Seven Health Physics Calculator Programs for the HP-41CV

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ABSTRACT

Several user-oriented programs for the Hewlett-Packard HP-41CV are explained. (This hand-held programmable calculator has alphanumeric display prompting that facilitates data input and continuous memory and simplifies field use.) The first program builds, stores, alters, and ages a list of radionuclides. This program only handles single- and double-decay chains. The second program performs convenient conversions for the six nuclides of concern in plutonium handling. The conversions are between mass, activity, and weight percents of the isotopes. The source can be aged and/or neutron generation rates can be computed. The third program is a timekeeping program that improves the process of manually estimating and tracking personnel exposure during high dose rate tasks by replacing the pencil, paper, and stopwatch method. This program requires a time module. The remaining four programs deal with computations of time-integrated air concentrations at various distances from an airborne release. Building wake effects, source depletion by ground deposition, and sector averaging can all be included in the final printout of the "X/Q - Hanford" and "X/Q - Pasquill" programs. The shorter versions of these, "H/Q" and "P/Q," compute centerline or sector-averaged values and include a subroutine to facilitate dose estimation by entering dose factors and quantities released. The horizontal and vertical dispersion parameters in the Pasquill-Gifford programs were modeled with simple, two-parameter functions that agreed very well with the usual textbook graphs.

CONTENTS

Introduction	1
Radionuclide Programs.	1
Radionuclide Decay Programs - "DK" and "DK*"	1
Plutonium Programs - "PU" and "NT".	2
Timekeeping Program.	2
Time-Integrated Air Concentrations	3
Emergency Response - "H/Q".	3
"X/Q - Hanford"	4
Emergency Response - "P/Q".	4
"X/Q - Pasquill".	4
Summary and Conclusions.	5
Bibliography	7
Appendixes:	
A. Radionuclide Decay Programs - "DK" and DK*"	A-1
B. Plutonium Programs - "PU" and "NT".	B-1
C. Timekeeping Program	C-1
D. Emergency Response - "H/Q".	D-1
E. "X/Q - Hanford"	E-1
F. Emergency Response - "P/Q".	F-1
G. "X/Q - Pasquill".	G-1

INTRODUCTION

The Hewlett-Packard HP-41CV is a hand-held calculator with over 120 built-in functions and 2.2 kb of random access memory. The calculator's memory is retained even when the calculator is turned off, so programs and data need not be read from cards or other storage media whenever the program is to be run. Further, the liquid crystal display can be used for alphanumeric messages of up to 24 characters, which allows the creation of highly user-oriented programs (i.e., programs that guide the user through the necessary data inputs and thereby reduce opportunities for input errors). The widespread use of this calculator, as well as a frequent need for programs of this type to prepare input to the shielding and dose computation computer codes used in radiological analyses by the Radiological Engineering and Effluent Controls group of Rockwell Hanford Operations, Richland, Washington, led to the creation of the radionuclide and time-integrated air concentration programs. The timekeeping program was developed in response to a request by a facility health physics staff member to improve the accuracy of the manual method used to estimate external dose. Timekeeping is the most reliable, though least accurate, dosimetric tool currently in use.

RADIONUCLIDE PROGRAMS

Computer codes used by the Radiological Engineering and Effluent Controls group for shielding design, dose rates through existing shielding, and environmental dose calculations all require careful input to obtain meaningful results. All of these codes lack in one or both of the following areas: (1) they cannot age the source initially or (2) they cannot accept plutonium inputs as either masses or activities or by weight percents, given the total mass. To speed the generation of accurate inputs, two HP-41CV programs were developed. The first is for fission product sources. The second is for plutonium sources. Accurate computation of daughter ingrowth is assured by use of the HP-41CV function ($e^X - 1$), which is particularly useful at short decay times.

RADIONUCLIDE DECAY PROGRAMS - "DK" AND "DK*"

This program builds a data base and allows for aging. The user-prompting inputs include the alphanumeric identity, half-life, initial quantity, and decay time. The menu for time units allows seconds, minutes, hours, days, or years. Once a data base is entered, the program gives the option of recording it on magnetic cards. If a data base was read from cards, the data entry portion of the program may be skipped. This program runs with or without a printer attached. Input data are displayed, or displayed and printed.

In the HP-41CV, enough memory is free to permit up to 73 radionuclides to be entered. Prior to data entry, the nuclides must be grouped by single- or double-decay kinds. Certain double-decay nuclides may be treated as single-decay types if equilibrium is already established. For example, in

the ^{90}Sr and ^{90}Y sequence, the pair should be treated as a two-step decay chain with a parent half-life of 28.6 yr, a branching ratio to ^{90}Y of 1.000, and a daughter half-life of 64 h. However, if the strontium were more than a few weeks old, the two could be treated as single decay nuclides, but both the ^{90}Sr and ^{90}Y would be assigned a half-life of 28.6 yr.

Further details on the radionuclide decay program are given in Appendix A. Included in the appendix are detailed program user instructions, a program flowsheet, and an annotated program listing. Program "DK*", which is described at the end of Appendix A, addresses the need to occasionally multiply all the initial activities by a constant factor to scale the source up or down.

PLUTONIUM PROGRAMS - "PU" AND "NT"

The program "PU" is designed first of all to facilitate weight percent, mass, and activity transformations among the six isotopes of concern in most plutonium handling: ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu , and ^{241}Am . Second, the program gives total curies of alpha and beta emitters, total mass, and total heat generation rates for the source. Third, the program permits the source to be aged and gives the amounts of the uranium isotopes which build in. Fourth, the program "NT" computes neutron generation rates (neutrons per second) produced from spontaneous fission and alpha-neutron reactions in five materials: oxide, nitrate, fluoride, carbide, or beryllium. The neutron production rates are computed for both the original source and the aged source (if aged). A sample printout is shown in Appendix B.

Detailed user instructions, data tables, a program flowsheet, and annotated program listings are found in Appendix B.

TIMEKEEPING PROGRAM

This program is designed to make the HP-41CV useful in estimating and tracking personnel exposure during high dose rate tasks. The calculator is wrapped in a thin plastic bag to protect it from contamination during field use. A "time module" is a required accessory for this program. Typically, an operator is assigned the task of estimating personnel dose using a stopwatch, pencil, and paper. The HP-41CV replaces these tools.

Program operation is in three parts: initialization, timekeeping, and final printout. During initialization, the program prompts the operator for alphanumeric input of up to five names or identification numbers. Once these are entered, the timekeeping portion begins. The buttons labeled A, B, C, D, and E are used to update the individual's dose rate. A new dose rate is entered, and the button for that individual is pressed. The calculator then computes the current total dose and displays it along with the current dose rate and button label (A through E). Two functions are available for use during timekeeping. The first is "STATIM," which allows the operator to compute how long it will take an individual to reach a

specified dose limit at a given dose rate. The second is "DVIEW," which cycles through the names initially entered and displays their current dose rate, button label, and accumulated total dose.

Once the task is complete, zero dose rates are entered to terminate dose accumulation. The dose totals can be read out at this time and recorded manually or a printer can be attached to obtain dose totals for each of the initially entered names as well as the total dose for the task.

Timekeeping is intended to be a fail-safe backup to the usual dosimetry equipment (e.g., self-reading pencils and thermoluminescent dosimeters). Concern that operators might become unable to track doses without a calculator has resulted in limited use of this tool.

Detailed program descriptions are found in Appendix C. Two versions of the program are described there: a version that optimizes speed and a version that minimizes program storage.

TIME-INTEGRATED AIR CONCENTRATIONS

These programs began as a simple improvement over the existing emergency response calculator program for the HP-67/97 and a dose estimation worksheet. The program "H/Q" replaced the four separate programs and included a subroutine to replace the worksheet. (Two advantages of the HP-41CV version over the HP-67/97 are alphanumeric prompting to minimize data entry errors and an option to view all the input data.) This program was expanded to enable ground deposition corrections and building wake effects. Finally, analogous programs using the Pasquill-Gifford (PG) turbulence classes were developed for the HP-41CV.

EMERGENCY RESPONSE - "H/Q"

As described in the preceding paragraph, "H/Q" permits computation of either sector-averaged or centerline time-integrated air concentrations and estimation of inhalation or submersion doses from the passing cloud. The program uses the usual gaussian plume model and Hanford dispersion parameters for very stable and moderately stable conditions. Sutton's form has been modified slightly; the vertical dispersion parameter (σ_z) is not allowed to exceed 2,000 m.

The dose computation requires entry of curies released and the appropriate dose factor for the isotope. The dose factors used already include a breathing rate and have units of (rem/Ci $\cdot$ m³/s).

Detailed user instructions, a flowsheet, and an annotated program listing are given in Appendix D.

"X/Q - HANFORD"

This program was developed to include ground deposition and building wake effects into the normalized, integrated exposure calculation. After considerable testing, a method to speed the numeric integration was developed. To integrate from 0 to X, the interval is divided into exponentially increasing segments (similar to a logarithmic scale on graph paper) and Simpson's rule is applied to each. Accuracy of the integral is better than 0.2% in all cases, and program running time is about 1 min per distance used.

Detailed user instructions, a sample of output, and an annotated program listing are given in Appendix E. The mathematical models used are also described there.

EMERGENCY RESPONSE - "P/Q"

For comparison with the Hanford model, the program "P/Q" was developed to compute time-integrated exposures for the usual PG classes A through F. Because the available formulas poorly represented the vertical dispersion parameter, a new set of parameterizations was developed. These agree with the PG curves to better than 10% over the entire length of the curves from 0.1 km to 100 km. Program "P/Q" does for the PG classes what "H/Q" does for the Hanford classes.

Detailed user instructions and an annotated program listing are given in Appendix F.

"X/Q - PASQUILL"

To complete the time-integrated air concentration program library, ground deposition and building wake effect had to be included in a version of "X/Q" which uses the PG classes. Because the parameterizations of the dispersion parameters lead to a source depletion integral that diverges with zero release height, the program uses a release height of 0.1 m whenever the input height is less than this.

Detailed user instructions, an annotated program listing, and the mathematical formulas used are included in Appendix G. A sample printout is also presented there.

SUMMARY AND CONCLUSIONS

Because the HP-41CV fits into a moderately sized pocket, it is a powerful tool for the workplace. In an office environment, the calculator can be a useful adjunct to larger computer systems that lack the immediate accessibility of a hand-held calculator. The seven programs described in this report, together with numerous other programs currently available, are evidence of the calculator's important function.

Future applications are dependent on future hand-held computing needs. One potential use for the calculator is in Radiation Protection Technologist dose rate logging at standard checkpoints within a facility. The technician would measure various dose rates at a given checkpoint and enter the location and the readings into an HP-41CV. The calculator would then be interfaced with a desk-top computer to store data and eventually process the data into summary and trend reports.

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APPENDIX A

RADIONUCLIDE DECAY PROGRAMS - "DK" AND "DK*"

USER INSTRUCTIONS: "DK"

- A. Load "DK" into the calculator (three cards), execute SIZE 225 or less. If nuclide data stored on magnetic cards will be used, SIZE according to what is on the cards then read the cards. Program "DK" will run with or without a printer attached.
- B. Press R/S to begin program execution. The program permits three methods to build and use a nuclide data base.
 1. Manually enter the nuclide data as it is prompted by the calculator. Enter the initial activities for each nuclide. Finally, enter the decay time and allow the program to compute the final activities.
 2. Read nuclide data from magnetic cards. Manually enter new initial activities. Then enter a decay time.
 3. Read nuclide data from cards and use the initial activities stored on the cards. Enter a decay time only.

On the flowsheet, the first option is presented with the "NEW SOURCE?" prompt. If only R/S is pressed, the second option is offered by means of the "NEW ACTIVITY?" prompt. If no entry is made and only R/S is pressed, the program goes to the third option and prompts for a decay time.

- C. Manual input of nuclide data is performed in the order described here. The program is designed to handle only single- and two-step decay chains. The number of nuclides which can be entered ranges up to 62 or 73, depending on the relative number of single and double decays.
 1. At the "NEW SOURCE?" prompt, enter any number and press "R/S". Alphanumeric labels and half-lives of nuclides that decay to stable daughters are requested first. The "NAME 1" prompt refers to the alphanumeric identification of the first nuclide, such as ^{134}Cs . Nuclides that are part of two-step decay chains, such as ^{90}Sr and ^{90}Y , should be entered later unless the user is confident that equilibrium is effectively reached (i.e., the ratio of the parent activity to the daughter activity is fixed, and both appear to decay with the half-life of the parent). If no single decay nuclides will be entered, press R/S and the program will go directly to the two-step decay chain prompts.
 2. For each nuclide, the alphanumeric identification is limited to a six-character maximum. The half-life is next, and is followed by a unit prompt. The available units are seconds (1), minutes (2), hours (3), days (4), or years (5). The program converts these to hours, computes a decay constant, and stores it together with the name.

3. When all single-decay nuclide data has been entered, the program will prompt for the next name. Simply press R/S and the program will begin with the two-step decay prompts. The first such prompt is "NAME PARENT" which refers to the alphanumeric identification of the first nuclide in a two-step decay chain. Possible types of decay chains are shown below.

NOTE: B.R. is the fraction of the decays of nuclide A in which nuclide B is the daughter.

(1-B.R.) is the fraction of the decays of A for which C results.

An example of "a" is $^{90}\text{Sr} \longrightarrow ^{90}\text{Y} \longrightarrow ^{90}\text{Zr}$

4. If no two-step chains will be entered, press only R/S; the program will go to the activity prompts. Otherwise, enter the name of the parent. After the parent half-life (and time unit) has been entered, the branching ratio of the parent to radioactive daughter will be prompted. Enter the correct value and press R/S. Last of all, enter the daughter identification and half-life.
5. When the final daughter is entered, the "NAME PARENT" prompt will again appear. Press only R/S; the program will begin prompting for the initial activities of each nuclide. If the initial activity of any isotope is zero, simply press R/S; zero will automatically be entered. Isotopes with zero activity will not be displayed (or printed, if the printer is attached).
6. Once the activity of the last isotope in the data base has been entered, the program will offer the option of recording this data base on cards. If desired, enter any number and press R/S. The calculator will prompt for the cards, track by track. After writing the cards, the program displays the memory size requirement for the data base. Record this on the cards for later reference.

- D. The final section of the program computes the activities remaining after a specified decay time. When the "DECAY TIME?" prompt appears, enter the desired decay period. The decay time prompt is followed by the unit menu. As before, select seconds, minutes, hours, days, or years. The final activities are computed and displayed/printed. Zero values of activity are neither displayed or printed. The formulas used to compute final activities are as follows:

$$A_1 = A_{10} e^{-\lambda_1 t}$$

$$A_2 = A_{20} e^{-\lambda_2 t} + \frac{(B.R.) A_{10} \lambda_2}{\lambda_2 - \lambda_1} (e^{-\lambda_1 t} - e^{-\lambda_2 t}) \quad \lambda_1 \neq \lambda_2$$

$$A_2 = A_{20} e^{-\lambda_2 t} + (B.R.) A_{10} \lambda_2 t e^{-\lambda_2 t} \quad \lambda_1 = \lambda_2$$

Note that negative decay times may be entered to compute the activities of some earlier time.

INSTRUCTIONS AND LISTING - "DK"

"DK": Common Multiplier for the "DK" Data Base

This program is designed to multiply each of the activities stored in the "DK" data base by a common number. User instructions are as follows.

1. Press GTO.. to pack memory; enter the card containing "DK."
2. To run "DK," press R/S or XEQ "DK."
3. At the "FACTOR = " prompt, enter the common multiplier and press R/S. In the absence of keyboard input, the multiplier used is unity.

4. If a printer is attached, the factor is printed along with each nonzero activity.
5. The last line of "DK*" returns it to "DK" where execution continues with the "NEW SOURCE?" prompt. If "DK*" will be used repetitively, the last line, GTO "DK," should be deleted.

NOTE: The constant multiplier is in the X register, the indirect address for the activities is in the Y register. Memory and flag usage is the same as it is in "DK."

LBL "DK"

END 85 BYTES

01+LBL "DK"

02 F 01

03 SCZ C

04 I

05 "FACTOR="

06 PROMPT

07 ARCL Y

08 AVIEW

09 RCL 02

10 X=0?

11 GTO 02

12 SF 00

13 X<>Y

14+LBL 00

15 CLA

16 ARCL IND Y

17 ISG Y

18 ISG Y

19 ST* IND Y

20 ARCL IND Y

21 X>0?

22 AVIEW

23 FS? 00

24 GTO 01

25 FS?C 01

26 GTO 01

27 ISG Y

28 SF 01

29+LBL 01

30 ISG Y

31 GTO 00

32 FC?C 00

33 GTO 03

34 ENTER+

35+LBL 02

36 X<>Y

37 RCL 03

38 X=0?

39 GTO 03

40 X<>Y

41 GTO 00

42+LBL 03

43 ADV

44 GTO "DY"

45 ENI

SAMPLE PROBLEM

SINGLE HALF-LIVES
 CS134 3.050E0 YP
 CS137 3.050E0 YP
 Ba137*4.72E0 YP
 SR90 2.00E1
 Y 90 2.00E1
 ZP95 4.34E1
 Nb95 6.60E1

TWO STEP HALF-LIVES
 SR90 2.00E1 YP
 B.R.= 1.00000
 Y 90 6.400E1 HP
 ZR95 6.400E1 HP
 B.R.= 1.00000
 Nb95 3.510E1 HP

CURIES
 CS134 1.000E1
 CS137 5.000E1
 Ba137*4.730E0
 SR90 2.000E1
 Y 90 1.900E1
 ZP95 6.000E1
 Nb95 8.000E1

SIZE = 37

FIRST, THE NAMES AND
 HALF-LIVES OF THE
 ISOTOPES ARE ENTERED.

