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PERSONAL COMPUTER PROGRAM FOR CHEMICAL HAZARD PREDICTION (D2PC)

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The findings in this repcrt are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

PREFACE

The work described in this report was authorized under Project No. 1L162706A553, CB Defense and General Investigations, Technical Area 3-B, Analysis and Integration of Chemical Defense Systems. This work was started in February 1985 and completed in October 1985.

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APPENDIXES

PERSONAL COMPUTER PROGRAM FOR CHEMICAL HAZARD PREDICTION (D2PC)

1. SCOPE

1.1 Objective.

It is the object of this report to document a personal computer program that will provide computational assistance in estimating chemical downwind hazard in terms of peak vapor concentration or accumulated dosage.

1.2 Background.

This program is a revision of program D2, which was documented earlier.[1] The methodology is based on DODESB Technical Paper No. 10, Change 3, Methodology for Chemical Hazard Prediction, June 1980.[2]

1.3 Approach.

The program is written in FORTRAN 77 for an IBM compatible personal computer. It is conversational, employing a modified form of menu input with a data base provided for standard chemical agents and munitions. Estimates of hazard distance are made for either the expected peak concentration of vapor, the dosage, or the accumulated dose that an individual might receive at that distance.

2. DESCRIPTION OF THE PROGRAM

2.1 Organization.

The program is made up of a MASTER and 12 subroutines. It is the function of the MASTER to obtain the required information from the user by selecting the questions to be asked for a given problem. The data that is input and retrieved from the tables is then organized for use by one of the downwind distance calculators (DDS or CDS), which makes the estimate of distance and returns it to the operator. The exchange of information between subroutines is diagrammed in Figure 1.

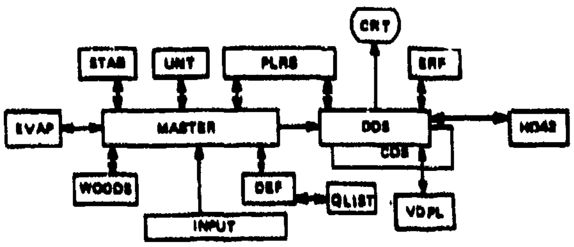

Figure 1. Information Exchange Between Subroutines

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[1]Whitacre, C.G., and Myirski, M.M. ARCSL-TR-82014. Computer Program for Chemical Hazard Prediction (D2). September 1982. UNCLASSIFIED Report.

[2]Technical Paper No. 10. Methodology for Chemical Hazard Predictions. Department of Defense Explosives Safety Board. March 1975. UNCLASSIFIED Report.

Selection of subroutine DDS or CDS is determined by the choice of dosage or concentration as the exposure index for downwind distance. Subroutine DDS is supported by the error function, ERF, and by subroutine HD42, which is called when an explosive release of HD is requested. Also the plume rise subroutine, PLRS, may be called by DDS or CDS if a rising cloud is to be traced with distance.

The other subroutines support the MASTER. Subroutine EVAP is called to determine the airborne source when the release is by evaporation. STAB is called to select the Pasquill stability category if the meteorological observations are input. When release is in a wooded area, subroutine WOODS is called to select the special diffusion parameters for the particular type of woods. Subroutine PLRS may be called by MASTER to compute the rise of a heated cloud or to initialize for the call from DDS or CDS as explained above.

Subroutines DEF and QLIST work with MASTER to provide variable definitions to the user when needed. DEF also blocks the repetition of request for the same information on successive runs.

2.2 Operation.

The modified menu form of input was developed for this program to accommodate a wide range of user applications and a wide range of experience in the user. A data base is provided for defined storage sites, standard munitions, and agents. The appropriate data for these systems is recovered by selecting the site and system from menus. The menus also include a nonstandard or nondefined option and, when these are used, the needed data is then requested. This approach permits the full power of the models to be drawn out.

The format of the questions is selected by the operator to match his experience level. Four levels are provided. In the most lengthy form, all options are listed and defined with each question. In the shortest form, each question is one line, and the operator is expected to remember the options. However, at any point, the listing for that question may be recalled by answering with question marks. The question is then repeated.

For all numeric inputs, the units are specified in the question; these are generally metric. Other units may be used as long as the strange units are identified by the proper code. Again, question marks (or an error) will cause these codes to be displayed and the question repeated.

When all of the essential questions have been asked for a given run (execution of the downwind hazard estimator), the questions will terminate with the request "ALL OTHER INPUT." At this point, output and control options may be entered. The options may be displayed as tables by typing TAB and the number of the table. The tables are defined as follows:

1. Control options
2. Assessment options
3. Output options
4. Alphabetic listing of parameter codes

This list may be displayed by entering three question marks (???). From the control options, you will see that the code ALL will cause the program to continue and execute. When execution has terminated, the program will return to the ALL question (ALL OTHER INPUT). Here you may change options and reexecute, restart, or stop. The control options are listed in Tables 1, 2, and 3. These tables may be displayed with TAB 1, TAB 2, or TAB 3 commands as described above.

Table 1. Control Options Run Control

RST	Restart at question 1, clear input blocks
RSN	Rescan from question 2
ALL	Execute downwind calculation
STP	Stop
GTO	Go to entry point specified (question number)
IRT	Return to specified question
INP	Clear input block for specified question
HLD	Hold variable at present value
RLS	Release hold of variable
TAB	Display table
DSP	Question definition
???	List of table codes

Table 2. Assessment Control

IMA	= 0	Dosage (default)
	= 1	Concentration (mg/m^3)
	= 2	Concentration (ppm)
	= 3	Fumigation concentration
2MC	= 1	Do not use 2-minute correction with GB and VX vapor
	= 2	Use 2-minute correction with GB and VX vapor (default value)
MNR	= 0	No effects, no deaths, 1 percent lethality (default)
	= 1	No deaths, 1 percent lethality
	= 2	1 percent lethality
VDP	= 0	Without vapor depletion (default)
	= 1	With vapor depletion

Table 3. Output Control

NOV	= 0	List only input variable
	= 1	List variable and options
	= 2	List variable and options with definitions
OPO	= 0	Output short heading and interpolated distance only (default)
	= 1	Include diffusion parameters and D versus X
	= 2	Above plus components of D
	3	Crosswind width of cloud with distance
OPC	= 0	Use HT max from PLRS
	= 1	List f(x); use HT max
	= 2	Use HT = f(x)
	= 3	List f(x); use HT = f(x)

The ALL question may also be used to input new parameter values directly. For example, if you had made an estimate of the hazard distance for a wind speed of 1 m/sec, you could obtain an estimate for 5 m/sec by typing the following:

```
WND  5.
ALL
```

The program will rescan the question list, display the current value of each parameter, and stop again at the ALL question for further instruction. The code ALL will then cause it to execute for 5 m/sec and display the new estimate. If multiple parameter changes are required, these are made as separate entries (giving the code and the value for each) before the first ALL response. The stop for the second ALL permits the user to review the parameter values before the next execution. Of course, more changes can be made then, but the program may rescan again and stop again.

The program's decision to rescan after entries in the ALL question is based on the changes that the new parameter value might make in the input questions and the data retrieval from the data base. It is important to realize that this retrieval is repeated with each rescan. Thus, a parameter value that may have been entered as different from the data base would normally be changed back to the data base value on rescan. This change can be avoided if a hold is placed on the specific parameter. This is done by the command code HLD and the parameter code. As an example,

```
HLD HML
```

will prevent the height of the mixing layer, HML, from being changed by rescan. Of course, this is not needed unless a nonstandard value has been entered. The hold is released with the command RLS and the parameter code. The HLD command may be stated for any parameter, but it is only useful for those variables that may be changed by rescan. The following is the list of variables with which HLD is effective.

VARIABLES USED WITH HLD

Code	Variable
FMW	Molecular weight
HML	Height of the mixing layer
MNR	Minimum response level
NCI	Concentrations of interest (see Section 4.4)
NDI	Dosages of interest
PMM	Atmospheric pressure
QQQ	Source strength
SXS, SYS, SZS	Source sigmas
2MC	Two-minute correction control

The control and parameter codes that can be entered through the ALL questions are given in Table 4. These may be displayed by the program with TAB 4. Here the display is in four pages and progresses to the next page each time the return key is pressed.

Table 4. Options For the ALL Question

Code	Input Variable	
AGN	Agent, see Section 3.6 or DSP 6	
ALL	Control word, execute program	
ALF	Slope of the sigma-y versus x curve	
ARE	Area of puddle	(m^2)
BPT	Boiling point	(°K)
BRT	Breathing rate	(1/min)
BTA	Slope of the sigma-z versus x curve	
CCT	Cloud cover	(1/10)
CHT	Cloud height	(ft)
CRD	Cloud radius	(m)
DLX	Change in x (first cycle)	(m)
DSP	Display question definition	
DST	Diameter of stack	(m)
FMV	Molecular volume	(cm^3/gm mole)
FMW	Molecular weight	(gm/mole)
FRO	Slope of the frost wind profile	
GTO	Control. Go to specified question	
HML	Height of the mixing layer	(m)
HLD	Hold value of symbol	
HRL	Heat released	(cal)
HRS	Local standard military time	(hr)
HST	Height of stack	(m)
HTS	Height of source	(m)
IDD	Number of the day	
IMA	Method of assessment control, see TAB 2	
IMM	Number of the month	
INP	Control. Clear input block for question	
IRT	Control. Return to specified question	
LEN	Length of puddle, downwind	(m)
LOC	Location, see Section 3.2 or DSP 2	
MNR	Minimum response level, see TAB 2	
MUN	Munition, see Section 3.5 or DSP 5	
NCI	Number of concentrations of interest	
NDI	Number of dosages of interest	
NMU	Number of munitions	
NOV	Novice level	
NQI	Number of source intervals	
OPC	Output for stack, see TAB 3	
OPO	Output control, see TAB 3	
PMM	Atmospheric pressure	(mm hg)
QQQ	Airborne source	(mg)
RDE	Relative density of effluent	
REF	Reflection coefficient (default = 1)	
REL	Method of release, see Section 3.8 or DSP 8	
RLS	Release hold of symbol value	
RSN	Rescan from question 2	
RST	Control. Restart	
SEA	Season, see Section 3.3 or DSP 3	
SKF	Skin factor for subject clothing	

Table 4. (cont'd)

Code	Input Variable	
SLA	Latitude	(°)
SLO	Longitude	(°)
SMH	Sampling height	(m)
STR	Stability, see Section 3.9 or DSP 9	
SUN	Sun elevation angle	(°)
SUR	Surface type, see Section 3.17 or DSP 17	
SEV	Settling velocity of cloud centroid (default=0)	(m/sec)
SXS	Source sigma x	(m)
SYR	Reference sigma y at 100 m	(m)
SYS	Source sigma y	(m)
SZR	Reference sigma z at 100 m	(m)
SZS	Source sigma z	(m)
TAB	Table display	
TEV	Time of evaporation	(min)
TIM	Time after functioning (INS, HD)	(min)
TMC	Time to met change	(min)
TMP	Temperature	(°C)
TST	Temperature of stack	(°C)
VAP	Vapor pressure	(mm Hg)
VST	Velocity of effluent from stack	(m/sec)
WND	Transport wind speed	(m/sec)
WOO	Woods type, see Section 3.36 or DSP 36	
ZZO	Roughness length	(m)
2MC	Two-minute corrections control, see TAB 2	
???	Display list of tables	

When the program rescans, it repeats the same logic string that was followed in selecting the initial questions. The original questions are relisted along with the current value of the parameter, but the program does not stop for input unless a new question is needed. It will then type the word "INPUT" and stop. All calculations done to establish initial data, such as the selection of the stability class or the amount evaporating from a puddle, will also be recomputed and relisted. The format of this listing will be discussed in Section 4.8.

3. INPUT

3.1 Question 1, INPUT; NOVICE LEVEL 3, 2, 1, or 0 NOV.

This question is answered by a single digit. Digit 2 will cause the program to list the possible options and a one-line definition for each input variable. Digit 1 will supply a one-line list of options for the multiple choice questions, and digit 0 lists only the questions. The digit 3 will list the options and definitions as described for 2, but will begin by displaying two pages of general information about the operation of the program. The novice level may be changed by a return to question 1 (RST) or by assigning a new value to NOV in the ALL statement.

3.2 Question 2, LOCATION LOC.

This question is answered by a three-character code that identifies one of the U.S. chemical storage sites or by "NDF" if some other location is being considered. If a listed site is specified, the location, average pressure, and height of mixing layer are recovered from the data base. When the location is not defined by this list, these parameters are requested as required. The following is a list of the option codes.

LOC Code	Location
AAD	Anniston Army Depot
DPG	Dugway Proving Ground and Tooele Army Depot
EWA	Edgewood Area, Aberdeen Proving Ground
JHI	Johnston Island
LBG	Lexington-Blue Grass Army Depot
NAP	Newport Ammunition Plant
PBA	Pine Bluff Arsenal
PAD	Pueblo Army Depot
RMA	Rocky Mountain Arsenal
UAD	Umatilla Army Depot
EUR	USAEUR
NDF	Not defined

3.3 Question 3, SEASON SEA.

When this question is asked, a three-letter code must be specified to select one of the four seasons. The season is used to select the height of the mixing layer for the listed storage sites. (This question is not asked when the location is listed as NDF.) The following is the list of season codes.

SEA Code	Season
WIN	Winter
SPR	Spring
SUM	Summer
FAL	Fall

3.4 Question 4, HEIGHT OF THE MIXING LAYER HML.

This question is asked to obtain the height of the mixing layer when it is not defined by the location and season. If a different height is to be specified for a standard location, this is done by declaring the new value in the ALL question (Section 3.15).

3.5 Question 5, MUNITION TYPE MUN.

Selection from 10 standard chemical rounds may be made or "NON" may be specified for other items. For the standard item, fill weight, agent type, and source dimensions are recovered. For this entry, any three characters may be entered and will be carried through to output. Data is available only on the following items:

MUN Code	MUN
105	105-mm Cartridge, M60, M360
155	155-mm Projectile, M110, M121A1
8IN	8-inch Projectile, M426
500	500-lb Bomb, MK94
750	750-lb Bomb, MC-1
M55	115-mm Rocket, M55
525	525-lb Bomb, MK116
139	Bomblet, M139
M23	Land Mine, M23
4.2	4.2 Inch Cartridge, M2A1
NON	Nonmunition

3.6 Question 6, AGENT TYPE AGN.

The agent type requires a two-character code and again will pass any two characters through to output. The physical constants are stored for the substances listed below. Dosage values estimating 1 percent lethality, no deaths, and no effects are retrieved for all of these substances except UDMH. The values for 1 percent lethality were taken from DODESB TP No. 10.[2] The no deaths and no effects are best current estimates based primarily on ORG 40.[3] The following is a list of the agent codes:

AGN Code	Agent	AGN Code	Agent
GA	Tabun	H1	HN-1, Nitrogen mustard
GB	Sarin	H3	HN-3, Nitrogen mustard
GD	Soman	HT	60% HD and 40% T
GF	EA 1212	LL	Lewisite
VX	EA 1701	AC	Hydrogen cyanide
BZ	Incap agent	CG	Phosgene
HY	Hydrazine	CK	Cyanogen chloride
UD	UDMH	DM	Adamsite
HD	Distilled mustard	NA	Nonagent

3.7 Question 7, SPILL OR AIRBORNE SOURCE QQQ.

For evaporative release, this is the amount that is initially spilled. The EVAP program takes this as Q and then computes Q', which is the amount that becomes airborne. For other forms of release, this is the total amount that is airborne over the release period. The exception is continuous release, which is explained in the next section (3.8).

[3]Solomon, Irving *et al*. ORG Report 40. Methods of Estimating Hazard Distances from Accidents Involving Chemical Agent. Operations Researh Group, Edgewood Arsenal, Maryland. February 1970. CONFIDENTIAL Report.

3.8 Question 8, RELEASE TYPE REL.

The code for release type must be selected from the list given below.

REL Code	Type of Release (REL)
INS	Instantaneous (explosion)
EVP	Evaporation from a puddle formed by a spill
SEM	Semicontinuous. Constant for a finite time.
VAR	Variable. The source is defined as a number of release intervals, each constant for a finite time (maximum of 6).
STK	Release of heated effluent from a stack
STJ	Release from a stack when inertial or jet effect dominates
FLS	Flash fire from ground level
FIR	Fire burning for finite time
IGL	IGL fire for M55 with GB or VX
EVS	Still air evaporation (see Section 4.10)

When the distance is to be based on peak concentration, a time of infinity (1.E36) may be specified for the semicontinuous release, which converts this into a continuous release. In this event the input, Q, is now the rate of release in mg/min.

3.9 Question 9, STABILITY TYPE STB.

This is a single-character input. The Pasquill categories are identified as A through F; the U option will cause the program to request the diffusion parameters; S will select the Pasquill category from additional data; and W will select from a table of diffusion rates for different types of woods. The logic of the stability selection and the table of woods parameters are given in Appendix A.

STB Code		Atmospheric Stability (Pasquill) (STB)
A	unstable	Pasquill Stability Categories
B		
C		
D		
E		
F	stable	
U		Undefined. Used when ALF, SYR, BTA, SZR are input.
S		Select stability from meteorological observations
W		Wooded areas

3.10 Question 10, WIND SPEED (m/sec) WND.

The transport wind speed is entered in meters per second as indicated. Other units, such as knots or miles per hour, may be used if the number is preceded with the proper two-character code. The list of codes may be displayed by typing two question marks.

When the WOODS option is specified for stability, the wind speed is input for a height of 10 meters. The speed is converted by the program to the expected below canopy rate. In order to enter the below canopy rate directly, the number is entered as negative.

3.11 Question 11, ALF, SYR (m), BTA, SZR (m).

The diffusion parameters for the sigma y and sigma z distributions are requested when the U option is specified for stability. The variable ALF is the slope of log sigma y versus log distance, and 3TA is the slope for log sigma z versus log distance. The reference values SYR and SZR are taken at 100 meters.

3.12 Question 12, TEMPERATURE (°C).

For instantaneous release of HD and when the EVP release option is used, question 12 is preceded by the word SURFACE. This indicates that the temperature specified should be the temperature of the liquid surface. Other releases that request temperature employ the air temperature. (When the temperature is not requested, the number printed with temperature in the output summary has no effect on the prediction).

3.13 Question 13, Q () (mg), QT () (min) NQI.

Question 13 is provided to input source time increments (that is the quantity released and the time over which the release was made.) This form is used for all types of release except instantaneous and evaporative. For semi-continuous release (SEM), one time interval is implied and does not have to be entered. For the remaining releases, the number of intervals, NQI, is requested. From one to six intervals may be defined. This is followed by one Q and TQ pair for each (maximum of 6). The quantity, Q, is the amount released in that interval, and the time is cumulative as measured from the beginning of the first interval.

3.14 Question 14, MOLECULAR WEIGHT FMW.

If the substance released is not in the agent list given above (Section 3.6) and the molecular weight enters into the calculation, this will be requested here.

3.15 Question 15, ALL OTHER INPUT.

Although not otherwise specified, the ALL question is 15th in sequence. The other questions are numbered so that the operator may refer to a specific question with control statements. These statements are INP, GTO, and IRT as listed in Table 1 above. The GTO option will initiate a rescan and stop for input at the question specified. Any other questions defined by IMP will also stop for input. The IRT option is like GTO except that it is repeated automatically at the end of each execution. Once set, this is cleared by setting the question to zero (IRT 0).

The assessment controls IMA, 2MC, MNR, and the output, OPO, are all set to default values as indicated in Table 2. If other options are required, these should be set at this time. Options IMA, NOV, and OPO will remain as set until another option is given. Options 2MC and MNR are reset to the default values on rescan unless a hold is placed on each (HLD 2MC or HLD MNR). The command DSP with a question number will display the options and definitions for that question.

3.16 Question 16, ATMOSPHERIC PRESSURE (mm Hg) PMM.

The atmospheric pressure is requested, when needed, if the standard site has not been defined. The pressure for a standard site may be changed in the ALL question. To keep this value, a hold should be placed on PMM (HLD PMM).

3.17 Question 17, SURFACE CODE SUR.

Surface codes for gravel (GRA) and concrete (NPR) are provided that will make a rough estimate of the puddle size that would be formed on level terrain. The NDF option permits the wetted area to be input.

3.18 Question 18, TIME OF EVAPORATION (min) TIM.

This is the time of evaporation. If the time given is greater than the time required for total evaporation, the time is reset by the program.

3.19 Question 19, AREA OF THE WETTED SURFACE (sq m) ARE.

If the surface code is given as NDF, the area of the puddle will be requested.

3.20 Question 20, LENGTH OF SURFACE DOWNWIND (m) LEN.

This is the estimated fetch of the vapor over the wetted surface of the puddle.

3.21 Question 21, FMW, FMV, VAP (mm Hg), BPT (deg K).

If the physical constants are not available in the data base, the molecular weight, molecular volume, vapor pressure (at the temperature of interest), and boiling point are requested.

3.22 Question 22, TIME AFTER FUNCTIONING TIM.

This question is asked only for explosive release of HD from a standard round. The time is the lapsed time from functioning to the time the cumulative dosage is measured.

3.23 Question 23, OUTPUT CODE OPC.

One of the output options listed under OPC in Table 4 is entered here. These options refer only to the output when the plume rise options STK and STJ are specified. These options control what is displayed but also control whether the cloud is traced with distance (f(x)) or is assumed to rise as one step above the stack.

3.24 Question 24, HEIGHT OF STACK (m) HST.

3.25 Question 25, DIAMETER OF STACK (m) DST.

3.26 Question 26, TEMPERATURE OF STACK (deg C) TST.

3.27 Question 27, VELOCITY OF EFFLUENT (m/sec) VST.

3.28 Question 28, RELATIVE DENSITY OF EFFLUENT RDE.

3.29 Question 29, FROST PROFILE EXPONENT FRO.

This is the log-log slope of the wind profile.

3.30 Question 30, HEAT RELEASED (cal) HRL.

3.31 Question 31, CLOUD RADIUS (m) CRD.

3.32 Question 32, STATION LATITUDE and LONGITUDE (deg) SLA and SLO.

3.33 Question 33, MONTH, DAY, HOUR IMM, IDD, and HRS.

The first three letters of the month, the day as two digits, and the standard military time as four digits are entered here (JAN,01,1200). The output of the month will be displayed as a numeric (1-12) and, if the month is changed in the ALL statement, it is entered as a numeric (IMM 4). The first time the S option is used for stability the program will request the year. This is done to compute the vernal equinox for the year specified.

3.34 Question 34, CLOUD COVER (1/10), CLOUD HEIGHT (ft) CCT and CHT.

This is the number of tenths of coverage (overcast = 10) and the cloud height in feet.

3.35 Question 35, SUN ELEVATION ANGLE (deg) SUN.

This is entered as degrees above the horizon.

3.36 Question 36, WOODS TYPE WOO.

This is entered as a two-digit code as defined in the following table:

WOO = DW Deciduous, winter
MW Mixed, winter
CF Coniferous forest
MS Mixed, summer
RF Rain forest

4. DISCUSSION

4.1 Program Input Rescan.

When the program forms its first input string of questions, it may copy data on munitions, agents, and locations from tables for input to the downwind distance calculator (DDS or CDS). Also the EVAP, STAB, or WOODS subroutines may be called in this process. Once the program has executed and returned to "ALL OTHER INPUT" (question 15), all of these values are retained and the same problem would be rerun if the word ALL is input again at this point.

The RST option will reinitialize the program and establish a new input string for the next run. However, if the next run is similar to the first, the user can take advantage of the data already present and input only the changes. These changes can include any of the variables listed in Table 4.

Many of these variables will affect the data copied from the tables in the first scan and thus a rescan of the input phase is needed. The variables that may require input rescan are listed below.

AGN	DOW	IMM	PMM	SLO	TIM
ARE	FMV	INP	QQQ	STB	TMP
BPT	FMW	LOC	REL	SUN	VAP
CCT	HRS	MUN	SEA	SUR	WND
CHT	IDD	NMU	SLA	TEV	WOO

4.2 Rescan and the HLD Command.

Although the automatic table look-up feature is designed to aid the user, there are conflicts that must be understood. The table look-up is repeated with each rescan. Thus, a variable value can be stored in the ALL statement but, if the combination of inputs causes the input rescan, the value may be overwritten by a value from the tables. See Section 2.2 and 3.15 for further discussion.

4.3 Concentration Options.

The downwind concentration, CDS, is selected when values of 1, 2, or 3 are assigned to IMA in the ALL question. When any of these values of IMA are input, a message (DEFINE NCI) will be printed. This is to remind the user that the concentrations of interest must be specified since there are no tabular values for concentration. When a value is assigned to NCI, the instruction INPUT: CI()S will be printed. The values of CI should be in ascending order and the number of entries must agree with NCI. If NCI is not defined, the program will use any numbers left from a dosage run as if they were concentrations, or the program will return to ALL as explained in Section 4.4 if no dosage has been defined.

When concentration is selected by setting IMA to 1, 2, or 3, the program automatically places a hold on NCI to prevent the rescan procedure from overwriting the concentrations of interest with the tabular dosages. This hold is released when IMA is again set to zero. (A hold on either NDI or NCI will bypass the table lookup for dosages of interest.)

4.4 DEFINE NDI or NCI.

If the program attempts to enter the downwind distance calculators (DDS or CDS) without a defined dosage or concentration of interest, the demand DEFINE NDI or DEFINE NCI is printed and control returned to the ALL statement.

4.5 Multiple Munitions.

If a calculation is being made for two or more munitions functioning or being spilled at the same location, the source strength can be increased in unit multiples by assigning a number to NMU in the ALL statement. This approach, of course, assumes that all munitions are the same and that agent is released in the same manner. Thus, the scenario for a pallet of M55 rockets will still require two runs, one for the munitions that function and one for those that leak. However, the number of munitions in each release may be entered directly as NMU. Although NMU is displayed as an integer, the value may be entered as a real number or fraction. In this manner, adjustments may be made for partial spills or partial releases. When there is no fractional part, NMU is displayed in the header as an integer. When there is a fractional part, the header will list numbers less than 10 and greater than .009 with two decimal digits.

4.6 Wind Speed in Woods.

The meteorological parameters given in DODESB TP No. 10 for wooded areas indicate a reference wind speed outside the woods as well as the transport wind within the woods. The program is designed to convert from reference (outside) to transport (inside) so that the normal input would be the reference wind speed. However, provisions are made to enter the transport speed directly if this is known. This signal to the program is to specify the wind speed as negative. Thus, if you wish to specify the in-woods wind speed, enter the number as negative.

4.7 Units Conversion.

Subroutine UNT permits the conversion of units for many of the variables. The system is designed to be invisible to the user who enters the conventional metric units requested. When "strange" units are used, the first two characters of the space that would normally be numeric are replaced with two alpha characters that identify the input. This system is operable on all input questions that contain only one numeric variable. The units that may be converted and the two character codes that will initiate this change are given in the following table:

UNIT CODES

ATM = AT	SQ FT = SF	LB = LB	MB = MB	GAL = GL
BAR = BR	GM = GM	M = MT	OZ = OZ	L = LT
CM = CM	HR = HR	M/MIN = PM	SEC = SC	ML = ML
DEG F = DF	IN = IN	C M/MIN = M3	TON(L) = TL	PT = PT
FT = FT	KT = KT	MI/HR = MH	TON = TN	QT = QT

It should be noted that the questions in which the units can be converted include question 15 (the ALL question). Thus, the variables that appear in the "multi-numeric" questions, which cannot be converted directly, may still be converted in the ALL question by reentering the variable name, a space or comma, the two-character conversion code, and the numeric value in the "strange" units.

Whenever the units conversion function is employed, the program will list the input units, the output units, and the converted numeric value. If meters are input as the conversion code (MT), this will be converted to feet. The only place where this conversion is appropriate would be in the conversion of cloud height, if it were known in meters. There is no internal check to assure that the conversion is appropriate for the variable. It is thus the responsibility of the user to assure that the final units agree with the input requested. Conversion errors may be corrected by repeating the input in the ALL question.

If question marks are entered for the conversion code or an undefined code is used, the units code table given above will be listed. The program will then repeat the input question. For the ALL question, no variable name is listed but control remains in the ALL loop so that the variable may be re-entered on the next cycle.

The last five unit codes (Gal, l, ml, pt, qt) are measures of volume. These are converted to weights by using the density of the substances. The densities are stored for the 17 substances in the agent list. For other substances the program will request the density.

4.8 Calculations During Input.

When the EVP option of release is used, the EVAP3 subroutine is called during input to compute the airborne source. Each time this subroutine is executed, two lines are output to summarize the results. The surface code is listed and then values of the following:

EVP	Evaporation rate from puddle (mg/min-sq m)
AREA	Area of puddle (sq m)
VPR	Vapor pressure of liquid (mm Hg)
Q	Initial quantity spilled (mg)
Q'	Airborne source (mg)
TEV	Time of evaporation (min)

One line is output each time the stability selector is called. The computed values are as follows:

SR	Sunrise (standard military time)
SS	Sunset
AE	Elevation angle of sun above the horizon (deg)
STAB	Stability category

4.9 Igloo Fires.

Subroutine IGL has been added to D2PC programs released after June 1986. This subroutine contains the unit-weighting factors for the igloo fire scenario for the M55 containing either GB or VX. The subroutine is called by specifying the method of release as IGL. The number of rounds is specified with NMU in the ALL statement. The program will display the three release intervals employed for GB and the single interval used with VX.

4.10 Still Air Evaporation.

In program D2 and in the early version of D2PC, the still air evaporation option could be called only by specifying a small wind speed. In the version released after June 1986, a release option, EVS, has been added to treat a spill within an enclosure where the vapor would then escape to the outside. When EVS is specified, the still air model is used to determine the amount that evaporates within the enclosure, but the wind speed specified by the user is then used to compute the downwind travel and dosage. This avoids having to run the program first as an evaporation source with a small wind speed to determine the source and then again, as a semicontinuous source with the outside wind speed to determine the transport.

5. ERROR MESSAGES

Most of the error messages are self explanatory. A few refer back to the methodology and some additional comments are given below.

CON NOT DEF FOR INS VX HD - Concentration not defined for instantaneous release of VX or HD. This message is produced when the concentration model is requested (IMA = 1) with instantaneous release of VX or HD from a munition. The models for this combination that are contained in the program are designed for dose or dosage only. Concentrations can be computed by providing the amount airborne and specifying a nonmunition (NON).

DEFINE HML - Define the height of the mixing layer. This message occurs when the table look-up has not defined a value for HML.

DEFINE NCI - A reminder that the number of concentrations of interest must be defined

DEFINE NDI - A reminder that the number of dosages of interest must be defined

DEFINE NQI - A reminder that Q is changed by defining NQI

DHJ NOTE: UNSTABLE MET CONDITIONS - Jet plume note: Unstable meteorological conditions. This a reminder that the jet plume model proposed by Briggs-Thomas is limited to stable and neutral conditions.

DHS NOTE: VS/UZ LT 4 - Jet plume note: The stack velocity divided by the wind speed is less than 4. The model is derived for greater than 4.

DHH/DHB/DHBT Note: STK TMP LESS THAN AIR TMP - Note for Holland, Briggs, and Briggs-Thomas plume models: Stack temperature is less than air temperature. A reminder that the models are derived for a positive difference (T_s - T_a).

FUMIGATION - A reminder that the fumigation equation has been used (Equation 66, Appendix A). It should be noted that the distance computed by this model is not the distance from the initial source but the distance from the cloud at the time the ground level inversion breaks up.

HEIGHT DEFINED FOR STABLE CONDITIONS ONLY - A reminder that the model applies only for neutral and stable conditions

MUNITION-AGENT NOT DEFINED - This message occurs when the combination given is not in the standard table.

Q' EQ ZERO - The airborne sources, Q', is zero. Control returns to the ALL statement.

STILL AIR - This message is a reminder that the still air model for evaporation has been used.

TMP GREATER THAN BOILING POINT - Temperature greater than boiling point of liquid. The program will continue with the total amount spilled as the airborne source.

TMP LESS THAN FREEZING - Temperature less than freezing. Q' is set to zero and control is returned to the ALL statement.

6. OUTPUT

Output is controlled by the three variables NOV, OPO, and OPC, which are defined in Table 3. The options for NOV were discussed in Section 3.1. The long listing displayed when NOV equals 2 or 3 will become tedious after the user has gained some experience with the program. A shift to one is recommended as soon as the options can be recognized by the operator.

