JUN 22 1969

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NUCLEAR DIVISION

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U.S. ATOMIC ENERGY COMMISSION

ORNL - TM-1865

COPY NO. - 47

DATE - May 17, 1967

ANALYSIS OF PULSE-HEIGHT ANALYZER TEST DATA WITH A SMALL COMPUTER

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CPSTI PRICES

ABSTRACT

H.C. \$ 3.00; MN 65

All multichannel pulse-height analyzers purchased by ORNL are tested to determine whether they are acceptable to the Laboratory. A PDP-8 computer program was prepared for evaluation of these test data, that is, to determine the extent of the integral and differential nonlinearities of the instruments. The program will also examine smooth spectra of radioactive decay.

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CONTENTS

	Page
1. INTRODUCTION	4
2. DESCRIPTION OF PROGRAM	4
2.1 Integral Linearity	4
2.2 Differential Linearity	7
2.3 Examination of Statistical Data	7
3. PROGRAM OPERATION	10
3.1 Program Loading	10
3.2 Transfer of Control to Program	11
3.3 Definitions of Abbreviations	11
3.4 Data Loading	13
3.5 Program Calculation	13
3.6 Routines and Subroutines	15
4. APPENDIX	52
4.1 Reference List for Program Abbreviations	52
4.2 Rim Loader Locations	53
4.3 Algorithm for Linear Least-Squares Fit	54
4.4 Tape Formats	55

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1. INTRODUCTION

All multichannel pulse-height analyzers purchased by ORNL must pass rigorous tests performed by the Laboratory before they can be accepted. The voluminous data obtained from these tests are analyzed by a PDP-8 computer; this report describes the program prepared for this purpose. The program determines integral and differential nonlinearities and examines smooth spectra of radioactive decay.

The basic equipment required is a PDP-8 computer with an ASR-33 teleprinter.

This program provides a more accurate test with greatly reduced labor expense for testing, and at the same time provides a more detailed evaluation than was previously done manually (a rough guess is that the time required for a test is reduced 95% from previous manual tests).

2. DESCRIPTION OF PROGRAM

2.1 Integral Linearity

The first portion of the program, which checks integral linearity, calculates the centroids of observed pulser peaks contained on the analyzer output punched-paper tape. These pulser peaks are obtained as follows:

1. A precision pulser dial setting is normalized at the highest channel of interest.
2. A minimum of 1000 counts is accumulated at this setting.
3. The pulser is turned off and the dial is decreased by $1/N$ times the normalized setting, where N is the number of points to be observed.
4. Step 3 is repeated until at least 1000 counts have been stored at each of N dial settings. The peaks must be separated enough so that there is at least one channel between them whose content is zero. Some resolution spread is necessary in the pulser peaks to allow accurate centroids to be calculated.

By use of the algorithm in the Appendix for the linear least-squares method, the best fitting straight line is calculated. The theoretical channel number (identifying the location of the centroid) is subtracted from the corresponding observed centroid, and the difference is printed out. An option provides for a qualitative plot of the difference on the printer.

Example 1 illustrates this program.

Example 1: Integral Linearity

PN=1/ NW=40/ PY=2/ LI=0/ FM=2/ L,D&S=-0.5/1.0/24

001 +	9.97	002 +	19.97	003 +	29.83	004 +	39.48
005 +	49.19	006 +	59.04	007 +	68.95	008 +	78.88
009 +	88.70	010 +	98.46	011 +	108.24	012 +	118.06
013 +	128.00	014 +	137.93	015 +	147.79	016 +	157.60
017 +	167.40	018 +	177.23	019 +	187.09	020 +	197.02
021 +	206.98	022 +	216.92	023 +	226.81	024 +	236.69
025 +	246.54	026 +	256.39	027 +	266.27	028 +	276.18
029 +	286.12	030 +	296.06	031 +	306.01	032 +	315.98
033 +	325.95	034 +	335.90	035 +	345.89	036 +	355.81
037 +	365.70	038 +	375.63	039 +	385.46	040 +	395.17

B=- .31 M=+ 9.88 LA=3

001 +	9.56	+ .40	002 +	19.45	+ .52	003 +	29.33	+ .50
004 +	39.21	+ .26	005 +	49.10	+ .09	006 +	58.98	+ .05
007 +	68.86	+ .09	008 +	78.75	+ .13	009 +	88.63	+ .07
010 +	98.51	- .04	011 +	108.39	- .15	012 +	118.28	- .21
013 +	128.16	- .16	014 +	138.04	- .11	015 +	147.93	- .13
016 +	157.81	- .21	017 +	167.69	- .28	018 +	177.57	- .34
019 +	187.46	- .36	020 +	197.34	- .32	021 +	207.22	- .24
022 +	217.11	- .18	023 +	226.99	- .17	024 +	236.87	- .18
025 +	246.76	- .21	026 +	256.64	- .24	027 +	266.52	- .24
028 +	276.40	- .22	029 +	286.29	- .16	030 +	296.17	- .11
031 +	306.05	- .04	032 +	315.94	+ .04	033 +	325.82	+ .12
034 +	335.70	+ .19	035 +	345.58	+ .30	036 +	355.47	+ .33
037 +	365.35	+ .34	038 +	375.23	+ .39	039 +	385.12	+ .34
040 +	395.00	+ .17						

Example 1 (continued): Integral Linearity

M=+9.88

LA=0

001 +	9.56 + .40	.	+
002 +	19.45 + .52	>	
003 +	29.33 + .50	>	
004 +	39.21 + .26	.	+
005 +	49.10 + .09	.	+
006 +	58.98 + .05	.	+
007 +	68.86 + .09	.	+
008 +	78.75 + .13	.	+
009 +	88.63 + .07	.	+
010 +	98.51 - .04	+	.
011 +	108.39 - .15	+	.
012 +	118.28 - .21	+	.
013 +	128.16 - .16	+	.
014 +	138.04 - .11	+	.
015 +	147.93 - .13	+	.
016 +	157.81 - .21	+	.
017 +	167.69 - .28	+	.
018 +	177.57 - .34	+	.
019 +	187.46 - .36	+	.
020 +	197.34 - .32	+	.
021 +	207.22 - .24	+	.
022 +	217.11 - .18	+	.
023 +	226.99 - .17	+	.
024 +	236.87 - .18	+	.
025 +	246.76 - .21	+	.
026 +	256.64 - .24	+	.
027 +	266.52 - .24	+	.
028 +	276.40 - .22	+	.
029 +	286.29 - .16	+	.
030 +	296.17 - .11	+	.
031 +	306.05 - .04	+	.
032 +	315.94 + .04	.	+
033 +	325.82 + .12	.	+
034 +	335.70 + .19	.	+
035 +	345.58 + .30	.	+
036 +	355.47 + .33	.	+
037 +	365.35 + .34	.	+
038 +	375.23 + .39	.	+
039 +	385.12 + .34	.	+
040 +	395.00 + .17	.	+

2.2 Differential Linearity

The differential linearity routine processes data obtained with a sliding pulser. An average of the number of counts per channel is compared with each channel of interest. A tally is kept of the number of channels whose content exceeds the allowable percentage deviation.

The address of the channel in error is listed along with the percentage that its content exceeds the allowable percentage deviation. The operator can choose the number of channels used in calculating the average number of counts per channel, and also can choose the number of channels whose deviation is calculated. An option permits printing of only the total number of errors, if desired. (See Example 2.)

2.3 Examination of Statistical Data

The third routine (Example 3) is for examination of statistical data, such as obtained with a plastic scintillator. Data from ^{54}Mn taken with a NaI detector are also suitable if the amplifier gain is set high so that the photopeak is off scale and precautions are taken to keep the backscatter peak at a minimum. Meaningful results might not be obtained if there are sharp peaks and valleys in the spectrum. This method is used for checking the variation in the widths of adjacent and near-adjacent channels under random signal input conditions. Its use is mainly for evaluating odd-even effects and small discontinuities in the observed channel width vs the average channel width of adjacent channels.

The following definitions should simplify an explanation of the method:

N	channel under examination
R	integral number (≥ 1) of channels selected on each side adjacent to N
k	percent allowable deviation
M	average of contents of $2R$ channels
L	$kM - \sqrt{M}$
U	$kM + \sqrt{M}$
C(N)	contents of channel N.