THIRD, THE ACTIVITIES
 CAN BE AGED.

T= 3.000E1 DAY
 CS134 3.13E0
 CS137 4.09E0
 Ba137*4.72E0
 SR90 2.00E1
 Y 90 2.00E1
 ZP95 4.34E1
 Nb95 6.60E1

T= 3.000E1 YP
 CS134 3.93E-4
 CS137 2.51E0
 Ba137*2.38E0
 SR90 9.54E0
 Y 90 9.54E0
 ZR95 1.88E-50
 Nb95 4.16E-50

SECOND, THE INITIAL
 ACTIVITIES ARE
 ENTERED.

T= 3.000E2 YP
 CS134 8.85E-44
 CS137 5.11E-3
 Ba137*4.84E-7
 SR90 1.22E-2
 Y 90 1.22E-2

NOTICE THAT Zr-95 AND Nb-95
 HAVE DECAYED TO LESS THAN
 1.0 E-50 CI AND ARE NO
 LONGER PRINTED/DISPLAYED.

FINALLY, EACH INITIAL
 ACTIVITY IS MULTIPLIED
 BY A COMMON FACTOR.

FACTOR=2.00E0
 CS134 2.00E1
 CS137 1.00E1
 Ba137*1.00E0
 SR90 4.00E1
 Y 90 3.80E1
 ZP95 1.20E2
 Nb95 1.60E2

*YES FLOW PATHS ARE OBTAINED BY ENTERING ANY NUMBER AND PRESSING R/S. PRESSING R/S ALONE CAUSES EXECUTION ALONG THE NO FLOW PATHS.

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FIGURE 1. Flowsheet for Program "DK."

PROGRAM LISTING

```

LBL "D"
END      657 ENDS

01+LBL "D"
02 CF 01
03 CF 22
04 CF 29
05 "NEW SOURCE "
06 PROMPT
07 FS? 22 } NUMERIC INPUT
08 GTO 18 } MEANS NEW
09 "NEW ACT. ?" } ISOTOPES WANTED
10 PROMPT
11 FS? 22 } NUMERIC INPUT
12 GTO 20 } MEANS NEW
13 GTO 21 } ACTIVITIES
14+LBL 04 } DECAY EXISTING
15 AS U Y } DATA BASE
16 "S.M.H.D.Y=1.2 3"
17 "F.4.5"
18 PROMPT
19 CLA
20 ARCL 2
21 V Y
22 SCI 3
23 ARCL Y
24 XEQ IND Y
25 AVIEW
26 *
27 RTN
28+LBL 04 } APPENDS THE UNIT
29 "F DAY" } AND ENTERS THE
30 24 } CONVERSION
31 RTN } FACTOR TO HOURS
32+LBL 05
33 "F YR"
34 8760
35 RTN
36+LBL 07
37 "F HR"
38 1
39 RTN
40+LBL 02
41 "F MIN"
42 60
43 1
44 RTN
45+LBL 01
46 "F SEC"
47 3600
48 1
49 RTN
50+LBL 03
51 RCL IND 00
52 RCL 01
53 *
54 E1X
55 ISG 00
56 RCL IND 00
57 *
58 RTN
59+LBL 12 } COMPUTES A0-λt
60 ADV } NAME AND
61 "SINGLE HALF-LIFE" } HALF-LIFE
62 "FS" } ENTRY
63 FS? 55
64 PRP
65 1.2
66 STO 01
67 2
68 +
69 STO 00
70 STO 03
71 SF 00 } FLAG 0 SET FOR
72+LBL 19 } SINGLE DECAYS
73 FIX 0
74 CF 23
75 "NPME "
76 ARCL 01
77 ANH
78 PPROMPT
79 AOFF
80 FC? 27 } NO ALPHA INPUT
81 GTO 03 } MEANS LEAVE THIS
82 ISG 00 } LOOP
83 "F T1 2"
84 ASTO IND 00
85 PROMPT
86 XEQ 09
87 ISG 00
88 1
89 2
90 1
91 *
92 STO IND 00
93 ISG 01
94 FC? 21 } FLAG 1 IS SET WHEN
95 GTO 02 } DOING PARENT
96 FC? 00 } BOTH FLAGS ARE
97 GTO 01 } CLEAR WHEN DOING
98 ISG 0 } DAUGHTER
99 GTO 19
100+LBL 07
101 RCL 03
102 RCL 00
103 -
104 X=0? } TESTS FOR NO
105 GTO 06 } SINGLES/DOUBLES
106 RCL 00
107 INT
108 1 E2
109
110 RCL 03
111 ISG 0
112 INT
113 +
114+LBL 00
115 FC?C 00 } CLEARS FLAG 0 TO
116 GTO 00 } DO DOUBLE
117 STO 02 } DECAYS LATER
118 RCL 00 } SKIPS TO C1 ENTRY
119 STO 03
120 ADV
121 "TWO STEP HALF-LIFE"
122 "FVES"
123 FS? 55
124 PRP
125 GTO 04
126+LBL 01
127 ADV
128+LBL 04
129 SF 01 } FLAG 1 IS SET FOR
130 "PARENT" } THE PARENT ONLY
131 GTO 07
132+LBL 03
133 ISG 00
134 "BR. RATIO"
135 PPROMPT } BRANCHING RATIO
136 STO IND 00 } PROMPT
137 FIX 5
138 "B.P. = "
139 ARCL 2
140 AVIEW
141 "END"

```

PROGRAM LISTING

142+LBL 07	184 FTO 10	228 $\lambda=0$	} TESTS FOR A NULL SINGLE DECAY POINTER
143 ASTO 01	185 FCTO 00	229 GTO 07	
144 GTO 19	186 GTO 00	230 SF 00	
145+LBL 00	187+LBL 01	231+LBL 22	
146 STO 03	188 RCL 07	232 CLP	
147 CF 01	189 STO 00	233 ARCL IND 00	← RECALLS NAME
148+LBL 20	190 $\lambda=0$	234 ISG 00	
149 ADV	191 GTO 10	235 RCL IND 00	← RECALLS λ
150 SF 12	192+LBL 00	236 YEO 00	← $A_0 - \lambda t$
151 * COPIES	193 CF 22	237 FST 00	} SINGLE DECAYS
152 AVIEW	194 *RECORD DATA	238 GTO 02	
153 CF 12	195 PROMPT	239 ARCL λ	
154 SCI 2	196 FCT 22	240 $X=0$	} DOES NOT SHOW ZERO RESULTS
155 RCL 00	197 GTO 21	241 AVIEW	
156 STO 00	198 RCL 03	242 RCL IND 00	← RECALLS A_1
157 $\lambda=0$	199 $\lambda=0$	243 ISG 00	
158 GTO 01	200 RCL 00	244 RCL IND 00	← RECALLS B R
159 SF 00	201 FRC	245 *	
160+LBL 10	202 WDTA	246 ISG 00	
161 CLV	203 FIY 0	247 CLP	
162 CLP	204 ADV	248 ARCL IND 00	← NAME DAUGHTER
163 ARCL IND 00	205 1 E3	249 ISG 00	
164 $\lambda=0$ CI	206 *	250 RCL IND 00	← RECALLS λ_2
165 PROMPT	207 1	251 *	
166 2	208 +	252 $X=0$	} IF $A_1 = 0$, PROGRAM SKIPS THE BUILD UP CALCULATION
167 ST+ 00	209 *SIZE =	253 GTO 01	
168 $\lambda=0$	210 ARCL λ	254 R+	
169 ASTO	211 AVIEW	255 LASTV	
170 CLP	212 PSE	256 $X=Y$	} IF $\lambda_1 \neq \lambda_2$, GOES TO LBL 00
171 ARCL λ	213+LBL 21	257 GTO 00	
172 ARCL λ	214 ADV	258 RDN	
173 STO IND 00	215 CF 22	259 RCL 01	} FOR $\lambda_1 = \lambda_2$ $(A_1 * \lambda_2 t + A_2) e^{-\lambda_2 t}$ $A_1 * = A_1 (B R)$
174 $X=0$	216 *DECAY TIME	260 ST+ 2	
175 AVIEW	217 PROMPT	261 *	
176 FST 00	218 FCT 22	262 E+11	
177 GTO 00	219 GTO "D1"	263 ISG 00	
178 FST 01	220 $\lambda=0$	264 RCL IND 00	
179 GTO 00	221 YEO 00	265 RCL 2	
180 ISG 00	222 CHS	266 -	
181 SF 01	223 STO 01	267 *	
182+LBL 0	224 SF 21	268 GTO 02	
183 ISG 00	225 SCI 2		
	226 RCL 02		
	227 STO 00		

NEW ACTIVITY ENTRY (IN CI)

IF THE SINGLE DECAY POINTER IS ZERO, PROGRAM GOES TO LBL 01

0 IS IN THE X-REGISTER ALREADY

IF THE TWO-STEP POINTER IS ZERO, PROGRAM GOES TO LBL 00

TESTS FOR NUMERIC INPUT

RECORDS DATA FROM REGISTER 00 TO LAST REGISTER USED

COMPUTES NEEDED MEMORY SIZE FOR THIS DATA

NO NUMBER ENTRY → START OVER

UNITS

MAKES SURE EXECUTION STOPS WITHOUT PRINTER

SINGLE DECAYS GTO 00

FLAG 1 IS SET FOR THE DAUGHTER ONLY

PROGRAM LISTING

<u>269+LBL 00</u>	<u>289+LBL 02</u>	
270 X>Y?	290 ORCL X	} DOES NOT SHOW ZERO RESULTS.
271 X<Y	291 X>0?	
272 -	292 RVIEW	
273 LASTX	293 ISG 00	
274 RCL 01	294 GTO 22	
275 *	295 FC?C 00	} FLAG 1 IS NOT USED IN THIS LOOP.
276 E+X	296 GTO 00	
277 ST* Z	<u>297+LBL 03</u>	
278 RDN	298 PCL 03	
279 /	299 STO 00	
280 LASTX	300 X>0?	
281 RCL 01	301 GTO 22	
282 *	<u>302+LBL 00</u>	
283 E+X-1	303 ADV	
284 *	304 FC? 55	
285 CHS	305 CF 21	
<u>286+LBL 01</u>	306 GTO 21	
287 XE0 00	307 END	
288 +		

Daughter buildup computed as follows:

$$\begin{aligned}
 \lambda_1 > \lambda_2: & \frac{A_1 * \lambda_2 e^{-\lambda_2 t}}{\lambda_1 - \lambda_2} \begin{bmatrix} e^{-(\lambda_1 - \lambda_2)t} & -1 \end{bmatrix} \\
 \lambda_2 > \lambda_1: & \frac{A_1 * \lambda_2 e^{-\lambda_1 t}}{\lambda_2 - \lambda_1} \begin{bmatrix} e^{-(\lambda_2 - \lambda_1)t} & -1 \end{bmatrix}
 \end{aligned}$$

MEMORY USE:

00: Pointer in use
 01: Negative decay time
 02: Single-decay pointer
 03: Two-step pointer

FLAG USE:

00: Single-decay nuclides
 01: Two-step decays

RHO-HS-ST-5 P

APPENDIX B

PLUTONIUM PROGRAMS - "PU" and "NT"

USER INSTRUCTIONS

- A. Load "PU" by executing SIZE 081, reading in the data cards (3 tracks), and finally reading in the program cards (10 tracks). The printer is required for program execution. Place the print mode switch in the "MAN" position.
- B. XEQ "PU" (or just press R/S after reading the cards). The first prompt, "%, M, OR AC ?," requires the user to inform the program whether the initial data to be entered is the weight percents, masses, or activities of the various isotopes. Use the alpha keyboard to enter either "%", "M", or "AC." Press R/S; the program will begin prompting for the appropriate data entries. Enter the data requested and press R/S. Zeroes will automatically be entered if no other number is input.
- C. After printing tables of the initial percent, mass, and activities; the program prompts for a decay time in years. If no decay is desired, enter nothing; press R/S. If decay is desired, enter the decay time, in years, and press R/S. After printing tables of the final percent, masses, and activities; the program prompts for a second decay time. If a second set of tables is desired, enter the appropriate number of years and press R/S. (The decay time may be negative to compute masses and activities of an earlier date.) If a second decay time is not desired, simply press R/S.
- D. The next option allows one to keep the initial weight percents, but adjust the total mass of Pu plus Am. To change the total mass, enter the new mass and press R/S. To go to the next option, enter nothing; press R/S.
- E. The program now asks where to go next. The menu is displayed:
 "PU, AGE, M2, NT."
 "PU" - Starts the program from the beginning (see instruction A).
 "AGE" - Prompts for a decay time to age the source (see instruction D).
 "M2" - Prompts for a new total mass (see instruction E).
 "NT" - Permits computation of neutron production rates for various compounds; however, this program is separate from the present, and must be loaded into the calculator (see instruction F).
- F. User Instructions for "NT."
 1. Press GT0.. to pack memory; enter the two cards containing "NT." It is not necessary that "PU" be in the calculator, but it is imperative that "PU" has been run so that the proper data base has been created.

2. XEQ NT and the program prompts for the chemical form of the plutonium: "O2, NO3, F4, C, Be?". To request oxide, for example, enter "0" and "2" from the alpha keyboard and press R/S. If bare metal is of interest, enter any chemical form and just ignore the alpha-neutron result in the neutron production rate.
3. The program returns to the chemical form menu. If no additional forms need to be computed, press R/S and the program will return to the "PU" program at the menu prompt discussed in instruction E.

SAMPLE PROBLEM

* PU DECAY *
REV 3 2-12-84

NAME	%	GRAMS
PU238	16.667	1.000+03
PU239	16.667	1.000+03
PU240	16.667	1.000+03
PU241	16.667	1.000+03
PU242	16.667	1.000+03
AM241	16.667	1.000+03
GRAMS TOTAL		6.000+03
TOTAL WATTS:		6.963+02

SELECT MASS
INPUT AND ENTER
1000 g FOR EACH.

NAME	CURIES
PU238	1.713+04
PU239	6.201+01
PU240	2.269+02
PU241	1.031+05
PU242	3.933+00
AM241	3.434+00
TOTAL ALPHA:	2.085+04 CI
TOTAL BETA:	1.031+05 CI

10.0 YEARS ← ENTER 10 yr
DECAY TIME.

NAME	CURIES
U 234	4.668-01
U 235	6.107-07
U 236	6.712-05
NP237	1.332-02
PU238	1.582+04
PU239	6.200+01
PU240	2.266+02
PU241	6.369+04
PU242	3.933+00
AM241	4.680+03
U 237	1.560+00
TOTAL ALPHA:	2.080+04 CI
TOTAL BETA:	6.369+04 CI

NAME	%	GRAMS
U 234	1.245	7.467+01
U 235	0.005	2.824-01
U 236	0.017	1.037+00
NP237	0.315	1.888+01
PU238	15.405	9.240+02
PU239	16.667	9.997+02
PU240	16.654	9.985+02

PU241 10.302 6.179+02
PU242 16.671 1.000+03
AM241 22.720 1.363+03
GRAMS TOTAL 5.998+03
TOTAL WATTS: 6.930+02

NO CHANGE IN
TOTAL MASS AT
THIS TIME; GO TO
"NT" AND CHOOSE
"02".

PuO2 n/sec
 α -n 1.626+E7
S-F 5.344+05
Total 2.161+07

AFTER 10.0 YEARS
 α -n 1.622+07
S-F 5.145+06
Total 2.136+07

PRESS N/S ONLY AND
PROGRAM RETURNS TO
MAIN MENU. GO TO
"M2" AND INPUT 287.8 g
TO OBTAIN A 1000 CI
TOTAL ALPHA ACTIVITY.

NEW TOT MASS

NAME	%	GRAMS
PU238	16.667	4.797+01
PU239	16.667	4.757+01
PU240	16.667	4.797+01
PU241	16.667	4.797+01
PU242	16.667	4.797+01
AM241	16.667	4.797+01
GRAMS TOTAL		2.878+02
TOTAL WATTS:		3.340+01

NAME	CURIES
PU238	8.215+02
PU239	2.975+00
PU240	1.088+01
PU241	4.943+03
PU242	1.886-01
AM241	1.647+02
TOTAL ALPHA:	1.000+03 CI
TOTAL BETA:	4.943+03 CI

1000 CI TOTAL
ALPHA ACTIVITY.

GO TO "NT" AND
CHOOSE PuF₄ THIS TIME.
NOTICE THE AGED
ACTIVITIES ARE GONE.

PuF4 n/sec
 α -n 1.189+05
S-F 2.564+05
Total 1.192+08

PS8408-68

FIGURE 2. Flowsheet for Program "PU."

TABLE 1. Isotope Data Used by "PU".

