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**COMPUTERIZED QUANTITATIVE
ANALYSIS BY GAMMA-RAY SPECTROMETRY.
VOL. IV. AUXILIARY PROGRAMS FOR GAMANAL**

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Other Volumes

- VOL. I. Description of the GAMANAL Program (1972)
- VOL. II. Source Listing of the GAMANAL Program (1971)
- VOL. III. A User's Guide to GAMANAL (1971)
- VOL. V. Decay-Scheme Data Library for GAMANAL
(planned revision of UCID-15439)

COMPUTERIZED QUANTITATIVE ANALYSIS BY GAMMA-RAY SPECTROMETRY. VOL. IV. AUXILIARY PROGRAMS FOR GAMANAL

Abstract

This report describes and lists four small programs that are used in conjunction with the GAMANAL program. They are used to prepare a decay scheme library and to determine some of the parameters that characterize the counting systems.

Introduction

The GAMANAL program is primarily intended for complete computer analysis of high-resolution gamma-ray spectra obtained from mixtures of radioactive species such as fission products. For this purpose it examines the pulse-height data for "background" and "peak" regions, fits these peaks with the proper shape functions, and corrects for the effects of geometry, attenuation, and detector efficiency in evaluating the photon emission rate and for nonlinearities in the equipment in setting up an energy scale. These intermediate results are listed and plotted and, if no further data reduction is requested, the program goes on to the next spectrum. Otherwise, it proceeds to search a "library" of decay scheme information in order to make tentative assignments for each of the peaks. This collection of "candidates" is examined for interactions between the photopeaks of the proposed nuclides and is divided into sets of species which interfere with each other at any point. A least-squares solution of the corresponding set of simultaneous equations is made and the amounts of various components originally present are calculated and listed, along with their estimated errors.

The following programs are used to prepare the decay scheme "library" and to determine the various parameters used to describe the linearity and the efficiency of a system.

The EFFICIENCY Program

This auxiliary program fits a polynomial equation to a set of efficiency data for a Ge(Li) detector. The coefficients of the resulting polynomial can then be used to describe the intrinsic efficiency of the detector.

Since we were unable to describe the efficiency adequately over the entire energy region with a single 6th or 7th order polynomial, we have chosen to use separate

equations to describe the low energy region and the high energy region. A crossover energy, generally somewhere between 50 and 200 keV, is selected to give an optimum overall fit.

The input to this program consists of gamma-ray energies, the corresponding intrinsic efficiencies, and the associated errors, if greater than 1%. Also specified are the terminal energy for the fitting range of the first polynomial and the starting energy for the fitting of the second polynomial. These specifications should result in an appreciable overlap within which a good crossover energy position can be chosen.

An equation of the following form will be fitted to the data (by the method of least-squares):

$$\ln \epsilon_i = \sum_{j=1}^N a_j (\ln E_i)^{j-1}$$

where

ϵ_i = intrinsic efficiency at energy E_i

a_j = polynomial coefficients

The resulting values of a_j are placed on Type 5 cards as explained in Vol. III of this report.¹

¹J. B. Niday and R. Gunnink, Computerized Quantitative Analysis by Gamma-Ray Spectroscopy. Vol. III, A User's Guide to GAMANAL, Lawrence Livermore Laboratory, Rept. UCRL-51061, Vol. III (1971).

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*      FORTRAN      EFFICIENCY      1972 AD      G05/03      00.331 MONITOR402      C.271

4      CODE ANALYSIS
5
6      C      THIS PROGRAM CALCULATES COEFFICIENTS TO POLYNOMIAL EQUATIONS WHICH
7      C      ARE SUBSEQUENTLY USED TO DESCRIBE THE EFFICIENCY OF A DETECTOR
8
9      C      FIRST DATA CARD * COL. 2- 9 (F8.3) GAMMA RAY ENERGY (KEV)
10     C      COL. 10-18 (E9.3) EFFICIENCY VALUE
11     C      COL. 19-21 (F3.1) PERCENT ERROR
12     C      COL. 22-29 (A8) SOURCE LABEL
13     C      COL. 30-69 (5A8) PROBLEM IDENTIFICATION
14     C      COL. 70-75 (16) ENDING ENERGY FOR 1ST POLYNOMIAL
15     C      COL. 76-80 (15) STARTING ENERGY FOR 2ND POLYNOMIAL
16     C      ADDITIONAL DATA CARDS * COL. 1-29 SAME AS ABOVE
17     C      USE ONE CARD FOR EACH EFFICIENCY MEASUREMENT
18     C      USE A BLANK CARD TO SEPARATE PROBLEMS
19     C      USE AN ADDITIONAL BLANK CARD TO TERMINATE THE RUN
20
21
22     COMMON ENERGY(50),EFF(50),SOURCE(50),ERGLOG(50,9),EFFLOG(50),
23     1ERG1(200),EFF1(200),ERG2(300),EFF2(300),IC(51,X(9),B(50,9),R(50),
24     2W(9),V(9),EFFSTD(50),PCTDEV(50),WTEFF(50),WTUERG(50,9),PCTERR(50)
25     1,ENT(50,9),EF(50),XX(9),ND(5)
26
27     CALL CRTID (2HRG,1,0)
28     NORDER = 5
29     1 NUK = NORDER
30     DO 20 J = 1,9
31     DO 30 I = 1,50
32     30 ERGLOG(I,J) = 0.0
33     20 CONTINUE
34     N=0
35     100 N=N+1
36     READ INPUT TAPE 2, 10,ENERGY(N) ,EFF(N),PCTERR(N),SOURCE(N),ND,
37     1 IE,i5
38     10 FORMAT (1X,F8.3,E9.3,F3.1,A8,5A8,16,15)
39     IF(PCTERR(N) ) 115, ,115
40     PCTERR(N) = 1.0
41     115 IF (N-1) , ,116
42     IF (ENERGY(N)) ,100C,
43     IEND = 1L
44     ISTART = 1S
45     DO 117 I = 1,5
46     117 IO(I) = NO(I)
47     116 IF (ENERGY(N)) , ,10C
48     120 N = N -1
49
50     C      DETERMINE THE LOGARITHMS OF THE ENERGY AND EFFICIENCY VALUES.
51
52     DO 130 J =1,N
53     ERGLOG(J,1) = 1.0

```

```

54      ERGLOG(J,2) = LOGF (ENERGY(J) * .001)
55      DO 131 I = 3, NUM + 1
56      I1 = I - 1
57      131 ERGLOG(J,I) = ERGLOG(J,I1) * ERGLOG(J,2)
58      EFFLOG(J) = LOGF (EFF(J))
59      130 CONTINUE
60
61      C      APPLY WEIGHTING FACTORS
62
63      DO 135 J = 1,N
64      WEIGHT = 100. /PCTERR(J)
65      WTDEFF(J)=EFFLOG(J)*WEIGHT
66      DO 134 I = 1, NUM + 1
67      WTDERG(J,I) = ERGLOG(J,I)*WEIGHT
68      134 CONTINUE
69      135 CONTINUE
70
71      DO 141 J=1,N
72      IF(ENERGY(J) -IEND) , ,142
73      DO 144 I = 1, NUM
74      144 EN(J,I) = WTDERG(J,I)
75      EF(J) = WTDEFF(J)
76      141 CONTINUE
77      142 N1 = J - 1
78      IF (N1 - NUM) A142, ,
79      X(NUM+1) = 0.0
80
81      C      PERFORM LEAST-SQUARES FIT TO LOW ENERGY SET OF VALUES (UP TO IEND)
82
83      CALL MLR(50,N1,NUM,EN,EF,X,B,R,W,V)
84
85      A142 N2 = 0
86      NUM = NUM + 1
87      DO 143 J=1,N
88      IF(ENERGY(J) -ISTART)143, ,
89      N2 = N2 + 1
90      DO 145 I = 1, NUM
91      145 EN(N2,I) = WTDERG(J,I)
92      EF(N2)= WTDEFF(J)
93      143 CONTINUE
94
95      C      PERFORM LEAST-SQUARES FIT TO HIGH ENERGY SET OF VALUES (ABOVE ISTART)
96
97      CALL MLR(50,N2,NUM,EN,EF,XX,B,R,h,V)
98
99      C      CALCULATE CURVE VALUES OF THE EFFICIENCY FOR EACH INPUT ENERGY
100
101      DO 133 J = 1,N1
102      EFFSTD(J) = X(1)
103      DO 132 I = 2,NUM - 1
104      132 EFFSTD(J) = EFFSTD(J) + X(1) * ERGLOG(J,2) ** (I-1)
105      EFFSTD(J) = EXPF (EFFSTD(J))

```

```

106   PCTDEV(J) = (EFFSTD(J) - EFF(J)) * 100. / EFF(J)
107   133   CONTINUE
108       K = N1
109       DO 137 J = (N-N2+1), N
110         K = K + 1
111         EFFSTD(K) = XX(I)
112         DO 136 I = 2, NUM
113       136   EFFSTD(K) = EFFSTD(K) + XX(I) * ERGLOG(J,2) ** (I-1)
114         EFFSTD(K) = EXPF (EFFSTD(K))
115         PCTDEV(K) = (EFFSTD(K) - EFF(J)) * 100. / EFF(J)
116       137   CONTINUE
117
118   C   GENERATE A TABLE OF ENERGY VS. EFFICIENCY VALUES
119
120   NPTS1 = 0
121
122   MI = 0.1 * ENERGY(1)
123   ERG1(1) = 5 * MI
124   ERG2(1) = ERG1(1)
125   IF (ISART) ,B140,
126   DO 140 J=1,200
127     L = J +1
128     ERGL = LOGF(ERG1(J) *.0C1)
129     EFFL = X(1)
130     DO 150 I =2,NUM-1
131       150   EFFL = EFFL +X(I)*ERGL ** (I-1)
132     EFF1(J) = EXPF (EFFL)
133     IF (ERG1(J) - IEND) , ,A140
134     ERG1(L) = ERG1(J) + 5.
135   140   CONTINUE
136     J = J - 1
137   A140   NPTS1 = J
138     M1 = ERG1(J) * .1
139     ERG2(1) = M1 * 10
140   B140   ERGEND = ENERGY(N) + 500.
141     DO 205 J = 1,300
142       L = J +1
143       ERGL = LOGF(ERG2(J) *.0C1)
144       EFFL = XX(1)
145       DO 154 I =2,NUM
146         154   EFFL = EFFL+XX(I)*ERGL ** (I-1)
147     150   CONTINUE
148     IF (EFFL - 10.) , ,210
149     EFF2(J) = EXPF (EFFL)
150     IF (ERG2(J)- 500.) 160,170,170
151   160   ERG2(L)=ERG2(J)+10.
152     GO TO 205
153   170   IF (ERG2(J)- 1000.) 180,190,190
154   180   ERG2(L)=ERG2(J) + 50.
155     GO TO 205
156   190   IF (ERG2(J)- ERGEND) ,210,210

```