Some integral number $R \geq 1$ is selected and M is computed:

Example 2: Differential Linearity

PN=2/ NW=100/ PY=1/ LI=10/ FM=2/ IC=8/ OF=0

```

074800 000000 000000 038645 284100 366036 325098 333519 341389 345537
349125 351903 354163 355321 356785 356868 357345 358151 358169 357677
357900 356751 356959 356251 356292 355605 355240 355086 355508 355064
355014 354153 354394 353999 354587 353446 353449 353594 353913 353616
353875 352417 353297 352293 352981 352402 352559 352196 352618 352356
353188 352064 352697 352065 352268 351806 352191 351935 352510 352109
352718 351693 352376 351418 352118 352107 351685 351511 352117 352437
352604 352609 353252 352553 353147 353113 353350 353132 353700 353149
353459 352995 353541 352721 353933 353840 354420 353600 354157 353962
354530 353810 354602 353747 353668 353985 353644 353517 353660 353848

```

SUM=+XXXXXXX MEAN=+353472.2

PL=2.0/ SA=8/ LA=6/

008 - 1.4 009 - .2

ERRORS=002

PL=1.0/ SA=8/ LA=6

008 - 2.4 009 - 1.2 010 - .2 016 + .0 017 + .3 018 + .3

019 + .1 020 + .2

ERRORS=008

PL=0.5/ SA=8/ LA=0

ERRORS=022

PL=0.5/ SA=0/ LA=6

008 - 2.9 009 - 1.7 010 - .7 013 + .0 014 + .4 015 + .4

016 + .5 017 + .8 018 + .8 019 + .6 020 + .7 021 + .4

022 + .4 023 + .2 024 + .2 025 + .1 026 + .0 028 + .0

061 - .0 063 - .0 066 - .0 067 - .0

ERRORS=022

Example 3: Examination of Statistical Data

PN=3/ NW=100/ PY=1/ LI=10/ FM=2/ OF=0

```

003968 591145 864707 267194 769342 540635 504241 502500 468227 375712
262341 189561 150373 127466 114058 105205 098963 095041 091757 088877
087405 085238 084203 083531 082991 081939 081299 081092 080668 079352
079761 079032 079347 078667 078446 077890 077578 077089 076769 075955
076301 075466 075726 074693 074208 074276 074113 073509 072946 072670
072155 071832 071136 070737 070766 069896 069610 068656 069242 068323
068674 067900 067682 066959 066857 065948 066897 066192 065501 065806
065188 064704 064709 064965 064051 064135 063721 063717 063412 062897
063111 062443 062522 061948 062387 062098 061734 061116 061847 061434
061226 060570 061156 060759 060728 060301 060148 059415 060036 059556

```

PL=0.5/ CC=90/ R=1/ SA=8/ LA=6/

```

008 + 5.9 009 + 2.1 010 - 6.4 011 - 7.4 012 - 4.3 013 - 2.8
014 - 1.1 015 - .4 016 - .3 029 - .2 057 - .2 058 + .2
059 - .0 065 - .5 066 + .3 073 + .0 087 - .1 088 + .0
091 - .1 097 - .2
N>PL+1SIGMA=020 +22.22
008 + 5.8 009 + 2.0 010 - 6.3 011 - 7.1
012 - 4.1 013 - 2.5 014 - .8 015 - .1 016 - .0 065 - .1
N>PL+2SIGMA=010 +11.11

```

```

008 + 5.6 009 + 1.8 010 - 6.1 011 - 6.9 012 - 3.8 013 - 2.2
014 - .5
N>PL+3SIGMA=007 + 7.77

```

PL=0.5/ CC=82/ R=5/ SA=13/ LA=6/

```

013 - 33.9 014 - 27.3 015 - 18.6 016 - 12.0 017 - 7.2 018 - 4.5
019 - 3.4 020 - 1.8 021 - 1.8 022 - 1.1 023 - .3 029 - .3
057 - .1 065 - .3 066 + .0 087 - .0
N>PL+1SIGMA=016 +19.51
013 - 33.7 014 - 27.0
015 - 18.3 016 - 11.7 017 - 6.9 018 - 4.2 019 - 3.1 020 - 1.4
021 - 1.5 022 - .8 023 - .0 029 - .0
N>PL+2SIGMA=012 +14.63
013 - 33.4 014 - 26.7
015 - 18.1 016 - 11.4 017 - 6.6 018 - 3.9 019 - 2.7 020 - 1.1
021 - 1.1 022 - .4
N>PL+3SIGMA=010 +12.19

```

PL=0.5/ CC=72/ R=10/ SA=18/ LA=0/

```

N>PL+1SIGMA=015 +20.83
N>PL+2SIGMA=011 +15.27
N>PL+3SIGMA=011 +15.27

```

$$M = \frac{\sum_{i=N-R}^{N-1} C(N_i) + \sum_{i=N+1}^{N+R} C(N_i)}{2R}$$

The address of channel N and the percentage that its content exceeds the allowable deviation limit as defined by $L \leq C(N) \leq U$ is listed by the teleprinter. If desired, only the total number of errors will be listed.

Assuming that a sufficient number of channels is checked, at least 68.3% of the channels should pass this test. If k is varied until exactly 68.3% of the channels pass, then k should be a reasonable measure of the adjacent channel width variation.

Some care should be used in evaluating these data to ensure that those channels which fall outside the limits are fairly uniformly distributed over the whole channel range. If they are concentrated in particular regions, the width variation in those regions may fall well outside the value arrived at for k.

3. PROGRAM OPERATION

3.1 Program Loading

Programs are loaded as follows:

1. Assuming that the binary loader is in the core, set 7777 in the switch register. If the binary loader is not in the core, check to ensure that the rim loader is in locations 7756-7777.

If the rim loader is in the core, set 7756 in the Switch Register. Place the binary loader tape in the reader and turn it on. Depress Key Load Address and then Key Start. After the tape has been read in, turn the reader off and return to step 1.

2. Place the program tape in the reader.

3. Depress Key Load Address and Key Start, in that order.

4. Turn on the reader. The program will read in, and the computer should halt with $C(AC) = \text{zero}$. If $C(AC)$ is not zero, an error has occurred. Load the tape again.

5. Depress Key Continue to load Floating Point II package (Digital 8-5B-S). The C(AC) should be zero when the computer halts. If C(AC) is not zero, load again.

3.2 Transfer of Control to Program

Transfer of control so that the program will control and start computer operation is accomplished by setting 3200 in the Switch Register and depressing Key Load Address and then Key Start. The program will begin asking for information via the teleprinter. Type the information and terminate with any nondigit character.

The overflow and percent limit input is processed by the floating point input routine. Numbers from 1×10^{-6} to 1×10^6 may be used. Information being entered for either of these requests may be erased by striking "Rubout," which must be struck before the input delimiter. All other information called is processed by a single precision conversion routine; therefore, no more than three decimal digits plus the sign should be entered. If more than three digits are entered, the result will not be predictable. Alt-Mode is used instead of Rubout to erase digits that have been inserted. Any printing nondigit character is a legal input delimiter. However, it is suggested that slant or carriage return be used exclusively.

3.3 Definitions of Abbreviations

The program requests for information are abbreviated queries on the teleprinter. The definitions of these abbreviations are:

PN=	The number 1, 2, or 3 is typed in to select the desired program (all other numbers are illegal).
PN=1/	Selects <u>integral linearity</u> .
PN=2/	Selects <u>differential linearity</u> .
PN=3/	Selects program for processing statistical data such as obtained with plastic scintillators.
NW=	Asks for number of words of data to read for programs 2 and 3. Program 1 wants the number of observed points. If more than <u>512</u> words are inputted, the program will be destroyed.
PY	Asks for parity: type 0/ for no parity, 1/ for odd parity, or 2/ for even parity.

- LI** 0/ suppresses listing of input data. If the data tape contains carriage returns to separate the lines, X/ may be typed--where X is any number other than zero. If there is no carriage return information on the tape, the desired number of words to a line should be typed. For example, 10/ will cause ten words per line to be listed. Always type 0/ for program 1.
- FM=** Asks for data tape format. Format 1 will read ASCII formats provided there is no address information on the tapes. (It will also read these; however, the addresses will be recognized as data.) Its principal use is for typing information via the keyboard. Format 2 is an input routine that will read the following formats, each having at least five digits of data and no more than four digits of address information: ASCII formats, Nuclear Data format, TMC format, and ORACLE format. Any of these may have odd, even, or no parity. If a parity error is detected by the program, a carriage return and linefeed combination is issued. The address of the word that contains the character in error will be typed at the left margin and another carriage return linefeed will be issued. Format 2 will not read binary, hexadecimal, or formats in which the address information and data are not delimited. Special subroutines will be available for these formats. These will reside in the same memory location as Format 2; therefore, when FM= is printed, type 2/. (See Appendix, Sect. 4.4 for details.)

The preceding information is asked for all three programs. Programs 1 and 2 also type the following abbreviated query:

- OF=** If overflow has occurred, type the actual number of excess counts. For example, if it is known that a $10^5 - 1$ analyzer has overflowed twice, type 200,000/. The number typed in will be added to the contents of all channels; therefore, if all channels have not overflowed the same number of times, the data cannot be processed with this program.

Program 2 also asks:

- IG=** Wants the number of low-order channels to be ignored. Since specifications for the instrument usually require the upper 98% of the channels to meet the linearity requirements, the contents of the first 2% are not ordinarily used in the calculation of the average number of counts per channel. Any number of channels may be ignored, but this number should never be equal to or greater than the number of channels to be processed.

Even though contents of the ignored channels are not used in the calculation of the average, they may be compared with the computed average.

Program 1 also prints: L, D, and S. This information is needed to compute the scale factor for the plot routine as follows:

$$D_s = (X - L) \frac{S}{D},$$

where D_s is scaled data, X is data, L is the least algebraic data to be plotted, D is the algebraic difference between the largest algebraic number and least algebraic number to be plotted, and S is the total number of teleprinter spaces available. It is important to type a minus sign for L if it is less than zero. Both D and S will always be positive. It is permissible to type a plus, but it is not required.

3.4 Data Loading

After all program requests for information have been taken care of, the computer waits to read the data tape. Place the tape in the reader on leader and turn the reader on. The data will be loaded and the computer will halt. This halt is necessary to turn the reader off, since further information will be requested (the computer cannot determine whether information comes from the keyboard or reader).

3.5 Program Calculation

Turn off the reader and press Key Continue. The following will occur:

Program 1 will calculate the best fitting straight line (according to the linear least-squares method), subtract Y(calculated) from Y(observed), and list the values of Y(calculated) and Δ (the difference).

