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BETA/ALPHA CONTINUOUS AIR MONITOR

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CONTRACTUAL ORIGIN OF THE INVENTION

The United States Government has rights in this invention pursuant to Contract No. DE-AC07-76ID01570 between the U.S. Department of Energy and EG&G Idaho, Inc.

BACKGROUND OF THE INVENTION

This invention relates to a method and apparatus for the detection and monitoring of beta and alpha particles, and in particular to the use of a single deep layer silicon detector in combination with a microcomputer to monitor air quality by measuring and discriminating among the energy levels of air-borne radioactive particles.

Air pollution due to plutonium dust is extremely harmful to the human body. However, slight deviations above the legally permissable concentrations are difficult to detect because of the presence of daughter nuclides of natural radon and thoron isotopes. Plutonium emits alpha particles with an energy level of 5.3 meV while the daughter nuclides emit alpha particles with energy levels of 6.0 meV and 7.68 meV, but instruments using this basis for differentiation must allow for the fact that concentrations of radon and thoron daughters vary widely depending upon atmospheric as well as ground conditions.

The problem is complicated when there is need as well to detect the presence of beta emitting fission products. In a standard proportional type ionization counter, alpha particles may lose their energy and generate an electrical response from the detector as beta particles. The 'straggled' alpha pulses become virtually indistinguishable from the beta pulses.

Proportional counters which operate with two energy channels are common. The higher energy alpha particles will be recorded at one voltage, while both alpha and the lower energy particles will be recorded at another voltage. Except for alpha straggling, the difference between the two will be a measure of beta activity.

Similarly, in a plutonium background compensating monitor, one channel will measure the higher energy alpha particles emitted by radon daughters, and another channel will measure the lower energy of alpha particles emitted by plutonium. An attempt is made to eliminate false measurement due to straggling by substracting a fraction of the higher energy pulse from the plutonium count.

Multichannel analyzers which record the true energy spectrum of both alpha and beta particles are often complicated and expensive. Differentiation of background and straggling counts requires the imposition on data of average counting rates arrived at experimentally, or curve fitting based on assumptions of normal distribution. By design, these instruments often neglect the need for instantaneous response in favor of accuracy by cumulative measurement, or, conversely, sound alarms repeatedly without reporting or analyzing minor deviations from a cumulative pattern.

No single instrument of the prior art efficiently combines the functions of measuring beta and alpha activity, as well as distinguishing beta and alpha activity from ambient background noise.

It is an object of this invention to provide an improved air monitor to record both alpha and beta activities and the energy of each pulse.

It is another object of this invention to provide an improved air monitor which rapidly distinguishes energy peaks due to alpha activity from natural radon and thoron daughters.

It is a further object of this invention to provide an improved air monitor to record natural beta activity present and discriminate in favor of beta emitting contaminants.

It is another object of this invention to provide an improved air monitor which operates remotely and automatically, recording both instantaneous and long-term radiation activity.

Additional objects, advantages and novel features of the invention will become apparent to those skilled in the art upon examination of the following and by practice of the invention.

SUMMARY OF THE INVENTION

To achieve the foregoing and other objects, this invention comprises a single deep layer silicon detector in combination with a microcomputer, recording both alpha and beta activity and the energy of each pulse, distinguishing energy peaks using a novel curve fitting technique to reduce the natural alpha counts in the energy region where plutonium and other transuranic alpha emitters are present, and using a novel algorithm to strip out radon daughter contribution to actual beta counts.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is depicted in the accompanying drawings, graphs and computer program. The problems addressed by the invention are illustrated by graphically displaying the energy levels of the particles to be distinguished. The apparatus and method of the invention are described in detail.

Fig. 1 is a typical alpha energy spectrum of radon/thoron daughters.

Fig. 2 is a beta/alpha energy spectrum of radon/thoron daughters in successive 15 minute counts.

Fig. 3 is a beta/alpha energy spectrum of radon/thoron daughters under equilibrium conditions.

Fig. 4 is the alpha energy spectrum of Pu-239 on a glass fiber filter.

Fig. 5 is a logrithmic plot of a radon/thoron daughter energy spectrum with a high radon background.

Fig. 6 is a superposition of a logrithmic Pu-239 energy spectrum on a radon/thoron spectrum.

Fig. 7 is a schematic of the apparatus of the improved beta/alpha monitor.

Fig. 8 is a replication of actual data on the data screen of the improved beta/alpha monitor.

Fig. 9 is an exemplary computer listing showing the manner in which the invention was implemented.

The first several figures depict the energy spectra of the radon daughter background and some plutonium spectra, to illustrate the improved monitor's discrimination capabilities.

Fig. 1 is a typical radon and thoron daughter alpha energy spectrum collected from a membrane filter with a 3 mm air path. In this case, the detector was a 100 micron depletion depth detector common in the prior art. The spectrum using this detector shows very little beta response 50 -- beta response 50 if any being recorded in the first few channel numbers. The first alpha peak 51 is the Po-218 (RaA), first daughter of Rn-222 at 6.00 meV. The second alpha peak 52 is due to Po-214 (RaC') at 7.68 meV. The third alpha peak 53 is due to Po-211 (ThC') from the thoron decay chain at 8.78 meV. This spectrum represents the equilibrium situation after more than 24 hours of sampling. Ordinarily, the ThC' peak 53 would not be observed in sampling times of less than an hour, since there is a 10.6 hour intermediate half-life involved. There is another thoron daughter alpha that is hidden under the RaA peak for long sampling times.

Fig. 2 shows a similar energy spectrum using a 1000 micron depletion depth detector, with four successive 15 minute counts starting with a clean filter. Note the beta response 50 at low channel numbers and the build-up toward equilibrium. The RaA peak 51 is almost at equilibrium in the first 15 minute count because the half-life is only 3.05 minutes. It takes nearly an hour of sampling for the RaC' peak 52 and the betas 50 to reach equilibrium. There are few of the ThC' counts 53 above channel 200 because several hours are required to collect enough of the thoron daughter activity.

Fig. 3 depicts the activity after 24 hours of sampling, with the ThC' peak 53 now close to equilibrium. Note in particular, the "straggling" of the RaA alpha peak 51 below approximately channel 125; this is where the plutonium peak occurs.

Fig. 4 is a plot of the alpha energy spectrum of Pu-239 using the same energy scale. The source is plutonium oxide chemically deposited on a glass fiber filter. The subject invention uses membrane filters rather than glass fiber filters. However, this source accurately simulates the straggling one would observe from plutonium mixed with dust on a membrane filter. The upper energy edge 54 appears at approximately channel 123. Most of the plutonium counts are above channel 80.

Fig. 5 is another plot of the radon daughter energy spectrum on the same horizontal scale, but the vertical scale is a logrithmic plot. This is a very high radon daughter background. This illustrates one problem which the subject invention addresses -- detecting a few counts due to Pu-239 around channels 80-125 completely hidden by the straggling from the RaA alpha peak 51.

Fig. 6 superimposes the plutonium peak 54 on the same logrithmic plot. The plutonium peak 54 illustrated here represents about 100DAC-h, with the Pu above the radon background in this case. Prior art monitors typically could not see this amount of plutonium in a background as high as that depicted, because the alarm level would have been set at a relatively high level to avoid false alarms.

The subject invention is most useful in the instance depicted in Fig. 6 when the radon background in high. Starting just above the Pu-239 upper energy edge, the computer calculates an average of the three channel counts just above the Pu-239 peak. Then the computer generates a stripping function, where each successively lower channel count is a constant fraction of the count in the channel immediately higher. The first trial stripping function assumes that the constant fraction will lie halfway between the lower and upper limits of 0.7 and 1.0, or (0.7 + 1.0)/2. The derived count at channel 80 is compared to the average of the actual counts observed in channels 79 + 80 + 81, and if the derived count does not match the observed average count, successive tries are made using the computer method termed a binary search until the derived count does match the observed average. When this match is obtained, this stripping function is subtracted channel by channel from the observed energy spectrum in the Pu-239 region. Thus, the stripping function forms a gradual tail extending down to channel 80, below the major portion of a Pu-239 peak if such is present.

The computer does this fitting in approximately two seconds, even if it must search for the appropriate fractional decrease several times before matching the actual count at the lower energy position. The net count after stripping the extrapolated background curve is termed the excess plutonium counts.

At the same time an algorithm is used (based on the sum of the RaC' and ThC' counts) to strip out the radon daughter contribution to the actual beta counts. This algorithum is based on the average ratio of radon daughter beta counts to radon daughter alpha counts. The difference is termed the excess beta counts.

Fig. 7 is a schematic of the apparatus of the improved beta/alpha monitor. Sample air is conveyed by the pump 41 from the air intake 11 through the sample head 10, to the air outlet 42, at a rate of 20 liters/minute. The sample head 10 is comprised of a membrane filter 12 and a silicon detector 13. The membrane filter 12 is a 47 mm diameter 0.45 micron Millipore filter stopped down to match a 450 square mm area ruggedized diffused junction silicon detector 13. A 1,000 micron depletion depth detector 13 is used to record both beta and alpha particles. The air spacing between the filter 12 and detector 13 is 3 mm at ambient pressure.