```

157 200 ERG2(I) = ERG2(J) + 200.
158 205 CONTINUE
159 J = J - 1
160 NPTS2= J
161
162 C OUTPUT DATA
163
164 WRITE OUTPUT TAPE 3,220, 10
165 220 FORMAT (1H1,19X,24HEFFICIENCY VS ENERGY OF ,5A8)
166 WRITE OUTPUT TAPE 3,230,NORDER
167 230 FORMAT(//20X,21HPOLYNOMIAL FIT IS OF ,11,8HTH ORDER //)
168 WRITE OUTPUT TAPE 3,240
169 240 FORMAT(2CX,57HEENERGY EFFICIENCY PCTERR CALC EFF PCTDEV SOURCE
170 1 USED //)
171 WRITE OUTPUT TAPE 3,250,(ENERGY(I),EFF(I),PCTERR(I),EFFSTD(I),
172 1PCTDEV(I),SOURCE(I),I=1,N1)
173 WRITE OUTPUT TAPE 3,251,NUM
174 251 FORMAT (19X, 30HCROSSOVER -- POLYNOMIAL IS OF ,11,8HTH ORDER //)
175 NO = N1+N2-N
176 WRITE OUTPUT TAPE 3,250,(ENERGY(I),EFF(I),PCTERR(I),EFFSTD(I+NO)
177 1,PCTDEV(I+NO),SOURCE(I),I=(N-N2+1),N )
178 250 FORMAT (19X,F7.2,F11.6,F7.1,F10.6,F9.1,6X,A8 //)
179 WRITE OUTPUT TAPE 3,255
180 255 FORMAT(//20X,37HCOEFFICIENTS OF THE POLYNOMIALS ARE / 25X, 26H
181 1LOW ENERGY HIGH ENERGY / )
182 WRITE OUTPUT TAPE 3,256,(X(I),XX(I),I =1,NUM)
183 256 FORMAT (20X, 2E16.6)
184 WRITE OUTPUT TAPE 3,260
185 260 FORMAT (1H1,19X,69HVALUES OF EFFICIENCY VS ENERGY CALCULATED FROM
186 1FIT OF THE ABOVE DATA //)
187 WRITE OUTPUT TAPE 3,265
188 265 FORMAT(22X,44HEENERGY EFFICIENCY ENRGY EFFICIENCY /)
189 WRITE OUTPUT TAPE 3, 270, ((ERG1(I), EFF1(I), I = 1,NPTS1),
190 1(ERG2(I), EFF2(I), I = 1,NPTS2))
191 270 FORMAT(20X, F8.2, F14.7, F9.2, F14.7 /)
192 CALL XSERTH(10,6,12)
193 CALL AMINMX (EFF2,1,NPTS2,1,XMIN,XMAX )
194 CALL GRID(14, 50,5000,1,60HEENERGY(MeV)
195 1 ,0,XMIN ,.5,1,10HEFFICIENCY ,2)
196 CALL XPLOT(ERG1,1,NPTS1)
197 CALL YPLOT(EFF1,1,1)
198 CALL XPLOT(ERG2,1,NPTS2)
199 CALL YPLOT(EFF2,1,1)
200 CALL XPLOT(ENERGY,1,N)
201 CALL YPLOT(EFF ,1,0)
202 GO TO 1
203 1000 CALL EXIT
204 END

```

*** CODE ANALYSIS ***

/ NAME IN NO EXECUTABLE INSTRUCTION
C DENOTES ORIGINAL COUNT IN CLICHE.
* DENOTES NAME DEFINED OR LABEL USE

BANK

ADDRESS	BASE	TYPE	CLASS	NAME	SOURCE	LINE	REFERENCES											
0001150	MAIN.	INTEGER	LITERAL	0	27	34	85	120	195	201								
0001151	MAIN.	REAL	LITERAL	0.0	32	79												
0001157	MAIN.	REAL	LITERAL	0.1	121													
0000005	MAIN.	STATEMENT	LABEL	1	27	29*	30	31	35	41	45	48	52	53				
					55	56	63	66	66	71	73	77	79	86				
					87	89	90	101	102	103	104	109	110	111				
					113	121	122	123	123	125	126	128	129	130				
					136	139	141	142	144	146	159	172	177	182				
					190	190	193	193	195	195	196	197	197	198				
					199	199	200	201	202									
0000000		FORMAT	LABEL	/ 10	37	38*	134											
0000027	MAIN.	STATEMENT	LABEL	100	35*	47												
0001142	MAIN.	STATEMENT	LABEL	1000	42	203*												
0001164	MAIN.	REAL	LITERAL	1000.	153													
0001156	MAIN.	REAL	LITERAL	100.	64	106	115											
0001163	MAIN.	REAL	LITERAL	10.	148	151												
0000066	MAIN.	STATEMENT	LABEL	115	39	39	41*											
0000103	MAIN.	STATEMENT	LABEL	116	41	47*												
0000077	MAIN.	STATEMENT	LABEL	/ 117	45	46*												
0001170	MAIN.	INTEGER	LITERAL	12	192													
0000106	MAIN.	STATEMENT	LABEL	/ 120	48*													
0000151	MAIN.	STATEMENT	LABEL	/ 130	52	59*												
0000132	MAIN.	STATEMENT	LABEL	/ 131	55	57*												
0000341	MAIN.	STATEMENT	LABEL	/ 132	103	104*												
0000365	MAIN.	STATEMENT	LABEL	/ 133	101	107*												
0000173	MAIN.	STATEMENT	LABEL	/ 134	66	68*												
0000177	MAIN.	STATEMENT	LABEL	/ 135	63	69*												
0000407	MAIN.	STATEMENT	LABEL	/ 136	112	113*												
0000434	MAIN.	STATEMENT	LABEL	/ 137	109	116*												
0001171	MAIN.	INTEGER	LITERAL	14	195													
0000510	MAIN.	STATEMENT	LABEL	/ 140	125	135*												
0000226	MAIN.	STATEMENT	LABEL	/ 141	71	76*												
0000232	MAIN.	STATEMENT	LABEL	142	72	77*												
0000307	MAIN.	STATEMENT	LABEL	143	87	88	93*											
0000217	MAIN.	STATEMENT	LABEL	/ 144	73	74*												
0000275	MAIN.	STATEMENT	LABEL	/ 145	90	91*												
0000474	MAIN.	STATEMENT	LABEL	/ 150	129	131*												
0000554	MAIN.	STATEMENT	LABEL	/ 154	145	147*												
0000570	MAIN.	STATEMENT	LABEL	160	150	151*												
0000575	MAIN.	STATEMENT	LABEL	170	150	150	153*											
0000601	MAIN.	STATEMENT	LABEL	180	153	154*												
0000606	MAIN.	STATEMENT	LABEL	190	153	153	156*											
0001153	MAIN.	REAL	LITERAL	1.0	40	53												
0001152	MAIN.	INTEGER	LITERAL	2	37	54	57	103	104	112	113	129	145	195				
0000021	MAIN.	STATEMENT	LABEL	/ 20	30	33*												
0000611	MAIN.	STATEMENT	LABEL	/ 200	25	25	125	157*										
0001166	MAIN.	REAL	LITERAL	200.	157													
0000614	MAIN.	STATEMENT	LABEL	205	141	152	155	158*										

0000622	MAIN.	STATEMENT	LABEL	210	148	156	156	160*									
0000000		FORMAT	LABEL	/ 220	164	165*											
0000000		FORMAT	LABEL	/ 230	166	167*											
0000000		FORMAT	LABEL	/ 240	168	170*											
0000000		FORMAT	LABEL	/ 250	172	177	178*										
0000000		FORMAT	LABEL	/ 251	173	174*											
0000000		FORMAT	LABEL	/ 255	179	181*											
0000000		FORMAT	LABEL	/ 256	182	183*											
0000000		FORMAT	LABEL	/ 260	184	186*											
0000000		FORMAT	LABEL	/ 265	187	188*											
0000000		FORMAT	LABEL	/ 270	190	191*											
0001155	MAIN.	INTEGER	LITERAL	3	55	164	166	168	172	173	177	179	182	184			
					187	190											
0000015	MAIN.	STATEMENT	LABEL	/ 30	31	32*											
0000000		INTEGER	LITERAL	/ 300	25	25	141										
0000000		INTEGER	LITERAL	/ 5	25	25	28	45	122								
0001145	MAIN.	INTEGER	LITERAL	50	25	25	25	75	25	25	24	25	25	25			
					25	25	25	25	31	83	97						
0001172	MAIN.	REAL	LITERAL	5000.	195												
0001162	MAIN.	REAL	LITERAL	500.	140	150											
0001165	MAIN.	REAL	LITERAL	50.	154	195											
0001160	MAIN.	REAL	LITERAL	5.	134												
0001167	MAIN.	INTEGER	LITERAL	6	192												
0000000		INTEGER	LITERAL	/ 9	25	25	25	25	25	25	25	25	30				
0000516	MAIN.	STATEMENT	LABEL	A140	133	137*											
0000253	MAIN.	STATEMENT	LABEL	A142	78	85*											
0000000		SUBPROGRAM	NAME	/ AMINMX	193												
0003200	9999999	REAL	ARRAY	B	25	83	97										
0000525	MAIN.	STATEMENT	LABEL	B140	124	140*											
0000000		SUBPROGRAM	NAME	/ CRTID	27												
0006322	9999999	REAL	ARRAY	EF	25	75*	83	92*	97								
0000062	9999999	REAL	ARRAY	EFF	25	37*	58	106	106	115	115	172	177	201			
0001522	9999999	REAL	ARRAY	EFF1	25	132*	190	197									
0002506	9999999	REAL	ARRAY	EFF2	25	149*	190	193	199								
0001205	MAIN.	HOLLERITH	LITERAL	EFFICIENCY	195												
0001326	MAIN.	REAL	VARIABLE	EFFFL	128*	130*	130	132	144*	146*	146	148	149				
0001130	9999999	REAL	ARRAY	EFFLOW	25	58*	65										
0004206	9999999	REAL	ARRAY	EFFSTD	25	102*	104*	104	105*	105	106	111*	113*	113			

0001307 MAIN.	INTEGER	VARIABLE	I	31*	32	45*	46	46	55*	56	57	66*	67
				67	73*	74	74	90*	91	91	103*	104	104
				112*	113	113	129*	130	130	145*	146	146	172
				172	172	172	172	172	172*	177	177	177	177
				177	177	177*	182	182	182*	190	190	190*	190
				190	190*								
0003162 9999999	INTEGER	ARRAY	ID	25	46*	164	192						
0001311 MAIN.	INTEGER	VARIABLE	IE	37*	43								
0001313 MAIN.	INTEGER	VARIABLE	IEND	43*	72	133							
0001315 MAIN.	INTEGER	VARIABLE	II	56*	57								
0001312 MAIN.	INTEGER	VARIABLE	IS	37	44								
0001314 MAIN.	INTEGER	VARIABLE	ISTART	44*	88	124							
0001306 MAIN.	INTEGER	VARIABLE	J	30*	32	52*	53	54	54	57	57	57	58
				58	63*	64	65	65	67	67	71*	72	74
				74	75	75	77	87*	88	91	92	101*	102
				104	104	104	105	105	106	106	106	106	109*
				113	115	115	125*	126	127	132	133	134	136*
				136	137	138	141*	142	143	149	150	151	153
				154	156	157	159*	159	160				
0001321 MAIN.	INTEGER	VARIABLE	K	108*	110*	110	111	113	113	114	114	115	115
0001324 MAIN.	INTEGER	VARIABLE	L	126*	134	142*	151	154	157				
0000000	SUBPROGRAM	NAME	/ LOGF	54	58	127	143						
0001323 MAIN.	INTEGER	VARIABLE	MI	121*	122	138*	139						
0000000	SUBPROGRAM	NAME	/ MLR	83	97								
0001310 MAIN.	INTEGER	VARIABLE	N	34*	35*	35	37	37	37	37	39	40	41
				42	47	48*	48	52	63	71	87	109	109
				140	175	177	177	200					
0001317 MAIN.	INTEGER	VARIABLE	N1	77*	78	83	101	108	172	175			
0001320 MAIN.	INTEGER	VARIABLE	N2	85*	89*	89	91	92	97	109	175	177	
0006415 9999999	INTEGER	ARRAY	NO	25	37*	46							
0001331 MAIN.	INTEGER	VARIABLE	NO	175*	177	177							
0001304 MAIN.	INTEGER	VARIABLE	NORDER	28*	29	166							
0001322 MAIN.	INTEGER	VARIABLE	NPTS1	120*	137*	190	196						
0001330 MAIN.	INTEGER	VARIABLE	NPTS2	160*	190	193	198						
0001305 MAIN.	INTEGER	VARIABLE	NUM	29*	55	66	73	78	79	83	86*	86	90
				97	103	112	129	145	173	182			
0004270 9999999	REAL	ARRAY	PCTDEV	25	106*	115*	172	177					
0005336 9999999	REAL	ARRAY	PCTERR	25	37*	39	40*	64	172	177			
0004102 9999999	REAL	ARRAY	R	25	83	97							
0001174 MAIN.	HOLLERITH	LITERAL	RG	27									
0000144 9999999	REAL	ARRAY	SOURCE	25	37*	172	177						
0004175 9999999	REAL	ARRAY	V	25	83	97							
0004164 9999999	REAL	ARRAY	W	25	83	97							
0001316 MAIN.	REAL	VARIABLE	WEIGHT	64*	65	67							
0004352 9999999	REAL	ARRAY	WTDEFF	25	65*	75	92						
0004434 9999999	REAL	ARRAY	WTDERG	25	67*	74	91						
0003167 9999999	REAL	ARRAY	X	25	79*	83	102	104	120	130	182		
0001333 MAIN.	REAL	VARIABLE	XMAX	193									
0001332 MAIN.	REAL	VARIABLE	XMIN	193	195								

0000000	SUBPROGRAM NAME	/ XPLOT	196	198	200				
0000000	SUBPROGRAM NAME	/ XSERTH	192						
0006404 9999999\$	REAL	ARKAY	25	97	111	113	144	146	182
0000000	SUBPROGRAM NAME	/ YPLOT	197	199	201				
0001154 MAIN.	REAL	LITERAL	54	127	143				
0001161 MAIN.	REAL	LITERAL	.1						
0001173 MAIN.	REAL	LITERAL	.5						

The LIBETP Program

In order to identify and evaluate quantitatively the nuclides represented by a spectrum, one must have access to a library compatible with the method used in reducing the spectral data. This program generates a decay-scheme library that is suitable for GAMANAL and then records it on magnetic tape.

Two blocks of data are read in from cards. The first is on a set of cards identified by a 1 in column 1. There is a card for each of the nuclides which contains its nuclide number (combined atomic number and mass number), its half-life, and the nuclide numbers of any parent or daughter nuclides that should be considered with it.

The second set consists of one card for each gamma ray and has a 2 in column 1. These cards carry the nuclide number of the source, the energy and branching intensity of the gamma ray, an error estimate for this branching intensity if greater than 1%, and a list of up to four other gamma rays that should be found in association with this one. If these "associative" gamma rays are in the decay scheme of the parent or the daughter nuclide, they are so tagged.

LIBETP rearranges and cross-references this input information in such a way that GAMANAL will have no need to search for correlated information. In this process the gamma-ray list is first ordered according to increasing energy. An associated array is created for the branching intensity of each gamma ray and another for a packed set of indices to the locations of the corresponding associative gamma rays and of the source nuclide. The list of nuclides is also structured for easy reference to the corresponding half-lives and any parent-daughter relationship.

To reckon with two irregularities that are commonly encountered, the following conventions are used: 1) the mass number of meta-stable nuclides is increased by 300 and 2) the branching intensities associated with double and single-escape, pair-peaks are tagged respectively as 10^{-10} and 10^{-20} times the full-energy, peak-branching intensities.

After the data have been properly organized and packed for economy of space, the arrays are written onto magnetic tape in a suitable format for use by GAMANAL.

FORTRAN

LIBETP

1972 AD

G05/03

00.316 MONITOR402

C.271

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4
5
6 C   THIS PROGRAM PREPARES THE DECAY SCHEME LIBRARY FOR GAMANAL
7
8 C   FIRST CARD* COL 1 = 1
9 C   COL 11-20 = FILE NAME FOR OUTPUT
10 C   COL 61-66 = VAULT NO. FOR OUTPUT TAPE
11 C   COL 71-72 = UNIT NO. FOR OUTPUT TAPE
12 C   ISOTOPE CARDS* COL 1 = 1
13 C   COL 2- 6 (15) NUCLIDE NUMBER (ATOMIC AND MASS NO.)
14 C   ADD 300 TO MASS OF META-STABLE NUCLIDES
15 C   COL 8-16 (F9.3) HALF-LIFE IN DAYS
16 C   COL 20-24 (15) NUCLIDE NUMBER OF THE PARENT
17 C   COL 26-30 (15) NUCLIDE NUMBER OF THE DAUGHTER
18
19 C   BLANK CARD
20
21 C   GAMMA RAY CARDS* COL 1 = 2
22 C   COL 2 - 6 (15) ATOMIC AND MASS NUMBER
23 C   COL 7 -15 (F9.3) GAMMA RAY ENERGY IN KEV
24 C   COL 16-24 (E9.3) BRANCHING INTENSITY
25 C   COL 25-27 (13) ERROR ASSIGNED TO BRANCHING INTENSITY
26 C   COL 30 (11) FLAGS 1ST ASSOCIATIVE GAMMA AS BEING
27 C   FROM THE SAME, THE PARENT, OR DAUGHTER
28 C   NUCLIDE IF = TO 0, 1, OR 2, RESPECTIVELY
29 C   COL 31-39 (F9.3) ENERGY OF 1ST ASSOCIATIVE GAMMA RAY
30 C   COL 40-49 (11,F9.3) DITTO FOR 2ND ASSOCIATIVE GAMMA
31 C   COL 50-59 (11,F9.3) DITTO FOR 3RD ASSOCIATIVE GAMMA
32 C   COL 60-69 (11,F9.3) DITTO FOR 4TH ASSOCIATIVE GAMMA
33 C   ONLY THE FIRST TWO ASSOCIATIVE GAMMA RAYS LYING IN THE
34 C   ENERGY RANGE OF THE SPECTRUM WILL BE USED
35 C   TERMINATE INPUT WITH A BLANK CARD
36
37   CODE ANALYSIS
38   PARAMETER (MXGM = 1800, MXN = 300)
39   COMMON/BLNK/BUFF(100),NUMBER(MXN),PASS(MXN),LK(MXGM),JERR(MXGM),
40   INUCLK(MXGM),ENERGY(MXGM),BRANCH(MXGM),KIN(4,MXGM),ASSOC(4,MXGM),
41   2 KK(MXGM),INDEXN(MXGM),INDEXP(MXN),INDEXD(MXN),NUCLN(MXN),
42   3 NPARNT(MXN),NDGHTN(MXN),INDEX(4),AE(4),INKDER,LBTL(5)
43   BYTE SYMBOL(12)
44   COMMON/CLIBT/NUMBRN,NUMBRK,SYMBOL(100),ETC(80),NUKL(MXN),
45   1 THALF(MXN),EEE(MXGM),BR(MXGM),NDCES(MXGM),LZLBL(MXN)
46   DIMENSION ISYMBL(100)
47   EQUIVALENCE (SYMBOL,ISYMBL)
48   DIMENSION TWOS(5000)
49   EQUIVALENCE (NUMBRN,TWOS(1))

