TR 84-1

PDCALC
A COMPUTER ROUTINE FOR PROBABILITY
OF
DAMAGE CALCULATIONS

THE JOINT CHIEFS OF STAFF

JOINT STRATEGIC TARGET PLANNING STAFF

OFFUTT AFB, NEBRASKA

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PDCALC - A COMPUTER ROUTINE FOR PROBABILITY OF DAMAGE CALCULATIONS

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JOINT STRATEGIC TARGET PLANNING STAFF
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FOREWORD

This report supersedes JSTPS-TR-79-1, May 1979. It incorporates all changes made to the JSTPS computer routine since that date. Two major changes have been incorporated. First, the program has been restructured to increase the speed of computation. This change will not affect the user in any way except to reduce the program run time. Minor changes in allowed input variables have resulted (JT=1, 2, or 3 is no longer allowed and KF=7, 8, or 9 when JT=X point to different curves). Second, new curve fits for "P" type targets with adjusted vulnerability numbers 36 or greater have been incorporated. These fits were developed by the Academy for Interscience Methodology. This report was written by:

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ABSTRACT

The purpose of this report is to provide guidance to users of the JSTPS computer routine PDCALC for nuclear weapon damage assessments. No attempt is made to detail the mathematical theory asssociated with any procedure used in the computer routine except in those cases where the source is not generally available. Generally available reference sources are noted. The JSTPS computer routine consists of a flexible assemblage of FORTRAN IV subroutines suitable for interactive software applications as well as batch process programs. The routine is maintained by JSTPS to ensure timely response to changes in vulnerability data and methodology. Correspondence pertaining to this report should be addressed to:

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TABLE OF CONTENTS

TABLES

1 - INTRODUCTION

PDCALC is a computer routine used to calculate the probability of achieving at least a specified level of damage to an installation or personnel resulting from a nuclear weapon detonation. The level and type of damage is determined by the vulnerability number (references 1 and 2). The probability of damage (POD)[1] is computed by this routine for a single nuclear weapon and target (installation or personnel) combination. Calculations involving multiple weapon detonations and multiple targets must be accomplished by computer programs which employ PDCALC. PDCALC has been designed to support strategic targeting analysis at the Joint Strategic Target Planning Staff (JSTPS). Other potential users should ensure the routine is valid for their proposed application before employing PDCALC. PDCALC is employed at JSTPS as a subprogram in a variety of large computer programs. This subprogram, written in FORTRAN IV, will be described in this report.

To calculate the POD PDCALC requires information about both the target and the weapon. It also makes certain assumptions about the data it receives. The routine will calculate the POD to point, circular normal, and equivalent area targets given the vulnerability number (VNTK).

The VNTK normally consists of three parts. First, a number (VN) which denotes the target's relative susceptibility to damage by a 20KT nuclear weapon; second, a letter (T) indicating the dominant damage mechanism (overpressure, dynamic pressure, crater, etc); third, a numeric factor (K) which allows the VN to be adjusted to yields other than 20KT (reference 2). The VNTK system has been supplemented by JSTPS for several special situations.

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[1]Notation in this report will agree with the FORTRAN variable used in PDCALC.

Personnel vulnerabilities have been assigned at "T" of X. Special cratering targets described in the DIA Physical Vulnerability Data Sheets (reference 5) have been assigned a "T" of Y. These vulnerability codes are described in more detail in Appendix F and Appendix H, respectively. A special Equivalent Target Area (ETA) vulnerability with a "T" of F has also been defined and is described in the next chapter.

The VNTK defines a specific probability of damage versus distance function. This function is assumed to be a circular log normal distribution which can be characterized by a weapon radius (WR) and damage sigma (DSIG). The weapon radius is the radial distance where the expected damage inside the circle is equal to the expected damage outside. The damage sigma characterizes the radial distribution of damage. A low value of the damage sigma will result in a very sharp drop in damage expectancy near the weapon radius. A larger value will produce a slower drop off in damage expectancy. In addition to the VNTK, the target's location and size must also be specified.

Single installation targets are described as point targets. Targets which can be characterized by a concentration of target elements in the center with the number of elements diminishing as the distance from the center increases are described as circular normal targets. The distribution is assumed to be circular normal and is described by an R95. This is the radius which will include 95% of the target elements. ETAs are targets such as bridges and dams for which a specified degree of damage to some part satisfies the damage objective (reference 4).

The weapon system is described by the yield, height of burst, and circular error probable (CEP) of the delivery system. The distribution of potential detonation points about the aimpoint is assumed to be circular normal. The

CEP is the radius which will include 50% of these detonation points. The target-to-aimpoint offset distance completes the required specification for most targets. ETA targets also require the azimuth to the aimpoint.

It is assumed that the target and the actual ground zero are on a common plane, neglecting both the effect of terrain and any differences in elevation. The effect of these simplifications in the mathematical model on the computed probability of damage is difficult to estimate. A Monte Carlo analysis (reference 3) of the effect of variability in pressure range data, weapon yield, and distance-damage sigma alone demonstrated that a weapon-target combination with an "average" PD of 0.70 actually had a PD of between 0.58 and 0.79 in 90% of the trials for the best case (desired ground zero on the target), and between 0.36 and 0.94 in 90% of the trials for the worst case (fixed ground zero, CEP=0). The dominant factor was the uncertainty associated with the pressure range data; i.e., the uncertainty in the basic weapons effects data.

Vertical and horizontal target location uncertainties are not treated directly in PDCALC. However, they can be treated by computer programs using PDCALC. The method used is described in Appendix D.

PDCALC is structured as an executive routine and eight subroutines. The subroutines are the working portion of the program, with the executive routine serving as an interface between the calling program and the subroutines.

2 - DESCRIPTION

General

PDCALC is composed of an executive routine, six major subroutines, and two supporting subroutines. The executive routine interprets the input data, accesses the proper subroutines, and returns the required result to the program using PDCALC. The result returned by this program is dependent on the input data.

Input/Output

Twelve variables transmit information to and from PDCALC. These variables are IFLG, D, POD, WR, IV, JT, KF, YLD, HOB1, R95, CEP, and AZMTH. The function to be performed by PDCALC is controlled by the value of IFLG. The use of the D, POD, and WR variables is also dependent on the value of IFLG. The functions available and the use of these variables is shown in Table I. Certain functions are restricted to certain types of VNTK. These restrictions are also shown on this table. The input/output variables are described below:

IFLG - A four-digit integer numeric flag. The right two digits are used to select the function as explained above. The left two digits are used to suppress error messages. Error messages are described in Appendix I. Each of the left two digits may be assigned a value of zero or one. A value of one will suppress certain error messages. The first digit (left) allows error message 10 to be suppressed. The second digit allows error message 2 to be suppressed. Each time PDCALC is used these two digits are returned as zero.

D - The offset in nautical miles from the weapon aimpoint to the installation. May either be an input or an output depending on the value of IFLG. See Table I.

TABLE 1

PDCALC FUNCTIONS

IFLG	FUNCTION	VULNERABILITY NUMBER (VNTK)	OFFSET DISTANCE (D)	PROBABILITY OF DAMAGE (POD)	WEAPON RADIUS (WR)
1	Compute POD and WR (Maximum POD is .99.)	All	Input	Output	Output[1]
2	Compute POD and WR (Maximum POD is .999.)	All	Input	Output	Output[1]
3	Compute WR	Not ETA	Input	Not used	Output
4	Same as 3[2]		Input	Not used	Output
5	Given POD, compute D and WR	Not ETA	Output	Input	Output
6	Same as 5[2]		Output	Input	Output
7	Simultaneously compute fatalities and casualties	"T" = X only "K" must specify a fatality curve.	Input	Output-value is probability of fatality	Output-value is probability of casualty
8	Given damage sigma, compute POD & WR. (Max POD is .99.)	Not ETA Not "T"= X only	Input	Dual use: Input-damage sigma; output-POD	Output
9	Given damage sigma and WR, compute POD (Max POD is .99.)	All[3]	Input	Dual use: Input-damage sigma; output-POD	Input-weapon radius; output-same weapon radius

IFLG	FUNCTION	VULNERABILITY NUMBER (VNTK)	OFFSET DISTANCE (D)	PROBABILITY OF DAMAGE (POD)	WEAPON RADIUS (WR)
10	Given WR, compute POD (Routine computes damage sigma. Max POD is .99.)	Not ETA Not "T" = X	Input	Output	Input-weapon radius; output-same weapon radius

[1]See text for explanation of value output for ETA targets.
[2]Functions have been deleted. Default functions assigned to keep the meaning of following IFLG values intact.
[3]Any valid VNTK may be input, the value will not be used.

POD - Normally the probability of achieving the damage associated with the VNTK given the specified weapon and offset distance. The variable is also used to input other types of data depending on the value of IFLG. See Table I.

WR - Normally the weapon radius, in feet, of the specified weapon-target combination. The variable is used to communicate other information as specified in Table I. Its use also changes when an ETA target is a lock or dam. For these installations a weapon detonated on one side may be more effective than one detonated on the other side. The absolute value of the difference between the two weapon radii divided by two is returned in WR. A sign is added to this result. For locks a positive sign indicates that the center of the ETA is in the direction of the open watercourse, while for a dam a positive sign indicates that the center of the ETA is in the upstream direction and a negative sign indicates it is in the downstream direction. This information is useful to any program calling PDCALC that needs information concerning the center of the ETA when that center does not correspond to the reference point for the target.

IV, JT, KF - These variables are used to input the VNTK. IV (VN) is a two digit integer. JT (T) is a single alphabetic character. KF (K) is a single character which may be an integer or alphabetic. Normally, the VNTK values are those described in references 2 and 4. A list of valid target types is given in Table II. References 2 and 4 do not describe VNTKs with the JT equal to X, Y, or F. If JT is equal to F, the target is an ETA installation. For JT equal to X or Y the IV (VN) variable is not used. The KF variable is used in those cases to select the data curves given in Table IV, Appendix F for X types and Table VI, Appendix H for Y types. The meaning of IV and KF are described in Table III for JT = F.

TABLE II

TARGET TYPES AND DAMAGE SIGMA

TARGET TYPES	"T"	DSIG
Dynamic Pressure Sensitive (Q type)	R	.1
	S	.2
	Q	.3
	T	.4
	U	.5
Overpressure Sensitive (P type)	L	.1
	P	.2
	M	.3
	N	.4
	O	.5
Crater Required	Z	.3
	Y	.3
Personnel	X	Value Calculated
ETA	A	Value Calculated
	B	" "
	C	" "
	D	" "
	E	" "
	F	" "

TABLE III

DECODE OF VNTK FOR F-TYPE ETA

Decode of IV

First Digit (Length)	Second Digit (Width)	Decode of KF
1 - 10,000 feet	1 - 2,000 feet	1 - 13Q5
2 - 9,500 feet	2 - 1,900 feet	2 - 11Q4
3 - 8,500 feet	3 - 1,700 feet	
4 - 7,500 feet	4 - 1,500 feet	
5 - 6,500 feet	5 - 1,300 feet	
6 - 5,500 feet	6 - 1,100 feet	
7 - 4,500 feet	7 - 900 feet	
8 - 3,500 feet	8 - 700 feet	
9 - 2,500 feet	9 - 500 feet	
0 - 2,000 feet	0 - 300 feet	

YLD - A number which gives the weapon yield in kilotons.

HOB1 - Weapon height of burst (above ground level) in feet.

R95 - A number giving the radius in nautical miles of a circle encompassing 95% of the target area. For ETA-type targets R95 is the angle (clockwise and positive) in degrees (0-359) divided by 10, between a true north vector and a vector parallel to the long axis of the target. Which of the two possible vectors parallel to the long axis is used depends on the type of ETA target:

a. Dams - For dams the direction of the parallel vector is chosen so that the vector "R95 times 10" points in the direction of the reservoir (upstream direction).

b. Locks - For locks the direction of the parallel vector is chosen so that the vector "R95 times 10" points in the direction of the open watercourse, if one exists. If there is an open watercourse at both ends of the lock, the parallel vector is chosen so that the R95 field will reflect the smallest angle.

c. Bridges and Other ETA-type Targets - For bridges and other ETA-type targets (indicated by JT=F) the direction of the parallel vector is chosen so that the R95 field reflects the smallest angle.

CEP - A number which gives the weapon delivery system circular error probable in feet.

AZMTH - A number, in degrees, giving the angle measure clockwise between a true north vector and a vector from the DGZ to the target. It is required as an input in the case of an ETA target when the offset distance (D) is not equal to zero. When D=0 or the target is not to be treated as an ETA, AZMTH is not a required input.

Routine Descriptions

The executive routine transmits and processes the input/output described above, assigns damage sigmas as indicated in Table II and makes calls as required on six of the eight subroutines. These subroutines are WRCALC, WRPERS, WRCLCY, LNCALC, INTGF, ETCALC, and WRCRTR. Flow diagrams for the executive routine and each subroutine are provided in Appendix A. The function of each subroutine will be discussed briefly below.

WRCALC - This routine calculates the weapon radius for overpressure sensitive ("P" type), dynamic pressure sensitive ("Q" type), and crater type ("T" = Z) targets. This is acccomplished by using curve fits described in reference 1. These fits have been supplemented by the curve described in Appendix G, "Hard "P" Type Vulnerabillity Curves."

WRPERS - This routine calculates the weapon radius and damage sigma from the personnel vulnerabililty curves of reference 3, Part III. The techniques used to fit these curves is described in Appendix F, "Personnel Vulnerability Curves."

WRCLCY - The routine which calculates the weapon radius for special crater type targets ("T" = Y). The curves used are described in Appendix H, "Special Crater Vulnerability Curves."

LNCALC - This routine either calculates the probability of damage (fatality-casualty) or calculates the offset distance for a specific probability of damage. The routine uses the cumulative lognormal function to describe the distance damage function. The method used to calculate POD is described in reference 1, Appendix E, pages 69-78. Basically, the method uses the error function to evaluate the distance-damage function, a series expansion of the zeroth order hyperbolic Bessel function to evaluate the distance-density function, and a 10-point Gauss-Legendre quadrature formula to evaluate the resulting integral. Appendix E gives a summary of this formulation of PD. A detailed description of the erf function, the series expansion of the Bessel function, and the Gauss-Legendre quadrature can be found in reference 8. To calculate an offset distance the routine iterates an offset distance until the calculated probability of damage is within .001 of the desired probability of damage. This iteration starts with calculating the probability of damage at zero offset (D=0). The offset distance is then incremented by an amount equal to the weapon radius (WR) until the calculated value is less than the desired value. The increment is then changed to -WR/2 and the probability of damage calculated as before. When the value calculated exceeds the value desired the increment is cut in half again and its sign changed. This process continues until the desired result is achieved.

INTGF - A support subroutine called by LNCALC. It provides the function f(r) described in Appendix E. It is the function which is integrated by the Gauss-Legendre quadrature.

ETCALC - This routine calculates the probability of damage to ETA-type targets. If the weapon is detonated at a valid height of burst, this routine calculates the weapon radii required to transform the target into an equivalent target area. This is accomplished by decoding the VNTK in accordance with the appropriate category description of reference 4. The weapon radii are obtained from WRCALC if a pressure is identified or WRCRTR if a crater is required. After obtaining the weapon radii that are required to transform the target into an equivalent target area, ETCALC next rotates the coordinate system. This rotation is explained in Appendix C. Basically, a coordinate system centered on the DGZ with positive "y" in the direction of true north is rotated clockwise to a system centered on the DGZ with positive "y'" defined as the direction of a vector pointing in the direction specified by the ORIEN field. The "x" and "y" coordinates of the target reference point in the new coordinate system are then calculated as explained in Appendix C. The length and width of the ETA are established by using the decoded IV number for the length and width of the target itself and the weapon radii that were calculated earlier to extend the area as explained in reference 1, pages 30-33. By combining this information with the coordinates of the target reference point in the new coordinate system, ETCALC then establishes the boundaries of the ETA in the new coordinate system. The erf function is then used as described in reference 1, pages 30-33, to calculate the probability that the actual ground zero will fall within the ETA, which, in accordance with the ETA methodology, is assumed to be the probability of damage for that target.

WRCRTR - The purpose of WRCRTR is to calculate a weapon radius for ETCALC when a crater radius factor (CRF) is given in paragraph 9 of the appropriate category description of reference 4. WRCRTR is only called by ETCALC. The use of a CRF for this purpose is described on page I-2 of reference 2. CRF is determined by ETCALC by decoding the JT and KF arguments of PDCALC. In some cases, ETCALC will provide a negative CRF to WRCRTR. This only serves the purpose of a flag to WRCRTR that Figure II-2 of reference 2, Part II, is to be used in computing a scaled crater radius. Before using CRF to calculate a weapon radius, the sign of any negative CRF is changed.

WRCRTR checks to see if the target is a lock, a dam, or some other type of ETA target. If it is a lock and a length weapon radius is the desired output, then Figure II-2b of reference 2, Part II, is used to get the scaled weapon radius. If the target is an earthern dam, Figure 2 of reference 2, Part II, is used to get a downstream scaled crater radius, while Figure II-2b, reference 2, Part II, is used to get an upstream scaled crater radius.

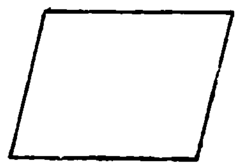
Once WRCRTR has determined the proper scaled crater radius to use, the weapon radius is computed by multiplying this by the one-third power of the yield, the crater radius factor, and 1.1. The 1.1 factor corresponds to a damage sigma of .3 as described on page II-1 of reference 2.

ERRMSG - The purpose of ERRMSG is to print an error message in the batch version of PDCALC when errors in the input data are detected. No flow diagram is provided in Appendix A for ERRMSG. It is called by the executive routine whenever that routine has identified an error in the input data. ERRMSG then causes the statement, "You have input error No. (IERR); your inputs are as follows: IV, JT, YLD, CEP, HOB1, R95, D, WR, POD, IFLG." After listing the input data, ERRMSG then prints a different statement for each IERR value. These statements are listed with their corresponding IERR value in Appendix I.