Pulses representing the energy deposited in the deep depletion layer by both beta and alpha particles are communicated to a pre-amplifier 15 and amplifier 16, which are standard Tennelec modules in a mini-NIM bin, and thence on to a controller 21, equipped with a Nucleus multichannel analyzer board 22. A screen display 23 provides a live spectral display of the beta and alpha energy spectra.

An alarm indicator 30 controlled by the IBM PC provides red, yellow and green status lights as well as an audible alarm when a significant increase occurs in designated count rates. The alarm indicator 30 and sample head 10 may both be located remotely, in the working environment, as much as 1500 feet from the controller 21.

Results are displayed on a three strip chart recorder display 24 and in a spectral and digital display on the PC screen 23 in Fig. 7. Fig. 8 is a replication of actual data in a screen display. The bottom display 61 is the beta and alpha energy spectrum plotted on a log scale. The energy regions are labeled on the bottom for easy identification. The apparatus updates this display continuously so it is essentially a live spectral display that is erased at the beginning of each 15 minute count. The printed information 62 just above the spectrum at the left shows the actual and excess count rate in the beta channels and in the plutonium channels. These count rates 62 are updated every 10 seconds, and the computer will trigger the alarm 30 within 10 seconds (remotely, in the working environment) if a significant increase occurs in either the excess beta or excess plutonium count rates. The status of the lights and alarm 30 are also indicated on the monitor 23, away from the working environment.

The next display just above the bottom spectrum is a time history of the radon daughter background 63 plotted in working levels. This display is updated every 15 minutes, and the chart scrolls to the left so that the previous 32 hour history is displayed continuously.

The top display is the time history of the excess beta counts 64. The next display is the time history of the excess plutonium counts 65. These charts represent the previous 32 hour history of the net counts after the stripping has been applied following each 15 minute count.

Fig. 9 is an exemplary listing showing the manner in which the invention was implemented for an IBM PC-XT with 20 megabyte hard disk, 640K RAM, and a PCA multi-channel analyzer board. The language used is BASIC using NUCLEUS machine language subroutines. As with all computer programs, they must be written for the particular hardware and carefully debugged. Fig. 9 is a useful example of one implementation.

Depicted on Fig. 9 are the elements of the method used. They are as listed in Table I following:

TABLE I

Lines 80-150	Sets up files for storing spectral data and parameter data,
Lines 170-760	Nucleus PCA-1000 software parameters for operating IBM-PC as a multi-channel analyzer,
Lines 770-1670	Screen graphics for display of energy spectrum (betas and alphas) and three time histories (excess betas, excess plutonium and radon daughters in working levels),
Lines 1680-1810	Acquires spectral data,
Lines 1820-2500	Updates screen alarms if PUCH counts or beta counts coming in at excessive rates,
Lines 2510-3890	Examines 15 minute spectrum in detail, curve fits and subtracts background from PUCH channels,
Lines 3900-4280	Nucleus PCA machine language software routines for controlling MCA board.

In an alternate embodiment, the method of the subject invention uses the apparatus described and least squares exponentials and power series methods of curve fitting known to the prior art. If the radon daughter background is relatively low this method subtracts the "straggling" of the RaA peak that falls in the plutonium channels.

In another embodiment using the apparatus of the subject invention, the shape of the RaC' peak can be fitted and transferred to the RaA peak "straggling" in the plutonium channels, thereby distinguishing a low radon daughter background.

The foregoing description of a preferred embodiment of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments described explain the principles of the invention and practical application and enable others skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

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ABSTRACT

A single deep layer silicon detector in combination with a microcomputer, recording both alpha and beta activity and the energy of each pulse, distinguishing energy peaks using a novel curve fitting technique to reduce the natural alpha counts in the energy region where plutonium and other transuranic alpha emitters are present, and using a novel algorithm to strip out radon daughter contribution to actual beta counts.

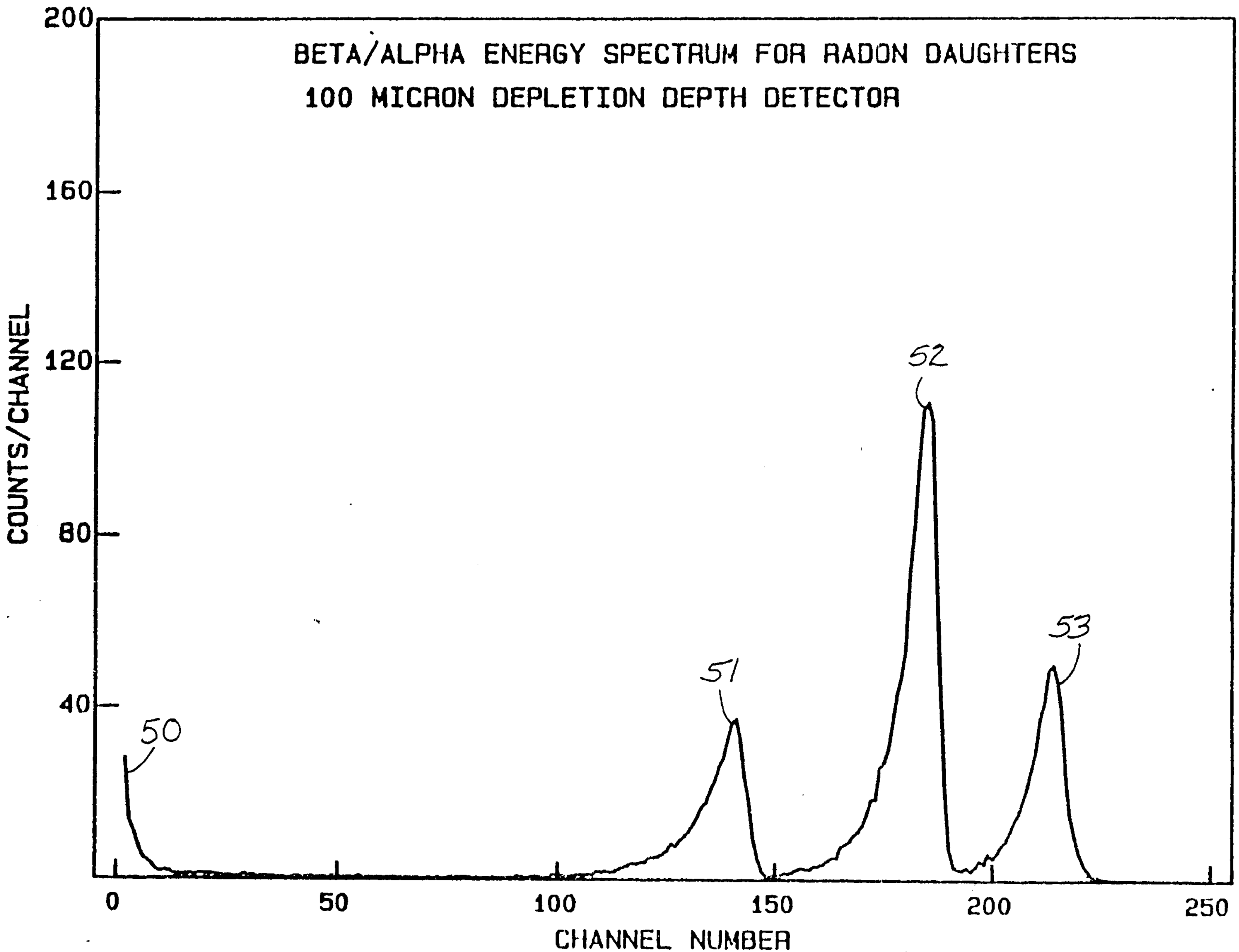
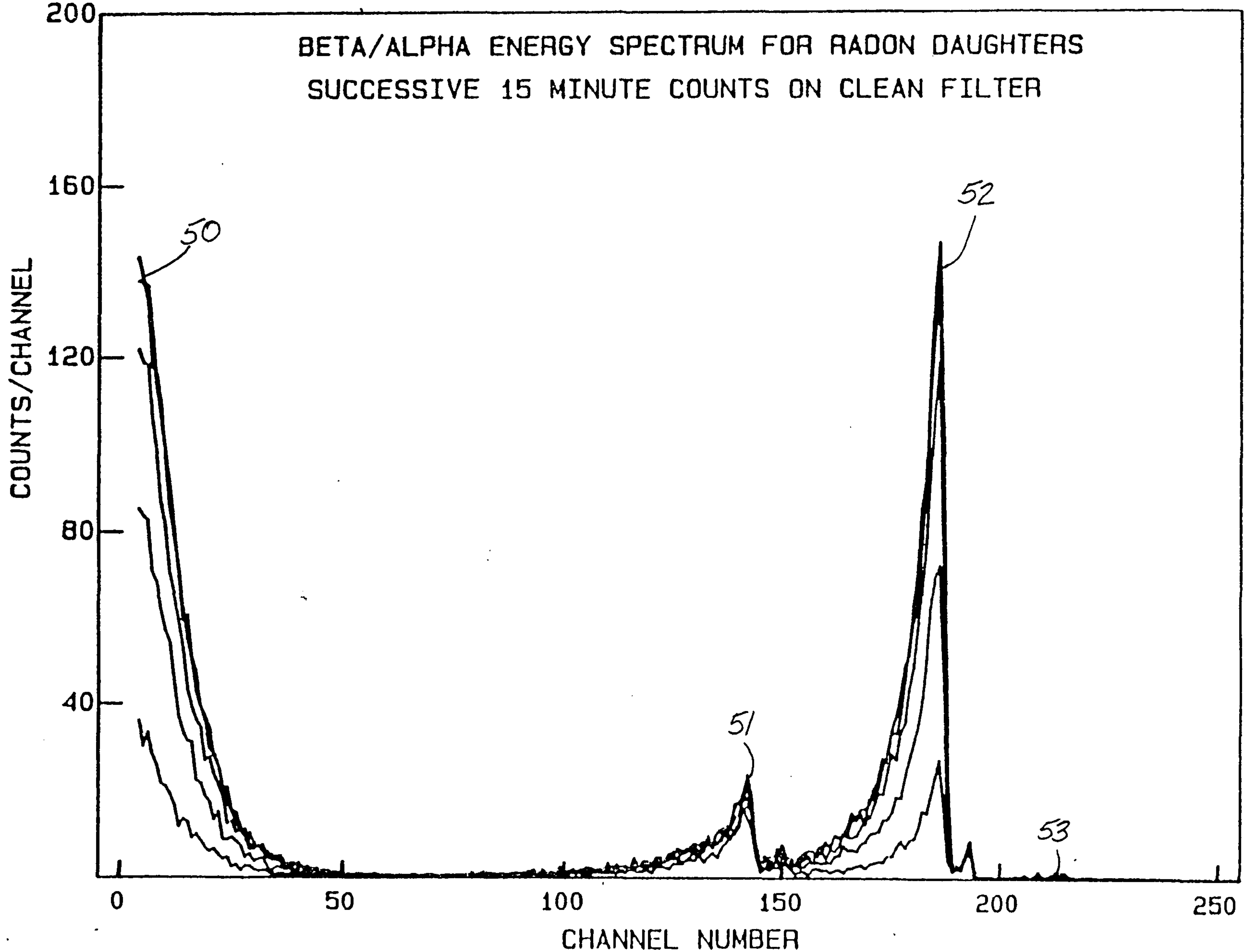