Isotope	Isotopic mass	Half-life	% SF*	Ci/g	g/Ci	W/g	W/Ci
²³⁸ Pu	238.052	8.775 E+01 yr	1.84 E-07	1.713 E+01	5.839 E-02	54.687 E-02	.0332
²³⁴ U	234.041	2.445 E+05 yr	0.12 E-08	6.252 E-03	1.600 E+02	1.801 E-04	.0288
²³⁹ Pu	239.052	24.131 E+03 yr	0.44 E-09	6.201 E-02	1.613 E+01	1.929 E-03	.0311
²³⁵ U	235.044	7.038 E+08 yr	0.20 E-06	2.163 E-06	4.624 E+05	5.818 E-08	.0269
²⁴⁰ Pu	240.054	6.569 E+03 yr	4.95 E-06	2.269 E-01	4.408 E+00	7.055 E-03	.0311
²³⁶ U	236.046	23.414 E+06 yr	0.12 E-06	6.472 E-05	15.450 E+03	1.754 E-06	.0271
²⁴¹ Pu	241.057	0.144 E+02 yr		1.031 E+02	9.703 E-03	0.423 E-02	.000041
²³⁷ U	237.049	0.675 E+01 day		8.16 E+04	1.225 E-05	0.384 E+03	.0047
²⁴¹ Am	241.057	4.322 E+02 yr	3.77 E-10	3.434 E+00	2.912 E-01	1.143 E-01	.0333
²³⁷ Np	237.048	0.214 E+07	0.20 E-09	7.052 E-04	1.418 E+03	2.024 E-05	.0287
²⁴² Pu	242.059	3.758 E+05 yr	0.55 E-03	3.933 E-03	2.543 E+02	1.160 E-04	.0295
²³⁸ U	238.051	4.468 E+09 yr	0.55 E-04	3.363 E-07	2.973 E+06	0.851 E-08	.0253

*%SF = the percent of decays that undergo spontaneous fission.

TABLE 2. Neutron (n) Yields Used by "NT" Program.

Isotope	Spontaneous		Oxide		Fluoride		Carbide		Beryllium		Alpha energy (MeV)
	n per g/s	n per Ci/s	n per g/s	n per Ci/s	n per g/s	n per Ci/s	n per g/s	n per Ci/s	n per g/s	n per Ci/s	
²³⁸ Pu	26.20 E+02	1.53 E+02	13.400 E+03	782	2.04 E+06	0.191 E+06	14.900 E+03	870	4.38 E+07	2.557 E+06	5.50
²³⁴ U	0.58 E-02	0.92 E+00									4.78
²³⁹ Pu	0.28 E-01	0.45 E+00	0.380 E+02	613	63.50 E+02	1.024 E+05	0.373 E+02	601	1.36 E+05	2.192 E+06	5.15
²³⁵ U	0.33 E-03	1.53 E+02									4.4
²⁴⁰ Pu	10.20 E+02	45.00 E+02	0.145 E+03	639	23.50 E+03	1.036 E+05	0.138 E+03	608	5.02 E+05	2.213 E+06	5.17
²³⁶ U	0.58 E-02	0.90 E+02									4.49
²⁴² Pu	17.00 E+02	4.33 E+05	0.213 E+01	542	2.83 E+02	7.205 E+04	0.209 E+01	532	60.70 E+02	1.543 E+06	4.90
²⁴¹ Am	0.11 E+01	0.33 E+00	2.680 E+03	782	4.09 E+05	1.190 E+05	2.980 E+03	869	8.77 E+06	2.555 E+06	5.49

PROGRAM LISTING

LBL *PU

END 1013 BYTES

01+LBL *PU*

02 SF 12

03 ADV

04 * PU DECAY *

05 PRA

06 CF 12

07 CLX

08 STO 07

09 CF 29

10 4

11 SKPCHR

12 *REV 3*

13 ACA

14 SKPCHR

15 *2-12-84*

16 ACA

17 PRBUF

18 *%, M, OR AC ?*

19 AON

20 PROMPT

21 AOFF

22 XEQ 25 ← INITIALIZES
POINTERS.

23 SF 00

24 ASTO X

25 GTO IND X

26+LBL *M* ← MASS INPUTS.

27 CLX

28 STO 08

29+LBL 00

30 *GRAMS *

31 ARCL IND 00

32 PROMPT

33 STO IND 04

34 ST+ 08

35 ISG 00

36 CLX

37 ISG 04

38 GTO 00

39 XEQ 25

40 XEQ 26

41 GTO 21

42+LBL *%* ← WT% INPUTS.

43 ADV

44 CLA

45 ARCL 06

46 *+GRAMS?*

47 PROMPT

48 STO 08

49 CLX

50 STO 05

51 FIX 3

52+LBL 01

53 * % *

54 ARCL IND 00

55 PROMPT

56 STO IND 03

57 ST+ 05

58 ISG 00

59 CLX

60 ISG 03

61 GTO 01

62 * *

63 ARCL 06

64 *+%: *

65 ARCL 05

66 PRA

67+LBL 20 ← COMPUTES MASSES
AND TOTAL HEAT
OUTPUT FROM
INPUT %'s AND
TOTAL MASS.

68 XEQ 25

69 XEQ 28

70 CLX

71 STO 05

72+LBL 02

73 FIX 3

74 CLA

75 ARCL IND 00

76 RCL 08

77 RCL IND 03

78 10

79 X>Y?

80 *+ *

81 RDN

82 ARCL X

83 *+ *

84 %

85 STO IND 04

86 SCI 3

87 XEQ 14 ← PRINTS TABLE.

88 RCL IND 02

89 *

90 ST+ 05

91 ISG 00

92 ISG 02

93 ISG 03

94 CLX

95 ISG 04

96 GTO 02

97 XEQ 27

98+LBL 21← COMPUTES
ACTIVITIES
FROM MASS.

99 XEQ 25

100 XEQ 29

101 CLX

102 STO 02

103+LBL 03

104 * *

105 ARCL IND 00

106 *+ *

107 RCL IND 04

108 RCL IND 01

109 *

110 RCL 09

111 *

112 224.03

113 RCL 00

114 ISG 00

115 GTO 10

116 RDN

117 17

118+LBL 10

119 +

120 /

121 STO IND 05

122 ST+ 02

123 XEQ 14 ← PRINTS.

124 ISG 01

125 ISG 04

126 ISG 05

127 GTO 03

128 RCL 78

129 XEQ 30

130 GTO 22

131+LBL *AC* ← ACTIVITY INPUTS.

132 XEQ 29

133 CLX

134 STO 02

135 SCI 3

136+LBL 04

137 * C1 *

138 ARCL IND 00

139 PROMPT

140 STO IND 05

141 ST+ 02

142 * *

143 ARCL IND 00

144 *+ *

145 XEQ 14 ← PRINTS.

146 ISG 05

147 CLX

PROGRAM LISTING

```

148 CLA
149 ISG 00
150 GTO 04
151 RCL 78
152 XEQ 30
153 XEQ 25
154 XEQ 31
155 XEQ 25
156 XEQ 26
157+LBL 22
158+LBL "AGE"
159 ADV
160 CF 22
161 "YEARS DECAY?"
162 PROMPT
163 FC? 22
164 GTO "M2"
165 CF 00 ← FLAG 00. CLEARED
             IF SOURCE IS AGED.
166 FIX 1
167 95
168 X/Y?
169 FIX 0
170 RDN
171 ADV
172 ASTO L
173 CLA
174 SF 12
175 ARCL X
176 "+ "
177 ARCL L
178 PRA
179 CF 12
180 CHS
181 STO 07
182 XEQ 25
183 SCI 3
184 10.01
185 ST+ 02
186+LBL 05
187 RCL IND 01
188 RCL 07
189 *
190 E+X
191 RCL IND 05
192 *
193 STO IND 02
194 ISG 01
195 ISG 02
196 ISG 05
197 GTO 05
198 RCL 31
199 RCL 49

```

As -It COMPUTED
AND STORED.

```

200 *
201 STO 52 ← A1 U-237
202 RCL 30
203 RCL 24
204 XEQ 23
205 STO 45
206 RCL 28
207 RCL 24
208 XEQ 23
209 RCL 45
210 -
211 CHS
212 RCL 28
213 RCL 30
214 -
215 LASTX
216 /
217 /
218 RCL 78
219 *
220 RCL 45
221 RCL 80
222 *
223 +
224 STO 45 ← A1 Hp-237
225 RCL 25
226 RCL 21
227 XEQ 23
228 RCL 75
229 *
230 STO 42 ← A1 U-234
231 RCL 26
232 RCL 22
233 XEQ 23
234 RCL 76
235 *
236 STO 43 ← A1 U-235
237 RCL 27
238 RCL 23
239 XEQ 23
240 RCL 77
241 *
242 STO 44 ← A1 U-236
243 RCL 28
244 RCL 30
245 XEQ 23
246 RCL 78
247 *
248 ST+ 51 ← A1 Am-241
249 XEQ 29
250 XEQ 24
251 .001

```

PROGRAM LISTING

252 ST+ 00	269 XEQ 30	286 CF 12
253 CLX	270 XEQ 24	287 CLX
254 STO 02	271 XEQ 31	288 STO 07
255+LBL 06 ← PRINTS FINAL ACTIVITY TABLE.	272 XEQ 24	289 GTO 20
256 " "	273 XEQ 26	290+LBL 10
257 ARCL IND 00	274 GTO 22	291+LBL "Σa"
258 "t"	275 ADV	292 ADV
259 RCL IND 05	276+LBL "M2"	293 "PU, AGE, M2 NT"
260 XEQ 14	277 CF 22	294 AON
261 ST+ 02	278 "NEW TOT MASS"	295 PROMPT
262 ISG 00	279 PROMPT	296 AOFF
263 CLX	280 FC? 22	297 ASTO X
264 ISG 05	281 GTO 10	298 GTO IND X
265 GTO 06	282 STO 08	299+LBL 23 ← COMPUTES $\frac{\lambda_2 e^{-\lambda_2 t}}{\lambda_1 \lambda_2} (1 - e^{-(\lambda_1 + \lambda_2)t})$
266 RCL 52	283 ADV	300 -
267 RCL 49	284 SF 12	301 LASTX
268 +	285 PRA	302 LASTX
		303 RCL 07

Formulas Used:

$$A_1 = A_{10} e^{-\lambda_1 t}$$

$$A_2 = A_{20} e^{-\lambda_2 t} + \frac{\lambda_2 A_{10}}{\lambda_1 - \lambda_2} (e^{-\lambda_2 t} - e^{-\lambda_1 t})$$

$$A_3 = \frac{\lambda_2 A_{10}}{\lambda_1 - \lambda_2} \left[\frac{\lambda_3}{\lambda_2 - \lambda_3} (e^{-\lambda_3 t} - e^{-\lambda_2 t}) - \frac{\lambda_3}{\lambda_1 - \lambda_3} (e^{-\lambda_3 t} - e^{-\lambda_1 t}) \right] + \frac{\lambda_3 A_{20}}{\lambda_2 - \lambda_3} (e^{-\lambda_3 t} - e^{-\lambda_2 t})$$

PROGRAM LISTING

304 *	358 10	410 ADV
305 E1Y	359 PCL IND 04	411 3
306 *	360 RCL 06	412 SKPCHR
307 X<Y	361 /	413 *NAME CURIE"
308 /	362 RCL 01	414 ACP
309 LASTY	363 *	415 PRBUF
310 PCL 07	364 FS? 00	416 RTN
311 *	365 STO IND 03	<u>417*LBL 30</u>
312 E+Y-1	366 RND	418 ST- 02
313 CHS	367 X\Y?	419 CLA
314 *	368 "t "	420 ARCL 06
315 RTN	369 .001	421 "tALPHA "
<u>316*LBL 24</u>	370 X\Y	422 RCL 02
317 10.019	371 X\Y?	423 XEQ 10
318 XEQ 10	372 CLX	424 CLA
319 LASTX	373 ARCL Y	425 ARCL 06
320 +	374 "t "	426 "tBETA "
321 1	375 SCI 2	427 X<Y
322 -	376 RCL IND 04	<u>428*LBL 10</u>
323 STO 03	377 XEQ 14	429 ACA
324 STO 05	378 RCL IND 02	430 ACX
325 53.062	379 *	431 " CI"
326 STO 04	380 ST+ 05	432 ACA
327 RTN	381 ISG 00	433 PPBUF
<u>328*LBL 25</u>	382 ISG 02	<u>434 RTN</u>
329 75.08	383 ISG 03	<u>435*LBL 31</u>
330 STO 05	384 CLX	← COMPUTES MASS FROM ACTIVITY
331 6.00E	385 ISG 04	436 CLY
332 -	386 GT0 07	437 STO 08
333 STO 04	<u>387*LBL 27</u>	438*LBL 08
334 LASTX	388 "GRAMS "	439 RCL IND 05
335 -	389 ARCL 06	440 RCL IND 01
336 STO 03	390 RCL 00	441
337 14.019	391 XEQ 14	442 RCL 09
338*LBL 10	392 CLA	443 /
339 STO 06	393 ARCL 06	444 224.03
340 11.011	394 "tWATTS "	445 RCL 00
341 +	395 RCL 05	446 ISG 00
342 STO 01	<u>396*LBL 14</u>	447 GT0 10
343 LASTX	397 Y=0?	448 RDN
344 +	398 PTN	449 17
345 STO 02	399 ACA	<u>450*LBL 10</u>
346 PTN	400 ACY	451 +
<u>347*LBL 26</u>	401 PPBUF	452 *
348 XEQ 26	402 RTN	453 STO IND 04
349 CLY	<u>403*LBL 20</u>	454 ST+ 08
350 STO 05	404 ADV	455 ISG 01
351 0	405 " NAME "	456 ISG 05
352 104X	406 "tGRAMS"	457 ISG 04
353 STO 01	407 PFG	458 GT0 08
354*LBL 07	408 PTN	459 PTN
355 CLP	<u>409*LBL 09</u>	460 END
356 ARCL IND 00		
357 F1Y ?		

INITIALIZES
FULL MEMORY
POINTERS

INITIALIZES
DATA INPUT
POINTERS

COMPUTES %
FROM MASS AND
PRINTS % AND
MASS TABLE

COMPUTES MASS
FROM ACTIVITY

MEMORY USE:

00: Name
 01: λ
 02: W/g
 03: %
 04: M
 05: A
 06: "TOTAL "
 07: -age
 08: Total mass
 09: 5.161+05

FLAG USE:

00: Set for data entry; cleared for aging.
 01: Set to indicate $\text{Pu}(\text{NO}_3)_2$.
 02: Set when computing aged n/s.

LABEL 25

00: 14.019
 01: 25.030
 02: 36.041
 03: 63.068
 04: 69.074
 05: 75.080

LABEL 24

00: 10.019
 01: 21.030
 02: 32.041
 03: 42.052
 04: 53.062
 05: 42.052

Name	$\lambda (\text{yr}^{-1})$	W/g	A _f	M _f				
10: "U 234 "	21: 2.835-06	32: 1.801-04	42:	53:				
11: "U 235 "	22: 9.849-10	33: 5.818-08	43:	54:				
12: "U 236 "	23: 2.960-08	34: 1.754-06	44:	55:				
13: "NP237 "	24: 3.239-07	35: 2.024-05	45:	56:	%	M _O	A _O	
14: "PU238 "	25: 7.899-03	36: 5.687-01	46:	57:	63:	69:	75:	
15: "PU239 "	26: 2.872-05	37: 1.929-03	47:	58:	64:	70:	76:	
16: "PU240 "	27: 1.055-04	38: 7.055-03	48:	59:	65:	71:	77:	
17: "PU241 "	28: 4.814-02	39: 4.230-03	49:	60:	66:	72:	78:	
18: "PU242 "	29: 1.844-06	40: 1.160-04	50:	61:	67:	73:	79:	
19: "AM241 "	30: 1.604-03	41: 1.143-01	51:	62:	68:	74:	80:	
20: "U 237 "	31: 2.450-05		52:					

LBL *NT

END 400 ENTER

01*LBL "NT"		53*LBL "NO3" ← Pu(NO ₃) ₂		106 SF 02	
02 CF 01		54 SF 01		107 FIX 1	
03 CF 02		55*LBL "O2" ← PuO ₂		108 " AFTER "	
04 CF 23		56 782		109 CHS	
05 "O2,NO3,F4	MENU.	57 613		110 ARCL Y	
06 RDN		58 639		111 "+ YEARS"	
07 PROMPT		59 542		112 PRA	
08 ROFF		60 XEQ 34		113 SCI 3	
09 FC? 23		61 ENTER+		114 SF 12	
10 GTO "Σa"	NO ALPHA ENTRY → RETURN TO "Pu".	62 FS? 01		115 46.1	PUTS FINAL ACTIVITIES IN REGISTERS 69 TO 74.
11 SCI 3		63 +		116*LBL 33	
12 ASTO 03		64*LBL 09		117 STO 05	
13 SF 12		65 4		118 69.074	
14 "P"		66 ACCHP		119 STO 04	
15 ACA		67 RDN		120*LBL 11	
16 117		68 "-N "		121 RCL IND 05	
17 ACCHP		69 SF 13		122 STO IND 04	MOVES INITIAL OR FINAL ACTIVITIES.
18 CLA		70 XEQ 35	PRINTS α-n RESULT.	123 ISG 05	
19 ARCL 03		71 SF 12		124 ISG 04	
20 ACA		72 "S-F "		125 GTO 11	
21 SF 13		73 RCL -69		126 "C"	
22 " N/SEC"		74 153		127 ASTO X	
23 ACA		75 *		128 RCL 03	
24 PRBUF		76 RCL 70		129 X=Y?	
25 75.1	PUTS INITIAL ACTIVITIES IN REGISTERS 69 AND 74.	77 .45		130 GTO 32	
26 GTO 33		78 *		131 GTO IND X	
27*LBL 32	← PuC.	79 +		132*LBL 34	← COMPUTES α-n RATE.
28 870		80 RCL 71		133 STO 02	
29 601		81 4497	SPONTANEOUS FISSION n/sec COMPUTATION.	134 RDN	
30 606		82 *		135 RCL 71	← Pu-240.
31 532		83 +		136 *	
32 XEQ 34		84 RCL 73		137 X>Y	
33 GTO 09		85 433 E3		138 RCL 70	← Pu-239.
34*LBL "Be"	← PuBe.	86 *		139 *	
35 255.7		87 +		140 +	
36 219		88 RCL 74		141 X<>Y	
37 221		89 .33		142 RCL 69	← Pu-238.
38 154.3		90 *		143 RCL 74	← Am-241.
39 XEQ 34		91 +		144 +	
40 4		92 XEQ 35	← PRINTS S-F RESULT.	145 *	
41 10*X		93 +		146 +	
42 *		94 SF 12		147 RCL 02	
43 GTO 09		95 "T"		148 RCL 73	← Pu-242.
44*LBL "F4"	← PuF ₄ .	96 ACA		149 *	
45 1191		97 "OTAL "		150 +	
46 1024		98 SF 13		151 RTN	← PRINTING SUBROUTINE.
47 1036		99 XEQ 35	← PRINTS TOTAL n/sec RESULT.	152*LBL 35	
48 720		100 ADV		153 ACA	
49 XEQ 34		101 RCL 07		154 CF 12	
50 100		102 FS? 02		155 CF 13	
51 *		103 CLX		156 ACX	
52 GTO 09		104 X=0"		157 PRBUF	
		105 GTO "NT"		158 END	

RHO-HS-ST-5 P

APPENDIX C

TIMEKEEPING PROGRAM

USER INSTRUCTIONS

1. XEQ SIZE 100; switch to USER mode. (Actually, the allowed memory size ranges from 021 to 215; using SIZE 100 is just a suggestion.) Read in the cards. The calculator must be in USER mode during card entry to read the USER mode assignments given to the first and third rows of keys.
2. XEQ "INITIAL" (or switch to USER mode and press shift STO). This subroutine zeroes the storage registers and then requests alphanumeric input for up to five names or identification numbers. Six characters are the maximum permitted in each. Press R/S after entering each name. If fewer than five names are needed, simply press R/S (before pressing any other key) when the next name is prompted for. The "* READY *" display indicates that all the names entered have been stored and the calculator is ready for use as a timekeeping tool.
2. Record each individual's dose rate, in mR/h (or mrad/h) by using the number keys to enter the number and then pressing the A, B, C, D, or E key in the top row. The calculator displays the most recent dose rate entry and the individual's accumulated dose in the following format.

dose rate, mR/h (A, B, C, D, or E) dose, mR

The number to the left is the current dose rate; the number to the right is the accumulated dose rate.