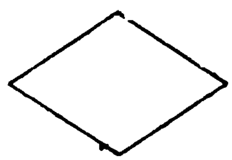
APPENDIX A

FLOW DIAGRAMS

Simplified flow diagrams for the PDCALC executive routine and six of the seven subroutines are provided. (No flow diagrams are provided for the INTGF, ERRMSG, and WRCLCY subroutines.) These simplified diagrams follow the basic logic without including all the steps in these routines. The symbology used in the flow diagrams is as follows:

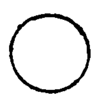


- INPUT/OUTPUT

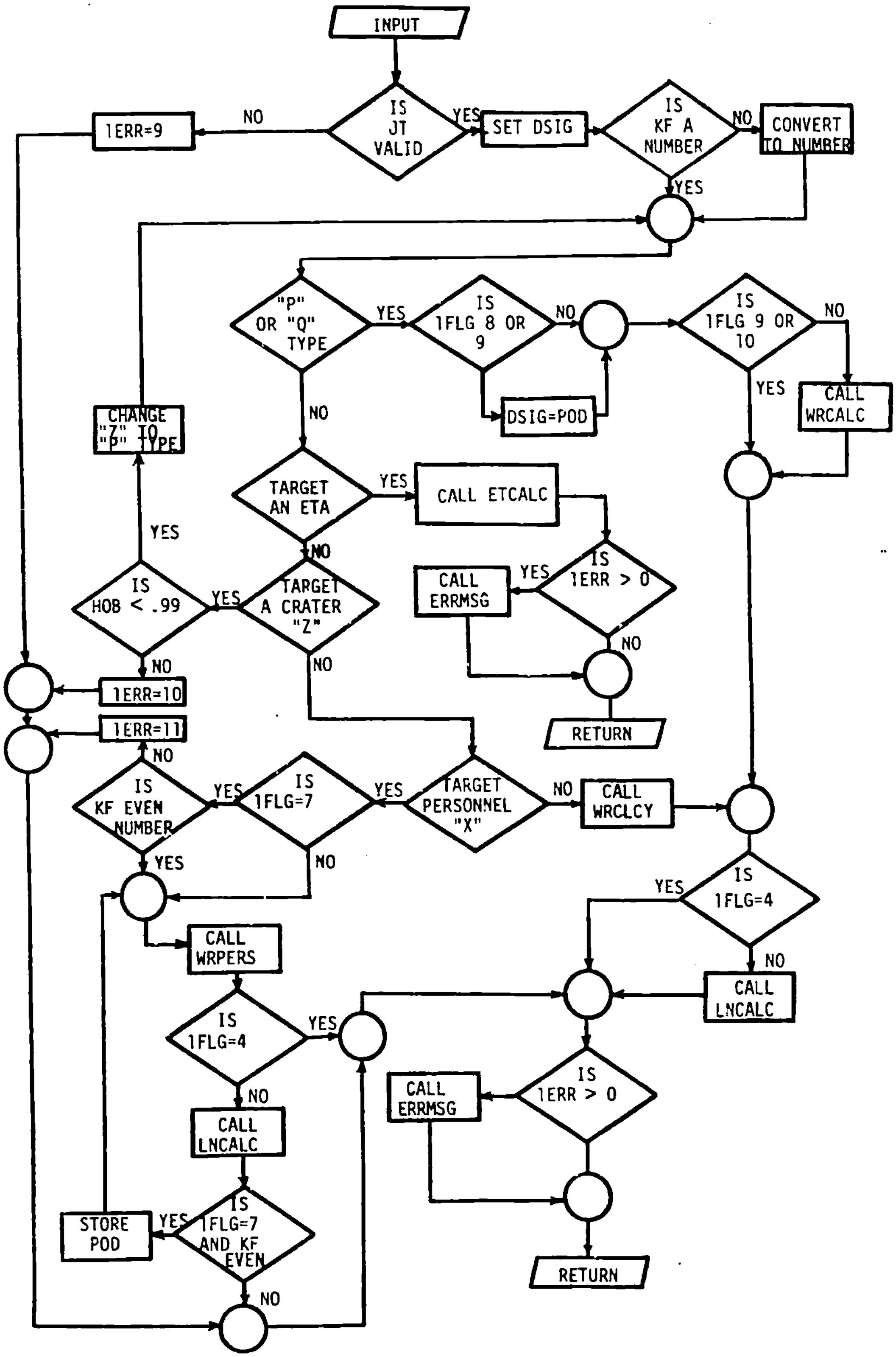


- DECISION

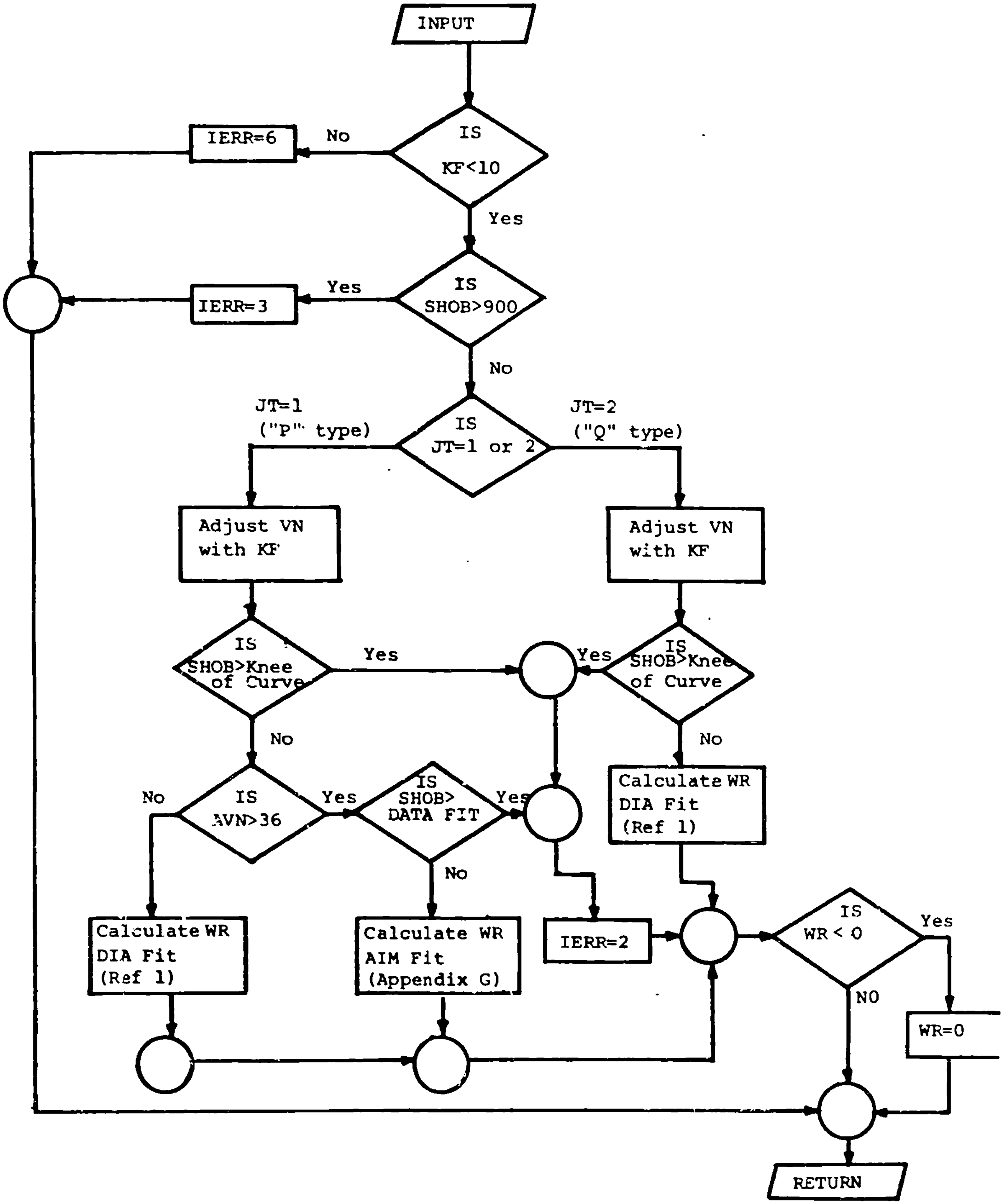
- PROCESS

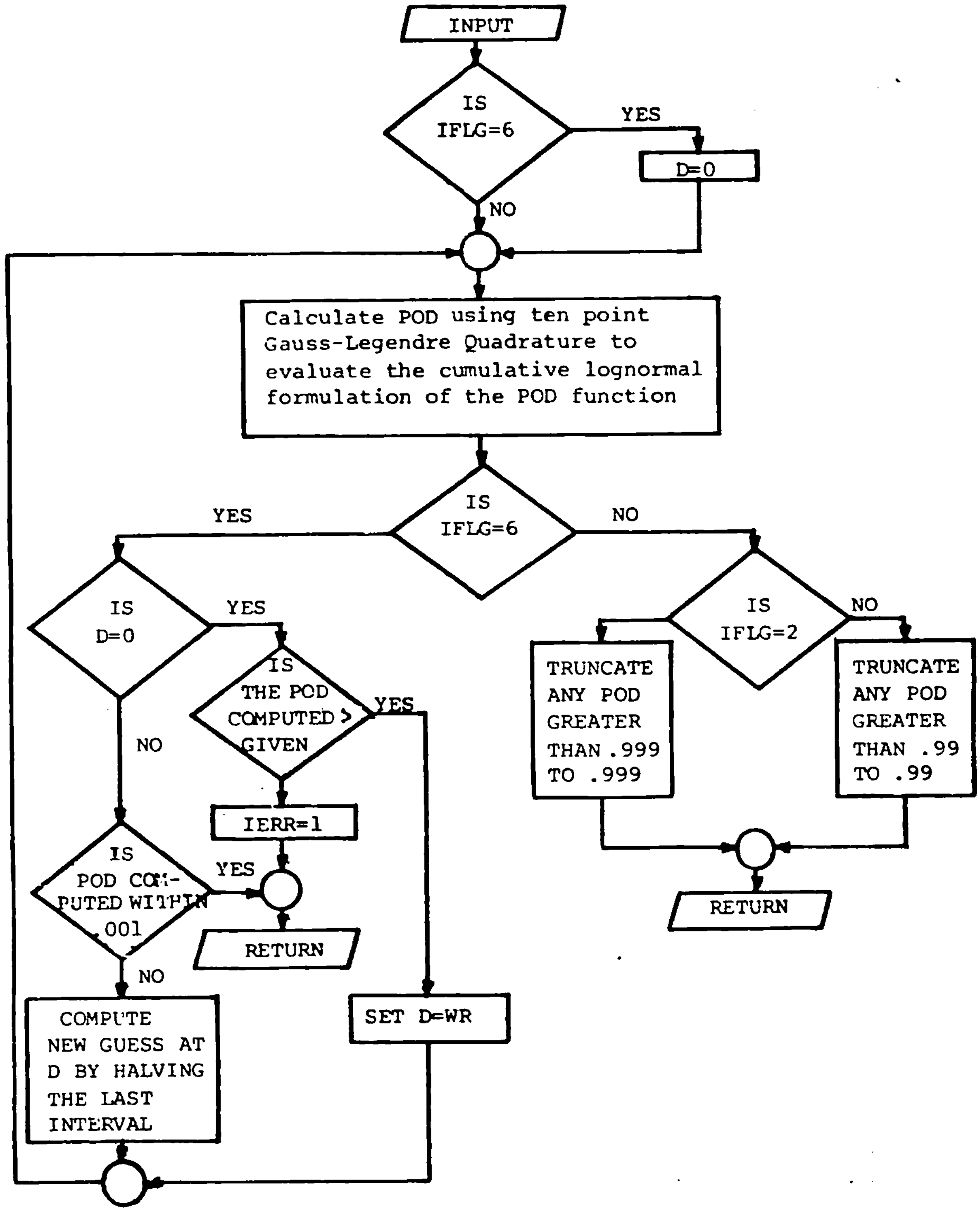


- CONNECTOR

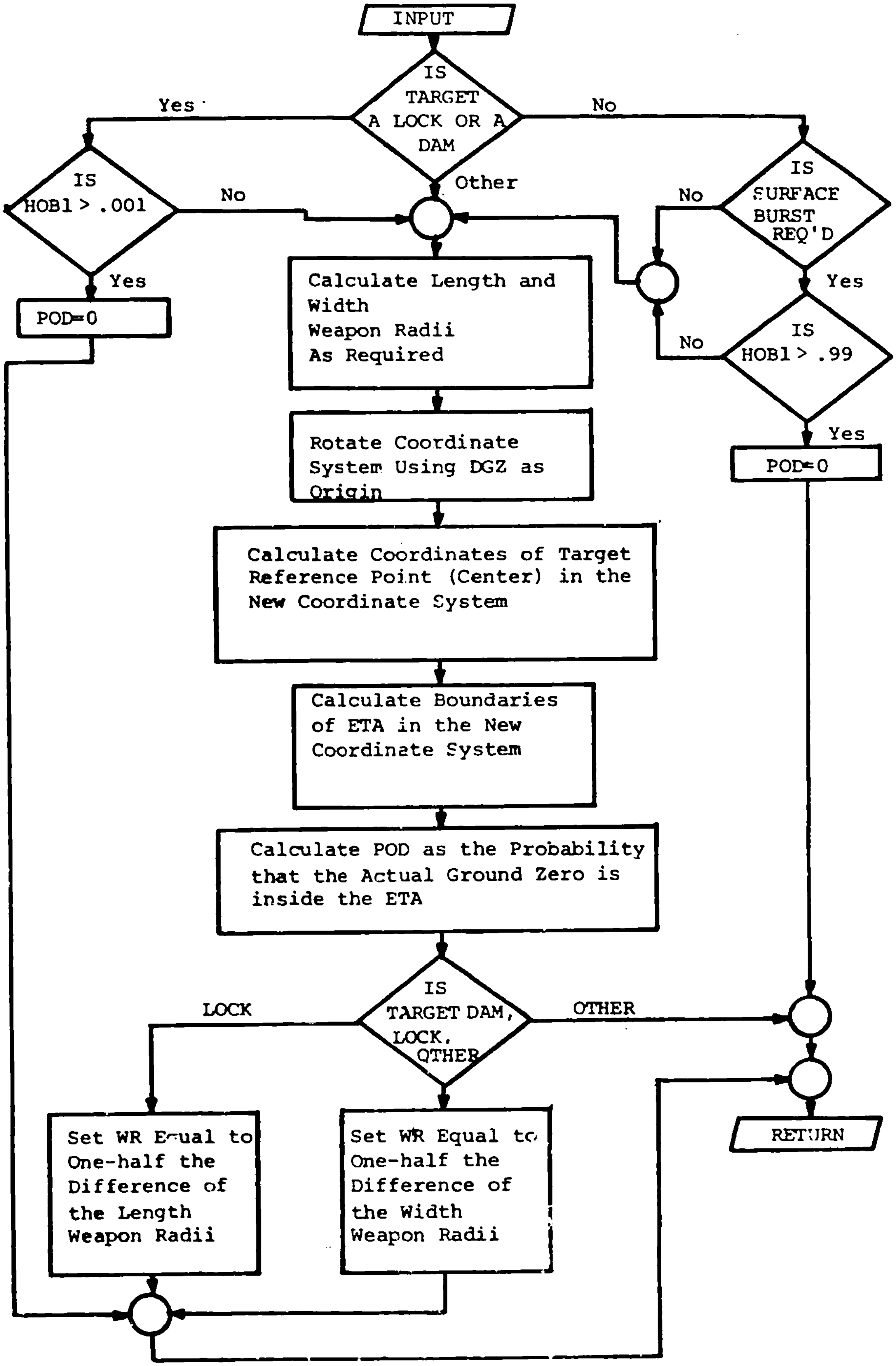

INPUT
IS JT VALID
NO
YES
IERR=9
SET DSIG
IS KF A NUMBER
NO
YES
CONVERT TO NUMBER
"P" OR "Q" TYPE
YES
NO
IS IFLG 8 OR 9
NO
DSIG=POD
IS IFLG 9 OR 10
NO
YES
CALL WRCALC
CHANGE "Z" TO "P" TYPE
TARGET AN ETA
YES
NO
CALL ETCALC
IS IERR > 0
YES
NO
CALL ERRMSG
RETURN
IS HOB < .99
YES
NO
TARGET A CRATER "Z"
YES
NO
IERR=10
IERR=11
IS KF EVEN NUMBER
YES
NO
IS IFLG=7
YES
NO
TARGET PERSONNEL "X"
YES
NO
CALL WRCLCY
IS IFLG=4
YES
NO
CALL LNCALC
CALL WRPERS
IS IFLG=4
YES
NO
CALL LNCALC
IS IERR > 0
CALL ERRMSG
RETURN
STORE POD
IS IFLG=7 AND KF EVEN
YES
NO

WRCALC SUBROUTINE

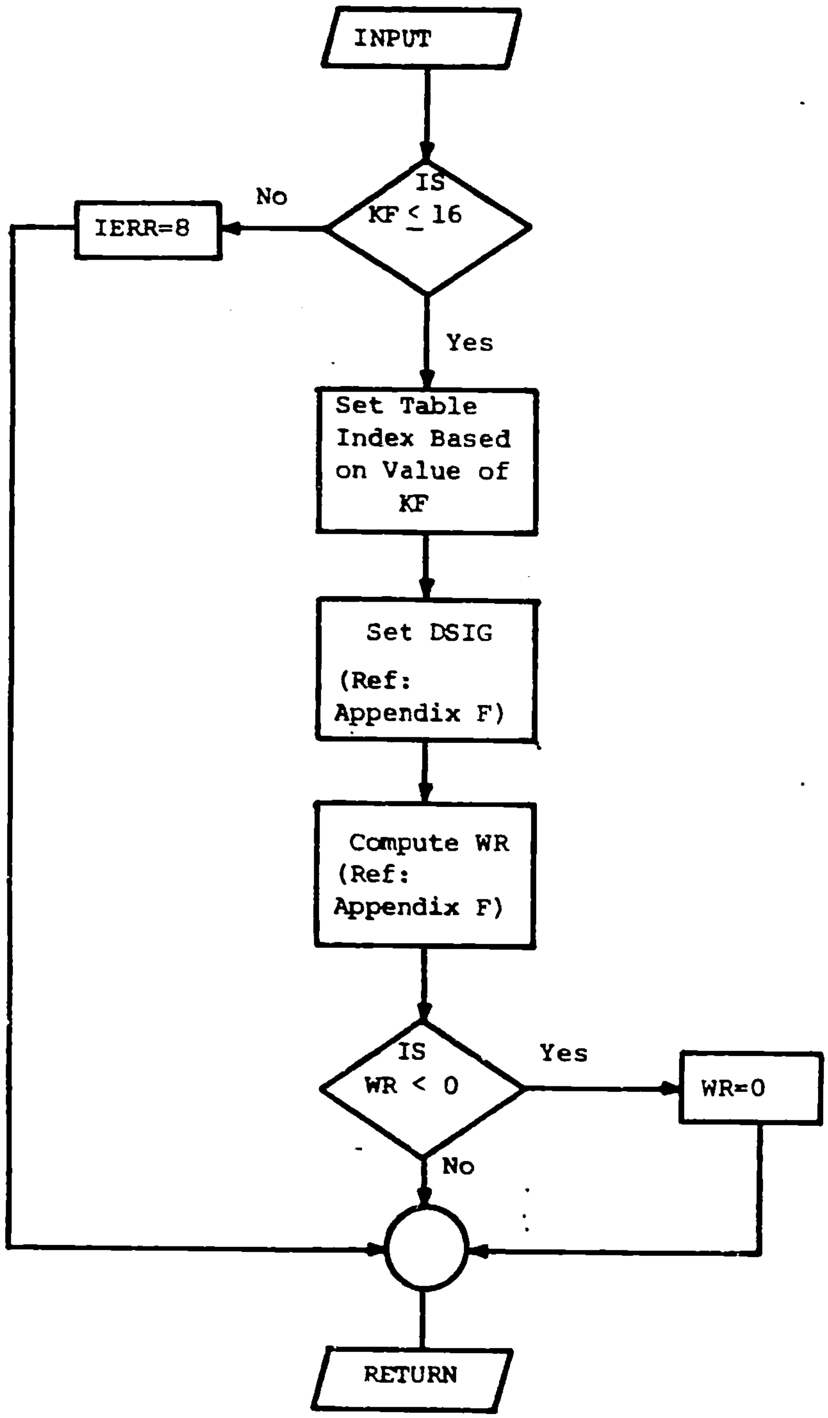



INPUT
IS IFLG=6
YES
D=0
NO
Calculate POD using ten point Gauss-Legendre Quadrature to evaluate the cumulative lognormal formulation of the POD function
IS IFLG=6
YES
NO
IS D=0
YES
IS THE POD COMPUTED > GIVEN
YES
NO
IS IFLG=2
NO
TRUNCATE ANY POD GREATER THAN .999 TO .999
TRUNCATE ANY POD GREATER THAN .99 TO .99
IERR=1
IS POD COMPUTED WITHIN .001
YES
RETURN
NO
COMPUTE NEW GUESS AT D BY HALVING THE LAST INTERVAL
SET D=WR
RETURN

