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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

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 $\cdot$ m^3/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.

BIBLIOGRAPHY

Hanna, S. R., G. A. Briggs and R. P. Haskar, Jr. (1982), Handbook on Atmospheric Diffusion. National Technical Information Service, Springfield, Virginia.

Kathren, R. L., D. P. Higby, and M. A. McKinney (1984), Computer Applications in Health Physics. Columbia Chapter of the Health Physics Society, Richland, Washington.

Kocher, D. C. (1981), Radioactive Decay Data Tables. National Technical Information Service, Springfield, Virginia.

Lederer, C. M. and V. S. Shirley (1978), Table of Isotopes. John Wiley and Sons, New York.

Slade, D. H. (1968), Meterology and Atomic Energy, National Technical Information Service, Springfield, Virginia.

Strenge, D. L., W. E. Kennedy, Jr., and J. P. Corley (1982), Environmental Dose Assessment Methods for Normal Operations at DOE Nuclear Sites. Technical Report PNL-4410, Pacific Northwest Laboratory, Richland, Washington.

Till, J. E. and H. R. Meyer (1983), Radiological Assessment. National Technical Information Service, Springfield, Virginia.

Zimmerman, M. G., and D. H. Thomsen (1975), A Shielding Calculational System for Plutonium. Technical Report BNWL-1855, Pacific Northwest Laboratories, Richland, Washington.

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.

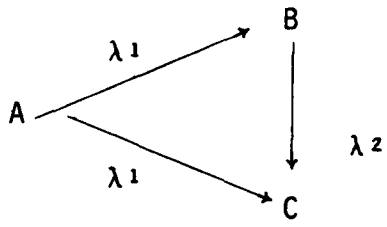
2. For each nuclide, the alphanumeric identification is limited to a six-character maximum. The half-life is next, and is followed by a unit prompt. The available units are seconds (1), minutes (2), hours (3), days (4), or years (5). The program converts these to hours, computes a decay constant, and 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.

a. $A \xrightarrow{\lambda_1} B \xrightarrow{\lambda_2} C$ B.R. = 1.000

parent daughter stable

b.



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 $^{90}Sr \longrightarrow {}^{90}Y \longrightarrow {}^{90}Zr$

An example of "b" is $^{137}Cs \rightarrow {}^{137m}Ba \rightarrow {}^{137}Ba$ B.R. = .946

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:

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

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

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

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 SCI 2
04 1
05 "FACTOR="
06 PROMPT
07 ARCL X
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 "DK"
45 END
```

SAMPLE PROBLEM

```
SINGLE HALFLIVES
CS134 2.050E0 YR
CS137 3.0[illegible]E1 YR
Ba137*2.02E-1 YR

TWO STEP HALFLIVES
SR90  2.810E1 YR
B.R.= 1.000000
Y 90  6.400E1 HR

ZR95  6.400E1 DAY
B.R.= 1.000000
Nb95  3.510E1 DAY

  CURIES
CS134 1.000E1
CS137 5.000E
Ba137*4.730E0
SR90  2.000E1
Y 90  1.900E1
ZR95  6.000E1
Nb95  8.000E1

[illegible] = 27
```

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

SECOND, THE INITIAL ACTIVITIES ARE ENTERED.

NOTICE THAT Zr-95 AND Nb-95 HAVE DECAYED TO LESS THAN 1.0 E-09 CI AND ARE NO LONGER PRINTED/DISPLAYED.

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

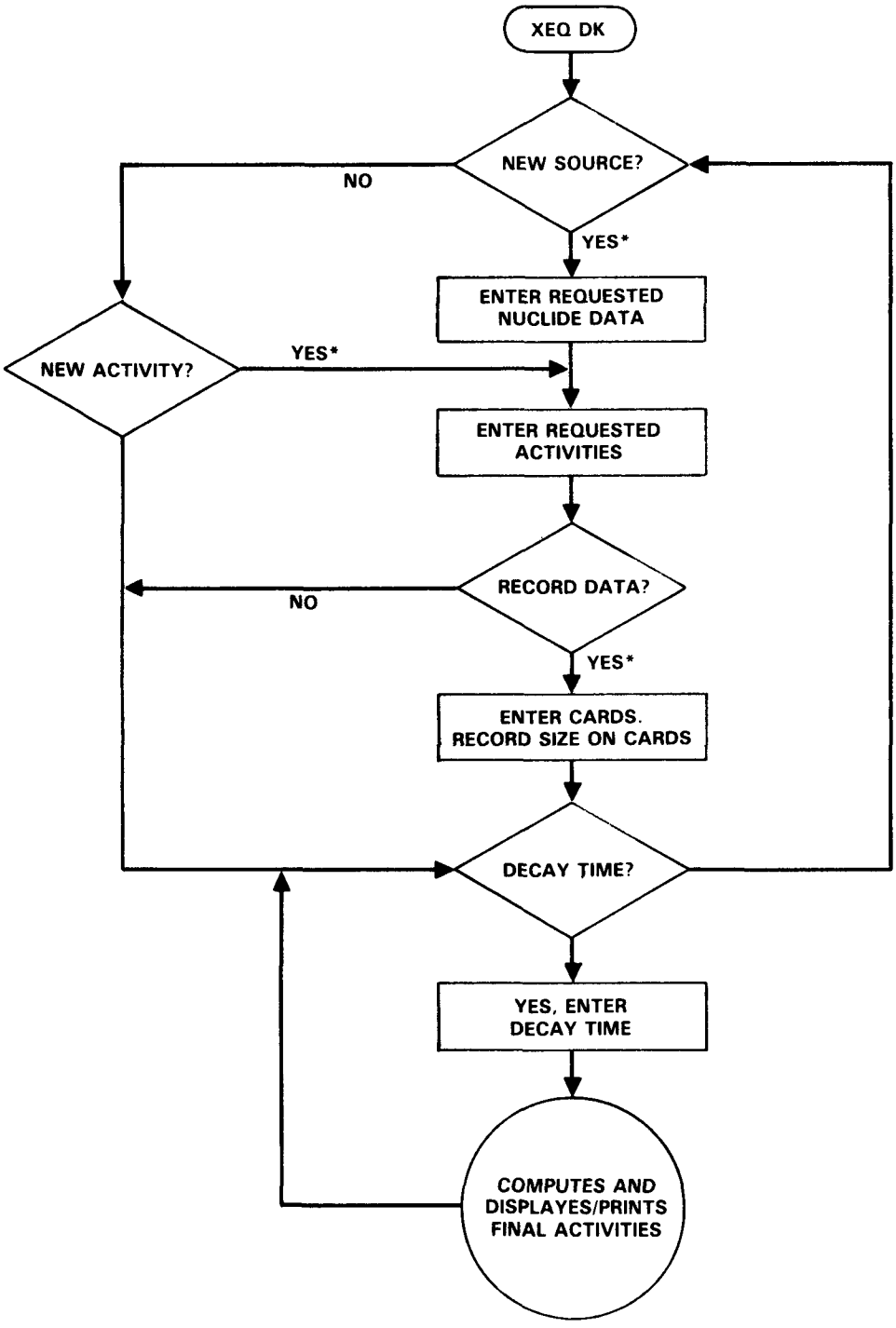
THIRD, THE ACTIVITIES CAN BE AGED.

```
T= 3.000E1 DAY
CS134 3.73E0
CS137 4.99E0
Ba137*4.72E0
SR90  2.00E1
Y 90  2.00E1
ZR95  4.34E1
Nb95  6.68E1

T= 3.000E1 YR
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

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

FACTOR=2.00E0
CS134 2.00E1
CS137 [illegible]E1
ba137*-.--E0
SR90  4.00E
Y 90  3.80E1
ZR95  1.20E2
Nb95  1.60E2
```

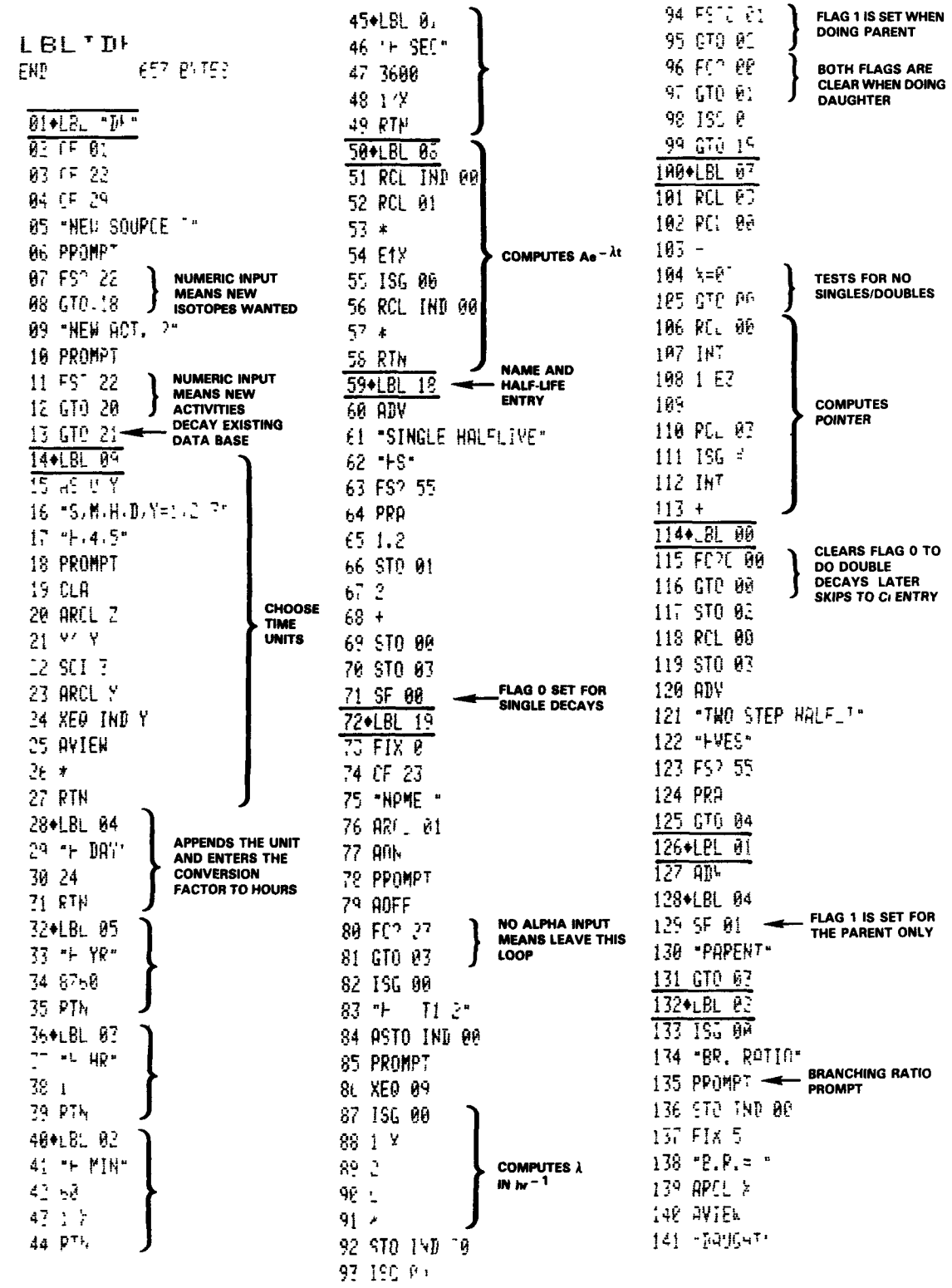


*YES FLOW PATHS ARE OBTAINED BY ENTERING ANY NUMBER AND PRESSING R/S. PRESSING R/S ALONE CAUSES EXECUTION ALONG THE NO FLOW PATHS.

PS8408-66

FIGURE 1. Flowsheet for Program "DK."

PROGRAM LISTING



PROGRAM LISTING