BETA/ALPHA ENERGY SPECTRUM FOR RADON DAUGHTERS
100 MICRON DEPLETION DEPTH DETECTOR
COUNTS/CHANNEL
200
160
120
80
40
0
50
100
150
200
250
CHANNEL NUMBER
50
51
52
53

FIG. 1



BETA/ALPHA ENERGY SPECTRUM FOR RADON DAUGHTERS
SUCCESSIVE 15 MINUTE COUNTS ON CLEAN FILTER
COUNTS/CHANNEL
200
160
120
80
40
0
50
100
150
200
250
CHANNEL NUMBER
50
51
52
53

FIG. 2

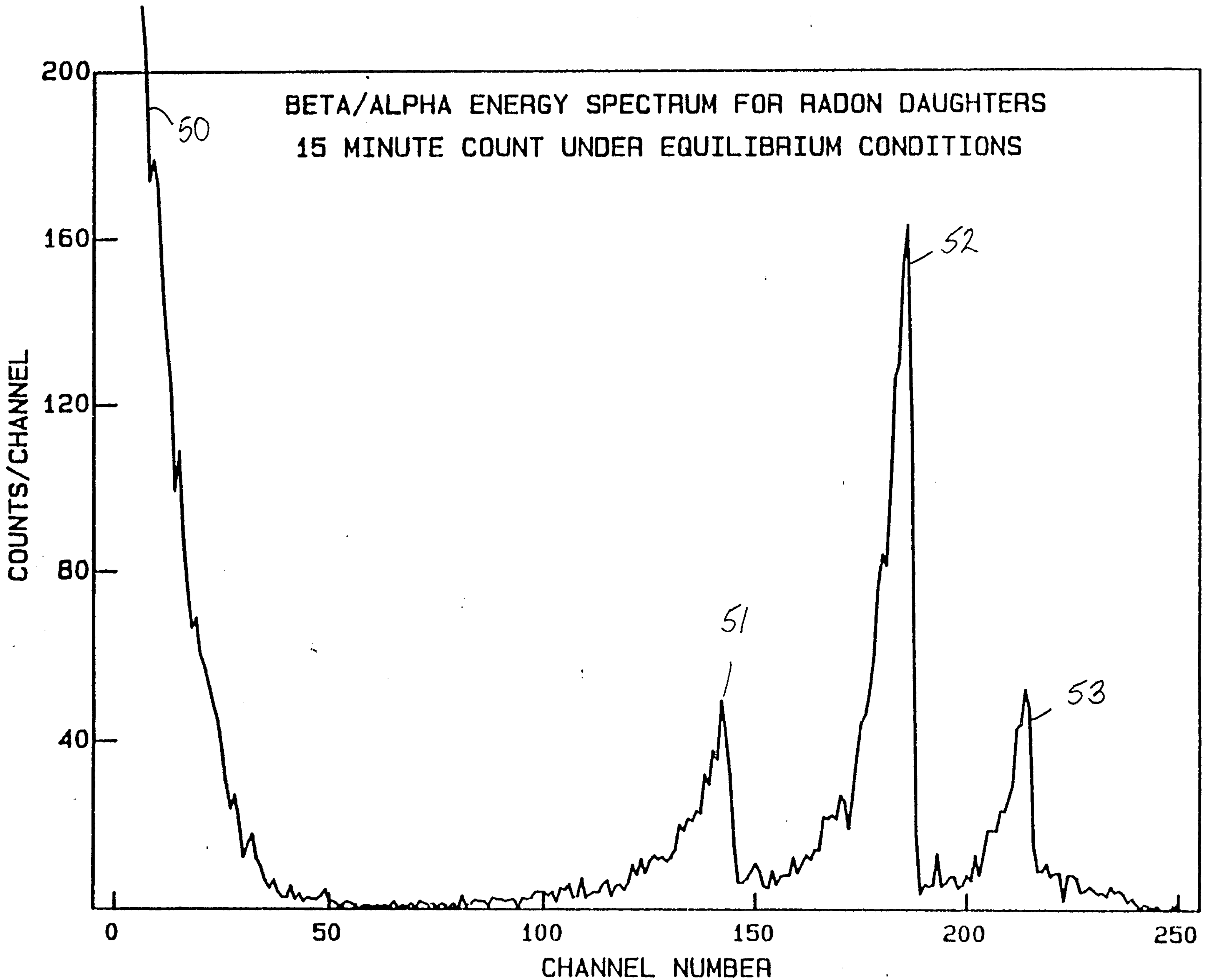
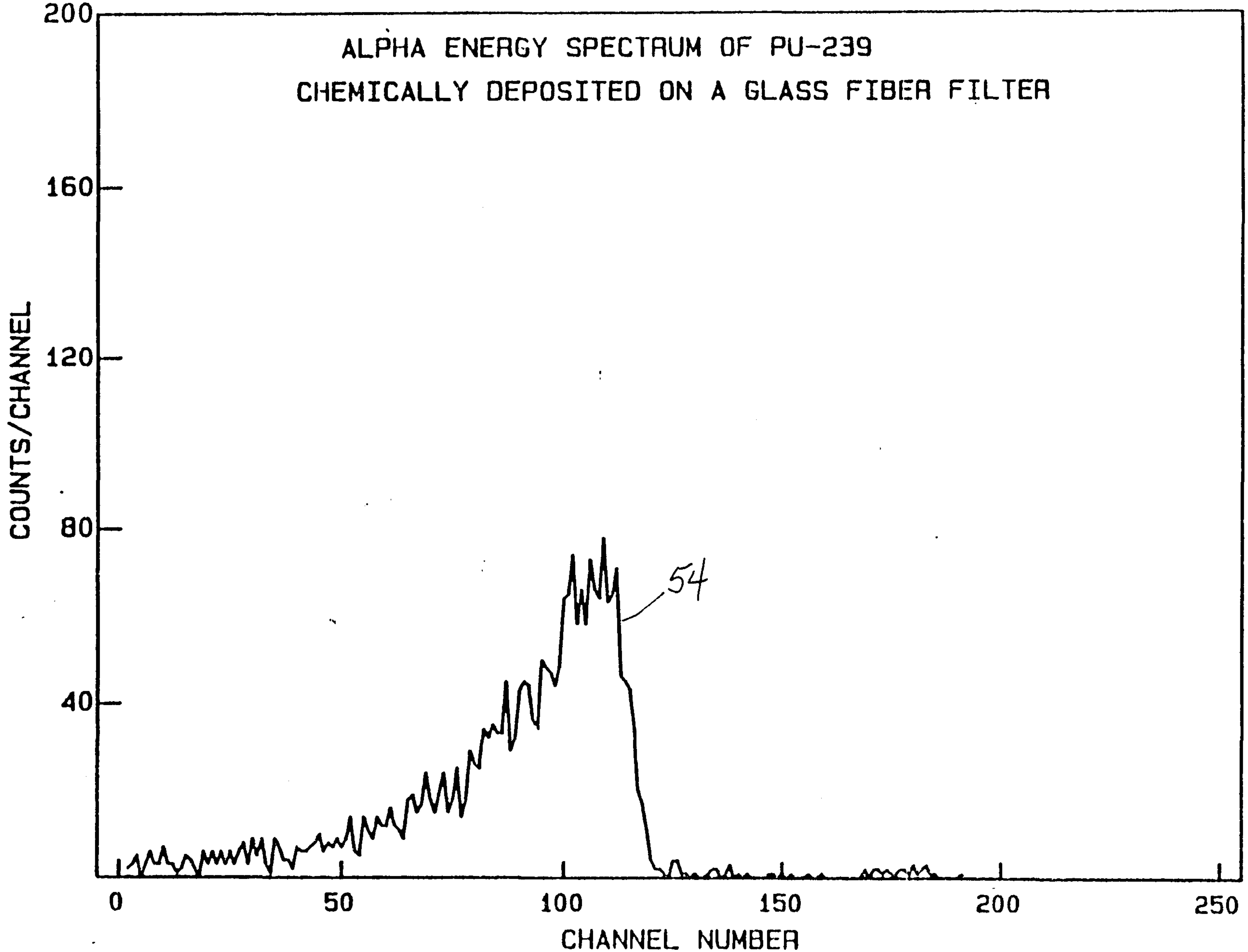

