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A Crystallographic Fourier Summation Programme
for the IBM 1620 Data Processing System.

G. S. D. King and D. van der Helm (Chemistry
Department, University of Oklahoma).

January 31, 1963

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Abstract

This programme carries out two- and three-dimensional crystallographic Fourier summations. Input is from cards and output is numerically by cards or typewriter or as an alphameric plot by typewriter.

Machine requirements : Basic 20 K 1620 with card input/output. No additional features are required.

Programme details : The programme is written in SPS I and uses only fixed-point arithmetic. A Beavers-Lipson method is used for the summation. The first summation is carried out for a given value of x as the data are read in. The results are held in storage until all values for one kl have been treated. These are used directly in the second summation whose results are stored. The third summation is calculated and punched (printed) line by line. The data are read in again for the next value of x which is calculated automatically.

Range : Indices may not exceed 99. The summations are calculated at intervals of $n/100$ of the cell edge where n is any integer.

Storage requirements : The programme and working storage take up the whole machine. The first active statement in the symbolic programme defines the machine size so that the programme may be assembled to take advantage of any size machine. In a 20K machine 14388 storage positions are available to hold from 1797 to 1748 second summation results (e. g. a complete summation of 101 points with a maximum l index of 16) with from 3 to 101 third summation results.

Running time depends on the magnitude of the problem. An example is given in the text.

Remarks : A programme (ERA 235) is available to prepare the input of this programme from structure factor programme (ERA 164) output cards for any triclinic, monoclinic or orthorhombic space group except $Fdd2$ and $Fddd$.

1. Introduction

This programme has been written for the IBM 1620 data processing system with card input and output to carry out three- (and two-)dimensional Fourier summations for crystal structure analysis. It can be used to calculate electron or vector density at intervals of any desired multiple of one hundredth of the unit cell in each direction. The results are obtained as any or all of punched cards, numerical list or alphanumeric plot.

The programme was originally written (by DvdH while at the Institute for Cancer Research, Philadelphia, Pa., USA) for a 1620 with tape input and output (programme ICR1) and has been modified (by GSDK) to use card input and output and at the same time to increase the available working storage.

II. General Theory

The electron density can be evaluated at any point xyz (fractional coordinates are used throughout) of the unit cell by the expression :

$$\rho(xyz) = \frac{2}{V} \sum_{h=0}^{\infty} \sum_{k=0}^{\infty} \sum_{l=0}^{\infty} [A'(hkl)\cos 2\pi(hx+ky+lz) + B'(hkl)\sin 2\pi(hx+ky+lz)] \quad \text{II, 1}$$

It is impracticable to use this expression directly because of the amount of calculation involved. Thus in the case of a centrosymmetric space group with 2000 Fourier coefficients it would take the IBM 1620 about 140 hours to calculate a summation over 25x25x50 points.

The expression II, 1 can be rewritten following Lipson and Beevers (Proc. Phys. Soc., 1936, 48, 772) in the form :

$$\begin{aligned} \rho(xyz) = & \frac{1}{V} \sum_{l=0}^{\infty} \left[\sum_{k=0}^{\infty} \left\{ \sum_{h=0}^{\infty} (A(hkl)\cos 2\pi hx + E(hkl)\sin 2\pi hx)\cos 2\pi ky \right. \right. \\ & \left. \left. + \sum_{h=0}^{\infty} (F(hkl)\cos 2\pi hx + B(hkl)\sin 2\pi hx)\sin 2\pi ky \right\} \cos 2\pi lz \right. \\ & \left. + \sum_{k=0}^{\infty} \left\{ \sum_{h=0}^{\infty} (G(hkl)\cos 2\pi hx + C(hkl)\sin 2\pi hx)\cos 2\pi ky \right. \right. \\ & \left. \left. + \sum_{h=0}^{\infty} (D(hkl)\cos 2\pi hx + H(hkl)\sin 2\pi hx)\sin 2\pi ky \right\} \sin 2\pi lz \right] \quad \text{II, 2} \end{aligned}$$

$$\text{where } A = A'(hkl) + A'(\bar{h}kl) + A'(h\bar{k}l) + A'(\bar{h}\bar{k}l) \quad \text{II, 3}$$

$$B = -A'(hkl) + A'(\bar{h}kl) + A'(h\bar{k}l) - A'(\bar{h}\bar{k}l) \quad \text{II, 4}$$

$$C = -A'(hkl) + A'(\bar{h}kl) - A'(h\bar{k}l) + A'(\bar{h}\bar{k}l) \quad \text{II, 5}$$

$$D = -A'(hkl) - A'(\bar{h}kl) + A'(h\bar{k}l) + A'(\bar{h}\bar{k}l) \quad \text{II, 6}$$

$$E = B'(hkl) - B'(\bar{h}kl) + B'(h\bar{k}l) - B'(\bar{h}\bar{k}l) \quad \text{II, 7}$$

$$F = B'(hkl) + B'(\bar{h}kl) - B'(h\bar{k}l) - B'(\bar{h}\bar{k}l) \quad \text{II, 8}$$

$$G = B'(hkl) + B'(\bar{h}kl) + B'(h\bar{k}l) + B'(\bar{h}\bar{k}l) \quad \text{II, 9}$$

$$H = -B'(hkl) + B'(\bar{h}kl) + B'(h\bar{k}l) - B'(\bar{h}\bar{k}l) \quad \text{II, 10}$$

For centrosymmetric space groups $B(hkl) = 0$ and $A'(hkl)$ may be replaced by $F(hkl)$. The terms A, B...H should take account of multiplicity.

The use of the form (II, 2) reduces the number of arithmetic operations by a factor of about 15 at the expense of complicating the logical sequence of the programme. In fact it divides the calculation into three parts being the summations along the three reciprocal axes.

