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ED (Emergency Doses)-Revision 3: A Calculator Code for Environmental Dose Computations

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CONTENTS

CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

ED (EMERGENCY DOSES) - REVISION 3: A CALCULATOR CODE FOR ENVIRONMENTAL DOSE COMPUTATIONS

1.0 INTRODUCTION

1.1 HISTORY

The calculator program ED (Emergency Doses) was developed from several HP-41CV calculator programs documented in the report *Seven Health Physics Calculator Programs for the HP-41CV*, RHO-HS-ST-5P (Rittman 1984). The original ED was documented by an internal memo to R. H. Sudmann, dated May 18, 1984 (Appendix A). The program was developed at his request to enable estimates of offsite impacts more rapidly and reliably than was possible with the software available for emergency response at that time. The ED used the Hanford Stable and Sutton's Neutral and Unstable methods for calculating plume spread with distance. Inhalation dose factors from DACRIN were used for seven materials. Many of the features found in the present version were present then, such as USER mode operation, stored parameters to minimize inputs, and a nuclide choice menu tree.

The first revision to ED came through an internal memo to D. E. Bihl dated July 20, 1984 (Appendix B). This revision increased the number of radioactive materials that could be released from 7 to 19.

The second revision to ED came through an internal memo dated February 19, 1985 (Appendix D). This revision was motivated by an incident in the 200 East Area in which the downwind air sample data was used to estimate total release amounts. The ED - Revision 2 used the Pasquill stability class designations; it added the ability to calculate air concentrations and doses off the plume center line and, most importantly, added the ability to calculate release amounts from downwind measurements of air concentrations or ground contamination.

The ED - Revision 3, documented in this report, revises the inhalation dose model to match that of ICRP 30, and adds the simple estimates for air concentration downwind from a chemical release. In addition, the method for calculating the Pasquill dispersion parameters was revised to match the GENII code within the limitations of a hand-held calculator (e.g., plume rise and building wake effects are not included).

The summary report generator for printed output, which had been present in the code from the original version, was eliminated in Revision 3 to make room for the dispersion model, the chemical release portion, and the method of looping back to an input menu until there is no further change. The number of nuclide choices was reduced from 19 to 17 by removing both forms of ^{103}Ru.

1.2 HARDWARE REQUIREMENT

This program runs on the Hewlett-Packard programmable calculators known as the HP-41CV and the HP-41CX. It will run on the original HP-41C only if the 'quad' memory module is in place. A card reader is needed only to load the program initially.

A printer is optional. If present, it will be ignored unless the printer is placed in 'Normal' mode. In this mode it will print the alphanumeric displays prompting the user for data entry, the values that are entered by the user, and the results displayed by the program.

1.3 DOCUMENTATION

The documentation for ED - Revision 3 includes a guide for users, sample problems, detailed verification tests and results, model descriptions, code description (with program listing), and independent peer review. The ED has evolved from earlier versions, and required no major code development effort. Thus, there exists no software development plan. The current version of ED meets all other Westinghouse Hanford Company software configuration management requirements.

This software is intended to be used by individuals with some training in the use of air transport models. There are some user inputs that require intelligent application of the model to the actual conditions of the accident. The results calculated using ED-Revision 3 are only correct to the extent allowed by the mathematical models.

2.0 SUMMARY

The calculator program ED (which stands for Emergency Doses) operates on the Hewlett-Packard HP-41C series of hand-held calculators. It is intended for rapid assessment of the downwind impacts of hazardous material releases into the air.

Version 3 of ED offers the following analysis capabilities and user conveniences:

- Dispersion calculation using the Pasquill-Gifford model, with reflection from the mixing layer included
- Receptor location may be off the plume center line
- Option on whether to use SI units or English units for display of lengths and wind speed
- Menu items show current values and repeat until the value shown is accepted without change
- All data entered by the user is stored, and will be reused unless the user enters new values
- Through USER mode, a single input data item, such as distance downwind, can be modified and the calculation repeated
- Air concentrations of a hazardous chemical calculated in units of parts per million (by volume) and milligrams per cubic meter from user input of total pounds released or stack data (concentration released and exhaust flow rate) together with the formula weight of the chemical released
- Downwind air concentrations of radionuclides in microcuries per cubic centimeter
- Total curies released may be entered directly, calculated from stack data, calculated from a downwind air concentration measurement, or calculated from a downwind surface contamination measurement
- Inhalation dose calculated for any one of 17 radioactive materials, or the user may enter the name and dose factor of materials not stored in the calculator.

3.0 INSTRUCTIONS TO USERS OF ED - REVISION 3

3.1 LOADING THE PROGRAM

A. Check to see if the program is already in the calculator.

1. Switch the calculator to USER mode (i.e., press the button labeled "USER", which makes the word "USER" appear in small letters on the left side of the display).

2. Press the button labeled "XEQ".

3. If the display shows the words "ED - Rev 3", then the program is already loaded. Skip over the directions following to step 3.2.B.

4. If the display shows the word "XEQ __", then the program needs to be loaded. Turn off the calculator and follow the directions for loading the program, which begin in the next step.

B. Prepare the Calculator.

1. Clear the program memory.

   a. Turn off the calculator.

   b. While holding down the delete button (arrow left), turn on the calculator.

   c. The display will show "MEMORY LOST".

2. Allocate 20 registers for data storage by pressing the following keys, in succession: "XEQ", "ALPHA", S, I, Z, E, "ALPHA", 0, 2, 0.

C. Switch to USER mode by pressing the button labeled "USER", which makes the word "USER" appear on the left side of the display.

D. Feed the 10 program cards into the card reader.

1. Make sure the rechargeable battery is fully charged. The cards may be read in any order.

2. If the message "MALFUNCTION" appears when reading any of the cards, the following should be executed:

   a. Read another card, and come back to the ‘problem’ card later.

b. If this does not work (i.e., other cards also show the error) then either the card reader needs service, or the cards themselves have been damaged. Knowledgeable, qualified personnel are required for these problems.

3.2 STARTING THE PROGRAM

A. Switch to USER mode (i.e., press the button labeled "USER", which makes the word USER appear in small letters on the left side of the display).

B. Press the button labeled "XEQ" to start the program. The display should show the words "ED - Rev 3" if the program is properly loaded. Press the "R/S" button to continue. Step-by-step instructions begin in Section 3.3.

C. The following is general information about the program.

1. The program is divided in two major sections.

   a. Atmospheric Dispersion--User prompts show the current value for a variable. When a new value is entered, the user must verify the number before the program continues.

   b. Release Amount or Rate--Current values are not shown in the display. To see the current value of a requested quantity, press the delete button (arrow left). When a value is entered, the program goes on to the next menu item without asking the user to verify the input.

2. At any data entry prompt, the value entered on a previous run will be used unless a new value is entered. Thus the entire calculation can be repeated from the "ED - Rev 3" display to the dose display simply by pressing the "R/S" button again and again.

3. The program is designed to allow correction of a previous input value or menu choice. The directions to go back and change a value are as follows.

   a. Switch the calculator to USER mode by pressing the "USER" switch. When the calculator is in USER mode, the word "USER" will appear in the display on the lower left.

   b. In USER mode, some of the keys will not perform the usual function. The redefined keys are listed below in the order they appear on the face of the calculator. Press the button corresponding to the variable you need to change.

HP-41 Key →	A	B	C	D	E
ED - Rev 3 →	X	Y	V	D	DUR
HP-41 Key →	F	G	H	I	J
ED - Rev 3 →	UNITS	SOURCE	H	ISO	X/Q
HP-41 Key →	shift	XEQ	L	M	SST
ED - Rev 3 →		ED3		MET	

For example, to change the distance, press "A" and the program will begin at Section 3.3.F.

c. Before entering a new value, press the USER switch to take the calculator out of USER mode. If the calculator is left in USER mode, the program will take short cuts and only show computed results. The program skips all later inputs. Unless you intend to take advantage of this feature, be sure the word "USER" is not showing in the display.

d. Enter the new value, and press "R/S" to go on.

4. The execution of the program stops at each menu displayed. The calculator is then just a calculator. To allow the program to continue, the "R/S" button must be pressed. While the program execution is in progress, the letters "PRGM" will appear on the right side of the display.

5. If the "R/S" button is accidentally pressed during execution of the program, the calculator will stop and display the current value in the X register. To continue execution, simply press the "R/S" button again.

3.3 ATMOSPHERIC DISPERSION

A. Choosing Units

1. Choose either "METRIC" or "U.S.A. UNITS" for distances. "METRIC" means meters or kilometers, while "U.S.A. UNITS" means feet or miles.

2. The current selection is displayed.

   a. If you want to switch to the other unit system, press any number and then press "R/S". All previous entries will automatically be converted to the new units. They do not need to be re-entered.

b. To continue, press "R/S".

B. **Atmospheric Stability Class Input**

1. The display "MET = Z ?" means that the current selected value for atmospheric stability class is Z. Allowable values for Z are A, B, C, D, E, F, or G. These letters are printed in blue on the calculator buttons.

2. The best values for Pasquill-Gifford stability are obtained from the Hanford Meteorological Station (telephone 509-373-2716). If you have a source of actual weather data, be sure to get the following information: (1) stability class (A-G), (2) mixing layer depth, (3) wind speed, and (4) wind direction. Each will be needed.

3. If current conditions are not available, estimate the stability class from either of the following tables (Tables 1 and 2).

Table 1. Rule of Thumb Table for Estimating Stability Class.

Wind speed (mph)	Daytime cloud cover little	half	overcast	Night cloud cover > half	< half
< 5	A	A	B	E	F
5 - 10	B	B	C	E	F
10 - 15	B	C	C	D	E
> 15	C	D	D	D	D

Slade (1968).

Table 2. Alternate Method Stability Class by Month and Time of Day.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
midn-1	F	F	F	F	F	F	F	F	F	F	F	F
2 - 3	F	F	F	F	F	F	F	F	F	F	F	F
4 - 5	F	F	F	F	E	E	E	E	F	F	F	F
6 - 7	E	E	E	E	E	D	D	D	E	E	F	F
8 - 9	E	E	D	D	D	D	B	B	C	D	E	E
10 - 11	D	D	D	D	B	B	A	A	A	D	D	D
noon-1	D	D	B	B	B	A	A	A	A	B	D	D
2 - 3	D	D	D	B	A	A	A	A	B	C	D	D
4 - 5	E	D	D	D	B	B	B	C	D	D	E	E
6 - 7	E	E	E	D	D	D	D	D	D	E	E	E

Table 2. Alternate Method Stability Class by Month and Time of Day. (cont)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8 - 9	E	E	E	E	D	D	D	D	E	F	F	F
10 - 11	E	E	E	E	E	E	D	D	E	F	F	F

4. If the value shown in the display is correct, press "R/S". If not, type in a better value and then press "R/S".

C. **Mixing Layer Depth Input**

1. The mixing layer depth (D) is the vertical dispersion limit. If a current measurement is not available, estimate it from Table 3. Mixing depth is important at great distances and more unstable conditions. The values shown on the following tables (Tables 3 through 6) are conservative estimates.

2. The display "D= Z M" or "D= Z FT" means that the current value for mixing depth is Z in the units shown.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

Table 3. Estimating Mixing Depth in Meters.

Month	Sunrise	Midday	Sunset	Night
Jan-Feb	200	200	200	150
Mar-Apr	300	400	300	150
May-Jun	400	800	400	150
Jul-Aug	500	1,000	500	150
Sep-Oct	350	700	350	150
Nov-Dec	200	300	200	150

Table 4. Estimating Mixing Depth in Feet.

Month	Sunrise	Midday	Sunset	Night
Jan-Feb	656	656	656	492
Mar-Apr	984	1,312	984	492
May-Jun	1,312	2,625	1,312	492
Jul-Aug	1,640	3,281	1,640	492
Sep-Oct	1,148	2,297	1,148	492
Nov-Dec	656	984	656	492

Table 5. Alternate Method Mixing Layer Depths in Meters.

Stab	Winter	Spring	Summer	Autumn
A	500	850	1,000	900
B	500	600	750	600
C	300	500	650	500
D	200	400	500	400
E	200	250	250	250
F	150	150	150	150
G	100	100	100	100

Table 6. Alternate Method Mixing Layer Depths in Feet.

Stab	Winter	Spring	Summer	Autumn
A	1,640	2,789	3,281	2,953
B	1,640	1,969	2,461	1,969
C	984	1,640	2,133	1,640
D	656	1,312	1,640	1,312
E	656	820	820	820
F	492	492	492	492
G	328	328	328	328

Winter = Jan., Feb., Mar.
Spring = Apr., May., June
Summer = July, Aug., Sep.
Autumn = Oct., Nov., Dec.

D. **Wind Speed Input**

1. The display "V= Z M/S ?" or "V= Z FT/S ?" means that the current wind speed is Z in the units shown.

2. If actual weather data are not available, use 5 to 10 mi/h (2 to 5 m/s), which is a typical wind speed for the Hanford Site.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

E. **Effective Release Height Input**

1. The vertical height of the release above the receptor (H) includes any estimates of plume rise or downwash. If time is limited, just use the stack height. If the effective stack

height is less than 2.5 times the height of nearby buildings, the release must be treated as originating at ground level.

2. The display "H= Z M" or "H= Z FT" means that the current value for release height is Z in the units shown.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

F. **Downwind Distance Input**

1. Using the assumed wind direction and a map, determine the distance to the downwind receptor in the direction the wind is traveling. The wind transport direction is the X-axis in the coordinate system of the dispersion model being used.

2. The display "X= Z KM ?" or "X= Z MI ?" means that the current value for distance is Z in the units shown. The minimum value for X is 0.1 km or 0.0622 mi. If a smaller value is entered, the program will insert the minimum distance.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

G. **Plume Offset Input**

1. The distance perpendicular to the wind transport direction is called the plume offset, or 'Y'.

2. The display "Y= Z M" or "Y= Z FT" means that the current value for plume offset is Z in the units shown.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

H. **Normalized Exposure Results**

1. The normalized exposure (X/Q) has units of seconds per cubic meter. It is calculated from the wind speed, release height, horizontal and vertical plume spread parameters (ΣY and ΣZ). These parameters depend on the stability class, the distance downwind, and the mixing depth.

2. The first result displayed is "ΣY= Z M ?" or "ΣY= Z FT ?", which means that the current value for horizontal plume spread parameter is Z in the units shown. The question mark signifies that a new value may be entered if necessary; step H.4 tells how to do this.

3. The second result displayed is "ΣZ= Z M ?" or "ΣZ= Z FT ?" meaning that the current value for vertical plume spread parameter is Z with the units shown. The question mark

signifies that a new value may be entered, if necessary; step H.4 tells how to do this.

4. For ground-level releases, the effect of plume meander or building wake may be included by changing the displayed values for horizontal and vertical plume spread. Type in the revised value and press "R/S". If you are unsure how to do this, leave the displayed values alone and just press "R/S".

   For elevated releases, an X/Q value for fumigation may be calculated by entering a mixing depth, D, equal to the height of the stack. Then, when the vertical plume spread value is displayed, enter a value that is greater than 1.2 times D. This will force the program to calculate an X/Q in which there is a uniform concentration between ground level and the top of the stack.

5. The third result displayed is "X/Q= a.bcE-d?", which means that the computed value for normalized exposure is a.bcE-d seconds per cubic meter. Again, the question mark signifies that a new value may be entered, if necessary.

6. To change the value for X/Q used in subsequent calculations, enter the new value and press "R/S". If you do not wish to change X/Q, press "R/S" to go on.

I. Release Duration Input

1. The release duration is used to estimate air concentrations downwind or total release, depending on later inputs for release amount.

2. The display "DUR= Z HR" means that the current value for release duration is Z hours.

3. If the value shown is correct, press "R/S". If not, type in the correct value and then press "R/S".

J. Type of Material Released

1. The material released can be either radioactive or chemical.

   a. If "RAD SOURCE?" is displayed, radioactivity released will be used to determine the inhalation dose downwind.

   b. If "CHEM SOURCE?" is displayed, chemical release rate will be used to determine air concentrations downwind.

2. The current selection is displayed.

   a. If you want to switch to the other type of release, press any number and then press "R/S".

b. To accept the displayed source type and continue, press "R/S". Calculations for the chemical source are described next. Radiological source calculations are described in Section 3.5.

3.4 RELEASE RATE FOR A CHEMICAL RELEASE

A. "ST, TOTAL= 1,2?"

"ST, TOTAL= 1,2?" offers two ways to establish release rate. Enter either "1" or "2" to select, and press "R/S" to continue. It is important to enter either a "1" or a "2". Any other entry will cause the program to continue at an incorrect location.

- "1" chooses "ST" and means that the release rate will be based on a stack concentration and flow rate.
- "2" chooses "TOTAL" and means the total mass released will be input next. The release rate is then calculated from the release duration.

B. "ST" - Stack Data

1. Use this item when the average air concentration at the point of release is known. It is important that this be the peak concentration during the release, not an average over a larger time period.
2. "STACK CONC?" is the next prompt. It requests input for the air concentration in either parts per million (by volume) or mass density (milligrams per cubic meter). Type in the number and press "R/S".
3. The next prompt displays the currently assumed units. The choice is either "PPM ?" or "MG/M3?".
   a. To switch to the other units, press any number and then press "R/S".
   b. To accept the displayed units and go on, press "R/S".
4. The final prompt is "STACK CFM ?". Enter a value for the total exhauster flow rate, in cubic feet per minute. The tables in Section 4.0 list typical values for most of the effluent stacks on site. After the stack flow rate has been entered, press "R/S" to continue with Section 3.4.D.

C. **"TOTAL" - Total Mass Released**

1. Use this option to enter the total mass released.

2. "TOT LB REL ?" is the next prompt. Enter a value for the total number of pounds estimated to have been released. Press "R/S" and the program will continue.

D. **Air Concentration at Downwind Location (X,Y)**

1. The program displays the air concentration at the downwind location (X,Y).

2. The air concentration message "X,Y MG/M3=a.bE-c" or "X,Y PPM=a.bE-c" may be too long to fit in the display. If it is, the calculator scrolls the visible portion of it from left to right. All or part of the "X,Y" disappears in a few seconds.

   a. To view the entire message again, press the "ALPHA" switch. This puts the calculator in ALPHA mode and displays the message register.

   b. When you are ready to continue, press the "ALPHA" switch again to take the calculator out of alpha mode. Make sure the word "ALPHA" is gone from the lower right side of the display.

E. **Conversion from milligrams per cubic meter to parts per million by volume, or parts per million to milligrams per cubic meter**

1. When you press "R/S" to leave the air concentration display, the program displays "FORMULA WT?". The program is requesting a value for the formula weight of the chemical in order to convert from milligrams per cubic meter to ppm, or parts per million to milligrams per cubic meter. For example, the value for ammonia is 17 g/mol, and for chlorine it is 71 g/mol.

2. Enter a value for formula weight and press "R/S" to continue. The program then displays the air concentration at (X,Y) in the other units (see Section 3.4.D.).

3. If you press "R/S" twice when the final air concentration is displayed, the program will begin again at "ED - Rev 3" (Section 3.2.B.).

3.5 RELEASE AMOUNT FOR A RADIONUCLIDE RELEASE

A. **"ST,CI,AR,GD=1-4"**

"ST,CI,AR,GD=1=4" offers four ways to establish the number of curies released. Enter a number from 1 to 4, as discussed in the following subsections, to select, and press "R/S" to continue. It is important to enter a number from 1 to 4 because any other entry will cause the program to continue at an incorrect location.

- "1" chooses "ST" and means the total release will be based on a stack concentration and stack flow rate.
- "2" chooses "CI" and means the total curies released will be input next.
- "3" chooses "AR" and means the total release will be estimated from an air concentration measurement downwind.
- "4" chooses "GD" and means the total release will be estimated from a ground contamination measurement downwind.

B. **"ST" - Stack Data**

1. Choose this (enter "1") when the average air concentration at the point of release is known. It is important that this be the concentration during the release, not an average over a longer time period.
2. "CONC OR DPM?" is the next prompt. It is requesting input for either air concentration in micro-Curies per cubic centimeter, or the activity measured on an air sample filter in disintegrations per minute (dpm).
   a. The program tells the difference by comparing the value to unity. It assumes that all air concentrations will be less than 1 μCi/cc at the point of release.
   b. To enter a concentration greater than 1 μCi/cc, divide it by a convenient factor (like 10 or 100) to get it below 1. Then adjust the stack flow rate upward by the same factor.
   c. If a value of less than 1 μCi/cc is selected, the program skips step 3, proceeding to step 4 next.
3. If you entered a value greater than 1 (for dpm on an air sample), the next prompt will be "CU.FT SAMPLD?". This is a request for a figure for the volume of air pulled through the sample filter, in cubic feet. For example, if the sampler operated at 2 cfm for 5 min, the volume would be 10 ft^3.

After a value is entered, press "R/S" and the program will continue by displaying the calculated air concentration at the point of release, in micro-Curies per cubic centimeter. Press "R/S" to continue with the program.

4. The final prompt is "STACK CFM ?". Enter a value for the total exhauster flow rate, in cubic feet per minute. The tables in the next section list typical values for most of the effluent stacks on site. After the stack flow rate has been entered, press "R/S" and the program displays the total activity released. Press "R/S" to continue with Section 3.5.F below.

C. **"CI" - Total Curies Released**

1. Use this option to enter the total curies released.

2. "CURIES REL ?" is the next prompt. Enter the value and press "R/S". The program continues with Section 3.5.F.

D. **"AR" - Air Concentration at (X,Y)**

1. Use this item to interpret downwind air concentration measurements. The X/Q computed earlier must be for a location (X,Y) at which the air sample was taken.

2. "CONC OR DPM?" is the next prompt. This is a request for a value for either air concentration in micro-Curies per cubic centimeter, or the activity on an air sample filter in dpm.

   a. The program tells the difference by comparing the value to unity. It is assumed that all downwind air concentrations will be less than 1 μCi/cc, and all filter activities greater than 1 dpm. Enter a value and press "R/S".

   b. If you enter a value less than 1 μCi/cc, the program skips step 3 and goes directly to step 4.

3. If you entered a value greater than 1 (for dpm on an air sample), the next prompt will be "CU.FT SAMPLD?". It is requesting a figure for the volume of air pulled through the sample filter, in cubic feet. For example, if the sampler operated at 2 cfm for 5 min, the volume would be 10 ft^3. After a value is entered, press "R/S" and the program continues by displaying the calculated air concentration at (X,Y), in micro-Curies per cubic centimeter. Press "R/S" to continue with the program.

4. The final prompt is "HRS SAMPLED?". This information is needed to correct for downwind air samples that were running longer than the release. For example, if the downwind sampler had been running for a total of 40 h, even though the release

lasted only 2 h, the average concentration computed would be lower, by a factor of 20, than the actual concentration during the passage of the plume. The program uses the longer of the release duration or sample period to calculate the total release.

Note that as long as the sample period includes the entire release, or else begins and ends during the release, the total release estimate will be correct. Otherwise, the total release computed by the program will be low according to the portion of the release that was not sampled.

5. After entering a value for hours sampled, press "R/S" and the program will display the total activity released. Press "R/S" to continue to Section F.

E. **"GD" - Ground Contamination at (X,Y)**

1. Use this item to interpret downwind ground contamination measurements. The X/Q computed earlier must be for a location (X,Y) where the ground contamination was measured.

2. "DPM/SQ.CM ?" is the next prompt. Enter the measured surface contamination downwind and press "R/S". If direct survey data are available, the detector face area must be taken into account. Use the following chart:

Probe type	Face type
GM: P-11	15 cm^2
PAM	54 cm^2

Note that direct survey readings should represent the average measured over about a square meter, rather than the maximum reading in that area.

3. "DEP. SP? CM/S" is the final prompt. Enter an appropriate value for the ground deposition speed. Typically this is about 0.1 cm/s, although it may be higher for certain chemical forms (halogens). The ground deposition speed also varies with humidity, surface moisture, and vegetation cover.

4. After entering a value for deposition speed, press "R/S" and the program will display the total activity released. Press "R/S" to continue.

F. **Air Concentration at Downwind Location (X,Y)**

1. The last result displayed before entering the nuclide choices portion of the program is the air concentration at the downwind location (X,Y).

2. The air concentration message "X,Y UCI/CC=a.bE-c" is too long to fit in the display, so the calculator scrolls the visible portion of it from left to right. The "X,Y" disappears in a few seconds.

   a. To view the entire message again, press the "ALPHA" switch. This puts the calculator in ALPHA mode and displays the message register.

   b. When you are ready to continue, press the "ALPHA" switch again to take the calculator out of alpha mode. Make sure the word "ALPHA" is gone from the lower right side of the display.

3.6 NUCLIDE CHOICES AND DOSE EQUIVALENT

A. **"a,B1,B2,NEW=1-4" offers four nuclide menus**

1. Enter a number from 1 to 4 to select; press "R/S" to continue. Each choice is described in detail in the following subsections.

2. The menu choices are arranged so that lower numbers will give higher doses. So, when in doubt between two choices, select the one with the lower menu number.

3. It is important to enter a number from 1 to 4 because any other entry will cause the program to continue at an incorrect location. (To recover from pressing the wrong number, switch to ALPHA mode, press the blue "G", and then switch out of ALPHA mode.)

B. **"a" - Alpha-Emitting Nuclides**

1. "PU,AM,NP,U= 1-4?" lists the alpha emitting choices.

   a. Enter a number from 1 to 4 to select, and press "R/S" to continue.

   b. In all cases, the dose to the bone surface will be limiting.

   c. It is important to enter a number from 1 to 4 because any other entry will cause the program to continue at an incorrect location.

