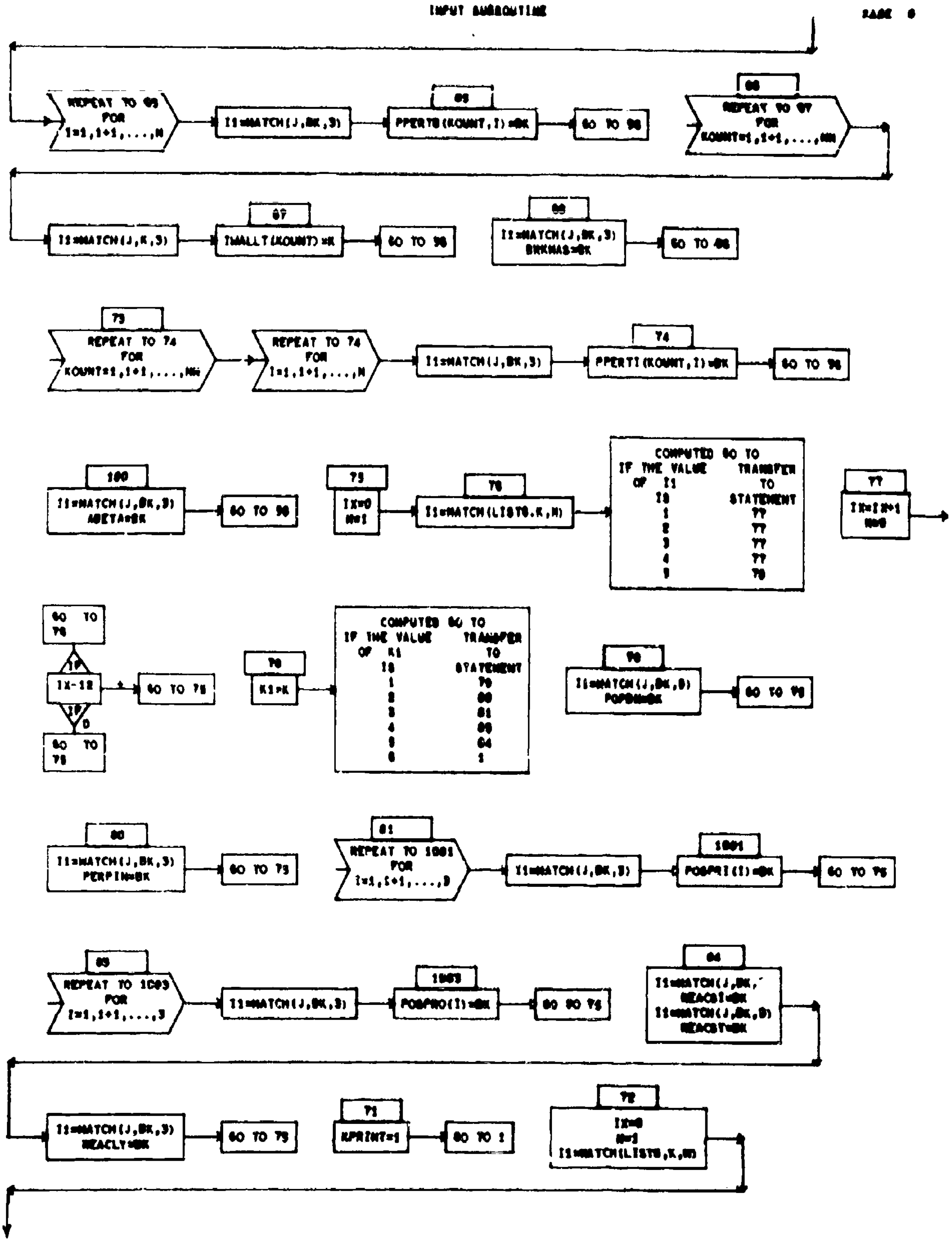
COMPUTED GO TO IF THE VALUE OF K1 IS	TRANSFER TO STATEMENT
1	27
2	28
3	110
4	37
5	45
6	101
7	103
8	106
9	96
10	1130
11	35
12	38
13	39
14	40
15	41
16	42
17	43
18	44
19	47
20	48
21	49
22	50
23	51
24	52
25	53
26	54
27	82
28	130
29	132
30	134




110
REPEAT TO 111 FOR I=1,1+1,...,NN
I1=MATCH(J,K,3)
111
IBT(I)=K
GO TO 23
37
REPEAT TO 112 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
112
COMPER(KOUNT)=BK
GO TO 23
45
REPEAT TO 113 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
113
BUILDW(KOUNT)=BK
GO TO 23
101
REPEAT TO 102 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
102
BILDHT(KOUNT)=BK
GO TO 23
105
REPEAT TO 106 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
106
BILDLT(KOUNT)=BK
GO TO 23
107
REPEAT TO 108 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
108
BILDWI(KOUNT)=BK
GO TO 23
89
I1=MATCH(J,BK,3) SS=BK I1=MATCH(J,BK,3) SN=BK
I1=MATCH(J,BK,3) SE=BK I1=MATCH(J,BK,3) SW=BK
GO TO 23
1398
NP=NP+1
GO TO 1
33
I1=MATCH(J,BK,3) PERCOA=BK
GO TO 23
38
REPEAT TO 30 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
30
WALPAN(KOUNT)=BK
GO TO 23
39
REPEAT TO 31 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
31
WALDEN(KOUNT)=BK
GO TO 23
40
REPEAT TO 32 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
32
FLORTH(KOUNT)=BK
GO TO 23

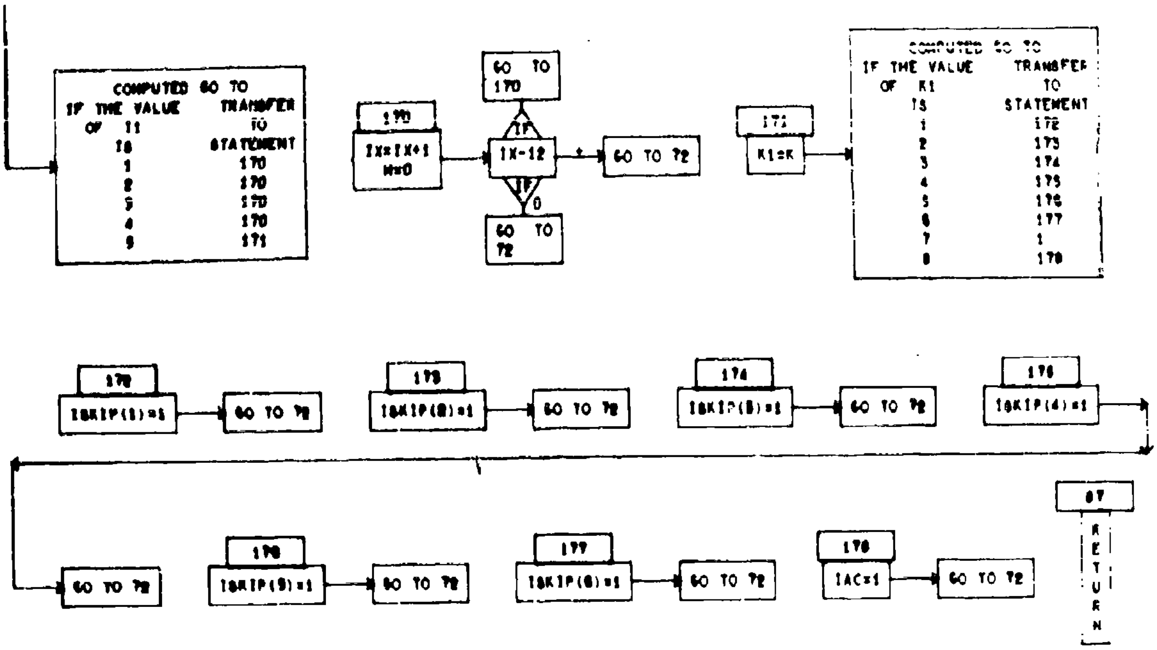

41
REPEAT TO 33 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
33
FLORDN(KOUNT)=BK
GO TO 23
42
REPEAT TO 34 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
34
ROOFTH(KOUNT)=BK
REPEAT TO 80 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
80
GO TO 23
43
REPEAT TO 120 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
120
BASETH(KOUNT)=BK
REPEAT TO 121 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
121
BASEDN(KOUNT)=BK
GO TO 23
44
REPEAT TO 122 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
122
ROTLDN(KOUNT)=BK
GO TO 23
47
REPEAT TO 123 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,K,3)
123
RPL(KOUNT)=K
GO TO 23
48
REPEAT TO 124 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
124
PERCNT(KOUNT)=BK
GO TO 23
49
REPEAT TO 125 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
125
STLHT(KOUNT)=BK
GO TO 23
130
REPEAT TO 131 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
131
PERBE(KOUNT)=BK/100.
GO TO 23
50
REPEAT TO 126 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
126
PERBCE(KOUNT)=BK/100.
GO TO 23
51
REPEAT TO 127 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
127
PERG(KOUNT)=BK/100.
GO TO 23
REPEAT TO 600 FOR KOUNT=1,1+1,...,NN


I1=MATCH(J,BK,3)
132
PERS6(KOUNT)=BK/100.
GO TO 23
98
REPEAT TO 133
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
133
PERS6(KOUNT)=BK/100.
GO TO 23
134
REPEAT TO 135
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
135
PERS66(KOUNT)=BK/100.
GO TO 23
REPEAT TO 129
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
129
PERDBS(KOUNT)=BK/100.
GO TO 23
94
REPEAT TO 130
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
130
EXRL(KOUNT)=BK
GO TO 23
92
REPEAT TO 802
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
802
AIXTRL(KOUNT)=BK
GO TO 23
96
IX=0
M=1
57
I1=MATCH(LISTS,K,M)
COMPUTED GO TO
IF THE VALUE OF I1 IS
TRANSFER TO STATEMENT
1
2
3
4
5
98
IX=IX+1
M=0
GO TO 57
IF
IX-18
GO TO 98
GO TO 96
98
K1=K
COMPUTED GO TO
IF THE VALUE OF K1 IS
TRANSFER TO STATEMENT
1
2
3
4
5
6
7
8
100
REPEAT TO 801
FOR
KOUNT=1,1+1,...,NN
I1=MATCH(J,BK,3)
801
PMEAN(KOUNT)=BK
GO TO 98
61
I1=MATCH(J,K,3)
M=K
GO TO 98
64
REPEAT TO 66
FOR
KOUNT=1,1+1,...,NN


REPEAT TO 95 FOR I=1,I+1,...,N
I1=MATCH(J,BK,3)
95
PPERTB(KOUNT,I)=BK
GO TO 98
96
REPEAT TO 97 FOR KOUNT=1,1+1,...,NN
I1=MATCH(J,K,3)
97
IWALLT(KOUNT)=K
GO TO 98
98
I1=MATCH(J,BK,3) BNKNAS=BK
GO TO 46
73
REPEAT TO 74 FOR KOUNT=1,1+1,...,NN
REPEAT TO 74 FOR I=1,I+1,...,N
I1=MATCH(J,BK,3)
74
PPERTI(KOUNT,I)=BK
GO TO 98
100
I1=MATCH(J,BK,3) ABETA=BK
GO TO 98
75
IX=0 M=1
76
I1=MATCH(LISTS,K,M)
COMPUTED GO TO
IF THE VALUE OF I1 IS
TRANSFER TO STATEMENT
1 77
2 77
3 77
4 77
5 78
77
IX=IX+1 M=0
GO TO 76
IF
IX-12
+
GO TO 78
IF
0
GO TO 75
78
K1=K
COMPUTED GO TO
IF THE VALUE OF K1 IS
TRANSFER TO STATEMENT
1 79
2 80
3 81
4 83
5 84
6 1
79
I1=MATCH(J,BK,3) POPBM=BK
GO TO 75
80
I1=MATCH(J,BK,3) PERPIN=BK
GO TO 75
81
REPEAT TO 1001 FOR I=1,I+1,...,3
I1=MATCH(J,BK,3)
1001
POSPRI(I)=BK
GO TO 75
83
REPEAT TO 1003 FOR I=1,I+1,...,3
I1=MATCH(J,BK,3)
1003
POSPRO(I)=BK
GO TO 75
84
I1=MATCH(J,BK,3) REACSI=BK
I1=MATCH(J,BK,3) REACST=BK
I1=MATCH(J,BK,3) REACLT=BK
GO TO 75
71
KPRINT=1
GO TO 1
72
IX=0
M=1
I1=MATCH(LISTS,K,M)

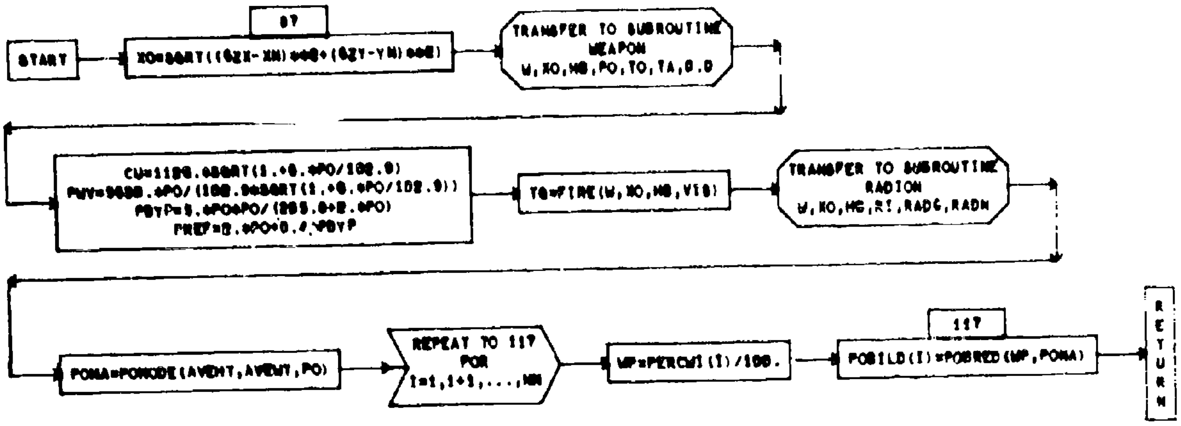
INPUT SUBROUTINE

PAGE 7



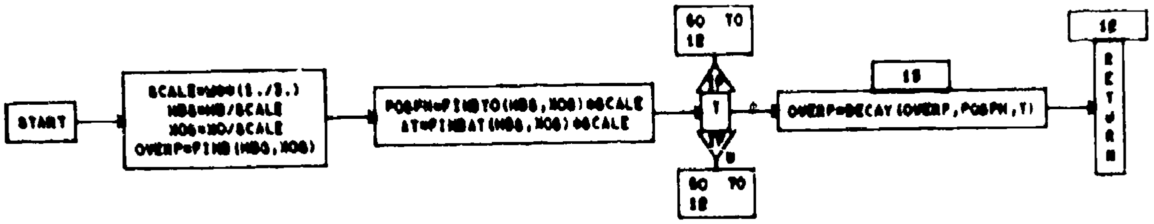
EFFECT SUBROUTINE

PAGE 1

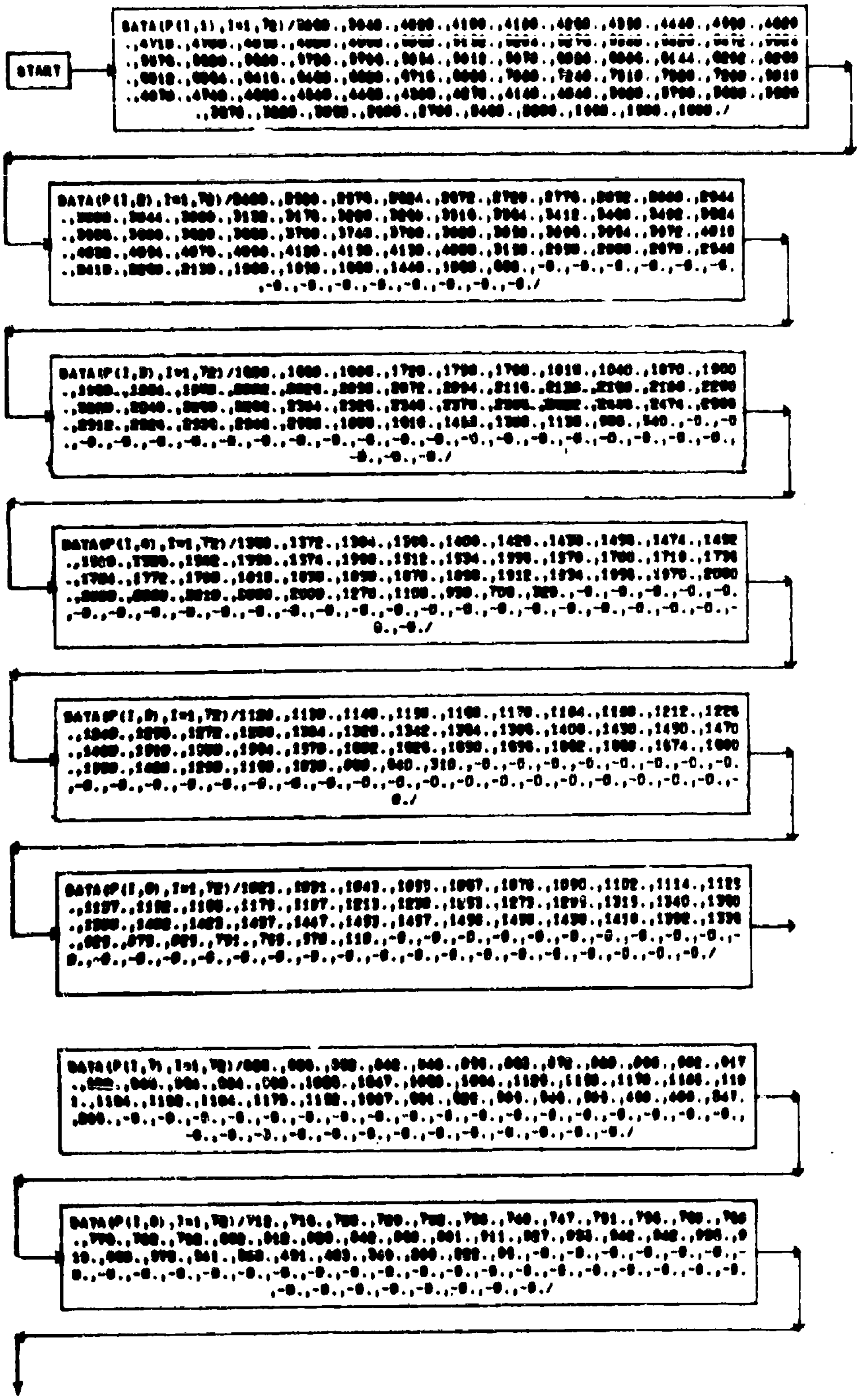


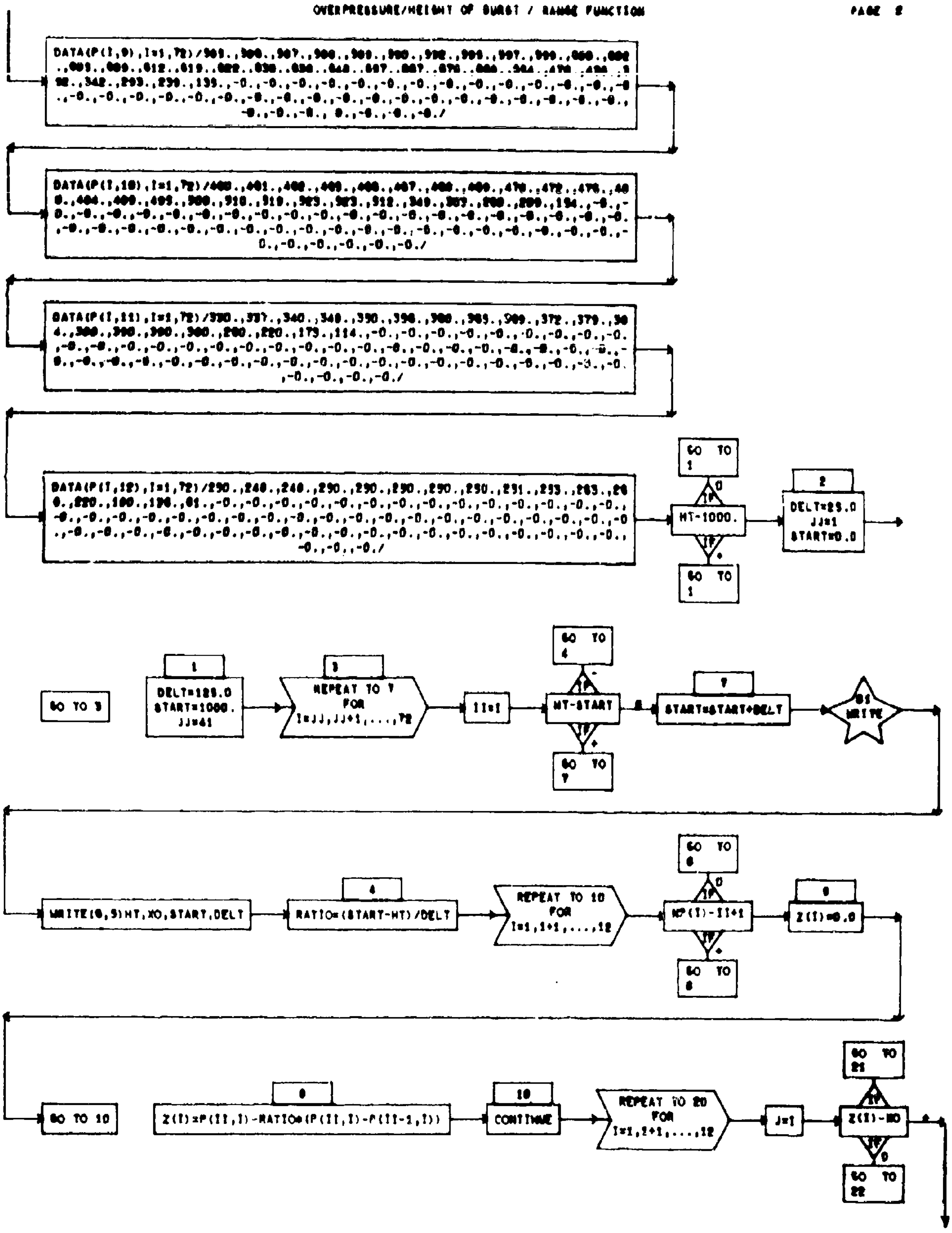
WEAPON SUBROUTINE

PAGE 1

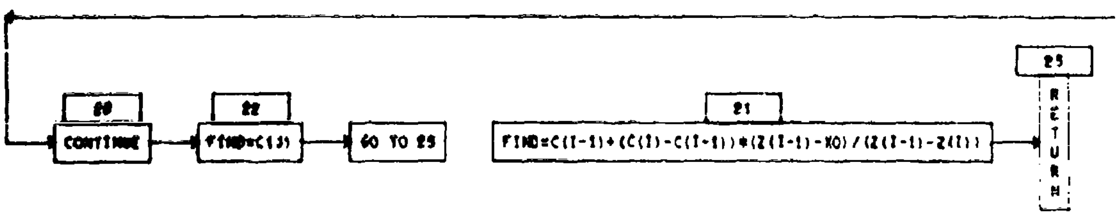


OVERPRESSURE/HEIGHT OF BURST / RANGE FUNCTION PAGE 1



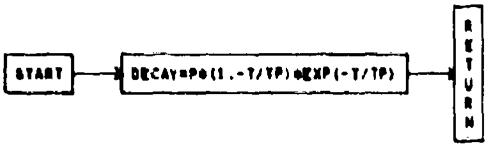

DATA(P(I,9),I=1,72)/301.,300.,307.,300.,303.,300.,302.,305.,307.,300.,000.,002
.,003.,009.,012.,019.,022.,030.,030.,048.,087.,087.,078.,000.,364.,470.,430.,3
92.,342.,293.,230.,135.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0
.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,
-0.,-0.,-0., 0.,-0.,-0.,-0./
DATA(P(I,10),I=1,72)/400.,401.,402.,403.,400.,407.,400.,400.,470.,472.,476.,40
0.,404.,400.,495.,500.,510.,519.,525.,523.,512.,340.,303.,200.,200.,134.,-0.,-
0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.
,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-
0.,-0.,-0.,-0.,-0.,-0./
DATA(P(I,11),I=1,72)/330.,337.,340.,340.,350.,358.,300.,365.,309.,372.,379.,30
4.,300.,300.,300.,300.,200.,220.,173.,114.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.
,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-
0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-3.,-0.
,-0.,-0.,-0.,-0./
DATA(P(I,12),I=1,72)/230.,240.,240.,230.,230.,230.,230.,230.,231.,233.,203.,20
0.,220.,100.,136.,01.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,
-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0
.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,-0.,
-0.,-0.,-0./
GO TO 1
0
IF
HT-1000.
IF
+
GO TO 1
2
DELT=25.0
JJ=1
START=0.0
GO TO 3
1
DELT=125.0
START=1000.
JJ=41
3
REPEAT TO 7 FOR I=JJ,JJ+1,...,72
II=I
GO TO 4
-
IF
HT-START
0
IF
+
GO TO 7
7
START=START+DELT
05 WRITE
WRITE(6,5)HT,XO,START,DELT
4
RATIO=(START-HT)/DELT
REPEAT TO 10 FOR I=1,I+1,...,12
GO TO 6
0
IF
NP(I)-II+1
IF
+
GO TO 8
6
Z(I)=0.0
GO TO 10
8
Z(I)=P(II,I)-RATIO*(P(II,I)-P(II-1,I))
10
CONTINUE
REPEAT TO 20 FOR I=1,I+1,...,12
J=1
GO TO 21
IF
Z(I)-HO
+
IF
0
GO TO 22

OVERPRESSURE/HEIGHT OF BURST / RANGE FUNCTION PAGE 3



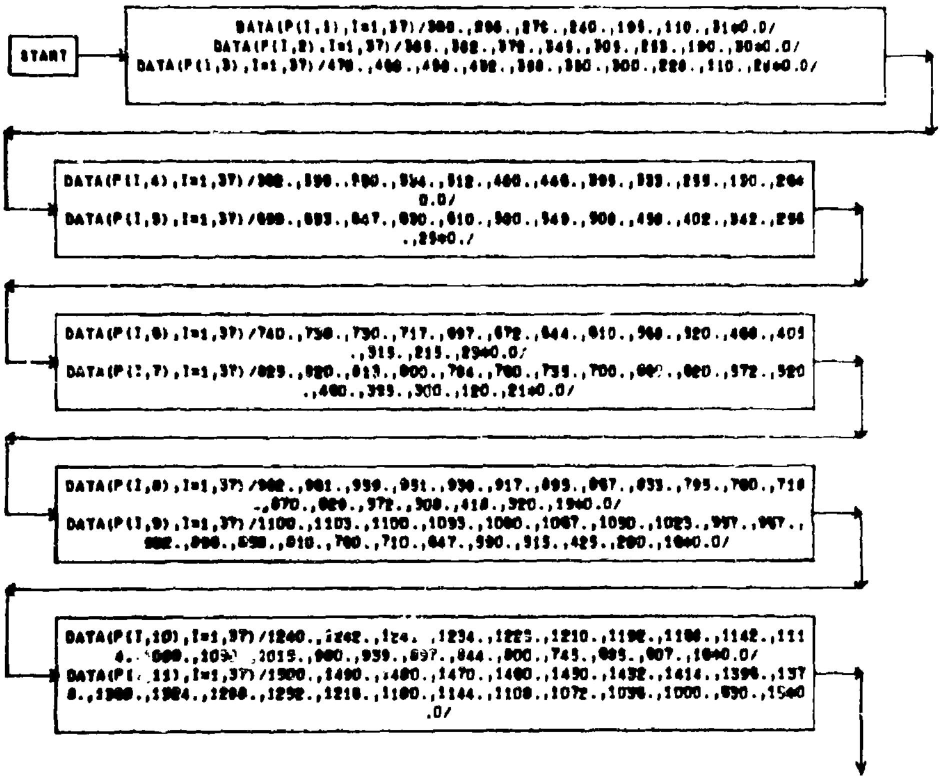
```
20 CONTINUE
22 FIND=C(1)
   GO TO 25
21 FIND=C(I-1)+(C(I)-C(I-1))*(Z(I-1)-XO)/(Z(I-1)-Z(I))
25 RETURN
```

OVERPRESSURE DECAY FUNCTION PAGE 1

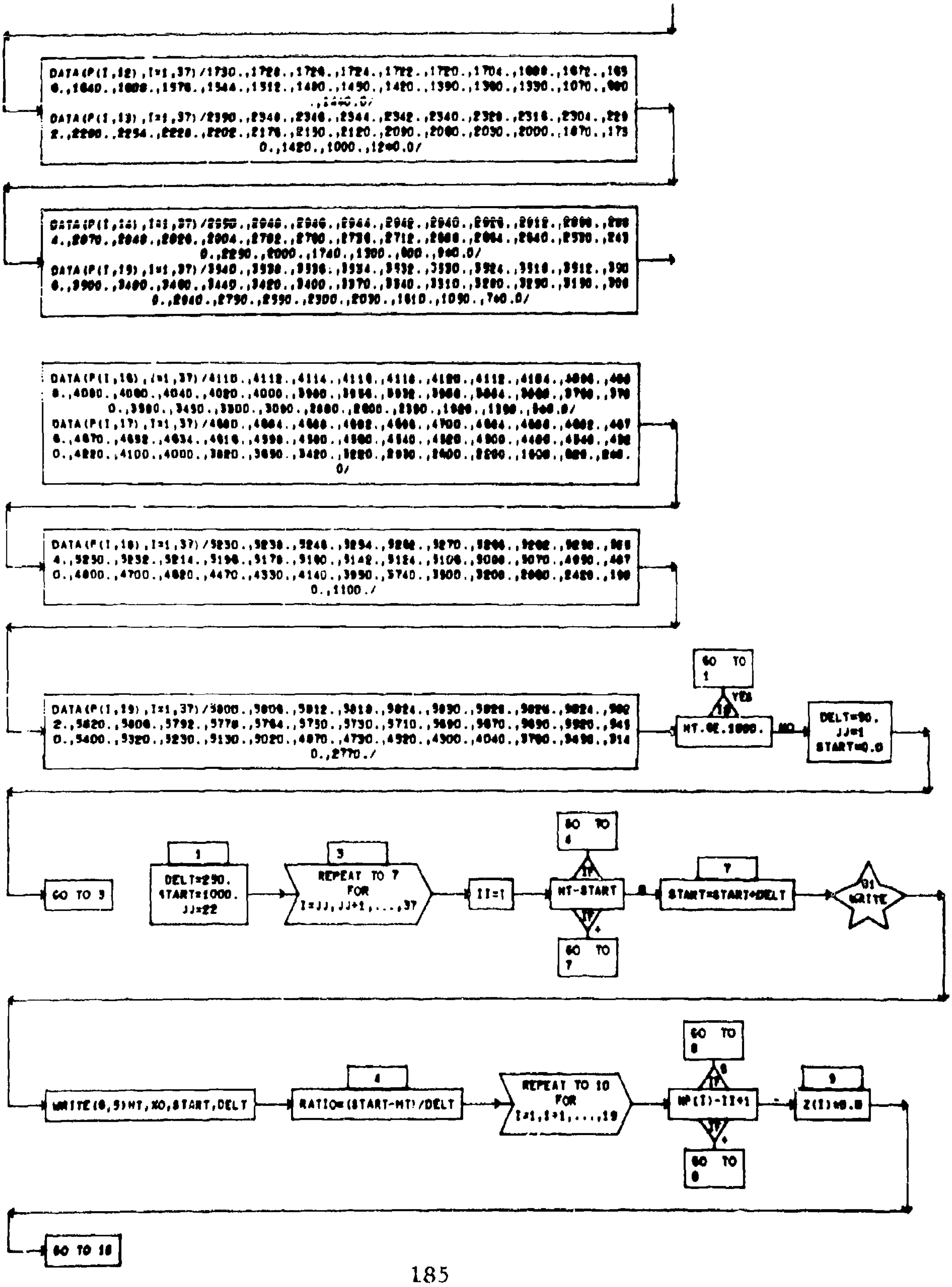


```
START
DECAY=P*(1.-T/TP)*EXP(-T/TP)
RETURN
```

ARRIVAL TIME / HEIGHT OF BURST / RANGE FUNCTION PAGE 1

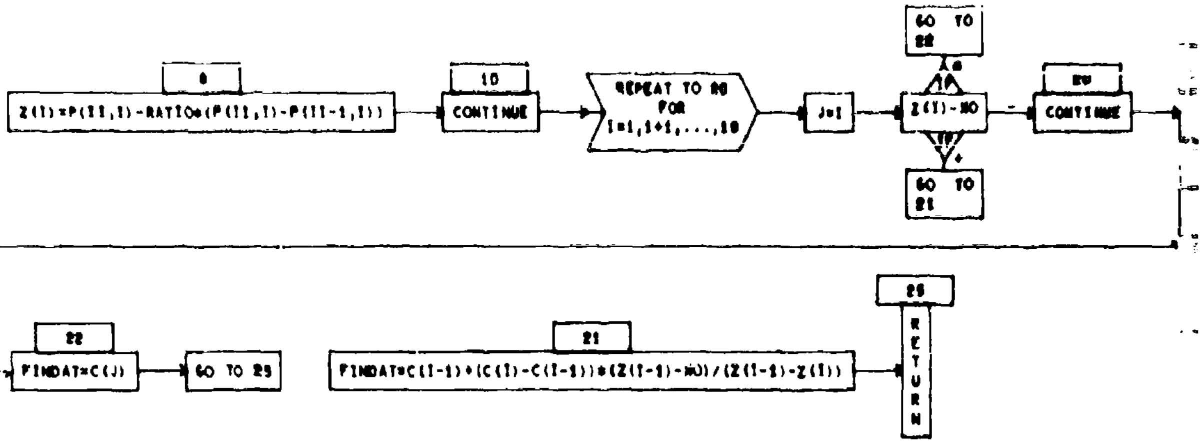


```
START
DATA(P(I,1),I=1,37)/300.,296.,276.,240.,195.,110.,31*0.0/
DATA(P(I,2),I=1,37)/385.,382.,370.,345.,305.,255.,190.,30*0.0/
DATA(P(I,3),I=1,37)/470.,468.,458.,432.,388.,350.,300.,228.,110.,28*0.0/

DATA(P(I,4),I=1,37)/568.,558.,530.,514.,512.,460.,440.,395.,333.,255.,150.,26*
0.0/
DATA(P(I,5),I=1,37)/655.,653.,647.,630.,610.,580.,540.,500.,450.,402.,342.,256
.,25*0./

DATA(P(I,6),I=1,37)/740.,750.,730.,717.,697.,672.,644.,610.,560.,520.,460.,405
.,315.,215.,23*0.0/
DATA(P(I,7),I=1,37)/825.,820.,813.,800.,784.,760.,735.,700.,662.,620.,572.,520
.,460.,385.,300.,120.,21*0.0/

DATA(P(I,8),I=1,37)/962.,961.,959.,951.,930.,917.,895.,867.,833.,795.,760.,718
.,670.,620.,572.,500.,418.,320.,19*0.0/
DATA(P(I,9),I=1,37)/1100.,1103.,1100.,1093.,1080.,1067.,1050.,1023.,997.,967.,
932.,896.,858.,810.,760.,710.,647.,590.,515.,425.,280.,16*0.0/

DATA(P(I,10),I=1,37)/1240.,1242.,124[illegible].,1234.,1223.,1210.,1192.,1168.,1142.,111
4.,1080.,1035.,1015.,980.,939.,897.,844.,800.,745.,685.,607.,16*0.0/
DATA(P(I,11),I=1,37)/1500.,1490.,1480.,1470.,1460.,1450.,1432.,1414.,1396.,137
8.,1360.,1324.,1288.,1252.,1216.,1180.,1144.,1108.,1072.,1036.,1000.,930.,15*0
.0/
```

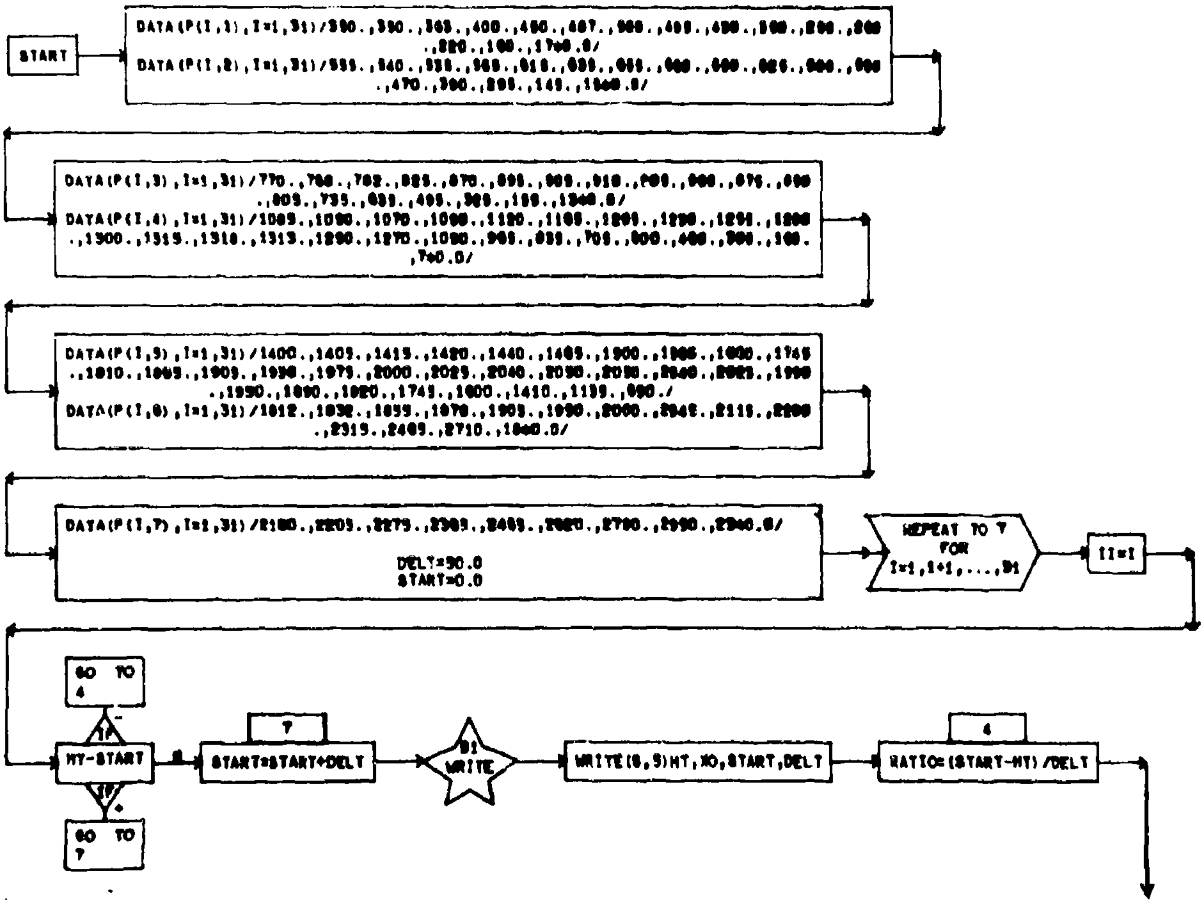


```
DATA(P(I,12),I=1,37)/1730.,1728.,1726.,1724.,1722.,1720.,1704.,1688.,1672.,165
6.,1640.,1608.,1576.,1544.,1512.,1480.,1450.,1420.,1390.,1360.,1330.,1070.,800
.,1440.0/
DATA(P(I,13),I=1,37)/2350.,2348.,2346.,2344.,2342.,2340.,2320.,2316.,2304.,229
2.,2280.,2254.,2228.,2202.,2176.,2150.,2120.,2090.,2060.,2030.,2000.,1870.,173
0.,1420.,1000.,1240.0/
DATA(P(I,14),I=1,37)/2950.,2948.,2946.,2944.,2942.,2940.,2920.,2912.,2898.,288
4.,2870.,2848.,2826.,2804.,2782.,2760.,2736.,2712.,2688.,2664.,2640.,2530.,243
0.,2290.,2000.,1740.,1300.,800.,940.0/
DATA(P(I,15),I=1,37)/3540.,3538.,3536.,3534.,3532.,3530.,3524.,3518.,3512.,350
6.,3500.,3480.,3460.,3440.,3420.,3400.,3370.,3340.,3310.,3280.,3250.,3190.,306
0.,2840.,2790.,2550.,2300.,2030.,1610.,1050.,760.0/
DATA(P(I,16),I=1,37)/4110.,4112.,4114.,4116.,4118.,4120.,4112.,4104.,4096.,408
8.,4080.,4060.,4040.,4020.,4000.,3980.,3956.,3932.,3908.,3884.,3860.,3780.,370
0.,3580.,3450.,3300.,3090.,2880.,2600.,2350.,1980.,1350.,560.0/
DATA(P(I,17),I=1,37)/4680.,4684.,4688.,4692.,4696.,4700.,4684.,4668.,4652.,467
6.,4670.,4652.,4634.,4616.,4598.,4580.,4560.,4540.,4520.,4500.,4460.,4340.,430
0.,4220.,4100.,4000.,3820.,3650.,3420.,3220.,2930.,2600.,2200.,1600.,820.,240.
0/
DATA(P(I,18),I=1,37)/5230.,5238.,5246.,5254.,5262.,5270.,5266.,5262.,5258.,525
4.,5250.,5232.,5214.,5196.,5178.,5160.,5142.,5124.,5106.,5088.,5070.,4990.,487
0.,4800.,4700.,4620.,4470.,4330.,4140.,3950.,3740.,3500.,3200.,2880.,2420.,190
0.,1100./
DATA(P(I,19),I=1,37)/5800.,5806.,5812.,5818.,5824.,5830.,5828.,5826.,5824.,582
2.,5820.,5806.,5792.,5778.,5764.,5750.,5730.,5710.,5690.,5670.,5650.,5580.,545
0.,5400.,5320.,5230.,5130.,5020.,4870.,4730.,4520.,4300.,4040.,3780.,3490.,314
0.,2770./
```