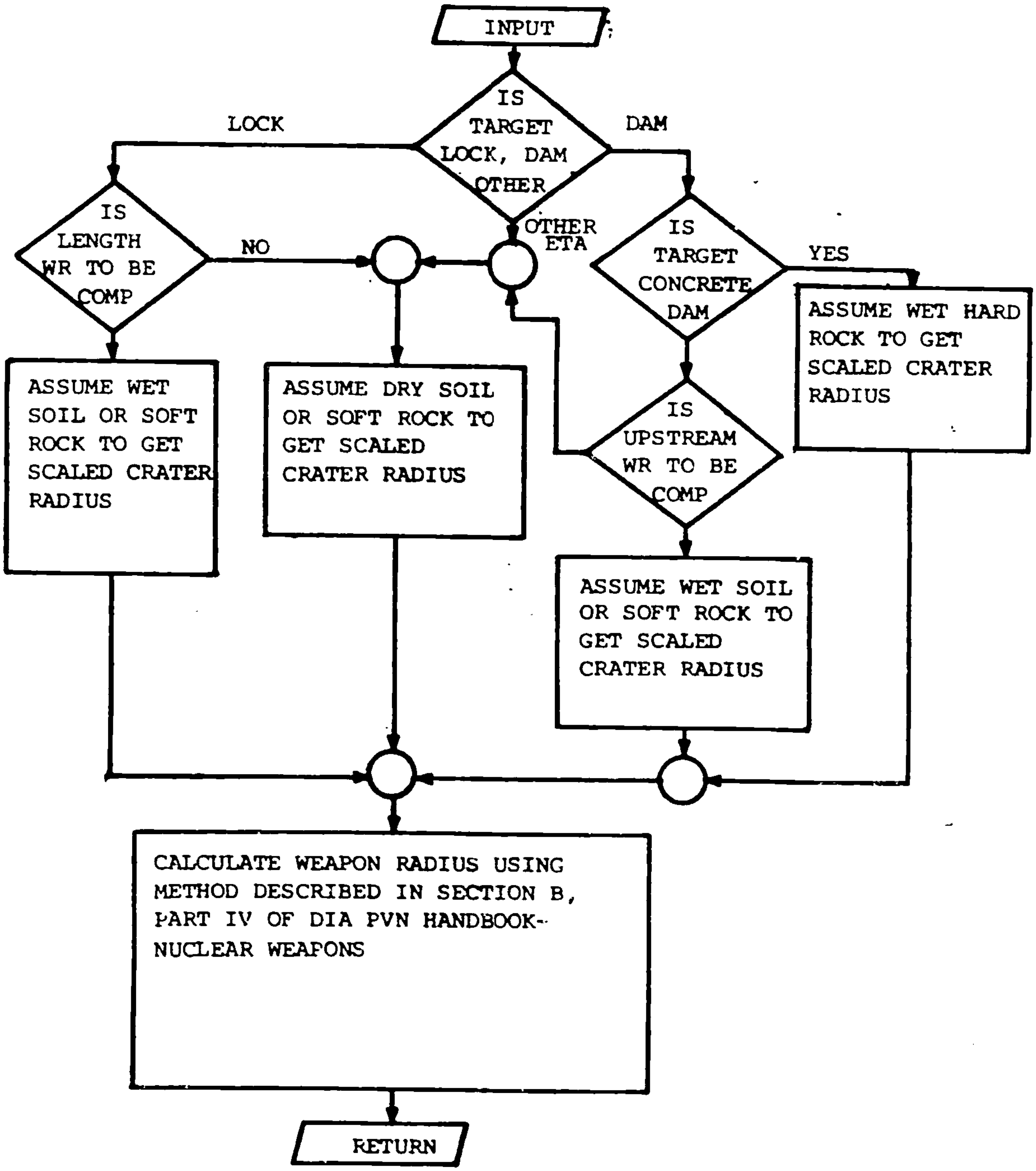
ETCALC SUBROUTINE



WRPERS SUBROUTINE



WRCRTR SUBROUTINE



APPENDIX B

FORTRAN LISTING

A sequence number for each card in the PDCALC deck appears as an eight-digit number in the FORTRAN listing. The eight-digit field corresponds to card columns 73 through 80.