```

```

50
51 C FOLLOWING ARE THE ELEMENT SYMBOLS
52 DATA (ISYML=200H HHEL1BL 8 C N C FENAMGALS I P SCLAR KCASCTI VCR
53 1MMFECONICUZNAGEASSEBRKRRBSR YZRNBMCTCRURHPCAGCDINSNSBT IXCESBALA
54 2CEPRNDPMSEUGDTBDYHDERTYBLUHFTA WRECSIRPTAUNGTL PBBIPCATRNFHRAACTH
55 3PA UNPPUAMCMBCFCESFM)
56
57 CALL OONLGE(BUFF,1000,2,INKDER)
58 IF (INKDER-1) , ,95E
59
60 C READ CARD WITH A FILE NAME AND TAPE NUMBER AND UNIT FOR OUTPUT

```

```

61 RIT 2,LBF,LCARD,LBTL(1),NVAULT,ITMP,LT
62 LBF FORMAT (R1,9X,A10,40X,R6,4X,2R1)
63 IF (LCARD - 1RT) ,12,
64 IF (LCARD - 1R1)998, ,998
65 LBTL(1) = NVAULT = 0
66 CALL BSPACE(2)
67 12 ITMP = (ITMP-16) * 1C
68 IF (ITMP) , ,13
69 ITMP = C
70 13 LT = LT-16+ITMP
71 IF (LT) , ,14
72 LT = 16

```

```

73 C
74 C READ HALF-LIFE AND PARENT-DAUGHTER INFORMATION FOR THE VARIOUS NUCLIDES
75 C (INDEX THESE ARRAYS BY N)
76

```

```

77 14 N = 0
78 20 N = N + 1
79 READ INPUT TAPE 2,30,1D , NUCLN(N),T1HALF(N),NPARNT(N),NCGHTR(N)
80 30 FORMAT (I1,I5,1X,E9.3,3X,I5,1X,I5)
81 DECODE 35,(NUCLN(N)),36,(NUMBER(N),MASS(N))
82 35 FORMAT (I5)
83 36 FORMAT (I2,I3)
84 IF (1D - 1) 40,20,40
85 40 NUMBRN = N - 1
86

```

```

87 C READ ENERGY AND BRANCHING DATA FOR A GAMMA RAY AND ENERGIES OF UP TO FOUR
88 C ASSOCIATIVE GAMMA RAYS (INDEX ARRAYS BY K)
89

```

```

90 K = 0
91 50 K = K + 1
92 READ INPUT TAPE 2,60, 1D ,NUCLK(K),ENERGY(K),BRANCH(K), JERR(K),
93 1 (KIN(J,K),ASSOC(J,K),J=1,4)
94 60 FORMAT (I1,I5,2E9.3,I3,2X,4(I1,F9.3))
95 IF (1D - 2) 70,50,70
96 70 NUMBRK = K - 1

```



```

97 C
98 C ORDER THE GAMMA RAYS BY ENERGY (I ARRAYS)
99 C
100 EEE(I) = AKINAF (ENERGY,I,NUMBRK,I,M)
101 BR (I) = BRANCH(I)
102 KK (I) = M
103 LK(I) = I
104 LASTK = M
105 DO 100 I = 2,NUMBRK
106 SMALLE = 10000.0
107 DO 110 K = 1,NUMBRK
108 IF (ENERGY(K) - EEE(I-1)) 110,120,130
109 120 IF (K - LASTK) 130,110,110
110 130 IF (ENERGY(I) - SMALLE) 140,140,110
111 140 SMALLE = ENERGY(K)
112 M = K
113 110 CONTINUE
114 EEE(I) = ENERGY (M)
115 BR (I) = BRANCH (M)
116 KK (I) = M
117 LK(I) = I
118 LASTK = M
119 100 CONTINUE
120 C

121 C CROSS-REFERENCE DATA IN THE I ARRAYS WITH INFORMATION IN THE N ARRAYS
122 C STORE INDICES TO THE N ARRAYS
123 C
124 DO 200 I = 1,NUMBRK
125 K = KK(I)
126 NNN = NUCLK(K)
127 DO 201 J = 1,NUMBRN
128 IF (NNN-NUCLN(J))201, ,201
129 INDEXN(I) = J
130 GO TO 200
131 201 CONTINUE
132 210 WRITE OUTPUT TAPE 3,220,NUCLK(I)
133 220 FORMAT (/, 22H NO ISOTOPE NUMBER OF ,15,31H HAS BEEN STORED IN NO.
134 (I, 10X)
135 GO TO 998
136 200 CONTINUE
137 C
138 C LOCATE THE ASSOCIATIVE GAMMA RAYS IN I ARRAYS (ORDERED BY ENERGY)
139 C PACK INDICES INTO ONE WORD AND STORE
140 C
141 DO 300 I = 1,NUMBRK
142 K = KK(I)
143 DO 400 M=1,4
144 IF (ASSOC(M,K))500,500,
145 AAA = ASSOC(M,K)
146 DO 331 J = 1,NUMBRK
147 CELT = AB5F (AAA - EEE(J))