During execution the first line of output comes from the MASTER program and is essentially a summary of the input information. The next two lines come from subroutine DDS and list the source (Q), the release time (TS), the release height (HTS), the height of the mixing layer (HML), and the source sigmas (SXS, SYS, SZS). When the default value of OPO is used, the program will execute and list the distance to each of the three response levels, 1 percent lethality, no deaths, and no effects. If other dosages are specified by the operator, these dosages will be listed with each estimated distance.

When the 2-minute correction is used with estimates for nerve agents, an extra header line (w/2-min correction) is displayed; when this correction is dropped, a (w/o 2-min correction) line is shown.

Options 1 and 2 will also cause the diffusion parameters to be listed as lines 4 and 5. These lines will also list XY and XZ, which are the offset distances for sigma -y and sigma -z that are given in the methodology as parameters B and C. The last output at the end of line 5 (OPO = 1 or 2) is the wind speed used in the calculation. This may differ from the wind speed given in the first line when the woods parameters are selected.

The following is a list of definitions for the output under options 1 and 2:

X	Downwind distance (m)
DP	Peak dosage (mg min/m^3)

DP2	Peak dosage with 2-minute correction
ED	Effective dosage (mg min/m^3)
ED2	Effective dosage with 2-minute correction
RF	Fraction reflected from mixing layer
2MF	Two-minute correction factor
EDI	Inhalation component of ED2
EDS	Skin deposition component of ED2

When OPO option 3 is used, a header is printed for the contour dosages and then the contour half-widths.

7. SUMMATION OF DOSAGE DISTRIBUTION

A provision has been made to sum the dosage at each downwind distance so that the hazard distance from multiple sources may be output directly. This process, of course, is limited to sources of the same agent.

To utilize this feature, three control commands have been added to the ALL question:

SMC	Clear sum D(X)
SMD	Add current D(X) to sum D(X)
SMP	Print X(DI) from sum D(X) plus current D(X)

Sum D(X) and current D(X) are each 51 element tables that store the dosage for each distance and thus define the downwind distribution. With each run, the dosages generated are stored as the current D(X).

The sum D(X) table will initially be cleared to zero and, if the SMD command is executed, this will store the current D(X) values in the sum D(X) table. After the changes for the next distribution have been input, the next run will generate and store a new current D(X), leaving the previous values stored by SMD in the sum D(X) table.

If the downwind distances are to be based on the sum of these two distributions, the second run should be preceded with the command SMP, which will tell the program to add the value in the sum D(X) table to the current value in estimating the distance. The SMP command does not change the values stored in either table.

Repeated use of the SMD command will continue to add the dosages in the current D(X) table into the sum D(X) table. The sum D(X) table is cleared with the command SMC.

Thus, the sum D(X) table is controlled by SMC and SMD, and the current D(X) table is changed only by executing a new run. When a run is preceded by SMP, the downwind distance will be based on the current D(X) plus the sum D(X) values. The SMP command is cleared each time the program gets to the ALL question, so the SMP command must be repeated if the command is given before a rescan.

The user is cautioned to assure that the dosages from the previous run extend beyond the dosages of interest in the final run. For example, if the first run is terminated at the 1 percent distance, then the dosage will only be stored to the next regular distance. If the sum would extend the curve beyond this distance, then the remaining portion of the first curve will be missing and the answer would be incorrect.

The recommended procedure is to define a small cutoff dosage for the first run using NDI in the ALL question. In this manner the dosages will be stored beyond the distance estimated with the sum. The storage table for the dosages is dimensioned at 51 and thus can store dosages to a distance of 900 km.

In operation, the current D(X) table always retains the dosages of the last run. The SMD command does not clear (or change) the current D(X) table. The SMP command leaves the current D(X) table with the last component generated. This is not the sum on which the distances are based. This component can be regenerated and printed (OPO = 1) by repeating the run without the SMP command.

In this version of D2PC, the intravenous doses that were output for VX deposition are converted to effective dosages so that these can be added directly in the summation process. These are converted for a breathing rate of 25 l/min. If another rate is needed, the breathing rate, BRT, should be changed in the ALL question.

8. VAPOR DEPLETION

In response to a request from the U.S. Army Toxic and Hazardous Materials Agency (THAMA), a vapor depletion option has been written into the program. (This was done to support Oakridge National Laboratory in their support of the M55 demilitarization effort.)

The approach chosen is based on the current open literature and has not as yet been reviewed or approved as a part of TP 10 by the DOD Explosive Safety Board.

The vapor depletion option is controlled by the indicator VDP, which can be defined in the ALL question. Vapor depletion is called by setting VDP to one and is released by setting it to zero. (The default value is zero.)

The vapor depletion is computed as a reduction of the source strength by computing the mass of vapor that would have been lost to the distance of interest. This is done by computing a deposition velocity as a function of wind speed, stability, and roughness length and then multiplying this by the integrated area-dosage (or area-concentration) to the point of interest. The fraction remaining is listed before each downwind estimate. Comments on the computer implementation of this process are given in Appendix B. The methodology is presented, along with the source references, in Appendix C.

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APPENDIX A

METHODOLOGY

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APPENDIX A

METHODOLOGY

1. INTRODUCTION

This appendix presents the methodology for the atmospheric diffusion, plume rise, and liquid evaporation employed in this program. The diffusion methodology is limited to estimating the axial dosage or concentration at ground level. This restriction is appropriate for hazard distance estimates.

2. TOTAL DOSAGE MODELS

The basic equation for computing the axial dosage from a point or virtual point source is given by

$$D(x) = \frac{Q}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2\,(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad \text{(A-1)}$$

where

$D(x)$ = axial dosage at the point x downwind (mg min/m^3),

Q = source strength (mg),

σ_y or $\sigma_y(x)$ = standard deviation of crosswind concentration at x (m),

σ_z or $\sigma_z(x)$ = standard deviation of vertical concentration at x (m),

U = mean wind speed (m/sec),

H_m = height of the surface mixing layer (m),

H = effective height of the source (m).

The standard deviations, $\sigma_y(x)$ or $\sigma_z(x)$, or σ_z, are computed for the appropriate distance, x, as follows:

$$\sigma_y(x) = \sigma_{yr}\left(\frac{x + B}{x_{yr}}\right)^{\alpha} \quad \text{(A-2)}$$

$$\sigma_z(x) = \sigma_{zr}\left(\frac{x + C}{x_{zr}}\right)^{\beta} \quad \text{(A-3)}$$

where

σ_{yr}, σ_{zr} = reference sigma values at the distances x_{yr}, x_{zr}, respectively (m),

x_{yr}, x_{zr} = reference distances (100 m),

α = expansion coefficient in the crosswind direction (dimensionless),

β = expansion coefficent in the vertical (dimensionless),

B = virtual distance calculated for volume source (m)

$$= x_{yr}\left(\frac{\sigma_{ys}}{\sigma_{yr}}\right)^{1/\alpha}$$

σ_{ys} = standard deviation of initial source in the crosswind direction (m),

C = virtual distance calculated for volume source (m)

$$= x_{zr}\left(\frac{\sigma_{zs}}{\sigma_{zr}}\right)^{1/\beta}$$

σ_{zs} = standard deviation of initial source in vertical (m).

The basic total dosage model simplifies somewhat when the clouds become trapped under a mixing layer cap and eventually result in a cloud with a uniform distribution of concentration in the vertical. Mathematically, this occurs as the infinite series

$$e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)$$

approaches

$$\sqrt{\frac{\pi}{2}} \cdot \frac{\sigma_z}{H_m}$$

for sufficiently large x. This new formulation of the total dosage model

$$D(x) = \frac{Q}{60\sqrt{2\pi}\sigma_y H_m U} \qquad \text{(A-4)}$$

is commonly called the "box moael."

When the initial source is uniform over a line of finite length, L, in the crosswind direction (y), the ground level total dosage along the cloud's axis (the line starting at the midpoint of L in the direction of the wind) is given by

$$D(x) = \frac{\sqrt{2}\,Q}{60\sqrt{\pi}L\sigma_z U}\left(\text{erf}\left(\frac{L}{2\sqrt{2}\sigma_y}\right)\right)\cdot\left[e^{-1/2(H/\sigma_z)^2} + \Sigma\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)2}\right)\right] \qquad \text{(A-5)}$$

where

L = line length (m),

erf (v) = error function evaluated at v

$$= \frac{2}{\sqrt{\pi}}\int_0^v e^{-w^2}\,dw.$$

All others as defined above.

3. DIFFUSION PARAMETERS

The set of diffusion parameters used in the derivation of the tables and graphs presented in this handbook was taken directly from Technical Paper No. 10.[1] Table A-1 gives the required reference sigmas and expansion coefficients.

Table A-1. Recommended Values of Parameters

($x_{yr} = x_{zr} = 100$ m)

Stability category	σ_{yr} (2.5 sec) (m)	σ_{yr} (10 min) (m)	σ_{zr} (m)	α	β
A	9.0	27.0	14.0	1.0	1.4
B	6.33	19.0	11.0	1.0	1.0
C	4.8	12.5	7.5	1.0	0.9
D	4.0	8.0	4.5	0.9	0.85
E	3.0	6.0	3.5	0.8	0.8
F	2.0	4.0	2.5	0.7	0.75

4. TWO-MINUTE CORRECTION MODEL

This methodology[2] is required to implement the changes in effective dosages of GB and VX as a function of exposure time in agent clouds of nonuniform concentration. Since dosage is a function of exposure time, the degree of hazard will be reduced in those accidents where the vapors are evolved slowly over a substantial time as compared with nearly instantaneous releases. This is a result of a nonlinear relationship between dosage, exposure time, and the expected physiological response.

The basic model for calculating ground level partial dosages is as follows:

$$D(x;\Delta\theta) = \frac{Q}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] 1/2 \left[\operatorname{erf}\left(\frac{x - U\theta_1}{\sqrt{2}\sigma_x}\right) - \operatorname{erf}\left(\frac{x - U\theta_2}{\sqrt{2}\sigma_x}\right)\right] \quad \text{(A-6)}$$

where

$\Delta\theta$ = time interval of interest (min),

$= \theta_2 - \theta_1$,

θ_1, θ_2 = beginning and end of time interval as measured from the release time,

σ_x or $\sigma_x(x)$ = standard deviation of the concentration in the x direction (m).

All others as defined above.

For an instantaneous source, dosage buildup at a point as a function of time is readily determined from equation A-6. For releases occurring at a uniform rate, $\Delta Q/\Delta t$, for a time period from the initiation of emission, $\theta_0(=0)$ to θs, computation of the dosage for an arbitrary interval, $\Delta\theta = \theta_2 - \theta_1$, requires application of the more complicated expressions:

$$D(x;\Delta\theta) = K(T_5 - T_2 + T_4) \qquad \text{for } \theta_s > \theta_2 > \theta_1$$

$$D(x;\Delta\theta) = K(T_1 - T_2 - T_3 + T_4) \qquad \text{for } \theta_2 > \theta_1 > \theta_s \qquad \text{(A-7)}$$

where

$$K = \frac{\Delta Q/\Delta t}{3600 \cdot 2\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right]$$

$$T_1 = (\theta_2 - \theta_s - x/u)\ \mathrm{erf}\left\{\frac{x - u(\theta_2 - \theta_s)}{\sqrt{2}\sigma_x}\right\} - (\theta_1 - \theta_s - x/u)\ \mathrm{erf}\left\{\frac{x - u(\theta_1 - \theta_s)}{\sqrt{2}\sigma_x}\right\}$$

$$T_2 = (\theta_2 - x/u)\quad \mathrm{erf}\left\{\frac{x - u\theta_2}{\sqrt{2}\sigma_x}\right\} - (\theta_1 - x/u)\quad \mathrm{erf}\left\{\frac{x - u\theta_1}{\sqrt{2}\sigma_x}\right\}$$

$$T_3 = \frac{\sqrt{2}\sigma_x}{\sqrt{\pi}u}\left[\exp\ -\left\{\frac{(x - u(\theta_2 - \theta_s))^2}{2\sigma_x^2}\right\} - \exp\ -\left\{\frac{(x - u(\theta_1 - \theta_s))^2}{2\sigma_x^2}\right\}\right]$$

$$T_4 = \left[\frac{\sqrt{2}\sigma_x}{\sqrt{\pi}u}\quad \exp\ -\left\{\frac{(x - u\ \theta_2)^2}{2\sigma_x^2}\right\} - \exp\ -\left\{\frac{(x - u\ \theta_1)^2}{2\sigma_x^2}\right\}\right]$$

$$T_5 = (\theta_2 - \theta_1)\quad \mathrm{erf}\left\{\frac{x}{\sqrt{2}\sigma_x}\right\}$$

If $\theta_1<\theta_s<\theta_2$, the total time period is partitioned into the segments θ_1 to θ_s and θ_s to θ_2. The dosage contribution for each time segment is derived separately from the appropriate form of the equation and the results added. Equation A-6 is also readily adapted to cases of variable rate of agent generation, provided the total emission time can be divided into a set of intervals for each, where a constant $\Delta Q/\Delta t$ can be assumed. The contribution of a "source segment," as defined by $\Delta Q/\Delta t$ over a given time interval, to the total dosage accumulated during $\Delta\theta$ may be computed independently for each such segment from equation A-6.* The sum over the set of values so obtained is the total dosage of interest.

*In applying equation A-6, it should be noted that agent emission is defined in the expressions as occurring from the origin ($\theta_0 = 0$) of the time scale to θ_s. For cases involving a series of uniform generation rates, appropriate translations of the time scale (i.e., agent emission from θ_a to θ_b) will be necessary.

The expansions for σ_y and σ_z are noted in section 2 of this appendix.

Values for σ_x may be computed from a study of long-distance cloud travel, which was done by Halvey* in 1973. This work resulted in the following relationship:

$$\sigma_x = .1522\ x^{.9294}$$

It follows from the dosage response curves[2] that an effective dosage for an exposure time t (expressed in minutes) can be obtained by multiplying the corresponding reference "2-minute" value by the factor

$$M = 0.827\ t^{0.274} \quad (t > 2 \text{ minutes}). \qquad \text{(A-8)}$$

A rationale was developed for the computation of the multiplier M by means of a numerical procedure that allows for discrete changes in agent concentration as the cloud moves over a ground location. In essence, a "pseudo" exposure time is determined through a sequence of adjustments for successive time increments covering cloud passage. This "pseudo" exposure time, which must be 2 minutes or greater for equation A-7 to be applicable, can be considered essentially as an integrated average. The precise sequential mathematical procedure is as follows:

let

t_i = clock time in minutes,

τ_i = "pseudo" exposure time in minutes,

ΔD_i = dosage accumulation in interval i,

D_i = cumulative dosage to time t_i,

D_{0i} = 2-minute reference dosage.

Subscript m denotes the value computed from transport and diffusion mode.

Subscript e denotes the extrapolated value as indicated below:

<u>1st Interval</u>: Select clock time interval $t_0 \longrightarrow (t_1 - t_0) > 2$ minutes

a. Determine D_{1m} for interval $t_1 - t_0$ from transport and diffusion model,

b. Set $\tau_1 = t_1 - t_0$,

*Halvey, David D. Estimation of Cloud Length for Long Distance Travel. Unpublished data, Operations Research Group, Egewood Arsenal, Maryland, July 1973. UNCLASSIFIED.

c. Compute.

$$D_{01} = \frac{D_{1m}}{(0.827)\ (\tau_1)^{0.274}}$$

<u>2d Interval</u>: Select clock time interval $t_1 \longrightarrow t_2$

a. Determine ΔD_{2m} for interval $t_2 - t_1$ from transport and diffusion model.

b. Compute (1) $D_{2m} = D_{1m} + \Delta D_{2m}$,

(2) $D_{2e} = 0.827\ D_{01}\ (\tau_1 + t_2 - t_1)^{0.274} - (\tau_1)^{0.274}$,

c. Compare ΔD_{2m} with ΔD_{2e}

(1) If $\Delta D_{2m} = \Delta D_{2e}$, set $\tau_2 = \tau_1 + t_2 - t_1$,

(2) If $\Delta D_{2m} > \Delta D_{2e}$, compute

(a) $D_{2e} = D_{1m} + \Delta D_{2e}$

(b) $$\tau_2 = \left[\frac{D_{2e}(\tau_1 + t_2 - t_1)^{0.274} + (\Delta D_{2m} - \Delta D_{2e})\ (t_2 - t_1)^{0.274}}{D_{2m}}\right]^{\frac{1}{0.274}}$$

(3) If $\Delta D_{2m} < \Delta D_{2e}$, compute

$$\tau_2 = \left[\frac{\frac{\Delta D_{2m}}{t_2 - t_1}\ (t_2 - t_0)\ (\tau_1 + t_2 - t_1)^{0.274} + \left[D_{1m} - \frac{\Delta D_{2m}}{t_2 - t_1}(t_1 - t_0)\right]\ \tau_1^{\ 0.274}}{D_{2m}}\right]^{\frac{1}{0.274}}$$

d. Compute $D_{02} = \dfrac{D_{2m}}{0.827(\tau_2)^{0.274}}$.

<u>General Case</u>: Select clock time interval $t_{i-1} - \longrightarrow t_i$

a. Determine Δd_{im} for interval $t_i - t_{i-1}$ from transport and diffusion model,

b. Compute

(1) $D_{im} = D_{(i-1)m} + \Delta D_{im},$

(2) $$\Delta D_{ie} = 0.827\ D_{0(i-1)} \left[(\tau_{i-1} + t_i - t_{i-1})^{0.274} - (\tau_{i-1})^{0.274}\right]$$

c. Compare ΔD_{im} with ΔD_{ie}

(1) If $\Delta D_{im} = \Delta D_{ie}$ set $\tau_i = \tau_{i-1} + t_i - t_{i-1}$,

(2) If $\Delta D_{im} > \Delta D_{ie}$, compute

(a) $D_{ie} = D_{(i-1)m} + \Delta D_{ie}$

(b) $$\tau_i = \left[\frac{D_{ie}(\tau_{i-1} + t_i - t_{i-1})^{0.274} + (\Delta D_{im} - \Delta D_{ie})\ (t_i - t_{i-1})^{0.274}}{D_{im}}\right]^{\frac{1}{0.274}}$$

(3) If $D_{im} < D_{ie}$, compute

$$\tau_i = \left[\frac{\dfrac{\Delta D_{im}}{t_i - t_{i-1}}(t_i - t_0)(\tau_{i-1} + t_i - t_{i-1})^{0.274} + \left[D_{(i-1)m} - \dfrac{\Delta D_{im}}{t_i - t_{i-1}}(t_{i-1} - t_0)\right]\tau_{i-1}^{0.274}}{D_{im}}\right]^{\frac{1}{0.274}}$$

d. Compute $D_{0i} = \dfrac{D_{im}}{0.827(\tau_i)^{0.274}}$.

For n increments, the reference 2-minute dosage D_{0n} is the value used in constructing the generalized curves for GB and VX respiratory effects.

In using the above procedure, three precautions must be observed. Firstly, τ_i cannot be permitted to decrease below 2 minutes. Although such occurrence would generally be unlikely, the possibility should be recognized in the computational procedure. Secondly, D_{0i} must be nondecreasing for successive increments. If $D_{0(k+1)} < D_{0k}$, as could occur through consideration of very low dosages produced by the trailing edge of a cloud over an extended time period, it is recommended that $D_{0(k+1)}$ be set equal to D_{0k} before proceeding to the next interval. Thirdly, since it is not apparent that the maximum value of D_{0i} will always exceed the actual peak 2-minute accumulation during cloud passage, a numerical comparison should be made, with the larger value obviously accepted as the basis for hazard-distance estimation.

5. CONCENTRATION MODELS

The mathematical model representing the maximum ground level concentration from an instantaneous point or virtual point source at a distance x is given by

$$\chi(x) = \frac{Q}{\sqrt{2}\pi^{3/2}\sigma_x\sigma_y\sigma_z}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad \text{(A-9)}$$

where

$\chi(x)$ = concentration at the point x (mg/m^3).

All others as defined above.

For the continuous case, differentiation is made between the purely continuous release and that of the quasi-continuous release. In the purely continuous case, the emission time is assumed to be sufficiently large so that a steady-state concentration is reached at each point downwind. The concentration[3] from a continous point source is numerically equal to the dosage from an instantaneous source whose total emission is numerically equal to the rate of the continous source, $\Delta Q/\Delta t$, thus,

$$\chi(x) = \frac{\Delta Q/\Delta t}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \Sigma\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad \text{(A-10)}$$

where

$\Delta Q/\Delta t$ = rate of emission (mg/min).

All others as defined above.

For the quasi-continuous releases,[4] the maximum axial concentration at a distance x is given by

$$\chi(x) = \frac{\Delta Q/\Delta t}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \text{ for } x < X_c,$$

$$\chi(x) = \frac{\Delta Q/\Delta t \; t_s}{\sqrt{2}\pi^{3/2}\sigma_x\sigma_y\sigma_z}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \text{ for } x > X_c. \quad \text{(A-11)}$$

where

$$X_c = \exp\left[\ln\ \{(t_s \cdot 60 \cdot u)/0.1522 \cdot \sqrt{2\pi}\}/0.9294\right] ,$$

ts = release time (min).

All others as defined above.

For a finite line source, either instantaneous or continuous, where the release is uniform over a line of length, L, in the crosswind direction, the axial concentration is given by

$$\chi(x) = \frac{Q}{L\sigma_x\sigma_z} \ \mathrm{erf}\left(\frac{L}{2\sqrt{2}\sigma_y}\right)\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad \text{(A-12)}$$

when all variables are as defined above.

6. EVAPORATION MODEL

The evaporation rate model[5] is reproduced here as it was originally presented in ORG report 40.[2] The only change in the methodology has been the conversion to metric units for consistency with this handbook. The procedure is as follows:

Determine the dimensionless Reynold's number, N_{Re} for the airflow from the equation

$$N_{Re} = \lambda \cdot U \cdot \rho / \mu \times 10^4 \quad \text{(A-13)}$$

where

λ = downwind length of the puddle (m),

U = wind speed (m/sec),

ρ = density of the air (gm/cm^3),

μ = viscosity of the air (poise(gm/cm · sec)).

The density of air in gm/cm^3 can be determined by

$$\rho = \frac{0.35232}{T} \cdot P \quad \text{(A-14)}$$

where

T = temperature (°K),

P = ambient pressure (atm),

The viscosity of air can be determined from

$$\mu = e^{(4.36 + .002844\ T)} \times 10^{-6}. \qquad \text{(A-15)}$$

From the Reynolds number, calculate the mass transfer factor, j_m, as follows:

$$j_m = 0.664\ N_{Re}^{\ -0.5} \qquad \text{for } N_{Re} < 20{,}000$$

$$j_m = 0.036\ N_{Re}^{\ -0.2} \qquad \text{for } N_{Re} > 20{,}000 \qquad \text{(A-16)}$$

With this, the mass transfer coefficient, Kg, is calculated by

$$K_g = G_m \cdot j_m \cdot (\mu/\rho d)^{-2/3} \qquad \text{(A-17)}$$

where

K_g = mass transfer coefficient (gm moles/sec · cm^2),

G_m = molar mass velocity of air (gm moles/sec · cm^2),

$(\mu/\rho d)$ = Schmidt number (dimensionless),

d = diffusivity (cm^2/sec).

The molar mass velocity of air can be detemined by the formula

$$G_m = \frac{U \cdot \rho}{M_A} \times 10^2 \qquad \text{(A-18)}$$

where M_A = molecular weight of air (gm/gm mole).

The diffusivity of air, d, may be computed from

$$d = 0.0043 \frac{T^{3/2}}{P(V_A^{\ 1/3} + V_L^{\ 1/3})^2} \cdot \left(\frac{1}{M_A} + \frac{1}{M_L}\right)^{1/2} \qquad \text{(A-19)}$$

where

T = temperature (°K),

P = ambient pressure (atm),

V_A = molecular volume of air at normal boiling point (cm^3/gm mole),

V_L = molecular volume of liquid at normal boiling point (cm^3/gm mole),

M_L = molecular weight of liquid (gm/gm mole).

Finally the evaporation rate, E, is defined by

$$E = K_g \cdot M_L \cdot P_L/(760 \cdot P) \cdot 6 \times 10^5 \qquad \text{(A-20)}$$

where

E = evaporation rate of liquid (gm/m^2 min)

P_L = vapor pressure of liquid at liquid air interface (mm Hg).

7. EVAPORATION RATE INTO STILL AIR

The model for evaporation in still air is reported in change 3 (June 1980) to TP10.[1] This methodology is to be used when the incident occurs within a closed building or other confined location that precludes the movement of air during the evaporation of the toxic liquid. The evaporation rate into still air is calculated using the following semiempirical equation:[6]

$$Es = 292(1 + 0.51\, Re^{1/2}\, Sc^{1/3})\ \ln\left(\frac{1}{1-P_v}\right) \frac{M_L}{T}\ d\ \frac{\lambda}{2} \qquad \text{(A-21)}$$

where

Es = evaporation rate (gram/min)

R_e = Reynolds number (using a wind speed of .03 m/sec)

Sc = Schmidt number

P = ambient pressure (atmospheres)

P_v = vapor pressure of liquid (atmospheres)

M_L = molecular weight of liquid

T = ambient temperature (°K)

d = diffusivity of air (cm^2/sec)

λ = diameter of spill (meters)

with

$$Re = \frac{0.03\ \lambda\ \rho}{\mu} \times 10^4 \tag{A-22}$$

ρ = density of vapor (g/cm^3)
μ = viscosity of vapor (g/cm/s)

$$s_c = \frac{\mu}{\rho d} \tag{A-23}$$

In calculating the Reynold's number, the effect of the agent vapor on the air viscosity and density will be ignored.

$$\rho = \frac{.3482}{T} \text{ (for water vapor pressure of 25 mm Hg)} \tag{A-24}$$

If the evaporation is into air with a molecular weight of 29 and the liquid has a molecular weight between 27 and 278, then the diffusivity of the liquid's vapor, following the Wilke-Lee equation, can be stated as follows:

$$d = \frac{.00205 T^{3/2} \sqrt{\frac{1}{29} + \frac{1}{M_L}}}{P \sigma^2_{12}\ \Omega_D} \tag{A-25}$$

where

d = diffusivity (cm^2/sec)

$$\sigma_{12} = \frac{\sigma_1 + \sigma_2}{2} = \text{average molecular collision diameter (angstroms)} \tag{A-26}$$

The collision diameter is estimated from the molecular volume as:[6]

$$\sigma = 1.18\ V_L^{1/3} \tag{A-27}$$

and

Ω_D = collision integral for diffusion

An empirical equation for Ω_D has been developed by Chen[7] as follows:

$$\Omega_D = 1.075 \left(T \frac{\kappa}{\epsilon_{12}}\right)^{-.1615} + 2 \left(10 \frac{\kappa}{\epsilon_{12}} T\right)^{-.74 \log \left(10 \frac{\kappa}{\epsilon_{12}} T\right)} \qquad \text{(A-28)}$$

where

$$\frac{\epsilon_{12}}{\kappa} = \sqrt{\left(\frac{\epsilon_1}{\kappa}\right) \cdot \left(\frac{\epsilon_2}{\kappa}\right)} \qquad \text{(A-29)}$$

where

κ is the Boltzman constant

ϵ_{12} is the energy of molecular interaction (ergs)

the value of ϵ/κ for the vapor may be estimated by:[6]

$$\epsilon/\kappa = 1.21\ T_b \qquad \text{(A-30)}$$

when T_b is the boiling point of the liquid (°K).

Since ϵ/κ for air is given as 78.6,* the value of $T\ \epsilon/\kappa_{12}$ in the Chen equation may be estimated as follows:

$$T \frac{\kappa}{\epsilon_{12}} = .1025 \frac{T}{\sqrt{T_b}} \qquad \text{(A-31)}$$

8. IMPACTION MODEL

The amount of VX that would impact on a man-sized object as a function of downwind distance and wind speed is estimated as follows[2]:

$$d_p = 0.454 \cdot Q_F \cdot (U/x)^{2.38} \qquad \text{(A-32)}$$

where

d_p is the amount deposited (dose per man) (mg)

Q_F is the munition fill weight (mg)

U is the wind speed (m/sec)

x is the downwind distance (m)

*NASA Technical Report R-132.

9. VX INHALATION-DEPOSITION

In order to consider the combined effects of aerosol impaction and vapor inhalation as would occur from an exploding VX filled M55, the combined toxicological effects are considered by converting to the intravenous dose d_I. This approach was developed for ORG 40[2] and explained in the handbook.[8] The equation relating the components can be expressed as follows:

$$d_I = D\,B + d_p\,F_s \qquad \text{(A-33)}$$

where

d_I is the intravenous dose (mg)

D is the inhaled dosage (mg-min/m^3)

B is the breathing rate (m^3/min)

d_p is the percutaneous dose (mg)

F_s is the skin factor

The inhaled dosage, D, can be computed using Equation 7.

However, if the agent fill weight, Q_F is used as the source, a factor must be introduced to adjust the dosage for the airborne-vapor efficiency of the explosion. An analysis done by Systems Analysis Directorate at ARRCOM, based on tests of the M55 conducted at Dugway Proving Ground, suggests that 13 percent is an appropriate figure. Thus, to compute the intravenous dose from inhalation:

$$DB = D_F \,.\, E_V \;\; B_\ell/1000 \qquad \text{(A-34)}$$

where

DB is the intravenous dose from inhalation (mg)

D_F is the 2-minute computed dosage from Q_F (mg min/m^3)

E_V is the vapor efficiency

B_ℓ is the breathing rate (ℓ/min).

If $E_V = 0.13$ and $B_\ell = 25$ ℓ/min, then:

$$DB = D_F\, 0.00325 \qquad \text{(A-35)}$$

From ORG 40[2] and the handbook,[8] the intravenous dose from deposition on the skin can be computed as follows:

$$d_p F_s = 0.455\ (u/x)^{2.38} F_s \qquad \text{(A-36)}$$

If F_s = 0.022 for light summer clothing,

$$d_p F_s = 0.01\ (u/x)^{2.38} \qquad \text{(A-37)}$$

10. HAZARD DISTANCES FOR THE M23 LAND MINE

From an analysis of experimental data conducted by Systems Development Division,[9] the following model was developed to estimate the impaction, or deposition dose, on a man-sized target downwind of a bursting M23 land mine filled with VX. The model is similar to that adopted for the M55 rocket except that the land mine produced very little vapor. Thus, the model for intravenous dose (equation A-33) contains only the deposition component for the M23 mine.

The depositon on a man-sized target is estimated by the following equation:

$$d_p = 0.262\ Q_F \left(\frac{u}{x}\right)^{2.24} \qquad \text{(A-38)}$$

where

d_p is the peak deposition dose per man (mg)

Q_F is the fill weight (mg)

u is the wind speed (m/sec),

x is the downwind distance (m)

If one assumes the vapor to be negligible, then

$$d_I = d_p F_s \qquad \text{(A-39)}$$

where

d_I is the intravenous dose (mg)

F_s is the skin factor

The downwind distance may be computed directly from

$$x = u \left(\frac{.262\ Q_F F_s}{d_I}\right)^{.4464} \qquad \text{(A-40)}$$

or for Q_F = 5.2E6, F_s = .022, and d_I = .1,

$$x = 279\ u \qquad \text{(A-41)}$$

Equation A-41 estimates the 1 percent lethality distance with light summer clothing from on bursting M23 mine, filled with VX.

For N mines, the equation is

$$x = 279\ u\ N^{.4464} \qquad \text{(A-42)}$$

11. HD EXPLOSIVE SOURCE

The methodology specified for explosive release of HD (as from the 4.2-inch mortar) in ORG 40[2] and the handbook[8] is not a physical analog in the same sense as the other models. It is a system of factors computed from wind speed, temperature, stability, and time that determines an agent recovery factor, R. This factor is multiplied by the fill weight, Q_F, and the product is used in an empirically fit version of the Gaussian diffusion model to estimate downwind hazard distance.

The tabular-graphic system appearing in the handbook[8] was approximated by a system of equations to permit automation on either a computer (FORTRAN) or a Pocket calculator. These equations are summarized as follows:

$$Q = Q_F R \qquad \text{(A-43)}$$

where R is the agent recovery factor

$$R = 1 \qquad \ln F_E < -1.2 \qquad \text{(A-44)}$$

$$R_1 = \exp(0.365 - 0.862 \ln F_E)$$

$$R = R_1 - \exp(-0.248 - 1.14 \ln F_E) \qquad -1.2 < \ln F_E < 0.4$$

$$R = R_1 - \exp(-0.0513 - 1.68 \ln F_E) \qquad \ln F_E > 0.4$$

The environmental factor, F_E, is defined by:

$$F_E = F_s \cdot F_W \cdot F_T \quad \frac{120}{t_A} \qquad \text{(A-45)}$$

where

F_E is the environmental factor

F_W is the wind speed factor

F_T is the temperature factor

t_A is the lapsed time after detonation (min)

Then

$$F_T = \exp(2.2 - 0.0837\ T_C) \qquad T_C < 27$$

$$F_T = \exp(2.05 - 0.077\ T_C) \qquad T_C > 27 \qquad \text{(A-46)}$$

where

T_C is the temperature (°C)

$$F_W = 1.55\ u^{-0.79} \qquad \text{A-47)}$$

The values of Fs are defined in Table A-2.