BETA/ALPHA ENERGY SPECTRUM FOR RADON DAUGHTERS
15 MINUTE COUNT UNDER EQUILIBRIUM CONDITIONS
COUNTS/CHANNEL
CHANNEL NUMBER
200
160
120
80
40
0
50
100
150
200
250
50
51
52
53

FIG. 3



ALPHA ENERGY SPECTRUM OF PU-239
CHEMICALLY DEPOSITED ON A GLASS FIBER FILTER
200
160
120
80
40
COUNTS/CHANNEL
0
50
100
150
200
250
CHANNEL NUMBER
54

FIG. 4

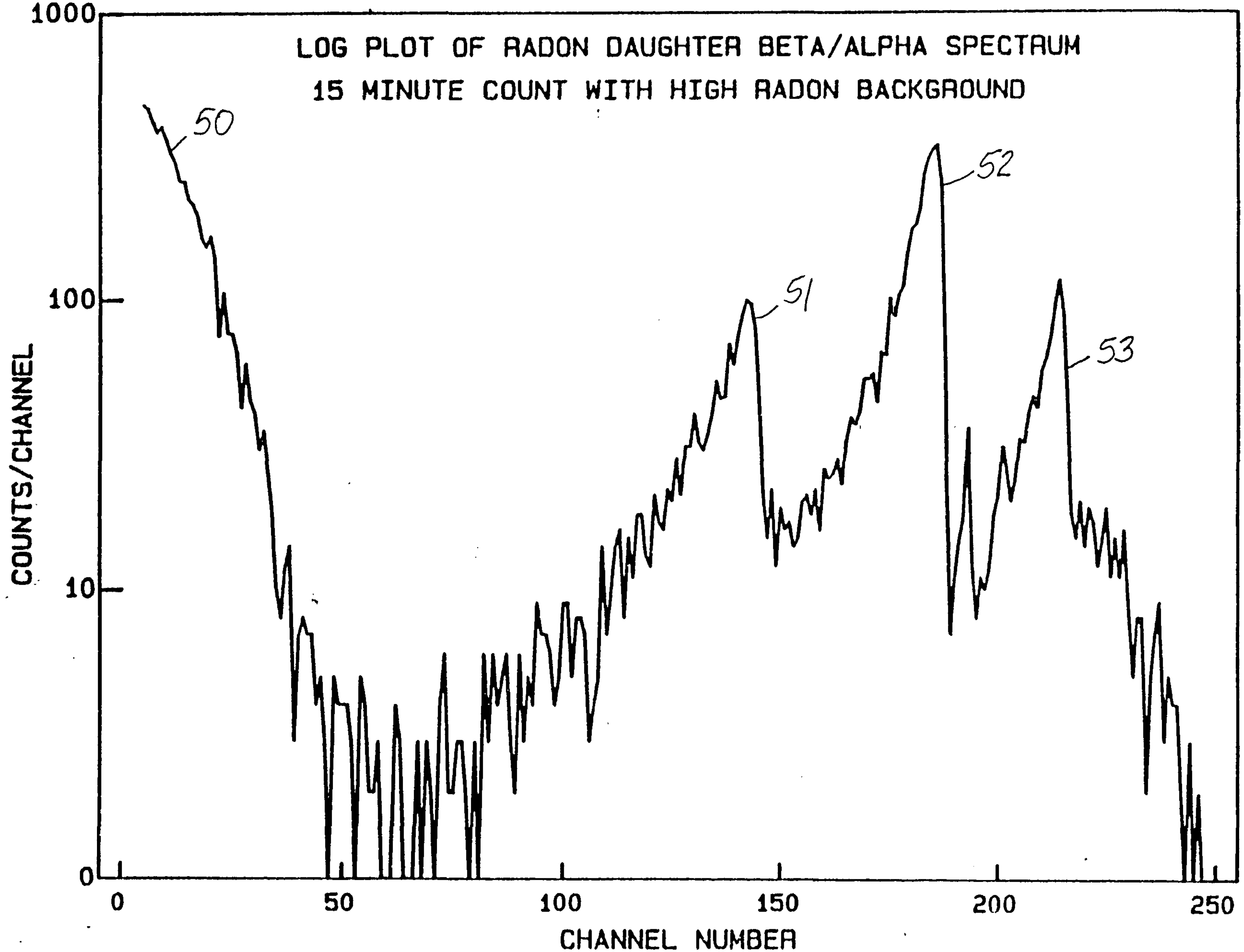

LOG PLOT OF RADON DAUGHTER BETA/ALPHA SPECTRUM
15 MINUTE COUNT WITH HIGH RADON BACKGROUND
1000
100
10
0
COUNTS/CHANNEL
0
50
100
150
200
250
CHANNEL NUMBER
50
51
52
53