2. "PU" is a 12% ^{240}Pu mixture (0.098 Ci/g). Table 7 shows a typical composition.

Table 7. Plutonium Composition Used in ED.

Nuclide	Weight percent	Curies per 1 Ci alpha
^{238}Pu	0.093	0.163
^{239}Pu	84.00	0.534
^{240}Pu	13.00	0.303
^{241}Pu	2.88	30.4
^{242}Pu	0.027	1.1 E-05

If this plutonium mixture is selected, the next prompt is "NO3, O2 = 1, 2". The choice here is between plutonium nitrate (inhalation Class W) and plutonium oxide (inhalation Class Y). Make your choice and press "R/S".

3. "AM" is pure ^{241}Am (inhalation Class W, 3.43 Ci/g).

4. "NP" is pure ^{237}Np (inhalation Class W, 7.04×10^{-4} Ci/g).

5. "U" is one of three uranium compounds, commonly found in the 200 Areas. The typical isotopic composition is shown in Table 8.

Table 8. Uranium Composition Used in ED.

Nuclide	Weight percent	Curies per 1 Ci alpha
^{234}U	0.009	0.625
^{235}U	0.836	0.019
^{236}U	0.073	0.002
^{238}U	99.082	0.354

If this uranium mixture is selected, the next prompt is "UO,UO3,UNH=1-3".

a. "UO" is inhalation Class Y compounds such as UO_2 or U_3O_8.

b. "UO3" is an inhalation Class W compound with a specific activity of 7.8 x 10^{-7} Ci/g, or 0.78 Ci/Mt or 3.5 x 10^{-4} Ci/lb or 0.71 Ci/ton.

c. "UNH" is Class D with a typical uranium concentration of 4 lb/gal as shipped from PUREX, or 10 lb/gal entering the UO_3 facility calciner.

C. **"B1" - First Beta Emitter List**

1. "SR,RU,I,CS= 1-4" lists the beta emitter choices on this menu.

   a. Enter a number from 1 to 4 to select, and press "R/S" to continue.

   b. It is important to enter a number from 1 to 4 because any other entry will cause the program to continue at an incorrect location.

2. "SR" is ^{90}Sr along with its daughter ^{90}Y. If 1 Ci is released, the program interprets this as 1 Ci ^{90}Sr and 1 Ci ^{90}Y, which potentially could exaggerate the doses by a factor of 2, depending on how the release amount was determined.

3. "RU" is ^{106}Ru. The next menu is "INSOL, SOL = 1,2", which allows the selection of either inhalation class Y (INSOL) or inhalation class D (SOL). The ^{106}Ru has a radioactive daughter, ^{106}Rh. Entering a value of 1 Ci of ^{106}Rh is interpreted as 1 Ci of the parent and an equal amount (1 Ci) of the ^{106}Rh daughter.

4. "I" is either ^{129}I or ^{131}I. If "I" is selected, the next prompt is "I129, I131 = 1,2".

5. "CS" is ^{137}Cs. Again, if 1 Ci ^{137}Cs is released, an equal amount of its daughter, ^{137m}Ba, is added to this.

D. **"B2" - Second Beta Emitter List**

1. "CO,KR,H = 1-3" lists the beta emitter choices on this menu.

   a. Enter a number from 1 to 3 to select, and press "R/S" to continue.

   b. It is important to enter a number from 1 to 3 because any other entry will cause the program to continue at an incorrect location.

2. "CO" is ^{60}Co. The next menu is "INSOL, SOL = 1,2", which allows the selection of either inhalation class Y (INSOL) or inhalation class W (SOL).

3. "KR" is ^{85}Kr. A semi-infinite plume model is used, which could seriously underestimate the dose rates near a stack release.

4. "H" is H-3, or tritium, as water vapor. Skin absorption is included in the inhalation dose calculation.

E. **"NEW" - User Input Dose Factor**

1. "ISO NAME ?" is the first prompt. The calculator is left in ALPHA mode to facilitate text entry.

   a. You select the characters using the symbols printed in blue on the calculator keys. A list of all the letters available is located on the back of the calculator. The shift key (yellow button on the left) must be used to enter numbers.

   b. The program will store and use up to 6 characters (the first 6 entered), so choose them carefully.

2. "REM/UCI ?" is requesting input of the inhalation dose factor in units of rem per microCuries inhaled. Enter this value and press "R/S" to begin the dose calculation. The assumed breathing rate is 330 cc/s. Several additional dose factors are provided in Tables 26 and 27 (Section 6).

F. **Dose Equivalent Result**

1. The program calculates both the effective dose equivalent (EDE) and the largest organ dose. In this way, the results can be compared with Protective Action Guides for EDE or organs. However, the program will display only the dose that is closer to exceeding an action level. The other dose can be seen by pressing the "X<>Y" key, which interchanges the X and Y registers. Note that a small "O" will appear in the lower part of the display if the organ dose is limiting. The organ dose is always the greater of the two doses.

2. The dose equivalent is displayed in millirem. The nuclide identity is shown first. In most cases, the display will scroll, from left to right, because the line is too long to fit in the display.

   a. To look at the entire message again, press the "ALPHA" switch. This puts the calculator in ALPHA mode and displays the message register.

b. When you are ready to continue, press the "ALPHA" switch again to take the calculator out of alpha mode. Make sure the word "ALPHA" is gone from the lower right side of the display.

c. The dose is also stored in the X register (the one normally displayed when the calculator is turned on). In addition, the message register has the identity of the nuclide or mixture that was selected for the dose calculation. Press the ALPHA switch to see the message; press the ALPHA switch again to see the X register.

4. Press "R/S" to see the type of dose that was displayed in the message register. The calculator will beep and display either "EDE LIMITS" or "ORGAN LIMITS".

5. Press the "X<>Y" key to interchange the X and Y registers and see the other dose. This is the end of the program.

3.7 GENERAL NOTES

A. At any data entry prompt, the value entered on a previous run will be used unless a new value is entered. Thus the entire calculation can be repeated from the "ED - Rev 3" display to the dose display simply by repeatedly pressing "R/S".

B. The program is designed to make it easy to change just one input value or menu choice and rerun the case. The directions follow.

1. Switch the calculator to USER mode by pressing the "USER" switch. When the calculator is in USER mode, the word "USER" will appear in the display on the lower left.

2. In USER mode, some of the keys will not perform the usual function. The redefined keys are listed below in the order they appear on the face of the calculator.

HP-41 Key →	A	B	C	D	E
ED - Rev 3 →	X	Y	V	D	DUR
HP-41 Key →	F	G	H	I	J
ED - Rev 3 →	UNITS	SOURCE	H	ISO	X/Q
HP-41 Key →	shift	XEQ	L	M	SST
ED - Rev 3 →		ED3		MET	

3. For example, to change the distance, press the "A" and the program will begin at Section 3.3.D. in the directions previously given. Enter a new value for X, press "R/S" (as often as needed) and the program will show the E.T.A., the dispersion values, X/Q, the previously computed total curie amount released, the ground-level concentration at (X,Y), and the dose.

4. The total amount released is only recomputed if "G" is pressed to begin at Section 3.4.A. In this way, downwind data can be used to estimate the total release. Then doses and concentrations at other locations can be computed without changing this number.

C. When running cases in USER mode, if some of the intermediate values that are displayed just flash and are quickly replaced with menus, set flag 21 to make them stop. Execute the set flag function by pressing the yellow-colored shift button and then the number 7, which has "SF" written above it. The display will prompt you for two numbers, so type in 21. Note that if a printer is connected and turned on, these displays are printed and the program does not stop. Also, when the calculator is turned off, flag 21 is automatically cleared, hence the need to manually set it when necessary.

Table 9. Summary of Data Register and Flag Use.

Registers		Flags	
00	miscellaneous values	00	clear if EDE limits
01	X/Q, s/m^3	01	temporary for X < 1 km
02	unit conversion factor	02	temporary use for ppm
03	unit string	05	set for USA units
04	Stability class, MET, A to G	06	set for Class G
05	wind speed, V, m/s	07	set for chem release
06	distance, X, meters	08	set for ppm units
07	distance, Y, meters		
08	release height, H, meters		
09	release duration, DUR, hours		
10	AMT menu choice, 1 to 4		
11	conc or dpm value; formula wt		
12	cu.ft sampled; chem release rate		
13	stack conc; air conc; grd cont		
14	stack cfm; hours sampled; Vd		
15	total curies released		
16	top-level menu choice, 1 to 4		
17	second choice or user name		
18	third choice or user dose factor		
19	mixing depth, meters		

4.0 TYPICAL EXHAUST FLOW RATES FROM WESTINGHOUSE HANFORD COMPANY FACILITIES

4.1 100 AREA EFFLUENT STACKS

Table 10. 100-N Stacks.*

Stack emission point	Typical flow rate, cfm
116-N Stack	210,000
109-N Zone I Vent	120,000
109-N Cell 6 Vent	14,000
Zone II, EF 7, 8	23,000
Zone III, EF 10	130,000
Zone IV, EF 14, 15	16,000
105-N Transfer Area	28,000
105-N Spacer Decontamination Facility	4,800
105-N 14-ft Decontamination Facility	6,400
107-N Exhaust	7,300

**100 Area Environmental Releases for 1988* (WHC 1988).

Table 11. 100-K Stacks.*

Stack emission point	Typical flow rate, cfm
105-KE Vents	27,000
105-KW Vents	27,000
1706-KE	12,000
1706-KER	2,500

**100 Areas Environmental Releases for 1988* (WHC 1988).

4.2 200 EAST AREA EFFLUENT STACKS

Table 12. PUREX Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-A-1	200 ft	120,000
296-A-1	Q-Cell and PR Room	5,000
296-A-2	West Sample Gallery	4,000
296-A-3	East Sample Gallery	3,000
296-A-5A	Lab West	18,000
296-A-5B	Lab East	20,000
296-A-6	E Sample Gallery and U-Cell	20,000
296-A-7	W Sample Gallery and R-Cell	20,000
296-A-8	White Room Exhauster	16,000
296-A-10	Equipment Disposal Tunnel	4,000
296-A-14	Outback (293-A) Exhaust	5,000
296-A-24	Ammonia Offgas	1,500
296-A-31	Storage Gallery	12,000
296-A-32	Vacuum Pump Exhaust	1,800
296-A-33	Wall Exhauster, EF-3-5	4,000
296-A-34	Wall Exhauster, EF-3-6	6,000
296-A-35	Wall Exhauster, EF-3-7	7,000
296-A-36	Wall Exhauster, EF-3-8	4,300
296-A-37	Wall Exhauster, EF-3-9	8,000
296-A-38	Wall Exhauster, EF-3-10	2,300
296-A-39	SWP Lobby Exhaust	unknown

**Effluent Discharges and Solid Waste Management Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 13. B Plant/WESF Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-B-1	200 ft	40,000
296-B-5	271-B	1,500
296-B-10	WESF	20,000
296-B-13	221-BF, BCF Tanks	800
296-B-14	221-B Vessel Vent	250

**Effluent Discharges and Solid Waste Management Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 14. East Tank Farm Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-A-12	244-AR Vessel Vent (150 ft)	1,000
296-A-13	244-AR Canyon	6,000
296-A-17	A, AX, AY, AZ Tanks	4,000
296-A-18	101-AY Annulus	1,200
296-A-19	102-AY Annulus	1,200
296-P-17	Tank 105-A	2,000
296-A-20	AZ Annuli	2,000
296-A-21	242-A Evaporator	20,000
296-A-22	242-A Vessel Vent	700
296-A-25	244-A Catch Tank	160
296-A-26	204-AR Tank Car Building	2,000
296-A-27	AW Tanks	1,100
296-A-28	AW Annuli	4,600
296-A-29	AN Tanks	900
296-A-30	AN Annuli	6,000
296-A-40	AP Tanks	1,000
296-A-41	AP Annuli	10,000
296-B-28	244-BX Saltwell Vessel	300
296-C-5	244-CR Vault	3,000
296-P-16	Tanks 105-C and 106-C	3,500

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

4.3 200 WEST AREA EFFLUENT STACKS

Table 15. S Plant Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-S-1	200 ft	20,000
296-S-2	202-S Sample Gallery	600
296-S-4	202-S SWP Lobby	5,000
296-S-6	202-S Silo	10,000
296-S-7E	233-S Building Exhaust	9,000
296-S-7W	233-S Building Exhaust	9,000
296-S-16	218-S Tanks	150
296-S-21	222-S Laboratories	70,000

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 16. T Plant Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-T-1	200 ft	40,000
296-T-11	224-T Storage East	13,000
296-T-12	224-T Storage West	13,000
296-T-13	221-T Roof	40,000
296-W-1	Laundry	20,000

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 17. U Plant Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-U-1	200 ft	28,000
296-U-2	Powder Handling Offgas	1,400
296-U-4	224-U Calciners	2,500
296-U-13	224-U Load-out Room	6,000

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 18. Z Plant Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
291-Z-1	200 ft (234-5,232,236,242)	240,000
296-Z-3	241-Z Sump and Vessels	1,800
296-Z-5	2736-ZB	10,000
296-Z-6	2736-ZA	11,000

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

Table 19. West Tank Farm Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
296-P-22	SY Annuli	450
296-P-23	SY Tanks	1,000
296-S-15	SX Tanks	5,000
296-S-18	242-S Building Exhaust	20,000
296-S-22	244-S Saltwell Receiver	200
296-T-17	242-T Cells	2,000
296-T-18	244-TX Saltwell Receiver	300
296-W-03	213-W Waste Compactor	2,500

**Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas* (WHC 1988).

4.4 300 AREA EFFLUENT STACKS

Table 20. 300 Area Effluent Stacks.*

Stack ID	Descriptor	Typical flow rate, cfm
303-M	Oxide Facility	3,000
306-E	UO_2 Laboratory	3,200
308	Glovebox	3,400
308	Etch and Clean	4,300
308	TRIGA Reactor	2,400
309	Containment	7,000
313	Engineering Hot Laboratory	800
333	Building	3,200
340	Neutralization Tank and Vault	1,900
340	Decontamination Facility	1,000
340-B	Tank Car Loadout	8,500

**Effluent Report for 300, 400, and 1100 Area Operations for Calendar Year 1988* (WHC 1988).

4.5 400 AREA EFFLUENT STACKS

Table 21. The 400 Area Effluent Stacks.*

Stack emission point	Typical flow rate, cfm
Combined Exhaust	24,000
Lower Reactor Service Building	13,000
HTS-South	4,200
MASF Building Exhaust	16,000

**Effluent Report for 300, 400, and 1100 Area Operations for Calendar Year 1988* (WHC 1988).

5.0 SAMPLE PROBLEMS FOR ED - REVISION 3

5.1 STACK RELEASE OF HYDROGEN FLUORIDE

A. **Scenario** - Severe damage to process equipment at the Plutonium Finishing Plant has resulted in a release of hydrogen fluoride (HF) to the exhaust system. The accident is assumed to occur on May 31, at 10:00 pm. Winds are blowing toward the west at 5 mph. Calculate the HF concentration at the Site boundary and at Highway 240. The HF comes to PFP in 150-lb cylinders.

B.

Calculator Display	Hazard Evaluator Entry
(an arbitrary number)	USER mode switch; XEQ
ED - Rev 3	R/S
U.S.A. UNITS ?	R/S
MET = A ? (or any letter)	E (Table 2); R/S
MET = E ?	R/S
D = 2,625.0 FT ? (or any number)	820 (Table 6); R/S
D = 820.0 FT ?	R/S
V = 2.2 MPH ? (or any number)	5; R/S
V = 5.0 MPH ?	R/S
H = 6.3 FT ? (or any number)	200 (main stack); R/S
H = 200.0 FT ?	R/S
X = 15.00 MI ? (or any number)	7.6 (Site Bdy); R/S
X = 7.60 MI ?	R/S
Y = 0.0 FT ? (assumed okay)	R/S
ΣY = 1,685.9 FT ?	R/S
ΣZ = 278.1 FT ?	R/S
X/Q = 2.52E-6 ?	R/S
DUR = 4.0 HR ? (or any number)	0.5 (assumed); R/S
DUR = 0.5 HR ?	R/S
RAD SOURCE?	3 (or any number); R/S
CHEM SOURCE?	R/S
ST, TOTAL = 1,2 ?	2; R/S
TOT LB REL ?	150 (assumed); R/S
X,Y MG/M3 = 9.5E-2	R/S
FORMULA WT?	19 (grams/mole); R/S
X,Y PPM = 1.1E-1	

The above concentration is well below the U.S. Department of Energy protective action guide of 20 mg/m^3.

Next, the Hazard Evaluator estimates the HF concentration at Highway 240.

1.1E-1	USER mode switch; A
X = 7.60 MI ?	2.8 (Hwy 240); R/S
X = 2.80 MI ?	R/S
ΣY = 684.2 FT ?	R/S
ΣZ = 175.8 FT ?	R/S

Calculator Display (continued)	Hazard Evaluator Entry
X/Q = 6.67E-6 ?	R/S
X,Y MG/M3 = 2.5E-1	R/S
FORMULA WT?	R/S (already entered)
X,Y PPM = 3.0E-1	

The above concentration is well below the protective action guide. Next the Hazard Evaluator estimates the concentration at the Yakima Barricade for a release of 270 lb.

3.0E-1	USER mode switch; G
CHEM SOURCE?	USER mode switch; R/S
ST, TOTAL = 1,2 ?	R/S (already entered)
TOT LB REL ?	270; R/S
X,Y MG/M3 = 4.5E-1	R/S
FORMULA WT?	R/S (already entered)
X,Y PPM = 5.4E-1	

5.2 GROUND RELEASE WITH DOWNWIND FIELD DATA

A. **Scenario** - A radioactive plume of unknown origin in the 241-C Tank Farm has caused measurable surface contamination in the vicinity of PUREX. The wind is currently blowing toward the SSE at 5 mph, at a stability best described as Class D. An air sample 3,600 ft downwind and 250 ft off the plume centerline has been running for 81 h when it is counted with field instruments and reads about 2,000 cpm above background. How much activity was released, and what dose would be estimated for the Site boundary? Use a mixing depth of 500 ft. Assume a detector efficiency of 10%, and an air sample flow rate of 2 cfm.

B. **Calculator Display** / **Hazard Evaluator Entry**

Calculator Display	Hazard Evaluator Entry
(an arbitrary number)	USER mode switch; XEQ
ED - Rev 3	R/S
U.S.A. UNITS ?	R/S
MET = E ? (leftover from previous)	D; R/S
MET = D ?	R/S
D = 820.0 FT ?	500; R/S
D = 500.0 FT ?	R/S
V = 5.0 MPH ?	R/S
H = 200.0 FT ?	5; R/S
H = 5.0 FT ?	R/S
X = 2.80 MI ?	3600; ENTER↑;
3600.00	5280; ÷; R/S
X = 0.68 MI ?	R/S
Y = 0.0 FT ?	250; R/S
Y = 250.0 FT ?	R/S
ΣY = 268.7 FT ?	R/S

Calculator Display (continued)	Hazard Evaluator Entry
ΣZ = 110.5 FT ?	R/S
X/Q = 3.35E-5 ?	R/S
DUR = 0.5 HR ?	R/S
CHEM SOURCE?	3 (or any number); R/S
RAD SOURCE?	R/S
ST,CI,AR,GD= 1-4	3; R/S
CONC OR DPM ?	20,000 (dpm); R/S
CU.FT SAMPLD?	81; ENTER↑; 2; x;
162.0	R/S
2.0E-9 UCI/CC	R/S
HRS SAMPLED?	81; R/S
REL: 1.7E1 CI	R/S
X,Y UCI/CC=3.2E-7	R/S
a,B1,B2,NEW= 1-4	2 (worst beta); R/S
SR,RU,I,CS= 1-4	1; R/S
SR-90: 5.1E2 MR	R/S
ORGAN LIMITS	

This would be the bone dose from inhalation of airborne Sr-90 if someone had been standing near the air sample station during the entire release. To calculate the dose at the Site boundary, 12 mi SSE, do the following:

5.1E2	USER mode switch; A
X = 0.68 MI ?	12; R/S
X = 12.00 MI ?	R/S
ΣY = 3,581.4 FT ?	B
Y = 200.0 FT ?	0; R/S
Y = 0.0 FT ?	R/S
ΣY = 3,581.4 FT ?	R/S
ΣZ = 630.0 FT ?	R/S
X/Q = 1.07E-6 ?	R/S
REL = 1.7E1 CI	R/S
X,Y UCI/CC= 1.0E-8	R/S
SR-90: 1.6E1 MR	

The projected offsite organ dose (bone) of 16 mrem would put this accident in the Alert category.

6.0 VERIFICATION OF ED - REVISION 3 CALCULATIONS

Verification: Code verification is the comparison of code results with the results of hand calculations and the results of other codes. In this section, values computed by ED - Revision 3 are compared with the GENII code, Version 1.436, and with hand calculations.

6.1 X/Q CALCULATION

A. The atmospheric dispersion model is the same as that found in GENII, but without some of the advanced features such as building wake and plume rise. The calculator model does include plume reflection from both the ground and mixing layer.

B. The GENII program was induced to supply X/Q values at specific stability classes and release heights by using special joint frequency data files. In addition, to obtain a value of X/Q with three meaningful digits, the X/Q value stored in the buffer file ENV.IN was used in the comparisons. The file used for calculating the Class F, ground level X/Q values is shown in the following chart.

Joint Frequency File for Ground Level, Class F, X/Q Computations

```
10 M - Pasquill F
Created 6-Aug-90  PDR
    1    7    1    1   10.0
  .89    2.65   4.7    7.15   9.8   12.7   15.6   19.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

C. Verification of X/Q values began with a carefully selected series of test cases to exercise relevant portions of the code without unnecessary duplication. Ground level X/Q is verified first, then stack X/Q, then treatment of reflection from the mixing layer, wind speed effects, and finally, off-axis X/Q.

1. The mixing depths in all cases is 1,000 m, (the value contained in the GENII code).

2. The wind speed is 0.89 m/s, except where noted.

3. The distance of 1,000 m is chosen because this is a transition distance where the model changes from one set of parameters to another. The 100-m and 10-km distances verify near and far behavior.

D. Ground level X/Q results from both ED and the computer program GENII (Version 1.436) are shown on the following tables. Note that GENII does not reveal the values of Sigma Y and Sigma Z that are used. Therefore, the Sigma values could not be compared.

Table 22. Atmospheric Dispersion Parameters Calculated by ED.

P-G Class	100 m Sigma Y	100 m Sigma Z	1,000 m Sigma Y	1,000 m Sigma Z	10 km Sigma Y	10 km Sigma Z
A	23.4	14.3	187.3	448.4	1,498.5	57,035
B	17.6	10.9	140.9	110.2	1,126.9	1,358.3
C	13.4	7.5	107.0	61.1	855.7	497.8
D	9.4	4.6	75.3	31.5	602.6	133.0
E	6.7	3.5	53.6	21.5	428.5	77.7
F	4.6	2.2	37.0	13.9	295.8	46.1
G	3.1	1.3	24.6	8.4	197.0	27.7

P-G Class	Distance downwind (X) 100 m	1,000 m	10 km
A	1.07 E-03	4.26 E-06	2.99 E-07
B	1.87 E-03	2.30 E-05	3.98 E-07
C	3.57 E-03	5.47 E-05	8.40 E-07
D	8.34 E-03	1.51 E-04	4.46 E-06
E	1.53 E-02	3.10 E-04	1.07 E-05
F	3.44 E-02	6.95 E-04	2.62 E-05
G	8.62 E-02	1.74 E-03	6.56 E-05

Table 23. Ground Level X/Q Values Computed by GENII.

P-G Class	Distance downwind (X) 100 m	1,000 m	10 km
A	1.07 E-03	4.26 E-06	2.99 E-07
B	1.86 E-03	2.30 E-05	3.98 E-07
C	3.57 E-03	5.47 E-05	8.40 E-07
D	8.32 E-03	1.51 E-04	4.46 E-06
E	1.54 E-02	3.10 E-04	1.07 E-05
F	3.44 E-02	6.95 E-04	2.62 E-05
G	8.55 E-02	1.72 E-03	6.57 E-05

Table 24. Percent Differences Between ED and GENII Ground Level X/Q Results.

P-G Class	Distance downwind (X) 100 m	1,000 m	10 km
A	0.0	0.0	0.0
B	0.5	0.0	0.0
C	0.0	0.0	0.0
D	0.2	0.0	0.0
E	-0.7	0.0	0.0
F	0.0	0.0	0.0
G	0.8	1.2	-0.2

Explanation of Differences: Most of the differences observed are due to the different representation of real numbers in the two different computers. The difference for the first two distances in the Class G row is due to a slight difference in calculating Simga Z. GENII calculates Sigma Z using the parameters shown in Table 28 (7.1, Section C) with the exception that Az(2) is 0.052 rather than 0.0516 shown on the table. The ED calculates Sigma Z for Class F and then multiplies by 0.6 to arrive at the Sigma Z for Class G. In effect, ED uses the value 0.0516 shown on the table.

E. Using the joint frequency file for 61 meter stack releases in the following chart, the GENII program computed a X/Q value of 3.32×10^{-5} s/m^3 at Pasquill Class C, and at a distance of 1,000 m. The ED gives the same result.

Joint Frequency File for 61 m, Class C, X/Q Computations

```
61 M - Pasquill C
Created 6-Aug-90 PDR

   1    3    1    1    61.0
 .89    2.65    4.7    7.15    9.8    12.7    15.6    19.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```

F. To test the treatment of reflection from the mixing layer, the X/Q values at a few distances near the transition point ($\Sigma z = 1.2*D$) were compared. Results are shown in Table 25. The unusual release height of 900 m was used to test the effect of a release height that was near the mixing depth.