ARRIVAL TIME / HEIGHT OF BURST / RANGE FUNCTION PAGE 9

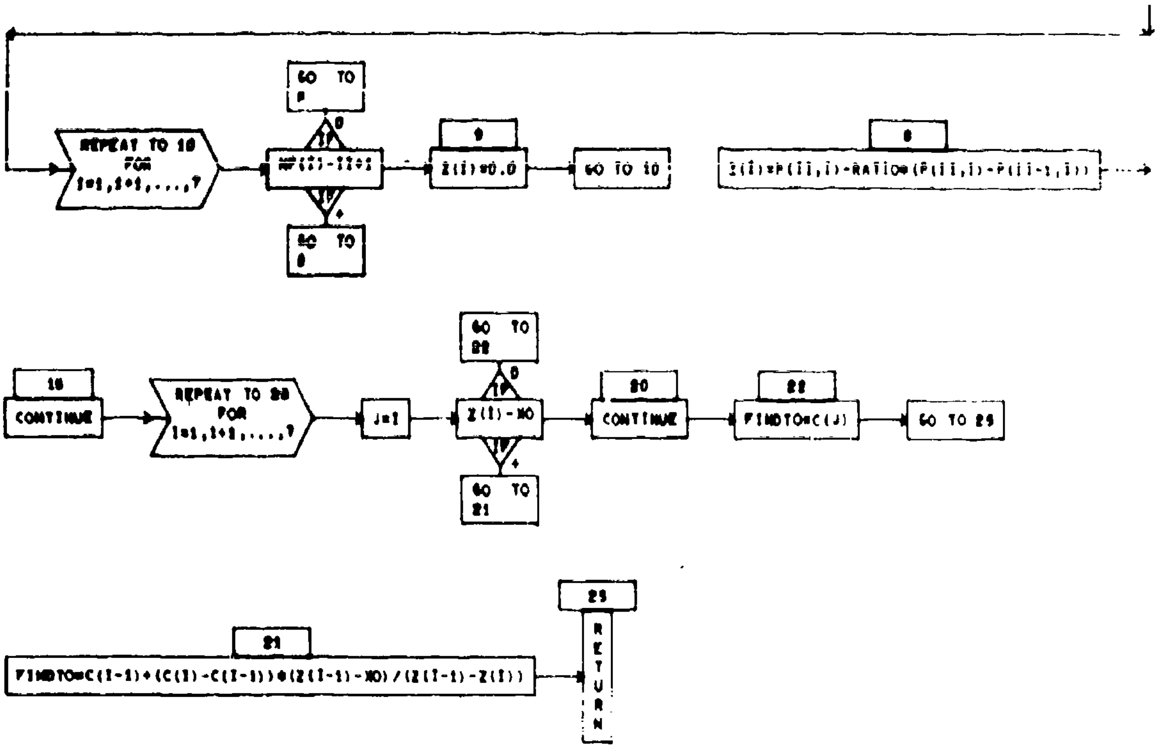


POSITIVE PHASE DURATION / HEIGHT OF BURST / RANGE FUNCTION PAGE 1



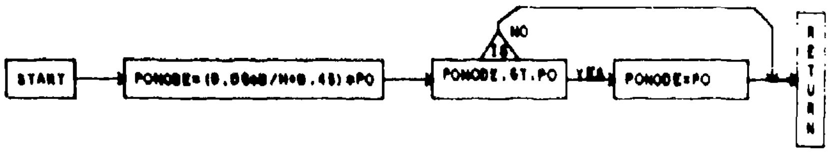
POSITIVE PHASE DURATION / HEIGHT OF BURST / RANGE FUNCTION

PAGE 2

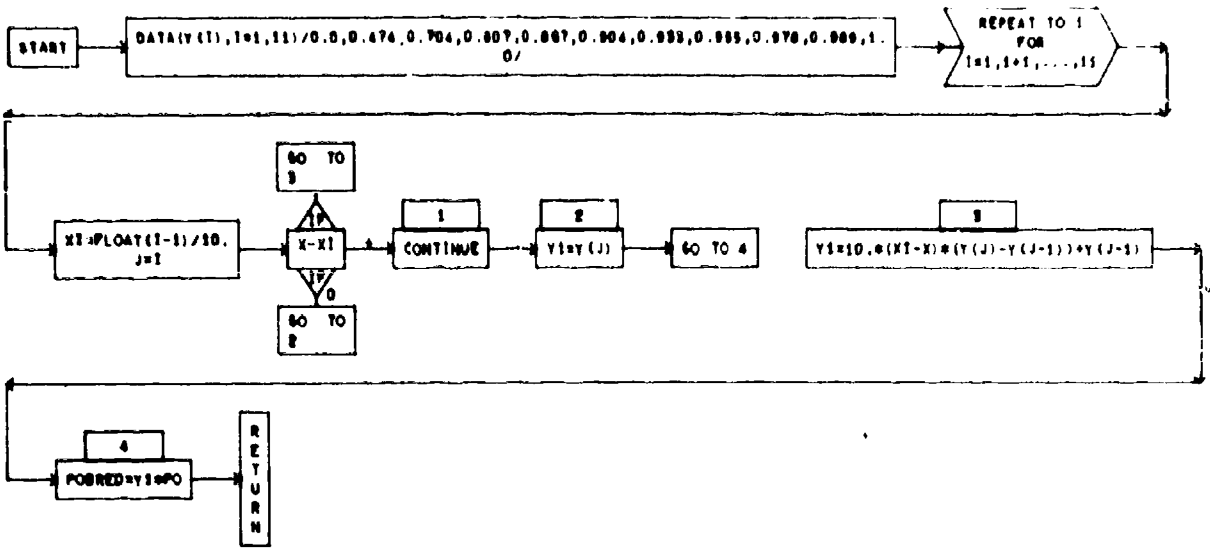


BLAST INTERACTION WITH SURROUNDING STRUCTURES

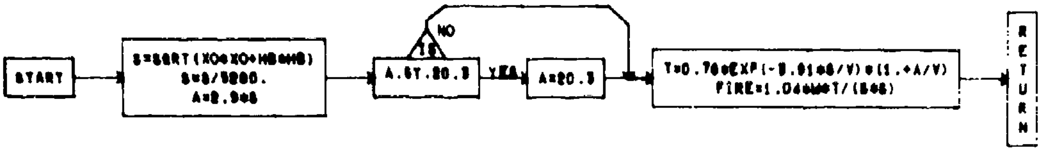
PAGE 1



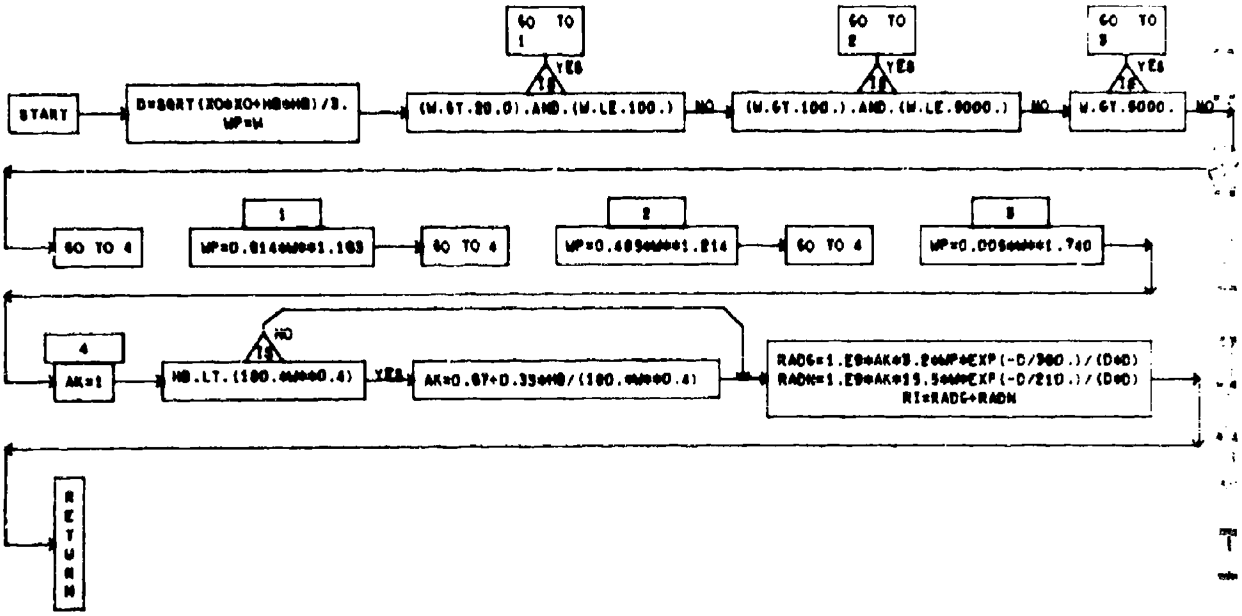
BLAST INTERACTION WITH BUILDING APERATURES PAGE 1



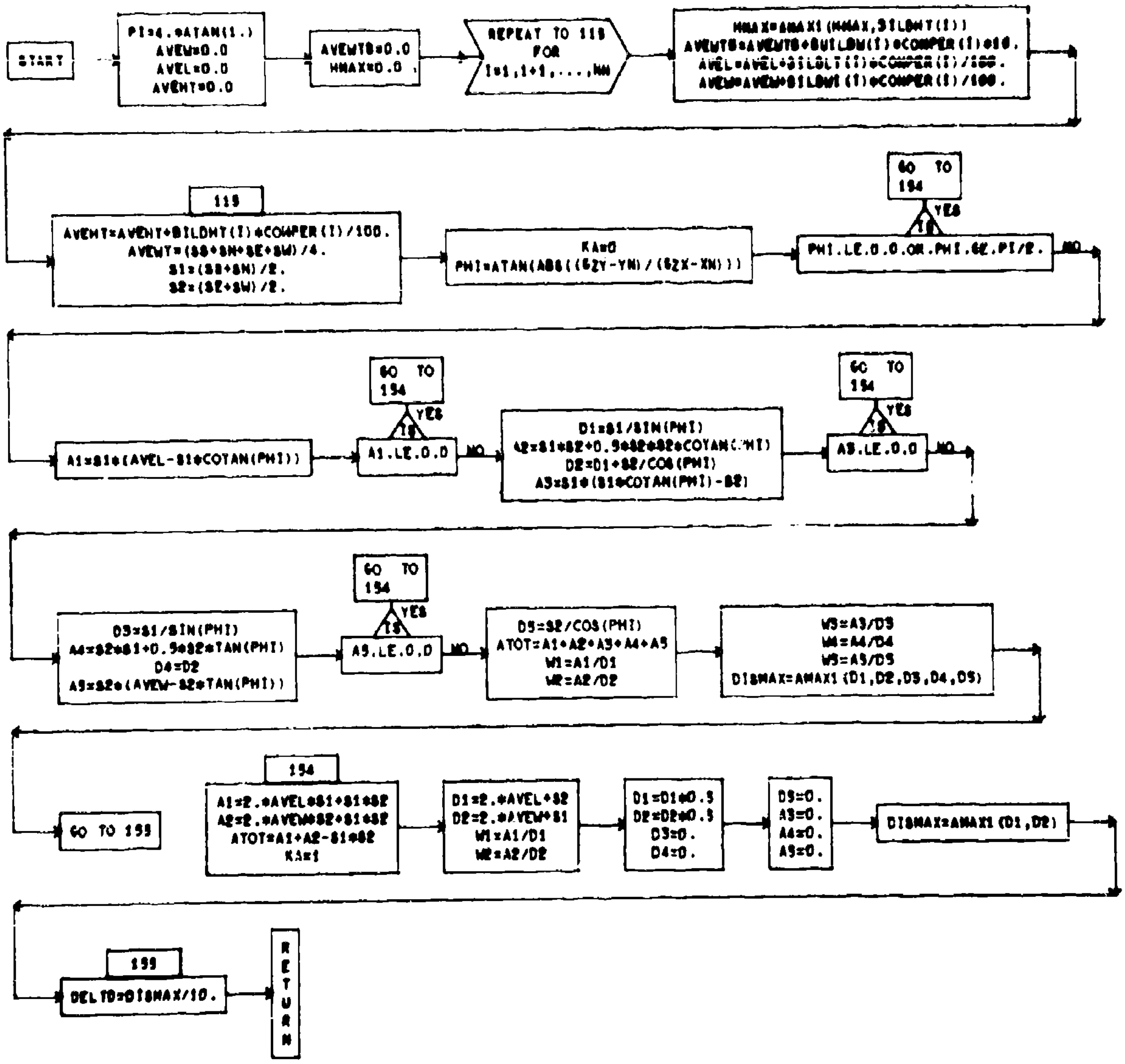
THERMAL ENERGY / RANGE FUNCTION PAGE 1



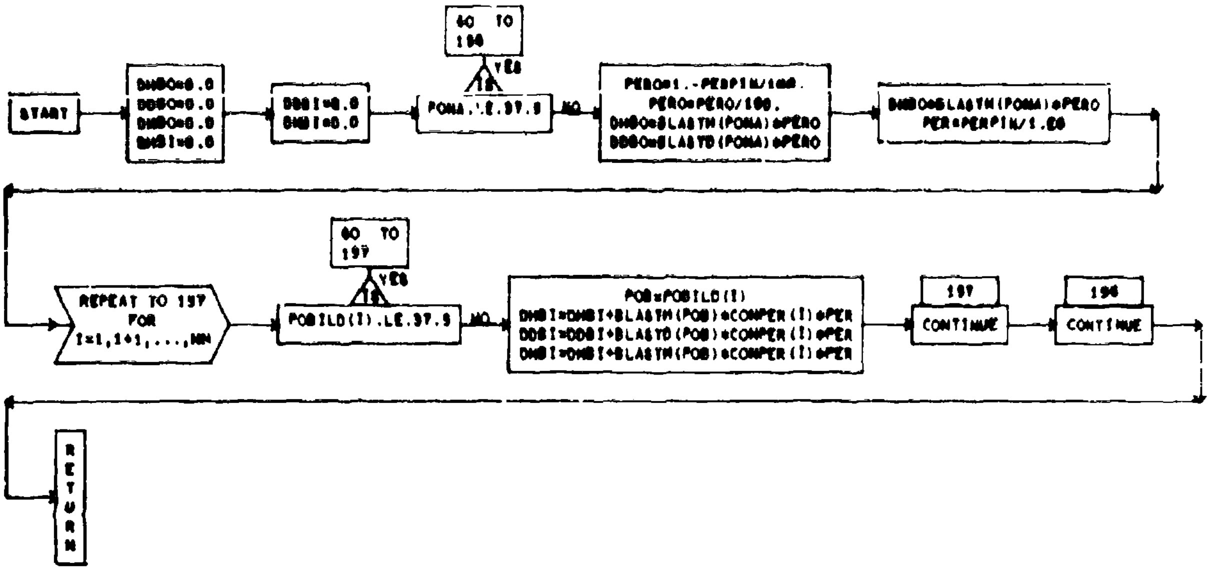
GAMMA / NEUTRON RAY FUNCTION PAGE 1



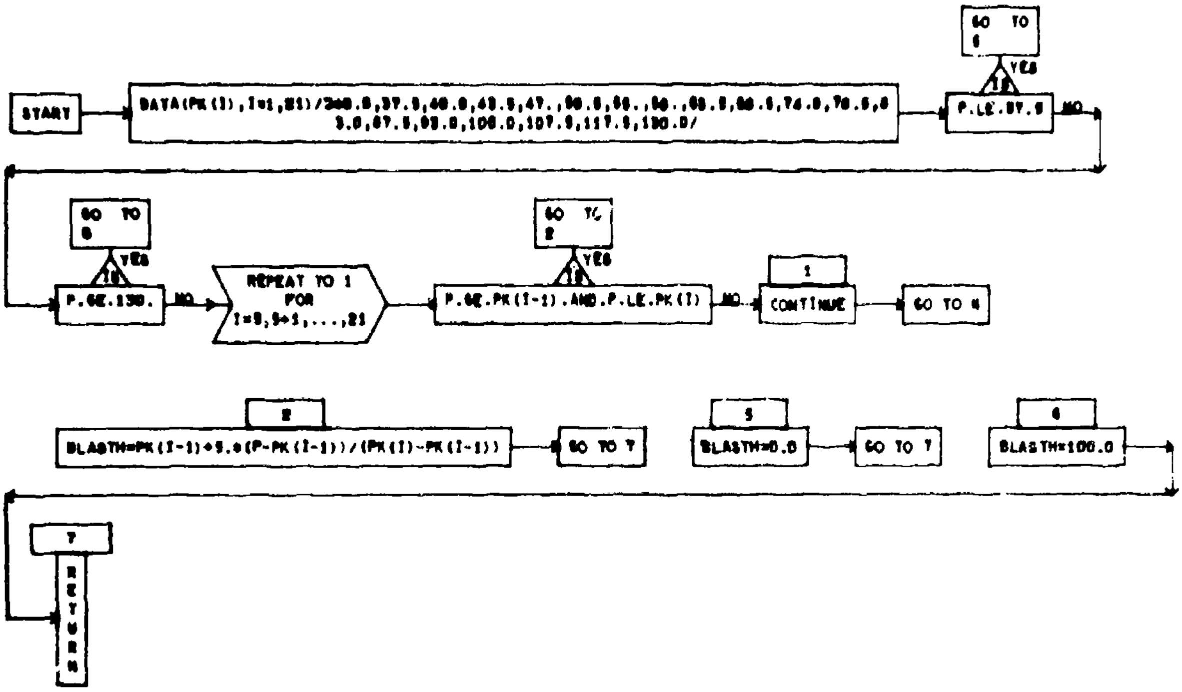
NODE GEOMETRY SUBROUTINE



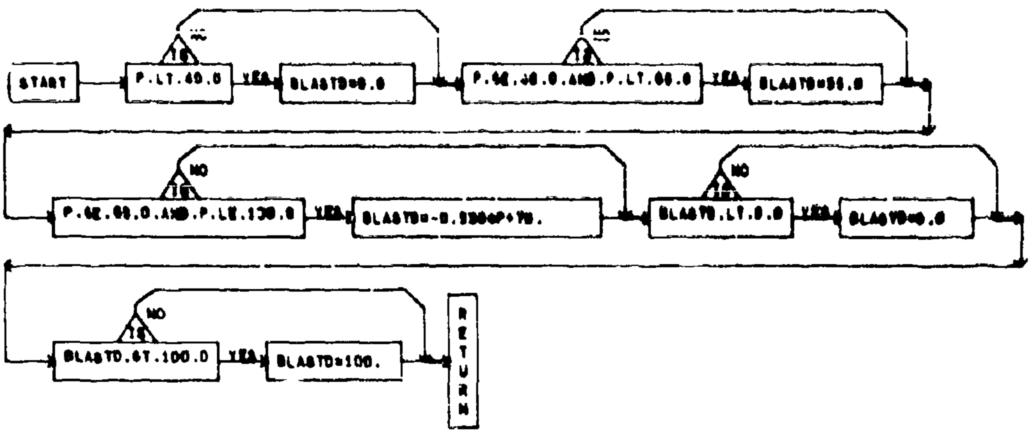
BLAST CASUALTY SUBROUTINE PAGE 1



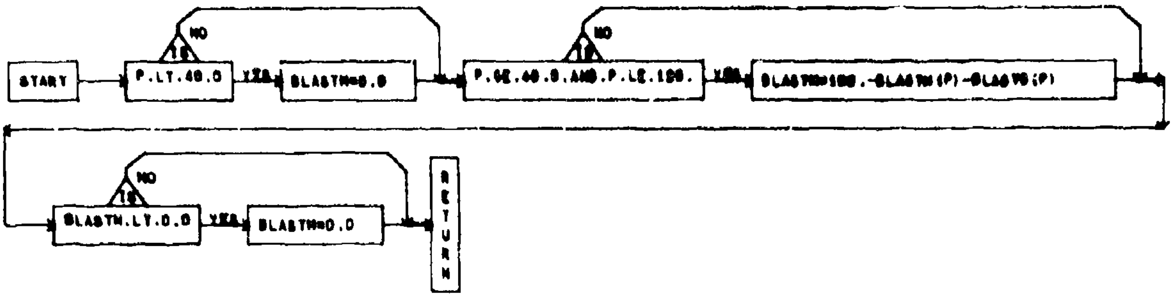
DEAD HOUR FROM BLAST / OVERPRESSURE FUNCTION PAGE 1



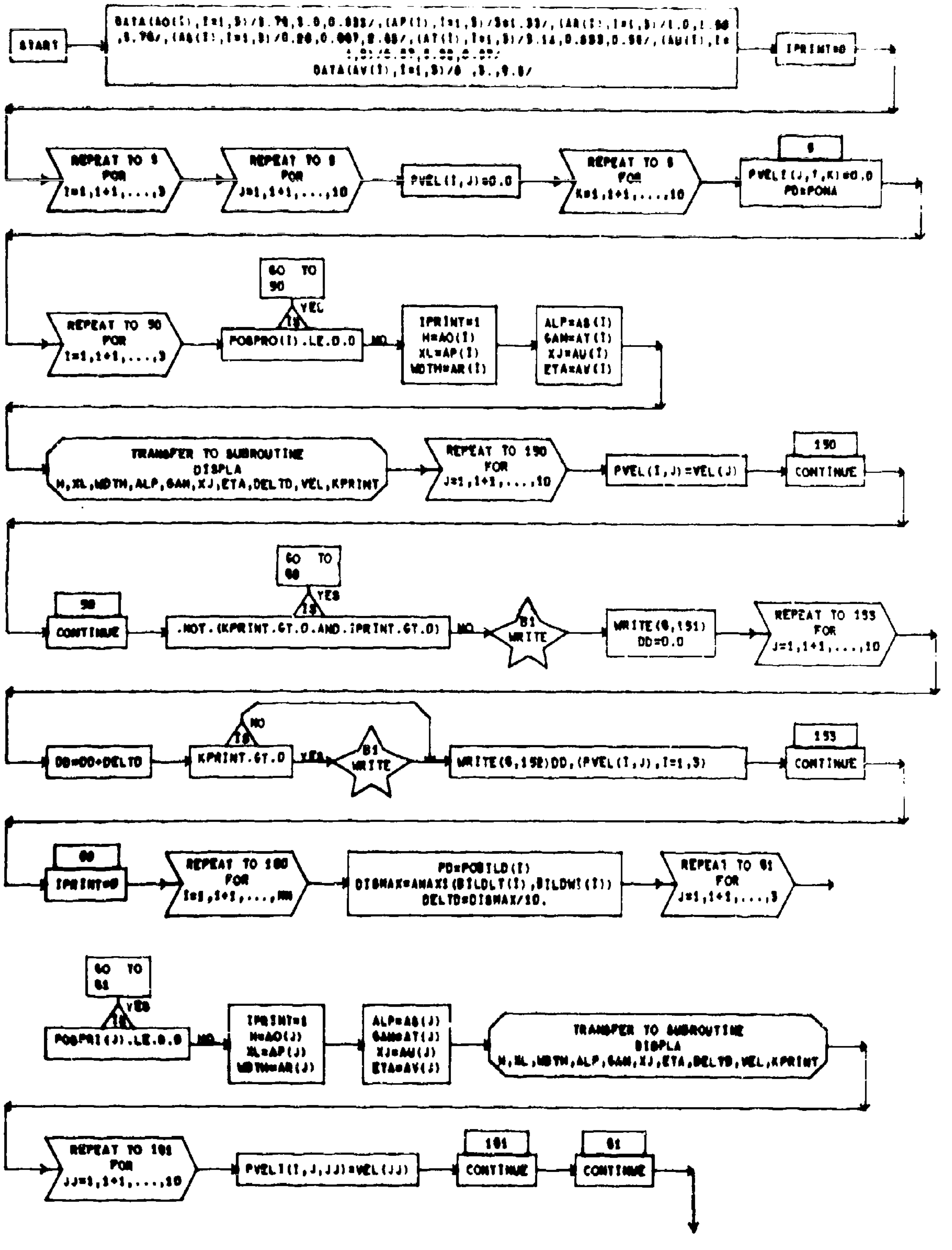
DEAD DAY FROM BLAST / OVERPRESSURE FUNCTION PAGE 1



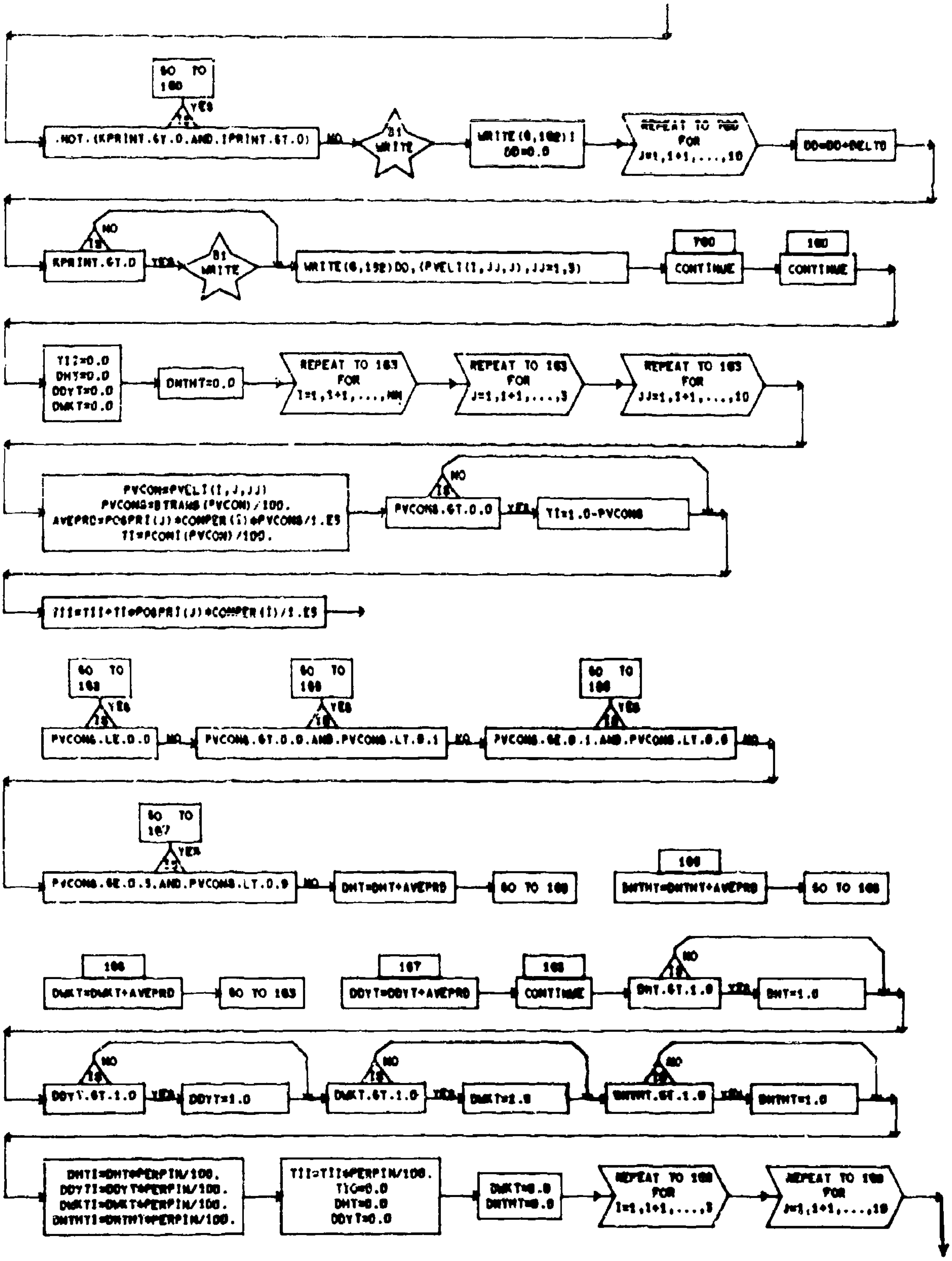
DEAD MONTH FROM BLAST / OVERPRESSURE FUNCTION PAGE 1

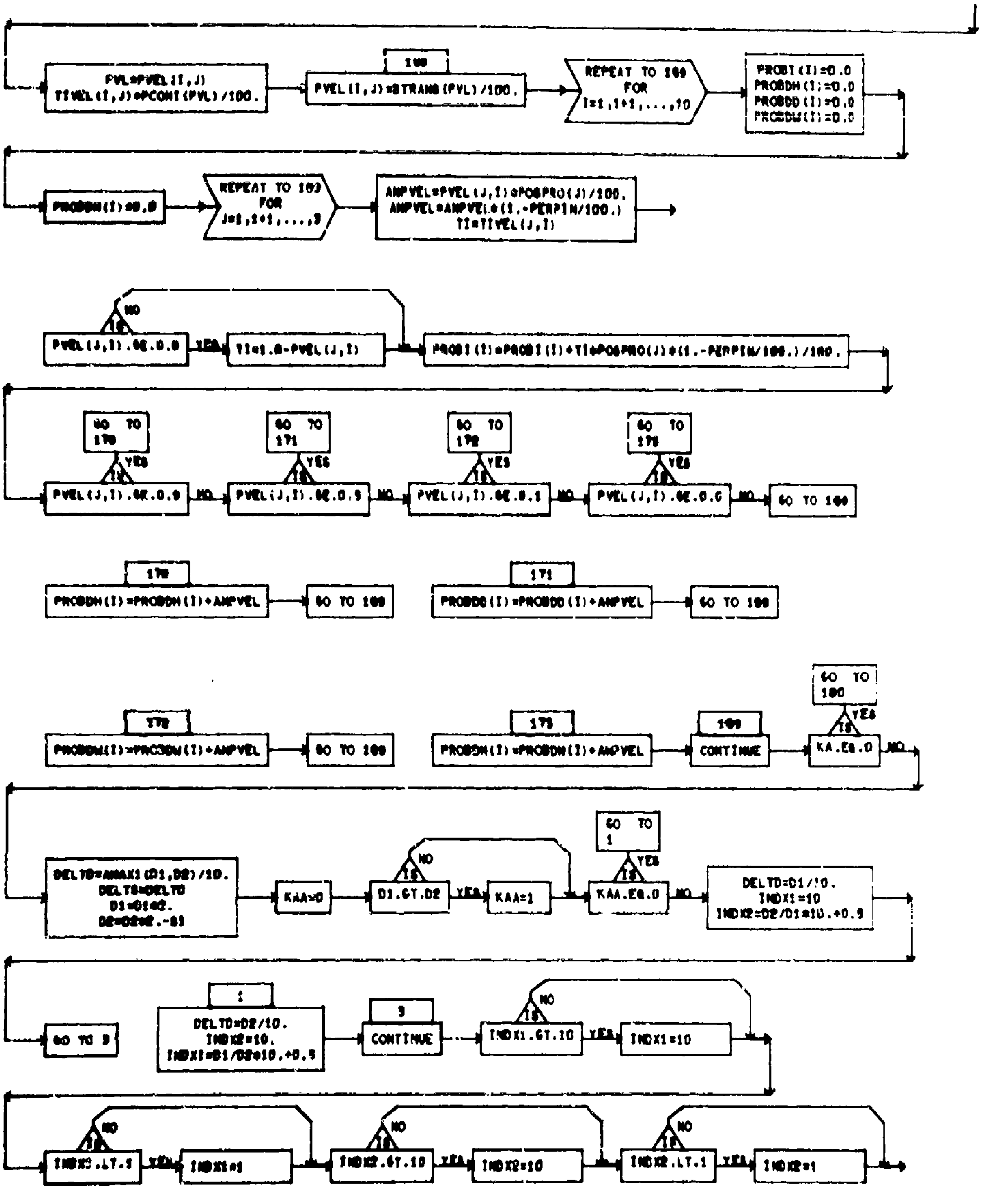


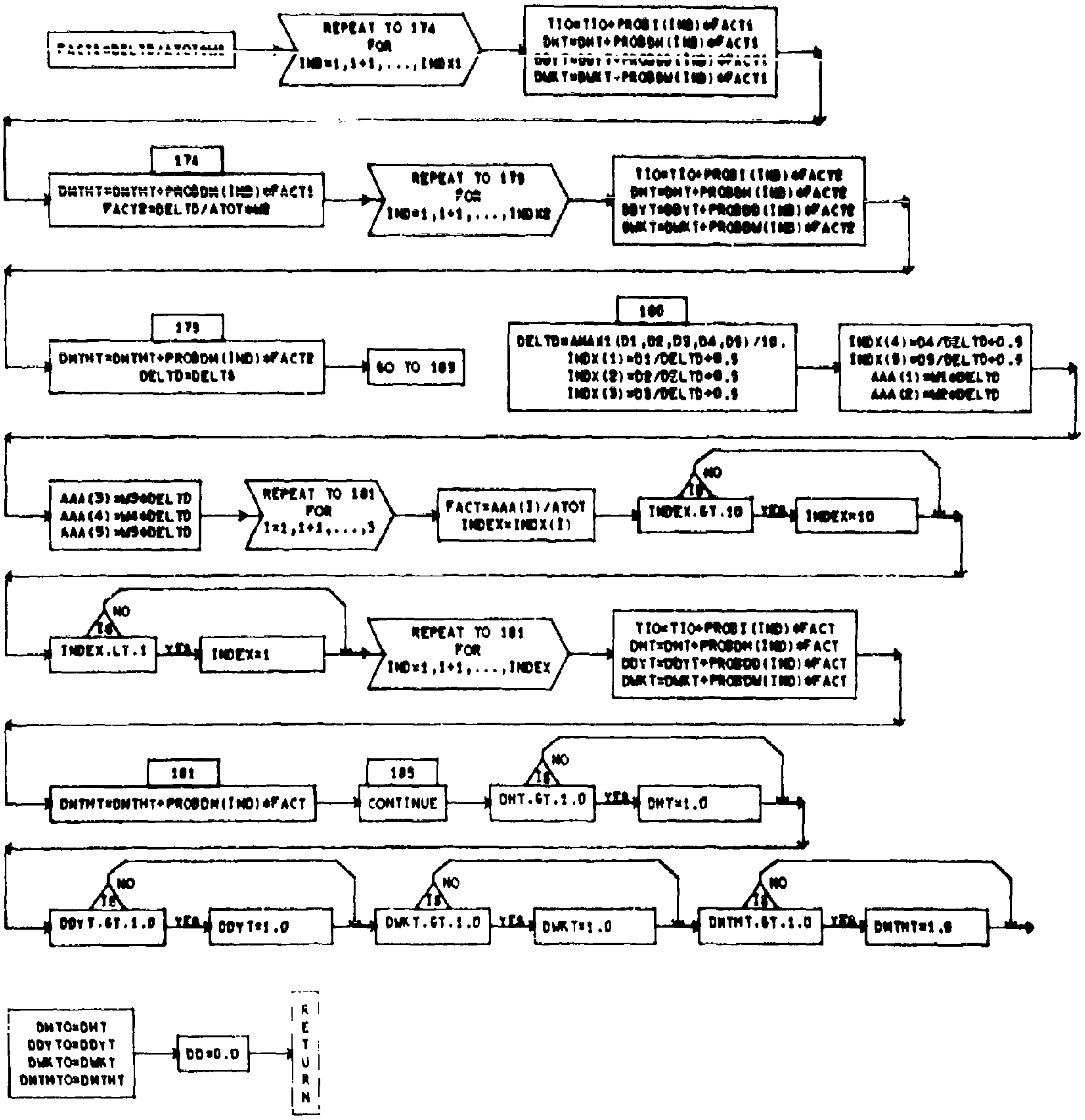
PEOPLE TRANSLATION CASUALTY SUBROUTINE PAGE 1



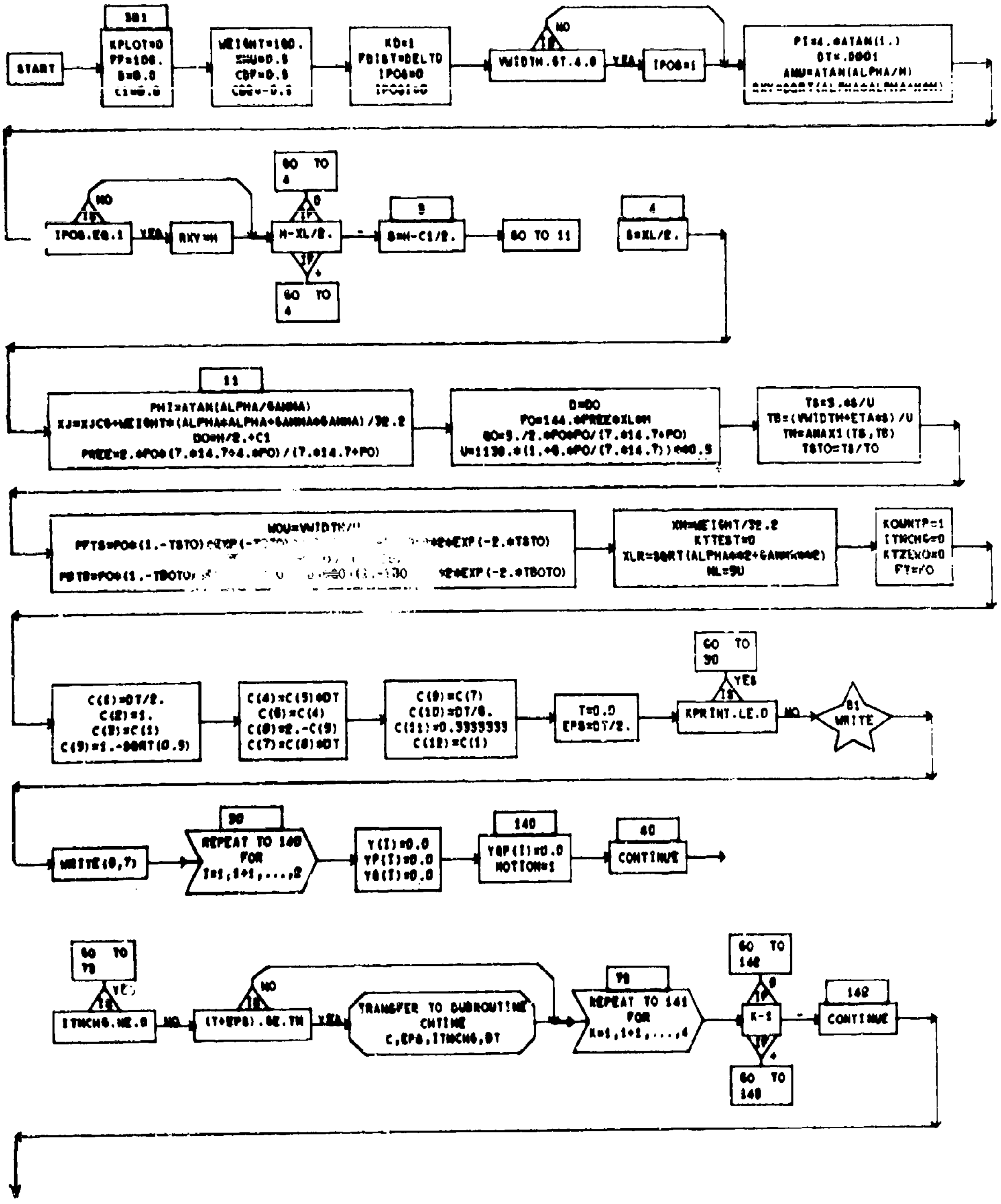
PEOPLE TRANSLATION CAPABILITY SUBROUTINE

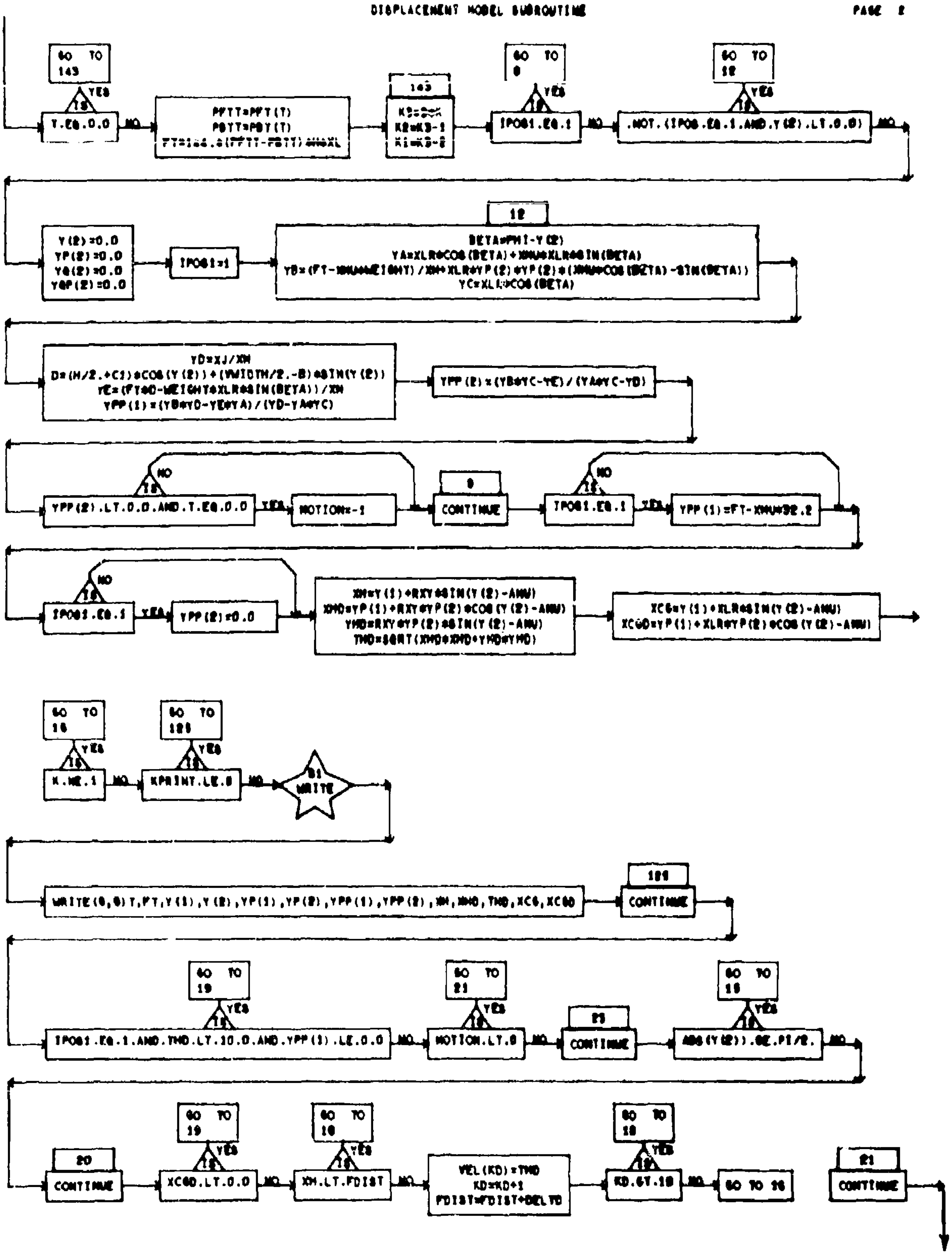



PVL=PVEL(I,J)
TIVEL(I,J)=PCONI(PVL)/100.
100
PVEL(I,J)=BTRANS(PVL)/100.
REPEAT TO 180 FOR I=1,1+1,...,10
PROBI(I)=0.0
PROBDH(I)=0.0
PROBDD(I)=0.0
PROBDW(I)=0.0
PROBDN(I)=0.0
REPEAT TO 183 FOR J=1,1+1,...,5
ANPVEL=PVEL(J,I)*POSPRO(J)/100.
ANPVEL=ANPVEL*(1.-PERPIN/100.)
TI=TIVEL(J,I)
IS
NO
PVEL(J,I).GE.0.0
YES
TI=1.0-PVEL(J,I)
PROBI(I)=PROBI(I)+TI*POSPRO(J)*(1.-PERPIN/100.)/100.
GO TO 170
GO TO 171
GO TO 172
GO TO 173
YES
PVEL(J,I).GE.0.9
NO
PVEL(J,I).GE.0.5
NO
PVEL(J,I).GE.0.1
NO
PVEL(J,I).GE.0.0
NO
GO TO 183
170
PROBDH(I)=PROBDH(I)+ANPVEL
GO TO 183
171
PROBDD(I)=PROBDD(I)+ANPVEL
GO TO 183
172
PROBDW(I)=PROBDW(I)+ANPVEL
GO TO 183
173
PROBDN(I)=PROBDN(I)+ANPVEL
183
CONTINUE
GO TO 180
YES
KA.EQ.0
NO
DELTD=AMAX1(D1,D2)/10.
DELTS=DELTD
D1=D1*2.
D2=D2*2.-D1
KAA=0
D1.GT.D2
YES
KAA=1
GO TO 1
KAA.EQ.0
NO
DELTD=D1/10.
INDX1=10
INDX2=D2/D1*10.+0.5
GO TO 3
1
DELTD=D2/10.
INDX2=10.
INDX1=D1/D2*10.+0.5
3
CONTINUE
INDX1.GT.10
YES
INDX1=10
INDX1.LT.1
YES
INDX1=1
INDX2.GT.10
YES
INDX2=10
INDX2.LT.1
YES
INDX2=1

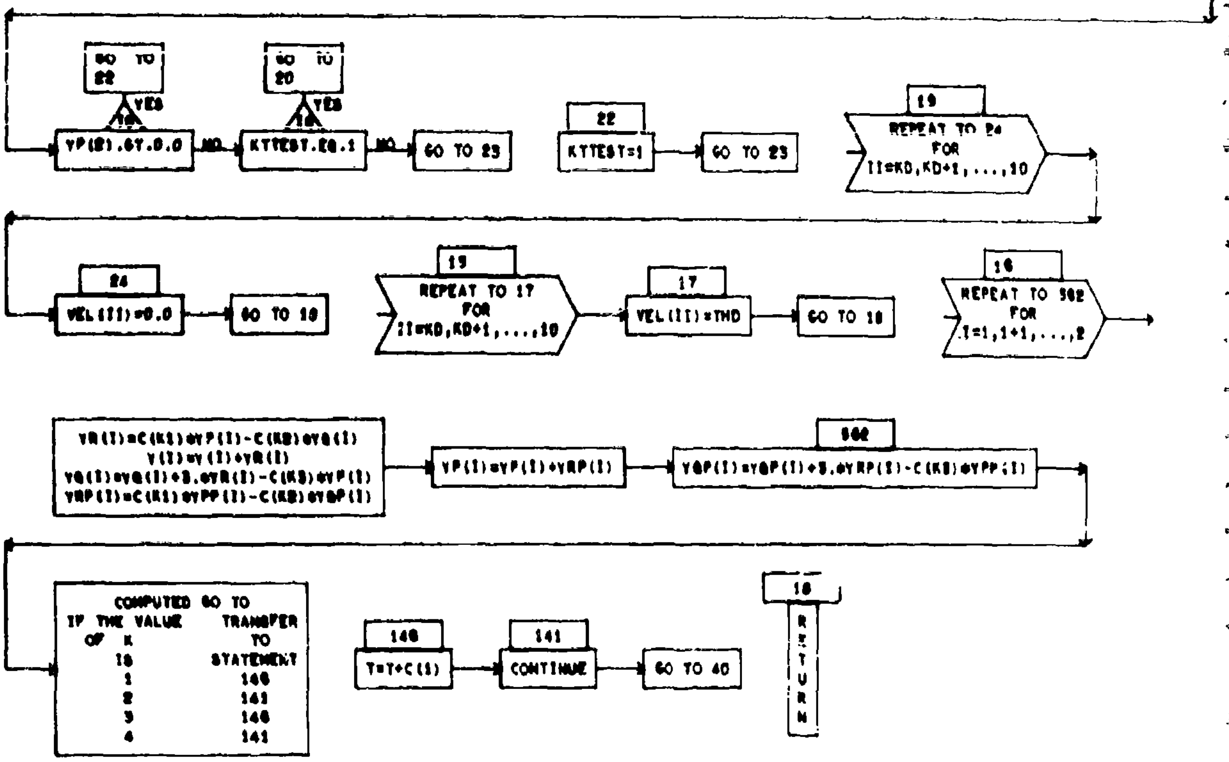

FACT1=DELTD/ATOT*W1
REPEAT TO 174 FOR IND=1,1+1,...,INDX1
TIO=TIO+PROBI(IND)*FACT1
DMT=DMT+PROBDM(IND)*FACT1
DDYT=DDYT+PROBDD(IND)*FACT1
DWKT=DWKT+PROBDM(IND)*FACT1
174
DMTMT=DMTMT+PROBDM(IND)*FACT1
FACT2=DELTD/ATOT*W2
REPEAT TO 175 FOR IND=1,1+1,...,INDX2
TIO=TIO+PROBI(IND)*FACT2
DMT=DMT+PROBDM(IND)*FACT2
DDYT=DDYT+PROBDD(IND)*FACT2
DWKT=DWKT+PROBDM(IND)*FACT2
175
DMTMT=DMTMT+PROBDM(IND)*FACT2
DELTD=DELTS
GO TO 185
180
DELTD=AMAX1(D1,D2,D3,D4,D5)/10.
INDX(1)=D1/DELTD+0.5
INDX(2)=D2/DELTD+0.5
INDX(3)=D3/DELTD+0.5
INDX(4)=D4/DELTD+0.5
INDX(5)=D5/DELTD+0.5
AAA(1)=W1*DELTD
AAA(2)=W2*DELTD
AAA(3)=W3*DELTD
AAA(4)=W4*DELTD
AAA(5)=W5*DELTD
REPEAT TO 181 FOR I=1,1+1,...,5
FACT=AAA(I)/ATOT
INDEX=INDX(I)
IS
NO
INDEX.GT.10
YES
INDEX=10
IS
NO
INDEX.LT.1
YES
INDEX=1
REPEAT TO 181 FOR IND=1,1+1,...,INDEX
TIO=TIO+PROBI(IND)*FACT
DMT=DMT+PROBDM(IND)*FACT
DDYT=DDYT+PROBDD(IND)*FACT
DWKT=DWKT+PROBDM(IND)*FACT
181
DMTMT=DMTMT+PROBDM(IND)*FACT
185
CONTINUE
IS
NO
DMT.GT.1.0
YES
DMT=1.0
IS
NO
DDYT.GT.1.0
YES
DDYT=1.0
IS
NO
DWKT.GT.1.0
YES
DWKT=1.0
IS
NO
DMTMT.GT.1.0
YES
DMTMT=1.0
DMTO=DMT
DDYTO=DDYT
DWKTO=DWKT
DMTMTO=DMTMT
DD=0.0
RETURN

DISPLACEMENT MODEL SUBROUTINE

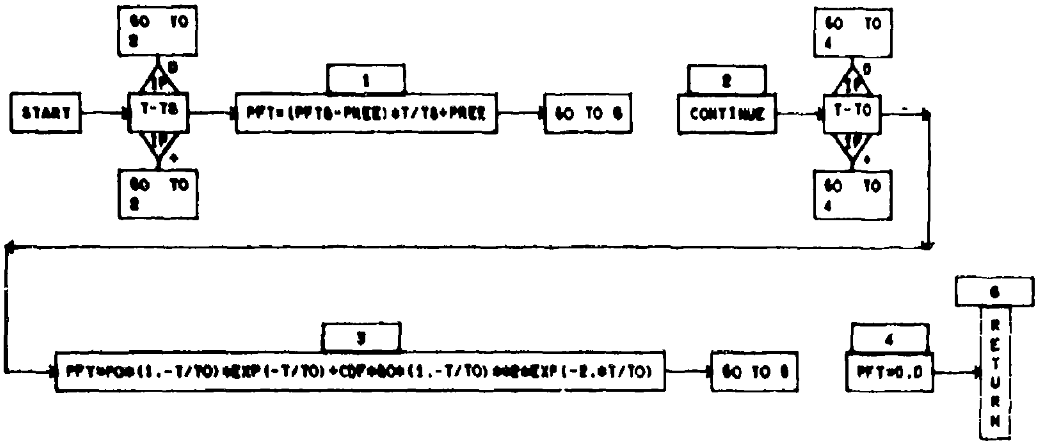



GO TO 143
YES
18
T.EQ.0.0
NO
PFTT=PFT(T)
PBTT=PBT(T)
FT=144.*(PFTT-PBTT)*XNUXL
143
K3=3*K
K2=K3-1
K1=K3-2
GO TO 8
YES
18
IPOS1.EQ.1
NO
GO TO 12
YES
18
.NOT.(IPOS.EQ.1.AND.Y(2).LT.0.0)
NO
Y(2)=0.0
YP(2)=0.0
YQ(2)=0.0
YQP(2)=0.0
IPOS1=1
12
BETA=PHI-Y(2)
YA=XLR*COS(BETA)+XNU*XLR*SIN(BETA)
YB=(FT-XNU*WEIGHT)/XM+XLR*YP(2)*YP(2)*(XNU*COS(BETA)-SIN(BETA))
YC=XLR*COS(BETA)
YD=XJ/XM
D=(H/2.+C1)*COS(Y(2))+(WIDTH/2.-B)*SIN(Y(2))
YE=(FT*D-WEIGHT*XLR*SIN(BETA))/XM
YPP(1)=(YB*YD-YE*YA)/(YD-YA*YC)
YPP(2)=(YB*YC-YE)/(YA*YC-YD)
NO
18
YPP(2).LT.0.0.AND.T.EQ.0.0
YES
MOTION=-1
8
CONTINUE
NO
18
IPOS1.EQ.1
YES
YPP(1)=FT-XNU*32.2
NO
18
IPOS1.EQ.1
YES
YPP(2)=0.0
XM=Y(1)+RXY*SIN(Y(2)-ANU)
XMD=YP(1)+RXY*YP(2)*COS(Y(2)-ANU)
YMD=RXY*YP(2)*SIN(Y(2)-ANU)
TMD=SQRT(XMD*XMD+YMD*YMD)
XCG=Y(1)+XLR*SIN(Y(2)-ANU)
XCGD=YP(1)+XLR*YP(2)*COS(Y(2)-ANU)
GO TO 16
YES
18
K.NE.1
NO
GO TO 121
YES
18
KPRINT.LE.8
NO
81
WRITE
WRITE(6,8)T,FT,Y(1),Y(2),YP(1),YP(2),YPP(1),YPP(2),XM,XMD,TMD,XCG,XCGD
121
CONTINUE
GO TO 19
YES
18
IPOS1.EQ.1.AND.TMD.LT.10.0.AND.YPP(1).LE.0.0
NO
GO TO 21
YES
18
MOTION.LT.0
NO
23
CONTINUE
GO TO 18
YES
18
ABS(Y(2)).GE.PI/2.
NO
20
CONTINUE
GO TO 19
YES
18
XCGD.LT.0.0
NO
GO TO 18
YES
18
XM.LT.FDIST
NO
VEL(KD)=TMD
KD=KD+1
FDIST=FDIST+DELTD
GO TO 18
YES
18
KD.GT.18
NO
GO TO 16
21
CONTINUE