After the centroids have been calculated and listed by the teleprinter, the computer will halt for the input tape to be removed and the reader turned off. When Key Continue is depressed, instructions for listing the answers are asked. If a 0 is struck, the calculated channel number and the difference between the calculated and observed values are printed, and the difference is also plotted on the same line. Any other digit causes that number of answers to be typed on a single line and the plotting suppressed.

Programs 2 and 3 will ask for more information as follows:

- PL= Type percent deviation allowed.
- SA= Type address to start checking for errors. In the case of program 3, this must be greater than or equal to R.
- LA= If zero is inserted, the number of errors will be printed. Any other number causes the address and percentage of number of counts above or below the prescribed limit to be output. The number of such outputs per line is determined by the number typed in.

Program 3 also asks

- CC= Wants to know the number of channels to check for error. This number must never be larger than the total number of words read in minus 2R.
- R= Type the number of channels each side of word being checked to sum and average.

3.6 Routines and Subroutines

3.6.1 Constants and Temporary Storage

		*0000	
0000	7772	M6,	0-6
0001	0004	WRDLIN,	4
0002	0000	GOOFS,	0
0003	7775	M3,	7775
0004	7400		7400
0005	0000	C3,	0
0006	7200		7200
0007	5600		5600
		*20	
0020	4400	INSCI,	INASCI
0021	5200	MESAJ,	MESSAGE
0022	4503	FXINP,	FIXINP
0023	5311	DPRT,	DECPRT
0024	0004	P4,	4
0025	7347	P7347,	7347
0026	5365	TB,	TTB
0027	5373	TS,	TSP
0030	5360	TR,	TCR
0031	4363	LAD,	LISTAD
0032	4533	FLO,	FIXFLO
0033	4522	ZER,	ZERON
0034	4433	ADEC,	ASDEC
0035	3657	BUF,	BUFDIG
0036	7773	M5,	0-5
0037	0177	P177,	177
		*62	
0062	0000	DIGITZ,	0
0063	0000	DEZMAL,	0
0064	0000	C,	0
0065	0000	C1,	0
0066	0000	C2,	0
0067	7753	M25,	0-25
0070	0000	FP0,	0
0071	0000		0
0072	0000		0
0073	0001	FP1,	1
0074	2000		2000
0075	0000		0
0076	0007	FHUN,	7
0077	3100		3100
0100	0000		0

0101	0000	TSUM,	0	/ALSO OFLO,
0102	0000		0	
0103	0000		0	
0104	0000	TSUMP,	0	
0105	0000		0	/ALSO ZEROS
0106	0000		0	
0107	0000	TYI,	0	
0110	0000		0	
0111	0000		0	
0112	0000	SUMY,	0	/ALSO FSUM
0113	0000		0	
0114	0000		0	
0115	0000	SUMSQ,	0	/ALSO FSIGMA
0116	0000		0	
0117	0000		0	
0120	0000	SUMPR,	0	/ALSO FCON
0121	0000		0	
0122	0000		0	
0123	0000	SUMX,	0	/ALSO FNBAR
0124	0000		0	
0125	0000		0	
0126	0000	XBUF,	0	
0127	0000		0	
0130	0000		0	
0131	0000	FBUFI,	0	
0132	0000		0	
0133	0000		0	
0134	0000	FBUFO,	0	
0135	0000		0	
0136	0000		0	
0137	0000	FDIVSR,	0	
0140	0000		0	
0141	0000		0	
0142	0000	DEL,	0	
0143	0000		0	
0144	0000		0	
0145	0000	FN,	0	
0146	0000		0	
0147	0000		0	

0150	0000	INSW,	0
0151	0000	OUTSW,	0
0152	0000	PRSW,	0
0153	6046	SLT,	TLS
0154	0002	P2,	2
0155	0003	P3,	3
0156	0111	P147,	SUMY-1
0157	0200	P200,	200
0160	0017	P17,	17
0161	0020	P20,	20
0162	0077	P77,	77
0163	0012	P12,	12
0164	0000	STAD,	0
0165	0000	ADRES,	0
0166	0000	ADREZ,	0
0167	0000	FSTAD,	0
0170	7400	FLINPT,	7400
0171	3671	D1,	DUM1
0172	0000	D2,	0
0173	7147	DUM,	7147
0174	7150	DUMY,	7150
0175	3412	DEPOZ,	DCA I 12
0176	0000	N,	0
0177	0000	N1,	0

3.6.2 Routine for Selection of Desired Program

```

*3200
3200 6046 BEGIN, TLS /CLEAR TELEPRINTER FLAG
3201 4432 JMS I FLO /REPAIR FL POINT
3202 4421 NO, JMS I MESAJ /NO, GET PROG NUM
3203 4543 4543
3204 2016 2016
3205 7500 7500
3206 4420 JMS I INSCI /CONV TO BIN
3207 3120 DCA 120 /LSD=1 * DR MC PHAPT=2 :
3210 4426 JMS I TB /TAB DR MOAK=3
3211 4421 JMS I MESAJ
3212 1627 1627 /NW GET NR OF WDS TO READ
3213 7500 7500 /=
3214 4420 JMS I INSCI /CONV TO BIN
3215 3176 DCA N /SAVE
3216 4422 JMS I FXINP /CONV TO FP
3217 4407 JMS I 7
3220 6145 FPUT FN /SAVE
3221 0000 FEXT /EXIT FP
3222 4426 JMS I TB
3223 4421 JMS I MESAJ /GET PARITY
3224 2031 2031 /GET PARITY
3225 7500 7500 /PY= NONE=0, EVEN=2, ODD=1
3226 4420 JMS I INSCI /CONV TO BIN
3227 7450 SNA /NO PARITY?
3230 5236 JMP .+6 /YES
3231 7110 CLL RAR /ROT8 CH11 TO LINK
3232 7620 SNL CLA /IS IT ODD?
3233 5235 JMP .+2 /NO, IT IS EVEN
3234 1240 TAD .+4 /MAKE SZL CLA
3235 1241 TAD .+4 /MAKE SNL CLA
3236 1006 TAD 6
3237 3742 DCA I PAR /FIX PARITY
3240 0010 0010 /CHECKER FOR
3241 0420 0420 /PROPER PARITY
3242 4426 JMS I TB
3243 4421 JMS I MESAJ
3244 1411 1411
3245 7500 7500
3246 4420 JMS I INSCI /CONV TO BIN
3247 3172 DCA D2 /SAVE ANSWER IN D2
3250 4426 JMS I TB

```

3251	4421	JMS I MESAJ	/GET FORMAT
3252	0615	0615	/FM=
3253	7500	7500	
3254	4420	JMS I INSCI	
3255	0155	AND P3	
3256	1334	TAD ADWORD	
3257	3260	DCA .+1	
3260	7000	NOP	
3261	3004	DCA 4	
3262	1120	TAD 120	/PROG NR TO AC
3263	1333	TAD PROCED+4	
3264	3327	DCA PROCED	/PREPARE EXIT TO RIGHT PROG
3265	1120	TAD 120	
3266	7110	CLL RAR	
3267	7450	SNA	/IS IT LSD? (INSW NOW FREE)
3270	5343	JMP LS	
3271	7430	SZL	/IS IT HOOKUMCHOW?
3272	5305	JMP DM	/NO! MUST BE MOAK
3273	4426	JMS I TB	
3274	4421	JMS I MESAJ	/GET NR TO IGNORE
3275	1107	1107	
3276	7500	7500	
3277	4420	JMS I INSCI	
3300	3177	DCA N1	/SAVE IN N1
3301	4422	JMS I FXINP	/CONV TO FP
3302	4407	JMS I 7	
3303	6134	FPUT FBUFO	/SAVE IN FN1
3304	0000	FEXT	
3305	4426	JMS I TB	
3306	4421	JMS I MESAJ	
3307	1706	1706	/OF= GET OVERFLOW
3310	7500	7500	
3311	4570	JMS I FLINPT	
3312	1060	TAD 60	
3313	7650	SNA CLA	
3314	5311	JMP .-3	
3315	4407	JMS I 7	
3316	6101	FPUT TSUM	/SAVE IN OFLO
3317	0000	FEXT	
3320	7240	CLA CMA	
3321	3151	DCA OUTSW	
3322	3165	DCA ADRES	
3323	7240	CLA CMA	

3324	3150		DCA INSW
3325	7040		CMA
3326	3065		DCA C1
3327	0000	PROCED,	0
3330	4604		LSD
3331	3400		UMCHOW
3332	4000		MOAK
3333	5727		JMP I PROCED
3334	1335	ADWORD,	TAD .+1
3335	3341		HALT
3336	3560		REGLAR
3337	3600		UNIVER
3340	3600		3600
3341	7402	HALT,	HLT
3342	4241	PAR,	PARITY
3343	4421	LS,	JMS I MESAJ
3344	4040		4040
3345	1454		1454
3346	0446		0446
3347	2375		2375
3350	0000		0000
3351	1003		TAD M3
3352	3064		DCA C
3353	1074		TAD FP1+1
3354	3164	DSTAD,	DCA STAD
3355	4570		JMS I FLINPT
3356	4407		JMS I 7
3357	6564		FPUT I STAD
3360	0000		FEXT
3361	1164		TAD STAD
3362	1155		TAD P3
3363	2064		ISZ C
3364	5354		JMP DSTAD
3365	7200		CLA
3366	1076		TAD FHUN
3367	3062		DCA 62
3370	1154		TAD P2
3371	3063		DCA 63
3372	1024		TAD P4
3373	3001		DCA WRDLIN
3374	7240		CLA CMA
3375	3152		DCA PRSW
3376	5320		JMP COMN