FIG 5

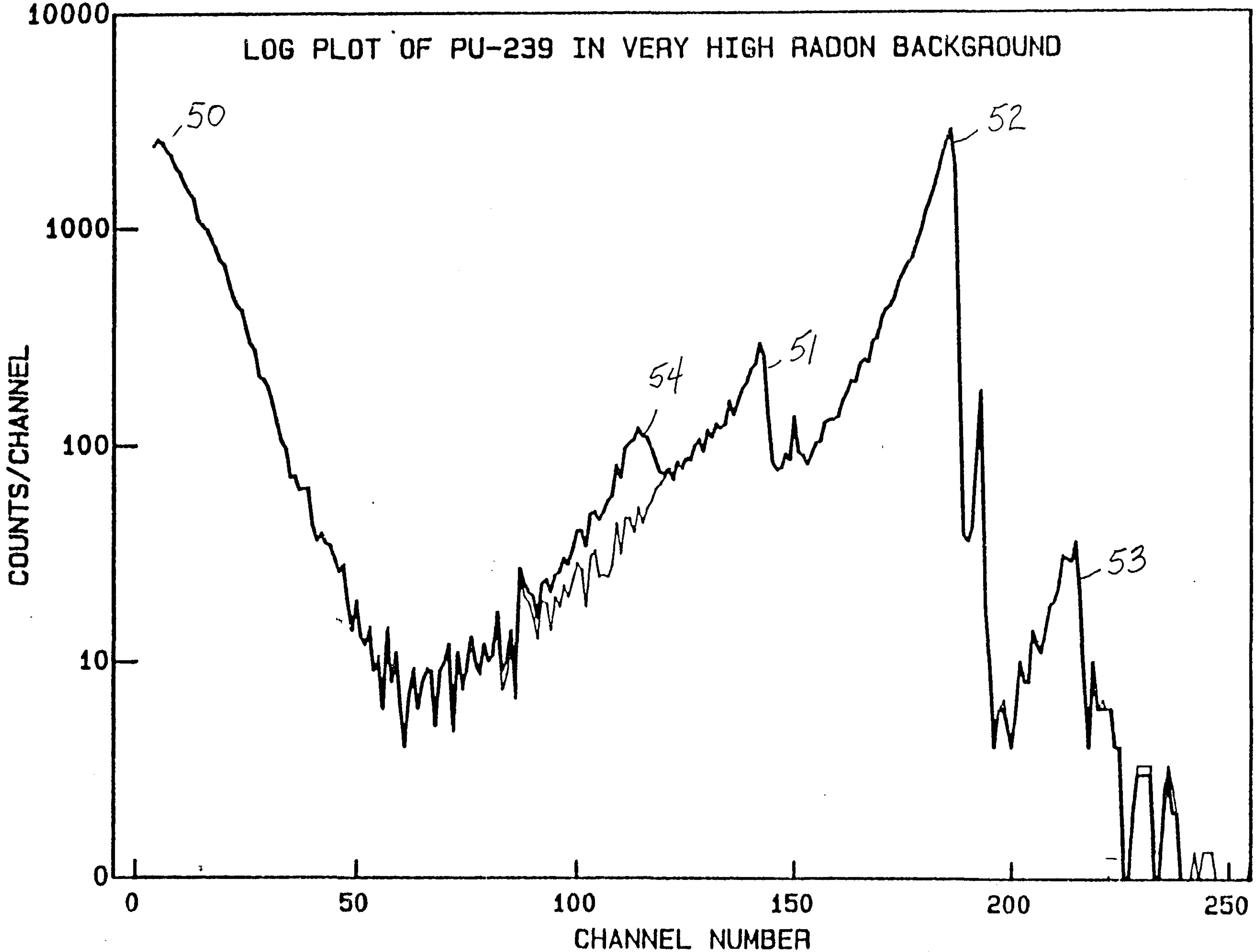

LOG PLOT OF PU-239 IN VERY HIGH RADON BACKGROUND
10000
1000
100
10
0
COUNTS/CHANNEL
0
50
100
150
200
250
CHANNEL NUMBER
50
51
52
53
54

FIG 6

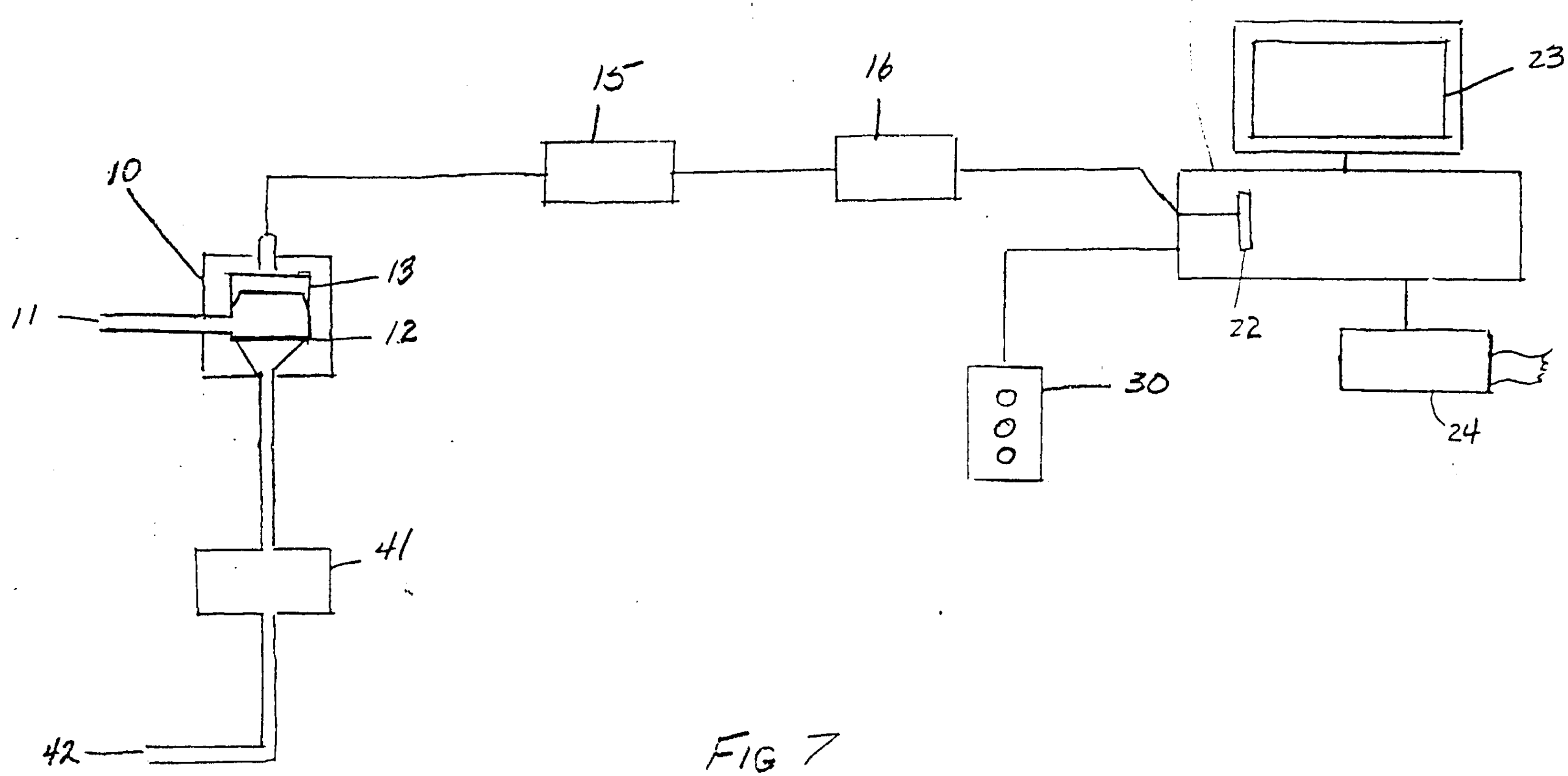


FIG 7

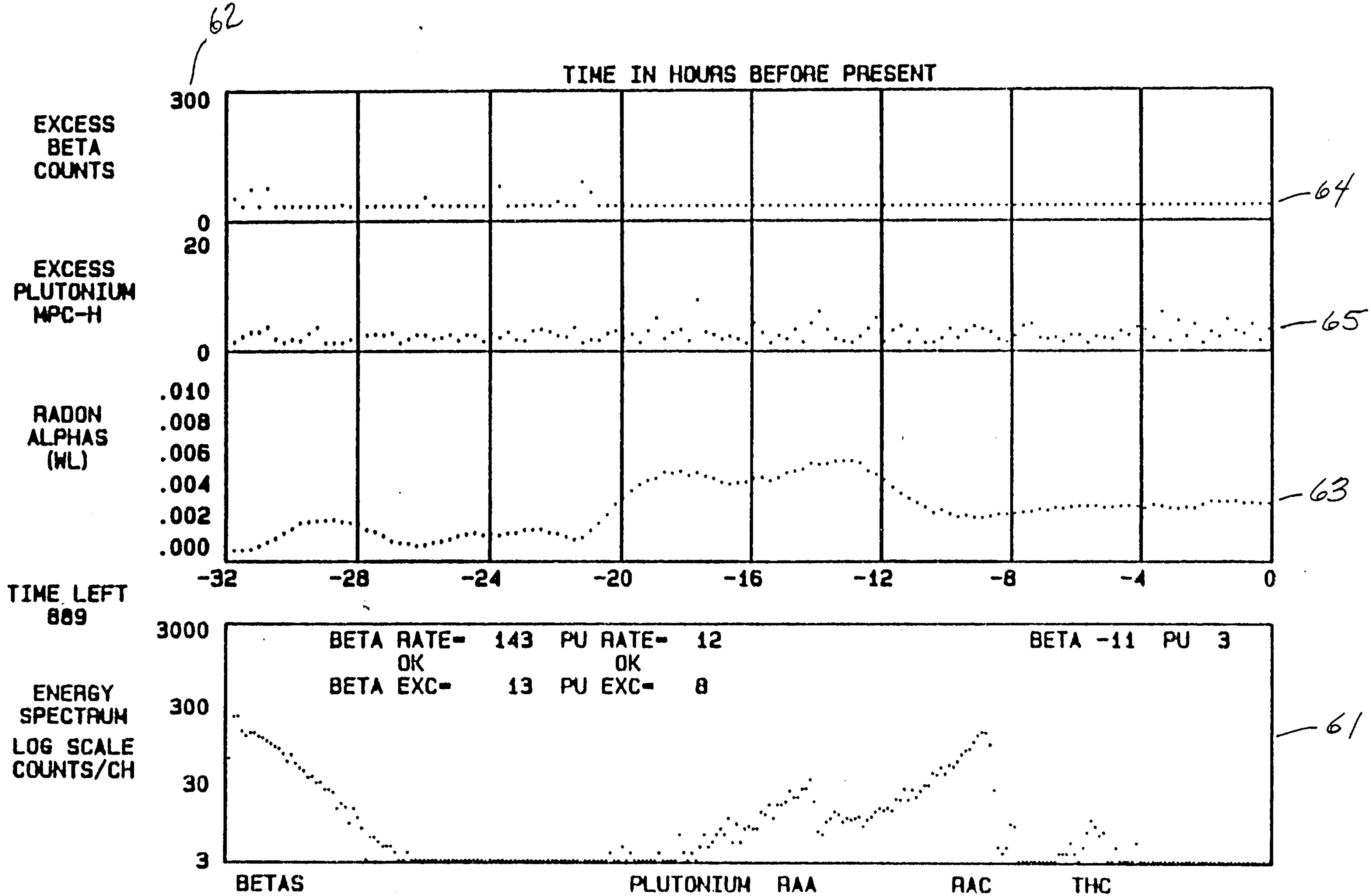

62
TIME IN HOURS BEFORE PRESENT
300
EXCESS
BETA
COUNTS
0
20
EXCESS
PLUTONIUM
MPC-H
0
RADON
ALPHAS
(WL)
.010
.008
.006
.004
.002
.000
64
65
63
-32
-28
-24
-20
-16
-12
-8
-4
0
TIME LEFT
889
3000
300
30
3
ENERGY
SPECTRUM
LOG SCALE
COUNTS/CH
BETA RATE= 143 PU RATE= 12
OK OK
BETA EXC= 13 PU EXC= 8
BETA -11 PU 3
61
BETAS
PLUTONIUM
RAA
RAC
THC