```
143*LBL 02
147 ASTO 01
144 GTO 19
145*LBL 00          <- NEW ACTIVITY ENTRY (IN CI)
14E STO 05
147 CF 01
148*LBL 20
149 AD+
150 SF 13
151 " CURIES"
152 AVIEW
153 CF 13
154 SCI 2
155 RCL 0E
156 STO 00
157 X=0?            } IF THE SINGLE DECAY POINTER IS ZERO, PROGRAM GOES TO LBL 01
158 GTO 01          }
159 SF 00
160*LBL 10
161 CLX             <- 0 IS IN THE X-REGISTER ALREADY
162 CLA
163 ARCL IND 00
164 "T= ? CI"
165 PROMPT
166 2
167 ST+ 00
168 X<>Y
169 ASTO
170 CLA
171 ARCL L
172 ARCL Y
173 STO IND 00
174 X>0?
175 AVIEW
176 FS? 00          } SINGLE DECAYS GTO 00
177 GTO 00          }
178 FS?C 01         } FLAG 1 IS SET FOR THE DAUGHTER ONLY
179 GTO 00          }
180 ISG 00
181 SF 01
182*LBL 0
183 ISG 00
184 GTO 10
185 FC?C 00
186 GTO 00
187*LBL 01
188 RCL 03
189 STO 0C
190 X=0?            } IF THE TWO-STEP POINTER IS ZERO, PROGRAM GOES TO LBL 00
191 GTO 10          }
192*LBL 00
193 CF 22
194 "RECORD DATA?"
195 PROMPT
196 FC? 22          } TESTS FOR NUMERIC INPUT
197 GTO 21          }
198 RCL 03
199 X=0?
200 RCL 0C
201 FRC             <- RECORDS DATA FROM REGISTER 00 TO LAST REGISTER USED
202 WDTA?
203 FIX 0
204 ADV
205 1 E3            } COMPUTES NEEDED MEMORY SIZE FOR THIS DATA
206 *               }
207 1               }
208 +               }
209 "SIZE = "
210 ARCL X
211 AVIEW
212 PSE
213*LBL 21
214 ADV
215 CF 22
216 "DECAY TIME ?"
217 PROMPT
218 FC? 22          } NO NUMBER ENTRY -> START OVER
219 GTO "D?         }
220 "T= "
221 XEQ 09          <- UNITS
222 CHS
223 STO 01
224 SF 21           <- MAKES SURE EXECUTION STOPS WITHOUT PRINTER
225 SCI 3
226 RCL 02
227 STO 00
228 X=0?            } TESTS FOR A NULL SINGLE DECAY POINTER
229 GTO 02          }
230 SF 00
231*LBL 22
232 CLA
233 ARCL IND 00     <- RECALLS NAME
234 ISG 00
235 RCL IND 00      <- RECALLS λ
236 YEX 05          <- Ae^-λt
237 FS? 00          } SINGLE DECAYS
238 GTO 02          }
239 ARCL X
240 X>0?            } DOES NOT SHOW ZERO RESULTS
241 AVIEW           }
242 RCL IND 00      <- RECALLS A1
243 ISG 00
244 RCL IND 00      <- RECALLS B R
245 *
246 ISG 00
247 CLA
248 ARCL IND 00     <- NAME DAUGHTER
249 ISG 00
250 RCL IND 00      <- RECALLS λ2
251 *
252 X=0?            } IF A1 = 0, PROGRAM SKIPS THE BUILD UP CALCULATION
253 GTO 01          }
254 R↑
255 LASTX
256 X≠Y?            } IF λ1 ≠ λ2, GOES TO LBL 00
257 GTO 00          }
258 RDN             } FOR λ1 = λ2
259 RCL 01          } (A1*λ2t+A2) e^-λ2t
260 ST* 03          } A1* = A1 (B R)
261 *               }
262 E↑X             }
263 ISG 00          }
264 RCL IND 00      }
265 RCL 03          }
266 -               }
267 *               }
268 GTO 02          }
```

PROGRAM LISTING

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

Daughter buildup computed as follows:

$$\lambda_1 > \lambda_2: \quad \frac{A_1 * \lambda_2 \, e^{-\lambda_2 t}}{\lambda_1 - \lambda_2} \left[e^{-(\lambda_1 - \lambda_2)t} - 1 \right]$$

$$\lambda_2 > \lambda_1: \quad \frac{A_1 * \lambda_2 \, e^{-\lambda_1 t}}{\lambda_2 - \lambda_1} \left[e^{-(\lambda_2 - \lambda_1)t} - 1 \right]$$

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

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 GTO.. 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 "O" 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+02
TOTAL ALPHA: 2.085+04 CI
TOTAL BETA: 1.031+05 CI
```

```
10.0 YEARS
```

ENTER 10 w 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  1.027+00
NP237  0.315  1.888+01
PU238 15.405  9.240+02
PU239 16.667  9.997+02
PU240 16.654  9.989+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+07
S-F     5.344+06
Total   2.161+07

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

PRESS R/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  4.797+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 PuF_4 THIS TIME. NOTICE THE AGED ACTIVITIES ARE GONE.

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

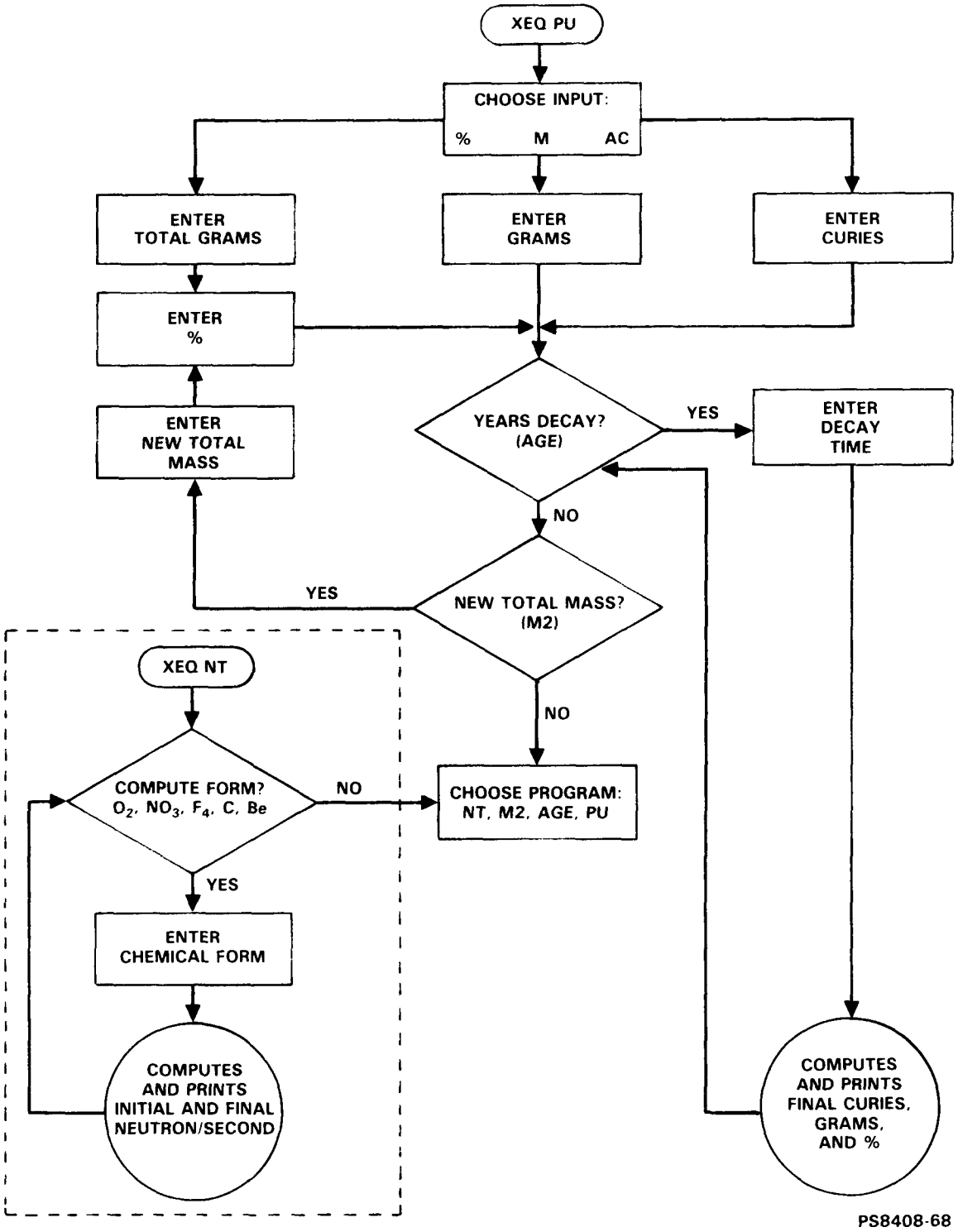


FIGURE 2. Flowsheet for Program "PU."

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.

	Spontaneous		Oxide		Fluoride		Carbide		Beryllium		Alpha energy (MeV)
Isotope	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             COMPUTES MASSES AND TOTAL HEAT
67♦LBL 20          ← 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 "  CI  "
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
```

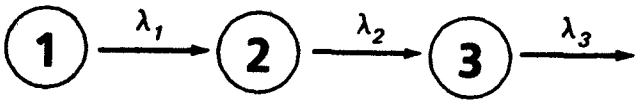
(186–193: $A_e = A_0 e^{-\lambda t}$ COMPUTED AND STORED.)