3.6.3 /Routine for Calculation of Differential Linearity with Sliding Pulser Data

```

*3400
3400 7200  UMCHOW,  CLA
3401 1177          TAD N1
3402 7041          CIA
3403 1176          TAD N
3404 7740          SMA SZA CLA          /IS N1 =< N?
3405 5213          JMP .+6          /NO! GO ON
3406 4421          JMS I MESAJ.        /YES, KNOCK IT OFF
3407 1625          1625
3410 2423          2423
3411 4100          4100
3412 7402          HLT
3413 1160          TAD P17
3414 7041          CIA
3415 4433          JMS I ZER  /O TO FP TEMPS
3416 0103          TSUMP-1
3417 1176          TAD N
3420 7041          CIA
3421 3064          DCA C          /-N TO C
3422 1157          TAD P200
3423 3167  REPT,   DCA FSTAD  /INIT STAD
3424 4404          JMS I 4
3425 4407          JMS I 7
3426 1101          FADD TSUM  /READ WORD&ADD OFLO
3427 6567          FPUT I FSTAD      /SAVE IT
3430 0000          FEXT
3431 1167          TAD FSTAD
3432 1155          TAD P3
3433 2064          ISZ C          /FINISHED?
3434 5223          JMP REPT  /NO, KEEP GOING
3435 7240          CLA CMA
3436 3056          DCA 56
3437 4432          JMS I FLO  /YES, REPAIR F P
3440 7402          HLT
3441 4407          JMS I 7
3442 5145          FGET FN
3443 2134          FSUB FBUFO /NR TO RD-NR TO IGNORE
3444 6137          FPUT FDIVSR      /TO DIVISOR
3445 0000          FEXT
3446 1157          TAD P200
3447 1177          TAD N1
3450 1177          TAD N1

```

3451	1177	TAD N1	
3452	3167	DCA FSTAD	/INIT STAD
3453	1176	TAD N	
3454	7041	CIA	/NEGATE
3455	1177	TAD N1	
3456	4756	JMS I FS	
3457	4421	JMS I MESAJ	/GET SUM
3460	4543	4543	
3461	2325	2325	
3462	1575	1575	
3463	0000	0	
3464	1076	TAD FHUN	
3465	3062	DCA 62	
3466	7001	IAC	
3467	3063	DCA 63	
3470	4406	JMS I 6	
3471	4426	JMS I TB	
3472	4421	JMS I MESAJ	
3473	1505	1505	/MEAN=
3474	0116	0116	
3475	7500	7500	
3476	4757	JMS I DVIDR	/GET NBAR
3477	1154	TAD P2	
3500	4406	JMS I 6	/TYPE IT
3501	6032	KCC	
3502	1170	TAD FLINPT	
3503	3004	DCA 4	
3504	7040	CMA	
3505	3056	DCA 56	
3506	1024	TAD P4	
3507	3062	DCA DIGITZ	
3510	7001	IAC	
3511	3063	DCA DEZMAL	
3512	4774	JMS I LIM	/GET % LIMIT
3513	4775	JMS I SA	/GET STARTING ADD
3514	4431	JMS I LAD	/LIST ADDRESS?
3515	1003	TAD M3	
3516	4433	JMS I ZER	
3517	0114	114	
3520	1176	TAD N	
3521	7041	CIA	
3522	1166	TAD ADREZ	
3523	3064	DCA C	
3524	3002	DCA GOOFS	/O THE ERROR TALLY
3525	1166	TAD ADREZ	

REPEAT,

3526	3165		DCA ADRES
3527	1157		TAD P200 /INITIALIZE
3530	1166		TAD ADREZ
3531	1166		TAD ADREZ
3532	1166		TAD ADREZ
3533	3164	CACD,	DCA STAD
3534	4776		JMS I CLIMT /CALCULATE LIMITS
3535	4777		JMS I CKLM /CHECK FOR ERROR
3536	2165		ISZ ADRES /INC AD
3537	1164		TAD STAD
3540	1155		TAD P3
3541	2064		ISZ C /FINISHED
3542	5333		JMP CACD /NO,CONTINUE
3543	4421		JMS I MESAJ
3544	4543		4543
3545	0522		0522
3546	2217		2217
3547	2223		2223
3550	7500		7500
3551	1002		TAD GOOFS
3552	4423		JMS I DPRT
3553	4430		JMS I TR
3554	7402		HLT
3555	5312		JMP REPEAT
3556	3642	FS,	FSUMR
3557	4350	DVIDR,	DVIDER
3560	0000	REGLAR,	0
3561	1172		TAD D2
3562	7640		SZA CLA
3563	5366		JMP .+3
3564	1373		TAD .+7
3565	3574		DCA I DUMY
3566	4570		JMS I FLINPT
3567	1060		TAD 60
3570	7650		SNA CLA
3571	5366		JMP .-3
3572	5760		JMP I REGLAR
3573	7410		SKP
3574	4307	LIM,	PERLIM
3575	4340	SA,	STRAD
3576	4322	CLIMT,	CALIMT
3577	4252	CKLM,	CHKLIM

3.6.4 Routine that Allows Reading of Different Tape Formats

```

*3600
3600 0000 UNIVER, 0
3601 2150      ISZ INSW
3602 5222      JMP ON
3603 3056      DCA 56
3604 3005      DCA C3
3605 3126      DCA XBUF
3606 1236      TAD DWORD
3607 3573      DCA I DUM
3610 4430 CRLF, JMS I TR
3611 1172      TAD D2
3612 7440      SZA
3613 5217      JMP .+4
3614 1216      TAD .+2
3615 3574      DCA I DUMY
3616 7410      SKP
3617 7001      IAC
3620 7041      CIA
3621 3065      DCA C1
3622 2065 ON,  ISZ C1
3623 7410      SKP
3624 5210      JMP CRLF
3625 1036 IN,  TAD M5
3626 3066      DCA C2
3627 4570      JMS I FLINPT
3630 1066      TAD C2
3631 7700      SMA CLA
3632 5600      JMP I UNIVER
3633 5225      JMP IN
3634 4225 PARCH, PARCK
3635 0375 ALT,  375
3636 4571 DWORD, JMS I D1
3637 0027 P27,  27
3640 0040 P40,  40
3641 0057 P57,  57
3642 0000 FSUMR, 0
3643 3271      DCA DUM1
3644 4407      JMS I 7
3645 5112      FGET SUMY
3646 1567      FADD I FSTAD
3647 6112      FPUT SUMY
3650 0000      FEXT

```

3651	2167	ISZ FSTAD
3652	2167	ISZ FSTAD
3653	2167	ISZ FSTAD
3654	2271	ISZ DUM1
3655	5244	JMP FSUMR+2
3656	5642	JMP I FSUMR
3657	0000	BUFDIG, 0
3660	3012	DCA 12
3661	1175	TAD DEPOZ
3662	3425	DCA I P7347
3663	7001	IAC
3664	4406	JMS I 6
3665	1153	TAD SLT
3666	3425	DCA I P7347
3667	4434	JMS I ADEC
3670	5657	JMP I BUFDIG
3671	0000	DUM1, 0
3672	3057	DCA 57
3673	4634	JMS I PARCH
3674	1057	TAD 57
3675	0037	AND P177
3676	7450	SNA
3677	5350	JMP EXIT-1
3700	3057	DCA 57
3701	1057	TAD 57
3702	7041	CIA
3703	1163	TAD P12
3704	7450	SNA
3705	5367	JMP ALF
3706	1155	TAD P3
3707	7450	SNA
3710	5367	JMP ALF
3711	7001	IAC
3712	7450	SNA
3713	5371	JMP TMCSP
3714	1154	TAD P2
3715	7450	SNA
3716	5346	JMP EXIT-3
3717	1160	TAD P17
3720	7450	SNA
3721	5350	JMP EXIT-1
3722	7001	IAC
3723	7450	SNA
3724	5352	JMP LOOK
3725	1160	TAD P17

3726	7450		SNA
3727	5357		JMP TMCR
3730	1241		TAD P57
3731	7450		SNA
3732	5365		JMP ALF-2
3733	1237		TAD P27
3734	7450		SNA
3735	5365		JMP ALF-2
3736	1163		TAD P12
3737	7650		SNA CLA
3740	5374		JMP SET
3741	2066	DATA,	ISZ C2
3742	7000		NOP
3743	1057		TAD 57
3744	0160		AND P17
3745	1161		TAD P20
3746	1240		TAD P40
3747	1157		TAD P200
3750	3057		DCA 57
3751	5671	EXIT,	JMP I DUM1
3752	1126	LOOK,	TAD XBUF
3753	7640		SZA CLA
3754	5341		JMP DATA
3755	3065		DCA C1
3756	5346		JMP EXIT-3
3757	1005	TMCR,	TAD C3
3760	7650		SNA CLA
3761	5364		JMP .+3
3762	4430		JMS I TR
3763	5225		JMP IN
3764	7040		CMA
3765	3005		DCA C3
3766	5346		JMP EXIT-3
3767	1057	ALF,	TAD 57
3770	5347		JMP EXIT-2
3771	3005	TMCR,	DCA C3
3772	3057		DCA 57
3773	5346		JMP EXIT-3
3774	7040	SET,	CMA
3775	3126		DCA XBUF
3776	1235		TAD ALT
3777	5350		JMP EXIT-1


```

*5360
5360 0000 TCR, 0
5361 4421 JMS I MESAJ
5362 4543 4543
5363 0000 0
5364 5760 JMP I TCR
5365 0000 TTB, 0
5366 4421 JMS I MESAJ
5367 4040 4040
5370 4040 4040
5371 4000 4000
5372 5765 JMP I TTB
5373 0000 TSP, 0
5374 4421 JMS I MESAJ
5375 4000 4000
5376 5773 JMP I TSP