The sequence numbers provide a means for collation and referencing.

```
C*********************************************************************
C
      SUBROUTINE PDCALC(IV,JT,KF,YLD,HOB1,R95,CEP,D,WR,POD,IFLG,AZMTH)
C
C*********************************************************************
C
C
C  PDCALC IS A SUBROUTINE IN FORTRAN 4 WHICH CALCULATES THE AVERAGE
C         PROBABILITY OF ACHIEVING AT LEAST THE LEVEL OF DAMAGE,
C         SPECIFIED BY A VULNERABILITY NUMBER, TO AN INSTALLATION
C         USING A SPECIFIC WEAPON TARGETTED AGAINST AN EXPLICIT
C         DGZ LOCATION. OPTIONAL CALCULATIONS ARE AVAILABLE THROUGH
C         IFLG CONTROL.
C
C
C
C     CONTINUE
C
C    THE SUBROUTINE ARGUMENTS HAVE THE FOLLOWING MEANINGS:
C
C          IV = AN INTEGER NUMBER DESCRIBING TARGET HARDNESS OR
C               TARGET DIMENSIONS (ETA). INDICATES VULNERABILITY
C               NUMBER (VN OF VNTK).
C     CONTINUE
C          JT = 'T' PORTION OF VNTK. CAN BE 1, 2, OR 3 IN ADDITION
C               TO ALPHABETICS DEFINED IN TDI HANDBOOK.
C          KF = 'K' PORTION OF VNTK WHICH IS NORMALLY AN INTEGER NUMBER
C               FROM 0 TO 9. FOR P AND Q TYPE TARGETS THIS DENOTES
C               TARGET RESPONSE TO SHOCK DURATION. FOR POPULATION EF-
C               FECTS IT DENOTES THE DOMINANT STRUCTURE IN THE AREA,
C               AND CAN BE AN ALPHABETIC A THRU P.
C     CONTINUE
C         YLD = YIELD OF WEAPON IN KILOTONS
C
C        HOB1 = ACTUAL HEIGHT OF BURST OF THE WEAPON IN FEET.
C
C         R95 = RADIUS IN NAUTICAL MILES (TO THE NEAREST ONE-TENTH)
C               OF A CIRCLE ENCOMPASSING 95 PERCENT OF THE CIRCULAR
C               NORMAL TARGET AREA.
C               FOR ETA TARGETS, R95*10 = ORIENTATION OF THE TARGET
C               IN DEGREES.
C     CONTINUE
C         CEP = CIRCULAR ERROR PROBABLE OF THE SPECIFIED WEAPON SYSTEM
C               IN FEET.
C
C           D = DISTANCE IN NAUTICAL MILES FROM DGZ TO TARGET.
C
C          WR = WEAPON RADIUS IN FEET.
C
C         POD = PROBABILITY OF ACHIEVING THE SPECIFIED LEVEL OF DAMAGE
C               AGAINST THE GIVEN TARGET WITH THE GIVEN WEAPON.
C
C     CONTINUE
C        IFLG = THERE ARE DIFFERENT RESULTS THAT PDCALC CAN PRODUCE.
C               THE OUTPUT CREATED IS CONTROLLED BY GIVING IFLG THE
C               FOLLOWING VALUES:
C     CONTINUE
C               1 = PRODUCE POD UP TO VALUE OF .990. D MUST BE INPUT.
C                   CLN FUNCTION IS USED.
C
C               2 = PRODUCE POD UP TO VALUE OF .999. D MUST BE INPUT.
```

```
C                    CLN FUNCTION IS USED.
C
C                3 = SEE 4.
C
C                4 = PRODUCE WEAPON RADIUS.
C     CONTINUE
C                5 = SEE 6.
C
C                6 = PRODUCE D, THE MAXIMUM DISTANCE AT WHICH A GIVEN POD
C                    CAN BE ACHIEVED.  POD MUST BE INPUT. (LNCALC USED)
C
C                7 = PRODUCE FATALITY POD AND CASUALTY POD.
C                    THESE VALUES ARE RETURNED IN POD AND WR
C                    VARIABLES, RESPECTIVELY. D MUST BE INPUT.
C     CONTINUE
C                8 = DAMAGE SIGMA IS INPUT THROUGH POD VARIABLE. POD IS
C                    OUTPUT,  (D IS INPUT)
C
C                9 = DAMAGE SIGMA AND WEAPON RADIUS ARE INPUT. POD IS
C                    OUTPUT.  (D IS INPUT)
C
C               10 = WR INPUT. POD IS OUTPUT. (D IS INPUT)
L
C        AZMTH = AZIMUTH IN DEGREES FROM DGZ TO TARGET.
C
C            *** OPTION ***
C     IF IFLG > 1000 THEN ERROR MESSAGE 12 IS SUPRESSED. 1000 IS THEN
C     SUBTRACTED FROM IFLG AND ITS VALUE IS CHECKED AGAIN.
C     IF IFLG > 100 THEN ERROR MESSAGES 2 AND 10 ARE SUPPRESSED.
C     100 IS SUBTRACTED FROM IFLG IN THIS CASE. PROCESSING THEN CONTINUES
C     AS BEFORE.   IFLG IS NOT RETURNED TO ITS ORIGINAL VALUE.  THIS
C     MEANS THAT IFLG MUST BE RESET BEFORE EACH CALL TO PDCALC  IF YOU
C     WANT TO USE THIS OPTION.
C
C         IERR IS A FLAG FOR FINDING PROBLEMS IN THE INPUT DATA IF
C              THEY EXIST.
C ***********************************************************************
C   THIS IS THE NEW VERSION OF PDCALC, WRITTEN BY CAPTAIN MICHAEL J.
C   PIOTROWSKI (ADWNDA) WITH GUIDANCE OF MAJ BRUCE BAUER, MAJ STEVE
C   SPERRY, AND LTCMDR RON CARPENTER (ALL THREE OF JLTW) 6 MAY 1981
C ***********************************************************************
      DIMENSION DDSIG(19),JTD(19),JJTD(19),KFN(27),KFI(27)
      DATA JTD /'R','S','Q','T','U','L','P','M','N','O',
     1          'Z','Y','A','B','C','D','E','F','X'/
      DATA JJTD / 5*2, 5*1, 2*4, 5, 6, 7, 8, 9, 10, 3 /
      DATA DDSIG / .1,.2,.3,.4,.5,.1,.2,.3,.4,.5,.3,.3, 7*1. /
      DATA IX, IZ / 'X','Z' /
C  TABLE KFN CONTAINS POSSIBLE NUMERIC LITERALS (EBCDIC) FOR KF THAT
C  NEED TO BE CONVERTED INTO INTEGER
      DATA KFN /'0','1','2','3','4','5','6','7','8','9','A','B','C','D',
     1          'E','F','G','H','I','J','K','L','M','N','O','P','Q'/
      DATA KFI / 0,1,2,3,4,5,6,7,8,9,1,2,3,4,5,6,7,8,9,10,11,12,13,14,
     1          15,16,17 /
C
      DO 10 M=1,19
      IF(JT.EQ.JTD(M)) GO TO 11
   10 CONTINUE
C        JT IS NOT A VALID ALPHA CHARACTER
      IERR = 9
      GO TO 990
   11 JJT = JJTD(M)
```

```
      DSIG = DDSIG(M)                                                    01230009
C     CONVERT KF TO INTEGER IF IT IS NUMERIC LITERAL (EBCDIC)            01240009
      IF (KF.GE.0) GO TO 6                                               01250009
      DO 5 I=1,27                                                        01260009
      IF (KF.NE.KFN(I)) GO TO 5                                          01270009
      KF = KFI(I)                                                        01280009
      GO TO 6                                                            01290009
 5    CONTINUE                                                           01300009
 6    IERR = 0                                                           01310009
C        DECODE IFLG                                                     01320009
      IFHFLG = 0                                                         01330009
      IFGFLG = 0                                                         01340000
      IF  (IFLG.GT.1000) IFHFLG = 1                                      01350009
      IF  (IFLG.GT.1000) IFLG = IFLG - 1000.                             01360009
      IF  (IFLG.GT.100)  IFGFLG = 1                                      01370000
      IF  (IFLG.GT.100)  IFLG = IFLG - 100                               01380000
      IF  (IFLG.EQ.5)    IFLG = 6                                        01390009
      IF  (IFLG.EQ.3)    IFLG = 4                                        01400009
      IFLH = IFLG                                                        01410009
C            IFLG OF 7 MUST HAVE AN 'X' VNTK                             01420010
      IF (IFLG.NE.7) GO TO 14                                            01430010
      IF (JJT.EQ.3) GO TO 100                                            01440010
      IERR = 5                                                           01450010
      GO TO 990                                                          01460010
 14   IF (JJT.GT.2) GO TO 100                                            01470010
C       OVER PRESSURE, DYNAMIC PRESSURE AND CRATER TYPE VNTKS            01480009
 15   IF (IFLG.EQ.8.OR.IFLG.EQ.9) DSIG = POD                             01490009
      IF (IFLG.GE.9) GO TO 20                                            01500009
C*********************************************************************** 01510000
      CALL WRCALC(YLD,HOB1,IV,JJT,KF,DSIG,WR,IERR)                       01520000
C*********************************************************************** 01530000
      IF (IERR.NE.0) GO TO 990                                           01540009
 19   IF (IFLG.NE.4) GO TO 20                                            01550010
      POD = 0.                                                           01560010
      RETURN                                                             01570010
C*********************************************************************** 01580000
 20   CALL LNCALC (CEP, DSIG, WR, R95, POD, D, IFLH, IERR)               01590006
C*********************************************************************** 01600000
      IF (IERR.NE.0) GO TO 990                                           01610009
      RETURN                                                             01620009
 100  IF (JJT.LE.4) GO TO 200                                            01630009
C      ETA TYPE VNTKS                                                    01640009
C      CHECK FOR VALID IFLG TO USE ETA                                   01650009
      IF (IFLG.LE.2) GO TO 110                                           01660009
      IERR = 4                                                           01670009
      GO TO 990                                                          01680009
 110  JTS = JJT - 4                                                      01690009
C*********************************************************************** 01700000
      CALL ETCALC (IV,JTS,KF,YLD,CEP,HOB1,R95,AZMTH,D,POD,WR,IERR)       01710000
C*********************************************************************** 01720000
      IF (IERR.NE.0) GO TO 990                                           01730000
      RETURN                                                             01740000
C     CHECK FOR AND APPROPRIATELY PROCESS 'X', 'Y', AND 'Z' TYPE VNTKS   01750009
 200  IF (JT.NE.IZ) GO TO 210                                            01760009
      JJT=1                                                              01770009
      IF (HOB1.LT..99) GO TO 15                                          01780009
      GO TO 215                                                          01790009
 210  IF (JT.EQ.IX) GO TO 225                                            01800009
      IF (HOB1.LT..99) GO TO 220                                         01810009
 215  IERR = 10                                                          01820009
      GO TO 990                                                          01830009
```

```
C*************************************************************************
  220  CALL WRCLCY(KF,YLD,WR,IERR)
C*************************************************************************
       IF (IERR.EQ.0) GO TO 19
C       INVALID JT='Y' VNTK; SET POD, WR, AND/OR TO ZERO AND RETURN
       IF (IFLG.EQ.6)                        D = .0
       IF ((IFLG.NE.9).AND.(IFLG.NE.10))     WR = .0
       IF (IFLG.NE.6)                        POD = .0
       RETURN
  225  IFLH = 2
       IF (IFLG.NE.7) GO TO 230
       KK = KF/2*2
       IF (KF.NE.KK) GO TO 230
       IERR = 11
       GO TO 990
C*************************************************************************
  230  CALL WRPERS(YLD,HOB1,IV,JJT,KF,DSIG,WR,IERR)
C*************************************************************************
       IF (IERR.NE.0) GO TO 990
       IF (IFLG.EQ.4) RETURN
C*************************************************************************
       CALL LNCALC (CEP, DSIG, WR, R95, POD, D, IFLH, IERR)
C*************************************************************************
       IF (IERR.NE.0) GO TO 990
       IF (IFLG.NE.7) RETURN
       IF ((KF/2*2).EQ.KF) GOTO 231
       P1 = POD
       KF = KF + 1
       GO TO 230
  231  WR=POD
       POD=P1
       RETURN
  990  CONTINUE
       IF ((IFHFLG.EQ.1) .AND. (IERR.EQ.10)) GO TO 991
       IF ((IFGFLG.EQ.1) .AND. (IERR.EQ.2)) GO TO 991
C*************************************************************************
       CALL ERRMSG (IERR,IV,JT,KF,YLD,CEP,HOB1,R95,D,WR,POD,IFLG)
C*************************************************************************
       RETURN
C
  991  IF ((IFLG.EQ.5).OR.(IFLG.EQ.6))            D = .0
       IF ((IFLG.NE.9).AND.(IFLG.NE.10))          WR = .0
  992  IF ((IFLG.NE.5).AND.(IFLG.NE.6))           POD = .0
       RETURN
       END
C*************************************************************************
C
       SUBROUTINE WRCALC (YLD, HOB1, IV, JJT, KF, DSIG, WR, IERR)
C
C*************************************************************************
C
C              WRCALC IS THE SUBROUTINE WHICH CALCULATES WEAPON RADIUS
C
       DIMENSION WP(8,2,10),WQ(8,10), TVNP(9), TVNQ(9)
       DIMENSION WP1(88), WP2(72), WQ1(72), WQ2(8)
       EQUIVALENCE  (WP(1), WP1(1)),  (WP(89), WP2(1)),
      A             (WQ(1), WQ1(1)),  (WQ(73), WQ2(1))
       DATA  WP1 /
C
C         ARRAY WP CONTAINS THE VALUES FOR THE 7TH ORDER POLYNOMIAL
C              APPROXIMATION FOR WR COMPUTATIONS FOR P-TYPE TARGETS
```

```
C
C                       SHOB = 0,   AVN.LE.7.5
     A 8.206936, -.09866222,-.004270532, .00044673610, 4*.0,
C
C                       SHOB = 0    AVN.LE.1000
     B 8.263243, -.12109524, .001274266, -.9206549E-5, 4*.0,
C
C                       SHOB = 100, AVN.LE.7.5
     C 8.29123, -.1132939, .3119908E-3, 5*0.0,
C
C                       SHOB = 100, AVN.LE.51
     D 8.29959, -.1104334, -.48494085E-3, .658301E-4,-.91680378E-6,
     4 3*.0,
C
C                       SHOB = 200, AVN.LE.41
     E 8.395223,-.14717856, .01274489,-.002063277, .1667591E-3,
     5 -.689342E-5,.1423714E-6,-.11675015E-8,
C
C                       SHOB = 200, AVN.LE.41 (THIS MUST BE REPEATED)
     E 8.395223,-.14717856, .01274489,-.002063277, .0001667591,
     5 -.689342E-5,.1423714E-6,-.11675015E-8,
C
C                       SHOB = 300, AVN.LE.34
     F 8.41958,-.09982782,-.0041872797,.5449084E-3,-.3758352E-4,
     6 .1400969E-5,-.20170989E-7, .0,
C
C                       SHOB = 300, AVN.LE.34
     F 8.41958,-.09982782,-.0041872797,.5449084E-3,-.3758352E-4,
     6 .1400969E-5,-.20170989E-7, .0,
C
C                       SHOB = 400, AVN.LE.30
     G 8.499489,-.1096521,-.003444575, .7261706E-3,-.710905E-4,
     7 .3319013E-5,-.5668505E-7, .0,
C
C                       SHOB = 400, AVN.LE.30    (REPEAT)
     G 8.499489,-.1096521,-.003444575, .7261706E-3,-.710905E-4,
     7 .3319013E-5,-.5668505E-7, .0,
C
C                       SHOB = 500  AVN.LE.27
     H 8.525985,-.06312055,-.02562219, .005426447,-.5926339E-3,
     8 .3485504E-4,-.1022865E-5,.114432E-7/
      DATA  WP2     /
C
C                       SHOB = 500, AVN.LE.27    (REPEAT)
     H 8.525985,-.06312055,-.02562219, .005426447,-.5926339E-3,
     8 .3485504E-4,-.1022865E-5,.114432E-7,
C
C                       SHOB = 600, AVN.LE.25
     I 8.586222, -.1002711,-.009917176, .00260232,-.3602822E-3,
     9  .2802515E-4,-.1082636E-5,.1541557E-7,
C
C                       SHOB = 600, AVN.LE.25    (REPEAT)
     I 8.586222, -.1002711,-.009917176, .00260232,-.3602822E-3,
     9  .2802515E-4,-.1082636E-5,.1541557E-7,
C
C                       SHOB = 700, AVN.LE.22
     J 8.655962,-.1367989, .01426281,-.004092999, .5028125E-3,
     1 -.2571224E-4,.4379003E-6,.0,
C
C                       SHOB = 700, AVN.LE.22   (REPEAT)
     J 8.655962,-.1367989, .01426281,-.004092999, .5028125E-3,
```

```
     1 -.2571224E-4,.4379003E-6,.0,
C
C                   SHOB = 800, AVN.LE.7.5
     K 8.681285,-.1143286,-.001788869, .1595909E-3, 4*.0,
C
C                   SHOB = 800, AVN.LE.21
     L12.51342,-1.516344, .1769944,-.008900835, .1400736E-3, 3*.0,
C
C                   SHOB = 900, AVN.LE.7.5
     M 8.719654,-.1215853, .001203604,-.1386328E-3,4*.0,
C
C                   SHOB = 900, AVN.LE.20
     N13.47289,-1.971983, .2547267,-.014325115,.2640371E-3, 3*.0 /
C
C
C
      DATA WQ1   /
C
C       ARRAY WQ CONTAINS THE VALUES FOR THE 7TH ORDER POLYNOMIAL
C           APPROXIMATION FOR WR CALCULATIONS FOR O TYPE TARGETS.
C
C                   SHOB =   0, AVN.LE.35
     A 8.315159,-.106087, .5224E-3,-.313E-3,.32265E-4,-.123227E-5,
     1 .196707E-7,-.105880E-9,
C
C                   SHOB = 100, AVN.LE.35
     B 8.376082,-.104295,-.0012014,-.391136E-4,.128757E-4,
     2 -.497579E-6,.577257E-8, .0,
C
C                   SHOB = 200, AVN.LE.35
     C 8.42024,-.109473, .001462288,-.5969792E-3,.6697002E-4,
     3 -.3014946E-5,.6188228E-7,-.4866633E-9,
C
C                   SHOB = 300, AVN.LE.35
     D 8.485315,-.103139,-.0034114, .3087E-3,-.107267E-4,.315662E-6,
     4 -.556646E-8, .0,
C
C                   SHOB = 400, AVN.LE.31
     E 8.576,-.103989,-.0065788, .0012382,-.1333E-3,.801387E-5,
     5 -.234684E-6,.251295E-8,
C
C                   SHOB = 500, AVN.LE.28
     F 8.6435,-.1110564,-.0041904, .6644E-3,-.776848E-4,.598695E-5,
     6 -.227079E-6,.300626E-8,
C
C                   SHOB = 600, AVN.LE.26
     G 8.686697,-.116482, .3634E-3,-.6169E-3,.857541E-4,-.407263E-5,
     7 .566402E-7, .0,
C
C                   SHOB = 700, AVN.LE.25
     H 8.70745,-.117550, .0023483,-.0013054,.1909E-3,-.1152E-4,
     8 .?83079E-6,-.244704E-8,
C
C                   SHOB = 800, AVN.LE.23
     I 8.736328,-.1151805, .0021175,-.0015218,.2654E-3,-.19675E-4,
     9 .618015E-6,-.720562E-8/
      DATA WQ2   /
C
C                   SHOB = 900, AVN.LE.22
     J 8.793042,-.1154885, .1871E-3,-.0011008, .2357E-3,-.201562E-4,
     K .69752E-6,-.874866E-8/
```

```
C
C
C
C
      DATA TVNP   /
C
C       ARRAY TVNP CONTAINS YIELD LIMITS FOR P-TYPE TARGETS
C
     A  54.,51.,34.,30.,27.,27.,22.,21.,20./
C
C
      DATA TVNQ   /
C
C       ARRAY TVNQ CONTAINS YIELD LIMITS FOR Q-TYPE TARGETS
C
     A 3*35., 31., 28., 26., 25., 23., 22./
C
C  DIMENSION SUBSCRIPTS RELATIONSHIPS GIVEN FOR A REPRESENTATIVE GROUP
C    ARRAYS: WO(I,JT) I GOES FROM 1 TO 10, DEPENDING ON THE SCALED HGT
C    OF BURST.
C
      DATA THIRD/.33333333/
C
      IF (KF.LT.10) GO TO 6
      IERR = 6
      RETURN
 6    JT = JJT
      VN = IV
      FK = KF
      YLDCU = YLD**THIRD
      YLDIC= 1./YLDCU
      SHOB= HOB1*YLDIC
      DS2 = 1. / (1.-DSIG**2)
      FK10 = FK*.1
C
C            COMPUTE SUBSCRIPTS FOR ENTERING COEFFICIENT TABLE
C
      SIL = SHOB * 1.E-2+ 1.0001
      IL = SIL
      IF (IL.LT.10) GO TO 7
      IERR=3
      RETURN
    7 FAC=(IL-1)*100
      FAC=(SHOB-FAC)*1.E-2
C
C           CHECK FOR P OR Q
C
      IF (JT.EQ.1) GO TO 240
C
C       CALCULATE THE ADJUSTED VN FOR Q TYPE TARGETS.
C
      R2=3.0
C  ALGORITHM FOR IMPROVING R2
10    R1=1.-FK10*(1.-2.7144176*YLDIC*(R2**THIRD))
      ABDIF=R1-R2
      R2 = R1
      ABDIF = ABS(ABDIF)
      IF (ABDIF.LT..001) GO TO 15
      GO TO 10
15    CONTINUE
      AVN=VN+2.742*ALOG(R2)
```

```
      AX=1.10
C
C          COMPUTE WR FOR Q TYPE TARGETS
C
C
C          CHECK THE VN RANGE FIRST.
C
      IF(AVN.LE.TVNQ(IL)) GO TO 107
      IERR=2
      GO TO 400
C
C          USE THE TABLE DATA.
C
  107 SWRL=WQ(1,IL)+AVN*(WQ(2,IL)+AVN*(WQ(3,IL)+AVN*(WQ(4,IL)+
     1AVN*(WQ(5,IL)+AVN*(WQ(6,IL)+AVN*(WQ(7,IL)+AVN*WQ(8,IL)))))))
      IH=IL+1
      SWRH=WQ(1,IH)+AVN*(WQ(2,IH)+AVN*(WQ(3,IH)+AVN*(WQ(4,IH)+
     1AVN*(WQ(5,IH)+AVN*(WQ(6,IH)+AVN*(WQ(7,IH)+AVN*WQ(8,IH)))))))
      GO TO 300
  240 CONTINUE
C
C       CALCULATE THE ADJUSTED VN FOR P TYPE TARGETS.
C
C
C  R2 IS VN ADJUSTMENT NUMBER WHICH WILL BE IMPROVED ON BY AN
C    ALGORTTHM
      R2=2.0
C  ALGORITHM FOR IMPROVING R2
11    R1=1.-FK10*(1.-2.7144176*YLDIC*(R2**.5))
      ABDIF=R1-R2
      R2 = R1
      ABDIF = ABS(ABDIF)
      IF (ABDIF.LT..001) GO TO 16
      GO TO 11
16    CONTINUE
      AVN = VN + 5.485 * ALOG(R2)
      AX = 1.04
C
C          COMPUTE WR FOR P TYPE TARGFTS
C
C
C          CHECK THE VN RANGE FIRST.
C
C
      IF(AVN.LE.TVNP(IL)) GO TO 257
      IERR=2
      GO TO 400
  257 IF (AVN.LT.36.) GO TO 260
C
C     FUNCTIONAL FIT TO HIGH VN RANGE PROVIDED BY AIM.
C
C
C     CHECK THE RANGE OF VALIDITY OF AIM FIT.
C
      SHCK=-9.*AVN+560.
      IF (SHOB.LE.SHCK) GO TO 258
      IERR=2
      GO TO 400
C
C     CALCULATE WR USING THE AIM FIT.
C
```

```
  258 VX=(AVN-46.)/10.
      WO=88.-VX*(53.-VX*(21.-VX*8.))
      IF(SHOB.NE.0.)GO TO 259
      WR=WO*YLDCU*DS2/AX
      GO TO 400
  259 HM=70.-5.*VX*(7.-VX)
      WM=102.-VX*(63.-17.*VX)
      CON=1.6+.2*VX
      HX=SHOB/HM
      DW=WM-WO
      WR=WO+DW*HX*(2.-HX-CON*(1.-HX)**2)
      WR=WR*YLDCU*DS2/AX
      GO TO 400
C
C          USE THE TABLE DATA.
C
  260 J=1
      IF(AVN.GT.7.5) J=2
      SWRL=WP(1,J,IL)+AVN*(WP(2,J,IL)+AVN*(WP(3,J,IL)+AVN*(WP(4,J,IL)+
     1AVN*(WP(5,J,IL)+AVN*(WP(6,J,IL)+AVN*(WP(7,J,IL)+AVN*WP(8,J,IL))))
     2)))
      IH=IL+1
      SWRH=WP(1,J,IH)+AVN*(WP(2,J,IH)+AVN*(WP(3,J,IH)+AVN*(WP(4,J,IH)+
     1AVN*(WP(5,J,IH)+AVN*(WP(6,J,IH)+AVN*(WP(7,J,IH)+AVN*WP(8,J,IH))))
     2)))
C
  300 CONTINUE
C
      SWRL = EXP(SWRL)
      SWRH = EXP(SWRH)
      WR =  (SWRL + FAC*(SWRH-SWRL)) * YLDCU * DS2 / AX
  400 CONTINUE
      IF (WR.LE..0) WR = .0
      RETURN
      END
C**********************************************************************
C
      SUBROUTINE WRCLCY (KF, YLD, WR, IERR)
C
C**********************************************************************
C     THIS SUBROUTINE CALCULATES WEAPON RADIUS FOR 'Y' TYPE VNTKS.
C     Y IS A SPECIAL CHARACTER USED BY JSTPS TO INDICATE THE
C     INSTALLATION DOES NOT CORRESPOND TO A "NORMAL" VNTK AND A SPECIAL
C     CURVE MUST BE USED.
C
      DIMENSION YCOF(17), YEXP(17)
C  TABLES YCOF AND YEXP ARE USED TO COMPUTE WR FOR JT='Y' VNTKS
      DATA YCOF / 28.,89.,131.,136.,140.,141.,146.,148.,155.,185.,209.,
     A            214.,219.,229.,230.,231.,232. /
      DATA YEXP / .546,.381,.352,.357,.324,.323,.323,.325,.375,.367,
     A            .333,.338,.334,.311,.321,.310,.316 /
C
      IF (KF.GT.17) GO TO 10
      WR = YCOF(KF) * YLD ** YEXP(KF)
      RETURN
   10 CONTINUE
      IERR = 7
      RETURN
      END
C**********************************************************************
C
```

```
      SUBROUTINE WRPERS (YLD, HOB1, IV, JJT, KF, DSIG, WR, IERR)
C
C*************************************************************************
C
      DIMENSION S(6),T(6),NM(16),LI(39),LK(40),A(32),B(32),CH(562)
      DIMENSION CH1(64),CH65(60),CH125(53),CH178(69),CH247(70),
     X CH317(72),CH389(48),CH437(42),CH479(42),CH521(42)
      EQUIVALENCE (CH1(1),CH(1)),(CH65(1),CH(65)),(CH(125),CH125(1)),
     X (CH178(1),CH(178)),(CH247(1),CH(247)),(CH(317),CH317(1)),
     X (CH389(1),CH(389)),(CH437(1),CH(437)),(CH479(1),CH(479)),
     X (CH521(1),CH(521))
C  THE FOLLOWING TABLES ARE USED FOR CALCULATING WEAPON RADIUS OF 99X
C  TYPE TARGETS.
C
C     LISTS S AND T ARE USED TO STORE TERMS OF CHEBYSHEV POLYNOMIALS
C     FOR NORMALIZED YIELD AND SHOB
C     LIST NM IS CUMULATIVE KEY TO WR FIT SUBTABLES
C     LISTS LI AND LK SUPPLY KEYS TO LIST CH
C     LIST CH CONTAINS COEFFICIENTS FOR WR FIT
C
      DATA S(1),T(1)/1.,1./
     +,NM/1,4,6,9,11,14,16,19,22,25,26,30,32,35,38,39/ ,LI/3,4*4,3,4*4,
     +5,3,3*4,5,4,3,5,4,3,6,5,3,5,5,4,3*3,5,6,4,4,6,4,4,6,6/
     +,LK/0,12,24,36,52,64,76,88,100,112,124,144,153,165,177,189,214,234
     +,246,271,283,292,316,336,348,373,388,400,406,412,421,436,454,466,
     +478,496,508,520,544,562/
C
C     DATA (CH(I),I=  1, 64)  /
C     TABLE III - 1  ., N=1
      DATA  CH1              /
     A     538.1,      -39.5,     -52.1,      -30.9,
     B     422.2,      -62.4,     -62.8,      -52.4,
     C      44.1,      -14.8,     -17.6,      -18.9,
C     TABLE III - 1   , N=2
     D    1706.3,      197.2,    -107.1,
     E    3334.9,     1036.8,     142.0,
     F    1031.1,       76.8,    -121.8,
     G     621.6,      181.0,      28.2,
C     TABLE III - 1   , N=3
     H    5055.6,    -4552.1,    1862.5,
     I  -11696.7,    22289.7,   -8102.4,
     J    5038.9,    -5562.1,    2274.4,
     K   -4369.0,     7269.2,   -2684.7,
C     TABLE III - 2   , N=4
     L    3591.6,     1515.9,     399.9,      361.3,
     M    5127.9,     2364.2,     666.0,      586.1,
     N    2195.9,     1099.2,     351.0,      310.6,
     O     464.2,      240.9,      92.1,       83.0,
C     TABLE III - 2   , N=5
     P    3116.5,      710.2,     -49.3,
     Q    6719.7,     1755.5,    -137.0,
     R    1756.3,      399.1,     -26.4,
     S    1169.2,      300.3,     -26.0/
C     TABLE III - 3   , N=6
      DATA  CH65           /
     A     511.1,      -44.2,     -26.3,        3.3,
     B     343.5,      -72.1,     -23.4,       -2.7,
     C      15.9,      -18.1,      -4.5,       -2.9,
C     TABLE III - 3   , N=7
     D    1475.7,      427.2,      35.2,
     E    2369.8,      478.3,      52.6,
```

```
      F     903.1,     375.9,      34.1,                                 06110000
      G     448.2,      -9.2,     -29.5,                                 06120000
C      TABLE III - 3    , N=8                                            06130000
      H     310.6,    2224.8,    -581.9,                                 06140000
      I    2943.8,   -1062.7,     -21.9,                                 06150000
      J      -8.5,    1901.6,    -363.2,                                 06160000
      K    1264.4,   -1308.1,     397.0,                                 06170000
C      TABLE III - 4    , N=9                                            06180000
      L    3195.1,    1464.3,     279.8,                                 06190000
      M    4503.0,    2298.3,     470.8,                                 06200000
      N    1964.7,    1091.7,     246.4,                                 06210000
      O     435.5,     246.5,      63.6,                                 06220000
C      TABLE III - 4    , N=10                                           06230000
      P    2821.6,     604.3,     -59.2,                                 06240000
      Q    5935.3,    1618.3,     -94.5,                                 06250000
      R    1602.9,     328.2,     -40.1,                                 06260000
      S    1034.0,     278.1,     -12.7/                                 06270000
C      DATA (CH(I),I=125,177)  /                                         06280000
C      TABLE III - 5    , N=11                                           06290000
       DATA  CH125            /                                          06300000
      A    1496.5,     372.6,      78.3,       3.3,                      06310000
      B    1956.8,     577.2,     119.2,     -16.9,                      06320000
      C     943.8,     332.0,      60.6,     -12.6,                      06330000
      D     356.8,     100.3,       9.6,       -.1,                      06340004
      E      64.6,      -7.0,     -10.9,       -.8,                      06350008
C      TABLE III - 5    , N=12                                           06360009
      F     881.3,    -535.8,      38.3,                                 06370009
      G     874.4,    -804.2,      65.8,                                 06380009
      H     190.8,    -278.2,      27.7,                                 06390009
C      TABLE III - 5    , N=13                                           06400009
      I    1418.4,     835.9,     660.6,                                 06410009
      J   -1473.6,    3950.5,   -3648.9,                                 06420009
      K     757.4,    1053.0,     696.4,                                 06430009
      L     204.4,     143.8,    -410.1,                                 06440009
C      TABLE III - 6    , N=14                                           06450009
      M    1816.8,     303.2,    -209.0,                                 06460009
      N    2265.0,     448.0,    -314.6,                                 06470009
      O     847.8,     187.3,    -154.1,                                 06480009
      P     171.7,      30.8,     -39.2/                                 06490009
C      DATA (CH(I),I=178,246)  /                                         06500009
C      TABLE III - 6    , N=15                                           06510009
       DATA  CH178            /                                          06520009
      A    2213.5,     430.9,     -71.5,                                 06530009
      B    4457.7,    1154.4,     -15.5,                                 06540009
      C    1173.5,     253.9,     -54.2,                                 06550009
      D     801.4,     184.7,      -3.7,                                 06560009
C      TABLE III -11A   , N=16                                           06570009
      E    -247.8,   -1234.0,    -621.2,    -148.2,      20.3,           06580009
      F    -767.2,   -2067.6,   -1033.6,    -256.2,      45.1,           06590009
      G    -635.7,   -1202.3,    -612.5,    -150.9,      38.7,           06600000
      H    -262.0,    -471.1,    -247.6,     -53.9,      22.1,           06610001
      I     -53.3,    -102.6,     -55.0,      -9.2,       7.2,           06620002
C      TABLE III -11A   , N=17                                           06630003
      J   -3617.0,   -7824.1,   -6433.1,   -3799.1,   -1141.6,           06640004
      K    4213.8,    8832.9,   11023.7,    8211.2,    2830.5,           06650005
      L   -3966.9,   -7719.2,   -6392.5,   -3806.3,   -1134.1,           06660006
      M    1178.4,    2731.0,    3395.8,    2551.9,     901.9,           06670007
C      TABLE III -11A   , N=18                                           06680008
      N  -27720.8,  -49305.0,  -27982.8,   -8218.3,                      06690009
      O   37489.9,   65058.5,   37703.2,   11270.9,                      06700009
      P  -10966.7,  -19824.7,  -11131.7,   -3256.3/                      06710009
```

```
C     DATA (CH(I),I=247,316) /                                     06720009
      DATA  CH247          /                                       06730009
C     TABLE III -12A   , N=19                                      06740009
     A    325.1,   -986.7,   -741.7,   -416.4,   -133.5,           06750009
     B    220.1,  -1491.4,  -1118.4,   -648.9,   -199.0,           06760009
     C     45.5,   -667.7,   -525.6,   -318.0,    -94.5,           06770009
     D     63.3,   -179.0,   -158.5,    -98.5,    -32.0,           06780009
     E     27.7,    -29.7,    -30.3,    -18.5,     -7.3,           06790009
C     TABLE III -12A   , N=20                                      06800009
     F    931.3,  -1252.0,   -164.1,                               06810009
     G   1034.8,  -1886.8,   -295.4,                               06820009
     H    257.1,   -793.2,   -208.7,                               06830009
     I     20.8,   -148.6,    -77.5,                               06840009
C     TABLE III -12A   , N=21                                      06850009
     J   2312.0,  -1951.4,   -451.1,                               06860009
     K   1267.0,  -2232.0,   1482.1,                               06870009
     L   1773.7,  -1609.5,   -173.8,                               06880009
C     TABLE III -11B   , N=22                                      06890009
     M    448.3,   -307.1,   -101.0,    -17.3,                     06900009
     N    405.8,   -524.7,   -179.0,    -57.8,                     06910009
     O    139.1,   -192.5,    -69.9,    -38.8,                     06920009
     P    193.9,    143.2,     75.4,     13.5,                     06930009
     Q    130.6,    149.2,     72.1,     18.5,                     06940009
     R      4.0,     -5.9,    -10.4,     -3.7/                     06950009
C     DATA (CH(I),I=317,388) /                                     06960009
      DATA  CH317          /                                       06970009
C     TABLE III -11B   , N=23                                      06980009
     A  -1092.0,    659.2,  -1525.0,    630.3,                     06990009
     B  -2302.9,   1343.1,  -2677.2,   1136.4,                     07000009
     C  -1705.2,   1128.3,  -1753.1,    784.3,                     07010009
     D   -799.2,    669.9,   -816.3,    392.0,                     07020009
     E   -212.7,    225.3,   -222.2,    114.6,                     07030009
C     TABLE III -11B   , N=24                                      07040009
     F   5145.1,  -7147.4,   3164.7,   -144.9,                     07050009
     G  -6229.4,   9549.0,  -4581.7,    897.3,                     07060009
     H   2352.1,  -2946.0,   1198.2,    192.0,                     07070009
C     TABLE III -12B   , N=25                                      07080009
     I   1552.9,    252.5,    -60.7,    -68.7,    -26.5,           07090009
     J   2096.1,    382.0,    -78.9,   -108.1,    -34.9,           07100009
     K    915.6,    181.8,    -36.2,    -46.5,    -13.6,           07110009
     L    297.0,     46.3,    -14.0,    -11.8,     -4.9,           07120009
     M     58.0,      3.1,     -3.5,     -2.1,     -1.5,           07130009
C     TABLE III -14    , N=26                                      07140009
     N   2495.8,    530.8,    -39.0,                               07150009
     O   3584.0,    836.7,    -50.3,                               07160009
     P   1716.9,    392.1,    -40.2,                               07170009
     Q    521.7,     91.8,    -18.6,                               07180009
     R     72.1,     11.0,       .6/                               07190009
C     DATA (CH(I),I=389,436) /                                     07200009
      DATA  CH389          /                                       07210009
C     TABLE III -14    , N=27                                      07220009
     A    883.9,   2319.7,   -538.2,                               07230009
     B    989.4,   3616.8,   -790.9,                               07240009
     C    447.4,   1590.4,   -267.7,                               07250009
     D    152.6,    297.2,    -14.8,                               07260009
C     TABLE III -14    , N=28                                      07270009
     E -30638.8,  43111.4,                                         07280009
     F  43828.5, -52525.1,                                         07290009
     G -24879.6,  34686.8,                                         07300009
C     TABLE III -14    , N=29                                      07310009
     H   8664.5,   1263.4,                                         07320009
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     I   -5298.4,   -1069.9,                                       07330009
     J    5902.9,     777.7,                                       07340009
C     TABLE III -15    , N=30                                      07350009
     K     869.2,     161.4,      -26.6,                           07360009
     L     804.6,     224.6,      -23.8,                           07370009
     M     153.1,      73.8,       -4.8,                           07380009
C     TABLE III -15    , N=31                                      07390009
     N    4188.7,    1085.1,      -67.6,                           07400009
     O    5210.5,    1195.5,     -112.9,                           07410009
     P    3268.1,     949.0,      -43.5,                           07420009
     Q     616.9,      72.4,      -21.8,                           07430009
     R     277.0,     116.9,        6.2/                           07440009
C     DATA (CH(I),I=437,478)  /                                    07450009
      DATA  CH437           /                                      07460009
C     TABLE III -16A   , N=32                                      07470009
     A    2763.7,     475.7,      -92.8,                           07480009
     B    4165.0,     879.8,     -158.0,                           07490009
     C    1998.9,     624.0,     -105.5,                           07500009
     D     678.7,     313.1,      -53.3,                           07510009
     E     180.8,     100.1,      -14.4,                           07520009
     F      39.1,      16.6,        2.3,                           07530009
C     TABLE III -16A   , N=33                                      07540009
     G      54.4,   -3019.6,    -1270.6,                           07550009
     H     -71.6,   -4518.7,    -1848.7,                           07560009
     I    -159.0,   -1967.7,     -751.6,                           07570009
     J     -59.9,    -416.8,     -144.4,                           07580009
C     TABLE III -16A   , N=34                                      07590009
     K  358367.6,  520343.9,   165511.7,                           07600000
     L -559255.1, -822777.0,  -263079.9,                           07610001
     M  291463.4,  424061.4,   135192.3,                           07620002
     N  -65192.0,  -96277.0,   -31131.7/                           07630003
C     DATA (CH(I),I=479,520)  /                                    07640004
      DATA  CH479           /                                      07650005
C     TABLE III -16B   , N=35                                      07660006
     A    3659.6,     809.4,     -118.7,                           07670007
     B    5515.8,    1458.8,     -210.0,                           07680008
     C    2638.5,    1003.0,     -140.6,                           07690009
     D     891.8,     489.0,      -68.2,                           07700009
     E     241.5,     148.3,      -13.4,                           07710009
     F      55.1,      21.0,        8.1,                           07720009
C     TABLE III -16B   , N=36                                      07730009
     G     -55.5,   -4178.2,    -1704.7,                           07740009
     H    -312.6,   -6309.3,    -2497.8,                           07750009
     I    -351.8,   -2809.3,    -1034.0,                           07760009
     J    -131.2,    -620.8,     -206.6,                           07770009
C     TABLE III -16B   , N=37                                      07780009
     K  505974.8,  734336.1,   232815.5,                           07790009
     L -792454.4,-1163833.9,  -370734.3,                           07800009
     M  413597.8,  601382.9,   191085.0,                           07810009
     N  -94345.2, -138879.9,   -44740.8/                           07820009
C     DATA(CH(I),I=521,562)   /                                    07830009
      DATA CH521            /                                      07840009
C     TABLE III -13     , N=38                                     07850009
     A     195.8,     -56.9,      -34.1,      -6.7,                07860009
     B     249.7,    -154.1,     -105.2,     -33.7,                07870009
     C     144.2,      -2.3,         .3,       2.5,                07880009
     D      22.0,     -45.5,      -32.6,     -12.0,                07890009
     E      16.8,      12.1,        9.4,       4.2,                07900009
     F       -.1,      -5.3,       -3.9,      -1.1,                07910009
C     TABLE III -16C   , N=39                                      07920009
     G    4604.8,    1135.1,      -84.1,                           07930009
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     H    6750.2,     1763.8,     -118.9,
     I    3250.3,      840.2,      -60.1,
     J     984.3,      241.6,      -15.9,
     K     196.7,       64.9,        -.2,
     L      57.1,       23.5,       -1.5/
C
      DATA THIRD /.33333333/
C
      DATA A/1.6,2.3,.75,1.6,.25,.9,1.6,1.5,1.7,
     +-.5,.55,3.7,2.79,1.35,2.15,-1.3,2.,2.79,.225,3.99,1.,1.5,2.2,-.4,
     +.7,1.55,.8,1.2,1.8,-2.,.9,1.6/ ,B/-.00071,-.000999,.0005,0.,
     +-.000249,-.00055,-.000749,-.00067,-.00053,.0024,-.0005,-.00233,
     +.00071,.00175,-.00225,.0035,.00175,-.0022,.0035,-.00229,-.00067,
     +-.00067,-.00087,.0012,.0004,0.,-.00055,-.00045,-.00055,0.,-.0006,
     +-.00065/
C
      IF(KF.LE.16)GOTO 5
      IERR=8
      RETURN
    5 YLDCU=YLD**THIRD
      SHOB=HOB1/YLDCU
      WR=0.
      DSIG=.3
      XL=ALOG10(YLD)
      X=(XL+1.)/2.65052-1.
      Y=SHOB/500.-1.
      IF(KF.EQ.15) Y=(SHOB/200.)-1.
      IF (ABS(X).LE.1..AND.ABS(Y).LE.1.)GO TO 46
      IERR = 12
      RETURN
46    S(2)=X
      T(2)=Y
      DO 1 L=3,6
      S(L)=2.*X*S(L-1)-S(L-2)
    1 T(L)=2.*Y*T(L-1)-T(L-2)
      N=NM(KF)
      GOTO (101,102,103,104,105,106,107,108,109,110,111,112,113,113,115,
     +116),KF
C                          FIND SECTION OF TABLE
  101 KS=2
      IF (SHOB.GT.700.)KS=4
      IF (YLD.LT.10.) GOTO 142
      N=N+1
      IF (SHOB.GE.800.) N=N+1
      GOTO 142
  102 KS=6
      IF (YLD.GT.10.) N=N+1
      GOTO 141
  103 IF (YLD.LE.10.) GOTO 200
      N=N+1
      IF (SHOB.GT.700.) N=N+1
      GOTO 200
  104 KS=8
      IF (YLD.GT.10.) N=N+1
      GOTO 143
  105 KS=9
      IF (SHOB.GT.750.) KS=10
      IF (SHOB.LE.700.) GOTO 144
      N=N+1
      IF (YLD.GT.40.) N=N+1
      GOTO 144
```