DISPLACEMENT MODEL SUBROUTINE PAGE 5

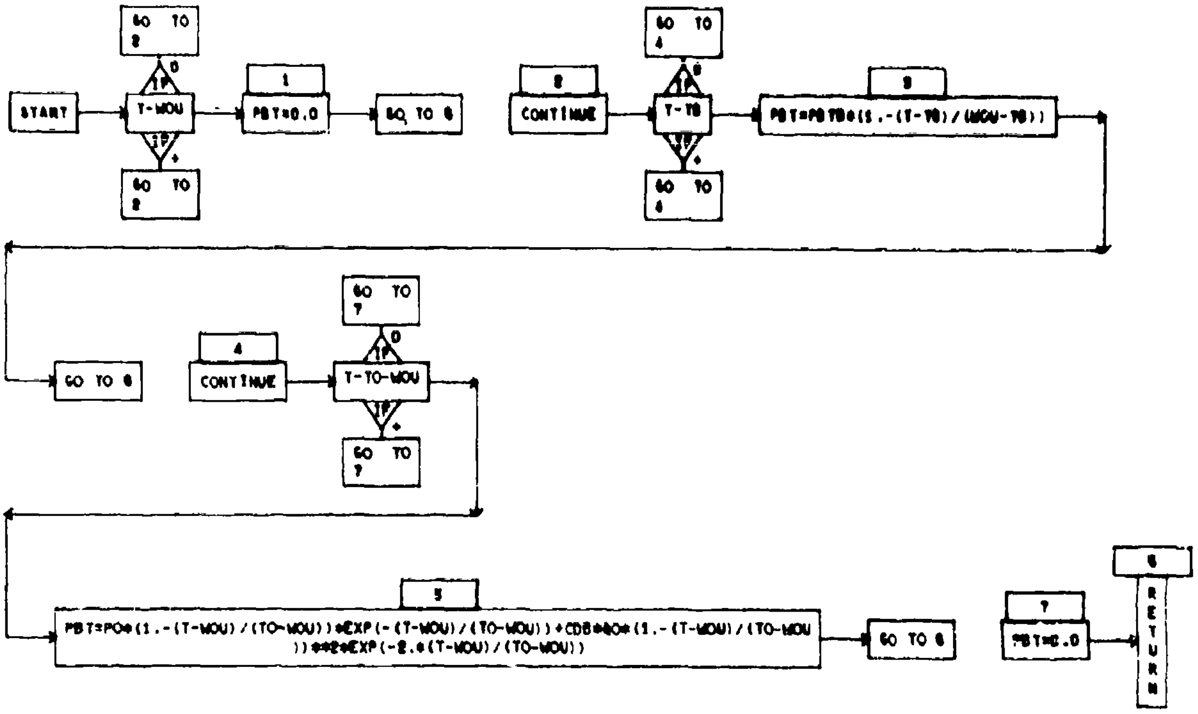


PRESSURE ON FRONT FACE OF TRANSLATION MODEL PAGE 1



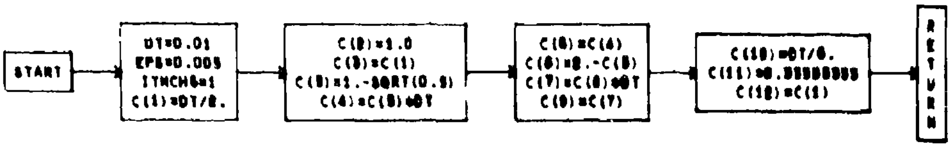
PRESSURE ON BACK FACE OF TRANSLATION MODEL

PAGE 1

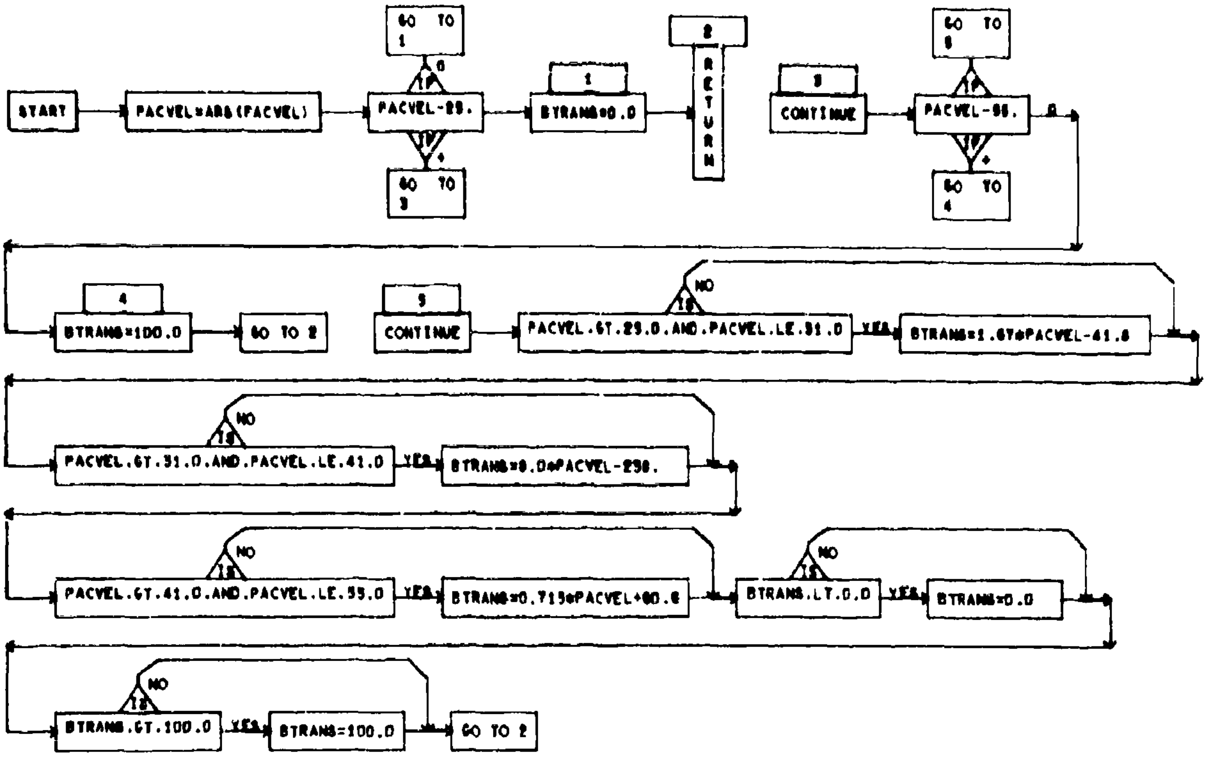


INTEGRATION INTERVAL CHANGE SUBROUTINE

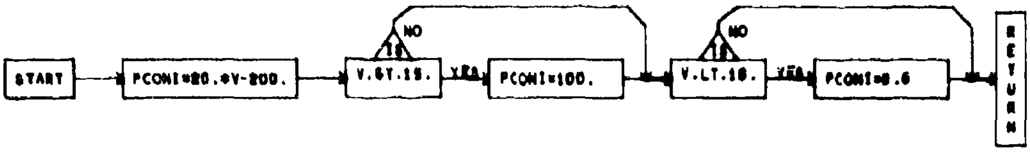
PAGE 1

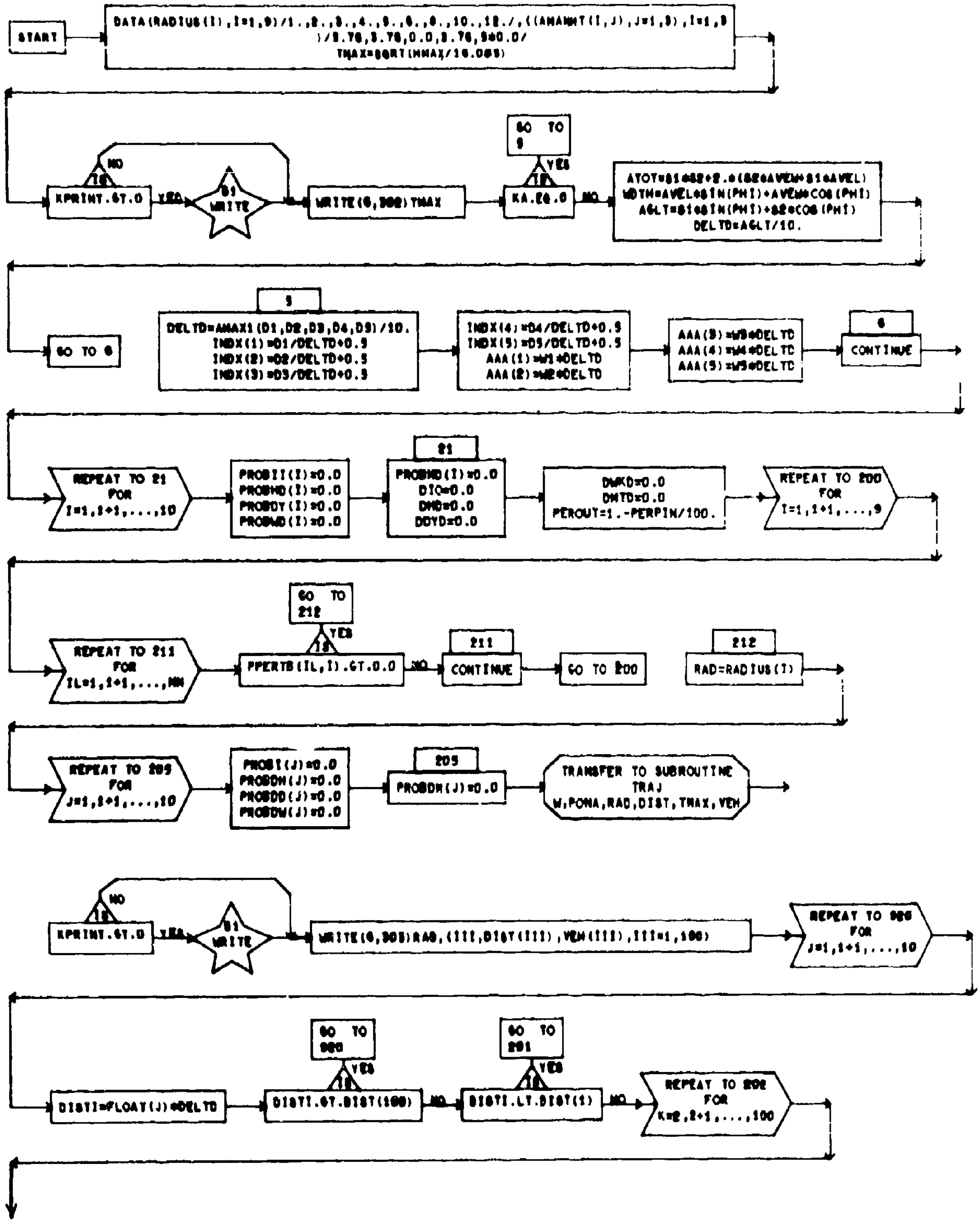


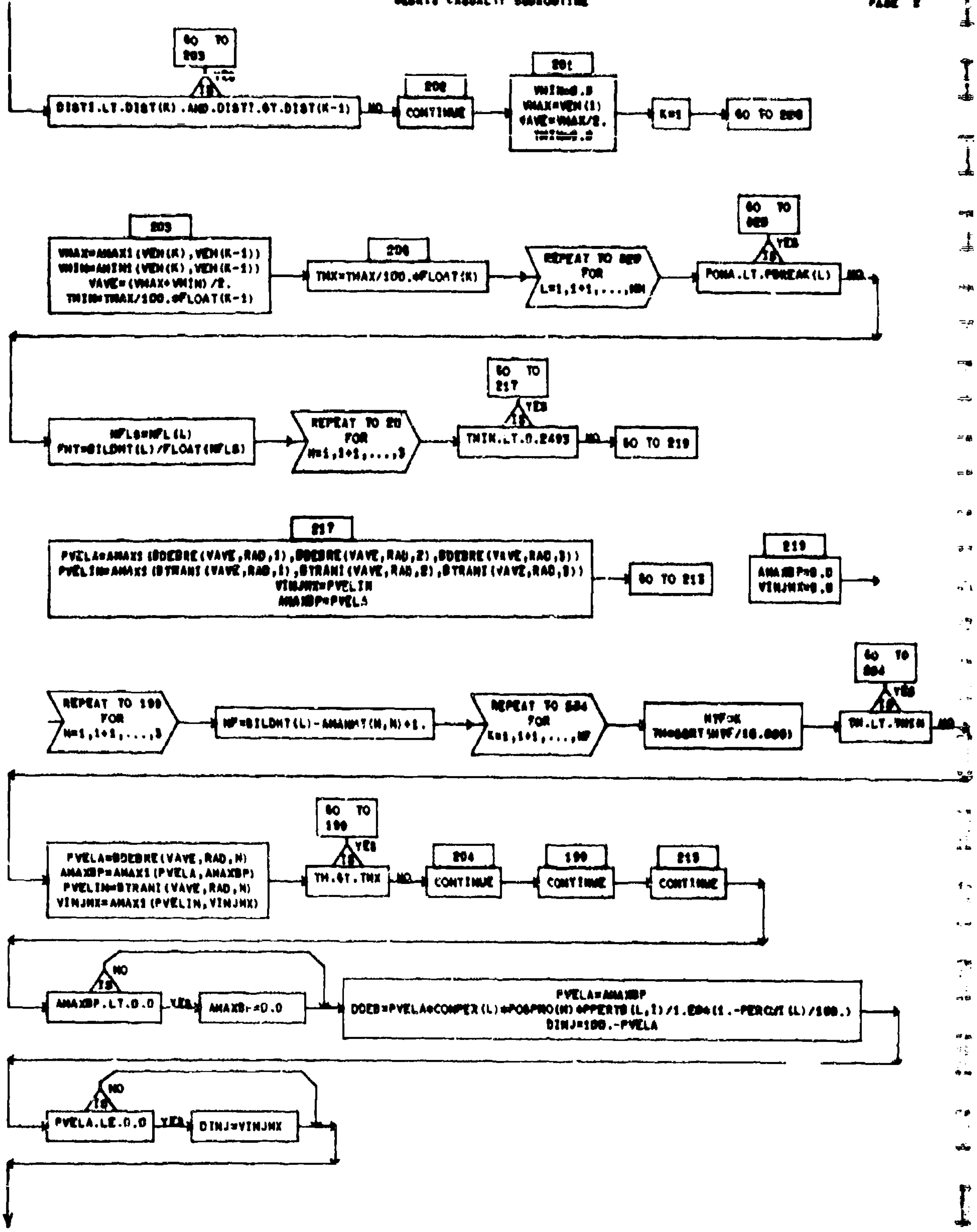
TIME OF DEATH TRANSLATION CASUALTY FUNCTION PAGE 1

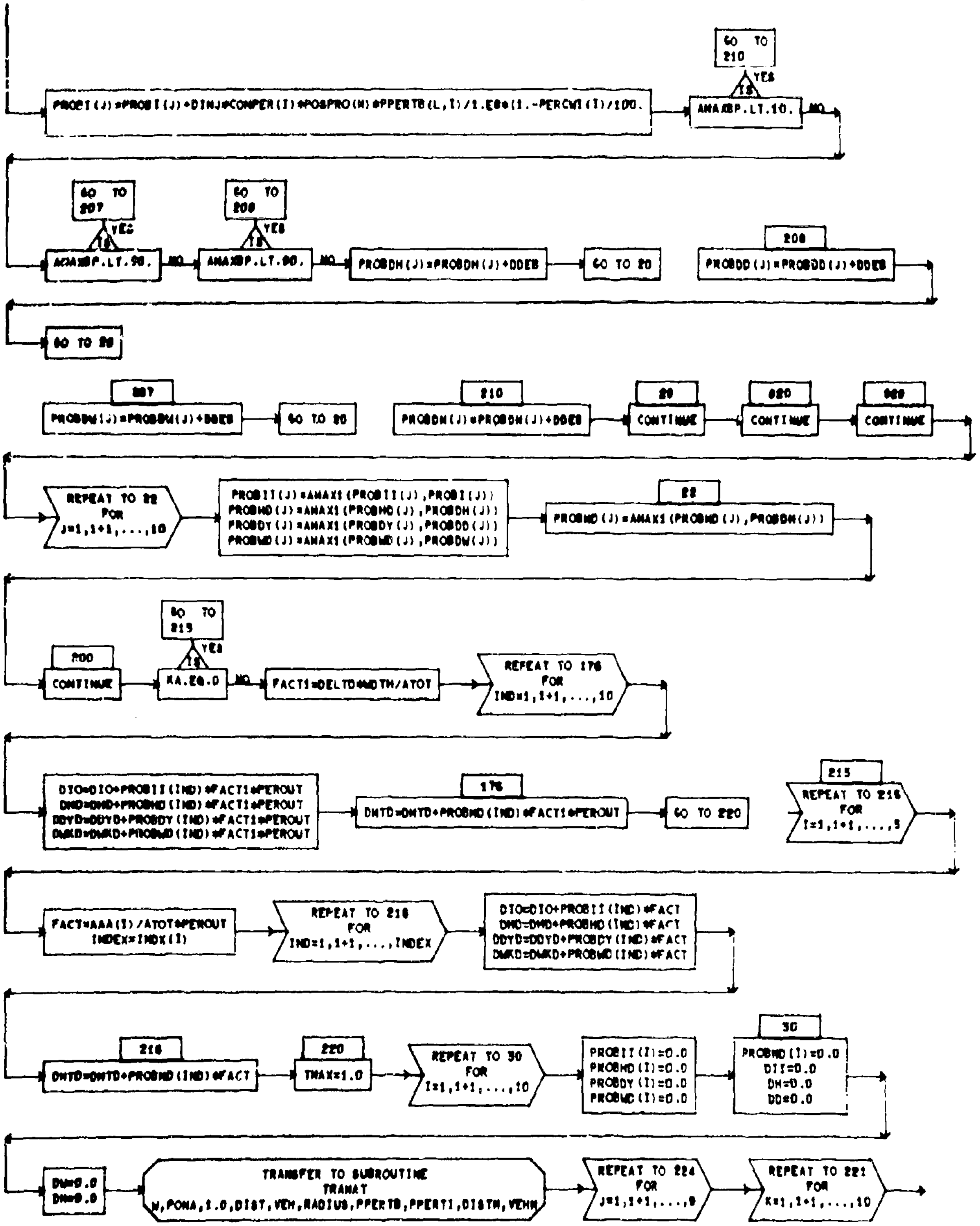


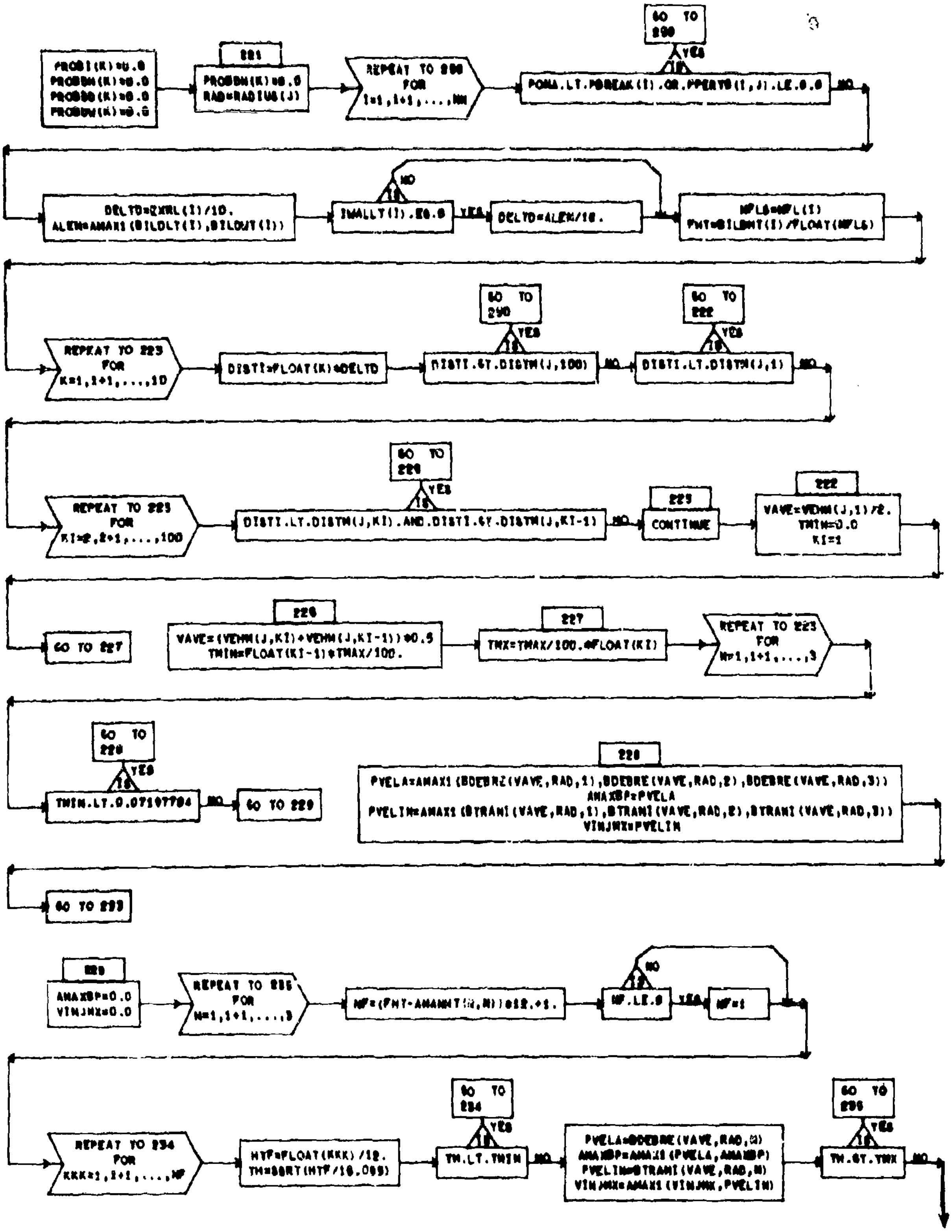
INJURY FROM TRANSLATION SUBROUTINE PAGE 1

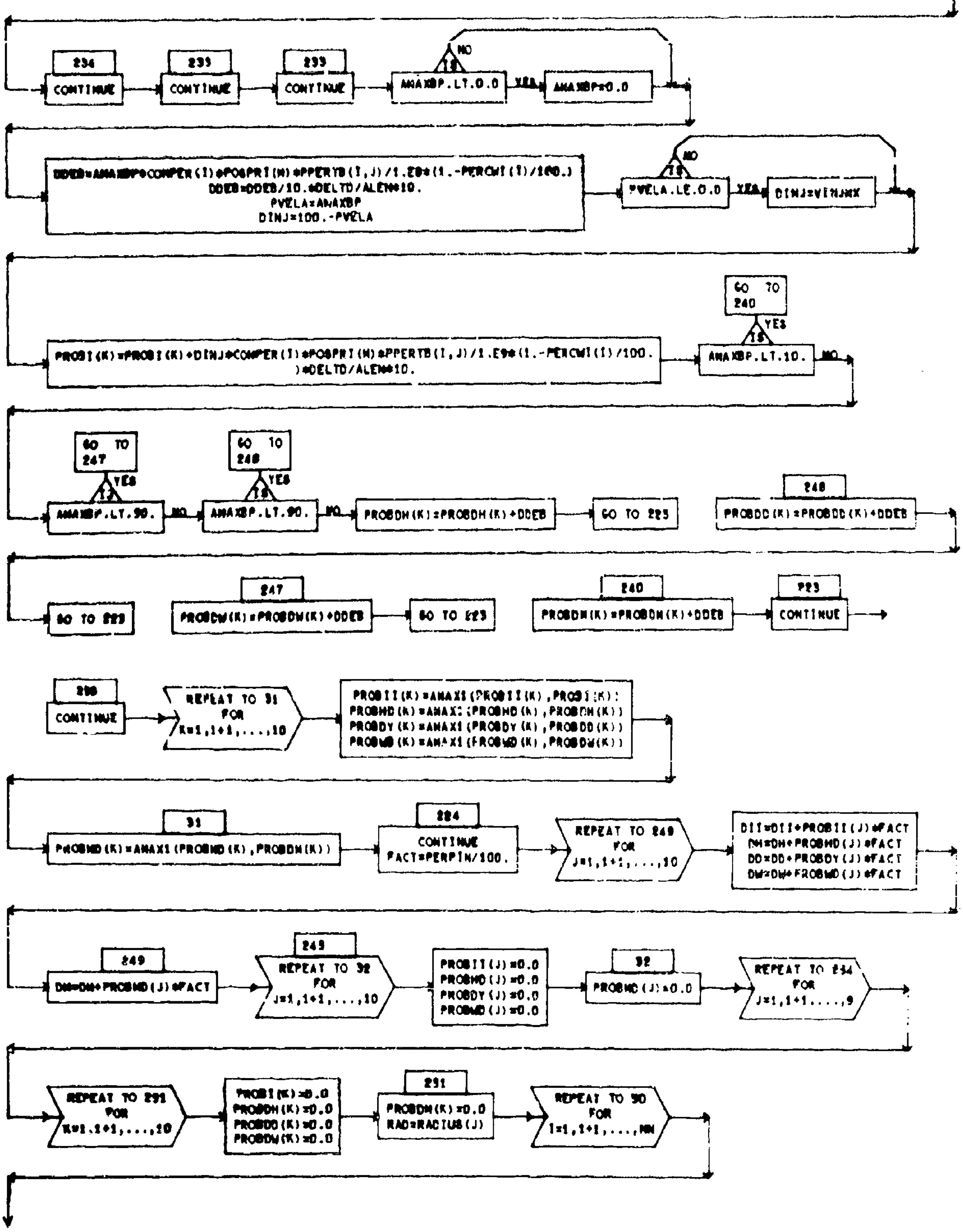


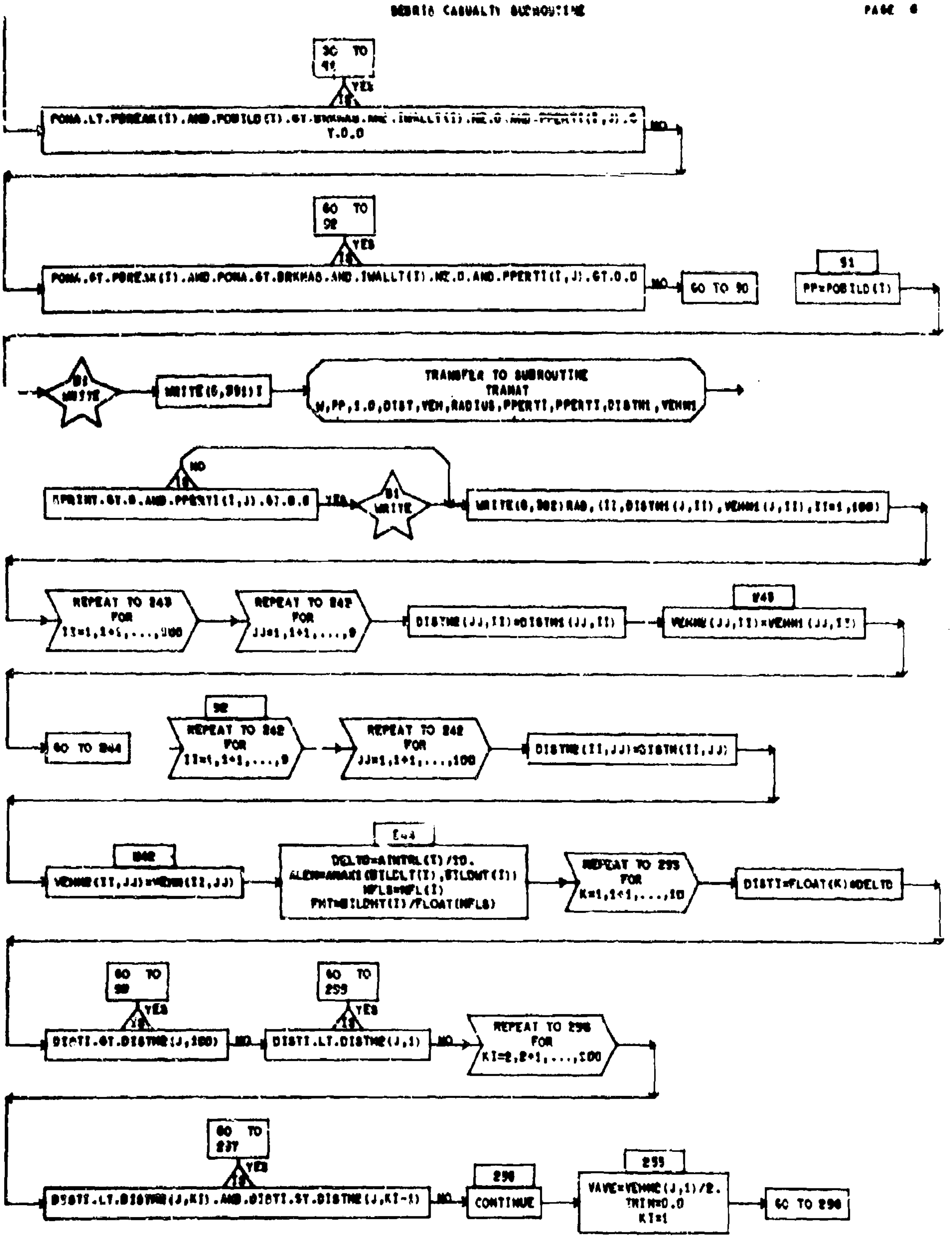

START
DATA(RADIUS(I),I=1,9)/1.,2.,3.,4.,5.,6.,8.,10.,12./,((AMANWT(I,J),J=1,3),I=1,3
)/3.76,3.76,0.0,3.76,5*0.0/
TMAX=SQRT(HMAX/16.085)
NO
IS
KPRINT.GT.0
YES
D1
WRITE
WRITE(6,302)TMAX
GO TO
5
YES
IS
KA.EQ.0
NO
ATOT=S1*S2+2.*(S2*AVEM+S1*AVEL)
WDTH=AVEL*SIN(PHI)+AVEM*COS(PHI)
AGLT=S1*SIN(PHI)+S2*COS(PHI)
DELTD=AGLT/10.
GO TO 6
5
DELTD=AMAX1(D1,D2,D3,D4,D5)/10.
INDX(1)=D1/DELTD+0.5
INDX(2)=D2/DELTD+0.5
INDX(3)=D3/DELTD+0.5
INDX(4)=D4/DELTD+0.5
INDX(5)=D5/DELTD+0.5
AAA(1)=W1*DELTD
AAA(2)=W2*DELTD
AAA(3)=W3*DELTD
AAA(4)=W4*DELTD
AAA(5)=W5*DELTD
6
CONTINUE
REPEAT TO 21
FOR
I=1,1+1,...,10
PROBII(I)=0.0
PROBHD(I)=0.0
PROBDY(I)=0.0
PROBWD(I)=0.0
21
PROBMD(I)=0.0
DIO=0.0
DHD=0.0
DDYD=0.0
DWKD=0.0
DHTD=0.0
PEROUT=1.-PERPIN/100.
REPEAT TO 200
FOR
I=1,1+1,...,9
GO TO
212
YES
IS
REPEAT TO 211
FOR
IL=1,1+1,...,NN
PPERTB(IL,I).GT.0.0
NO
211
CONTINUE
GO TO 200
212
RAD=RADIUS(I)
REPEAT TO 205
FOR
J=1,1+1,...,10
PROBI(J)=0.0
PROBDH(J)=0.0
PROBDD(J)=0.0
PROBDW(J)=0.0
205
PROBDH(J)=0.0
TRANSFER TO SUBROUTINE
TRAJ
W,PONA,RAD,DIST,TMAX,VEH
NO
IS
KPRINT.GT.0
YES
D1
WRITE
WRITE(6,303)RAD,(III,DIST(III),VEH(III),III=1,100)
REPEAT TO 206
FOR
J=1,1+1,...,10
GO TO
206
YES
IS
GO TO
201
YES
IS
DISTI=FLOAT(J)*DELTD
DISTI.GT.DIST(100)
NO
DISTI.LT.DIST(1)
NO
REPEAT TO 202
FOR
K=2,2+1,...,100

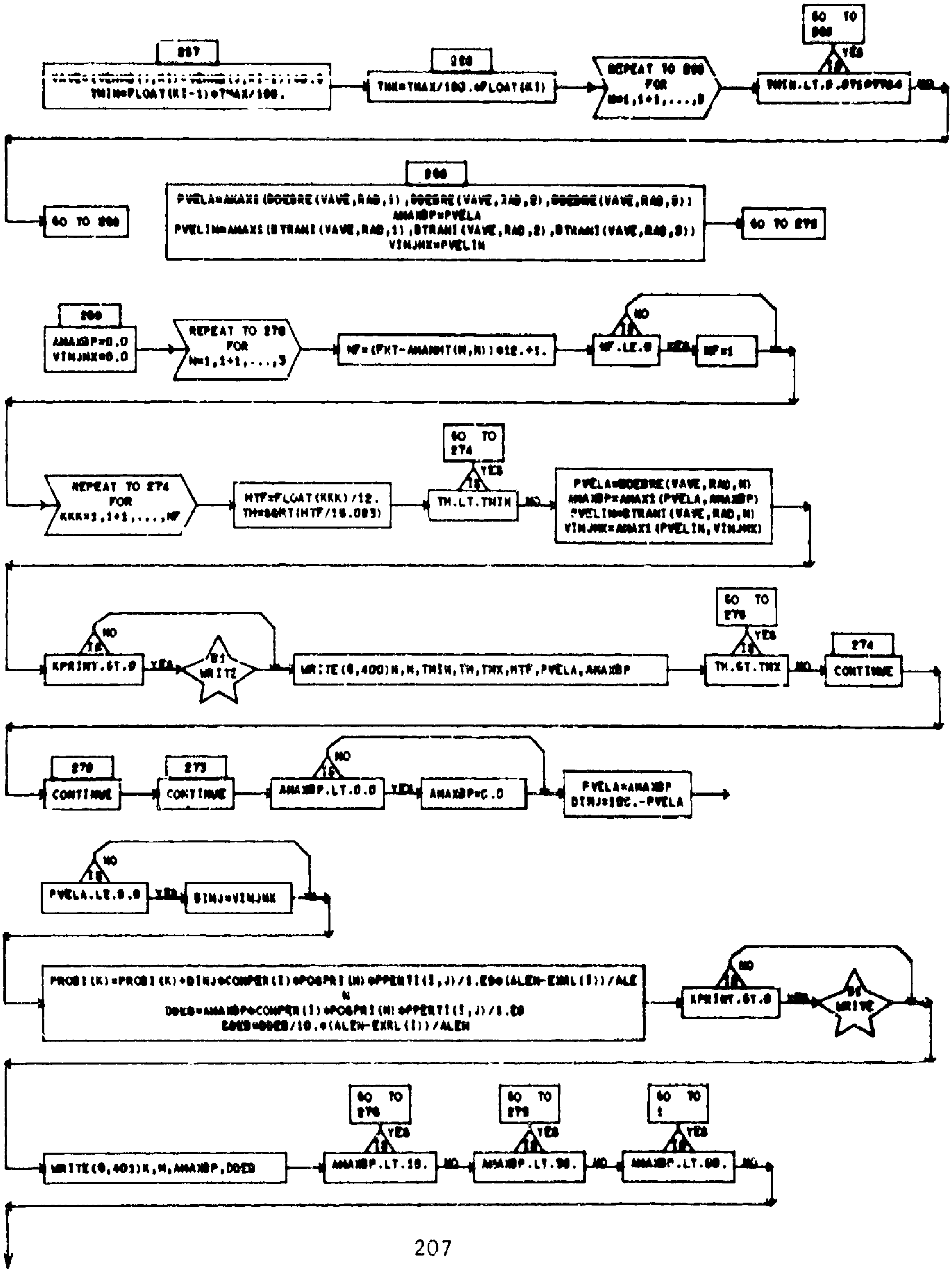

GO TO 203
YES
IS
DIST1.LT.DIST(K).AND.DIST1.GT.DIST(K-1)
NO
202
CONTINUE
201
VMIN=0.0
VMAX=VEN(1)
VAVE=VMAX/2.
TMIN=0.0
K=1
GO TO 206
203
VMAX=AMAX1(VEN(K),VEN(K-1))
VMIN=AMIN1(VEN(K),VEN(K-1))
VAVE=(VMAX+VMIN)/2.
TMIN=TMAX/100.*FLOAT(K-1)
206
TMX=TMAX/100.*FLOAT(K)
REPEAT TO 220 FOR L=1,1+1,...,NN
GO TO 220
YES
IS
POMA.LT.POMEAK(L)
NO
NFLS=NFL(L)
PNT=BILDHT(L)/FLOAT(NFLS)
REPEAT TO 213 FOR N=1,1+1,...,3
GO TO 217
YES
IS
TMIN.LT.0.2493
NO
GO TO 219
217
PVELA=AMAX1(BDEBRE(VAVE,RAD,1),BDEBRE(VAVE,RAD,2),BDEBRE(VAVE,RAD,3))
PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD,3))
VINJMX=PVELIN
AMAXBP=PVELA
GO TO 213
219
AMAXBP=0.0
VINJMX=0.0
REPEAT TO 199 FOR N=1,1+1,...,3
NF=BILDHT(L)-AMANAT(N,N)+1.
REPEAT TO 204 FOR K=1,1+1,...,NF
HTF=K
TH=SQRT(HTF/16.000)
GO TO 204
YES
IS
TH.LT.TMIN
NO
PVELA=BDEBRE(VAVE,RAD,N)
AMAXBP=AMAX1(PVELA,AMAXBP)
PVELIN=BTRANI(VAVE,RAD,N)
VINJMX=AMAX1(PVELIN,VINJMX)
GO TO 199
YES
IS
TH.GT.TMX
NO
204
CONTINUE
199
CONTINUE
213
CONTINUE
NO
IS
AMAXBP.LT.0.0
YES
AMAXBP=0.0
PVELA=AMAXBP
DDEB=PVELA*COMPEX(L)*POBPRO(N)*PPERTB(L,I)/1.E04*(1.-PERCNT(L)/100.)
DINJ=100.-PVELA
NO
IS
PVELA.LE.0.0
YES
DINJ=VINJMX


PROBI(J)=PROBI(J)+DINJ*CONPER(I)*POSPRO(M)*PPERTB(L,I)/1.E8*(1.-PERCWI(I)/100.
ANAXBP.LT.10.
IS
YES
GO TO 210
NO
ANAXBP.LT.90.
IS
YES
GO TO 207
NO
ANAXBP.LT.80.
IS
YES
GO TO 208
NO
PROBDH(J)=PROBDH(J)+DDEB
GO TO 20
208
PROBDD(J)=PROBDD(J)+DDEB
GO TO 20
207
PROBDW(J)=PROBDW(J)+DDEB
GO TO 20
210
PROBDH(J)=PROBDH(J)+DDEB
20
CONTINUE
820
CONTINUE
989
CONTINUE
REPEAT TO 22 FOR J=1,1+1,...,10
PROBII(J)=AMAX1(PROBII(J),PROBI(J))
PROBHD(J)=AMAX1(PROBHD(J),PROBDH(J))
PROBDY(J)=AMAX1(PROBDY(J),PROBDD(J))
PROBWD(J)=AMAX1(PROBWD(J),PROBDW(J))
22
PROBMD(J)=AMAX1(PROBMD(J),PROBDM(J))
200
CONTINUE
KA.EQ.0
IS
YES
GO TO 215
NO
FACT1=DELTD*WDTM/ATOT
REPEAT TO 176 FOR IND=1,1+1,...,10
DIO=DIO+PROBII(IND)*FACT1*PEROUT
DHD=DHD+PROBHD(IND)*FACT1*PEROUT
DDYD=DDYD+PROBDY(IND)*FACT1*PEROUT
DWKD=DWKD+PROBWD(IND)*FACT1*PEROUT
176
DMTD=DMTD+PROBMD(IND)*FACT1*PEROUT
GO TO 220
215
REPEAT TO 216 FOR I=1,1+1,...,5
FACT=AAA(I)/ATOT*PEROUT
INDEX=INDX(I)
REPEAT TO 216 FOR IND=1,1+1,...,INDEX
DIO=DIO+PROBII(IND)*FACT
DHD=DHD+PROBHD(IND)*FACT
DDYD=DDYD+PROBDY(IND)*FACT
DWKD=DWKD+PROBWD(IND)*FACT
216
DMTD=DMTD+PROBMD(IND)*FACT
220
THAX=1.0
REPEAT TO 30 FOR I=1,1+1,...,10
PROBII(I)=0.0
PROBHD(I)=0.0
PROBDY(I)=0.0
PROBWD(I)=0.0
30
PROBMD(I)=0.0
DII=0.0
DH=0.0
DD=0.0
DW=0.0
DM=0.0
TRANSFER TO SUBROUTINE TRANAT
W,POMA,1.0,DIST,VEH,RADIUS,PPERTB,PPERTI,DISTM,VEHM
REPEAT TO 224 FOR J=1,1+1,...,9
REPEAT TO 221 FOR K=1,1+1,...,10

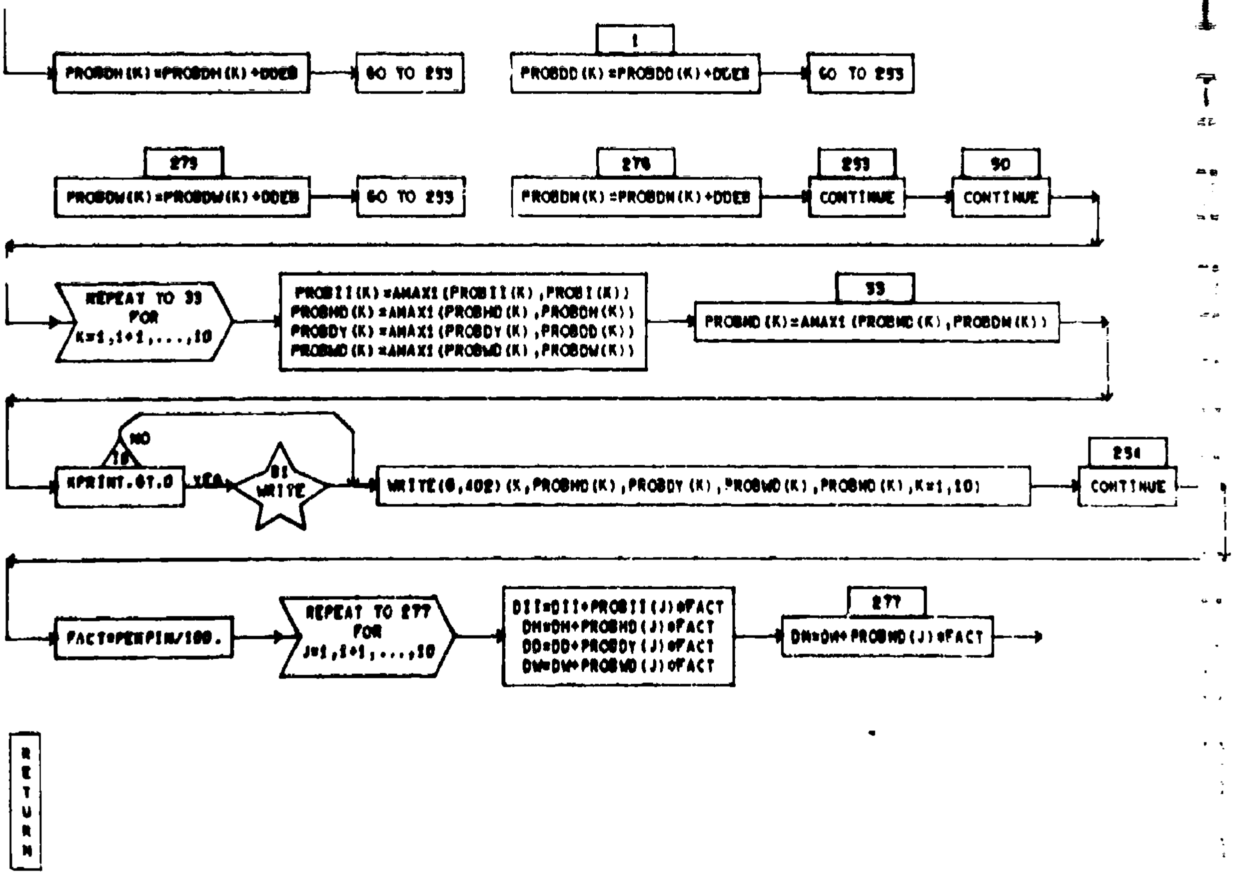

PROBI(K)=0.0
PROBDH(K)=0.0
PROBSO(K)=0.0
PROBUW(K)=0.0
221
PROBDH(K)=0.0
RAD=RADIUS(J)
REPEAT TO 290 FOR I=1,1+1,...,NN
GO TO 290
YES
IS
POMA.LT.PBREAK(I).OR.PPERYB(I,J).LE.0.0
NO
DELTD=ZXRL(I)/10.
ALEN=AMAX1(BILDLT(I),BILOUT(I))
NO
IS
IWALLT(I).EQ.0
YES
DELTD=ALEN/10.
NFLS=NFL(I)
FWT=BILBWT(I)/FLOAT(NFLS)
REPEAT TO 223 FOR K=1,1+1,...,10
DISTI=FLOAT(K)*DELTD
GO TO 290
YES
IS
DISTI.GT.DISTM(J,100)
NO
GO TO 222
YES
IS
DISTI.LT.DISTM(J,1)
NO
REPEAT TO 225 FOR KI=2,2+1,...,100
GO TO 226
YES
IS
DISTI.LT.DISTM(J,KI).AND.DISTI.GT.DISTM(J,KI-1)
NO
225
CONTINUE
222
VAVE=VEHM(J,1)/2.
TMIN=0.0
KI=1
GO TO 227
226
VAVE=(VEHM(J,KI)+VEHM(J,KI-1))*0.5
TMIN=FLOAT(KI-1)*TMAX/100.
227
TMX=TMAX/100.*FLOAT(KI)
REPEAT TO 223 FOR N=1,1+1,...,3
GO TO 228
YES
IS
TMIN.LT.0.07197794
NO
GO TO 229
228
PVELA=AMAX1(BDEBRE(VAVE,RAD,1),BDEBRE(VAVE,RAD,2),BDEBRE(VAVE,RAD,3))
AMAXBP=PVELA
PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD,3))
VINJMX=PVELIN
GO TO 223
229
AMAXBP=0.0
VINJMX=0.0
REPEAT TO 235 FOR N=1,1+1,...,3
NF=(FWT-AMANWT(M,N))*12.+1.
NO
IS
NF.LE.0
YES
NF=1
REPEAT TO 234 FOR KKK=1,1+1,...,NF
HTF=FLOAT(KKK)/12.
TM=SQRT(HTF/16.085)
GO TO 234
YES
IS
TM.LT.TMIN
NO
PVELA=BDEBRE(VAVE,RAD,N)
AMAXBP=AMAX1(PVELA,AMAXBP)
PVELIN=BTRANI(VAVE,RAD,N)
VINJMX=AMAX1(VINJMX,PVELIN)
GO TO 235
YES
IS
TM.GT.TMX
NO


234
CONTINUE
233
CONTINUE
233
CONTINUE
IS
NO
ANAXBP.LT.0.0
YES
ANAXBP=0.0
DDEB=ANAXBP*COMPER(I)*POSPRI(M)*PPERTB(I,J)/1.E9*(1.-PERCWI(I)/100.)
DDEB=DDEB/10.*DELTD/ALEN*10.
PVELA=ANAXBP
DINJ=100.-PVELA
IS
NO
PVELA.LE.0.0
YES
DINJ=VINJMX
PROBI(K)=PROBI(K)+DINJ*COMPER(I)*POSPRI(M)*PPERTB(I,J)/1.E9*(1.-PERCWI(I)/100.
)*DELTD/ALEN*10.
GO TO
240
YES
IS
ANAXBP.LT.10.
NO
GO TO
247
YES
IS
ANAXBP.LT.90.
NO
GO TO
248
YES
IS
ANAXBP.LT.90.
NO
PROBDH(K)=PROBDH(K)+DDEB
GO TO 223
248
PROBDD(K)=PROBDD(K)+DDEB
GO TO 223
247
PROBDW(K)=PROBDW(K)+DDEB
GO TO 223
240
PROBDH(K)=PROBDH(K)+DDEB
223
CONTINUE
230
CONTINUE
REPEAT TO 31
FOR
K=1,1+1,...,10
PROBII(K)=AMAX1(PROBII(K),PROBI(K))
PROBHD(K)=AMAX1(PROBHD(K),PROBDH(K))
PROBDY(K)=AMAX1(PROBDY(K),PROBDD(K))
PROBWD(K)=AMAX1(PROBWD(K),PROBDW(K))
31
PROBMD(K)=AMAX1(PROBMD(K),PROBDH(K))
224
CONTINUE
FACT=PERPIN/100.
REPEAT TO 249
FOR
J=1,1+1,...,10
DII=DII+PROBII(J)*FACT
DH=DH+PROBHD(J)*FACT
DD=DD+PROBDY(J)*FACT
DW=DW+PROBWD(J)*FACT
249
DM=DM+PROBMD(J)*FACT
249
REPEAT TO 32
FOR
J=1,1+1,...,10
PROBII(J)=0.0
PROBHD(J)=0.0
PROBDY(J)=0.0
PROBWD(J)=0.0
32
PROBMC(J)=0.0
REPEAT TO 234
FOR
J=1,1+1,...,9
REPEAT TO 231
FOR
K=1,1+1,...,10
PROBI(K)=0.0
PROBDH(K)=0.0
PROBDD(K)=0.0
PROBDW(K)=0.0
231
PROBDM(K)=0.0
RAD=RADIUS(J)
REPEAT TO 30
FOR
I=1,1+1,...,NN

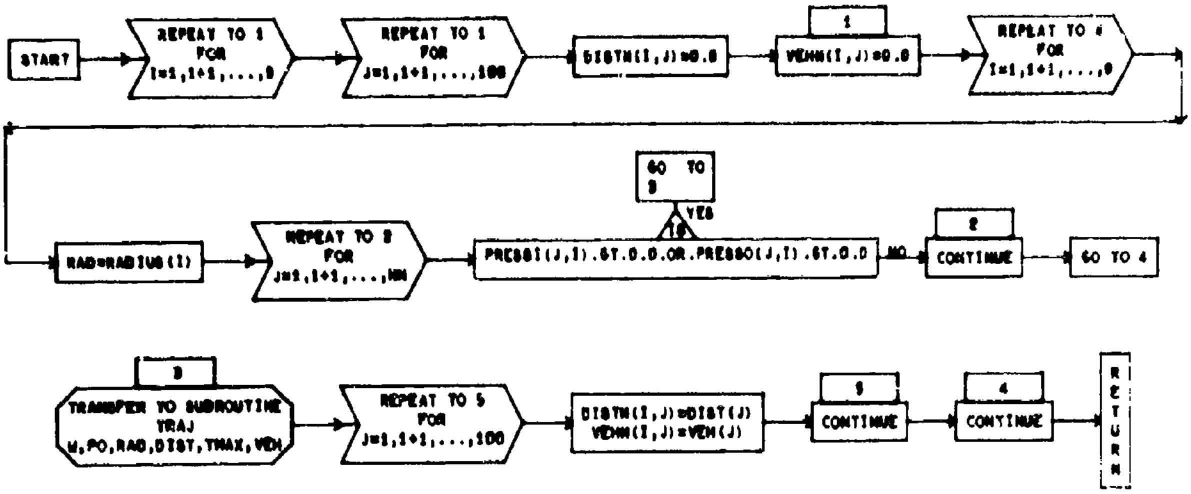

GO TO 91
YES
IF
PONA.LT.PBREAK(I).AND.POBILD(I).GT.BRKMAS.AND.IWALLT(I).NE.0.AND.PPERTI(I,J).G
T.0.0
NO
GO TO 92
YES
IF
PONA.GT.PBREAK(I).AND.PONA.GT.BRKMAS.AND.IWALLT(I).NE.0.AND.PPERTI(I,J).GT.0.0
NO
GO TO 90
91
PP=POBILD(I)
DI WRITE
WRITE(6,991)I
TRANSFER TO SUBROUTINE
TRANAT
W,PP,1.0,DIST,VEM,RADIUS,PPERTI,PPERTI,DISTM1,VEMM1
NO
IF
NPRINT.GT.0.AND.PPERTI(I,J).GT.0.0
YES
DI WRITE
WRITE(6,992)RAD,(II,DISTM1(J,II),VEMM1(J,II),II=1,100)
REPEAT TO 243 FOR II=1,1+1,...,100
REPEAT TO 242 FOR JJ=1,1+1,...,9
DISTM2(JJ,II)=DISTM1(JJ,II)
243
VEMM2(JJ,II)=VEMM1(JJ,II)
GO TO 244
92
REPEAT TO 242 FOR II=1,1+1,...,9
REPEAT TO 242 FOR JJ=1,1+1,...,100
DISTM2(II,JJ)=DISTM(II,JJ)
242
VEMM2(II,JJ)=VEMM(II,JJ)
244
DELTD=AINTRL(I)/10.
ALEN=AMAX1(BILDLT(I),BILDWT(I))
NFLS=NFL(I)
FHT=BILDHT(I)/FLOAT(NFLS)
REPEAT TO 295 FOR K=1,1+1,...,10
DISTI=FLOAT(K)*DELTD
GO TO [illegible]
YES
IF
DISTI.GT.DISTM2(J,100)
NO
GO TO 255
YES
IF
DISTI.LT.DISTM2(J,1)
NO
REPEAT TO 296 FOR KI=2,2+1,...,100
GO TO 297
YES
IF
DISTI.LT.DISTM2(J,KI).AND.DISTI.GT.DISTM2(J,KI-1)
NO
296
CONTINUE
255
VAVE=VEMM2(J,1)/2.
TMIN=0.0
KI=1
GO TO 296

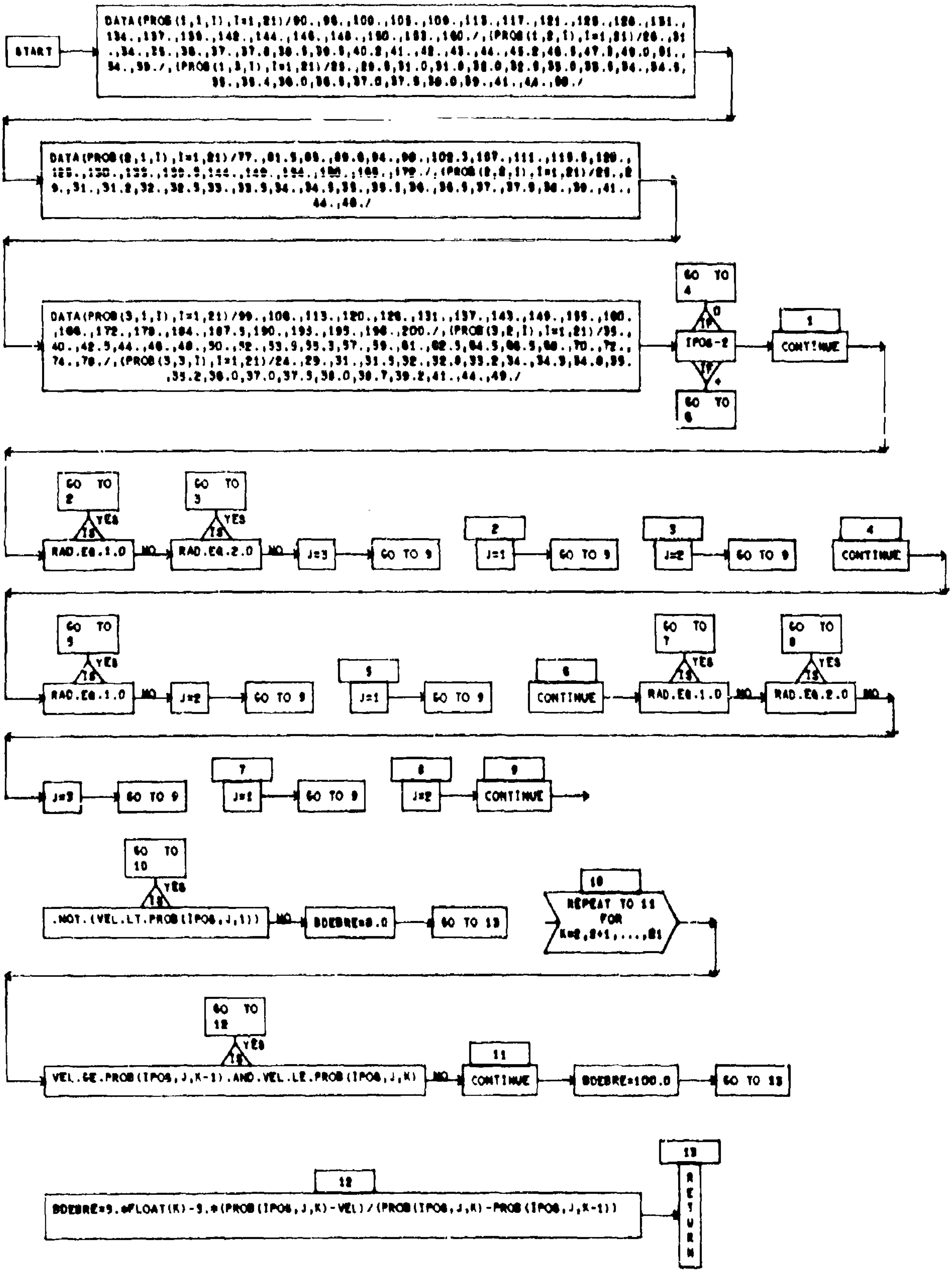

207
TMIN=FLOAT(KI-1)*TMAX/100.
200
TMX=TMAX/100.*FLOAT(KI)
REPEAT TO 800 FOR N=1,1+1,...,3
GO TO 800
YES
IF
TMIN.LT.0.0YIPPT04
NO
GO TO 200
800
PVELA=AMAX1(DDEBRE(VAVE,RAD,1),DDEBRE(VAVE,RAD,2),DDEBRE(VAVE,RAD,3))
AMAXBP=PVELA
PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD,3))
VINJMX=PVELIN
GO TO 271
200
AMAXBP=0.0
VINJMX=0.0
REPEAT TO 270 FOR N=1,1+1,...,3
NF=(FKT-AMANMT(N,M))*12.+1.
NF.LE.0
NO
YES
NF=1
REPEAT TO 274 FOR KKK=1,1+1,...,NF
HTF=FLOAT(KKK)/12.
TH=SQRT(HTF/16.083)
GO TO 274
TH.LT.TMIN
PVELA=DDEBRE(VAVE,RAD,N)
AMAXBP=AMAX1(PVELA,AMAXBP)
PVELIN=BTRANI(VAVE,RAD,N)
VINJMX=AMAX1(PVELIN,VINJMX)
KPRINT.GT.0
B1 WRITE
WRITE(6,400)N,M,TMIN,TH,TMX,HTF,PVELA,AMAXBP
GO TO 270
TH.GT.TMX
274
CONTINUE
270
CONTINUE
273
CONTINUE
AMAXBP.LT.0.0
AMAXBP=0.0
PVELA=AMAXBP
DINJ=100.-PVELA
PVELA.LE.0.0
DINJ=VINJMX
PROBI(K)=PROBI(K)+DINJ*COMPER(I)*POSPRI(M)*PPERTI(I,J)/1.E8*(ALEN-EXRL(I))/ALEN
DDED=AMAXBP*COMPER(I)*POSPRI(M)*PPERTI(I,J)/1.E8
EDED=DDED/10.*(ALEN-EXRL(I))/ALEN
KPRINT.GT.0
B2 WRITE
WRITE(6,401)K,M,AMAXBP,DDED
GO TO 275
AMAXBP.LT.10.
GO TO 275
AMAXBP.LT.50.
GO TO 1
AMAXBP.LT.90.