4. Once the dose rate is stored, the accumulated dose is not updated until a new dose rate is entered or the A, B, C, D, or E key is pressed with no number entry. To facilitate these updates, the subroutine "DVIEW" was created. Simply press shift XEQ and the calculator will automatically update and display each individual's dose. To remove the calculator from the repeating loop, simply press R/S.
5. When the work is complete, enter zero dose rate for each person.
6. Final doses may be obtained by pressing shift XEQ. The current dose rate should be zero. To obtain a final total listing by name and the total for the group, press shift RCL. If the printer is attached, the date and day of the week will also be printed. See the sample printout.
7. To facilitate stay time computations, there is a subroutine called "STATIM," which may be executed at any time by pressing shift SST. The calculator prompts for the dose limit; enter this and press R/S. Then the 41-CV prompts for the dose rate; enter this and press R/S. The calculator then computes the number of minutes it will take to reach the dose limit if the person stays in that dose rate.

MEMORY USE:

00: A
01: B Time
02: C storage
03: D registers.
04: E

05: A
06: B Dose rate
07: C storage
08: D registers.
09: E

10: A
11: B Accumulated
12: C dose storage
13: D registers.
14: E

15: A
16: B Alphanumeric
17: C name storage
18: D registers.
19: E

20: Total Dose

FLAG USE:

F 05 Set if no A.
F 06 Set if no B.
F 07 Set if no C
F 08 Set if no D.
F 09 Set if no E.

USUAL FINAL PRINTOUT:

FRIDAY 09/07/1991

FINAL DOSES

NANCY 60mR
BETSY 89mR
EL 14mR
GEORGE 9mR
JANE 116mR

TOTAL= 311mR

SAMPLE CASE:

NAMES 6 LETTERS MAX ← XEQ "INITIAL"
SUE (IN USER MODE
RALPH PRESS SHIFT AND
PAUL STO).

3600 <A> 0 ← (NO 4TH AND 5TH
3600 0 INDIVIDUALS).
3600 <C> 0 ENTER 3600, PRESS B.
← ENTER 3600, PRESS C.
XEQ "DVIEW" (PRESS
SHIFT AND XEQ).

3600 <A> 14
3600 13
3600 <C> 12

3600 <A> 23
3600 22
3600 <C> 22

3600 <A> 33
3600 32
3600 <C> 31

3600 <A> 42
3600 41
3600 <C> 41 ← PRESS R/S, THEN
ENTER 7200 mR/hr
AND PRESS B.

7200 61 ← XEQ "DVIEW" AGAIN.

3600 <A> 61
7200 79
7200 <C> 69

0 <A> 85 ← PRESS R/S.
0 130
0 <C> 101 } ENTER 0 mR/hr AND
PRESS A,B,C.
1800 130 ENTER 1800 mR/hr,
PRESS B.

FRIDAY 09 00 ← XEQ "PRODOSE"
(PRESS SHIFT AND
RCL).

FINAL DOSES

SUE 85mR
RALPH 130mR
NOT ZEROED
PAUL 101mR
TOTAL= 316mR

THIS MESSAGE
INDICATES THAT THE
DOSE RATE FOR RALPH
(B) WAS NOT ZERO
WHEN PRODOSE WAS
EXECUTED. THUS,
RALPH'S ACTUAL DOSE
ESTIMATE IS SOMEWHAT
HIGHER, DEPENDING ON
HOW LONG HE
ACTUALLY WAS IN THE
LAST DOSE RATE
ENTERED OR UPDATED.

PROGRAM LISTING

```

LBL "INITIAL
LBL "DVIEW
LBL "STATIM
LBL "AA
LBL "BB
LBL "CC
LBL "DD
LBL "EE
LBL "PRDO

```

END 723 BYTES

01*LBL "INITIAL"

```

02 CLRG
03 CF 12
04 CF 29
05 FIX 0
06 "NAMES: 6 "
07 "LETTERS MAX"
08 BEEP
09 AVIEW
10 PSE
11 CF 12
12 "A"
13 ASTO 15
14 SF 05
15 "B"
16 ASTO 16
17 SF 06
18 "C"
19 ASTO 17
20 SF 07
21 "D"
22 ASTO 18
23 SF 08
24 "E"
25 ASTO 19
26 SF 09
27 15.019
28 AON
29 5
30*LBL 10
31 CF 23
32 "I.D. OF "
33 RCL IND 1

```

INITIALIZES
NAME INPUTS.

```

34 PROMPT
35 FC? 23
36 GTO 00
37 " "
38 ASTO IND Y
39 FS? 55
40 PRA
41 CF IND X
42 1
43 +

```

CLEAR A FLAG
FOR EACH NAME
ENTERED.

```

44 ISG Y
45 GTO 10
46*LBL 00
47 AOFF
48 ADV
49 " * READY *"
50 SF 27
51 PROMPT

```

52*LBL "DVIEW" DOSE UPDATING
LOOP.

```

53 CF 22
54*LBL 11
55 ADV
56 XEQ "AA"
57 PSE
58 XEQ "BB"
59 FC? 06
60 PSE
61 XEQ "CC"
62 FC? 07
63 PSE
64 XEQ "DD"
65 FC? 08
66 PSE
67 XEQ "EE"
68 FC? 09
69 PSE
70 GTO 11
71*LBL "STATIM"
72 "LIMIT, MR"
73 PROMPT
74 "RATE, MR/HR"
75 PROMPT
76 /

```

```

77 60
78 *
79 10
80 X<>Y
81 X<=Y?
82 FIX 1
83 "S.T.= "
84 ARCL X
85 "F MIN"
86 FIX 0
87 AVIEW
88 RTN

```

89*LBL "AA"

```

90 FC?C 22
91 RCL 05
92 FS? 05
93 RTN
94 CLA
95 ARCL X
96 X<> 05
97 RCL 00
98 TIME
99 STO 00
100 X<>Y
101 HMS-
102 HR
103 *
104 ST+ 10
105 "F <A> "
106 ARCL 10
107 AVIEW
108 RTN

```

109*LBL "BB"

```

110 FC?C 22
111 RCL 06
112 FS? 06
113 RTN
114 CLA
115 ARCL X
116 X<> 06
117 RCL 01
118 TIME

```

IF NO NUMERIC
INPUT, USES
PRESENT DOSE
RATE.

IF NO SECOND
NAME WAS
ENTERED, NO
CALCULATION
IS PERFORMED.

PROGRAM LISTING

119 STO 01	161 HMS-	203 GTO 00
120 X<>Y	162 HR	204*LBL 02
121 HMS-	163 *	205 - TUESDAY -
122 HR	164 ST+ 13	206 GTO 00
123 *	165 "F <D> "	207*LBL 03
124 ST+ 11	166 ARCL 13	208 "WEDNESDAY"
125 "F "	167 AVIEW	209 GTO 00
126 ARCL 11	168 RTN	210*LBL 04
127 AVIEW	<u>169*LBL "EE"</u>	211 - THURSDAY-
128 RTN	170 FC?C 22	212 GTO 00
<u>129*LBL "CC"</u>	171 RCL 09	213*LBL 05
130 FC?C 22	172 FS? 09	214 - FRIDAY -
131 RCL 07	173 RTN	215 GTO 00
132 FS? 07	174 CLA	216*LBL 06
133 RTN	175 ARCL X	217 - SATURDAY-
134 CLA	176 X<> 09	218*LBL 00
135 ARCL X	177 RCL 04	219 "F "
136 X<> 07	178 TIME	220 DATE
137 RCL 02	179 STO 04	221 ADATE
138 TIME ← A TIME MODULE FUNCTION.	180 X<>Y	222 PRA
139 STO 02	181 HMS-	223 SF 12
140 X<>Y	182 HR	224 ADV
141 HMS-	183 *	225 "FINAL DOSES"
142 HR	184 ST+ 14	<u>226 PRA</u>
143 *	185 "F <E> "	<u>227*LBL 19</u>
144 ST+ 12	186 ARCL 14	228 CLX
145 "F <C> "	187 AVIEW	229 STO 20
146 ARCL 12	188 RTN	230 FIX 0
147 AVIEW	<u>189*LBL "PROSE"</u>	231 15.019
148 RTN	190 FC? 55	232 ADV
<u>149*LBL "DD"</u>	191 GTO 19	233 5
150 FC?C 22	192 FIX 6	234*LBL 07
151 RCL 08	193 CF 12	235 FS? IND X
152 FS? 08	194 ADV	236 G . 01
153 RTN	195 DATE	237 CLA
154 CLA	196 DOW	238 ARCL IND Y
155 ARCL X	197 GTO IND X	239 5
156 X<> 08	198*LBL 00	240 +
157 RCL 03	199 - SUNDAY -	241 RCL IND X
158 TIME	200 GTO 00	242 ST+ 20
159 STO 03	201*LBL 01	243 XEQ 02
160 X<>Y	202 - MONDAY -	244 RDN

} SKIPS DAY
AND DATE
CALCULATION.

} LEAVES PRINTOUT
LOOP IF IT ENCOUNTERS
A SET FLAG.

PROGRAM LISTING

```

245 5
246 -
247 RCL IND X      ← RECALLS CURRENT
248 " NOT ZEROED" ← DOSE RATE.
                    ← ERROR MESSAGE.
249 X#0?
250 AVIEW
251 RDN
252 1
253 +
254 1SG Y
255 GTO 07
256*LBL 01
257 ADV
258 "TOTAL="
259 RCL 20
260 XEQ 02
261 ADV
262 ADV
263 ADV
264 ADV
265 ADV
266 RTN
267*LBL 02
268 FC? 55
269 GTO 00
270 ACA
271 CLA

```

```

272 RND
273 1 E3
274 X>Y?
275 " "
276 RDN
277 1 E2
278 X>Y?
279 " "
280 SORT
281 X>Y?
282 " "
283 RDN
284 SF 13
285 ARCL X
286 "FM"
287 ACA
288 CF 13
289 "R"
290 ACA
291 PRBUF
292 RTN
293*LBL 00
294 " "
295 ARCL X
296 "FMR"
297 AVIEW
298 PSE
299 END

```

FORMATTING
STEPS.

Condensed, but Slower Version of Timekeeping Program.

LBL*INITIAL	45 GTO 10	95 RTN
LBL*DVVIEW	46*LBL 00	96 ASTO L
LBL*STATIM	47 ROFF	97 CLA
LBL*PRDOSE	48 ADV	98 ARCL X
END 634 BYTES	49 " * READY *"	99 ARCL L
	50 SF 27	100 X<> IND Y
	51 PROMPT	101 5
<u>01*LBL "INITIAL"</u>	<u>52*LBL "DVVIEW"</u>	102 ST- 2
02 CLRG	53 CF 22	103 RDN
03 CF 12	54*LBL 11	104 RCL IND Y
04 CF 29	55 ADV	105 TIME
05 FIX 0	56 XEQ A	106 STO IND T
06 "NAMES 6 "	57 PSE	107 X<>Y
07 "LETTERS MAX"	58 XEQ B	108 HMS-
08 BEEP	59 FC? 06	109 HR
09 AVIEW	60 PSE	110 *
10 PSE	61 XEQ C	111 10
11 SF 12	62 FC? 07	112 ST+ 2
12 "A"	63 PSE	113 RDN
13 ASTO 15	64 XEQ D	114 ST+ IND Y
14 SF 05	65 FC? 08	115 ARCL IND Y
15 "B"	66 PSE	116 AVIEW
16 ASTO 16	67 XEQ E	117 RTN
17 SF 06	68 FC? 09	<u>118*LBL A</u>
18 "C"	69 PSE	119 5
19 ASTO 17	70 GTO 11	120 " <A> "
20 SF 07	<u>71*LBL "STATIM"</u>	121 GTO 20
21 "D"	72 "LIMIT, MR"	<u>122*LBL B</u>
22 ASTO 18	73 PROMPT	123 6
23 SF 08	74 "RATE, MR/HP"	124 " "
24 "E"	75 PROMPT	125 GTO 20
25 ASTO 19	76 /	<u>126*LBL C</u>
26 SF 09	77 60	127 7
27 15.019	78 *	128 " <C> "
28 RDN	79 10	129 GTO 20
29 5	80 X< Y	<u>130*LBL D</u>
<u>30*LBL 10</u>	81 X<=Y?	131 8
31 CF 23	82 FIX 1	132 " <D> "
32 "I.D. OF "	83 "S.T. = "	133 GTO 20
33 ARCL IND Y	84 ARCL X	<u>134*LBL E</u>
34 PROMPT	85 "T MIN"	135 9
35 FC? 23	86 FIX 0	136 " <E> "
36 GTO 00	87 AVIEW	137 GTO 20
37 "T "	88 RTN	<u>138*LBL "PRDOSE"</u>
38 ASTO IND Y	<u>89*LBL 20</u>	139 FC? 55
39 FS? 55	90 FS? 22	140 GTO 19
40 PRA	91 X<>Y	141 FIX 6
41 CF IND Y	92 FC? 22	142 CF 12
42 1	93 RCL IND X	143 ADV
43 +	94 FS? IND Y	144 DATE
44 15G Y		

THESE LOCAL LABELS
INITIALIZE, THEN ROUTE
EXECUTION BACK TO
LBL 20

Condensed, but Slower Version of Timekeeping Program.

145 DOW	179 FIX 0	214 ADV
146 GTO IND X	180 15.019	215 RTN
147+LBL 00	181 ADV	216+LBL 02
148 " SUNDAY "	182 5	217 FC? 55
149 GTO 00	183+LBL 07	218 GTO 00
150+LBL 01	184 FS? IND X	219 ACA
151 " MONDAY "	185 GTO 01	220 CLA
152 GTO 00	186 CLA	221 RND
153+LBL 02	187 ARCL IND Y	222 1 E3
154 " TUESDAY "	188 5	223 X>Y?
155 GTO 00	189 +	224 " "
156+LBL 03	190 RCL IND X	225 RDN
157 "WEDNESDAY"	191 ST+ 20	226 1 E2
158 GTO 00	192 XEQ 02	227 X>Y?
159+LBL 04	193 RDN	228 "t "
160 " THURSDAY"	194 5	229 SORT
161 GTO 00	195 -	230 X>Y?
162+LBL 05	196 RCL IND X	231 "t "
163 " FRIDAY "	197 " NOT ZEROED"	232 RDN
164 GTO 00	198 X#0?	233 SF 13
165+LBL 06	199 AVIEW	234 ARCL X
166 " SATURDAY"	200 RDN	235 "tM"
167+LBL 00	201 1	236 ACA
168 "t "	202 +	237 CF 13
169 DATE	203 ISG Y	238 "R"
170 ADATE	204 GTO 07	239 ACA
171 PRA	205+LBL 01	240 PRBUF
172 SF 12	206 ADV	241 RTN
173 ADV	207 "TOTAL="	242+LBL 00
174 "FINAL DOSES"	208 RCL 20	243 "t "
175 PRA	209 XEQ 02	244 ARCL X
176+LBL 19	210 ADV	245 "tMR"
177 CLX	211 ADV	246 AVIEW
178 STO 20	212 ADV	247 PSE
	213 ADV	248 END

SPEED COMPARISON USING "DVIEW"

ORIGINAL

NAMES: 6 LETTERS MAX

AAA

BBB

CCC

DDD

EEE

CONDENSED

NAMES: 6 LETTERS MAX

AA

BB

CC

DD

EE

← GO OUT OF USER MODE
GTO 11, ENTER 9000
PRESS R/S. →

9000 <A> 0
0 0
0 <C> 0
0 <D> 0
0 <E> 0

THIS ENTERS 9000 mR/hr
DOSE RATE FOR A AND
BEGINS THE DVIEW
CYCLE.