Table A-2. Parameters for Explosive HD

Stability	F_S	α,β	SY1	SZ1
A,B	0.7	3.3	0.00000147	0.0000628
C,D	1.0	1.4	0.0108	0.0204
E,F	1.25	1.02	0.0622	0.0636

The dosage at x is then computed from:

$$D(x) = \frac{Q}{60\pi\ \sigma_y(x)\ \sigma_z(x)\ u} \qquad \text{(A-48)}$$

where

$$\sigma_y\ (x) = \sigma_{y1}\ (x + B)^{\alpha}$$
$$\sigma_z\ (x) = \sigma_{z1}\ (x + C)^{\beta}$$
$$B = (3.8/\sigma_{y1})^{1/\alpha}$$
$$C = (0.2/\sigma_{z1})^{1/\beta} \qquad \text{(A-49)}$$

Equation A-48 is of the same form as equation A-5, except that source sigmas of 3.8 and 0.2 have been introduced. Please note that the values of α,β,σ_{y1} and σ_{z1} are not the same in Tables A-1 and A-2. The values in Table A-2 are to be used only for explosive HD sources.

12. PLUMES AND OTHER HEATED SOURCES

This section deals with the techniques involved in the calculation of an effective height of release

$$H = H_s + \Delta h$$

where

H_s is the release height

Δh is the amount of rise due to buoyancy or momentum of a release of agent possessing positive vertical-movement tendencies.

This tendency to rise, either by momentum or buoyancy, creates a pseudo release point at some particular height above the ground and at a distance downwind from the initial release point. The methods presented here are concerned with tracing the centerline as the cloud rises.

Several assumptions are present either explicitly or implicitly in the methods presented. The first is the absence of any major aerodynamic effects present to influence cloud rise. For example. the presence of buildings, topographical features, or the stack itself, in the case of plumes, can create wakes that may result in extremely high concentrations at ground level. A rule of thumb applicable to smoke stacks is that a stack 2.5 times the height of an adjacent building will minimize this phenomenon of downwash.[10] Also, a stack efflux velocity of at least 1.5 times the average wind speed at the top of the stack is usually enough to overcome the downwind pressure gradient creating the downwash effect.[10]

Another assumption is that the height of the mixing layer is greater than the estimate of the effective release height. In situations where this is not the case, the user is directed to Brigg's work,[10] where a methodology is presented for predicting whether a plume can penetrate through the mixing layer cap. In situations where the plume penetrates this cap, the effluent or pollutants are trapped above the surface mixing layer so that only negligible concentrations are expected at ground level.

12.1 Holland Model.

The Holland equation[11] has seen wide use for the determination of plume rise from industrial stacks. This equation frequently underestimates the effective height of the stack and, therefore, provides a slight safety factor in hazard distance calculations. Its major advantage is that each of the variables required is usually easily obtained or estimated. The form of the equation is as follows:

$$\Delta h = \frac{V_s d_s}{U}\left(1.5 + 2.68 \times 10^{-3}\, P_a\, \frac{T_s - T_a}{T_s} \cdot d_s\right) \qquad \text{(A-50)}$$

where

Δh = rise of plume above the stack (m),

V_s = mean stack effluent velocity (m/sec)

d_s = inside diameter of stack (m),

U = mean wind speed (m/sec),

P_a = ambient air pressure (mbar), not corrected to sea level.

T_s = stack effluent temperature (°K).

T_a = ambient air temperature (°K), and

2.68×10^{-3} is a constant with units $mbar^{-1}\ m^{-1}$

Holland[11] suggests that 10 to 20 percent of the rise given by the equation be added for unstable conditions and/or equal amounts subtracted for inversions.

Since the Holland equation is an empirical formulation, it should not be applied to stacks exceeding the ranges on which it was developed, i.e., stack diameters from 1.7 to 4.3 meters and stack temperatures from 82 to 205 °C.[12] It should also be noted that the downwind displacement between the stack and the point at which the maximum rise occurs is not measured by this method. Thus, this technique should not be used if the resulting hazard distance is within a few hundred meters from the stack, since this value will tend to underestimate the true distance.

When more accurate estimates of cloud rise are required, the following methods derived by Briggs are capable of providing such results.

12.2 The Briggs Model.

An important result of the study by Briggs[10,13] was that buoyant plumes were found to follow a 2/3 power law. The assumptions were made that buoyancy is conserved and that any initial momentum is negligible for a very buoyant plume in unstratified surroundings.[13] The form of the equation:

$$\Delta h = 1.6\ F^{1/3}\ x^{2/3}\ U_z^{-1} \quad \text{(A-51)}$$

where

F = initial buoyancy flux divided by $\pi\rho$ (m^4/sec^3).

$$= \left(\frac{T_s - T_a}{T_s}\right) \left(\frac{g\ V_s\ d_s^2}{4}\right)$$

T_a = ambient temperature (°K),

T_s = plume temperature (°K),

V_s = mean stack effluent velocity (m/sec).

g = gravitational constant (9.8 m/sec^2),

d_s = internal stack diameter (m),

x = downwind distance from stack (m), and

U_z = average wind speed at top of stack (m/sec).

The constant, 1.6, in equation A-51 is based on a "best-fit" of empirical data and corresponds to a value of the entrainment coefficient of 0.6, which is typical of large fossil-fuel plants.

The vertical structure of the wind in the lowest turbulent layer, from the surface to approximately 300 m, has been adequately described by the empirical power law in which

$$U_z = U_r(z/z_r)^p \tag{A-52}$$

where

U_r = wind speed measured at height z_r (m/sec),

z = stack height (m), and

p = wind profile exponent (nondimensional).

Values for p are provided for various locations in Appendix D of the handbook.[8] Since the values presented there are topographically dependent and not site-dependent, the wind profile exponents can also be used for sites not included. On the basis of terrain type, values associated with Dugway Proving Ground can be used for flat terrain, those for Anniston Army Depot for rolling or hilly terrain, and those for Johnston Island can be used for marine sites.

For neutral stability, a good approximation is given by:

$$\Delta h = 1.6\ F^{1/3}\ U_z^{-1}\ x^{2/3} \qquad \text{when } x < 3.5\ x^*$$

$$\Delta h = 1.6\ F^{1/3}\ U_z^{-1}\ (3.5\ x^*)^{2/3} \qquad \text{when } x > 3.5\ x^* \tag{A-53}$$

where x^* is calculated by the relationships,

$$x^* = 14\ F^{5/8} \qquad \text{when } F < 55\ m^4/sec^3$$

$$x^* = 34\ F^{2/5} \qquad \text{when } F > 55\ m^4/sec^3. \tag{A-54}$$

For stable regimes, equation A-51 is valid approximately to the maximum distance $x = 2.4\ U_z\ s^{-1/2}$ where s is defined by:

$$s = \frac{g}{T_a}\frac{\partial\theta}{\partial z} \tag{A-55}$$

where $\frac{\partial\theta}{\partial z}$ = average potential temperature gradient (°K/m).

Beyond the distance, x, defined above, the height of the plume centerline levels off under stable conditions at about

$$\Delta h = 2.5\ (F/U_z s)^{1/3} \tag{A-56}$$

In situations where there are calm or very light winds under stable conditions, the following formula developed by Morton, Taylor, and Turner[14] best applies if it gives a lower plume rise than equation A-50:

$$\Delta h = 5.0\ F^{1/4} s^{-3/8}. \qquad \text{(A-57)}$$

Briggs[13] notes that equations A-53 and A-54 apply satisfactorily in unstable conditions as well, and also in slightly stable conditions, if they give a lower plume rise than equation A-56.

12.3 The Briggs-Thomas Model.

Thomas[15] also working with the "two-thirds power law," determined plume rise to correspond to the following formulation, which uses the Pasquill categories for determining atmosphere stability classification.

$$\Delta h = C F^{1/3} U_s^{-1}\ x^{2/3} \qquad \text{(A-58)}$$

Based on observations under various stability conditions:

$$C = 1.065 - 6.25\ \frac{\partial \theta}{\partial z} \qquad \text{(A-59)}$$

where $\frac{\partial \theta}{\partial z}$, the average potential tempeature gradient, is defined in Table A-3.

Table A-3. Average Potential Temperature Gradient

Stability	Pasquill stability category	$\frac{\partial \theta}{\partial z}$ ($^{\circ}$K/m)
Extremely unstable	A	-0.010
Moderately unstable	B	-0.008
Slightly unstable	C	-0.006
Neutral	D	0.000
Slightly stable	E	0.010
Moderately stable	F	0.037

12.4 Jet Plumes.

In the case of jet plumes, where momentum is the overriding factor in plume rise, it is recommended that in neutral, windy conditions the trace of the centerline is given by:

$$\Delta h = 1.44 d_s (V_s/U_z)^{2/3} (x/d_s)^{1/3} \quad \text{(A-60)}$$

and is valid at least to the point

$$\Delta h = 3 \cdot V_s/U_z \cdot d_s \text{ providing } V_s/U_z > 4. \quad \text{(A-61)}$$

For windless conditions, the jet rises to

$$\Delta h = 4(F_m/s)^{1/4} \quad \text{(A-62)}$$

where

$$Fm = \text{momentum flux parameters}$$

$$= \frac{\rho_o}{\rho_A} V_s^2 \cdot \frac{d_s^2}{4}$$

ρ_O = density of gases emitted from stack (gm/m^3)

ρ_A = density of ambient air (gm/m^3).

Other variables as defined above.

From a purely theoretical standpoint, Briggs suggests using the following formula in a stable regime with some wind and also recommends its use if it predicts a lower rise than either equation A-61 or A-62. The theoretical formula based on his model is:

$$\Delta h = 1.5 (F_m/U_z)^{1/3} s^{-1/6} \quad \text{(A-63)}$$

12.5 Rise of Heated Clouds.

Technical Paper No. 10[1] presents a methodology for the calculation of the rise of a heated cloud resulting from a fire or explosion in a stable atmosphere. The method is based on the work by Briggs[13] and extended by Dumbauld et al.[16] This presentation of the method has been simplified and the notations made to conform with that used in this handbook.

The maximum cloud rise, Δh, downwind from an instantaneous source in a stable atmosphere, is given by

$$\Delta h = \left[\frac{6F}{\gamma_I^{3} s} + \left(\frac{r}{\gamma_I} \right)^4 \right]^{1/4} - \frac{r}{\gamma_I} \qquad \text{(A-64)}$$

F = buoyancy parameter

$$= \frac{gQ_h}{\pi \rho_\alpha C_p T_a}$$

g = acceleration due to gravity (9.8 m/sec^2),

Q_h = effective heat released (cal),

ρ_α = density of ambient air (gm/m^3),

C_p = specific heat of air at constant presssure (0.24 cal/gm °K),

T_a = ambient air temperature (°K),

γ_I = entrainment coefficient for an instantaneous source (dimensionless),

r = initial cloud radius (m),

$s = \frac{g}{T_a} \frac{\partial \theta}{\partial z}$ restoring acceleration per unit vertical displacement for adiabatic motion in atmosphere (sec^{-2}),

$\frac{\partial \theta}{\partial z}$ = vertical potential temperature gradient (°K/m).

(Estimates for this are provided in Table A-3.)

It is recommended[1] that a value for γ_I of 0.64 be used for large explosive releases.

The maximum cloud rise Δh, downwind from a quasi-continuous source (see section 7.4 of the handbook)[8] in a stable atmosphere is given by:

$$\Delta h = \left[\frac{6\ F_c}{U\gamma_c^{2} s} + \left(\frac{r}{\gamma_c} \right)^3 \right]^{1/3} - \frac{r}{\gamma_c} \qquad \text{(A-65)}$$

where

U = mean wind speed (m/sec),

F_C = continuous buoyance parameter

$$\frac{gQ_c}{\pi \rho_a C_p T_a}$$

Q_C = effective heat released (cal/sec),

γ_C = entrainment coefficient for a quasi-continuous source dimensionless

Other variables as defined above.

Briggs[13] cites a value of 0.5 for γ_C for buoyant plumes such as those resulting from uncontrolled fires.

13. CONCENTRATION IN AN INVERSION BREAKUP FUMIGATION

A ground-level inversion may be eliminated by the upward transfer of heat when the ground is being warmed by solar radiation. In the transient situation, substances that have been emitted into the stable layer will be mixed vertically as they are reached by the thermal eddies. As a result, the ground level concentrations can increase over what would be expected under either stable or unstable conditions. This process has been called fumigation.

In the Workbook of Atmospheric Dispersion Estimates, Turner[17] recommends essentially a box model with the height taken as the height of release plus 2 sigma-Z. He further suggests that the cloud width be increased by a 15-degree angle through the downward transport.

$$\chi_F = \frac{Q}{\sqrt{2\pi}\, U \sigma_{yF} H_I} \tag{A-66}$$

χ_F = the peak concentration under fumigation conditions

$\sigma_{yF} = \sigma_y + H/8$

$H_I = H + 2\sigma_z$

σ_y is for stable conditions

Other parameters are as defined previously.

14. IGLOO FIRE MODEL, M55 ROCKET

The most complete report on the consequences of an igloo fire containing M55 chemical munitions is given in ORG Report 44.[18] The reader is advised to consult this report for an understanding of the many aspects of this problem. The following is a tabulation of particulars extracted from this report that may be useful in routine downwind hazard calculations.

14.1 GB Fill.

14.1.1 The source is taken as the fill of 2.52 percent of the rockets stored.

14.1.2 The agent is released according to the following schedule:

Time interval (min)	Source (%)	Cumulative time (min)
15	91	15
5	6	20
40	3	60

14.2.1 VX Fill.

14.2.1 The VX source is taken as 0.164 percent of the total fill.

14.2.2 This source is released over a period of 5 minutes.

15. PALLET MODEL, M55 ROCKET

Data on sympathetic detonation within a pallet of M55 rockets is reported in AEO Report No. 24-77.[19] This report concluded that the equivalent of 2 rockets would detonate, and the contents of the remaining 13 would spill and be distributed over an area 9 x 61 meters. A subsequent analysis by CSL* indicated that this evaporative source could be approximated as a normal volume where SXS = 0.83 m and SYS = 7.0 m.

16. SELECTION OF ATMOSPHERIC STABILITY

The classification scheme for atmospheric stability employed in subroutine PSST3 is based on a system proposed by Pasquill.[20] The system was quantified and reduced by a system of logical decisions by Turner[21] based on the elevation angle of the sun, cloud cover, and cloud height. These parameters determine a net radiation index for heating of the surface during the day and for cooling at night. The stability class is then estimated as a function of wind speed. This logic is summarized in Tables A-4 and A-5.

17. DIFFUSION PARAMETERS IN FOREST TERRAIN

The diffusion parameters recovered from subroutine WOODS are a matter of professional judgment based on a body of field data. These estimates first

*Analysis done by C. G. Whitacre, CRDEC, in 1978 in which rocket fragments were traced to infer the distribution of liquid agent. Unpublished data.

appeared in a GCA Corporation progress report for January 1967. The author, Dr. Harrison E. Cramer, revised these estimates in April of that year at the request of ORG. The values were recorded in a Memorandum for Record, 5 May 1967, by Mr. Irving Solomon of ORG.* See Table A-6.

Table A-4. Net Radiation Index

	Day						Night*			
Cloud cover (1/10)	0-5	6-9			10		10		9-5	4-0
Cloud height (1000 ft)		> 16	16-7	< 7	≥ 7	< 7	< 7	≥ 7		
Solar altitude										
< 15°	1	1	1	1	1	0	0	-1	-1	-2
15-35°	2	2	1	1	1	0				
35-60°	3	3	2	1	2	0				
> 60°	4	4	3	2	3	0				

*Night is defined as the period from 1 hour before sunset to 1 hour after sunrise.

Table A-5. Pasquill Stability Category as a Function of Net Radiation Index and Wind speed

Wind speed m/sec	Net radiation index						
	4	3	2	1	0	-1	-2
< 1	A	A	B	C	D	F	F
1	A	B	B	C	D	F	F
2	A	B	C	D	D	E	F
3	B	B	C	D	D	E	F
4	B	C	C	D	D	D	E
5	C	C	D	D	D	D	E
6	C	C	D	D	D	D	D
> 6	C	D	D	D	D	D	D

*A copy of this memorandum is on file in the Studies and Analysis Office, CRDEC.

Table A-6. Diffusion Parameters in Forest Terrain

Windspeed: Reference outside canopy (mph)	Windspeed: Reference outside canopy (m/sec)	Windspeed: Transport under canopy (m/sec)	α	S_{y100}	β	S_{z100}
Deciduous Forest, Winter						
1	0.45	0.089	0.8	12.8	1.2	8.97
5	2.20	0.45	1.0	12.1	1.2	9.66
12	5.40	1.1	1.0	12.0	1.2	10.35
20	8.90	1.8	1.0	12.0	1.2	10.35
Mixed Deciduous and Coniferous Forest, Winter						
1		0.089	0.8	18.2	1.3	12.96
5		0.36	1.0	17.5	1.3	13.78
12		0.8	1.0	16.8	1.3	13.78
20		1.3	1.0	14.5	1.3	13.78
Coniferous Forest						
1		0.089	0.8	23.5	1.3	14.59
5		0.36	1.0	22.5	1.3	15.4
12		0.8	1.0	19.0	1.3	15.4
20		1.3	1.0	14.0	1.3	15.4
Mixed Deciduous and Coniferous Forest, Summer, and Deciduous Forest, Summer						
1		0.045	0.8	29.0	1.4	20.4
5		0.22	1.0	26.5	1.4	20.4
12		0.54	1.0	22.5	1.4	20.4
20		0.89	1.0	16.5	1.4	20.4
Tropical Rain Forest						
1		0.045	1.0	53.0	1.0	34.5
5		0.13	1.0	36.0	1.0	34.5
12		0.27	1.0	26.0	1.0	34.5
20		0.45	1.0	23.0	1.0	34.5

LITERATURE CITED

1. Technical Paper No. 10. Methodology for Chemical Hazard Predictions. Department of Defense Explosives Safety Board. March 1975. UNCLASSIFIED Report.

2. Solomon, Irving et al. ORG Report 40. Methods of Estimating Hazard Distances from Accidents Involving Chemical Agent. Operations Research Group, Edgewood Arsenal, Maryland. February 1970. CONFIDENTIAL Report.

3. Milly, George H. ORG Study No. 17. Atmospheric Diffusion and Generalized Munitions Expenditures. Operations Research Group, Army Chemical Center, Maryland. May 1958. UNCLASSIFIED Report.

4. Robinson, Philip E. Model for the Estimation of Concentration Levels from a Finite Time (Semi-Continuous) Release. FORTRAN Programs Listing, Systems Analysis Office, Edgewood Arsenal, Aberdeen Proving Ground, Maryland. June 1975. UNCLASSIFIED Report.

5. Chemical Engineers' Handbook, 3d Edition. J.H. Perry, Editor. McGraw-Hill Book Company, Inc. New York, N.Y. 1950.

6. Rife, R.R. THAMA Report No. DRXTH-ES-TM-81101. Calculation of Evaporation Rates for Chemical Agent Spills. March 1981. UNCLASSIFIED Report.

7. Chen, N.H. Empirical Equation for the Collision Function on Lennard-Jones Potential for Gas Diffusion Coefficient. Ind. Eng. Chem. 51, 1494 (1959).

8. Handbook for Chemical Hazard Prediction. U.S. Army Materiel Development and Readiness Command. March 1971. UNCLASSIFIED Document.

9. Whitacre, C. Glenvil. ARCSL-TR-79023. Downwind Hazard from Bursting M23 Land Mine. April 1979. UNCLASSIFIED Report.

10. Briggs, Gary A. AEC Critical Review Series, No. TID-25075. Plume Rise. November 1969. UNCLASSIFIED Report.

11. AEC Report ORO-99. A Meteorological Survey of the Oak Ridge Area. U.S. Weather Bureau, Washington, DC. 1953. UNCLASSIFIED Report.

12. Moses, H., Strom, G.H., and Carson, J.E. Effects of Meteorological and Engineering Factors on Stack Plume Rise. Nucl. Saf. 6(1), 1-19 (1964).

13. Briggs, Gary A. Some Recent Analyses of Plume Rise Observation. Proc. Second Int. Clean Air Congr., Academic Press. New York, NY. 1971.

14. Morton, B.R., Taylor, G.I., and Turner, J.S. Turbulent Gravitational Convection from Maintained and Instantaneous Sources. Proc. R. Soc. London Ser. A 234, 1-23 (1956).

15. Thomas, F.W., Carpenter, S.B., and Colbaugh, W.C. Plume Rise Estimates for Electric Generating Stations. Philos. Trans. R. Soc. London 265, 221-243 (1969).

16. Dumbauld, R.K., Bjorklund, J.R., and Bowers, J.F. NASA Contractor Report CR-61327. NASA/MSFC Multilayer Diffusion Models and Computer Program for Operational Prediction of Toxic Fuel Hazards. NASA Marshall Space Flight Center, Huntsville, Alabama. 1973. UNCLASSIFIED Report.

17. Turner, D.B. Workbook of Atmospheric Dispersion Estimates. p. 53. Public Health Service Publication 999-AP-26, Robert A. Taft Sanitary Engineering Center, Cincinnati, OH. 1967.

18. Solomon, Irving et al. ORG Report 44. Hazards Associated with the Handling and Storage of M55 Chemical Rockets (U). Operations Research Group, Edgewood Arsenal, MD. May 1971. CONFIDENTIAL Report.

19. AEO Report No. 24-77. T410 Propagation Between Munitions for Palletized M61 Rockets, Ammunition Equipment Office. Tooele Army Depot, Tooele, UT. October 1977. UNCLASSIFIED Report.

21. Turner, D. Bruce. Relationship Between 24-Hour Mean Air Quality Measurements and Meteorological Factors at Nashville, Tennessee. J. Air Poll. Contr. Assoc. 11, 483-489 (1961).

APPENDIX B

NOTES ON PROGRAM CONSTRUCTION

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APPENDIX B

NOTES ON PROGRAM CONSTRUCTION

1. INTRODUCTION

The following is a collection of notes on the internal workings of the D2PC program. These are like external comment cards (on paragraphs). The normal user of the program will not need to remember all of this, but it should be useful for any future modifications.

The program is written in FORTRAN 77 and was originally compiled and tested on the UNIVAC 1100/60 computer. The source program was then transferred to an IBM compatible Eagle PC and recompiled with microsoft FORTRAN 3.3. The only changes made in the source code were the format of the INCLUDE statement in MASTER (see Section B-5 below) and the addition of a back slash (\) to line 27 of subroutine DEF. This permits keyboard entries to be displayed on the same line with the word INPUT.

2. COMMON

Communication between MASTER and the subroutines is, for the most part, accomplished through a block of unlabeled common (107 words). With the expansion of the ALL statement to include all input variables, common was extended to all of the subroutines except ERF, WOODS, UNT, and READA. The other subroutines that have arguments in their CALL statements (EVAP, PLRS, STAB, and DEF) employ the common block but identify only a segment of the variable names in each. Of course, the segment in each subroutine must coincide with the position in MASTER. This is accomplished by introducing dummy arrays before and after the segment to position the variable of interest. The remaining values are exchanged through the argument list. The MASTER and subroutines DDS, CDS, and QLIST contain the complete common list.

3. THE ALL QUESTION

Beyond the exchange of information, the common block of data is also used by MASTER to assign values to the variables during the random order input from the ALL question. This is accomplished through a parallel array, PNU, which lists the three-letter literal name of each variable as it is known in the ALL question. The PNU array corresponds to the COMMON block beginning with variable PR(1) and ending with ID2.

This random order input is accomplished by first searching the PNU table to identify the position of the variable name and then storing the argument in the corresponding position in COMMON. The variables PR(1), LOCT(1), and IPR(1) are taken as the reference positions.

There are several complications in this storage process. The variable name is always alphabetic, but the argument can be real, integer, or alphanumeric. The real and integer can be entered through the free format available in FORTRAN, but an alphabetic input in the data field is more troublesome. This is accomplished in FORTRAN 77 by reading the field, initially, as a character string and then rereading this string with different formats. This created another problem in that the rereading statement (where the string variable name is given as the input channel) would not accept the free format designation. The free format is approximated by using the BN (blank null) option in the format; this permits free positioning within the field specified, but each variable must be in a new field as specified. Thus, the free format is limited to one variable per input. This is acceptable for the ALL question since the first field is always three alphanumeric characters, and only the second field needs to be in free format.

Table B-1. Storage Process

	Variable				Variable		
	Literal	Program	J		Literal	Program	J
1.	TIM	RP(1)	1	35.	CRD	CR	1
2.	DLX	DXT		36.	SLA	SLA	1
3.	HTS	HT		37.	SLO	SLO	1
4.	HML	HML		38.	CCT	CC	1
5.	SXS	SXS		39.	CHT	CH	1
6.	SYS	SYS		40.	SUN	AE	1
7.	SZS	SZS		41.	PMM	PMM	1
8.	TMC	TIVCH		42.	ZZO	ZO	
9.	WND	UT	1	43.	LOC	LOCT(1)	1
10.	BRT	BR		44.	SEA	SEAT	1
11.	SKF	SF		45.	MUN	MUNT	1
12.	TMP	TMP	1	46.	AGN	AGNT	1
13.	ALF	ALFA		47.	REL	REL	1
14.	SYR	SY100		48.	STB	MTC	1
15.	BTA	BETA		49.	SUR	SUR	1
16.	SZR	SZ100		50.	WOO	WT	1
17.	SMH	Z		51.	HLD		
18.	REF	RC		52.	RLS		
19.	SEV	V		53.			
20.	QQQ	QS	1	54.	IRT	IPR(1)	
21.	TEV	TEVP	1	55.	NDI	ND	
22.	ARE	SAVP	1	56.	OPO	IPO	
23.	LEN	FL	1	57.	2MC	I2MC	
24.	FMW	FMW	1	58.	IMA	IMA	
25.	FMV	FMV	1	59.	OPC	IPC	
26.	VAP	VP	1	60.	IMM	IMM	1
27.	BPT	BP	1	61.	IDD	IDD	1
28.	HST	HS		62.	HRS	IHR	1
29.	DST	DS		63.	NOV	NOV	
30.	TST	TSC		64.	INP	INP	1
31.	VST	VS		65.	MNR	MRL	
32.	RDE	RDE		66.	NMU	NMU	1
33.	FRO	P		67	NCI	ND	
34.	HRL	HR					

For convenience, this storage process divides the PNU table into three segments. Elements 1 through 42 are input as real variables; 43 through 53 are alpha, and 54 through 67 are integer. The integer portion uses variable IPR(1) as a new reference point. Table B-1 lists the variable names as identified by PNU, the name of the variable as it appears in COMMON, and the corresponding flags in the J table. (The J table is discussed later under rescan).

The control variables (ALL, STP, RST, RSN, GTO, etc.) do not require storage of an argument, and these are intercepted by a scan against PNUC before the scan of the PNU table.

The commands hold (HLD) and release (RLS) are identified from the PNU table to determine the value of the index I. An additional scan of the PNU table is then performed with the argument (PRT) to establish which variables are to be flagged for hold. This generates the index II, which stores or clears a flag in the K array.

The operation of the program rescan in successive runs was discussed in the body of the report. The mechanism that controls this rescan is based on the sum of J(I), which is accumulated with each entry in the ALL question. When the word ALL is given, this sum is tested and if greater than zero the rescan will occur.

4. INDEX NAMES

All of the multiple choice answers that are read in questions 2, 3, 4, 6, 8, and 9 are converted to integer index values for use in the program logic. Table B-2 identifies the variable name with the index name for each.

Table B-2. Variable and Index Names

Variable	Index
LOC	IL
SEA	IS
MUN	IMU
AGN	IA
REL	IR
STB	IM

5. THE INCLUDE STATEMENT

The MASTER program contains an INCLUDE (line 22). The operation of this statement will be explained to help the user develop an alternative if his system does not permit the INCLUDE statement.

In the UNIVAC version of this program the statement appears as INCLUDE HMLMDR. Here HMLMDR is a FORTRAN PROC that is listed at the end of the program (Appendix E). In operation, the PROC is included at compile time as if the statements were written into the program.

In the 1100/60 system, the PROC must be prepared by processing with a PDP,F processor and available in the file whenever the calling program is compiled. For the MICROSOFT processor, the format of the INCLUDE statement is changed to $INCLUDE: 'HMLMDR.FOR' with the dollar sign in column 1.

6. INTERNAL INDICATORS

Internal indicators are variables that are assigned values within a program to convey information to another part in the program or to remember for a later time. A few of these will be discussed here for the user's (programmer's) information.

The indicator IDEP is used by MASTER to select the downwind model in subroutine DDS. A value of -1 indicates that the instantaneous release of HD is requested. This will cause DDS to CALL HD42, which will compute the airborne source and assign special diffusion parameters.

IDEP is assigned a value of 1 when the inhalation-deposition model based on the M55 rocket is used. Here the vapor source is taken as 13 percent of the fill weight, and the downwind dosage at each distance is converted to the intraveneous dose, which is then added to the percutaneous dose from the impaction model. IDEP is assigned a value of 2 for the M23 land mine. The downwind hazard calculation for the M23 is based on the percutaneous dose alone. Both the M55 and M23 models are part of DDS.

The indicator I2MC is the internal equivalent of 2MC in the ALL statement and is used to control the 2-minute correction in DDS. Normally the 2-minute correction is applied to GB and VX vapor at levels of response above "no effects." In program D2 the D(1) level of response will not contain the 2-minute correction unless specifically instructed. In normal operation, when the response dosages are drawn from the tables automatically, the "no effects" value is written into D(1). Then, if the value of MNR is set to zero, the DDS subroutine will change I2MC to zero after the distance for D(2) has been computed, and thus drop the 2-minute correction for D(1).

In the event that one does not wish I2MC to change for D(1), a hold can be placed on I2MC (HLD 2MC) in the ALL question. The hold flag is stored in the K table, but the K table is not available to subroutine DDC. Therefore, the hold signal is transmitted to DDC by setting the value of I2MC at 1 instead of 2, which is the usual 2-minute correction signal.

The K table is used by MASTER to remember the variables that have been flagged as hold. This is a 67-element table that corresponds to PNU. A flag can be set for any variable (in ALL), but only the few that can be overwritten by rescan have inhibit tests installed.

Element 67 in the K table corresponds to NCI in the PNU list. This element is used to place an automatic hold on NCI when IMA is set to 1, 2, or 3. The value of K(67) is given the value of PRT at the time IMA is identified in the ALL statement. Then, since IMA = 0 in the dosage configuration, this releases the hold on NCI automatically. The D table in COMMON is used to store both the values of DI and CI, and NDI and NCI are defined within the program as ND. Thus, a hold placed on either NDI or NCI will prevent the table look-up of DI.

When the plume rise subroutine, PLRS, is called by specifying releases STK, STJ, FLS, or FIR, a special programming problem is created by permitting the cloud to rise with downwind distance (OPC = 2 or 3). When these release modes are specified, the MASTER calls PLRS with the argument XI set to zero. This begins a process in PLRS that can list the DHT = f(x) table (OPC = 1 or 3) or the various values of DHTMX, which is the maximum cloud rise. In this process, the distance for maximum rise (XMX) is stored, and the stack height (HST) is added to DHTMX and stored in COMMON as HT. This is the value used by DDS or CDS if OPC is given as 0 or 1. If OPC is given as 2 or 3, this maximum height is listed as the release height in the second line of output from DDS or CDS, but HT is now recalculated for each downwind distance and listed in the output.

To control the interchange between PLRS and DDS or CDS, a control indicator, IRTP, is initially assigned a value of IRTP = 1 (or IRTP = 0 when 4 < IR < 9) in DDC or CDC. This first controls the bypass of CALL PLRS. If PLRS is called, IRTP is redefined in PLRS as -1 when OPC = 2 or 3. Then as x increases beyond XMX, the value of IRTP is changed to one. This now bypasses the call to PLRS. IRTP is also used in the logic of selecting the contour length (or hazard distance) to a specified dosage. Here the calculation of downwind distance continues one cycle beyond the height where the maximum height of the cloud has been reached. This prevents the program from selecting the hazard distance from the first mode of the bimodal distribution, which can be caused by the rising cloud.