Table 25. Comparison of ED and GENII for Reflection from the Mixing Layer (using Pasquill B stability and mixing layer depth of 1,000 m).

Release height	Distance km	Sigma Z m	X/Q Value, s/m^3 ED	X/Q Value, s/m^3 GENII	Percent difference
Ground level	5.0	635.6	9.47 E-07	9.47 E-07	0.0
Ground level	7.0	918.8	5.66 E-07	5.66 E-07	0.0
Ground level	8.8	1,180.7	4.46 E-07	4.47 E-07	-0.2
Ground level	9.0	1,210.2	4.37 E-07	4.38 E-07	-0.2
900 m stack	5.0	635.6	5.52 E-07	5.52 E-07	0.0
900 m stack	7.0	918.8	5.33 E-07	5.33 E-07	0.0
900 m stack	8.8	1,180.7	4.45 E-07	4.46 E-07	-0.2
900 m stack	9.0	1,210.2	4.37 E-07	4.37 E-07	0.0

G. One additional test of the mixing layer reflection is to enter a mixing depth equal to the release height. This should give an X/Q value twice as large as the no-reflection case (i.e., with a mixing depth much larger than the Sigma Z). For example, using Pasquill Class D stability, a release height of 61 m, and a distance of 1,000 m, the unreflected X/Q is 2.31×10^{-5} s/m^3, while the X/Q with a mixing depth of 61 m is 4.63×10^{-5} s/m^3.

H. Two additional cases with wind speeds of 0.445 m/s and 1.78 m/s were used to verify the inverse dependence on wind speed.

1. At 0.445 m/s, all the X/Q values are twice what they are at 0.89 m/s.

2. Similarly, at 1.78 m/s, the X/Q values are halved. Only one row was tested, as the wind speed enters the calculation after the program calculates the Sigma Y and Sigma Z values.

I. Finally, the off-axis (Y) behavior is verified. Using a value for Y that is 1.1774 (= SQRT(2*ln 2)) times greater than Sigma Y should reduce the X/Q by a factor of exactly 2. Similarly, applying a factor of 1.6651 (= SQRT(2*ln 4)) to Sigma Y reduces X/Q by a factor of exactly 4. Both changes were tested at three distances and two release heights. Only one stability class needs to be tested because the program calculates the off-axis factor after calculating Sigma Y and Sigma Z values.

6.2 DOWNWIND CHEMICAL CONCENTRATIONS

A. The example input and results summarized in the following two subsections thoroughly test all features of the chemical source characterization portion of ED. Note that the lines that begin with "==>" are results computed using a spreadsheet to independently check ED.

B. The following input data were used to verify the program using the **ST** option:

X/Q = 1.0 x 10^{-4} s/m^3
Exhauster flow rate = 106,000 cfm (50 m^3/s)
Chemical formula weight = 17 g/mole (ammonia)

Stack concentration = 700 ppm
==> downwind concentration = 3.50 ppm ==> 2.66 mg/m^3

Stack concentration = 700 mg/m^3
==> downwind concentration = 3.50 mg/m^3 ==> 4.61 ppm

C. The following data were used to verify the program using the **TOTAL** option:

X/Q = 1.0 x 10^{-4} s/m^3
Release duration = 4 h
Chemical formula weight = 17 g/mole (ammonia)

Total release amount = 600 lb
==> downwind concentration = 1.89 mg/m^3 ==> 2.49 ppm

6.3 ESTIMATION OF TOTAL CURIES RELEASED

A. The example input and results summarized in the following subsections thoroughly test all features of the radionuclide source characterization portion of ED. Note that the lines that begin with "==>" are results computed using a spreadsheet to independently check ED.

B. The following input data were used to verify the program using the **ST** option for stack releases:

X/Q = 1.0 x 10^{-4} s/m^3
Release duration = 4 h
Exhauster flow rate = 106,000 cfm (50 m^3/s)
Stack concentration = 2.0 x 10^{-7} μCi/cc
==> total activity released = 0.144 Ci
==> downwind concentration = 1.00 x 10^{-9} μCi/cc

Activity on air sample = 80,000 dpm
Volume of air sampled = 10 ft^3
==> stack concentration = 1.27×10^{-7} μCi/cc
==> total activity released = 0.0917 Ci
==> downwind concentration = 6.37×10^{-1} μCi/cc

C. The following data were used to verify the program using the **CI** option for entering the total activity released:

$X/Q = 1.0 \times 10^{-4}$ s/m^3
Release duration = 4 h
Total activity released = 5 Ci
==> downwind concentration = 3.47×10^{-8} μCi/cc

D. The following data were used to verify the program using the **AR** option for an air concentration measurement downwind:

$X/Q = 1.0 \times 10^{-4}$ s/m^3
Release duration = 4 h

Air concentration = 5.0×10^{-8} μCi/cc
Sampling period = 8 h
==> total activity released = 14.4 Ci
==> downwind concentration = 1.00×10^{-7} μCi/cc

Sampling period = 3 h
==> total activity released = 7.20 Ci
==> downwind concentration = 5.00×10^{-8} μCi/cc

Activity on air sample = 40,000 dpm
Volume of air sampled = 20 ft^3
==> air concentration = 3.18×10^{-8} μCi/cc
Sampling period = 4 h
==> total activity released = 4.58 Ci
==> downwind concentration = 3.18×10^{-8} μCi/cc

E. The following data were used to verify the program using the **GD** option for a surface contamination measurement downwind:

$X/Q = 1.0 \times 10^{-4}$ s/m^3
Release duration = 4 h

Surface contamination = 800 dpm/cm^2
Ground deposition speed = 0.15 cm/s
==> total activity released = 24.0 Ci
==> downwind concentration = 1.67×10^{-7} μCi/cc

6.4 DOSE CALCULATIONS

A. All possible radionuclide choices were tested in actual dose calculations with ED. Doses were calculated for an X/Q of

2/330 s/m^3 and a total release of 0.0005 Ci. These choices of dispersion factor and release amount produce doses that are numerically equal to the dose factor stored in the program.

B. Several inert gas dose factors are listed in Table 26. The final column shows the values actually used by ED to simplify the dose calculation. The numbers in the last column are the submersion dose factors (rem/s per Ci/m^3) divided by the breathing rate used in ED (330 cc/s). ED calculates the external dose by multiplying the dose factor by the breathing rate, the quantity released and the X/Q value.

C. The inhalation dose factors used by ED are listed in Table 27. Table 27 lists more dose factors than are used by the program. The final column shows whether the EDE or the organ dose should be considered limiting.

   1. The EDE is limiting if the ratio of the organ to EDE is less than 3.

   2. The organ is limiting if the organ-to-EDE dose ratio is greater than 5.

   3. For ratios between 3 and 5, the actual ratio is printed in the table.

   4. The factors of 3 and 5 come from the emergency action level criteria.

Table 26. External Dose Factors for Inert Gases.

Inert gases	Sv/h per Bq/m^3	Rem/s per Ci/m	Effective rem/μCi
^{41}Ar	2.17 E-10	2.23 E-01	6.76 E-04
^{85m}Kr	2.98 E-11	3.06 E-02	9.28 E-05
^{85}Kr	4.70 E-13	4.83 E-04	1.46 E-06
^{87}Kr	1.42 E-10	1.46 E-01	4.42 E-04
^{88}Kr	3.60 E-10	3.70 E-01	1.12 E-03
^{89}Kr	5.00 E+00	5.14 E+09	1.56 E+07
^{131m}Xe	1.48 E-12	1.52 E-03	4.61 E-06
^{133m}Xe	5.38 E-12	5.53 E-03	1.68 E-05
^{133}Xe	6.07 E-12	6.24 E-03	1.89 E-05
^{135m}Xe	7.53 E-11	7.74 E-02	2.35 E-04
^{135}Xe	4.68 E-11	4.81 E-02	1.46 E-04
^{137}Xe	5.00 E+00	5.14 E+09	1.56 E+07
^{138}Xe	1.92 E-10	1.97 E-01	5.98 E-04

Table 27. Inhalation Dose Factors for Particulates.*

Isotope	ICRP CLASS	Sv/Bq EDE	Sv/Bq Max organ	rem/μCi EDE	rem/μCi Max organ	Limiting
^{3}H	H2O	1.73 E-11	1.73 E-11	9.60 E-05	9.60 E-05	EDE
^{14}C	ORG	5.64 E-10	5.64 E-10	2.09 E-03	2.09 E-03	EDE
^{14}C	CO2	6.36 E-12	6.36 E-12	2.35 E-05	2.35 E-05	EDE
^{14}C	CO	7.83 E-13	7.83 E-13	2.90 E-06	2.90 E-06	EDE
^{54}Mn	W	1.81 E-09	6.66 E-09	6.70 E-03	2.46 E-02	3.7
^{54}Mn	D	1.42 E-09	2.56 E-09	5.25 E-03	9.47 E-03	EDE
^{60}Co	Y	5.91 E-08	3.45 E-07	2.19 E-01	1.28 E+00	Organ
^{60}Co	W	8.94 E-09	3.57 E-08	3.31 E-02	1.32 E-01	4.0
^{90}Sr	Y	3.51 E-07	2.86 E-06	1.30 E+00	1.06 E+01	Organ
^{90}Y	Y	2.28 E-09	9.31 E-09	8.44 E-03	3.44 E-02	4.1
^{90}Sr	D	6.47 E-08	7.27 E-07	2.39 E-01	2.69 E+00	Organ
^{90}Y	W	2.13 E-09	2.78 E-10	7.88 E-03	1.03 E-03	EDE
^{103}Ru	Y	2.42 E-09	1.56 E-08	8.95 E-03	5.77 E-02	Organ
^{103}Ru	W	1.75 E-09	9.86 E-09	6.48 E-03	3.65 E-02	Organ
^{103}Ru	D	8.25 E-10	1.03 E-09	3.05 E-03	3.80 E-03	EDE
^{106}Ru	Y	1.29 E-07	1.04 E-06	4.77 E-01	3.85 E+00	Organ
^{106}Ru	W	3.18 E-08	2.11 E-07	1.18 E-01	7.81 E-01	Organ
^{106}Ru	D	1.52 E-08	1.80 E-08	5.62 E-02	[illegible]6 E-02	EDE
^{129}I	D	4.69 E-08	1.56 E-06	1.74 E-01	5.77 E+00	Organ
^{131}I	D	8.89 E-09	2.92 E-07	3.29 E-02	1.08 E+00	Organ
^{132}I	D	1.03 E-10	1.74 E-09	3.81 E-04	6.44 E-03	Organ
^{133}I	D	1.58 E-09	4.86 E-08	5.85 E-03	1.80 E-01	Organ
^{135}I	D	3.32 E-10	8.46 E-09	1.23 E-03	3.13 E-02	Organ
^{137}Cs	D	8.63 E-09	8.82 E-09	3.19 E-02	3.26 E-02	EDE
^{144}Ce	Y	1.01 E-07	7.91 E-07	3.74 E-01	2.93 E+00	Organ
^{144}Ce	W	5.84 E-08	1.83 E-07	2.16 E-01	6.77 E-01	3.1
^{147}Pm	Y	1.06 E-08	7.74 E-08	3.92 E-02	2.86 E-01	Organ
^{147}Pm	W	6.97 E-09	1.02 E-07	2.58 E-02	3.77 E-01	Organ
^{192}Ir	Y	7.61 E-09	5.24 E-08	2.82 E-02	1.94 E-01	Organ
^{192}Ir	W	4.88 E-09	2.55 E-08	1.81 E-02	9.44 E-02	Organ
^{192}Ir	D	5.10 E-09	1.15 E-08	1.89 E-02	4.26 E-02	EDE
^{212}Pb	D	4.56 E-08	3.71 E-07	1.69 E-01	1.37 E+00	Organ
^{226}Ra	W	2.32 E-06	1.61 E-05	8.58 E+00	5.96 E+01	Organ
^{232}Th	W	4.43 E-04	1.11 E-02	1.64 E+03	4.11 E+04	Organ
^{232}Th	Y	3.11 E-04	4.99 E-03	1.15 E+03	1.85 E+04	Organ
^{233}U	Y	3.66 E-05	3.04 E-04	1.35 E+02	1.12 E+03	Organ
^{233}U	W	2.16 E-06	1.62 E-05	7.99 E+00	5.99 E+01	Organ
^{233}U	D	7.53 E-07	1.12 E-05	2.79 E+00	4.14 E+01	Organ
U	UO	3.44 E-05	2.86 E-04	1.27 E+02	1.06 E+03	Organ
U	UO3	2.05 E-06	1.54 E-05	7.58 E+00	5.68 E+01	Organ
U	UNH	7.12 E-07	1.05 E-05	2.64 E+00	3.88 E+01	Organ
^{237}Np	W	1.46 E-04	3.27 E-03	5.40 E+02	1.21 E+04	Organ
Pu 12%	W	1.82 E-04	3.35 E-03	6.74 E+02	1.24 E+04	Organ
Pu 12%	Y	1.23 E-04	1.35 E-03	4.56 E+02	4.99 E+03	Organ
^{241}Am	W	1.20 E-04	2.17 E-03	4.44 E+02	8.03 E+03	Organ
^{244}Cm	W	6.70 E-05	1.17 E-03	2.48 E+02	4.33 E+03	Organ

Table 27. Inhalation Dose Factors for Particulates (continued).*

Isotope	ICRP CLASS	Sv/Bq EDE	Sv/Bq Max organ	rem/μCi EDE	rem/μCi Max organ	Limiting
^{252}Cf	Y	4.24 E-05	2.99 E-04	1.57 E+02	1.11 E+03	Organ
^{252}Cf	W	3.70 E-05	6.86 E-04	1.37 E+02	2.54 E+03	Organ

**Federal Guidance Report Number 11* (EPA-520/1-88-020, September 1988).

7.0 CONCEPTUAL MODELS USED IN ED - REVISION 3

7.1 ATMOSPHERIC DISPERSION MODEL

A. A gaussian plume model is used for X/Q. Assuming that the wind blows steadily along the X-axis at a speed V, and that the vertical spread of the plume is reflected at both the ground plane (elevation 0) and the mixing layer plane (elevation D), then the X/Q value is computed using the following formula:

$$X/Q = \frac{EXP[-0.5*((H/\Sigma z)^2+(Y/\Sigma y)^2)]}{\pi*V*\Sigma y*\Sigma z} * \Big[1 + EXP[2*(D/\Sigma z)^2*(1-H/D)]$$

$$+ EXP[2*(D/\Sigma z)^2*(1+H/D)] + EXP[-4*(D/\Sigma z)^2*(1-H/D)]\Big]$$

Note that if $\Sigma z > 1.2*D$, then the plume is uniformly distributed between the ground and the mixing layer. In this case the formula for X/Q simplifies to the following:

$$X/Q = \frac{EXP[-0.5*(Y/\Sigma y)^2]}{SQRT(2*\pi)*V*\Sigma y*D}$$

B. The Pasquill-Gifford curves for Sigma Y and Sigma Z (i.e., Σy and Σz) were approximated using the same formula as is used in GENII. However, distances less than 100 m are excluded. The following formula illustrates this:

$$Sigma = A*X^B + C$$

C. The parameters A, B, and C are listed below. For Sigma Y, Cy = 0, By = 0.9031, and Ay values are shown in Table 28. For Sigma Z, there are two distance ranges for each.

The parameters shown for Class G are the equivalent parameters that ED uses, in effect, when calculating Sigma values. The ED actually calculates Class G Sigma Z values by calculating Class F Sigma Z values and multiplying by 0.6. The Class G values for Az and Cz are just the Class F values multiplied by this factor.

7.2 DOWNWIND CHEMICAL CONCENTRATIONS

A. The downwind concentration is the release rate times the X/Q value, with appropriate conversion factors added to give the desired final concentration units.

Table 28. Parameters used by ED in the Calculation of Sigma Y and Sigma Z (By = 0.9031 and Cy = 0.0).

Class	Ay	Az(2)	Az(3)	Bz(2)	Bz(3)	Cz(2)	Cz(3)
A	0.3658	0.00066	0.00024	1.941	2.094	9.27	-9.6
B	0.2751	0.0382	0.055	1.149	1.098	3.3	2
C	0.2089	0.113	0.113	0.911	0.911	0	0
D	0.1471	0.222	1.26	0.725	0.516	-1.7	-13
E	0.1046	0.211	6.73	0.678	0.305	-1.3	-34
F	0.0722	0.086	18.05	0.74	0.18	-0.35	-48.6
G	0.0481	0.0516	10.83	0.74	0.18	-0.21	-29.16

(2) means that the distance $X \leq 1,000$ m
(3) means that $X > 1,000$ m.

B. The **TOTAL** option: If the total number of pounds estimated to have been released during the length of the release, then the downwind concentration, in mg/m³ is given by the following formula:

$$\text{Downwind conc (mg/m}^3) = \frac{\text{Pounds released * X/Q}}{\text{Release duration}} * \frac{\text{453,592 mg/lb}}{\text{3,600 s/h}}$$

C. The **ST** option: If the exhaust stack flow rate (cfm) and the effluent concentration (in either ppm or mg/m³) are known, then the downwind concentration can be estimated using the formula below. Note that the exhaust concentration and the downwind concentration have the same units.

Downwind conc = Exhaust conc * Flow rate * X/Q

D. The conversion from mg/m³ to ppm (by volume) is done assuming ideal gas behavior. In other words, one formula weight of the chemical is assumed to occupy a volume of 22.4 L. The formula for this conversion is shown below.

$$\text{ppm (by volume)} = 10^6 * \text{mg/m}^3 * \frac{\text{22.4 L * 0.001 g/mg}}{\text{Formula weight * 1,000 L/m}^3}$$

7.3 ESTIMATION OF TOTAL CURIES RELEASED

A. The **ST** option: The exhaust flow rate (cfm), the activity concentration at the point of release (μCi/cc), and the duration of the release (hours) can be used to compute the total activity released. The conversion factors ED applies are 2,119 cfm*s/m^3 and 3,600 s/h. The following formula is used by ED:

Total Ci released = Exhaust conc * Flow rate * Exhaust time

B. The **AR** option: The average downwind air concentration (μCi/cc) and the air sample time can be used to estimate total activity released. The formula used by ED is the following:

$$\text{Total Ci released} = \frac{\text{Conc at (X,Y)} * \text{Sample time}}{\text{X/Q at Air sampler}}$$

Note that if the sample time is less than the release duration, then activity is scaled up by the ratio of release duration to sample time.

C. The **GD** option: Downwind surface contamination (distance per minute per square centimeter), the ground deposition speed (centimeters/second), and the release duration can be used to estimate the total activity released. The ED uses the following formula:

$$\text{Total Ci Released} = \frac{\text{Surface contamination}}{\text{Deposition speed} * \text{X/Q}} * \frac{10^6 \text{ cm}^3 \text{ per m}^3}{2.22 \times 10^{12} \text{ dpm/Ci}}$$

7.4 DOWNWIND AIR CONCENTRATION AND DOSE EQUIVALENT

A. The air concentration downwind at (X,Y) is the release rate times the X/Q value. The ED uses the following formula:

$$\text{Air conc at (X,Y)} = \frac{\text{Total Ci released}}{\text{Release duration} * \text{X/Q}} * \frac{1 \text{ h}}{3{,}600 \text{ s}}$$

B. The inhalation dose is the product of the total activity released (Ci), the X/Q value, the assumed breathing rate (330 cc/s), and the inhalation dose factor (rem/μCi inhaled). Inhalation dose commitment factors are listed in Table 27.

Inhalation Dose at (X,Y) = (Total Ci Released) * (X/Q) * (Breathing Rate) * (Dose Factor)

C. The external dose from submersion in the plume is the product of the total activity released (Ci), the X/Q value, and the external dose rate factor (rem/s per Ci/m^3). To facilitate the calculation ED divides the external dose rate factor by the breathing rate (330 cc/s) to produce a dose factor that can be treated as the inhalation dose factor. These effective dose factors are listed in Table 26.

7.5 DOSE FACTORS FOR PLUTONIUM AND URANIUM MIXTURES

A. Because mixtures of plutonium isotopes or uranium isotopes are handled instead of a pure isotopic form, the inhalation dose factors for common mixtures are used in ED. Tables 29 and 30 summarize the assumed composition for plutonium. Table 29 gives the inhalation dose factors for the individual isotopes of plutonium. Table 30 gives the composition and resulting composite dose factor.

Table 29. Plutonium Inhalation Dose Factors.

	Sv/Bq				rem/µCi			
Isotope	Class Y		Class W		Class Y		Class W	
	EDE	Bone	EDE	Bone	EDE	Bone	EDE	Bone
^{238}Pu	7.79 E-05	7.25 E-04	1.06 E-04	1.90 E-03	288	2680	392	7030
^{239}Pu	8.33 E-05	8.21 E-04	1.16 E-04	2.11 E-03	308	3040	429	7810
^{240}Pu	8.33 E-05	8.21 E-04	1.16 E-04	2.11 E-03	308	3040	429	7810
^{241}Pu	1.34 E-06	1.78 E-05	2.23 E-06	4.20 E-05	4.96	65.9	8.25	155
^{242}Pu	7.92 E-05	7.81 E-04	1.11 E-04	2.01 E-03	293	2890	411	7440
^{241}Am	8.82 E-05	8.28 E-04	1.20 E-04	2.17 E-03	326	3060	444	8030

Table 30. Inhalation Dose Factors for a Mixture of Plutonium Isotopes.

	12% Pu-240		Inhalation Dose Factors in Sv/Bq			
Isotope	Weight	Activity	Class Y		Class W	
	Percent	Ci/g Pu	EDE	Bone	EDE	Bone
^{238}Pu	0.093	1.59 E-02	1.27 E-05	1.18 E-04	1.73 E-05	3.10 E-04
^{239}Pu	84.000	5.21 E-02	4.45 E-05	4.39 E-04	6.20 E-05	1.13 E-03
^{240}Pu	13.000	2.95 E-02	2.52 E-05	2.48 E-04	3.51 E-05	6.38 E-04
^{241}Pu	2.880	2.97 E+00	4.08 E-05	5.42 E-04	6.79 E-05	1.28 E-03
^{242}Pu	0.027	1.06 E-06	8.62 E-10	8.50 E-09	1.21 E-09	2.19 E-08
^{241}Am	0.000	0.00 E+00	0.00 E+00	0.00 E+00	0.00 E+00	0.00 E+00
Totals	100.000	9.75 E-02	1.23 E-04	1.35 E-03	1.82 E-04	3.35 E-03

B. Tables 31 through 34 summarize the calculation of the composite dose factors for uranium. Table 31 gives the inhalation EDE factors for the individual isotopes of uranium. Table 32 gives the organ dose factors. Table 33 gives the composition commonly used for N Reactor fuel, and Table 34 lists the resulting composite dose factors for the EDE and organ of concern.

Table 31. Uranium Inhalation Dose Factors (EDE).

Isotope	Sv / Bq Class Y	Sv / Bq Class W	Sv / Bq Class D	rem / μCi Class Y	rem / μCi Class W	rem / μCi Class D
^{234}U	3.58 E-05	2.13 E-06	7.37 E-07	132	7.88	2.73
^{235}U	3.32 E-05	1.97 E-06	6.85 E-07	123	7.29	2.53
^{236}U	3.39 E-05	2.01 E-06	7.01 E-07	125	7.44	2.59
^{238}U	3.20 E-05	1.90 E-06	6.62 E-07	118	7.03	2.45
^{234}Th	9.47 E-09	8.04 E-09	8.04 E-09	0.0350	0.0297	0.0297

Table 32. Uranium Inhalation Dose Factors (Maximum Organ).

Isotope	Sv / Bq Class Y Lung	Sv / Bq Class W Lung	Sv / Bq Class D Bone	rem / μCi Class Y Lung	rem / μCi Class W Lung	rem / μCi Class D Bone
^{234}U	2.98 E-04	1.60 E-05	1.09 E-05	1103	59.2	40.3
^{235}U	2.76 E-04	1.48 E-05	1.01 E-05	1021	54.8	37.4
^{236}U	2.82 E-04	1.51 E-05	1.04 E-05	1043	55.9	38.5
^{238}U	2.66 E-04	1.42 E-05	9.78 E-06	984	52.5	36.2
^{234}Th	6.39 E-08	4.66 E-08	7.83 E-09	0.236	0.172	0.0290

Table 33. Mixture of Uranium Isotopes -- N Reactor Fuel.

Isotope	Weight percent	Ci/g	Alpha percent
^{234}U	0.0090	5.87 E-07	62.47
^{235}U	0.8360	1.81 E-08	1.92
^{236}U	0.0730	1.58 E-09	0.17
^{238}U	99.0820	3.33 E-07	35.44
^{234}Th	1.44 E-09	3.33 E-07	
Totals	100.0000	9.40 E-07	

Table 34. Inhalation Dose Factors for the Mixture of Uranium Isotopes (Sv/Bq).

Isotope	Effective dose equivalent Class Y	Effective dose equivalent Class W	Effective dose equivalent Class D	Maximum organ dose Class Y	Maximum organ dose Class W	Maximum organ dose Class D
^{234}U	2.24 E-05	1.33 E-06	4.60 E-07	1.86 E-04	9.99 E-06	6.81 E-06
^{235}U	6.39 E-07	3.79 E-08	1.32 E-08	5.31 E-06	2.85 E-07	1.94 E-07
^{236}U	5.69 E-08	3.38 E-09	1.18 E-09	4.74 E-07	2.54 E-08	1.75 E-08
^{238}U	1.13 E-05	6.73 E-07	2.35 E-07	9.43 E-05	5.03 E-06	3.47 E-06
^{234}Th	3.36 E-09	2.85 E-09	2.85 E-09	2.26 E-08	1.65 E-08	2.78 E-09
Totals	3.44 E-05	2.05 E-06	7.12 E-07	2.86 E-04	1.54 E-05	1.05 E-05

8.0 LINE-BY-LINE DESCRIPTION OF ED - REVISION 3

8.1 INTRODUCTION

A. ED - Revision 3 is divided into five distinct modules in a structured approach to the problem of organizing a lengthy program. The five modules are as follows:

- Atmospheric dispersion
- Choice of chemical or radiological release
- Chemical calculation
- Nuclide choice
- Dose calculation

B. A complete program listing is supplied at the end of this report. The descriptions in 8.1 Section D reference line numbers in the program listing.