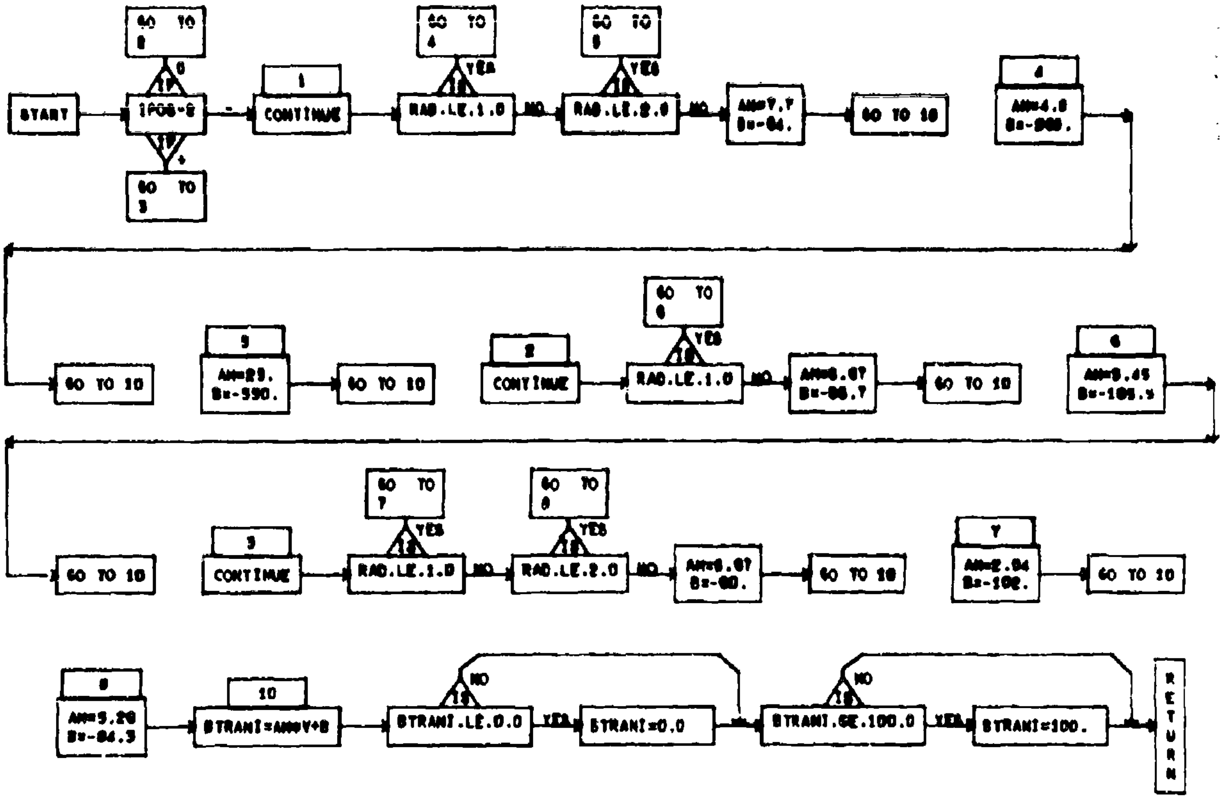
DEBRIS CASUALTY SUBROUTINE PAGE 8



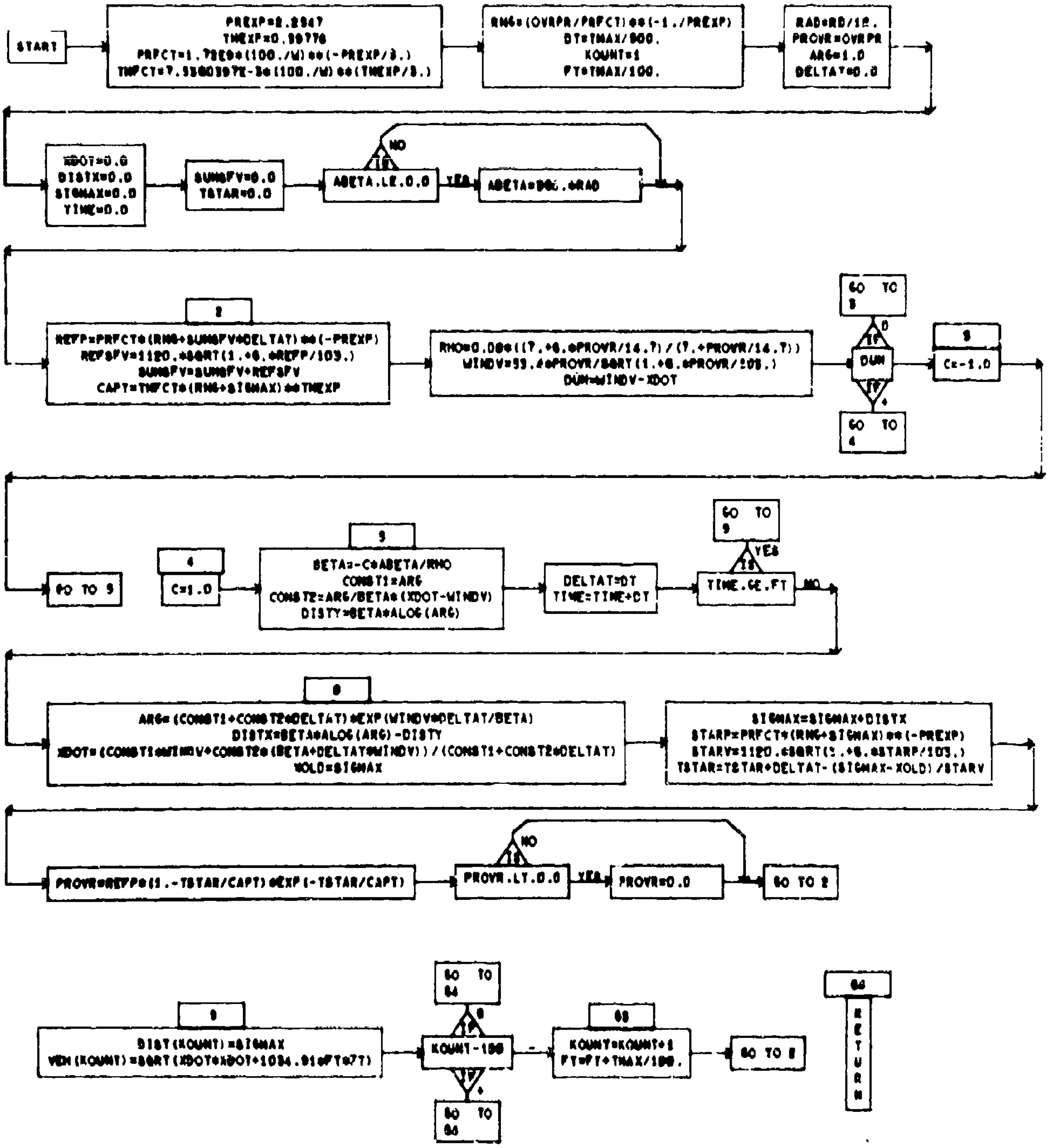
DISPLACEMENT / VELOCITY / TIME RELATIONSHIP FOR DEBRIS PAGE 1



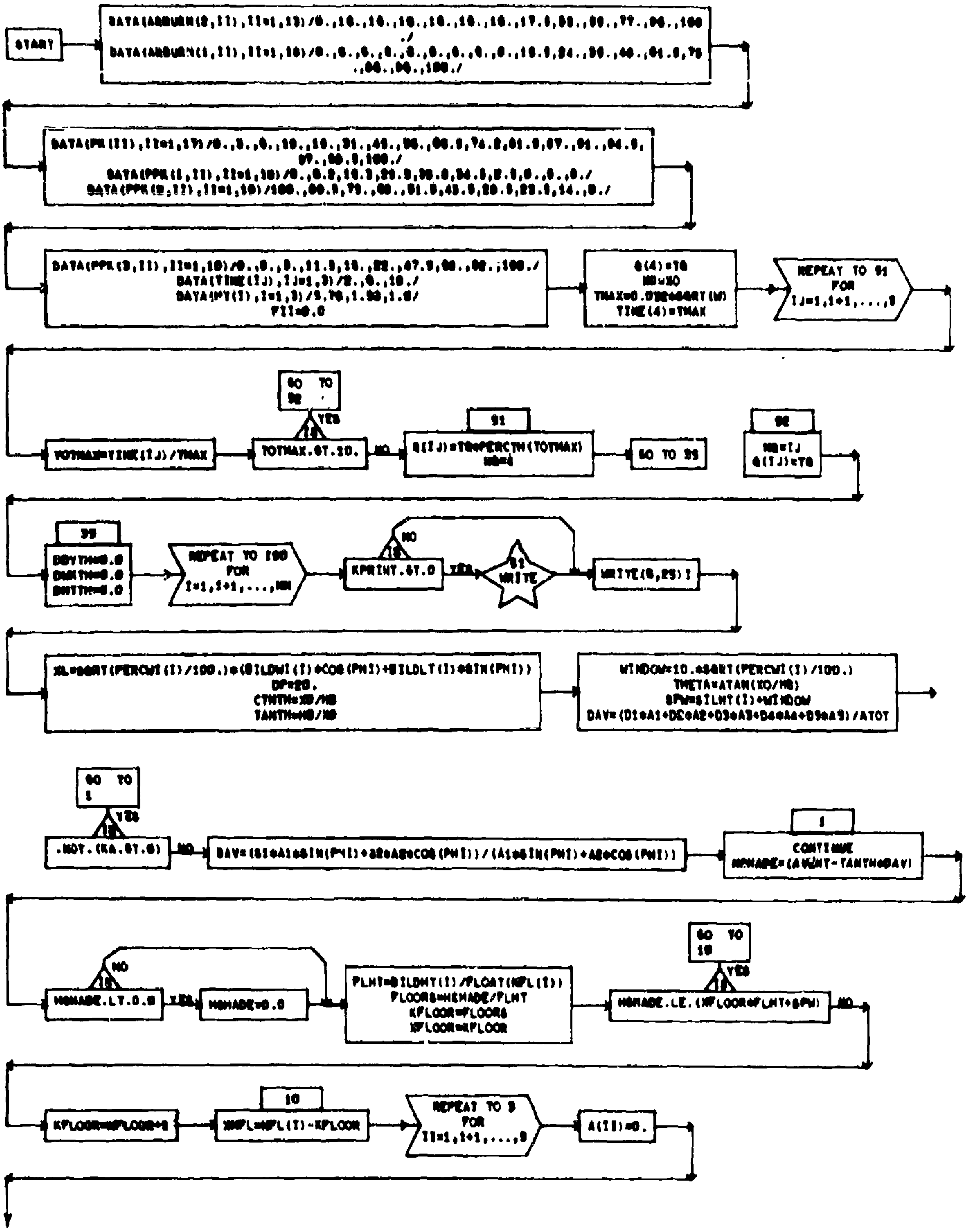

START
DATA(PROB(1,1,I),I=1,21)/90.,98.,100.,103.,108.,113.,117.,121.,125.,128.,131.,
134.,137.,139.,142.,144.,146.,148.,150.,153.,160./,(PROB(1,2,I),I=1,21)/26.,31
.,34.,35.,36.,37.,37.8,38.5,39.5,40.2,41.,42.,43.,44.,45.2,46.5,47.5,49.0,51.,
54.,58./,(PROB(1,3,I),I=1,21)/28.,29.5,31.0,31.8,32.0,32.5,33.0,33.5,34.,34.5,
35.,35.4,36.0,36.5,37.0,37.5,38.0,39.,41.,44.,50./
DATA(PROB(2,1,I),I=1,21)/77.,81.5,85.,89.0,94.,98.,102.3,107.,111.,115.5,120.,
125.,130.,135.,139.5,144.,149.,154.,158.,165.,172./,(PROB(2,2,I),I=1,21)/26.,2
9.,31.,31.2,32.,32.5,33.,33.5,34.,34.5,35.,35.5,36.,36.5,37.,37.5,38.,39.,41.,
44.,48./
DATA(PROB(3,1,I),I=1,21)/99.,106.,113.,120.,126.,131.,137.,143.,149.,155.,160.
,166.,172.,178.,184.,187.5,190.,193.,195.,198.,200./,(PROB(3,2,I),I=1,21)/35.,
40.,42.5,44.,46.,48.,50.,52.,53.9,55.3,57.,59.,61.,62.5,64.5,66.5,68.,70.,72.,
74.,78./,(PROB(3,3,I),I=1,21)/24.,29.,31.,31.5,32.,32.8,33.2,34.,34.5,34.8,35.
,35.2,36.0,37.0,37.5,38.0,38.7,39.2,41.,44.,49./
GO TO 4
0
IF
IPOS-2
IF
+
GO TO 6
1
CONTINUE
GO TO 2
YES
IS
RAD.EQ.1.0
NO
GO TO 3
YES
IS
RAD.EQ.2.0
NO
J=3
GO TO 9
2
J=1
GO TO 9
3
J=2
GO TO 9
4
CONTINUE
GO TO 5
YES
IS
RAD.EQ.1.0
NO
J=2
GO TO 9
5
J=1
GO TO 9
6
CONTINUE
GO TO 7
YES
IS
RAD.EQ.1.0
NO
GO TO 8
YES
IS
RAD.EQ.2.0
NO
J=3
GO TO 9
7
J=1
GO TO 9
8
J=2
9
CONTINUE
GO TO 10
YES
IS
.NOT.(VEL.LT.PROB(IPOS,J,1))
NO
BDEBRE=0.0
GO TO 13
10
REPEAT TO 11
FOR
K=2,2+1,...,21
GO TO 12
YES
IS
VEL.GE.PROB(IPOS,J,K-1).AND.VEL.LE.PROB(IPOS,J,K)
NO
11
CONTINUE
BDEBRE=100.0
GO TO 13
13
RETURN
12
BDEBRE=5.*FLOAT(K)-5.*(PROB(IPOS,J,K)-VEL)/(PROB(IPOS,J,K)-PROB(IPOS,J,K-1))


START
IF
IPOS-2
0
GO TO 2
+
GO TO 3
-
1
CONTINUE
IF
RAD.LE.1.0
YES
GO TO 4
NO
IF
RAD.LE.2.0
YES
GO TO 5
NO
AN=7.7
B=-84.
GO TO 10
4
AN=4.8
B=-300.
GO TO 10
5
AN=23.
B=-550.
GO TO 10
2
CONTINUE
IF
RAD.LE.1.0
YES
GO TO 6
NO
AN=8.07
B=-86.7
GO TO 10
6
AN=8.45
B=-105.5
GO TO 10
3
CONTINUE
IF
RAD.LE.1.0
YES
GO TO 7
NO
IF
RAD.LE.2.0
YES
GO TO 8
NO
AN=6.07
B=-60.
GO TO 10
7
AN=2.84
B=-102.
GO TO 10
8
AN=5.20
B=-84.5
10
BTRANI=AN*V+B
IF
BTRANI.LE.0.0
NO
YES
BTRANI=0.0
IF
BTRANI.GE.100.0
NO
YES
BTRANI=100.
RETURN

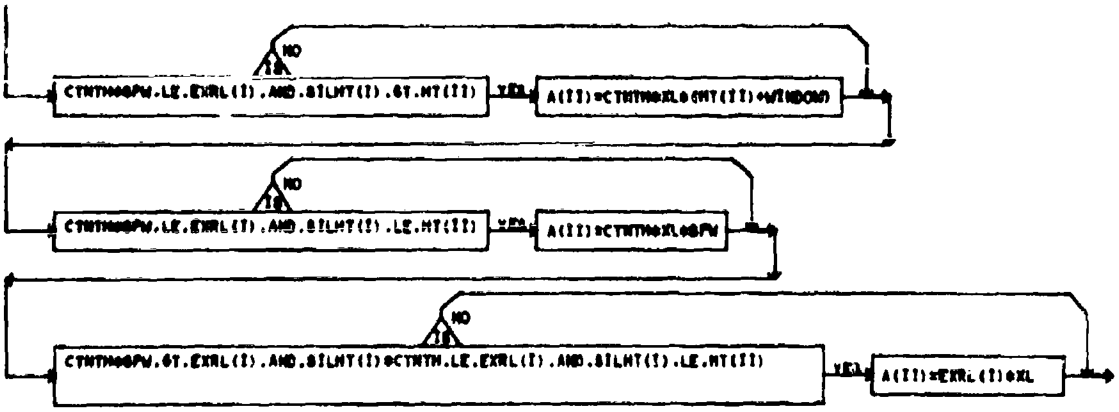
DEBRIS TRAJECTORY CALCULATION SUBROUTINE



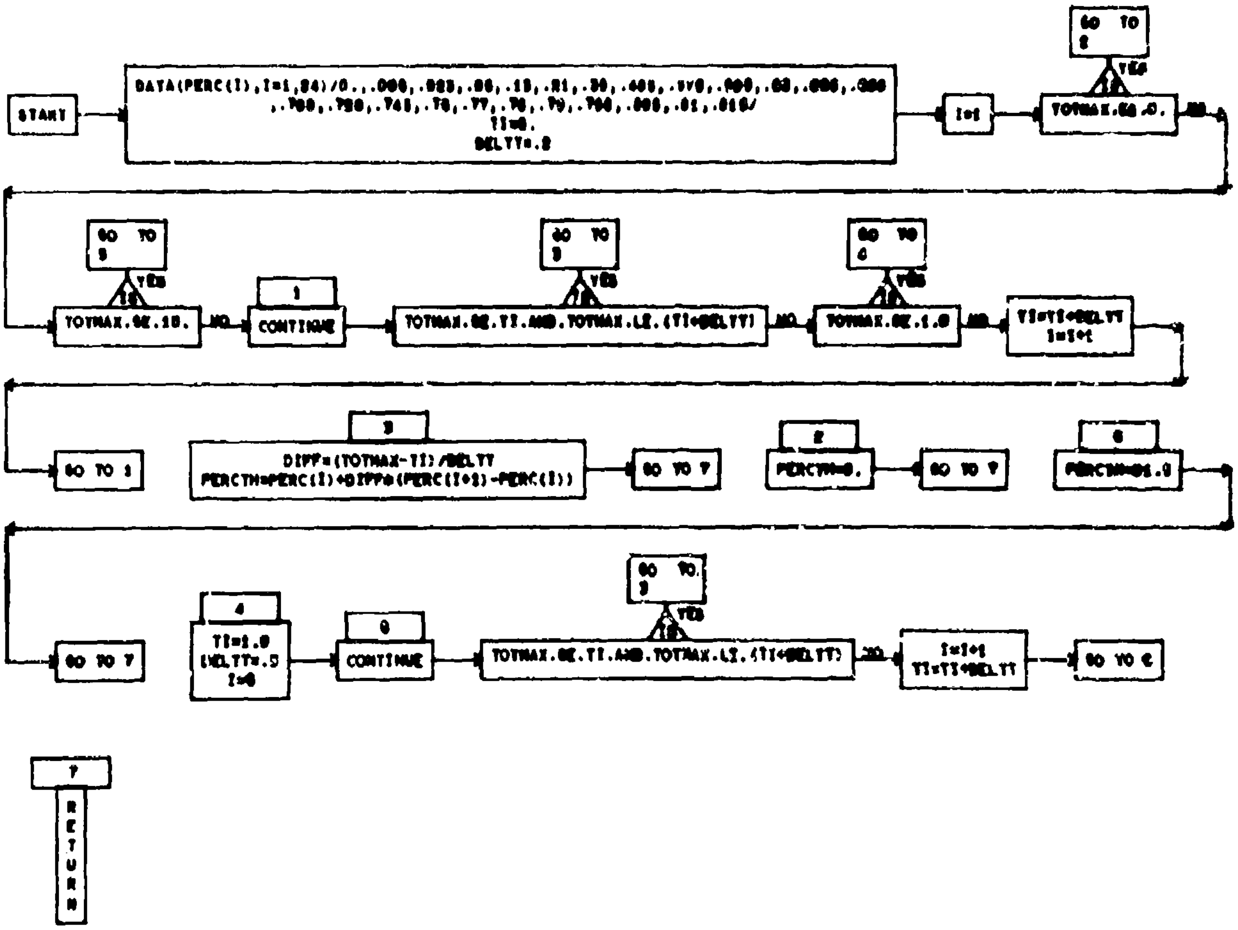
`


START
DATA(ARBURN(2,II),II=1,13)/0.,10.,10.,10.,10.,10.,10.,17.5,33.,50.,77.,96.,100./
DATA(ARBURN(1,II),II=1,18)/0.,0.,0.,0.,0.,0.,0.,0.,0.,10.5,24.,30.,40.,61.5,75.,86.,96.,100./
DATA(PK(II),II=1,17)/0.,3.,6.,10.,19.,31.,45.,56.,66.5,74.2,81.5,87.,91.,94.5,97.,98.5,100./
DATA(PPK(1,II),II=1,10)/0.,6.2,10.3,20.5,30.6,34.1,2.1,0.,0.,0./
DATA(PPK(2,II),II=1,10)/100.,90.5,75.,60.,51.5,45.5,30.5,23.5,14.,0./
DATA(PPK(3,II),II=1,10)/0.,0.,5.,11.5,16.,22.,47.5,60.,82.,100./
DATA(TIME(IJ),IJ=1,3)/2.,5.,10./
DATA(PT(I),I=1,3)/5.75,1.93,1.0/
FII=0.0
Q(4)=TQ
HB=HO
TMAX=0.032*SQRT(W)
TIME(4)=TMAX
REPEAT TO 91 FOR IJ=1,1+1,...,4
TOTMAX=TIME(IJ)/TMAX
TOTMAX.GT.10.
IF
YES
GO TO 92
NO
91
Q(IJ)=TQ*PERCTM(TOTMAX)
NN=4
GO TO 35
92
NN=IJ
Q(IJ)=TQ
35
DBYTHM=0.0
DAKTHM=0.0
DNTTHM=0.0
REPEAT TO 100 FOR I=1,1+1,...,NN
KPRINT.GT.0
IF
NO
YES
51 WRITE
WRITE(6,25) I
XL=SQRT(PERCWI(I)/100.)*(BILDWI(I)*COS(PHI)+BILDLT(I)*SIN(PHI))
DP=20.
CTNTH=XO/HB
TANTH=HB/XO
WINDOW=10.*SQRT(PERCWI(I)/100.)
THETA=ATAN(XO/HB)
SPW=SILHT(I)+WINDOW
DAV=(D1*A1+D2*A2+D3*A3+D4*A4+D5*A5)/ATOT
.NOT.(KA.GT.0)
IF
YES
GO TO 1
NO
DAV=(S1*A1*SIN(PHI)+S2*A2*COS(PHI))/(A1*SIN(PHI)+A2*COS(PHI))
1
CONTINUE
HSHADE=(AVGHT-TANTH*DAV)
HSHADE.LT.0.0
IF
NO
YES
HSHADE=0.0
FLHT=BILDHT(I)/FLOAT(NFL(I))
FLOORS=HSHADE/FLHT
KFLOOR=FLOORS
XFLOOR=KFLOOR
HSHADE.LE.(XFLOOR*FLHT+SPW)
IF
YES
GO TO 10
NO
KFLOOR=KFLOOR+1
10
XNFL=NFL(I)-KFLOOR
REPEAT TO 5 FOR II=1,1+1,...,5
A(II)=0.

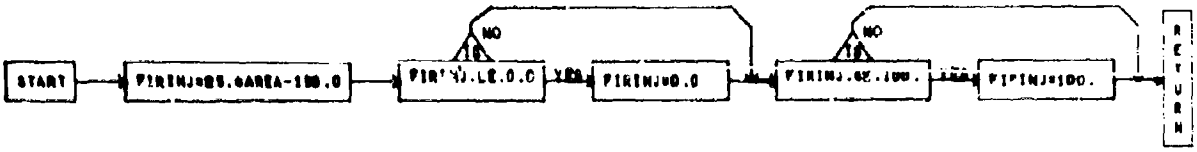
THERMAL CASUALTY PROGRAM PAGE 2



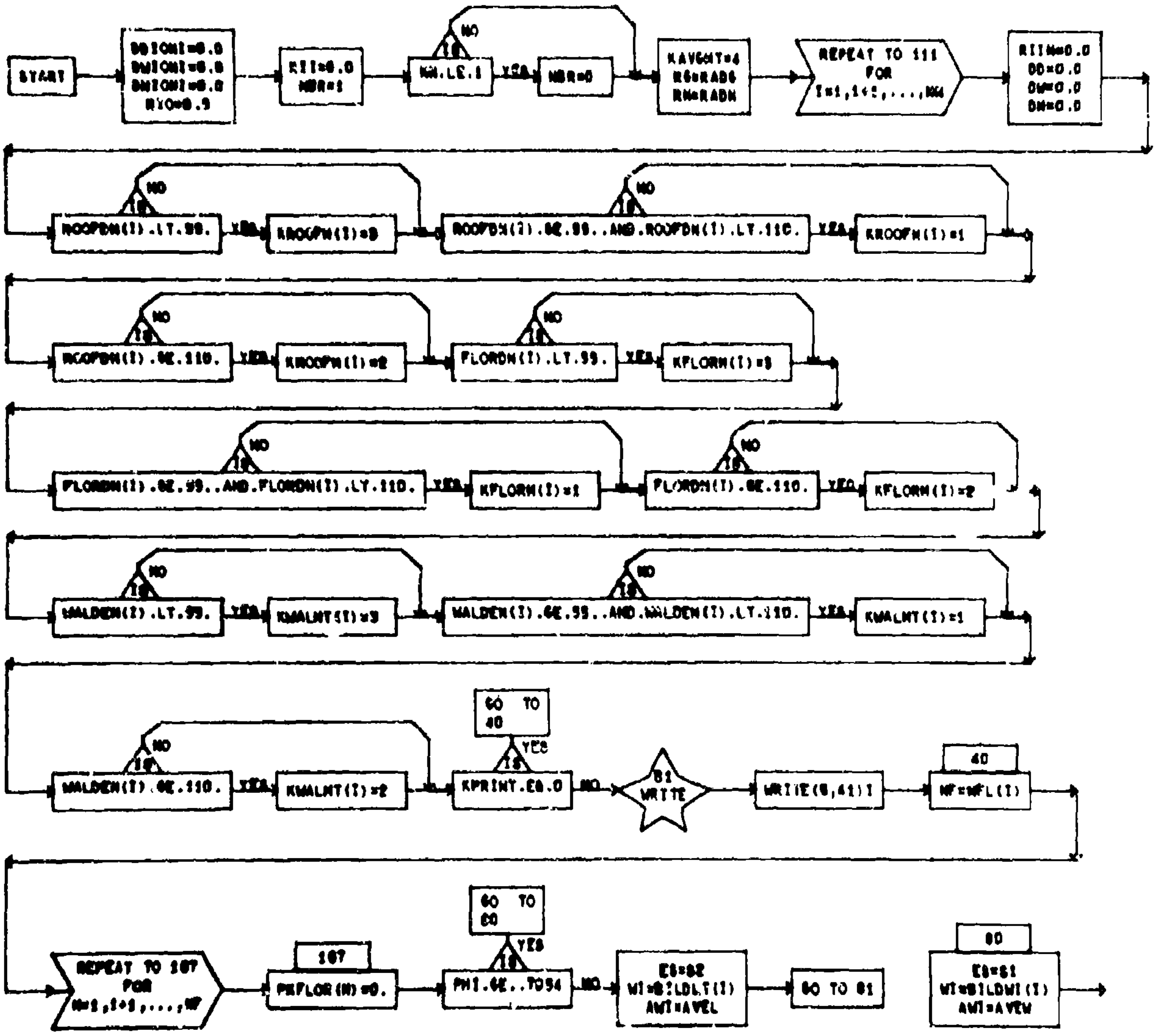
THERMAL ENERGY ATTENUATION WITH TIME FUNCTION PAGE 1

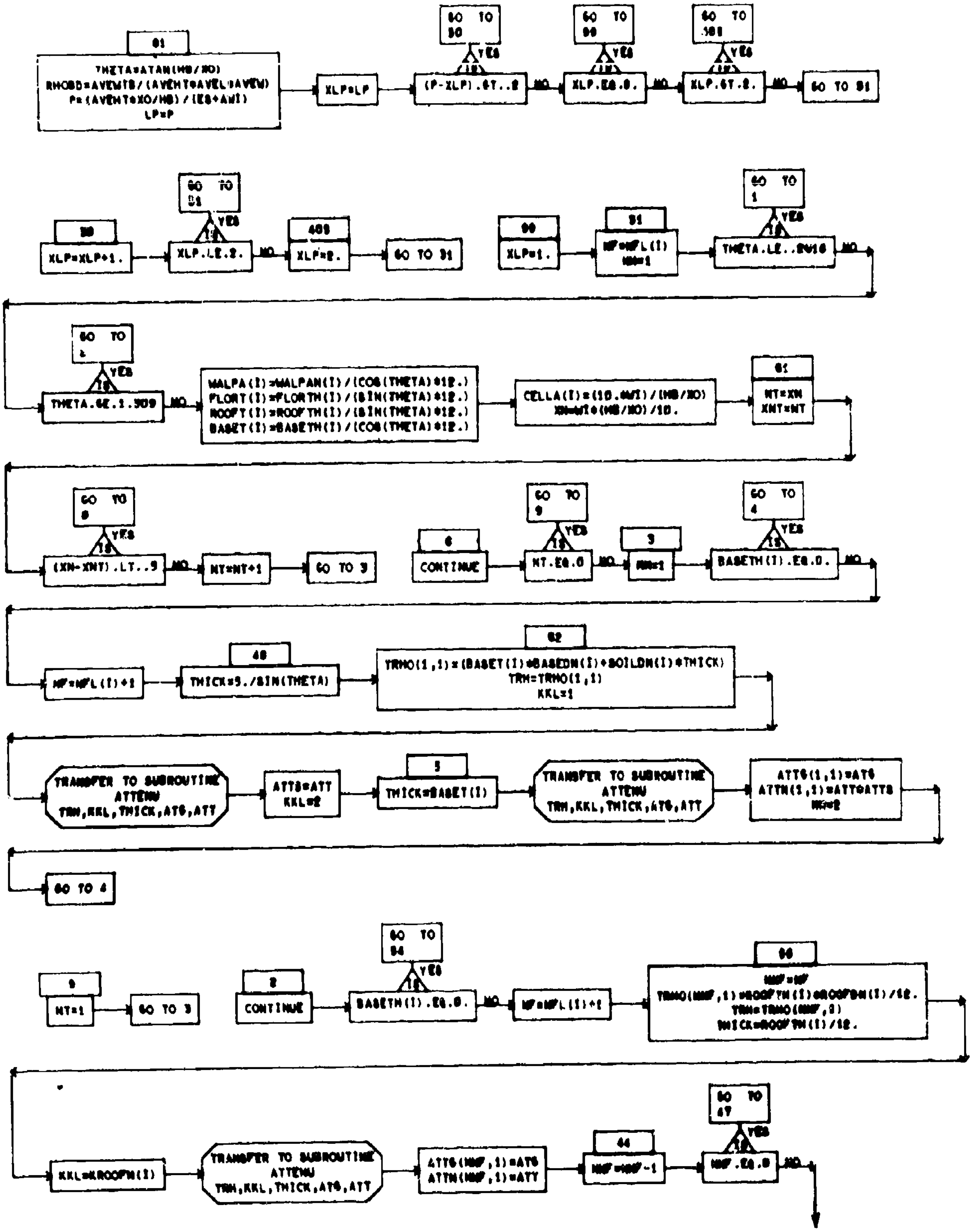


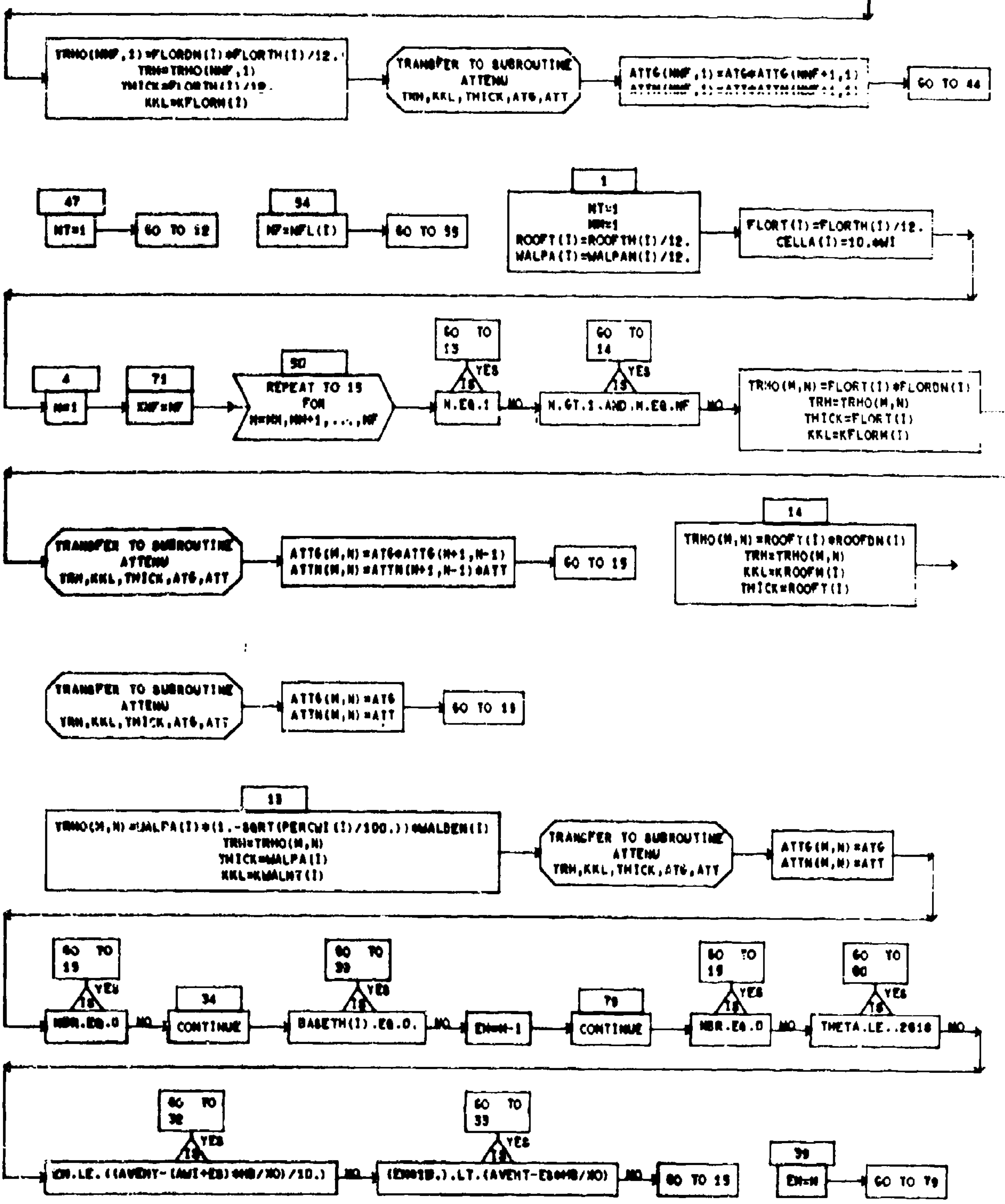
INJURY FROM THERMAL ENERGY FUNCTION PAGE 1

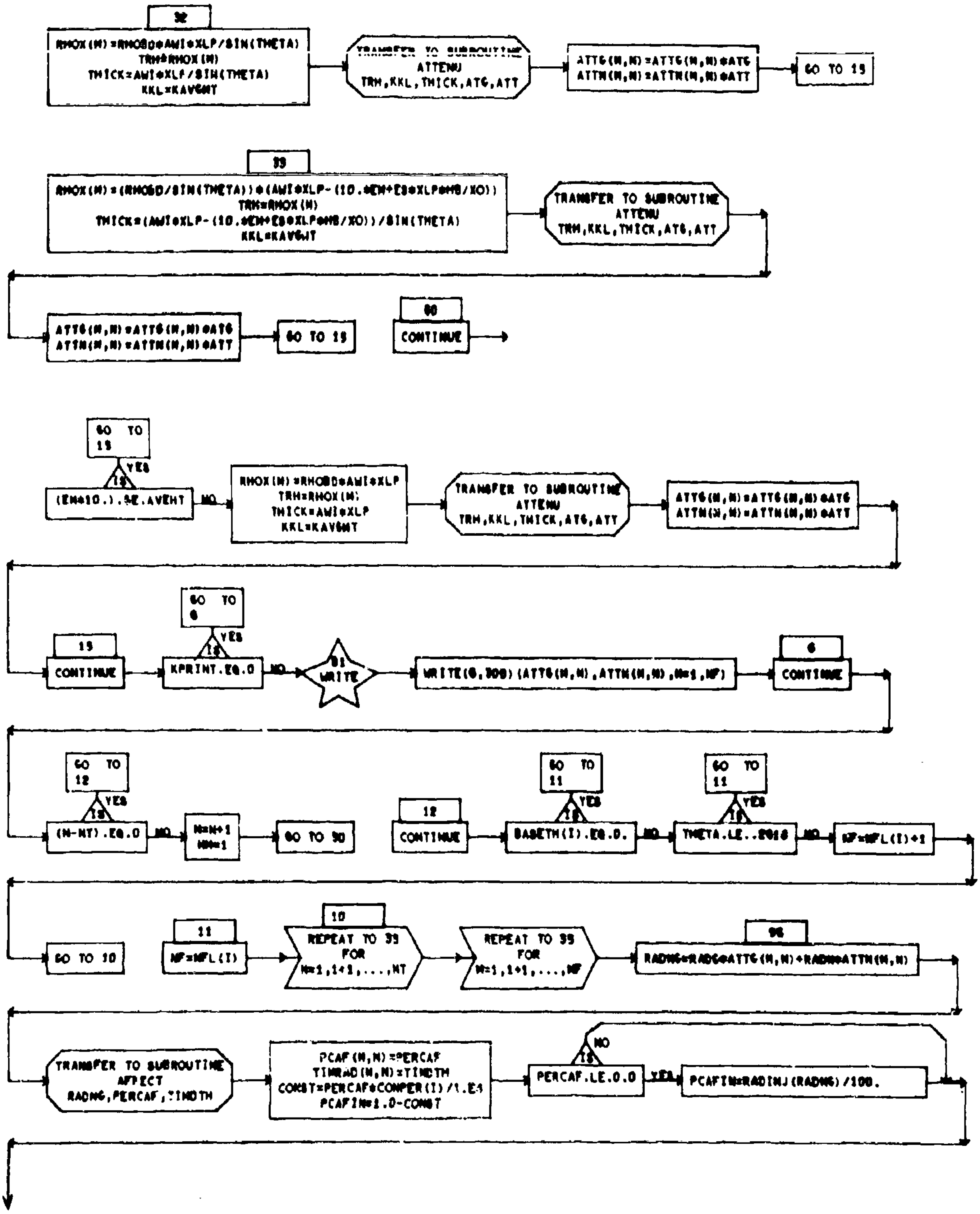


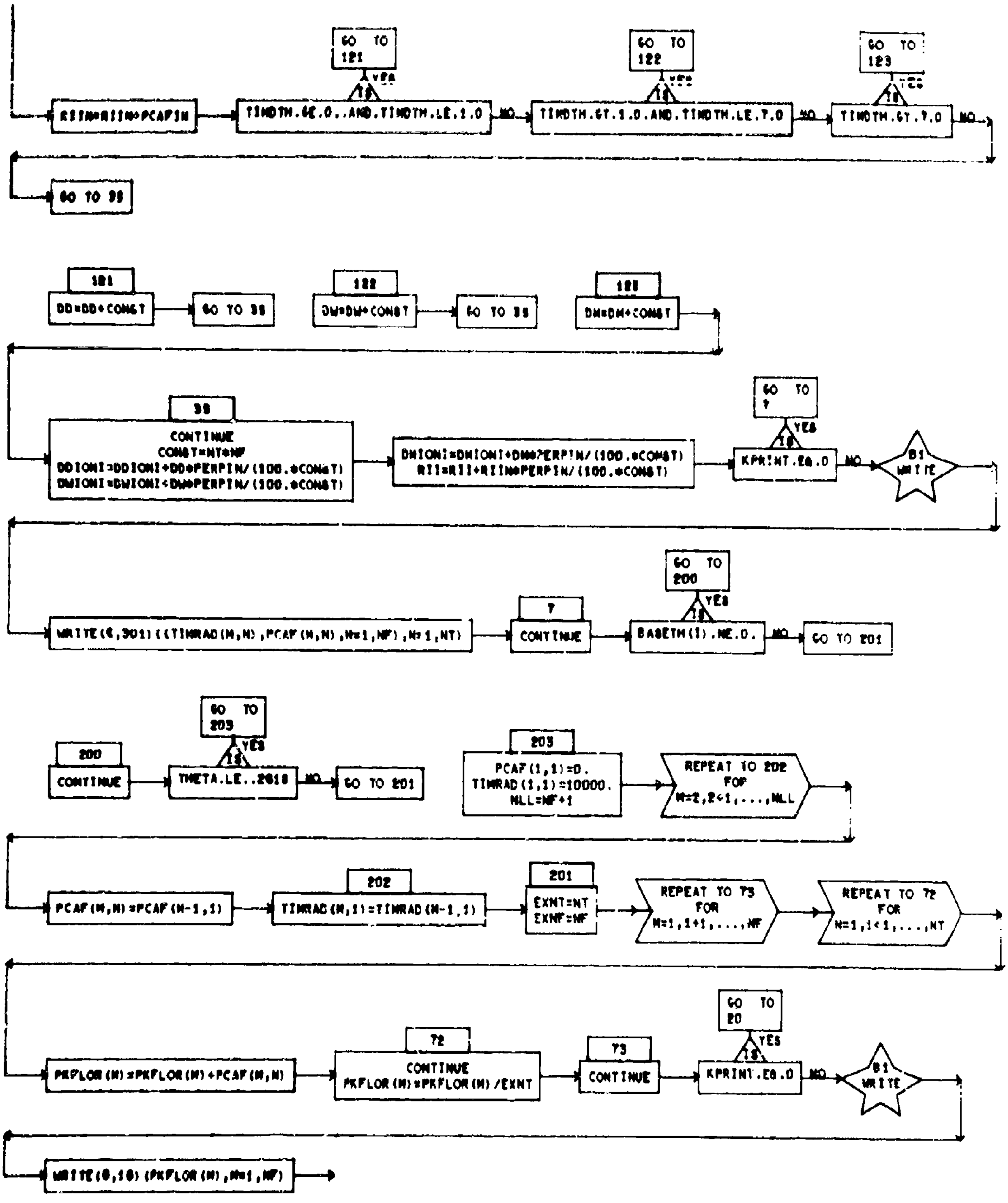
IONIZING RADIATION CASUALTY PROGRAM PAGE 1

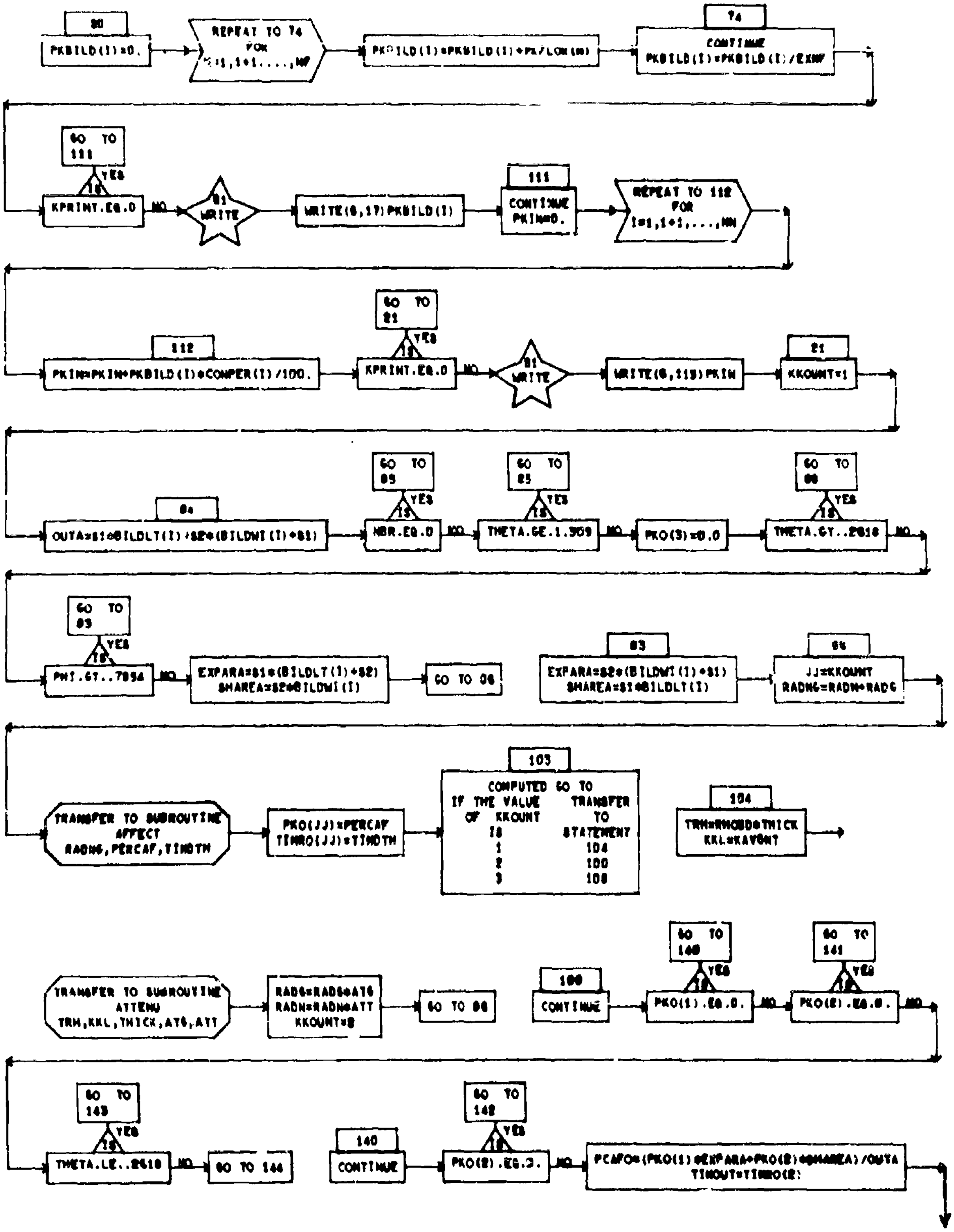


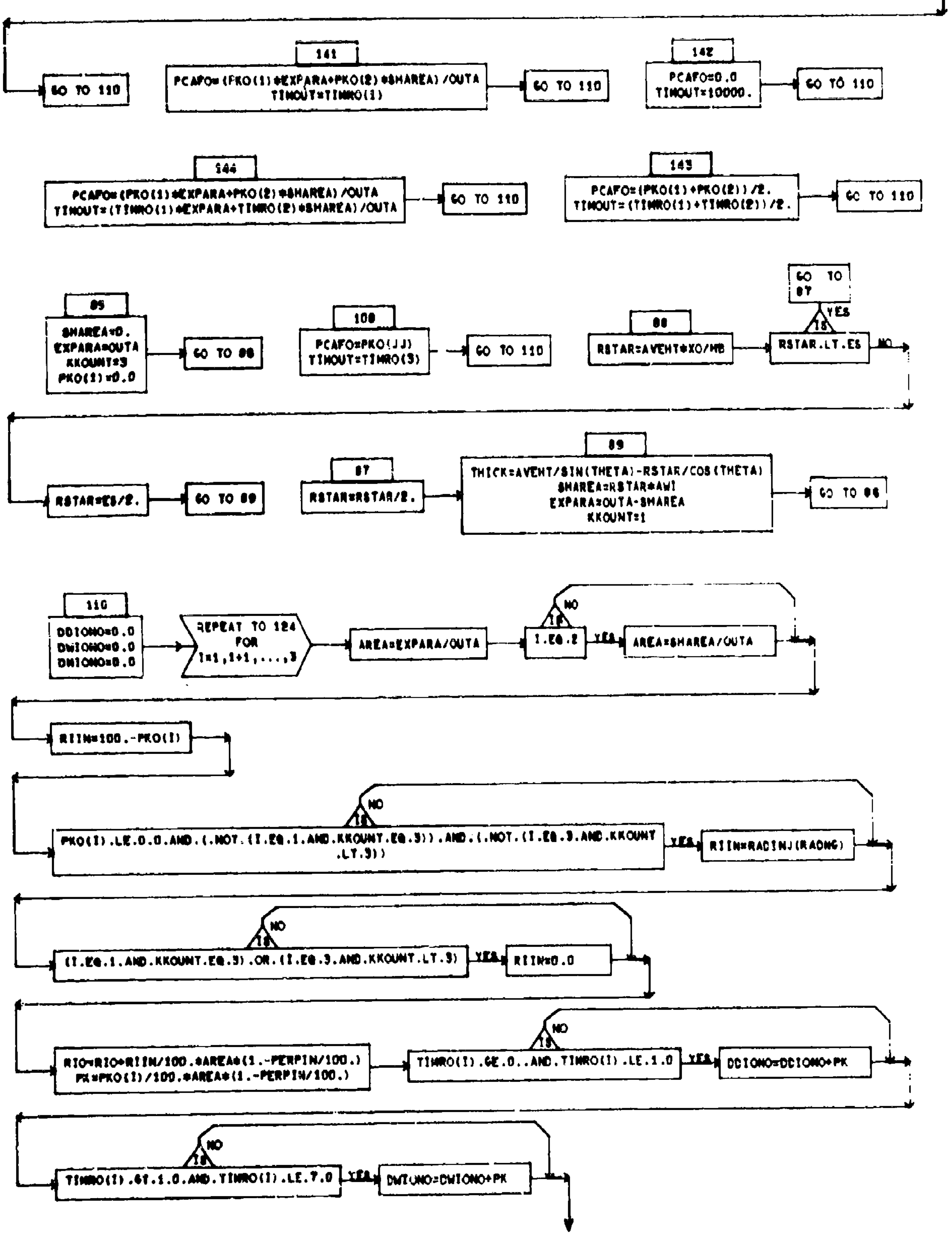

81
THETA=ATAN(HB/XO)
RHOBD=AVEWTB/(AVEHT*AVEL*AVEW)
P=(AVEHT*XO/HB)/(ES+AWI)
LP=P
XLP=LP
(P-XLP).GT..2
GO TO 30
YES
IS
NO
XLP.EQ.0.
GO TO 90
XLP.GT.2.
GO TO 301
GO TO 31
30
XLP=XLP+1.
XLP.LE.2.
GO TO 31
403
XLP=2.
GO TO 31
90
XLP=1.
31
NF=NFL(I)
NN=1
THETA.LE..2618
GO TO 1
GO TO 2
THETA.GE.1.309
WALPA(I)=WALPAN(I)/(COS(THETA)*12.)
FLORT(I)=FLORTH(I)/(SIN(THETA)*12.)
ROOFT(I)=ROOFTH(I)/(SIN(THETA)*12.)
BASET(I)=BASETH(I)/(COS(THETA)*12.)
CELLA(I)=(10.*WI)/(HB/XO)
XN=WI*(HB/XO)/10.
61
NT=XN
XNT=NT
GO TO 8
(XN-XNT).LT..5
NT=NT+1
GO TO 3
8
CONTINUE
GO TO 9
NT.EQ.0
3
NN=1
GO TO 4
BASETH(I).EQ.0.
NF=NFL(I)+1
48
THICK=5./SIN(THETA)
62
TRHO(1,1)=(BASET(I)*BASEDN(I)+SOILDN(I)*THICK)
TRH=TRHO(1,1)
KKL=1
TRANSFER TO SUBROUTINE ATTENU TRH,KKL,THICK,ATG,ATT
ATTS=ATT
KKL=2
5
THICK=BASET(I)
TRANSFER TO SUBROUTINE ATTENU TRH,KKL,THICK,ATG,ATT
ATTG(1,1)=ATG
ATTN(1,1)=ATT*ATTS
NN=2
GO TO 4
9
NT=1
GO TO 3
2
CONTINUE
GO TO 84
BASETH(I).EQ.0.
NF=NFL(I)+1
86
NNF=NF
TRHO(NNF,1)=ROOFTH(I)*ROOFDN(I)/12.
TRH=TRHO(NNF,1)
THICK=ROOFTH(I)/12.
KKL=KROOFN(I)
TRANSFER TO SUBROUTINE ATTENU TRH,KKL,THICK,ATG,ATT
ATTG(NNF,1)=ATG
ATTN(NNF,1)=ATT
44
NNF=NNF-1
GO TO 47
NNF.EQ.0

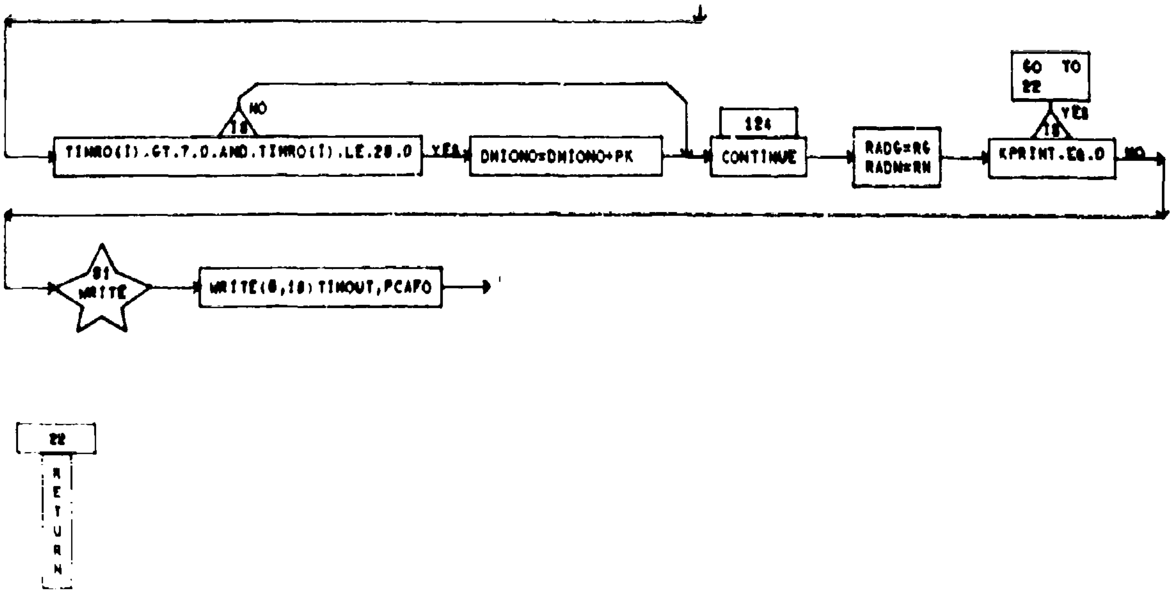

TRHO(NNF,1)=FLORDN(I)*FLORTH(I)/12.
TRH=TRHO(NNF,1)
THICK=FLORTH(I)/12.
KKL=KFLORM(I)
TRANSFER TO SUBROUTINE
ATTENU
TRH,KKL,THICK,ATG,ATT
ATTG(NNF,1)=ATG*ATTG(NNF+1,1)
ATTN(NNF,1)=ATT*ATTN(NNF+1,1)
GO TO 44
47
NT=1
GO TO 12
54
NF=NFL(I)
GO TO 55
1
NT=1
NN=1
ROOFT(I)=ROOFTH(I)/12.
WALPA(I)=WALPAN(I)/12.
FLORT(I)=FLORTH(I)/12.
CELLA(I)=10.*WI
4
M=1
71
KNF=NF
50
REPEAT TO 15
FOR
N=NN,NN+1,...,NF
GO TO 13
YES
IS
N.EQ.1
NO
GO TO 14
YES
IS
N.GT.1.AND.N.EQ.NF
NO
TRHO(M,N)=FLORT(I)*FLORDN(I)
TRH=TRHO(M,N)
THICK=FLORT(I)
KKL=KFLORM(I)
TRANSFER TO SUBROUTINE
ATTENU
TRH,KKL,THICK,ATG,ATT
ATTG(M,N)=ATG*ATTG(M+1,N-1)
ATTN(M,N)=ATTN(M+1,N-1)*ATT
GO TO 15
14
TRHO(M,N)=ROOFT(I)*ROOFDN(I)
TRH=TRHO(M,N)
KKL=KROOFM(I)
THICK=ROOFT(I)
TRANSFER TO SUBROUTINE
ATTENU
TRH,KKL,THICK,ATG,ATT
ATTG(M,N)=ATG
ATTN(M,N)=ATT
GO TO 15
13
TRHO(M,N)=WALPA(I)*(1.-SQRT(PERCWI(I)/100.))*WALDEN(I)
TRH=TRHO(M,N)
THICK=WALPA(I)
KKL=KWALMT(I)
TRANCFER TO SUBROUTINE
ATTENU
TRH,KKL,THICK,ATG,ATT
ATTG(M,N)=ATG
ATTN(M,N)=ATT
GO TO 15
YES
IS
NBR.EQ.0
NO
34
CONTINUE
GO TO 39
YES
IS
BASETH(I).EQ.0.
NO
EN=M-1
79
CONTINUE
GO TO 15
YES
IS
NBR.EQ.0
NO
GO TO 80
YES
IS
THETA.LE..2618
NO
GO TO 32
YES
IS
EN.LE.((AVENT-(AWI+EB)*HB/XO)/10.)
NO
GO TO 33
YES
IS
(EN*10.).LT.(AVENT-EB*HB/XO)
NO
GO TO 15
39
EN=M
GO TO 79


32
RHOX(M)=RHOBD*AWI*XLP/SIN(THETA)
TRM=RHOX(M)
THICK=AWI*XLP/SIN(THETA)
KKL=KAVGHT
TRANSFER TO SUBROUTINE
ATTENU
TRM,KKL,THICK,ATG,ATT
ATTG(M,N)=ATTG(M,N)*ATG
ATTN(M,N)=ATTN(M,N)*ATT
GO TO 15
33
RHOX(M)=(RHOBD/SIN(THETA))*(AWI*XLP-(10.*EM+ES*XLP*HB/XO))
TRM=RHOX(M)
THICK=(AWI*XLP-(10.*EM+ES*XLP*HB/XO))/SIN(THETA)
KKL=KAVGHT
TRANSFER TO SUBROUTINE
ATTENU
TRM,KKL,THICK,ATG,ATT
ATTG(M,N)=ATTG(M,N)*ATG
ATTN(M,N)=ATTN(M,N)*ATT
GO TO 15
80
CONTINUE
GO TO 15
YES
IS
(EM*10.).GE.AVEHT
NO
RHOX(M)=RHOBD*AWI*XLP
TRM=RHOX(M)
THICK=AWI*XLP
KKL=KAVGHT
TRANSFER TO SUBROUTINE
ATTENU
TRM,KKL,THICK,ATG,ATT
ATTG(M,N)=ATTG(M,N)*ATG
ATTN(M,N)=ATTN(M,N)*ATT
15
CONTINUE
GO TO 6
YES
IS
KPRINT.EQ.0
NO
B1
WRITE
WRITE(6,300)(ATTG(M,N),ATTN(M,N),N=1,NF)
6
CONTINUE
GO TO 12
YES
IS
(M-NT).EQ.0
NO
M=M+1
NM=1
GO TO 30
12
CONTINUE
GO TO 11
YES
IS
BASETH(I).EQ.0.
NO
GO TO 11
YES
IS
THETA.LE..2618
NO
NF=NFL(I)+1
GO TO 10
11
NF=NFL(I)
10
REPEAT TO 33
FOR
M=1,1+1,...,NT
REPEAT TO 33
FOR
N=1,1+1,...,NF
96
RADNG=RADG*ATTG(M,N)+RADN*ATTN(M,N)
TRANSFER TO SUBROUTINE
AFFECT
RADNG,PERCAF,TIMOTH
PCAF(M,N)=PERCAF
TIMRAD(M,N)=TIMDTH
CONST=PERCAF*CONPER(I)/1.E4
PCAFIN=1.0-CONST
NO
IS
PERCAF.LE.0.0
YES
PCAFIN=RADINJ(RADNG)/100.