The indicator IER is used in the interpretation of question 15 to remember that there was an error on the initial reading of PRT. After PNUT is identified, IER causes PRT to be reread as an alpha field.

The variable IRL is set to one to remember that the dosages of interest have been drawn from the tables and thus that the interpolated distances can be labeled on output (1%, ND, NE). Values that are input with NDI are not labeled.

The indicator ISM is set to one when the command SMD is used to initiate execution of DDS. When ISM equals one, the table of dosages (DS(K)) is not cleared from the previous run. The dosages for corresponding values of X are always added to the current value so that this will sum the dosages from the previous run (or runs) with the present and thus accumulate the dosages for multiple releases.

The arguments interchanged with subroutine DEF are normally the question number, IQ, and the return indicator, IRT, that tells the calling subroutine when the question has been asked (0 = N, 1 = Y). (Note that this internal IRT is different from the IRT in the control commands.) Many variations are used. A zero value for IQ causes the IQT table (which remembers which questions have been asked) to be cleared to zero; a negative question number clears the block on that question only. An IQ value greater than 40 will print the options and definitions for the question defined by the number minus 40. An IQ value of 39 prints the information table when NOV equals 3.

When IQ equals 40, a negative value of IRT will print one of the four tables requested with the TAB command. A positive value of IRT will list the options and definitions requested for the question requested by a DSP command. An IQ value of 40 and an IRT of zero prints the table definition requested by three question marks. These controls are set up in the MASTER in response to commands TAB, ???, and DSP.

When TMC (time to met change) is assigned a value in the ALL question, the program converts this time into the distance (XCH) the cloud would travel at the specified wind speed. If the distance to minimum response exceeds XCH, the program will stop with the questions:

INPUT: STB
INPUT: WND, HML, TMC.

This is a request for the new met conditions. The new value of TMC is now the length of the next interval in minutes. Internally, the interplay between MASTER and DDS is controlled by TIVCH, which transmits the value of TMC to DDS, and the indicator, IMTCH, which controls the special return to MASTER.

7. ADDITIONAL CAPABILITIES

There is a data base for stability categories I and N. These are recognized by MASTER, and values for the diffusion parameters are given in DDS and CDS. These parameters are intended for inversion and neutral stability in urban areas. These values were taken from a 1957 Fort Detrick Report* and further study is planned.

An additional capability is a provision to compute the cloud width with distance (OPO = 3). The user is cautioned in following these estimates of width in safety applications. The width is measured from the pattern centroid, but the centroid is subject to shifts with wind direction, terrain, and obstructions. Thus the width is useful for area calculations, but a safety corridor should be wider.

The commands RUN and PEEK are intended for deep debugging. The RUN command will cause the program to execute the downwind hazard estimate without considering if the program should first rescan. The PEEK command will cause the program to display the current values in COMMON. The PEEK options are as follows.

PEEK 1 List QT(), TWL()
2 List DI(), DIL()
3 List 42 real values
4 List 11 alphanumeric codes
5 List 21 integer values
6 List D-A generated by vapor depletion run

Options 3, 4, and 5 will display the three-character code for each variable (TAB 4) with the current numeric value.

*CML 2564. Semi-Annual Report, April-September 1954, Contract #DA-18-064-CML-2564, Department of Chemistry, Stanford University. UNCLASSIFIED Report.

8. SUBROUTINE UNT

The units conversion capability provided by subroutine UNT is designed to be invisible to the user when conventional metric units (as specified in the questions) are used. That is, the user needs to input no special code to identify these units. Other units, however, must be identified so that the program can initiate the conversion.

The conversion process is initiated when a read error is created in one of the questions requesting numeric input. This error occurs when alpha characters are found in the free format portion normally used to input numeric information. At this point, the program rereads the last input, now extracting the first two characters as the conversion code. If this is successful, the code is searched with the literal codes in table MNE to identify the proper conversion factor from table UC. Then, if the units are recognized as a volume, the density from table DN25 is included. If the code is not understood or the reread contains an error, the program clears the input block, lists the unit codes, and loops back to repeat the question.

9. SUBROUTINE READA

Subroutine READA is provided to extract the units conversion code from numeric inputs and call UNT. The arguments are defined as follows:

UM is the unit code
IA is the agent index
PRT is the argument being converted
IQ is the question number
IRT is the return message to repeat.

The argument is processed as PRT but returned to the calling program as the fourth argument in the call statement.

10. SUBROUTINE QLIST

The text of the numbered questions now come from subroutine QLIST. In operation the program calls DEF with the question number. DEF determines if the question has been asked and if not prints options and definitions as directed by the value of NOV. It then calls QLIST, transmitting the value of IRT. If the question has not been asked, the question and code are printed. On rescan when the question has been asked, QLIST also recovers the current value of the parameters from COMMON and displays this with the question.

The text of the questions is stored as array QTAB and the three-character parameter codes are listed in a parallel array, SYM. When IRT = 1, the text of the question and the parameter code indicated by IQ are displayed. When IRT = 1, the question and code are followed by the current value of the parameter. This is accomplished through array IQR, which identifies the location of each parameter in COMMON in terms of the question number. Another array, IQM, specifies how many values are associated with each question.

The use of arrays PR(1), LOCT(1), and IPR(1) as markers in the common table is recognized as somathing of a tour de force in this program.

Equivalence arrays would have been easier to follow (or explain). It should also be noted that placing the character strings in COMMON is not standard for the UNIVAC FORTRAN 77 and it will complain, but it still works.

11. SUMMING D(X)

A two-column table, DS (dimensioned 51,2) is defined in subroutine DDS to sum dosages at corresponding distances from multiple releases. The current (last generated) dosages are written in level 1 with each execution. Level 1 may be summed into level 2 with the command SMD. If the command SMP is given before the last ALL, the next downwind distance is distance based on the last Sum (level 2) and the current DP (level 1). The Sum column is cleared with the command SMC.

These operations are performed in subroutine DDS and are controlled from MASTER by indicator ISM. ISM is set to zero for SMC, to 1 for SMD, and 2 for SMP. Otherwise, ISM equals 3.

These control commands are intercepted in the PNUC loop in HDS3 (line 250). The commands SMC and SMD set the value of ISM in HDS3 and then call DDS. In DDS the value of ISM causes DS(I,2) to be cleared or summed from DS(I,1). Control then returns to the ALL loop in HDS3. The command SMP sets ISM to 2, which will cause DS(I,2) to be added to DP at each X in the next execution of DDS. ISM is set to 3 each time the ALL loop is entered.

12. VAPOR DEPLETION

The vapor depletion model that is described in Appendix C is implemented in the program by subroutine VDPL. This subroutine is divided into four parts which are (in effect) entered separately. The first computes the deposition velocity, DEVP, as a function of wind speed, stability, and roughness length.

The second entry estimates the peak dosage (or concentration) and establishes the table of dosages over which the area will be integrated. The lower limit for this distribution is taken as one-tenth of the minimum dosage of interest specific in the main program. This dosage-area table can be output at the end of the program with a PEEK 6 command from the ALL question. The output option, OPO 4, will cause the contour half-widths for this distribution to be listed and then the dosage-area table.

The third entry is called for each downwind distance, and the area coverage is accumulated as a function of X. With each call a new estimate of the function of the source still airborne (SDEPL) is made and the adjusted peak value is returned. Two peak values (DP and DPA) are transmitted to the subroutine to accommodate the 2-minute correction for GB and VX. (The area distribution is based on the noncorrected value.) The other parameter values (DX, DXA, XS, and XCH) are provided to adjust the area integration when a stability change is called from the master program.

The fourth entry point lists the dosage-area distribution. This is printed by a PEEK 6 or at the end of a run with OPO 4.

The UNIVAC version of this program uses the different entry points. The PC version enters at the top and then branches to the section as directed by the indication INT. The function of the source remaining airborne (SDEPL) is printed for each distance when OPO is greater than zero and before each estimated distance when OPO equals zero.

The area is accumulated by summing the rectangular strings defined by delta-X, or DX, and the contour half-width. This is rather crude and can be improved by decreasing DX from the default value of 10. This can be changed by assigning a new value to DLX in the ALL question; this value will be augmented by the program according to the following rules:

If (X $\geq$ DX*10.)   DX = DX*10.

with $X_{i+1} = X_i + DX$

except $X_1 = 1$

and $X_2 = DX$

Thus, DLX should be selected with the progression it will produce in mind. A value of two is a reasonable alternative.

13. DATA TABLES IN D2PC

The following list identifies the data tables for each subroutine in program D2PC. These variables are selected with the expectations that some users may wish to add to the present data sets or substitute others in these tables. The dimensions of each table are listed, and each component is specified for cross reference. The parameters marked with an asterisk would require logic changes in the program if these are altered. Those marked with two asterisks would require logic changes if certain items (numeric position) were changed.

<u>HDS3</u>

HMLT (6, 4, 11) Height of the mixing layer (m)
- 6 Stability categories A → F
- 4 Seasons winter to fall
- 11 Sites specified

QF (10, 3) Item fill weights (mg)
- 10 Items
- 3 Fills

SYSM (10) Lateral source sigma for each item (m)

SZSM (10) Vertical source sigma for each item (m)

PMMT (12) Average atmospheric pressure at each site (mm Hg)

DI (3, 17) Dosage response levels (mg-min/m^3)
- 3 Levels (ascending dosage)
- 17 Substances

FMWT (17) Molecular weight of substances

*RELT (10) Methods of release

**AGN (17) Substance codes (2 characters) (first three have complex logic control)

*PNUC (16) Control codes (3 characters)

*PNU (77) Parameter codes (3 characters)

*J (67) Rescan indicator for parameters

MUN (10) Item codes

*IST (11) Stability codes (1 character)

LOC (12) Site codes (3 characters)

SEA (4) Season codes (3 characters)

<u>EVAP</u>

AGN (15) Substance codes (2 characters)

FMW (16) Molecular weight
FMV (16) Molecular volume
PP (16) Boiling (°K)
} 16th space for read-in

A (15)
B (15)
C (15)
} Constants for vapor pressure of substances

FP (15) Freezing point (°K)

<u>DDS</u>
<u>CDS</u>

ALFAT (6) Alfa for Pasquill Category (A → F)

BETAT (6) Beta for Pasquill Category (A → F)

SY100I (6) Reference sigma Y at 100 m for instantaneous release (m)

SY100T (6) Reference sigma Y at 100 m for continuous release (m)

SZ100T (6) Reference sigma Z at 100 m (m)

*Revision will require program logic changes.
**Certain items (in numeric order) will require logic changes.

*SY100C (2, 3) Reference sigma Y at 100 m in urban areas (m)
  2 Stability (neutral and stable)
  3 Wind speed classes

*SZ20C (2, 3) Reference sigma Z at 20 m in urban areas (m)
  2 Stability (neutral and stable)
  3 Wind speed classes

*BETAC (2, 3) Beta for urban areas
  2 Stability (neutral and stable)
  3 Wind speed classes

*ST (11) Stability codes (A-F, N, I, U, S, W)

RL (3) Response level labels

UNT

UMT (25) Input unit code (2 characters)

**UC (25) Conversion constant (4th is °F → °C)

DN25 (18) Density of substances at 25 °C (18th is space for read-in)

MNE (34) Standard names of units

IK (25) Selects output for units input

QLIST

IQR (36) Locates variable in common list by questions

IQM (36) Specifies number of variables by question

QTAB (37) Question list (30 characters) (37th extension of question 29)

SYM (37) Symbol for variable by question

VDPL

PT (6, 3) PT from model by stability and surface
  6 By stability (A → F)
  3 By surface type (flat, rolling, sea)

ITT (12) Surface type by site

FKMS (6) kms from model by stability (A → F)

ZOT (12) Roughness length by site (cm)

*See footnote on page 70.

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APPENDIX C

VAPOR DEPLETION

by

Dale W. Sloop

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APPENDIX C

VAPOR DEPLETION

1. INTRODUCTION

After agent is released from chemical munitions, fine aerosols and gases transport with the wind and are eventually removed from the atmosphere by deposition upon many types of surfaces (water, soil, vegetation, etc.) with possibly some chemical changes occurring with time. Atmospheric turbulence, Brownian motion, impaction, and sorption are some of the processes causing agent to be dropped from the cloud and retained on surfaces.

The most common mathematical techniques for consideration of the agent fall-out mechanisms and surface deposition are called the "source depletion" and "partial reflection" models.[1] These models apply to very fine aerosols and vapors of approximately 10 μm or less, in diameter. The partial reflection approach seems to perform well near the source and is fairly easy to use. However, the "source depletion" technique has been shown to perform better for far downwind distances. For this reason, the source depletion course was followed for use in our general chemical hazard prediction model.

Chamberlain[2] and other investigators have presented the mathematical derivation of a depletion factor as a function of downwind distance for various continuously emitting plume type sources. However, as far as can be determined, source depletion models that characterize "instantaneous" type source releases, such as would be expected for chemical projectiles and rockets, have never been reported in the open literature. Therefore, an attempt was made to adapt the "continuous source" approach to an instantaneous release. However, this did not work out because the numerical integration became quite messy and was not followed through.

2. EMPIRICAL DEPLETION MODEL

Still faced with a need for an instantaneous depletion technique, an alternate empirical approach was proposed. This proposed technique and dosage requires calculation of an effective deposition velocity (v_d) and dosage and/or concentration area coverage as a function of downwind distance. The v_d values is easy enough to calculate, and the current D2 program is readily adaptable to computing dosage/concentration contours. Hence, this simple empirical approach was chosen for incorporation into the Chemical Hazard Prediction Methodology and is presented below.

For a surface that has perfect retention[3] of the material reaching it, the v_d value can be determined in terms of the wind-speed profile, friction velocity, and surface roughness length parameter as follows:

Using the wind speed profile investigated by R. Frost[4] and represented by a power law function across stability conditions as follows:

$$u(z) = u(2) \cdot \left(\frac{z}{2}\right)^{\lambda}$$

where

$u(2)$ is the 2-meter wind speed

λ is the Frost power parameter

and

Using the following relationship, compute the friction velocity parameter[5] ($u*$)

$$u_* = \lambda \cdot K_m^* \cdot u(2) \left(\frac{z}{2}\right)^{\lambda}$$

where

K_m^* is a generalized stability parameter with the following values

Stability	A	B	C	D	E	F
K_m^*	0.9	0.8	0.6	0.4	0.2	0.05

For near surface estimates, z is set equal to 0.01 meters since $u* \neq 0$ at $z = 0$.

Now

Compute the surface deposition velocity[5] (ν_d) using the following formula

$$\nu_d = \frac{u_*^2}{u(z)} \left(1 + \frac{u_*}{u(z)} \cdot B^{-1}\right)^{-1}$$

again

using $z = 0.01$ for near surface estimates.

This equation is correct only for vapor adsorption material. The B^{-1} parameter (the dimensionless reciprocal Stanton number) can be computed as follows:

$$B^{-1} = 0.06\ (196 \cdot u_* \cdot z_o)^{0.45}$$

where

$u*$ is computed as stated above and zo is the conventional surface roughness length.

The B^{-1} equation above was deduced from the following formula[6]

$$k\ B^{-1} \sim 0.2\ (30 R_{e_*})^{0.45} \cdot \sigma^{0.8}$$

with the following assumptions,

k (Von Karman's constant) equals 0.4, the

Schmidt number σ equals 0.076.

Using

$$\textbf{Reynolds number } R_{e_*} = \frac{u_* z_o}{\nu}$$

where

ν is the kinematic viscosity of air and using a value of 0.153 cm^2/sec, then the following equation is obtained

$$.4\ B^{-1} = 0.2 \left(30 \left(\frac{u_* z_o}{.153} \right) \right)^{0.45} \cdot 0.076^{0.8}$$

This reduces to the equation,

$$B^{-1} = 0.06\ (196\ u_* z_o)^{0.45}$$ **as stated above.**

Now that the technique for calculating the ν_d parameter has been presented, formulation of the source depletion factor can be expressed as follows:

The factor for the diminishing amount of material remaining airborne is defined as:

$$\frac{Q(x)}{Q(o)}$$

where

Q(o) is the initial amount of agent released in mg for dosage. Then the amount of material deposited within a dosage contour class can be estimated by using the following functional relationship,

$$QD(x) = \sum_{I-1}^{ND} \left[\left(\frac{D(I) + D(I+1)}{2} \right) \cdot \left(AR(I) - AR(I+1) \right) \cdot \nu_d \right]$$

where

D(I)'s are the dosage contour levels in ascending order, and AR(I)'s are the corresponding accumulative areas as a function of downwind distance-x for these dosage contours.
ν_d is the vapor deposition velocity as calculated above in meters per minute.

then

The resulting source strength factor as a function of downwind distance x can be calculated for use in the Gaussian equations as follows:

$$\frac{Q(x)}{Q(o)} = \frac{Q(o) - QD(x)}{Q(o)}$$

then, from the above equation, the axial peak dosage can be adjusted for vapor depletion for the next x-distance as follows:

$$DP(x+1) = DP(x+1) \cdot \left(\frac{Q(x)}{Q(o)}\right)$$

The above equations were presented using dosage terms. When the user asks for concentration estimates from the program, then the program logic has the following changes.

Q(o) becomes a rate of release; the D(I)'s are in terms of concentration, mg/min; and the AR(I)'s are the corresponding areas for those concentration contours. Then, the axial peak concentration is adjusted as a function of downwind distance -x as

$$CP(x+1) = CP(x+1) \cdot \left(\frac{Q(x)}{Q(o)}\right)$$

The rest of the model constants and relationships used in calculation of the v_d parameter remain the same as for dosage.

The estimate of the fraction of material remaining airborne $\frac{Q(x)}{Q(o)}$ as a function of distance is based upon the amount of area accumulated across dosage contour classes. Hence, this method is sensitive to the number of contour levels chosen (ND) and the incrementation step of the x-distance in representing cloud coverage. These parameter values are internally controlled by the D2PC program and are designed to provide reasonable results.

We feel this approach to be a reasonable alternative for lack of a more vigorous mathematical form. The advantage is that it is not limited in use. It applies equally well to dosage or concentration predictions for partial or total dosage times and across all source release heights and types (point, volume, continuous emitting).

3. MODEL VALIDATION

No attempt has been made to verify this theory with actual field experimentation. However, the program has been run to compare its predicted depletion factors against estimates reported in the literature[7] and to demonstrate the expected change as a function of stability with downwind distance.

Table C-1 provides the vertical and horizontal reference distance standard deviations and expansion exponents representing three investigators. The Hansen and D2PCA diffusion parameters are taken directly from the referenced reports; however, what are identified as Pasquill parameters are rather coarse straight-line estimates through the curves provided in reference 7. Table C-2 shows the comparison of the three diffusion sets (Pasquill, Hansen, D2PCA) to the "SLADE" depletion values extracted from continuous source depletion curves on page 205 of reference 7. For the Hansen results, a surface roughness value of $z_0 = 10$ cm set was used. To be compatible with the other two, a $z_0 = 1$ cm set of values for σ_{z100} and B should have been used. Then the results for Hansen would have followed the D2PCA predictions much closer than the Pasquill values in Table C-2.

4. CONCLUSIONS

Some conclusions that can be drawn from Table C-2 are:

- Using this empirical depletion technique, the D2PCA diffusion parameters continue to keep the amount of airborne vapor up closer to the "SLADE" estimates for stability categories A, B, and C. However, for stability categories D, E, and F, D2PCA, Hansen and Pasquill continue to hold the amount of airborne vapor up when "SLADE" shows it should be falling off significantly.

- Overall, for the first one-thousand meters all three sets of diffusion parameter do equally well in comparing with the "SLADE" estimates.

- For hazard analysis studies, it appears that this technique can be used to improve the predictions and provide safe conservative estimates across stability categories and potential diffusion values.

Table C-1. Diffusion Parameters Values Used to Compute the Results of Table C-2

Stability category	Investigator	σ_{y100}	α	σ_{z100}	β
A	Pasquill*	25.2	0.90	18.0	1.63
	Hansen**	25.2	0.90	17.6	0.90
	D2PCA†	27.0	1.0	14.0	1.4
B	Pasquill	20.2	0.90	11.3	1.191
	Hansen	20.2	0.90	11.3	0.85
	D2PCA	19.0	1.0	11.0	1.0
C	Pasquill	13.9	0.90	8.9	0.852
	Hansen	13.9	0.90	8.9	0.81
	D2PCA	12.5	1.0	7.5	0.90
D	Pasquill	9.02	0.90	6.5	0.682
	Hansen	9.02	0.90	6.5	0.76
	D2PCA	8.0	0.90	4.5	0.85
E	Pasquill	6.43	0.90	4.0	0.664
	Hansen	6.43	0.90	4.0	0.73
	D2PCA	6.1	0.80	3.5	0.80
F	Pasquill	4.80	0.90	2.6	0.633
	Hansen	4.80	0.90	2.6	0.67
	D2PCA	4.0	0.7	2.5	0.75

*These estimates are straight-line estimates through the curves.[7]
**Translated to reference distance of 100 meters.[8]
†Taken from the earlier D2PC report.

Table C-2. Source Depletion Fraction Q(x)/Q(o) for a Wind Speed U_2 of 1 m/sec and v_d of 0.01 m/sec CONC, Values for a Continuous Source (Surface Release)

Stability category	Investigator/ Diffusion category	Distance from source (meters) 10^1	10^2	10^3	10^4	10^5
A	Slade*	.95	.80	.75	.71	.70
	Pasquill**	.93	.74	.68	.46	.14
	Hansen†	.94	.81	.66	.46	.14
	D2PCA††	.93	.72	.65	.60	.50
B	Slade	.92	.75	.62	.60	.59
	Pasquill	.93	.71	.58	.41	.13
	Hansen	.93	.73	.56	.38	.15
	D2PCA	.93	.72	.56	.48	.41
C	Slade	.92	.70	.55	.39	.28
	Pasquill	.93	.71	.53	.36	.12
	Hansen	.93	.71	.53	.36	.12
	D2PCA	.93	.69	.52	.36	.28
D	Slade	.90	.62	.41	.17	.039
	Pasquill	.93	.69	.44	.24	.13
	Hansen	.93	.68	.45	.28	.12
	D2PCA	.93	.61	.38	.26	.12
E	Slade	.90	.55	.30	.071	.006
	Pasquill	.93	.59	.33	.16	.09
	Hansen	.93	.59	.35	.19	.11
	D2PCA	.93	.58	.32	.18	.08
F	Slade	.90	.50	.15	.015	.0005
	Pasquill	.92	.53	.22	.10	.06
	Hansen	.92	.53	.23	.11	.06
	D2PCA	.92	.54	.25	.12	.06

*Reference 7, curves on p 205
**Reference 7, diffusion curves on pp 408-409
†Reference 8, p 7
††Dispersion parameters as used in CRDC Chemical Hazard Prediction Program-D2PCA.

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LITERATURE CITED

1. Hanna, S.R., Briggs, G.A., and Hosker, R.P., Jr. Handbook on Atmospheric Diffusion. DOE/TIC-11223. Technical Information, U.S. Department of Energy, 1982.

2. Chamberlain, A.C., and Chadwick, R.C. Deposition of Airborne Radio-Iodine Vapor. Nucleonics 8, 22-25 (1953).

3. Pasquill, F., and Smith, F.B. Atmospheric Diffusion. pp 251-256. Third Edition. 1983.

4. Sutton, O.G. Micrometeorology. p 238. McGraw-Hill Book Company, New York, NY. 1953.

5. Webb, E.K. Aerial Microclimate. In Meteorological Monographs. pp 27-58. Volume 6, No. 28. Boston, MA. July 1965.

6. Garratt, J.R., and Hicks, B.B. Momentum, Heat and Water Vapor Transfer To and From Natural and Artificial Surfaces. Q. J. R., Meteorol. Soc. 99, 680-687 (1973).

7. Slade, D.H., Editor. Meteorology and Atomic Energy. Technical Information Center, U.S. Department of Energy. July 1968.

8. Hansen, F.V. Engineering Estimates for the Calculation of Atmospheric Dispersion Coefficients. Internal Report, U.S. Army Electronics Research and Development Command Atmospheric Sciences Laboratory, White Sands Missile Range, NM. September 1979. UNCLASSIFIED Report.

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APPENDIX D

GLOSSARY

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APPENDIX D

GLOSSARY

Atmospheric stability (low level) — This is a relative classification of the mixing of the air near the surface. This mixing has been measured as a standard deviation of wind direction changes (σ_A, σ_E) or, in a more indirect way, as the difference in air temperature at two reference heights. (Temperature gradient between 1/2 and 4 meters.) An even more generalized concept is used in this report based on the Pasquill stability categories. In this system, the heating or cooling of the surface is used to establish a net radiation index. These are then tabulated against windspeed to form a table of comparable mixing categories. For the Pasquill system these are identified as A through F, going from very unstable to stable with category D taken as neutral.

Breathing rate (liters/minute) — As used in these models, the breathing rate is the average volume of air aspirated per minute. The rate is usually stated in liters per minute, but must be converted to m^3/min when multiplied by dosage to provide consistent units.

Broken (cloud cover) — This is a description of a sky cover of .6 to .9 (5/8 to 7/8)

Concentration (mg/m^3) — This is the quantity of a vapor or aerosol suspended in a volume of air.

Peak concentration — This term is used to describe the maximum concentration at a given distance that will result from a variable passing field.

Deposition density (mg/m^2) — This is the density of liquid or particulate contaminate that is deposited on the ground. It is employed as an assessment index and has been related to the percutaneous dose. In the current form of this relation, the percutaneous dose equals 1.62 times the deposition density raised to the 0.8 power. This relation has been derived from the short-range fallout from explosive munitions.

Dosage ($mg/min/m^3$) — Dosage is the integration of concentration in mg/m^3 and time in minutes, also referred to as Ct. This is a mathematical concept that makes a useful exposure index to vapors and small aerosols that can be absorbed by inhalation. When the dosage is multiplied by a breathing rate and retention efficiency, the result is an inhaled dose.

Total dosage	This is the concentration time integral accumulated over the time of passage of the total cloud.
Partial dosage	If an evasive action is possible, such as donning a mask or moving out of the path of the cloud, then the exposure is to a partial dosage that is calculated from the time of release to the time the evasive action is complete. Thus, if the evasive action is accomplished in time t, the partial dosage: $D(t) = 0$ for $x > ut + 3\ SX$, where SX is the standard deviation of the downwind dimension of the cloud, and u is the windspeed.
Dose (mg)	Dose is the quantity of a substance ingested into the body or placed on the body surface or clothing.
Inhaled dose	This is the quantity absorbed by the body by inhalation.
Intravenous dose	This is the amount reaching the blood stream.
Percutaneous dose	This is the amount applied to clothing or skin, or both.
Downwind length (m)	This is the length in the downwind direction across the surface of the spill. Like the evaporation time, this is assumed to be constant over the period of evaporation.
Evaporation time (min)	This is the time from the beginning of a spill to the total containment or neutralization of the agent. The model employed in SEVP2 assumes that the rate of release is constant over this period and thus is a safe-sided estimate of the total amount released.
Inhalation-deposition	When a substance with low volatility is released by explosion, both vapor and aerosol are produced. If the aerosol impacts on clothing or the skin and is not removed, a fraction will penetrate the skin and add to the dose that the body may have accumulated from inhalation. These are additive at the intravenous level and thus the intravenous dose, D_I, is the response index.
Mixing layer (m)	This layer is the region above the surface where mixing tends to approach uniformity. If travel proceeds for a sufficient distance, the vertical distribution tends to become uniform within this layer. Two forms of the mixing layer are considered in this report. The best defined of these is formed by an elevated temperature inversion that forms a cap to vertical diffusion. This cap is modeled as a reflective surface that would

produce multiple reflections to approach this uniformity. The other form of the mixing boundary is the result of the inertial forces acting on the eddies formed by the surface friction layer. This has been extended from the surface itself to objects on the surface and even the terrain which would affect this mixing. The same model is used for predictive purposes. Thus, this second category is achieved by entering a value that will approximate the inertial layer. (See Table 5.)

Overcast (cloud cover)	This is the description of a sky cover of 1.0 (8/8).
Rawinsonde (radiosonde)	This is balloon-borne instrumentation that is capable of measuring and transmitting the wind speed and direction, temperature, pressure, and humidity aloft during its ascension; analysis of this information can provide stability characteristics for various layers of the atmosphere.
Scattered (cloud cover)	This is a description of a sky cover of .1 to .5 (1/8 to 4/8).
Skin penetration factor	This factor is the ratio of intravenous dose to percutaneous dose. The skin penetration factor is defined for a specific type of exposure and a specific type of clothing.
Source sigmas (m)	These are characteristic dimensions of the source cloud. These are stated for the three directions X,Y, and Z and are expressed as the standard deviations (SXS, SYS, SZS). Through the diluting process of diffusion, the cloud is approximated as a Gaussian distribution moving with the wind and expanding.
Source strength (mg)	This is the quantity airborne. This release can occur instantaneously as with an explosive release or over a period of time as from a spill.
Source time (min)	This is the period of time over which the substance is emitted into the air. Zero is specified for an instantaneous release and infinity (1E36) for a continuous release.
Subsidence inversion	This is a temperature inversion produced by the warming of a layer of descending air and most frequently associated with a large high-pressure system. The inversion will have its base at some point above the ground and is enhanced by vertical mixing in the layer of air below. This type of inversion is often very persistent and frequently produces conditions requiring air pollution advisories.

Surface inversion (radiation inversion)	This is a temperature inversion that has the earth's surface as its base. It is an increase of temperature with height beginning at the ground, a very stable layer of air in contact with the ground, a phenomenon that is established during nighttime hours and enhanced by clear skies and light winds.
Time after release (min)	A large component of the dosage computed by program HD42 is derived from the evaporation of the liquid splash. Thus, the dosage at the time of assessment is dependent on the amount that has evaporated to that time. This adjustment is contained within the model.
Two-minute correction	It has been shown that the dosage of GB or VX vapor required to produce a given physiological effect (with a constant breathing rate) is dependent on the time of accumulation. Thus, the total dosage is not an adequate index for long exposures (>2 min). Since the time of exposure is dependent on the size of the cloud, which changes with downwind distance, a correction has been developed for the diffusion model that converts the accumulated dosage at any point to the equivalent 2-minute dosage and thus permits the 2-minute value to be used as an index. The 2-minute correction is used for GB and VX vapor except when the no-effects (or lesser physiological effects) level is being considered.