C. It is assumed in these descr ptions of the code that the reader has become acquainted with the basic syntax of the HP-41C programming language. The syntax is described in the owner's manual, including numerous examples.

Table 35. Summary of Data Register and Flag Use.

Registers		Flags	
00	miscellaneous values	00	clear if EDE limits
01	X/Q, s/m^3	01	temporary for X < 1 km
02	unit conversion factor	02	temporary use for ppm
03	unit string	05	set for USA units
04	Stability Class, MET, A to G	06	set for Class G
05	wind speed, V, m/s	07	set for chem release
06	distance, X, meters	08	set for ppm units
07	distance, Y, meters		
08	release height, H, meters		
09	release duration, DUR, hours		
10	AMT menu choice, 1 to 4		
11	conc or dpm value; formula wt		
12	cu.ft sampled; chem release rate		
13	stack conc; air conc; grd cont		
14	stack cfm; hours sampled; Vd		
15	total curies released		
16	top-level menu choice, 1 to 4		
17	second choice or user name		
18	third choice or user dose factor		
19	mixing depth, meters		

8.2 ATMOSPHERIC DISPERSION

A. Lines 1 through 6 are the starting location for the program.

1. These lines initialize two flags, display the program name and revision number, and stop execution.

2. The label "ED3" is assigned to the key labeled "XEQ" for ready access through the USER mode of the calculator.

B. Lines 7 through 31 display the current unit choice, and allow a switch to the alternate system.

1. The label "U" is assigned to the key labeled "F."

2. Flag 05 is set for English units, and cleared for metric units.

3. Once the choice has been made, execution continues at line 18, where the commonly used unit of length is stored in registers 02 and 03 in the unit system selected.

4. The final two lines (30 and 31) skip further input prompts when in USER mode, and the program immediately begins the calculation of atmospheric dispersion parameters beginning in line 127.

C. Lines 32 through 46 display the current atmospheric stability class (A to G) and allow a new value to be entered.

1. The label "P" is assigned to the key labeled "M."

2. In USER mode, execution will jump to line 127 and begin the X/Q calculation.

D. Lines 47 through 55 display the current atmospheric mixing depth and allow a new value to be entered.

1. The label "MD" is assigned to the key labeled "D."

2. A subroutine at label 09 (lines 321 to 331) is used to convert the depth in the X register to the proper units and display the result. After pressing "R/S" the program converts the value in the X register to meters and returns to the line following the line that called this subroutine.

3. In USER mode, execution will jump to line 127 and begin the X/Q calculation.

E. Lines 56 through 81 display the current wind speed and allow a new value to be entered.

1. The label "V" is assigned to the key labeled "C."

2. Lines 59 through 69 ensure that the proper units (mph or m/s) are displayed.

3. In USER mode, execution will jump to line 127 and begin the X/Q calculation.

F. Lines 82 through 90 display the current release height and allow a new value to be entered.

1. The label "HT" is assigned to the key labeled "H."

2. A subroutine at label 09 (lines 321 through 331) is used to convert the release height in the X register to the proper units and display the result. After pressing "R/S" the program converts the value in the X register to meters and returns to the line following the line that called this subroutine.

3. In USER mode, execution will jump to line 127 and begin the X/Q calculation.

G. Lines 91 through 119 display the current downwind distance and allow a new value to be entered.

1. The label "X" is assigned to the key labeled "A."

2. Lines 94 through 111 ensure that the proper units (miles or kilometers) are displayed.

3. Lines 112 through 114 ensure that no distance less than 0.1 K can be entered.

4. In USER mode, execution will jump to line 127 and begin the X/Q calculation.

H. Lines 120 through 126 display the current plume offset distance and allow a new value to be entered.

1. The label "Y" is assigned to the key labeled "B."

2. A subroutine at label 09 (lines 321 through 331) is used to convert the plume offset in the X register to the proper units and display the result. After pressing "R/S" the program converts the value in the X register to meters and returns to the line following the line that called this subroutine.

I. Lines 127 through 383 calculate X/Q from the input data provided in steps A through H above.

1. Lines 128 through 137 prepare for the calculation by converting the distance to meters and comparing it to 1,000 m. Flag 01 is set if the distance is less than or equal to 1,000 m.

2. Lines 138 through 163 branch, according to stability class, to the location with the constants that are needed to compute Sigma Y and Sigma Z. Note that if a value for stability class other than A through F has been entered, then the program assumes the value will be class F.

3. Lines 164 through 176 insert the values for Cz, Az, and Bz to be used in calculating the Class A Sigma Z. Lines 178 through 180 actually compute Sigma Z. Line 181 inserts the value for Ay, in preparation for the jump to line 278, where Sigma Y is computed.

4. Lines 183 through 277 repeat the previous step for stability classes B to F. Class G is treated somewhat differently in that the Sigma Z for class G is 0.6 times the Sigma Z for class F (lines 269 through 273).

5. Lines 278 through 293 compute and display the value for Sigma Y. Note that this value may be changed during the call to the subroutine at label 09 (lines 321 through 331).

6. Before displaying the value for Sigma Z, lines 294 through 307 compute a portion of the X/Q formula shown below, and store it in register 00.

$$\frac{\mathrm{EXP}[-0.5 * (Y/\Sigma y)^2]}{\pi * V * \Sigma y}$$

7. Lines 308 through 311 display the value of Sigma Z computed earlier.

8. Lines 312 through 320 compute the remaining portion of the X/Q formula for the case where there is uniform mixing between the ground and the mixing layer. Full use is made of the calculator stack to make efficient use of the computational resources.

9. Lines 332 through 383 compute the remaining portion of the X/Q formula for conditions where plume reflection from the mixing layer may be important. Note that no tests for large negative arguments to the exponential function are necessary because the calculator's exponential function automatically sets the result equal to zero.

J. Lines 384 through 396 display the current value for X/Q and allow a new value to be entered.

   1. The label "X/Q" is assigned to the key labeled "J."

2. In USER mode, execution will stop at this location to display the computed X/Q value. When "R/S" is pressed, execution will jump to line 426, where the program branches to either the chemical or radioactive calculation.

K. Lines 397 through 409 display the current release duration and allow a new value to be entered.

1. The label "T" is assigned to the key labeled "E."

2. In USER mode, execution will jump to line 426, where the program branches to either the chemical or radioactive calculation.

8.3 CHOICE OF CHEMICAL OR RADIOLOGICAL RELEASE

A. Lines 410 through 422 display the current selection for type of source, and allow a switch to the alternate.

1. The label "Q" is assigned to the key labeled "G."

2. Flag 07 is set for chemical releases, and is cleared for radioactive releases.

B. Once the choice has been made, execution continues at line 423 where execution branches according whether or not the calculator is in USER mode.

1. In USER mode, the data input steps are skipped. For chemical releases the program goes to line 476. For radioactive releases the program continues at line 575, recalling the total curies released and then jumping to the display of this total activity in line 595.

2. If not in USER mode, execution proceeds to line 430. For chemical releases the program continues at line 434, while for radioactive releases the program continues at line 511.

C. Note that if this section is entered in USER mode, and no change is made, the calculator remains in USER mode. However, if the source type is changed, then the calculator is taken out of USER mode to force subsequent data entry.

8.4 CHEMICAL CALCULATION

A. Lines 434 through 437 request entry of a choice for either a stack release or total release calculation. The current choice is displayed in the X register.

1. Execution will branch in line 437 according to the number present in the X register when execution continues.

2. If a number other than 1 or 2 has been entered, the program will jump to an incorrect location and all subsequent calculations will be invalid.

B. If a stack calculation was selected, then execution continues at line 438.

1. Lines 439 through 442 request input of the stack concentration.

2. Lines 443 through 453 display the current units assumed for the stack concentration, and allow a switch to the alternate units.

3. Lines 454 through 458 request input of the stack flow rate, in cubic feet per minute.

4. Lines 459 through 463 compute the chemical release rate.

5. Line 464 jumps to line 476 for the calculation and display of downwind concentration.

C. If total pounds released was selected, then execution continues at line 465.

1. Lines 465 through 469 request input of the total pounds of chemical released.

2. Lines 470 through 475 calculate the chemical release rate.

D. Lines 476 through 484 compute the downwind air concentration.

1. Flag 02 is set to match flag 08. Flag 02 determines the units that are displayed in the subroutine at label 09.

2. The subroutine at label 09 (lines 499 through 509) is used to display the concentration in the X register in the proper units. After pressing "R/S" the program returns to the line following the line which called this subroutine.

E. Lines 485 through 488 request input of the formula weight of the chemical. This is needed to convert to the alternate units.

F. Lines 489 through 509 convert to the alternate units and display the result. Here the subroutine at label 09 is used as before, with the exception that the RTN statement causes program execution to stop. Pressing "R/S" again will cause the program to start over at line 1.

8.5 ESTIMATION OF TOTAL CURIES RELEASED

A. Lines 511 through 515 allow selection of the type of source information to use.

1. Execution will branch in line 515 according to the number present in the X register when execution continues.

2. If a number other than 1, 2, 3, or 4 has been entered, the program will jump to an incorrect location and all subsequent calculations will be invalid.

B. Selections numbered 1 and 3 are computed first, because both begin with the entry of an air concentration.

1. Lines 516 through 521 request input of the air concentration (in μCi/cc) or the activity on the sample filter (in dpm).

2. Lines 522 through 525 test whether the number entered was less than 1. If so, it is assumed that an air concentration was entered, and execution continues on line 541 or line 545 depending on the type of source calculation.

3. Lines 526 through 529 request input of the volume of air sampled (in cubic feet).

4. Lines 530 through 539 compute and display the air concentration.

5. Line 540 jumps to either line 541 or line 545 depending on the type of source calculation.

C. Selection number 1, for input of exhaust stack data, requests input of the stack flow rate (in cfm) in lines 541 through 544.

1. Note that execution does not stop until line 563.

2. Lines 568 through 574 calculate the total activity released, which is displayed in lines 595 through 602.

D. Selection number 3, for input of downwind concentration data, requests input of the sample duration period in lines 545 through 548.

1. Note that execution does not stop until line 563.

2. Lines 578 through 588 calculate the total activity released, which is displayed in lines 595 through 602.

E. Selection number 2, for input of total activity released, requests input of total curies in lines 549 through 553. Execution then jumps to the downwind air concentration calculation beginning at line 603.

F. Selection number 4, for input of surface contamination data, requests input of dpm/cm^5 in lines 555 through 559.

1. Lines 560 through 563 request input of the ground deposition speed (in centimeters per second).

2. Lines 589 through 594 calculate the total activity released, which is displayed in lines 595 through 602.

G. Before beginning the nuclide selection, two important quantities are displayed.

1. Lines 595 through 602 display the total activity released.

2. Lines 603 through 613 compute and display the downwind air concentration.

3. Lines 614 and 615 skip the nuclide selection menus by jumping to line 686 if the calculator is in USER mode.

8.6 RADIONUCLIDE IDENTITY

A. Lines 616 through 625 allow selection of the nuclide menu to use.

1. Execution will branch in line 625 according to the number present in the Y register.

2. If a number other than 1, 2, 3, or 4 has been entered, the program will jump to an incorrect location and all subsequent calculations will be invalid.

B. Selection number 4, to input new inhalation dose factors, requests the name and dose factor in lines 626 through 638. Execution then jumps to line 691 for the calculation of inhalation dose.

C. Selection number 1 enters the submenus at line 639. Menu choice number 2 enters its submenus at line 655. Finally, selection number 3 enters its submenus at line 670.

D. Execution of all menu choices eventually branch to line 686 to begin the dose calculation. Note that in certain cases the organ limiting flag 00 is set.

8.7 DOSE CALCULATIONS

A. Lines 686 through 695 test for new dose factors before proceeding.

B. Lines 696 through 707 compute a branching address based on the menu choices entered previously. The formula used is the following:

$$8 * (REG\ 016) + 2 * (REG\ 017) + (REG\ 018) - 11$$

where

REG 016 is the top-level menu choice (1, 2, or 3)
REG 017 is the second-level menu choice (1, 2, 3, or 4)
REG 018 is the third-level menu choice (1, 2, or 3)

Table 36 summarizes the calculation of the dose factor address. Line 707 jumps to the label with the dose factors requested. For example, if the analyst has selected B1 (REG 016 = 2), RU (REG 017 = 2), and SOL (REG 018 = 2), execution will jump to label 8 * 2 + 2 * 2 + 2 - 11 = 11, which is on line 755.

Table 36. Calculation of Dose Factor Address.

REG 016: top menu:	1 a,				2 B1,				3 B2,		
REG 017: nuclide:	1 PU,	2 AM,	3 NP,	4 U	1 SR,	2 RU,	3 I,	4 CS	1 CO,	2 KR,	3 H
REG 018:	1,2	2	2	1,2,3	2	1,2	1,2	2	1,2	2	2
address:	00 01	02	05	06 07 08	09	10 11	12 13	15	16 17	19	21

C. Lines 708 through 796 insert the name, and the dose factors for the EDE and worst organ into the stack for later computation.

1. In certain cases, flag 00 is set to indicate that the organ dose will be limiting. For most nuclides, the organ flag was set (if needed) at the nuclide selection menus.

2. For Kr-85 and H-3, the organ dose factor equals the EDE and leads to the shortcut shown in lines 794 through 796.

D. Inhalation dose is computed and displayed in lines 797 through 819. The limiting dose (EDE or organ) is displayed first.

1. The limiting dose is stored in the X Register. Flag 00 is set (and visible in the display) if the organ dose is limiting.

2. The dose to the non-limiting organ can only be seen by interchanging the X and Y registers with the "X<>Y" key.

E. Lines 820 and 821 restore the typical configuration in which the calculator is operated (scientific with two digits after the decimal point and not in USER mode).

9.0 PROGRAM LISTING
(sheet 1 of 6)

```
LBLTED3

END        2079 BYTES

01♦LBL "ED3"
02 CF 01
03 CF 02
04 " ED - REV 3"
05 PROMPT
06 CF 27
07♦LBL "U"
08 CF 22
09 " METRIC ?"
10 FS? 05
11 "U.S.A. UNITS ?"
12 PROMPT
13 FC? 22
14 GTO 00
15 FC?C 05
16 SF 05
17 GTO "U"
18♦LBL 00
19 FC? 05
20 GTO 00
21 " FT ?"
22 .3048
23 GTO 01
24♦LBL 00
25 " M ?"
26 1
27♦LBL 01
28 ASTO 03
29 STO 02
30 FS? 27
31 GTO 03
32♦LBL "P"
33 CF 23
34 " MET = "
35 ARCL 04
36 "⊢ ?"
37 AON
38 PROMPT
39 AOFF
40 FC? 23
41 GTO 00
42 ASTO 04
43 GTO "P"
44♦LBL 00
45 FS? 27
46 GTO 03
47♦LBL "MD"
48 RCL 19
49 "D= "
50 XEQ 09
51 STO 19
52 FS? 22
53 GTO "MD"
54 FS? 27
55 GTO 03
56♦LBL "V"
57 RCL 05
58 "V= "
59 FC? 05
60 GTO 00
61 .447
62 /
63♦LBL 00
64 FIX 1
65 ARCL X
66 FS? 05
67 "⊢ MPH ?"
68 FC? 05
69 "⊢ M/S ?"
70 CF 22
71 PROMPT
72 FC? 05
73 GTO 00
74 .447
75 *
76♦LBL 00
77 STO 05
78 FS? 22
79 GTO "V"
80 FS? 27
81 GTO 03
82♦LBL "HT"
83 RCL 08
84 "H= "
85 XEQ 09
86 STO 08
87 FS? 22
88 GTO "HT"
89 FS? 27
90 GTO 03
91♦LBL "X"
92 RCL 06
93 "X= "
94 FC? 05
95 GTO 00
96 1.609
97 /
98♦LBL 00
99 FIX 2
100 ARCL X
101 FS? 05
102 "⊢ MI ?"
103 FC? 05
104 "⊢ KM ?"
105 CF 22
106 PROMPT
107 FC? 05
108 GTO 00
109 1.609
110 *
111♦LBL 00
112 .1
113 X<=Y?
114 X<>Y
115 STO 06
116 FS? 22
117 GTO "X"
118 FS? 27
119 GTO 03
120♦LBL "Y"
121 RCL 07
122 "Y= "
123 XEQ 09
124 STO 07
125 FS? 22
126 GTO "Y"
127♦LBL 03
128 CF 06
129 CF 01
130 RCL 06
131 1 E3
132 *
133 STO 01
134 LASTX
```

9.0 PROGRAM LISTING
(sheet 2 of 6)

```
135 X<>Y
136 X<=Y?
137 SF 01
138 RCL 04
139 "A"
140 ASTO Y
141 X=Y?
142 GTO 01
143 "B"
144 ASTO Y
145 X=Y?
146 GTO 02
147 "C"
148 ASTO Y
149 X=Y?
150 GTO 03
151 "D"
152 ASTO Y
153 X=Y?
154 GTO 04
155 "E"
156 ASTO Y
157 X=Y?
158 GTO 05
159 "G"
160 ASTO Y
161 X=Y?
162 SF 06
163 GTO 06
164◆LBL 01
165 FS?C 01
166 GTO 00
167 -9.6
168 24 E-5
169 RCL 01
170 2.094
171 GTO 01
172◆LBL 00
173 9.27
174 66 E-5
175 RCL 01
176 1.941
177◆LBL 01
178 Y↑X
179 *
180 -
181 .3658
182 GTO 08
183◆LBL 02
184 FS?C 01
185 GTO 00
186 2
187 .055
188 RCL 01
189 1.098
190 GTO 01
191◆LBL 00
192 3.3
193 .0382
194 RCL 01
195 1.149
196◆LBL 01
197 Y↑X
198 *
199 +
200 .2751
201 GTO 08
202◆LBL 03
203 CF 01
204 .113
205 RCL 01
206 .911
207 Y↑X
208 *
209 .2089
210 GTO 08
211◆LBL 04
212 FS?C 01
213 GTO 00
214 13
215 1.26
216 RCL 01
217 .516
218 GTO 01
219◆LBL 00
220 1.7
221 .222
222 RCL 01
223 .725
224◆LBL 01
225 Y↑X
226 *
227 -
228 CHS
229 .1471
230 GTO 08
231◆LBL 05
232 FS?C 01
233 GTO 00
234 34
235 6.73
236 RCL 01
237 .305
238 GTO 01
239◆LBL 00
240 1.3
241 .211
242 RCL 01
243 .678
244◆LBL 01
245 Y↑X
246 *
247 -
248 CHS
249 .1046
250 GTO 08
251◆LBL 06
252 FS?C 01
253 GTO 00
254 48.6
255 18.05
256 RCL 01
257 .18
258 GTO 01
259◆LBL 00
260 .35
261 .086
262 RCL 01
263 .74
264◆LBL 01
265 Y↑X
266 *
267 -
268 CHS
269 FC? 06
270 GTO 00
271 .6
272 *
```

9.0 PROGRAM LISTING
(sheet 3 of 6)

```
273◆LBL 00
274 FC? 06
275 .0722
276 FS? 06
277 .0481
278◆LBL 08
279 RCL 01
280 .9031
281 Y↑X
282 *
283 STO 00
284 X<>Y
285 STO 01
286 RCL 00
287 "ΣY= "
288 10
289 X>Y?
290 FIX 1
291 RDN
292 XEQ 09
293 STO 00
294 RCL 07
295 X<>Y
296 /
297 X↑2
298 -2
299 /
300 E↑X
301 RCL 00
302 RCL 05
303 PI
304 *
305 *
306 /
307 STO 00
308 RCL 01
309 "ΣZ= "
310 XEQ 09
311 STO 01
312 1.2
313 RCL 19
314 *
315 X>Y?
316 GTO 00
317 1.253
318 LASTX
319 /
320 GTO 04
321◆LBL 09
322 RCL 02
323 /
324 FIX 1
325 ARCL X
326 ARCL 03
327 CF 22
328 PROMPT
329 RCL 02
330 *
331 RTN
332◆LBL 08
333 LASTX
334 RCL 01
335 /
336 X↑2
337 -2
338 *
339 1
340 RCL 08
341 RCL 19
342 /
343 -
344 LASTX
345 RDN
346 *
347 E↑X
348 1
349 +
350 LASTX
351 R↑
352 +
353 LASTX
354 X<> T
355 *
356 LASTX
357 RDN
358 E↑X
359 +
360 X<>Y
361 CHS
362 2
363 +
364 R↑
365 *
366 2
367 *
368 E↑X
369 +
370 RCL 08
371 RCL 01
372 /
373 X↑2
374 -2
375 /
376 E↑X
377 RCL 01
378 /
379 *
380◆LBL 04
381 RCL 00
382 *
383 STO 01
384◆LBL "X/Q"
385 CF 22
386 SCI 2
387 RCL 01
388 "X/Q="
389 ARCL X
390 "⊢?"
391 PROMPT
392 STO 01
393 FS? 22
394 GTO "X/Q"
395 FS? 27
396 GTO 01
397◆LBL "T"
398 RCL 09
399 FIX 1
400 "DUR= "
401 ARCL X
402 "⊢ HR ?"
403 CF 22
404 PROMPT
405 STO 09
406 FS? 22
407 GTO "T"
408 FS? 27
409 GTO 01
410◆LBL "Q"
```

9.0 PROGRAM LISTING
(sheet 4 of 6)

```
CF 22
"RAD"
FS? 07
"CHEM"
"├ SOURCE?"
PROMPT
FC? 22
GTO 00
FC?C 07
SF 07
CF 27
GTO "Q"
♦LBL 00
FC? 27
GTO 00
♦LBL 01
FS? 07
GTO 08
GTO 10
♦LBL 00
RCL 10
FC? 07
GTO 07
"ST, TOTAL=1,2?"
PROMPT
STO 10
GTO IND 10
♦LBL 01
RCL 13
"STACK CONC?"
PROMPT
STO 13
♦LBL c
"MG/M3 ?"
FS? 08
" PPM ?"
CF 22
PROMPT
FC? 22
GTO 00
FC?C 08
SF 08
GTO c
♦LBL 00
RCL 14
"STACK CFM?"
PROMPT
STO 14
RCL 13
*
2119
/
STO 12
GTO 08
♦LBL 02
RCL 15
"TOT LB REL?"
PROMPT
STO 15
RCL 09
/
126
*
CF 08
STO 12
♦LBL 08
CF 02
FS? 08
SF 02
RCL 12
RCL 01
*
STO 00
XEQ 09
RCL 11
"FORMULA WT?"
PROMPT
STO 11
22.4
/
RCL 00
X<>Y
FS? 08
*
FC? 08
/
FC?C 02
SF 02
♦LBL 09
CLA
SCI 1
"X,Y "
FS? 02
"├PPM="
FC? 02
"├MG/M3="
ARCL X
PROMPT
RTN
GTO "ED3"
♦LBL 07
"ST,CI,AR,GD=1-4"
PROMPT
STO 10
GTO IND 10
♦LBL 01
♦LBL 03
RCL 11
"CONC OR DPM?"
PROMPT
STO 11
STO 13
1
X>Y?
GTO IND 10
RCL 12
"CU.FT SAMPLD?"
PROMPT
STO 12
RCL 11
X<>Y
/
6287 E7
/
STO 13
CLA
ARCL 13
"├ UCI/CC"
PROMPT
GTO IND 10
♦LBL 01
RCL 14
"STACK CFM ?"
GTO 00
♦LBL 03
RCL 14
"HRS SAMPLED?"
GTO 00
```

9.0 PROGRAM LISTING
(sheet 5 of 6)

```
549♦LBL 02
550 RCL 15
551 "CURIES REL?"
552 PROMPT
553 STO 15
554 GTO 06
555♦LBL 04
556 RCL 13
557 "DPM/SQ.CM. ?"
558 PROMPT
559 STO 13
560 RCL 14
561 "DEP. SP? CM/S"
562♦LBL 00
563 PROMPT
564 STO 14
565 RCL 13
566 X<>Y
567 GTO IND 10
568♦LBL 01
569 *
570 RCL 09
571 *
572 1.7
573 *
574 GTO 05
575♦LBL 10
576 RCL 15
577 GTO 05
578♦LBL 03
579 RCL 09
580 X>Y?
581 X<>Y
582 RDN
583 *
584 RCL 01
585 /
586 3600
587 *
588 GTO 05
589♦LBL 04
590 /
591 RCL 01
592 /
593 222 E4
594 /
595♦LBL 05
596 STO 15
597 SCI 1
598 SF 21
599 "REL: "
600 ARCL 15
601 "⊢ CI"
602 PROMPT
603♦LBL 06
604 RCL 01
605 *
606 RCL 09
607 /
608 3600
609 /
610 SCI 1
611 "X,Y UCI/CC="
612 ARCL X
613 PROMPT
614 FS? 27
615 GTO 11
616♦LBL "ISO"
617 RCL 16
618 "a,B1,B2,NEW=1-4"
619 PROMPT
620 STO 16
621 4
622 +
623 RCL 17
624 CF 00
625 GTO IND Y
626♦LBL 08
627 "ISO NAME ?"
628 CF 23
629 AON
630 PROMPT
631 AOFF
632 FS? 23
633 ASTO 17
634 RCL 18
635 "REM/UCI ?"
636 PROMPT
637 STO 18
638 GTO 08
639♦LBL 05
640 "PU,AM,NP,U=1-4?"
641 PROMPT
642 STO 17
643 RCL 18
644 SF 00
645 GTO IND Y
646♦LBL 01
647 "NO3, O2 =1, 2"
648 GTO 00
649♦LBL 02
650♦LBL 03
651 GTO 01
652♦LBL 04
653 "UO,UO3,UNH=1-3"
654 GTO 00
655♦LBL 06
656 "SR,RU,I,CS=1-4"
657 PROMPT
658 STO 17
659 RCL 18
660 GTO IND Y
661♦LBL 03
662 SF 00
663 "I129, I131=1,2"
664 GTO 00
665♦LBL 01
666♦LBL 04
667 GTO 03
668♦LBL 02
669 GTO 01
670♦LBL 07
671 "CO,KR,H3=1-3?"
672 PROMPT
673 STO 17
674 RCL 18
675 GTO IND Y
676♦LBL 01
677 "INSOL, SOL=1,2"
678♦LBL 00
679 PROMPT
680 GTO 00
681♦LBL 02
682♦LBL 03
683 2
684♦LBL 00
685 STO 18
686♦LBL 11
```

9.0 PROGRAM LISTING
(sheet 6 of 6)

```
+
RCL 16
X≠Y?
GTO 00
♦LBL 08
CLA
ARCL 17
RCL 18
GTO 04
♦LBL 00
3
*
RCL 17
RCL 17
+
+
RCL 18
+
11
-
GTO IND X
♦LBL 00
"PU NO3"
674
12400
GTO 04
♦LBL 01
"PU O2"
456
4990
GTO 04
♦LBL 03
"AM-241"
444
8030
GTO 04
♦LBL 05
"NP-237"
540
12100
GTO 04
♦LBL 06
"UO"
127
1060
GTO 04
♦LBL 07
"UO3"
7.58
56.8
GTO 04
♦LBL 08
"UNH"
2.64
38.8
GTO 04
♦LBL 09
"SR-90"
SF 00
.247
2.69
GTO 04
♦LBL 10
SF 00
"RU106 INS"
.477
3.35
GTO 04
♦LBL 11
"RU106 SOL"
.0562
.0666
GTO 04
♦LBL 12
"I-129"
.174
5.77
GTO 04
♦LBL 13
"I-131"
.0329
1.08
GTO 04
♦LBL 15
"CS-137"
.0319
.0326
GTO 04
♦LBL 16
SF 00
"CO-60 INS"
.219
1.28
GTO 04
♦LBL 17
SF 00
"CO-60 SOL"
.0331
.132
GTO 04
♦LBL 19
"KR-85"
146 E-8
GTO 00
♦LBL 21
"H-3"
96 E-6
♦LBL 00
ENTER↑
X<>Y
♦LBL 04
SCI 1
33 E4
RCL 15
*
RCL 01
*
*
X<>Y
LASTX
*
FS? 00
X<>Y
"├: "
ARCL X
"├ MR"
PROMPT
BEEP
" EDE"
FS? 00
"ORGAN"
"├ LIMITS"
AVIEW
SCI 2
CF 27
END
```

10.0 REFERENCES

Eckerman, K. F., A. B. Wolbarst, and A. C. B. Richardson, September 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report No. 11, EPA-520/1-88-020, Environmental Protection Agency.