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  106 KS=11
      IF (YLD.GT.10.) N=N+1
      GOTO 144
  107 KS=12
      IF (SHOB.GT.300.) KS=13
      IF (YLD.GT.100.) N=N+1
      IF (YLD.GE.2000.) N=N+1
      GOTO 144
  108 KS=14
      IF (SHOB.GT.200.) KS=15
      IF (SHOB.GT.600.) KS=16
      IF (SHOB.LT.700.) GOTO 144
      N=N+1
      IF (YLD.GT.200.) N=N+1
      GOTO 144
  109 KS=17
      IF (SHOB.GT.200.) KS=18
      IF (SHOB.GT.450.) KS=19
      IF (SHOB.GT.650.) KS=20
      IF (SHOB.LT.500.) GOTO 144
      N=N+1
      IF (YLD.LE.700..AND.X.LT..53-.5*Y) GOTO 144
      IF (SHOB.GT.800.) RETURN
      N=N+1
      GOTO 144
  110 DSIG=.4
      GOTO 200
  111 KS=22
      IF (SHOB.GT.750.) KS=25
      IF (YLD.GT.200.) GOTO 121
      IF (SHOB.GE.800.) N=N+1
      GOTO 141
  121 IF (SHOB.LT.900.) GOTO 141
      N=N+2
      IF (YLD.GE.1000.) N=N+1
      GOTO 141
  112 KS=28
      IF (YLD.GT.4.) N=N+1
      GOTO 141
  113 IF (YLD.GE.400.) GOTO 123
      IF (SHOB.LT.300.) N=N+1
      GOTO 200
  123 IF (SHOB.LE.200.) N=N+2
      GOTO 200
  115 IF (SHOB.GT.400.) RETURN
      IF (X.LT..75*Y-1.) RETURN
      GOTO 200
  116 KS=31
C                                   FIND KSIG PARTITIONS
  141 X45=A(KS+1)+B(KS+1)*SHOB
      IF (XL.LE.X45) GO TO 142
      DSIG = .5
      GO TO 200
  142 X25=A(KS-1)+B(KS-1)*SHOB
      IF( XL .LE. X25 ) DSIG=.2
  143 X35=A(KS)+B(KS)*SHOB
      IF( XL .GT. X35 ) DSIG = .4
      GO TO 200
  144 DSIG = .4
      X45=A(KS)+B(KS)*SHOB
      IF( XL .LT. X45 ) DSIG=.5
```