APPENDIX E

PROGRAM LISTING

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APPENDIX E

PROGRAM LISTING

HDS3.FOR

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C  HAZARD DISTANCE / MASTER PROGRAM / C.G.WHITACRE
C  ADAPTED TO MS-FORTRAN BY J.H.GRINER III AND RICHARD L. ZUM BRUNNEN
      CHARACTER*1 IST,MTC,AA1,AB1
      CHARACTER*2 AGN,UM,AGNT,AA2,WT
      CHARACTER*3 PNU,PNUT,PNUC,MUN,MUNT,REL,RELT,LOC,LOCT,SEA,SEAT,
     1PRTT,SUR
      CHARACTER*12 ADH
      CHARACTER*20 APRT
      COMMON NQI,QT(6),TWL(6),D(10),DL(10)
      COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
     1BETA,SZ100,Z,RC,V,QS
      COMMON TEVP,SA,FL,FMW,FMV,VP,BP
      COMMON HS,DS,TSC,VS,RDE,FP,HR,CR
      COMMON SLA,SLO,CC,CH,AE,PMM,ZO
      COMMON LOCT(1),SEAT,MUNT,AGNT,AA1,REL,MTC,AA2,SUR,WT,AB1,ADH,ADR,
     1AD2
      COMMON IPR(1),ND,IPO,I2MC,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,NMU,ID2,
     1IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
      DIMENSION MUN(10),QF(10,3),SYSM(10),SZSM(10),AGN(18),D1(3,17)
      DIMENSION FMWT(17),IST(11),LOC(12),SEA(4),HMLT(6,4,11),PMMT(12),
     1PNU(77),J(67),K(67),RELT(10),PNUC(16),QTS(6)
$INCLUDE:'A:HMLMDR1.FOR'
      DATA RELT/'INS','EVP','SEM','VAR','STK','STJ','FLS','FIR','IGL',
     1'EVS'/
      DATA AGN/'GB','VX','HD','AC','CG','CK','GA','GD','GF','H1','H3',
     1'HT','LL','HY','UD','BZ','DM','NA'/
      DATA PNUC/'ALL','STP','RST','INP','GTO','RSN','NQI','SMC','SMD',
     1'SMP','RUN','TAB','???','DSP','PEE','VDP'/
      DATA PNU/'TIM','DLX','HTS','HML','SXS','SYS','SZS','TMC','WND',
     1'BRT','SKF','TMP','ALF','SYR','BTA','SZR','SMH','REF','SEV','QQQ',
     2'TEV','ARE','LEN','FMW','FMV','VAP','BPT','HST','DST','TST','VST',
     3'RDE','FRO','HRL','CRD','SLA','SLO','CCT','CHT','SUN','PMM','ZZO',
     4'LOC','SEA','MUN','AGN','REL','STB','SUR','WOO','HLD','RLS','AD3',
     5'IRT','NDI','OPO','2MC','IMA','OPC','IMM','IDD','HRS','NOV','INP',
     6'MNR','NMU','NCI','IDE','IMT',' IM',' IR',' IL','IRL','ISM','IVD',
     7'K33','K42'/
      DATA J/1,7*0,1,2*0,1,7*0,8*1,8*0,6*1,0,8*1,9*0,3*1,0,1,0,1,0/
      DATA MUN/'105','155','81N','500','750','M55','525','139','M23',
     1'4.2'/
      DATA IST/'A','B','C','D','E','F','N','I','U','S','W'/
      DATA LOC/'AAD','DPG','EWA','JHI','LBG','NAP','PBA','PAD','RMA',
     1'UAD','EUR','NDF'/
      DATA SEA/'WIN','SPR','SUM','FAL'/
      DATA I3,I4,I5/42,11,24/
      WRITE (*,*) '                 ---------------------------------'
      WRITE (*,*) '                 \ DOWNWIND HAZARD PROGRAM D2PC \'
      WRITE (*,*) '                 ---------------------------------'
 1    DO 2 I=1,74
      QT(I)=0.
 2    CONTINUE
```

```
      DO 3 I=1,11
      LOCT(I)='   '
    3 CONTINUE
      DO 4 I=1,22
      IPR(I)=0
    4 CONTINUE
      TIVCH=1.E36
      DXT=10.
      Z=0.
      NMU=1
      FNMU=1.
      RC=1.
      V=0.
      BR=25.
      SF=.022
      DO 5 I=1,67
      K(I)=0
    5 CONTINUE
      ND=0
      CALL DEF (0,IRT)
C     1. NOVICE LEVEL
      WRITE (*,*) '    TYPE ? FOR DEFINITIONS'
    6 CALL DEF (1,IRT)
      IF (IRT.EQ.0) READ (*,'(BN,I5)',ERR=10) NOV
      IF (NOV.GT.2) CALL DEF (39,IRT)
      IF (NOV.GT.(-1)) GO TO 7
      CALL DEF(80,IRT)
      READ(*,93)LOCT(1),SEAT,MUNT,AGNT,REL,MTC,US
    7 UT=US
C     2. LOCATION
      CALL DEF (2,IRT)
      IF (IRT.EQ.0) READ (*,'(A3)') LOCT(1)
      DO 8 IL=1,12
      IF (LOCT(1).EQ.LOC(IL)) GO TO 11
    8 CONTINUE
      WRITE (*,9)
    9 FORMAT (' LOCATION NOT DEFINED')
      CALL DEF (42,IRT)
      GO TO 7
   10 CALL DEF (41,IRT)
      GO TO 6
C     3. SEASON
   11 IF (IL.EQ.12) GO TO 14
      CALL DEF (3,IRT)
      IF (IRT.EQ.0) READ (*,'(A3)') SEAT
      DO 12 IS=1,4
      IF (SEAT.EQ.SEA(IS)) GO TO 13
   12 CONTINUE
      CALL DEF (43,IRT)
      GO TO 11
   13 IF (K(41).EQ.0.AND.IL.NE.12) PMM=PMMT(IL)
      IF (IL.NE.12) GO TO 15
C     4. HEIGHT OF MIXING LAYER
   14 CALL READA (4,IRT,IA,HML)
      IF (IRT.LT.0) GO TO 14
```

```
 15   IDEF=0
      IF (K(3).EQ.0) HT=0.
      IF (K(57).EQ.0) I2MC=0
      INQ=0
      IMTCH=0
C     5. MUNITION TYPE
 16   CALL DEF (5,IRT)
      IF (IRT.EQ.0) READ (*,'(A3)') MUNT
      IF (MUNT.NE.'???') GO TO 17
      CALL DEF (45,IRT)
      GO TO 16
 17   DO 18 IMU=1,10
      IF (MUNT.EQ.MUN(IMU)) GO TO 19
 18   CONTINUE
      INQ=1
C     6. AGENT TYPE
 19   CALL DEF (6,IRT)
      IF (IRT.EQ.0) READ (*,'(A2)') AGNT
      IF (AGNT.NE.'??') GO TO 20
      CALL DEF (46,IRT)
      GO TO 19
 20   DO 21 IA=1,18
      IF (AGNT.EQ.AGN(IA)) GO TO 22
 21   CONTINUE
      IA=18
C     8. RELEASE TYPE
 22   CALL DEF (8,IRT)
      IF (IRT.EQ.0) READ (*,'(A3)') REL
      IF (REL.NE.'???') GO TO 23
      CALL DEF (48,IRT)
      GO TO 22
 23   DO 24 IR=1,10
      IF (RELT(IR).EQ.REL) GO TO 25
 24   CONTINUE
      WRITE (*,*) ' RELEASE NOT DEFINED'
      CALL DEF (48,IRT)
      GO TO 22
C     9. STABILITY TYPE
 25   CALL DEF (9,IRT)
      IF (IRT.EQ.0) READ (*,'(A1)') MTC
      IF (MTC.NE.'?') GO TO 26
      CALL DEF (49,IRT)
      GO TO 25
 26   DO 27 IM=1,11
      IF (MTC.EQ.IST(IM)) GO TO 28
 27   CONTINUE
      WRITE (*,*) ' STABILITY NOT DEFINED'
      CALL DEF (49,IRT)
      GO TO 25
 28   IF (IMTCH.EQ.1) GO TO 29
C     10. WINDSPEED
      CALL READA (10,IRT,IA,US)
      IF (IRT.LT.0) GO TO 28
 29   UT=US
      IF (IM.EQ.10) CALL STAB (US,IM,IL,IMM,IDD)
```

```
      IF (IM.EQ.11) CALL WOODS (UT,ALFA,SY100,BETA,SZ100,WT)
      IF (IM.NE.9) GO TO 30
C     11. ALF,SYR,BTA,SZR
      CALL DEF (11,IRT)
      IF (IRT.EQ.0) READ (*,*) ALFA,SY100,BETA,SZ100
 30   IF (IMTCH.EQ.1) GO TO 83
      IF (IA.EQ.18) GO TO 34
      IF (K(24).EQ.0) FMW=FMWT(IA)
      IF (IA.LE.2.AND.K(57).EQ.0) I2MC=2-K(57)
      IF (K(55).EQ.1.OR.K(67).GT.0) GO TO 32
      DO 31 I=1,3
      D(I)=D1(I,IA)
 31   CONTINUE
      ND=3
      IRL=1
      IF (K(65).EQ.0) MRL=0
 32   IF (IA.EQ.2.AND.REL.EQ.'INS') GO TO 34
      WRITE (*,33) (D(I),I=1,ND)
 33   FORMAT (' DI=',10F8.1)
 34   IF (IR.LT.4.OR.IR.EQ.10) NQI=1
      GO TO (35,35,48,48,43,43,43,43,95,35), IR
 35   IF (INQ.EQ.0) GO TO 37
C     7. SPILL OR AIRBORNE SOURCE
 36   CALL READA (7,IRT,IA,QS)
      IF (IRT.LT.0) GO TO 36
      GO TO 40
 37   IF (IA.GT.3) GO TO 38
      IF (QF(IMU,IA).GT.0.) GO TO 39
 38   WRITE (*,*) ' MUNITION-AGENT NOT DEFINED'
      GO TO 36
 39   IF (K(20).EQ.0) QS=QF(IMU,IA)
 40   QT(1)=QS*FNMU
 41   IF ((IR.EQ.1.AND.IA.EQ.3).OR.IR.EQ.2.OR.IR.EQ.10) WRITE (*,42)
      IF (IR.NE.1) GO TO 43
      IF (IA.EQ.2.OR.IA.GT.3.OR.INQ.EQ.1) GO TO 44
C     12. TEMPERATURE
 42   FORMAT (5X,'SURFACE')
 43   IF (IR.EQ.9) GO TO 48
      CALL READA (12,IRT,IA,TMP)
      IF (IRT.LT.0) GO TO 41
 44   IF (IR.GT.2.AND.IR.LT.10) GO TO 48
      IF (IR.EQ.2.OR.IR.EQ.10) GO TO 51
      TWL(1)=.08
      IF (K(6).EQ.0.AND.INQ.EQ.0) SYS=SYSM(IMU)
      IF (K(7).EQ.0.AND.INQ.EQ.0) SZS=SZSM(IMU)
      IF (K(5).EQ.0.AND.INQ.EQ.0) SXS=SYS
      IF (IA.EQ.2) GO TO 46
      IF (IA.NE.1) GO TO 52
      IF (INQ.EQ.1) GO TO 52
      IF (QF(IMU,1).GT.4.5E7) GO TO 45
      QT(1)=QT(1)*(.5+(.00782*TMP))
      GO TO 52
 45   QT(1)=QT(1)*(.5+(.0022*TMP))
      GO TO 52
 46   IDEP=1
```

```
      D(1)=.44
      D(2)=1.76
      D(3)=4.
      WRITE (*,47) D(1),D(2),D(3)
 47   FORMAT (' EDI='3F5.2)
      IF (IMU.NE.9) GO TO 52
      IDEP=2
      GO TO 52
C  13. NQI,Q(),QT() OR Q,QT
 48   CALL DEF (13,IRT)
      IF (IRT.EQ.1) GO TO 49
      IF (IR.NE.3) READ (*,*) NQI,(QTS(I),TWL(I),I=1,NQI)
      IF (IR.EQ.3) READ (*,*) QTS(1),TWL(1)
 49   DO 50 I=1,NQI
      QT(I)=QTS(I)*FNMU
 50   CONTINUE
      GO TO 52
 51   IF (IR.EQ.2) CALL EVAP (AGNT,QT(1),PMM,UT,TMP,TWL(1),SUR,IL)
      IF (IR.EQ.10) CALL EVAP(AGNT,QT(1),PMM,.01,TMP,TWL(1),SUR,IL)
      SXS=FL/3.
      SYS=SA/(FL*3.)
      SZS=.1
 52   IF (IM.GT.6.AND.IL.NE.12.AND.K(4).NE.1) HML=HMLT(4,IS,IL)
      IF (IM.LE.6.AND.IL.NE.12.AND.K(4).NE.1) HML=HMLT(IM,IS,IL)
 53   ISM=0
 54   ISM=3
      IF (HML.EQ.0.) WRITE (*,55)
 55   FORMAT (' DEFINE HML')
      WRITE (*,56)
 56   FORMAT (' ALL OTHER INPUT')
 57   IER=1
      READ (*,'(A3,1X,A20)') PNUT,APRT
      READ (APRT,'(BN,F20.0)',ERR=59) PRT
      IER=0
      DO 58 I=1,16
      IF (PNUT.EQ.PNUC(I)) GO TO 75
 58   CONTINUE
C
 59   DO 66 I=1,67
      IF (PNUT.NE.PNU(I)) GO TO 66
      IF (I.LT.43.OR.I.GT.53) GO TO 62
      READ (APRT,'(A3)') PRTT
      IF (I.LT.51.OR.I.GT.52) GO TO 63
      DO 60 II=1,67
      IF (PRTT.EQ.PNU(II)) GO TO 61
 60   CONTINUE
 61   K(II)=52-I
      IF (II.EQ.57.AND.I2MC.NE.0) I2MC=I-50
      GO TO 57
 62   IF (IER.EQ.0) GO TO 63
      READ (APRT,'(A2,BN,F18.0)',ERR=54) UM,PRT
      CALL UNT (UM,IA,PRT)
 63   IF (I.LT.43) PR(I)=PRT
      IF (I.GT.42.AND.I.LT.53) LOCT(I-42)=PRTT
      IF (I.GT.53) IPR(I-53)=PRT
```

```
      IF (I.EQ.66) FNMU=PRT
      JSM=JSM+J(I)
      IF (I.EQ.55.OR.I.EQ.67) GO TO 68
      IF (I.EQ.58) K(67)=PRT
      IF (I.EQ.58.AND.PRT.GT.0.AND.PRT.LT.4) WRITE (*,64)
 64   FORMAT (' DEFINE NCI')
      IF (I.EQ.9) US=UT
      IF (I.EQ.47.AND.PRTT.EQ.'SEM'.OR.PRTT.EQ.'VAR') CALL DEF (-13,IRT)
      IF (I.EQ.20.AND.IR.GT.2) WRITE (*,65)
 65   FORMAT (' DEFINE NQI')
      GO TO 57
 66   CONTINUE
      WRITE (*,67)
 67   FORMAT (' SYM NOT FOUND')
      GO TO 54
 68   IF (IMA.EQ.0) WRITE (*,69)
 69   FORMAT (' INPUT: DI()S')
      IF (IMA.EQ.0) GO TO 71
      WRITE (*,70)
 70   FORMAT (' INPUT: CI()S')
      ND=PRT
 71   READ (*,*) (D(I),I=1,ND)
      MRL=0
      IAL=0
      GO TO 54
 72   NQI=PRT
      WRITE (*,73)
 73   FORMAT (' INPUT: Q()(MG), TQ()(MIN)')
      READ (*,*) (QT(I),TWL(I),I=1,NQI)
      DO 74 I=1,NQI
      QTS(I)=QT(I)
 74   CONTINUE
      GO TO 54
 75   NIQ=(-PRT)
      IF (I.EQ.13) NIQ=0
      IF (I.EQ.14) NIQ=PRT
      IF (I.GT.11.AND.I.LT.15) CALL DEF(40,NIQ)
      IF (I.EQ.16) IVD=PRT
      IF (I.EQ.4.OR.I.EQ.5) CALL DEF (NIQ,IRT)
      GO TO (77,89,1,59,6,7,72,76,76,76,78,54,54,54,90,57), I
 76   ISM=I-8
      IF (I.EQ.10) GO TO 57
      CALL DDS
      GO TO 54
 77   IF (JSM.GT.0) GO TO 7
 78   IF (ND.GT.0) GO TO 80
      IF (IMA.EQ.0) WRITE (*,79)
 79   FORMAT (' DEFINE NDI')
      IF (IMA.GT.0) WRITE (*,64)
      GO TO 57
 80   IF (IMA.NE.2.OR.IA.NE.18) GO TO 81
C     14. MOLECULAR WEIGHT
      CALL DEF (14,IRT)
      IF (IRT.EQ.0) READ (*,*) FMW
 81   IF ((FNMU-NMU).GT.0.) GO TO 96
```

```
      WRITE (*,82) NMU,MUNT,AGNT,REL,UT,TMP,LOCT(1),SEAT,MTC
   82 FORMAT (//I5,' MUN:',A3,2X,'AGN:',A2,2X,'REL:',A3,2X,'WND=',F4.1,
     1'(M/S)',2X,'TMP=',F4.1,'(C)',2X,A3,'-',A3,1X,'STB:',A1)
   98 IF (IA.EQ.3.AND.IR.EQ.1) IDEP=-1
   83 IF (IR.LE.4.OR.IR.GT.8) GO TO 84
      CALL PLRS (UT,TMP,PMM,IL,IM,IR,0.,HT,HML,IPC,IRTP)
   84 IF (HT.GT.HML) WRITE (*,85)
   85 FORMAT (' HEIGHT OF RELEASE IS GREATER THAN MIXING LAYER')
      IF (QT(1).EQ.0.) WRITE (*,86)
   86 FORMAT(' THE SOURCE STRENGTH IS SET AT ZERO')
      IF (UT.EQ.0.) WRITE (*,88)
      IF (HML.EQ.0..OR.HT.GT.HML.OR.QT(1).EQ.0..OR.UT.EQ.0.) GO TO 54
      IF (IVD.EQ.1.AND.IL.EQ.12) GO TO 91
      IF (IDEP.EQ.-1.AND.IM.EQ.11) GO TO 99
      IF (IVD.EQ.1.AND.IM.GT.6) GO TO 94
   92 K33 = K(33)
      K42 = K(42)
      IF (IMA.EQ.0) CALL DDS
      IF (IMA.GT.0) CALL CDS
      IF (IMTCH.EQ.1) GO TO 87
      IF (IPR(1).EQ.0) GO TO 53
      CALL DEF ((-IPR(1)),IRT)
      GO TO 7
   87 WRITE (*,*) ' INPUT: STB'
      READ (*,'(A1)') MTC
      WRITE(*,*)' INPUT: WND, HML, TMC'
      READ (*,*) US,HML,TIVCH
      GO TO 26
   88 FORMAT (' DEFINE WND')
   90 IF (PRT.EQ.1.) WRITE(*,'(1P2E10.3)')(QT(I),TWL(I),I=1,6)
      IF (PRT.EQ.2.) WRITE(*,'(1P2E10.3)')(D(I),DL(I),I=1,10)
      IF (PRT.EQ.3.) WRITE(*,'(2(A5,1PE10.3))')
     $(PNU(I),PR(I),I=1,I3)
      IF (PRT.EQ.4.) WRITE(*,'(A5,A4)')
     $(PNU(I+42),LOCT(I),I=1,I4)
      IF (PRT.EQ.5.) WRITE(*,'(2(A5,I6))')
     $(PNU(I+53),IPR(I),I=1,I5)
C THE FOLLOWING CALL IS A DUMMY CALL THE ONLY IMPORTAIN VARIABLE IS
C LAST ONE (4).
      IF (PRT.EQ.6) CALL VDPL(DD,DD,ID,ID,ID,ID,DD,DD,DD,DD,DD,DD,
     1DD,DD,DD,DD,DD,DD,DD,4)
      GO TO 54
C     29. FROST PROFILE EXP AND ROUGHNESS LENGTH
   91 CALL DEF(29,IRT)
      IF (IRT.EQ.0) READ(*,*) FP,Z0
      GO TO 92
   93 FORMAT(A3,1X,A3,1X,A3,1X,A2,1X,A3,1X,A1,1X,BN,F10.0)
   94 WRITE(*,*) ' VAPOR DEPLETION ONLY DEFINED FOR STABILITIES A-F'
      GO TO 53
   95 CALL IGLO(QTS,TWL,NQI,IMU,IA,IR)
      IF (IR.EQ.9) GO TO 53
      GO TO 49
   96 WRITE(*,97) FNMU,MUNT,AGNT,REL,UT,TMP,LOCT(1),SEAT,MTC
   97 FORMAT(//F5.2,' MUN:',A3,2X,'AGN:',A2,2X,'REL:',A3,2X,'WND=:',
     $F4.1,'(M/S)',2X,'TMP=',F4.1,'(C)',2X,A3,'-',A3,1X,'STB:',A1)
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```
      GO TO 98
   99 WRITE(*,*) ' INSTANTANEOUS RELEASE OF HD IN WOODS NOT DEFINED'
      GO TO 53
   89 STOP
      END
```

EVAP3.FOR

```
C  EVAPORATION FROM A PUDDLE W/AREA W/STILL AIR /CGW
      SUBROUTINE EVAP (AGNT,QT,PMM,U,TC,TS,SUR,IL)
      COMMON EDM(52),QS,TEVP,SA,FL,FMWT,FMVT,VP,BPT,ED2(50)
      CHARACTER*3 SUR
      CHARACTER*2 AGN,AGNT
      DIMENSION AGN(25),FMW(25),FMV(25),BP(25),A(26),B(26),C(26),FP(26)
      DATA AGN/'GB','VX','HD','AC','CG','CK','GA','GD','GF','H1','H3',
     1'HT','LL','HY','UD','QL','DF','DC','TC','PR','IP','ZS','KB',
     1'DM','DM'/
      DATA FMW/140.1,267.4,159.1,27.02,98.92,61.48,162.18,182.18,180.2,
     1170.08,204.54,189.4,207.35,32.05,60.1,235.3,100.0,132.9,119.0,
     179.1,60.09,46.07,145.7,0.,0./
      DATA FMV/150.3,342.2,149.7,39.6,70.4,51.4,188.,211.4,196.8,184.3,
     1202.8,150.,130.1,34.5,81.7,332.37,81.93,105.4,79.5,89.3,81.9,
     162.3,208.0,0.,0./
      DATA BP/431.,571.,490.,298.7,281.4,285.8,518.,471.,512.,467.,529.,
     1501.,463.,386.6,337.1,517.7,372.7,439.6,348.8,388.3,355.2,
     1351.3,463.1,0.,0./
      DATA A/8.5916,7.281,7.47009,7.7446,7.460,8.6642,8.305,10.1174,
     110.8872,9.0715,8.986,0.,6.40361,9.0347,8.2223,6.52001,7.5444,
     17.2442,7.18757,7.05878,7.74144,8.17753,8.6883,0.,0.,0./
      DATA B/-2424.5,-2072.1,-1935.47,-1453.1,-1289.2,-1654.6,-2820.,
     1-3136.,-3590.5,-2890.7,-3232.,0.,-1237.037,-2348.18,-1799.31,
     1-1428.57,-1577.8,-1669.7,-1384.18,-1385.39,-1360.183,-1630.863,
     1-2663.33,0.,0.,0./
      DATA C/273.,172.5,204.2,273.,273.,273.,273.,273.,273.,273.,
     1273.2,273.,155.2,273.,273.,147.8,238.6,216.1,245.567,216.338,
     1197.593,229.581,268.48,0.,0.,0./
      DATA FP/-56.,-51.,14.45,-13.3,-128.,-6.9,-50.,-42.,-30.,-34.,
     1-3.7,-14.,-18.,1.4,-58.,-45.6,-36.9,33.,-105.,-42.,-85.8,-110.5,
     1-39.,0.,0.,0./
      IF(U.EQ.0) U=.03
      DO 10 IA=1,25
      IF(AGNT.EQ.AGN(IA)) GO TO 15
   10 CONTINUE
      IA=26
   15 IF (IL.NE.12) GO TO 40
C     16. ATMOSPHERIC PRESSURE
   20 CALL READA (16,IRT,IA,PMM)
      IF (IRT.LT.0) GO TO 20
C     17. SURFACE CODE
   40 CALL DEF(17,IRT)
      IF(IRT.EQ.0) READ(*,'(A3)') SUR
C     18. TIME OF EVAPORATION
   60 CALL READA (18,IRT,IA,TEVP)
      IF (IRT.LT.0) GO TO 60
      P=PMM/760.
      TA=TC+273.
      RHOA=.3487*P/TA
      FMUA=EXP(4.36+.002844*TA)*1.E-6
```

```
      SCD=FMUA/RHOA
      IF (SUR.EQ.'GRA') GO TO 120
      IF (SUR.EQ.'NPR') GO TO 130
      IF (SUR.EQ.'NDF') GO TO 80
      WRITE(*,70)
   70 FORMAT (' SURFACE CODE NOT DEFINED')
      CALL DEF (57,IRT)
      GO TO 40
C     19. AREA OF WETTED SURFACE
   80 CALL READA (19,IRT,IA,SA)
      IF (IRT.LT.0) GO TO 80
C     20. LENGTH OF SURFACE DOWNWIND
  100 CALL READA (20,IRT,IA,FL)
      IF (IRT.LT.0) GO TO 100
      GO TO 150
  120 SA=.153E-6*QT
      GO TO 140
  130 SA=1.21E-6*QT
  140 FL=SA**.5
  150 IF (IA.LT.26.AND.IA.NE.12) GO TO 180
C     21. FMW,FMV,VAP,BPT
      CALL DEF (21,IRT)
      IF (IRT.EQ.0) READ(*,*) FMWT,FMVT,VP,BPT
      IF (IRT.EQ.0) IVP=1
      IF (VP.GT.0.) GO TO 170
      WRITE(*,*) ' INPUT ANTOINE CONSTANTS: A,B,C, FP(DEG C)'
      READ(*,*) A(26),B(26),C(26),FP(26)
      IVP=(-1)
  170 IF (IVP) 185,185,205
  180 FMWT=FMW(IA)
      FMVT=FMV(IA)
      BPT=BP(IA)
  185 IF (TC.GT.FP(IA)) GO TO 200
      WRITE(*,190)
  190 FORMAT (' TEMPERATURE LESS THAN FREEZING')
      TS=1.E36
      QT=0.
      RETURN
  200 VP=10.**(A(IA)+B(IA)/(TC+C(IA)))
  205 IF (VP.LT.PMM) GO TO 230
      WRITE(*,210)
  210 FORMAT (' TEMPERATURE GREATER THAN BPT')
      TS=.1
      RETURN
  230 TS=TEVP
      FD=TA**1.5*(.03448+1./FMWT)**.5/P
      D=FD*.0043/(3.1034+FMVT**.3333)**2
      RE=FL*U/SCD*1.E4
      FJM=.036/RE**.2
      IF (RE.LE.20000.) FJM=.664/RE**.5
      GM=U*RHOA*3.448
      FKG=GM*FJM/(SCD/D)**.667
      EVR=FKG*FMWT*VP/PMM*6.E8
      AK=.1025*TA/BPT**.5
      OM=(1.075*AK**(-.1615))+2.*(10.*AK)**(-.74*ALOG10(10.*AK))
```

```
      CD=1.18*FMVT**.3333
      DS=FD*.00205/(OM*((3.711+CD)/2.)**2)
      FLC=(4.*SA/3.14159)**.5
      RES=FLC*.03/SCD*1.E4
      EVRS=292.*(1.+.51*RES**.5*(SCD/DS)**.3333)*ALOG(1./(1.-VP/PMM))*
     1FMWT/TA*DS/FLC*2./3.14159*1000.
      IF (EVRS.GT.EVR) EVR=EVRS
      IF (EVRS.EQ.EVR) WRITE(*,240)
  240 FORMAT (' STILL AIR')
  250 FORMAT(1X,A3,'  EVR='1PE9.3,'(MG/MIN-SQ M)  AREA='E9.3,'(SQ M)',
     1'  VPR='E9.3/,' Q='E9.3,'(MG)  '3HQ'=E9.3,'(MG)  ',
     2'  TEV='E9.3,'(MIN)')
      Q=SA*TEVP*EVR
      TS=TEVP
      IF (Q.LE.QT) GO TO 260
      TS=QT/EVR/SA
      Q=QT
  260 WRITE(*,250) SUR,EVR,SA,VP,QT,Q,TS
      QT=Q
      RETURN
      END
```

37G3.FOR

```
C  AXIAL DOSAGE/ SEMI-CONT/ VAR SOURCE/ VAR MET ORG CGW
      SUBROUTINE DDS
      CHARACTER*1 ST,MTC,AA1,AB1
      CHARACTER*2 AGNT,WT,AA2,CST,I2
      CHARACTER*3 MUNT,REL,LOCT,SEAT,SUR,I3,I4,I5
      CHARACTER*12 ADH,RL
      COMMON NQI,QT(6),TWL(6),D(10),DL(10)
      COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
     1BETA,SZ100,Z,RC,V,QS
      COMMON DDM(12),FP,DDM1(8),ZO,LOCT(1),SEAT,MUNT,AGNT,AA1,REL,
     $       MTC,AA2,SUR,WT,AB1,ADH,ADR,AD2
      COMMON IPR(1),ND,IPO,I2MCS,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,ID1,
     1ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
      DIMENSION SY100T(6),SZ100T(6),SY100I(6),ALFAT(6),BETAT(6),ST(11),
     1SY100C(2,3),SZ20C(2,3),BETAC(2,3),TWLS(6),AR(10),Y(10),VF(2),CI(2)
     2,S(2),RL(3),DS(31,2)
      DATA ALFAT/1.,1.,1.,.9,.8,.7/
      DATA BETAT/1.4,1.,.9,.85,.8,.75/
      DATA SY100I/9.,6.33,4.8,4.,3.,2./
      DATA SY100T/27.,19.,12.5,8.,6.1,4./
      DATA SZ100T/14.,11.,7.5,4.5,3.5,2.5/
      DATA SY100C/41.19,31.18,66.56,30.98,26.17,29.33/
      DATA SZ20C/3.,1.652,.797,1.934,.705,1.242/
      DATA BETAC/1.344,.755,1.218,.949,1.182,1./
      DATA ST/'A','B','C','D','E','F','N','I','U','S','W'/
      DATA VF,CI,S/.13,0,.454,.262,2.38,2.24/
      DATA I4,I5/'EDI','EDS'/
      DATA RL/'NO EFFECTS  ','NO DEATHS   ','1% LETHALITY'/
      IF (ISM.GT.1) GO TO 2
      DO 1 I=1,51
    1 DS(I,2)=(DS(I,1)+DS(I,2))*ISM
      RETURN
    2 IF (IMTCH) 3,3,7
    3 DX=DXT
      DO 4 I=1,ND
      AR(I)=0.
    4 DL(I)=ALOG(D(I))
      K=1
      DLDG=1.
      DLDGS=1.
      X=0.
      TWHML=HML+HML
      IC=ND
      MXLF=0
      XX=0.
      XY=0.
      XZ=0.
      XS=0.
      DPMX=0.
      IRTP=1
```

```
      IF (IR.GT.4.AND.IR.LT.8) IRTP=0
      DPL=-87.5
      DPLS=-87.5
      I2MC=I2MCS
      TQS=0.
      QRMX=0.
      SDEPL=1.
      QTTL=0.
      DO 5 I=1,NQI
      QTTL=QTTL+QT(I)
      TWLS(I)=TWL(I)*60.
      QR=QT(I)/(TWLS(I)-TQS)
      IF (QRMX.GT.QR) GO TO 5
      QRMX=QR
      TQ2=TWLS(I)
      TQ1=TQS
    5 TQS=TWLS(I)
      TOMXS=(TQ2-TQ1)/2.+TQ1
      IF (IDEP) 6,7,7
    6 CALL HD42
      IF (QT(1).EQ.0.) RETURN
      GO TO 11
    7 IMTCH=0
      IF (IM.EQ.9.OR.IM.EQ.11) GO TO 11
      IF (IM.LE.6) GO TO 9
      IF (IM.LE.8) GO TO 10
      WRITE (*,8)
    8 FORMAT (' MET CODE NOT DEFINED')
      RETURN
    9 IF (TOMXS.LE.2.4) SY100=SY100I(IM)
      IF (TOMXS.GT.2.4) SY100=SY100T(IM)
      SZ100=SZ100T(IM)
      ALFA=ALFAT(IM)
      BETA=BETAT(IM)
      GO TO 11
   10 IF (UT.LE.2.235) I=1
      IF (UT.GT.2.235.AND.UT.LE.4.47) I=2
      IF (UT.GT.4.47) I=3
      MC=IM-6
      SY100=SY100C(MC,I)
      SZ100=SZ20C(MC,I)*5**BETAC(MC,I)
      ALFA=.5
      BETA=BETAC(MC,I)
   11 U=UT
      XCH=1.E36
      IF (TIVCH.NE.1.E36) XCH=U*TIVCH*60.+X
      IF (X.LE.0.) X=1.
      IF (SXS.GT.0.) XX=(SXS/.1522)**(1./.9294)-X
      IF (SYS.GT.0.) XY=100.*(SYS/SY100)**(1./ALFA)-X
      IF (SZS.GT.0.) XZ=100.*(SZS/SZ100)**(1./BETA)-X
      WRITE (*,12)
   12 FORMAT (/4X,'Q(MG)',3X,'TS(MIN)',2X,'HTS(M)',3X,'HML(M)',3X,
     1'SXS(M)',3X,'SYS(M)',3X,'SZS(M)')
      CST=ST(IM)
      IF(IM.EQ.11) CST=WT
```