```

3.6.5 /Routine for Reduction of Statistical Data such as that Obtained with Plastic Scintillators

```

*4000
4000 1024 MOAK, TAD P4
4001 3062 DCA 62
4002 1176 TAD N /NR OF CH TO RD TO AC
4003 7041 CIA /NEGATE
4004 3064 DCA C /SAVE
4005 1157 TAD P200
4006 3167 LOOP, DCA FSTAD
4007 4404 JMS I 4 /GET A WORD
4010 4407 JMS I 7 /ENTER FP
4011 1101 FADD TSUM /ADD OFLO
4012 6567 FPUT I FSTAD /SAVE
4013 0000 FEXT
4014 1167 TAD FSTAD
4015 1155 TAD P3 /INCR ADD
4016 2064 ISZ C /FINISHED?
4017 5206 JMP LOOP /NO, GOURD HEAD
4020 4432 JMS I FLO /YES, REPAIR FP
4021 7240 CLA CMA
4022 3056 DCA 56
4023 4430 JMS I TR
4024 7402 HLT
4025 6032 KCC
4026 4774 ITER8, JMS I LM
4027 4426 JMS I TB
4030 4421 JMS I MESAJ
4031 0303 0303 /GET NR OF CH TO COMPARE
4032 7500 7500
4033 4420 JMS I INSCI
4034 3176 DCA N /SAVE
4035 4422 JMS I FXINP /CONV TO FP
4036 4407 JMS I 7
4037 6145 FPUT FN /SAVE IN FN
4040 0000 FEXT
4041 4426 JMS I TB
4042 4421 JMS I MESAJ /RANGE-
4043 2275 2275
4044 0000 0
4045 4420 JMS I INSCI
4046 7041 CIA
4047 3177 DCA N1

```

4050	4422	JMS I FXINP	/ALSO CONV RANGE TO FP
4051	4407	JMS I 7	
4052	6137	FPUT FDIVSR	
4053	1137	FADD FDIVSR	
4054	6137	FPUT FDIVSR	
4055	5070	FGET FPO	
4056	6120	FPUT SUMPR	
4057	0000	FEXT	/MULT BY 2 AND SAVE
4060	1371	TAD JAMS	
4061	3344	DCA SIG	
4062	4775	JMS I SAD	
4063	4431	JMS I LAD	/LIST ADD?
4064	1155	TAD P3	
4065	7041	CIA	
4066	3065	DCA C1	
4067	4407	JMS I 7	
4070	5120	FGET SUMPR	
4071	1073	FADD FP1	
4072	6120	FPUT SUMPR	
4073	5070	FGET FPO	
4074	6104	FPUT TSUMP	
4075	0000	FEXT	/O TO ERROR TALLY
4076	3002	DCA GOOFS	
4077	1176	TAD N	
4100	7041	CIA	
4101	3064	DCA C	
4102	1166	TAD ADREZ	
4103	3165	DCA ADRES	
4104	1166	TAD ADREZ	
4105	1166	TAD ADREZ	
4106	1166	TAD ADREZ	
4107	1157	TAD P200	
4110	3164	DCA STAD	
4111	1003	TAD M3	
4112	4433	JMS I ZER	
4113	0111	SUMY-1	
4114	1177	TAD N1	/3(-N1) TO AC
4115	1177	TAD N1	
4116	1177	TAD N1	
4117	1164	TAD STAD	/+STAD
4120	3167	DCA FSTAD	
4121	1177	TAD N1	
4122	4772	JMS I FSR	/SUM N1 CHS
4123	1164	TAD STAD	
4124	1155	TAD P3	
4125	3167	DCA FSTAD	

4126	1177		TAD N1
4127	4772		JMS I FSR /SUM N1 CHS ON UPPER SIDE
4130	4773		JMS I VIDR
4131	4776		JMS I CLIM
4132	4777		JMS I CKIM
4133	2165		ISZ ADRES
4134	1164		TAD STAD
4135	1155		TAD P3
4136	2064		ISZ C /FINISHED?
4137	5310		JMP STWK /NO, KEEP WORKING
4140	4421		JMS I MESAJ
4141	4543		4543
4142	1676		1676
4143	2014		2014
4144	5361	SIG,	5361
4145	2311		2311
4146	0715		0715
4147	0175		0175
4150	0000		0
4151	1002		TAD GOOFS
4152	4423		JMS I DPRT
4153	4426		JMS I TB
4154	4407		JMS I 7
4155	5104		FGET TSUMP
4156	4145		FDIV FN
4157	3076		FMPY FHUN
4160	0000		FEXT
4161	1154		TAD P2
4162	4406		JMS I 6
4163	2344		ISZ SIG
4164	4430		JMS I TR
4165	2065		ISZ C1
4166	5267		JMP ITRATE
4167	7402		HLT
4170	5226		JMP ITER8
4171	5361	JAMS,	5361
4172	3642	FSR,	FSUMR
4173	4350	VIDR,	DVIDER
4174	4307	LM,	PERLIM
4175	4340	SAD,	STRAD
4176	4322	CLIM,	CALIMT
4177	4252	CKIM,	CHKLIM

3.6.6 Output Routine

/ENTER WITH NR OF WORDS TO LINE IN WRD LIN, NR OF DIGITS
/TO WORD IN 62, NR OF PLACES TO RIGHT OF DECIMAL IN DEZMAL

```

*4200
4200 0000 OUTPUT, 0
4201 2151 ISZ OUTSW
4202 5207 JMP CACL
4203 1001 TAD WRDLIN
4204 7041 CIA
4205 3307 DCA PERLIM
4206 4430 JMS I TR
4207 1152 CACL, TAD PRSW
4210 7650 SNA CLA
4211 5215 JMP .+4 /DO NOT PRINT ADDRESS
4212 1165 TAD ADRES /PR ADD
4213 4423 JMS I DPRT
4214 4427 JMS I TS
4215 1063 TAD DEZMAL
4216 4406 JMS I 6
4217 4427 JMS I TS
4220 2307 ISZ PERLIM
4221 5600 JMP I OUTPUT /EXIT
4222 7240 CLA CMA
4223 3151 DCA OUTSW
4224 5221 JMP .-3
4225 0000 PARCK, 0
4226 3017 DCA 17
4227 1251 TAD M10
4230 3015 DCA 15
4231 1057 TAD 57
4232 7110 RAR CLL
4233 7430 SZL
4234 2017 ISZ 17
4235 2015 ISZ 15
4236 5232 JMP .-4
4237 1017 TAD 17
4240 7010 RAR
4241 0000 PARITY, 0
4242 5625 JMP I PARCK
4243 4430 JMS I TR
4244 1176 TAD N
4245 1064 TAD C
4246 4423 JMS I DPRT
4247 4430 JMS I TR

```

4250	5625		JMP I PARCK	
4251	7770	M10,	7770	
4252	0000	CHKLIM,	0	
4253	4407		JMS I 7	
4254	5564		FGET I STAD	
4255	2134		FSUB FBUFO	
4256	0000		FEXT	
4257	1045		TAD 45	
4260	7740		SMA SZA CLA	/TOO BIG?
4261	5271		JMP .+10	/YES
4262	4407		JMS I 7	
4263	5564		FGET I STAD	
4264	2131		FSUB FBUFI	
4265	0000		FEXT	/IF N-LL=>0, IT'S OK
4266	1045		TAD 45	
4267	7700		CLA SMA	/IS N TOO SMALL?
4270	5652		JMP I CHKLIM	/NO, OK
4271	4407		JMS I 7	
4272	3076		FMPY FHUN	
4273	4123		FDIV SUMX	
4274	0000		FEXT	
4275	1152		TAD PRSW	
4276	7640		SZA CLA	
4277	4200		JMS OUTPUT	/YES
4300	4407		JMS I 7	
4301	5104		FGET TSUMP	
4302	1073		FADD FPI	
4303	6104		FPUT TSUMP	
4304	0000		FEXT	
4305	2002		ISZ GOOFS	
4306	5652		JMP I CHKLIM	
4307	0000	PERLIM,	0	
4310	4421		JMS I MESAJ	
4311	4543		4543	
4312	2014		2014	
4313	7500		7500	
4314	4570		JMS I FLINPT	
4315	4407		JMS I 7	
4316	4076		FDIV FHUN	
4317	6142		FPUT DEL	
4320	0000		FEXT	
4321	5707		JMP I PERLIM	
4322	0000	CALIMT,	0	
4323	4407		JMS I 7	
4324	5123		FGET SUMX	
4325	3142		FMPY DEL	