```
C                                  COMPUTE WR
  200 K=LK(N)
      IL=LI(N)
      JL=(LK(N+1)-K)/IL
      DO 2 I=1,IL
      C=0.
      DO 3 J=1,JL
      K=K+1
    3 C=C+CH(K)*T(J)
    2 WR=WR+C*S(I)
      IF (WR.LT.0.) WR=0.
      WR=WR*10.
      RETURN
      END
C*********************************************************************
C
      SUBROUTINE LNCALC (CEP, DSIG, WR, R95, POD, D, IFLG, IERR)
C
C*********************************************************************
C
C       SUBROUTINE LNCALC IS A SUBROUTINE USED TO CALCULATE POD AND
C               OFFSET DISTANCE USING THE LOG NORMAL PROBABILITY FCTN
C
      DIMENSION W(5), ZP(5)
      LOGICAL CROSS
C
      DATA  W / .0666713443, .1494513492, .2190863625, .2692667193,
     W          .2955242247/,
     Z      ZP / .9739065285, .8650633667, .6794095683, .4333953941,
     P          .1488743390/
C
C
C
      IF (IFLG.EQ.6) D=0.
      D = D * 6076.1155
      ITCH=0
      RR5 = 6076.1155 * R95
      ADCEP = SQRT(CEP**2 + .231 * RR5**2)
      IF (WR.LE..001) GO TO 40
C
C  COMPUTE BETA-FACTOR USED IN COMPUTING Z, THE UPPER LIMIT OF THE
C    INTEGRAL. ALSO COMPUTE 'ADJUSTED CEP', ADCEP, USE IT TO NORMALIZE
C    D AND WR.
C
 10   EX = 1.-DSIG**2
      BETA = SQRT(-ALOG(EX))
      IF (ADCEP.GT.0.00) GO TO 50
C
C  COMPUTE POD WHEN CEP = R95 = 0
C
C  IF  D ALSO EQUALS 0 SET POD = .999
C    OTHERWISE, COMPUTE POD. THIS IS DIFFERENT THAN THE GENERAL
C    CASE AS D AND WR CANNOT BE NORMALIZED.
      IF (D.EQ.0.0) GO TO 20
C  COMPUTE Z
      Z = (1/BETA) * ALOG((WR*EX)/D)
C
C  IF Z > 3.87 POD =.999, IF Z IS CLOSE TO 0, POD =.50
C    IF Z <-3.87 POD IS 0 FOR ALL PRACTICAL PURPOSES.
C
      IF (Z.GT.3.87) GO TO 20
```

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      ZAB = ABS(Z)
      IF (ZAB.LT.5.E-7) GO TO 30
      IF (Z.LT.-3.87) GO TO 40
C  POD EQUALS .5 + .5 * (ABS(Z)/Z) * ERF(Z)
      C = .70710678*ABS(Z)
      ERFU = 1.- 1./(((1.+C*(.0705230784 +C*(.0422820123 +C*(.0092705272
     A +C*(.0001520143 +C*(.0002765672 +.0000430638*C))))))**16)
      SIGN = 1.
      IF (Z.LT.0.) SIGN = -1.
      POV = .5 + .5 * SIGN * ERFU
      GO TO 120
   20 POV = .999
      GO TO 120
   30 POV = .500
      GO TO 130
   40 POV = 0.00
      GO TO 130
   50 CONTINUE
C
C  NORMALIZE WR AND D.
C  X IS THE SYMBOL USED FOR NORMALIZED D
C
      WRN = 1.1774 * WR / ADCEP
        X = 1.1774 *  D / ADCEP
C
C  FSUM WILL SUM TERMS OF GAUSSIAN QUADRATURE
C
      FSUM = 0.0
      BMINSA = .0
C  IF DN-4 < 0 BEGIN INTEGRATION WITH RADIUS OF ZERO, OTHERWISE AT DN-4.
C  SET INTEGRATION INTERVAL.
      XBB = 1.06 * WRN * EXP (2.86 * DSIG)
      XB = X + 4.0
      IF (XBB .LT. XB)  XB = XBB
      IF (X -4.0) 70,70,80
   70 XA = 0.0
      BPLUSA = XB
      BMINSA = XB
      GO TO 90
   80 XA = X - 4.0
      BPLUSA = XA + XB
      BMINSA = XB - XA
      IF (BMINSA.LE.0.) GO TO 110
C
C  COMPUTE POD THROUGH LOOP 100
C
C                    BEGINNING OF LOOP
C
   90 WRNX=WRN*EX
      BETAI=1./BETA
      DO 100 N=1,5
      R1 =.5* (-BMINSA * ZP(N) + BPLUSA)
      R2 =.5* (BMINSA * ZP(N) + BPLUSA)
C  COMPUTE Z'S, UPPER LIMITS OF INTEGRALS
      Z1 = BETAI * (ALOG(WRNX/R1))
      Z2 = BETAI * (ALOG(WRNX/R2))
      CALL INTGF(Z1,R1,X,F)
      FSUM=FSUM+W(N)*F
      IF (Z2.LT.-3.87) GO TO 100
      CALL INTGF(Z2,R2,X,F)
      FSUM=FSUM+W(N)*F
```

```
100   CONTINUE
C
C                          END OF LOOP
C
110   CONTINUE
C
C
      POV = .5* FSUM * BMINSA
120   CONTINUE
C
C  WE NOW HAVE A GOOD POD
C
C  WHERE DO WE GO FROM HERE?                               FOR D GO TO 140.
      IF (IFLG.EQ.6) GO TO 140
      IF (POV.LE..99) GO TO 130
      IF (IFLG.EQ.1) POV=.99
      IF (POV.GT..999) POV=.999
130   POD = POV
      D = D / 6076.1155
      RETURN
C
140   CONTINUE
C
C  THIS IS WHERE COMPUTATION OF D, OFFSET DISTANCE, OCCURS IF IT IS
C    DESIRED.  THIS COMPUTES THE MAX DISTANCE AT WHICH A GIVEN
C    MINIMUM POD CAN BE OBTAINED.
C
C  SINCE IN THIS CASE POV WAS COMPUTED WITH D =0, IF DESIRED POD > POV,
C    POD IS UNATTAINABLE.
      IF (ITCH.GT.0) GO TO 150
      IF (POV.LT.POD) GO TO 180
      ITCH = 1
      ACC = .001
      CROSS = .FALSE.
      DD = WR
      D = WR
      GO TO 10
150   PDA = ABS(POD-POV)
      IF (PDA.LT.ACC)  GO TO 170
      IF (POD.GT.POV)  GO TO 160
      IF (CROSS) DD = DD * .5
      D = D + DD
      GO TO 10
160   CROSS = .TRUE.
      DD = DD * .5
      D = D -DD
      GO TO 10
170   D = D / 6076.1155
C
C  HERE IS WHERE CONTROL IS RETURNED TO MAIN PROGRAM FROM OFFSET
C    DISTANCE COMPUTATION.
C
      RETURN
180   CONTINUE
      IERR = 1
      D    = 0.0
      RETURN
      END
C***********************************************************************
C
      SUBROUTINE INTGF(Z,R,X,F)
```

```
C
C*****************************************************************************
      RX=R*X
      IF (RX.GT.3.75) GO TO 1
      TS=.071111111*(RX**2)
      F = (R* EXP(-.5*(R**2 + X**2)))*(1.+TS*(3.5156229+TS*
     A (3.0899424+TS*(1.2067492 + TS*(0.2659732 +TS*(0.0360768 +
     B TS*0.0045813))))))
      IF (Z.LE.3.87) GO TO 2
      RETURN
    1 TI = 3.75/RX
      F = .51639778 * R * EXP(-.5*(X-R)**2) * SQRT(TI) *
     A ((((((((.00392377*TI -.01647633)*TI +.02635537) * TI
     B - .02057706)*TI + .00916281)*TI - .00157565)*TI
     C + .00225319)*TI + .01328592)*TI + .39894228)
      IF (Z.GT.3.87) RETURN
    2 SIGN = 1.
      IF (Z.LT.0.) SIGN = -1.
      U = .70710678 * ABS(Z)
      F = F * (0.5 + .5 * SIGN * ( 1. -1./
     A((1. + U*(.278393 + U*(.230389 + U*(.000972 + U*.078108))))**4)))
      RETURN
      END
C*****************************************************************************
C
      SUBROUTINE ETCALC (IV,JT,KF,YLD,CEP,HOB1,ORIEN,AZMTH,DI,POD,WR,
     A                  IERR)
C
C*****************************************************************************
C
C       ETCALC CALCULATES POD FOR EQUIVALENT TARGET AREA TYPE TARGETS.
C             THESE TGTS INCLUDE BRIDGES, CANAL LOCKS, DAMS, AND
C             A SPECIAL CASE.
C
      DIMENSION  INW(3,10,6),  CRW( 10,6),  DSWV( 10,6),  VNW(10,6),
     A           INL(6,10,6),  CRL(2,10,6),  DSLV(2,10,6),  VNL(10,6)
C
C             *****   FUNCTIONS   *****
      DD(B,C) = ABS(B) / (SQ2*C)
C
      ER(B,C) = 1. + DD(B,C)*(W1+DD(B,C)*(W2+DD(B,C)*(W3+DD(B,C)*(W4+
     A  DD(B,C)*(W5+DD(B,C)*W6)))))
C
      ERFP(B,C) = (1. - (1./ER(B,C))**16) * ABS(B)/(2.*B)
C
C                **  POD FUNCTION  **
      P(B,C,D,E,F,G,H,A) = (ERFP(D,E) - ERFP(B,C)) *
     A                     (ERFP(H,A) - ERFP(F,G))
C
C                 **  DELIVERY SIGMA FUNCTION  **
      ACEP(A,B) = SQRT(CEP**2 + (1.1774*A*B)**2)/ 1.1774
C
C
C
      DATA  INW    /
C
C     INW(I,J,L) CONTAINS VNTK VALUES TARGET WIDTHS IF THEY EXIST.
C      I=1 IS VN, I=2 IS T, I=3 IS K. J=KF+1. L=1,2,3 IS FOR BRIDGES,
C       K=4 IS FOR DAMS, L=5 IS FOR LOCKS, L=6 IS FOR SPECIAL CASE.
C
C                  BRIDGES
```

```
     A  0,0,0,  0,0,0,  0,0,0, 31,1,0, 25,2,6, 20,2,6, 18,2,6, 25,2,8,
     B 15,2,9, 16,2,8, 0,0,0, 18,2,9, 17,2,9, 16,2,8, 15,2,9, 17,2,8,
     C14,2,9, 16,2,9, 16,2,9, 0,0,0,
     D18,2,9, 17,2,9, 16,2,8, 15,2,9, 16,2,9, 17,2,8, 17,2,8, 9*0,
C                   DAMS (UPSTREAM VNTK)
     E 41,1,0, 38,1,0, 38,1,0, 42,1,0, 39,1,0, 39,1,0, 39,1,0, 35,1,0,
     F 35,1,0, 0,0,0,
C                   LOCKS
     G 30 * 0,
C                   SPECIAL CASE
     H 3*0, 13,2,5, 11,2,4, 21*0/
C
      DATA CRW          /
C
C    CRW(J,L) CONTAINS CRATER RADIUS FACTOR FOR WIDTH TGTS IF IT EXISTS.
C
C                   BRIDGES
     A 1.5, 2.0, 1.5, 27*.0,
C                     DAMS (UPSTREAM CRF)
     C  9*.0, 1.0,
C                   LOCKS
     D 1.0, 1.5, 1.0, 1.5, 1.0, 1.5, 4*.0,
C                   SPECIAL CASE
     E 10*.0/
C
      DATA  INL           /
C
C    INL(I.J.L) CONTAINS LENGTH VNTK FOR ETA TGT FOR BOTH FRONT AND BACK.
C              SUBSCRIPTS HAVE MEANINGS SIMILAR TO INW.
C
C                     BRIDGES
     A 18*0, 38,1,0,0,0,0,    29,2,6,0,0,0, 23,2,6,0,0,0, 21,2,6,0,0,0,
     B 29,2,8,0,0,0, 18,2,9,0,0,0, 22,2,8, 9*0, 22,2,9,0,0,0,20,2,9,
     2 0,0,0, 19,2,8,
     C 0,0,0, 21,2,7,0,0,0, 23,2,8,0,0,0, 23,2,7,0,0,0, 25,2,8,0,0,0,
     D 25,2,8, 9*0,
     E 22,2,8,3*0, 22,2,8,3*0, 22,2,8,3*0, 23,2,7,3*0,
     3 25,2,8,3*0, 23,2,7,3*0, 25,2,8, 21*0,
C                        DAMS (DOWNSTREAM VNTK)
     F 60 * 0,
C                    LOCKS
     G 12*0, 31,1,4*0, 31,1,4*0, 31,1,0, 31,1,0, 31,1,0, 31,1,25*0,
C                    SPECIAL CASE
     H 6*0, 13,2,5, 3*0, 11,2,4, 45*0/
C
      DATA    CRL          /
C
C    CRL(I,J,L) CONTAINS FRONT AND REAR CRF'S FOR ETA TGTS
C
C                        BRIDGES
     A 1.25,0., 1.5,.0, 1.25,.0, 34*.0,
     B 20*.0,
C                        DAMS (DOWNSTREAM CRF)
     C .5,.0, .5, .0, .5,.0, .5,.0, .5,.0,.5,.0, .5,.0, .5,.0, .5,.0,
     3 1.5, .0,
C                    LOCKS
     D 2*1.0, 2*1.5, .0,1.0, .0,1.5, 12*.0,
C                    SPECIAL CASE
     E 20*.0/
C
      DATA     DSWV            /
```

```
C
C   DSWV(J,K) CONTAINS WIDTH DAMAGE SIGMAS
C                   BRIDGES
     A 3*.3, .2, 6*.3,.0, 8*.3, .0,
     B 7*.3, 3*.0,
C                              DAMS (UPSTREAM DSIG)
     C 9*.2, .3,
C                             LOCKS
     D 6*.3, 4*.0,
C                             SPECIAL CASE
     E .0, .3, .3, 7*.0/
C
      DATA  DSLV                 /
C
C   DSLV(I,J,L) CONTAINS LENGTH DAMAGE SIGMAS AND DOWNSTREAM DSIG'S
C                              BRIDGES
     A .3,.0,.3,.0,.3,.0, .2,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,
     1 .0,.0, .3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0, .0,.0,
     B .3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,7*.0,
C                                DAMS  (W/DOWNSTREAM DSIG'S)
     C .0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,.0,.3,
C                                LOCKS
     D 4*.3, .2,.3, .2,.3, 4*.2, 8*.0,
C                                SPECIAL CASE
     E 2*.0, .3,.0, .3,.0, 14*.0/
C
      DATA  VNW          /
C
C   VNW(J,L) CONTAINS WIDTH DIMENSIONS.
C
C                               BRIDGES
     A 5., 15., 25., 35., 45., 55., 65., 75., 85., 90.,
     A 5., 15., 25., 35., 45., 55., 65., 75., 85., 90.,
     A 5., 15., 25., 35., 45., 55., 65., 75., 85., 90.,
C                             DAMS
     B 5., 15., 26., 40., 57., 82., 114., 163., 229., 262.,
C                             LOCKS
     C 33., 40., 60., 75., 90.,110., 125., 145., 180., 200.,
C                             SPECIAL CASE
     D 2000.,1900.,1700.,1500.,1300.,1100.,900.,700.,500.,300./
C
      DATA    VNL          /
C
C   VNL(J.L) CONTAINS LENGTH DIMENSIONS.
C
C                            BRIDGES
     A 50.,150.,400.,800.,1200.,1600.,2000.,2400.,2800.,3000.,
     A 50.,150.,400.,800.,1200.,1600.,2000.,2400.,2800.,3000.,
     A 50.,150.,400.,800.,1200.,1600.,2000.,2400.,2800.,3000.,
C                             DAMS
     B 500.,750.,1500.,2500.,3500.,4500.,7500.,12500.,20000.,25750.,
C                             LOCKS
     C 98.,130., 250., 500.,800.,1300.,2000., 2450., 2800., 3000.,
C                             SPECIAL CASE
     D 10000.,9500.,8500.,7500.,6500.,5500.,4500.,3500.,2500.,2000./
C
      DATA W1, W2, W3, W4, W5, W6   /
C
C   WI'S ARE THE CONSTANTS FOR THE ERROR FUNCTION APPROXIMATION
     A .0705230784,.0422820123,.0092705272,.0001520143,.0002765672,
     B .0000430638/
```

```
C
C              SET CONSTANTS AND INITIALIZE VARIABLES.
      SQ2 = SQRT (2.)
      IGV = IV/10
      IGN = IV - (IGV*10)
      WRL1 = .0
      WRL2 = .0
      WRW1 = .0
      KK = KF +1
C           CHECK DIMENSION SUBSCRIPTS
      IF (IGN.EQ.0)IGN = 10
      IF (IGV .EQ. 0) IGV =10
C                   DECODE JT
      JTS=JT
      GO TO (100,110,110,300,200,400), JTS
C
C             ****  BRIDGE SECTION  ****
C
C                JTS TO 1 OR 2 OR 3 FOR BRIDGES
C
C    IF AIR-BURST FOR A0, A1, OR A2 TYPE BRIDGES, SET POD TO ZERO.
  100 IF ((KF.LT.3).AND.(HOB1.GT..99)) GO TO 500
C                DETERMINE WEAPON RADII
C
C                SEE IF CRATER OR NON-CRATER
  110 IF (CRL(1,KK,JTS).GT.0) CALL WRCRTR(YLD,CRL(1,KK,JTS),WRL1,JTS,KF)
      IF (INL(2,KK,JTS).GT.0) CALL WRCALC (YLD,HOB1,INL(1,KK,JTS),
     A        INL(2,KK,JTS), INL(3,KK,JTS),DSLV(1,KK,JTS),WRL1,IERR)
C
      IF (CRW(KK,JTS).GT.0) CALL WRCRTR (YLD,CRW(KK,JTS),WRW1,JTS,KF)
      IF (INW(2,KK,JTS).GT.0) CALL WRCALC(YLD,HOB1,INW(1,KK,JTS),
     A       INW(2,KK,JTS),INW(3,KK,JTS),DSWV(  KK,JTS),WRW1,IERR)
C
C
C             DETERMINE X AND Y OFFSET DISTANCES
C                  ORIEN IS TARGET ORIENTATION
C                  AZMTH IS AZIMUTH FROM DGZ TO TARGET
C                  XO IS THE EAST-WEST COMPONENT
C                  YO IS THE NORTH-SOUTH COMPONENT
      DDUM = DI * 6076.1155
      ANGLE = (AZMTH - ORIEN * 10.) / 57.295779
      XO = DDUM * SIN(ANGLE)
      YO = DDUM * COS(ANGLE)
C
C                   COMPUTE BOUNDARIES
C
      W = VNW(IGN,JTS)
      SL= VNL(IGV,JTS)
C
      A = -W/2. - WRW1 + XO
      B =  W/2. + WRW1 + XO
      C = -SL/2. - WRL1 + YO
      D =  SL/2. + WRL1 + YO
C
C                COMPUTE DELIVERY SIGMAS
C
      AA = ACEP(WRW1, DSWV(KK,JTS))
      AB = AA
      AC = ACEP(WRL1, DSLV(1,KK,JTS))
      AD = AC
C
```

```
C         **   COMPUTE POD   **
C
      POD = P(A,AA,B,AB,C,AC,D,AD)
C
      RETURN
C
C           ****   LOCK SECTION   ****
C
C
C                 IF AIR-BURST SET POD TO ZERO
  200 IF (HOB1 .GT. .001) GO TO 500
C
C               DETERMINE WEAPON RADII
C           SEE IF CRATER OR NOT AND COMPUTE WR'S ACCORDINGLY
C
      IF (CRL(1,KK,JTS).GT.0) CALL WRCRTR(YLD,CRL(1,KK,JTS),WRL1,JTS,KF)
      IF (INL(2,KK,JTS).GT.0) CALL WRCALC (YLD,HOB1,INL(1,KK,JTS),
     A        INL(2,KK,JTS), INL(3,KK,JTS),DSLV(1,KK,JTS),WRL1,IERR)
      IF (CRL(2,KK,JTS).GT.0) CALL WRCRTR(YLD,CRL(2,KK,JTS),WRL2,JTS,KF)
      IF (INL(5,KK,JTS).GT.0) CALL WRCALC (YLD,HOB1,INL(4,KK,JTS),
     A        INL(5,KK,JTS), INL(6,KK,JTS),DSLV(1,KK,JTS),WRL2,IERR)
      IF (CRW(KK,JTS).GT.0) CRW(KK,JTS)=-CRW(KK,JTS)
      IF (CRW(KK,JTS).LT.0) CALL WRCRTR (YLD,CRW(KK,JTS),WRW1,JTS,KF)
      IF (INW(2,KK,JTS).GT.0) CALL WRCALC(YLD,HOB1,INW(1,KK,JTS),
     A       INW(2,KK, JTS),INW(3,KK,JTS),DSWV(  KK,JTS),WRW1,IERR)
C
      WR = (WRL2-WRL1)/2.0
      IF (INL(2,KK,JTS).GT.0) WR=(WRL1-WRL2)/2.0
C
C              DETERMINE X AND Y OFFSET DISTANCES
C                    ORIEN IS TARGET ORIENTATION
C                    AZMTH IS AZIMUTH FROM DGZ TO TARGET
C                    XO IS THE EAST-WEST COMPONENT
C                    YO IS THE NORTH-SOUTH COMPONENT
      DDUM = DI * 6076.1155
      ANGLE = (AZMTH - ORIEN * 10.) / 57.295779
      XO = DDUM * SIN(ANGLE)
      YO = DDUM * COS(ANGLE)
C
C         COMPUTE BOUNDARIES AND DELIVERY SIGMAS
      W = VNW (IGN,JTS)
      SL= VNL (IGV,JTS)
C
      A = -W/2. - WRW1 + XO
      B = W/2. + WRW1 +XO
      AA = ACEP(WRW1,DSWV(KK,JTS))
      AB = AA
C
      IF (INL(2,KK,JTS).GT.0) GO TO 210
      C = -SL/2. -WRL1 +YO
      D = SL/2. +WRL2 +YO
      AC = ACEP(WRL1,DSLV(1,KK,JTS))
      AD = ACEP(WRL2,DSLV(2,KK,JTS))
      GO TO 220
C
  210                CONTINUE
      C = -SL/2. -WRL2 + YO
      D = SL/2. +WRL1 + YO
      AC = ACEP(WRL2,DSLV(2,KK,JTS))
      AD = ACEP(WRL1,DSLV(1,KK,JTS))
C
```

```
 220                  CONTINUE
C
C              *  COMPUTE POD   *
      POD = P(A,AA,B,AB,C,AC,D,AD)
C
      RETURN
C
C              ****   DAM SECTION   ****
C
C                   JTS = 4 FOR DAMS
C
C               IF AIR-BURST SET POD TO ZERO
 300  IF (HOB1 .GT. .001) GO TO 500
C
C               DETERMINE WEAPON RADII
C
      IF (CRL(1,KK,JTS).GT.0) CRL(1,KK,JTS)=-CRL(1,KK,JTS)
      IF (CRL(1,KK,JTS).LT.0) CALL WRCRTR(YLD,CRL(1,KK,JTS),WRL1,JTS,KF)
      IF (INL(2,KK,JTS).GT.0) CALL WRCALC (YLD,HOB1,INL(1,KK,JTS),
     A          INL(2,KK,JTS), INL(3,KK,JTS),DSLV(1,KK,JTS),WRL1,IERR)
      IF (CRW(KK,JTS).GT.0) CALL WRCRTR (YLD,CRW(KK,JTS),WRW1,JTS,KF)
      IF (INW(2,KK,JTS).GT.0) CALL WRCALC(YLD,HOB1,INW(1,KK,JTS),
     A        INW(2,KK,JTS),INW(3,KK,JTS),DSWV(  KK,JTS),WRW1,IERR)
C
      WR=(WRW1-WRL1)/2.0
C
C             DETERMINE X AND Y OFFSET DISTANCES
C                 ORIEN IS TARGET ORIENTAION
C                 AZMTH IS AZIMUTH FROM DGZ TO TARGET
C                 XO IS THE EAST-WEST COMPONENT
C                 YO IS THE NORTH-SOUTH COMPONENT
      DDUM = DI * 6076.1155
      ANGLE = (AZMTH - ORIEN * 10.) / 57.295779
      XO = DDUM * SIN(ANGLE)
      YO = DDUM * COS(ANGLE)
C
C         COMPUTE BOUNDARIES
      W = VNW (IGN,JTS)
      SL= VNL (IGV,JTS)
      C = -SL/2. +YO
      D = SL/2.  +YO
      IF (KF.EQ.9) GO TO 310
      A = -WRW1 -.10 + XO
      B =  WRL1 -.10 + XO
      GO TO 320
C
 310                  CONTINUE
      A = -WRW1 +W/2. + XO
      B =  WRL1 -W/2. + XO
C
 320                  CONTINUE
C                             COMPUTE DELIVERY SIGMAS
      AA = ACEP(WRW1,DSWV(KK,JTS))
      AB = ACEP(WRL1,DSLV(2,KK,JTS))
      AC = ACEP (SL/2.,DSLV(1,KK,JTS))
      AD = AC
C
C               *  COMPUTE POD  *
C
      POD = P(A,AA,B,AB,C,AC,D,AD)
C
```

```
C              IF POD IS NEGATIVE, SET IT TO ZERO AND RETURN.
      IF (POD.LT.0) GO TO 500
C
      RETURN
C
C              ***  SPECIAL CASE SECTION   ***
C
C                    DETERMINE WEAPON RADIUS
 400  CALL WRCALC(YLD,HOB1,INL(1,KK,JTS),INL(2,KK,JTS),INL(3,KK,JTS),
     A             DSLV(1,KK,JTS),WRL1,IERR)
      WRW1=WRL1
C
C              DETERMINE X AND Y OFFSET DISTANCES
C                   ORIEN IS TARGET ORIENTAION
C                   AZMTH IS AZIMUTH FROM DGZ TO TARGET
C                   XO IS THE EAST-WEST COMPONENT
C                   YO IS THE NORTH-SOUTH COMPONENT
      DDUM = DI * 6076.1155
      ANGLE = (AZMTH - ORIEN * 10.) / 57.295779
      XO = DDUM * SIN(ANGLE)
      YO = DDUM * COS(ANGLE)
C
C                        COMPUTE BOUNDARIES
      W = VNW (IGN,JTS)
      SL= VNL (IGV,JTS)
C
      A = -W/2. -WRW1 + XO
      B =  W/2. +WRW1 + XO
      C = -SL/2. -WRL1 + YO
      D =  SL/2. +WRL1 +YO
C
C                      COMPUTE DELIVERY SIGMAS
C
      AA = ACEP(WRW1,DSWV(KK,JTS))
      AB = AA
      AC = ACEP(WRW1,DSLV(1,KK,JTS))
      AD =AC
C
C       ** COMPUTE POD **
C
      POD = P(A,AA,B,AB,C,AC,D,AD)
C
      RETURN
C
 500  POD = .0
      RETURN
      END
C***********************************************************************
C
      SUBROUTINE WRCRTR (YLD,CRF,WR,JTS,KF)
C
C***********************************************************************
C
      SOILCF=61.0
      IF (JTS.EQ.4.AND.KF.EQ.9.AND.CRF.GT.0) SOILCF=82.0
      IF (JTS.EQ.5.AND.CRF.GT.0) SOILCF=82.0
      IF (JTS.EQ.4.AND.KF.LT.9) SOILCF=58.
      IF (CRF.LT.0) CRF=-CRF
      WR = 1.1 * CRF * SOILCF * YLD**.30
      RETURN
      END
```

```
C***********************************************************************
C
      SUBROUTINE ERRMSG(IERR,IV,JT,KF,YLD,CEP,HOB1,R95,D,WR,POD,IFLG)
C
C***********************************************************************
      DIMENSION  JJ(3),IKF(18)
      DATA JJ,IKF /'1','2','3','0','1','2','3','4','5','6','7','8','9',
     A             '10','11','12','13','14','15','16','17'/
      IT = JT
      IF (((JT.EQ.1) .OR. (JT.EQ.2)) .OR. (JT.EQ.3)) IT = JJ(JT)
      IF (KF.LT.0) GO TO 2
      I = KF + 1
      KKF = IKF(I)
      GO TO 4
    2 KKF = KF
    4 CONTINUE
      WRITE (6,5) IERR,IV,IT,KKF,YLD,HOB1,R95,CEP,D,WR,POD,IFLG
    5 FORMAT (' ','YOU HAVE INPUT ERROR NO. ',I2,' YOUR INPUTS ARE AS FO
     ALLOWS:',/,' ',I4,3X, A4,3X, A4,2X,
     B  F10.1, 2F10.2, 2F8.2, F10.0, F5.2, I2)
C
      IF ((IFLG.EQ.5).OR.(IFLG.EQ.6))             D = .0
      IF ((IFLG.NE.9).AND.(IFLG.NE.10))           WR = .0
      IF ((IFLG.NE.5).AND.(IFLG.NE.6))            POD = .0
C
      GOTO (10,20,30,40,50,60,70,80,90,100,110,120),IERR
C
 10   WRITE (6,11)
 11   FORMAT ('  YOU CANNOT ACHIEVE DESIRED POD WITH THIS WEAPON')
      RETURN
C
 20   WRITE (6,21)
 21   FORMAT(' VN (IV) IS TOO LARGE TO USE FOR AVAILABLE DATA CURVES')
      RETURN
C
 30   WRITE (6,31)
 31   FORMAT (' SHOB GREATER THAN 900 FEET - TOO LARGE FOR AVAILABLE DAT
     1A CURVES')
      RETURN
C
 40   WRITE (6,41)
 41   FORMAT (' THE ONLY OPTIONS AVAILABLE W/ ETA TGTS ARE IFLG=1 OR 2.
     A. YOUR IFLG CONTAINS SOME OTHER VALUE.')
      RETURN
C
 50   WRITE (6,51)
 51   FORMAT (' T OF VNTK MUST BE AN X WHEN IFLG = 7')
      RETURN
C
 60   WRITE (6,61)
 61   FORMAT(' K FOR THIS TYPE OF VNTK MUST BE LESS THAN 10')
      RETURN
C
 70   WRITE (6,71)
 71   FORMAT (' K OF PERSONNEL VNTK MUST BE 1-9 OR A-Q')
      RETURN
C
 80   WRITE (6,81)
 81   FORMAT (' K OF SPECIAL CRATER VNTK MUST BE 1-9 OR A-P')
      RETURN
C
```

```
 90   WRITE (6,91)
 91   FORMAT (' T OF VNTK IS NOT A VALID CHARACTER')
      RETURN
C
 100  WRITE (6,101)
 101  FORMAT (' CRATER REQUIRED BY VNTK (T=Z OR Y) A CONTACT BURST IS RE
     1QUIRED')
      RETURN
C
 110  WRITE (6,111)
 111  FORMAT (' K OF VNTK MUST SPECIFY A FATALITY CURVE FOR "IFLG=7 "')
      RETURN
C
 120  WRITE (6,121)
 121  FORMAT (' SHOB GREATER THAN 1000 FT  - TOO LARGE FOR AVAILABLE DAT
     1A CURVES')
      RETURN
      END
```