```
      WRITE(*,13) QT(1),TWL(1),HT,HML,SXS,SYS,SZS,CST
   13 FORMAT (1X,1PE9.3,6(1X,E8.2),2X,A2)
      IF (NQI.EQ.1) GO TO 15
      DO 14 I=2,NQI
      WRITE(*,13) QT(I),TWL(I)
   14 CONTINUE
   15 IF (IVD.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,XCH,DP,
     1DPA,SDEPL,1)
      IF(IDEP.GE.1) WRITE(*,18) BR,SF
      IF(I2MC.GT.0) WRITE(*,103)
      IF(ISM.EQ.2) WRITE(*,105)
      IF (IPO.LT.1.OR.IPO.EQ.4) GO TO 25
      WRITE(*,16)
   16 FORMAT (/3X,'ALFA',5X,'SYR',4X,'BETA',5X,'SZR',5X,'XY',6X,'XZ')
      WRITE(*,17) ALFA,SY100,BETA,SZ100,XY,XZ,UT
   17 FORMAT (1X,7(1PE8.2))
   18 FORMAT (/' BRT=',F4.0,'   SKF=',1PE8.2)
      I2='DP'
      IF (IDEP.GT.0) I2='ED'
      I3='  '
      IF (I2MC.GT.0) I3='2MC'
      IF (IPO.NE.3) GO TO 21
      WRITE(*,19) (D(I),I=1,ND)
   19 FORMAT(/6X,'DOSAGE CONTOURS',10F5.0)
      WRITE(*,20) I2,I3
   20 FORMAT(/7X,'X',7X,A2,A1,3X,'CONTOUR HALF-WIDTH')
      GO TO 25
   21 IF (IDEP.EQ.0) WRITE(*,24) I2,I3,I3
      IF (IDEP.GT.0) WRITE(*,24) I2,I3,I3,I4,I5
   24 FORMAT(/7X,'X',7X,A2,A1,7X,'RF',7X,A3,7X,A3,7X,A3)
      IF (ISM.EQ.2) WRITE(*,100)
   25 IF (X.GT.XCH) X=XCH
      B=X/U
      IIND=0
      IF (IRTP.GT.0) GO TO 26
      CALL PLRS (U,TMP,PMM,IL,IM,IR,X,HT,HML,IPC,IRTP)
   26 DXA=DX
      IF (X.GE.(DX*10.)) DX=DX*10.
      DXA=DXA+DX
      SX=.1522*(XX+X)**.9294
      SY=SY100*((X+XY)*.01)**ALFA
      SZ=SZ100*((X+XZ)*.01)**BETA
      IF (IVD.EQ.1.AND.X.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
     1XCH,DP,DPA,SDEPL,2)
      DP=0.
      IF (I2MC.EQ.0) GO TO 27
      A=1./(1.414*SX)
      G=.7979*SX/U
      H=.5/(SX*SX)
      TSX=SX/U
      IT=0
      TTO=B+TOMXS
      TT1=TTO-60.
      TT2=TT1+120.
   27 TSZSQ=SZ*SZ*2.
```

```
      HPZ=HT+Z
      HMZ=HT-Z
      VT=V*X/U
      FAC=0.
      HML2=1.E36
      ARG=(HMZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) FAC=FAC+EXP(-ARG)
      ARG=(HPZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) FAC=FAC+RC/EXP(ARG)
      ZFAC=0.
      IF (HML.GT.1.E10.OR.MXLF.EQ.1) GO TO 30
      DO 28 JJ=1,20
      SMHML=TWHML*JJ
      ARG=(SMHML-HPZ+VT)**2/TSZSQ
      IF (NOV.EQ.4) WRITE(*,*) ' ARG',ARG
      IF (ARG.GT.87.) GO TO 29
      ZFAC=ZFAC+RC**(JJ-1)/EXP(ARG)
      ARG=(SMHML-HMZ+VT)**2/TSZSQ
      IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
      ARG=(SMHML+HMZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
      ARG=(SMHML+HPZ-VT)**2/TSZSQ
   28 IF (ARG.LT.87.) ZFAC=ZFAC+RC**(JJ+1)/EXP(ARG)
   29 IF ((FAC+ZFAC).NE.0.) HML2=(2.5066283*SZ)/(FAC+ZFAC)
      IF (HML.GT.HML2.AND.(HML-HML2).LT.1) MXLF=1
   30 RF=(FAC+ZFAC)/2.
      IF (IIND) 33,33,31
   31 TT0=B-TSX-TSX
      TT1=TT0
      TT3=B+TWLS(NQI)+TSX+TSX
      TT3S=TT3
      TT3=TT3-120.
      DTT=(TT3-TT0)/30.
      IF (DTT.LT.10.) DTT=10.
      TT2=TT1+120.
      DOS=0.
      IF (DTT.LT.120.) GO TO 33
   32 TT2=TT1+DTT
   33 TWLT=0.
      DLDP=0.
      DO 63 ITWL=1,NQI
      TS=TWLS(ITWL)-TWLT
      IF (MXLF) 35,35,34
   34 C=QT(ITWL)/(300.79539*U*TS*SY*HML)
      GO TO 36
   35 C=QT(ITWL)*RF/(376.991*U*TS*SY*SZ)
   36 IF (I2MC.GT.0) GO TO 37
      DP=DP+C*2.*TS
      GO TO 63
   37 T1=TT1-TWLT
      IF (T1) 38,39,39
   38 T1=0.
   39 T2=TT2-TWLT
      IF (T2) 63,63,40
   40 I=3
```

```
      PT1=T1
      PT2=T2
      P=T2-TS
      R=T1-TS
      IF (P) 42,42,41
41    IF (R) 44,43,43
42    I=1
      GO TO 45
43    I=2
      GO TO 45
44    T2=TS
      R=0.
45    E=X-U*T2
      EE=E*E
      F=X-U*T1
      FF=F*F
      W=(T2-B)*ERFF(E*A)
      CC=(T1-B)*ERFF(F*A)
      ARG1=EE*H
      ARG2=FF*H
      IF (ARG1-82.6) 47,47,46
46    ARG1=0.
      GO TO 49
47    ARG1=EXP(-ARG1)
48    ARG2=EXP(-ARG2)
      GO TO 51
49    IF (ARG2-82.6) 48,48,50
50    ARG2=0.
51    DD=G*(ARG1-ARG2)
      GO TO (52,54,52,54), I
52    QQ=(T2-T1)*ERFF(X*A)
      XTERM=C*(QQ-W+CC+DD)
      IF (I-3) 62,53,94
53    PART=XTERM
      I=4
      T2=PT2
      T1=TS
      GO TO 45
54    ARG3=X-U*P
      ARG4=X-U*R
      HH=(T2-B-TS)*ERFF(ARG3*A)
      PP=(T1-B-TS)*ERFF(ARG4*A)
      ARG3=(ARG3**2)*H
      ARG4=(ARG4**2)*H
      IF (ARG3-82.6) 56,56,55
55    ARG3=0.
      GO TO 58
56    ARG3=EXP(-(ARG3))
57    ARG4=EXP(-(ARG4))
      GO TO 60
58    IF (ARG4-82.6) 57,57,59
59    ARG4=0.
60    GG=G*(ARG3-ARG4)
      XTERM=C*(HH-PP-W+CC-GG+DD)
      IF (I-4) 62,61,94
```

```
   61 T1=P11
      I=3
      XTERM=XTERM+PART
   62 DLDP=DLDP+XTERM
      TWLT=TWLS(ITWL)
   63 CONTINUE
      DPA=DP
      IF (I2MC.EQ.0) GO TO 75
      IF (IIND) 64,64,65
   64 IIND=1
      TDLDP=DLDP+0.
      GO TO 31
   65 DP=DP+DLDP
      IF (IT) 66,66,67
   66 IT=1
      TT2C=TT2-TT0
      GO TO 71
   67 TT10=TT1-TT0
      TT20=TT2-TT0
      TT21=TT2-TT1
      TT121=TT2C+TT2-TT1
      TT10P=TT2C**.274
      TT20P=TT121**.274
      TT21P=TT21**.274
      DELDC=.2696*(D0*(TT20P-TT10P))
      IF (DELDC-DLDP) 69,68,70
   68 TT2C=TT121
      GO TO 71
   69 DPC=DPS+DELDC
      TT2C=(((DPC*TT20P)+((DLDP-DELDC)*TT21P))/DP)**3.6496
      GO TO 71
   70 TT2C=((DLDP/TT21)*TT20*TT20P)+((DPS-(DLDP/TT21)*TT10)*TT10P)
      TT2C=(TT2C/DP)**3.6496
   71 DPS=DP
      D0=DP/(.2696*(TT2C**.274))
      IF (DOS-D0) 72,72,73
   72 TT2CS=TT2C+0.
      DOS=D0
   73 TT1=TT2
      IF (TT2-TT3S) 32,74,74
   74 DLDG=.2696*TT2CS**.274
      IF (DLDG.LT.1.) DLDG=1.
      DPA=DP
      DP=DP/DLDG
      IF (DP.LT.TDLDP) DP=TDLDP
   75 IF (IDEP.LT.1) GO TO 76
      DPA=DPA*VF(IDEP)
      DOSI=DP*VF(IDEP)
      DOSIS=QT(1)*SF*CI(IDEP)*(U/X)**S(IDEP)*1000/BR
      DP=(DOSI+DOSIS)
   76 IF (IVD.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
     1XCH,DP,DPA,SDEPL,3)
      IF (K.LT.52) DS(K,1)=DP
      IF (ISM.EQ.2) DP=DS(K,2)+DP
      IF (DP.LE.0.) GO TO 83
```

```
      DPL=ALOG(DP)
      IF (XS.EQ.0..OR.DPL.GE.DPLS) GO TO 83
      IND=1
      IF (IC-MRL) 84,84,77
   77 IF (DPMX.LT.D(IC)) GO TO 78
      IF (DP.GT.D(IC).OR.DPLS.LT.DL(IC)) GO TO 84
      XL=ALOG(X)
      XLS=ALOG(XS)
      XINT=EXP(XLS+(XL-XLS)*(DL(IC)-DPLS)/(DPL-DPLS))
      IF (IVD.EQ.1) WRITE(*,'(F5.2)') SDEPL
      IF (IRL.EQ.0) WRITE(*,101) XINT,D(IC)
      IF (IRL.EQ.1) WRITE(*,102) XINT,RL(IC)
   78 IF (D(IC).EQ.1.E36) WRITE(*,79)
   79 FORMAT (' RESP NOT DEF')
      IC=IC-1
      IF (IC.GT.1.OR.I2MC.LT.2) GO TO 81
      DPLS=ALOG(EXP(DPLS)*DLDGS)
      DPL=ALOG(DP*DLDG)
      I2MC=0
      IF (IC.GT.MRL) WRITE(*,80)
   80 FORMAT (' W/O 2-MINUTE CORRECTION')
   81 IF (IC-MRL) 84,84,77
   83 IND=0
      I2MC=I2MCS
      IF (DP.LT.DPMX) GO TO 84
      DPMX=DP
      XDMX=X
   84 IPOP1=IPO+1
      GO TO (92,85,87,88,92), IPOP1
   85 IF (RF.EQ.1..OR.MXLF.EQ.1) GO TO 86
      WRITE(*,98) X,DP,RF
      GO TO 92
   86 WRITE(*,98) X,DP
      GO TO 92
   87 IF (IDEP.EQ.0) WRITE(*,98) X,DP,RF,DLDG
      IF (IDEP.GE.1) WRITE(*,98) X,DP,RF,DLDG,DOSI,DOSIS
      GO TO 92
   88 IF (DP.LT.D(1)) GO TO 92
      DO 89 IY=1,ND
      ARG=DPL-DL(IY)
      IF (ARG.LT.0.) GO TO 90
      Y(IY)=1.41421*SY*SQRT(ARG)
      IF (X.NE.XCH) AR(IY)=AR(IY)+Y(IY)*DXA
      IF (X.EQ.XCH) AR(IY)=AR(IY)-Y(IY)*(XS+DX-XCH)
   89 CONTINUE
      IY=ND+1
   90 IY=IY-1
      WRITE(*,91) X,DP,(Y(I),I=1,IY)
   91 FORMAT (1X,F10.0,1PE10.3,0P10F5.0)
   92 XS=X
      DPLS=DPL
      DLDGS=DLDG
      IF (X.NE.XCH) GO TO 93
      IMTCH=1
      SXS=SX
```

```
      SYS=SY
      SZS=SZ
      RETURN
 93   IF (X.EQ.1..AND.DX.GT.1.) X=0.
      X=X+DX
      K=K+1
      IF (X.GT.9.E6) RETURN
      IF (IND.EQ.0.OR.DP.GT.D(MRL+1) OR.IRTP.LT.1) GO TO 25
      IF (DPMX.LT.D(MRL+1)) WRITE(*,104) XDMX,DPMX
 94   WRITE(*,*)
      IF (IPO.EQ.3) WRITE(*,96)
 96   FORMAT (4X,'DOSAGE',5X,'AREA')
      IF (IPO.EQ.3) WRITE(*,99) (D(I),AR(I),I=ND,1,-1)
      IF (IVD.EQ.1.AND.IPO.EQ.4) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
     1XCH,DP,DPA,SDEPL,4)
      IF (K.GT.51) RETURN
      DO 97 I=K,51
 97   DS(I,1)=0.
      RETURN
 98   FORMAT (1X,F10.0,1P5E10.3)
 99   FORMAT (1X,1P2E10.3)
 100  FORMAT (15X,'SUM')
 101  FORMAT (/1X,F10.0,' (M) IS DISTANCE TO ',E10.3,' (MG-MIN/M^3)')
 102  FORMAT (/1X,F10.0,' (M) IS DISTANCE TO ',A12/)
 103  FORMAT (/' W/2-MINUTE CORRECTION')
 104  FORMAT (/' MINIMUM DOSAGE NOT ATTAINED',//4X,'XDMAX',9X,'DMAX',
     $        /F10.0,6X,E10.3)
 105  FORMAT (/' DOSAGE IS BEING SUMMED')
      END
```

HD42.FOR

```
C  FIT TO ORG 40 PAR FOR 4.2/ CGW
      SUBROUTINE HD42
      COMMON NQI,QT(6),TWL(6),D(10),DL(10)
      COMMON TIM,DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
     1BETA,SZ100,Z,RC,V,QS
      COMMON HDM(33),IPR(1),ND,IPO,I2MC,IMA,OPC,IMM,IDD,IHS,NOV,INP,MRL,
     1NMU,ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD
      DIMENSION FWT(10),FST(3),ALBT4(3),SZR4(3)
      DATA FWT/1.6,.89,.64,.52,.43,.37,.33,.3,.27,.25/
      DATA FST/.7,1.,1.25/
      DATA SYR4/6.82/
      DATA ALBT4/3.33,1.4,1.02/
      DATA SZR4/287.,12.84,6.97/
      TF=1.8*TMP+32.
      IF (TF.LT.50.) GO TO 4
      IUT=UT+.5
      IF (IUT.GT.10) IUT=10
      IMT=(IM+1)/2
      IF (TF.LE.80.) FT=EXP(3.6889-.046052*TF)
      IF (TF.GT.80.) FT=EXP(3.4239-.042799*TF)
C     22. TIME AFTER FUNCTIONING
 1    CALL READA (22,IRT,3,TIM)
      IF (IRT.LT.0) GO TO 1
      FEL=ALOG(FST(IMT)*FWT(IUT)*FT*120./TIM)
      R=1.
      IF (FEL.LT.-1.2) GO TO 3
      R=EXP(.36464-.86189*FEL)
      IF (FEL.GT..4) R=R-EXP(-.05129-1.6767*FEL)
      IF (FEL.LE..4) R=R-EXP(-.24846-1.1373*FEL)
 3    QT(1)=QS*R*NMU
      SY100=SYR4
      SZ100=SZR4(IMT)
      ALFA=ALBT4(IMT)
      BETA=ALBT4(IMT)
      SYS=3.8
      SZS=.2
      SXS=SYS
      RETURN
 4    WRITE(*,5)
 5    FORMAT(' TEMPERATURE FUNCTION NOT DEFINED BELOW 10 DEG C')
      QT(1)=0.
      RETURN
      END
```

FTC3.FOR

```
C  PEAK CONCENTRATION/ INS/ CON/ FUM/ SAO PER CGW-JHG
      SUBROUTINE CDS
      CHARACTER*1 IST
      COMMON NQI,QT(6),TWL(6),CI(10),CL(10)
      COMMON PR(1),DXT,H,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALF,SYR,BTA,
     1SZR,Z,RC,V,QS,TEVP,SA,FL,FMW,CDM(8),FP,CDM1(8),Z0,CDM2(11)
      COMMON IPR(1),ND,IP0,I2MC,IMA,IPC,IMM,IDD,
     1IHR,NOV,INP,MRL,ID1,ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
      DIMENSION ALFA(6),BETA(6),SY100(6,2),SZ100(6)
      DIMENSION SY100C(2,3),SZ20C(2,3),BETAC(2,3)
      DIMENSION IST(11),Y(10),AR(10)
      DATA ALFA/1.0,1.0,1.0,.9,.8,.7/
      DATA BETA/1.4,1.,.9,.85,.8,.75/
      DATA SY100/9.,6.33,4.8,4.,3.,2.,27.,19.,12.5,8.,6.,4./
      DATA SZ100/14.,11.,7.5,4.5,3.5,2.5/
      DATA SY100C/41.19,31.18,66.56,30.98,26.17,29.33/
      DATA SZ20C/3.,1.652,.797,1.934,.705,1.242/
      DATA BETAC/1.344,.755,1.218,.949,1.182,1./
      DATA IST/'A','B','C','D','E','F','N','I','U','S','W'/
      DATA HK/0./
      IF (IDEP.EQ.0) GO TO 42
      WRITE(*,1)
 1    FORMAT ('CONCENTRATION NOT DEFINED FOR INSTANTEOUS'
     $' RELEASE OF VX OR HD')
      RETURN
 42   IF (IMTCH) 2,2,43
 2    DO 3 I=1,ND
      AR(I)=0.
      CL(I)=LOG(CI(I))
 3    CONTINUE
      X=0.
      DX=DXT
      SDEPL=1.
      Q=QT(1)
      IS=1
      IF (TWL(1).GT..083) IS=2
 43   IMTCH=0
      IF (IM.GT.8) GO TO 5
      IF (IM.GT.6) GO TO 4
      ALF=ALFA(IM)
      SYR=SY100(IM,IS)
      BTA=BETA(IM)
      SZR=SZ100(IM)
      GO TO 5
 4    I=UT/2.235+1
      IF (I.GT.3) I=3
      MC=IM-6
      BTA=BETAC(MC,I)
      ALF=.5
      SYR=SY100C(MC,I)
```

```
      SZR=SZ20C(MC,I)*5**BTA
    5 XC=1.E36
      IF (TWL(1).EQ.1.E36) GO TO 6
      Q=QT(1)/TWL(1)
      XC=0.
      IF (IS.EQ.1) GO TO 6
      XC=EXP(ALOG(TWL(1)*UT*157.27)/.9294)
    6 QOU=Q/UT
      HKOU=HK/UT/60.
      XCH=1.E36
      IF (TIVCH.NE.1.E36) XCH=UT*TIVCH*60.+X
      IF (IMTCH.EQ.1) GO TO 44
      MXLF=0
      TWHML=HML+HML
      IC=ND
      IND=0
      IRTP=1
      IF (IR.GT.4.AND.IR.LT.8) IRTP=0
      CPMX=0.
      CPLSAV=-87.5
      XSAVE=0.
   44 A=0.
      B=0.
      C=0.
      IF (SXS.NE.0.) A=(SXS/.1522)**1.076-X
      IF (SYS.NE.0.) B=100*(SYS/SYR)**(1./ALF)-X
      IF (SZS.NE.0.) C=100.*(SZS/SZR)**(1./BTA)-X
      WRITE(*,7)
    7 FORMAT(/5X,'Q(MG)',4X,'TS(MIN)',3X,'HTS(M)',4X,'HML(M)',
     +6X,'WND')
      WRITE (*,8) QT(1),TWL(1),H,HML,UT,IST(IM)
    8 FORMAT (3X,1PE9.3,4(1X,F9.3),4X,A2)
      WRITE (*,9)
    9 FORMAT(/4X,'ALF',2X,'SYR',4X,'BTA',3X,'SZR',8X,'SYS(M)',
     +2X,'SZS(M)',2X,'XY(M)',3X,'XZ(M)',3X,'XC(M)')
      WRITE (*,10) ALF,SYR,BTA,SZR,SYS,SZS,B,C,XC
   10 FORMAT (1X,4F6.2,6X,1P5E8.1/)
      IF (IVD.EQ.1) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,XCH,CP,CP,
     1SDEPL,1)
      IF (IMA.EQ.3) WRITE(*,11)
   11 FORMAT (' FUMIGATION')
      IF (IPO.NE.3) GO TO 13
      WRITE(*,12) (CI(I),I=1,ND)
   12 FORMAT('        CONCENTRATIONS',10F5.0)
      WRITE(*,*)
      WRITE(*,*) '         X         CP     CONTOUR HALF-WIDTHS'
   13 IF (IPO.LT.3) WRITE(*,41)
      IF (IMA.EQ.2) WRITE(*,*)'                          PPM'
   14 IF (X.GT.XCH) X=XCH
      DXA=DX
      IF (X.GE.(DX*10.)) DX=DX*10.
      DXA=DXA+DX
      IF (X.EQ.0) X=1
      SY=SYR*((X+B)*.01)**ALF
      SZ=SZR*((X+C)*.01)**BTA
```

```
      IF (IVD.EQ.1.AND.X.EQ.1.) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
     1XCH,CP,CP,SDEPL,2)
      IF (IRTP.GT.0) GO TO 15
      CALL PLRS (UT,TMP,PMH,IL,IM,IR,X,H,HML,IPC,IRTP)
   15 IF (IMA.NE.3) GO TO 16
      SYF=SY+(H*.125)
      CP=QOU/(150.39770*SYF*(H+SZ+SZ))
      GO TO 24
   16 IF (MXLF) 18,18,17
   17 CP=QOU/(150.39770*SY*HML)
      GO TO 22
   18 CP=QOU/(188.49556*SZ*SY)
      TSZSQ=SZ*SZ*2.
      HPZ=H+Z
      HMZ=H-Z
      VT=V*X/UT
      FAC=0.
      HML2=1.E36
      ARG=(HMZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) FAC=FAC+EXP(-ARG)
      ARG=(HPZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) FAC=FAC+RC/EXP(ARG)
      ZFAC=0.
      IF (HML.GT.1.E10.OR.MXLF.EQ.1) GO TO 21
      DO 19 JJ=1,20
      SMHML=TWHML*JJ
      ARG=(SMHML-HPZ+VT)**2/TSZSQ
      IF (ARG.GT.87.) GO TO 20
      ZFAC=ZFAC+RC**(JJ-1)/EXP(ARG)
      ARG=(SMHML-HMZ+VT)**2/TSZSQ
      IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
      ARG=(SMHML+HMZ-VT)**2/TSZSQ
      IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
      ARG=(SMHML+HPZ-VT)**2/TSZSQ
   19 IF (ARG.LT.87.) ZFAC=ZFAC+RC**(JJ+1)/EXP(ARG)
   20 IF((FAC+ZFAC).NE.0.)HML2=(2.5066283*SZ)/(FAC+ZFAC)
      IF (HML.GT.HML2.AND.(HML-HML2).LT.1) MXLF=1
   21 RF=(FAC+ZFAC)/2.
      CP=CP*RF
   22 IF (X.LT.XC) GO TO 23
      SX=.1522*((X+A)**.9294)
      CP=CP*TWL(1)*UT*23.936537/SX
   23 IF (HK.GT.0.) CP=CP/EXP(X*HKOU)
   24 IF (CP.LT.1.E-35) GO TO 36
      IF (IVD.EQ.1) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
     1XCH,CP,CP,SDEPL,3)
      IF (IMA.EQ.2) CP=CP*24.45/FMW
      CPL=LOG(CP)
      IF (XSAVE.EQ.0..OR.CPL.GE.CPLSAV) GO TO 28
      IND=1
   25 IF (CPMX.LT.CI(IC)) GO TO 26
      IF (CP.GT.CI(IC).OR.CPLSAV.LT.CL(IC)) GO TO 29
      XLNA=ALOG(X)
      XLNB=ALOG(XSAVE)
      XLNC=XLNB+(XLNA-XLNB)*(CL(IC)-CPLSAV)/(CPL-CPLSAV)
```

```
      XINT=EXP(XLNC)
      IF (IVD.EQ.1) WRITE(*,'(F5.2)') SDEPL
      WRITE (*,27) XINT,CI(IC)
   26 IC=IC-1
      IF (IC-MRL) 29,29,25
   27 FORMAT (/1X,F10.0,'* ',1PE10.3)
   28 IND=0
      IC=ND
      IF (CP.LT.CPMX) GO TO 29
      CPMX=CP
      XCMX=X
   29 IF (IPO.NE.3) GO TO 32
      SYRT2=1.41421*SY
      Y(1)=0.
      DO 30 IY=1,ND
      ARG=CPL-CL(IY)
      IF (ARG.LT.0.) GO TO 31
      Y(IY)=SYRT2*SQRT(ARG)
      IF (X.NE.XCH) AR(IY)=AR(IY)+Y(IY)*DXA
      IF (X.EQ.XCH) AR(IY)=AR(IY)-Y(IY)*(XSAVE+DX-XCH)
   30 CONTINUE
      IY=ND+1
   31 IY=IY-1
      WRITE (*,39) X,CP,(Y(I),I=1,IY)
      GO TO 35
   32 IF (IPO.EQ.0.OR.IPO.EQ.4) GO TO 35
      IF (RF.EQ.1.0.OR.MXLF.EQ.1) GO TO 34
      WRITE (*,33) X,CP,RF
   33 FORMAT (1X,F10.0,2X,1P2E10.3)
      GO TO 35
   34 WRITE (*,33) X,CP
   35 IF (IND.EQ.1.AND.CPL.LT.CL(1+MRL).AND.IRTP.GT.0) GO TO 37
      XSAVE=X
      CPLSAV=CPL
      IF (X.NE.XCH) GO TO 36
      IMTCH=1
      SXS=SX
      SYS=SY
      SZS=SZ
      RETURN
   36 IF (X.EQ.1..AND.DX.GT.1.) X=0.
      X=X+DX
      GO TO 14
   37 IF (CPMX.LT.CI(1+MRL)) WRITE(*,39) XCMX,CPMX
      IF (IPO.EQ.3) WRITE (*,40) (CI(I),AR(I),I=ND,1,-1)
      IF (IVD.EQ.1.AND.IPO.EQ.4) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
     1XCH,CP,CP,SDEPL,4)
      RETURN
   38 FORMAT (21X,10F5.0)
   39 FORMAT (1X,F10.0,1PE10.3,0P10F5.0)
   40 FORMAT (//5X,'C',8X,'AREA',/(1P2E10.3))
   41 FORMAT(/9X,'X',8X,'CP',8X,'RF')
      END
```

PLR3.FOR

```
C  STACK PROGRAM/ PLUME RISE/ GROUND FIRE/ CGW
         SUBROUTINE PLRS (UR,TMP,PMM,IL,IM,IR,XI,HT,HML,IPC,IRTP)
         COMMON PDM(60),HS,DS,TSC,VS,RDE,P,HR,CR,PDZ(42)
         DIMENSION DELF(6),DTDZ(6),PT(6,3),ITT(12)
         DATA DXT /10./
         DATA G /9.8/
         DATA ZR /2./
         DATA CP /.24/
         DATA GI /.64/
         DATA GC /.5/
         DATA DELF/1.2,1.1,1.,1.,.9,.8/
         DATA DTDZ/-.01,-.008,-.006,0.,.01,.037/
         DATA PT/.05,.05,.1,.1,.15,.15,.05,.1,.15,.2,.25,.3,.1,.15,.2,.25,
        1.3,.35/
         DATA ITT/3,2,3,1,3,2,3,2,2,3,3,0/
         IF (XI.EQ.0.) GO TO 30
         IF (IPC.GT.1) GO TO 10
         IRTP=1
         RETURN
   10    X=XI
         IF (XI.LT.XMX) GO TO 20
         X=XMX
         IRTP=IRTP+1
   20    IF (IR-6) 280,290,320
   30    IRTP=-1
         TA=TMP+273.
         S=G*DTDZ(IM)/TA
         IF (IL.NE.12) GO TO 60
C        16. ATMOSPHERIC PRESSURE
   40    CALL READA (16,IRT,IA,PMM)
         IF (IRT.LT.0) GO TO 40
   60    PA=1013.*PMM/760.
C        23. OUTPUT CONTROL CODE
   50    CALL DEF (23,IRT)
         IF (IRT.EQ.0) READ(*,*,ERR=70) IPC
         GO TO 80
   70    CALL DEF (63,IRT)
         GO TO 50
   80    IF (IR.GT.6) GO TO 300
C        24. HEIGHT OF STACK
   90    CALL READA (24,IRT,IA,HS)
         IF (IRT.LT.0) GO TO 90
C        25. DIAMETER OF STACK
  100    CALL READA (25,IRT,IA,DS)
         IF (IRT.LT.0) GO TO 100
C        26. TEMPERATURE OF STACK
  110    CALL READA (26,IRT,IA,TSC)
         IF (IRT.LT.0) GO TO 110
C        27. VELOCITY OF EFFLUENT
  120    CALL READA (27,IRT,IA,VS)
```

```
      IF (IRT.LT.0) GO TO 120
C     28. RELATIVE DENSITY OF EFFLUENT
 130  CALL DEF (28,IRT)
      IF (IRT.EQ.0) READ(*,*) RDE
 140  TS=TSC+273.
      F=0.
      IF (TS.LT.TA) WRITE(*,150)
 150  FORMAT(' DHH/DHB/DHBT NOTE: STK TMP LESS THAN AIR TMP')
      IF (TS.LT.TA) GO TO 160
      F=(TS-TA)/TS*G*VS*DS**2/4.
      IF (F.LE.55.) XA=14.*F**.625
      IF (F.GT.55.) XA=34.*F**.4
      XMX=3.5*XA
 160  IT=ITT(IL)
      IF (IT.NE.0) P=PT(IM,IT)
      IF (IT.NE.0) GO TO 170
C     29. FROST PROFILE EXPONENT
      CALL DEF (29,IRT)
      IF (IRT.EQ.0) READ(*,*) P
 170  UZ=UR*(HS/ZR)**P
      IF (S.GT.0.) XMX=2.4*UZ/S**.5
      FM=RDE*VS*VS*DS*DS/4.
      IF (UZ.LT.1..AND.S.GE.0.) GO TO 200
      VR=VS/UZ
      IF (VR.LT.4) WRITE(*,180)
 180  FORMAT (' DHJ NOTE: VS/UZ LT 4')
      IF (S.LT.0.) WRITE(*,190)
 190  FORMAT (' DHJ NOTE: UNSTABLE MET CONDITIONS')
      DHJ=3.*VR*DS
      GO TO 210
 200  DHJ=4.*(FM/S)**.25
 210  IF (S.LE.0.) GO TO 220
      DHJB=1.5*(FM/UZ)**.333/S**.167
      IF (DHJB.LT.DHJ) DHJ=DHJB
 220  X=1.
      IF (IR.EQ.5.AND.IPC.EQ.0) X=XMX
      DELH=(VS*DS/UR)*(1.5+(2.68E-3*PA*((TS-TA)/TS)*DS))
      DHH=DELH*DELF(IM)
      WRITE(*,230)
 230  FORMAT (/8X,'X',8X,'DHH',7X,'DHB',6X,'DHBT',5X,'DHJ')
      DEL=1.6*(F**.333)/UZ
 240  IF (IR.EQ.5.AND.X.GT.XMX) X=XMX
      DHB=DEL*X**.667
      IF (S.LE.0.) GO TO 250
      DHB=2.5*(F/(UZ*S))**.333
      IF (UR.GE.1.) GO TO 250
      DHMTT=5.*(F**.25)/(S**.375)
      IF (DHMTT.LT.DHB) DHB=DHMTT
 250  DHJX=1.44*DS*(VS/UZ)**.667*(X/DS)**.333
      IF (DHJX.GT.DHJ) DHJX=DHJ
      DHBT=F**.333*X**.667/UZ*(1.065-6.25*DTDZ(IM))
      IF (IPC.EQ.1.OR.IPC.EQ.3) WRITE(*,260) X,DHH,DHB,DHBT,DHJX
      IF (IR.EQ.5.AND.X.GE.XMX) GO TO 270
      IF (IR.EQ.6.AND.DHJX.GE.DHJ) GO TO 270
 260  FORMAT (6F10.2)
```