FIG. 8

Fig. 9

S-66,050

```
10 KEY OFF
20 OPEN "COM1:9600,N,8,1,RS,CS,DS" AS #1
30 PRINT #1, CHR$(0)
40 DIM T$(120),BETA(128),RAA(128),RAC(128),THC(128)
50 DIM WL(128),EXPUCH1(128),EXBETA(128)
60 DIM X(256)
70 DIM COUNT(256),A3(256),Z2(256),Z3(256)
80 'NAME AND DATE OF FILE FOR TIME DATA STORAGE
90 V$=DATE$
100 A$=MID$(V$,1,6)
110 B$=MID$(V$,9,2)
120 FILE2$="C:"+A$+B$+".TMD"
130 FILE3$="C:"+A$+B$+".SPM"
140 PRINT "THE NAME OF THE SPECTRAL FILE IS ";FILE3$
150 PRINT "THE NAME OF THE TIMEDATA FILE IS ";FILE2$
170     NOP=0:PARMSINIT=1:DISPINIT=2:PARMSUD=3:SPUD=4:
        ACQU=5:ERASEDATA=6
180     GROUP=7:TRANSFER=8:OVERLAP=9:OVLOFFSET=10:EXPAND=
        11:IDCODEDIS=12
190     STOREDATA=13:LOADDATA=14:CENTROID=15:CENTROIDAL=
        16:FWHM=17
200     FWHMALT=18:PHAMODE=19:MCSMODE=20:DADDMODE=21:
        DSUBMODE=22:GAINDIS=23
210     ADCOFSTDIS=24:PHATIMEDIS=25:MCSDTPPDIS=26:LIVE-
        TIME=27:REALTIME=28
220     CFSHME=29:CFSI=30:CFSD=31:MKRHME=32:MKRPGR=33:
        MKRMRT=34:MKRPGL=35
230     MKRMLT=36:EXPSCRLUP=37:EXPSCRLDN=38:ROI1GRP=39:
        ROI2GRP=40:IO1=41
240     IO2=42:IO3=43:IO4=44:IO5=45:IO6=46:IO7=47:MAIN-
        MENU=48:MOREMENU=49
250     SETUPMENU=50:TIMEMENU=51:OPTIONMENU=52:CLSPEC=
        53:CVDB=54:ALPHAI=55
260     GRMI=56
270     REM
```

```
280      REM
290      REM
300      DGROUP=128:NUMCHL=129:ADCMGNUM=130:ADCMGSC=131:
         ADCMGDR=132
310      ADCMGAR=133:PHAFLG=134:MCSFLG=135:ADDFLG=136:
         SUBFLG=137
320      LIVTMF=138:RELTMF=139:ACQFLG=140:ACQPT=141:
         ACQET=142:ACQTR=143
330      MCSTIMECHLF=144:MCSTIMELBL=145:MCSDWLNUM=146:
         MCSPSTPASS=147
340      MCSPASCNT=148:MCSPASREM=149:MCSDWLTBL=150:MCSD-
         WLTBLBIN=151
350      GAINN=152:OFFSN=153:CFS=154:MKRMGCN=155:MKRAR=
         156:MKRDR=157
360      ROI1FLG=158:ROI2FLG=159:ROIPN=160:ROIBEGAR=161:
         ROIENDAR=162
370      ROINCHLS=163:ROIGIACC=164:ROIBKGACC=165:ROINI-
         ACC=166:ROINISIGN=167
380      CENTROIDUDFLG=168:CENTROIDCHLFP=169:CENTROIDKE-
         VFP=170
390      CENTROIDTIMEFP=171:FWHMUDFLG=172:FWHMCHLFP=173:
         FWHMKEVFP=174
400      FWHMTIMEFP=175:ERALKF=176:EXPNDFLG=177:OVERLAP-
         FLG=178
410      TRANSCRTXT=179:TRANSCRMGN=180:TRANDSTTXT=181:
         TRANDSTMGN=182
420      IDCODEBUF=183:DISKFILIDF=184:HLLIDISPFLG=185:
         PCAUSERUDFLG=186
430       REM
440       REM
450 REM SET UP PCA SEGMENT AND OFFSET VARIABLES
460      DEF SEG=%HO
470      PCAOFFSET=PEEK(%H3C9)*256+PEEK(%H3C8)
480      PCASEG=PEEK(%H3CB)*256+PEEK(%H3CA)
490      PCAFUNN=PCAOFFSET+3
500      DEF SEG=PCASEG
510      DEF USR=PCAOFFSET
520     REM
530     REM
540     REM
550     REM
560 REM INITIALIZE RECYCLE DISPLAY
570      F=CVDB:GOSUB 4110   'CLEAR ENTIRE VIDEO DISPLAY
580      F=ALPHAI:GOSUB 4110    'SET COMPUTER FOR ALPHA-
         NUMERIC MODE
590      'INHIBIT PCA DISPLAY OUTPUT FOR NOW
600      F=HLLIDISPFLG:GOSUB 4230:DEF SEG=PARMSEG:POKE
         PARMOFFSET,255
610      'DISPLAY RECYCLE TITLE MESSAGE
620      PRINT TAB(31);"SET INITIAL VALUES":PRINT:PRINT
```

```
630 GN=5:'SETS CONVERSION GAIN TO 256 CHANNELS, CHANGE
    GN TO OTHER VALUES
640 GOSUB 4040:'GO SET CONVERSION GAIN
650 REM "PT" IS THE PRESET LIVE TIME, CHANGE AS DESIRED
660 PT=900
670    PT1=INT(PT/10000)
680    PT2=INT((PT-PT1*10000)/100)
690    PT3=INT(PT-PT1*10000-PT2*100)
700    'CONVERT HEX VALUES TO DECIMAL
710    PT1=INT(PT1/10)*16+INT(PT1-(INT(PT1/10)*16)*(10/
       16))
720    PT2=INT(PT2/10)*16+INT(PT2-(INT(PT2/10)*16)*(10/
       16))
730    PT3=INT(PT3/10)*16+INT(PT3-(INT(PT3/10)*16)*(10/
       16))
740 REM
750 MGN=4:GOSUB 3930: 'SETS MEMORY GROUP TO Q1
760 REM
770 CLS
780 SCREEN 2,0
790 LINE (107,8)-(621,68),1,B
800 LINE (107,38)-(621,118),1,B
810 LINE (107,133)-(621,190),1,B
820 LINE (172,8)-(236,118),1,B
830 LINE (300,8)-(364,118),1,B
840 LINE (428,8)-(492,118),1,B
850 LINE (556,8)-(556,118),1
860 LOCATE 2,2
870 PRINT" EXCESS"
880 LOCATE 3,2
890 PRINT" BETA   "
900 LOCATE 4,1
910 PRINT" COUNTS"
920 LOCATE 2,10
930 PRINT" 300"
940 LOCATE 5,10
950 PRINT"   0"
960 LOCATE 6,2
970 PRINT" EXCESS"
980 LOCATE 7,2
990 PRINT"PLUTONIUM"
1000 LOCATE 8,2
1010 PRINT" MPC-HR"
1020 LOCATE 9,9
1030 PRINT"    0"
1040 LOCATE 6,9
1050 PRINT"   20"
1060 LOCATE 11,1
1070 PRINT" RADON"
1080 LOCATE 12,1
```

```
1090 PRINT" ALPHAS"
1100 LOCATE 13,1
1110 PRINT"   WL"
1120 LOCATE 10,9
1130 PRINT"  .10"
1140 LOCATE 11,9
1150 PRINT"  .08"
1160 LOCATE 12,9
1170 PRINT"  .06"
1180 LOCATE 15,9
1190 LOCATE 13,9
1200 PRINT"  .04"
1210 LOCATE 14,9
1220 PRINT"  .02"
1230 LOCATE 15,6
1240 PRINT"     .00"
1250 LOCATE 20,2
1260 PRINT"ENERGY"
1270 LOCATE 21,1
1280 PRINT"SPECTRUM"
1290 LOCATE 22,1
1300 PRINT"LOG SCALE"
1310 PRINT"COUNTS/CH"
1320 LOCATE 24,11
1330 PRINT"  3";
1340 LOCATE 22,10
1350 PRINT"  30"
1360 LOCATE 20,10
1370 PRINT" 300"