```
200 *
201 STO 52   ← Af 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   ← Af Np-237
225 RCL 25
226 RCL 21
227 XEQ 23
228 RCL 75
229 *
230 STO 42   ← Af U-234
231 RCL 26
232 RCL 22
233 XEQ 23
234 RCL 76
235 *
236 STO 43   ← Af U-235
237 RCL 27
238 RCL 23
239 XEQ 23
240 RCL 77
241 *
242 STO 44   ← Af U-236
243 RCL 28
244 RCL 30
245 XEQ 23
246 RCL 78
247 *
248 ST+ 51   ← Af Am-241
249 XEQ 29
250 XEQ 24
251 .001
```

PROGRAM LISTING

```
252 ST+ 00
253 CLX
254 STO 02
255♦LBL 06   ← PRINTS FINAL ACTIVITY TABLE.
256 "  "
257 ARCL IND 00
258 "+ "
259 RCL IND 05
260 XEQ 14
261 ST+ 02
262 ISG 00
263 CLX
264 ISG 05
265 GTO 06
266 RCL 52
267 RCL 49
268 +
269 XEQ 30
270 XEQ 24
271 XEQ 31
272 XEQ 24
273 XEQ 26
274 GTO 22
275 ADV
276♦LBL "M2"
277 CF 22
278 "NEW TOT MASS"
279 PROMPT
280 FC? 22
281 GTO 10
282 STO 08
283 ADV
284 SF 12
285 PRA
286 CF 12
287 CLX
288 STO 07
289 GTO 20
290♦LBL 10
291♦LBL "Σa"
292 ADV
293 "PU, AGE, M2  NT"
294 AON
295 PROMPT
296 AOFF
297 ASTO X
298 GTO IND X
299♦LBL 23   ← COMPUTES λ2e^(-λ2t)/(λ1-λ2) (1-e^(-(λ1-λ2)t)).
300 -
301 LASTX
302 LASTX
303 RCL 07
```

Formulas Used:



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

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

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

$$+ \frac{\lambda_3 A_{20}}{\lambda_2 - \lambda_3}\left(e^{-\lambda_3 t} - e^{-\lambda_2 t}\right)$$

PROGRAM LISTING

```
304 *
305 E↑Y
306 ↑
307 X<>Y
308 /
309 LASTX
310 RCL 07
311 *
312 E↑X-1
313 CHS
314 *
315 RTN
316♦LBL 24          <- INITIALIZES FULL MEMORY POINTERS
317 10.019
318 XEQ 10
319 LASTX
320 +
321 1
322 -
323 STO 03
324 STO 05
325 53.062
326 STO 04
327 RTN
328♦LBL 25          <- INITIALIZES DATA INPUT POINTERS
329 75.08
330 STO 05
331 6.00E
332 -
333 STO 04
334 LASTX
335 -
336 STO 03
337 14.019
338♦LBL 10
339 STO 00
340 11.011
341 +
342 STO 01
343 LASTX
344 +
345 STO 02
346 RTN
347♦LBL 26          <- COMPUTES % FROM MASS AND PRINTS % AND MASS TABLE
348 XEQ 28
349 CLX
350 STO 05
351 2
352 10↑X
353 STO 01
354♦LBL 07
355 CLR
356 ARCL IND 00
357 FIX 2
358 10
359 RCL IND 04
360 RCL 06
361 /
362 RCL 01
363 *
364 FS? 00
365 STO IND 03
366 RND
367 X<Y?
368 "+ "
369 .001
370 X<>Y
371 X<Y?
372 CLX
373 ARCL Y
374 "+ "
375 SCI 2
376 RCL IND 04
377 XEQ 14
378 RCL IND 02
379 *
380 ST+ 05
381 ISG 00
382 ISG 02
383 ISG 03
384 CLX
385 ISG 04
386 GTO 07
387♦LBL 27
388 "GRAMS "
389 ARCL 06
390 RCL 00
391 XEQ 14
392 CLA
393 ARCL 06
394 "+WATTS "
395 RCL 05
396♦LBL 14
397 Y=0?
398 RTN
399 ACA
400 ACX
401 PPBUF
402 RTN
403♦LBL 29
404 ADV
405 " NAME    "
406 "+GRAMS"
407 PFA
408 RTN
409♦LBL 39
410 ADV
411 3
412 SKPCHR
413 "NAME    CURIES"
414 ACP
415 PRBUF
416 RTN
417♦LBL 30
418 ST- 02
419 CLA
420 ARCL 06
421 "+ALPHA "
422 RCL 02
423 XEQ 10
424 CLA
425 ARCL 06
426 "+BETA "
427 X<>Y
428♦LBL 10
429 ACA
430 ACX
431 " CI"
432 ACA
433 PPBUF
434 RTN
435♦LBL 31          <- COMPUTES MASS FROM ACTIVITY
436 CLX
437 STO 08
438♦LBL 08
439 RCL IND 05
440 RCL IND 01
441
442 RCL 09
443 /
444 224.03
445 RCL 00
446 ISG 00
447 GTO 10
448 RDN
449 17
450♦LBL 10
451 +
452 *
453 STO IND 04
454 ST+ 08
455 ISG 01
456 ISG 05
457 ISG 04
458 GTO 08
459 RTN
460 END
```

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 $Pu(NO_3)_2$.
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	λ(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 BYTES
```

```
01♦LBL "NT"
02 CF 01
03 CF 02
04 CF 23
05 "02,NO3,F4                    MENU.
06 AON
07 PROMPT
08 AOFF
09 FC? 23                        NO ALPHA ENTRY →
10 GTO "Σa"                      RETURN TO "Pu".
11 SCI 3
12 ASTO 03
13 SF 12
14 "P"
15 ACA
16 117
17 ACCHR
18 CLA
19 ARCL 03
20 ACA
21 SF 13
22 " N/SEC"
23 ACA
24 PRBUF
25 75.1                          PUTS INTITAL
26 GTO 33                        ACTIVITIES IN
                                 REGISTERS 69 AND
                                 74.
27♦LBL 32                        ← PuC.
28 870
29 601
30 606
31 532
32 XEQ 34
33 GTO 09
34♦LBL "Be"                      ← PuBe.
35 255.7
36 219
37 221
38 154.3
39 XEQ 34
40 4
41 10↑X
42 *
43 GTO 09
44♦LBL "F4"                      ← PuF4.
45 1191
46 1024
47 1036
48 720
49 XEQ 34
50 100
51 *
52 GTO 09
```

```
53♦LBL "NO3"                     ← Pu(NO3)2.
54 SF 01
55♦LBL "02"                      ← PuO2.
56 782
57 613
58 639
59 542
60 XEQ 34
61 ENTER↑
62 FS?C 01
63 +
64♦LBL 09
65 4
66 ACCHR
67 RDN
68 "-N  "
69 SF 13
70 XEQ 35                        ← PRINTS α-n
                                   RESULT.
71 SF 12                         SPONTANEOUS
72 "S-F  "                       FISSION n/sec
73 RCL 69                        COMPUTATION.
74 153
75 *
76 RCL 70
77 .45
78 *
79 +
80 RCL 71
81 4497
82 *
83 +
84 RCL 73
85 433 E3
86 *
87 +
88 RCL 74
89 .33
90 *
91 +
92 XEQ 35                        ← PRINTS S-F RESULT.
93 +
94 SF 12
95 "T"
96 ACA
97 "OTAL "
98 SF 13
99 XEQ 35                        ← PRINTS TOTAL n/sec
                                   RESULT.
100 ADV
101 RCL 07
102 FS? 02
103 CLX
104 X=0?
105 GTO "NT"
```

```
106 SF 02
107 FIX 1
108 "  AFTER "
109 CHS
110 ARCL Y
111 "+ YEARS"
112 PRA
113 SCI 3
114 SF 12
115 46.1                         PUTS FINAL
                                 ACTIVITIES IN
                                 REGISTERS 69 TO 74.
116♦LBL 33
117 STO 05
118 69.074
119 STO 04
120♦LBL 11                       MOVES INITIAL
121 RCL IND 05                   OR FINAL
122 STO IND 04                   ACTIVITIES.
123 ISG 05
124 ISG 04
125 GTO 11
126 "C"
127 ASTO X
128 RCL 03
129 X=Y?
130 GTO 32
131 GTO IND X
132♦LBL 34                       ← COMPUTES α-n
                                   RATE.
133 STO 02
134 RDN
135 RCL 71                       ← Pu-240.
136 *
137 X<>Y
138 RCL 70                       ← Pu-239.
139 *
140 +
141 X<>Y
142 RCL 69                       ← Pu-238.
143 RCL 74                       ← Am-241.
144 +
145 *
146 +
147 RCL 02
148 RCL 73                       ← Pu-242.
149 *
150 +
151 RTN
152♦LBL 35                       ← PRINTING
                                   SUBROUTINE.
153 ACA
154 CF 12
155 CF 13
156 ACX
157 PRBUF
158 END
```

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   09/07/1984

FINAL DOSES

NANCY      61mR
BESS       89mR
EL         74mR
GEORGE      9mR
JANE      116mR

TOTAL=  311mR
```

SAMPLE CASE:

```
NAMES & LETTERS DA?      <- XEQ "INITIAL" (IN USER MODE PRESS SHIFT AND STO).
SUE
RALPH
PAUL
                         (NO 4TH AND 5TH INDIVIDUALS).
3600 <A>  0              <- ENTER 3600, PRESS A.
3600 <B>  0              <- ENTER 3600, PRESS B.
3600 <C>  0              <- ENTER 3600, PRESS C.
                         <- XEQ "DVIEW" (PRESS SHIFT AND XEQ).
3600 <A> 14
3600 <B> 13
3600 <C> 12

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

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

3600 <A> 42
3600 <B> 41
3600 <C> 41
                         <- PRESS R/S, THEN ENTER 7200 mR/hr AND PRESS B.
7200 <B> 61
                         <- XEQ "DVIEW" AGAIN.
3600 <A> 61
3600 <B> 79
3600 <C> 69
                         <- PRESS R/S.
0  <A>  85   }
0  <B> 130   }  ENTER 0 mR/hr AND PRESS A,B,C.
0  <C> 101   }
1800 <B> 130             ENTER 1800 mR/hr, PRESS B.

FRIDAY  09   84          <- XEQ "PRDOSE" (PRESS SHIFT AND RCL).

FINAL DOSES

SUE        85mR
RALPH     130mR
 NOT ZEROED              <- THIS MESSAGE INDICATES THAT THE DOSE RATE FOR RALPH (B) WAS NOT ZERO WHEN PRDOSE 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.
PAUL      101mR

TOTAL=  316mR
```

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 Y
```

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 +
44 ISG Y
45 GTO 10
46♦LBL 00
47 AOFF
48 ADV
49 " * READY *"
50 SF 27
51 PROMPT
52♦LBL "DVIEW"
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 /
```

CLEARS A FLAG FOR EACH NAME ENTERED.

DOSE UPDATING LOOP.