Houston, J. R., D. L. Strenge, and E. C. Watson, 1974, *DACRIN: A Computer Program for Calculating Organ Dose from Acute or Chronic Radionuclide Inhalation*, BNWL-B-389, Pacific Northwest Laboratory, Richland, Washington.

Napier, B. A., R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell, December 1988, *GENII - The Hanford Environmental Radiation Dosimetry Software System*, PNL-6584, Pacific Northwest Laboratory, Richland, Washington.

Rittmann, P. D., August 1984, *Seven Health Physics Calculator Programs for the HP-41CV*, RHO-HS-ST-5P, Rockwell Hanford Operation, Richland, Washington.

Slade, D. H. (Ed.), 1968, *Meteorology and Atomic Energy*, USAEC Report TID-24190, NTIS.

Strenge, D. L., 1975, *DACRIN - Modification of Gastrointestinal Tract Dose*, BNWL-B-389 SUPP, Pacific Northwest Laboratory, Richland, Washington.

WHC, 1988, *100 Areas Environmental Releases for 1988*, WHC-EP-0165-1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1988, *Effluent Discharges and Solid Waste Mangement Report for Calendar Year 1988: 200/600 Areas*, WHC-EP-0141-1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1988, *Effluent Report for 300, 400, and 1100 Area Operations for Calendar Year 1988*, WHC-EP-0267, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

Internal Letter **Rockwell International**

Date May 18, 1984 No 72322-84-WU-243

TO: (Name, Organization, Internal Address)
R. H. Sudmann

FROM: (Name, Organization, Internal Address, Phone)
P. D. Rittmann
3-3542

Subject: HP-41CV Program for Rapid Assessment of Environmental Doses

An HP-41-CV program to enable users to quickly compute inhalation doses following a release of radioactive material to the air has been thoroughly tested and validated in the attached analysis. The program currently prompts for input data such as release height, wind speed, and stack flow rate in common English units (ft, mph, cfm) as a convenience to users who normally use these units.

User instructions and appropriate data tables for stack parameters and distances will be distributed under a separate cover letter.

Paul Rittmann

P. D. Rittmann
Radiological Engineering
and Effluent Controls
West Area Unit

PDR/tjk

cc: D. E. Bihl
G. F. Boothe
D. D. Brekke
W. A. Decker
D. Paine
D. B. Howe
H J. Goldberg
L. N. Sutton
J. A. Bates
D. A. Marsh
T. Chiao

Rockwell International
Rockwell Hanford Operations
Energy Systems Group

DESIGN ANALYSIS

FOR RH Sudmann
LOCATION 222 U
SUBJECT

PAGE 1 of 12
JOB NO. G-056-PDR-84
DATE April 30, 1984
BY Paul Rittmann
CHECKED BY [illegible]

I. Problem

Compare the HP-41CV program "ED" dose calculations with DACRIN results, and hand calculations where necessary.

II. Assumptions / Input

A. Pu composition:

Isotope	% by wt	Ci/kg Pu	Ci for 1 Ci α
Pu-238	.093	15.9	.163
Pu-239	84.0	52.1	.535
Pu-240	13.0	29.5	.302
Pu-241	2.88	2980	30.6
Pu-242	.027	.00104	1.07×10^{-5}
	Total α :	97.4 Ci/kg	

Lung model: (ICRP 30)
$Pu(NO_3)_x$ is class W
PuO_2 is class Y

B. U composition
1% enriched, meaning that the U-235 percentage is 1.0% by weight

Isotope	Ci/g U (1%)	1 Ci α total:
U-238	3.363×10^{-7}	.408 Ci
β emitter → Th-234	3.363×10^{-7}	.408 Ci
U-234	4.671×10^{-7}	.566 Ci
U-235	2.163×10^{-8}	.0262 Ci
Total α :	8.25×10^{-7} Ci/g U	1.000 Ci

(1.212×10^{6} g U per Ci α)

← $\frac{U\text{-}234}{U\text{-}235} = \frac{1.0}{.72}$ ← U-235 in natural U

(U-234 is enriched by the same relative amount as U-235)

Lung model (ICRP 30)
UNH is class D UO_3 is class W (U_3O_8 + UO_2 are class Y)

(NOTE: U-natural has .489 Ci U-238, U-234 + Th-234, and .0226 Ci U-235.)

BD-6400-060.1 (N-2-79)

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FOR
LOCATION
SUBJECT

PAGE 2
JOB NO. G-056-PDR-84
DATE May 2, 1984
BY Paul Rittmann
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C. Sr 90/Y-90

Since stack concentrations would be given as gross beta μCi/cc, and both Sr and Y emit a beta, one curie of gross beta as Sr-90 is taken to be 0.5 Ci Sr-90 and 0.5 Ci Y-90.

D. Other dose factors compositions

1. 1 Ci Cs-137 is 1.0 Ci Cs-137 and 0.946 Ci Ba-137m

2. 1 Ci I-131

3. 4% Plutonium and 20% enriched Plutonium
The following compositions were assumed to indicate trends.

Isotope	wt %	Ci/Kg	Ci for 1 Ci α	wt %	Ci/Kg	Ci for 1 Ci α
Pu-238	.007	1.20	.0172	.37	63.4	.409
Pu-239	95.63	59.3	.849	71.3	44.2	.286
Pu-240	4.12	9.35	.134	20.8	47.2	.305
Pu-241	.225	232	3.32	5.97	6150	39.7
Pu-242	.011	.00043	6.2 E-6	1.58	.0621	4.01 E-4
		69.85 Ci α			155 Ci α	

4. 180 day MFP

Sr 89	.0482	Ag 110m	.000265	Ba 137m	.00986
Sr 90	.00934	Sn 123	.000492	Ce 141	.0171
Y 90	.00934	Sb 125	.00069	Ce 144	.173
Y 91	.0781	Te 125m	.000164	Pr 144	.173
Zr 95	.111	Te 127m	.00103	Pm 147	.0329
Nb 95	.211	Te 127	.00100	Pm 148m	.000653
Ru 103	.0232	Te 129m	.000696	Pm 148	.000038
Rh 103m	.0232	Te 129	.000446	Eu 154	.000110
Ru 106	.0312	Cs 134	.00153	Eu 155	.000078
Rh 106	.0312	Cs 137	.0104	Sm 151	.000026

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DESIGN ANALYSIS

FOR
LOCATION
SUBJECT

PAGE 3
JOB NO. 6-056-PDR-84
DATE May 3 1984
BY Paul Rittmann
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III. Results

Using DACRIN, and assuming 1 um AMAD particles and inputting the deposition fractions used in ICRP 30, Dose factors (rem/uCi inhaled) were computed, and are listed on the following page. The dose factors selected for use in the HP-41CV program are given below:

Plutonium: 12 % Pu-240 was assumed

$PuNO_3$ class W : 53 rem/uCi to lung 1st yr
2650 rem/uCi to bone 50 yr

PuO_2 is Class Y : 21.9 rem/uCi to lung 1st yr
970 rem/uCi to bone 50 yr

Uranium: 1% enriched Uranium was assumed

UNH is Class D : 22.1 rem/uCi to bone 1st yr
38.6 rem/uCi to bone 50 yr

UO_3 is Class W : 45.5 rem/uCi to lung 1st yr
45.8 rem/uCi to lung 50 yr

Strontium 1.15 rem/uCi to bone 1st year
13.3 rem/uCi to bone 50 year

I-131 1.19 rem/uCi to thyroid both 1st yr + 50 yr

MFP .155 rem/uCi to lung 1st year
.388 rem/uCi to bone 50 year

BD-6400-060.1 (N-2-79)

Dose Factors from DACRIN using 1 micron particles

rem/μCi inhaled

			TOTAL BODY	KIDNEYS	LIVER	SPLEEN	BONE	LUNGS	THYROID	
U-Natural	D	1 yr	2.14+000	8.69+000	1.02-002	.00	2.19+001	7.48-001	.00	
		50 yr	2.32+000	8.69+000	1.02-002	.00	3.84+001	7.48-001	.00	
	W	1	5.35-001	2.25+000	1.82-003	.00	5.30+000	4.51+001	.00	
		50	6.08-001	2.27+000	1.82-003	.00	1.00+001	4.53+001	.00	
	Y	1	6.00-002	2.75-001	9.69-005	.00	5.74-001	1.78+002	.00	
		50	2.71-001	1.01+000	9.69-005	.00	4.47+000	4.47+002	.00	
1% Enriched U	D	1	2.16+000	8.77+000	8.52-003	.00	2.21+001	7.55-001	.00	UNH
		50	2.34+000	8.77+000	8.52-003	.00	3.86+001	7.55-001	.00	
	W	1	5.40-001	2.27+000	1.51-003	.00	5.33+000	4.55+001	.00	UO_3
		50	6.14-001	2.29+000	1.51-003	.00	1.01+001	4.58+001	.00	
	Y	1	6.06-002	2.78-001	8.08-005	.00	5.78-001	1.80+002	.00	
		50	2.74-001	1.02+000	8.08-005	.00	4.50+000	4.52+002	.00	
4% Pu	W	1	1.73+000	7.86+000	2.81+001	.00	4.07+001	5.19+001	.00	
		50	8.10+001	3.34+002	1.02+003	.00	1.75+003	5.23+001	.00	
	Y	1	1.14-001	5.18-001	1.85+000	.00	2.68+000	2.07+002	.00	
		50	3.09+001	1.28+002	3.97+002	.00	6.69+002	5.19+002	.00	
12% Pu	W	1	3.48+000	1.61+001	4.16+001	.00	8.89+001	5.29+001	.00	Nitrat
		50	1.15+002	4.85+002	1.23+003	.00	2.65+003	5.33+001	.00	
	Y	1	2.29-001	1.06+000	2.74+000	.00	5.85+000	2.19+002	.00	Oxide
		50	4.21+001	1.79+002	4.67+002	.00	9.70+002	5.48+002	.00	
12% Pu Aged 5 yr	W	1	2.81+000	1.36+001	3.67+001	.00	7.02+001	5.33+001	.00	
		50	9.92+001	4.54+002	1.15+003	.00	2.29+003	5.36+001	.00	
	Y	1	1.85-001	8.98-001	2.42+000	.00	4.63+000	2.17+002	.00	
		50	3.69+001	1.70+002	4.41+002	.00	8.49+002	5.44+002	.00	
20% Pu	W	1	4.08+000	1.89+001	4.65+001	.00	1.05+002	5.40+001	.00	
		50	1.24+002	5.30+002	1.28+003	.00	2.90+003	5.44+001	.00	
	Y	1	2.68-001	1.25+000	3.07+000	.00	6.92+000	2.26+002	.00	
		50	4.52+001	1.93+002	4.83+002	.00	1.05+003	5.64+002	.00	
Sr90 Y90	D	1	7.63-002	.00	.00	.00	1.15+000	9.47-003	.00	Sr
		50	8.93-001	.00	.00	.00	1.33+001	9.47-003	.00	
	W	1	3.71-002	.00	.00	.00	5.55-001	3.77-001	.00	
		50	4.66-001	.00	.00	.00	6.95+000	3.79-001	.00	
Cs_{137} Ba-137m	D	1	4.00-002	2.25-002	6.08-002	4.30-002	4.21-002	1.04-002	.00	
		50	4.49-002	2.25-002	6.46-002	4.64-002	5.01-002	1.17-002	.00	
I-131	D	1	2.08-003	6.04-003	3.44-003	1.27-003	2.54-003	2.60-003	1.19+000	
		50	2.08-003	6.04-003	3.44-003	1.27-003	2.54-003	2.60-003	1.19+000	
MFP	D/W	1	7.76-003	2.13-002	3.18-002	1.55-003	1.22-001	1.55-001	4.44-005	
		50	2.47-002	2.83-002	3.96-002	1.60-003	3.88-001	1.55-001	4.45-006	

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DESIGN ANALYSIS

FOR
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SUBJECT

PAGE 5
JOB NO. G-056-PDR-84
DATE May 3, 1984
BY Paul Rittmann
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The following tests were conducted, and are detailed below:

1. Check for correct ψ/Q calculation, including interpolation for $\sigma_\theta u$ or C_y, C_z, and sector averaging (durations of 8 to 24hr)
2. For curie releases, that average ground concentration is correctly computed, and dose results agree with a separate DACRIN calculation.
3. For stack releases, that ground concentrations are correct, and that dose results are also correct

Test Results:

1. ψ/Q validation (notice the excellent agreement)

X (meters)	X/Q DACRIN	X/Q "ED"	X (miles)	Release Particulars
350 - 8500	5.75 E-3 1.08 E-4	5.75 E-3 1.08 E-4	.218 5.28	u=1 m/sec 10 min ⇒ $\sigma_\theta u$ = .024 h=1 m Very stable
750 - 8500	1.47 E-3 7.15 E-5	1.47 E-3 7.15 E-5	.466 5.28	same as above except 60 min release ⇒ $\sigma_\theta u$ = .04
750 - 15500	2.85 E-4 1.41 E-5	2.85 E-4 1.41 E-5	.466 9.63	same as above, except u = 5 M/sec ⇒ $\sigma_\theta u$ = .25
4000 - 24000	6.84 E-8 5.91 E-7	6.92 E-8 5.91 E-7	2.49 14.9	u=5m/sec Mod. Stable h=60m 8 hr ⇒ $\sigma_\theta u$ = 0.70
750 - 24000	8.04 E-6 1.90 E-7	8.04 E-6 1.90 E-7	.466 14.9	same as above except Neutral ⇒ $C_y = C_z$ = 0.12 (1 hour release duration)
350 - 4000	6.29 E-4 8.86 E-6	6.29 E-4 8.86 E-6	.218 2.49	u=1m/sec Neutral h=1m C_y=.21 C_z=.17
350 - 8500	6.50 E-5 5.96E-7	6.50 E-5 5.96 E-7	.218 5.28	u= 1m/sec Unstable h= 60m $C_y = C_z$ = 0.30

BD-6400-060.1 (N-2-79)

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FOR
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PAGE 6
JOB NO. G-056-PDR-84
DATE May 3, 1984
BY Paul Rittmann
CHECKED BY [signature]

Interpolation is accomplished using values given on the next page. Values are not extrapolated beyond the bounds of the table, thus 10 min durations give the same $\sigma_\theta u$ as 1 minute releases, or 20 m/sec winds have the same $\sigma_\theta u$ as 10 m/sec winds.

test cases:

1 min, 5 m/sec $\quad \sigma_\theta u = .200$

1 min, 2 m/sec $\quad \sigma_\theta u = \left(\frac{.10 - .024}{2.5 - 1.0}\right)(2.0 - 1.0) + .024 = .075$

90 min, 15 m/sec $\quad \sigma_\theta u = 0.400$

240 min, 7.0 m/sec $\quad \sigma_\theta u = .540$

300 min, .5 m/sec $\quad \sigma_\theta u = .120$

10 min, .5 m/sec $\quad \sigma_\theta u = .024$

30 min, 4 m/sec $\quad \sigma_\theta u = \left(\frac{.22 - .12}{5 - 2.5}\right)(4 - 2.5) + .12 = .180$

ground level (< 10 m)

N, .5 m/sec $\quad C_y = .210 \quad C_z = .170$

UN, 2.5 m/sec $\quad C_y = C_z = \left(\frac{.30 - .35}{5 - 1}\right)(2.5 - 1) + .35 = .331$

N, 15 m/sec $\quad C_y = .140 \quad C_z = .130$

elevated (h > 10 m)

UN, .5 m/sec $\quad C_y = C_z = .300$

N, 2.5 m/sec $\quad C_y = C_z = \left(\frac{.12 - .15}{5 - 1}\right)(2.5 - 1) + .15 = .139$

UN, 15 m/sec $\quad C_y = C_z = 0.240$

→ All results using "ED" agree with the above test cases.

page 7

Values for Wind Meander ($\sigma_\theta u$)

release duration	wind speeds 1 m/sec	2.5 m/sec	5 m/sec	10 m/sec
10 min	.024	.10	.20	.30
60 min	.04	.15	.25	.35
120 min	.06	.25	.35	.45
240 min	.10	.40	.50	.60
480 min	.18	.60	.70	.90

Values for Sutton's Parameters, C_y and C_z

Release Level	Wind Speed	C_y, C_z	n = .20 UNSTABLE	n = .25 NEUTRAL
GROUND	1 m/sec	C_y	.35	.21
		C_z	.35	.17
	5 m/sec	C_y	.30	.15
		C_z	.30	.14
	10 m/sec	C_y	.28	.14
		C_z	.28	.13
ELEVATED	1 m/sec	C_y, C_z	.30	.15
	5 m/sec	C_y, C_z	.26	.12
	10 m/sec	C_y, C_z	.24	.11

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DESIGN ANALYSIS

FOR
LOCATION
SUBJECT

PAGE 8
JOB NO. G-056-8DR-84
DATE May 3, 1984
BY Paul Rittmann
CHECKED BY NJW

sector Averaged Ψ/Q values are used if the release duration exceeds 8 hours. These are computed using the formula

$$\Psi/Q = \frac{8\sqrt{\frac{2}{\pi}}}{\pi u \sigma_z X} e^{-\left(\frac{h^2}{2\sigma_z^2}\right)} \quad \text{(sector averaged, 22.5° sector)}$$

in place of the usual formula for centerline Ψ/Q:

$$\Psi/Q = (\pi u \sigma_z \sigma_y)^{-1} e^{-\left(\frac{h^2}{2\sigma_z^2}\right)} \quad \text{(centerline, } y=0\text{)}$$

a simple method to check "ED" sector averaging is to use the "ΣY" it displays in the course of listing the input.

$$(\Psi/Q)_{SA} = (\Psi/Q)_{center} \left(\frac{\sigma_y}{X} 8\sqrt{\frac{2}{\pi}} \right)$$

one sample is sufficient and is printed below:

```
E.T.A.=52.6 MIN
N X/Q=8.7E-5
MET = N
U = 1.1 MPH
X = 1.00 MI
DUR.= 1.0 HR
H = 10.0 FT
CY = 0.210
CZ = 0.170
ΣY = 311. FT
ΣZ = 252. FT

N X/Q=3.3E-5
MET = N
U = 1.1 MPH
X = 1.00 MI
DUR.= 12.0 HR
H = 10.0 FT
CZ = 0.170
ΣY = 827. FT
ΣZ = 252. FT
```

notice that $\frac{3.3 \times 10^{-5} \text{ sec/m}^3}{8.7 \times 10^{-5} \text{ sec/m}^3} = .379$

while $\left(\frac{311 \text{ ft}}{5280 \text{ ft}}\right) 8\sqrt{\frac{2}{\pi}} = .376$

which is close enough

BD-6400-060.1 (N-2-79)

Rockwell International
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Energy Systems Group

DESIGN ANALYSIS

FOR
LOCATION
SUBJECT

PAGE 9
JOB NO. G-056-PDR-84
DATE May 4, 1984
BY Paul Rittmann
CHECKED BY

2. Dose result comparison : (DACRIN results are written in)

```
E.T.A.=5.8 MIN
VS X/Q=5.7E-3
        5.75-03    ***
GRD UCI/CC:9.6E-6
PUNO3
LUNG 1 Y=1.1E5 MR → 106 rem
BONE 50Y=5.3E6 MR → 5330 rem
        1.07+05    ***
        5.33+06    ***

MET = VS
U = 2.2 MPH
X = 0.22 MI
DUR.= 0.17 HR
H = 3.3 FT
SIGU= 0.024
ΣY = 27.5 FT
ΣZ = 21.4 FT
CI REL:1.0E0
TYPE:  PUNO3
```

```
E.T.A.=2.5 MIN
VS X/Q=2.8E-4
        2.85-04    ***
GRD UCI/CC:7.9E-8
UNH
BONE 1 Y=2.2E3 MR → 2.20 rem
BONE 50Y=3.8E3 MR → 3.85 rem
        2.20+03    ***
        3.85+03    ***

MET = VS
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 3.3 FT
SIGU= 0.250
ΣY = 118. FT
ΣZ = 20.2 FT
CI REL:1.0E0
TYPE:  UNH
```

```
E.T.A.=2.5 MIN
N X/Q=8.0E-6
        8.04-06    ***
GRD UCI/CC:2.2E-9
SR90
BONE 1 Y=3.2E0 MR → 3.23 mrem
BONE 50Y=3.7E1 MR → 37.5 mrem
        3.23+00    ***
        3.74+01    ***

MET = N
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 197. FT
CY = 0.120
CZ = 0.120
ΣY = 91.2 FT
ΣZ = 91.2 FT
CI REL:1.0E0
TYPE:  SR90
```

Assumed breathing rate is 350 cc/sec.

```
E.T.A.=12.5 MIN
VS X/Q=1.5E-3
        1.47-03    ***
GRD UCI/CC:4.1E-7
PUO2
LUNG 1 Y=1.1E5 MR → 113 rem
BONE 50Y=5.0E5 MR → 500 rem
        1.13+05    ***
        5.00+05    ***

MET = VS
U = 2.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 3.3 FT
SIGU= 0.040
ΣY = 97. FT
ΣZ = 23.8 FT
CI REL:1.0E0
TYPE:  PUO2
```

```
E.T.A.=13.3 MIN
MS X/Q=6.9E-8
        6.92-08    ***
GRD UCI/CC:2.4E-12
UO3
LUNG 1 Y=1.1E0 MR → 1.09 mrem
LUNG 50Y=1.1E0 MR → 1.10 mrem
        1.10+00    ***
        1.11+00    ***

MET = MS
U = 11.2 MPH
X = 2.5 MI
DUR.= 8.0 HR
H = 197. FT
SIGU= 0.700
ΣY = 1,084. FT
ΣZ = 62.3 FT
CI REL:1.0E0
TYPE:  UO3
```

```
E.T.A.=5.8 MIN
UN X/Q=6.5E-5
        6.50-05    ***
GRD UCI/CC:1.8E-8
I131
THYROID 1 Y=2.7E1 MR → 27.0 mrem
THYROID 50Y=2.7E1 MR → 27.0 mrem
        2.71+01    ***

MET = UN
U = 2.2 MPH
X = 0.22 MI
DUR.= 1.0 HR
H = 197. FT
CY = 0.300
CZ = 0.300
ΣY = 136. FT
ΣZ = 136. FT
CI REL:1.0E0
TYPE:  I131
```