1380 LOCATE 18,9
1390 PRINT" 3000"
1400 LOCATE 25,15
1410 PRINT" BETAS          PLUTONIUM RAA      RAC    THC";
1420 LOCATE 1,30
1430 PRINT"TIME IN HOURS BEFORE PRESENT"
1440 LOCATE 16,13
1450 PRINT"-32"
1460 LOCATE 16,21
1470 PRINT"-28"
1480 LOCATE 16,29
1490 PRINT"-24"
1500 LOCATE 16,37
1510 PRINT"-20"
1520 LOCATE 16,45
1530 PRINT"-16"
1540 LOCATE 16,53
1550 PRINT"-12"
1560 LOCATE 16,61
1570 PRINT"-8"
1580 LOCATE 16,69
```

```
1590 PRINT"-4"
1600 LOCATE 16,78
1610 PRINT"0"
1620 LOCATE 17,1
1630 PRINT"TIME LEFT"
1640 LOCATE 18,17:PRINT"BETA RATE"
1650 LOCATE 18,32:PRINT"  PU RATE"
1660 LOCATE 20,17:PRINT"BETA EXC"
1670 LOCATE 20,33:PRINT" PU EXC "
1680    F=HLLIDISPFLG:GOSUB 4230:DEF SEG=PARMSEG:POKE
        PARMOFFSET,0
1690     F=ACQFLG:GOSUB 4230:DEF SEG=PARMSEG:POKE PARM-
         OFFSET,1
1700    F=ERASEDATA:GOSUB 4110
1710    REM SET PRESET TIME
1720    F=ACQPT:GOSUB 4230:DEF SEG=PARMSEG
1730    POKE PARMOFFSET,PT3:POKE PARMOFFSET+1,PT2:POKE
        PARMOFFSET+2,PT1
1740    F=PHATIMEDIS:GOSUB 4110      'COMPLETE PRESET
        TIME ENTRY
1750    REM START ACQUISITION
1760    F=ACQU:GOSUB 4110'START ACQUIRE
1770 T$=TIME$:HR$=MID$(T$,1,2):MIN$=MID$(T$,4,2):SEC$=
     MID$(T$,7,2)
1780 SECS=VAL(HR$)*3600+VAL(MIN$)*60+VAL(SEC$)
1790 START=PT+SECS
1800 TIMBETA2=900:TIMPUCH4=900:TIMPUCH7=900:TIMPUCH8=
     900:TIMRAA2=900:TIMRAC2=900
1810 BETA4=0:RAA4=0:RAC4=0:PUCH4=0:PUCH7=0:PUCH8=0
1820 REM UPDATE OF SCREEN
1830 BETA3=0:PUCH3=0:RAA3=0:RAC3=0:THC3=0:EXPUCH3=0:
     PUCH5=0:PUCH6=0
1840 F9=F9+1
1850 DEF SEG=%HE000'CHANNEL DATA AT HEX E000
1860 FOR J=0 TO 255
1870 IF Z2(J)<3 THEN Z2(J)=3
1880 PSET (2*J+108,197-LOG(Z2(J))*60/8),0
1890 K=INT(J*4)
1900 Z2(J)=PEEK(K)+PEEK(K+1)*256+PEEK(K+2)*65536!
1910 COUNT(J)=Z2(J)
1920 IF J>188 THEN THC3=THC3+COUNT(J)
1930 IF J<189 AND J>144 THEN RAC3=RAC3+COUNT(J)
1940 IF J<145 AND J>125 THEN RAA3=RAA3+COUNT(J)
1950 IF J<125 AND J>79 THEN PUCH3=PUCH3+COUNT(J)
1960 IF J<116 AND J>85 THEN PUCH5=PUCH5+COUNT(J)
1970 IF J<131 AND J>126 THEN PUCH6=PUCH6+COUNT(J)
1980 IF J<14 AND J>4 THEN BETA3=BETA3+COUNT(J)
1990 IF Z2(J)<3 THEN Z2(J)=3
2000 PSET (2*J+108,197-LOG(Z2(J))*60/8),1
2010 T$=TIME$:HR$=MID$(T$,1,2):MIN$=MID$(T$,4,2):SEC$=
     MID$(T$,7,2)
```

```
2020 SECS=VAL(HR$)*3600+VAL(MIN$)*60+VAL(SEC$)
2030 TR=START-SECS
2040 LOCATE 18,3:PRINT TR
2050 IF J=9 THEN TIMBETA1=TR
2060 IF J=180 THEN TIMRAC1=TR
2070 IF J=110 THEN TIMPUCH5=TR
2080 IF J=128 THEN TIMPUCH6=TR
2090 IF J=115 THEN TIMPUCH3=TR
2100 IF J=140 THEN TIMRAA1=TR
2110 NEXT J
2120 IF RRA3<1 THEN RAA3=1
2130 BETAINC=(BETA3-BETA4)/(TIMBETA2-TIMBETA1)*60
2140 RAAINC=(RAA3-RAA4)/(TIMRAA2-TIMRAA1)*60
2150 RACINC=(RAC3-RAC4)/(TIMRAC2-TIMRAC1)*60
2160 ZB$="  OK   "
2162 ADDR1=251:ADDR2=243
2170 IF BETAINC>3.3*RAAINC THEN ZB$="YELLOW"
2180 IF BETAINC>3.3*RAAINC THEN ADDR1=249
2182 IF BETAINC>400 THEN ZB$=" RED  "
2183 IF BETAINC>400 THEN ADDR2=242
2184 IF BETAINC>800 THEN AB$=" RED  "
2185 IF BETAINC>800 THEN ADDR2=240
2190 EXBETA3=INT(BETAINC-.3*RACINC)
2191 IF EXBETA3>EXBETA5 THEN EXBETA5=EXBETA3
2192 IF EXBETA5>400 THEN ADDR2=242
2193 IF EXBETA5>800 THEN ADDR2=240
2200 LOCATE 18,26:PRINT"      "
2210 LOCATE 18,26:PRINT USING"#####":BETAINC
2220 LOCATE 19,19:PRINT ZB$
2230 LOCATE 20,26:PRINT"      "
2240 LOCATE 20,26:PRINT USING"#####":EXBETA3
2250 BETA4=BETA3
2260 RAA4=RAA3
2270 RAC4=RAC3
2280 PUCH5=PUCH5/(TIMPUCH7-TIMPUCH5)*60
2290 PUCH6=PUCH6/(TIMPUCH8-TIMPUCH6)*60
2300 F4=INT(PUCH5-1.2*PUCH6)
2310 ZP$="  OK  "
2320 PUCHINC=(PUCH3-PUCH4)-(RAA3-RAA4)/RAA3*PUCH
2330 IF PUCHINC<0 THEN PUCHINC=0
2340 IF PUCHINC>1.1*(PUCH3-PUCH4) THEN PUCHINC=PUCH3-
     PUCH4
2350 PUCHINC=PUCHINC/(TIMPUCH4-TIMPUCH3)*60
2360 IF F4>50 THEN ZP$="YELLOW"
2365 IF F4>50 THEN ADDR1=249
2370 IF F4>100 THEN ZP$=" RED  "
2375 IF F4>100 THEN ADDR2=242
2380 IF F4>200 THEN ADDR2=240
2381 IF ADDR2<243 THEN ADDR1=251
2383 PRINT #1,CHR$(ADDR1)
```

```
2384 PRINT #1,CHR$(ADDR2)
2390 EXPUCH3=F4
2400 LOCATE 18,42:PRINT"      "
2410 LOCATE 18,43:PRINT USING"####";(PUCH3-PUCH4)/(TIM-
     PUCH4-TIMPUCH3)*60
2420 LOCATE 19,35:PRINT ZP$
2430 LOCATE 20,43:PRINT"      "
2440 LOCATE 20,42:PRINT USING"####";EXPUCH3
2450 PUCH4=PUCH3
2460 TIMBETA2=TIMBETA1:TIMRAA2=TIMRAA1:TIMRAC2=TIMRAC1
2470 TIMPUCH4=TIMPUCH3
2480 TIMPUCH7=TIMPUCH5:TIMPUCH8=TIMPUCH6
2490    F=ACQFLG:GOSUB 4230:DEF SEG=PARMSEG:ACQ=PEEK-
        (PARMOFFSET)
2500 IF ACQ<>0 THEN 2520
2510 GOTO 1820
2520 DEF SEG=%HE000:'CHANNEL DATA STARTS AT MEMORY
     LOCATION HEX E000
2530 REM READS 256 CHANNELS OF DATA FROM MEMORY TO COUNT
     (J) ARRAY
2540 FOR J=0 TO 256
2550 K=INT(J*4)
2560 COUNT(J)=PEEK(K)+PEEK(K+1)*256+PEEK(K+2)*65536!
2570 Z3(J)=COUNT(J)
2580 NEXT J
2590 OPEN FILES3$ FOR APPEND AS #3
2600 WRITE #3,T$
2610 FOR J=0 TO 255
2620 WRITE #3,COUNT(J)
2630 NEXT J
2640 CLOSE #3
2650 FOR J=79 TO 134