APPENDIX C

RECTANGULAR OFFSETS FOR ETA TARGETS

GENERAL

This appendix derives the equations used in the PDCALC subroutine ETCALC to obtain the x and y coordinates of the reference point of the target in the coordinate used to carry out the probability of damage calculations described in Reference 1, pages 30-33. These equations are:

XO = DDUM * SIN(ANGLE)

YO = DDUM * COS(ANGLE)

Where:

XO = x coordinate in rotated coordinate system.

YO = y coordinate in rotated coordinate system.

DDUM = offset distance in feet from DGZ to target reference point

ANGLE = (AZMTH-ORIEN) expressed in radians.

AZMTH = as defined in ETCALC subroutine description.

ORIEN = as defined in ETCALC subroutine description.

To simplify the derivation, the following substitute notation is used:

XO = $x1'$

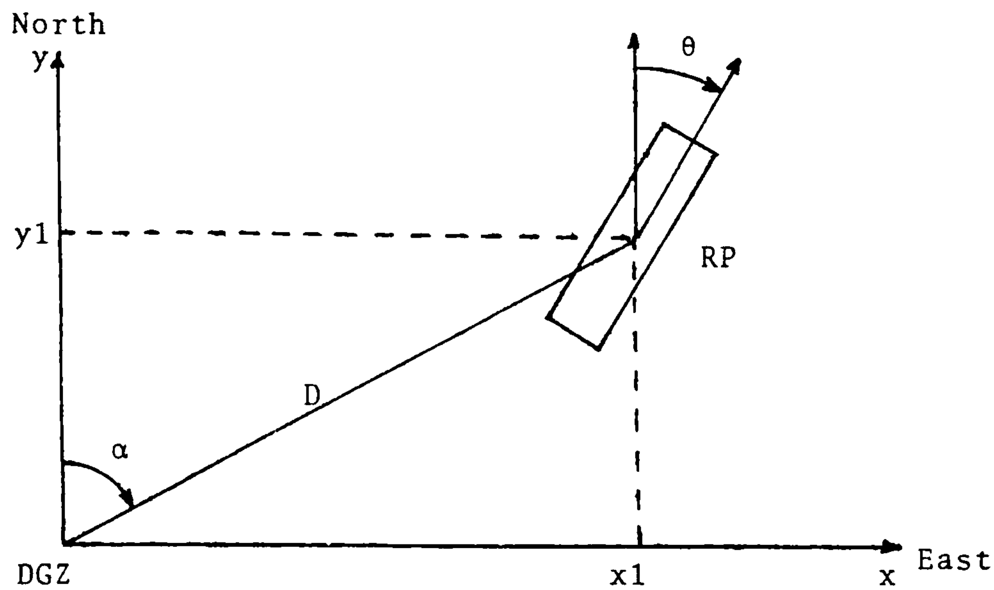
YO = $y1'$

DDUM = D

AZMTH = α

ORIEN = θ

The derivation is general and does not depend on the quadrant in which the target lies, or the orientation of the target. For illustrative purposes only, a target in the first quadrant with an orientation between 0 and 90° will be used:

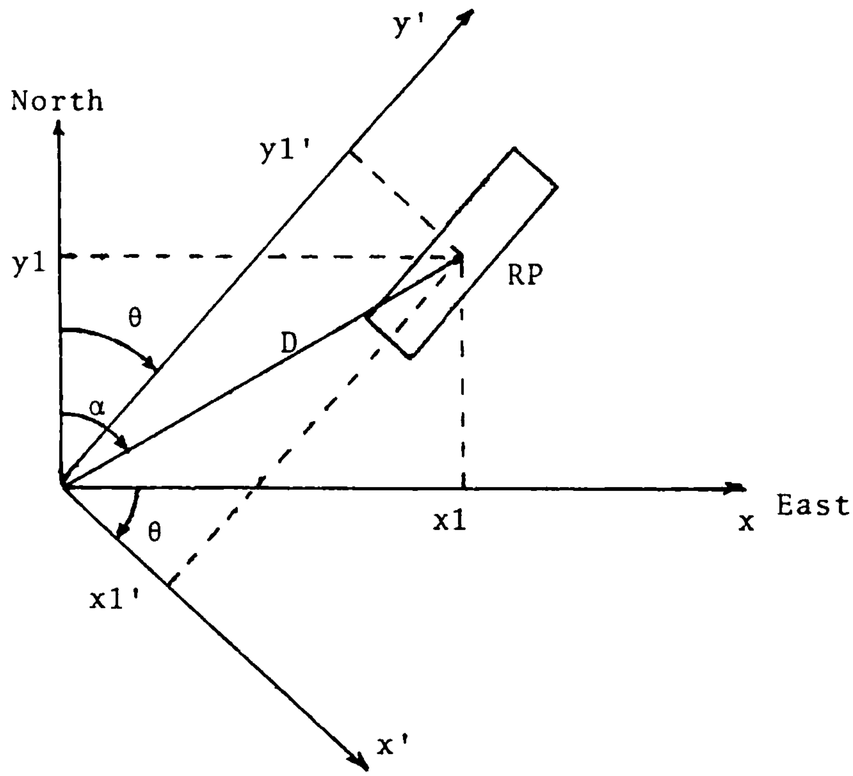


In this figure, the standard coordinate system is shown, with positive y in the direction of true north, and the DGZ at the origin. α and θ as shown are in accordance with the definition of **AZMTH** and **ORIEN** as given in the section describing ETCALC. The x and y coordinates of the target reference point in this coordinate system are denoted by x1 and y1, respectively.

ROTATED COORDINATE SYSTEM

To use the method described in Reference 1, pages 30-33, to calculate probability of damage, it is necessary that the x and y coordinates of the coordinate system used be parallel to the sides of the target. To accomplish this, the coordinate system must be rotated through the orientation angle.

This rotation is illustrated in the following figure:



In this figure, x_1' and y_1' denote the x and y coordinates of the target RP in the rotated coordinate system.

RECTANGULAR OFFSETS IN ROTATED COORDINATE SYSTEM

After the coordinate system has been rotated, the desired equations can be derived by solving for x_1' and y_1' in terms of D, α, and θ. To do this, first define the vector from the origin (DGZ) to the reference point as $\vec{u}$. Using scalar component notation (Reference 9):

$$\vec{u} = [\, x_1,\ y1]$$

in the original coordinate system.

Next, unit vectors in the direction of the positive x' and y' directions are defined in terms of their direction cosines (Reference 9):

$$\vec{V}x = [\cos\theta, \cos(90^\circ + \theta)]$$

$$\vec{V}y = [\cos(90^\circ - \theta), \cos\theta]$$

Or, since cos $90^\circ + \theta) = -\sin\theta$ and $\cos(90^\circ - \theta) = \sin\theta$:

$$\begin{aligned} \vec{V}x &= [\cos\theta, -\sin\theta] \\ Vy &= [\sin\theta, \cos\theta] \end{aligned}$$

Next, because the projection of a vector on a line segment is equal to the dot (scalar) product of the vector and a unit vector in the direction of the line segment (Reference 9), it is possible to write:

$$x_1' = \vec{U} \cdot \vec{V}_x$$

$$y_1' = \vec{U} \cdot \vec{V}_y$$

Using the earlier definitions of $\vec{u}$, $\vec{V}_x$, and $\vec{V}_y$, x_1' and y_1' can then be written as:

$$x_1' = x_1 \cos\theta + Y_1(-\sin\theta)$$

$$y_1' = x_1 \sin\theta + y_1 \cos\theta$$

Since: $x_1 = D \sin\alpha$

$$y_1 = D \cos\alpha$$

the above expressions for x_1' and y_1' may be written as:

$$x_1' = D\sin\alpha\cos\theta + D\cos\alpha(-\sin\theta)$$

$$y_1' = D\sin\alpha\cos\theta + D\cos\alpha\cos\theta$$

By factoring out D and using the identities:

$$\sin(\alpha - \theta) = \sin\alpha\cos\theta - \cos\alpha\sin\theta$$

$$\cos(\alpha - \theta) = \sin\alpha\sin\theta + \cos\alpha\cos\theta$$

these equations reduce to:

$$x_1' = D\sin(\alpha - \theta)$$

$$y_1' = D\cos(\alpha - \theta)$$

which are the equations used in the ETCALC subroutine.

APPENDIX D

METHOD FOR INCLUDING INSTALLATION LOCATION UNCERTAINTY

GENERAL

The PDCALC computer program, as described in this report, includes no provision to account for uncertainty associated with the location (coordinates, elevation) of the target installation. This appendix describes a procedure which can be used to account for this uncertainty, provided the uncertainty is known and the type of weapon system to be used in delivering the warhead to the DGZ is known.

The method used assumes that the uncertainty in the installation coordinates is formulated as a circular normal distribution, with the accuracy figure given as a 90% probability that the actual coordinates are within a specified distance from the given coordinates. For elevation, the assumption is that a linear normal distribution fromulation has been used, with the accuracy figure given as a 90% probability that the actual elevation is within plus or minus a specified distance from the given elevation. The presumption is also made that sufficient knowledge of the weapon system used is available so that the angle between the weapon flight and the horizontal at detonation is known.

With this information, it is possible to determine an adjustment to R95 (either inside of PDCALC or before R95 is given to PDCALC) which will account the uncertainty. It is possible to adjust CEP instead of R95 with no more difficulty and with the same results. R95 has been chosen in this derivation two reasons. First, CEP is a weapon-related characteristic while uncertainty in target location and R95 is target-related. Second, it is inappropriate to apply the method to ETA-type targets, and the fact that the R95 input to PDCALC has a different meaning for ETA-targets than for other targets, serves to emphasize this point.

NOTATION

In the derivation the following notation is used:

- H - given accuracy (in feet) for horizontal coordinates as described above.
- V - given accuracy (in feet) for elevation as described above.
- θ - angle between the horizontal and the weapon flight path at detonation.
- σ_N - standard deviation of the horizontal circular normal distribution.
- σ_V - standard deviation of the vertical linear normal distribution.
- k - $\cot \theta$
- σ_{MD} - standard deviation of the downrange miss distribution resulting from installation location uncertainty.
- σ_{MC} - standard deviation of the crossrange miss distribution resulting from installation location uncertainty.
- σ_{MDV} - that portion of the downrange miss distribution standard deviation caused by the vertical uncertainty.
- σ_{MDH} - that portion of the downrange miss distribution standard deviation caused by the horizontal uncertainty.
- σ_{MCV} - that portion of the crossrange miss distribution standard deviation caused by the vertical uncertainty.
- σ_{MCH} - that portion of the crossrange miss distribution standard deviation caused by the horizontal uncertainty.
- CEP_{ILU} - the installation location uncertainty converted to an equivalent CEP.
- $R95_{ILU}$ - the installation location uncertainty converted to an equivalent R95.