BD-6400-060.1 (N-2-79)

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DESIGN ANALYSIS

PAGE 10
JOB NO. G-056-PDA-84
DATE May 4, 1984
BY Paul Rittmann
CHECKED BY [illegible]

FOR
LOCATION
SUBJECT

Entering release type 0 for manual dose factor entry, and using the dose factors for Cs-137 given on page 4, (whole body is critical organ)

```
E.T.A.=5.8 MIN
N X/Q=6.3E-4
          6.29-04    ***
GRD UCI/CC:1.7E-7
CS137
1 Y=8.8E0 MR -> 8.81 mrem
50Y=9.9E0 MR -> 9.88 mrem
          8.80+00    ***
          9.88+00    ***

MET = N
U = 2.2 MPH
X = 0.22 MI
DUR.= 1.0 HR
H = 3.3 FT
CY = 0.210
CZ = 0.170
ΣY = 82.0 FT
ΣZ = 66.4 FT
CI REL:1.0E0
TYPE: CS137
DF 1 Y=4.0E-2
DF 50Y=4.5E-2
```

DACRIN results are again very close to the calculator results

Finally, for the MFP choice (180d 12% N-reactor fuel)

```
E.T.A.=80.0 MIN
MS X/Q=5.9E-7
          5.91-07    ***
GRD UCI/CC:2.1E-11
MFP
LUNG 1 Y=3.2E-2 MR
BONE 50Y=8.0E-2 MR
          3.21-02    ***
          8.03-02    ***

MET = MS
U = 11.2 MPH
X = 14.9 MI
DUR.= 8.0 HR
H = 197. FT
SIGU= 0.700
ΣY = 2,953. FT
ΣZ = 134. FT
CI REL:1.0E0
TYPE: MFP
```

These were verified using manual input of the MFP dose factors listed on page 4

```
*MFP*
1 Y=3.2E-2 MR
50Y=8.0E-2 MR
          3.21-02    ***
          8.03-02    ***

MET = MS
U = 11.2 MPH
X = 14.9 MI
DUR.= 8.0 HR
H = 197. FT
SIGU= 0.700
ΣY = 2,953. FT
ΣZ = 134. FT
CI REL:1.0E0
TYPE: *MFP*
DF 1 Y=1.6E-1
DF 50Y=3.9E-1
```


BD-6400-060.1 (N-2-79)

Rockwell International
Rockwell Hanford Operations
Energy Systems Group

DESIGN ANALYSIS

FOR ______
LOCATION ______
SUBJECT ______

PAGE 11
JOB NO. G-056-PDR-84
DATE May 4, 1984
BY Paul Bittmann
CHECKED BY [illegible]

3. To check the dose calculations for stack releases and to verify ground concentrations for both types, the following formulas are used:

lump release

$$\text{Grd Conc} = \left(\frac{X}{Q}\right)\left(\frac{Q}{\text{Dur.}}\right) = \left(\frac{\text{sec}}{m^3}\right)\left(\frac{\text{Ci released}}{\text{no. hours}}\right)$$

$$\text{Inhal. Dose} = (X/Q)(BR)(D.F.)(Q) = \left(\frac{\text{sec}}{m^3}\right)\left(\frac{cm^3}{\text{sec}}\right)\left(\frac{\text{rem}}{\mu Ci}\right)(\text{Ci released})$$

stack releases

$$\text{Grd Conc} = (X/Q)(\text{STK CFM})(\text{STK Conc}) = \left(\frac{\text{sec}}{m^3}\right)\left(\frac{ft^3}{\text{min}}\right)\left(\frac{\mu Ci}{cc}\right)$$

$$\text{Inhal. Dose} = (X/Q)(B.R.)(D.F.)(\text{STK CFM})(\text{STK Conc})(\text{Dur.}) =$$

$$= \left(\frac{\text{sec}}{m^3}\right)\left(\frac{cc}{\text{sec}}\right)\left(\frac{\text{rem}}{\mu Ci}\right)\left(\frac{ft^3}{\text{min}}\right)\left(\frac{\mu Ci}{cc}\right)(\text{hours})$$

To verify the lump release ground conc., consider the first case on page 9, with $X/Q = 5.75 \times 10^{-3}$ sec/m³ and Dur = 10 min and 1.0 Ci released,

$$\text{Grd Conc} = \left(5.75 \times 10^{-3}\ \frac{\text{sec}}{m^3}\right)\left(\frac{1\ Ci}{10\ \text{min}}\right)\left(\frac{1\ \text{min}}{60\ \text{sec}}\right)\left(\frac{10^6\ \mu Ci}{Ci}\right)\left(\frac{1\ m^3}{10^6\ cc}\right) = 9.6 \times 10^{-6}\ \frac{\mu Ci}{cc}$$

The inhalation doses were verified using DACRIN.

BD-6400-060.1 (N-2-79)

Rockwell International
Rockwell Hanford Operations
Energy Systems Group

DESIGN ANALYSIS

PAGE 12
JOB NO. G-056-PDR-84
DATE May 4, 1984
BY Paul Rittmann
CHECKED BY

FILE
LOCATION
SUBJECT

To verify the stack release results, the following test case was chosen since it releases one Curie of Sr 90: 1 hour release of 10^{-5} µCi/cc at a stack flow rate of 58,858 cfm.

$$1(\ hr)\left(10^{-5}\frac{\mu Ci}{cc}\right)\left(58,858\frac{ft^3}{min}\right)\left(\frac{60 min}{hr}\right)\left(\frac{28,316 cc}{ft^3}\right)\left(\frac{10^{-6} Ci}{\mu Ci}\right) = 1.000 Ci$$

```
E.T.A.=2.5 MIN
N X/Q=8.0E-6
GRD UCI/CC:2.2E-9
SR90
BONE 1 Y=3.2E0 MR
BONE 50Y=3.7E1 MR
```

these results are the same as the doses computed on page 9 for the Sr 90 case

```
MET = N
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 197. FT
CY = 0.120
CZ = 0.120
ΣY = 91.2 FT
ΣZ = 91.2 FT
STK CFM=5.89E4
STK UCI/CC:1.0E-5
TYPE: SR90
```

IV Conclusion

The program computes doses from airborne releases in excellent agreement with DACRIN, and appropriate hand calculations validate the other numeric results.

BD-6400-060.1 (N-2-79)

"ED" Original Version

(April 1984)

```
LBL'ED
END         1679 BYTES

01♦LBL "ED"
02♦LBL J
03 CF 27
04 FIX 1
05♦LBL A            previous stability
06 CF 06            choice recalled
07 RCL 05      <-   prior to prompt
08 "VS,MS,N,UN=0,1,"
09 "⊢2,3"
10 PROMPT
11 STO 05
12 FS? 27
13 GTO 01
14♦LBL B
15 RCL 00
16 .447        <- 1 mph = .447 m/sec
17 /
18 "WIND SP? MPH"
19 PROMPT
20 .447
21 *
22 STO 00      <- wind speed is stored in units
23 RCL 01         of m/sec
24 FS? 27
25 GTO 00
26♦LBL C
27 RCL 01
28 1609        <- 1 mile = 1609 m
29 /
30 "DISTANCE? MI"
31 PROMPT
32 1609
33 *
34 STO 01      <- distance is stored in units
35♦LBL 00          of meters.
36 SF 21
37 RCL 00
38 /
39 STO 02
40 60
41 /
42 FIX 1       } Estimated
43 "E.T.A.="   } Time of
44 ARCL X      } Arrival
45 "⊢ MIN"
46 AVIEW
47 FS? 27
48 GTO 01
49♦LBL D
50 RCL 04
51 "REL DUR? HR"
52 PROMPT
53 STO 04
54 CF 07
55 8           } if duration > 8 hr
56 X<Y?        } then sector
57 SF 07       } average
58 RDN
59 24          } if duration > 24 hr
60 X<Y?        } then return to
61 GTO D       } duration prompt
62 FS? 27
63 GTO 01
64♦LBL E
65 RCL 03
66 3.28          1m = 3.28 ft
67 *
68 "REL HT? FT"
69 PROMPT
70 3.28
71 /
72 STO 03      <- h stored in
73♦LBL 01          units of m
74 CF 27
75 GTO IND 05
76♦LBL 00
77 40          b    }
78 1/X              }
79 -34         -a   } Very
80 "VS"             } stable
81 -88 E-5     -k²  }
82 GTO 00
83♦LBL 01
84 .33         b    }
85 "MS"             } Mod.
86 -97         -a   } stable
87 -25 E-5     -k²  }
88♦LBL 00
89 RCL 02      }
90 X↑2         }
91 *           }
92 E↑X-1       }
93 *           } Computes
94 X<>Y        } σz for
95 RCL 02      } VS + MS
96 *           }
97 +           }
98 SQRT        }
99 STO 06      }
100 FS? 07
101 GTO 01
102 XEQ 13     -> obtains value
103 232           for (σθ u)
104 *
105 13
106 +
107 STO 08     — A
108 RCL 07
109 X↑2
110 2
111 *
112 /
113 STO 09     — α
114 RCL 02
115 X<>Y       }
116 /          }
117 CHS        }
118 E↑X-1      } Computes
119 RCL 09     } σy for
120 *          } VS + MS
121 RCL 02     }
122 +          }
123 RCL 08     }
124 *          }
125 SQRT       }
126 GTO 04
127♦LBL 02
128 "N"          Neutral
129 .875       <- (1 - n/2)
130 GTO 00
131♦LBL 03
132 "UN"         Unstable
133 .9         <- (1 - n/2)
134♦LBL 00
135 STO 09
136 SF 06
137 XEQ 23     <- obtains Cy and Cz
138 RCL 08     }
139 RCL 01     }
140 RCL 09     } computes
141 Y↑X        } σz for
142 2          } N + UN
143 SQRT       }
144 /          }
145 *          }
146 2 E3       }
147 X>Y?       } ensures σz ≤ 2000m
148 X<>Y       }
149 STO 06
150 LASTX      }
151 RCL 07     } computes σy
152 *          } for N+UN
153 FC? 07
154 GTO 04
155♦LBL 01
156 RCL 01
157 6.383      = 8√(2/π)
158 /
159♦LBL 04
160 SF 21
```

```
STO 10
ASTO 11
RCL 03
RCL 06
/
X↑2
CHS
E↑X
SQRT
RCL 06
/
RCL 10
/
PI
/
RCL 00
/
```

computes Ψ/Q

```
STO 12
SCI 1
"├ X/Q="
ARCL X
AVIEW
CF 09
XEQ 07
♦LBL F
CF 27
RCL 13
"STACK CFM ?"
PROMPT
STO 13
X=0?
GTO 00
RCL 14
"STK CONC ?"
PROMPT
STO 14
RCL 13
*
2119
```

$= \left[\frac{28316cc}{ft^3} \cdot \frac{1min}{60sec} \cdot \frac{m^3}{10^6cc} \right]^{-1}$

```
GTO 01
♦LBL 00
RCL 14
"CI REL ?"
PROMPT
STO 14
RCL 04
3600
*
♦LBL 01
/
SF 21
RCL 12
*
SCI 1
"GRD UCI/CC:"
ARCL X
AVIEW
♦LBL G
CF 27
RCL 15
"PU,U,BETA=1,2,3"
PROMPT
STO 15
X≠0?
GTO 00
CF 23
" NAME ?"
AON
PROMPT
AOFF
FS? 23
ASTO 17
"1"
RCL 16
XEQ 01
STO 16
"50"
RCL 18
XEQ 01
STO 18
RCL 16
X<>Y
SF 02
GTO 16
♦LBL 01
"├ YR R/UCI?"
PROMPT
RTN
♦LBL 00
CF 05
CF 08
RCL 16
SQRT
GTO IND 15
♦LBL 01
"NO3, O2 =1, 2"
PROMPT
X↑2
STO 16
SF 01
GTO IND 16
♦LBL 01
53
"PUNO3"
2650
```

1yr / 50yr — 12% Pu Class W rem/μCi inhaled

```
GTO 00
♦LBL 04
219
"PUO2"
970
```

12% Pu class Y

```
GTO 00
♦LBL 02
"UNH, UO3=1, 2"
PROMPT
X↑2
STO 16
GTO IND 16
♦LBL 01
22.1
SF 08
"UNH"
38.6
```

U class D

```
GTO 00
♦LBL 04
45.5
"UO3"
45.8
```

U class W

```
GTO 00
♦LBL 03
"SR, I, MFP=1,2,"
"├3"
PROMPT
X↑2
STO 16
GTO IND 16
♦LBL 01
1.15
SF 08
"SR90"
13.3
```

Sr-90 + Y-90 class D

```
GTO 00
♦LBL 04
1.19
ENTER↑
SF 05
X<>Y
"I131"
```

I-131

```
GTO 00
♦LBL 09
.155
SF 01
"MFP"
.388
```

12% MFP soluble

```
♦LBL 00
ASTO 17
FC? 55
CF 21
♦LBL 16
SF 12
CLA
ARCL 17
AVIEW
CF 12
SCI 1
RCL 13
```

```
326 X=0?
327 GTO 00
328 RCL 04
329 *
330 59.47   = 28316cc/ft3 · 60min/hr · 350cc/sec · 1m3/10^6cc · 10^3 mrem/rem · 10^-4
331 *
332 GTO 01
333◆LBL 00
334 RDN
335 35   = 350cc/sec · 10^3 mrem/rem · 10^-4
336◆LBL 01
337 RCL 14
338 *
339 RCL 12
340 *
341 1 E4
342 *
343 *
344 STO 09
345 X<>Y
346 LASTX
347 *
348 SF 21
349 XEQ 00
350 "⊢1 Y="
351 ARCL X
352 "⊢ MR"
353 AVIEW   — 1st year dose
354 XEQ 00
355 CF 02
356 RCL 09
357 "⊢50Y="
358 ARCL X
359 "⊢ MR"
360 AVIEW   — 50 yr dose
361 SF 09
362 XEQ 07
363 ADV
364 SF 27
365◆LBL H
366 "** READY **"
367 PROMPT
368◆LBL J
369 GTO J
370◆LBL A
371 GTO A
372◆LBL B
373 GTO B
374◆LBL C
375 GTO C
376◆LBL D
377 GTO D
378◆LBL E
379 GTO E
380◆LBL F
381 GTO F
```

these speed execution of USER mode labels

```
382◆LBL G
383 GTO G
384◆LBL 00
385 CLA
386 FS? 02
387 RTN
388 "LUNG "
389 FS? 08
390 "BONE "
391 FS?C 01
392 SF 08
393 FS? 05
394 "THYROID "
395 RTN
396◆LBL 07
397 CF 22
398 "INPUT LIST ?"
399 PROMPT
400 FC? 22
401 RTN
402◆LBL I
403 FS? 27
404 CF 09
405 FS? 09
406 GTO 02
407 SF 21
408 SF 12
409 "MET = "
410 ARCL 11
411 AVIEW
412 CF 12
413 FIX 1
414 "U = "
415 RCL 00
416 .447
417 /
418 ARCL X
419 "⊢ MPH"
420 AVIEW
421 "X = "
422 2
423 RCL 01
424 1609
425 /
426 X<=Y?
427 FIX 2
428 ARCL X
429 "⊢ MI"
430 AVIEW
431 FIX 1
432 "DUR.= "
433 1
434 RCL 04
435 X<Y?
436 FIX 2
```

```
437 ARCL X
438 "⊢ HR"
439 AVIEW
440 "H = "
441 RCL 03
442 XEQ 03
443 FIX 3
444 FS? 06
445 GTO 00
446 FS? 07
447 GTO 01
448 "SIGU= "
449 ARCL 07
450 AVIEW
451 GTO 01
452◆LBL 00
453 "CY = "
454 ARCL 07
455 FC? 07
456 AVIEW
457 "CZ = "
458 ARCL 08
459 AVIEW
460◆LBL 01
461 "ΣY = "
462 RCL 10
463 XEQ 03
464 "ΣZ = "
465 RCL 06
466 XEQ 03
467 FS? 27
468 GTO 02
469 ADV
470 RTN
471◆LBL 02
472 RCL 13
473 X=0?
474 GTO 00
475 SCI 2
476 "STK CFM="
477 ARCL X
478 AVIEW
479 "STK UCI/CC:"
480 GTO 01
481◆LBL 00
482 "CI REL:"
483◆LBL 01
484 SCI 1
485 ARCL 14
486 AVIEW
487 SF 12
488 "TYPE: "
489 ARCL 17
490 AVIEW
491 CF 12
```

```
RCL 15
X≠0?
GTO 00
"DF 1 Y="
ARCL 16
AVIEW
"DF 50Y="
ARCL 18
AVIEW
♦LBL 00
ADV
ADV
FC? 27
RTN
♦LBL H
GTO H
♦LBL I
GTO I
♦LBL 03
3.28
*
FIX 0
95
X>Y?
FIX 1
RDN
2
X>Y?
FIX 2
RDN
ARCL X
"├ FT"
AVIEW
RTN
♦LBL 13
```

computes $\sigma_\theta u$

```
5
STO 10
CF 02
1
RCL 00
X<=Y?
GTO 00
DSE 10
2.5
X<>Y
X<=Y?
GTO 01
DSE 10
5
X<>Y
X<=Y?
GTO 01
DSE 10
10
X<>Y
```

assigns number corresponding to the wind speed

```
X<=Y?
GTO 01
♦LBL 00
RDN
ENTER↑
♦LBL 01
X=Y?
SF 02
```

indicates an exact wind speed

```
RDN
X<>Y
STO 08
-
STO 09
5
ST* 10
STO 12
CF 01
6
1/X
RCL 04
X<=Y?
GTO 00
DSE 12
1
X<>Y
X<=Y?
GTO 01
DSE 12
2
X<>Y
X<=Y?
GTO 01
DSE 12
4
X<>Y
X<=Y?
GTO 01
DSE 12
8
```

assigns number corresponding to release duration

```
X<>Y
X<=Y?
GTO 01
♦LBL 00
RDN
ENTER↑
♦LBL 01
X=Y?
SF 01
```

indicates an exact release duration

```
RDN
X<>Y
STO 11
-
X<> 12
ST+ 10
29
XEQ 20
STO 07
FS?C 02
GTO 00
24
XEQ 20
ST- 07
RCL 07
RCL 09
/
RCL 00
RCL 08
-
*
+
STO 07
```

interpolates between wind speeds

```
♦LBL 00
CF 01
RTN
♦LBL 20
RCL 10
-
ENTER↑
X<>Y
1
+
XEQ IND X
FS? 01
RTN
XEQ IND Z
-
LASTX
X<>Y
RCL 12
/
RCL 04
RCL 11
-
*
+
```

interpolates between release durations

```
RTN
♦LBL 00
.024
RTN
♦LBL 01
.04
RTN
♦LBL 02
.06
RTN
♦LBL 03
.1
RTN
♦LBL 04
.18
RTN
```

table values for $\sigma_\theta u$

```
658♦LBL 05
659 .1
660 RTN
661♦LBL 06
662 .15
663 RTN
664♦LBL 07
665 .25
666 RTN
667♦LBL 08
668 .4
669 RTN
670♦LBL 09
671 .6
672 RTN
673♦LBL 10
674 .2
675 RTN
676♦LBL 11
677 .25
678 RTN
679♦LBL 12
680 .35
681 RTN
682♦LBL 13
683 .5
684 RTN
685♦LBL 14
686 .7
687 RTN
688♦LBL 15
689 .3
690 RTN
691♦LBL 16
692 .35
693 RTN
694♦LBL 17
695 .45
696 RTN
697♦LBL 18
698 .6
699 RTN
700♦LBL 19
701 .9
702 RTN
```

σ_θ u values

```
703♦LBL 23
704 CF 01
705 RCL 03
706 10
707 X<=Y?
708 SF 01
709 3
710 STO 12
711 CF 02
712 1
```

computes C_y & C_z

h >10m ⇒ elevated release

```
713 RCL 00
714 X<=Y?
715 GTO 00
716 DSE 12
717 5
718 X<>Y
719 X<=Y?
720 GTO 01
721 DSE 12
722 10
723 X<>Y
724 X<=Y?
725 GTO 01
```

assigns number corresponding to the wind speed

```
726♦LBL 00
727 RDN
728 ENTER↑
729♦LBL 01
730 X=Y?
731 SF 02
732 RDN
733 X<>Y
734 STO 10
735 -
736 STO 11
737 CLST
738 RCL 05
739 2
740 -
741 6
742 *
743 FS?C 01
744 7
745 +
746 ST- 12
747 3
748 RCL 12
749 -
750 XEQ IND X
751 STO 08
752 X<>Y
753 STO 07
754 FS?C 02
755 RTN
756 DSE Z
757 XEQ IND Z
758 ST- 08
759 X<>Y
760 ST- 07
761 RCL 11
762 ST/ 07
763 ST/ 08
764 RDN
765 RCL 00
766 RCL 10
767 -
```

```
768 ST* 07
769 ST* 08
770 RDN
771 ST+ 07
772 X<>Y
773 ST+ 08
774 RTN
775♦LBL 00
776 .21
777 .17
778 RTN
779♦LBL 01
780 .15
781 .14
782 RTN
783♦LBL 02
784 .14
785 .13
786 RTN
787♦LBL 03
788 .15
789 ENTER↑
790 RTN
791♦LBL 04
792 .12
793 ENTER↑
794 RTN
795♦LBL 05
796 .11
797 ENTER↑
798 RTN
799♦LBL 06
800 .35
801 ENTER↑
802 RTN
803♦LBL 07
804 .3
805 ENTER↑
806 RTN
807♦LBL 08
808 .28
809 ENTER↑
810 RTN
811♦LBL 09
812 .3
813 ENTER↑
814 RTN
815♦LBL 10
816 .26
817 ENTER↑
818 RTN
819♦LBL 11
820 .24
821 ENTER↑
822 END
```

C_y & C_z values from the table

APPENDIX B

Internal Letter | **Rockwell International**

Date: 7/20/84 | No: 72322-84-WU-320

TO: (Name, Organization, Internal Address)
D. E. Bihl

FROM: (Name, Organization, Internal Address, Phone)
P. D. Rittmann

Subject: Validation Of "ED" Revision 1

The HP-41CV calculator program for rapid assessment of environmental doses from inhalation of airborne releases has been revised and upgraded in the following areas:

1. Isotopic choices have been added, increasing the number of possibilities from 7 to 19.

2. Estimated time arrival (ETA) is given in units of minutes if ETA is less than 99 minutes. Otherwise it is given in units of hours.

The attached comparison of current results with previous results simply validates the calculator results by their agreement with DACRIN and SUBDOSA (for Kr-85).

If you have any questions, contact me on 3-3542.

Paul Rittmann

P. D. Rittmann
Radiological Engineering
and Effluent Controls

PDR/tjk

cc: J. A. Bates
G. F. Boothe
D. D. Brekke
T. Chiao
W. A. Decker
H. J. Goldberg
D. B. Howe
D. A. Marsh
D. Paine
R. H. Sudmann
L. N. Sutton

Rockwell International
Rockwell Hanford Operations
Energy Systems Group

WHC-EP-0368

DESIGN ANALYSIS

JOB NO. G-RE-PDR-82-84
DATE July 16, 1984
BY Paul Rittmann
CHECKED BY LNS

FOR D. Bihl
LOCATION 222-U
SUBJECT Validation of "ED"-Rev 1

I. Problem

Ensure the "ED"-Rev 1, emergency dose calculation program for the HP-41CV performs correctly.

II. Method

Rev 1 contains additional dose factors, which are summarized on the next page. Arrows denote those dose factors used by "ED".

Dose results from Rev 1 were compared with dose results computed by DACRIN, and in the case of Kr-85, SUBDOSA. These results are summarized in Internal Letter 72322-84-WU-243, May 18, 1984, PD Rittmann to RH Sudmann, "HP-41CV Program for Rapid Assessment of Environmental Doses" in which the original version of "ED" was validated.

Kr-85 dose factors were obtained from a SUBDOSA run by dividing the 7 mg/cm² beta dose and the 5 cm depth gamma dose by the Ψ/Q used.

beta: $.0463 \frac{\text{rem m}^3}{\text{Ci-sec}}$ ✓   gamma: $5.0 \times 10^{-4} \frac{\text{rem m}^3}{\text{Ci-sec}}$ ✓

The distance chosen for the gamma dose factor was great enough that it would approximate a semi-infinite cloud.