9000 <A> 0
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 35
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 42
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 70
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 84
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 105
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 126
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 141
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 168
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 176
0 0
0 <C> 0
0 <D> 0
0 <E> 0

9000 <A> 210
0 0
0 <C> 0
0 <D> 0
0 <E> 0

$\frac{176}{5} = 35.2$ mR AVERAGE
9000 mR/hr = 2.5 mR/sec, SO 35.2 mR
ACCRUES IN 14.08 sec. THUS, A SINGLE
EXECUTION OF "AA" TAKES 2.82 sec
(INCLUDES A PSE).

$\frac{210}{5} = 42.0$ mR AVERAGE
WHICH TAKES $\frac{42.0 \text{ mR}}{2.5 \text{ mR/sec}} = 16.8$ sec.
THUS, A SINGLE EXECUTION OF "A"
REQUIRES 3.36 sec.

DIFFERENCE IS 0.54 sec.

RHO-HS-ST-5 P

APPENDIX D

•

EMERGENCY RESPONSE - "H/Q"

USER INSTRUCTIONS

- A. Enter program (read three cards).
- B. Press XEQ "H/Q." Program may be run with or without a printer. If the printer is off or not attached, all displayed results will stop program execution. To continue, simply press R/S.
- C. Input requested information; press R/S after each entry.
 1. Release height (h) in meters.
 2. Wind speed at the point of release (u) in meters per second.
 3. Downwind distance to receptor (x) in meters.
 4. If sector averaging (22.5 degree sectors) is desired, enter any number. For centerline X/Q, do not enter any number.
 5. Stability class - enter one of the following:

VS = Hanford very stable

MS = Hanford moderately stable

UN = Sutton's unstable

N = Sutton's neutral
 6. Specific meteorological parameters are entered last. Tables of recommended values are given in Tables 3 and 4. Stable conditions require a wind meander parameter; neutral and unstable conditions require input of Sutton's parameters.

NOTE: The wind meander is used by only the horizontal dispersion variables (σ_y). Thus, when sector averaging, wind meander is not prompted.
- D. Once X/Q has been computed, the program asks "INPUT LIST?" which means the option to review input parameters and computed values of σ_y and the vertical dispersion variable (σ_z) is available. If a listing is desired, enter any number and press R/S. Press R/S to view successive parameters if no printer is attached or if the printer is off. If the listing is not desired, enter nothing; press R/S.

NOTE: When sector averaging, the parameter σ_y is replaced with the quantity $(x/8)\sqrt{\pi/2}$.

- E. The next option facilitates dose computation for each isotope using unit dose factors and curies released.
 - If such a computation will be done, enter the first dose factor (rem/Ci.m³/s) and the activity released for each isotope. The program computes the dose from each isotope and displays it. Once all isotopes have been computed, the program prompts for another dose factor. Press R/S and the sum total will be displayed.
 - If no dose computation is desired, enter nothing; press R/S and "H/Q" will execute from the beginning.
- F. Finally, the user may simply want to change one or two input parameters and rerun the X/Q calculation. This capability is realized in two ways:
 1. Switch to USER mode.
 - a. To change h, enter the new h and press A.
 - b. To change u, enter the new u and press B.
 - c. To change x, enter the new x and press C.
 - d. To switch to sector averaging or to remove this option, press H.
 - e. To change stability class, press D. The MET choices will then be displayed. Enter the new MET and press R/S. The program will store and execute the new MET, prompting for the necessary parameters. If no change in these parameters is desired, enter nothing; press R/S. Program "H/Q" automatically begins execution.
 - f. To execute the program, press E.
 2. Execute "H/Q" from the beginning.
 - a. As each item is prompted, enter either the new value and press R/S or the previous value by pressing only R/S.
 - b. Previous values of h, u, and x are recalled to the x-register just prior to their prompt and may be viewed by clearing the display. Centerline X/Q will be computed unless sector averaging is requested.
- G. Mathematical formulas are listed in the "X/Q" program instructions.

VALUES

TABLE 3. Values for Wind Meander ($\sigma_{\theta u}$).

Release duration	Wind Speed			
	1 m/s	2.5 m/s	5 m/s	10 m/s
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

TABLE 4. 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/s	C_y	.35	.21
		C_z	.35	.17
	5 m/s	C_y	.30	.15
		C_z	.30	.14
	10 m/s	C_y	.28	.14
		C_z	.28	.13
Elevated	1 m/s	C_y, C_z	.30	.15
	5 m/s	C_y, C_z	.26	.12
	10 m/s	C_y, C_z	.24	.11

PS8408-67

FIGURE 3. Flowsheet for Program "HQ."

PROGRAM LISTING

LBL "H/Q"
END 658 BYTES

01+LBL "H/Q"
02 CF 27
03 CF 29
04 RCL 01 ← RECALLS PREVIOUS
RELEASE HEIGHT.
05 "REL. HT? M"
06 PROMPT
07+LBL R
08 STO 01
09 FS? 27
10 STOP
11 RCL 02 ← RECALLS PREVIOUS
WIND SPEED
12 "WIND SP? M/S"
13 PROMPT
14+LBL B
15 STO 02
16 RCL 03 ← RECALLS X.
17 FS? 27 } COMPUTES TIME OF
18 GTO C } FLIGHT IN USER.
19 "DISTANCE? M"
20 PROMPT
21+LBL C
22 STO 03
23 RCL 02 } t = X/U
24 / }
25 STO 04
26 FS? 27
27 STOP
28 CF 00
29 CF 22
30 "SECTOR AVE?"
31 PROMPT
32 FC? 22
33 GTO D
34+LBL H
35 FC?C 00 } CLEARS FLAG 0 IF
36 SF 00 } SET, SETS FLAG 0
37 FS? 27 } IF CLEAR.
38 STOP
39+LBL I
40 CF 23
41 "MET? VS. MS. N. UN"
42 RDN
43 PROMPT
44 ROFF
45 FS? 23 } NEW MET IS
46 ASTO 00 } STORED. OTHER-
47 SF 02 } WISE, PREVIOUS
ONE REMAINS.
INDICATES (σ₀U) OR
C_y AND C_z MUST
BE PROMPTED.

48+LBL E
49 CF 01
50 FC? 55 } ENSURES PROGRAM
51 CF 21 } WILL NOT STOP AT
AN AVIEW.
52 GTO IND 00
53+LBL "UN"
54 FC?C 02 } SKIPS C_y, C_z
55 GTO 01 } PROMPT IF CLEAR.
56 .9 ← 0.9 = 1-1/2 (0.20).
57 STO 09
58 RCL 07
59 "CY, CZ ?"
60 PROMPT
61 STO 07
62 STO 08
63 GTO 01
64+LBL "N"
65 FC?C 02 } SKIPS C_y AND C_z
66 GTO 01 } PROMPTS IF CLEAR.
67 .875 ← 0.875 = 1-1/2 (0.25).
68 STO 09
69 FS? 00 } SKIPS C_y PROMPT
70 GTO 00 } IF SECTOR
71 RCL 07 } AVERAGING.
72 "CY ?"
73 PROMPT
74 STO 07
75+LBL 00
76 RCL 08
77 "CZ ?"
78 PROMPT
79 STO 08
80+LBL 01
81 RCL 08
82 RCL 03
83 RCL 09
84 Y+X
85 2
86 SQRT
87 /
88 *
89 2 E3
90 X>Y? } ENSURES
91 X<Y } σ_z ≤ 2000 m.
92 STO 05
93 LASTX
94 RCL 07
95 *
96 SF 01
97 GTO 22

98+LBL "MS"
99 .25 ← b
100 -97 ← -a
101 -25 E-5 ← -k²
102 GTO 06
103+LBL "V"
104 40
105 1/X ← b
106 -34 ← -a
107 -88 E-5 ← -k²
108+LBL 00
109 RCL 04
110 X+2
111 *
112 E+X-1
113 *
114 X<Y } σ_z
VS AND MS
115 RCL 04
116 *
117 +
118 SQRT
119 STO 05
120 FS? 00 } SKIPS σ_y WHEN
121 GTO 22 } SECTOR
AVERAGING.
122 FC?C 02 } SKIPS (σ₀U) PROMPT
123 GTO 00 } WHEN CLEAR.
124 CF 22
125 "SIGTHETA*U ?"
126 PROMPT
127 FC? 22
128 GTO 00
129 STO 07
130 232
131 *
132 13 } A
133 +
134 STO 08
135 RCL 07
136 X+2
137 2 } σ_y
138 * } N AND UN
139 /
140 STO 09

PROGRAM LISTING

141+LBL 00	190 ARCL 00	240 STO 11	
142 RCL 04	191 "t="	241+LBL 03	← PLUME DOSE COMPUTATION LOOP.
143 RCL 09	192 ARCL X	242 CF 22	
144 /	193 AVIEW	243 FIX 0	
145 CHS	194 CF 22	244 "R*M3/CI*S "	
146 E+X-1	195 "INPUT LIST?"	245 ARCL 12	
147 RCL 09	196 PROMPT	246 PROMPT	
148 *	197 FC? 22	247 FC? 22	} ONLY WAY OUT OF LOOP IS NO ENTRY.
149 RCL 04	198 GTO 02	248 GTO 00	
150 +	199 "H = " ← H	249 "CI "	
151 RCL 08	200 RCL 01	250 ARCL 12	
152 *	201 XEQ 05	251 "t = ?"	
153 SQRT	202 "U = " ← U	252 PROMPT	
154+LBL 22	203 FIX 1	253 *	
155 ADV	204 ARCL 02	254 RCL 10	
156 "CENTERLINE"	205 "t M/S"	255 *	
157 FC? 00	206 AVIEW	256 ST+ 11	
158 GTO 00	207 "X = " ← X	257 "NO. "	
159 "SECTOR AVE."	208 RCL 03	258 ARCL 12	
160 RCL 03	209 XEQ 05	259 "t="	
161 6	210 FS?C 01	260 FIX 4	
162 /	211 GTO 00	261 RND	
163 P↑	212 FS? 00	262 ARCL X	
164 2	213 GTO 01	263 "t F"	
165 /	214 FIX 3	264 AVIEW	
166 SQRT	215 "SIGU=" ← (σ ₀ U)	265 ISG 12	
167 +	216 ARCL 07	266 GTO 03	
168+LBL 00	217 AVIEW	267+LBL 00	
169 VIEW	218 GTO 01	268 FIX 3	
170 SF 21	219+LBL 00	269 RCL 11	} RETURNS TO BEGINNING IF NO DOSE WAS COMPUTED.
171 STO 06	220 FIX 2	270 X=0?	
172 RCL 01	221 "CY = " ← C _y	271 GTO "H/C"	
173 RCL 05	222 ARCL 07	272 "TOT. REM="	} OTHERWISE, DISPLAYS TOTAL DOSE.
174 /	223 FC? 00	273 ARCL 11	
175 X12	224 AVIEW	274 AVIEW	
176 CHS	225 "CZ = " ← C _z	275 GTO 02	
177 E+X	226 ARCL 08	276+LBL 05	
178 SQRT	227 AVIEW	277 FIX 0	
179 RCL 05	228+LBL 01	278 90	
180 /	229 RCL 06	279 X/Y?	
181 RCL 06	230 "EY = " ← σ _y	280 FIX 1	
182 /	231 XEQ 05	281 ARCL Y	
183 FI	232 RCL 05	282 "t M"	
184 /	233 "EZ = " ← σ _z	283 AVIEW	
185 RCL 02	234 XEQ 05	284 END	
186 /	235+LBL 02		
187 STO 10 ← X/O	236 ADV		
188 SCI 2	237 1.2		
189 "X/O "	238 STO 12		
	239 CLX		

σ_y
VS AND MS

SECTOR
AVERAGING
REPLACES σ_y
WITH (X/81)/7/2.

EXECUTION STOPS
AT AVIEW UNLESS
PRINTER
ATTACHED.

SKIPS (σ₀U) IF
MET IS N OR UN.

SKIPS (σ₀U)
DISPLAY IF SECTOR
AVERAGING.

C_y NOT DISPLAYED
WHEN SECTOR
AVERAGING.

MEMORY USE:

00: Stability class
 01: Release height (m)
 02: Wind speed (m/s)
 03: Downwind distance (m)
 04: Time of flight (s)
 05: σ_z
 06: σ_y
 07: ($\sigma_{\theta u}$) or C_y
 08: A or C_z
 09: α or $(1-n/2)$
 10: ψ/Q
 11: Dose sum, rem
 12: Pointer

FLAG USE:

00: Sector averaging
 01: Met is N or UN
 02: Whenever label D is
 run

RHO-HS-ST-5 P

APPENDIX E

"X/Q - HANFORD"

USER INSTRUCTIONS

- A. Attach printer and partition calculator memory as follows before reading in the program (7 cards): $SIZE = 23 + 3N$, where N is the number of downwind distances to be used. In the standard HP-41CV, the maximum $SIZE$ allowed with "X/Q" is 096, which allows 24 distances.
- B. Execute "X/Q" and enter the following necessary information, pressing R/S after each input.
1. Release height (h) in meters.
 2. Wind speed (u) in meters per second.
 3. Deposition speed (v_d) in centimeters per second. Zero is automatically entered if only R/S is pressed.
 4. Building area (S) in square meters. If building wake effects will not be included, simply press R/S without entering a number. Zero area is automatically entered.
 5. If sector averaging is desired, enter any number. To leave out the sector average option, enter nothing; press R/S.
 6. The first distance to be used. The program then prompts for each distance. If sector averaging is selected, the program also prompts for the population at each distance. Please bear in mind the following:
 - a. To reduce program running time, enter distances in increasing order.
 - b. Zero is not an allowed distance.
 - c. Unit populations are automatically entered if no other values are input by the user.
 - d. Distance (and population) data are not altered by program execution. If data from the previous run (or data card entry) will be used, press R/S when the first distance prompt appears.

When all distances have been entered, press R/S at the next distance prompt.

7. Hanford atmospheric stability class. Because the calculator is now in ALPHA mode, simply enter the appropriate letters, as follows:

VS - Hanford very stable
MS - Hanford moderately stable
N - Sutton's neutral
UN - Sutton's stable.

If all four stability classes will be run, enter nothing; just press R/S.

8. Specific meteorological parameters (listed here) are entered last. Recommended values are given in Tables 5 and 6.

VS & MS: Enter value of wind meander ($\sigma_{\theta u}$) or the release duration if wind speed is 1 m/s.

N & UN: Enter value of C_y and C_z .

If all four classes will be run, the program prompts for all the necessary parameters before beginning X/Q computations.

- C. Once the output is complete, the input data may be changed and the program run again. To restart from the beginning, press R/S. To change only a few items and execute, switch to USER mode and input the changes using local alpha labels as follows:

1. To change h, enter the new h and press A.
2. To change u, enter the new u and press B.
3. To change v_d , enter the new v_d and press F.
4. To change S, enter the new S and press G.
5. To switch to sector-averaged X/Q or to remove this option, press H. Be sure to enter population data, if necessary.
6. To change distances (and populations if sector averaging), press C and enter the requested information.
7. To change stability class or stability class parameters, press D. The program begins executing with the "MET? VS, MS, N, UN" prompt. Enter your selections according to the instructions given in the preceding steps B.7. and B.8. Please bear in mind the following.
 - a. The wind meander parameter required by VS and MS classes is stored so that it never needs to be reentered unless it changes. When it or release duration is prompted for, press R/S and no changes will be made.

- b. Sutton's parameters are also stored and only need to be reentered when changing from all four classes to a specific class (or vice versa).
- 8. To execute a run without changing stability class, press E.

VALUES

TABLE 5. Values for Wind Meander ($\sigma_{\theta u}$).

Release duration	Wind speeds			
	1 m/s	2.5 m/s	5 m/s	10 m/s
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

TABLE 6. 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/s	C_y	.35	.21
		C_z	.35	.17
	5 m/s	C_y	.30	.15
		C_z	.30	.14
	10 m/s	C_y	.28	.14
		C_z	.28	.13
Elevated	1 m/s	C_y, C_z	.30	.15
	5 m/s	C_y, C_z	.26	.12
	10 m/s	C_y, C_z	.24	.11

SAMPLE OUTPUT

The sample on the left was produced using the sector-averaging option. Only one atmospheric stability class was chosen, Hanford moderately stable with a release duration of 1h.

The sample on the right was generated by clearing the sector-averaging option and choosing all four classes.