```
77 60
78 *
79 10
80 X<>Y
81 X<=Y?
82 FIX 1
83 "S.T.= "
84 ARCL X
85 "┣ 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 "┣ <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
120 X<>Y
121 HMS-
122 HR
123 *
124 ST+ 11
125 "⊢ (B) "
126 ARCL 11
127 AVIEW
128 RTN
129♦LBL "CC"
130 FC?C 22
131 RCL 07
132 FS? 07
133 RTN
134 CLA
135 ARCL X
136 X<> 07
137 RCL 02
138 TIME
139 STO 02
140 X<>Y
141 HMS-
142 HR
143 *
144 ST+ 12
145 "⊢ (C) "
146 ARCL 12
147 AVIEW
148 RTN
149♦LBL "DD"
150 FC?C 22
151 RCL 08
152 FS? 08
153 RTN
154 CLA
155 ARCL X
156 X<> 08
157 RCL 03
158 TIME
159 STO 03
160 X<>Y
```

A TIME MODULE FUNCTION.

```
161 HMS-
162 HR
163 *
164 ST+ 13
165 "⊢ (D) "
166 ARCL 13
167 AVIEW
168 RTN
169♦LBL "EE"
170 FC?C 22
171 RCL 09
172 FS? 09
173 RTN
174 CLA
175 ARCL X
176 X<> 09
177 RCL 04
178 TIME
179 STO 04
180 X<>Y
181 HMS-
182 HR
183 *
184 ST+ 14
185 "⊢ (E) "
186 ARCL 14
187 AVIEW
188 RTN
189♦LBL "PROSE"
190 FC? 55
191 GTO 19
192 FIX 6
193 CF 12
194 ADV
195 DATE
196 DOW
197 GTO IND X
198♦LBL 00
199 " SUNDAY  "
200 GTO 00
201♦LBL 01
202 " MONDAY  "
```

SKIPS DAY AND DATE CALCULATION.

```
203 GTO 00
204♦LBL 02
205 " TUESDAY "
206 GTO 00
207♦LBL 03
208 "WEDNESDAY"
209 GTO 00
210♦LBL 04
211 " THURSDAY"
212 GTO 00
213♦LBL 05
214 " FRIDAY "
215 GTO 00
216♦LBL 06
217 " SATURDAY"
218♦LBL 00
219 "⊢  "
220 DATE
221 ADATE
222 PRA
223 SF 12
224 ADV
225 "FINAL DOSES"
226 PRA
227♦LBL 19
228 CLX
229 STO 20
230 FIX 0
231 15.019
232 ADV
233 5
234♦LBL 07
235 FS? IND X
236 G . 01
237 CLA
238 ARCL IND Y
239 5
240 +
241 RCL IND X
242 ST+ 20
243 XEQ 02
244 RDN
```

LEAVES PRINTOUT LOOP IF IT ENCOUNTERS A SET FLAG.

PROGRAM LISTING

```
245 5
246 -
247 RCL IND X          <-- RECALLS CURRENT DOSE RATE.
248 " NOT ZEROED"      <-- ERROR MESSAGE.
249 X≠0?
250 AVIEW
251 RDN
252 1
253 +
254 ISG 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 SQRT
281 X>Y?
282 "+ "
283 RDN
284 SF 13
285 ARCL X
286 "+M"
287 ACA
288 CF 13
289 "R"
290 ACA
291 PRBUF
292 RTN
293*LBL 00
294 "+ "
295 ARCL X
296 "+MR"
297 AVIEW
298 PSE
299 END
```

FORMATTING STEPS.

Condensed, but Slower Version of Timekeeping Program.

```
LBL"INITIAL
LBL"DVIEW
LBL"STATIM
LBL"PRDOSE
END          634 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 SF 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 ARCL IND Y
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 +
44 ISG Y
45 GTO 10
46♦LBL 00
47 AOFF
48 ADV
49 " * READY *"
50 SF 27
51 PROMPT
52♦LBL "DVIEW"
53 CF 22
54♦LBL 11
55 ADV
56 XEQ A
57 PSE
58 XEQ B
59 FC? 06
60 PSE
61 XEQ C
62 FC? 07
63 PSE
64 XEQ D
65 FC? 08
66 PSE
67 XEQ E
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 "+ MIN"
86 FIX 0
87 AVIEW
88 RTN
89♦LBL 20
90 FS? 22
91 X<>Y
92 FC?C 22
93 RCL IND X
94 FS? IND Y
95 RTN
96 ASTO L
97 CLA
98 ARCL X
99 ARCL L
100 X<> IND Y
101 5
102 ST- Z
103 RDN
104 RCL IND Y
105 TIME
106 STO IND T
107 X<>Y
108 HMS-
109 HR
110 *
111 10
112 ST+ Z
113 RDN
114 ST+ IND Y
115 ARCL IND Y
116 AVIEW
117 RTN
118♦LBL A
119 5
120 " <A> "
121 GTO 20
122♦LBL B
123 6
124 " <B> "
125 GTO 20
126♦LBL C
127 7
128 " <C> "
129 GTO 20
130♦LBL D
131 8
132 " <D> "
133 GTO 20
134♦LBL E
135 9
136 " <E> "
137 GTO 20
138♦LBL "PRDOSE"
139 FC? 55
140 GTO 19
141 FIX 6
142 CF 12
143 ADV
144 DATE
```

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

Condensed, but Slower Version of Timekeeping Program.

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

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

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

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

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

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

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

9000 <A> 176
0 <B> 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).

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

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

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

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

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

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

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

DIFFERENCE IS 0.54 sec.

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 meterological 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 $_3$ computation will be done, enter the first dose factor (rem/Ci.m^3/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

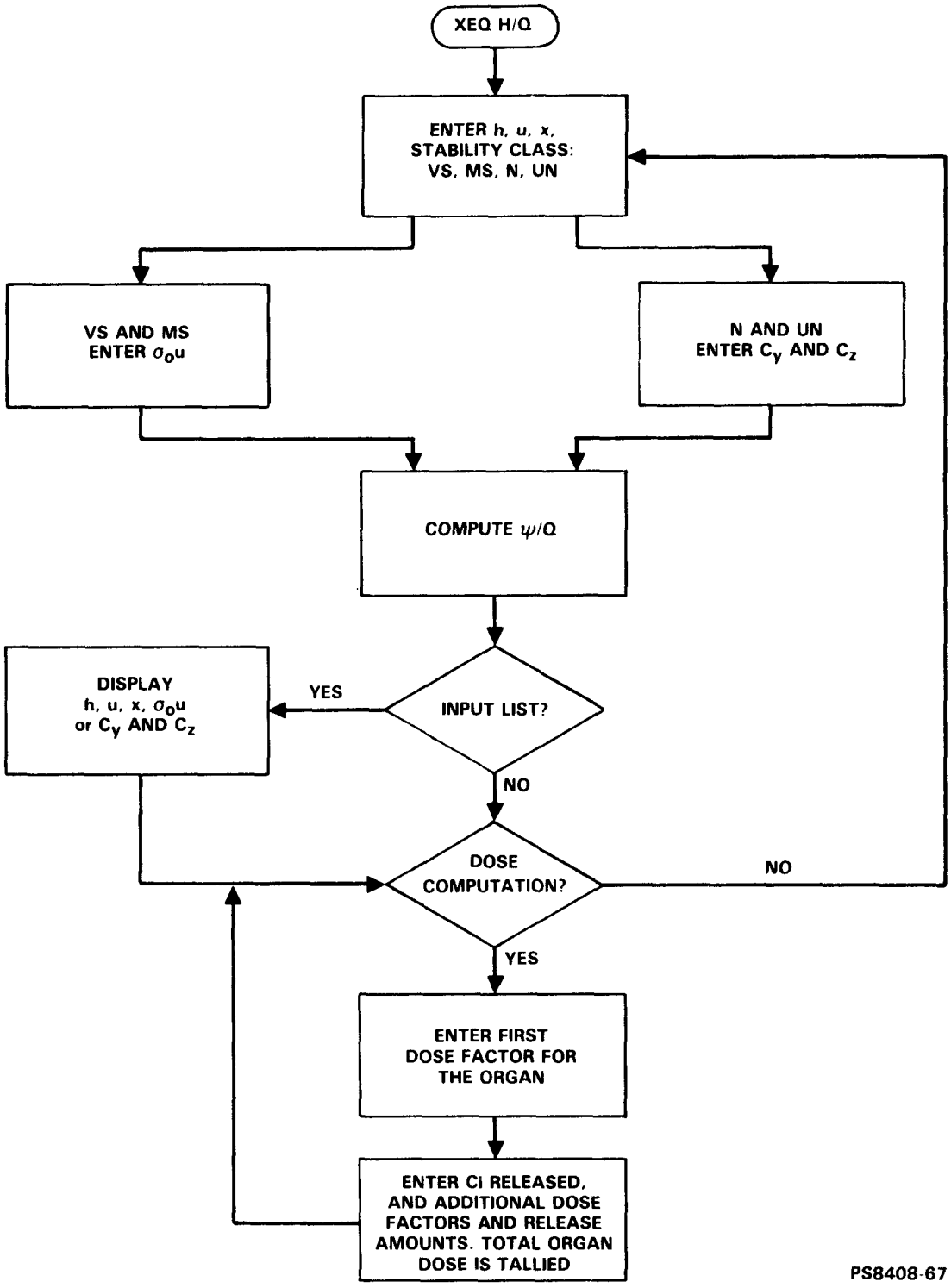


FIGURE 3. Flowsheet for Program "HQ."

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 A
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
               } IF CLEAR.
37 FS? 27
38 STOP
39♦LBL D
40 CF 23
41 "MET? VS,MS,N,UN"
42 AON
43 PROMPT
44 AOFF
45 FS? 23      } NEW MET IS
46 ASTO 00     } STORED. OTHER-
               } WISE, PREVIOUS
               } ONE REMAINS.
47 SF 02       ← INDICATES ($\sigma_0$U) OR $C_y$ AND $C_z$ MUST BE PROMPTED.
```

```
48♦LBL E
49 CF 01
50 FC? 55      } ENSURES PROGRAM
51 CF 23       } 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
               } AVERAGING.
71 RCL 07
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         } $\sigma_z$
85 2           } N AND UN
86 SQRT        }
87 /           }
88 *           }
89 2 E3        }
90 X>Y?        } ENSURES
91 X<>Y        } $\sigma_z \leq 2000$ m.
92 STO 05
93 LASTX       }
94 RCL 07      }
95 *           } $\sigma_y$
96 SF 01       } N AND UN
97 GTO 22      }
```

```
98♦LBL "MS"
99 .33         ← b
100 -97        ← -a
101 -25 E-5    ← $-k^2$
102 GTO 00
103♦LBL "VS"
104 40
105 1/X        ← b
106 -34        ← -a
107 -88 E-5    ← $-k^2$
108♦LBL 00
109 RCL 04     }
110 X↑2        }
111 *          }
112 E↑X-1      }
113 *          } $\sigma_z$
114 X<>Y       } VS AND MS
115 RCL 04     }
116 *          }
117 +          }
118 SQRT       }
119 STO 05
120 FS? 00     } SKIPS $\sigma_y$ WHEN
121 GTO 22     } SECTOR
               } AVERAGING.
122 FC?C 02    } SKIPS ($\sigma_0$U) 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          } $\alpha$
138 *          }
139 /          }
140 STO 09     }
```