BD-6400-060.1 (N-2-79)

Isotope/mixture	Class	Dose Time (days)	Total Body	Kidney	Liver	Bone	Lung	Thyroid
1% Enriched Uranium	D	3.65+002	2.16+000	8.77+000	8.52-003	2.21+001	7.55-001	.00
		1.83+004	2.34+000	8.77+000	8.52-003	3.86+001	7.55-001	.00
	W	3.65+002	5.40-001	2.27+000	1.51-003	5.33+000	4.55+001	.00
		1.83+004	6.14-001	2.29+000	1.51-003	1.01+001	4.58+001	.00
	Y	3.65+002	6.06-002	2.78-001	8.08-005	5.78-001	1.80+002	.00
		1.83+004	2.74-001	1.02+000	8.08-005	4.50+000	4.52+002	.00
6% Pu (180d)	W	3.65+002	1.95+000	8.88+000	2.98+001	4.65+001	5.21+001	.00
		1.83+004	8.49+001	3.53+002	1.04+003	1.86+003	5.24+001	.00
	Y	3.65+002	1.28-001	5.85-001	1.96+000	3.07+000	2.08+002	.00
		1.83+004	3.22+001	1.34+002	4.05+002	7.04+002	5.23+002	.00
12% Pu (180d)	W	3.65+002	3.48+000	1.61+001	4.16+001	8.89+001	5.29+001	.00
		1.83+004	1.15+002	4.85+002	1.23+003	2.65+003	5.33+001	.00
	Y	3.65+002	2.29-001	1.06+000	2.74+000	5.85+000	2.19+002	.00
		1.83+004	4.21+001	1.79+002	4.67+002	9.70+002	5.48+002	.00
Sr90 + Y90	D	3.65+002	7.63-002	.00	.00	1.15+000	9.47-003	.00
		1.83+004	8.93-001	.00	.00	1.33+001	9.47-003	.00
Am-241	W	3.65+002	1.63+000	1.11+001	2.84+001	3.61+001	5.57+001	.00
		1.83+004	6.52+001	4.75+002	1.03+003	1.64+003	5.60+001	.00
Cs-137	D	3.65+002	4.00-002	2.25-002	6.08-002	4.21-002	1.04-002	.00
		1.83+004	4.49-002	2.25-002	6.46-002	5.01-002	1.17-002	.00
both class D: I-131		3.65+002	2.08-003	6.04-003	3.44-003	2.54-003	2.60-003	1.19+000
		1.83+004	2.08-003	6.04-003	3.44-003	2.54-003	2.60-003	1.19+000
I-129		3.65+002	5.33-003	3.68-003	1.67-003	2.06-003	7.56-004	4.18+000
		1.83+004	5.79-003	3.68-003	1.67-003	2.06-003	7.56-004	4.55+000
Co-60	W	3.65+002	4.23-003	.00	3.11-003	.00	3.91-001	.00
		1.83+004	4.25-003	.00	3.13-003	.00	3.94-001	.00
	Y	3.65+002	2.57-003	.00	1.89-003	.00	1.50+000	.00
		1.83+004	3.11-003	.00	2.29-003	.00	3.17+000	.00
C-14	D	3.65+002	3.59-004	3.59-004	3.59-004	1.79-003	3.59-004	3.59-004
		1.83+004	3.59-004	3.59-004	3.59-004	1.79-003	3.59-004	3.59-004
H-3	D	3.65+002	7.69-005	7.69-005	7.69-005	.00	7.69-005	7.69-005
		1.83+004	7.69-005	7.69-005	7.69-005	.00	7.69-005	7.69-005
12% MFP (180d)	Sol.	3.65+002	1.05-002	2.73-002	3.55-002	1.34-001	1.38-001	1.17-005
		1.83+004	2.74-002	3.44-002	4.34-002	4.00-001	1.38-001	1.17-005
	Insol.	3.65+002	3.63-003	3.03-003	3.66-003	5.47-002	4.87-001	4.44-006
		1.83+004	1.93-002	4.43-003	5.55-003	2.89-001	6.34-001	4.45-006

Table of Dose Factors for Acute Inhalation in rem/μCi inhaled.

Page 2
LNS

Rockwell International
Rockwell Hanford Operations
Energy Systems Group

DESIGN ANALYSIS

FOR
LOCATION
SUBJECT

PAGE 3
JOB NO. G-RE-PDR-82-84
DATE July 16, 1984
BY Paul Rittmann
CHECKED BY LNS

Even though Kr-85 is an external hazard, to simplify program execution, an effective inhalation dose factor was created by dividing the above dose factors by 350 cc/sec. Skin dose is the sum of the beta and gamma dose factors. (The 0 cm depth gamma dose is less than 7% higher than the 5 cm gamma dose, thus this approximation is valid).

Skin: 1.34×10^{-4} $\frac{rem}{\mu Ci}$ ✓ other organs: 1.43 E-6 $\frac{rem}{\mu Ci}$

The doses computed by "ED" are the following:

1st year: critical organ dose, where weighting factors are used to determine critical organ.

total body : bone/thyroid : other organ = 5 : 30 : 15

50 year: maximum organ dose, since 50 year committments are normally used to evaluate risk to the public.

Comparisons are outlined on the next three pages.

3D-6400-060.1 (N-2-79)

page 4 LWS

The dose results highlighted by the right bracket are the same as those listed on page 9 of the referenced analysis. The dose results with the ☆ are added dose factor results.

E.T.A.=5.8 MIN
VS X/Q=5.7E-3
GRD UCI/CC:9.6E-6
12%NO3
LUNG 1 Y=1.1E5 MR
BONE 50Y=5.3E6 MR ✓

MET = VS
U = 2.2 MPH
X = 0.22 MI
DUR.= 0.17 HR
H = 3.3 FT
SIGU= 0.024
ΣY = 27.5 FT
ΣZ = 21.4 FT
CI REL: 1.00E0
TYPE: 12%NO3

6% NO3 ☆
LUNG 1 Y=1.0E5 MR
BONE 50Y=3.7E6 MR

AM241 ☆
LUNG 1 Y=1.1E5 MR
BONE 50Y=3.3E6 MR

E.T.A.=2.5 MIN
VS X/Q=2.8E-4
GRD UCI/CC:7.9E-8
UNH
BONE 1 Y=2.2E3 MR
BONE 50Y=3.8E3 MR ✓

MET = VS
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 3.3 FT
SIGU= 0.250
ΣY = 118 FT
ΣZ = 20.2 FT
CI REL: 1.00E0
TYPE: UNH

E.T.A.=2.5 MIN
N X/Q=8.0E-6
GRD UCI/CC:2.2E-9
SR/Y90
BONE 1 Y=3.2E0 MR
BONE 50Y=3.7E1 MR ✓

MET = N
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 197 FT
CY = 0.120
CZ = 0.120
ΣY = 91.2 FT
ΣZ = 91.2 FT
CI REL: 1.00E0
TYPE: SR/Y90

E.T.A.=12.5 MIN
VS X/Q=1.5E-3
GRD UCI/CC:4.1E-7
12% O2
LUNG 1 Y=1.1E5 MR
BONE 50Y=5.0E5 MR

MET = VS
U = 2.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 3.3 FT
SIGU= 0.040
ΣY = 97 FT
ΣZ = 23.8 FT
CI REL: 1.00E0
TYPE: 12% O2

6% O2 ☆
LUNG 1 Y=1.1E5 MR
BONE 50Y=3.6E5 MR

E.T.A.=13.3 MIN
MS X/Q=6.9E-8
GRD UCI/CC:2.4E-12
UO3
LUNG 1 Y=1.1E0 MR
LUNG 50Y=1.1E0 MR

MET = MS
U = 11.2 MPH
X = 2.5 MI
DUR.= 8.0 HR
H = 197 FT
SIGU= 0.700
ΣY = 1084 FT
ΣZ = 62.3 FT
CI REL: 1.00E0
TYPE: UO3

U308 ☆
LUNG 1 Y=4.4E0 MR
LUNG 50Y=1.1E1 MR

E.T.A.=5.8 MIN
UN X/Q=6.5E-5
GRD UCI/CC:1.8E-8
I131
THYROD 1 Y=2.7E1 MR
THYROD 50Y=2.7E1 MR

MET = UN
U = 2.2 MPH
X = 0.22 MI
DUR.= 1.0 HR
H = 197 FT
CY = 0.300
CZ = 0.300
ΣY = 136 FT
ΣZ = 136 FT
CI REL: 1.00E0
TYPE: I131

I129 ☆
THYROD 1 Y=9.5E1 MR
THYROD 50Y=1.0E2 MR

page 5
LNS

These results agree with the results on page 10 of the referenced analysis.

E.T.A.=5.8 MIN
N X/Q=6.3E-4
GRD UCI/CC:1.7E-7
CS137
BODY 1 Y=8.8E0 MR
LIVER 50Y=1.4E1 MR

MET = N
U = 2.2 MPH
X = 0.22 MI
DUR.= 1.0 HR
H = 3.3 FT
CY = 0.210
CZ = 0.170
ΣY = 82.0 FT
ΣZ = 66.4 FT
CI REL: 1.00E0
TYPE: CS137

E.T.A.=80.0 MIN
MS X/Q=5.9E-7
GRD UCI/CC:2.1E-11
FP-SOL
LUNG 1 Y=2.9E-2 MR
BONE 50Y=8.3E-2 MR

MET = MS
U = 11.2 MPH
X = 14.9 MI
DUR.= 8.0 HR
H = 197 FT
SIGU= 0.700
ΣY = 2953 FT
ΣZ = 134 FT
CI REL: 1.00E0
TYPE: FP-SOL

FP-INS
LUNG 1 Y=1.0E-1 MR
LUNG 50Y=1.3E-1 MR

CO-INS
LUNG 1 Y=3.1E-1 MR
LUNG 50Y=6.6E-1 MR

CO-SOL
LUNG 1 Y=3.1E-2 MR
LUNG 50Y=8.2E-2 MR

C-14
BODY 1 Y=7.4E-5 MR
BONE 50Y=3.7E-4 MR

KR-85
SKIN 1 Y=2.8E-5 MR
SKIN 50Y=2.8E-5 MR

H-3
BODY 1 Y=1.6E-5 MR
BODY 50Y=1.6E-5 MR

The difference in dose factors for MFP-soluble follows from a somewhat different choice of inhalation (lung clearance) categories for the isotopes.

In this analysis, ICRP 30 choices for soluble & insoluble are assigned to each isotope independent of the others.

page 6
LNS

These results agree with the results on page 12 of the referenced analysis.

```
E.T.A.=2.5 MIN
N X/Q=8.0E-6
GRD UCI/CC:2.2E-9
SR/Y90
BONE 1 Y=3.2E0 MR
BONE 50Y=3.7E1 MR
```

} based on stored dose factors

```
MET = N
U = 11.2 MPH
X = 0.47 MI
DUR.= 1.0 HR
H = 197. FT
CY = 0.120
CZ = 0.120
ΣY = 91.2 FT
ΣZ = 91.2 FT
STK CFM=5.89E4
STK UCI/CC:1.00E-5
TYPE: SR/Y90
```

```
*SR90*
BONES 1 Y=3.2E0 MR
BONES 50Y=3.7E1 MR
STK CFM=5.89E4
STK UCI/CC:1.00E-5
TYPE: *SR90*
DF 1 Y=1.15E0
DF 50Y=1.33E1
```

} based on manual input of isotope name and dose factor/organ for 1yr + 50yr committments

III. Conclusion

The revised "ED" program correctly calculates acute inhalation doses using the dose factors on page 2 of the current analysis.

APPENDIX C

Internal Letter

Rockwell International

Date August 9, 1984

No. 72322-84-WU-340

TO: (Name, Organization, Internal Address)

Those Listed

FROM: (Name, Organization, Internal Address, Phone)

P. D. Rittmann

Subject . User Instructions For The Emergency Response HP-41CV Program

Attached are the detailed user instructions for the program "ED" developed for the HP-41CV to facilitate estimates of inhalation doses following accidental airborne releases. Detailed documentation of meteorology models, dose models and a program listing will be sent under a separate cover letter.

If you have any questions on program use, or suggestions to improve the program, please contact me on 3-3542.

Paul Rittmann

P. D. Rittmann
Radiological Engineering
and Effluent Controls

PDR/tjk

cc: J. A. Bates
D. E. Bihl
G. F. Boothe
D. D. Brekke
T. Chiao
G. Christensen
W. A. Decker
H. J. Goldberg
D. B. Howe
D. A. Marsh
D. Paine
R. H. Sudmann
L. N. Sutton

INSTRUCTIONS FOR "ED" - EMERGENCY DOSE CALCULATION PROGRAM FOR THE HP-41CV

A. Getting Started

1. Switch the calculator to USER mode, i.e., make the small word "USER" appear on the left side of the display.

2. Press the button labeled "XEQ" which is located to the right of the tan colored button. The words "ED-REV 1" should appear in the display. If the display shows "XEQ __ " then the program is not in the calculator, or is improperly loaded. The program can be reloaded as follows:

   a. Clear the calculator memory, i.e. turn off the calculator, press and hold the " ← " button. The "MEMORY LOST" display appears to indicate the calculator is ready.

   b. Allocate 21 registers for data storage by pressing the keys "XEQ" "ALPHA" "S" "I" "Z" "E" "ALPHA" "0" "2" "1".

   c. Switch to USER mode and begin feeding cards into the card reader until all 19 tracks of "ED" are entered.

   d. After "ED" is loaded, it can be started up using the steps in Part A.1. and A.2. above.

B. ATMOSPHERIC DISPERSION. Once the "ED-REV 1" prompt appears, press R/S to begin the data entry prompts for calculating atmospheric dispersion.

1. "VS, MS, N, UN = 0-3". This prompt requires entry of a number (0, 1, 2, or 3) to indicate which atmospheric stability class applies to this release:
   VS = Very Stable (0), MS = Moderately Stable (1), N = Neutral (2), UN = Unstable (3). The stability class can be determined one of two ways:

   a. Phone the Hanford Meteorological Station, (HMS), 373-2716 and ask for the current stability class, wind speed and direction. All three will be needed.

   b. Or, estimate the stability class from the following tables

Day Time

Wind Speed	Clear	Cloudy	Overcast
< 10 mph	UN	UN	UN
>10 mph	UN	N	N

	Nighttime	
Wind Speed	< 50% Clouds	> 50% Clouds
< 5 mph	MS	MS
5-10 mph	N	MS
> 10 mph	N	N

Enter your selection (0, 1, 2 or 3) and press "R/S"

2. "WIND SP? MPH" This prompt is asking for the wind speed at the point of release in units of miles per hour. If the HMS could not be reached, then wind speed estimates can be used. Enter the wind speed and press "R/S".

   NOTE: Convert wind speed in meters-per-second to miles-per-hour by dividing by .447 (1 mph = 0.477 m/sec).

3. "DISTANCE? MI" This prompt requires entry of the number of miles downwind to the individual of interest. A crucial question at this point is "Which way is the wind blowing?" HMS gives the wind direction, or if HMS cannot be reached, the direction can be estimated. Be careful not to mis-interpret HMS wind direction reports. "Wind direction" normally is the direction the wind is coming from. To track a release plume you must have the direction the wind is blowing toward, i.e., the direction the released activity will travel. If you phone HMS, ask the meteorologist to clarify which way the wind is blowing in terms of the geographical area it blows toward.

   After the direction of travel of the plume is established, pull out a map of Hanford and lay a ruler along this direction at the point of release. Select an appropriate location within ± 10° of the wind direction to determine inhalation dose (e.g. Highway 240, site boundary, FFTF, N-Reactor, 2750E, etc.). Use the calculator if necessary to convert the ruler measurement to miles. Enter the distance and press "R/S".

   NOTE: Convert meters to miles by dividing by 1609. (1 mile = 1609 meters).

4. "E.T.A. = ________". This is the time of flight result (estimated time of arrival). In other words, how long it will take the puff to travel the distance at the wind speed you entered. Press "R/S" to continue program execution.

5. "REL DUR? HR". This prompt is asking for the release duration in hours. Any number greater than zero up to and including 24 hours is acceptable. Durations greater than 8 hours result in sector averaged X/Q values. Enter the release duration and press "R/S".

6. "REL HT? FT". This prompt is asking for the release height in feet. If significant plume rise is observed, a release height greater than the stack height can be used. Normally, just the stack height is entered at this point.

   If a stack's height is less than 2.5 times the height of nearby buildings, building wake turbulence brings the stack's effluent down to ground level. Thus, in the 200 areas there are only 200 foot stacks and ground level stacks, with the exception of the 150 foot vessel vent stack on top of 244 AR. Enter the release height, and press R/S.

7. The X/Q value is displayed next. The display shows the stability class and the computed X/Q value in seconds per cubic meter. Press "R/S" to go on.

8. "INPUT LIST?". This prompt gives you the option of reviewing the meteorology inputs and related results. If you do not wish to review your input, press "R/S" and the calculator will go to paragraph C.1., below. If you want to review input, enter any number and press "R/S". Press "R/S" to view successive inputs.

   a. "MET = ____" shows the stability class
   b. "U = ____ MPH" shows wind speed
   c. "X = ____ MI" shows downwind distance
   d. "DUR = ____ HR" shows release duration
   e. "H = ____ FT" shows release height
   f. "SIGU = ____ or "CY = ____", "CZ = ____"show the parameter used in the X/Q computation. If the release duration exceeds 8 hours, only the Cz parameter will be displayed.
   g. "ΣY = ____ FT" shows the computed σy value used. It is a measure of the spread of the plume horizontally from the centerline at the distance chosen.
   h. "ΣZ = ____ FT" shows the computed σz value used. It is a measure of the spread of the plume vertically.

C. Release Amount and Type

1. "STACK CFM?". This prompt actually offers a choice on whether the release quantity will be determined from stack flow rate and concentration, or total curies released. These two data entry paths are described as follows:

   a. If there was a stack release, and a stack air concentration is known, find the flow rate for the stack on the Tables at the end of these instructions. Enter this flow rate and press "R/S". The next prompt is "STK CONC?" and requires entry of the measured stack air concentration in units of microcuries per cubic centimeter. Enter the concentration and press "R/S" and the program continues with paragraph C.2. below.

b. If the release is not from a stack, or has been estimated as a lump sum total number of curies released, then data entry should be done as follows. When the "STACK CFM?" prompt appears enter zero cfm and press "R/S". The next prompt will be "CI REL?". Enter the total number of curies released and press "R/S".

2. "GRD UCI/CC:______". This shows the computed average ground level concentration at the previously entered downwind distance. The units are microcuries per cubic centimeter. Because this message is too large for one display, the calculator scrolls the message to the left. Thus the "GRD" disappears in a few seconds. To see the entire message again, press the "ALPHA" button and watch it scroll left. Be sure to press the "ALPHA" button a second time before continuing. This will make sure the calculator is not in "ALPHA" mode, i.e., that the small word "ALPHA" does not appear on the right side of the display.

3. "a, FP, AP, NEW = 1-4". This prompt gives the categories of isotopes available to the user. Alpha emitters, fission products, activation products or new dose factors are chosen by entering 1, 2, 3, or 4 and pressing "R/S". The results of each choice are explained below.

a. "a" (enter 1): This chooses the alpha emitter menu, "12%, 6%, AM, U = 1-4". The choices are summarized in the table below.

Category	Number Entry	Explanation
12%	1	180d, 12% Pu-240
6%	2	180d, 6% Pu-240
AM	3	Am-241, class W
U	4	Uranium

If a "1" or "2" is entered, the program prompts with "NO3, O2 = 1,2". Selecting nitrate (1) means class W plutonium dose factors are used; choosing oxide (2) means class Y plutonium dose factors are used.

If "3" is entered the dose results come next.

If "4" is entered, the program prompts with "UO, UO3, UNH = 1-3". "UO" is class Y uranium compounds such as UO2 or U3O8. "UO3" is class W, and "UNH" is class D.

b. "FP" (enter 2): This choses the fission product menu,
"SR, I, MFP, CS = 1-4".
The choices are summarized in the table below.

Category	Number Entry	Explanation
SR	1	Sr-90 plus Y-90 in a 50-50 mix
I	2	I-129 or I-131
MFP	3	180d, 12% Pu-240, mixed fission products
CS	4	Cs-137

If a "1" or "4" is entered the dose results come next. If a "2" is entered, the next prompt is "I129, I131 = 1, 2" which allows one to choose either isotope.

If a "3" is entered, the next prompt is "INSOL, SOL = 1, 2" which allows one to chose the approximate chemical form of the MFP.

c. "AP" (enter 3): This chooses the activation product menu,
"CO, C, KR, H = 1-4".
These choices are summarized in the table below:

Category	Number Input	Explanation
CO	1	Co-60
C	2	C-14
KR	3	Kr-85
H	4	H-3

If a "1" is entered, the program prompts with "INSOL, SOL = 1,2". Insoluble chemical forms of cobalt are oxides, hydroxides, halides and nitrates. Other cobalt compounds are considered soluble (class w).

If "2", "3", or "4" is entered, the program computes dose results next.

d. "NEW" - (enter 4): This allows you to input your own dose factors. After pressing "R/S", the "NAME?" prompt appears together with the small word "ALPHA" which indicates the calculator is in alpha mode. Press the appropriate blue lettered keys to spell out the name of this isotope or mixture. Numbers are entered in alpha mode by first pressing the shift key (tan colored), then pressing the number. Up to 24 characters may be entered, but the program will only retain six, so abbreviate accordingly. The next prompt, "1 YR R/UCI?", is asking for numeric input of the new dose factor for first year dose in units of rem per microcurie inhaled. Press "R/S" and the "CRIT ORGAN?" prompt appears. The calculator is again in "ALPHA" mode, so use the blue lettered keys to spell out the organ for which the previously entered first year dose factor applies. Again, only six characters will be retained so abbreviate as necessary. Press "R/S" and the 50 year committed dose factor and organ prompts appear. Enter the appropriate data and press "R/S". The program then computes first year and 50 year organ doses using the dose factors just entered.

4. Dose results are displayed as follows:

   a. The name of the isotope or mixture is displayed momentarily. Do not press "R/S" to continue, The small word "PRGM" on the right side of the display means the program is running.

   b. After the name display comes the first year dose result, which has the general format

      "__(organ name)__ 1Y = ________MR".

      The dose result has units of mrem. The organ is on the left, and since the display scrolls left, in a few seconds the organ cannot be seen.

   c. The 50 year dose committments have the same format as the first year committments. Press "ALPHA" to take another look, or "R/S" to continue.

5. "INPUT LIST?" As before, this prompt gives the option of reviewing input data. If you do not wish to review input, then press "R/S" and the program returns to the beginning prompt "ED - REV 1". If you would like to review your input, enter any number and press "R/S". Press "R/S" to view successive inputs.

   a. If a stack flow rate was entered, the first and second displays are "STK CFM = ____" and "STK UCI/CC: ____" showing the stack flow rate and stack air concentration. If zero was entered as the flow rate, then the first and only display is "CI REL: ____" showing the number of curies released.

b. "TYPE: ____". Shows the isotope or mixture selected for dose computation. If the "NEW" option was selected in step C.3 above, then the name you entered is shown. Also, on the next displays will be the first year and 50 year dose factors which were entered. If the "NEW" option was not selected then the program returns to the beginning prompt "ED-REV 1" after displaying the material type.

D. Running Additional Cases

1. Check whether the small word "USER" disappears on the left side of the display. If it doesn't, press the USER key to place the calculator in "USER" mode.

2. The top two rows of keys (blue labels A through I) are assigned so that changes can easily be made at any point in the sequence of data entry described in parts B and C above. For example, to change the distance down wind, press the key with the blue label "C" and the prompt "DISTANCE? MI" will appear. You can enter a new distance and press "R/S" or just press "R/S" and the previous distance will be used. (To see what the previous entry was, just press the "←" key to clear the display.) The program will now execute skipping all further data entry prompts. The E.T.A. and X/Q results will be shown, and then will come the dose results. Key reassignments for "USER" mode are listed below:

Internal Label	Blue Label	Program Display When Pressed In "USER" Mode
ED	K	"ED-REV 1"
MET	A	"VS, MS, N, UN = 0-3"
MPH	B	"WIND SP? MPH"
DIST	C	"DISTANCE? MI"
DUR	D	"REL DUR? HR"
HT	E	"REL HT? FT"
CFM	F	"STACK CFM?"
CI	G	"STK CONC? or "CI REL?"
ISO	H	"a, FP, AP, NEW = 1-4"
INPUT	I	"MET = ____" and other input data

3. General Notes:

   a. On any data entry prompt, the value input on the previous run will be used unless a new value is entered. Thus the entire calculation can be duplicated from the "ED-REV 1" prompt to the dose result simply by pressing "R/S" again and again.

   b. Menu prompts are arranged so that the more severe consequence results from a lower number entry as a general rule, So, when in doubt, take the lower number choice.

   c. The choice between soluble or insoluble can be made on the basis of the general physical form of the material. Liquids are soluble; solids are insoluble; fires always produce insoluble material.

   d. Plutonium and uranium quantities are commonly given in units of mass, such as grams or pounds. Relationships to convert from mass to activity are listed below. In use they are simply multiplied by the given mass. Note that here "Ci" refers to curies of alpha emitters only.

12% Pu:	.097 Ci/g	or	44 Ci/lb	
6% Pu:	.075 Ci/g	or	34 Ci/lb	
U:	8.2 E-7 Ci/g	or	3.7 E-4 Ci/lb	or
	.82 Ci/Mt	or	.74 Ci/ton	

   UNH Solution: 4 lb U/gal as received from PUREX
   10 lb U/gal entering calciner

   e. In the event of a criticality, the inhalation and external doses from the short lived inert gases and iodine should be estimated from the table on the next page. This table provides upper bounds on possible doses at each distance for an event with 1.0 E+19 fissions spread over eight hours. Current values for atmospheric stability and wind speed are not needed.