$R95_a$ - the R95 of the target after adjustment to account for installation location uncertainty.

DEVIATION

The given H and V are first converted to σ_H and σ_V by using conversion factors from Reference 10, Table 1 (page 6) and Table 2 (page 9):

$$\sigma_H = \frac{H}{2.146} \quad \text{and} \quad \sigma_V = \frac{V}{1.645} \quad \text{Equations (1)}$$

Next, σ_H and σ_V need to be related to σ_{MD} and σ_{MC}. In the case of the horizontal uncertainty, there is a one-to-one relationship which can be stated as:

$$\sigma_{MDH} = \sigma_H$$

$$\sigma_{MCH} = \sigma_H$$

In the case of the vertical uncertainty, the downrange miss distance (M) equals the vertical error (E) times the contangent of θ since:

$$\cot\theta = \frac{M}{E}$$

Because E has a normal distribution, M is also distributed normally with standard deviation:

$$\sigma_{MDV} = k\sigma_V$$

The crossrange miss distance on the other hand is not affected by elevation uncertainty, unless rotation of the earth is considered. The crossrange miss caused by considering such rotation would be small and is ignored in thhis derivation, allowing the following relationship to be established:

$$\sigma_{MCV} = 0$$

$$\sigma_{MD} = \sqrt{\sigma_H^2 + k^2\sigma_V^2}$$

$$\sigma_{MD} = \sigma_H$$

These equations imply a bivariate normal distribution with unequal standard deviations. To combine the two unequal standard deviations, the following equation from Reference 11 is used[1].

$$CEP = 0.5632\sigma_{MAX} + 0.6142\sigma_{MIN}$$

which leads in the present case to:

$$CEP_{ILU} = 0.5632\sqrt{\sigma_H^2 + k^2\sigma_V^2} + 0.6142\sigma_H$$

The next step is to transform CEP_{ILU} to $R95_{ILU}$. To do this, the following equations from Reference 1 are used:

$$\sigma = CEP/1.1774$$

$$\sigma = R95/2.448$$

which can be combined to obtain the equation:

$$R95 = 2.079\ CEP$$

or, in the present case:

$$R95 = 2.079\left[0.5632\sqrt{\sigma_H^2 + k^2\sigma_V^2} + 0.6142\sigma_H\right]$$

Substituting for σ_H and σ_V in accordance with Equations (1) above and dividing the right side by 6,076 to get $R95_{ILU}$ in nautical miles:

$$R95_{ILU} = \left[8.980\sqrt{H^2 + 1.7k^2V^2} + 9.793H\right] \times 10^{-5}$$

---

[1]Since the two standard deviations are close in value in most cases, a strong case can be made for equally weighting the two σ's ($CEP = .589\ (\sigma_{MAX} + \sigma_{MIN})$). The end result is not sensitive to which combination is used to account for the rare cases of unequal σ's.

Finally, $R95_a$ is obtained by root sum squaring $R95_{ILU}$ with the given R95 for the installation, assuming independence of installation size and installation location uncertainty:

$$R95_a = \sqrt{(R95)^2 + (R95_{ILU})^2}$$

APPENDIX E

MATHEMATICAL FORMULATION OF PROBABILITY OF DAMAGE

CUMULATIVE LOGNORMAL DAMAGE FUNCTION

For the general case of an area target offset from a DGZ, the calculation of the average probability of damage requires the numerical integration of the function (Reference 1):

$$PD = \int_{0}^{\infty} \left[\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Z(r)} e^{-Z^2/2}\, dz \right] \frac{r}{\sigma^2}\; e^{-\frac{1}{2\sigma^2}(r^2+s^2)}\; I_o(rs/\sigma^2)\, dr$$

where s is the offset distance, Io ( ) is the zeroth order hyperbolic Bessel function of the first kind, and the term in brackets is the cumulative lognormal distribution Pd(r) where:

$$Z(r) = \frac{1}{\sqrt{-\ln(1-\sigma_d^2)}} \ln\left(\frac{WR(1-\sigma_d^2)}{r} \right)$$

σ_d - Damage sigma

WR - Weapon radius

and σ^2 is the parameter of the distance density function:

$$\sigma^2 = \left(\frac{CEP}{\sqrt{2\ \ln 2}}\right)^2 + \left(\frac{R95}{\sqrt{2\ \ln 20}}\right)^2$$

CEP - Weapon system circular error probable

R95 - Radius of area target

The numerical integration is performed by a 10-point Gauss-Legendre quadrature, a description of which can be found in Reference 8, paragraph 25.430, or Reference 12.

$$\int_a^b f(r)\, dr = \frac{(b-a)}{2} \sum_{i=1}^{10} \omega_i f(r_i) + R_n$$

where the abscissas xi are the i-th zero of the n-th Legendre polynomial Pn(x), and the weights wi are given by:

$$\omega_i = \frac{2}{(1+\chi_i)^2 \left[P_n'(\chi_i)\right]^2}$$

$$r_i = \left(\frac{b-a}{2}\right)\chi_i + \left(\frac{b+a}{2}\right)$$

The residual Rn, neglected in the approximate numerical integration, is given by:

$$R_n = \frac{2^{2n+1} (n!)^4}{(2n+1)\left[(2n)!\right]^2} f^{(2n)}(\xi) \qquad (-1<\xi<1)$$

For the 10-point integration, Rn $\leq$ 0.0001 according to Reference 1. The values of xi and wi, tabulated in Table 25.4 of Reference 8 to 15 places, are rounded to nine places for the PDCALC program:

	xi	wi
1.	0.148874338981631	0.295524224714753
2.	0.433395394129247	0.269266719309996
3.	0.679409568299024	0.219086362515982
4.	0.865063366688985	0.149451349150581
5.	0.973906528517172	0.066671344308688

The limits of integration are set to eliminate AGZs further than 4σ[1] from the DGZ, since the probability of such an AGZ is less than 0.00005:

$$a = \max\left(0, \frac{s}{\sigma}-4\right)$$

$$b = \min\left(1.04 \text{ WR } e^{2.84\sigma_d}, \frac{s}{\sigma}+4\right)$$

---

[1]This σ refers to the standard deviation of the distribution of impact points about the DGZ rather than the σ of the distribution-density function defined earlier.

Determination of f (r_i) requires evaluation of Pd (•) and Io (•). The function Pd (•) is evaluated by an approximation to the erf function, as described in Reference 8, paragraph 7.1.28.

$$P_d(r) = 0.5 + 0.5 \frac{|Z|}{Z} \operatorname{erf}\left(\frac{|Z|}{Z}\right)$$

$$\operatorname{erf}(\chi) = 1 - \left(\frac{1}{D}\right)^{16} + \varepsilon(\chi) \qquad 0 \leq \chi \leq \infty, \ |\varepsilon(\chi)| \leq 3 \times 10^{-7}$$

$$D = 1 + \sum_{i=1}^{6} a_i \chi_i$$

where the values of ai are tabulated as:

$a_1 = 0.0705230784$	$a_4 = 0.0001520143$
$a_2 = 0.0422820123$	$a_5 = 0.0002765672$
$a_3 = 0.0092705272$	$a_6 = 0.0000430638$

The Bessel function is evaluated by polynomial approximation, which is described in Reference 8, paragraphs 9.8.1 and 9.8.2. For t = x/3.75:

$$-3.75 \leq \chi \leq 3.75$$

$$Io(x)=1+3.5156229t^2+3.3.0899424t^4+1.206749t^6+0.2659732t^8+0.0360768t^{10}+ 0.0045813t^{12}+ \varepsilon \qquad |\varepsilon| < 1.6 \times 10^{-7}$$

$$3.75 \leq \chi < \infty$$

$$x^{\frac{1}{2}}e^{-x}Io(x)=0.39894228+0.01328592t^{-1}+0.00225319t^{-2}-0.00157565t^{-3} +0.00916281t^{-4}-0.020577006t^{-5}+0.02635537t^{-6} +0.01647633t^{-7}+0.00392377t^{-8}+ \varepsilon \qquad |\varepsilon| < 1.9 \times 10^{-7}$$

APPENDIX F

PERSONNEL VULNERABILITY CURVES[1]

Introduction

This appendix describes the WRPERS routine which was developed for JSTPS. The routine provides a means of generating the weapon radii and damage sigmas associated with various personnel environments found in the Physical Vulnerability Handbook (reference 2). The weapon radii and damage sigmas have been fit as a function of yield (YLD) and scaled height of burst (SHOB) for 16 personnel environments (Table IV) with two variable Chebyshev polynomials. A total of 39 polynomials were required to achieve a desirable fit.

Weapon Radius Polynomials

Personnel vulnerability radii are tabulated in the Physical Vulnerability Handbook for specific yields (YLD) from .1KT to 20,000KT and for scaled heights of burst (SHOB) from 0 to 1,000 feet. A sum of products of Chebyshev polynomials was chosen to represent the two dimensional function WR (YLD, SHOB). One set of polynomials varies with YLD and the other varies with SHOB. Chebyshev polynomials were selected because they are easy to compute and the coefficients indicate the relative importance of each term.

Normalized variables are used to define the legitimate area of the fit. The function WR will have no meaning outside this area.

---

[1]This appendix consists of material extracted from reference 6.

TABLE IV

PERSONNEL VULNERABILITY CURVES

("T" = X)

Environment for Unwarned Personnel	"K" Value (Reference 2) Fatalities	Casualties	Any Injury
Wood frame buildings, all single story buildings, wall bearing buildings, adobe buildings and forests	A or 1 (III-1)	B or 2 (III-2)	
Multistory residential, commercial or industrial buildings steel or reinforced concrete framed	C or 3 (III-3)	D or 4 (III-4)	
Basements	E or 5 (III-5)	F or 6 (III-6)	
Deliberate underground shelters	G or 7 (III-11a)	H or 8 (III-12a)	
Expedient underground shelters	I or 9 (III-11b)	J (III-12b)	
Open urban or open rural	K (III-14)	L (III-15)	
Exposed thermal	M (III-16a)	N (III-16b)	
Underground command post	O (III-13)	O (III-13)	
Urban			P (III-16c)

Let YLD = Yield in kilotons

$$\text{Define } X = \frac{\log_{10}(\text{YLD})+1}{2.65052} - 1 \qquad (1)$$

then $-1 \leq x < 1$ for $.1 \leq \text{YLD} \leq 20{,}000$. That is, x is a logarithmic function of yield such that $|X| \leq 1$.

Let HGT = scaled height of burst (SHOB) in $\text{ft/KT}^{1/3}$.

$$\text{Define } y = \frac{\text{HGT}-500}{500} \qquad (2)$$

then $-1 \leq y \leq 1$ for $0 \leq \text{HGT} \leq 1{,}000$. That is, y is a linear function of height such that $|y| \leq 1$.

The weapon radius can now be defined as

$$\text{WR} = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} T_i(x)\, T_j(y) \qquad (3)$$

where T_i and T_j are the Chebyshev polynomials of degree i-1 and j-1. They are computed by the recurrence relations:

$T_1(x) = 1$

$T_2(x) = X$

$T_{k+1}(x) = 2 \times T_k(x) - T_{k-1}(x)$

The numerical approximation procedure requires the development of a choice for m, n, and the coefficients C_{ij}. To maintain a smooth fit and minimize computation time m and n should be as small as feasible. On the other hand, values too low may give a poor fit in some spots.

Instead of fitting each area with a single set of high degree polynomials, each area was fit with two or three low degree polynomial sets. The partition lines were selected to ensure the functions overlapped and agreed well along the seam. The number of coefficients required is large, about 20% of the number of values given in the original tables. Use of the polynomial fits reduces the amount of data which must be stored and eliminates the need for interpolating for values not in the tables. The error in the fits is summarized in Table V where the percent error is the maximum over tabled yields of:

$$\text{ERROR (\%)} = \frac{\text{ABS}(WR_{POLY} - WR_{TABLE})}{\text{MAX } WR_{TABLE} \text{ for YIELD}} \times 100$$

and WR_{POLY} - Weapon radius from fit

WR_{TABLE} - Weapon radius from the table

ABS - Absolute value

The tabulated values are considered to be accurate only to ± 20%.

Damage Sigma

The personnel damage sigma is a function of yield and scaled height of burst for 11 of the 16 environments. The five exceptions are:

K	DSIG
C, M, N, O	.3
J	.4

The remaining damage sigmas must be fit over the same yield and scaled height of burst range used in the weapon radius fit. Damage sigmas in this context are valid only to tenths[2]. This fact was used to define "cross-over" curves. These are fits to the five-hundredth value between valid damage sigma value (e.g., .25 is between .2 and .3). Points on the high side of these fits assume the larger value, the low side the lower value. For convenience, the fits were accomplished using the logarithm of the yield rather than the yield. The cross-over curves were approximated by 32 straight lines of the form A+BxSHOB.

---

[2]Page II-3, reference 2.

TABLE V

PERSONNEL VULNERABILITY WEAPON RADIUS ERROR

("T" = X)

K	Maximum Percent Error
A	3.0
B	3.0
C	3.1
D	2.6
E	3.1 Except SHOB = 1000
F	2.4
G	4.5
H	2.8 Except SHOB = 1000
I	2.8
J	1.7
K	2.3 Except SHOB = 1000
L	2.4
M	4.5
N	4.8
O	1.6 Except Y = .1
P	2.1

Cross-over curves were developed to establish all of the sigma cross-overs for the 11 environments where sigma is not constant. Some environments required only one cross-over line, that is only two sigma values occur, and one line satisfactorily definedthe table division. Some environments required several cross-over lines since more than two sigma values occurred. Some environments required several lines in order to piecewise approximate cross-overs between one pair of sigmas at different heights.

APPENDIX G

HARD "P" TYPE VULNERABILITY CURVES[1]

Introduction

This appendix describes a functional fit to the curves depicting scaled weapon radius as a function of height of burst for "P" type targets with adjusted vulnerabilities (AVN) of 36 or greater. These curves are a fit to the data presented in the DIA Physical Vulnerabililty Handbook - Nuclear Weapons (reference 3). The curve fits replace those of reference 1 for the range stated.

Functional Fit

The scaled weapon radius (WR) of a surface burst is:

$VX=(AVn-46.)/10.$

$WR=Wo=88.-VX(53.-VX(21.VX*8.)).$

This may be extended to other burst heights as a function of the scaled height of burst (SHOB) which is the height of burst divided by the cube root of the yield. The additional parameters needed are:

Scaled height of burst at which weapon radius is maximum - $Hm=70.-5.*VX*(7.-VX)$.

Maximum weapon radius - $Wm=102.-VX*(63.-17.*VX)$

Adjustment constant - $C=1.6+.2*VX$

Ratio of actual scaled height of burst to the scaled height of burst corresponding to the maximum weapon radius - $Hx=SHOB/Hm$

The curve for the weapon radius becomes $WR=Wo+(Wm-Wo)*HX*(2.-Hx-C*(1.-Hx)**2)$. This curve has been developed for a damage sigma of .2. Adjustments to other damage sigmas can be made in the normal way.

---

[1]This appendix consists of material extracted from reference 7.

Range

The curve fit developed above will generate radius values which are outside of those given in reference 2. To limit this an additional curve is required.

$$SHOB_{ck} = -9.*AVN+560.$$

$SHOB_{ck}$ is a fit to the maximum scaled height of burst at the AVN given for which data exists.

APPENDIX H

SPECIAL CRATERING TARGETS

This appendix describes the WRCLCY routine which provides weapon radius curves for special cratering targets. These installations will be assigned a VNTK with the "T" = Y. The height of burst must be contact. The installations which should use these vulnerability numbers are specified in reference 5. The "K" value assigned to each curve is given in Table VI. The "VN" portion of the VNTK is not used.

TABLE VI

SPECIAL CRATER WEAPON RADIUS EQUATION

"K"	WR
A or 1	$28Y^{.546}$
B or 2	$89Y^{.381}$
C or 3	$131Y^{.352}$
D or 4	$136Y^{.357}$
E or 5	$140Y^{.324}$
F or 6	$141Y^{.323}$
G or 7	$146Y^{.323}$
H or 8	$148Y^{.325}$
I or 9	$155Y^{.375}$
J	$185Y^{.367}$
K	$209Y^{.333}$
L	$214Y^{.328}$
M	$219Y^{.334}$
N	$229Y^{.311}$
O	$230Y^{.321}$
P	$231Y^{.310}$
Q	$232Y^{.316}$

Y = Weapon Yield in Kilotons

APPENDIX I

ERROR MESSAGES

Introduction

This appendix describes the error processing which is accomplished by the executive routine and the ERRMSG subroutine. The errors identified will result from improper input data or from input data which would result in an invalid result. As these situations are encountered a variable (IERR) is set to an appropriate value. This value produces an appropriate error message from the ERRMSG subroutine. (This value is returned to the program using PDCALC in the on-line version.) These messages are given in Table VII. The desired output from PDCALC is set to zero when an error is encountered.

TABLE VII

ERROR MESSAGES

IERR	Message	IFLG	Cause
1	"You cannot achieve desired POD with this weapon."	5,6	POD at zero offset less than specified POD.
2	"VN (IV) is too large for available data curves."	1-8	Weapon radius curves are given for a limited range of VNTKs and scaled heights of burst. Range of tables has been exceeded for scaled height of burst used.
3	"SHOB greater than 900 feet - too large for available data curves."	1-6, 8	Similar to IERR=2. Scaled height of burst has exceeded 900 feet, the maximum value used in the tables.
4	"The only option available /ETA targets are IFLG=1 or 2. Your IFLG contains some other value."	3-10	Invalid IFLG for ETA-type VNTK. See Table I, PDCALC Functions.
5	"T" of VNTK must be an X when IFLG=7."	7	Invalid VNTK for personnel.
6	"K for this type of VNTK must be less than 10."	1-6, 8	K when used to yield adjust the VN must be less than 10.

IERR	Message	IFLG	Cause
7	"K of personnel VNTK must be 1-9 or A-Q."	1-7	No vulnerabiluty curve assigned to K value used. See Table IV, Personnel Vulnerability Curves.
8	"K of Special Crater VNTK must be 1-9 or A-P."	1-6, 8	No vulnerability curves assigned to K valuie used. See Table VI, Special Crater Weapon Radius Equation.
9	"T of VNTK is not a valid character."	All	T of VNTK must be one of those in Table II, Target Types and Damage Sigma.
10	"Crater required by VNTK (T=Z or Y), a contact burst is required."	1-6, 8	POD is zero if HOB is not zero.
11	"K of VNTK must specify a fatality curve for 'IFLG=7'".	7	Routine calculates fatalities and casualties. Curves are paired as shown in Table . Personnel Vulnerability Curves.
12	"SHOB greater than 1,000 feet - too large for available data curves."	1-8	Same as IERR=3, except "T" of VNTK is X. Scaled height of burst has exceeded 1000 feet, the maximum value in the personnel vulnerability tables.

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