4326	6131		FPUT FBUFI
4327	1123		FADD SUMX
4330	1115		FADD SUMSQ /MEAN +FL+K*SQRT MEAN
4331	6134		FPUT FBUFO /TO UPPER LIMIT
4332	5123		FGET SUMX /MEAN-(FL+K*SIGMA)
4333	2131		FSUB FBUFI
4334	2115		FSUB SUMSQ
4335	6131		FPUT FBUFI /TO LOWER LIMIT
4336	0000		FEXT
4337	5722		JMP I CALIMT
4340	0000	STRAD,	0
4341	4426		JMS I TB
4342	4421		JMS I MESAJ
4343	2301		2301 /START ADD
4344	7500		7500
4345	4420		JMS I INSCI
4346	3166		DCA ADREZ
4347	5740		JMP I STRAD
			SQRT=2
4350	0000	DVIDER,	0
4351	4407		JMS I 7
4352	5112		FGET SUMY
4353	4137		FDIV FDI VSR
4354	6123		FPUT SUMX
4355	0002		SQRT
4356	3120		FMPY SUMPR
4357	6115		FPUT SUMSQ
4360	5123		FGET SUMX /NBAR TO FPAC
4361	0000		FEXT
4362	5750		JMP I DVIDER
4363	0000	LISTAD,	0
4364	4426		JMS I TB
4365	4421		JMS I MESAJ
4366	1401		1401
4367	7500		7500
4370	4420		JMS I INSCI
4371	3001		DCA WRDLIN
4372	1001		TAD WRDLIN
4373	3152		DCA PRSW
4374	7240		CLA CMA
4375	3151		DCA OUTSW
4376	4430		JMS I TR
4377	5763		JMP I LISTAD

3.6.7 Routine for Inputting ASCII and Conversion to BCD

```

*4400
4400 0000 INASCI, 0
4401 1156 TAD P147
4402 3012 DCA 12
4403 4747 MORE, JMS I KON
4404 3412 DCA I 12
4405 1057 TAD 57
4406 1363 TAD SPACE
4407 1364 TAD MPLUS
4410 7450 SNA
4411 5203 JMP MORE
4412 1367 TAD MINUS
4413 7450 SNA
4414 5203 JMP MORE
4415 1362 TAD RUBOUT
4416 7650 SNA CLA
4417 5201 JMP INASCI+1
4420 1057 TAD 57
4421 1365 TAD M9
4422 7500 SMA
4423 5231 JMP DEC
4424 1163 TAD P12
4425 7710 SPA CLA
4426 5231 JMP DEC
4427 5203 RON, JMP MORE
4430 7402 HLT
4431 4233 DEC, JMS ASDEC
4432 5600 JMP I INASCI
4433 0000 ASDEC, 0
4434 7240 CLA CMA
4435 3333 DCA FIXFLO
4436 1156 TAD P147
4437 3012 DCA 12
4440 3057 DCA 57
4441 7200 D57, CLA
4442 1412 TAD I 12
4443 3322 DCA ZERON
4444 1322 TAD ZERON
4445 1363 TAD SPACE
4446 7450 SNA
4447 5241 JMP D57
4450 1364 TAD MPLUS

```

4451	7450		SNA
4452	5241		JMP D57
4453	1367		TAD MINUS
4454	7640		SZA CLA
4455	5260		JMP .+3
4456	3333		DCA FIXFLO
4457	5241		JMP D57
4460	1322		TAD ZERON
4461	1365		TAD M9
4462	7500		SMA
4463	5275		JMP AS
4464	1163		TAD P12
4465	7510		SPA
4466	5275		JMP AS
4467	3013		DCA 13
4470	1057		TAD 57
4471	7106		CLL RTL
4472	7006		RTL
4473	1013		TAD 13
4474	5240		JMP D57-1
4475	7200	AS,	CLA
4476	1057		TAD 57
4477	4766		JMS I BBIN
4500	2333		ISZ FIXFLO
4501	7041		CIA
4502	5633		JMP I ASDEC
4503	0000	FIXINP,	0
4504	1156		TAD P147
4505	3012		DCA 12
4506	1347		TAD KON
4507	3015		DCA 15
4510	1370		TAD INSERT-4
4511	3016		DCA 16
4512	1416	XINP,	TAD I 16
4513	7450		SNA
4514	5317		JMP .+3
4515	3415		DCA I 15
4516	5312		JMP XINP
4517	4570		JMS I FLINPT
4520	4432		JMS I FLO
4521	5703		JMP I FIXINP
4522	0000	ZERON,	0
4523	3013		DCA 13
4524	1722		TAD I ZERON
4525	3016		DCA 16

4526	2322		ISZ ZERON
4527	3416		DCA I 16
4530	2013		ISZ 13
4531	5327		JMP .-2
4532	5722		JMP I ZERON
4533	0000	FIXFLO,	0
4534	7200		CLA
4535	1347		TAD KON
4536	3010		DCA 10
4537	1350		TAD KON+1
4540	3341		DCA .+1
4541	0000		0
4542	7450		SNA
4543	5733		JMP I FIXFLO
4544	3410		DCA I 10
4545	2341		ISZ .-4
4546	5341		JMP .-5
4547	7142	KON,	7142
4550	1351		TAD KON+2
4551	7200		CLA
4552	6031		KSF
4553	5344		5344
4554	6036		KRB
4555	3057		DCA 57
4556	1057		TAD 57
4557	4766		4766
4560	1057		TAD 57
4561	0000		0
4562	7660	RUBOUT,	255-375
4563	7540	SPACE,	0-240
4564	7765	MPLUS,	240-253
4565	7506	M9,	0-272
4566	5257	BBIN,	BCDBIN
4567	7776	MINUS,	253-255
4570	4570		+.0
4571	1412		TAD I 12
4572	3057		DCA 57
4573	1057		TAD 57
4574	5742	INSERT,	5742
4575	0000		0

3.6.8 Routine for Calculation of Integral Linearity

```

/READ N OBSERVATIONS, CALCULATE THE CENTROIDS
/AND Y=MX +B USING LINEAR LEAST SQUARES METHOD
/CALCULATE AND LIST Y(CALC.)AND Y(C)-Y(OBS.)
*4600
4600 0012 THOU,      12
4601 3630          3630
4602 4200 OPUT,     OUTPUT
4603 2003 D,        2003
4604 4407 LSD,      JMS I 7
4605 4603          FDIV I D
4606 6137          FPUT FDIVSR
4607 3474          FMPY I FP1+1
4610 0000          FEXT
4611 1156          TAD P147
4612 4435          JMS I BUF
4613 7510          SPA
4614 7041          CIA
4615 3177          DCA N1
4616 1067          TAD M25
4617 4433          JMS I ZER
4620 0106          TYI-1
4621 1176          TAD N
4622 7041          CIA
4623 3064          DCA C
4624 1157          TAD P200
4625 3167 HERE,     DCA FSTAD
4626 1000          TAD M6
4627 4433          JMS I ZER
4630 0100          TSUM-1
4631 4404 THERE,    JMS I 4
4632 1045          TAD 45
4633 7650          SNA CLA
4634 5251          JMP INCY
4635 4407          JMS I 7
4636 6131          FPUT FBUFI
4637 1101          FADD TSUM
4640 6101          FPUT TSUM
4641 5107          FGET TYI
4642 1073          FADD FP1
4643 6107          FPUT TYI
4644 3131          FMPY FBUFI
4645 1104          FADD TSUMP
4646 6104          FPUT TSUMP
4647 0000          FEXT

```

4650	5231		JMP THERE
4651	4407	INCY,	JMS I 7
4652	5107		FGET TYI
4653	1073		FADD FP1
4654	6107		FPUT TYI
4655	5101		FGET TSUM
4656	2200		FSUB THOU
4657	0000		FEXT
4660	1045		TAD 45
4661	7710		SPA CLA
4662	5226		JMP HERE+1
4663	4407		JMS I 7
4664	5104		FGET TSUMP
4665	4101		FDIV TSUM
4666	6567		FPUT I FSTAD
4667	0000		FEXT
4670	2165		ISZ ADRES
4671	4602		JMS I OPUT
4672	1167		TAD FSTAD
4673	1155		TAD P3
4674	2064		ISZ C
4675	5225		JMP HERE
4676	7240		CLA CMA
4677	3056		DCA 56
4700	4432		JMS I FLO
4701	7402		HLT
4702	6032		KCC
			SQUARE=1
4703	1176	CALXY,	TAD N
4704	7041		CIA
4705	3064		DCA C
4706	1067		TAD M25
4707	4433		JMS I ZER
4710	0106		TYI-1
4711	1157		TAD P200
4712	3167	LOUP,	DCA FSTAD
4713	4407		JMS I 7
4714	5126		FGET XBUF
4715	1073		FADD FP1
4716	6126		FPUT XBUF
4717	1123		FADD SUMX
4720	6123		FPUT SUMX
4721	5126		FGET XBUF
4722	3567		FMPY I FSTAD
4723	1120		FADD SUMPR
4724	6120		FPUT SUMPR