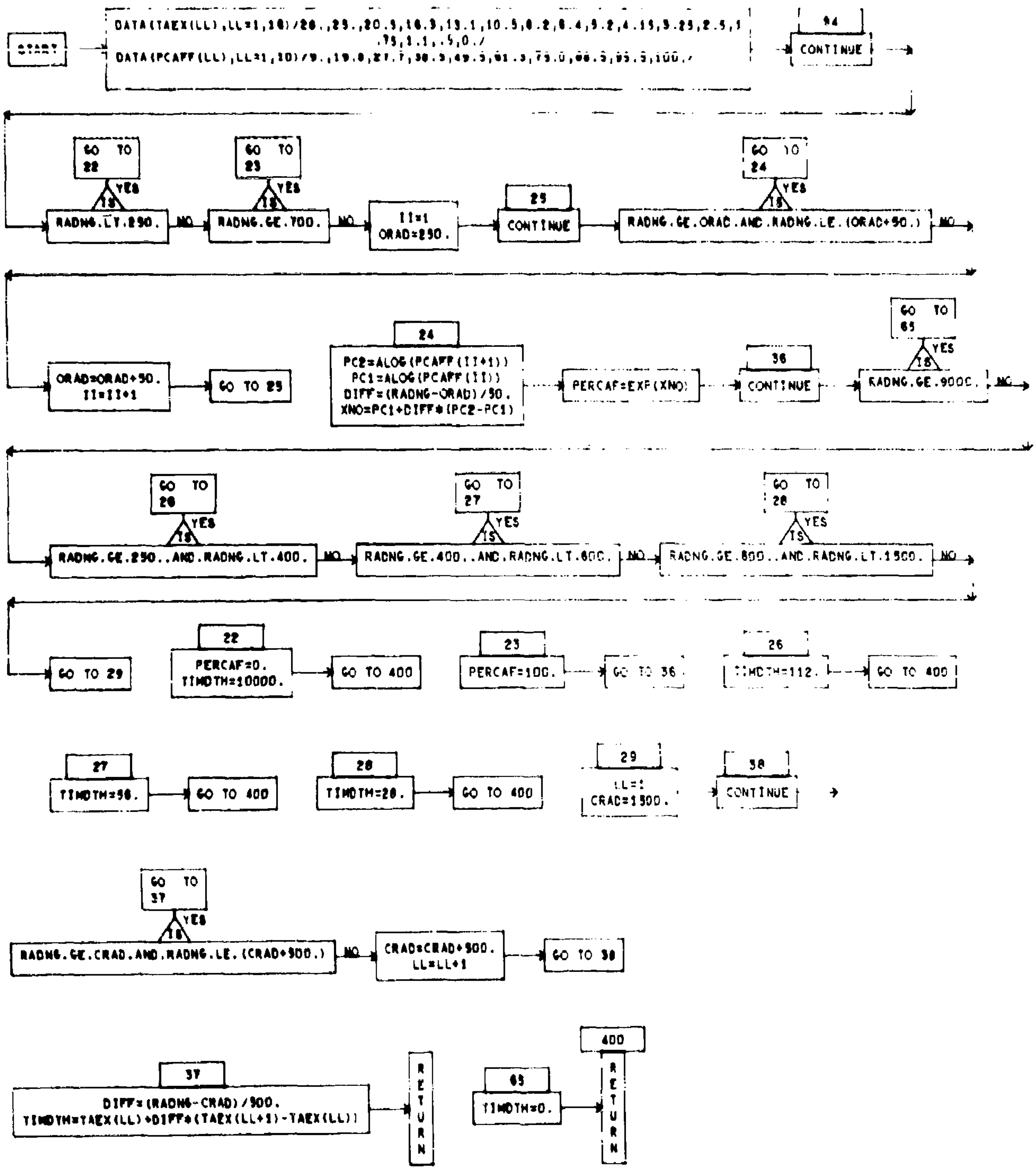

RIIN=RIIN+PCAFIN
GO TO 121
YES
IS
TIMDTH.GE.0..AND.TIMDTH.LE.1.0
NO
GO TO 122
YES
IS
TIMDTH.GT.1.0.AND.TIMDTH.LE.7.0
NO
GO TO 123
YES
IS
TIMDTH.GT.7.0
NO
GO TO 35
121
DD=DD+CONST
GO TO 35
122
DW=DW+CONST
GO TO 35
123
DW=DW+CONST
35
CONTINUE
CONST=NT*NF
DDIONI=DDIONI+DD*PERPIN/(100.*CONST)
DWIONI=DWIONI+DW*PERPIN/(100.*CONST)
DNIONI=DNIONI+DN*PERPIN/(100.*CONST)
RII=RII+RIIN*PERPIN/(100.*CONST)
GO TO 7
YES
IS
KPRINT.EQ.0
NO
B1
WRITE
WRITE(6,301)((TIMRAD(M,N),PCAF(M,N),M=1,NF),N=1,NT)
7
CONTINUE
GO TO 200
YES
IS
BASETH(I).NE.0.
NO
GO TO 201
200
CONTINUE
GO TO 203
YES
IS
THETA.LE..2618
NO
GO TO 201
203
PCAF(1,1)=0.
TIMRAD(1,1)=10000.
NLL=NF+1
REPEAT TO 202
FOR
M=2,2+1,...,NLL
PCAF(M,N)=PCAF(M-1,1)
202
TIMRAD(M,1)=TIMRAD(M-1,1)
201
EXNT=NT
EXNF=NF
REPEAT TO 73
FOR
M=1,1+1,...,NF
REPEAT TO 72
FOR
N=1,1+1,...,NT
PKFLOR(M)=PKFLOR(M)+PCAF(M,N)
72
CONTINUE
PKFLOR(M)=PKFLOR(M)/EXNT
73
CONTINUE
GO TO 20
YES
IS
KPRINT.EQ.0
NO
B1
WRITE
WRITE(6,10)(PKFLOR(M),M=1,NF)


80
PKBILD(I)=0.
REPEAT TO 74 FOR I=1,1+1,...,NF
PKBILD(I)=PKBILD(I)+PK/LOW(M)
74
CONTINUE
PKBILD(I)=PKBILD(I)/EXNF
GO TO 111
YES
IS
KPRINT.EQ.0
NO
81 WRITE
WRITE(6,17)PKBILD(I)
111
CONTINUE
PKIN=0.
REPEAT TO 112 FOR I=1,1+1,...,NN
112
PKIN=PKIN+PKBILD(I)*CONPER(I)/100.
GO TO 21
YES
IS
KPRINT.EQ.0
NO
81 WRITE
WRITE(6,115)PKIN
21
KKOUNT=1
84
OUTA=S1*BILDLT(I)+S2*(BILDWI(I)+S1)
GO TO 83
YES
IS
NBR.EQ.0
NO
GO TO 85
YES
IS
THETA.GE.1.309
NO
PKO(3)=0.0
GO TO 86
YES
IS
THETA.GT..2618
NO
GO TO 83
YES
IS
PHI.GT..7854
NO
EXPARA=S1*(BILDLT(I)+S2)
SHAREA=S2*BILDWI(I)
GO TO 86
83
EXPARA=S2*(BILDWI(I)+S1)
SHAREA=S1*BILDLT(I)
86
JJ=KKOUNT
RADNG=RADN+RADG
TRANSFER TO SUBROUTINE AFFECT
RADNG,PERCAF,TIMOTH
PKO(JJ)=PERCAF
TIMRO(JJ)=TIMOTH
103
COMPUTED GO TO
IF THE VALUE OF KKOUNT IS
TRANSFER TO STATEMENT
1 104
2 100
3 108
104
TRH=RHOBD*THICK
KKL=KAVGNT
TRANSFER TO SUBROUTINE ATTENU
TRH,KKL,THICK,ATG,ATT
RADG=RADG*ATG
RADN=RADN*ATT
KKOUNT=2
GO TO 86
100
CONTINUE
GO TO 140
YES
IS
PKO(1).EQ.0.
NO
GO TO 141
YES
IS
PKO(2).EQ.0.
NO
GO TO 143
YES
IS
THETA.LE..2618
NO
GO TO 144
140
CONTINUE
GO TO 142
YES
IS
PKO(2).EQ.3.
NO
PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
TIMOUT=TIMRO(2)


GO TO 110
141
PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
TIMOUT=TIMRO(1)
GO TO 110
142
PCAFO=0.0
TIMOUT=10000.
GO TO 110
144
PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
TIMOUT=(TIMRO(1)*EXPARA+TIMRO(2)*SHAREA)/OUTA
GO TO 110
143
PCAFO=(PKO(1)+PKO(2))/2.
TIMOUT=(TIMRO(1)+TIMRO(2))/2.
GO TO 110
85
SHAREA=0.
EXPARA=OUTA
KKOUNT=3
PKO(1)=0.0
GO TO 88
100
PCAFO=PKO(JJ)
TIMOUT=TIMRO(3)
GO TO 110
88
RSTAR=AVENT*XO/HB
IS
RSTAR.LT.ES
YES
GO TO 87
NO
RSTAR=ES/2.
GO TO 89
87
RSTAR=RSTAR/2.
89
THICK=AVENT/SIN(THETA)-RSTAR/COS(THETA)
SHAREA=RSTAR*AWI
EXPARA=OUTA-SHAREA
KKOUNT=1
GO TO 88
110
DDIONO=0.0
DWIONO=0.0
DNIONO=0.0
REPEAT TO 124
FOR
I=1,I+1,...,3
AREA=EXPARA/OUTA
IS
I.EQ.2
NO
YES
AREA=SHAREA/OUTA
RIIN=100.-PKO(I)
IS
PKO(I).LE.0.0.AND.(.NOT.(I.EQ.1.AND.KKOUNT.EQ.3)).AND.(.NOT.(I.EQ.3.AND.KKOUNT
.LT.3))
NO
YES
RIIN=RADINJ(RADNG)
IS
(I.EQ.1.AND.KKOUNT.EQ.3).OR.(I.EQ.3.AND.KKOUNT.LT.3)
NO
YES
RIIN=0.0
RIO=RIO+RIIN/100.*AREA*(1.-PERPIN/100.)
PK=PKO(I)/100.*AREA*(1.-PERPIN/100.)
IS
TIMRO(I).GE.0..AND.TIMRO(I).LE.1.0
NO
YES
DDIONO=DDIONO+PK
IS
TIMRO(I).GT.1.0.AND.TIMRO(I).LE.7.0
NO
YES
DWIONO=DWIONO+PK

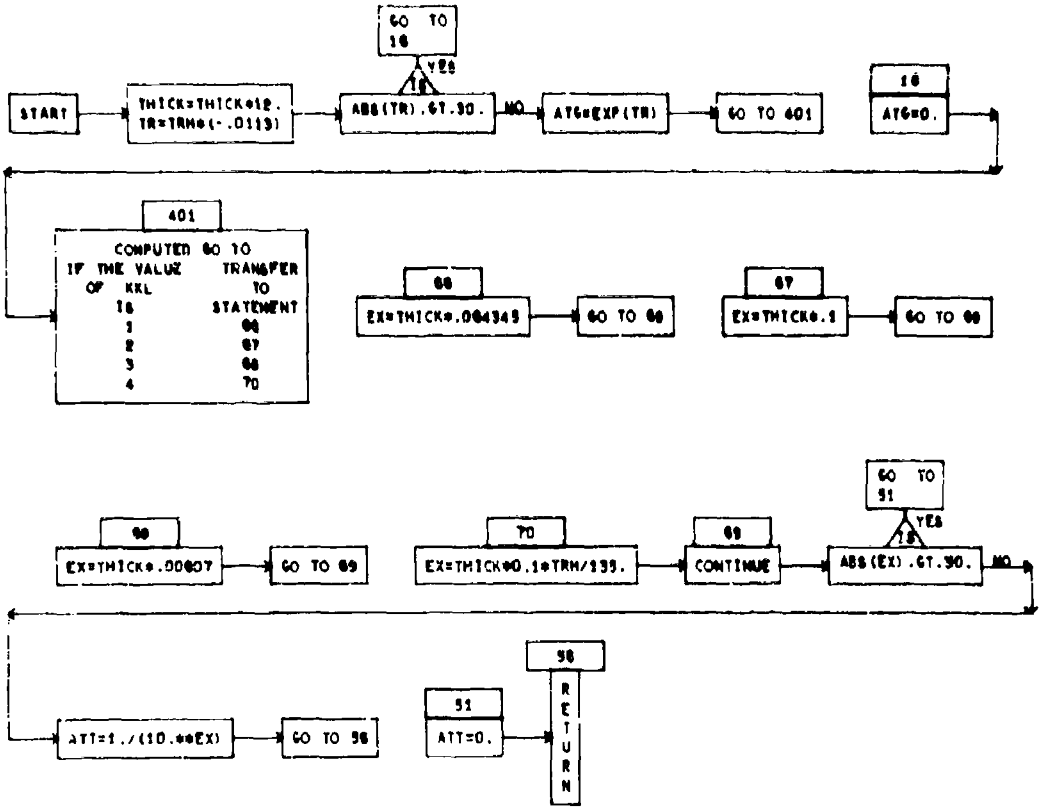

IF
NO
TIMRO(I).GT.7.0.AND.TIMRO(I).LE.28.0
YES
DNIONO=DNIONO+PK
124
CONTINUE
RADG=RG
RADN=RN
GO TO 22
YES
IF
KPRINT.EQ.0
NO
81
WRITE
WRITE(6,18) TINOUT,PCAFO
22
RETURN