PROGRAM LISTING

```
141♦LBL 00
142 RCL 04
143 RCL 09
144 /
145 CHS
146 E↑X-1
147 RCL 09
148 *
149 RCL 04
150 +
151 RCL 08
152 *
153 SQRT
154♦LBL 22
155 ADV
156 "CENTERLINE"
157 FC? 00
158 GTO 00
159 "SECTOR AVE."
160 RCL 03
161 8
162 /
163 PI
164 2
165 /
166 SQRT
167 *
168♦LBL 00
169 AVIEW
170 SF 21
171 STO 06
172 RCL 01
173 RCL 05
174 /
175 X↑2
176 CHS
177 E↑X
178 SQRT
179 RCL 05
180 /
181 RCL 06
182 /
183 PI
184 /
185 RCL 02
186 /
187 STO 10
188 SCI 2
189 "X/Q "
190 ARCL 00
191 "H="
192 ARCL X
193 AVIEW
194 CF 22
195 "INPUT LIST?"
196 PROMPT
197 FC? 22
198 GTO 02
199 "H = "
200 RCL 01
201 XEQ 05
202 "U = "
203 FIX 1
204 ARCL 02
205 "↑ M/S"
206 AVIEW
207 "X = "
208 RCL 03
209 XEQ 05
210 FS?C 01
211 GTO 00
212 FS? 00
213 GTO 01
214 FIX 3
215 "SIGU="
216 ARCL 07
217 AVIEW
218 GTO 01
219♦LBL 00
220 FIX 2
221 "CY = "
222 ARCL 07
223 FC? 00
224 AVIEW
225 "CZ = "
226 ARCL 08
227 AVIEW
228♦LBL 01
229 RCL 06
230 "SY = "
231 XEQ 05
232 RCL 05
233 "SZ = "
234 XEQ 05
235♦LBL 02
236 ADV
237 1.2
238 STO 12
239 CLX
240 STO 11
241♦LBL 03
242 CF 22
243 FIX 0
244 "R*M3/CI*S "
245 ARCL 12
246 PROMPT
247 FC? 22
248 GTO 00
249 "CI "
250 ARCL 12
251 "↑ = ?"
252 PPOMPT
253 *
254 RCL 10
255 *
256 ST+ 11
257 "NO. "
258 ARCL 12
259 "↑="
260 FIX 4
261 RND
262 ARCL X
263 "↑ R"
264 AVIEW
265 ISG 12
266 GTO 03
267♦LBL 00
268 FIX 3
269 RCL 11
270 X=0?
271 GTO "H/Q"
272 "TOT. REM="
273 ARCL 11
274 AVIEW
275 GTO 02
276♦LBL 05
277 FIX 0
278 90
279 X>Y?
280 FIX 1
281 ARCL Y
282 "↑ M"
283 AVIEW
284 END
```

σ_y VS AND MS

SECTOR AVERAGING REPLACES σ_y WITH $(X/8)\sqrt{\pi/2}$.

EXECUTION STOPS AT AVIEW UNLESS PRINTER ATTACHED.

X/Q

H

U

SKIPS (σ_oU) IF MET IS N OR UN.

SKIPS (σ_oU) DISPLAY IF SECTOR AVERAGING.

(σ_oU)

C_y

C_y NOT DISPLAYED WHEN SECTOR AVERAGING.

C_z

σ_y

σ_z

PLUME DOSE COMPUTATION LOOP.

ONLY WAY OUT OF LOOP IS NO ENTRY.

RETURNS TO BEGINNING IF NO DOSE WAS COMPUTED.

OTHERWISE, DISPLAYS TOTAL DOSE.

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

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 meterological 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
-----------------------

  σθ*u: 0.040 m/sec
MOD. STABLE
  X    X/Q    Fd
 8000  3.93-06  0.819
15500  1.34-06  0.744

  DISTANCE  POP*X/Q
    8000    3.93-06
   15500    2.69-03
  TOTAL.    2.69-03
```

```
*** 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

  σθ*u. 0.040 m/sec
VERY STABLE
  X    X/Q    Fd
 8000  4.25-05  0.619
15500  1.45-05  0.456

  σθ*u 0.040 m/sec
MOD. STABLE
  X    X/Q    Fd
 8000  1.83-05  0.819
15500  7.17-06  0.744

Cy = 0.21     Cz = 0.17
   NEUTRAL
  X    X/Q    Fd
 8000  2.39-06  0.900
15500  7.42-07  0.896

Cy = 0.35     Cz = 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

$u = 1$ 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:

Parameter	Very stable	Moderately stable
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.

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

C. Building wake effects.

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

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

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.

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

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

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

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

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

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 m^2

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:
08:
09: These 3 flags sequence the stability classes when all four classes are run

10: used in the building wake logic

PROGRAM LISTING

```
LBL"M/D
END          1565 BYTES

01♦LBL "M/D"
02 CF 27
03 CF 29
04♦LBL 46
05 FS? 27
06 STOP
07 "H = ? M"
08 RCL 20
09 PROMPT
10♦LBL A
11 STO 20
12 FS? 27
13 GTO 46
14 XEQ 04
15 "U = ? M/S"
16 RCL 02
17 PROMPT
18♦LBL B
19 STO 02
20 CF 01
21 1
22 X=Y?
23 SF 01
24 FS? 27
25 GTO 46
26 XEQ 05
27 "Vd = ? CM/S"
28 CLX
29 PROMPT
30♦LBL F
31 CF 00
32 X=0?
33 SF 00
34 STO 17
35 FS? 27
36 GTO 46
37 XEQ 06
38 "BLDG. AREA ?"
39 CLX
40 PROMPT
41♦LBL G
42 CF 02
43 2
44 /
45 PI
46 /
47 STO 13
48 X≠0?
49 SF 02
50 FS? 27
51 GTO 46
52 XEQ 07
53 CF 23
54 CF 03
55 "SECTOR AVE. ?"
56 PROMPT
57 FC? 22
58 GTO C
59♦LBL P
60 FC?C 03
61 SF 03
62 FS? 27
63 GTO 46
64♦LBL C
65 1.1
66 STO 00
67 STO 03
68 22
69 +
70 STO 04
71♦LBL 00
72 FIX 0
73 "X "
74 ARCL 00
75 "H = ? M"
76 CLX
77 PROMPT
78 X<=0?
79 GTO 02
80 STO IND 04
81 3
82 FC? 03
83 GTO 01
84 FIX 0
85 ISG 04
86 "POP. "
87 ARCL 00
88 "H ?"
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?
102 GTO 03
103 RCL 04
104 RCL 03
105 -
106 3
107 10↑X
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
124 CF 22
125 AOFF
126 FC? 23
127 SF 06
128 FS? 23
129 ASTO 21
130♦LBL E
131 CF 05
132 CF 07
133 CF 08
134 CF 09
135 FC? 06
136 GTO IND 21
137 FC? 10
138 GTO 01
139 "CY N ?"
140 PROMPT
141 FC? 22
142 GTO 01
143 STO 15
144 "CZ N ?"
145 PROMPT
146 STO 16
```

SPEEDS USER MODE TO END AT THE BEGINNING.

RECALLS PREVIOUS RELEASE HEIGHT.

RECALLS PREVIOUS WIND SPEED.

FLAG 01 SET IF U = 1 m/sec.

ZERO WILL BE ENTERED UNLESS A NUMBER IS ENTERED.

FLAG 00 SET IF V_d = 0 cm/sec.

ZERO WILL BE ENTERED UNLESS A NUMBER IS INPUT.

FLAG 02 IS SET FOR BUILDING WAKE.

SET IF FLAG 03 IS CLEAR, CLEARED IF SET.

DISTANCE AND POPULATION DATA ENTRY LOOP.

ONLY WAY TO LEAVE THE LOOP.

SKIPS POPULATION PROMPT WHEN NOT SECTOR AVERAGING.

TESTS FOR ANY INPUT DATA.

INDICATES (σ_oU) OR C_y AND C_z PROMPT IS NECESSARY.

FLAG 06 SET IF ALL FOUR WILL BE RUN.

SINGLE STABILITY.

DO SINGLE STABILITY.

SKIPS (σ_oU) AND C_y AND C_z PROMPTS.