```

```

148      IF (DELT - .00001) , .331
149      INDEX(M) = J
150      GO TO 350
151 331 CONTINUE
152 340 DELTAE = 10000.
153      DO 360 J = 1, NUMBRK
154      DELT = ABSF (ASSOC(M,K) - EEE(J))
155      IF (DELTAE - DELT) 380, 370, 370
156 370 DELTAE = DELT
157 360 CONTINUE
158      J = J - 1
159      IF (DELTAE - .2) 390, 350, 400
160 390 WRITE OUTPUT TAPE 3, 410, ASSOC(P,K), NLCLK(K), EEE(J)
161 410 FORMAT (/20H NO GAMMA ENERGY OF ,F7.2,B3H EXISTS IN THE ENERGY TAB
162      1LE WHICH EXACTLY AGREES WITH THE ASSOCIATIVE GAMMA RAY OF ,15, /
163      266H THEREFORE A GAMMA RAY OF CLOSEST ENERGY WAS FOUND WHCSE ENERGY
164      3 IS ,F7.2 )
165      INDEX(M) = J
166 C
167 C CHECK TO SEE THAT THE ASSOCIATIVE GAMMA RAY ISOTOPE NUMBER AGREES
168 C WITH THAT SPECIFIED IN THE INPLT
169 C
170 350 DO 480 JL = J, NUMBRK
171      N = INDEX(M)
172      IF (KIN (M,K) - 1) 420, 440, 430
173 420 IF (NUCLK(K) - NUCLN(INDEXN(N))) 450, 460, 450
174 430 IF (NUCLK(K) - NPARNT(INDEXN(N))) 450, 460, 450
175 440 IF (NUCLK(K) - NDCNTR(INDEXN(N))) 450, 460, 450
176 450 INDEX(M) = INDEX(M) + 1
177 460 CONTINUE
178      WRITE OUTPUT TAPE 3, 470, NLCLK(K), ASSOC(P,K)
179 470 FORMAT (/52H THE NUCLIDE NUMBER OF THE ASSOCIATIVE GAMMA RAY OF ,
180      115, 56H DOES NOT AGREE WITH THAT WHICH WAS SPECIFIED. ENERGY = ,
181      2 F7.2 )
182      GO TO 500
183 480 WRITE OUTPUT TAPE 3, 482, ASSOC(P,K), NLCLK(K)
184 482 FORMAT (/20HNO GAMMA ENERGY OF ,F7.2, 79H KEV EXISTS IN THE ENERGY
185      1 TABLE WHICH AGREES WITH THE ASSOCIATIVE GAMMA RAY OF ,15, / 35H
186      2THEREFORE THE INDEX IS SET = TC C. )
187 500 INDEX(M) = 0
188 460 CONTINUE
189      NDCES(1) = INDEXN(1)
190      CALL SBYT (NDCES(1), 12, 12, INDEX(4))
191      CALL SBYT (NDCES(1), 24, 12, INDEX(3))
192      CALL SBYT (NDCES(1), 36, 12, INDEX(2))
193      CALL SBYT (NDCES(1), 48, 12, INDEX(1))
194 300 CONTINUE
195 C
196 C LOCATE SPECIFIED PARENTS OR DAUGHTERS IN ISOTOPE ARRAY AND STORE INDICES (N)
197 C
198      DO 600 N = 1, NUMBRN
199      IF (NPARNT(N)) 610, 620, 610

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```

200      610 NNN = NPARNT(N)
201          DO 611 J = 1,NUMBRN
202              IF (NNN-NUCLN(J))611, .611
203              INDEXP(N) = J      $ GO TO 620
204      611 CONTINUE
205          GO TO 998
206      620 IF (NDGHTN(N)) 630,600,630
207      630 NNN = NDGHTN(N)
208          DO 621 J = 1,NUMBRN
209              IF (NNN-NUCLN(J))621, .621
210              INDEXP(N) = J
211          GO TO 600
212      621 CONTINUE
213          GO TO 998
214      600 CONTINUE
215
216      C   PACK NUCLIDE NUMBER, SYMBOL, MASS, AND P - O INDICES IN ONE WORD
217
218          DO MRG, M=1,NUMBRN
219              NUKL(M) = INDEXP(M)
220              CALL SBYT (NUKL(M),9,9,INDEXP(M))
221              CALL SBYT (NUKL(M),18,10,MASS(M))
222              CALL SBYT (NUKL(M),40,20,NUCLN(M))
223              ISY = SYMBOL(NUMBER(M))
224              CALL SBYT (NUKL(M), 28,12,ISY)
225              REWIND 63
226              WRITE (63,1085)ISY,MASS(M)
227              READ (63,1086)IZLBL(M)
228      1085  FORMAT (1X,R2,I3)
229      1086  FORMAT (A6)
230      MRG CONTINUE
231
232      C   WRITE INFORMATION ON TAPE, IDENTIFYING FILE BY HEADER RECORD
233      C
234          CALL CLOCK (ITT,ITTT)
235          IF (LBLT(1))640, .64C
236          LBLT(1) = 6RGELIB#
237      640  LBLT(2) = 102+3*MXGM+3*MXN
238          ITMP = 40000628
239          CALL SBYT(ITMP,24,36,NVALT)
240          LBLT(4) = ITMP
241          CALL SBYT (ITT,0,36,ITTT)
242          LBLT(5) = ITT
243      641  DO 642 L=1,3
244              BUFFER OUT (LT,1)(LBLT(1),LBLT(5))
245              WOT 3,1640,(LBLT(1),L=1,3)
246      1640  FORMAT (5X,21HTAPE HEADER RECCRD 15 /5(2X,G20))
247          U40 IF (UNIT,LT)U40,645, ,
248              CALL BSPACE (LT)
249          U41 IF (UNIT,LT)U41, , ,
250      642 CONTINUE
251          CALL WRBLNK (LT)
252          NO = NO+1
253      U42 IF (UNIT,LT)U42, .998,
254          IF (NO-10)641,641,998

```

```

255
256 645 NXT = 1
257     LST = 512
258     NBF5 = C.9999 + LBLT(2)/512.
259     DO 660 JB = 1,NBF5
260     DO 655 JR = 1,10
261     BUFFER OUT (LT,1)(TWOS(NXT),TWOS(LST))
262     UL2 IF (UNIT,LT,JWDS)UL2,657, 647
263         IF (EOF,LT) 998
264     647 CALL BSPACE(LT)
265     UL3 IF (UNIT,LT)UL3, ,
266         CALL BSPACE (LT)
267     UL4 IF (UNIT,LT)UL4, ,
268         BUFFER IN (LT,1)(KK(1),KK(512))
269     UL5 IF (UNIT,LT)UL5, ,
270         CALL WRBLNK (LT)
271     UL6 IF (UNIT,LT)UL6, ,
272     655 CONTINUE
273     GO TO 998
274
275     657 NXT = LST+1
276     LST = LST + 512
277     IF (LST-LBLT(2))660,66C,
278     LST =LBLT(2)
279     660 CONTINUE
280     CALL WRTEOF (LT)
281
282 C
283 C
284     WOT 3,730,ITT,ITTT
285     700 FORMAT (1H1,19X,58H THE FOLLOWING INFORMATION WAS WRITTEN ON MAGNE
286         TIC TAPE ON ,A8,1X,A8//)
287     WRITE OUTPUT TAPE 3,710,(SYMBOL(I), I = 1,100)
288     710 FORMAT (15X, 10R8//)
289     WRITE OUTPUT TAPE 3,720
290     720 FORMAT (/ 15X,68HINDEX ISOTOPE HALF-LIFE PARENT NO INDEXP
291         10AUGHTER NO INDEXD //)
292     WRITE (3,730)
293     DO ISYM, N=1,NUMBRN
294     NSYM = NUMBER(N)
295     XMIT N,NSYM,SYMBOL(NSYM),MASS(N), T1HALF(N),NPARNT(N),INCEXP(N),
296     1 NOGHTR(N),INDEXD(N)
297     TSYM CONTINUE
298     FIN
299     730 FORMAT (15X,14,3X,12, R3,1X,13,5X,E9.3,2X,15,6X,14,4X,15,8X,14/)
        K = 1
        JO