4725	5567	FGET I FSTAD
4726	1112	FADD SUMY
4727	6112	FPUT SUMY
4730	5126	FGET XBUF
4731	0001	SQUARE
4732	1115	FADD SUMSQ
4733	6115	FPUT SUMSQ
4734	0000	FEXT
4735	1167	TAD FSTAD
4736	1155	TAD P3
4737	2064	ISZ C
4740	5312	JMP LOUP
4741	4407	JMS I 7
4742	5123	FGET SUMX
4743	3123	FMPY SUMX
4744	6126	FPUT XBUF
4745	5115	FGET SUMSQ
4746	3145	FMPY FN
4747	2126	FSUB XBUF
4750	6142	FPUT DEL
4751	5123	FGET SUMX
4752	3112	FMPY SUMY
4753	6126	FPUT XBUF
4754	5120	FGET SUMPR
4755	3145	FMPY FN
4756	2126	FSUB XBUF
4757	4142	FDIV DEL
4760	6101	FPUT TSUM /NOW =M
4761	5123	FGET SUMX
4762	3120	FMPY SUMPR
4763	6126	FPUT XBUF
4764	5115	FGET SUMSQ
4765	3112	FMPY SUMY
4766	2126	FSUB XBUF
4767	4142	FDIV DEL
4770	6104	FPUT TSUMP /B=C(TSUMP)
4771	0000	FEXT
4772	4430	JMS I TR
4773	4421	JMS I MESAJ
4774	0275	0275
4775	0000	0
4776	1154	TAD P2
4777	4406	JMS I 6

CALPAR,

5000	4407	JMS I 7
5001	5070	FGET FPO
5002	6126	FPUT XBUF
5003	5101	FGET TSUM
5004	0000	FEXT
5005	4421	JMS I MESAJ
5006	4015	4015
5007	7500	7500
5010	1154	TAD P2
5011	4406	JMS I 6
5012	4431	JMS I LAD
5013	1001	TAD WRDLIN
5014	7104	CLL RAL
5015	3001	DCA WRDLIN
5016	7240	CLA CMA
5017	3151	DCA OUTSW
5020	3165	DCA ADRES
5021	1176	TAD N
5022	7041	CIA
5023	3064	DCA C
5024	1157	TAD P200
5025	3167	DCA FSTAD
5026	4407	JMS I 7
5027	5126	FGET XBUF
5030	1073	FADD FP1
5031	6126	FPUT XBUF
5032	3101	FMPY TSUM
5033	1104	FADD TSUMP
5034	6131	FPUT FBUFI
5035	5567	FGET I FSTAD
5036	2131	FSUB FBUFI
5037	6134	FPUT FBUFFO
5040	5131	FGET FBUFFI
5041	0000	FEXT
5042	1076	TAD FHUN
5043	3062	DCA 62
5044	7040	CMA
5045	3152	DCA PRSW
5046	2165	ISZ ADRES
5047	4771	JMS I OUT
5050	4407	JMS I 7
5051	5134	FGET FBUFFO
5052	0000	FEXT
5053	1155	TAD P3

LOOPY,

5054	3062		DCA 62
5055	3152		DCA PRSW
5056	4771		JMS I OUT
5057	1001		TAD WRDLIN
5060	7650		SNA CLA
5061	4270		JMS PLOT
5062	1155		TAD P3
5063	1167		TAD FSTAD
5064	2064		ISZ C
5065	5225		JMP LOOPY
5066	7402		HLT
5067	5200		JMP LOOPY-25
5070	0000	PLOT,	0
5071	3151		DCA OUTSW
5072	4407		JMS I 7
5073	5134		FGET FBUFO
5074	2474		FSUB I FP1+1
5075	3137		FMPY FDI VSR
5076	0000		FEXT
5077	4427		JMS I TS
5100	1045		TAD 45
5101	7710		SPA CLA
5102	5345		JMP TYPE-1
5103	1373		TAD PLUS
5104	3366		DCA SYMBOL
5105	1156		TAD PI47
5106	4435		JMS I BUF
5107	7041		CIA
5110	3142		DCA DEL
5111	1142		TAD DEL
5112	1177		TAD N1
5113	7540		SMA SZA
5114	5333		JMP MINUZ
5115	1177		TAD N1
5116	7750		SPA SNA CLA
5117	5344		JMP TYPE-2
5120	1007		TAD 7
5121	3366		DCA SYMBOL
5122	1177		TAD N1

5123	7041		CIA
5124	4356		JMS PRINT
5125	1373		TAD PLUS
5126	3366		DCA SYMBOL
5127	7001		IAC
5130	1142		TAD DEL
5131	1177		TAD N1
5132	5353		JMP PRINT-3
5133	7650	MINUZ,	SNA CLA
5134	5346		JMP TYPE
5135	1142		TAD DEL
5136	4356		JMS PRINT
5137	1007		TAD 7
5140	3366		DCA SYMBOL
5141	7040		CMA
5142	1142		TAD DEL
5143	5351		JMP PRINT-5
5144	1157		TAD P200
5145	1372		TAD P14
5146	1157	TYPE,	TAD P200
5147	1007		TAD 7
5150	3366		DCA SYMBOL
5151	1177		TAD N1
5152	7041		CIA
5153	4356		JMS PRINT
5154	4430		JMS I TR
5155	5670		JMP I PLOT
5156	0000	PRINT,	0
5157	7500		SMA
5160	5365		JMP SYMBOL-1
5161	3002		DCA GOOFS
5162	4427		JMS I TS
5163	2002		ISZ GOOFS
5164	5362		JMP .-2
5165	4421		JMS I MESAJ
5166	0000	SYMBOL,	0
5167	7200		CLA
5170	5756		JMP I PRINT
5171	4200	OUT,	OUTPUT
5172	1400	P14,	1400
5173	5300	PLUS,	5300

3.6.9 Subroutines by DEC

```

/DIGITAL 8-18-U
/MESSAGE TYPE-OUT
/CALL WITH A JMS MESSAGE
/WITH DATA FOLLOWING
/RETURN FOLLOWING END OF MESSAGE
/CODE(00)

```

```

*5200
5200 0000 MESSAGE, 0
5201 7240 CLA CMA /SET C(AC)=-1
5202 1200 TAD MESSAGE /ADD LOCATION
5203 3010 DCA 10 /AUTO-INDEX REGISTER
5204 1410 TAD I 10 /FETCH FIRST WORD
5205 3216 DCA MSRGHT /SAVE IT
5206 1216 TAD MSRGHT
5207 7012 RTR
5210 7012 RTR /ROTATE 6 BITS RIGHT
5211 7012 RTR
5212 4217 JMS TYPECH /TYPE IT
5213 1216 TAD MSRGHT /GET DATA AGAIN
5214 4217 JMS TYPECH /TYPE RIGHT HALF
5215 5204 JMP MESSAGE+4 /CONTINUE
5216 0000 MSRGHT, 0 /TEMPORARY STORAGE

5217 0000 TYPECH, 0 /TYPE CHARACTER IN C(AC)6-11
5220 0250 AND MASK77
5221 7450 SNA /IS IT END OF MESSAGE?
5222 5410 JMP I 10 /YES: EXIT
5223 1251 TAD M40 /SUBTRACT 40
5224 7500 SMA /<40?
5225 5230 JMP .+3 /NO
5226 1252 TAD C340 /YES: ADD 300
5227 5243 JMP MTP /TO CODES <40
5230 1003 TAD M3 /SUBTRACT 3
5231 7440 SZA /IS IT ZERO?
5232 5235 JMP .+3 /NO
5233 1253 TAD C212 /YES: CODE 43 IS
5234 5243 JMP MTP /LINE-FEED (212)
5235 1254 TAD M2 /SUBTRACT 2
5236 7440 SZA /IS IT ZERO?
5237 5242 JMP .+3 /NO

```

5240	1255		TAD C215	/YES: CODE 45 IS
5241	5243		JMP MTP	/CARRIAGE-RETURN (215)
5242	1256		TAD C245	/ADD 200 TO OTHERS >40
5243	6041	MTP,	TSF	
5244	5243		JMP .-1	
5245	6046		TLS	
5246	7200		CLA	/SET: CLEAR C(AC)
5247	5617		JMP I TYPECH	/RETURN
/CONSTANTS				
5250	0077	MASK77,	77	
5251	7740	M40,	-40	
5252	0340	C340,	340	
5253	0212	C212,	212	
5254	7776	M2,	-2	
5255	0215	C215,	215	
5256	0245	C245,	245	

```

/BINARY-CODED-DECIMAL TO BINARY CONVERSION SUBROUTINE
5257 0000 BCDBIN, 0
5260 3310 DCA TEMPH /STORE INPUT
5261 1310 TAD TEMPH
5262 0305 AND LDIGIT
5263 7112 CLL RTR
5264 3307 DCA COUNT
5265 1307 TAD COUNT
5266 7010 RAR
5267 1307 TAD COUNT
5270 7041 CMA IAC
5271 1310 TAD TEMPH /160 H + 16 M + L
5272 3310 DCA TEMPH
5273 1310 TAD TEMPH
5274 0306 AND MDIGIT
5275 7112 CLL RTR
5276 3307 DCA COUNT
5277 1307 TAD COUNT
5300 7010 RAR
5301 1307 TAD COUNT /60 H + 6 M
5302 7041 CMA IAC
5303 1310 TAD TEMPH
5304 5657 JMP I BCDBIN /EXIT
5305 7400 LDIGIT, 7400
5306 7760 MDIGIT, 7760
5307 0000 COUNT, 0
5310 0000 TEMPH, 0