TIME OF DEATH AS A FUNCTION OF RADIATION DOSE PAGE 1



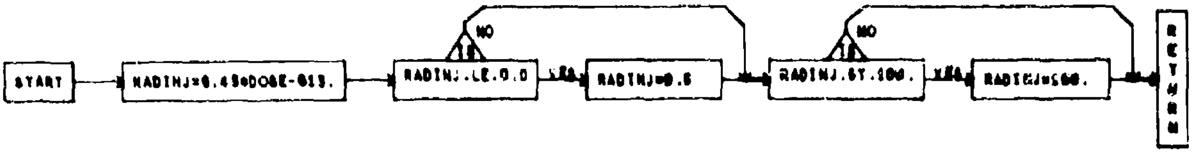
ATTENUATION OF IONIZING RADIATION FUNCTION

PAGE 1



INJURY FROM IONIZING RADIATION FUNCTION

PAGE 5



APPENDIX IV

PROGRAM LISTINGS

```
$IBFTC MAIND    M94,XP7
      COMMON/BLK1/TS,PREE,PFTS,PD,TO,CDF,QO,WOU,TB,PBTR,CDR
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PFRPIN,     POPDN,REACSI,REACST,REACLY
      COMMON/BLK5/ TA,CU,PWV,PDYP,PREF
      COMMON/BLK6/ PO,    TQ,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK8/ PPERTB(10,9),PPERTI(10,9),BRKMAS
      COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
     1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
      COMMON /BLK10/ NHILL,HX(10),HY(10),HILLHT(10),HILLL(10),HILLW(10)
      COMMON /BLK11/ WALPAN(10),WALDEN(10),FLORTH(10),FLORDN(10),ROOFTH(
     110),ROOFDN(10),BASETH(10),BASEDN(10),SOILDN(10),SILHT(10),PERSCR(1
     20),PERSG(10),PERGG(10),PERUBS(10),PERG(10),PERDE(10),PERGGS(10)
      COMMON /BLK12/ DDYTHI,DWKTHI,DMTTHI,DDYTHO,DWKTHO,DMTTHO
      COMMON/BLK13/ AVEWTB,RADG,RADN,DHBO,DDBO,DMBO,DHBI,DDBI,DMBI,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LIST8(9),ABETA,IAC
C
C     START NEW PROBLEM
C
  400 WRITE(6,100)
  100 FORMAT(1H1)
C
C     SET KPRINT=0 UNLESS THIS IS CHANGED NO CONDITIONAL OUTPUT TAKES
C     PLACE
C
      KPRINT=0
C
C     READ IN PROBLEM DATA
C
      CALL INPUT(KPRINT)
C
C     CALCULATE AVERAGE GEOMETRIC QUANTITIES AND SPECIAL NODE AREAS
C
      CALL GEOMET(KPRINT)
C
C     CALCULATE ALL FREE FIELD WEAPON EFFECTS
C
      CALL EFFECT(KPRINT)
C
C     PRINT ALL WEAPON EFFECTS INFORMATION
C
```

```
      WRITE(6,88)     XO,PO,TO,TA
   88 FORMAT(40H1DISTANCE FROM GROUND ZERO TO NODE POINT,    3H IS,F10.0,
     14H FT./41H0FREE FIELD OVERPRESSURE AT NODE POINT IS,F7.2, 4H PSI/
     241H0POSITIVE PHASE DURATION AT NODE POINT IS,F8.3,4H SEC/30H0ARRIV
     3AL TIME AT NODE POINT IS,F8.3,4H SEC)
      WRITE(6,90) TQ
   90 FORMAT(30H0THERMAL ENERGY AT NODE POINT=,F10.2,10H CAL/CM**2)
      WRITE(6,91) RI
   91 FORMAT(34H0IONIZING RADIATION IN(RAD) UNITS=,F10.2,5H RADS)
      WRITE(6,116) PONA
  116 FORMAT(30H0ATTENUATED NODE OVERPRESSURE=,F6.1,4H PSI)
  117 WRITE(6,118)   (POBILD(I),I,I=1,NN)
  118 FORMAT(1H0,F6.1,25H PSI WITHIN BUILDING TYPE,I3)
      WRITE(6,89) CU,PWV,PDYP,PREF
   89 FORMAT(16H0SHOCK VELOCITY=,F10.2,4H FPS/20H0PEAK WIND VELOCITY=,F1
     10.2,4H FPS/23H0PEAK DYNAMIC PRESSURE=,F10.2,4H PSI/20H0REFLECTED P
     2RESSURE=,F10.2,4H PSI)
C
C     CALCULATE CASUALTIES DUE TO BLAST ALONE
C
      IF(ISKIP(1).EQ.0) CALL BLAST(KPRINT)
C
C     CALCULATE CASUALTIES DUE TO BLAST TRANSLATION
C
      IF(ISKIP(2).EQ.0) CALL BLSDIS(KPRINT)
C
C     CALCULATE CASUALTIES DUE TO BLAST DEBRIS
C
      IF(ISKIP(3).EQ.0) CALL DEBRIS(KPRINT)
C
C     CALCULATE CASUALTIES DUE TO THERMAL RADIATION
C
      IF(ISKIP(4).EQ.0) CALL THERM(KPRINT)
C
C     CALCULATE CASUALTIES DUE TO IONIZING RADIATION
C
      IF(ISKIP(5).EQ.0) CALL NUCLAR(KPRINT)
C
C     PRINT SUMMARY OF INDIVIDUAL KILL MECHANISMS
C
      WRITE(6,300) DHBI,DDBI,DMBI,DHBO,DDBO,DMBO,DHTI,DDYTI,DWKTI,DMTHTI
     1,TII
      WRITE(6,301) DHTO,DDYTO,DWKTO,DMTHTO,TIO,DH,DD,DW,DM,DII,DHD,DDYD,
     1DWKD,DMTD,DIO,DDYTHI,DWKTHI,DMTTHI,FII
      WRITE(6,302) DDYTHO,DWKTHO,DMTTHO,FIO,DDIONI,DWIONI,DMIONI,RII,
     1DDIONO,DWIONO,DMIONO,RIO
  300 FORMAT(73H1INDIVIDUAL EFFECT MATRIX FOR FATALITIES AND INJURIES (F
     2RACTION OF TOTAL),///1H ,88(1H+),/9H + EFFECT,21X,59H+ DEAD HOUR +
     3 DEAD DAY + DEAD WEEK + DEAD MONTH + INJURED +,/1H ,88(1H+),/15H +
     4 INDOOR BLAST,15X,4H+   ,F5.2,6H    +  ,F5.2,4H   +,11X,4H+   ,F5.2
```

```
     5,4X,1H+,9X,1H+,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,1H+,9X,1H
     6+,/16H + OUTDOOR BLAST,14X,4H+    ,F5.2,6H    +  ,F5.2,4H    +,11X,4H
     7+    ,F5.2,4X,1H+,9X,1H+,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,
     81H+,9X,1H+,/21H + INDOOR TRANSLATION,9X,4H+    ,F5.2,6H    +  ,2(F5.
     92,7H    +    ),F5.2,4X,3H+   ,F5.2,3H   +)
 301 FORMAT(2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,1H+,9X,1H+,/22H +
     2OUTDOOR TRANSLATION,8X,4H+    ,F5.2,6H    +   ,2(F5.2,7H    +    ),F5.2
     3,4X,3H+   ,F5.2,3H   +,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,1H+
     4,9X,1H+,/16H + INDOOR DEBRIS,14X,4H+    ,F5.2,6H    +   ,2(F5.2,7H
     5+    ),F5.2,4X,3H+   ,F5.2,3H   +,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1
     6H+,12X,1H+,9X,1H+,/17H + OUTDOOR DEBRIS,13X,4H+    ,F5.2,6H    +   ,2
     7(F5.2,7H    +    ),F5.2,4X,3H+   ,F5.2,3H   +,/2H +,28X,1H+,11X,1H+,10
     8X,1H+,11X,1H+,12X,1H+,9X,1H+,/31H + INDOOR THERMAL RADIATION    +,1
     91X,3H+   ,2(F5.2,7H    +    ),F5.2,4X,3H+   ,F5.2,3H   +)
 302 FORMAT(2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,1H+,9X,1H+,/31H +
     2OUTDOOR THERMAL RADIATION   +,11X,3H+   ,2(F5.2,7H    +    ),F5.2,4X,3
     3H+   ,F5.2,3H   +,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12X,1H+,9X,1
     4H+,/31H + INDOOR IONIZING RADIATION   +,11X,3H+   ,2(F5.2,7H    +    )
     5,F5.2,4X,3H+   ,F5.2,3H   +,/2H +,28X,1H+,11X,1H+,10X,1H+,11X,1H+,12
     6X,1H+,9X,1H+,/31H + OUTDOOR IONIZING RADIATION +,11X,3H+   ,2(F5.2,
     77H    +    ),F5.2,4X,3H+   ,F5.2,3H   +,/1H ,88(1H+))
C     DESCRIBE POST ATTACK CONDITION OF STRUCTURES AT NODE
C
      IF(ISKIP(6).EQ.0) CALL BIL IS
C
C     COMBINE EFFECTS AND PRINT RESULTS
C
      CALL COMBNE
C
C     PROBLEM IS FINISHED EITHER CHANGE PARAMETERS OF GO ON TO NEXT NODE
C
      GO TO 400
      END
```

```
$IBFTC DAT
      BLOCK DATA
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,WA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,     POPDN,REACSI,REACST,REACLY
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWT(10),POSPRO(3),POSPRI(3),NFL(10),AINTPL(10),EXPL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK8/ PPERTB(10,9),PPERTI(10,9),BRKMAS
      COMMON /BLK10/ NHILL,HX(10),HY(10),HILLHT(10),HILLL(10),HILLW(10)
      COMMON /BLK11/ WALPAN(10),WALDEN(10),FLORTH(10),FLORDN(10),ROOFTH(
     110),ROOFDN(10),BASETH(10),BASEDN(10),SOILDN(10),SILHT(10),PERSCR(1
     20),PERSG(10),PERGG(10),PERDBS(10),PERG(10),PERDE(10),PERGGS(10)
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LISTA(9),ABETA,IAC
      DATA (LIST1(I),I=1,6)/5,6HOYIELD,6HFISSIO,6HHEIGHT,6HGROUND,6HOONE
     1XT/
      DATA (LIST2(I),I=1,9) /8,6HOOOAIR,6HVISIDI,6HNUMBER,6HOOHILL,6HHEI
     1GHT,6HSEASON,6HOOTIME,6HOONEXT/
      DATA(LIST3(I),I=1,31)/30,6HNUMBER,6HLOCATI,6HBUILDI,6HCONSTR,6HWEI
     1GHT,6HHEIGHT,6HLENGTH,6HOWIDTH,6HAVERAG,6HOONEXT,
     2                                          6HOOAREA,6HOOWALL,6HDE
     3NSIT,6HOFLOOR,6HMATERI,6HOOROOF,6HBASEME,6HOOSOIL,6HSTORIE,6HWINDO
     4W,6HOOSILL,6HSCREEN,6HSINGLE,6HDOUBLE,6HDRAPER,6HDISTAN,6HOINNER,
     56HOOOONO,6HCOMBIN,6HSHIELD/
      DATA (LIST5(I),I=1,9)/8,6HOVERPR,6HNUMBER,6HOUTSID,6HOOWALL,6HMASO
     1NR,6HINSIDE,6HOONEXT,6HACCELE/
      DATA (LIST6(I),I=1,7)/6,6HPOPULA,6HINDOOR,6HINTERI,6HOUTDOO,6HREAC
     1TI,6HOONEXT/
      DATA (LIST7(I),I=1,9)/8,6HWEAPON,6HWEATHE,6HOONODE,6HCHARAC,6HDESC
     1RI,6HOSOLVE,6HINTERM,6HOOSKIP/,(LISTA(I),I=1,9)/8,6HOBLAST,6HTRANS
     2L,6HDEBRIS,6HTHERMA,6HIONIZI,6HBUILDI,6HOONEXT,6HACCUMU/
      DATA W,AIRDEN,VIS,ISEASN,TODAY,NN,XN,IBT,CONPER,SS,SN,SE,SW,WALPAN
     1,FLORTH,ROOFTH,BASETH,WALDEN,FLORDN,ROOFDN,BASEDN,SOILDN,NFL,PERPI
     2N,POSPRI,POSPRO,HB,GZX,GZY,HX,HY,HILLHT,HILLL,HILLW,YN,BUILDW,BILD
     3HT,BILDLT,BILDWT,PERCOA,PERCWI,SILHT,PERDE,PERSCR,PERG,PERSG,PERGG
     4,PERGGS,PERDBS,EXPL,AINTPL,PBREAK,PPERTB,PPERTI,BRKMAS,POPDN,REACS
     5I,REACST,REACLY,NHILL,IWALLT/1.0,0.075,10.,2,1.0,1,3600.,1,9*0,100
     6.,9*0.0,4*1000.,40*12.0,40*135.,10*75.,10*1,100.,0.0,100.,0.0,100.
     7,0.0,0.0,400*0.0,11*0/,ABETA,POPDN,PERCOA,TUNINJ,TFATAL,TAINJR/
     80.0,2*1.0,3*0.0
      END
```

```
$IBFTC CBINE
      SUBROUTINE COMBNE
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,   POPDN,REACSI,REACST,REACLY
      COMMON/BLK7/ NM,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
     1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
      COMMON /BLK12/ DDYTHI,DWKTHI,DMTTHI,DDYTHO,DWKTHO,DMTTHO
      COMMON/BLK13/ AVEWTB,RADG,RADN,DHBO,DDBO,DMBO,DHBI,DDBI,DMBI,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LIST8(9),ABETA,IAC
      DIMENSION SURV(10,5)
      FIN=PERPIN/100.
      FOUT=1.0-FIN
      SURV(1,1)=FIN-DHBI
      SURV(1,2)=SURV(1,1)-DDBI
      SURV(1,3)=SURV(1,2)
      SURV(1,4)=SURV(1,3)-DMBI
      SURV(1,5)=SURV(1,4)
      SURV(2,1)=FOUT-DHBO
      SURV(2,2)=SURV(2,1)-DDBO
      SURV(2,3)=SURV(2,2)
      SURV(2,4)=SURV(2,3)-DMBO
      SURV(2,5)=SURV(2,4)
      SURV(3,1)=FIN-DHTI
      SURV(3,2)=SURV(3,1)-DDYTI
      SURV(3,3)=SURV(3,2)-DWKTI
      SURV(3,4)=SURV(3,3)-DMTHTI
      SURV(3,5)=SURV(3,4)-TII
      SURV(4,1)=FOUT-DHTO
      SURV(4,2)=SURV(4,1)-DDYTO
      SURV(4,3)=SURV(4,2)-DWKTO
      SURV(4,4)=SURV(4,3)-DMTHTO
      SURV(4,5)=SURV(4,4)-TIO
      SURV(5,1)=FIN-DH
      SURV(5,2)=SURV(5,1)-DD
      SURV(5,3)=SURV(5,2)-DW
      SURV(5,4)=SURV(5,3)-DM
      SURV(5,5)=SURV(5,4)-DII
      SURV(6,1)=FOUT-DHD
      SURV(6,2)=SURV(6,1)-DDYD
      SURV(6,3)=SURV(6,2)-DWKD
      SURV(6,4)=SURV(6,3)-DMTD
      SURV(6,5)=SURV(6,4)-DIO
      SURV(7,1)=FIN
```

```
      SURV(7,2)=FIN-DDYTHI
      SURV(7,3)=SURV(7,2)-DWKTHI
      SURV(7,4)=SURV(7,3)-DMTTHI
      SURV(7,5)=SURV(7,4)-FTI
      SURV(8,1)=FOUT
      SURV(8,2)=FOUT-DDYTHO
      SURV(8,3)=SURV(8,2)-DWKTHO
      SURV(8,4)=SURV(8,3)-DMTTHO
      SURV(8,5)=SURV(8,4)-FTO
      SURV(9,1)=FIN
      SURV(9,2)=FIN-DDIONI
      SURV(9,3)=SURV(9,2)-DWIONI
      SURV(9,4)=SURV(9,3)-DMIONI
      SURV(9,5)=SURV(9,4)-RTI
      SURV(10,1)=FOUT
      SURV(10,2)=FOUT-DDIONO
      SURV(10,3)=SURV(10,2)-DWIONO
      SURV(10,4)=SURV(10,3)-DMIONO
      SURV(10,5)=SURV(10,4)-RIO
      WRITE(6,400) ((SURV(I,J),J=1,5),I=1,3)
      WRITE(6,401) ((SURV(I,J),J=1,5),I=4,7)
      WRITE(6,402) ((SURV(I,J),J=1,5),I=8,10)
  400 FORMAT(///59H INDIVIDUAL EFFECT MATRIX FOR SURVIVAL  (FRACTION OF
     2TOTAL),///1H ,94(1H+),/9H + EFFECT,21X,65H+ SURV. HOUR + SURV. DAY
     3 + SURV. WEEK + SURV. MONTH + UNINJURED +,/1H ,94(1H+),/15H + INDO
     4OR BLAST,15X,1H+,4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4H    +,4X,F5
     5.2,4X,4H+    ,F5.2,4H    +,/2H +,28X,1H+,12X,1H+,11X,1H+,12X,1H+,13X
     6,1H+,11X,1H+,/16H + OUTDOOR BLAST,14X,1H+,4X,F5.2,4H    +,4X,F5.2,3
     7H   +,4X,F5.2,4H    +,4X,F5.2,4X,4H+    ,F5.2,4H    +,/2H +,28X,1H+,12
     8X,1H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+,/21H + INDOOR TRANSLATION,9X
     9,1H+,4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4H    +,4X,F5.2,4X,4H+
     1,F5.2,4H    +,/2H +,28X,1H+,12X,1H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+
     2)
  401 FORMAT(22H + OUTDOOR TRANSLATION,8X,1H+,4X,F5.2,4H    +,4X,F5.2,3H
     2 +,4X,F5.2,4H    +,4X,F5.2,4X,4H+    ,F5.2,4H    +,/2H +,28X,1H+,12X,
     31H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+,/16H + INDOOR DEBRIS,14X,1H+,4
     4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4H    +,4X,F5.2,4X,4H+    ,F5.2,
     54H    +,/2H +,28X,1H+,12X,1H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+,/17H
     6+ OUTDOOR DEBRIS,13X,1H+,4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4H
     7 +,4X,F5.2,4X,4H+    ,F5.2,4H    +,/2H +,28X,1H+,12X,1H+,11X,1H+,12X
     8,1H+,13X,1H+,11X,1H+,/31H + INDOOR THERMAL RADIATION    +,4X,F5.2,4
     9H    +,4X,F5.2,3H   +,4X,F5.2,4H    +,4X,F5.2,4X,4H+    ,F5.2,4H    +)
  402 FORMAT(2H +,28X,1H+,12X,1H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+,/31H +
     2 OUTDOOR THERMAL RADIATION   +,4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2
     3,4H    +,4X,F5.2,4X,4H+    ,F5.2,4H    +,/2H +,28X,1H+,12X,1H+,11X,1H
     4+,12X,1H+,13X,1H+,11X,1H+,/31H + INDOOR IONIZING RADIATION   +,4X,F
     55.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4H    +,4X,F5.2,4X,4H+    ,F5.2,4H
     6  +,/2H +,28X,1H+,12X,1H+,11X,1H+,12X,1H+,13X,1H+,11X,1H+,/31H + O
     7UTDOOR IONIZING RADIATION +,4X,F5.2,4H    +,4X,F5.2,3H   +,4X,F5.2,4
     8H    +,4X,F5.2,4X,4H+    ,F5.2,4H    +,/1H ,94(1H+))
```

```
      SURVHI=1.0
      SURVDI=1.0
      SURVWI=1.0
      SURVMI=1.0
      SURVHO=1.0
      SURVDO=1.0
      SURVWO=1.0
      SURVMO=1.0
      SURVI=1.0
      SURVO=1.0
      DO 1 I=1,10,2
      SURVHI=SURVHI*SURV(I,1)/FIN
      SURVDI=SURVDI*SURV(I,2)/FIN
      SURVWI=SURVWI*SURV(I,3)/FIN
      SURVMI=SURVMI*SURV(I,4)/FIN
      SURVI=SURV(I,5)*SURVI/FIN
      SURVO=SURV(I+1,5)*SURVO/FOUT
      SURVHO=SURVHO*SURV(I+1,1)/FOUT
      SURVDO=SURVDO*SURV(I+1,2)/FOUT
      SURVWO=SURVWO*SURV(I+1,3)/FOUT
    1 SURVMO=SURVMO*SURV(I+1,4)/FOUT
      SURVHI=SURVHI*FIN
      SURVDI=SURVDI*FIN
      SURVWI=SURVWI*FIN
      SURVMI=SURVMI*FIN
      SURVI=SURVI*FIN
      SURVO=SURVO*FOUT
      SURVHO=SURVHO*FOUT
      SURVDO=SURVDO*FOUT
      SURVWO=SURVWO*FOUT
      SURVMO=SURVMO*FOUT
      TOTSRV=SURVMI+SURVMO
      POP=POPDN*PERCOA
      SURV=SURVI+SURVO
      UNINJ=SURV*POP
      FATAL=(1.-TOTSRV)*POP
      AINJR=POP-FATAL-UNINJ
      WRITE(6,403) SURVHI,SURVDI,SURVWI,SURVMI,SURVI,SURVHO,SURVDO,SURVW
     1O,SURVMO,SURVO
  403 FORMAT( //47H SURVIVAL FROM  ALL EFFECTS (FRACTION OF TOTAL),//11H
     2   LOCATION,21X,61HSURV. HOUR   SURV. DAY   SURV. WEEK   SURV. MON
     3TH   UNINJURED,//10H   INDOORS,25X,F5.2,8X,F5.2,7X,2(F5.2,8X),F5.2
     4,//11H   OUTDOORS,24X,F5.2,8X,F5.2,7X,2(F5,2,8X),F5.2)
      WRITE(6,404) UNINJ,FATAL,AINJR
  404 FORMAT( //30H TOTALS FOR THIS NODE (PEOPLE),//17H NUMBER UNINJURED
     2,7X,F9.0,//24H NUMBER OF FATALITIES   ,F9.0,//19H NUMBER OF INJURI
     3ES,5X,F9.0)
      IF(IAC.GT.0) GO TO 10
      TUNINJ=TUNINJ+UNINJ
      TFATAL=TFATAL+FATAL
      TAINJR=TAINJR+AINJR
      WRITE(6,405) TUNINJ,TFATAL,TAINJR
  405 FORMAT( //41H CUMULATIVE TOTALS FOR ALL NODES (PEOPLE),//17H NUMBE
     2R UNINJURED,6X,F10.0,//23H NUMBER OF FATALITIES   ,F10.0,//19H NUMB
     3ER OF INJURIES,4X,F10.0)
   10 RETURN
      END
```

```
$IBFTC BILDS
      SUBROUTINE BILDIS
C
C     DESCRIBES POST ATTACK CONDITION OF STRUCTURES AT NODE
C
      COMMON/BLK6/ PO,   TQ,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPPO(3),POSPRI(3),NFL(10),AINTPL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCDA,BILDHT(10)
      COMMON/BLK8/ PPERTB(10,9),PPERTI(10,9),BRKMAS
      WRITE(6,10)
      DO 1 I=1,NN
      WRITE(6,11) IBT(I)
      IF(PONA.LT.PBREAK(I).AND.POBILD(I).LT.BRKMAS) WRITE(6,12)
      IF(PONA.GE.PBREAK(I).AND.IWALLT(I).NE.0) WRITE(6,13)
      IF(PONA.LT.PBREAK(I).AND.IWALLT(I).NE.0.AND.POBILD(I).GE.BRKMAS)
     1WRITE(6,14)
      IF(PONA.GE.PBREAK(I).AND.IWALLT(I).EQ.0) WRITE(6,15)
    1 CONTINUE
   10 FORMAT(38H0POST ATTACK DESCRIPTION OF STRUCTURES)
   11 FORMAT(14H0BUILDING TYPE,I3)
   12 FORMAT(31H0EXTERIOR WALLS HAVE NOT FAILED/39H INTERIOR MASONRY WAL
     1LS HAVE NOT FAILED)
   13 FORMAT(27H0EXTERIOR WALLS HAVE FAILED/35H INTERIOR MASONRY WALLS H
     1AVE FAILED)
   14 FORMAT(31H0EXTERIOR WALLS HAVE NOT FAILED/35H INTERIOR MASONRY WAL
     1LS HAVE FAILED)
   15 FORMAT(27H0EXTERIOR WALLS HAVE FAILED/26H NO MASONRY INTERIOR WALL
     1S)
      RETURN
      END





      BLOCK DATA
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LIST8(9),ABETA,IAC
      COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
     1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
      COMMON /BLK12/ DDYTHI,DWKTHI,DMTTHI,DDYTHO,DWKTHO,DMTTHO
      COMMON/BLK13/ AVEWTR,RADG,RADN,DHBO,DDBO,DMBO,DHBI,DDBI,DMBI,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      DATA ISKIP/6*0/,DHBI,DDBI,DMBI,DHBO,
     8DDBO,DMBO,DHTI,DDYTI,DWKTI,DMTHTI,DHTO,DDYTO,DWKTO,DMTHTO,DH,DD,DW
     9,DM,DHD,DDYD,DWKD,DMTD,DDYTHI,DWKTHI,DMTTHI,DDYTHO,DWKTHO,DMTTHO,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO/34*0.0/,ABETA/0.0/
      DATA TII,TIO,DII,DIO,FII,FIO,RII,RIO/8*0.0/,IAC/0/
      END
```

```
$IBFTC INPT
      SUBROUTINE INPUT (KPRINT)
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,     POPDN,REACSI,REACST,REACLY
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK8/ PPERTB(10,9),PPERTI(10,9),BRKMAS
      COMMON /BLK10/ NHILL,HX(10),HY(10),HILLHT(10),HILLL(10),HILLW(10)
      COMMON /BLK11/ WALPAN(10),WALDEN(10),FLORTH(10),FLORDN(10),ROOFTH(
     110),ROOFDN(10),BASETH(10),BASEDN(10),SOILDN(10),SILHT(10),PERSCR(1
     20),PERSG(10),PERGG(10),PERDBS(10),PERG(10),PERDE(10),PERGGS(10)
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LIST8(9),ABETA,IAC
C
C     READ LIST OF DESCRIPTORS
C
      NP=0
    1 IX=0
      M=1
    2 I1=MATCH(LIST7,K,M)
      GO TO(3,3,3,3,4),I1
    3 IX=IX+1
      M=0
      IF(IX-12)2,1,1
    4 K1=K
      GO TO(5,13,23,56,75,87,71,72),K1
C
C     WEAPON PARAMETERS
C
    5 IX=0
      M=1
    6 I1=MATCH(LIST1,K,M)
      GO TO(7,7,7,7,8),I1
    7 IX=IX+1
      M=0
      IF(IX-12)6,5,5
    8 K1=K
      GO TO(9,10,11,12,1),K1
    9 I1=MATCH(J,BK,3)
      W=BK*1000.
      GO TO 5
   10 I1=MATCH(J,BK,3)
      FFR=BK
      GO TO 5
   11 I1=MATCH(J,BK,3)
      HB=BK
```

```
      GO TO 5
   12 I1=MATCH(J,BK,3)
      GZX=BK
      I1=MATCH(J,BK,3)
      GZY=BK
      GO TO 5
C
C     WEATHER AND TOPOGRAPHY
C
   13 IX=0
      M=1
   14 I1=MATCH(LIST2,K,M)
      GO TO(15,15,15,15,16),I1
   15 IX=IX+1
      M=0
      IF(IX-12)14,13,13
   16 K1=K
      GO TO(17,18,19,19,19,21,22,1),K1
   17 I1=MATCH(J,BK,3)
      AIRDEN=BK
      GO TO 13
   18 I1=MATCH(J,BK,3)
      VIS=BK
      GO TO 13
   19 I1=MATCH(J,K,3)
      NHILL=K
      IF(NHILL.LE.0) GO TO 13
      DO 20 I=1,NHILL
      I1=MATCH(LIST2,BK,1)
      I1=MATCH(J,BK,3)
      HX(I)=BK
      I1=MATCH(J,BK,3)
      HY(I)=BK
      I1=MATCH(LIST2,BK,1)
      I1=MATCH(J,BK,3)
      HILLHT(I)=BK
      I1=MATCH(J,BK,3)
      HILLL(I)=BK
      I1=MATCH(J,BK,3)
   20 HILLW(I)=BK
      GO TO 13
   21 I1=MATCH(J,K,3)
      ISEASN=K
      GO TO 13
   22 I1=MATCH(J,BK,3)
      TODAY=BK
      GO TO 13
C
C     NODE AND BUILDING PARAMETERS
C
```

```
 23 IX=0
    M=1
 24 I1=MATCH(LIST3,K,M)
    GO TO(25,25,25,25,26),I1
 25 IX=IX+1
    M=0
    IF(IX-12)24,23,23
 26 K1=K
    GO TO (27,28,110,37,45,101,105,109,55,1155,35,38,39,40,41,42,43,44
   1,47,48,49,50,51,52,53,54,82,136,132,134),K1
 27 I1=MATCH(J,K,3)
    NN=K
    GO TO 23
 28 I1=MATCH(J,BK,3)
    XN=BK
    I1=MATCH(J,BK,3)
 29 YN=BK
    GO TO 23
110 DO 111 I=1,NN
    I1=MATCH(J,K,3)
111 IBT(I)=K
    GO TO 23
 37 DO 112 KOUNT=1,NN
    I1=MATCH(J,BK,3)
112 CONPER(KOUNT)=BK
    GO TO 23
 45 DO 113 KOUNT=1,NN
    I1=MATCH(J,BK,3)
113 BUILDW(KOUNT)=BK
    GO TO 23
101 DO 102 KOUNT=1,NN
    I1=MATCH(J,BK,3)
102 BILDHT(KOUNT)=BK
    GO TO 23
105 DO 106 KOUNT=1,NN
    I1=MATCH(J,BK,3)
106 BILDLT(KOUNT)=BK
    GO TO 23
109 DO 108 KOUNT=1,NN
    I1=MATCH(J,BK,3)
108 BILDWI(KOUNT)=BK
    GO TO 23
 55 I1=MATCH(J,BK,3)
    SS=BK
    I1=MATCH(J,BK,3)
    SN=BK
    I1=MATCH(J,BK,3)
    SE=BK
    I1=MATCH(J,BK,3)
    SW=BK
```

```
      GO TO 23
 1155 NP=NP+1
      GO TO 1
   35 I1=MATCH(J,BK,3)
      PERCOA=BK
      GO TO 23
   38 DO 30 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   30 WALPAN(KOUNT)=BK
      GO TO 23
   39 DO 31 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   31 WALDEN(KOUNT)=BK
      GO TO 23
   40 DO 32 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   32 FLORTH(KOUNT)=BK
      GO TO 23
   41 DO 33 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   33 FLORDN(KOUNT)=BK
      GO TO 23
   42 DO 34 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   34 ROOFTH(KOUNT)=BK
      DO 36 KOUNT=1,NN
      I1=MATCH(J,BK,3)
   36 ROOFDN(KOUNT)=BK
      GO TO 23
   43 DO 120 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  120 BASETH(KOUNT)=BK
      DO 121 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  121 BASEDN(KOUNT)=BK
      GO TO 23
   44 DO 122 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  122 SOILDN(KOUNT)=BK
      GO TO 23
   47 DO 123 KOUNT=1,NN
      I1=MATCH(J,K,3)
  123 NFL(KOUNT)=K
      GO TO 23
   48 DO 124 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  124 PERCWI(KOUNT)=BK
      GO TO 23
   49 DO 125 KOUNT=1,NN
      I1=MATCH(J,BK,3)
```

```
  125 SILHT(KOUNT)=BK
      GO TO 23
  136 DO 131 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  131 PERDE(KOUNT)=BK/100.
      GO TO 23
   50 DO 126 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  126 PERSCR(KOUNT)=BK/100.
      GO TO 23
   51 DO 127 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  127 PERG(KOUNT)=BK/100.
      GO TO 23
  132 DO 133 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  133 PERSG(KOUNT)=BK/100.
      GO TO 23
   52 DO 128 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  128 PERGG(KOUNT)=BK/100.
      GO TO 23
  134 DO 135 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  135 PERGGS(KOUNT)=BK/100.
      GO TO 23
   53 DO 129 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  129 PERDBS(KOUNT)=BK/100.
      GO TO 23
   54 DO 130 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  130 EXRL(KOUNT)=BK
      GO TO 23
   82 DO 602 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  602 AINTRL(KOUNT)=BK
      GO TO 23
C
C     CHARACTERISTICS OF WALL FRAGMENTATION
C
   56 IX=0
      M=1
   57 I1=MATCH(LIST5,K,M)
      GO TO(58,58,58,58,59),I1
   58 IX=IX+1
      M=0
      IF(IX-12)57,56,56
   59 K1=K
      GO TO(60,61,64,66,68,73,1,180),K1
```

```
   60 DO 601 KOUNT=1,NN
      I1=MATCH(J,BK,3)
  601 PBREAK(KOUNT)=BK
      GO TO 56
   61 I1=MATCH(J,K,3)
      N=K
      GO TO 56
   64 DO 65 KOUNT=1,NN
      DO 65 I=1,N
      I1=MATCH(J,BK,3)
   65 PPERTB(KOUNT,I)=BK
      GO TO 56
   66 DO 67 KOUNT=1,NN
      I1=MATCH(J,K,3)
   67 IWALLT(KOUNT)=K
      GO TO 56
   68 I1=MATCH(J,BK,3)
      BRKMAS=BK
      GO TO 56
   73 DO 74 KOUNT=1,NN
      DO 74 I=1,N
      I1=MATCH(J,BK,3)
   74 PPERTI(KOUNT,I)=BK
      GO TO 56
  180 I1=MATCH(J,BK,3)
      ABETA=BK
      GO TO 56
C
C     DESCRIPTION OF PERSONNEL
C
   75 IX=0
      M=1
   76 I1=MATCH(LIST6,K,M)
      GO TO(77,77,77,77,78),I1
   77 IX=IX+1
      M=0
      IF(IX-12)76,75,75
   78 K1=K
      GO TO(79,80,81,83,84,1),K1
   79 I1=MATCH(J,BK,3)
      POPDN=BK
      GO TO 75
   80 I1=MATCH(J,BK,3)
      PERPIN=BK
      GO TO 75
   81 DO 1081 I=1,3
      I1=MATCH(J,BK,3)
 1081 POSPRI(I)=BK
      GO TO 75
   83 DO 1083 I=1,3
```

```
      I1=MATCH(J,BK,3)
 1083 POSPRO(I)=BK
      GO TO 75
   84 I1=MATCH(J,BK,3)
      REACSI=BK
      I1=MATCH(J,BK,3)
      REACST=BK
      I1=MATCH(J,BK,3)
      REACLY=BK
      GO TO 75
   71 KPRINT=1
      GO TO 1
   72 IX=0
      M=1
      I1=MATCH(LIST8,K,M)
      GO TO (170,170,170,170,171),I1
  170 IX=IX+1
      M=0
      IF(IX-12)170,72,72
  171 K1=K
      GO TO(172,173,174,175,176,177,1,178),K1
  172 ISKIP(1)=1
      GO TO 72
  173 ISKIP(2)=1
      GO TO 72
  174 ISKIP(3)=1
      GO TO 72
  175 ISKIP(4)=1
      GO TO 72
  176 ISKIP(5)=1
      GO TO 72
  177 ISKIP(6)=1
      GO TO 72
  178 IAC=1
      GO TO 72
C ********************************************************************
C                                        THIS ENDS INPUT PHASE
C
C ********************************************************************
   87 RETURN
      END
```

```
$IBFTC EFFEC
      SUBROUTINE EFFECT(KPRINT)
      COMMON/BLK1/YS,PREE,PFTS,PD,TO,CDF,QO,WOU,YB,PBYB,CDB
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ITOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,     POPDN,REACSI,REACST,REACLY
      COMMON/BLK5/ TA,CU,PWV,PDYP,PREF
      COMMON/BLK6/ PO,   TQ,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWT(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK13/ AVEWTB,RADG,RADN,DHBO,DDBO,DMBO,DHB1,DDB1,DMB1,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
C
C     CALCULATE OVERPRESSURE AND POSITIVE PHASE DURATION AT NODE POINTS
C     (FREE FIELD) AND PRINT
C
   87 XO=SQRT((GZX-XN)**2+(GZY-YN)**2)
      CALL WEAPON(W,XO,HB,PO,TO,TA,0,0)
C
C     USE R-H EQUATIONS TO COMPUTE SHOCK VELOCITY, WIND VELOCITY, PEAK
C     DYNAMIC PRESSURE, AND REFLECTED OVER PRESSURE AND PRINT
C
      CU=1126.*SQRT(1.+6.*PO/102.9)
      PWV=5630.*PO/(102.9*SQRT(1.+6.*PO/102.9))
      PDYP=5.*PO*PO/(205.8+2.*PO)
      PREF=2.*PO+0.4*PDYP
C
C     CALCULATE THERMAL ENERGY AT NODE POINT (CAL/CM**2) AND PRINT (FF)
C
      TQ=FIRE(W,XO,HB,VIS)
C
C     CALCULATE IONIZING RADIATION IN RADS AND PRINT (FF)
C
      CALL RADION(W,XO,HB,RI,RADG,RADN)
C
C     COMPUTE ATTENUATED NODE OVERPRESSURE
C
      PONA=PONODE(AVEHT,AVEWT,PO)
C
C     COMPUTE ATTENUATED INTERIOR OVERPRESSURE FOR EACH BUILDING TYPE
C
      DO 117 I=1,NN
      WP=PERCWI(I)/100.
  117 POBILD(I)=POBRED(WP,PONA)
      RETURN
      END
```

```
$IBFTC WEAP
      SUBROUTINE WEAPON(W,XO,HP,OVERP,POSPH,AT,T)
      SCALE =W**(1./3.)
      HBS=HB/SCALE
      XOS=XO/SCALE
      OVERP=FIND(HBS,XOS)
      POSPH=FINDTO(HBS,XOS)*SCALE
      AT=FINDAT(HBS,XOS)*SCALE
      IF(T)12,12,13
   13 OVERP=DECAY(OVERP,POSPH,T)
   12 RETURN
      END
```

```
$IBFTC DINT
      FUNCTION FIND(HT,XO)
      DIMENSION NP(12),C(12),P(72,12),Z(12)
      DATA C,NP/1.,2.,4.,6.,8.,10.,15.,20.,30.,50.,100.,200.,72,58,48,46
     1,44,43,41,38,32,26,20,16/
      DATA (P(I,1),I=1,72)/
     X3860.,3940.,4020.,4100.,4180.,4260.,4350.,4440.,4530.,4620.,4710.,
     X4780.,4850.,4920.,4990.,5060.,5132.,5204.,5276.,5348.,5420.,5472.,
     X5524.,5576.,5628.,5680.,5738.,5796.,5854.,5912.,5970.,6028.,6086.,
     X6144.,6202.,6260.,6312.,6364.,6416.,6468.,6520.,6710.,6920.,7080.,
     X7240.,7310.,7320.,7280.,5010.,4870.,4740.,4630.,4540.,4460.,4380.,
     X4270.,4140.,4040.,3920.,3790.,3630.,3520.,3370.,3220.,3050.,2900.,
     X2700.,2460.,2200.,1950.,1500.,1000./
      DATA (P(I,2),I=1,72)/
     X2480.,2528.,2576.,2624.,2672.,2720.,2776.,2832.,2888.,2944.,3000.,
     X3044.,3088.,3132.,3176.,3220.,3268.,3316.,3364.,3412.,3460.,3492.,
     X3524.,3556.,3588.,3620.,3660.,3700.,3740.,3780.,3820.,3858.,3896.,
     X3934.,3972.,4010.,4032.,4054.,4076.,4098.,4120.,4150.,4130.,4000.,
     X3150.,2950.,2800.,2670.,2540.,2410.,2260.,2130.,1980.,1850.,1660.,
     X1440.,1060., 650.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
      DATA (P(I,3),I=1,72)/
     X1630.,1660.,1690.,1720.,1750.,1780.,1810.,1840.,1870.,1900.,1930.,
     X1954.,1978.,2002.,2026.,2050.,2072.,2094.,2116.,2138.,2160.,2180.,
     X2200.,2220.,2240.,2260.,2282.,2304.,2326.,2348.,2370.,2396.,2422.,
     X2448.,2474.,2500.,2512.,2524.,2536.,2548.,2560.,1600.,1610.,1450.,
     X1300.,1130., 900., 540.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
      DATA (P(I,4),I=1,72)/
     X1360.,1372.,1384.,1396.,1408.,1420.,1438.,1456.,1474.,1492.,1510.,
     X1526.,1542.,1558.,1574.,1590.,1512.,1534.,1556.,1578.,1700.,1718.,
     X1736.,1754.,1772.,1790.,1810.,1830.,1850.,1870.,1890.,1912.,1934.,
     X1956.,1978.,2000.,2000.,2000.,2010.,2000.,2000.,1270.,1100., 930.,
     X 700., 320.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
      DATA (P(I,5),I=1,72)/
     X1120.,1130.,1140.,1150.,1160.,1170.,1184.,1198.,1212.,1226.,1240.,
     X1256.,1272.,1288.,1304.,1320.,1342.,1364.,1386.,1408.,1430.,1450.,
     X1470.,1490.,1510.,1530.,1554.,1578.,1602.,1626.,1650.,1656.,1662.,
     X1668.,1674.,1680.,1550.,1420.,1290.,1160.,1030., 860., 640., 310.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
      DATA (P(I,6),I=1,72)/
     X1023.,1031.,1043.,1055.,1067.,1078.,1090.,1102.,1114.,1125.,1137.,
     X1152.,1165.,1179.,1197.,1213.,1230.,1253.,1273.,1295.,1315.,1340.,
     X1360.,1380.,1402.,1423.,1437.,1447.,1453.,1457.,1458.,1450.,1438.,
     X1418.,1392.,1336., 925., 875., 825., 791., 765., 570., 110.,  -0.,
```

```
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,7),I=1,72)/
X 820., 826., 832., 842., 848., 855., 863., 872., 880., 890., 902.,
X 917., 932., 946., 964., 984., 998.,1023.,1047.,1068.,1094.,1125.,
X1150.,1170.,1183.,1191.,1194.,1192.,1184.,1173.,1152.,1087., 661.,
X 622., 585., 546., 505., 458., 400., 347., 295.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,8),I=1,72)/
X 712., 716., 720., 729., 732., 738., 740., 747., 751., 756., 760.,
X 768., 776., 782., 792., 802., 812., 828., 842., 860., 881., 911.,
X 927., 936., 942., 942., 936., 919., 850., 575., 541., 500., 451.,
X 403., 349., 288., 222.,  95.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,9),I=1,72)/
X 585., 586., 587., 588., 589., 590., 592., 595., 597., 599., 600.,
X 602., 605., 609., 612., 619., 622., 630., 638., 648., 657., 667.,
X 670., 669., 654., 478., 438., 392., 342., 293., 239., 135.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,10),I=1,72)/
X 460., 461., 462., 465., 466., 467., 468., 469., 470., 472., 476.,
X 480., 484., 489., 495., 500., 510., 519., 523., 523., 512., 349.,
X 303., 260., 209., 154.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,11),I=1,72)/
X 330., 337., 340., 348., 350., 356., 360., 365., 369., 372., 379.,
X 384., 388., 390., 390., 380., 260., 220., 173., 114.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
 DATA (P(I,12),I=1,72)/
X 250., 248., 248., 250., 250., 250., 250., 250., 251., 253., 263.,
X 266., 220., 180., 136.,  61.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
X  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,  -0.,
```

```
     X  -0.,  -0.,  -0.,  -0.,  -0.,  -0./
      IF(HT-1000.)2,1,1
    2 DELT=25.0
      JJ=1
      START=0.0
      GO TO 3
    1 DELT=125.0
      START=1000.
      JJ=41
    3 DO 7 I=JJ,72
      II=I
      IF(HT-START)4,7,7
    7 START=START+DELT
      WRITE(6,5) HT,XO,START,DELT
    5 FORMAT(22H0PRESSURE OUT OF RANGE/4H HT=,E20.8/4H XO=,E20.8/7H STAR
     1T=,E20.8/6H DELT=,F20.8)
    4 RATIO=(START-HT)/DELT
      DO 10 I=1,12
      IF(NP(I)-II+1)9,8,8
    9 Z(I)=0.0
      GO TO 10
    8 Z(I)=P(II,I)-RATIO*(P(II,I)-P(II-1,I))
   10 CONTINUE
      DO 20 I=1,12
      J=I
      IF(Z(I)-XO)21,22,20
   20 CONTINUE
   22 FIND=C(J)
      GO TO 25
   21 FIND=C(I-1)+(C(I)-C(I-1))*(Z(I-1)-XO)/(Z(I-1)-Z(I))
   25 RETURN
      END
```

```
$IBFTC DECA
      FUNCTION DECAY(P,TP,T)
      DECAY=P*(1.-T/TP)*EXP(-T/TP)
      RETURN
      END
```

```
$IBFTC FINDT    M94,XR7
      FUNCTION FINDAT(HT,XO)
      DIMENSION NP(19),C(19),P(37,19),Z(19)
      DATA C,NP/0.04,0.07,0.1,0.15,0.2,0.25,0.30,0.40,0.50,0.60,0.80,1.0
     X,1.5,2.0,2.5,3.0,3.5,4.0,4.5,6,8,9,11,13,14,16,18,21,21,22,23,25,
     X28,30,32,35,27,27/
      DATA (P(I,1),I=1,37)/
     X300.,298.,279.,240.,195.,110.,31*0.0/
      DATA (P(I,2),I=1,37)/
     X385.,382.,372.,345.,305.,253.,190.,30*0.0/
      DATA (P(I,3),I=1,37)/
     X470.,468.,458.,432.,398.,350.,300.,228.,110.,28*0.0/
      DATA (P(I,4),I=1,37)/
     X562.,559.,550.,534.,512.,480.,446.,395.,333.,255.,130.,26*0.0/
      DATA (P(I,5),I=1,37)/
     X658.,653.,647.,630.,610.,580.,549.,508.,458.,402.,342.,256.,25*0./
      DATA (P(I,6),I=1,37)/
     X740.,738.,730.,717.,697.,672.,644.,610.,568.,520.,468.,405.,315.,
     X215.,23*0.0/
      DATA (P(I,7),I=1,37)/
     X825.,820.,813.,800.,784.,760.,735.,700.,660.,620.,572.,520.,460.,
     X395.,300.,120.,21*0.0/
      DATA (P(I,8),I=1,37)/
     X962.,961.,959.,951.,938.,917.,895.,867.,833.,795.,760.,718.,670.,
     X628.,572.,508.,418.,320.,19*0.0/
      DATA (P(I,9),I=1,37)/
     X1100.,1103.,1100.,1093.,1080.,1067.,1050.,1023.,997.,967.,932.,
     X896.,850.,810.,760.,710.,647.,590.,515.,425.,280.,16*0.0/
      DATA (P(I,10),I=1,37)/
     X1240.,1242.,1241.,1234.,1225.,1210.,1192.,1168.,1142.,1114.,1080.,
     X1050.,1015.,980.,939.,897.,844.,800.,745.,685.,607.,16*0.0/
      DATA (P(I,11),I=1,37)/
     X1500.,1490.,1480.,1470.,1460.,1450.,1432.,1414.,1396.,1378.,1360.,
     X1324.,1288.,1252.,1216.,1180.,1144.,1108.,1072.,1036.,1000.,630.,
     X15*0.0/
      DATA (P(I,12),I=1,37)/
     X1730.,1728.,1726.,1724.,1722.,1720.,1704.,1688.,1672.,1656.,1640.,
     X1608.,1576.,1544.,1512.,1480.,1450.,1420.,1390.,1360.,1330.,1070.,
     X680.,14*0.0/
      DATA (P(I,13),I=1,37)/
     X2350.,2348.,2346.,2344.,2342.,2340.,2328.,2316.,2304.,2292.,2280.,
     X2254.,2228.,2202.,2176.,2150.,2120.,2090.,2060.,2030.,2000.,1870.,
     X1730.,1420.,1000.,12*0.0/
      DATA (P(I,14),I=1,37)/
     X2950.,2948.,2946.,2944.,2942.,2940.,2926.,2912.,2898.,2884.,2870.,
     X2848.,2826.,2804.,2782.,2760.,2736.,2712.,2688.,2664.,2640.,2530.,
     X2430.,2250.,2000.,1740.,1300.,600.,9*0.0/
      DATA (P(I,15),I=1,37)/
     X3540.,3538.,3536.,3534.,3532.,3530.,3524.,3518.,3512.,3506.,3500.,
     X3480.,3460.,3440.,3420.,3400.,3370.,3340.,3310.,3280.,3250.,3150.,
```

```
     X3080.,2940.,2750.,2550.,2300.,2030.,1610.,1050.,700.0/
      DATA (P(I,16),I=1,37)/
     X4110.,4112.,4114.,4116.,4118.,4120.,4112.,4104.,4096.,4088.,4080.,
     X4060.,4040.,4020.,4000.,3980.,3956.,3932.,3908.,3884.,3860.,3750.,
     X3700.,3580.,3450.,3300.,3090.,2880.,2600.,2350.,1920.,1350.,500.0/
      DATA (P(I,17),I=1,37)/
     X4680.,4684.,4688.,4692.,4696.,4700.,4694.,4688.,4682.,4676.,4670.,
     X4652.,4634.,4616.,4598.,4580.,4560.,4540.,4520.,4500.,4480.,4340.,
     X4320.,4220.,4100.,4000.,3820.,3650.,3420.,3220.,2930.,2600.,2200.,
     X1650.,620.,200,0/
      DATA (P(I,18),I=1,37)/
     X5230.,5238.,5246.,5254.,5262.,5270.,5266.,5262.,5258.,5254.,5250.,
     X5232.,5214.,5196.,5178.,5160.,5142.,5124.,5106.,5038.,5070.,4950.,
     X4870.,4800.,4700.,4620.,4470.,4330.,4140.,3950.,3740.,3500.,3200.,
     X2860.,2420.,1900.,1100./
      DATA (P(I,19),I=1,37)/
     X5800.,5806.,5812.,5818.,5824.,5830.,5828.,5826.,5824.,5822.,5820.,
     X5806.,5792.,5778.,5764.,5750.,5730.,5710.,5690.,5670.,5650.,5520.,
     X5450.,5400.,5320.,5230.,5130.,5020.,4870.,4700.,4520.,4300.,4040.,
     X3760.,3450.,3140.,2770./
      IF(HT.GE.1000.) GO TO 1
      DELT=50.
      JJ=1
      START=0.0
      GO TO 3
    1 DELT=250.
      START=1000.
      JJ=22
    3 DO 7 I=JJ,37
      II=I
      IF(HT-START)4,7,7
    7 START=START+DELT
      WRITE(6,5) HT,XO,START,DELT
    5 FORMAT(26H0ARRIVAL TIME OUT OF RANGE/4H HT=,E20.8/4H XO=,E20.8/7H
     XSTART=,E20.8/6H DELT=,E20.8)
    4 RATIO=(START-HT)/DELT
      DO 10 I=1,19
      IF(NP(I)-II+1)9,8,8
    9 Z(I)=0.0
      GO TO 10
    8 Z(I)=P(II,I)-RATIO*(P(II,I)-P(II-1,I))
   10 CONTINUE
      DO 20 I=1,19
      J=I
      IF(Z(I)-XO)20,22,21
   20 CONTINUE
   22 FINDAT=C(J)
      GO TO 25
   21 FINDAT=C(I-1)+(C(I)-C(I-1))*(Z(I-1)-XO)/(Z(I-1)-Z(I))
   25 RETURN
      END
```

```
$IBFTC FINDP    M94,XR7
      FUNCTION FINDTO(HT,XO)
      DIMENSION NP(7),C(7),P(31,7),Z(7)
      DATA C,NP/0.1,0.15,0.20,0.25,0.30,0.35,0.40,14,16,18,24,31,13,8/
      DATA(P(I,1),I=1,31)/
     X350.,350.,363.,400.,450.,487.,500.,495.,430.,350.,290.,260.,220.,
     X160.,17*0.0/
      DATA(P(I,2),I=1,31)/
     X555.,540.,535.,565.,615.,635.,655.,660.,650.,625.,580.,530.,470.,
     X390.,295.,145.,15*0.0/
      DATA (P(I,3),I=1,31)/
     X770.,768.,782.,825.,870.,895.,905.,910.,905.,900.,875.,850.,805.,
     X735.,635.,495.,325.,155.,13*0.0/
      DATA (P(I,4),I=1,31)/
     X1085.,1090.,1070.,1090.,1120.,1165.,1205.,1230.,1255.,1280.,1300.,
     X1315.,1318.,1313.,1290.,1270.,1090.,965.,835.,705.,600.,460.,300.,
     X160.,7*0.0/
      DATA (P(I,5),I=1,31)/
     X1400.,1405.,1415.,1420.,1440.,1465.,1500.,1560.,1660.,1745.,1810.,
     X1865.,1905.,1938.,1975.,2000.,2025.,2040.,2050.,2050.,2040.,2023.,
     X1990.,1950.,1890.,1820.,1745.,1600.,1410.,1135.,650.,/
      DATA (P(I,6),I=1,31)/
     X1812.,1832.,1855.,1878.,1905.,1950.,2000.,2045.,2115.,2200.,2315.,
     X2465.,2710.,18*0.0/
      DATA (P(I,7),I=1,31)/2160.,2205.,2275.,2365.,2465.,2620.,2780.,
     X2950.,23*0.0/
      DELT=50.0
      START=0.0
      DO 7 I=1,31
      II=I
      IF(HT-START)4,7,7
    7 START=START+DELT
      WRITE(6,5) HT,XO,START,DFLT
    5 FORMAT(28H0PHASE DURATION OUT OF RANGE/4H HT=,E20.8/4H XO=,E20.8/
     X7H START=,E20.8/6H DELT=,E20.8)
    4 RATIO=(START-HT)/DELT
      DO 10 I=1,7
      IF(NP(I)-II+1)9,8,8
    9 Z(I)=0.0
      GO TO 10
    8 Z(I)=P(II,I)-RATIO*(P(II,I)-P(II-1,I))
   10 CONTINUE
      DO 20 I=1,7
      J=I
      IF(Z(I)-XO)20,22,21
   20 CONTINUE
   22 FINDTO=C(J)
      GO TO 25
   21 FINDTO=C(I-1)+(C(I)-C(I-1))*(Z(I-1)-XO)/(Z(I-1)-Z(I))
   25 RETURN
      END
```

```
$IBFTC PONOD   M94,XR7
      FUNCTION PONODE(H,D,PO)
      PONODE=(0.06*D/H+0.45)*PO
      IF(PONODE.GT.PO) PONODE=PO
      RETURN
      END
```

```
$IBFTC POBRE   M94,XR7
      FUNCTION POBRED(X,PO)
      DATA(Y(I),I=1,11)/0.0,0.474,0.704,0.807,0.867,0.904,0.933,0.955,
     10.978,0.989,1.0/
      DIMENSION Y(11)
      DO 1 I=1,11
      XI=FLOAT(I-1)/10.
      J=I
      IF(X-XI)3,2,1
    1 CONTINUE
    2 Y1=Y(J)
      GO TO 4
    3 Y1=10.*(XI-X)*(Y(J)-Y(J-1))+Y(J-1)
    4 POBRED=Y1*PO
      RETURN
      END
```

```
$IBFTC THERML   M94,XR7
      FUNCTION FIRE(W,XO,HB,V)
C
C     DETERMINATION OF Q BY GIBBONS EQUATIONS
C
      S=SQRT(XO*XO+HB*HB)
      S=S/5280.
      A=2.9*S
      IF(A.GT.20.3) A=20.3
      T=0.78*EXP(-3.91*S/V)*(1.+A/V)
      FIRE=1.04*W*T/(S*S)
      RETURN
      END
```

```
$IBFTC RADI
      SUBROUTINE RADION(W,XO,HB,RI,RADG,RADN)
C
C     DETERMINATION OF IONIZING RADIATION IN RADS FROM SOFT TARGET STUDY
C
      D=SQRT(XO*XO+HB*HB)/3.
      WP=W
      IF((W.GT.20.0).AND.(W.LE.100.)) GO TO 1
      IF((W.GT.100.).AND.(W.LE.5000.)) GO TO 2
      IF(W.GT.5000.) GO TO 3
      GO TO 4
    1 WP=0.614*W**1.163
      GO TO 4
    2 WP=0.485*W**1.214
      GO TO 4
    3 WP=0.005*W**1.740
    4 AK=1
      IF(HB.LT.(180.*W**0.4))AK=0.67+0.33*HB/(180.*W**0.4)
      RADG= 1.E9*AK*3.2*WP*EXP(-D/360.)/(D*D)
      RADN= 1.E9*AK*15.5*W*EXP(-D/210.)/(D*D)
      RI=RADG+RADN
      RETURN
      END
```

```
$IBFTC GEOM
       SUBROUTINE GEOMET(KPRINT)
       COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
       COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
      1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
      2,INDX1,INDX2,PERPIN,     POPDN,REACSI,REACST,REACLY
       COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
      1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXPL(10),
      2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
       COMMON /BLK13/AVEWTB,RADG,RADN,DHBO,DDBO,DWBO,DHBI,DWBI,DMBI,
      1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
C
C      CALCULATE AVERAGE QUANTITIES AND MAXIMUM HEIGHT
C
       PI=4.*ATAN(1.)
       AVEW=0.0
       AVEL=0.0
       AVEHT=0.0
       AVEWTB=0.0
       HMAX=0.0
       DO 115 I=1,NN
       HMAX=AMAX1(HMAX,BILDHT(I))
       AVEWTB=AVEWTB+BUILDW(I)*CONPER(I)*10.
       AVEL=AVEL+BILDLT(I)*CONPER(I)/100.
       AVEW=AVEW+BILDWI(I)*CONPER(I)/100.
   115 AVEHT=AVEHT+BILDHT(I)*CONPER(I)/100.
       AVEWT=(SS+SN+SE+SW)/4.
       S1=(SS+SN)/2.
       S2=(SE+SW)/2.
C
C      COMPUTE NODE POINT AREAS AND DISTANCES
C
       KA=0
       PHI=ATAN(ABS((GZY-YN)/(GZX-XN)))
       IF(PHI.LE.0.0.OR.PHI.GE.PI/2.)GO TO 154
       A1=  S1*(AVEL-S1*COTAN(PHI))
       IF(A1.LE.0.0) GO TO 154
       D1=  S1/SIN(PHI)
       A2=  S1*S2+0.5*S2*S2*COTAN(PHI)
       D2=  D1+S2/COS(PHI)
       A3=  S1*(S1*COTAN(PHI)-S2)
       IF(A3.LE.0.0) GO TO 154
       D3=  S1/SIN(PHI)
       A4=  S2*S1+0.5*S2*TAN(PHI)
       D4=  D2
       A5=S2*(AVEW-S2*TAN(PHI))
       IF(A5.LE.0.0) GO TO 154
       D5=S2/COS(PHI)
       ATOT=A1+A2+A3+A4+A5
       W1=A1/D1
```

```
      W2=A2/D2
      W3=A3/D3
      W4=A4/D4
      W5=A5/D5
      DISMAX=AMAX1(D1,D2,D3,D4,D5)
      GO TO 155
  154 A1=2.*AVEL*S1+S1*S2
      A2=2.*AVEW*S2+S1*S2
      ATOT=A1+A2-S1*S2
      KA=1
      D1=2.*AVEL+S2
      D2=2.*AVEW+S1
      W1=A1/D1
      W2=A2/D2
      D1=D1*0.5
      D2=D2*0.5
      D3=0.
      D4=0.
      D5=0.
      A3=0.
      A4=0.
      A5=0.
      DISMAX=AMAX1(D1,D2)
  155 DELTD=DISMAX/10.
      RETURN
      END
```

```
$IBFTC BLAS
      SUBROUTINE BLAST(KPRINT)
       COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
      1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
      2,INDX1,INDX2,PERPIN,     POPDN,REACSI,REACST,REACLY
       COMMON/BLK6/ PO,    TQ,PI,PONA
       COMMON/BLK7/ NN,PERCWT(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
      1(10),BILDWT(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXPL(10),
      2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
       COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
      1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
       COMMON/BLK13/ AVEWTD,RADO,RADN,DHBO,DDBO,DMBO,DHBI,DDBI,DMBI,
      1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
C      CALCULATE PERCENT OF BLAST CASUALTIES FOR EACH TIME TO DEATH FOR
C      OVERPRESSURE
C
       DHBO=0.0
       DDBO=0.0
       DMBO=0.0
       DHBI=0.0
       DDBI=0.0
       DMBI=0.0
C
C      OUTSIDE CONTRIBUTION
C
       IF(PONA.LE.37.5) GO TO 156
       PERO=1.-PERPIN/100.
       PERO=PERO/100.
       DHBO=BLASTH(PONA)*PERO
       DDBO=BLASTD(PONA)*PERO
       DMBO=BLASTM(PONA)*PERO
C
C      INSIDE CONTRIBUTION
C
       PER=PERPIN/1.E6
       DO 157 I=1,NN
       IF(POBILD(I).LE.37.5) GO TO 157
       POB=POBILD(I)
       DHBI=DHBI+BLASTH(POB)*CONPER(I)*PER
       DDBI=DDBI+BLASTD(POB)*CONPER(I)*PER
       DMBI=DMBI+BLASTM(POB)*CONPER(I)*PER
  157  CONTINUE
  156  CONTINUE
       RETURN
       END
```

```
$IBFTC H
      FUNCTION BLASTH(P)
      DIMENSION PK(21)
      DATA (PK(I),I=1,21)/3*0.0,37.5,40.0,43.5,47.,50.5,55.,58.,63.5,
     168.5,74.0,78.5,83.0,87.5,93.0,100.0,107.5,117.5,130.0/
      IF(P.LE.37.5) GO TO 5
      IF(P.GE.130.) GO TO 6
      DO 1 I=5,21
      IF(P.GE.PK(I-1).AND.P.LE.PK(I)) GO TO 2
    1 CONTINUE
      GO TO 6
    2 BLASTH=PK(I-1)+5.*(P-PK(I-1))/(PK(I)-PK(I-1))
      GO TO 7
    5 BLASTH=0.0
      GO TO 7
    6 BLASTH=100.0
    7 RETURN
      END
```

```
$IBFTC D
      FUNCTION BLASTD(P)
      IF(P.LT.40.0) BLASTD=0.0
      IF(P.GE.40.0.AND.P.LT.65.0) BLASTD=35.0
      IF(P.GE.65.0.AND.P.LE.130.0) BLASTD=-0.538*P+70.
      IF(BLASTD.LT.0.0) BLASTD=0.0
      IF(BLASTD.GT.100.0) BLASTD=100.
      RETURN
      END
```

```
$IBFTC M
      FUNCTION BLASTM(P)
      IF(P.LT.40.0) BLASTM=0.0
      IF(P.GE.40.0.AND.P.LE.120.) BLASTM=100.-BLASTH(P)-BLASTD(P)
      IF(BLASTM.LT.0.0) BLASTM=0.0
      RETURN
      END
```

```
$IBFTC BLSDS
      SUBROUTINE BLSDIS(KPRINT)
      COMMON/BLK1/TS,PREF,PETS,PD,TO,CDF,QO,WOU,TB,PBTB,CDP
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,    POPDN,REACSI,REACST,REACLY
      COMMON/BLK6/ PO,    TO,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),PROBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
     1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      DIMENSION AO(3),AP(3),AR(3),AS(3),AT(3),AU(3),PVEL(3,10),VEL(10),
     1PVELI(10,3,10),PROBDH(10),PROBDD(10),PROBDW(10),PROBDM(10),AV(3)
      DIMENSION TIVEL(3,10),PROBI(10)
      DATA (AO(I),I=1,3)/5.76,3.0,0.833/,(AP(I),I=1,3)/3*1.33/,(AR(I),I=
     11,3)/1.0,1.58,5.76/,(AS(I),I=1,3)/0.28,0.667,2.63/,(AT(I),I=1,3)/
     23.14,0.833,0.55/,(AU(I),I=1,3)/8.57,5.32,8.57/
      DATA (AV(I),I=1,3)/8.,3.,2.5/
C
C     CALCULATE BLAST DISPLACEMENT EFFECTS ON OUTSIDE
C
      IPRINT=0
      DO 5 I=1,3
      DO 5 J=1,10
      PVEL(I,J)=0.0
      DO 5 K=1,10
    5 PVELI(J,I,K)=0.0
      PD=PONA
      DO  50 I=1,3
      IF(POSPRO(I).LE.0.0) GO TO  50
      IPRINT=1
      H=AO(I)
      XL=AP(I)
      WDTH=AR(I)
      ALP=AS(I)
      GAM=AT(I)
      XJ=AU(I)
      ETA=AV(I)
      CALL DISPLA(H,XL,WDTH,ALP,GAM,XJ,ETA,DELTD,VEL,KPRINT)
      DO 150 J=1,10
      PVEL(I,J)=VEL(J)
  150 CONTINUE
   50 CONTINUE
      IF(.NOT.(KPRINT.GT.0.AND.IPRINT.GT.0)) GO TO 68
      WRITE(6,151)
  151 FORMAT(40H0OUTSIDE PEOPLE VELOCITY MATRIX(FT./SEC)/9H0DISTANCE,7X,
     1       8HSTANDING,8X,7HSITTING,9X,5HLYING///)
```

```
      DD=0.0
      DO 153 J=1,10
      DD=DD+DELTD
      IF(KPRINT.GT.0) WRITE(6,152) DD,(PVEL(I,J),I=1,3)
  152 FORMAT(1H ,4F14.6)
  153 CONTINUE
C
C     CALCULATE BLAST DISPLACEMENT EFFECTS ON INSIDE OF BUILDINGS
C
   68 IPRINT=0
      DO 160 I=1,NN
      PD=POBILD(I)
      DISMAX=AMAX1(BILDLT(I),BILDWI(I))
      DELTD=DISMAX/10.
      DO  61 J=1,3
      IF(POSPRI(J).LE.0.0) GO TO  61
      IPRINT=1
      H=AO(J)
      XL=AP(J)
      WDTH=AR(J)
      ALP=AS(J)
      GAM=AT(J)
      XJ=AU(J)
      ETA=AV(J)
      CALL DISPLA(H,XL,WDTH,ALP,GAM,XJ,ETA,DELTD,VEL,KPRINT)
      DO 161 JJ=1,10
      PVELI(I,J,JJ)=VEL(JJ)
  161 CONTINUE
   61 CONTINUE
      IF(.NOT.(KPRINT.GT.0.AND.IPRINT.GT.0)) GO TO 160
      WRITE(6,162) I
  162 FORMAT(32H0INSIDE VELOCITY MATRIX(FT./SEC)/14H0BUILDING TYPE,I3/9H
     10DISTANCE,7X,8HSTANDING,8X,7HSITTING,9X,5HLYING///)
      DD=0.0
      DO 760 J=1,10
      DD=DD+DELTD
      IF(KPRINT.GT.0) WRITE(6,152) DD,(PVELI(I,JJ,J),JJ=1,3)
  760 CONTINUE
  160 CONTINUE
C
C     CALCULATE PERCENT OF BLAST CASUALTIES FOR EACH TIME TO DEATH FROM
C     TRANSLATION - INDOORS
C
      TII=0.0
      DHT=0.0
      DDYT=0.0
      DWKT=0.0
      DMTHT=0.0
      DO 163 I=1,NN
      DO 163 J=1,3
```

```
      DO 163 JJ=1,10
      PVCON=PVELT(I,J,JJ)
      PVCONS=BTRANS(PVCON)/100.
      AVEPRD=POSPRI(J)*CONPER(I)*PVCONS/1.E5
      TI=PCONI(PVCON)/100.
      IF(PVCONS.GT.0.0) TI=1.0-PVCONS
      TII=TII+TI*POSPRI(J)*CONPER(I)/1.E5
      IF(PVCONS.LE.0.0) GO TO 163
      IF(PVCONS.GT.0.0.AND.PVCONS.LT.0.1) GO TO 165
      IF(PVCONS.GE.0.1.AND.PVCONS.LT.0.5) GO TO 166
      IF(PVCONS.GE.0.5.AND.PVCONS.LT.0.9) GO TO 167
      DHT=DHT+AVEPRD
      GO TO 163
  165 DMTHT=DMTHT+AVEPRD
      GO TO 163
  166 DWKT=DWKT+AVEPRD
      GO TO 163
  167 DDYT=DDYT+AVEPRD
  163 CONTINUE
      IF(DHT.GT.1.0) DHT=1.0
      IF(DDYT.GT.1.0) DDYT=1.0
      IF(DWKT.GT.1.0) DWKT=1.0
      IF(DMTHT.GT.1.0) DMTHT=1.0
      DHTI=DHT*PERPIN/100.
      DDYTI=DDYT*PERPIN/100.
      DWKTI=DWKT*PERPIN/100.
      DMTHTI=DMTHT*PERPIN/100.
      TII=TII*PERPIN/100.
C
C     CALCULATE PERCENT OF BLAST CASUALTIES FOR EACH TIME TO DEATH FOR
C     TRANSLATION - OUTDOORS
C
      TIO=0.0
      DHT=0.0
      DDYT=0.0
      DWKT=0.0
      DMTHT=0.0
      DO 168 I=1,3
      DO 168 J=1,10
      PVL=PVEL(I,J)
      TIVEL(I,J)=PCONI(PVL)/100.
  168 PVEL(I,J)=BTRANS(PVL)/100.
      DO 169 I=1,10
      PROBI(I)=0.0
      PROBDH(I)=0.0
      PROBDD(I)=0.0
      PROBDW(I)=0.0
      PROBDM(I)=0.0
      DO 169 J=1,3
      ANPVEL=PVEL(J,I)*POSPRO(J)/100.
```

```
      ANPVEL=ANPVEL*(1.-PERPIN/100.)
      TI=TIVEL(J,I)
      IF(PVEL(J,I).GE.0.0) TI=1.0-PVEL(J,I)
      PROBI(I)=PROBI(I)+TI*POSPRO(J)*(1.-PERPIN/100.)/100.
      IF(PVEL(J,I).GE.0.9) GO TO 170
      IF(PVEL(J,I).GE.0.5) GO TO 171
      IF(PVEL(J,I).GE.0.1) GO TO 172
      IF(PVEL(J,I).GE.0.0) GO TO 173
      GO TO 169
  170 PROBDH(I)=PROBDH(I)+ANPVEL
      GO TO 169
  171 PROBDD(I)=PROBDD(I)+ANPVEL
      GO TO 169
  172 PROBDW(I)=PROBDW(I)+ANPVEL
      GO TO 169
  173 PROBDM(I)=PROBDM(I)+ANPVEL
  169 CONTINUE
      IF(KA.EQ.0) GO TO 180
      DELTD=AMAX1(D1,D2)/10.
      DELTS=DELTD
      D1=D1*2.
      D2=D2*2.-S1
      KAA=0
      IF(D1.GT.D2) KAA=1
      IF(KAA.EQ.0) GO TO 1
      DELTD=D1/10.
      INDX1=10
      INDX2=D2/D1*10.+0.5
      GO TO 3
    1 DELTD=D2/10.
      INDX2=10.
      INDX1=D1/D2*10.+0.5
    3 IF(INDX1.GT.10) INDX1=10
      IF(INDX1.LT.1) INDX1=1
      IF(INDX2.GT.10) INDX2=10
      IF(INDX2.LT.1) INDX2=1
      FACT1=DELTD/ATOT*W1
      DO 174 IND=1,INDX1
      TIO=TIO+PROBI(IND)*FACT1
      DHT=DHT+PROBDH(IND)*FACT1
      DDYT=DDYT+PROBDD(IND)*FACT1
      DWKT=DWKT+PROBDW(IND)*FACT1
  174 DMTHT=DMTHT+PROBDM(IND)*FACT1
      FACT2=DELTD/ATOT*W2
      DO 175 IND=1,INDX2
      TIO=TIO+PROBI(IND)*FACT2
      DHT = DHT+PROBDH(IND)*FACT2
      DDYT=DDYT+PROBDD(IND)*FACT2
      DWKT=DWKT+PROBDW(IND)*FACT2
  175 DMTHT=DMTHT+PROBDM(IND)*FACT2
```

```
      DELTD=DELTS
      GO TO 185
  180 DELTD=AMAX1(D1,D2,D3,D4,D5)/10.
      INDX(1)=D1/DELTD+0.5
      INDX(2)=D2/DELTD+0.5
      INDX(3)=D3/DELTD+0.5
      INDX(4)=D4/DELTD+0.5
      INDX(5)=D5/DELTD+0.5
      AAA(1)=W1*DELTD
      AAA(2)=W2*DELTD
      AAA(3)=W3*DELTD
      AAA(4)=W4*DELTD
      AAA(5)=W5*DELTD
      DO 181 I=1,5
      FACT=AAA(I)/ATOT
      INDEX=INDX(I)
      IF(INDEX.GT.10) INDEX=10
      IF(INDEX.LT.1) INDEX=1
      DO 181 IND=1,INDEX
      TIO=TIO+PROBT(IND)*FACT
      DHT=DHT+PROBDH(IND)*FACT
      DDYT=DDYT+PROBDD(IND)*FACT
      DWKT=DWKT+PROBDW(IND)*FACT
  181 DMTHT=DMTHT+PROBDM(IND)*FACT
  185 CONTINUE
      OUT=1.0-PERPIN/100.
      IF(DHT.GT.OUT) DHT=OUT
      IF(DDYT.GT.OUT) DDYT=OUT
      IF(DWKT.GT.OUT) DWKT=OUT
      IF(DMTHT.GT.OUT) DMTHT=OUT
      DHTO=DHT
      DDYTO=DDYT
      DWKTO=DWKT
      DMTHTO=DMTHT
      DD=0.0
      RETURN
      END
```

```
$IBFTC DISPL
      SUBROUTINE DISPLA(H,XL,VWIDTH,ALPHA,GAMMA,XJCG,ETA,DELTD,VEL,KPRIN
     1T)
C
C                                PEOPLE DISPLACEMENT
C
      COMMON/BLK1/TS,PREE,PFTS,PO,TO,CDF,QO,WOU,TB,PBTB,CDB
      DIMENSION C(12),Y(2),YP(2),YPP(2),YQ(2),YQP(2),YR(2),YRP(2)
      DIMENSION VEL(1)
  301 KPLOT=0
      FF=100.
      B=0.0
      C1=0.0
      WEIGHT=160.
      XMU=0.5
      CDF=0.5
      CDB=-0.5
      KD=1
      FDIST=DELTD
      IPOS=0
      IPOS1=0
      IF(VWIDTH.GT.4.0) IPOS=1
      PI=4.*ATAN(1.)
      DT=.0001
      ANU=ATAN(ALPHA/H)
      RXY=SQRT(ALPHA*ALPHA+H*H)
      IF(IPOS.EQ.1) RXY=H
      IF(H-XL/2.)3,4,4