```

```

301      LAST = 0
302      MAX = 0
303      712 IF (LAST - NUCL(K))713, ,713
304      JND = JND - 1
305      713 LAST = 0
306      WRITE OUTPUT TAPE 3,714
307      714 FORMAT (1H1,27X,52HNUCLIDE HALF-LIFE ENERGY BRANCHING
308      1 ERROR / 41X,31H(DAYS) (KEV) INTENS(YY 1
309      716 MAX = MAX + 1
310      NUCNO = NUCL(K)
311      NREF = INDEXN(LK(K))
312      LS = NUMBER(NREF)
313      MS = MASS(NREF)
314      M = OM
315      IF (MS - 300) 718, ,
316      MS = MS - 300
317      M = 1MM
318      718 IF (LAST - NUCNO) ,721,
319      JND = JND + 1
320      IF (BRANCH(K) - 1.E-10) , ,719
321      WOT 3,1700,JND,LS,SYMBOL(LS),MS,M,T1HALF(NREF),ENERGY(K)
322      1700 FORMAT (/20X,14,15,R3,14,A1,E12.3,F10.2,13H PAIR PEAK)
323      MAX = MAX + 1
324      GO TO 728
325      719 IF (JERR(K)) , ,77C(
326      IF (MS) ,723,
327      WOT 3,1719,JND,LS,SYMBOL(LS),MS,M,T1HALF(NREF),ENERGY(K),BRANCH(K)
328      1719 FORMAT (/20X,14,15,R3,14,A1,E12.3,F10.2,E13.3)
329      MAX = MAX + 1
330      GO TO 728
331      723 WOT 3,1723,JND,LS,SYMBOL(LS),ENERGY(K),BRANCH(K)
332      1723 FORMAT (/20X,14,15,R3,7H X-RAYS,10X,F10.2,E13.3)
333      MAX = MAX + 1 $ GO TO 728
334      770 WRITE OUTPUT TAPE 3,722,JND,LS,SYMBOL(LS),MS,M,T1HALF(NREF),ENERGY
335      1(K),BRANCH(K),JERR(K)
336      722 FORMAT(/20X,14,15, R3,14,A1,E12.3,F10.2,E13.3,16 )
337      MAX = MAX + 1
338      GO TO 728
339      721 IF (BRANCH(K) - 1.E-10) , ,725
340      WRITE OUTPUT TAPE 3,726,ENERGY(K)
341      726 FORMAT ( 49X,F10.2,13H PAIR PEAK )
342      GO TO 728
343      725 IF (JERR(K)) , ,772
344      WRITE OUTPUT TAPE 3,773,ENERGY(K),BRANCH(K)
345      773 FORMAT( 49X,F10.2,E13.3 )
346      GO TO 728
347      772 WRITE OUTPUT TAPE 3,724,ENERGY(K),BRANCH(K),JERR(K)
348      724 FORMAT( 49X,F10.2,E13.3,16 )
349      728 LAST = NUCNO
350      K = K + 1
351      IF (K - NUMBER) , ,729
352      IF (MAX - 51) 716, ,

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```

353      MAX = 0
354      GO TO 712
355      720 K = 1
356      735 NO = K
357      WRITE OUTPUT TAPE 3,740
358      740 FORMAT (1H1,27X,57HNUCLIDE      ENERGY      BRANCHING      ASSOCIATIVE
359      1 GAMMA RAYS / 40X,19H(KEV)      INTENSITY )
360      MAX = NO +26
361      IF (MAX - NUMBRK) 742,742,
362      MAX = NUMBRK
363      742 DO 744 K = NC,MAX
364      INUM = INDEX(NK)
365      ISYM = NUMBER(INUM)
366      M = 0H
367      MS = MASS(INUM)
368      IF (MS - 300) 746, ,
369      MS = MS - 300
370      M = 1+M
371      746 NK = 0
372      DO 750 I=1,4
373      KR = 6C-I*12
374      KI = LBVT(NDCE(K),KR,12)
375      IF (KI) ,748,
376      AE(I) = EEE(KI)
377      GO TO 750
378      748 AE(I) = 0.
379      750 CONTINUE
380      NK = I-1
381      IF (MS) ,760,
382      IF (BR(K)-1.E-10) , ,800
383      WOT 3,1747,K,NUMBER(INUM),SYMBOL(ISYM),MS,M,EEE(K),(AE (N),N=1,NK)
384      GO TO 744
385      800 WOT 3,1800,K,NUMBER(INUM),SYMBOL(ISYM),MS,M,EEE(K),BR(K),
386      1 (AE(N),N=1,NK)
387      GO TO 744
388      760 WOT 3,1760,K,NUMBER(INUM),SYMBOL(ISYM),EEE(K),BR(K),(AE(N),N=1,NK)
389      1760 FORMAT (/20X,14,15,R3,6H X-RAY,F8.2,E13.3,2X,4F11.2)
390      1747 FORMAT(/20X,14,15, R3,14,A1,F 9.2,13H PAIR PEAK,2X, 4F11.2 )
391      1800 FORMAT(/20X,14,15, R3,14,A1,F 9.2,E13.3,2X,4F11.2 )
392      744 CONTINUE
393      IF (K-NUMBRK)735,735,EX
394      998 CALL PDUMP
395      EX IF (UNIT,LT)EX, ,
396      CALL WRTEOF (LT)
397      ULF IF (UNIT,LT)ULF, ,
398      CALL DOUNLGF(2)
399      CALL UNLOAD (LT)
400      CALL EXIT
401      END

```

*** CODE ANALYSIS ***

/ NAME IN MD EXECUTABLE INSTRUCTION
C DENOTES ORIGINAL COUNT IN CLICHE
* DENOTES NAME DEFINED OR LABEL USE

BANK	ADDRESS	BASE	TYPE	CLASS	NAME	SOURCE	LINE	REFERENCES										
	0002072	MAIN.	MULLERITH	LITERAL		314	366											
	0000000		MULLERITH	LITERAL	/ MHELIBE B	55												
	0000000		INTEGER	LITERAL	/ D	65	69	77	90	187	241	301	302	305	353			
						371												
	0002046	MAIN.	REAL	LITERAL	0.	378												
	0002044	MAIN.	REAL	LITERAL	0.9999	258												
	0002033	MAIN.	INTEGER	LITERAL	1	49	58	61	65	78	84	85	91	93	96			
						100	100	100	101	102	103	107	108	124	127			
						141	143	146	153	158	172	176	193	198	201			
						208	218	235	236	243	244	244	245	252	256			
						259	260	261	268	268	275	287	293	300	304			
						309	319	323	329	333	337	350	355	372	380			
						383	386	388										
	0002070	MAIN.	RT ADJUSTD	LITERAL	1	64												
	0000000		INTEGER	LITERAL	/ 10	67	221	254	260									
	0000252	MAIN.	STATEMENT	LABEL	/ 100	45	46	105	119*	287								
	0002031	MAIN.	INTEGER	LITERAL	1000	42	57											
	0002040	MAIN.	REAL	LITERAL	10000.	152												
	0002035	MAIN.	REAL	LITERAL	10000.0	106												
	0000000		INTEGER	LITERAL	/ 102	237												
	0000000		FORMAT	LABEL	/ 1085	226	228*											
	0000000		FORMAT	LABEL	/ 1086	227	229*											
	0000237	MAIN.	STATEMENT	LABEL	110	107	108	109	109	110	113*							
	0000033	MAIN.	STATEMENT	LABEL	12	43	63	67*	190	190	191	192	193	224	373			
						374												
	0000224	MAIN.	STATEMENT	LABEL	120	108	109*											
	0000040	MAIN.	STATEMENT	LABEL	13	68	70*											
	0000227	MAIN.	STATEMENT	LABEL	130	108	109	110*										
	0000045	MAIN.	STATEMENT	LABEL	14	71	77*											
	0000233	MAIN.	STATEMENT	LABEL	140	110	110	111*										
	0000000		INTEGER	LITERAL	/ 16	67	70	72										
	0000000		FORMAT	LABEL	/ 1640	245	246*											
	0000000		FORMAT	LABEL	/ 1700	321	322*											
	0000000		FORMAT	LABEL	/ 1719	327	328*											
	0000000		FORMAT	LABEL	/ 1723	331	332*											
	0000000		FORMAT	LABEL	/ 1747	383	390*											
	0000000		FORMAT	LABEL	/ 1760	388	389*											
	0000000		INTEGER	LITERAL	/ 18	221												
	0000000		FORMAT	LABEL	/ 1800	38	386	391*										
	0002045	MAIN.	REAL	LITERAL	1.1E-10	320	339	382										
	0002034	MAIN.	INTEGER	LITERAL	2	57	61	66	79	93	95	105	192	237	258			
						277	278	398										
	0000046	MAIN.	STATEMENT	LABEL	20	78*	84	222										
	0000316	MAIN.	STATEMENT	LABEL	200	124	130	136*										
	0000277	MAIN.	STATEMENT	LABEL	201	127	128	128	131*									
	0000303	MAIN.	STATEMENT	LABEL	/ 210	132*												
	0000000		FORMAT	LABEL	/ 220	132	134*											
	0000000		INTEGER	LITERAL	/ 24	191	239											
	0000000		INTEGER	LITERAL	/ 26	360												

0000000		INTEGER	LITERAL	/ 28	224									
0002036	MAIN.	INTEGER	LITERAL	3	132	160	178	183	191	237	237	243	245	284
					287	289	292	306	321	327	331	335	340	344
					347	357	383	386	388					
0000000		FORMAT	LABEL	/ 30	79	80*								
0000561	MAIN.	STATEMENT	LABEL	/ 300	38	141	194*	315	316	368	369			
0000352	MAIN.	STATEMENT	LABEL	331	146	148	151*							
0000356	MAIN.	STATEMENT	LABEL	/ 340	152*									
0000000		FORMAT	LABEL	/ 35	81	82*								
0000432	MAIN.	STATEMENT	LABEL	350	150	170*								
0000000		FORMAT	LABEL	/ 36	81	83*	192	239	241					
0000374	MAIN.	STATEMENT	LABEL	/ 360	153	157*								
0000373	MAIN.	STATEMENT	LABEL	370	155	155	156*							
0000401	MAIN.	STATEMENT	LABEL	380	155	158*								
0000406	MAIN.	STATEMENT	LABEL	390	159	159	160*							
0000000		INTEGER	LITERAL	/ 4	42	42	42		93	143	190	240	372	
0000122	MAIN.	STATEMENT	LABEL	40	84	84	85*	222						
0000513	MAIN.	STATEMENT	LABEL	400	159	183*								
0002043	MAIN.	BOOLEAN	LITERAL	4000062	238									
0000000		FORMAT	LABEL	/ 410	160	164*								
0000447	MAIN.	STATEMENT	LABEL	420	172	173*								
0000454	MAIN.	STATEMENT	LABEL	430	172	174*								
0000461	MAIN.	STATEMENT	LABEL	440	172	175*								
0000466	MAIN.	STATEMENT	LABEL	450	173	173	174	174	175	175	176*			
0000534	MAIN.	STATEMENT	LABEL	460	143	173	174	175	188*					
0000000		FORMAT	LABEL	/ 470	178	181*								
0000000		INTEGER	LITERAL	/ 48	193									
0000467	MAIN.	STATEMENT	LABEL	/ 480	170	177*								
0000000		FORMAT	LABEL	/ 482	183	186*								
0000000		INTEGER	LITERAL	/ 5	42	242	244	245						
0000125	MAIN.	STATEMENT	LABEL	50	91*	95								
0000532	MAIN.	STATEMENT	LABEL	500	144	144	182	187*						
0000000		INTEGER	LITERAL	/ 5000	48									
0000000		INTEGER	LITERAL	/ 51	352									
0000000		INTEGER	LITERAL	/ 512	257	268	276							
0000000		REAL	LITERAL	/ 512.	258									
0000000		FORMAT	LABEL	/ 60	93	94*	373							
0000637	MAIN.	STATEMENT	LABEL	600	198	206	211	214*						
0000573	MAIN.	STATEMENT	LABEL	610	199	199	200*							
0000607	MAIN.	STATEMENT	LABEL	611	201	202	202	204*						
0000614	MAIN.	STATEMENT	LABEL	620	199	203	206*							
0000632	MAIN.	STATEMENT	LABEL	621	208	209	209	212*						
0002042	MAIN.	INTEGER	LITERAL	63	225	226	227							
0000616	MAIN.	STATEMENT	LABEL	630	206	206	207*							
0000736	MAIN.	STATEMENT	LABEL	640	235	235	237*							
0000751	MAIN.	STATEMENT	LABEL	641	243*	254	254							
0001000	MAIN.	STATEMENT	LABEL	/ 642	243	250*								
0001021	MAIN.	STATEMENT	LABEL	645	247	256*								
0001054	MAIN.	STATEMENT	LABEL	647	262	264*								
0001104	MAIN.	STATEMENT	LABEL	/ 655	260	272*								
0001111	MAIN.	STATEMENT	LABEL	657	262	275*								