```
      IF (X.EQ.1.) X=0.
      X=X+DXT
      GO TO 240
  270 WRITE(*,260) X,DHH,DHB,DHBT,DHJ,P
      IF (IR.EQ.5) HT=HS+DHBT
      IF (IR.EQ.6) XMX=X
      IF (IR.EQ.6) HT=HS+DHJ
      RETURN
  280 DHBT=F**.333*X**.667/UZ*(1.065-6.25*DTDZ(IM))
      HT=HS+DHBT
      GO TO 360
  290 DHJX=1.44*DS*(VS/UZ)**.667*(X/DS)**.333
      IF (DHJX.GT.DHJ) DHJX=DHJ
      HT=HS+DHJX
      GO TO 360
C     30. HEAT RELEASED
  300 CALL READA (30,IRT,IA,HR)
      IF (IRT.LT.0) GO TO 300
C     31. CLOUD RADIUS
  305 CALL READA (31,IRT,IA,CR)
      IF (IRT.LT.0) GO TO 305
      HT=0.
      IF (IM.LT.4) GO TO 330
      IF (IM.EQ.4) S=G*3.322E-4/TA
      ROA=352320.*PMM/760./TA
      RTS=S**.5
      XMX=3.14159*UR/RTS
      X=XMX
      WRITE(*,310) XMX
  310 FORMAT (' XMX=',F7.0)
  320 FT=1.-COS(RTS*X/UR)
      FB=G*HR/(3.14159*ROA*CP*TA)
      IF (IR.EQ.8) GO TO 350
      HT=(3.*FB*FT/(S*GI**3)+(CR/GI)**4)**.25-(CR/GI)
      GO TO 360
  330 WRITE(*,340)
  340 FORMAT (' HEIGHT DEFINED FOR STABLE CONDITIONS ONLY')
      RETURN
  350 HT=(3.*FB*FT/(UR*GC*GC*S)+(CR/GC)**3)**.333-(CR/GC)
  360 IF (HT.LT.HML) GO TO 370
      HT=HML
  370 WRITE(*,380) HT
  380 FORMAT(' HTS=',F7.2)
      RETURN
      END
```

```
PSST3.FOR

C  PASQUILL STABILITY CATEGORY SELECTOR/ TURNER/CGW
      SUBROUTINE STAB (U,IS,IL,IM,ID)
      COMMON SDM(68),SLA,SLO,CC,CH,AE,SD2(21),IHR,SD3(15)
      CHARACTER*1 ISTA,MTC
      CHARACTER*20 ADH
      CHARACTER*3 IMO,IMOT
      DIMENSION AC(4),IST(7,8),ISTA(6),IDC(12),SE(4)
      DIMENSION IMOT(12),SLAT(10),SLOT(10)
      DATA AC/15.,35.,60.,90./
      DATA ISTA/'A','B','C','D','E','F'/
      DATA IST/6,6,4,3,2,1,1,6,6,4,3,2,2,1,6,5,4,4,3,2,1,6,5,4,4,3,2,2,
     15,4,4,4,3,3,2,5,4,4,4,4,3,3,4,4,4,4,4,3,3,4,4,4,4,4,4,3/
      DATA IDC/0,0,3,3,4,4,5,5,5,6,6,7/
      DATA IMOT /'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG',
     $           'SEP','OCT','NOV','DEC'/
      DATA VE,YRL /0.,0./
      DATA SE /92.78,93.64,89.83,89./
      DATA HY /182.62/
      DATA PH /1.570796/
      DATA PI /3.141593/
      DATA P2 /6.283185/
      DATA RD /57.2958/
      DATA SLAT/33.7,40.,39.3,16.7,38.,40.,34.,38.,40.,46./
      DATA SLOT/86.1,113.,76.,169.5,84.,87.5,92.,2*105.,120./
      IF (VE.GT.0.) GO TO 1
      WRITE(*,*) ' INPUT: YEAR(1986)'
      READ (*,*) YR
      DYO4=(YR-1976.)/4.
      VE=79.4931+(DYO4*.9688)-AINT(DYO4)
      IF ((DYO4-AINT(DYO4)).EQ.0.) YRL=1.
 1    IF (IL.LT.11) GO TO 30
C     32. STATION LATITUDE AND LONGITUDE
 10   CALL DEF(32,IRT)
      IF (IRT.EQ.0) READ(*,*) SLA,SLO
      GO TO 40
  30  SLA=SLAT(IL)
      SLO=SLOT(IL)
  40  A=SLA/RD
C     33. MONTH,DAY,HOUR (JAN,01,1200)
      CALL DEF(33,IRT)
      IF (IRT.EQ.1) GO TO 80
      READ(*,'(A3,1X,BN,A20)') IMO,ADH
      READ(ADH,'(BN,I2,1X,I4)') ID,IHR
  60  DO 70 IM=1,12
      IF(IMO.EQ.IMOT(IM)) GO TO 80
  70  CONTINUE
      GO TO 40
C     34. CLOUD COVER (1/10),CLOUD HEIGHT (FT)
  80  CALL DEF (34,IRT)
      IF (IRT.EQ.0) READ(*,*) CC,CH
```

```
      HRC=IHR/100.
      HRS=(HRC-INT(HRC))/0.6+INT(HRC)
      IF (IM.NE.0) GO TO 100
C     35. SUN ELEVATION ANGLE
      CALL DEF(35,RT)
      IF (IRT.EQ.0) READ(*,*) AE
      GO TO 130
  100 DJ=(IM-1)*31-IDC(IM)+ID
      IF (IM.GT.2) DJ=DJ+YRL
      DV=DJ-VE
      IF (DV.LT.0.) DV=DV+365.
      DT=DV
      DO 110 I=1,4
      IF (DT.LT.SE(I)) GO TO 120
      DT=DT-SE(I)
  110 CONTINUE
  120 DL=SIN(PH*((I-1)+DT/SE(I)))*.4091
      EQ=(10.*SIN((DV+89.)/HY*P2)+7.75*SIN((DV+78)/HY*PI))/60.
      HDL=ACOS(-.014538/COS(A)/COS(DL)-(TAN(A)*TAN(DL)))/.2618
      TC=12.+EQ+(SLO/15.-AINT(SLO/15.))
      ISR=(((TC-HDL)-AINT(TC-HDL))*.6+AINT(TC-HDL))*100.
      ISS=(((TC+HDL)-AINT(TC+HDL))*.6+AINT(TC+HDL))*100.
      AE=ASIN(SIN(A)*SIN(DL)+COS(A)*COS(DL)*COS((HRS-TC)*.2618))*RD
  130 I=0
      IF (CC.EQ.10.AND.CH.LT.7000.) GO TO 190
      IF (HRS.GT.(13.-HDL).AND.HRS.LT.(11.+HDL)) GO TO 140
      I=-2
      IF (CC.GT.4.) I=-1
      GO TO 190
  140 DO 150 I=1,4
      IF (AE.LT.AC(I)) GO TO 160
  150 CONTINUE
      I=4
  160 IF (CC.LT.6.OR.CH.GT.16000.) GO TO 190
      IF (CC.GT.9.OR.CH.GE.7000.) GO TO 170
      I=I-2
      GO TO 180
  170 I=I-1
  180 IF (I.LT.1) I=1
  190 I=I+3
      J=U+1.
      IF (U.GT.6.) J=8
      IS=IST(I,J)
      MTC=ISTA(IS)
      WRITE(*,200) ISR,ISS,AE,MTC
  200 FORMAT(' SR',I4,3X,' SS',I5,3X,' AE',F6.2,3X,' STAB ',A1)
      RETURN
      END
```

WOODS.FOR

```
      SUBROUTINE WOODS(U,ALFA,SY100,BETA,SZ100,WT)
      DIMENSION UT(4),W(4,5),ALW(4,5),SYW(4,5),BTW(5),SZW(4,5),WTT(5)
      CHARACTER*2 WTT,WT
      DATA UT/.45,2.2,5.4,8.9/
      DATA W/.089,.45,1.1,1.8,.089,.36,.8,1.3,.089,.36,.8,1.3,
     $ .045,.22,.54,.89,.045,.13,.27,.45/
      DATA ALW/.8,1.,1.,1.1,.8,3*1.,.8,3*1.,.8,7*1./
      DATA SYW/12.8,12.1,12.,12.,18.2,17.5,16.8,14.5,
     $ 23.5,22.5,19.,14.,29.,26.5,22.5,16.5,53.,36.,26.,23./
      DATA SZW/8.97,9.66,2*10.35,12.96,3*13.78,14.59,
     $ 3*15.4,4*20.,4*34.5/
      DATA BTW/1.2,1.3,1.3,1.4,1./
      DATA WTT/'DW','MW','CF','MS','RF'/
C     36. WOODS TYPE
   10 CALL DEF(36,IRT)
      IF (IRT.EQ.0) READ(*,30) WT
   30 FORMAT(A2)
      DO 40 I=1,5
      IF (WTT(I).EQ.WT) GO TO 60
   40 CONTINUE
      WRITE(*,50)
   50 FORMAT(' WOODS CODE NOT DEFINED')
      CALL DEF(76,IRT)
      GO TO 10
   60 IF (U.GT.0.) GO TO 90
      U=ABS(U)
      DO 70 J=1,4
      IF (W(J,I) .GE. U) GO TO 130
   70 CONTINUE
   80 ALFA=ALW(4,I)
      SY100=SYW(4,I)
      SZ100=SZW(4,I)
      GO TO 140
   90 DO 100  J=1,4
      IF (UT(J).GE.U) GO TO 110
  100 CONTINUE
      J=4
  110 IF (J.NE.1) GO TO 120
      U=W(J,I)
      GO TO 130
  120 S=ALOG(W(J,I)/W(J-1,I))/ALOG(UT(J)/UT(J-1))
      U=W(J-1,I)*(U/UT(J-1))**S
      IF (U.GT.W(4,I)) GO TO 80
  130 DUW=(U-W(J-1,I))/(W(J,I)-W(J-1,I))
      ALFA=ALW(J-1,I)+DUW*(ALW(J,I)-ALW(J-1,I))
      SY100=SYW(J-1,I)+DUW*(SYW(J,I)-SYW(J-1,I))
      SZ100=SZW(J-1,I)+DUW*(SZW(J,I)-SZW(J-1,I))
  140 BETA=BTW(I)
      RETURN
      END
```

DEF.FOR

```
      SUBROUTINE DEF(IQ,IRT)
      COMMON DDM(95),NOV,DD1(7),IR,DD2(6)
      DIMENSION IQT(40),IQI(7)
      DATA IQI/2,3,5,6,8,9,10/
      IF (IQ) 10,20,50
   10 IQQ=(-IQ)
      IQT(IQQ)=0
      RETURN
   20 DO 40 I=1,40
   30 IQT(I)=0
   40 CONTINUE
      RETURN
   50 IF (IQ.EQ.80) GO TO 140
      IF (IQ.GT.40) GO TO 110
      IF (IQ.EQ.40) GO TO 120
      IF (IQ.EQ.39) GO TO 130
      IF (IQT(IQ).EQ.0) GO TO 60
      IRT=1
      CALL QLIST(IQ,IRT)
      RETURN
  60  IRT=0
      IF(IQ.NE.12.AND.IR.NE.2) WRITE(*,*)
      CALL QLIST(IQ,IRT)
      IQT(IQ)=1
      IF (NOV-1) 70,90,100
   70 WRITE(*,80)
   80 FORMAT('  INPUT:'\)
      RETURN
   90 IF (IQ.EQ.2) WRITE(*,1001)
      IF (IQ.EQ.3) WRITE(*,1007)
      IF (IQ.EQ.5) WRITE(*,1003)
      IF (IQ.EQ.6) WRITE(*,1004)
      IF (IQ.EQ.8) WRITE(*,1005)
      IF (IQ.EQ.9) WRITE(*,1006)
      IF (IQ.EQ.17) WRITE(*,1012)
      IF (IQ.EQ.36) WRITE(*,1024)
      GO TO 70
 100  IF (IQ.EQ.1) WRITE(*,2000)
      IF (IQ.EQ.2) WRITE(*,2005)
      IF (IQ.EQ.3) WRITE(*,2010)
      IF (IQ.EQ.5) WRITE(*,2020)
      IF (IQ.EQ.6) WRITE(*,2030)
      IF (IQ.EQ.8) WRITE(*,2040)
      IF (IQ.EQ.9) WRITE(*,2050)
      IF (IQ.EQ.13.AND.IR.NE.3) WRITE(*,2060)
      IF (IQ.EQ.13) WRITE(*,2070)
      IF (IQ.EQ.17) WRITE(*,2080)
      IF (IQ.EQ.21) WRITE(*,2090)
      IF (IQ.EQ.23) WRITE(*,2095)
      IF (IQ.EQ.36) WRITE(*,2110)
```

```
      GO TO 70
  110 IQQ=IQ-40
      IQT(IQQ)=0
      IF (NOV.GT.1) RETURN
  115 IF (IQQ.EQ.1) WRITE(*,2000)
      IF (IQQ.EQ.2) WRITE(*,2005)
      IF (IQQ.EQ.3) WRITE(*,2010)
      IF (IQQ.EQ.5) WRITE(*,2020)
      IF (IQQ.EQ.6) WRITE(*,2030)
      IF (IQQ.EQ.8) WRITE(*,2040)
      IF (IQQ.EQ.9) WRITE(*,2050)
      IF (IQQ.EQ.17) WRITE(*,2080)
      IF (IQQ.EQ.21) WRITE(*,2090)
      IF (IQQ.EQ.23) WRITE(*,2095)
      IF (IQQ.EQ.36) WRITE(*,2110)
      RETURN
  120 IQQ=IRT
      IF (IQQ.GT.0) GO TO 115
      IF (IRT.EQ.-1) WRITE(*,601)
      IF (IRT.EQ.-2) WRITE(*,602)
      IF (IRT.EQ.-3) WRITE(*,603)
      IF (IRT.EQ.-4) THEN
      WRITE(*,604)
      PAUSE
      WRITE(*,605)
      PAUSE
      WRITE(*,606)
      PAUSE
      WRITE(*,607)
      PAUSE
      ENDIF
      WRITE(*,600)
      RETURN
  130 WRITE(*,500)
      PAUSE
      WRITE(*,501)
      PAUSE
      RETURN
  140 WRITE(*,*) ' LOC,SEA,MUN,AGN,REL,STB,WND'
      DO 145 I=1,7
  145 IQT(IQI(I))=1
      NOV=0
      RETURN
C----------------------------------------------
C CONTROL OPTION AND QUESTION FORMAT STATEMENTS
C----------------------------------------------
  600 FORMAT(//
     +' TABLE DISPLAY CODES  1 CONTROL OPTIONS',5X,
     +'2 ASSESSMENT OPTIONS'/,22X,'3 OUTPUT OPTIONS'
     +,6X,'4 ALPHABETIC LISTING'/)
  601 FORMAT(//
     +14X,'CONTROL OPTIONS'//,6X,'RST  RESTART'/,6X,'RSN  RESCAN'/,
     +6X,'ALL  EXECUTE'/,6X,'STP  STOP'//,6X,'GTO  GO TO '
     +'QUESTION NO. (GTO 3)'/,6X,'IRT  RETURN TO QUESTION NO.'/,
     +6X,'INP  INPUT QUESTION NO.'//,6X,'HLD  HOLD VARIABLE '
```

```
     +'(HLD HML)'/,6X,'RLS  RELEASE VARIABLE'//,6X,'TAB  DISPLAY'
     +' TABLE'/,6X,'DSP  DISPLAY QUESTION DEFINITION'/,6X,'??? '
     +' LIST OF DISPLAY CODES'/)
  602 FORMAT(///
     +16X,'ASSESSMENT CONTROLS'//,5X,'IMA=0  DOSAGE (DEFAULT)'/,
     +9X,'1  CONCENTRATION (MG/CU M)'/,9X,'2  CONCENTRATION (PPM)'
     +/,9X,'3  FUMIGATION CONCENTRATION'//,5X,'2MC=0  DO NOT'
     +'USE 2-MINUTE CORRECTION'/,12X,'WITH GB AND VX VAPOR'/,
     +9X,'2  USE 2-MINUTE CORRECTION WITH'/,12X,'GB AND VX'
     +' VAPOR (DEFAULT)'//,5X,'MNR=0  NO EFFECTS, NO DEATHS'
     +', 1% LETHALITY'/,9X,'1  NO DEATHS, 1% LETHALITY'/,
     +9X,'2  1% LETHALITY'//,5X,'VDP=0  W/O VAPOR DEPLETION '
     +'(DEFAULT)'/,9X,'1  W/VAPOR DEPLETION'/)
 603  FORMAT(//
     +15X,'OUTPUT CONTROLS'//,5X,'NOV=0  LIST QUESTIONS ONLY'/,9X,
     +'1  LIST QUESTIONS AND OPTIONS'/,9X,'2  LIST OPTIONS WITH'
     +' DEFINITIONS'//,5X,'OPO=0  OUTPUT SHORT HEADING (DEFAULT)'/,
     +9X,'1  LIST DOSAGE AND DISTANCE'/,9X,'2  ABOVE PLUS COMPON'
     +'ENTS OF D'/,9X,'3  CLOUD HALF-WIDTH WITH X'//,5X,
     +'OPC=0  USE HT MAX FROM PLRS'/,9X,'1  LIST F(X), USE '
     +'HT MAX'/,9X,'2  USE HT=F(X)'/,9X,'3  LIST AND USE F(X)'/)
  604 FORMAT(//
     +' CODE                          INPUT VARIABLE'/
     +'  AGN   AGENT, SEE  DSP 6'/
     +'  ALL   CONTROL WORD,EXECUTE PROGRAM'/
     +'  ALF   SLOPE OF THE SIGMA-Y VERSUS X CURVE'/
     +'  ARE   AREA OF PUDDLE                      (M^2)'/
     +'  BPT   BOILING POINT                       (DEG K)'/
     +'  BRT   BREATHING RATE                      (L/MIN)'/
     +'  BTA   SLOPE OF THE SIGMA-Z VERSUS X CURVE'/
     +'  CHT   CLOUD HEIGHT                        (FT)'/
     +'  CRD   CLOUD RADIUS                        (M)'/
     +'  DLX   CHANGE IN X (FIRST CYCLE)           (M)'/
     +'  DST   DIAMETER OF STACK                   (M)'/
     +'  FMV   MOLECULAR VOLUME                    (CM^3 /GM MOLE)'/
     +'  FMW   MOLECULAR WEIGHT'/
     +'  FRO   SLOPE OF THE FROST WIND PROFILE'/
     +'  GTO   CONTROL  GO TO SPECIFIED QUESTION'/
     +'  HML   HEIGHT OF MIXING LAYER          (M)'/
     +'  HLD   HOLD VALUE OF  SYMBOL'/
     +'  HRL   HEAT RELEASED                   (CAL)')
 605  FORMAT(//
     +'  HRS   LOCAL STANDARD MILITARY TIME    (HRS)'/
     +'  HST   HEIGHT OF STACK                 (M)'/
     +'  HTS   HEIGHT OF SOURCE                (M)'/
     +'  ICC   CLOUD COVER                     (1/10)'/
     +'  IDD   NUMBER OF THE DAY'/
     +'  IMA   METHOD OF ASSESSMENT, SEE TAB 2'/
     +'  IMM   NUMBER OF THE MONTH'/
     +'  INP   CONTROL.  CLEAR INPUT BLOCK FOR QUESTION'/
     +'  IRT   CONTROL.  RETURN TO SPECIFIED QUESTION'/
     +'  LEN   DOWNWIND LENGTH OF PUDDLE           (M)'/
     +'  LOC   LOCATION, SEE DSP 2'/
     +'  MNR   MINIMUN RESPONSE LEVEL, SEE TAB 2'/
     +'  MUN   MUNITION, SEE DSP 5'/
```

```
     +'  NCI   NUMBER OF CONCENTRATIONS OF INTEREST'/
     +'  NDI   NUMBER OF DOSAGES OF INTEREST'/
     +'  NMU   NUMBER OF MUNITIONS'/
     +'  NOV   NOVICE LEVEL'/
     +'  NQI   NUMBER OF SOURCE INTERVALS')
  606 FORMAT(//
     +'  OPC   OUTPUT FOR STACK, SEE TAB 3'/
     +'  OPO   OUTPUT CONTROL, SEE TAB 3'/
     +'  PMM   ATOMOSPHERIC PRESSURE                (MM HG)'/
     +'  QQQ   AIRBORNE SOURCE                      (MG)   '/
     +'  RDE   RELATIVE DENSITY OF EFFLUENT'/
     +'  REF   REFLECTION COEFFICIENT (DEFAULT=1)'/
     +'  REL   METHOD OF RELEASE, SEE DSP 8'/
     +'  RLS   RELEASE HOLD OF SYMBOL VALUE'/
     +'  RSN   RESCAN FROM QUESTION 2'/
     +'  RST   CONTROL.  RESTART'/
     +'  SEA   SEASON, SEE DSP 3'/
     +'  SKF   SKIN FACTOR FOR SUBJECT CLOTHING'/
     +'  SLA   LATITUDE                             (DEG)'/
     +'  SLO   LONGITUDE                            (DEG)'/
     +'  SMH   SAMPLING HEIGHT                      (M)'/
     +'  STB   STABILITY, SEE DSP 9'/
     +'  SUN   SUN ELEVATION ANGLE                  (DEG)'/
     +'  SUR   SURFACE TYPE, SEE DSP 13')
  607 FORMAT(//
     +'  SEV   SETTLING VELOCITY OF CLOUD CENTROID (DEFAULT=0)  (M/SEC)'/
     +'  SXS   SOURCE SIGMA -X                      (M)'/
     +'  SYR   REFERENCE SIGMA -Y AT 100M           (M)'/
     +'  SYS   SOURCE SIGMA -Y                      (M)'/
     +'  SZR   REFERNCE SIGMA -Z AT 100M            (M)'/
     +'  SZS   SOURCE SIGMA -Z                      (M)'/
     +'  TEV   TIME OF EVAPORATION                  (MIN)'/
     +'  TIM   TIME AFTER FUNCTIONING (INS,HD)      (MIN)'/
     +'  TMC   TIME TO MET CHANGE                   (MIN)'/
     +'  TMP   TEMPERATURE                          (DEG C)'/
     +'  TST   TEMPERATURE OF STACK                 (DEG C)'/
     +'  VAP   VAPOR PRESSURE                       (MM HG)'/
     +'  CDP   VAPOR DEPLETION INDICATOR, SEE TAB 2'/
     +'  VST   VELOCITY OF EFFLUENT FROM STACK      (M/SEC)'/
     +'  WND   TRANSPORT WIND SPEED                 (M/SEC)'/
     +'  WOO   WOODS TYPE, SEE DSP 36'/
     +'  ZZO   ROUGHNESS LENGHT                     (CM)'/
     +'  2MC   TWO MINUTE CONNECTIONS CONTROL, SEE TAB 2')
C------------------------
C NOV=1 FORMAT STATEMENTS
C-------------------------
 1001 FORMAT(8X,'AAD,DPG,EWA,JHI,LBG,NAP,PBA,PAD,RMA,UAD,EUR,NDF')
 1007 FORMAT(8X,'WIN,SPR,SUM,FAL')
 1003 FORMAT(8X,'105,155,8IN,500,750,M55,525,139,M23,4.2,NON')
 1004 FORMAT(8X,'GA,GB,GD,GF,VX,BZ,HY,UD,HD,H1,H3,HT,LL,AC,CG,CK',
     +           'DM,NA')
 1005 FORMAT(8X,'INS,EVP,SEM,VAR,STK,STJ,FLS,FIR,IGL,EVS')
 1006 FORMAT(8X,'A,B,C,D,E,F,U,S,W')
 1012 FORMAT(8X,'GRA,NPR,NDF')
 1024 FORMAT(8X,'DW,MW,CF,MS,RF')
```

```
C------------------------
C NOV=2 FORMAT STATEMENTS
C------------------------
 2000 FORMAT(8X,'0  SHORT LISTING FOR THE EXPERT'/,8X,'1  LISTS'
     $' OPTIONS FOR MULTIPLE CHOISE QUESTIONS'/,8X,'2  DEFINES'
     $' ALL OPTIONS FOR MULTIPLE CHOISE QUESTIONS'/,8X,'3  EXPL'
     $'AINS PROGRAM INPUTS'/)
 2005 FORMAT(8X,'AAD    ANNISTON ARMY DEPOT'/8X,
     $'DPG    DUGWAY PROVING GROUND AND TOOELE ARMY DEPOT'/ 8X,
     $'EWA    EDGEWOOD AREA,APG'/8X,'JHI    JOHNSTON ISLAND'/ 8X,
     $'LBG    LEXINGTON-BLUE GRASS ARMY DEPOT'/ 8X,
     $'NAP    NEWPORT AMMUNITION PLANT'/ 8X,'PBA    PINE BLUFF ARSENAL'
     $/8X,'PAD    PUEBLO ARMY DEPOT'/ 8X,'RMA    ROCKY MOUNTAIN ARSENAL'
     $/8X,'UAD    UMATILLA ARMY DEPOT'/8X,'EUR    USAEUR'/8X,
     $'NDF    NOT DEFINED')
 2010 FORMAT(8X,'WIN    WINTER'/8X,'SPR    SPRING'/8X,'SUM    SUMMER'/
     $8X,'FAL    FALL')
 2020 FORMAT(8X,'105    105-MM CARTRIDGE,M60,M360'/8X,
     $'155    155-MM PROJECTILE,M110,M121A1'/8X,
     $'8IN    8-INCH PROJECTILE,M126'/8X,'500    500-LB BOMB,MK94'/8X,
     $'750    750-LB BOMB,MC-1'/8X,'M55    115-MM ROCKET,M55'/8X,
     $'525    525-LB BOMB,MK116'/8X,'139    BOMBLET,M139'/8X,
     $'M23    LAND MINE,M23'/8X,'4.2    4.2-INCH CARTRIDGE,M2A4'/8X,
     $'NON    NONMUNITION')
 2030 FORMAT (8X,'GA  TABUN',15X,'H1  HN-1,NITROGEN MUSTARD'/ 8X,'GB  SA
     $RIN',15X,'H3  HN-3,NITROGEN MUSTARD'/ 8X,'GD  SOMAN',15X,'HT  60%
     $HD & 40% T' /8X,'GF  EA 1212',13X,'LL  LEWISITE'/ 8X,'VX  EA 1701'
     $,13X,'AC  HYDROGEN CYANIDE'/ 8X,'BZ  INCAP AGENT', 9X,'CG  PHOSGEN
     $E'/ 8X,'HY  HYDRAZINE',11X,'CK  CYANOGEN CHLORIDE'/ 8X,'UD  UDMH',
     $16X,'DM  ADAMSITE'/ 8X,'HD  DISTILLED MUSTARD', 3X,'NA  NOT AN AGE
     $NT')
 2040 FORMAT(8X,'INS    INSTANTANEOUS(EXPLOSIVE)'/8X,'EVP    EVAPORATION
     $ FROM A PUDDLE FORMED BY A SPILL'/8X,'SEM    UNIFORM RELEASE FOR A
     $FINITE TIME'/8X,'VAR    SOURCE DEFINED AS A NUMBER OF UNIFORM RELE
     $ASES(MAX 6)'/8X,'STK    RELEASE OF HEATED EFFLUENT FROM STACK'/8X,
     $'STJ    RELEASE FROM STACK WITH JET EFFECT'/8X,'FLS    FLASH FIRE
     $FROM GROUND LEVEL'/8X,'FIR    FIRE BURNING FOR FINITE TIME'/8X,
     $'IGL    M55 IGLOO FIRE'/8X,'EVS    EVAPORATION IN STILL AIR')
 2050 FORMAT(8X,'A',5X,'VERY UNSTABLE'/ 8X,'B',5X,'UNSTABLE'/8X, 'C',5X,
     $       'SLIGHTLY UNSTABLE'/,8X,'D',5X,'NEUTRAL'/,8X,'E',5X,
     $       'SLIGHTLY STABLE'/,8X,'F',5X,'STABLE'/,8X,'U',5X,
     $       'UNDEFINED'/,8X,'S',5X,'SELECT(PASQUILL)'/,8X,'W',5X,
     $       'WOODS')
 2060 FORMAT(8X,'NQI  NUMBER OF TIME INTERVALS')
 2070 FORMAT(8X,'Q()  SOURCE FOR EACH INTERVAL'/,
     $7X,'TQ()  CUMULATIVE TIME FROM BEGINNING OF FIRST')
 2080 FORMAT(8X,'GRA  GRAVEL'/8X,'NPR  NONPOROUS(CONCRETE)'/8X,'NDF  NOT
     $ DEFINED')
 2090 FORMAT(8X,'FMW  MOLECULAR WEIGHT',/8X,'FMV  MOLECULAR'
     $' VOLUME'/8X,'VAP  VAPOR PRESSURE (MM HG)'/8X,
     $'BPT  BOILING POINT (DEG K)'/)
 2095 FORMAT(8X,'0  USE HT MAX FROM PLRS'/,8X,'1  LIST F(X),'
     $' USE HT MAX'/,8X,'2  USE HT=F(X)'/,8X,'3  LIST F(X),'
     $' USE HT=F(X/)')
 2100 FORMAT(8X,'GRA     GRAVEL, LOOSE EARTH'/8X,'NPR     NONPOROUS,
```

```
     $ CONCRETE, BLACKTOP'/8X,'NDF     NOT DEFINED'/' NOTE: THIS CODE
     $ ONLY DETERMINES THE SIZE OF THE WETTED SURFACE')
2110 FORMAT(8X,'DW  DECIDUOUS, WINTER'/ 8X,'MW  MIXED, WINTER'/ 8X,
     $'CF  CONIFEROUS FOREST'/ 8X,'MS  MIXED SUMMER'/ 8X,
     $'RF  RAIN FOREST')
 500 FORMAT(//
     $'     THE OPERATOR MAY CONTROL THE LENGTH OF THE QUESTIONS BY'/
     $' SPECIFYING THE NOVICE LEVEL. LEVEL 2 WILL DEFINE ALL OPTIONS,'/
     $' LEVEL 1 WILL LIST THE OPTIONS AND LEVEL 0 WILL ONLY STATE THE'/
     $' QUESTIONS. RESPONDING WITH QUESTION MARKS PROVIDES THE LEVEL'/
     $' 2 LIST AND THE QUESTION IS REPEATED.'/
     $'     THE SEQUENCE OF QUESTIONS IS DETERMINED BY THE ANSWERS'/
     $' GIVEN.  UNITS ARE STATED FOR NUMERIC INPUTS. "FOREIGN" UNITS'/
     $' MAY BE CONVERTED BY PRECEEDING THE NUMBER WITH THE CHARACTER  '/
     $' CODE IDENTIFYING THE UNITS. TWO QUESTION MARKS WILL CAUSE THE '/
     $' CODE LIST TO BE DISPLAYED.'/
     $'     THE QUESTIONS TERMINATE WITH ALL OTHER INPUT.'/
     $' HERE ONLY CONTROL OPTIONS OR DATA CHANGES MAY BE ENTERED.'/
     $' AGAIN QUESTION MARKS WILL DISPLAY THE OPTIONS LIST. CONTROL '/
     $' OPTIONS INCLUDE RESTART(RST), STOP(STP) AND GO TO(GTO) ANY'/
     $' QUESTION NUMBER. THE CODE ALL WILL COMPLETE THIS INPUT AND'/
     $' CAUSE THE DOWNWIND HAZARD TO BE COMPUTED.'////)
 501 FORMAT(/
     $'     IF THE CHANGES MADE IN THE ALL QUESTIONS CAUSE THE'/
     $' PROGRAM TO REACCESS ITS DATA BASE THE INPUT LOGIC IS RE-'/
     $' SCANNED. THIS IS SHOWN BY A DISPLAY OF THE INPUT QUESTIONS,'/
     $' BUT NO INPUT IS REQUIRED UNLESS NEW QUESTIONS ARE ASKED. THE'/
     $' PROGRAM AGAIN STOPS AT THE ALL QUESTION, AND WILL PROCEED'/
     $' WITH THE ANSWER ALL.'/'     WHEN THE DOWNWIND HAZARD ESTI-'/
     $' MATE HAS BEEN MADE THE PROGRAM WILL TERMINATE AT THE ALL'/
     $' QUESTION. THE OPERATOR MAY CHANGE INDIVIDUAL PARAMETER VALUES'/
     $' [INCLUDING NOV] AND REPEAT THE RUN OR RESTART OR STOP.'/
     $' A HOLD[HLD] MAY BE PLACED ON ANY VARIABLE IF YOU DO NOT WISH'/
     $' ITS VALUE TO BE CHANGED BY RESCAN OF THE DATA BASE. INPUT HLD'/
     $' AND THE VARIABLE CODE(EG. HLD HML). RLS WILL RELEASE THE HOLD.'/
     $' FOR MORE INFORMATION SEE CHEMICAL SYSTEMS TECHNICAL REPORT'/
     $' ARCSL-TR-82014.'///////)
      END
```

UNT.FOR