    3 S=H-C1/2.
      GO TO 11
    4 S=XL/2.
   11 PHI=ATAN(ALPHA/GAMMA)
      XJ=XJCG+WEIGHT*(ALPHA*ALPHA+GAMMA*GAMMA)/32.2
      DO=H/2.+C1
      PREE=2.*PO*(7.*14.7+4.*PO)/(7.*14.7+PO)
      D=DO
      FO=144.*PREE*XL*H
      QO=5./2.*PO*PO/(7.*14.7+PO)
      U=1138.*(1.+6.*PO/(7.*14.7))**0.5
      TS=3.*S/U
      TB=(VWIDTH+ETA*S)/U
      TM=AMAX1(TS,TB)
      TSTO=TS/TO
      WOU=VWIDTH/U
      PFTS=PO*(1.-TSTO)*EXP(-TSTO)+CDF*QO*(1.-TSTO)**2*EXP(-2.*TSTO)
      TBOTO=(TB-WOU)/(TO-WOU)
      PBTB=PO*(1.-TBOTO)*EXP(-TBOTO)+CDB*QO*(1.-TBOTO)**2*EXP(-2.*TBOT
     1O)
      XM=WEIGHT/32.2
      KTTEST=0
```

```
      XLR=SQRT(ALPHA**2+GAMMA**2)
      NL=50
      KOUNTP=1
      ITMCHG=0
      KTZERO=0
      FT=F0
C
C     SET RKG COEFFICIENTS AND INITIALIZE TIME
C
      C(1)=DT/2.
      C(2)=1.
      C(3)=C(1)
      C(5)=1.-SQRT(0.5)
      C(4)=C(5)*DT
      C(6)=C(4)
      C(8)=2.-C(5)
      C(7)=C(8)*DT
      C(9)=C(7)
      C(10)=DT/6.
      C(11)=0.3333333
      C(12)=C(1)
      T=0.0
      EPS=DT/2.
      IF(KPRINT.LE.0) GO TO 30
      WRITE(6,7)
    7 FORMAT(1H ,4HTIME,8X,4HPRES,8X,4HY(1),8X,4HY(2),8X,5HYP(1),7X,5HYP
     1(2),7X,6HYPP(1),6X,6HYPP(2)/12X,2HXH,10X,3HXHD,9X,3HYHD,9X,3HXCG,9
     2X,4HXCGD)
C
C     SLIDING AND TIPPING COMPUTATION
C
   30 DO 140 I=1,2
      Y(I)=0.0
      YP(I)=0.0
      YQ(I)=0.0
  140 YQP(I)=0.0
      MOTION=1
   40 IF(ITMCHG.NE.0) GO TO 73
      IF((T+EPS).GE.TM) CALL CHTIME(C,EPS,ITMCHG,DT)
   73 DO 141 K=1,4
      IF(K-1)142,142,143
  142 IF(T.EQ.0.0) GO TO 143
      PFTT=PFT(T)
      PBTT=PBT(T)
      FT=144.*(PFTT-PBTT)*H*XL
  143 K3=3*K
      K2=K3-1
      K1=K3-2
      IF(IPOS1.EQ.1) GO TO 8
      IF(.NOT.(IPOS.EQ.1.AND.Y(2).LT.0.0)) GO TO 12
```

```
      Y(2)=0.0
      YP(2)=0.0
      YQ(2)=0.0
      YQP(2)=0.0
      IPOS1=1
   12 BETA=PHI-Y(2)
      YA=XLR*COS(BETA)+XMU*XLR*SIN(BETA)
      YB=(FT-XMU*WEIGHT)/XM+XLR*YP(2)*YP(2)*(XMU*COS(BETA)=SIN(BETA))
      YC=XLR*COS(BETA)
      YD=XJ/XM
      D=(H/2.+C1)*COS(Y(2))+(VWIDTH/2.-B)*SIN(Y(2))
      YE=(FT*D-WEIGHT*XLR*SIN(BETA))/XM
      YPP(1)=(YB*YD-YE*YA)/(YD-YA*YC)
      YPP(2)=(YB*YC-YE)/(YA*YC-YD)
      IF(YPP(2).LT.0.0.AND.T.EQ.0.0) MOTION=-1
    8 IF(IPOS1.EQ.1) YPP(1)=FT-XMU*32.2
      IF(IPOS1.EQ.1) YPP(2)=0.0
      XH=Y(1)+RXY*SIN(Y(2)-ANU)
      XHD=YP(1)+RXY*YP(2)*COS(Y(2)-ANU)
      YHD=RXY*YP(2)*SIN(Y(2)-ANU)
      THD=SQRT(XHD*XHD+YHD*YHD)
      XCG=Y(1)+XLR*SIN(Y(2)-ANU)
      XCGD=YP(1)+XLR*YP(2)*COS(Y(2)-ANU)
      IF(K.NE.1) GO TO 16
      IF(KPRINT.LE.0) GO TO 125
      WRITE(6,6) T,FT,Y(1),Y(2),YP(1),YP(2),YPP(1),YPP(2),XH,XHD,THD,XCG
     1,XCGD
    6 FORMAT(1H ,F8.4,7(1X,E11.4)/1H ,8X,5(1X,E11.4))
  125 CONTINUE
      IF(IPOS1.EQ.1.AND.THD.LT.10.0.AND.YPP(1).LE.0.0) GO TO 19
      IF(MOTION.LT.0) GO TO 21
   23 IF(ABS(Y(2)).GE.PI/2.) GO TO 15
   20 IF(XCGD.LT.0.0) GO TO 19
      IF(XH.LT.FDIST) GO TO 16
      VEL(KD)=THD
      KD=KD+1
      FDIST=FDIST+DELTD
      IF(KD.GT.10) GO TO 18
      GO TO 16
   21 IF(YP(2).GT.0.0) GO TO 22
      IF(KTTEST.EQ.1) GO TO 20
      GO TO 23
   22 KTTEST=1
      GO TO 23
   19 DO 24 II=KD,10
   24 VEL(II)=0.0
      GO TO 18
   15 DO 17 II=KD,10
   17 VEL(II)=THD
      GO TO 18
```

```
   16 DO 562 I=1,2
      YR(I)=C(K1)*YP(I)-C(K2)*YQ(I)
      Y(I)=Y(I)+YR(I)
      YQ(I)=YQ(I)+3.*YR(I)-C(K3)*YP(I)
      YRP(I)=C(K1)*YPP(I)-C(K2)*YQP(I)
      YP(I)=YP(I)+YRP(I)
  562 YQP(I)=YQP(I)+3.*YRP(I)-C(K3)*YPP(I)
      GO TO(146,141,146,141),K
  146 T=T+C(1)
  141 CONTINUE
      GO TO 40
   18 RETURN
      END
```

```
$IBFTC PF       M94,XR7
      FUNCTION PFT(T)
C
C                                         PRESSURE ON FRONT FACE
C
      COMMON/BLK1/TS,PREF,PFTS,PO,TO,CDF,QO,WOU,TB,PBTB,CDB
      IF(T-TS)1,2,2
    1 PFT=(PFTS-PREE)*T/TS+PREE
      GO TO 6
    2 IF(T-TO)3,4,4
    3 PFT=PO*(1.-T/TO)*EXP(-T/TO)+CDF*QO*(1.-T/TO)**2*EXP(-2.*T/TO)
      GO TO 6
    4 PFT=0.0
    6 RETURN
      END
```

```
$IBFTC PB       M94,XR7
      FUNCTION PBT(T)
C
C                                         PRESSURE ON BACK FACE
C
      COMMON/BLK1/TS,PREF,PFTS,PO,TO,CDF,QO,WOU,TB,PBTB,CDB
      IF(T-WOU)1,2,2
    1 PBT=0.0
      GO TO 6
    2 IF(T-TB)3,4,4
    3 PBT=PBTB*(1.-(T-TB)/(WOU-TB))
      GO TO 6
    4 IF(T-TO-WOU)5,7,7
    5 PBT=PO*(1.-(T-WOU)/(TO-WOU))*EXP(-(T-WOU)/(TO-WOU))+CDB*QO*(1.-(T-
     1WOU)/(TO-WOU))**2*EXP(-2.*(T-WOU)/(TO-WOU))
      GO TO 6
    7 PBT=0.0
    6 RETURN
      END
```

```
$IBFTC CHTIM    M94,XR7
      SUBROUTINE CHTIME(C,EPS,ITMCHG,DT)
      DIMENSION C(1)
      DT=0.01
      EPS=0.005
      ITMCHG=1
      C(1)=DT/2.
      C(2)=1.0
      C(3)=C(1)
      C(5)=1.-SQRT(0.5)
      C(4)=C(5)*DT
      C(6)=C(4)
      C(8)=2.-C(5)
      C(7)=C(8)*DT
      C(9)=C(7)
      C(10)=DT/6.
      C(11)=0.33333333
      C(12)=C(1)
      RETURN
      END



$IBFTC BT
      FUNCTION BTRANS(PACVEL)
      PACVEL=ABS(PACVEL)
      IF(PACVEL-25.)1,1,3
    1 BTRANS=0.0
    2 RETURN
    3 IF(PACVEL-55.)5,4,4
    4 BTRANS=100.0
      GO TO 2
    5 IF(PACVEL.GT.25.0.AND.PACVEL.LE.31.0) BTRANS=1.67*PACVEL-41.8
      IF(PACVEL.GT.31.0.AND.PACVEL.LE.41.0) BTRANS=8.0*PACVEL-238.
      IF(PACVEL.GT.41.0.AND.PACVEL.LE.55.0) BTRANS=0.715*PACVEL+60.6
      IF(BTRANS.LT.0.0) BTRANS=0.0
      IF(BTRANS.GT.100.0) BTRANS=100.0
      GO TO 2
      END



$IBFTC PCON
      FUNCTION PCONI(V)
C     INJURY CURVE FOR BLAST TRANSLATION
      PCONI=20.*V-200.
      IF(V.GT.15.) PCONI=100.
      IF(V.LT.10.) PCONI=0.0
      RETURN
      END
```

```
$IBFTC DEBR
      SUBROUTINE DEBRIS(KPRINT)
      COMMON/BLK2/ GZX,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,    POPDN,REACSI,REACST,REACLY
      COMMON/BLK6/ PO,   TQ,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWT(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON/BLK8/ PPERTB(10,9),PPERTI(10,9),BRKMAS
      COMMON/BLK9/ DHB,DDYB,DWKB,DHTO,DDYTO,DWKTO,DMTHTO,DHTI,DDYTI,DWKT
     1I,DMTHTI,DHD,DDYD,DWKD,DMTD, DH,DD,DW,DM
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      DIMENSION DISTM(9,100),DISTM1(9,100),DISTM2(9,100),VEHM(9,100),
     1VEHM1(9,100),VEHM2(9,100),DIST(100),VEH(100),PROBDH(10),PROBDD(10)
     2,PROBDW(10),PROBDM(10),RADIUS(9),AMANHT(3,3)
      DIMENSION PROBHD(10),PROBDY(10),PROBWD(10),PROBMD(10)
      DIMENSION PROBI(10),PROBII(10)
      DATA (RADIUS(I),I=1,9)/1.,2.,3.,4.,5.,6.,8.,10.,12./,((AMANHT(I,J)
     1,J=1,3),I=1,3)/5.76,3.76,0.0,3.76,5*0.0/
C
C     COMPUTE DEATHS DUE TO OUTDOOR DEBRIS
C
      TMAX=SQRT(HMAX/16.085)
      IF(KPRINT.GT.0) WRITE(6,302) TMAX
  302 FORMAT(30H0MAXIMUM TIME OF DEBRIS FLIGHT,F12.6,4H SEC)
C
C     OUTSIDE DEBRIS FROM OUTSIDE WALLS
C
      IF(KA.EQ.0) GO TO 5
      ATOT=S1*S2+2.*(S2*AVEW+S1*AVEL)
      WDTH=AVEL*SIN(PHI)+AVEW*COS(PHI)
      AGLT=S1*SIN(PHI)+S2*COS(PHI)
      DELTD=AGLT/10.
      GO TO 6
    5 DELTD=AMAX1(D1,D2,D3,D4,D5)/10.
      INDX(1)=D1/DELTD+0.5
      CALL TRAJ(W,PONA,RAD,DIST,TMAX,VEH)
      INDX(2)=D2/DELTD+0.5
      INDX(3)=D3/DELTD+0.5
      INDX(4)=D4/DELTD+0.5
      INDX(5)=D5/DELTD+0.5
      AAA(1)=W1*DELTD
      AAA(2)=W2*DELTD
      AAA(3)=W3*DELTD
      AAA(4)=W4*DELTD
      AAA(5)=W5*DELTD
    6 CONTINUE
```

```
      DO 21 I=1,10
      PROBII(I)=0.0
      PROBHD(I)=0.0
      PROBDY(I)=0.0
      PROBWD(I)=0.0
   21 PROBMD(I)=0.0
      DIO=0.0
      DHD=0.0
      DDYD=0.0
      DWKD=0.0
      DMTD=0.0
      PEROUT=1.-PERPIN/100.
C
C     CALCULATE DISTANCE,VELOCITY VS. TIME RELATIONS FOR EACH SIZE
C
      DO 200 I=1,9
      DO 211 IL=1,NN
      IF(PPERTB(IL,I).GT.0.0) GO TO 212
  211 CONTINUE
      GO TO 200
  212 RAD=RADIUS(I)
      DO 205 J=1,10
      PROBI(J)=0.0
      PROBDH(J)=0.0
      PROBDD(J)=0.0
      PROBDW(J)=0.0
  205 PROBDM(J)=0.0
      IF(KPRINT.GT.0) WRITE(6,303) RAD,(III,DIST(III),VEH(III),III=1,100
     1)
  303 FORMAT(16H0PARTICLE RADIUS,F10.2/39H0DEBRIS DISTANCE-VELOCITY RELA
     1TIONSHIPS/5H0TIME,7X,4HDIST,9X,8HVELOCITY/(1X,I5,3X,F12.2,9X,F12.2
     2))
C
C     FOR EACH INCREMENTAL DISTANCE,DOWNRANGE,OBTAIN AVERAGE VELOCITY
C     AND RANGE OF TIME(RANGE OF INITIAL HEIGHTS) TO GIVE THIS VELOCITY
C
      DO 920 J=1,10
      DISTI=FLOAT(J)*DELTD
      IF(DISTI.GT.DIST(100)) GO TO 920
      IF(DISTI.LT.DIST(1)) GO TO 201
      DO 202 K=2,100
      IF(DISTI.LT.DIST(K).AND.DISTI.GT.DIST(K-1)) GO TO 203
  202 CONTINUE
  201 VMIN=0.0
      VMAX=VEH(1)
      VAVE=VMAX/2.
      TMIN=0.0
      K=1
      GO TO 206
  203 VMAX=AMAX1(VEH(K),VEH(K-1))
```

```
      VMIN=AMIN1(VFH(K),VFH(K-1))
      VAVE=(VMAX+VMIN)/2.
      TMIN=TMAX/100.*FLOAT(K-1)
  206 TMX=TMAX/100.*FLOAT(K)
C
C     FOR EACH BUILDING TYPE AND EACH TORSO POSITION FIND THE MAXIMUM
C     PROB. OF DEATH IN EACH TIME TO DEATH CATAGORY FOR EACH INCREMENTAL
C     DISTANCE
C
      DO 820 L=1,NM
      IF(PONA.LT.PBREAK(L)) GO TO 820
      NFLS=NFL(L)
      FHT=BILDHT(L)/FLOAT(NFLS)
      DO 20 M=1,3
      IF(TMIN.LT.0.2493) GO TO 217
      GO TO 219
  217 PVELA=AMAX1(BDEBRE(VAVE,RAD,1),BDEBRE(VAVE,RAD,2),BDEBRE(VAVE,RAD,
     13))
      PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD
     1,3))
      VINJMX=PVELIN
      AMAXBP=PVELA
      GO TO 213
  219 AMAXBP=0.0
      VINJMX=0.0
      DO 199 N=1,3
      NF=BILDHT(L)-AMANHT(M,N)+1.
      DO 204 K=1,NF
      HTF=K
      TH=SQRT(HTF/16.085)
      IF(TH.LT.TMIN) GO TO 204
      PVELA=BDEBRE(VAVE,RAD,N)
      AMAXBP=AMAX1(PVELA,AMAXBP)
      PVELIN=BTRANI(VAVE,RAD,N)
      VINJMX=AMAX1(PVELIN,VINJMX)
      IF(TH.GT.TMX) GO TO 199
  204 CONTINUE
  199 CONTINUE
  213 IF(AMAXBP.LT.0.0) AMAXBP=0.0
      PVELA=AMAXBP
      DDEB=PVELA*CONPER(L)*POSPRO(M)*PPERTB(L,I)/1.E8*(1.-PERCWI(L)/100.
     1)
      DINJ=100.-PVELA
      IF(PVELA.LE.0.0) DINJ=VINJMX
      PROBI(J)=PROBI(J)+DINJ*CONPER(I)*POSPRO(M)*PPERTB(L,I)/1.E8*(1.-PE
     1RCWI(I)/100.)
      IF(AMAXBP.LT.10.) GO TO 210
      IF(AMAXBP.LT.50.) GO TO 207
      IF(AMAXBP.LT.90.) GO TO 208
      PROBDH(J)=PROBDH(J)+DDEB
```

```
      GO TO 20
  208 PROBDD(J)=PROBDD(J)+DDEB
      GO TO 20
  207 PROBDW(J)=PROBDW(J)+DDEB
      GO TO 20
  210 PROBDM(J)=PROBDM(J)+DDEB
   20 CONTINUE
  820 CONTINUE
  920 CONTINUE
      DO 22 J=1,10
      PROBII(J)=AMAX1(PROBII(J),PROBI(J))
      PROBHD(J)=AMAX1(PROBHD(J),PROBDH(J))
      PROBDY(J)=AMAX1(PROBDY(J),PROBDD(J))
      PROBWD(J)=AMAX1(PROBWD(J),PROBDW(J))
   22 PROBMD(J)=AMAX1(PROBMD(J),PROBDM(J))
  200 CONTINUE
      IF(KA.EQ.0) GO TO 215
      FACT1=DELTD*WDTH/ATOT
      DO 176 IND=1,10
      DIO=DIO+PROBII(IND)*FACT1*PEROUT
      DHD = DHD+PROBHD(IND)*FACT1*PEROUT
      DDYD=DDYD+PROBDY(IND)*FACT1*PEROUT
      DWKD=DWKD+PROBWD(IND)*FACT1*PEROUT
  176 DMTD=DMTD+PROBMD(IND)*FACT1*PEROUT
      GO TO 220
  215 DO 216 I=1,5
      FACT=AAA(I)/ATOT*PEROUT
      INDEX=INDX(I)
      DO 216 IND=1,INDEX
      DIO=DIO+PROBII(IND)*FACT
      DHD = DHD+PROBHD(IND)*FACT
      DDYD=DDYD+PROBDY(IND)*FACT
      DWKD=DWKD+PROBWD(IND)*FACT
  216 DMTD=DMTD+PROBMD(IND)*FACT
C
C     INSIDE DEBRIS FROM OUTSIDE WALLS
C
  220 TMAX=1.0
      DO 30 I=1,10
      PROBII(I)=0.0
      PROBHD(I)=0.0
      PROBDY(I)=0.0
      PROBWD(I)=0.0
   30 PROBMD(I)=0.0
      DII=0.0
      DH=0.0
      DD=0.0
      DW=0.0
      DM=0.0
      CALL TRAMAT(W,PONA,1.0,DIST,VEH,RADIUS,PPERTB,PPERTI,DISTM,VEHM)
```

```
      DO 224 J=1,9
      DO 221 K=1,10
      PROBI(K)=0.0
      PROBDH(K)=0.0
      PROBDD(K)=0.0
      PROBDW(K)=0.0
  221 PROBDM(K)=0.0
      RAD=RADIUS(J)
      DO 250 I=1,NN
      IF(PONA.LT.PBREAK(I).OR.PPERTB(I,J).LE.0.0) GO TO 250
      DELTD=EXPL(I)/10.
      ALEN=AMAX1(BILDLT(I),BILDWT(I))
      IF(IWALLT(I).EQ.0) DELTD=ALEN/10.
      NFLS=NFL(I)
      FHT=BILDHT(I)/FLOAT(NFLS)
      DO 223 K=1,10
      DISTI=FLOAT(K)*DELTD
      IF(DISTI.GT.DISTM(J,100)) GO TO 250
      IF(DISTI.LT.DISTM(J,1)) GO TO 222
      DO 225 KI=2,100
      IF(DISTI.LT.DISTM(J,KI).AND.DISTI.GT.DISTM(J,KI-1)) GO TO 226
  225 CONTINUE
  222 VAVE=VEHM(J,1)/2.
      TMIN=0.0
      KI=1
      GO TO 227
  226 VAVE=(VEHM(J,KI)+VEHM(J,KI-1))*0.5
      TMIN=FLOAT(KI-1)*TMAX/100.
  227 TMX=TMAX/100.*FLOAT(KI)
      DO 223 M=1,3
      IF(TMIN.LT.0.07197784) GO TO 228
      GO TO 229
  228 PVELA=AMAX1(BDFBRE(VAVE,RAD,1),BDFBRE(VAVE,RAD,2),BDFBRE(VAVE,RAD,
     13))
      AMAXBP=PVELA
      PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD
     1,3))
      VINJMX=PVELIN
      GO TO 233
  229 AMAXBP=0.0
      VINJMX=0.0
      DO 235 N=1,3
      NF=(FHT-AMANHT(M,N))*12.+1.
      IF(NF.LE.0) NF=1
      DO 234 KKK=1,NF
      HTF=FLOAT(KKK)/12.
      TH=SQRT(HTF/16.085)
      IF(TH.LT.TMIN) GO TO 234
      PVELA=BDFBRE(VAVE,RAD,N)
      AMAXBP=AMAX1(PVELA,AMAXBP)
```

```
      PVELIN=BTRANT(VAVE,RAD,N)
      VINJMX=AMAX1(VINJMX,PVELIN)
      IF(TH.GT.TMX) GO TO 235
  234 CONTINUE
  235 CONTINUE
  233 IF(AMAXBP.LT.0.0) AMAXBP=0.0
      DDEB=AMAXBP*CONPER(I)*POSPRI(M)*PPERTB(I,J)/1.E8*(1.-PERCWI(I)/100
     1.)
      DDEB=DDEB/10.*DELTD/ALEN*10.
      PVELA=AMAXBP
      DINJ=100.-PVELA
      IF(PVELA.LE.0.0) DINJ=VINJMX
      PROBI(K)=PROBI(K)+DINJ*CONPER(I)*POSPRI(M)*PPERTB(I,J)/1.E9*(1.-PE
     1RCWI(I)/100.)*DELTD/ALEN*10.
      IF(AMAXBP.LT.10.) GO TO 240
      IF(AMAXBP.LT.50.) GO TO 247
      IF(AMAXBP.LT.90.) GO TO 248
      PROBDH(K)=PROBDH(K)+DDEB
      GO TO 223
  248 PROBDD(K)=PROBDD(K)+DDEB
      GO TO 223
  247 PROBDW(K)=PROBDW(K)+DDEB
      GO TO 223
  240 PROBDM(K)=PROBDM(K)+DDEB
  223 CONTINUE
  250 CONTINUE
      DO 31 K=1,10
      PROBII(K)=AMAX1(PROBII(K),PROBI(K))
      PROBHD(K)=AMAX1(PROBHD(K),PROBDH(K))
      PROBDY(K)=AMAX1(PROBDY(K),PROBDD(K))
      PROBWD(K)=AMAX1(PROBWD(K),PROBDW(K))
   31 PROBMD(K)=AMAX1(PROBMD(K),PROBDM(K))
  224 CONTINUE
      FACT=PERPIN/100.
      DO 249 J=1,10
      DII=DII+PROBII(J)*FACT
      DH=DH+PROBHD(J)*FACT
      DD=DD+PROBDY(J)*FACT
      DW=DW+PROBWD(J)*FACT
  249 DM=DM+PROBMD(J)*FACT
  245 DO 32 J=1,10
      PROBII(J)=0.0
      PROBHD(J)=0.0
      PROBDY(J)=0.0
      PROBWD(J)=0.0
   32 PROBMD(J)=0.0
C
C     COMPUTATIONS FOR DEBRIS FROM INSIDE WALLS
C
      DO 254 J=1,9
```

```
      DO 251 K=1,10
      PROBI(K)=0.0
      PROBDH(K)=0.0
      PROBDD(K)=0.0
      PROBDW(K)=0.0
  251 PROBDM(K)=0.0
      RAD=RADIUS(J)
      DO 50 I=1,NN
      IF(PONA.LT.PBREAK(I).AND.POBILD(I).GT.BRKMAS.AND.IWALLT(I).NE.0.AN
     1D.PPERTI(I,J).GT.0.0) GO TO 51
      IF(PONA.GT.PBREAK(I).AND.PONA.GT.BRKMAS.AND.IWALLT(I).NE.0.AND.PPE
     1RTI(I,J).GT.0.0) GO TO 52
      GO TO 50
C
C     OUTSIDE WALLS DO NOT FAIL - BUT INSIDE MASONRY WALLS DO GO
C
   51 PP=POBILD(I)
      WRITE(6,351) I
  351 FORMAT(43H0INSIDE DEBRIS FROM INTERIOR WALLS,BUILDING,I3)
      CALL TRAMAT(W,PP,1.0,DIST,VEH,RADIUS,PPERTI,PPERTI,DISTM1,VEHM1)
      IF(KPRINT.GT.0.AND.PPERTI(I,J).GT.0.0) WRITE(6,303) RAD,(II,DISTM1
     1(J,II),VEHM1(J,II),II=1,100)
      DO 243 II=1,100
      DO 243 JJ=1,9
      DISTM2(JJ,II)=DISTM1(JJ,II)
  243 VEHM2(JJ,II)=VEHM1(JJ,II)
      GO TO 244
C
C     OUTSIDE WALLS GO AND INSIDE MASONRY WALLS GO
C
   52 DO 242 II=1,9
      DO 242 JJ=1,100
      DISTM2(II,JJ)=DISTM(II,JJ)
  242 VEHM2(II,JJ)=VEHM(II,JJ)
  244 DELTD=AINTRL(I)/10.
      ALEN=AMAX1(BILDLT(I),BILDWT(I))
      NFLS=NFL(I)
      FHT=BILDHT(I)/FLOAT(NFLS)
      DO 253 K=1,10
      DISTI=FLOAT(K)*DELTD
      IF(DISTI.GT.DISTM2(J,100)) GO TO 50
      IF(DISTI.LT.DISTM2(J,1)) GO TO 255
      DO 256 KI=2,100
      IF(DISTI.LT.DISTM2(J,KI).AND.DISTI.GT.DISTM2(J,KI-1))GO TO 257
  256 CONTINUE
  255 VAVE=VEHM2(J,1)/2.
      TMIN=0.0
      KI=1
      GO TO 258
  257 VAVE=(VEHM2(J,KI)+VEHM2(J,KI-1))*0.5
```

```
      TMIN=FLOAT(KT-1)*TMAX/100.
  258 TMX=TMAX/100.*FLOAT(KI)
      DO 253 M=1,3
      IF(TMIN.LT.0.07197784) GO TO 268
      GO TO 269
  268 PVELA=AMAX1(BDEBRE(VAVE,RAD,1),BDEBRE(VAVE,RAD,2),BDEBRE(VAVE,RAD,
     13))
      AMAXBP=PVELA
      PVELIN=AMAX1(BTRANI(VAVE,RAD,1),BTRANI(VAVE,RAD,2),BTRANI(VAVE,RAD
     1,3))
      VINJMX=PVELIN
      GO TO 273
  269 AMAXBP=0.0
      VINJMX=0.0
      DO 278 N=1,3
      NF=(FHT-AMANHT(M,N))*12.+1.
      IF(NF.LE.0) NF=1
      DO 274 KKK=1,NF
      HTF=FLOAT(KKK)/12.
      TH=SQRT(HTF/16.085)
      IF(TH.LT.TMIN) GO TO 274
      PVELA=BDEBRE(VAVE,RAD,N)
      AMAXBP=AMAX1(PVELA,AMAXBP)
      PVELIN=BTRANI(VAVE,RAD,N)
      VINJMX=AMAX1(PVELIN,VINJMX)
      IF(KPRINT.GT.0) WRITE(6,400) M,N,TMIN,TH,TMX,HTF,PVELA,AMAXBP
  400 FORMAT(33H M,N,TMIN,TH,TMX,HTF,PVELA,AMAXBP,2I5,6E14.5)
      IF(TH.GT.TMX) GO TO 278
  274 CONTINUE
  278 CONTINUE
  273 IF(AMAXBP.LT.0.0) AMAXBP=0.0
      PVELA=AMAXBP
      DINJ=100.-PVELA
      IF(PVELA.LE.0.0) DINJ=VINJMX
      PROBI(K)=PROBI(K)+DINJ*CONPER(I)*POSPRI(M)*PPERTI(I,J)/1.E9*(ALEN-
     1EXRL(I))/ALEN
      DDEB=AMAXBP*CONPER(I)*POSPRI(M)*PPERTI(I,J)/1.E8
      DDEB=DDEB/10.*(ALEN-EXRL(I))/ALEN
      IF(KPRINT.GT.0) WRITE(6,401) K,M,AMAXBP,DDEB
  401 FORMAT(16H K,M,AMAXBP,DDEB,2I5,2E20.8)
      IF(AMAXBP.LT.10.) GO TO 276
      IF(AMAXBP.LT.50.) GO TO 275
      IF(AMAXBP.LT.90.) GO TO 1
      PROBDH(K)=PROBDH(K)+DDEB
      GO TO 253
    1 PROBDD(K)=PROBDD(K)+DDEB
      GO TO 253
  275 PROBDW(K)=PROBDW(K)+DDEB
      GO TO 253
  276 PROBDM(K)=PROBDM(K)+DDEB
```

```
  253 CONTINUE
   50 CONTINUE
      DO 33 K=1,10
      PROBII(K)=AMAX1(PROBII(K),PROBI(K))
      PROBHD(K)=AMAX1(PROBHD(K),PROBDH(K))
      PROBDY(K)=AMAX1(PROBDY(K),PROBDD(K))
      PROBWD(K)=AMAX1(PROBWD(K),PROBDW(K))
   33 PROBMD(K)=AMAX1(PROBMD(K),PROBDM(K))
      IF(KPRINT.GT.0) WRITE(6,402) (K,PROBHD(K),PROBDY(K),PROBWD(K),PRO
     1MD(K),K=1,10)
  402 FORMAT(1H ,I5,4E20.8)
  254 CONTINUE
      FACT=PERPIN/100.
      DO 277 J=1,10
      DII=DII+PROBII(J)*FACT
      DH=DH+PROBHD(J)*FACT
      DD=DD+PROBDY(J)*FACT
      DW=DW+PROBWD(J)*FACT
  277 DM=DM+PROBMD(J)*FACT
      RETURN
      END
```

```
$IBFTC TRAMA
      SUBROUTINE TRAMAT(W,PO,TMAX,DIST,VEH,RADIUS,PRESSO,PRESSI,DISTM,VE
     1HM)
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWT(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXPL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      DIMENSION RADIUS(1),VEH(1),DIST(1),DISTM(9,100),VEHM(9,100),PRESSO
     1(10,9),PRESSI(10,9)
      DO 1 I=1,9
      DO 1 J=1,100
      DISTM(I,J)=0.0
    1 VEHM(I,J)=0.0
      DO 4 I=1,9
      RAD=RADIUS(I)
      DO 2 J=1,NN
      IF(PRESSI(J,I).GT.0.0.OR.PRESSO(J,I).GT.0.0) GO TO 3
    2 CONTINUE
      GO TO 4
    3 CALL TRAJ(W,PO,RAD,DIST,TMAX,VEH)
      DO 5 J=1,100
      DISTM(I,J)=DIST(J)
      VEHM(I,J)=VEH(J)
    5 CONTINUE
    4 CONTINUE
      RETURN
      END
```

```
  C BD
   FUNCTION BDEBRE(VEL,RAD,IPOS)
   DIMENSION PROB(3,3,21)
   DATA (PROB(1,1,I),I=1,21)/90.,96.,100.,105.,109.,113.,117.,121.,
  1125.,128.,131.,134.,137.,139.,142.,144.,146.,148.,150.,153.,160./,
  2(PROB(1,2,I),I=1,21)/26.,31.,34.,35.,36.,37.,37.8,38.5,39.5,40.2,
  341.,42.,43.,44.,45.2,46.5,47.3,49.0,51.,54.,59./,(PROB(1,3,I),I=1,
  421)/25.,29.5,31.0,31.8,32.0,32.5,33.0,33.5,34.,34.5,35.,35.4,36.0,
  536.5,37.0,37.5,38.0,39.,41.,44.,50./
   DATA (PROB(2,1,I),I=1,21)/77.,81.5,85.,89.6,94.,98.,102.5,107.,
  1111.,115.5,120.,125.,130.,135.,139.5,144.,149.,154.,160.,165.,172.
  2/,(PROB(2,2,I),I=1,21)/25.,29.,31.,31.2,32.,32.5,33.,33.5,34.,34.5
  3,35.,35.5,36.,36.5,37.,37.5,38.,39.,41.,44.,48./
   DATA (PROB(3,1,I),I=1,21)/99.,106.,113.,120.,126.,131.,137.,143.,
  1149.,155.,160.,166.,172.,178.,184.,187.5,190.,193.,195.,198.,200./
  X                                                            ,(PRO
  2B(3,2,I),I=1,21)/35.,40.,42.5,44.,46.,48.,50.,52.,53.5,55.3,57.,
  359.,61.,62.5,64.5,66.5,68.,70.,72.,74.,78./,(PROB(3,3,I),I=1,21)/
  424.,29.,31.,31.5,32.,32.8,33.2,34.,34.3,34.8,35.,35.2,36.0,37.0,
  537.5,38.0,38.7,39.2,41.,44.,49./
   IF(IPOS-2)1,4,6
 1 IF(RAD.EQ.1.0) GO TO 2
   IF(RAD.EQ.2.0) GO TO 3
   J=3
   GO TO 9
 2 J=1
   GO TO 9
 3 J=2
   GO TO 9
 4 IF(RAD.EQ.1.0) GO TO 5
   J=2
   GO TO 9
 5 J=1
   GO TO 9
 6 IF(RAD.EQ.1.0) GO TO 7
   IF(RAD.EQ.2.0) GO TO 8
   J=3
   GO TO 9
 7 J=1
   GO TO 9
 8 J=2
 9 IF(.NOT.(VEL.LT.PROB(IPOS,J,1))) GO TO 10
   BDEBRE=0.0
   GO TO 13
10 DO 11 K=2,21
   IF(VEL.GE.PROB(IPOS,J,K-1).AND.VEL.LE.PROB(IPOS,J,K)) GO TO 12
11 CONTINUE
   BDEBRE=100.0
   GO TO 13
12 BDEBRE=5.*FLOAT(K)-5.*(PROB(IPOS,J,K)-VEL)/(PROB(IPOS,J,K)-PROB(IP
  1OS,J,K-1))
13 RETURN
   END
```

```
$IBFTC BTRI
      FUNCTION BTRANI(V,RAD,IPOS)
C     INJURY CURVES FOR BLAST DEBRIS
      IF(IPOS-2) 1,2,3
    1 IF(RAD.LE.1.0) GO TO 4
      IF(RAD.LE.2.0) GO TO 5
      AM=7,7
      B=-64.
      GO TO 10
    4 AM=4.0
      B=-260.
      GO TO 10
    5 AM=25.
      B=-550.
      GO TO 10
    2 IF(RAD.LE.1.0) GO TO 6
      AM=6,67
      B=-66.7
      GO TO 10
    6 AM=3,45
      B=-165,5
      GO TO 10
    3 IF(RAD.LE.1.0) GO TO 7
      IF(RAD.LE.2.0) GO TO 8
      AM=6,67
      B=-60.
      GO TO 10
    7 AM=2,04
      B=-102.
      GO TO 10
    8 AM=5,26
      B=-84.3
   10 BTRANI=AM*V+B
      IF(BTRANI.LE.0.0) BTRANI=0.0
      IF(BTRANI.GE.100.0) BTRANI=100.
      RETURN
      END
```

```
$IBFTC TRAJE    M94,XR7
      SUBROUTINE TRAJ(W,OVRPR,RD,DIST,TMAX,VEH)
C
C     TO COMPUTE DEBRIS TRAJECTORIES
C
      COMMON/BLKD/LIST1(6),LIST2(9),LIST3(31),LIST5(9),LIST6(7),LIST7(9)
     1,ISKIP(6),LIST8(9),ABETA,IAC
      DIMENSION DIST(1),VEH(1)
      PREXP=2.2547
      TMEXP=0.59778
      PRFCT=1.72E9*(100./W)**(-PREXP/3.)
      TMFCT=7.5360397E-3*(100./W)**(TMEXP/3.)
      RNG=(OVRPR/PRFCT)**(-1./PREXP)
      DT=TMAX/500.
      KOUNT=1
      FT=TMAX/100.
      RAD=RD/12.
      PROVR=OVRPR
      ARG=1.0
      DELTAT=0.0
      XDOT=0.0
      DISTX=0.0
      SIGMAX=0.0
      TIME=0.0
      SUMSFV=0.0
      TSTAR=0.0
      IF(ABETA.LE.0.0) ABETA=360.*RAD
    2 REFP=PRFCT*(RNG+SUMSFV*DELTAT)**(-PREXP)
      REFSFV=1120.*SQRT(1.+6.*REFP/103.)
      SUMSFV=SUMSFV+REFSFV
      CAPT= TMFCT*(RNG+SIGMAX)**TMEXP
      RHO=0.08*((7.+6.*PROVR/14.7)/(7.+PROVR/14.7))
      WINDV=53.4*PROVR/SQRT(1.+6.*PROVR/103.)
      DUM=WINDV-XDOT
      IF(DUM)3,3,4
    3 C=-1.0
      GO TO 5
    4 C=1.0
    5 BETA=-C*ABETA/RHO
      CONST1=ARG
      CONST2=ARG/BETA*(XDOT-WINDV)
      DISTY=BETA*ALOG(ARG)
      DELTAT=DT
      TIME=TIME+DT
      IF(TIME.GE.FT) GO TO 9
    8 ARG=(CONST1+CONST2*DELTAT)*EXP(WINDV*DELTAT/BETA)
      DISTX=BETA*ALOG(ARG)-DISTY
      XDOT=(CONST1*WINDV+CONST2*(BETA+DELTAT*WINDV))/(CONST1+CONST2*DELT
     1AT)
      XOLD=SIGMAX
```

```
      SIGMAX=SIGMAX+DISTX
      STARP=PRFCT*(RNG+SIGMAX)**(-PREXP)
      STARV=1120.*SQRT(1.+6.*STARP/103.)
      TSTAR=TSTAR+DELTAT-(SIGMAX-XOLD)/STARV
      PROVR=REFP*(1.-TSTAR/CAPT)*EXP(-TSTAR/CAPT)
      IF(PROVR.LT.0.0) PROVR=0.0
      GO TO 2
    9 DIST(KOUNT)=SIGMAX
      VEH(KOUNT)=SQRT(XDOT*XDOT+1034.91*FT*FT)
      IF(KOUNT-100)63,64,64
   63 KOUNT=KOUNT+1
      FT=FT+TMAX/100.
      GO TO 2
   64 RETURN
      END
```

```
$IBFTC THER     M94,XR7
      SUBROUTINE THERM(KPRINT)
      COMMON/BLK2/ G7X,GZY,XN,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,    POPDN,REACSI,REACST,REACLY
      COMMON/BLK6/ PO,    TQ,RI,PONA
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),TWALLY(10),IBY(10),PERCOA,BILDHT(10)
      COMMON /BLK11/ WALPAN(10),WALDEN(10),FLORTH(10),FLORDN(10),ROOFTH(
     110),ROOFDN(10),BASETH(10),BASEDN(10),SOILDN(10),SILHT(10),PERSCR(1
     20),PERSG(10),PERGG(10),PERDBS(10),PERG(10),PERDE(10),PERGGS(10)
      COMMON /BLK12/ DDYTHI,DWKTHI,DMTTHI,DDYTHO,DWKTHO,DMTTHO
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      DIMENSION HT(3),A(3),ADE(3),ASCR(3),AG(3),ASG(3),AGG(3),AGGS(3),AD
     1BS(3),AREAO(5),DIST(5),AOUT(5),RADEX(7),
     2                             ABURN(7),PKT(7),                  ARB
     3URN(2,25),PK(25),PPK(3,15),PKDEM(3,4),PKSRM(3,4),PKGM(3,4),PKSGM(3
     4,4),PKGGM(3,4),PKGGSM(3,4),PKDBM(3,4),PKDEW(3,4),PKSRW(3,4),PKGW(3
     5,4),PKSGW(3,4),PKGGW(3,4),PKGGSW(3,4),PKDBW(3,4),PKDED(3,4),PKSRD(
     63,4),PKGD(3,4),PKSGD(3,4),PKGGD(3,4),PKGGSD(3,4),PKDBD(3,4),
     8 PKTM(3,7),PKTW(3,7),PKTD(3,7),PKTDO(7),PKTWO(7),PKTMO(7),TKM(3,4)
     9,TKW(3,4),TKD(3,4),Q(7),TIME(4)
      DIMENSION TKI(3,4),PINJ(3,7)
      DATA(ARBURN(2,II),II=1,13)/0.,16.,16.,16.,16.,16.,16.,17.5,33.,55.
     1,77.,96.,100./
      DATA(ARBURN(1,II),II=1,18)/0.,6.,6.,6.,6.,6.,6.,6.,8.,15.5,24.,35.
     1,48.,61.5,73.,86.,96.,100./
      DATA(PK(II),II=1,17)/0.,3.,6.,10.,19.,31.,45.,56.,65.5,74.2,81.5,8
     27.,91.,94.5,97.,98.5,100./
      DATA(PPK(1,II),II=1,10)/0.,6.2,16.3,29.5,33.8,34.5,2.5,0.,0.,0./
      DATA(PPK(2,II),II=1,10)/100.,89.5,75.,60.,51.5,43.5,28.5,23.5,14.,
     10./
      DATA(PPK(3,II),II=1,10)/0.,0.,5.,11.5,16.,22.,47.5,60.,82.,100./
      DATA(TIME(IJ),IJ=1,3)/2.,6.,10./
      DATA(HT(I),I=1,3)/5.76,1.58,1.0/
  106 FORMAT(3HOA=,E15.8)
   90 FORMAT(1X,4(E15.8,2X))
   91 FORMAT(7HORADEX=,E15.8)
   92 FORMAT(7HOABURN=,E15.8,2X,5H PKT=,E15.8)
   56 FORMAT(19HOTOTAL DEAD IN DAY=,E15.8,20H TOTAL DEAD IN WEEK=,E15.8,
     121H TOTAL DEAD IN MONTH=,E15.8)
   54 FORMAT(6HOTIME=,E15.8,2X,2HQ=,E15.8)
   48 FORMAT(31HOPERCENT KILLED OUTSIDE IN DAY=,E15.8/32H PERCENT KILLED
     1 OUTSIDE IN WEEK=,E15.8/33H PERCENT KILLED OUTSIDE IN MONTH=,E15.8
     2)
   25 FORMAT(14H1BUILDING TYPE,I3)
      FII=0.0
```

```
      Q(4)=TQ
      XO=XO
      TMAX=0.032*SQRT(W)
      TIME(4)=TMAX
      DO 51 IJ=1,3
      TOTMAX=TIME(IJ)/TMAX
      IF(TOTMAX.GT.10.) GO TO 52
   51 Q(IJ)=  TQ*PERCTH(TOTMAX)
      NQ=4
      GO TO 35
   52 NQ=IJ
      Q(IJ)=TQ
   35 DDYTH=0.0
      DWKTH=0.0
      DMTTH=0.0
      DO 190 I=1,NN
      IF(KPRINT.GT.0) WRITE(6,25) I
      XL=SQRT(PERCWI(I)/100.)*(BILDWI(I)*COS(PHI)+BILDLT(I)*SIN(PHI))
      DP=20.
      CTNTH=XO/HB
      TANTH=HB/XO
      WINDOW=10.*SQRT(PERCWI(I)/100.)
      THETA= ATAN(XO/HB)
      SPW=SILHT(I)+WINDOW
      DAV=(D1*A1+D2*A2+D3*A3+D4*A4+D5*A5)/ATOT
      IF( .NOT.(KA.GT.0)) GO TO 1
      DAV=(S1*A1*SIN(PHI)+S2*A2*COS(PHI))/(A1*SIN(PHI)+A2*COS(PHI))
    1 CONTINUE
      HSHADE=(AVEHT-TANTH*DAV)
      IF(HSHADE.LT.0.0) HSHADE =0.0
      FLHT=BILDHT(I)/FLOAT(NFL(I))
      FLOORS=HSHADE/FLHT
      KFLOOR=FLOORS
      XFLOOR=KFLOOR
      IF(HSHADE.LE.(XFLOOR*FLHT+SPW)) GO TO 10
      KFLOOR=KFLOOR+1
   10 XNFL=NFL(I)-KFLOOR
      DO 3 II=1,3
      A(II)=0.
      IF(CTNTH*SPW.LE.EXRL(I).AND.SILHT(I).GT.HT(II)) A(II)=CTNTH*XL*(HT
     1(II)+WINDOW)
      IF(CTNTH*SPW.LE.EXRL(I).AND.SILHT(I).LE.HT(II)) A(II)=CTNTH*XL*SPW
      IF(CTNTH*SPW.GT.EXRL(I).AND.SILHT(I)*CTNTH.LE.EXRL(I).AND.SILHT(I)
     1.LE.HT(II))A(II)=EXRL(I)*XL
      IF(CTNTH*SPW.GT.EXRL(I).AND.SILHT(I)*CTNTH.LE.EXRL(I).AND.SILHT(I)
     1.GT.HT(II))A(II)=XL*(EXRL(I)-CTNTH*(SILHT(I)-HT(II)))
      IF(CTNTH*SPW.GT.EXRL(I).AND.SILHT(I)*CTNTH.GT.EXRL(I).AND.SILHT(I)
     1.LT.HT(II)) A(II)=EXRL(I)*XL
      IF(CTNTH*SPW.GT.EXRL(I).AND.SILHT(I)*CTNTH.GT.EXRL(I).AND.SILHT(I)
     1.GE.HT(II).AND.SILHT(I)-EXRL(I)*TANTH.LT.HT(II)) A(II)=XL*(EXRL(I)
```

```
     2-(SILHT(I)-HT(II))*CTNTH)
      IF(KPRINT.GT.0) WRITE(6,106) A(II)
      AII=A(II)*XNFL
      ADE(II)=AII*PERDE(I)
      ASCR(II)=AII*PERSCR(I)
      AG(II)=AII*PERG(I)
      ASG(II)=AII*PERSG(I)
      AGG(II)=AII*PERGG(I)
      AGGS(II)=AII*PERGGS(I)
      ADBS(II)=AII*PERDBS(I)
      IF(KPRINT.GT.0) WRITE(6,90) ADBS(II),AGG(II),ASCR(II),ASG(II)
    3 CONTINUE
      AA=AVEHT*CTNTH
      AREAO(1)=A1
      AREAO(2)=A2
      AREAO(3)=A3
      AREAO(4)=A4
      AREAO(5)=A5
      DIST(1)=D1
      DIST(2)=D2
      DIST(3)=D3
      DIST(4)=D4
      DIST(5)=D5
      DO 12 II=1,5
      AOUT(II)=(DIST(II)-AA)*AREAO(II)/DIST(II)
      IF(AOUT(II).LE.0.) AOUT(II)=0.0
   12 CONTINUE
      IF(KA.EQ.0) GO TO 203
      BB=AA
      AA=BB*SIN(PHI)
      AOUT(1)=(D1-AA)*A1/D1
      AA=BB*COS(PHI)
      AOUT(2)=(D2+S1-AA)*A2/(D2+S1)
      AOUT(3)=-S1*S2
      AOUT(4)=0.0
      AOUT(5)=0.0
  203 KKOUNT=0
      K=2
      RFIN=22.
      RCHA=16.
      DO 40 J=1,NQ
      IF(KPRINT.GT.0) WRITE(6,54) TIME(J),Q(J)
      RADEX(1)=Q(J)
      RADEX(2)=Q(J)*.67
      RADEX(3)=Q(J)*.56
      RADEX(4)=Q(J)*.37
      RADEX(5)=Q(J)*.31
      RADEX(6)=Q(J)*.21
      RADEX(7)=0.0
      IF(W.LE.52000.) GO TO 70
```

```
      DO 125 LM=1,7
  125 RADEX(LM)= RADEX(LM)*(1000.**.[illegible])/(.425*(W**.2))
      GO TO 13
   70 DO 126 LM=1,7
  126 RADEX(LM)=(RADEX(LM)*(1000.**.3))/(W**.3)
   13 IF(KPRINT.GT.0) WRITE(6,9[illegible]) (RADEX(LM), LM=1,7)
      LG=7
  122 DO 121 LM=1,LG
      II=1
      DRE=2.
      ORAD=4.
      DRAD=6.
      IF(RADEX(LM).LT.4.) GO TO 17
      IF(RADEX(LM).GT.RCHA) GO TO 18
      IF(RADEX(LM).GE.4..AND.RADEX(LM).LE.6.) GO TO 16
      IF(RADEX(LM).GE.6..AND.RADEX(LM).LT.RCHA) GO TO 15
   16 DIFF=(RADEX(LM)-ORAD)/(DRAD-ORAD)
      ABURN(LM)=ABURN(K,II)+DIFF*(ABURN(K,II+1)-ABURN(K,II))
      GO TO 19
   17 ABURN(LM)=0.0
      GO TO 22
   18 ABURN(LM)=17.5+3.62*(RADEX(LM)-RCHA)
      IF(K.EQ.1) ABURN(LM)=16.0+2.74*(RADEX(LM)-RCHA)
      IF(ABURN(LM).GT.100.) ABURN(LM)=100.
      GO TO 19
   15 ABURN(LM)=RCHA
   19 IF(ABURN(LM).EQ.0.) GO TO 22
      IF(ABURN(LM).GE.80.) GO TO 41
      II=1
      DRE=5.
      ORAD=0.
      DRAD=ORAD+DRE
   60 IF(ABURN(LM).GE.ORAD.AND.ABURN(LM).LE.DRAD) GO TO 21
      ORAD=ORAD+DRE
      DRAD=ORAD+DRE
      II=II+1
      GO TO 60
   21 DIFF=(ABURN(LM)-ORAD)/(DRAD-ORAD)
      PKT(LM)=PK(II)+DIFF*(PK(II+1)-PK(II))
      GO TO 23
   22 PKT(LM)=0.0
      GO TO 23
   41 PKT(LM)=100.
   23 IF(KPRINT.GT.0) WRITE(6,92) ABURN(LM),PKT(LM)
      IF(ABURN(LM).LT.10.) GO TO 24
      IF(ABURN(LM).GE.45.) GO TO 33
      IJ=1
      II=1
      DRE=5.
      ORAD=10.
```

```
      DRAD=ORAD+DRE
      IF(ABURN(LM).GE.10..AND.ABURN(LM).LE.25.) GO TO 28
      IF(ABURN(LM).GT.25..AND.ABURN(LM).LT.30.) GO TO 27
      IF(ABURN(LM).GE.30..AND.ABURN(LM).LE.35.) GO TO 31
      IF(ABURN(LM).GT.35..AND.ABURN(LM).LE.36.5)GO TO 26
      IF(ABURN(LM).GT.36.5.AND.ABURN(LM).LE.40.)GO TO 34
      II=9
      DRAD=45.
      DRE=5.
      ORAD=40.
   28 IF(ABURN(LM).GE.ORAD.AND.ABURN(LM).LE.DRAD) GO TO 29
      II=II+1
      ORAD=ORAD+DRE
   30 DRAD=ORAD+DRE
      GO TO 28
   29 DIFF=(ABURN(LM)-ORAD)/(DRAD-ORAD)
      PKTM(K,LM)=(PKT(LM)/100.)*(PPK(IJ,II)+DIFF*(PPK(IJ,II+1)-PPK(IJ,II
     1)))
      IJ=IJ+1
      PKTW(K,LM)=(PKT(LM)/100.)*(PPK(IJ,II)+DIFF*(PPK(IJ,II+1)-PPK(IJ,II
     1)))
      IJ=IJ+1
      PKTD(K,LM)=(PKT(LM)/100.)*(PPK(IJ,II)+DIFF*(PPK(IJ,II+1)-PPK(IJ,II
     1)))
      PINJ(K,LM)=100.-PKT(LM)
      IF(PINJ(K,LM).LT.0.0) PINJ(K,LM)=0.0
      GO TO 121
   27 DRE=2.5
      II=4
      ORAD=25.
      GO TO 30
   31 II=6
      ORAD=30.
      GO TO 30
   26 DRE=1.5
      II=7
      ORAD=35.
      GO TO 30
   34 DRE=3.5
      II=8
      ORAD=36.5
      GO TO 30
   24 PKTM(K,LM)=0.
      PKTW(K,LM)=100.*PKT(LM)/100.
      PKTD(K,LM)=0.
      PINJ(K,LM)=FIRINJ(ABURN(LM))
      GO TO 121
   33 PKTM(K,LM)=0.
      PKTW(K,LM)=0.
      PKTD(K,LM)=100.*PKT(LM)/100.
```

```
      PINJ(K,LM)=100.-PKT(LM)
      IF(PINJ(K,LM).LT.0.0) PINJ(K,LM)=0.0
  121 CONTINUE
      IF(KKOUNT.EQ.0.AND.ISEASN.NE.1) GO TO 38
      GO TO 44
   50 K=1
      KKOUNT=1
      RFIN=28.
      RCHA=19.
      LG=1
      GO TO 122
   38 DENOM=BILDWI(I)*BILDLT(I)*FLOAT(NFL(I))
      DENOM=DENOM
      DO 39 II=1,3
      PKDEM(II,J)=ADE(II)/DENOM*PKTM(K,1)*POSPRI(II)/100.
      PKSRM(II,J)=ASCR(II)/DENOM*PKTM(K,2)*POSPRI(II)/100.
      PKGM  (II,J)=AG(II)/DENOM*PKTM(K,3)*POSPRI(II)/100.
      PKSGM(II,J)=ASG(II)/DENOM*PKTM(K,4)*POSPRI(II)/100.
      PKGGM(II,J)=AGG(II)/DENOM*PKTM(K,5)*POSPRI(II)/100.
      PKGGSM(II,J)=AGGS(II)/DENOM*PKTM(K,6)*POSPRI(II)/100.
      PKDBM(II,J)  =ADBS(II)/DENOM*PKTM(K,7)*POSPRI(II)/100.
      TKM(II,J)=PKDEM(II,J)+PKSRM(II,J)+PKGM(II,J)+PKSGM(II,J)+PKGGM(II,
     1J)+PKGGSM(II,J)+PKDBM(II,J)
      TKM(II,J)=TKM(II,J)*CONPER(I)/100.*PERPIN/1.E4
      PKDEW(II,J)=ADE(II)/DENOM*PKTW(K,1)*POSPRI(II)/100.
      PKSRW(II,J)=ASCR(II)/DENOM*PKTW(K,2)*POSPRI(II)/100.
      PKGW  (II,J)=AG(II)/DENOM*PKTW(K,3)*POSPRI(II)/100.
      PKSGW(II,J)=ASG(II)/DENOM*PKTW(K,4)*POSPRI(II)/100.
      PKGGW(II,J)=AGG(II)/DENOM*PKTW(K,5)*POSPRI(II)/100.
      PKGGSW(II,J)=AGGS(II)/DENOM*PKTW(K,6)*POSPRI(II)/100.
      PKDBW(II,J)= ADBS(II)/DENOM*PKTW(K,7)*POSPRI(II)/100.
      TKW(II,J)=PKDEW(II,J)+PKSRW(II,J)+PKGW(II,J)+PKSGW(II,J)+PKGGW(II,
     1J)+PKGGSW(II,J)+PKDBW(II,J)
      TKW(II,J)=TKW(II,J)*CONPER(I)/100.*PERPIN/1.E4
      PKDED(II,J)=ADE(II)/DENOM*PKTD(K,1)*POSPRI(II)/100.
      PKSRD(II,J)=ASCR(II)/DENOM*PKTD(K,2)*POSPRI(II)/100.
      PKGD(II,J)=AG(II)/DENOM*PKTD(K,3)*POSPRI(II)/100.
      PKSGD(II,J)=ASG(II)/DENOM*PKTD(K,4)*POSPRI(II)/100.
      PKGGD(II,J)=AGG(II)/DENOM*PKTD(K,5)*POSPRI(II)/100.
      PKGGSD(II,J)=AGGS(II)/DENOM*PKTD(K,6)*POSPRI(II)/100.
      PKDBD(II,J)= ADBS(II)/DENOM*PKTD(K,7)*POSPRI(II)/100.
      TKD(II,J)=PKDED(II,J)+PKSRD(II,J)+PKGD(II,J)+PKSGD(II,J)+PKGGD(II,
     1J)+PKGGSD(II,J)+PKDBD(II,J)
      TKD(II,J)=TKD(II,J)*CONPER(I)/100.*PERPIN/1.E4
      FACT=POSPRI(II)/(DENOM*100.)
      PIDED=ADE(II)*PINJ(K,1)*FACT
      PISRD=ASCR(II)*PINJ(K,2)*FACT
      PIGD=AG(II)*PINJ(K,3)*FACT
      PISGD=ASG(II)*PINJ(K,4)*FACT
      PIGGD=AGG(II)*PINJ(K,5)*FACT
```

```
      PIGGSD=AGGS(II)*PINJ(K,6)*FACT
      PIDBD=ADBS(II)*PINJ(K,7)*FACT
      TKI(II,J)=PIDED+PISRD+PIGD+PISGD+PIGGD+PIGGSD+PIDBD
      TKI(II,J)=TKI(II,J)*CONPER(I)*PERPIN/1.E6
   39 CONTINUE
      IF(KKOUNT.EQ.0.AND.ISEASN.EQ.1) GO TO 50
   44 AOU=AOUT(1)+AOUT(2)+AOUT(3)+AOUT(4)+AOUT(5)
      IF(AOU.LT.0.0) AOU=0.0
      RATIO=AOU/ATOT*(1.-PERPIN/100.)/100.
      PKTMO(J)=PKTM(K,1)*RATIO
      PKTWO(J)=PKTW(K,1)*RATIO
      PKTDO(J)=PKTD(K,1)*RATIO
      FIO=PINJ(K,1)*RATIO
      IF(KPRINT.GT.0) WRITE(6,200) AOU,ATOT,PKTMO(J),PKTWO(J),PKTDO(J)
  200 FORMAT(36H0AOU,ATOT,PKTMO(J),PKTWO(J),PKTDO(J),5E17.8)
   40 CONTINUE
      IF(KPRINT.GT.0) GO TO 55
      GO TO 53
   55 DO 46 J=1,NQ
      DO 46 II=1,3
      GO TO (130,131,132),II
  130 WRITE (6,133)
  133 FORMAT(9H0STANDING)
      GO TO 136
  131 WRITE(6,134)
  134 FORMAT(8H0SITTING)
      GO TO 136
  132 WRITE (6,135)
  135 FORMAT(6H0LYING)
  136 IF(KPRINT.LE.0) GO TO 46
      WRITE(6,47)PKDEM(II,J),PKSRM(II,J),PKGM(II,J),PKSGM(II,J),PKGGM(II
     1,J),PKGGSM(II,J),PKDBM(II,J),TKM(II,J),PKDEW(II,J),PKSRW(II,J),PKG
     2W(II,J),PKSGW(II,J),PKGGW(II,J),PKGGSW(II,J),PKDBW(II,J),TKW(II,J)
     3,PKDED(II,J),PKSRD(II,J),PKGD(II,J),PKSGD(II,J),PKGGD(II,J),PKGGSD
     4(II,J),PKDBD(II,J),TKD(II,J)
   47 FORMAT(43H0PERCENT KILLED IN MONTH (DIRECT EXPOSURE)=,E15.8/35H PE
     1RCENT KILLED IN MONTH (SCREENS)=,E15.8/40H PERCENT KILLED IN MONTH
     2 (SINGLE GLASS)=,E15.8/41H PERCENT KILLED IN MONTH (SCREENS,GLASS)
     3=,E15.8/41H PERCENT KILLED IN MONTH (DOUBLE GLASS)=,E15.8/48H PERC
     4ENT KILLED IN MONTH (DOUBLE GLASS,SCREENS)=,E15.8/41H PERCENT KILL
     5ED IN MONTH (DRAPES,BLINDS)=,E15.8,5X,23H TOTAL KILLED IN MONTH=,E
     615.8/42H PERCENT KILLED IN WEEK (DIRECT EXPOSURE)=,E15.8/34H PERCE
     7NT KILLED IN WEEK (SCREENS)=,E15.8/39H PERCENT KILLED IN WEEK (SIN
     8GLE GLASS)=,F15.8/40H PERCENT KILLED IN WEEK (SCREENS,GLASS)=,E15.
     98/40H PERCENT KILLED IN WEEK (DOUBLE GLASS)=,E15.8/47H PERCENT KIL
     1LED IN WEEK (DOUBLE GLASS,SCREENS)=,E15.8/40H PERCENT KILLED IN WE
     2EK (DRAPES,BLINDS)=,E15.8,5X,22H TOTAL KILLED IN WEEK=,E15.8/41H P
     3ERCENT KILLED IN DAY (DIRECT EXPOSURE)=,E15.8/33H PERCENT KILLED I
     4N DAY (SCREENS)=,E15.8/38H PERCENT KILLED IN DAY (SINGLE GLASS)=,E
     515.8/39H PERCENT KILLED IN DAY (SCREENS,GLASS)=,E15.8/39H PERCENT
```

```
     6KILLED IN DAY (DOUBLE GLASS)=,E15.8/46H PERCENT KILLED IN DAY (DOU
     7BLE GLASS,SCREENS)=,E15.8/39H PERCENT KILLED IN DAY (DRAPES,BLINDS
     8)=,E15.8,5X,21H TOTAL KILLED IN DAY=,E15.8)
  46 CONTINUE
  53 DO 191 II=1,3
     FII=FII+TKI(II,NQ)
     DDYTH=DDYTH+TKD(II,NQ)
     DWKTH=DWKTH+TKW(II,NQ)
 191 DMTTH=DMTTH+TKM(II,NQ)
 190 CONTINUE
     IF(KPRINT.GT.0) WRITE(6,48) PKTDO(NQ),PKTWO(NQ),PKTMO(NQ)
     TDDY=DDYTH+PKTDO(NQ)
     TDWK=DWKTH+PKTWO(NQ)
     TDMT=DMTTH+PKTMO(NQ)
     DDYTHI=DDYTH
     DWKTHI=DWKTH
     DMTTHI=DMTTH
     DDYTHO=PKTDO(NQ)
     DWKTHO=PKTWO(NQ)
     DMTTHO=PKTMO(NQ)
     IF(KPRINT.GT.0) WRITE(6,56) TDDY,TDWK,TDMT
     RETURN
     END
```

```
$IBFTC PERC     M94,XR7
      FUNCTION PERCTH(TOTMAX)
      DIMENSION PERC(25)
      DATA(PFRC(I),I=1,24)/0.,.006,.023,.06,.13,.21,.39,.485,.575,.595,
     1.63,.665,.698,.708,.728,.745,.76,.77,.78,.79,.798,.805,.81,.815/
      TI=0.
      DELTT=.2
      I=1
      IF(TOTMAX.EQ.0.) GO TO 2
      IF(TOTMAX.GE.10.) GO TO 5
    1 IF(TOTMAX.GE.TI.AND.TOTMAX.LE.(TI+DELTT))GO TO 3
      IF(TOTMAX.GE.1.0) GO TO 4
      TI=TI+DELTT
      I=I+1
      GO TO 1
    3 DIFF=(TOTMAX-TI)/DELTT
      PERCTH=PFRC(I)+DIFF*(PERC(I+1)-PERC(I))
      GO TO 7
    2 PERCTH=0.
      GO TO 7
    5 PERCTH=81.5
      GO TO 7
    4 TI=1.0
      DELTT=.5
      I=6
    6 IF(TOTMAX.GE.TI.AND.TOTMAX.LE.(TI+DELTT)) GO TO 3
      I=I+1
      TI=TI+DELTT
      GO TO 6
    7 RETURN
      END
```

```
$IBFTC FIRIN
      FUNCTION FIRINJ(AREA)
C     INJURY CURVES DUE TO FIRE
      FIRINJ=25.*AREA-150.0
      IF(FIRINJ.LE.0.0) FIRINJ=0.0
      IF(FIRINJ.GE.100.) FIRINJ=100.
      RETURN
      END
```

```
$IBFTC NUCL
      SUBROUTINE NUCLAR(KPRINT)
      COMMON/BLK2/ GZX,GZY,XX,YN,SS,SN,SW,SE,S1,S2,PHI
      COMMON/BLK3/ W,HB,VIS,XO,FFR,AIRDEN,ISEASN,TODAY
      COMMON/BLK4/ AVEHT,AVEWT,AVEW,AVEL,HMAX,A1,A2,A3,A4,A5,D1,D2,D3,D4
     1,D5,W1,W2,W3,W4,W5,KA,ATOT,DISMAX,DELTD,FACT1,FACT2,INDX(5),AAA(5)
     2,INDX1,INDX2,PERPIN,    POPDN,REACSI,REACST,REACLY
      COMMON/BLK7/ NN,PERCWI(10),POBILD(10),BUILDW(10),BILDLT(10),CONPER
     1(10),BILDWI(10),POSPRO(3),POSPRI(3),NFL(10),AINTRL(10),EXRL(10),
     2PBREAK(10),IWALLT(10),IBT(10),PERCOA,BILDHT(10)
      COMMON /BLK11/ WALPAN(10),WALDEN(10),FLORTH(10),FLORDN(10),ROOFTH(
     110),ROOFDN(10),BASETH(10),BASEDN(10),SOILDN(10),SILHT(10),PERSCR(1
     20),PERSG(10),PERGG(10),PERUBS(10),PERG(10),PERDE(10),PERGGS(10)
      COMMON/BLK13/ AVEWTB,RADG,RADN,DHBO,DDBO,DMBO,DHBI,DDBI,DMBI,
     1DDIONI,DWIONI,DMIONI,DDIONO,DWIONO,DMIONO
      COMMON/BLK14/TII,TIO,DII,DIO,FII,FIO,RII,RIO,TUNINJ,TFATAL,TAINJR
      DIMENSION KFLORM(10),WALPA(10),KROOFM(10),TRHO(10,100),ATTG(10,100
     1),ATTN(10,100),RHOX(100),CELLA(10),PCAFF(10),PCAF(10,100),TIMRAD(1
     20,100),TAEX(16),PKO(10),TIMRO(10),BASET(10),ROOFT(10),FLORT(10),
     3KWALMT(10),PKBILD(10),PKFLOR(100)
      DDIONI=0.0
      DWIONI=0.0
      DMIONI=0.0
      RIO=0.0
      RII=0.0
      NBR=1
      IF(NN.LE.1) NBR=0
      KAVGMT=4
      RG=RADG
      RN=RADN
      DO 111 I=1,NN
      RIIN=0.0
      DD=0.0
      DW=0.0
      DM=0.0
      IF(ROOFDN(I).LT.55.) KROOFM(I)=3
      IF(ROOFDN(I).GE.55..AND.ROOFDN(I).LT.110.) KROOFM(I)=1
      IF(ROOFDN(I).GE.110.) KROOFM(I)=2
      IF(FLORDN(I).LT.55.) KFLORM(I)=3
      IF(FLORDN(I).GE.55..AND.FLORDN(I).LT.110.) KFLORM(I)=1
      IF(FLORDN(I).GE.110.) KFLORM(I)=2
      IF(WALDEN(I).LT.55.) KWALMT(I)=3
      IF(WALDEN(I).GE.55..AND.WALDEN(I).LT.110.) KWALMT(I)=1
      IF(WALDEN(I).GE.110.) KWALMT(I)=2
      IF(KPRINT.EQ.0) GO TO 40
      WRITE (6,41) I
   41 FORMAT(14H1BUILDING TYPE,I4)
   40 NF=NFL(I)
      DO 167 M=1,NF
  167 PKFLOR(M)=0.
```

```
      IF(PHI.GE..7854) GO TO 80
      ES=S2
      WI=BILDLT(I)
      AWI=AVEL
      GO TO 81
   80 ES=S1
      WI=BILDWI(I)
      AWI=AVEW
   81 THETA=ATAN(HB/XO)
      RHOBD=AVEWTB/(AVEHT*AVEL*AVEW)
      P=(AVEHT*XO/HB)/(ES+AWI)
      LP=P
      XLP=LP
      IF((P-XLP).GT..2) GO TO 30
      IF(XLP.EQ.0.) GO TO 99
      IF(XLP.GT.2.) GO TO 405
      GO TO 31
   30 XLP=XLP+1.
      IF(XLP.LE.2.) GO TO 31
  405 XLP=2.
      GO TO 31
   99 XLP=1.
   31 NF=NFL(I)
      MM=1
      IF(THETA.LE..2618) GO TO 1
      IF(THETA.GE.1.309) GO TO 2
      WALPA(I)=WALPAN(I)/(COS(THETA)*12.)
      FLORT(I)=FLORTH(I)/(SIN(THETA)*12.)
      ROOFT(I)=ROOFTH(I)/(SIN(THETA)*12.)
      BASET(I)=BASETH(I)/(COS(THETA)*12.)
      CELLA(I)=(10.*WI)/(HB/XO)
      XN=WI*(HB/XO)/10.
   61 NT=XN
      XNT=NT
      IF((XN-XNT).LT..5) GO TO 8
      NT=NT+1
      GO TO 3
    8 IF(NT.EQ.0) GO TO 9
    3 MM=1
      IF(BASETH(I).EQ.0.) GO TO 4
      NF=NFL(I)+1
   48 THICK=5./SIN(THETA)
   62 TRHO(1,1)=(BASET(I)*BASEDN(I)+SOILDN(I)*THICK)
      TRH=TRHO(1,1)
      KKL=1
      CALL ATTFNU(TRH,KKL,THICK,ATG,ATT)
      ATTS=ATT
      KKL=2
    5 THICK=BASET(I)
      CALL ATTFNU(TRH,KKL,THICK,ATG,ATT)
```

```
      EXNF=NF
      DO 73 M=1,NF
      DO 72 N=1,NT
      PKFLOR(M)=PKFLOR(M)+PCAF(M,N)
   72 CONTINUE
      PKFLOR(M)=PKFLOR(M)/EXNT
   73 CONTINUE
      IF(KPRINT.EQ.0) GO TO 20
      WRITE (6,16)(PKFLOR(M),M=1,NF)
   16 FORMAT (26HOPERCENT KILLED PER FLOOR=,E15.8)
   20 PKBILD(I)=0.
      DO 74 M=1,NF
      PKBILD(I)=PKBILD(I)+PKFLOR(M)
   74 CONTINUE
      PKBILD(I)=PKBILD(I)/EXNF
      IF(KPRINT.EQ.0) GO TO 111
      WRITE (6,17)PKBILD(I)
   17 FORMAT(25HOPERCENT KILLED BUILDING=,E15.8)
  111 CONTINUE
      PKIN=0.
      DO 112 I=1,NN
  112 PKIN=PKIN+PKBILD(I)*CONPER(I)/100.
      IF(KPRINT.EQ.0) GO TO 21
      WRITE (6,113) PKIN
  113 FORMAT(23HOPERCENT KILLED INSIDE=,E15.8)
   21 KKOUNT=1
   84 OUTA=S1*BILDLT(I)+S2*(BILDWI(I)+S1)
      IF(NBR.EQ.0) GO TO 85
      IF(THETA.GE.1.309) GO TO 85
      PKO(3)=0.0
      IF(THETA.GT..2618) GO TO 88
      IF(PHI.GT..7854) GO TO 83
      EXPARA=S1*(BILDLT(I)+S2)
      SHAREA=S2*BILDWI(I)
      GO TO 86
   83 EXPARA=S2*(BILDWI(I)+S1)
      SHAREA=S1*BILDLT(I)
   86 JJ=KKOUNT
      RADNG=RADN+RADG
      CALL AFFECT(RADNG,PERCAF,TIMDTH)
      PKO(JJ)=PERCAF
      TIMRO(JJ)=TIMDTH
  103 GO TO (104,100,108),KKOUNT
  104 TRH=RHOBD*THICK
      KKL=KAVGMT
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      RADG=RADG*ATG
      RADN=RADN*ATT
      KKOUNT=2
      GO TO 86
```

```
      WRITE(6,300)(ATTG(M,N),ATTN(M,N),M=1,NF)
  300 FORMAT(6H0ATTG=,E15.8,6H ATTN=,E15.8)
    6 IF((N-NT).EQ.0) GO TO 12
      N=N+1
      MM=1
      GO TO 50
   12 IF(BASETH(I).EQ.0.) GO TO 11
      IF(THETA.LE..2618) GO TO 11
      NF=NFL(I)+1
      GO TO 10
   11 NF=NFL(I)
   10 DO 35 N=1,NT
      DO 35 M=1,NF
   96 RADNG=RADG*ATTG(M,N)+RADN*ATTN(M,N)
      CALL AFFECT(RADNG,PERCAF,TIMDTH)
      PCAF(M,N)=PERCAF
      TIMRAD(M,N)=TIMDTH
      CONST=PERCAF*CONPER(I)/1.E4
      PCAFIN=1,0-CONST
      IF(PERCAF.LE.0.0) PCAFIN=RADINJ(RADNG)/100.
      RIIN=RIIN+PCAFIN
      IF(TIMDTH.GE.0..AND.TIMDTH.LE.1.0) GO TO 121
      IF(TIMDTH.GT.1.0.AND.TIMDTH.LE.7.0) GO TO 122
      IF(TIMDTH.GT.7.0) GO TO 123
      GO TO 35
  121 DD=DD+CONST
      GO TO 35
  122 DW=DW+CONST
      GO TO 35
  123 DM=DM+CONST
   35 CONTINUE
      CONST=NT*NF
      DDIONI=DDIONI+DD*PERPIN/(100.*CONST)
      DWIONI=DWIONI+DW*PERPIN/(100.*CONST)
      DMIONI=DMIONI+DM*PERPIN/(100.*CONST)
      RII=RII+RIIN*PERPIN/(100.*CONST)
      IF(KPRINT.EQ.0) GO TO 7
      WRITE(6,301) ((TIMRAD(M,N),PCAF(M,N),M=1,NF),N=1,NT)
  301 FORMAT(8H0TIMRAD=,E15.8,6H PCAF=,E15.8)
    7 IF(BASETH(I).NE.0.) GO TO 200
      GO TO 201
  200 IF(THETA.LE..2618) GO TO 203
      GO TO 201
  203 PCAF(1,1)=0.
      TIMRAD(1,1)=10000.
      NLL=NF+1
      DO 202 M=2,NLL
      PCAF(M,N)=PCAF(M-1,1)
  202 TIMRAD(M,1)=TIMRAD(M-1,1)
  201 EXNT=NT
```

```
      TRH=TRHO(M,N)
      KKL=KROOFM(I)
      THICK=ROOFT(I)
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATG
      ATTN(M,N)=ATT
      GO TO 15
   13 TRHO(M,N)=WALPA(I)*(1.-SQRT(PERCWI(I)/100.))*WALDEN(I)
      TRH=TRHO(M,N)
      THICK=WALPA(I)
      KKL=KWALMT(I)
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATG
      ATTN(M,N)=ATT
      IF(NBR.EQ.0) GO TO 15
   34 IF(BASETH(I).EQ.0.) GO TO 39
      EM=M-1
   79 IF(NBR.EQ.0) GO TO 15
      IF(THETA.LE..2618) GO TO 60
      IF(EM.LE.((AVEHT-(AWI+ES)*HB/XO)/10.)) GO TO 32
      IF((EM*10.).LT.(AVEHT-ES*HB/XO)) GO TO 33
      GO TO 15
   39 EM=M
      GO TO 79
   32 RHOX(M)=RHOBD*AWI*XLP/SIN(THETA)
      TRH=RHOX(M)
      THICK=AWI*XLP/SIN(THETA)
      KKL=KAVGMT
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATTG(M,N)*ATG
      ATTN(M,N)=ATTN(M,N)*ATT
      GO TO 15
   33 RHOX(M)=(RHOBD/SIN(THETA))*(AWI*XLP-(10.*EM+ES*XLP*HB/XO))
      TRH=RHOX(M)
      THICK=(AWI*XLP-(10.*EM+ES*XLP*HB/XO))/SIN(THETA)
      KKL=KAVGMT
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATTG(M,N)*ATG
      ATTN(M,N)=ATTN(M,N)*ATT
      GO TO 15
   60 IF((EM*10.).GE.AVEHT) GO TO 15
      RHOX(M)=RHOBD*AWI*XLP
      TRH=RHOX(M)
      THICK=AWI*XLP
      KKL=KAVGMT
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATTG(M,N)*ATG
      ATTN(M,N)=ATTN(M,N)*ATT
   15 CONTINUE
      IF(KPRINT.EQ.0) GO TO 6
```

```
      ATTG(1,1)=ATG
      ATTN(1,1)=ATT*ATTS
      MM=2
      GO TO 4
    9 NT=1
      GO TO 3
    2 IF(BASETH(I).EQ.0.) GO TO 54
      NF=NFL(I)+1
   55 NNF=NF
      TRHO(NNF,1)=ROOFTH(I)*ROOFDN(I)/12.
      TRH=TRHO(NNF,1)
      THICK=ROOFTH(I)/12.
      KKL=KROOFM(I)
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(NNF,1)=ATG
      ATTN(NNF,1)=ATT
   44 NNF=NNF-1
      IF(NNF.EQ.0) GO TO 47
      TRHO(NNF,1)=FLORDN(I)*FLORTH(I)/12.
      TRH=TRHO(NNF,1)
      THICK=FLORTH(I)/12.
      KKL=KFLORM(I)
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(NNF,1)=ATG*ATTG(NNF+1,1
      ATTN(NNF,1)=ATT*ATTN(NNF+1,1
      GO TO 44
   47 NT=1
      GO TO 12
   54 NF=NFL(I)
      GO TO 55
    1 NT=1
      MM=1
      ROOFT(I)=ROOFTH(I)/12.
      WALPA(I)=WALPAN(I)/12.
      FLORT(I)=FLORTH(I)/12.
      CELLA(I)=10.*WI
    4 N=1
   71 XNF=NF
   50 DO 15 M=MM,NF
      IF(N.EQ.1) GO TO 13
      IF(N.GT.1.AND.M.EQ.NF) GO TO 14
      TRHO(M,N)=FLORT(I)*FLORDN(I)
      TRH=TRHO(M,N)
      THICK=FLORT(I)
      KKL=KFLORM(I)
      CALL ATTENU(TRH,KKL,THICK,ATG,ATT)
      ATTG(M,N)=ATG*ATTG(M+1,N-1)
      ATTN(M,N)=ATTN(M+1,N-1)*ATT
      GO TO 15
   14 TRHO(M,N)=ROOFT(I)*ROOFDN(I)
```

```
100 IF(PKO(1).EQ.0.) GO TO 140
    IF(PKO(2).EQ.0.) GO TO 141
    IF(THETA.LE..2618) GO TO 143
    GO TO 144
140 IF(PKO(2).EQ.0.) GO TO 142
    PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
    TIMOUT=TIMRO(2)
    GO TO 110
141 PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
    TIMOUT=TIMRO(1)
    GO TO 110
142 PCAFO=0.0
    TIMOUT=10000.
    GO TO 110
144 PCAFO=(PKO(1)*EXPARA+PKO(2)*SHAREA)/OUTA
    TIMOUT=(TIMRO(1)*EXPARA+TIMRO(2)*SHAREA)/OUTA
    GO TO 110
143 PCAFO=(PKO(1)+PKO(2))/2.
    TIMOUT=(TIMRO(1)+TIMRO(2))/2.
    GO TO 110
 85 SHAREA=0.
    EXPARA=OUTA
    KKOUNT=3
    PKO(1)=0.0
    GO TO 86
108 PCAFO=PKO(JJ)
    TIMOUT=TIMRO(3)
    GO TO 110
 88 RSTAR=AVEHT*XO/HB
    IF(RSTAR.LT.ES) GO TO 87
    RSTAR=ES/2.
    GO TO 89
 87 RSTAR=RSTAR/2.
 89 THICK=AVEHT/SIN(THETA)-RSTAR/COS(THETA)
    SHAREA=RSTAR*AWI
    EXPARA=OUTA-SHAREA
    KKOUNT=1
    GO TO 86
110 DDIONO=0.0
    DWIONO=0.0
    DMIONO=0.0
    DO 124 I=1,3
    AREA=EXPARA/OUTA
    IF(I.EQ.2)AREA=SHAREA/OUTA
    RIIN=100.-PKO(I)
    IF(PKO(I).LE.0.0.AND.(.NOT.(I.EQ.1.AND.KKOUNT.EQ.3)).AND.(.NOT.(I.
   1EQ.3.AND.KKOUNT.LT.3))) RIIN=RADINJ(RADNG)
    IF((I.EQ.1.AND.KKOUNT.EQ.3).OR.(I.EQ.3.AND.KKOUNT.LT.3)) RIIN=0.0
    RIO=RIO+RIIN/100.*AREA*(1.-PERPIN/100.)
    PK=PKO(I)/100.*AREA*(1.-PERPIN/100.)
```

```
      IF(TIMRO(I).GE.0..AND.TIMRO(I).LE.1.0) DDIONO=DDIONO+PK
      IF(TIMRO(I).GT.1.0.AND.TIMRO(I).LE.7.0) DWIONO=DWIONO+PK
      IF(TIMRO(I).GT.7.0.AND.TIMRO(I).LE.28.0) DMIONO=DMIONO+PK
  124 CONTINUE
      RADG=RG
      RADN=RN
      IF (KPRINT.EQ.0) GO TO 22
      WRITE (6,18)TIMOUT,PCAFO
   18 FORMAT(22H0TIME OF DEATH (DAYS)=,E15.8,21H PERCENTAGE AFFECTED=,E1
     15.8)
   22 RETURN
      END
```

```
$IBFTC AFFE     M94,XR7
      SUBROUTINE AFFECT(RADNG,PERCAF,TIMDTH)
      DIMENSION TAEX(15),PCAFF(10)
      DATA(TAEX(LL),LL=1,16)/28.,25.,20.5,16.3,13.1,10.5,8.2,6.4,5.2,4.1
     15,3.25,2.5,1.75,1.1,.5,0./
      DATA(PCAFF(LL),LL=1,10)/9.,19.8,27.7,38.5,49.5,61.3,75.0,88.5,95.5
     1,100./
   94 IF(RADNG.LT.250.) GO TO 22
      IF(RADNG.GE.700.) GO TO 23
      II=1
      ORAD=250.
   25 IF(RADNG.GE.ORAD.AND.RADNG.LE.(ORAD+50.)) GO TO 24
      ORAD=ORAD+50.
      II=II+1
      GO TO 25
   24 PC2=ALOG(PCAFF(II+1))
      PC1=ALOG(PCAFF(II))
      DIFF=(RADNG-ORAD)/50.
      XNO=PC1+DIFF*(PC2-PC1)
      PERCAF=EXP(XNO)
   36 IF(RADNG.GE.9000.) GO TO 65
      IF(RADNG.GE.250..AND.RADNG.LT.400.) GO TO 26
      IF(RADNG.GE.400..AND.RADNG.LT.600.) GO TO 27
      IF(RADNG.GE.600..AND.RADNG.LT.1500.) GO TO 28
      GO TO 29
   22 PERCAF=0.
      TIMDTH=10000.
      GO TO 400
   23 PERCAF=100.
      GO TO 36
   26 TIMDTH=112.
      GO TO 400
   27 TIMDTH=56.
      GO TO 400
   28 TIMDTH=28.
      GO TO 400
   29 LL=1
      CRAD=1500.
   38 IF(RADNG.GE.CRAD,AND.RADNG.LE.(CRAD+500.)) GO TO 37
      CRAD=CRAD+500.
      LL=LL+1
      GO TO 38
   37 DIFF=(RADNG-CRAD)/500.
      TIMDTH=TAEX(LL)+DIFF*(TAEX(LL+1)-TAEX(LL))
      RETURN
   65 TIMDTH=0.
  400 RETURN
      END
```

```
$IBFTC ATTEN    M94,XR7
      SUBROUTINE ATTENU(TRH,KKL,THICK,ATG,ATT)
      THICK=THICK*12.
      TR=TRH*(-.0113)
      IF(ABS(TR).GT.30.) GO TO 16
      ATG=EXP(TR)
      GO TO 401
   16 ATG=0.
  401 GO TO(66,67,68,70),KKL
   66 EX=THICK*.064345
      GO TO 69
   67 EX=THICK*.1
      GO TO 69
   68 EX=THICK*.00607
      GO TO 69
   70 EX=THICK*0.1*TRH/135.
   69 IF(ABS(EX).GT.30.) GO TO 51
      ATT=1./(10.**EX)
      GO TO 56
   51 ATT=0.
   56 RETURN
      END
```

```
$IBFTC RADIJ
      FUNCTION RADINJ(DOSE)
C     INJURY CURVES DUE TO IONIZING RADIATION
      RADINJ=6.45*DOSE-613.
      IF(RADINJ.LE.0.0) RADINJ=0.0
      IF(RADINJ.GT.100.) RADINJ=100.
      RETURN
      END
```