PROGRAM LISTING

```
147 "CY,C2  UN ?"
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 48
175*LBL 01
176 CF 04
177 FC?C 10          } SKIPS (σ0U)
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 .624             } COMPUTES (σ0U)
190 X<=Y?            } WHEN U = 1 m/sec.
191 X<>Y             }
192 .18              }
193 X>Y?             }
194 X<>Y             }
195 GTO 02
196*LBL 01
197 "SIGTHETA*U ?"
198 PROMPT
199 FC? 22
200 GTO 47
201*LBL 02
202 STO Y
203 232              }
204 *                }
205 13               } A
206 +                }
207 STO 18           }
208 X<>Y             }
209 X↑2              }
210 2                } σ
211 *                }
212 /                }
213 STO 19           }
214 GTO 47
215*LBL 04            <- PRINTS OUTPUT HEADER AND RELEASE HEIGHT.
216 SF 12
217 "*** X/Q ***"
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 "H "
231 ARCL 20
232 ACA
233 " M"
234 GTO 00
235*LBL 05            <- PRINTS U.
236 FIX 1
237 "WIND SPEED "
238 ARCL 02
239 ACA
240 " M/SEC"
241 GTO 00
242*LBL 06            <- PRINTS Vd.
243 FIX 3
244 "DEP. SPEED. "
245 ARCL 17
246 ACA
247 " CM/SEC"
248 GTO 00
249*LBL 07            <- PRINTS WAKE AREA.
250 FIX 0
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              <- IF SECTOR AVERAGING, PRINTS INPUT POPULATIONS.
266*LBL 09
267 "* SECTOR AVERAG"
268 "HED X/Q *"
269 PRA
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 8
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
299 "TOTAL     "
300 ARCL 04
301 ACA
302 SKPCHR
303 24                    } PRINTS DASHED LINE.
304 ADV
305 95
306♦LBL 11
307 ACCHR
308 DSE Y
309 GTO 11
310 ADV
311 RTN
312♦LBL "N"
313 1.75
314 GTO 01
315♦LBL "UN"
316 SF 05
317 1.8
318♦LBL 01
319 STO 07
320 SF 04
321 FC?C 10               } SKIPS Cy AND Cz PROMPTS IF CLEAR.
322 GTO 01
323 "CY = ?"
324 PROMPT
325 FC? 22
326 GTO 01
327 STO 08
328 STO 09
329 FS? 05
330 GTO 01
331 "CZ = ?"
332 PROMPT
333 STO 09
334♦LBL 47
335♦LBL 01
336 FC?C 27               } PRINTS INPUT DATA WHEN IN USER MODE.
337 GTO 48
338 XEQ 04
339 XEQ 05
340 XEQ 06
341 XEQ 07
342 FS? 03
343 XEQ 09
344♦LBL 48  ← OUTPUT HEADER FOR VS AND MS.
345 ADV
346 FS? 04
347 GTO 01
348 FIX 3
349 SF 12
350 " "
351 ACA
352 9
353 ACCHR
354 CF 12
355 16
356 ACCHR
357 "*U  "
358 RCL 18
359 13
360 -
361 232
362 /
363 ARCL X
364 "├ M/SEC"
365 XEQ 08
366 "VERY"
367 FS?C 05  ← CLEARS FLAG 05.
368 "MOD."
369 "├ STABLE"
370 GTO 02
371♦LBL 01  ← OUTPUT HEADER FOR N AND UN.
372 FIX 2
373 67
374 ACCHR
375 SF 13
376 "Y = "
377 ARCL 08
378 "├     "
379 ACA
380 CF 13
381 ACCHR
382 "Z = "
383 ARCL 09
384 XEQ 08
385 "  NEUTRAL"
386 FS? 05
387 "  UNSTABLE"
388♦LBL 02  ← COLUMN HEADER.
389 SF 12
390 PRA
391 " X  X/Q  Fd"
392 PRA
393 CF 12
394 RCL 22
395 STO 00
396 FS? 00                } AVOIDS NUMERIC INTEGRATION.
397 GTO 03
398 GTO 01
399♦LBL 49
400 FS? 00
401 GTO 03
402 RCL IND 00
403 RCL 03                } TESTS NEW X AGAINST PREVIOUS.
404 X<=Y?
405 GTO 12
406♦LBL 01
407 CLX
408 STO 03
409 STO 13
410 STO 14
411 3  ← BEGINNING UPPER LIMIT.
412 XEQ 57  ← 1ST INTEGRAL.
413♦LBL 12
414 RCL 03
415 10
416 *
417 RCL IND 00
418 X<=Y?                 } DOES FINAL INTEGRAL.
419 GTO 02
420 X<>Y
421 .9
422 *
423 XEQ 57
424 GTO 12
425♦LBL 02
426 RCL 03
427 -
428 XEQ 57  ← FINAL INTEGRAL.
429 .5319  ← 0.5319 = 2/3 √(2/π).
430 RCL 02
431 /
432 RCL 17
433 %
434 RCL 14
435 *
436 CHS
437 E↑X  ← Fd IS COMPLETE.
438 GTO 01
439♦LBL 03
440 RCL IND 00            } THESE ARE EXECUTED WHEN Vd=0.
441 STO 03
442 CLX
443 STO 04
444 XEQ 58
445 STO 01
446 1
447♦LBL 01
448 STO 04
449 CLA
```

PROGRAM LISTING

```
450 FIX 0
451 ARCL 03
452 "⊢  "
453 ACA
454 SCI 2
455 FC? 07      } COMPUTES σy IF
456 XEQ 59      } NO BUILDING WAKE.
457 RCL 01
458 PI
459 /
460 RCL 02
461 /
462 RCL 06
463 FC? 03      } SKIPS SECTOR
464 GTO 01      } AVERAGING STEPS IF CLEAR.
465 RDN
466 RCL 03
467 /
468 .02454      ← 0.02454 = π/128.
469◆LBL 01
470 SQRT
471 /
472 RCL 04
473 *
474 ACX         ← X/Q VALUE TO PRINTER.
475 2
476 FC? 03      } SKIPS POPULATION
477 GTO 02      } WEIGHTING IF CLEAR.
478 X<>Y
479 ISG 00
480 RCL IND 00
481 *
482 ISG 00
483 STO IND 00
484 0
485◆LBL 02
486 ST+ 00
487 2
488 SKPCHR
489 FIX 3
490 .1
491 RCL 04
492 X<=Y?
493 FIX 4
494 RND
495 ACX
496 X>Y.
497 1
498 SKPCHR
499 ADV

500 ISG 00
501 GTO 49
502 FC? 03      } SKIPS POPULATION
503 GTO 01      } WEIGHTED X/Q TABLE IF CLEAR.
504 RCL 22
505 STO 00
506 CLX
507 STO 04
508 ADV
509 "  DISTANCE  POP"
510 "⊢*X/Q"
511 PRA
512◆LBL 13       ← PRINTS TABLE OF DISTANCES AND POPULATION WEIGHTED X/Q VALUES.
513 FIX 0
514 CLA
515 ARCL IND 00
516 "⊢  "
517 ACA
518 2
519 ST+ 00
520 RCL IND 00
521 SCI 2
522 ACX
523 ST+ 04
524 5
525 SKPCHR
526 ADV
527 ISG 00
528 GTO 13
529 "  TOTAL  "
530 ACA
531 RCL 04
532 ACX
533 PRBUF
534◆LBL 01
535 CF 05
536 FS? 07      }
537 GTO "MS"    }
538 FS?C 08     } ROUTINGS WHEN ALL FOUR STABILITIES ARE RUN.
539 GTO 01      }
540 FS?C 09     }
541 GTO 02      }
542 ADV
543 ADV
544 SF 27       } ENTERS USER MODE
545 GTO 46      } AND STOPS AT 46.
546◆LBL 01       ← INITIALIZES FOR NEUTRAL STABILITY.
547 SF 04
548 SF 09
549 1.75

550 STO 07
551 RCL 15
552 STO 08
553 RCL 16
554 STO 09
555 GTO 48
556◆LBL 02       ← INITIALIZES FOR UNSTABLE.
557 SF 05
558 1.8
559 STO 07
560 RCL 21
561 STO 08
562 STO 09
563 GTO 48
564◆LBL 57       ← NUMERIC INTEGRATION SUBROUTINE (SIMPSON'S RULE ON EACH DECADE.)
565 10
566 /
567 STO 04
568 1.01
569 STO 01
570◆LBL 14
571 XEQ 58
572 ST+ 13
573 ISG 01
574 XEQ 58
575 ISG 01
576 GTO 14
577 STO 01
578 2
579 /
580 ST- 13
581 X<> 13
582 RCL 04
583 *
584 ST+ 14
585 RTN
586◆LBL 59
587 RCL 12       }
588 RCL 03       }
589 FS? 04       }
590 GTO 01       }
591 RCL 02       }
592 /            } σy² FOR VS AND MS.
593 ENTER↑       }
594 ENTER↑       }
595 RCL 19       }
596 /            }
597 CHS          }
598 E↑X-1        }
599 RCL 19       }
600 *            }
601 +            }
602 RCL 18       }
```

PROGRAM LISTING

```
603 GTO 02
604♦LBL 01
605 RCL 07
606 Y↑X
607 2
608 /
609 RCL 08
610 X↑2
611♦LBL 02
612 *
613 STO 06
614 /
615 1
616 +
617 STO 10
618 RTN
619♦LBL 58
620 RCL 04
621 ST+ 03
622 RCL 12
623 FS? 04
624 GTO 01
625 RCL 09
626 RCL 03
627 RCL 02
628 /
629 *
630 LASTX
631 X↑2
632 RCL 07
633 *
634 E↑X-1
635 RCL 05
636 *
637 +
638 GTO 02
639♦LBL 01
640 RCL 03
641 RCL 07
642 Y↑X
643 2
644 /
645 RCL 09
646 X↑2
647 *
648 4 E6
649 X<=Y?
650 X<>Y
651 RDN
652♦LBL 02
653 STO 05
654 STO 06
655 FC? 02
656 GTO 03
657 /
658 1
659 +
660 STO 11
661 STO 10
662 FC? 05
663 XEQ 59
664 9
665 RCL 10
666 RCL 11
667 *
668 X<=Y?
669 GTO 02
670 RCL 10
671 RCL 11
672 X<=Y?
673 GTO 01
674 SF 10
675 X<>Y
676♦LBL 01
677 3
678 X>Y?
679 GTO 01
680 STO 10
681 STO 11
682 CF 10
683 GTO 02
684♦LBL 01
685 X↑2
686 X<>Y
687 /
688 FC? 10
689 10
690 FS?C 10
691 11
692 X<>Y
693 STO IND Y
694♦LBL 02
695 RCL 11
696 ST* 05
697 RCL 10
698 ST* 06
699♦LBL 03
700 RCL 20
701 X↑2
702 RCL 05
703 /
704 CHS
705 E↑X
706 RCL 05
707 /
708 SQRT
709 ST+ 13
710 END
```

σ_y^2 FOR N AND UN.

$\left(\frac{\Sigma_y^2}{\sigma_y^2}\right)$

SKIPS WAKE CORRECTION.

SKIPS Σ_y^2 CALCULATION IF UNSTABLE.

σ_z^2 FOR VS AND MS.

σ_z^2 FOR N AND UN.

BUILDING WAKE LOGIC.

ENSURES $\sigma_z \leq 2000$ m.

INTEGRAND IS $1/\sigma_z \cdot e^{-h^2/2\sigma z^2}$.

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 ($rem/Ci \cdot m^3/s$) 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 D
30♦LBL H
31 FC?C 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 "HF"
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 "AVIEW".
46 CF 21           }
47 RCL 00
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
70 X≠Y?
71 GTO D
72 46               }
73 16               } CLASS F PARAMETERS.
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 σ2
89 *
90 RCL 03
91 *
92 1
93 +
94 *
95 RCL 03
96 *
97 GTO 00
98♦LBL 03          <- CLASS C PARAMETERS AND σ2.
99 139
100 RCL 03
101 .3
102 RCL 03
103 SQRT
104 *
105 1
106 +
107 /
108 83
109 *
110 GTO 00
111♦LBL 04         <- CLASS D PARAMETERS AND σ2.
112 90
113 RCL 03
114 1.1
115 RCL 03
116 *
117 1
118 +
119 SQRT
```

PROGRAM LISTING