*** X/Q ***
REV 4 3-13-84

RELEASE HEIGHT: 0.0 m
WIND SPEED: 1.0 m/sec
DEP. SPEED: 0.100 cm/sec
BUILDING AREA: 400 sq m
* SECTOR AVERAGED X/Q *
DISTANCE POPULATION
8000 1
15500 2000
TOTAL 2001

$\sigma_{\theta}u$: 0.040 m/sec
MOD. STABLE
X X/Q Fd
8000 3.93-06 0.919
15500 1.34-06 0.744

DISTANCE POP*/Q
8000 3.93-06
15500 2.69-07
TOTAL 2.69-07

*** X/Q ***
REV 4 3-13-84

RELEASE HEIGHT: 0.0 m
WIND SPEED: 1.0 m/sec
DEP. SPEED: 0.100 cm/sec
BUILDING AREA: 400 sq m

$\sigma_{\theta}u$: 0.040 m/sec
VERY STABLE
X X/Q Fd
8000 4.25-05 0.619
15500 1.45-05 0.456

$\sigma_{\theta}u$: 0.040 m/sec
MOD. STABLE
X X/Q Fd
8000 1.83-05 0.819
15500 7.17-06 0.744

$C_y = 0.21$ $C_z = 0.17$
NEUTRAL
X X/Q Fd
8000 2.39-06 0.908
15500 7.42-07 0.896

$C_y = 0.35$ $C_z = 0.35$
UNSTABLE
X X/Q Fd
8000 4.69-07 0.958
15500 1.42-07 0.953

MATHEMATICAL MODELS USED WITHIN "X/Q"

A. Hanford very stable and moderately stable.

$$\sigma_y^2 = A [t + \alpha (e^{-t/\alpha} - 1)]$$

where

$t = x/u$, x being the downwind distance and u , the wind speed

$$A = 13 + 232 (\sigma_\theta u)$$

$$\alpha = \frac{A}{2 (\sigma_\theta u)^2}$$

If

$$u = 1 \text{ m/s,}$$

then

$\sigma_\theta u$ is computed from the release duration as follows:

$$\sigma_\theta u = (\text{release duration})/3000 + .02$$

such that

$$.024 \leq \sigma_\theta u \leq .18$$

$$\sigma_z^2 = a (1 - e^{-k^2 t^2}) + bt$$

Values for a, b, and k^2 are listed below:

<u>Parameter</u>	<u>Very stable</u>	<u>Moderately stable</u>
a	34 m ²	97 m ²
b	.025 m ² /s	.33 m ² /s
k^2	.00088 s ⁻²	.00025 s ⁻²

B. Sutton's neutral and unstable.

$$\sigma_y^2 = \frac{1}{2} C_y^2 x^{(2-n)} \text{ and } \sigma_z^2 = \frac{1}{2} C_z^2 x^{(2-n)} \text{ and } \sigma_z < 2000 \text{ m}$$

C. Building wake effects.

σ_y and σ_z are replaced with Σ_y and Σ_z as follows:

$$\Sigma_y^2 = \sigma_y^2 + \frac{S}{2\pi} \quad \text{and} \quad \Sigma_z^2 = \sigma_z^2 + \frac{S}{2\pi}$$

such that

$$\Sigma_y \Sigma_z \leq 3 \sigma_y \sigma_z$$

D. Integrated ground deposition loss.

F_d is the fraction remaining at distance x .

$1 - F_d$ = fraction lost to ground deposition.

$$\ln F_d = - \sqrt{\frac{2}{\pi}} \frac{v_d}{u} \int_0^x \frac{dx}{\Sigma_z} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right)$$

Typical values for v_d are as follows:

0.1 cm/s for most particulate matter

1.0 cm/s for halogens (e.g., iodine).

E. Time-integrated air concentration.

1. Centerline X/Q

$$\frac{X}{Q} = \frac{F_d}{\pi u \Sigma_y \Sigma_z} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right)$$

2. Sector-averaged X/Q , 22.5 degree sectors

$$\frac{X}{Q} = \frac{8F_d}{\pi u x \Sigma_z} \sqrt{\frac{2}{\pi}} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right)$$

Sector-averaged X/Q values are normally used when determining population dose or when the release duration exceeds 8 h.

MEMORY USE:

00: distance pointer
 01: integration pointer
 02: u (wind speed)
 03: integration x
 04: x increment
 05: Σ_z^2
 06: Σ_y^2
 07: 2 - n
 08: C_y
 09: C_z
 10: $(\Sigma_y / \sigma_y)^2$
 11: $(\Sigma_z / \sigma_z)^2$
 12: $S / 2\pi$
 13: piecewise sum
 14: overall integration sum
 15. C_y N
 16. C_z N
 17: v_d (depletion speed)
 18: A
 19: α
 20: h (release height)
 21: C_y, C_z UN or specific MET
 22: distance pointer save
 23: 1st distance
 24: 1st population
 25: 1st (X/Q)(population)

USER MODE LABELS:

A: input new h
 B: input new u
 C: input new x values (and populations, if sector averaging)
 D: input new MET choice and run
 E: execute program
 F: input new v_d
 G: input new S
 H: choose or remove sector averaging (sets flag 03 if clear, and clears flag 03 if set)

FLAG USE:

00: $v_d = 0.0$ cm/s
 01: $u = 1.0$ m/s
 02: $S > 0$ m²
 03: sector averaging
 04: MET is one of Sutton's forms (N or UN)
 05: MET is UN or MS
 06: all 4 stability classes are run
 07: } These 3 flags sequence
 08: } the stability classes
 09: } when all four classes are run
 10: used in the building wake logic

PROGRAM LISTING

```

LBL *X/O
END      1565 ENTES

01+LBL "X/G"
02 CF 27
03 CF 29
04+LBL 46 } SPEEDS USER MODE
05 FS? 27 } TO END AT THE
06 STOP } BEGINNING.
07 "H = ? M"
08 RCL 20 ← RECALLS PREVIOUS
09 PROMPT RELEASE HEIGHT.
10+LBL A
11 STO 20
12 FS? 27
13 GTO 46
14 XEQ 04
15 "U = ? M/S"
16 RCL 02 ← RECALLS PREVIOUS
17 PROMPT WIND SPEED.
18+LBL B
19 STO 02
20 CF 01
21 1
22 X=Y? } FLAG 01 SET IF
23 SF 01 } U = 1 m/sec.
24 FS? 27
25 GTO 46
26 XEQ 05
27 "Vd = ? CM/S"
28 CLX ← ZERO WILL BE
29 PROMPT ENTERED UNLESS A
30+LBL F NUMBER IS
31 CF 00 ENTERED.
32 X=0? } FLAG 00 SET IF
33 SF 00 } Vd = 0 cm/sec.
34 STO 17
35 FS? 27
36 GTO 46
37 XEQ 06
38 "BLDG. AREA "
39 CLX ← ZERO WILL BE
40 PROMPT ENTERED UNLESS A
41+LBL G NUMBER IS INPUT.
42 CF 07
43 2
44 :
45 PI
46 :
47 STO 13

48 XEQ 07 } FLAG 02 IS SET FOR
49 SF 02 } BUILDING WAKE.
50 FS? 27
51 GTO 46
52 XEQ 07
53 CF 22
54 CF 03
55 "SECTOR AVE. "
56 PROMPT
57 FC? 22
58 GTO C
59+LBL P
60 FC? 07 } SET IF FLAG 03
61 SF 03 } IS CLEAR, CLEARED
62 FS? 27 IF SET.
63 GTO 46
64+LBL C ← DISTANCE AND
65 1.1 POPULATION DATA
66 STO 00 ENTRY LOOP.
67 STO 03
68 22
69 +
70 STO 04
71+LBL 00
72 FIX 0
73 "X "
74 ARCL 00
75 "t = ? M"
76 CLX
77 PROMPT
78 X<=0? } ONLY WAY TO
79 GTO 02 } LEAVE THE LOOP.
80 STO IND 04
81 3
82 FC? 03 } SKIPS POPULATION
83 GTO 01 } PROMPT WHEN
84 FIX 0 NOT SECTOR
85 ISG 04 AVERAGING.
86 "POP. "
87 ARCL 00
88 "t ?"
89 1
90 PROMPT
91 STO IND 04
92 2
93+LBL 01
94 ST+ 04
95 ISG 00
96 GTO 00

97+LBL 02
98 RCL 00
99 RCL 03
100 -
101 X=0? } TESTS FOR ANY
102 GTO 03 } INPUT DATA.
103 RCL 04
104 RCL 03
105 -
106 3
107 10+V
108 /
109 23
110 +
111 STO 22
112+LBL 03
113 FS? 27
114 GTO 46
115 FS? 03
116 XEQ 09
117+LBL D
118 CF 06
119 CF 23
120 "MET? VS.MS.N.UN"
121 AON
122 PROMPT
123 SF 10 ← INDICATES (σ0U) OR
124 CF 22 Cy AND Cz PROMPT
125 AOFF IS NECESSARY.
126 FC? 23 } FLAG 06 SET IF ALL
127 SF 06 } FOUR WILL BE RUN.
128 FS? 23 } SINGLE STABILITY.
129 ASTO 21 }
130+LBL E
131 CF 05
132 CF 07
133 CF 08
134 CF 09
135 FC? 06 } DO SINGLE
136 GTO IND 21 } STABILITY.
137 FC? 10 } SKIPS (σ0U) AND
138 GTO 01 } Cy AND Cz
139 "CY N ?" PROMPTS.
140 PROMPT
141 FC? 22
142 GTO 01
143 STO 15
144 "CZ N ?"
145 PROMPT
146 STO 16

```

PROGRAM LISTING

```

147 *CY,CZ UN 00
148 PROMPT
149 STO 21
150 CF 22
151+LBL 01
152 SF 07
153+LBL "VS"
154 -88 E-5 ← -k²
155 STO 07
156 -34 ← -a
157 STO 08
158 40
159 1/X ← b
160 STO 09
161 GTO 01
162+LBL "MS"
163 SF 05
164 FS?C 07
165 SF 08
166 -4 E3 ← -k²
167 1/X
168 STO 07
169 -97 ← -a
170 STO 08
171 .33 ← b
172 STO 09
173 FS? 08
174 GTO 40
175+LBL 01
176 CF 04
177 FC?C 10 } SKIPS (α₀U)
178 GTO 47 } PROMPT IF CLEAR.
179 FC? 01
180 GTO 01
181 "REL. DUR.? MIN"
182 PROMPT
183 FC? 22
184 GTO 47
185 3 E3
186 /
187 .02
188 +
189 .024
190 X(=Y?
191 X(>Y
192 .18
193 X>Y?
194 X(>Y
195 GTO 02
196+LBL 01
197 *SIGHTETA*H 00

198 PROMPT
199 FC? 22
200 GTO 47
201+LBL 02
202 STO Y
203 232
204 *
205 13
206 +
207 STO 18
208 X(>Y
209 X12
210 2
211 *
212 /
213 STO 19
214 GTO 47
215+LBL 04 ← PRINTS OUTPUT
216 SF 12 ← HEADER AND
217 "*** X/Q ***" ← RELEASE HEIGHT.
218 PRA
219 CF 12
220 "REV 4"
221 ACA
222 9
223 SKPCHR
224 "3-13-84"
225 ACA
226 ADV
227 ADV
228 FIX 1
229 "RELEASE HEIGHT:"
230 "I"
231 ARCL 20
232 ACA
233 "M"
234 GTO 08
235+LBL 05 ← PRINTS U.
236 FIX 1
237 "WIND SPEED"
238 ARCL 02
239 ACA
240 "M/SEC"
241 GTO 08
242+LBL 06 ← PRINTS V₀.
243 FIX 3
244 "DEP. SPEED."
245 ARCL 17
246 ACA
247 "CM/SEC"

248 GTO 08
249+LBL 07 ← PRINTS WAKE
250 FIX 0 ← AREA.
251 "BUILDING AREA"
252 RCL 12
253 2
254 *
255 PI
256 *
257 ARCL Y
258 ACA
259 "SQ M"
260+LBL 08
261 SF 13
262 ACA
263 PRBUF
264 CF 13
265 RTN
266+LBL 09 ← IF SECTOR
267 "* SECTOR AVERAG" ← AVERAGING,
268 "TED X/Q *" ← PRINTS INPUT
269 PRA ← POPULATIONS.
270 "DISTANCE POP"
271 "ULATION"
272 PRA
273 RCL 22
274 STO 00
275 CLX
276 STO 04
277 FIX 0
278+LBL 10
279 RCL IND 00
280 ACX
281 ISG 00
282 RCL IND 00
283 ISG 00
284 ST+ 04
285 CLA
286 0
287 RCL Y
288 LOG
289 INT
290 -
291 SKPCHR
292 RDN
293 ACX
294 6
295 SKPCHR
296 ADV
297 ISG 00

```

PROGRAM LISTING

298 GTO 10	349 SF 12	399+LBL 49
299 *TOTAL	350 " "	400 FS? 00
300 ARCL 04	351 ACA	401 GTO 03
301 ACA	352 9	402 RCL IND 00
302 SKPCHR	353 ACCHR	403 RCL 03
303 24	354 CF 12	404 X<=Y?
304 ADV	355 16	405 GTO 12
305 95	356 ACCHR	406+LBL 01
306+LBL 11	357 *U "	407 CLX
307 ACCHR	358 RCL 10	408 STO 03
308 DSE Y	359 13	409 STO 13
309 GTO 11	360 -	410 STO 14
310 ADV	361 232	411 3
311 RTN	362 /	412 XEQ 57
312+LBL "N"	363 ARCL X	413+LBL 12
313 1.75	364 "t M/SEC"	414 RCL 03
314 GTO 01	365 XEQ 08	415 10
315+LBL "UN"	366 "VERY"	416 *
316 SF 05	367 FS?C 05	417 RCL IND 00
317 1.8	368 "MOD."	418 X<=Y?
318+LBL 01	369 "t STABLE"	419 GTO 02
319 STO 07	370 GTO 02	420 X<>Y
320 SF 04	371+LBL 01	421 .9
321 FC?C 10	372 FIX 2	422 *
322 GTO 01	373 67	423 XEQ 57
323 "CY = ?"	374 ACCHR	424 GTO 12
324 PROMPT	375 SF 13	425+LBL 02
325 FC? 22	376 "Y = "	426 RCL 03
326 GTO 01	377 ARCL 08	427 -
327 STO 08	378 "t "	428 XEQ 57
328 STO 09	379 ACA	429 .5319
329 FS? 05	380 CF 13	430 RCL 02
330 GTO 01	381 ACCHR	431 /
331 "CZ = ?"	382 "Z = "	432 RCL 17
332 PROMPT	383 ARCL 09	433 %
333 STO 09	384 XEQ 08	434 RCL 14
334+LBL 47	385 " NEUTRAL"	435 *
335+LBL 01	386 FS? 05	436 CHS
336 FC?C 27	387 " UNSTABLE"	437 E+X
337 GTO 48	388+LBL 02	438 GTO 01
338 XEQ 04	389 SF 12	439+LBL 03
339 XEQ 05	390 PRA	440 RCL IND 00
340 XEQ 06	391 " X X/Q Fd"	441 STO 03
341 XEQ 07	392 PRA	442 CLX
342 FS? 03	393 CF 12	443 STO 04
343 XEQ 09	394 RCL 22	444 XEQ 58
344+LBL 48	395 STO 00	445 STO 01
345 ADV	396 FS? 00	446 1
346 FS? 04	397 GTO 03	447+LBL 01
347 GTO 01	398 GTO 01	448 STO 04
348 FI> 3		449 CLA

PRINTS DASHED LINE.

PRINTS INPUT DATA WHEN IN USER MODE.

OUTPUT HEADER FOR VS AND MS.

AVOIDS NUMERIC INTEGRATION.

TESTS NEW X AGAINST PREVIOUS.

BEGINNING UPPER LIMIT. 1ST INTEGRAL.

DOES FINAL INTEGRAL.

FINAL INTEGRAL $0.5319 = \frac{2}{3} \sqrt{\frac{2}{\pi}}$

F_d IS COMPLETE.

THERE ARE EXECUTED WHEN V_d=0.

SKIPS C_y AND C_z PROMPTS IF CLEAR.

CLEAR FLAG 05.

OUTPUT HEADER FOR N AND UN.

COLUMN HEADER.

PROGRAM LISTING

450 FIX 0	300 ISG 00	550 STO 07
451 ARCL 03	301 GTO 49	551 RCL 15
452 "+ "	302 FC? 03	552 STO 08
453 ACA	303 GTO 01	553 RCL 16
454 SCI 2	304 RCL 22	554 STO 09
455 FC? 01	305 STO 00	555 GTO 48
456 XEQ 55	306 CLX	<u>556+LBL 02</u>
457 RCL 01	307 STO 04	557 SF 05
458 PI	308 ADV	558 1.8
459 /	309 " DISTANCE POP"	559 STO 07
460 RCL 02	310 "+X/Q"	560 RCL 21
461 /	311 PRA	561 STO 08
462 RCL 06	<u>512+LBL 13</u>	562 STO 09
463 FC? 03	513 FIX 0	563 GTO 48
464 GTO 01	514 CLA	<u>564+LBL 57</u>
465 RDN	515 ARCL IND 00	565 10
466 RCL 03	516 "+ "	566 /
467 /	517 ACA	567 STO 04
468 .02454	518 2	568 1.01
<u>469+LBL 01</u>	519 ST+ 00	569 STO 01
470 SQRT	520 RCL IND 00	<u>570+LBL 14</u>
471 /	521 SCI 2	571 XEQ 58
472 RCL 04	522 ACX	572 ST+ 13
473 *	523 ST+ 04	573 ISG 01
474 ACX	524 5	574 XEQ 58
475 2	525 SKPCHR	575 ISG 01
476 FC? 03	526 ADV	576 GTO 14
477 GTO 02	527 ISG 00	577 STO 01
478 X<>Y	528 GTO 13	578 2
479 ISG 00	529 " TOTAL "	579 /
480 RCL IND 00	530 ACA	580 ST- 13
481 *	531 RCL 04	581 X<> 13
482 ISG 00	532 ACX	582 RCL 04
483 STO IND 00	533 PRBUF	583 *
484 0	<u>534+LBL 01</u>	584 ST+ 14
<u>485+LBL 02</u>	535 CF 05	585 RTN
486 ST+ 00	536 FS? 07	<u>586+LBL 59</u>
487 2	537 GTO "MS"	587 RCL 12
488 SKPCHR	538 FS? 08	588 RCL 03
489 FIX 3	539 GTO 01	589 FS? 04
490 .1	540 FS? 09	590 GTO 01
491 RCL 04	541 GTO 02	591 RCL 02
492 X<=Y?	542 ADV	592 /
493 FIX 4	543 ADV	593 ENTER↑
494 RND	544 SF 27	594 ENTER↑
495 ACX	545 GTO 46	595 RCL 19
496 X>Y.	<u>546+LBL 01</u>	596 /
497 1	547 SF 04	597 CHS
498 SKPCHR	548 SF 09	598 ETX-i
499 ADV	549 1.75	599 RCL 19
		600 *
		601 +
		602 RCL 18

COMPUTES σ_v IF NO BUILDING WAKE.
 SKIPS SECTOR AVERAGING STEPS IF CLEAR.
 SKIPS POPULATION WEIGHTED X/Q TABLE IF CLEAR.
 PRINTS TABLE OF DISTANCES AND POPULATION WEIGHTED X/Q VALUES.
 INITIALIZES FOR UNSTABLE.
 NUMERIC INTEGRATION SUBROUTINE (SIMPSON'S RULE ON EACH DECADE.)
 X/Q VALUE TO PRINTER.
 SKIPS POPULATION WEIGHTING IF CLEAR.
 ROUTINGS WHEN ALL FOUR STABILITIES ARE RUN.
 ENTERS USER MODE AND STOPS AT 48. INITIALIZES FOR NEUTRAL STABILITY.
 σ_v^2 FOR VS AND MS.