```
      SUBROUTINE UNT(UM,IA,PRT)
      DIMENSION UMT(25),UC(25),DN25(18),MNE(34),IK(25)
      CHARACTER*2 UM,UMT
      CHARACTER*6 MNE
      DATA UMT/'AT','BR','CM','DF','FT','SF','GM','HR','IN',
     $ 'KT', 'LB','MT','PM','M3','MH','MB','OZ','SC','TM',
     $ 'TN','GL', 'LT','ML','PT','QT'/
      DATA UC/760.,750.,.01,1.,.3048,.0929,1000.,60.,.0254,
     $ .5148, 4.53592E5,3.281,.01667,.001,.447,.75,28349.5,
     $ .01667, 1.E9,9.0718E8,3.785E6,1.E6,1000.,4.732E5,
     $ 9.464E5/
      DATA DN25/1.0887,1.0083,1.268,.687,1.37,1.18,1.073,
     $ 1.0222,1.12765,1.09,1.24,1.66,1.89,1.011,.7914,
     $ .51,1.65,0./
      DATA MNE/'   ATM','   BAR','    CM',' DEG F','    FT',
     $ ' SQ FT','    GM','    HR','    IN','    KT','    LB'
     $,'     M',' M/MIN','C M/MN',' MI/HR','    MB','    OZ'
     $,'   SEC','TON(M)','   TON','   GAL','     L','    ML'
     $,'    PT','    QT','MM HG','DEG C','SQ M','MG','MIN',
     $'M/SEC','L/MIN','M', 'FT'/
      DATA IK/26,26,33,27,33,28,29,30,33,31,29,34,31,32,31,
     $ 26,29,30,7*29/
   15 DO 1 IC=1,25
      IF (UM.EQ.UMT(IC)) GO TO 2
    1 CONTINUE
      WRITE(*,6)
    6 FORMAT (' UNIT CODES')
      DO 9 I=1,5
    9 WRITE(*,10) (MNE(II),UMT(II),II=I,25,5)
   10 FORMAT (1X,5(A6,'=',A2,3X))
      UM='ND'
      RETURN
    2 PRT=PRT*UC(IC)
      IF (IC.EQ.4) PRT=(PRT-32)/1.8
      IF (IC.LT.21) GO TO 8
      IF (IA.LT.18) GO TO 3
      WRITE(*,4)
    4 FORMAT (' INPUT: AGENT DENSITY')
      READ(*,*) DN25(18)
    3 PRT=PRT*DN25(IA)
    8 IO=IK(IC)
      WRITE(*,7) MNE(IC),MNE(IO),PRT
    7 FORMAT (1X,A6,' TO ',A5,E9.3)
   14 RETURN
      END
```

QLIST.FOR

```
      SUBROUTINE QLIST(IQ,IRT)
      CHARACTER*1 MTC,AA1,AB1
      CHARACTER*2 AGNT,AA2,WT
      CHARACTER*3      MUNT,REL,LOCT,SEAT,SUR,SYM
      CHARACTER*12 ADH
      CHARACTER*30 QTAB
      COMMON NQI,QT(6),TWL(6),D(10),DL(10)
      COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
     + BETA,SZ100,Z,RC,V,QS
      COMMON TEVP,SA,FL,FMW,FMV,VP,BP
      COMMON HS,DS,TSC,VS,RDE,FP,HR,CR
      COMMON SLA,SLO,CC,CH,AE,PMM,ZO
      COMMON LOCT(1),SEAT,MUNT,AGNT,AA1,REL,MTC,AA2,
     $       SUR,WT,AB1,ADH,ADR,AD2
      COMMON IPR(1),ND,IPO,I2MC,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,NMU,ID2,
     + IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
      DIMENSION IQM(36),IQR(36),QTAB(37),SYM(37)
      DATA IQR /63,43,44,4,45,46,0,47,48,9,13,12,0,24,0,41,49,21,
     +        22,23,24,1,59,28,29,30,31,32,33,34,35,36,60,38,40,50/
      DATA IQM / 10*1,4,9*1,4,10*1,2,3,2,1,1/
      DATA QTAB/
     $'YOUR NOVICE LEVEL: 3,2,1 OR 0 ','LOCATION                      ',
     $'SEASON                        ','HEIGHT OF MIXING LAYER        ',
     $'MUNITION TYPE                 ','AGENT TYPE                    ',
     $'SPILL OR AIRBORNE SOURCE (MG) ','RELEASE TYPE                  ',
     $'STABILITY TYPE                ','WINDSPEED (M/SEC)             ',
     $'ALF, SYR(M), BTA, SZR(M)      ','TEMPERATURE (DEG C)           ',
     $'Q()(MG), TQ()(MIN)            ','MOLECULAR WEIGHT              ',
     $'ALL OTHER INPUT               ','ATMOSPHERIC PRESSURE (MM HG)  ',
     $'SURFACE CODE                  ','TIME OF EVAPORATION (MIN)     ',
     $'AREA OF WETTED SURFACE (SQ M) ','LENGTH OF SURFACE DOWNWIND (M)',
     $'FMW,FMV,VAP(MM HG),BPT(DEG K) ','TIME AFTER FUNCTIONING (MIN)  ',
     $'OUTPUT CONTROL CODE           ','HEIGHT OF STACK (M)           ',
     $'DIAMETER OF STACK (M)         ','TEMPERATURE OF STACK (DEG C)  ',
     $'VELOCITY OF EFFLUENT (M/SEC)  ','RELATIVE DENSITY OF EFFLUENT  ',
     $'FROST PROFILE EXPONENT        ','HEAT RELEASED (CAL)           ',
     $'CLOUD RADIUS (M)              ','STATION LATITUDE AND LONGITUDE',
     $'MONTH,DAY,HOUR: (JAN,01,1200) ','CLOUD COVER(1/10),CLOUD HT(FT)',
     $'SUN ELEVATION ANGLE (DEG)     ','WOODS TYPE                    ',
     +'AND ROUGHNESS LENGTH (CM)     '/
      DATA SYM/
     $'NOV','LOC','SEA','HML','MUN','AGN','QQQ','REL','STB','WND',
     $'   ','TMP','   ','FMW','   ','PMM','SUR','TEV','ARE','LEN',
     $'   ','TIM','OPC','HST','DST','TST','VST','RDE','FRO','HRL',
     $'CRD','   ','   ','   ','SUN','WOO','ZZO'/
      IF (IQ.GT.36) RETURN
      IF (IQ.EQ.17.OR.IQ.EQ.22.OR.IQ.EQ.16.OR.IQ.EQ.23.OR.
     +IQ.EQ.29.OR.IQ.EQ.36) WRITE(*,*)
      IF (IRT.EQ.1) GO TO 10
      IF (IQ.EQ.13.AND.IR.NE.3) THEN
```

```
      WRITE(*,104) IQ,QTAB(IQ),SYM(IQ)
      RETURN
      ENDIF
      WRITE(*,100) IQ,QTAB(IQ),SYM(IQ)
      IF (IQ.EQ.30.AND.IR.EQ.8) WRITE(*,107)
      IF (IQ.EQ.29.AND.IVD.EQ.1) WRITE(*,106) QTAB(37),SYM(37)
      RETURN
   10 IF(IQ.EQ.13.OR.IQ.EQ.7) THEN
      WRITE(*,105) IQ,QTAB(IQ),(QT(I),TWL(I),I=1,NQI)
      RETURN
      ENDIF
      IC=IQR(IQ)
      IN=IQM(IQ)
      IF (IC.LT.43) WRITE(*,101) IQ,QTAB(IQ),SYM(IQ),
     $(PR(IC+I-1),I=1,IN)
      IF(IC.GT.42.AND.IC.LT.54) WRITE(*,102) IQ,QTAB(IQ),SYM(IQ),
     $(LOCT(IC-42+I-1),I=1,IN)
      IF (IC.GT.54) WRITE(*,103) IQ,QTAB(IQ),SYM(IQ),
     $(IPR(IC-53+I-1),I=1,IN)
      IF(IQ.EQ.29.AND.IVD.EQ.1)WRITE(*,106)QTAB(37),SYM(37),Z0
      IF (IQ.EQ.30.AND.IR.EQ.8) WRITE(*,107)
      RETURN
  100 FORMAT(1X,I2,'. ',A30,A3)
  101 FORMAT(1X,I2,'. ',A30,A3,4F10.2)
  102 FORMAT(1X,I2,'. ',A30,A3,2X,A3)
  103 FORMAT(1X,I2,'. ',A30,A3,3I7)
  104 FORMAT(1X,I2,'. NQI,',A30,A3)
  105 FORMAT(1X,I2,'. ',A30,1P2E10.3,/(35X,2E10.3))
  106 FORMAT(5X,A30,A3,F10.2)
  107 FORMAT(17X,' FOR FIR (CAL/SEC)')
      END
```

READA.FOR

```
      SUBROUTINE READA(IQ,IRT,IA,PRT)
      CHARACTER*80 CARD
      CHARACTER*2 UM
      CALL DEF(IQ,IRT)
      IF(IRT.NE.0) RETURN
      READ(*,'(BN,A80)') CARD
      READ(CARD,10,ERR=12) PRT
   10 FORMAT(BN,F12.0)
      RETURN
   12 READ(CARD,13,ERR=14) UM,PRT
   13 FORMAT(BN,A2,F12.0)
      CALL UNT(UM,IA,PRT)
      IF (UM.NE.'ND') RETURN
   14 CALL DEF(-IQ,IRT)
      IRT=(-1)
      RETURN
      END
```

ERFF.FOR

```
C  ERROR FUNCTION (HASTINGS APPROXIMATION)
      FUNCTION ERFF (A)
      DATA A1/0.070523078/,A2/0.042282012/,A3/0.0092705272/
      DATA A4/0.0001520143/,A5/0.0002765672/,A6/.0000430638/
      DATA C/1./
      C=SIGN(C,A)
      Z=ABS(A)
      IF (Z.LT..000001) GO TO 1
      IF (Z.GT.4.) GO TO 2
      ERR=((((((A6*Z+A5)*Z+A4)*Z+A3)*Z+A2)*Z+A1)*Z+1.)**16
      ERR=ABS(1.-(1./ERR))
      ERFF=ERR*C
      RETURN
 1    ERFF=0.
      RETURN
 2    ERFF=C
      RETURN
      END
```

IGLO.FOR

```
      SUBROUTINE IGLO(QTS,TWL,NQI,IMU,IA,IR)
      DIMENSION QTS(6),TWL(6),EFF(3),TWLT(3)
      DATA EFF/.022932,.001512,.000756/
      DATA TWLT/15.,20.,60./
      IF (IA.GT.2.OR.IMU.NE.6) GO TO 3
      IF (IA.EQ.2) GO TO 2
      DO 1 I=1,3
      QTS(I)=4.99E6*EFF(I)
    1 TWL(I)=TWLT(I)
      NQI=3
      IR=4
      RETURN
    2 QTS(1)=4.45E6*.00164
      TWL(1)=5.
      NQI=1
      IR=3
      RETURN
    3 WRITE(*,*) ' IGL IS ONLY DEFINED FOR M55 WITH GB OR VX.'
      RETURN
      END
```

VDPL.FOR

```
      SUBROUTINE VDPL(QTTL,SY,SZ,D1,X,DX,DXA,XS,XCH,DP,DPA,SDEPL,INT)
      COMMON VDM(41),UT,VDM1(23),FP,VDM2(8),Z0,VDM3(13),
     +IPO,I2MC,IMA,VDM4(11),IM,IR,IL,VDM5(3),K33,K42
      DIMENSION FKMS(6),ZOT(12),DDD(10),DDL(10),DDBR(10),
     +ARD(10),PT(6,3),ITT(12),Y(10)
      DATA PT/.05,.05,.1,.1,.15,.15,.05,.1,.15,.2,.25,.3,.1,
     +.15,.2,.25,.3,.35/
      DATA ITT/3,2,3,1,3,2,3,2,2,3,3,0/
      DATA FKMS/.9,.8,.6,.4,.2,.05/
      DATA ZOT/100.,.03,100.,.005,100.,10.,100.,100.,100.,
     +100.,100.,100./
      GOTO(101,102,103,104)INT
  101 ITI=ITT(IL)
      IF(K33.EQ.0.AND.IL.LT.12.AND.IM.LT.7) FP=PT(IM,ITI)
      IF (K42.EQ.0.AND.IL.LT.12) Z0=ZOT(IL)
      UZ=UT*.005**FP
      USTR=FP*FKMS(IM)*UZ
      DVF2=USTR/UZ
      DVF1=DVF2*USTR
      BINV=0.06*(19600.*USTR*Z0)**.45
      DEPV=DVF1/(1.+DVF2*BINV)
      WRITE(*,50)
   50 FORMAT(/5X,'FP',7X,'FKMS',7X,'UT',7X,'USTR',
     +6X,'BINV',6X,'DEPV',6X,'QTTL')
      WRITE(*,60) FP,FKMS(IM),UT,USTR,BINV,DEPV,QTTL
   60 FORMAT(1X,1P7E10.3)
      DEPV60=DEPV*60.
      RETURN
C     ENTRY VDPL1(SY,SZ,D1)
  102 DO 10 I=1,10
   10 ARD(I)=0.
      DDMX=QTTL/(188.496*SY*SZ*UT)
      DDD(1)=D1/10.
      DDDL=(ALOG(DDMX)-ALOG(DDD(1)))/9.
      DDL(1)=ALOG(DDD(1))
      DO 20 I=2,10
      DDL(I)=DDL(I-1)+DDDL
      DDD(I)=EXP(DDL(I))
   20 DDBR(I-1)=(DDD(I-1)+DDD(I))/2.
      IF (IPO.NE.4) RETURN
      IF (IMA.GT.0) GO TO 35
      WRITE(*,30) (DDD(I),I=1,10)
   30 FORMAT(/6X,'DOSAGE CONTOURS',10F5.0)
      WRITE(*,31)
   31 FORMAT(/7X,'X',7X,'DP',4X,'CONTOUR HALF-WIDTHS')
      RETURN
   35 WRITE(*,37) (DDD(I),I=1,10)
   37 FORMAT(/7X,'CONC. CONTOURS',10F5.0)
      WRITE(*,38)
   38 FORMAT(/7X,'X',7X,'CP',4X,'CONTOUR HALF-WIDTHS')
```

```
      RETURN
C     ENTRY VDPL2(X,DX,DXA,XS,XCH,DP,DPA,SDEPL)
  103 DP=DP*SDEPL
      DPA=DPA*SDEPL
      IF (DPA.LE.0) RETURN
      DPLA=ALOG(DPA)
      DO 70 IY=1,10
      ARG=DPLA-DDL(IY)
      IF (ARG.LT.0.) GO TO 80
      Y(IY)=1.41421*SY*SQRT(ARG)
      IF (X.NE.XCH) ARD(IY)=ARD(IY)+Y(IY)*DXA
      IF (X.EQ.XCH) ARD(IY)=ARD(IY)-Y(IY)*(XS+DX-XCH)
   70 CONTINUE
      IY=11
   80 QD=0.
      IF (IPO.GT.0) WRITE(*,'(F5.2)') SDEPL
      IY=IY-1
      DO 90 I=1,9
   90 QD=QD+DDBR(I)*(ARD(I)-ARD(I+1))*DEPV60
      SDEPL=(QTTL-QD)/QTTL
      IF (SDEPL.LT.0.) SDEPL=1.E-20
      IF (IPO.EQ.4) WRITE(*,100) X,DPA,(Y(I),I=1,IY)
  100 FORMAT(1X,F10.0,1PE10.3,0P10F5.0)
      RETURN
C     ENTRY VDPL3
  104 WRITE(*,*) '    C OR D     AREA'
      WRITE(*,'(1X,1P2E10.3)') (DDD(I),ARD(I),I=10,1,-1)
      RETURN
      END
```

HMLMDR1.FOR

```
      DATA HMLT/2*820.,710.,600.,420.,170.,2*1500.,1060.,620.,360.,
     1 170.,2*1670.,1080.,490.,440.,310.,2*1340.,945.,550.,360.,160.,
     2 2*540.,377.,215.,100.,50.,2*2310.,1277.,245.,150.,100.,
     3 2*3625.,1892.,200.,100.,80.,2*1470.,845.,220.,100.,80.,
     4 2*780.,750.,720.,530.,180.,2*1720.,1285.,850.,470.,140.,
     5 2*1970.,1245.,525.,360.,210.,2*1300.,925.,550.,400.,130.,
     6 4*2000.,1250.,500.,4*2000.,1250.,500.,4*2000.,1250.,500.,
     7 4*2000.,1250.,500.,2*740.,765.,790.,640.,430.,2*1500.,1215.,
     8 930.,560.,340.,2*1530.,1005.,480.,340.,250.,2*1230.,975.,720.,
     9 470.,280.,2*430.,440.,450. 320.,130.,2*1170.,840.,510.,320.,120.,
     $ 2*1440.,895.,350.,250.,140.,2*990.,715.,440.,260.,100.,
     1 2*780.,705.,630.,520.,160.,2*1460.,1065.,670.,510.,160.,
     2 2*1770.,1220.,670.,550.,220.,2*1270.,975.,680.,550.,140.,
     3 2*1020.,550.,3*85.,2*2780.,1480.,3*185.,2*3290.,1785.,3*180.,
     4 2*2010.,1050.,3*95.,2*1020.,550.,3*85.,2*2780.,1480.,3*185.,
     5 2*3290.,1785.,3*180.,2*2010.,1050.,3*95.,2*370.,345.,320.,290.,
     6 280.,2*1900.,1160.,420.,220.,200.,
     7 2*2455.,1427.,400.,145.,130.,2*1145.,667.,190.,135.,115.,
     8 2*700.,450.,200.,150.,100.,2*1200.,750.,300.,200.,150.,
     9 2*1500.,1000.,500.,300.,200.,2*1000.,650.,300.,200.,150./
      DATA QF/
     $7.39E5,2.95E6,6.58E6,4.9E7,9.98E7,4.99E6,1.58E8,5.9E5,0.,0.,
     $0.,2.72E6,6.58E6,0.,0.,4.54E6,0.,0.,5.22E6,0.,
     $1.35E6,4.4E6,0.,0.,0.,0.,0.,0.,0.,2.72E6/
      DATA SYSM/1.9,3.5,5.0,12.,17.,4.4,21.,1.7,0.,0./
      DATA SZSM/.63,1.2,1.7,4.0,5.7,1.5,7.0,.6,0.,0./
      DATA PMMT/747.,651.,760.,761.,737.,742.,755.,
     $ 641.,628.,730.,752.,0./
      DATA D1/.5,6.,10.,.4,2.5,4.3,2.,100.,150.,670.,810.,1180.,
     $120.,320.,385.,1525.,1850.,1.E36,1.,12.,20.,.5,6.,10.,
     $.5,6.,10.,2.,100.,150.,2.,100.,150.,1.,50.,75.,
     $2.,100.,150.,1.E36,1.E36,1.E36,1.E36,1.E36,1.E36,
     $1.E36,1.E36,31.,4.,2240.,1.E36/
      DATA FMWT/140.1,267.4,159.1,27.02,98.92,61.48,162.18,182.18,
     $ 180.2,170.08.204.54,189.4,207.35,32.05,60.1,337.4,277.57/
```

Blank

APPENDIX F

SAMPLE PROBLEMS

Blank

APPENDIX F

SAMPLE PROBLEMS

1. GB EXAMPLE

Find the 'no deaths' distance resulting from the detonation of a GB-filled 8-inch projectile given the following conditions:

- Location: Pine Bluff Arsenal
- Date/Time: 29 July, 1200 local standard time
- Air temperature: 32 °C (90 °F)
- Wind speed: 3 m/sec
- Stability: B

2. EXPLOSIVE M23 LAND MINE EXAMPLE

Determine the 1 percent lethality, no deaths, and distances for no effects from an explosive release of VX from an M23 land mine given the following conditions:

- Location: Umatilla Army Depot
- Date/Time: 15 January, 0800
- Temperature: 5 °C
- Wind speed: 4 m/sec
- Cloud cover: 10/10
- Cloud height: 3000 feet

3. <u>Pallet Example</u>

Determine the 1 percent lethality distance after an explosion within a pallet of GB-filled M55 rockets given the following conditions:

- Location: Lexington-Blue Grass Army Depot
- Season: Summer
- Temperature: 25 °C
- Wind speed: 3 m/sec
- Stability: D

- Assume open terrain
- Assume a decontamination time of 1 hour for the evaporative source
- The surface type should be labeled "NDF", i.e., "not defined"
- The area of the liquid puddle formed is 549 m^2 and the downwind length is 9 m
- The evaporative source should be approximated as a normal volume with SXS = 0.83 m and SYS = 7.0 m

4. TON CONTAINER EXAMPLE

Determine the distances to the 1.0 and .01 parts per million (ppm) concentrations resulting from a spill of HD agent when both valves of a ton container are sheared given the following conditions:

Location: Edgewood Arsenal

Season: Summer

Temperature: 22 °C

Wind speed: 8 knots

Stability: E

Leak occurs outside on a gravel surface

Decontamination time: 20 minutes

Twenty percent of the agent fill escapes

5. IGLOO EXAMPLE

Determine the 1 percent lethality distance resulting from a fire in an igloo filled with 1800 M55 rockets containing agent GB given the following conditions:

- Location: Pine Bluff Arsenal
- Date/Time: 17 June, 1400 local standard time
- Air temperature: 80 °F
- Wind speed: 5 m/sec
- Clouds: 6/10 at 30,000 feet

- Run the model assuming
  - (a) Wooded terrain (mixed summer forest)
  - (b) Open terrain

Blank

```
INPUT:D2PC
               | DOWNWIND HAZARD PROGRAM D2PC |
   TYPE ? FOR DEFINITIONS

1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
INPUT:0

2. LOCATION                      LOC
INPUT:PBA

3. SEASON                        SEA
INPUT:SUM

5. MUNITION TYPE                 MUN
INPUT:8IN

6. AGENT TYPE                    AGN
INPUT:GB

8. RELEASE TYPE                  REL
INPUT:INS

9. STABILITY TYPE                STB
INPUT:B

10. WINDSPEED (m/sec)            WND
 INPUT:3.
DI=       .5      6.0    10.0
12. TEMPERATURE (deg C)          TMP
 INPUT:32.
ALL OTHER INPUT
ALL

  1 MUN:8IN  AGN:GB  REL:INS  WND= 3.0(M/S)  TMP=32.0(C)  PBA-SUM STB:B

   Q(MG)    TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
4.937E+06 8.00E-02  .00E+00 1.77E+03 5.00E+00 5.00E+00 1.70E+00  B

W/2-MINUTE CORRECTION

     309. (M) IS DISTANCE TO 1% LETHALITY


     412. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

    1535. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STP
Stop - Program terminated.
```

```
A>D2PC

                    | DOWNWIND HAZARD PROGRAM D2PC |

   TYPE ? FOR DEFINITIONS

 1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
 INPUT:0'

 2. LOCATION                    LOC
 INPUT:UAD

 3. SEASON                      SEA
 INPUT:WIN

 5. MUNITION TYPE               MUN
 INPUT:M23

 6. AGENT TYPE                  AGN
 INPUT:VX

 8. RELEASE TYPE                REL
 INPUT:INS

 9. STABILITY TYPE              STB
 INPUT:S

10. WINDSPEED (m/sec)           WND
 INPUT:4.
 INPUT: YEAR(1986)
1986

33. MONTH,DAY,HOUR: (JAN,01,1200)
 INPUT:JAN,15,0800

34. CLOUD COVER(1/10),CLOUD HT(ft)
 INPUT:10,3000
SR 739    SS 1638    AE  2.22    STAB D
EDI=  .44 1.76 4.00
ALL OTHER INPUT
ALL


  1 MUN:M23  AGN:VX  REL:INS  WND= 4.0(M/S)  TMP=  .0(C)  UAD-WIN STB:S

   Q(MG)    TS(MIN)   HTS(M)   HML(M)   SXS(M)   SYS(M)   SZS(M)
5.220E+06 8.00E-02  .00E+00 3.20E+02  .00E+00  .00E+00  .00E+00  D

BRT= 25.   SKF=2.20E-02

W/2-MINUTE CORRECTION

     1116. (M) IS DISTANCE TO 1% LETHALITY


     1610. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

     2991. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
```

```
A>D2PC
                  ___________________________________
                  | DOWNWIND HAZARD PROGRAM D2PC |
                  ___________________________________
   TYPE ? FOR DEFINITIONS

 1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
 INPUT:0

 2. LOCATION                      LOC
 INPUT:LBG

 3. SEASON                        SEA
 INPUT:SUM

 5. MUNITION TYPE                 MUN
 INPUT:M55

 6. AGENT TYPE                    AGN
 INPUT:GB

 8. RELEASE TYPE                  REL
 INPUT:INS

 9. STABILITY TYPE                STB
 INPUT:D

10. WINDSPEED (m/sec)             WND
 INPUT:3.
DI=      .5     6.0    10.0
12. TEMPERATURE (deg C)           TMP
 INPUT:25.
ALL OTHER INPUT
NMU 2
ALL
 2. LOCATION                      LOC  LBG
 3. SEASON                        SEA  SUM
 5. MUNITION TYPE                 MUN  M55
 6. AGENT TYPE                    AGN  GB
 8. RELEASE TYPE                  REL  INS
 9. STABILITY TYPE                STB  D
10. WINDSPEED (m/sec)             WND      3.00
DI=      .5     6.0    10.0
12. TEMPERATURE (deg C)           TMP     25.00
ALL OTHER INPUT
NDI 1
INPUT: DI()S
0.1
ALL OTHER INPUT
ALL

   2 MUN:M55  AGN:GB  REL:INS  WND= 3.0(M/S)  TMP=25.0(C)  LBG-SUM STB:D

   Q(MG)    TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
6.941E+06 8.00E-02  .00E+00 4.80E+02 4.40E+00 4.40E+00 1.50E+00  D

W/2-MINUTE CORRECTION

    11881. (M) IS DISTANCE TO   .100E+00 (MG-MIN/M^3)
```

```
ALL OTHER INPUT
SMD
ALL OTHER INPUT
NMU 13
REL EVP
ALL
 2. LOCATION                      LOC  LBG
 3. SEASON                        SEA  SUM
 5. MUNITION TYPE                 MUN  M55
 6. AGENT TYPE                    AGN  GB
 8. RELEASE TYPE                  REL  EVP
 9. STABILITY TYPE                STB  D
10. WINDSPEED (m/sec)             WND       3.00
DI=       .5      6.0    10.0
    SURFACE
12. TEMPERATURE (deg C)           TMP     25.00

17. SURFACE CODE                  SUR
 INPUT:NDF
18. TIME OF EVAPORATION (min)     TEV
 INPUT:60.
19. AREA OF WETTED SURFACE (sq m) ARE
 INPUT:549.
20. LENGTH OF SURFACE DOWNWIND (m)LEN
 INPUT:9.
NDF  EVR=4.305E+03(mg/min-sq m)  AREA=5.490E+02(sq m)  VPR=2.856E+00
Q=6.487E+07(mg)  Q'=6.487E+07(mg)    TEV=2.745E+01(min)
ALL OTHER INPUT
SXS 0.83
SYS 7.
SMP
ALL


  13 MUN:M55  AGN:GB  REL:EVP  WND= 3.0(M/S)  TMP=25.0(C)  LBG-SUM STB:D

   Q(MG)    TS(MIN)  HTS(M)   HML(M)   SXS(M)   SYS(M)   SZS(M)
6.487E+07 2.74E+01  .00E+00 4.80E+02 8.30E-01 7.00E+00 1.00E-01  D

W/2-MINUTE CORRECTION

DOSAGE IS BEING SUMMED

     2260. (M) IS DISTANCE TO 1% LETHALITY


     3020. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

    16686. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STP
Stop - Program terminated.
```

```
   TYPE ? FOR DEFINITIONS

 1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
 INPUT:0

 2. LOCATION                      LOC
 INPUT:EWA

 3. SEASON                        SEA
 INPUT:SUM

 5. MUNITION TYPE                 MUN
 INPUT:NON

 6. AGENT TYPE                    AGN
 INPUT:HD

 8. RELEASE TYPE                  REL
 INPUT:EVP
 9. STABILITY TYPE                STB
 INPUT:E
10. WINDSPEED (m/sec)             WND
 INPUT:KT 8.
   KT TO M/SEC .412E+01
DI=     2.0    100.0    150.0
 7. SPILL OR AIRBORNE SOURCE (mg) QQQ
 INPUT:1.64E8
   SURFACE
12. TEMPERATURE (deg C)           TMP
 INPUT:22.

17. SURFACE CODE                  SUR
 INPUT:GRA
18. TIME OF EVAPORATION (min)     TEV
 INPUT:20.
GRA  EVR=2.026E+02(mg/min-sq m)  AREA=2.509E+01(sq m)  VPR=8.197E-02
Q=1.640E+08(mg)  Q'=1.017E+05(mg)     TEV=2.000E+01(min)
ALL OTHER INPUT
IMA 2
DEFINE NCI
NCI 2
INPUT: CI()S
.01,1.
ALL OTHER INPUT
ALL


   1 MUN:NON  AGN:HD  REL:EVP  WND= 4.1(M/S)  TMP=22.0(C)  EWA-SUM STB:E

    Q(MG)      TS(MIN)     HTS(M)     HML(M)       WND
  1.017E+05 2.000E+01  .000E+00 3.600E+02 4.118E+00      E

   ALF  SYR    BTA   SZR         SYS(M)  SZS(M)  XY(M)   XZ(M)   XC(M)
   .80  6.00   .80   3.50       1.7E+00 1.0E-01 2.0E+01 1.2E+00 2.7E+04


        X         CP         RF
                  PPM

        6.*  1.000E+00

      256.*  1.000E-02
ALL OTHER INPUT
STP
```

```
A>D2PC
                    | DOWNWIND HAZARD PROGRAM D2PC |

   TYPE ? FOR DEFINITIONS

 1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
 INPUT:0

 2. LOCATION                      LOC
 INPUT:PBA

 3. SEASON                        SEA
 INPUT:SUM

 5. MUNITION TYPE                 MUN
 INPUT:M55

 6. AGENT TYPE                    AGN
 INPUT:GB

 8. RELEASE TYPE                  REL
 INPUT:IGL

 9. STABILITY TYPE                STB
 INPUT:W

10. WINDSPEED (m/sec)             WND
 INPUT:5.


36. WOODS TYPE                    WOO
 INPUT:MS
DI=       .5      6.0     10.0
ALL OTHER INPUT
NMU 1800
ALL
 2. LOCATION                      LOC  PBA
 3. SEASON                        SEA  SUM
 5. MUNITION TYPE                 MUN  M55
 6. AGENT TYPE                    AGN  GB
 8. RELEASE TYPE                  REL  IGL
 9. STABILITY TYPE                STB  W
10. WINDSPEED (m/sec)             WND        5.0

36. WOODS TYPE                    WOO  MS
DI=       .5      6.0     10.0
ALL OTHER INPUT
ALL
```

```
1800 MUN:M55  AGN:GB  REL:IGL  WND=  .5(M/S)  TMP=  .0(C)  PBA-SUM STB:W

   Q(MG)     TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
2.060E+08 1.50E+01  .00E+00 6.70E+02  .00E+00  .00E+00  .00E+00  MS
1.358E+07 2.00E+01
6.790E+06 6.00E+01

W/2-MINUTE CORRECTION

     1209. (M) IS DISTANCE TO 1% LETHALITY


     1795. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

    39065. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STB S
ALL
 2. LOCATION                      LOC  PBA
 3. SEASON                        SEA  SUM
 5. MUNITION TYPE                 MUN  M55
 6. AGENT TYPE                    AGN  GB
 8. RELEASE TYPE                  REL  IGL
 9. STABILITY TYPE                STB  S
10. WINDSPEED (m/sec)             WND       5.0
 INPUT: YEAR(1986)
1986

33. MONTH,DAY,HOUR: (JAN,01,1200)
 INPUT:JUN,17,1400

34. CLOUD COVER(1/10),CLOUD HT(ft)
 INPUT:6,30000
SR 455     SS 1920    AE 63.40     STAB C
DI=       .5      6.0     10.0
ALL OTHER INPUT
ALL


1800 MUN:M55  AGN:GB  REL:IGL  WND= 5.0(M/S)  TMP=  .0(C)  PBA-SUM STB:S

   Q(MG)     TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
2.060E+08 1.50E+01  .00E+00 1.22E+03  .00E+00  .00E+00  .00E+00  C
1.358E+07 2.00E+01
6.790E+06 6.00E+01

W/2-MINUTE CORRECTION

     1450. (M) IS DISTANCE TO 1% LETHALITY


     1895. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

     8962. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STP
```


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