```
120 .
121 47
122 *
123 GTO 00
124*LBL 05          <- CLASS E PARAMETERS.
125 66
126 38
127 .85
128*LBL 06          <- CLASS E AND F σ2.
129 RCL 03
130 *
131 LN1+X
132 *
133*LBL 00
134 2 E3            \
135 X>Y?            | ENSURES σ2 ≤ 2000 m.
136 X<>Y            /
137 STO 05
138 ADV
139 RCL 03
140 "CENTERLINE"
141 FC? 00          \ SKIPS SECTOR
142 GTO 00          / AVERAGING.
143 "SECTOR AVE."
144 125             \
145 *               |
146 PI              |
147 2               | SECTOR AVERAGING
148 /               | STEPS.
149 SQRT            |
150 *               /
151 GTO 01
152*LBL 00          <- COMPUTES σy.
153 R↑
154 *
155 RCL 03
156 SQRT
157 2
158 /
159 1
160 +
161 SQRT
162 /
163*LBL 01
164 STO 04
165 AVIEW           \ ENSURES
166 SF 21           | EXECUTION STOP AT NEXT
167 RCL 01          | AVIEW.
168 RCL 05          /
169 /
170 Y↑X
171 -2
172 /
173 E↑X
174 RCL 05
175 /
176 PI
177 /
178 RCL 02
179 /
180 RCL 04
181 /               <- X/Q COMPUTED.
182 STO 06
183 FIX 0
184 CF 29
185 "X/Q "
186 ARCL 00
187 "├="
188 SCI 2
189 ARCL 06
190 AVIEW
191 CF 22
192 "INPUT LIST?"
193 PROMPT          <- SEE INPUTS BY PRESSING ANY NUMBER.
194 FC? 22
195 GTO 07
196 "H = "
197 RCL 01
198 XEQ 05
199 "U = "
200 ARCL 02
201 "├ M/S"
202 AVIEW
203 FIX 2
204 "X = "
205 ARCL 03
206 "├ KM"
207 AVIEW
208 RCL 04
209 "ΣY = "
210 XEQ 05
211 RCL 05
212 "ΣZ = "
213 XEQ 05
214*LBL 07
215 ADV
216 1.2             <- POINTER FOR DOSE CALCULATION LOOP.
217 STO 08
218 CLX
219 STO 07
220*LBL 08
221 CF 22
222 FIX 0
223 "R*M3/CI*S "
224 ARCL 08
225 PROMPT          <- ENTER DOSE FACTOR rem/Ci•m3/s.
226 FC? 22          \ ONLY WAY TO
227 GTO 00          / LEAVE THIS LOOP IS NO ENTRY.
228 "CI "
229 ARCL 08
230 "├ = ?"
231 PROMPT
232 *
233 RCL 06
234 *
235 ST+ 07
236 "NO. "
237 ARCL 08
238 "├="
239 FIX 4
240 ARCL X
241 "├ R"
242 AVIEW
243 ISG 06
244 GTO 08
245*LBL 00
246 FIX 3
247 RCL 07          \ GOES TO
248 X=0?            | BEGINNING IF NO
249 GTO "P/Q"       / DOSE COMPUTED.
250 "TOT. REM="     \
251 ARCL 07         | OTHERWISE GIVES
252 AVIEW           / TOTAL.
253 GTO 07
254*LBL 05
255 FIX 0
256 90
257 X>Y?
258 FIX 1
259 ARCL Y
260 "├ M"
261 AVIEW
262 END
```

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 AVERAGED X/Q *
 DISTANCE   POPULATION
    8.00          1
   15.50       2000
    TOTAL:     2001
-------------------------

 PASQUILL D
  X    X/Q    Fd
 8.00  1.61-06  0.85t
15.50  6.27-07  0.821

 DISTANCE  POP*X/Q
   8.00    1.81-0c
  15.50    1.25-07
  TOTAL    1.26-03


 PASQUILL E
  X    X/Q    Fd
 8.00  2.61-06  0.809
15.50  9.80-07  0.756

 DISTANCE  POP*X/Q
   8.00    2.61-06
  15.50    1.9b-03
  TOTAL    1.96-03
```

```
*** 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  2.20-05  0.77:
15.50  8.99-06  0.649

 PASQUILL E
  X    X/Q    Fd
 8.00  9.64-06  0.809
15.50  4.01-06  0.756

 PASQUIL  D
  X    X/Q    Fd
 8.00  4.85-06  0.656
15.50  1.88-06  0.821

 PASQUILL C
  X    X/Q    Fd
 8.00  1.14-06  0.920
15.50  3.92-07  0.909

 PASQUILL B
  X    X/Q    Fd
 8.00  1.59-07  0.957
15.50  9.09-08  0.950

 PASQUILL A
  X    X/Q    Fd
 8.00  1.25-07  0.970
15.50  7.17-08  0.967
```

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:

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

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

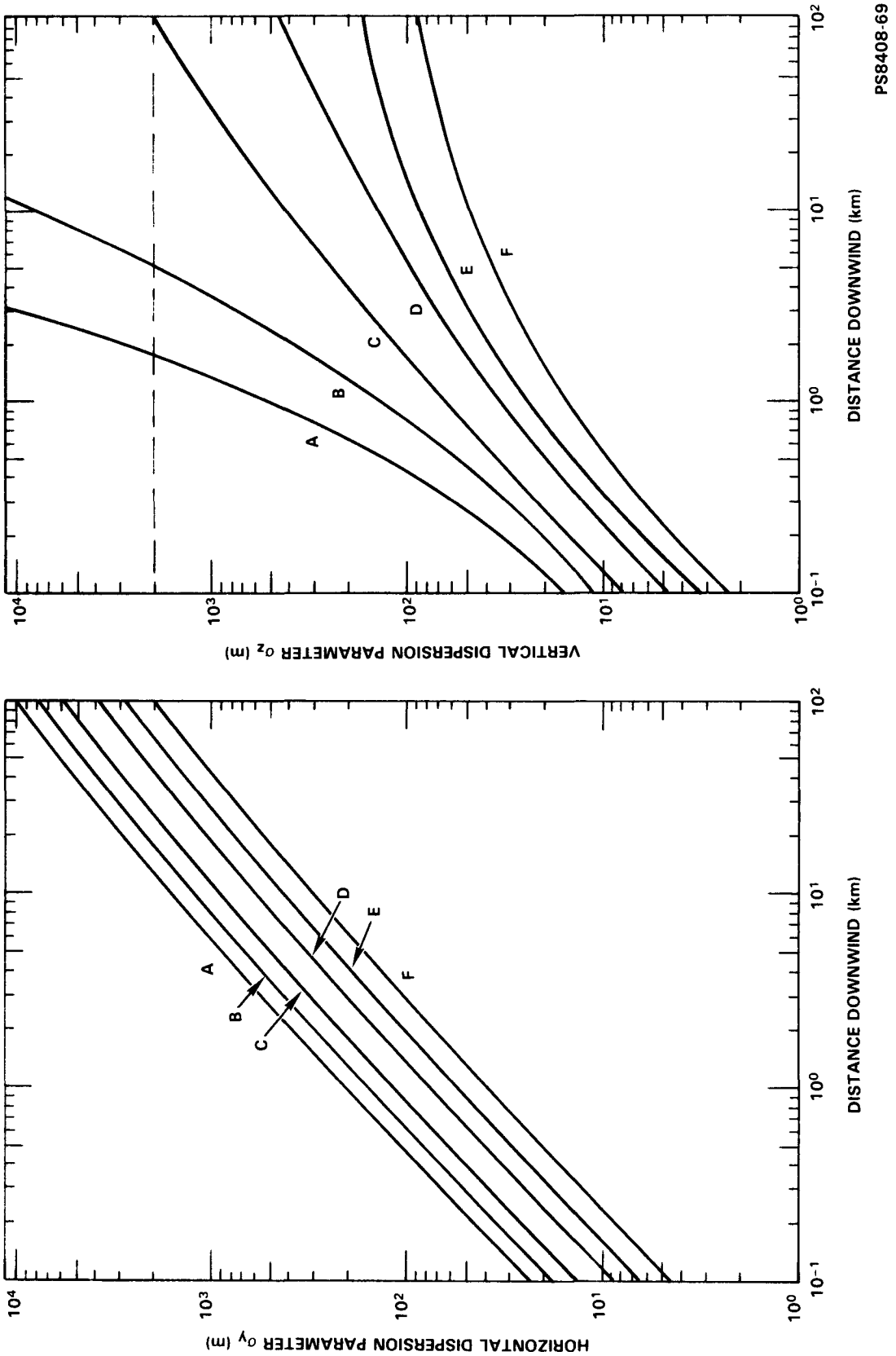


FIGURE 4. Plots of the Pasquill-Gifford Curves as Parameterized for "X/Q - Pasquill."

C. Integrated ground deposition loss.

F_d is the fraction remaining at distance x.

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

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

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

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

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: $S / 2\pi$

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 m^2

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/Y"
02 CF 21
03 CF 29
04♦LBL 4E
05 " * READY *
06 PSE 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 GTO 46
19 XEQ 04
20 "U = ? M/S"
21 RCL 03
22 PROMPT
23♦LBL B
24 STO 02
25 FS? 27
26 GTO 4E
27 XEQ 05
28 "Vd = ? CM/S"
29 CLX
30 PROMPT
31♦LBL F
32 CF 00
33 X=0?
34 SF 00
35 STO 17
36 FS? 27
37 GTO 4E
38 XEQ 06
39 "BLDG. AREA
40 CLX
41 PROMPT
42♦LBL G
43 CF 01
44 2
45
46 FI
```

PROGRAM ENDS HERE IN USER MODE.

ENTER RELEASE HEIGHT, m

IF h < 0.1 m. THEN SET h=0.1 m.

ENTER WIND SPEED, m/sec

ENTER GROUND DEPOSITION SPEED, cm/sec.

FLAG 00 SET IF V_d=0

ENTER BUILDING CROSS-SECTIONAL AREA, m^2

```
48 STO 12
49 X<0?
50 SF 01
51 FS? 27
52 CTL 1A
53 XEQ 07
54 CF 27
55 "SECTOR AVG, ?"
56 CF 03
57 PROMPT
58 FC? 22
59 GTO C
60♦LBL H
01 FC?C 02
02 SF 02
03 FS? 27
04 GTO 46
05♦LBL C
06 1.1
07 STO 00
08 STO 03
09 19
10 +
11 STO 04
12♦LBL 00
13 FIX 0
14 "Y "
15 ARCL 00
16 "H = ? KM"
17 CLX
18 PROMPT
19 X<=0?
20 GTO 02
21 STO IND 03
22 3
23 FC? 02
24 GTO 01
25 FIX A
26 ISG 04
27 "FOR, "
28 ARCL 00
29 "H ?"
30 1
31 PROMPT
32 STO IND 04
33 2
34♦LBL 01
35 ST+ 04
36 ISG 00
```

CHOOSE SECTOR AVERAGING BY ENTERING ANY NUMBER

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

ENTER DISTANCES AND POPULATIONS.

DOESN'T LEAVE DISTANCE LOOP UNTIL X ≤ 0