PROGRAM LISTING

603 GTO 02		652*LBL 02		694*LBL 02	
604*LBL 01		653 STO 05		695 RCL 11	
605 RCL 07	} σ_y^2 FOR N AND UN.	654 STO 06	} SKIPS WAKE CORRECTION.	696 ST* 05	
606 Y+X		655 FC? 02		697 RCL 10	
607 2		656 GTO 03		698 ST* 06	
608 /		657 /		699*LBL 02	← INTEGRAND IS $1/\sigma_z e^{-h^2/2\sigma_z^2}$
609 RCL 08		658 1		700 RCL 20	
610 X+2		659 +		701 X12	
611*LBL 02		660 STO 11		702 RCL 05	
612 *	} $\left(\frac{\Sigma y^2}{\sigma_y^2}\right)$	661 STO 10	} SKIPS Σ^2 CALCULATION IF UNSTABLE.	703 /	
613 STO 06		662 FC? 05		704 CHS	
614 /		663 XEQ 59		705 E+X	
615 1		664 9		706 RCL 05	
616 +		665 RCL 10		707 /	
617 STO 10		666 RCL 11		708 SQRT	
618 RTN		667 *		709 ST+ 13	
619*LBL 58		668 X<=Y?		710 END	
620 RCL 04		669 GTO 02			
621 ST+ 03		670 RCL 10			
622 RCL 12		671 RCL 11			
623 FS? 04		672 X<=Y?			
624 GTO 01		673 GTO 01			
625 RCL 09	} σ_z^2 FOR VS AND MS.	674 SF 10	} BUILDING WAKE LOGIC.		
626 RCL 03		675 X<>Y			
627 RCL 02		676*LBL 01			
628 /		677 3			
629 *		678 X>Y?			
630 LASTX		679 GTO 01			
631 X+2		680 STO 10			
632 RCL 07		681 STO 11			
633 *		682 CF 10			
634 E+X-1		683 GTO 02			
635 RCL 05		684*LBL 01			
636 *		685 X+2			
637 +		686 X<>Y			
638 GTO 02		687 /			
639*LBL 01	← σ_z^2 FOR N AND UN.	688 FC? 10			
640 RCL 02		689 10			
641 RCL 07		690 FS?C 10			
642 Y+X		691 11			
643 2		692 X<>Y			
644 /		693 STO IND Y			
645 RCL 09					
646 X+2					
647 *					
648 4 E6	} ENSURES $\sigma_z \leq 2000$ m.				
649 X<=Y?					
650 X<>Y					
651 RDN					

RHO-HS-ST-5 P

APPENDIX F

EMERGENCY RESPONSE - "P/Q"

USER INSTRUCTIONS

- A. Enter program (read three cards).
- B. Press XEQ "P/Q." Program may be run with or without a printer. If the printer is off or not attached, all displayed results will stop program execution. To continue, simply press R/S.
- C. Input requested information (listed here), pressing R/S after each entry.
 1. Release height (h) in meters.
 2. Wind speed at the point of release (u) in meters/second.
 3. Downwind distance to receptor (x) in kilometers.
 4. If sector averaging (22.5 degree sectors) is desired, enter any number. For centerline X/Q, do not enter any number.
 5. Stability class - enter one of the PG classes, A through F.
- D. Once X/Q has been computed, the program asks "INPUT LIST?," which means the option to review input parameters and see the computed values of σ_y and σ_z is available. If a listing is desired, enter any number and press R/S. Press R/S to view successive parameters if no printer is attached or if the printer is off. If the listing is not desired, enter nothing; just press R/S.

NOTE: When sector averaging, the parameter σ_y is replaced with the quantity $(125x) \sqrt{\pi}/2$.

- E. The next option facilitates dose computation for each isotope using unit dose factors and curies released.
 - If such a computation will be done, enter the first dose factor (rem/Ci·m³/s) and the activity released for each isotope. The program computes the dose from each isotope and displays it. Once all isotopes have been computed, the program prompts for another dose factor. Press R/S and the sum total will be displayed.
 - If no dose computation is desired, enter nothing; just press R/S and "P/Q" will execute from the beginning.

F. Finally, the user may simply want to change one or two input parameters and rerun the X/Q calculation. This capability is realized in two ways:

1. Switch to USER mode.

- a. To change h, enter the new h and press A.
- b. To change u, enter the new u and press B.
- c. To change x, enter the new x and press C.
- d. To switch to sector averaging or to remove this option, press H.
- e. To change stability class, press D. The MET choices will then be displayed. Enter the new MET and press R/S. The program will store and execute the new MET.
- f. To execute the program, press E.

2. Execute "P/Q" from the beginning.

- a. As each item is prompted, enter either the new value and press R/S or the previous value by pressing only R/S.
- b. Previous values of h, u, and x are recalled to the x-register just prior to their prompt and may be viewed by clearing the display. Centerline X/Q will be computed unless sector averaging is requested.

G. Mathematical formulas are listed in the "X/Q - Pasquill" program instructions.

MEMORY USE:

00: Stability class
 01: Release height, m
 02: Wind speed, m/s
 03: Downwind distance,
 04: σ_y
 05: σ_z
 06: ψ/Q
 07: Dose sum, rem
 08: Pointer

FLAG USE:

00: Sector averaging

PROGRAM LISTING

LBL "P/Q"
 END 575 BYTE

01+LBL "P/Q"
 02 CF 27
 03 RCL 01 ← RECALLS PREVIOUS
 RELEASE HEIGHT.
 04 "REL HT=? M"
 05 PROMPT ← ENTER RELEASE
 HEIGHT, m.
 06+LBL A
 07 STO 01
 08 FS? 27
 09 STOP
 10 RCL 02 ← RECALLS PREVIOUS
 WIND SPEED.
 11 "WIND SP? M/S"
 12 PROMPT ← ENTER WIND
 SPEED, m/sec.
 13+LBL B
 14 STO 02
 15 FS? 27
 16 STOP
 17 RCL 03 ← RECALLS PREVIOUS
 DISTANCE.
 18 "DISTANCE? KM"
 19 PROMPT ← ENTER DISTANCE.
 km.
 20+LBL C
 21 STO 03
 22 FS? 27
 23 STOP
 24 CF 00
 25 CF 22
 26 "SECTOR AVE"
 27 PROMPT ← CHOOSE SECTOR
 AVERAGING BY ANY
 NUMERIC INPUT
 28 FC? 22
 29 GTO B
 30+LBL H
 31 FC? 00 } SETS FLAG 0
 IF CLEAR, CLEARS
 FLAG 0 IF SET
 32 SF 00
 33 FS? 27
 34 STOP

35+LBL D
 36 CF 23
 37 "MET? A,B,C,D,E,"
 38 "F"
 39 AON
 40 PROMPT ← CHOOSE PASQUILL
 STABILITY CLASS.
 41 AOFF
 42 FS? 23
 43 ASTO 00
 44+LBL E
 45 FC? 55 } PREVENTS
 EXECUTION STOP
 AT "VIEW".
 46 CF 21
 47 RCL 04
 48 "A"
 49 ASTO Y
 50 X=Y?
 51 GTO 01
 52 "B"
 53 ASTO Y
 54 X=Y?
 55 GTO 02
 56 "C"
 57 ASTO Y
 58 X=Y?
 59 GTO 03
 60 "D"
 61 ASTO Y
 62 X=Y?
 63 GTO 04
 64 "E"
 65 ASTO Y
 66 X=Y?
 67 GTO 05
 68 "F"
 69 ASTO Y
 70 X=Y?
 71 GTO D
 72 46 } CLASS F
 PARAMETERS.
 73 16
 74 1.3
 75 GTO 06
 76+LBL 01 ← CLASS A
 PARAMETERS.

77 240
 78 146
 79 2.7
 80 RCL 03
 81 GTO 00
 82+LBL 02 ← CLASS B
 PARAMETERS.
 83 185
 84 102
 85 .26
 86 RCL 03
 87 SQRT
 88+LBL 00 ← CLASS A AND B
 02
 89 *
 90 RCL 03
 91 *
 92 1
 93 +
 94 *
 95 RCL 03
 96 *
 97 GTO 00
 98+LBL 03 ← CLASS C
 PARAMETERS
 AND 02.
 99 139
 100 RCL 03
 101 .3
 102 RCL 02
 103 SQRT
 104 *
 105 1
 106 +
 107 /
 108 03
 109 *
 110 GTO 00
 111+LBL 04 ← CLASS D
 PARAMETERS
 AND 02.
 112 90
 113 RCL 03
 114 1.1
 115 RCL 02
 116 *
 117 1
 118 +
 119 SQRT

PROGRAM LISTING

120 .	170 Y+Z	220+LBL 08
121 47	171 -2	221 CF 22
122 *	172 /	222 FIX 0
123 GTO 06	173 E+X	223 "R*M3/CI*5 "
124+LBL 05 ← CLASS E PARAMETERS.	174 RCL 05	224 ARCL 08
125 66	175 /	225 PROMPT ← ENTER DOSE FACTOR $\text{rem/Ci}\cdot\text{m}^3/\text{S}.$
126 38	176 PI	226 FC? 22 } ONLY WAY TO LEAVE THIS LOOP IS NO ENTRY.
127 .85	177 /	227 GTO 08
128+LBL 06 ← CLASS E AND F 02.	178 RCL 02	228 "CI "
129 RCL 07	179 /	229 ARCL 08
130 *	180 RCL 04	230 "t = ?"
131 LN1+X	181 / ← X/Q COMPUTED.	231 PROMPT
132 *	182 STO 06	232 *
133+LBL 00	183 FIX 0	233 RCL 06
134 2 E3	184 CF 29	234 *
135 X*Y?	185 "X/Q "	235 ST+ 07
136 X<Y	186 ARCL 00	236 "NO. "
137 STO 05	187 "t="	237 ARCL 08
138 ADV	188 SCI 2	238 "t="
139 RCL 03	189 ARCL 06	239 FIX 4
140 "CENTERLINE"	190 AVIEW	240 ARCL X
141 FC? 00	191 CF 22	241 "t R"
142 GTO 00	192 "INPUT LIST?"	242 AVIEW
143 "SECTOR AVE."	193 PROMPT ← SEE INPUTS BY PRESSING ANY NUMBER.	243 ISG 06
144 125	194 FC? 22	244 GTO 08
145 *	195 GTO 07	245+LBL 00
146 PI	196 "H = "	246 FIX 3
147 2	197 RCL 01	247 RCL 07
148 /	198 XEQ 05	248 X=0?
149 SQRT	199 "U = "	249 GTO "P/Q"
150 *	200 ARCL 02	250 "TOT. REM="
151 GTO 01	201 "t M/S"	251 ARCL 07
152+LBL 00 ← COMPUTES σ_y .	202 AVIEW	252 AVIEW
153 R+	203 FIX 2	253 GTO 07
154 *	204 "X = "	254+LBL 05
155 RCL 03	205 ARCL 03	255 FIX 0
156 SQRT	206 "t KM"	256 90
157 2	207 AVIEW	257 X*Y?
158 /	208 RCL 04	258 FIX 1
159 1	209 "ZY = "	259 ARCL Y
160 +	210 XEQ 05	260 "t M"
161 SQRT	211 RCL 05	261 AVIEW
162 /	212 "EZ = "	262 END
163+LBL 01	213 XEQ 05	
164 STO 04	214+LBL 07	
165 AVIEW	215 ADV	
166 SF 21 ← ENSURES EXECUTION STOP AT NEXT AVIEW.	216 1.2 ← POINTER FOR DOSE CALCULATION LOOP.	
167 RCL 01	217 STO 08	
168 RCL 05	218 CLX	
169 *	219 STO 07	

RHO-HS-ST-5 P

APPENDIX G

"X/Q - PASQUILL"

USER INSTRUCTIONS

- A. Attach printer and partition calculator memory as follows before reading in the program (6 cards): $SIZE = 20 + 3N$, where N is the number of downwind distances to be used. In the standard HP-41CV, the maximum $SIZE$ allowed with "X/Q" is 122, which allows 37 distances.
- B. Execute "X/Q" and enter the necessary information (listed here), pressing R/S after each input.
 1. Release height (h) in meters.
 2. Wind speed (u) in meters per second.
 3. Deposition speed (v_d) in centimeters per second. Zero is automatically entered if only R/S is pressed.
 4. Building areas (S) in square meters. If building wake effects will not be included, simply press R/S without entering a number. Zero area is automatically entered.
 5. If sector averaging is desired, enter any number. To leave out the sector-average option, enter nothing; just press R/S.
 6. The first distance to be used. The program then prompts for each distance. If sector averaging is selected, the program also prompts for the population at each distance. Please bear in mind the following:
 - a. To reduce program running time, enter distances in increasing order.
 - b. Zero is not an allowed distance.
 - c. Unit populations are automatically entered if no other values are input by the user.
 - d. Distance (and population) data are not altered by program execution. If data from the previous run (or data card entry) will be used, press R/S when the first distance prompt appears.

When all distances have been entered, press R/S at the next distance prompt.
 7. Pasquill-Gifford atmospheric stability class. Because the calculator is not in ALPHA mode, simply enter the appropriate letters or letters up to a maximum of six. Each stability will be computed in the order entered.

- C. Once the output is complete, the input data may be changed and the program run again. To restart from the beginning, press R/S. To change only a few items and execute, switch to USER mode and input the changes using local alpha labels as follows:
1. To change h, enter the new h and press A.
 2. To change u, enter the new u and press B.
 3. To change v_d , enter the new v_d and press F.
 4. To change S, enter the new S and press G.
 5. To switch to sector-averaged X/Q or to remove this option, press H. Be sure to enter population data, if necessary.
 6. To change distances (and populations if sector averaging), press C and enter the requested information.
 7. To change stability class or classes, press D. The program begins executing with the "MET? A, B, C, D, E, F" prompt. Enter your selections according to the instructions given in step B.7.
 8. To execute a run without changing stabilities, press E.

SAMPLE OUTPUT

The printout on the left below was obtained using sector averaging and selecting PG classes D and E.

The printout shown on the right was generated by clearing the sector-average option and choosing all six classes.

*** X/Q ***
PASQUILL 3-5-84

RELEASE HEIGHT 0.1 M
WIND SPEED 1.0 M/SEC
DEP. SPEED 0.100 CM/SEC
BUILDING AREA 400 SQ M
* SECTOR AVERAGE 1/6 *
DISTANCE POPULATION
8.00 1
15.50 2000
TOTAL 2001

PASQUILL D
X X/Q Fd
8.00 1.81-06 0.85E
15.50 6.27-07 0.82E

DISTANCE POP*% C
8.00 1.81-06
15.50 1.25-07
TOTAL 1.26-07

PASQUILL E
X X/Q Fd
8.00 2.61-06 0.80E
15.50 9.80-07 0.75E

DISTANCE POP*% C
8.00 2.61-06
15.50 1.96-07
TOTAL 1.96-07

*** X/Q ***
PASQUILL 3-5-84

RELEASE HEIGHT 0.1 M
WIND SPEED 1.0 M/SEC
DEP. SPEED 0.100 CM/SEC
BUILDING AREA 400 SQ M

PASQUILL F
X X/Q Fd
8.00 2.20-06 0.77E
15.50 8.99-06 0.64E

PASQUILL E
X X/Q Fd
8.00 9.64-06 0.80E
15.50 4.01-06 0.75E

PASQUILL D
X X/Q Fd
8.00 4.89-06 0.85E
15.50 1.28-07 0.82E

PASQUILL C
X X/Q Fd
8.00 1.14-06 0.92E
15.50 3.92-07 0.90E

PASQUILL B
X X/Q Fd
8.00 1.59-07 0.95E
15.50 9.09-06 0.45E

PASQUILL A
X X/Q Fd
8.00 1.25-07 0.97E
15.50 7.17-06 0.96E

MATHEMATICAL MODELS USED BY "X/Q - PASQUILL"

- A. Pasquill-Gifford curves for σ_y and σ_z are well approximated by the formulas given below, where x is in Km.