External And Inhalation Doses From 10^{19} Fissions, Adverse Meteorology, 8 Hour Release
(Release quantities from NRC Reg. Guide 3.35)

	Distance (miles)	.25 mi	0.50 mi	2.7 mi	5.3 mi	7.8 mi	10 mi
	Distance (meters)	400 m	800 m	4.4 Km	8.5 Km	12.5 Km	15.5 Km
Ground Level	Stability Class	N	VS	VS	MS	MS	VS
	Wind Speed (mph)	2.2	2.2	5.6	11	11	11
	Total Body (mrem)	600	220	14	5	3.3	2.7
	Thyroid (mrem)	3000	930	52	19	11	7.3
Elevated (200 foot stack)	Stability Class	UN	N	N	MS	MS	MS
	Wind Speed	2.2	2.2	2.2	2.2	2.2	2.2
	Total Body (mrem)	220	160	12	2.0	.84	.37
	Thyroid (mrem)	630	530	61	18	10	6.2

PUREX STACKS:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-A-1	A552	PUREX 200'	130,000
296-A-1	A540	Q-Cell	4,000
296-A-2	A542	W. Sample Gallery	3,600
296-A-3	A543	E. Sample Gallery	3.500
296-A-5A	A545	LAB West	8,000
296-A-5B	A546	LAB East	18,000
296-A-6	A547	E Sample Gallery & U Cell	13,000
296-A-7	A548	W Sample Gallery & R Cell	15,000
296-A-8	A549	White Room Exhauster	16,000
296-A-10	A550	Equip. Disposal Tunnel	5,000
296-A-14	A544	Outback (293-A) Exhaust	5,000
296-A-24	A539	Ammonia Scrubber Waste Conc.	1,700
296-A-31	A562	Storage Gallery	12,000
296-A-32	A563	Vacuum Pump Exhaust	1,800
296-A-33	A578	Wall Exhauster, EF-3-5	4,000
296-A-34	A579	Wall Exhauster EF-3-6	6,000
296-A-35	A580	Wall Exhauster EF-3-7	7,000
296-A-36	A582	Wall Exhauster EF-3-8	4,300
296-A-37	A583	Wall Exhauster EF-3-9	7,000
296-A-38	A584	Wall Exhauster EF-3-10	2,300
296-A-39	A516	SWP Lobby Exhaust	Unknown

B-Plant/WESF

Stack Number	EDP Code	Name	Typical High Flow Rate
291-B-1	B691	B-Plant Canyon 200 ft	40,000
296-B-5	B696	271-B	1,600
296-B-10	B748	WESF	18,000
296-B-13	B690	221-BF, BCP Tanks	900
296-B-14	B678	221-B Vessel Vent	200

East Tank Farm Stacks:

296-A-12	E058	244-AR Vessel Vent 150 ft.	450
296-A-13	E052	244-AR Canyon	4,000
296-A-17	E059	A, AX, AY, AZ Tanks	4,000
296-P-1	E120	Tank 105-A	1,500
296-A-20	E197	AZ Annuli	2,000
296-A-21	E645	242-A Evaporator	16,000
296-A-22	E643	242-A Vessel Vent	600
296-A-25	E080	244-A Catch Tank	150
296-A-26	E297	204-AR Unloading Facility	1,800
296-A-27	E270	AW Tanks	1,100
296-A-28	E272	AW Annuli	4,600
296-A-29	E901	AN Tanks	800
296-A-30	E903	AN Annuli	5,000
296-B-28	E886	244-BX Saltwell Vessel	200
291-C-1	E073	201-C, 200 ft.	9,000
296-C-5	E069	244-CR Vault	2,900
296-P-16	E-068	Tanks 105, 106-C	3,500

S-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-S-1	S006	202-S Canyon, 200 Ft	20,000
296-S-2	S032	202-S Sample Gallery	1,500
296-S-4	S008	202-S SWP Lobby	900
296-S-6	S004	202-S Silo	10,000
296-S-7E	S015	233-S Building Exhaust	8,500
296-S-7W	S016	233-S Building Exhaust	8,500
296-S-16	S264	218-S Tanks	200
296-S-21	S289	222-S Lab	70,000

T-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-T-1	T785	221-T Canyon, 200 Ft	40,000
296-T-11	T783	224-T East	13,000
296-T-12	T784	224-T West	13,000
296-T-13	T786	221-T Roof	40,000
296-W-1	L100	Laundry	25,000

U-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
296-U-1	U771	221-U Canyon, 200 ft	12,000
296-U-2	U133	Powder Handling Offgas	700
296-U-4	U777	224-U Calcinators	2,500
296-U-13	U878	224-U Load-out Room	4,500

Z-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-Z-1	Z810	234-5, 232-Z, 236-Z, 242-Z	240,000
296-Z-3	Z813	241-Z Sump & Vessel	1,300
296-Z-5	Z913	2736-ZB	10,000
296-Z-6	Z802	2736-ZA	12,000

West Tank Farm Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
296-P-22	W191	SY Annuli	400
296-P-23	W190	SY Tanks	800
296-S-15	W111	SX Tanks	5,000
296-S-18	W09E	242-S Building Exhaust	20,000
296-S-22	W880	244-S Salt Well Receiver	180
296-T-17	W117	242-T Cells	2,000
296-T-18	W882	244-TX Salt Well Receiver	200

APPENDIX D

Internal Letter Rockwell International

Date February 19, 1985 No. 72310-85-WG-049

TO (Name, Organization, Internal Address): Those Listed

FROM (Name, Organization, Internal Address, Phone): P. D. Rittmann, 3-3542

Subject Revision 2 of the HP-41CV Emergency Dose Program

Ref: Internal Letter 72320-84-WU-340, August 9, 1984, P. D. Rittmann to those Listed, "User Instructions for the Emergency Response HP-41CV Program"

The HP-41CV handheld calculator program for computing inhalation doses following an environmental release, has been revised as a result of the recent C-Farm incident to include the following features:

1. The Hanford atmospheric dispersion model has been replaced by the Pasquill-Gifford dispersion model. This change makes the program compatible with current reporting methods used by the Hanford Meteorology Station.

2. Calculation of integrated exposures (X/Q) not directly on the plume centerline is available. This facilitates the interpretation of environmental air sample results in cases where the release plume does not blow directly towards the sampler.

3. Values for X/Q generated by other dispersion models (for example, PNL-3777, or the Hanford model) may be directly entered and used by the program in place of the Pasquill choices.

4. Total curies released may be computed based on stack or environmental air concentration data, or even ground contamination data.

Attached are the revised instructions and supplementary tables. Program documentation and method verification will be sent in a separate letter. If you have any questions, suggestions, or would like a copy of the program, please contact me at the above number.

Paul Rittmann

P. D. Rittmann
Radiological Engineering
and Effluent Controls

PDR/tjj

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INSTRUCTIONS FOR "ED-REV 2"

EMERGENCY DOSE CALCULATION PROGRAM FOR THE HP-41CV

A. Getting Started

1. Switch the calculator to USER mode, i.e., make the small word "USER" appear on the left side of the display.

2. Press the button labeled "XEQ" which is located to the right of the tan colored button. The words "ED-REV 2" should appear in the display. If the display shows "XEQ ___ " then the program is not in the calculator, or is improperly loaded. The program can be reloaded as follows:

   a. Clear the calculator memory, i.e. turn off the calculator, turn it back on while holding the " ← " button. The "MEMORY LOST" display appears to indicate the calculator is ready.

   b. Allocate 20 registers for data storage by pressing the keys "XEQ" "ALPHA" "S" "I" "Z" "E" "ALPHA" "O" "2" "O".

   c. Switch to USER mode and begin feeding cards into the card reader until all 17 tracks of "ED" are entered.

   d. After "ED" is loaded, it can be started up using the steps in Part A.1. and A.2. above.

B. ATMOSPHERIC DISPERSION. Once the "ED-REV 2" prompt appears, press R/S to begin the data entry prompts for calculating atmospheric dispersion.

1. "MET? A-G = 1-7". This prompt requires entry of a number from 1 to 7 corresponding to the atmospheric stability class present at the time of the release.

   The stability class can be determined one of two way:

   a. Phone the Hanford Meteorological Station (HMS), 373-2716, and ask for the stability class, wind speed, and direction. All three will be needed.

   b. Or, estimate the stability class from the following table:

	Daytime Cloud Cover			Nightime Cloud Cover	
Wind Speed	Little	Half	Overcast	> Half	< Half
<5	A	A	B	E	F
5	A-B	B	C	E	F
10	B	B-C	C	D	E
15	C	C-D	D	D	D
>15	C	D	D	D	D

2. "WIND SP? MPH" This prompt is asking for the wind speed at the point of release in units of miles per hour. If the HMS could not be reached, then wind speed estimates can be used. Enter the wind speed and press "R/S".

   NOTE: Convert wind speed in meters-per-second to miles-per-hour by dividing by .447 (1 mph = 0.477 m/sec).

3. "DISTANCE? MI" This prompt requires entry of the number of miles downwind to the location of interest. A crucial question at this point is "Which way is the wind blowing?" HMS gives the wind direction, in degrees measured clockwise from north. If HMS cannot be reached, the direction can be estimated. Be careful not to misinterpret HMS wind direction reports. "Wind direction" normally is the direction the wind is coming from. To track a release plume you must have the direction the wind is blowing toward, i.e., the direction the released activity will travel. If you phone HMS, ask the meteorologist to clarify which way the wind is blowing in terms of the geographical area it blows toward.

   After the direction of travel of the plume is established, pull out a map of Hanford and lay a ruler along this direction at the point of release. Select an appropriate location e.g. Highway 240, site boundary, onsite building, or air sampler. Use the calculator if necessary to convert the ruler measurement to miles. Enter the distance and press "R/S".

   NOTE: Convert meters to miles by dividing by 1609. (1 mile = 1609 meters).

4. "E.T.A. = ________". This is the time of flight result (estimated time of arrival). In other words, how long it will take the puff to travel the distance at the wind speed you entered. Press "R/S" to continue program execution.

5. "OFFSET? FT". This prompt is requesting the distance measured from the plume centerline to the location of interest. If the location of interest is very close to the plume centerline, just enter a zero.

6. "REL HT? FT". This prompt is asking for the release height in feet. If significant plume rise is observed, a release height greater than the stack height can be used. Normally, just the stack height is entered at this point.

   If a stack's height is less than 2.5 times the height of nearby buildings, building wake turbulence brings the stack's effluent down to ground level. Thus, in the 200 areas there are only 200 foot stacks and ground level stacks, with the exception of the 150 foot vessel vent stack on top of 244-AR. Enter the release height, and press R/S.

7. "REL DUR? HR". This prompt is asking for the release duration in hours. Any number greater than zero up to and including 24 hours is acceptable. Durations greater than 8 hours result in sector averaged X/Q values. Enter the release duration and press "R/S".

8. The X/Q value is displayed next. The display shows the stability class and the computed X/Q value in seconds per cubic meter. Press "R/S" to go on.

9. "INPUT LIST?". This prompt gives you the option of reviewing the meteorology inputs and related results. If you do not wish to review your input, press "R/S" and the calculator will go to paragraph C.1., below. If you want to review input, enter any number and press "R/S". Press "R/S" to view successive inputs.

   a. "MET = PG _" shows the Pasquill-Gifford stability class
   b. "U = ____ MPH" shows wind speed
   c. "X = ____ MI" shows downwind distance
   d. "Y = ___FT" shows the plume offset distance
   e. "H = ____ FT" shows release height
   f. "DUR = ____ HR" shows release duration
   g. "ΣY = ____ FT" shows the computed σy value used. It is a measure of the spread of the plume horizontally from the centerline at the distance chosen.
   h. "ΣZ = ____ FT" shows the computed σz value used. It is a measure of the spread of the plume vertically.
   j. "X/Q = ____" shows the value for X/Q used in later calculations.

10. If you would like to enter your own X/Q from PNL-3777, Revision 1, or another atmospheric dispersion model, switch to USER mode and press the key with the blue "J". At the "ENTER X/Q" prompt, switch the calculator out of USER mode, enter the X/Q, and press "R/S".

C. <u>Release Amount and Type</u>

1. "ST, CI, AR, GD = 1-4". This prompt offers four ways to establish the number of curies released:

   1 = ST = stack release using a measured stack concentration
   2 = CI = direct entry of curies released
   3 = AR = using a measured ground level air concentration downwind
   4 = GD = using a surface contamination measurement downwind

   a. "ST" (enter 1) This is the option to use with a stack release, where the average stack concentration (gross beta or gross alpha) <u>during the release</u> is known.

      (i) "STK UCI/CC?" Enter the average stack concentration in units of micro-curies per cubic centimeter of air.

      (ii) "STACK CFM?" Look up the appropriate value on the tables at the end of this guide.

   b. "CI" (enter 2) This allows direct entry of the number of curies released. The next prompt will be "CI REL?".

   c. "AR" (enter 3) This enables one to interpret downwind air concentration measurements. The X/Q computed earlier must be at the location the air sample was taken.

(i) "AIR UCI/CC?" Enter the average air concentration measured at the air sampler. Use gross beta or gross alpha.

(ii) "HRS SAMPLED?" Enter the number of hours over which the sample was taken.

NOTE: As long as the sample period includes the entire release, or else begins and ends during the release, the program will work fine. Otherwise, the curie estimate will be too small, according to the portion of the release that was not sampled.

d. "GD" (enter 4) In the absence of downwind air sample data, the measured surface contamination can be used to estimate air concentrations and even the total curies released.

(i) "DPM/SQ.CM?" Enter the measured surface contamination downwind. If direct survey data is available, the detector face area must be taken into account. Use the following table:

Probe	Face Area
P-11	15 Cm^2
PAM	54 Cm^2

(ii) "DEP.SP? CM/S" Enter an appropriate value for the ground deposition speed. Typically this is around 0.1 cm/sec, although it may be higher for certain chemical forms (iodine) and varies with humidity, surface moisture, vegetation.

NOTE: An excellent way to measure deposition speed is by having air sample and ground contamination results for the same location. The deposition speed is computed by dividing the ground contamination by the air concentration, and then dividing this result by the sample time, where the sample time is long enough to include the entire release.

2. After entering the necessary information, the program now computes and displays the estimated curies releases, as well as the average air concentration during the release at the downwind location.

a. "REL:____CI" This is the number of curies released. Press "R/S" to continue.

b. "GRD UCI/CC = ____" This is the computed average ground level concentration during the release at the downwind location. Press "R/S" to continue.

NOTE: Because this message is too large to fit in the display, the calculator scrolls the message to the left. The word "GRD" dissappears in a few seconds. To see the entire message again, press the "ALPHA" button and watch it scroll left. Be sure to press the "ALPHA" button again to take the calculator out of "ALPHA" mode, i.e., make sure the small word "ALPHA" does not appear on the right side of the display.

3. "a, FP, AP, NEW = 1-4". This prompt gives the categories of isotopes available to the user. Alpha emitters, fission products, activation products or new dose factors are chosen by entering 1, 2, 3, or 4 and pressing "R/S". The results of each choice are explained below.

   a. "a" (enter 1): This chooses the alpha emitter menu,
      "12%, 6%, AM, U = 1-4".
      The choices are summarized in the table below.

Category	Number Entry	Explanation
12%	1	180d, 12% Pu-240
6%	2	180d, 6% Pu-240
AM	3	Am-241, class W
U	4	Uranium

      If a "1" or "2" is entered, the program prompts with "NO3, O2 = 1,2". Selecting nitrate (1) means class W plutonium dose factors are used; choosing oxide (2) means class Y plutonium dose factors are used.

      If "3" is entered the dose results come next.

      If "4" is entered, the program prompts with "UO, UO3, UNH = 1-3". "UO" is class Y uranium compounds such as UO2 or U3O8. "UO3" is class W, and "UNH" is class D.

b. "FP" (enter 2): This choses the fission product menu, "SR, I, MFP, CS = 1-4". The choices are summarized in the table below.

Category	Number Entry	Explanation
SR	1	Sr-90 plus Y-90 in a 50-50 mix
I	2	I-129 or I-131
MFP	3	180d, 12% Pu-240, mixed fission products
CS	4	Cs-137

If a "1" or "4" is entered the dose results come next. If a "2" is entered, the next prompt is "I129, I131 = 1, 2" which allows one to choose either isotope.

If a "3" is entered, the next prompt is "INSOL, SOL = 1, 2" which allows one to chose the approximate chemical form of the MFP.

c. "AP" (enter 3): This chooses the activation product menu, "CO, C, KR, H = 1-4". These choices are summarized in the table below:

Category	Number Input	Explanation
CO	1	Co-60
C	2	C-14
KR	3	Kr-85
H	4	H-3

If a "1" is entered, the program prompts with "INSOL, SOL = 1,2". Insoluble chemical forms of cobalt are oxides, hydroxides, halides and nitrates. Other cobalt compounds are considered soluble (class W).

If "2", "3", or "4" is entered, the program computes dose results next.

d. "NEW" - (enter 4): This allows you to input your own dose factors. After pressing "R/S", the "NAME?" prompt appears together with the small word "ALPHA" which indicates the calculator is in alpha mode. Press the appropriate blue lettered keys to spell out the name of this isotope or mixture. Numbers are entered in alpha mode by first pressing the shift key (tan colored), then pressing the number. Up to 24 characters may be entered, but the program will only retain six, so abbreviate accordingly. The next prompt, "1 YR R/UCI?", is asking for numeric input of the new dose factor for first year dose in units of rem per microcurie inhaled. Press "R/S" and the "CRIT ORGAN?" prompt appears. The calculator is again in "ALPHA" mode, so use the blue lettered keys to spell out the organ for which the previously entered first year dose factor applies. Again, only six characters will be retained so abbreviate as necessary. Press "R/S" and the 50 year committed dose factor and organ prompts appear. Enter the appropriate data and press "R/S". The program then computes first year and 50 year organ doses using the dose factors just entered.

4. Dose results are displayed as follows:

a. The name of the isotope or mixture is displayed momentarily. Do not press "R/S" to continue, since the small word "PRGM" on the right side of the display means the program is running.

b. After the name display comes the general first year dose result, which has the general format

"__(organ name)___ 1Y = ________MR".

The dose result has units of mrem. The organ is on the left, and since the display scrolls left, in a few seconds the organ cannot be seen.

c. The 50 year dose committments have the same format as the first year committments. Press "ALPHA" to take another look, or "R/S" to continue.

5. "INPUT LIST?" As before, this prompt gives the option of reviewing input data. If you do not wish to review input, then press "R/S" and the program returns to the beginning prompt "ED - REV 2". If you would like to review your input, enter any number and press "R/S". Press "R/S" to view successive inputs.

D. Running Additional Cases

1. Check whether the small word "USER" disappears on the left side of the display. If it doesn't, press the USER key to place the calculator in "USER" mode.

2. The top two rows of keys (blue labels A through K) are assigned so that changes can easily be made at any point in the sequence of data entry described in parts B and C above. For example, to change the distance down wind, press the key with the blue label "C" and the prompt "DISTANCE? MI" will appear. You can enter a new distance and press "R/S" or just press "R/S" and the previous distance will be used. (To see what the previous entry was, just press the "◀" key to clear the display.) The program will now execute skipping all further data entry prompts. The E.T.A., X/Q and CI results will be shown, and then will come the dose results. Key reassignments for "USER" mode are listed below:

Internal Label	Blue Label	Program Display When Pressed In "USER" Mode
ED	K	"ED-REV 2"
MET	A	"VS, MS, N, UN = 0-3"
MPH	B	"WIND SP? MPH"
DIST	C	"DISTANCE? MI"
OFFSET	D	"OFFSET? FT"
HT	E	"REL HT? FT"
DUR	F	"REL DUR? HR"
AMT	G	"ST, CI, AR, GD = 1-4"
ISO	H	"a, FP, AP, NEW = 1-4"
INPUT	I	"MET = ____" and other input data
X/Q	J	"ENTER X/Q"

3. General Notes:

a. On any data entry prompt, the value input on the previous run will be used unless a new value is entered. Thus the entire calculation can be duplicated from the "ED-REV 2" prompt to the dose result simply by pressing "R/S" again and again.

b. Menu prompts are arranged so that the more sev e consequence results from a lower number entry as a general rule, so, when in doubt, take the lower number choice.

c. The choice between soluble or insoluble can be made on the basis of the general physical form of the material. Liquids are soluble; solids are insoluble; fires always produce insoluble material.

d. Plutonium and uranium quantities are commonly given in units of mass, such as grams or pounds. Relationships to convert from mass to activity are listed below. In use they are simply multiplied by the given mass. Note that here "Ci" refers to curies of alpha emitters only.

12% Pu:	.097 Ci/g	or	44 Ci/lb	
6% Pu:	.075 Ci/g	or	34 Ci/lb	
U:	8.2 E-7 Ci/g	or	3.7 E-4 Ci/lb	or
	.82 Ci/Mt	or	.74 Ci/ton	

UNH Solution: 4 lb U/gal as received from PUREX
10 lb U/gal entering calciner

e. In the event of a criticality, the inhalation and external doses from the short lived inert gases and iodine should be estimated from the table on the next page. This table provides upper bounds on possible doses at each distance for an event with 1.0 E+19 fissions spread over eight hours. Current values for atmospheric stability and wind speed are not needed.

External And Inhalation Doses From 1 E19 Fissions, Adverse Meteorology, 8 Hour Release

(Release quantities from NRC Reg. Guide 3.35)

	Distance (miles)	.25 mi	0.50 mi	2.7 mi	5.3 mi	7.8 mi	10 mi
	Distance (meters)	400 m	800 m	4.4 Km	8.5 Km	12.5 Km	15.5 Km
Ground Level	Stability Class	N	VS	VS	MS	MS	VS
	Wind Speed (mph)	2.2	2.2	5.6	11	11	11
	Total Body (mrem)	600	220	14	5	3.3	2.7
	Thyroid (mrem)	3000	930	52	19	11	7.3
Elevated (200 foot Stack)	Stability Class	UN	N	N	MS	MS	MS
	Wind Speed	2.2	2.2	2.2	2.2	2.2	2.2
	Total Body (mrem)	220	160	12	2.0	.84	.37
	Thyroid (mrem)	630	530	61	18	10	6.2

PUREX STACKS:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-A-1	A552	PUREX 200'	130,000
296-A-1	A540	Q-Cell	4,000
296-A-2	A542	W. Sample Gallery	3,600
296-A-3	A543	E. Sample Gallery	3,500
296-A-5A	A545	LAB West	8,000
296-A-5B	A546	LAB East	18,000
296-A-6	A547	E Sample Gallery & U Cell	13,000
296-A-7	A548	W Sample Gallery & R Cell	20,000
296-A-8	A549	White Room Exhauster	16,000
296-A-10	A550	Equip. Disposal Tunnel	5,000
296-A-14	A544	Outback (293-A) Exhaust	5,000
296-A-24	A539	Ammonia Scrubber Waste Conc.	1,700
296-A-31	A562	Storage Gallery	12,000
296-A-32	A563	Vacuum Pump Exhaust	1,800
296-A-33	A579	Wall Exhauster, EF-3-5	4,000
296-A-34	A579	Wall Exhauster EF-3-6	6,000
296-A-35	A580	Wall Exhauster EF-3-7	7,000
296-A-36	A582	Wall Exhauster EF-3-8	4,300
296-A-37	A583	Wall Exhauster EF-3-9	8,000
296-A-38	A584	Wall Exhauster EF-3-10	2,300
296-A-39	A516	SWP Lobby Exhaust	Unknown

B-Plant/WESF

Stack Number	EDP Code	Name	Typical High Flow Rate
291-B-1	B691	B-Plant Canyon 200 Ft.	40,000
296-B-5	B686	271-B	1,600
296-B-10	B748	WESF	18,000
296-B-13	B690	221-BF, BCP Tanks	900
296-B-14	B678	221-B Vessel Vent	200

East Tank Farm Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate
296-A-12	E058	244-AR Vessel Vent 150 ft.	450
296-A-13	E052	244-AR Canyon	4,000
296-A-17	E059	A, AX, AY, AZ Tanks	4,000
296-A-18	E060	101 AY Annulus	1,200
296-A-19	E061	102 AY Annulus	1,000
296-P-1	E120	Tank 105-A	1,500
296-A-20	E197	AZ Annuli	2,000
296-A-21	E645	242-A Evaporator	16,000
296-A-22	E643	242-A Vessel Vent	600
296-A-25	E080	244-A Catch Tank	150
296-A-26	E297	204-AR Unloading Facility	2,000
296-A-27	E270	AW Tanks	1,100
296-A-28	E272	AW Annuli	4,600
296-A-29	E901	AN Tanks	900
296-A-30	E903	AN Annuli	5,000
296-B-28	E886	244-BX Saltwell Vessel	200
291-C-1	E073	201-C, 200 ft.	11,000
296-C-5	E069	244-CR Vault	3,000
296-P-16	E068	Tanks 105, 106-C	3,500
296-P-27	None	Tank 111-C	400

S-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-S-1	S006	202-S Canyon, 200 Ft	20,000
296-S-2	S032	202-S Sample Gallery	1,500
296-S-4	S008	202-S SWP Lobby	5,000
296-S-6	S004	202-S Silo	10,000
296-S-7E	S015	233-S Building Exhaust	8,500
296-S-7W	S016	233-S Building Exhaust	8,500
296-S-16	S264	218-S Tanks	200
296-S-21	S289	222-S Lab	70,000

T-Plant Stacks:

291-T-1	T785	221-T Canyon, 200 Ft	40,000
296-T-11	T783	224-T East	13,000
296-T-12	T784	224-T West	13,000
296-T-13	T786	221-T Roof	40,000
296-W-1	L100	Laundry	25,000

U-Plant Stacks:

296-U-1	U771	221-U Canyon, 200 ft	12,000
296-U-2	U133	Powder Handling Offgas	1,000
296-U-4	U777	224-U Calcinators	2,500
296-U-13	U878	224-U Load-out Room	4,500

Z-Plant Stacks:

Stack Number	EDP Code	Name	Typical High Flow Rate (cfm)
291-Z-1	Z810	234-5, 232-Z, 236-Z, 242-Z	240,000
296-Z-3	Z813	241-Z Sump & Vessel	1,300
296-Z-5	Z913	2736-ZB	10,000
296-Z-6	Z802	2736-ZA	12,000

West Tank Farm Stacks:

296-P-22	W191	SY Annuli	400
296-P-23	W190	SY Tanks	800
296-S-15	W111	SX Tanks	5,000
296-S-18	W096	242-S Building Exhaust	20,000
296-S-22	W880	244-S Salt Well Receiver	180
296-T-17	W117	242-T Cells	2,000
296-T-18	W882	244-TX Salt Well Receiver	200

Portable Exhausters:

296-P-6	4,000
296-P-25	1,000

END

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