```
37 GTO 00
38♦LBL 02
39 RCL 00
40 RCL 03
41 -
42 X=0?
43 GTO 07
44 RCL 04
45 RCL 07
46 -
47 ?
48 10^X
49 /
50 20
51 +
52 STO 19
53♦LBL 03
54 FS? 27
55 GTO 46
56 FS? 02
57 XEQ 09
58♦LBL D
59 CF 23
60 "MET? A,B,C,D E,"
61 "F"
62 AON
63 PROMPT
64 AOFF
65 FS? 23
66 ASTO 15
67♦LBL E
68 DEG
69 RCL 15
70 STO 16
71♦LBL 47
72 CF 07
73 CF 04
74 CF 05
75 "      "
76 ARCL 16
77 ASTO L
78 ASHF
79 "F "
80 ASTO 16
81 "  "
82 ASTO Y
83 ARCL L
84 ASHF
85 ASTO X
86 ASTO 01
87 X≠Y?
88 GTO IND X
```

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

ENTER STABILITY CLASS CHOICES.

CLEARS FLAG 43

ROUTES TO LEFT-MOST LETTER OF THE ALPHA STRING.

PROGRAM LISTING

```
149 ADV
150 CLX
151 ADV
152 SF 27
153 ADV
154 GTO 46          ← END OF PROGRAM EXECUTION
155♦LBL 04          ← PRINTS HEADER AND RELEASE HEIGHT
156 SF 12
157 "*** X/Q ***"
158 PRA
159 CF 12
160 " PASQUILL   "
161 "F   3-5-84"
162 PRA
163 ADV
164 FIX 1
165 "RELEASE HEIGHT "
166 "F "
167 ARCL 18
168 ACA
169 " M"
170 GTO 08
171♦LBL 05          ← PRINTS WIND SPEED
172 FIX 1
173 "WIND SPEED  "
174 ARCL 02
175 ACA
176 " M/SEC"
177 GTO 06
178♦LBL 06          ← PRINTS GROUND DEPOSITION SPEED
179 FIX 3
180 9
181 RCL 17
182 X>Y?
183 FIX 2
184 "DEP. SPEED  "
185 ARCL Y
186 ACA
187 " CM/SEC"
188 GTO 02
189♦LBL 07          ← PRINTS BUILDING WAKE AREA
190 FIX 0
191 "BUILDING AREA
192 RCL 12
193 2
194 *
195 PI
196 *
197 ARCL X
198 ACA
199 " SQ M"
200♦LBL A2
```

```
201 SF 1
202 ACA
203 PRBUF
204 CF 13
205 RTN
206♦LBL 09          ← IF SECTOR AVERAGING, PRINTS DISTANCE AND POPULATION TABLE
207 "* SECTOR AVERAG
208 "FED X/Q *"
209 PRA
210 " DISTANCE   POP"
211 "ULATION"
212 PRA
213 RCL 19
214 STO 00
215 CLX
216 STO 04
217♦LBL 10
218 FIX 2
219 RCL IND 00
220 ACX
221 ISG 00
222 FIX 0
223 RCL IND 00
224 ISG 00
225 ST+ 04
226 CLA
227 8
228 RCL \
229 LOG
230 INT
231 -
232 SKPCHR
233 RDN
234 ACX
235 6
236 SKPCHR
237 ADV
238 ISG 00
239 GTO 10
240 "TOTAL    "
241 ARCL 04
242 ACA
243 SKPCHR
244 24              ┐
245 ADV             │
246 95              │
247♦LBL 11          │ PRINTS 24 CHARACTER LINE.
248 ACCHR           │
249 DSE X           │
250 GTO 11          ┘
```

```
251 ADV
252 RTN
253♦LBL " A"        ← CLASS A PARAMETERS
254 240
255 2.7
256 146
257 GTO 03
258♦LBL " B"        ← CLASS B PARAMETERS.
259 185
260 .26
261 102
262 SF 05
263 GTO 02
264♦LBL " C"        ← CLASS C PARAMETERS.
265 139
266 .3
267 83
268 GTO 01
269♦LBL " D"        ← CLASS D PARAMETERS.
270 90
271 1.1
272 47
273 SF 05
274 GTO 01
275♦LBL " E"        ← CLASS E PARAMETERS.
276 66
277 .85
278 38
279 SF 03
280 GTO 02
281♦LBL " F"        ← CLASS F PARAMETERS
282 46
283 1.3
284 18
285 SF 03
286♦LBL 01
287 SF 04
288♦LBL 02
289 STO 07
290 RDN
291 STO 08
292 RDN
293 STO 09
294 FC?C 27
295 GTO 01
```

PROGRAM LISTING

```
296 XEQ 04
297 XEQ 05
298 XEQ 06
299 XEQ 07
300 FS? 02
301 XEQ 09
302*LBL 01
303 ADV
304 SF 12
305 " PASQUILL"
306 ARCL 01
307 PRA
308 " X  X/Q  Fd"
309 PRA
310 CF 12
311 RCL 19
    STO 00
313 FS? 00
314 GTO 03
315 GTO 01
316*LBL 49
317 FS? 00
318 GTO 03
319 RCL IND 00
320 RCL 03
321 X<=Y?
322 GTO 12
323*LBL 01
324 CLX
325 STO 03
326 STO 13
327 STO 14
328 .001
329 XEQ 57
330*LBL 12
331 RCL 03
332 10
333 *
334 RCL IND 00
335 X<=Y?
336 GTO 02
337 X<>Y
338 .9
339 *
340 XEQ 57
341 GTO 12
342*LBL 02
343 RCL 02
344 -
345 XEQ 57
346 5.3192
347 RCL 17
348 *
349 RCL 02
350 /
351 RCL 14
352 *
353 CHS
354 E↑X
355 GTO 01
356*LBL 03
357 RCL IND 00
358 STO 03
359 CLX
360 STO 04
361 XEQ 58
362 STO 01
363 1
364*LBL 01
365 STO 04
366 CLA
367 FIX 2
368 ARCL 03
369 "├  "
370 ACA
371 SCI 2
372 FC? 01
373 XEQ 59
374 RCL 01
375 PI
376 /
377 RCL 02
378 /
379 RCL 06
380 FC? 02
381 GTO 01
382 RDN
383 RCL 03
384 /
385 125
386 /
387 PI
388 2
389 /
390*LBL 01
391 SQRT
392 /
393 RCL 04
394 *
395 ACX
396 2
397 FC? 02
398 GTO 02
399 X<>Y
400 ISG 00
401 RCL IND 00
402 *
403 ISG 00
404 STO IND 00
405 0
406*LBL 02
407 ST+ 00
408 2
409 SKPCHR
410 FIX 3
411 .1
412 RCL 04
413 X<=Y?
414 FIX 4
415 RND
416 ACX
417 X>Y?
418 1
419 SKPCHR
420 ADV
421 ISG 00
422 GTO 49
423 FC? 02
424 GTO 47
425 RCL 13
426 STO 00
427 CLX
428 STO 04
429 ADV
430 "  DISTANCE  POP"
431 "├*X/Q"
432 PRA
433*LBL 12
434 FIX 2
435 CLA
436 ARCL IND 00
437 "├  "
438 ACA
439 2
440 ST+ 00
441 RCL IND 00
442 SCI 2
443 ACX
444 ST+ 04
445 5
```

PRINTS ALL INPUT INFORMATION WHEN IN USER MODE EXECUTION.

AVOIDS NUMERIC INTEGRATION IF $V_d = 0$.

TESTS NEW X AGAINST PREVIOUS.

UPPER LIMIT OF 1ST INTEGRAL.

1ST INTEGRAL.

10 TIMES THE PREVIOUS UPPER LIMIT.

DOES FINAL INTEGRATION.

5.3192 = $\frac{20}{3}\sqrt{\frac{2}{\pi}}$.

F_d IS COMPLETE.

DONE IF $V_d = 0$.

COMPUTES σ_y IF NO BUILDING WAKE.

AVOIDS SECTOR AVERAGING.

SECTOR AVERAGING STEPS.

X/Q VALUE TO PRINTER.

WHEN SECTOR AVERAGING, THIS STORES (X/Q*POP.).

SKIPS DISTANCE AND POPULATION*X/Q TABLE.

DOES TABLE OF DISTANCES AND POPULATION WEIGHTED X/Q VALUES.

PROGRAM LISTING

```
446 SKPCHP
447 ADV
448 ISG 00
449 GTO 13
450 " TOTAL. "
451 ACA
452 RCL 04
453 ACX
454 PRBUF
455 ADV
456 GTO 47   <- RETURNS TO BEGINNING.
457*LBL 57   <- NUMERIC INTEGRATION SUBROUTINE.
458 10
459 /
460 STO 04
461 1.01
462 STO 01
463*LBL 14
464 XEQ 58
465 ST+ 13
466 ISG 01
467 XEQ 58
468 ISG 01
469 GTO 14
470 STO 01
471 2
472 /
473 ST- 13
474 X<> 13
475 RCL 04
476 *
477 ST+ 14
478 RTN
479*LBL 58   <- COMPUTES σy² AND (1 + s/(2πσy²)).
480 RCL 04
481 ST+ 03
482 RCL 07
483 RCL 03
484 FS? 03
485 GTO 02
486 *
487 FS? 04
488 GTO 01
489 RCL 03
490 FS? 05
491 SQRT
492 RCL 03
493 *
494 RCL 08
495 *
496 1
497 +
498 *   <- COMPUTES σ2² AND (1 + s/(2πσy²)).
499 GTO 03
500*LBL 01
501 RCL 03
502 FC? 05
503 SQRT
504 RCL 08
505 *
506 1
507 +
508 FS? 05
509 SQRT
510 /
511 GTO 03
512*LBL 02
513 RCL 08
514 *
515 LN1+X
516 *
517*LBL 03
518 2 E3     } ENSURES σ2 < 2000 m.
519 X>Y?      }
520 X<>Y      }
521 X↑2
522 STO 05
523 FC? 01   } AVOIDS BUILDING WAKE LOGIC.
524 GTO 03   }
525 RCL 12
526 X<>Y
527 /
528 1
529 +
530 STO 11
531 XEQ 59
532 9
533 RCL 10
534 RCL 11
535 *
536 X<=Y?
537 GTO 02
538 RCL 11
539 RCL 10
540 X<=Y?
541 GTO 01
542 RAD   <- SETS FLAG 43. (NORMALLY OCCURS ONLY IN CLASS A, X > 0.4 km AND s > 160,000 m²).
543 X<>Y
544*LBL 01
545 3
546 X>Y?
547 GTO 01
548 STO 10
549 STO 11
550 GTO 02
551*LBL 01
552 X↑2
553 X<>Y
554 /
555 FC? 43
556 11
557 FS? 43
558 10
559 X<>Y
560 STO IND Y
561*LBL 02
562 DEG
563 RCL 11
564 ST* 05
565 RCL 10
566 ST* 06
567*LBL 03
568 RCL 18
569 X↑2
570 RCL 05
571 /
572 CHS
573 E↑X
574 RCL 05
575 /
576 SQRT
577 ST+ 13
578 RTN
579*LBL 59
580 RCL 12
581 RCL 03
582 RCL 09
583 *
584 X↑2
585 RCL 03
586 SQRT   <- INTEGRAND.
587 2
588 /
589 1
590 +
591 /
592 STO 06
593 /
594 1
595 +
596 STO 10
597 END
```