TABLE 7. Pasquill-Gifford Curves.

Stability class	$\sigma_y = a x / (1 + .5\sqrt{x})^{\frac{1}{2}}$	σ_z^*
A	$a = 240$	$146 x (1 + 2.7 x^2)$
B	$a = 185$	$102 x (1 + .26 x \sqrt{x})$
C	$a = 139$	$83 x / (1 + .3 \sqrt{x})$
D	$a = 90$	$47 x / (1 + 1.1 x)^{\frac{1}{2}}$
E	$a = 66$	$38 \ln (1 + .85x)$
F	$a = 46$	$18 \ln (1 + 1.3x)$

NOTE: Plots of these functions are shown in Figure 4.

*The vertical dispersion parameter is not allowed to exceed 2,000 m.

- B. Building wake effects.

σ_y and σ_z are replaced with Σ_y and Σ_z as follows:

$$\Sigma_y^2 = \sigma_y^2 + \frac{S}{2\pi} \quad \text{and} \quad \Sigma_z^2 = \sigma_z^2 + \frac{S}{2\pi}$$

$$\text{such that } \Sigma_y \Sigma_z \leq 3 \sigma_y \sigma_z$$

PS8408-69

FIGURE 4. Plots of the Pasquill-Gifford Curves as Parameterized for "X/Q - Pasquill."

C. Integrated ground deposition loss.

F_d is the fraction remaining at distance x .

$1 - F_d$ = fraction lost to ground deposition.

$$\ln F_d = \sqrt{\frac{2}{\pi}} \frac{v_d}{u} \left(\int_0^x \frac{dx}{\Sigma_z} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right) \right) \frac{10 \text{ m}^2}{\text{cm-Km}}$$

Typical values for v_d are as follows:

0.1 cm/s for most particulate matter

1.0 cm/s for halogens (e.g. iodine).

D. Time integrated air concentration.

1. Centerline X/Q

$$\frac{X}{Q} = \frac{F_d}{\pi u \Sigma_y \Sigma_z} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right)$$

2. Sector-averaged X/Q , 22.5 degree sectors

$$\frac{X}{Q} = \frac{.008 F_d}{\pi u x \Sigma_z} \sqrt{\frac{2}{\pi}} \exp \left(\frac{-h^2}{2 \Sigma_z^2} \right)$$

Sector-averaged X/Q values are normally used when dose population is determined or when the release duration exceeds 8 h.

MEMORY USE:

00: distance pointer
 01: integration pointer
 02: u (wind speed)
 03: integration x
 04: x increment
 05: Σ_z^2
 06: Σ_y^2
 07: A
 08: b σ_z
 09: a
 10: $(\Sigma_y / \sigma_y)^2$
 11: $(\Sigma_z / \sigma_z)^2$
 12: S / 2π
 13: piecewise sum
 14: overall integration sum
 15: MET save
 16: MET remaining
 17: v_d (depletion speed)
 18: h (release height)
 19: distance pointer save
 20: 1st distance
 21: 1st population
 22: 1st (X/Q) (population)

USER MODE LABELS:

A: input new H
 B: input new u
 C: input new x values (and populations if sector averaging)
 D: input new MET choice and run
 E: execute program
 F: input new v_d
 G: input new S
 H: choose or remove sector averaging (sets flag 02 if clear, and clears flag 02, if set)

FLAG USE:

00: $v_d = 0.0$ cm/s
 01: S > 0 m²
 02: sector averaging

TABLE 8.
Flags Used to Define the MET Class.

Flags			
MET	03	04	05
A			
B			Set
C		Set	
D		Set	Set
E	Set		
F	Set	Set	

PROGRAM LISTING

LBL *X-0
END

01+LBL "X/0"

02 CF 0

03 CF 29

04+LBL 4E

05 " * READY +

06 FS 27

07 PROMPT

08 "H = ? M"

09 RCL 18

10 PROMPT

11+LBL A

12 .1

13 X/Y

14 X/Y

15 X/Y

16 STO 18

17 FS 27

18 GTD 4E

19 XEQ 04

20 "U = ? M/S"

21 RCL 02

22 PROMPT

23+LBL E

24 STO 02

25 FS 27

26 GTD 4E

27 XEQ 05

28 "Vd = ? CM/SEC"

29 CLY

30 PROMPT

31+LBL F

32 CF 00

33 X=0?

34 9F 00

35 STO 17

36 FS 27

37 GTD 4E

38 XEQ 06

39 "BLDG. AREA"

40 CLY

41 PROMPT

42+LBL G

43 CF 01

44 0

45 0

46 FI

48 STO 17

49 X=0?

50 SF 01

51 FS 27

52 GTD 4E

53 XEQ 07

54 CF 27

55 "SECTOR AVE. ?"

56 CF 02

57 PROMPT

58 FC 22

59 GTD C

60+LBL H

61 FC 02

62 SF 02

63 FS 27

64 GTD 4E

65+LBL C

66 1.1

67 STO 00

68 STO 03

69 19

70 +

71 STO 04

72+LBL 00

73 FIX 0

74 "Y"

75 ARCL 0A

76 "t = ? KM"

77 CLY

78 PROMPT

79 X=0?

80 GTD 02

81 STO IND 1

82 3

83 FC 02

84 GTD 01

85 FIX 0

86 ISG 04

87 "FOP."

88 ARCL 00

89 "t"

90 1

91 PROMPT

92 STO IND 04

93 2

94+LBL 01

95 ST+ 04

96 ISG 00

97 GTD 00

98+LBL 02

99 RCL 00

100 RCL 03

101 -

102 X=0?

103 GTD 07

104 RCL 04

105 RCL 07

106 -

107 ?

108 10+Y

109 /

110 20

111 +

112 STO 19

113+LBL 02

114 FS 27

115 GTD 4E

116 FS 02

117 XEQ 09

118+LBL D

119 CF 23

120 "MET? A,B,C,D,E"

121 "F"

122 AON

123 PROMPT

124 AOFF

125 FS 23

126 ASTO 15

127+LBL E

128 DEG

129 RCL 15

130 STO 16

131+LBL 47

132 CF 07

133 CF 04

134 CF 05

135 " "

136 ARCL 16

137 ASTO L

138 ASHF

139 "t"

140 ASTO 16

141 " "

142 ASTO Y

143 ARCL L

144 ASHF

145 ASTO X

146 ASTO 01

147 X+Y

148 GTD IND X

THIS TESTS FOR
ANY NON ZERO
ENTRY WHILE IN
DISTANCE LOOP.

CHOOSE SECTOR
AVERAGING BY
ENTERING ANY
NUMBER

SETS FLAG 2 IF
CLEAR, CLEARS
FLAG 2 IF SET.

ENTER
DISTANCES AND
POPULATIONS.

ENTER STABILITY
CLASS CHOICES.

DOESN'T LEAVE
DISTANCE LOOP
UNTIL X ≤ 0

CLEARS FLAG 43

ROUTES TO LEFT.
MOST LETTER OF
THE ALPHA
STRING.

PROGRAM LISTING

149 ADV	201 SF 1"	251 ADV	
150 CLS"	202 ACA	252 RTN	
151 ADV	203 PRBUF	<u>253+LBL "A"</u>	← CLASS A PARAMETERS
152 SF 27	204 CF 13	254 340	
153 ADV	205 RTN	255 2.7	
154 GTO 4b	<u>206+LBL 09</u>	256 146	
<u>155+LBL 04</u>	207 "* SECTOR AVERAG"	<u>257 GTO 02</u>	
156 SF 12	208 "FED X/Q *	<u>258+LBL "B"</u>	← CLASS B PARAMETERS
157 "*** X/Q ***"	209 PRA	259 185	
158 PRA	210 "DISTANCE FOP"	260 .26	
159 CF 12	211 "FULATION"	261 102	
160 "PASQUILL "	212 PRA	262 SF 05	
161 "F 3-5-84"	213 RCL 19	<u>263 GTO 02</u>	
162 PRA	214 STO 00	<u>264+LBL "C"</u>	← CLASS C PARAMETERS
163 ADV	215 CLY	265 139	
164 FIX 1	<u>216 STO 04</u>	266 .3	
165 "RELEASE HEIGHT "	<u>217+LBL 10</u>	267 83	
166 "F "	218 FIX 2	<u>268 GTO 01</u>	
167 ARCL 18	219 RCL IND 00	<u>269+LBL "D"</u>	← CLASS D PARAMETERS
168 ACA	220 ACX	270 90	
169 "M"	221 ISG 00	271 1.1	
<u>170 GTO 06</u>	222 FIX 0	272 47	
<u>171+LBL 05</u>	223 RCL IND 00	273 SF 05	
172 FIX 1	224 ISG 00	<u>274 GTO 01</u>	
173 "WIND SPEED "	225 ST+ A4	<u>275+LBL "E"</u>	← CLASS E PARAMETERS
174 ARCL 02	226 CLA	276 66	
175 ACA	227 0	277 .85	
176 "M/SEC"	228 RCL 1	278 38	
177 GTO 06	229 LOG	279 SF 03	
<u>178+LBL 06</u>	230 INT	<u>280 GTO 02</u>	
179 FIX 3	231 -	<u>281+LBL "F"</u>	← CLASS F PARAMETERS
180 9	232 SKPCHR	282 46	
181 RCL 17	233 RDN	283 1.3	
182 X/Y?	234 ACX	284 18	
183 FIX 1	235 0	285 SF 03	
184 "DEP. SPEED "	236 SKPCHR	<u>286+LBL 01</u>	
185 ARCL Y	237 ADV	287 SF 04	
186 ACA	238 ISG 00	<u>288+LBL 02</u>	
187 "CM/SEC"	239 GTO 10	289 STO 07	
<u>188 GTO 02</u>	240 "TOTAL "	290 RDN	
<u>189+LBL 07</u>	241 ARCL 04	291 STO 08	
190 FIX 0	242 ACA	292 RDN	
191 "BUILDING AREA	243 SKPCHR	293 STO 09	
192 RCL 12	244 24	294 FC7C 27	
193 2	245 ADV	295 GTO 01	
194 +	246 95		
195 PT	<u>247+LBL 11</u>		
196 +	248 ACCHF		
197 ARCL Y	249 DSE +		
198 ACA	250 GTO 11		
199 "SQ M"			
<u>200+LBL 02</u>			

END OF PROGRAM EXECUTION
PRINTS HEADER AND RELEASE HEIGHT

IF SECTOR AVERAGING, PRINTS DISTANCE AND POPULATION TABLE

PRINTS WIND SPEED

PRINTS GROUND DEPOSITION SPEED

PRINTS BUILDING WAKE AREA

PRINTS 24 CHARACTER LINE.

PROGRAM LISTING

296 XEQ 04		346 5.3192 ← $5.3192 = \frac{20}{3} \sqrt{\frac{2}{\pi}}$	396 2	
297 XEQ 05	PRINTS ALL INPUT INFOR- MATION WHEN IN USER MODE EXECUTION.	347 RCL 17	397 FC? 02	
298 XEQ 06		348 *	398 GT0 02	
299 XEQ 07		349 RCL 02	399 X<>Y	WHEN SECTOR AVERAGING, THIS STORES (X/Q)*(POP.).
300 FS? 02		350 /	400 ISG 00	
301 XEQ 09		351 RCL 14	401 RCL IND 00	
302+LBL 01	352 *	402 *		
303 ADV	353 C+S	403 ISG 00		
304 SF 12		354 E+X ← F_d IS COMPLETE.	404 STO IND 00	
305 " PASQUILL"		355 GT0 01	405 0	
306 ARCL 01		356+LBL 03	406+LBL 02	
307 PRA		357 RCL IND 00	407 ST+ 00	
308 " X X/0 F_d "		358 STO 03	408 2	
309 PRA		359 CLX	409 SKPCHP	
310 CF 12		360 STO 04	410 FIX 3	
311 RCL 19		361 XEQ 58	411 .1	
312 STO 00		362 STO 01	412 RCL 04	
313 FS? 00	AVOIDS NUMERIC INTEGRATION IF $V_d=0$.	363 1	413 X<=Y?	
314 GT0 03		364+LBL 01	414 FIX 4	
315 GT0 01		365 STO 04	415 RND	
316+LBL 49		366 CLA	416 ACX	
317 FS? 00		367 FIX 2	417 X>Y?	
318 GT0 03		368 ARCL 03	418 1	
319 RCL IND 00		369 "+ "	419 SKPCHR	
320 RCL 03		370 ACP	420 ADV	
321 X<=Y?	TESTS NEW X AGAINST PREVIOUS.	371 SCI 2	421 ISG 00	
322 GT0 12		372 FC? 01	422 GT0 49	
323+LBL 01		373 XEQ 59	423 FC? 02	SKIPS DISTANCE AND POPULATION*X/Q TABLE.
324 CLX	374 RCL 01	424 GT0 47		
325 STO 03	375 PI	425 RCL 15		
326 STO 13		376 /	426 STO 00	
327 STO 14		377 RCL 02	427 CLX	
328 .001	← UPPER LIMIT OF 1ST INTEGRAL.	378 /	428 STO 04	
329 XEQ 57	← 1ST INTEGRAL.	379 RCL 06	429 ADV	
330+LBL 12		380 FC? 02	430 " DISTANCE POP"	
331 RCL 03	10 TIMES THE PREVIOUS UPPER LIMIT.	381 GT0 01	431 "+X/0"	
332 10		382 RDN	432 PRA	DOES TABLE OF DISTANCES AND POPULATION WEIGHTED X/Q VALUES.
333 *		383 RCL 03	433+LBL 12	
334 RCL IND 00	384 /	434 FIX 2		
335 X<=Y?		385 125	435 CLA	
336 GT0 02	← DOES FINAL INTEGRATION.	386 /	436 ARCL IND 00	
337 X<>Y		387 PI	437 "+ "	
338 .9		388 2	438 ACP	
339 *		389 /	439 2	
340 XEQ 57		390+LBL 01	440 ST+ 00	
341 GT0 12		391 SORT	441 RCL IND 00	
342+LBL 02		392 /	442 SCI 2	
343 RCL 03		393 RCL 04	443 ACX	
344 -		394 *	444 ST+ 04	
345 XEQ 57		395 ACX ← X/Q VALUE TO PRINTER.	445 5	

PROGRAM LISTING

446 SKPCHR		498 *	← COMPUTES σ_y^2 AND $(1 + \frac{s}{2\pi\sigma_y^2})$.	546 X<Y?
447 ADV		499 GTO 03		547 GTO 01
448 ISG 00		500+LBL 01		548 STO 10
449 GTO 13		501 RCL 03		549 STO 11
450 * TOTAL.		502 FC? 05		550 GTO 02
451 ACA		503 SQRT		551+LBL 01
452 RCL 04		504 RCL 00		552 X+2
453 ACY		505 *		553 X<>Y
454 PRBUF		506 1		554 /
455 ADV		507 +		555 FC? 43
456 GTO 47	← RETURNS TO BEGINNING.	508 FS? 05		556 11
457+LBL 57	← NUMERIC INTEGRATION SUBROUTINE.	509 SQRT		557 FS? 43
458 10		510 /		558 10
459 /		511 GTO 03		559 X<>Y
460 STO 04		512+LBL 02		560 STO IND Y
461 1.01		513 RCL 00		561+LBL 02
462 STO 01		514 *		562 DEG
463+LBL 14		515 LN1+X		563 RCL 11
464 XEQ 58		516 *		564 ST* 05
465 ST+ 13		517+LBL 03		565 RCL 10
466 ISG 01		518 2 E3	← ENSURES $\sigma_2 < 2000$ m.	566 ST* 06
467 XEQ 58		519 X<Y?		567+LBL 03
468 ISG 01		520 X<>Y		568 RCL 18
469 GTO 14		521 X+2		569 X+2
470 STO 01		522 STO 05		570 RCL 05
471 2		523 FC? 01	← AVOIDS BUILDING WAKE LOGIC.	571 /
472 /		524 GTO 03		572 CHS
473 ST- 13		525 RCL 12		573 E+Y
474 X<> 13		526 X<>Y		574 RCL 05
475 RCL 04		527 /		575 /
476 *		528 1		576 SQRT
477 ST+ 14		529 +		577 ST+ 13
478 RTN		530 STO 11		578 RTN
479+LBL 58	← COMPUTES σ_y^2 AND $(1 + \frac{s}{2\pi\sigma_y^2})$.	531 XEQ 59		579+LBL 59
480 RCL 04		532 9		580 RCL 12
481 ST+ 03		533 RCL 10		581 RCL 03
482 RCL 07		534 RCL 11		582 RCL 05
483 RCL 03		535 *		583 *
484 FS? 03		536 X<=Y?		584 X+2
485 GTO 02		537 GTO 02		585 RCL 03
486 *		538 RCL 11		586 SQRT ← INTEGRAND.
487 FS? 04		539 RCL 10		587 2
488 GTO 01		540 X<=Y?		588 /
489 RCL 03		541 GTO 01	← SETS FLAG 43. (NORMALLY OCCURS ONLY IN CLASS A. X > 0.4 km AND S > 100,000 m ²).	589 1
490 FS? 05		542 RND		590 +
491 SQRT		543 X<>Y		591 /
492 RCL 03		544+LBL 01		592 STO 06
493 *		545 3		593 /
494 RCL 08				594 1
495 *				595 +
496 1				596 STO 10
497 *				597 END