0001120	MAIN.	STATEMENT	LABEL	660	259	277	277	279*										
0000173	MAIN.	STATEMENT	LABEL	70	95	95	96*											
0000000		FORMAT	LABEL	/ 700	284	286*												
0000000		FORMAT	LABEL	/ 710	287	288*												
0001243	MAIN.	STATEMENT	LABEL	712	303*	354												
0001250	MAIN.	STATEMENT	LABEL	713	303	303	305*											
0000000		FORMAT	LABEL	/ 714	306	308*												
0001256	MAIN.	STATEMENT	LABEL	716	309*	352												
0001277	MAIN.	STATEMENT	LABEL	718	315	318*												
0001342	MAIN.	STATEMENT	LABEL	719	320	325*												
0000000		FORMAT	LABEL	/ 720	289	291*												
0001475	MAIN.	STATEMENT	LABEL	721	318	339*												
0000000		FORMAT	LABEL	/ 722	335	336*												
0001404	MAIN.	STATEMENT	LABEL	723	326	331*												
0000000		FORMAT	LABEL	/ 724	347	348*												
0001514	MAIN.	STATEMENT	LABEL	725	339	343*												
0000000		FORMAT	LABEL	/ 726	340	341*												
0001554	MAIN.	STATEMENT	LABEL	728	324	330	333	338	342	346	349*							
0001567	MAIN.	STATEMENT	LABEL	729	351	355*												
0000000		FORMAT	LABEL	/ 730	292	299*												
0001570	MAIN.	STATEMENT	LABEL	735	356*	393	393											
0000000		FORMAT	LABEL	/ 740	357	359*												
0001604	MAIN.	STATEMENT	LABEL	742	361	361	363*											
0001777	MAIN.	STATEMENT	LABEL	744	363	384	387	392*										
0001625	MAIN.	STATEMENT	LABEL	746	368	371*												
0001640	MAIN.	STATEMENT	LABEL	748	375	378*												
0001642	MAIN.	STATEMENT	LABEL	750	372	377	379*											
0001744	MAIN.	STATEMENT	LABEL	760	381	388*												
0001435	MAIN.	STATEMENT	LABEL	770	325	335*												
0001535	MAIN.	STATEMENT	LABEL	772	343	347*												
0000000		FORMAT	LABEL	/ 773	344	345*												
0000000		INTEGER	LITERAL	/ 80	45													
0001706	MAIN.	STATEMENT	LABEL	800	382	386*												
0000000		INTEGER	LITERAL	/ 9	220	220												
0002006	MAIN.	STATEMENT	LABEL	998	58	64	64	135	205	213	253	254	263	273				
0002354	MAIN.	REAL	VARIABLE	AAA	145*	147												
0000000		SUBPROGRAM	NAME	/ ABSF	147	154												
0072630	BLNK	REAL	ARRAY	AE	42	176*	378*	383	386	388								
0000000		SUBPROGRAM	NAME	/ AMINAF	100													
0042610	BLNK	REAL	ARRAY	ASSOC	42	93*	144	145	154	160	178	183						
0072642	BLNK	BLK COMMON	NAME	/ BLNK	42													
0004706	CLIBT	REAL	ARRAY	BR	45	101*	115*	382	386	388								
0021140	BLNK	REAL	ARRAY	BRANCH	42	93*	101	115	320	327	331	335	339	344				
0000000		SUBPROGRAM	NAME	/ BSPACE	66	248	264	266										
0000000	BLNK	REAL	ARRAY	BUFF	42	57												
0014402	CLIBT	BLK COMMON	NAME	/ CLIBT	45													
0000000		SUBPROGRAM	NAME	/ CLOCK	234													
0002355	MAIN.	REAL	VARIABLE	DELT	147*	148	154*	155	156									
0002356	MAIN.	REAL	VARIABLE	DELTAE	152*	155	156*	159										
0001276	CLIBT	REAL	ARRAY	EEE	45	100*	108	114*	147	154	160	376	383	386				
					388													

0015530	BLNK	REAL	ARRAY	ENERGY	42	93*	100	108	110	111	114	321	327	331
0000000		REAL	VARIABLE	/ EOF	335	340	344	347						
0000026	CL18T	REAL	ARRAY	/ ETC	263									
0002010	MAIN.	REAL	STATEMENT	LX	45									
0000000		REAL	EXTERNAL	/ EXIT	393	395*	395							
0002071	MAIN.	RT ADJUSTD	LITERAL	GELIBRE	400									
0002351	MAIN.	INTEGER	VARIABLE	I	236									
					105*	108	114	115	116	117	124*	125	129	141*
					142	189	189	190	191	192	193	245	245*	287
					287*	372*	373	376	379	380				
0002344	MAIN.	INTEGER	VARIABLE	ID	79*	84	93*	95						
0072624	BLNK	INTEGER	ARRAY	INDEX	42	149*	165*	171	176*	176	197*	190	191	192
					193									
0070344	BLNK	INTEGER	ARRAY	INDEXD	42	210*	219	296*						
0054260	BLNK	INTEGER	ARRAY	INDEXN	42	129*	173	174	175	189	311	364		
0067670	BLNK	INTEGER	ARRAY	INDEXP	42	203*	220	296*						
0072634	BLNK	INTEGER	VARIABLE	INKUER	42	57	58							
0002403	MAIN.	INTEGER	VARIABLE	INUM	364*	365	367	383	386	388				
0002360	MAIN.	INTEGER	VARIABLE	ISY	223*	224	226							
0002404	MAIN.	INTEGER	VARIABLE	ISYM	365*	383	386	388						
0000002	CL18T	INTEGER	EQUIVALENCE	ISYMBL	46	47	55							
0002341	MAIN.	INTEGER	VARIABLE	ITMP	61*	67*	67	68	69*	70	238*	239	240	
0002361	MAIN.	INTEGER	VARIABLE	ITT	234	241	242	284						
0002362	MAIN.	INTEGER	VARIABLE	ITTT	234	241	284							
0013726	CL18T	INTEGER	ARRAY	IZLBL	45	227								
0002346	MAIN.	INTEGER	VARIABLE	J	93	93	93*	127*	128	129	146*	147	149	153*
					154	158*	158	160	165	170	201*	202	203	208*
					209	210								
0002370	MAIN.	INTEGER	VARIABLE	JB	259*									
0006510	BLNK	INTEGER	ARRAY	JERR	42	93*	325	335	343	347				
0002357	MAIN.	INTEGER	VARIABLE	JL	170*									
0002376	MAIN.	INTEGER	VARIABLE	JNO	304*	304	319*	319	321	327	331	335		
0002371	MAIN.	INTEGER	VARIABLE	JR	260*									
0002372	MAIN.	INTEGER	VARIABLE	JWDS	262									
0002345	MAIN.	INTEGER	VARIABLE	K	90*	91*	91	93	93	93	93	93	93	96
					107*	108	109	110	111	112	125*	126	132	142*
					144	145	154	160	160	172	173	174	175	178
					178	183	183	300*	303	310	311	320	321	325
					327	327	331	335	335	335	335	339	340	343
					344	344	347	347	347	350*	350	351	355*	356
					363*	364	374	382	383	383	386	386	386	388
					388	388	393							
0002406	MAIN.	INTEGER	VARIABLE	KD	373*	374								
0002407	MAIN.	INTEGER	VARIABLE	KI	374*	375	376							
0024550	BLNK	INTEGER	ARRAY	KIN	42	93*	172							
0060650	BLNK	INTEGER	ARRAY	KK	42	102*	116*	125	142	268	268			
0002363	MAIN.	INTEGER	VARIABLE	L	243*									
0002374	MAIN.	INTEGER	VARIABLE	LAST	301*	303	305*	318	349*					
0002350	MAIN.	INTEGER	VARIABLE	LASTK	104*	109	118*							
0002664	MAIN.	STATEMENT	LABEL	LBF	61	62*								
0072635	BLNK	INTEGER	ARRAY	LBLT	42	61*	65*	235	236*	237*	240*	242*	244	244
					245	258	277	278						

0000000		SUBPROGRAM	NAME	/	LBVT	374												
0002337 MAIN.	INTEGER	VARIABLE	LCARD			61*	63	64										
0003100 BLNK	INTEGER	ARRAY	LK			42	103*	117*	311									
0002401 MAIN.	INTEGER	VARIABLE	LS			312*	321	321	327	327	331	331	335	335				
0002366 MAIN.	INTEGER	VARIABLE	LS1			257*	261	275	276*	276	277	278*						
0002342 MAIN.	INTEGER	VARIABLE	LT			61	70*	70	71	72*	244	247	248	249	251			
						253	261	262	263	264	265	266	267	268	269			
						270	271	280	395	396	397	399						
0002073 MAIN.	HOLLERITH	LITERAL	M			317	370											
0002347 MAIN.	INTEGER	VARIABLE	M			100	101	102	103	104	112*	114	115	116	117			
						118	143*	144	145	149	154	160	165	171	172			
						176	176	178	183	187	218*	219	219	220	220			
						221	221	222	222	223	224	226	227	314*	317*			
						321	327	325	366*	370*	383	386						
0002424 BLNK	INTEGER	ARRAY	MASS			42	81	221	226	296*	313	367						
0002375 MAIN.	INTEGER	VARIABLE	MAX			302*	309*	309	323*	323	329*	329	333*	333	337*			
						337	352	353*	360*	361	362*	363						
0000724 MAIN.	STATEMENT	LABEL	/ MRG			210	230*											
0002402 MAIN.	INTEGER	VARIABLE	MS			313*	315	316*	316	321	326	327	335	367*	368			
						369*	369	381	383	386								
0000000	FORMAT	LABEL	/ MKGM			38	42	42	42	42	42	42	42	42	42			
						45	45	45	237									
0000000	FORMAT	LABEL	/ MXM			38	42	42	42	42	42	42	42	45	45			
						45	237											
0002343 MAIN.	INTEGER	VARIABLE	N			77*	78*	78	79	79	79	79	81	81	81			
						85	171*	173	174	175	198*	199	200	203	206			
						207	210	293*	294	296*	296	296	296	296	296			
						296	383	383*	386	386*	388	388*						
0002367 MAIN.	INTEGER	VARIABLE	NBFS			258*	259											
0010316 CLIBT	INTEGER	ARRAY	NDCES			45	189*	190	191	192	193	374						
0072150 BLNK	INTEGER	ARRAY	NDGHTR			42	79*	175	206	207	296*							
0002405 MAIN.	INTEGER	VARIABLE	NK			371*	380*	383	386	388								
0002353 MAIN.	INTEGER	VARIABLE	NNN			126*	128	200*	202	207*	209							
0002364 MAIN.	INTEGER	VARIABLE	NO			252*	252	254	356*	360	363							
0071474 BLNK	INTEGER	ARRAY	NPARNT			42	79*	174	199	200	296*							
0002400 MAIN.	INTEGER	VARIABLE	NREF			311*	312	313	321	327	335							
0002373 MAIN.	INTEGER	VARIABLE	NSYM			294*	296*	296										
0012120 BLNK	INTEGER	ARRAY	NUCLK			42	93*	126	132	160	173	174	175	178	183			
						303	310											
0071020 BLNK	INTEGER	ARRAY	NUCLN			42	79*	81	128	173	202	209	222					
0002377 MAIN.	INTEGER	VARIABLE	NUCNO			310*	318	349										
0000146 CLIBT	INTEGER	ARRAY	NUKL			45	219*	220	221	222	224							
0001750 BLNK	INTEGER	ARRAY	NUMBER			42	81	223	294	312	365	383	386	388				
0000001 CLIBT	INTEGER	VARIABLE	NUMORK			45	96*	100	105	107	124	141	146	153	170			
						351	361	362	393									
0000000 CLIBT	INTEGER	VARIABLE	NUMBRN			45	49	85*	127	198	201	208	218	293				
0002340 MAIN.	INTEGER	VARIABLE	NUAULT			61*	65*	239										
0002365 MAIN.	INTEGER	VARIABLE	NXT			256*	261	275*										
0000000	SUBPROGRAM	NAME	/ DONLGE			57												
0000000	SUBPROGRAM	NAME	/ DONLGF			398												
0000000	REAL	EXTERNAL	/ PDUMP			394												
0000000	SUBPROGRAM	NAME	/ SBYT			190	191	192	193	220	221	222	224	239	241			