```

```

/DIGITAL 8-22-U
/UNSIGNED DECIMAL PRINT
/CALL WITH NUMBER TO BE TYPED IN C(AC)
/RETURN TO LOCATION FOLLOWING THE JMS
5311 0000 DECPRT, 0
5312 3353 DCA VALUE /SAVE INPUT
5313 3354 DCA DIGIT /CLEAR
5314 1346 TAD CNTRZA
5315 3355 DCA CNTRZB /SET COUNTER TO FOUR
5316 1345 TAD ADDRZA
5317 3324 DCA ARROW /SET TABLE POINTER
5320 7410 SKP
5321 3353 DCA VALUE /SAVE
5322 7100 CLL
5323 1353 TAD VALUE
5324 1347 ARROW, TAD TENPWR /SUBTRACT POWER OF TEN
5325 7430 SZL
5326 2354 ISZ DIGIT /DEVELOP BCD DIGIT
5327 7430 SZL
5330 5321 JMP ARROW-3 /LOOP
5331 7200 CLA /HAVE BCD DIGIT
5332 1354 TAD DIGIT /GET DIGIT
5333 1352 TAD K260 /MAKE IT ASCII
5334 6041 TSF /OR TAD DIGIT
5335 5334 JMP --1 / JMS TDIGIT(SEE 8-19-U)
5336 6046 TLS /TYPE DIGIT
5337 7200 CLA
5340 3354 DCA DIGIT /CLEAR
5341 2324 ISZ ARROW /UPDATE POINTER
5342 2355 ISZ CNTRZB /DONE ALL FOUR?
5343 5323 JMP ARROW-1 /NO: CONTINUE
5344 5711 JMP I DECPRT /YES: EXIT
5345 1347 ADDRZA, TAD TENPWR
5346 7775 CNTRZA, -3
5347 7634 TENPWR, -144 /ONE HUNDRED
5350 7766 -0012 /TEN
5351 7777 -0001 /ONE
5352 0260 K260, 260
5353 0000 VALUE, 0
5354 0000 DIGIT, 0
5355 0000 CNTRZB, 0

```

3.6.10 Listing of Symbols

ADDRZA	5345
ADEC	0034
ADRES	0165
ADREZ	0166
ADWORD	3334
ALF	3767
ALT	3635
ARROW	5324
AS	4475
ASDEC	4433
BBIN	4566
BCDBIN	5257
BEGIN	3200
BUF	0035
BUFDIG	3657
C	0064
CACD	3533
CACL	4207
CALIMT	4322
CALPAR	4741
CALXY	4703
CHKLIM	4252
CKIM	4177
CKLM	3577
CLIM	4176
CLIMT	3576
CNTRZA	5346
CNTRZB	5355
COMN	3320
COUNT	5307
CRLF	3610
C1	0065
C2	0066
C212	5253
C215	5255
C245	5256
C3	0005
C340	5252
D	4603
DATA	3741
DEC	4431
DECPRT	5311
DEL	0142

DEPOZ	0175
DEZMAL	0063
DIGIT	5354
DIGITZ	0062
DM	3305
DPRT	0023
DSTAD	3354
DUM	0173
DUMY	0174
DUM1	3671
DVIDER	4350
DVIDR	3557
DWORD	3636
D1	0171
D2	0172
D57	4441
EXIT	3751
FBUFI	0131
FBUFO	0134
FDIVSR	0137
FHUN	0076
FIXFLO	4533
FIXINP	4503
FLINPT	0170
FLO	0032
FN	0145
FPO	0070
FPI	0073
FS	3556
FSR	4172
FSTAD	0167
FSUMR	3642
FXINP	0022
GOOFS	0002
HALT	3341
HERE	4625
IN	3625
INASCI	4400
INCY	4651
INSCI	0020
INSERT	4574
INSW	0150
ITER8	4026
ITRATE	4067
JAMS	4171
KON	4547

K260	5352
LAD	0031
LDIGIT	5305
LIM	3574
LISTAD	4363
LM	4174
LOOK	3752
LOOP	4006
LOOPY	5025
LOUP	4712
LS	3343
LSD	4604
MASK77	5250
MDIGIT	5306
MESAGE	5200
MESAJ	0021
MINUS	4567
MINUZ	5133
MOAK	4000
MORE	4403
MPLUS	4564
MSRGHT	5216
MTP	5243
M10	4251
M2	5254
M25	0067
M3	0003
M40	5251
M5	0036
M6	0000
M9	4565
N	0176
NO	3202
N1	0177
ON	3622
OPUT	4602
OUT	5171
OUTPUT	4200
OUTSW	0151
PAR	3342

PARCH	3634
PARCK	4225
PARITY	4241
PERLIM	4307
PLOT	5070
PLUS	5173
PRINT	5156
PROCED	3327
PRSW	0152
P12	0163
P14	5172
P147	0156
P17	0160
P177	0037
P2	0154
P20	0161
P200	0157
P27	3637
P3	0155
P4	0024
P40	3640
P57	3641
P7347	0025
P77	0162
REGLAR	3560
REPEAT	3512
REPT	3423
RON	4427
RUBOIT	4562
SA	3575
SAD	4175
SET	3774
SIG	4144
SLT	0153
SPACE	4563
SQRT	0002
SQUARE	0001
STAD	0164
STRAD	4340
STWK	4110
SUMPR	0120
SUMSQ	0115
SUMX	0123
SUMY	0112
SYMBOL	5166
TB	0026
TCR	5360
TEMPH	5310
TENPWR	5347

THERE	4631
THOU	4600
TMCR	3757
TM CSP	3771
TR	0030
TS	0027
TSP	5373
TSUM	0101
TSUMP	0104
TTB	5365
TYI	0107
TYPE	5146
TYPECH	5217
UMCHOW	3400
UNIVER	3600
VALUE	5353
VIDR	4173
WRDLIN	0001
XBUF	0126
XINP	4512
ZER	0033
ZERON	4522

4. APPENDIX

4.1 Reference List for Program Abbreviations

The following is a quick reference to definitions of abbreviations:

PN=	/Program Number?
NW=	/Number of words to Input?
PY=	/Parity?
LI=	/List Input?
FM=	/Format Number?
IG=	/Number to ignore?
OF=	/Number of counts in overflow?
LA=	/Program 1 No. of centroids per line?
LA=	/Program 2 and 3 List addresses in error?
PL=	/Percent error limit?
SA=	/Address to start checking for errors?
CC=	/No. of channels to check for error?
R=	/Range?

4.2 Rim Loader Locations

7756/6032

7757/6031

7760/5357

7761/6036

7762/7106

7763/7006

7764/7510

7765/5357

7766/7006

7767/6031

7770/5367

7771/6034

7772/7420

7773/3776

7774/3376

7775/5356

7776/0000

7777/5275

4.3 Algorithm for Linear Least-Squares Fit

$$f(M, B) = \sum_{i=1}^n (MX_i + B - Y_i)^2$$

$$\begin{aligned} \frac{\partial f}{\partial M} &= \sum_{i=1}^n 2(MX_i + B - Y_i)X_i = 0 \\ \sum_{i=1}^n MX_i^2 + B \sum_{i=1}^n X_i - \sum_{i=1}^n X_i Y_i &= 0 \\ \sum_{i=1}^n X_i Y_i &= M \sum_{i=1}^n X_i^2 + B \sum_{i=1}^n X_i \end{aligned}$$

$$\begin{aligned} \frac{\partial f}{\partial B} &= \sum_{i=1}^n 2(MX_i + B - Y_i)1 = 0 \\ M \sum_{i=1}^n X_i + B \sum_{i=1}^n 1 - \sum_{i=1}^n Y_i &= 0 \\ \sum_{i=1}^n Y_i &= M \sum_{i=1}^n X_i + nB \end{aligned}$$

$$\Delta = \begin{vmatrix} \sum X_i & n \\ \sum X_i^2 & \sum X_i \end{vmatrix} = \sum_{i=1}^n X_i \sum_{i=1}^n X_i - n \sum_{i=1}^n X_i^2$$

$$\Delta M = \begin{vmatrix} \sum X_i Y_i & \sum X_i \\ \sum Y_i & n \end{vmatrix} = n \sum_{i=1}^n X_i Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n Y_i$$

$$\Delta B = \begin{vmatrix} \sum X_i^2 & \sum X_i Y_i \\ \sum X_i & \sum Y_i \end{vmatrix} = \sum_{i=1}^n X_i^2 \sum_{i=1}^n Y_i - \sum_{i=1}^n X_i \sum_{i=1}^n X_i Y_i$$

4.4 Tape Formats

Some of the tape formats that the input routine will read are illustrated in Fig. 1.

Figures 1a to c show three ASCII formats most frequently used. Actually no difficulty should be experienced in reading any ASCII type tapes as long as

- a. the address is delimited,
- b. the address contains no more than four digits,
- c. the data information contains at least five digits.

Figure 1d is a Nuclear Data format in which the digit zero is represented by the octal digits 40. This tape must be started so that at least one leader code (octal digits 177) is read before any data are read, otherwise these octal digits 40 will be interpreted as ASCII spaces.

Figure 1e is the Oracle format. There are several instruments at ORNL still using this type of paper tape output.

Figure 1f is a format in which the address is punched for each data word and is delimited by the octal characters 177.

Figure 1g is a TMC format where same precaution discussed for Fig. 1d applies. Also, the first word on this tape is an identification word and should be ignored. This is accomplished by simply ignoring information until the second carriage return, represented by the octal digits 57, is read.

Figure 1h shows a format that the routine will not read as written. Since the blanks that are used as word delimiters are ordinarily ignored, the following changes can be made to read this format.

Address	Usual Contents	Change To
3675	0037	7450
3676	7450	5346
3677	5350	0037

Fig. 1. Tape Formats.

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