APPENDIX V

TABLES AND GRAPHS

Tables 23 through 26 and Fig. 66 through 72 summarize the data employed in developing the various mass-velocity-probability relationships for Table 5. Conventional statistical analysis techniques were employed in determining the values and models. Concussion to the head and cerebral hemorrhage have not been treated.

Table 23

DATA ON PENETRATION OF THE ABDOMEN OF DOGS BY GLASS MISSILES (Ref. 8)

Group	Series	Dog No.	Average Missile Mass* gms	Average Missile Velocity and Standard Deviation ft/sec	Range of Missile Velocity ft/sec	Number of Shots	Number Penetrating Skin (Effect Number 1)	Number Penetrating Abdomen (Effect Number 2)	MV^4 $10^9 \text{gm} \frac{\text{ft}^4}{\text{sec}^4}$
I	1	C-14	0.0543	487 ± 8.8	+16, -17	25	13	9	3.06
	2	C-12	0.0543	858 ± 11.6	+24, -26	25	25	22	29.5
II	3	C-7	0.131	205 ± 3.9	+ 7, - 8	25	3	1	0.232
	4	C-8	0.131	262 ± 10.9	+13, -44	25	13	0	0.619
	5	C-9	0.131	456 ± 11.4	+19, -21	25	22	15	5.69
	6	C-13	0.131	649 ± 10.9	+17, -23	26	26	25	23.3
III	7	C-3	0.318	192 ± 4.0	+11, - 8	26	13	3	0.433
	8	C-8 C-2	0.318	305 ± 8.2	+16, -15	40	22	25	2.76
	9	C-7 C-1	0.318	419 ± 9.6	+16, -27	41	26	26	9.80
IV	10	C-4	0.769	200 ± 3.8	+ 8, - 7	24	15	6	1.23
	11	C-5	0.769	297 ± 4.9	+ 9, -10	25	22	15	5.98
	12	C-6	0.769	418 ± 10.4	+25, -28	25	25	22	23.5
V	13	C-10	1.895	170 ± 2.8	+ 5, - 4	21	7	3	1.59
	14	C-9 C-10	1.895	240 ± 9.3	+32, -10	19	15	13	6.38
	15	C-12	1.895	360 ± 6.3	+10, -10	7	7	7	32.0
	16	C-11	1.895	387 ± 4.5	+10, - 6	10	10	10	42.6

*Range of Missile Mass was ± 5 percent.

Table 24

EFFECTS OF MISSILES ON HUMAN CADAVERS (LIMBS) (Ref. 1, 9)

Mass gm	Velocity ft/sec	MV^4 $10^9 gm \frac{ft^4}{sec^4}$	MV^2 $10^6 gm \frac{ft^2}{sec^2}$	Effect and Number (Table 5)	
8.7	190	11.3		Slight skin laceration	3
8.7	230	24.3		Penetrating wound	4
7.4	360	124.3	0.954	Abrasion and crack of tibia	5
7.4	513	512.5	1.947	Travels through thigh	9
6-10	420-266	187-50	1.06-0.71	Threshold for bone injury	
6-15	751-476	1,909-770	3.38-3.39	Fractures large bones	10

Note: The calculation of the penetration statistic MV^4 and energy MV^2 is added.

Table 25

DATA ON SKULL FRACTURES (Ref. 10)

(Effect Number 7)

Range of Impact Velocities ft/sec	Nominal Velocity ft/sec	MV^2 for 10 lb* heads $10^6 gm (\frac{ft}{sec})^2$	Number of Subjects	Cumulative Percent Fracture	Expected Percent by the Probit Line
< 13.5	12.4	0.697	0**	0	3.0
13.5-14.9	14.2	0.915	9	19.6	18.0
15-16.9	16.0	1.161	10	41.3	43.0
17-18.9	18.0	1.470	12	67.4	73.0
19-20.9	20.0	1.814	11	91.3	91.0
21-22.9	22.0	2.195	4	100.0	97.5
LD50	16.5	1.231			
Confidence limits	15.7-17.2	1.123-1.347			
Slope		8.635			

* 10 lbs = 4,536 gm is used for the nominal mass of fresh-human skulls weighing 7 to 15 lbs.

** Assumed value not stated in the original source.

Table 25

EFFECTS OF MISSILE IMPACT ON THE CHEST (Ref. 12)

Effect No.	Biological Effects	Threshold Velocities for Missiles of Indicated Weights		MV^2 (10^6gm $\frac{ft^2}{sec^2}$)		MV (10^3gm $\frac{ft}{sec}$)		MV^4 (10^9gm $\frac{ft^4}{sec^4}$)	
		0.8 lb	0.4 lb	0.8 lb	0.4 lb	0.8 lb	0.4 lb	0.8 lb	0.4 lb
12	Lung Hemorrhage (unilateral)	45 ft/sec	80 ft/sec	0.735	1.16	16.3	14.5	1.49	7.41
13	Rib Fracture	60	120	1.31	2.61	21.7	21.7	4.70	35.5
11	Internal Lacerations from Fractured Ribs	90	120	2.94	2.61	32.7	21.7	23.8	37.5
5	Bilateral Lung Hemorrhage	110	125	4.39	2.83	39.9	22.6	53.1	44.2
6	Fatality within 1 hr	155	170	8.72	5.23	56.3	30.8	209.5	151.2

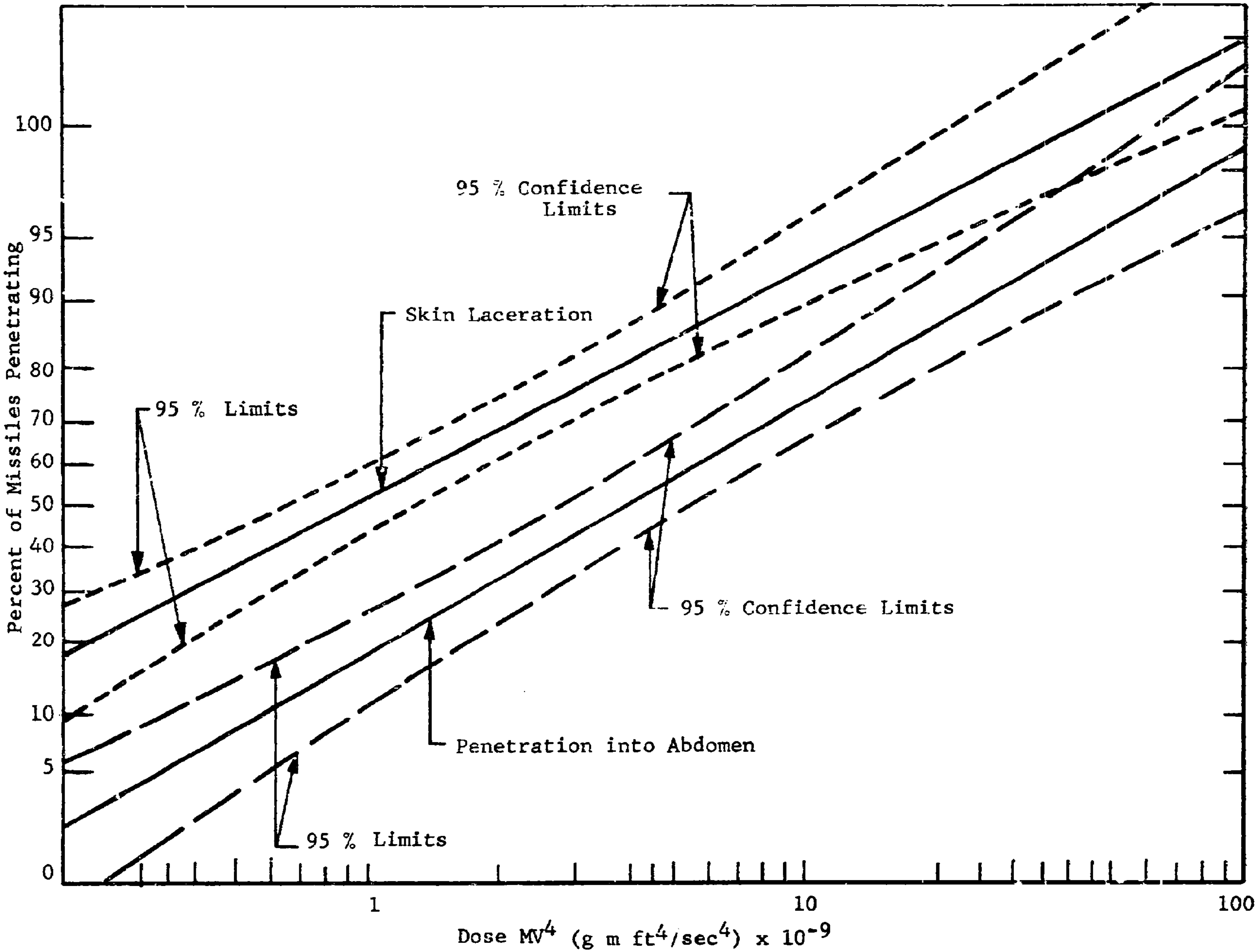


Fig. 66 PENETRATION AND LACERATION OF ABDOMEN BY GLASS

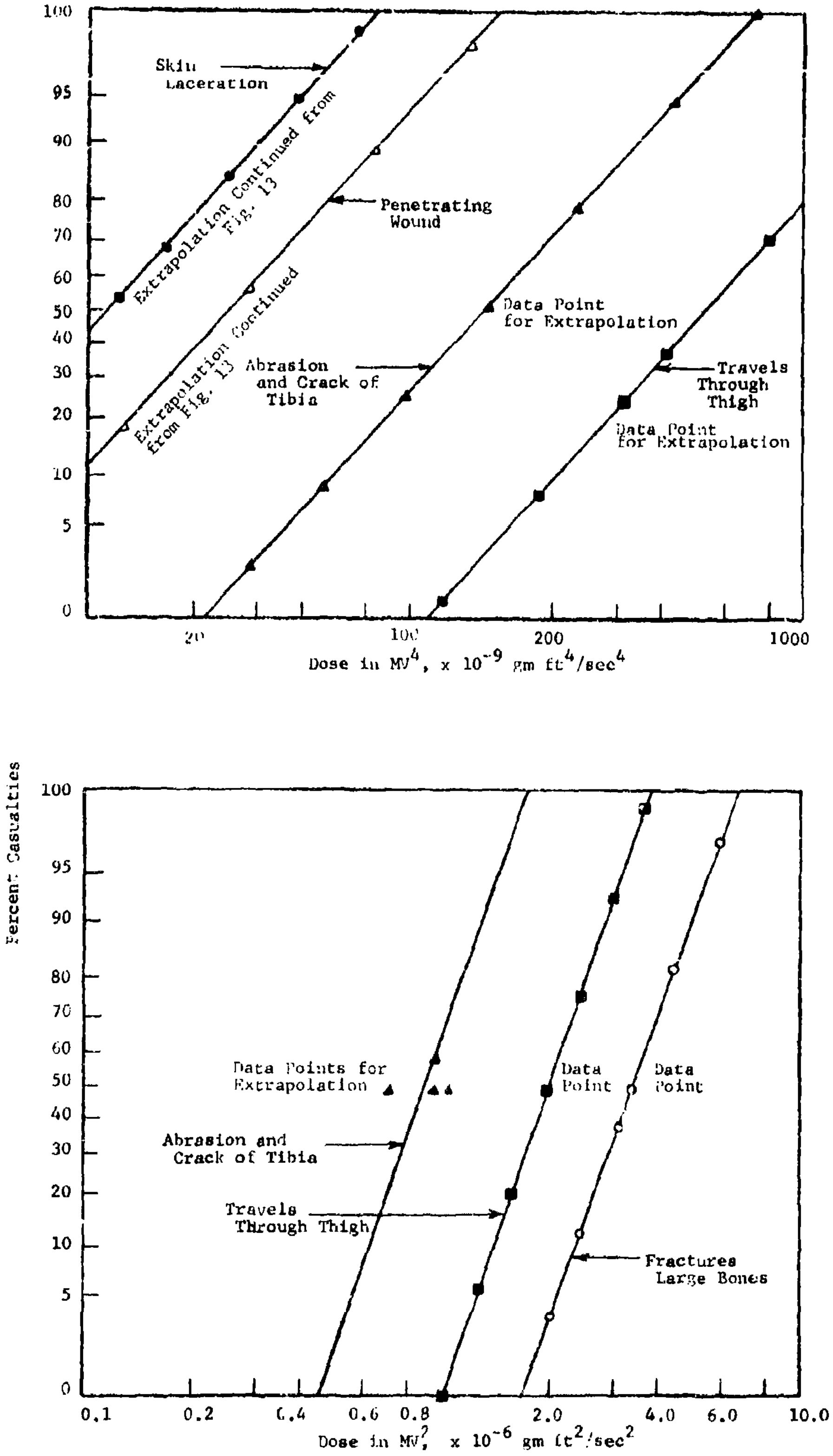


Fig. 67 EFFECTS OF SPHERICAL BULLETS ON HUMAN LIMBS (Bone damage)

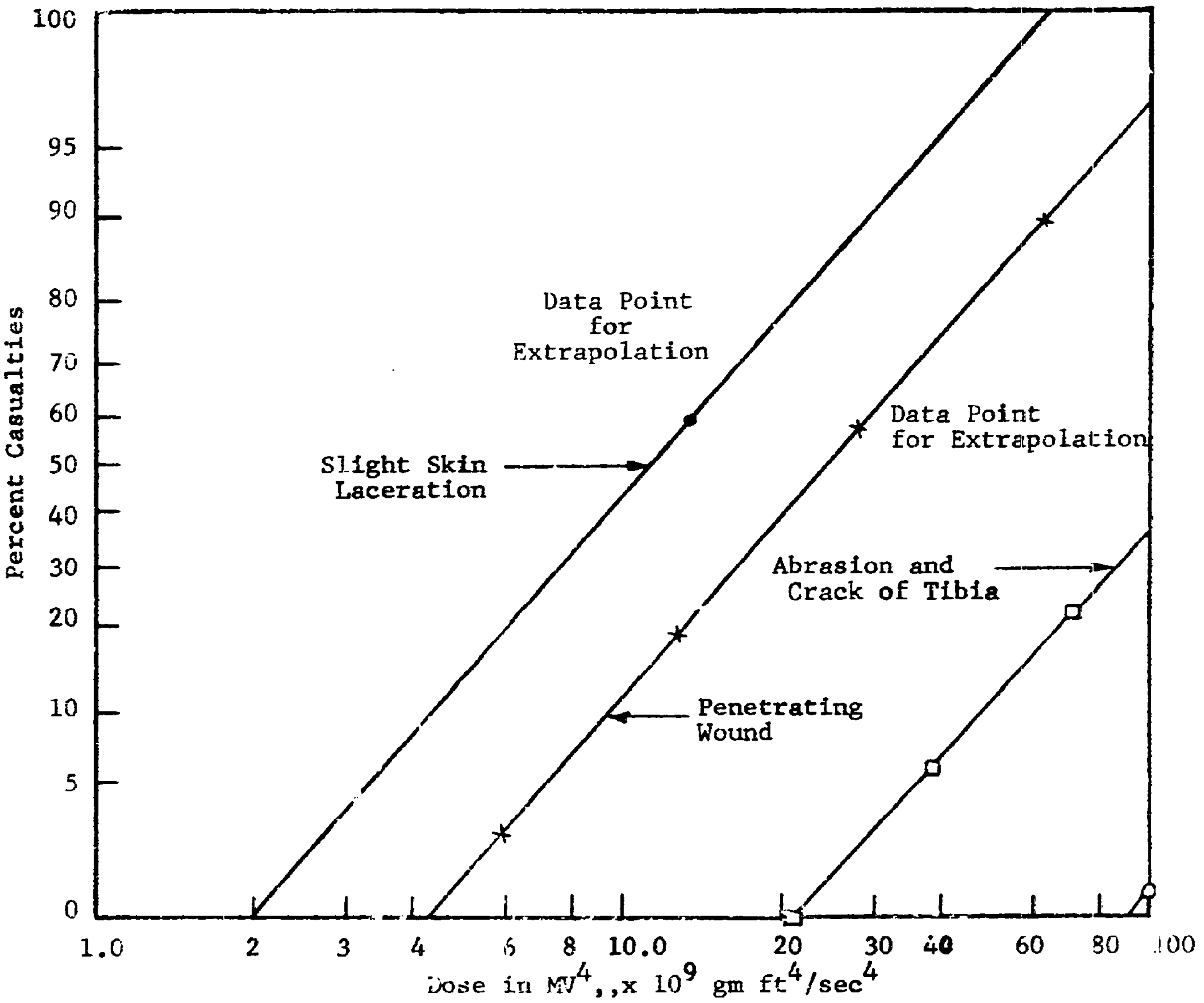


Fig. 68 EFFECTS OF SPHERICAL BULLETS ON HUMAN LIMBS (Flesh wounds)

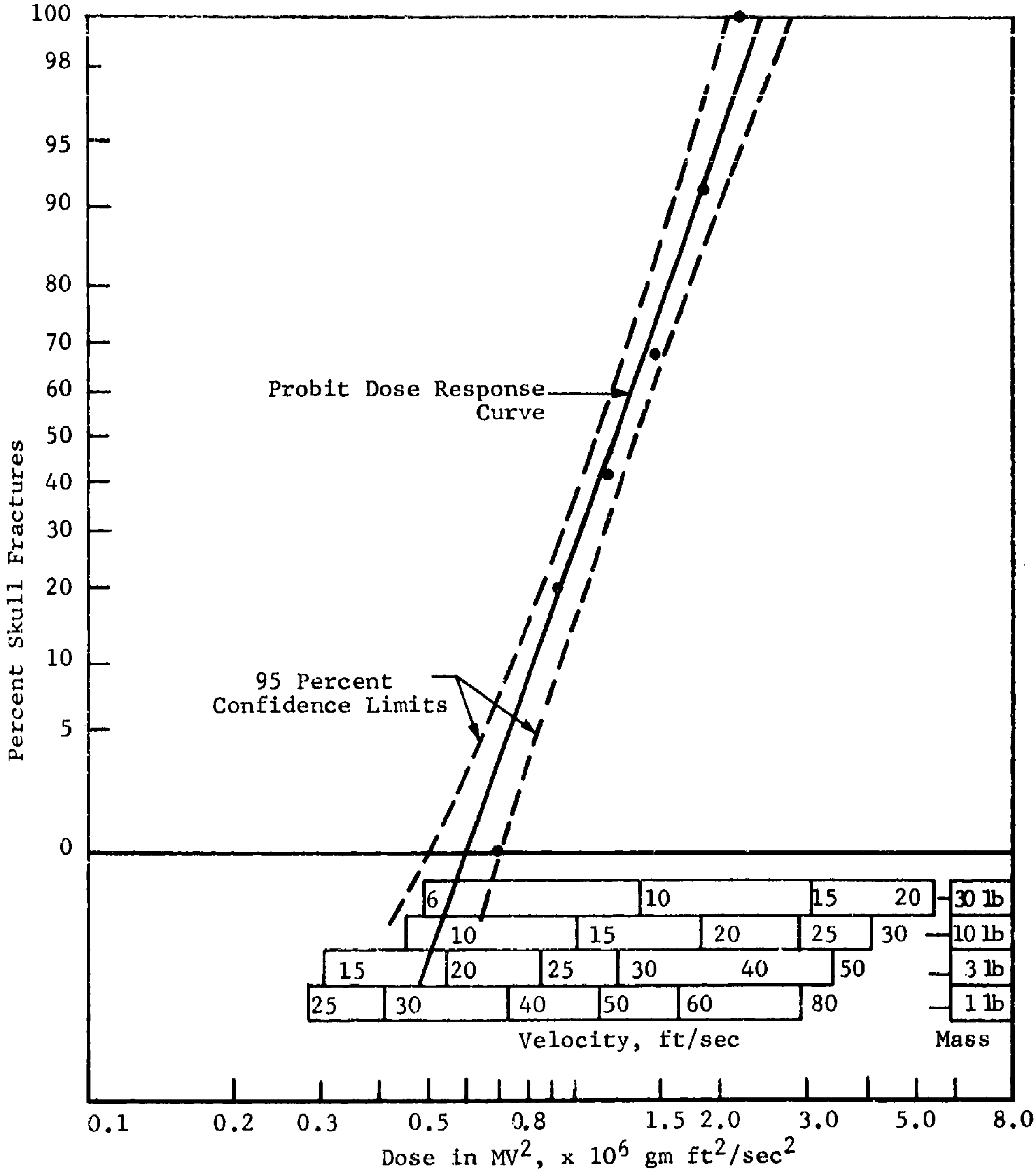


Fig. 69 SKULL FRACTURE BY LARGE BLUNT OBJECTS

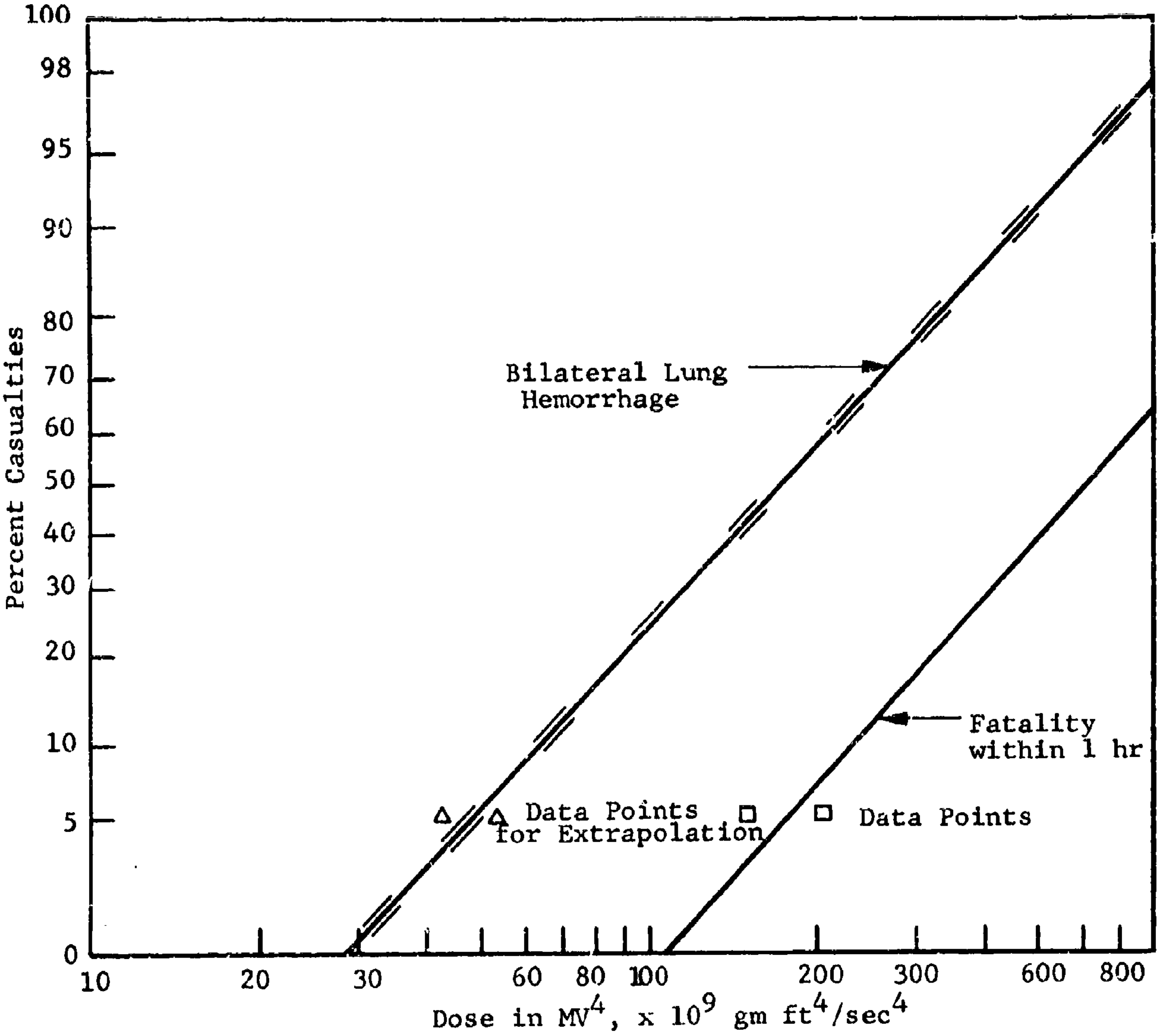


Fig. 70 EFFECTS OF BALLS IMPACTING ON THE THORAX (Near lethal)

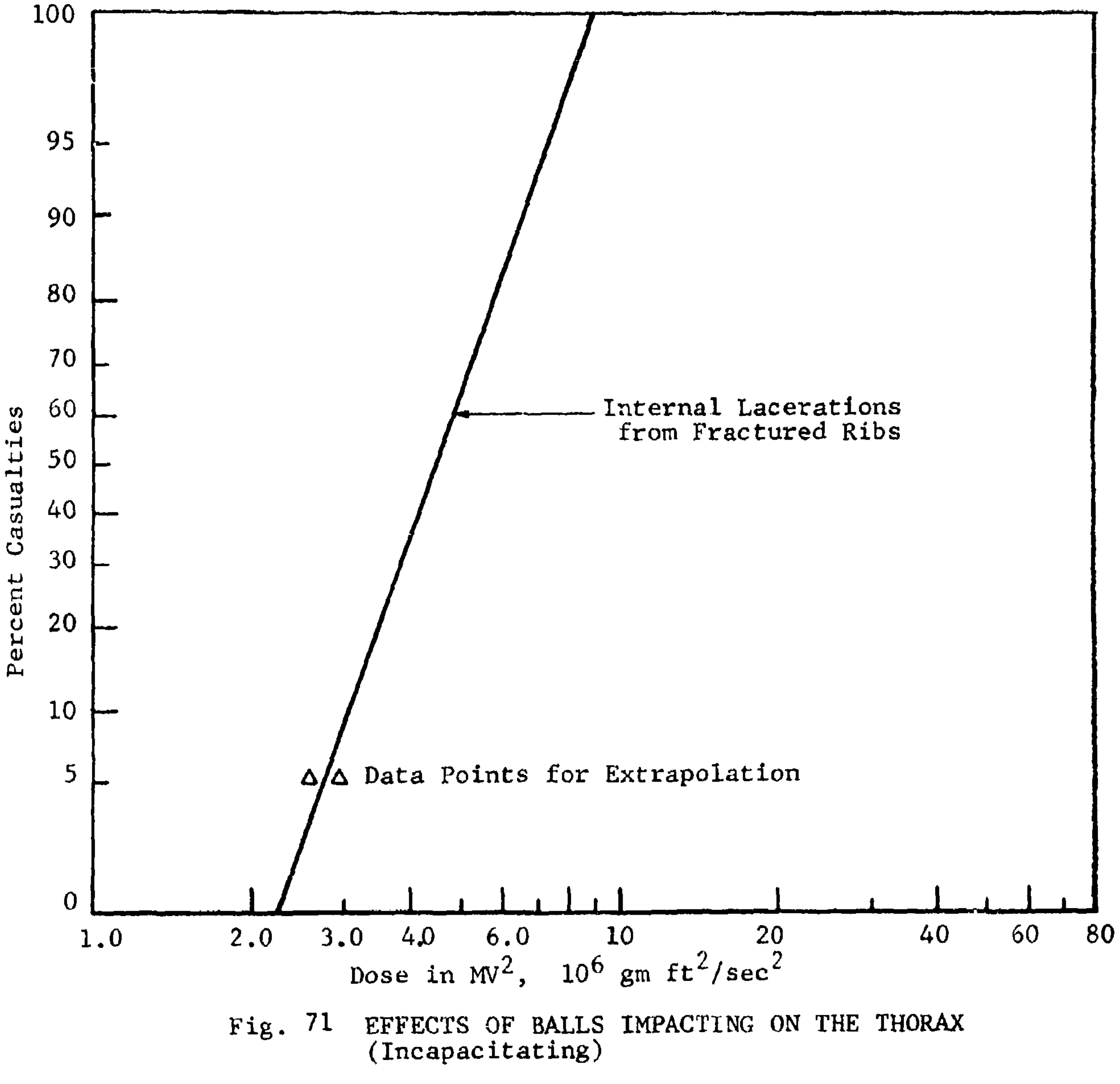


Fig. 71 EFFECTS OF BALLS IMPACTING ON THE THORAX (Incapacitating)

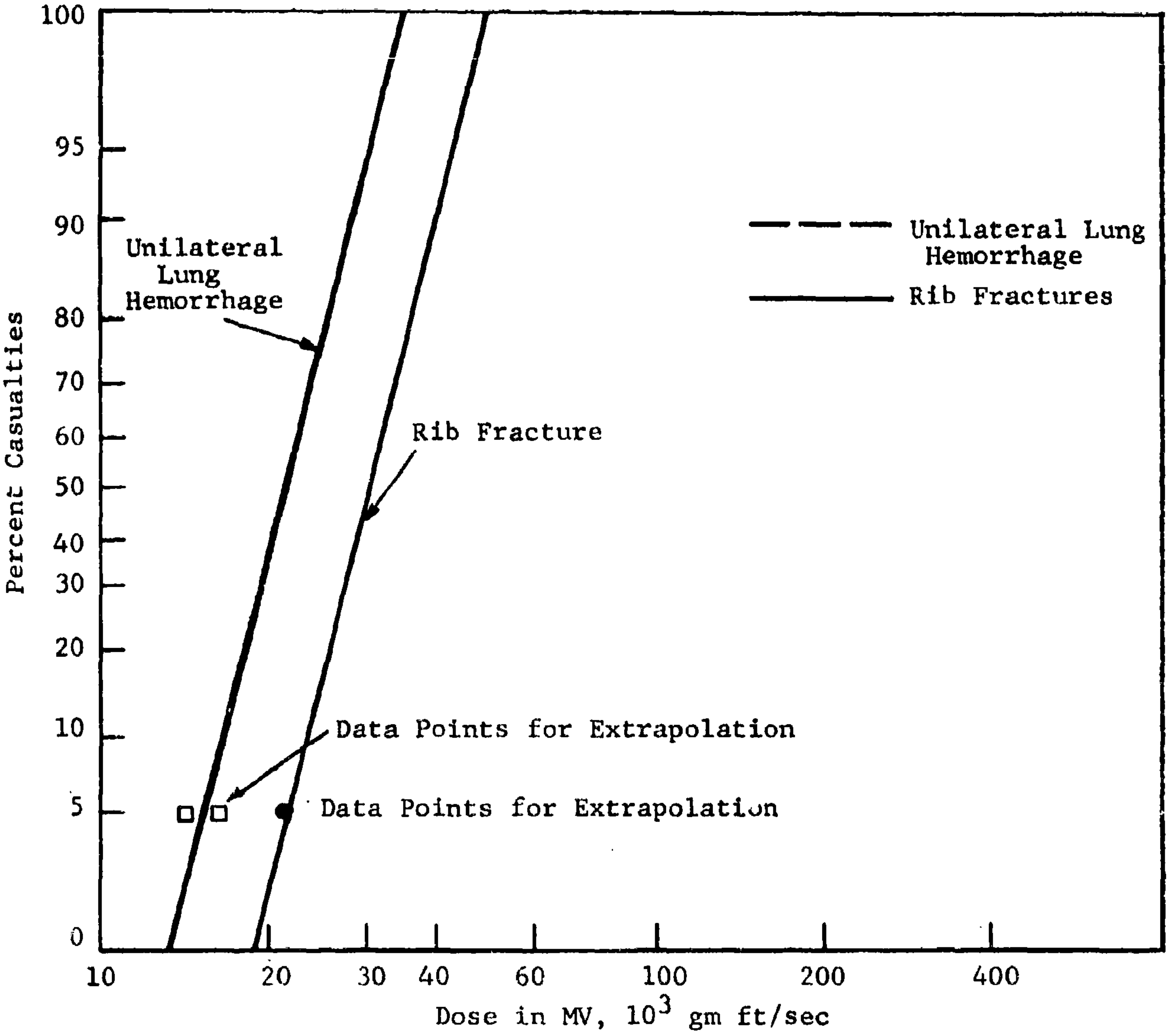


Fig. 72 EFFECTS OF BALLS IMPACTING ON THE THORAX (Superficial)

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* IIT Research Institute Technology Center Chicago, Illinois 60616	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP

3. REPORT TITLE

Personnel Casualty Study

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final Report

5. AUTHOR(S) *(First name, middle initial, last name)*

David I. Feinstein   Albert Weinstock
William F. Heugel
Merle L. Kardatzke

6. REPORT DATE July 1968	7a. TOTAL NO. OF PAGES 340	7b. NO. OF REFS 45

8a. CONTRACT OR GRANT NO. OCD-PS-64-201	9a. ORIGINATOR'S REPORT NUMBER(S) J6067
b. PROJECT NO. OCD Work Unit 1125-A	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of the Secretary of the Army, Office of Civil Defense Research, the Pentagon, Washington, D. C. 20310.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Secretary of the Army Office of Civil Defense Washington, D. C.

13. ABSTRACT

This investigation has resulted in the development of a computer code (SEP - Shelter Evaluation Program) which predicts casualties of personnel when subjected to the initial effects of a nuclear weapon. Conditions for both sheltered and unsheltered personnel were considered. Available casualty data were analyzed and functional relationships between casualty and appropriate weapon effects were approximated. Analytic models relating the weapon effects to these casualty functions were also developed for SEP Code. A validation of the code was performed using existing Hiroshima data. Finally, results are presented for a range of construction and weapon parameters to illustrate how SEP Code may be easily utilized to study shelter effectiveness in terms of added survivors.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Civil Defense, Personnel Casualty, Computers, Nuclear Weapon Effects, Blast Shelters, Radiation Effects.						

Unclassified
Security Classification