0002352 MAIN.	REAL	VARIABLE	SMALLE	106*	110	111*							
0000002 CLIBT	12 BIT OF	BYTE	SYMBOL	43	45	47	223	287	296*	321	327	331	335
				383	386	388							
0002067 MAIN.	RT ADJUSTC	LITERAL	T	63									
0000622 CLIBT	REAL	ARRAY	TIMALF	45	79*	296*	321	327	335				
0001232 MAIN.	STATEMENT	LABEL	/ TSYM	293	297*								
0000000 CLIBT	REAL	EQUIVALNCE	TWOS	48	49	261	261						
0000766 MAIN.	STATEMENT	LABEL	U40	247*	247								
0000775 MAIN.	STATEMENT	LABEL	U41	249*	249								
0001011 MAIN.	STATEMENT	LABEL	U42	253*	253								
0001041 MAIN.	STATEMENT	LABEL	UL2	262*	262								
0001056 MAIN.	STATEMENT	LABEL	UL3	265*	265								
0001064 MAIN.	STATEMENT	LABEL	UL4	267*	267								
0001073 MAIN.	STATEMENT	LABEL	UL5	269*	269								
0001101 MAIN.	STATEMENT	LABEL	UL6	271*	271								
0002016 MAIN.	STATEMENT	LABEL	ULF	397*	397								
0000000	REAL	VARIABLE	/ UNIT	247	249	253	262	265	267	269	271	395	397
0000000	SUBPROGRAM	NAME	/ UNLOAD	399									
0000000	SUBPROGRAM	NAME	/ WRBLNK	251	270								
0000000	SUBPROGRAM	NAME	/ WRTEOF	280	396								
0002037 MAIN.	REAL	LITERAL	.00001	148									
0002041 MAIN.	REAL	LITERAL	.2	159									

The LINEARITY Program

This program is used to determine the coefficients of the polynomial that best describes the non-linearity of a counting system. The input data can be either pulser-voltages or gamma-ray energies along with the corresponding peak positions in a pulse-height spectrum. The data are fitted by the method of least squares to an equation of the following form:

$$P_i = \sum_{j=1}^N a_j (CL_i)^{j-1}$$

where

CL_i = peak position associated with the pulser-voltage or gamma-ray energy P_i

a_j = one of a set of coefficients describing the nonlinearity of the system

The coefficients that are generated are placed on an appropriate Type 4 card (see Vol. III of this report^{*}).

Some systems may be quite nonlinear in the low-channel region. If the equation gives a poor fit in this region, there is a provision for adding a linear component to the low-channel data (algebraically) before fitting a polynomial. The input variables COFDEL and COFCHN describe the y-axis (zero energy) and x-axis intercepts of this line. If such an adjustment is made to the data, the values of COFDEL and COFCHN used must also be placed on the appropriate Type 4 card for that system.

^{*}Niday and Gunnink, p. 2.

FCHTRAN

LINEARITY

1972 AC

G05/03

00.343 MONITOR402

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4      CODE ANALYSIS
5
6      C      THIS PROGRAM DETERMINES A SET OF COEFFICIENTS TO A POLYNOMIAL
7      C      WHICH CAN BE USED TO DESCRIBE THE NONLINEARITY OF A SYSTEM.
8
9      C      FIRST CARD: COL. 1 = 0 OR BLANK
10     C      COL. 2-10 (F9.4) CHANNEL POSITION OF PEAK
11     C      COL. 11-19 (F9.4) ENERGY OF GAMMA RAY OR PULSER VOLTAGE
12     C      COL. 20-27 (A6) ALPHA-NUMERIC SOURCE LABEL
13     C      COL. 28-59 (4A8) ALPHA-NUMERIC ID OF THE PROBLEM
14     C      COL. 61-69 (F5.1) Y-AXIS INTERCEPT (SEE TEXT)
15     C      COL. 66-70 (F5.1) X-AXIS INTERCEPT (SEE TEXT)
16
17     C      ADDITIONAL DATA CARDS: COL. 1-27 SAME AS ABOVE
18     C      USE A BLANK CARD TO SEPARATE PROBLEMS
19     C      USE AN ADDITIONAL BLANK CARD TO TERMINATE THE RUN
20
21
22
23     COMMON CL(100),EN(100),SOURCE(100),AB(100,B),A(2),B(8),TITLE(4),
24     1 UB(100,B),RB(100),WB(9),VB(8),ULTCH(100),ULTEN(100),CALCEN(100),
25     2 XD(14)
26
27
28     NMLR = 100
29     NUM = 6
30     JIN = 2
31     JOUT = 3
32     1 J = 0
33     2 J = J + 1
34
35     C      READ IN DATA CARDS
36
37     READ INPUT TAPE JIN,910,CL(J),EN(J),SOURCE(J),XD,CO,CF
38     910 FORMAT (1X,2F9.4,A8,4A8,1X,2F5.1)
39     IF (J - 1) , ,5
40     IF (CL(J)) , ,110,
41     COFDEL = CO
42     COFCHN = CF
43     DO 4 I = 1,4
44     4 TITLE(I) = XD(I)
45     5 IF (CL(J)) , ,2
46     NJ = J - 1
47
48     C      MAKE ADJUSTMENT TO LOW CHANNEL DATA
49
50     DO 12 I = 1,NJ
51     IF (CL(I) - COFCHN) , ,14,14
52     CL(I) = CL(I) + COFDEL * (CL(I) - CL(I)) / COFCHN
53     12 CONTINUE

```