2660 COUNT(J)=(COUNT(J-1)+COUNT(J)+COUNT(J+1))/3
2670 NEXT J
2680 REM RESETS COUNTERS TO ZERO EACH PASS
2690 Q8=Q8+1
2700 BETA=0:PUCH=0:RAA=0:RAC=0:THC=0:EXBETA5=0
2710 PUCH7=0:PUCH8=0
2720 REM SUMS COUNTS FOR BETA, PUCH,RAA,RAC AND THC
2730 FOR J=0 TO 255
2740 IF J>4 AND J<14 THEN BETA=BETA+COUNT(J)
2750 IF J>79 AND J<126 THEN PUCH=PUCH+COUNT(J)
2760 IF J>85 AND J<116 THEN PUCH7=PUCH7+COUNT(J)
2770 IF J>127 AND J<146 THEN RAA=RAA+COUNT(J)
2780 IF J>126 AND J<131 THEN PUCH8=PUCH8+COUNT(J)
2790 IFJ>145 AND J<189 THEN RAC=RAC+COUNT(J)
2800 IF J>188 THEN THC=THC+COUNT(J)
2810 NEXT J
2820 IF RAA<1 THEN RAA=1
2830 U=1:L=.7
```

```
2840 F8=0
2850 RATIO=(U+L)/2
2860 F8=F8+1
2870 FOR J=124 TO 80 STEP -1
2880 Z3(J)=RATIO*Z3(J+1)*1033/(900+J)
2890 NEXT J
2900 AVG3=(COUNT(80)+COUNT(81)+COUNT(82))/3
2910 LOCATE 25,2
2920 PRINT"        ";
2930 AVG4=(Z3(80)+Z3(81)+Z3(82))/3
2940 LOCATE 25,2
2950 PRINT USING "###.#";ABS(AVG4-AVG3);
2960 IF ABS(AVG4-AVG3)<.1 THEN 3010
2970 IF F8>20 THEN 3010
2980 IF AVG4<AVG3 THEN 3000
2990 U=RATIO:GOTO 2850
3000 L=RATIO:GOTO 2850
3010 FOR J=145 TO 80 STEP -1
3020 X(J)=COUNT(J)
3030 IF J>82 AND J<125 THEN IF COUNT(J)>Z3(J) THEN X(J)=
     Z3(J)
3040 NEXT J
3050 P1=0:RAAPEAK=0
3060 REM LOCATES RAA PEAK CHANNEL
3070 FOR J=127 TO 146
3080 IF COUNT(J)>P1 THEN P1=COUNT(J):P2=J
3090 NEXT J
3100 REM RAA PEAK COUNTS AVERAGED
3110 FOR J=P2-1 TO P2+1
3120 RAAPEAK=RAAPEAK+COUNT(J)
3130 NEXT J
3140 RAAPEAK=RAAPEAK/3
3150 IF X(125)<1 THEN X(125)=1
3160 FOR J=145 TO 80 STEP -1
3170 A3(J)=X(J)/RAAPEAK
3180 NEXT J
3190 DIVID1=A3(125)
3200 IF DIVID1<.00001 THEN DIVID1=.00001
3210 FOR J=80 TO 145
3220 A3(J)=A3(J)DIVID1
3230 NEXT J
3240 C1=0:C2=0:C3=0:C4=0:C5=0
3250 FOR J=80 TO 124
3260 C3=C3+COUNT(J)-A3(J)*COUNT(125)
3270 NEXT J
3280 REM RATIOS COMPUTED
3290 PUCHINC=(PUCH-PUCH2)-(RAA-RAA2)/RAA*PUCH
3300 IF PUCHINC>1.1*(PUCH-PUCH2) THEN PUCHINC=(PUCH-
     PUCH2)
3310 PUCH2=PUCH
```

```
3320 RAA2=RAA
3330 F4=PUCH7-1.2*PUCH8
3340 EXPUCH1=C3
3350 IF EXPUCH1<0 THEN EXPUCH1=0
3360 EXPUCH1(128)=EXPUCH1
3370 EXBETA=(BETA-.03*RAC)
3380 IF EXBETA<0 THEN EXBETA=0
3390 EXBETA(128)=EXBETA
3400 WL=(RAA*6.05+RAC*7.68+THC*8.78)/21/15/.18/130000!
3410 WL(128)=WL*1000
3420 ZP2$="           "
3430 IF C3+PUCHINC>(SQR(PUCH)+SQR(RAA)) AND C3>25 THEN
     ZP2$="YELLOW1"
3440 IF F4>200 THEN ZP2$="YELLOW2"
3450 IF PUCHINC+C3>SQR(PUCH)+SQR(RAA)) AND F4>50 THEN
     ZP2$="RED1    "
3460 IF PUCHINC+C3>2*(SQR(RAA)) AND F4>100 THEN ZP2$=
     "RED2    "
3470 LOCATE 18,69
3480 PRINT "           "
3490 LOCATE 18,69
3500 PRINT ZP2$
3510 LOCATE 19,66:PRINT USING "####";EXBETA
3520 LOCATE 19,71:PRINT USING "####";C3
3530 FOR J=1 TO 127
3540 EXPUCH1(J)=EXPUCH1(J+1)
3550 EXBETA(J)=EXBETA(J+1)
3560 WL(J)=WL(J+1)
3570 IF WL(J)<1 THEN WL(J)=1
3580 NEXT J
3590 FOR J=127 TO 2 STEP -1
3600 PSET (4*J+110,INT(117-.5*WL(J))),1
3610 IF INT(117-.5*WL(J))=INT(117-.5*WL(J-1)) THEN 3630
3620 PSET(4*J+110,INT(117-.5*WL(J-1))),0
3630 PSET (4*J+110,INT(36-EXBETA(J)*28/2000)),1
3640 IF INT(36-EXBETA(J)*28/2000)=INT(36-EXBETA(J-1)*28/-
     20000) THEN 3660
3650 PSET (4*J+110,INT(36-EXBETA(J-1)*28/2000)),0
3660 PSET (4*J+110,INT(66-EXPUCH1(J)*28/500)),1
3670 IF INT(66-EXPUCH1(J)*28/500)=INT(66-EXPUCH1(J-1)-
     *28/500) THEN 3690
3680 PSET(4*J+110,INT(66-EXPUCH1(J-1)*28/500)),0
3690 NEXT J
3890 GOTO 1700
3900   'SELECT MEMORY GROUP
3910   'THIS ROUTINE SELECTS THE MEMORY GROUP WHOSE
       NUMBER
3920   'IS PASSED IN THE VARIABLE 'MGN'.
3930    F=ADCMGNUM:GOSUB 4230:DEF SEG=PARMSEG:POKE
        PARMOFFSET,MGN
```

```
3940    F=GROUP:GOSUB 4110
3950    RETURN
3960 REM
3970   'SET PCA CONVERSION GAIN
3980   '***********************
3990   'THIS ROUTINE SETS THE PCA CONVERSION GAIN TO
4000   'THE GAIN DEFINED BY THE NUMBER PASSED IN THE
4010   'VARIABLE 'GN'. VALID VALUES FOR 'GN' ARE: 8192=0,
4020   '4096=1, 2048=2, 1024=3, 512=4, 256=5.
4030 REM
4040    F=GAINN:GOSUB 4230:DEF SEG=PARMSEG:POKE PARM-
        OFFSET,GN
4050    F=GAINDIS:GOSUB 4110
4060    RETURN
4070 REM
4080   'CALL PASSED PCA USER FUNCTION
4090   '******************************
4100   'THE VALID PCA FUNCTION NUMBER IS PASSED IN
       THE VARIABLE F
4110   DEF SEG=PCASEG
4120   DEF USR=PCAOFFSET
4130   POKE PCAFUNN,F
4140   X=USR(0)
4150   RETURN
4160 REM
4170   'RETRIEVE PARAMETER SEGMENT AND OFFSET ADDRESSES
4180  '************************************************
4190   'THE PARAMETER NUMBER TO RETRIEVE IS PASSED IN
       THE VARIABLE 'F'
4200   'THE SEGMENT ADDRESS IS RETURNED IN THE VARIABLE
       'PARMSEG'.
4210   'THE OFFSET ADDRESS IS RETURNED IN THE VARIABLE
       'PARMOFFSETT;.
4220   REM
4230    DEF SEG=PCASEG:DEF USR=PCAOFFSET
4240    POKE PCAFUNN,F
4250    X=USR(0)
4260    PARMOFFSET=PEEK(PCAFUNN+2)*256+PEEK(PCAFUNN+1)
4270    PARMSEG=PEEK(PCAFUNN+4)*256+PEEK(PCAFUNN+3)
4280    RETURN
4290 END
```