```

54
55 C PERFORM LEAST SQUARES FIT
56
57 14 DO 100 NRES = 2,NUM
58 IB = NRES +2
59 NDEG = IB -1
60 DO 20 J = 1,NJ
61 AB(J,1) = 1.C
62 PRD = CL(J)
63 SPD = PKD
64 AB(J,2) = PRD
65 DO 20 I = 3,IB
66 PRD = PRD * SPD
67 AB(J,I) = PRD
68 20 CONTINUE
69
70 CALL MLR (NMLR,NJ, 2,AB,EN,A,BB,RB,WB,VB)
71 CALL MLR (NMLR,NJ,IB,AB,EN,B,BB,RB,WB,VB)
72
73 DO 30 J = 1,NJ
74 CALGEN(J) = B(1)
75 DO 35 I = 2,IB
76 35 CALGEN(J) = CALGEN(J) + B(I) * AB(J,I)
77 DLTC(J) = -AB(J,2) + (B(1) - A(1)) / A(2)
78 DLTEN(J) = EN(J) - CALGEN(J)
79 30 CONTINUE
80
81 WRITE OUTPUT TAPE JOUT,530,NDEG,(TITLE(J), J=1,4)
82 930 FORMAT (1H1,/// 9X,31HPLSE ENERGY TC CHANNEL FIT IS ,11,
83 1 26H1H ORDER POLYNOMIAL FOR+ ,4AB)
84 WRITE OUTPUT TAPE JOUT,940,CCFOEL,COFCHN
85 940 FORMAT (/ 10X, 24HLOWER CHANNEL ADJUSTMENT //11X,
86 1 13HDELTA CHAN = ,F4.1,14H*(1 - CHANNEL/ ,F4.0,1H) )
87 WRITE OUTPUT TAPE JOUT,950
88 950 FORMAT (// 11X,30HCOEFFICIENTS OF POLYNOMIAL ARE )
89 WRITE OUTPUT TAPE JOUT,960, (B(1), L=1,IB)
90 960 FORMAT (/ 15X,E14.5)
91 WRITE OUTPUT TAPE JOUT,970
92 970 FORMAT (// 11X,47H CHANNEL ENERGY CALC. ENERGY CELTA EN.
93 1,19HDELTA CHAN. SOURCE //)
94 WRITE OUTPUT TAPE JOUT,980, (J,CL(J),EN(J),CALGEN(J),
95 1 DLTEN(J),DLTC(J),SOURCE(J), J = 1,NJ )
96 980 FORMAT (7X,13,F9.3,F11.3,F13.3,F11.3,F12.3,4X,A8)
97 100 CONTINUE
98 GO TO 1
99 110 CALL EXIT
100 END

```

*** CODE ANALYSIS ***

/ NAME IN NO EXECUTABLE INSTRUCTION
C LENGTHS ORIGINAL COUNT IN CLICHE
* UENOTES NAME DEFINED OR LABEL USE

BANK	ADDRESS	BASE	TYPE	CLASS	NAME	SCURCE	LINE	REFERENCES								
0000000			INTEGER	LITERAL	/ 0	32										
0000005	MAIN.		STATEMENT	LABEL	1	32*	53	39	43	46	50	59	60	61	73	
						14	77	81	89	95	98					
0000326	MAIN.		STATEMENT	LABEL	/ 1'0	25	25	25	25	25	25	25	25	25	28	
						57	97*									
0000333	MAIN.		STATEMENT	LABEL	/ 110	40	99*									
0000070	MAIN.		STATEMENT	LABEL	/ 12	50	53*									
0000074	MAIN.		STATEMENT	LABEL	14	51	51	57*								
0000340	MAIN.		REAL	LITERAL	1.	52										
0000341	MAIN.		REAL	LITERAL	1.0	61										
0000006	MAIN.		STATEMENT	LABEL	2	25	30	33*	45	57	58	64	70	75	77	
						77										
0000125	MAIN.		STATEMENT	LABEL	/ 20	60	65	68*								
0000000			INTEGER	LITERAL	/ 3	31	65									
0000215	MAIN.		STATEMENT	LABEL	/ 30	73	79*									
0000177	MAIN.		STATEMENT	LABEL	/ 35	75	76*									
0000047	MAIN.		STATEMENT	LABEL	/ 4	25	25	43	43	44*	81					
0000053	MAIN.		STATEMENT	LABEL	5	39	45*									
0000000			INTEGER	LITERAL	/ 6	29										
0000000			INTEGER	LITERAL	/ 8	25	25	25	25							
0000000			INTEGER	LITERAL	/ 9	25										
0000000			FORMAT	LABEL	/ 910	37	38*									
0000000			FORMAT	LABEL	/ 930	81	83*									
0000000			FORMAT	LABEL	/ 940	84	86*									
0000000			FORMAT	LABEL	/ 950	87	88*									
0000000			FORMAT	LABEL	/ 960	89	90*									
0000000			FORMAT	LABEL	/ 970	91	93*									
0000000			FORMAT	LABEL	/ 980	95	96*									
0002114	9999999	REAL	AKKAY	A	25	70	77	77								
0000454	9999999	REAL	ARRAY	AB	25	61*	64*	67*	70	71	76	77				
0002116	9999999	REAL	AKKAY	B	25	71	74	76	89							
0002132	9999999	REAL	ARRAY	BB	25	70	71									
0004267	9999999	REAL	AKKAY	CALCEN	25	74*	76*	76	78	95						
0000425	MAIN.	REAL	VARIABLE	CD	37*	41										
0000426	MAIN.	REAL	VARIABLE	CF	37	42										
0000000	9999999	REAL	ARRAY	CL	25	37*	40	45	51	52*	52	52	62	95		
0000430	MAIN.	REAL	VARIABLE	COFCHN	42*	51	52	84								
0000427	MAIN.	REAL	VARIABLE	COFDEL	41*	52	84									
0003757	9999999	REAL	AKKAY	DLTCH	25	77*	95									
0004123	9999999	REAL	ARRAY	DLTEN	25	78*	95									
0000144	9999999	REAL	AKKAY	EN	25	37*	70	71	77	78	95					
0000000		REAL	EXTERNAL	/ EXIT	99											
0000431	MAIN.	INTEGER	VARIABLE	I	43*	44	44	50*	51	52	52	52	65*	67		
					75*	76	76									
0000434	MAIN.	INTEGER	VARIABLE	ID	58*	59	65	71	75	89						
0000424	MAIN.	INTEGER	VARIABLE	J	32*	33*	33	37	37	37	39	40	45	46		
					60*	61	62	64	67	73*	74	76	76	76		
					77	77	77	78	78	78	81	81*	95	95		
					95	95	95	95	95	95*						

0000422	MAIN.	INTEGER	VARIABLE	JIN	30*	37					
0000423	MAIN.	INTEGER	VARIABLE	JOUT	31*	81	84	87	89	91	95
0000000		INTEGER	VARIABLE	/ L	89	89*					
0000000		SUBPROGRAM	NAME	/ MLR	70	71					
0000435	MAIN.	INTEGER	VARIABLE	NDEG	59*	81					
0000432	MAIN.	INTEGER	VARIABLE	NJ	46*	50	60	70	71	73	95
0000420	MAIN	INTEGER	VARIABLE	NMLR	28*	70	71				
0000433	MAIN.	INTEGER	VARIABLE	NRES	57*	58					
0000421	MAIN.	INTEGER	VARIABLE	NUM	29*	57					
0000436	MAIN.	REAL	VARIABLE	PRD	62*	63	64	66*	66	67	
0003572	9999999	REAL	ARRAY	RB	25	70	71				
0000310	9999999	REAL	ARRAY	SOURCE	25	37*	95				
0000437	MAIN.	REAL	VARIABLE	SPD	63*	66					
0002176	9999999	REAL	ARRAY	TITLE	25	44*	81				
0003747	9999999	REAL	ARRAY	VB	25	70	71				
0003736	9999999	REAL	ARRAY	WB	25	70	71				
0004433	9999999	REAL	ARRAY	XU	25	37*	44				

The XDET Program

One of the parameters used for geometry calculations in GAMANAL is the distance from the detector surface to the window. Although an approximate value of this distance is generally available from assembly specifications, the program XDET is used to experimentally determine or to certify this distance. The input data needed consists of a series of integrated peak counts taken at different distances from the detector window, the detector radius and height, the gamma-ray energy, and an initial estimate of the window to detector surface distance.

The program proceeds to refine this trial value by seeking a best "least-squares" fit of the data to the following expression: (See Fig. 1)

$$\frac{t_i}{y_i} = c \left[(x_i + w + p)^2 + r^2 \right]$$

where

y_i = the peak count in time t_i

x_i = source-to-window distance

w = window-to-detector surface distance

p = effective photon penetration

r = effective radius of interaction

c = proportionality constant

Fig. 1. Geometric relationships for a point source and a cylindrical detector.

Since the equation is nonlinear, a Taylor's expansion is made about the trial values for c and $(w + p)$. The values of p and r are calculated in the program by using the formulas described in Section III D of Vol. I.² The Newton-Raphson iterative technique is then used to obtain the best least-squares answers for the quantity $(w + p)$. The various parameters are printed out along with tables showing the precision of the fit.

One must use caution when working with low energy sources. Many detectors have a significant "dead layer" of Ge in front of the active region. Many of the gamma rays from close-in sources will strike this "dead layer" at angles less than the normal to the surface and they will consequently suffer more attenuation than that experienced

²R. Gunnink and J. B. Niday, Computerized Quantitative Analysis by Gamma Ray Spectrometry. Vol. I. Description of the GAMANAL Program, Lawrence Livermore Laboratory, Rept. UCRL-51061, Vol. I (1972).

high gamma rays from a source placed at a large distance. The results from XDET for $(w + p)$ and consequently for w will tend to be too large for such low energy sources unless some compensation for the above phenomenon is incorporated into the calculations.

FORTRAN

XDET

1972 AC

G05/03

00-357 MONITOR402

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4
5 C THIS PROGRAM CALCULATES THE AVERAGE DISTANCE (W + P) THAT GAMMA
6 C RAYS TRAVEL BEYOND THE DETECTOR WINDOW BEFORE BEING STOPPED.
7 C
8 C FIRST CARD * COL. 1-10 (F10.3) NET COUNTS IN THE PEAK
9 C COL. 11-15 (F5.2) COUNTING TIME
10 C COL. 16-20 (F5.2) SOURCE-TO-WINDOW DISTANCE (CM)
11 C COL. 21-25 (F5.3) DETECTOR RADIUS (CM)
12 C COL. 26-30 (F5.3) INITIAL ESTIMATE OF WINDOW-TO-DETECTOR
13 C DISTANCE (CM)
14 C COL. 31-35 (F5.3) DETECTOR HEIGHT (CM)
15 C COL. 36-40 (F5.0) GAMMA RAY ENERGY (KEV)
16 C COL. 42 0 OR 2 IS FOR DETR. OF PENETRATION ONLY.
17 C 3 IS FOR DETR. OF PENETRATION AND EFFECTIVE
18 C RADIUS OF INTERACTION.
19 C COL. 43-74 (4AB) IDENTIFICATION FOR THE PROBLEM
20
21 C ADDITIONAL DATA * COL. 1-20 SAME AS ABOVE
22
23 C USE A BLANK CARD TO SEPARATE PROBLEMS
24 C USE AN ADDITIONAL BLANK CARD TO TERMINATE THE RUN
25
26 COMMON CTS(20),DIST(20),AA(20,3),Y(20),X(3),BH(60),RP(20),WH(3),
27 1 VM(3),PCTDIF(20),CALC(20),WTF(20),TIME(20),C(3),TITLE(4)
28
29 1 J=0
30 2 J=J+1
31 READ INPUT TAPE 2,1001,CTS(J),TIME(J),DIST(J),RAD,WDIS,HYT,ENE,N,
32 1 TITLE
33 1001 FORMAT (F10.3,2F5.2,3F5.3,F5.0,I2,4AB)
34 IF (J-1) , ,3
35 IF (CTS(J)) ,99,
36 ENERGY = ENE
37 DELT = WDIS
38 CETHT = HYT
39 NORDER = N
40 WRITE OUTPUT TAPE 3,1003, 1TITLE(1) , 1=1,4)
41 1003 FORMAT (1H1,10X, 33HDETECTOR POSITION ANALYSIS FOR * ,4AB)
42 WRITE OUTPUT TAPE 3,1007,ENE,HYT,RAD
43 1007 FORMAT (// 10X,19HGAMMA RAY ENERGY = ,F6.1,4H KEV,10X,17HDETECTOR
44 1 HEIGHT = ,F6.3,3H CM,10X,17HDETECTOR RADIUS = ,F6.3,3H CM, //)
45 S = (ENE - 60.) * .01
46 SD = S * S
47 SDR = SD / (1. + SD)
48 RAD = RAD * RAD
49 CON = (1. - 1./ (SQRTF(1. + RAD))) * 2./RAD
50 RD = (1. - CON) / CON
51 RSQ = RD - 0.4* RD * SDR * SQRTF (HYT)
52 REFF = SQRTF (RSQ)
53

```

```

54 C    CALCULATE AN EFFECTIVE ABSORPTION COEFFICIENT FOR GE DETECTOR
55
56 ENE = ENERGY * .001
57 XMU = -2.316 + 4.2 * EXPF (-1.434 - 0.478*LOGF (ENE))
58 XMU = EXPF (XMU)
59
60 C    NOW CALCULATE EFFECTIVE GAMMA RAY PENETRATION INTO THE DETECTOR
61
62 C = XMU * DETHT
63 EXPON = EXPF (-C)
64 P = (1. - (C * EXPON / (1. - EXPON))) / XMU
65
66 3 IF (CTS(J))199, .2
67   NUM = J-1
68   IF (NORDER) , .4
69   NORDER = 2
70 4 DO 5 J = 1,NUM
71   WTF(J) = 1.0 / SQRTF(CTS(J))
72 5 CONTINUE
73   B = DIST(NUM) + DELT + P
74   B = (B * B) + RSQ
75   CONST = CTS(NUM) * B / TIME(NUM)
76   LCNT = 0
77   WRITE OUTPUT TAPE 3,1002
78 1002 FORMAT(/10X,40HTHE ANSWERS FOLLOWING EACH ITERATION ARE /10X,37H
79   1CONST+ X(1) DELT+ X(2) RSQ+ X(3) //)
80   WRITE OUTPUT TAPE 3,1005,CONST,DELT,RSQ
81
82 10 DO 20 J = 1,NUM
83   D = DIST(J) + DELT
84   AX = 1.0 / ((D*D) + RSQ)
85   AA(J,1) = AX * WTF(J) * TIME(J)
86   AA(J,2) = -2. * CONST * D * AX * AA(J,1)
87   IF (NORDER - 2) 20,20.
88   AA(J,3) = -CONST * AX * AA(J,1)
89 20 Y(J) = (CTS(J) - CONST * TIME(J) * AX) * AX * WTF(J)
90
91   LCNT = LCNT + 1
92   CALL MLR (20,NUM,NORDER,AA,Y,X,UM,RM,WP,VM)
93
94   DELT = DELT + X(2)
95   CONST = CONST + X(1)
96   IF(NORDER -2) 22,22.
97   RSQ = RSQ + X(3)
98 22 WRITE OUTPLT TAPE 3,1005, CONST,DELT,RSQ
99 1005 FORMAT ( 8X,3E13.4)
100   IF(LCNT - 20) , .24
101   IF (ABS(X(2)) -.003) , 10,10
102
103 24 SUMR = 0.0
104   GDF = NUM - NORDER
105   DO 30 J = 1,NUM

```

```

106      SUMR = SUMR + RM(J) * RP(J)
107      B = DIST(J) * DELT
108      CALC(J) = CONST * TIME(J) / (B * B + RSC)
109      PCTDIF(J) = 100.* (CTS(J) - CALC(J)) / CTS(J)
110      30 CONTINUE
111
112      W = DELT - P      $$$ W = WINDOW TC DETECTION DISTANCE
113      QFIT = SUMR / DOF
114      IF (QFIT - 1.) , .26
115      QFIT = 1.0
116      26 CALL MLREIC)
117      ERR2 = SQRT(QFIT * C(2))
118      ERR3 = 0.0
119      IF (NORDER - 2) 35,35,
120      ERR3 = SQRT(QFIT * C(3))
121
122      35 WRITE OUTPUT TAPE 3,1006,ERR2,ERR3
123      1006 FORMAT(/13X, 8HERROR = ,2E13.4 )
124      WRITE OUTPUT TAPE 3,1009,HEFF,W,P
125      1009 FORMAT (/ / 10X,33HEFFECTIVE RADIUS OF INTERACTION = ,F6.3,3H CM, /
126      110X,29HWINDOW TO DETECTOR DISTANCE = ,F6.3,3H CM, / 10X,
127      2 33HGAMMA RAY PENETRATION INTO DET. = ,F6.3,3H CM )
128      WRITE OUTPUT TAPE 3,1010
129      1010 FORMAT (/ / 10X,52HCOMPARISON OF CALCULATED COUNTS WITH OBSERVED VAL
130      LUES // 10X,73HDISTANCE TIME(MIN) INPUT COUNTS CALC COUNTS PCT.
131      2 DIFFERENCE RESIDUAL //)
132      WRITE OUTPUT TAPE 3,1015, (DIST(J),TIME(J),CTS(J),CALC(J),PCTDIF
133      1 (J),RM(J), J = 1,NUM)
134      1015 FORMAT (10X, F7.3,F12.2,F12.1,F15.2,F11.2,F15.2 )
135      GO TO 1
136
137      99 CALL EXIT
138      END

```