Define a set of terms A, B...H with the same indices hkl an amplitude and a set of amplitudes with the same indices kl a group.

In the first summation over h, sums (or pairs of sums) are calculated of all terms with different h indices in the same group kl and for all required values of x. Suppose we wish to calculate a Fourier synthesis with 1500 amplitudes in 250 groups and a maximum value of $l = 15$. Suppose further that we wish to calculate 26 sections each of 51×51 points. As each group gives rise to four sums (formula II, 2) for each value of x, there will be $250 \times 4 \times 26 = 26000$ first summation results. Similarly, for each y value there will be two sums for each l and each x giving $51 \times 2 \times 16 = 1616$ sums for each section or 42016 sums for all 26 sections.

It is clearly impossible to store all the first or second summation results in a computer of the size of the 1620. There remain two possible courses of action. One is to punch the first summation results on cards which can then be sorted and reintroduced for the subsequent calculations. The other is to calculate one section at a time and to reintroduce the data for subsequent sections. The latter course is the one chosen here as it involves no manipulation of intermediate results, and consequently fewer possibilities of operator error.

The four first summations are :

$$M(klX) = \sum_{h=0}^{h \text{ max}} [A(hkl)\cos 2\pi hX + E(hkl)\sin 2\pi hX] \quad \text{II, 11}$$

$$N(klX) = \sum_{h=0}^{h \text{ max}} [F(hkl)\cos 2\pi hX + B(hkl)\sin 2\pi hX] \quad \text{II, 12}$$

$$O(klX) = \sum_{h=0}^{h \text{ max}} [G(hkl)\cos 2\pi hX + C(hkl)\sin 2\pi hX] \quad \text{II, 13}$$

$$P(klX) = \sum_{h=0}^{h \text{ max}} [D(hkl)\cos 2\pi hX + H(hkl)\sin 2\pi hX] \quad \text{II, 14}$$

in which X is the value of x for the particular section. These four values are accumulated in temporary storage locations and, as soon as a group kl has been completed, are used in the 2nd summation to give :

$$R(lXy) = \sum_{k=0}^{k \text{ max}} M(klX)\cos 2\pi ky + N(klX)\sin 2\pi ky \quad \text{II, 15}$$

$$\text{and } S(lXy) = \sum_{k=0}^{k \text{ max}} O(klX)\cos 2\pi ky + P(klX)\sin 2\pi ky \quad \text{II, 16}$$

for all required values of y. These pairs of four-digit sums are accumulated in blocks of constant l each containing N_y results where N_y is the number of points required in the y direction. This procedure requires that the data be sorted into blocks of increasing l, each of which contains groups of increasing k.

The third summation is

$$\rho(Xyz) = \sum_{l=0}^{l \text{ max}} [R(lXy)\cos 2\pi lz + S(lXy)\sin 2\pi lz] \quad \text{II, 17}$$

All N_z four-digit sums are calculated for each line of constant y and are then typed or punched line by line.

The storage required is thus $8N_y \times (l_{\text{max}} + 1)$ locations for the second summation results and $4N_z$ locations for the third summation. In a 20K machine there are 14388 storage locations available so that it is possible to store at least 1748 second summation results. If fewer than 101 third summation results are required, this value will be greater.

The programme implies that sections are always calculated in the bc plane along rows parallel to c, which is not necessarily the most convenient presentation. It is possible to permute the indices hkl and the terms A-H to give any desired presentation. The permutations corresponding to the different presentations are given in Table II. A programme (ERA 235) is available to prepare input cards for this programme from structure factor output cards.

Table II.

Data formats for the different possible output orientations.

Input card format		Columns										Output format			
		7-8	9-10	11-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40	41-44	Sections on	Vertical coordinate	Horizontal coordinate
h	k	h	k	l	A	B	C	D	E	F	G	H	x	y	z
k	h	l	h	l	A	B	D	C	F	E	G	II	y	x	z
k	l	h	A	D	A	B	C	C	F	G	E	H	y	z	x
h	l	k	A	C	A	B	D	D	E	G	F	H	x	z	y
l	h	k	A	C	A	B	B	B	G	E	F	H	z	x	y
l	k	h	A	D	A	D	C	B	G	F	E	H	z	y	x
0	k	l	A	0	0	0	0	D	0	F	G	0	-	y	z
0	h	l	A	0	0	0	C	C	0	E	G	0	-	x	z
0	l	h	A	0	0	0	C	C	0	G	E	0	-	z	x
0	l	k	A	0	0	0	D	D	0	G	F	0	-	z	y
0	h	k	A	0	0	0	B	B	0	E	F	0	-	x	y
0	k	h	A	0	0	0	B	B	0	F	E	0	-	y	x

The data cards must always be sorted first on columns 9-10, then 11-12

Running time. It is almost impossible to give a formula which would express the running time in terms of the many parameters involved. The first summation takes less than 240 msec per card so the card reading speed is the determining factor and the running time depends directly on the number of cards. The second summation running time is proportional to the number of groups kl . The third summation calculating time, to which must be added the output time, is proportional to $(l_{\max}+1) \cdot N_y \cdot N_z$. Thus, in order to reduce running time to a minimum it is best to make N_y small; i. e. when only half a section is required it is faster to calculate for $y = 0(1) 0.50$ and $z = 0(1) 1.00$ than for $y = 0(1) 1.00$ and $z = 0(1) 0.50$.

As an example we give the timing of a particular run with 1735 hkl values (corresponding to 2632 hkl and $\bar{h}kl$ reflexions) in 127 different groups kl and with 14 different l values. For each section 51 rows each of 51 values were calculated.

First and second summations (giving 51×14 pairs of second summation results) : 9.75 min.

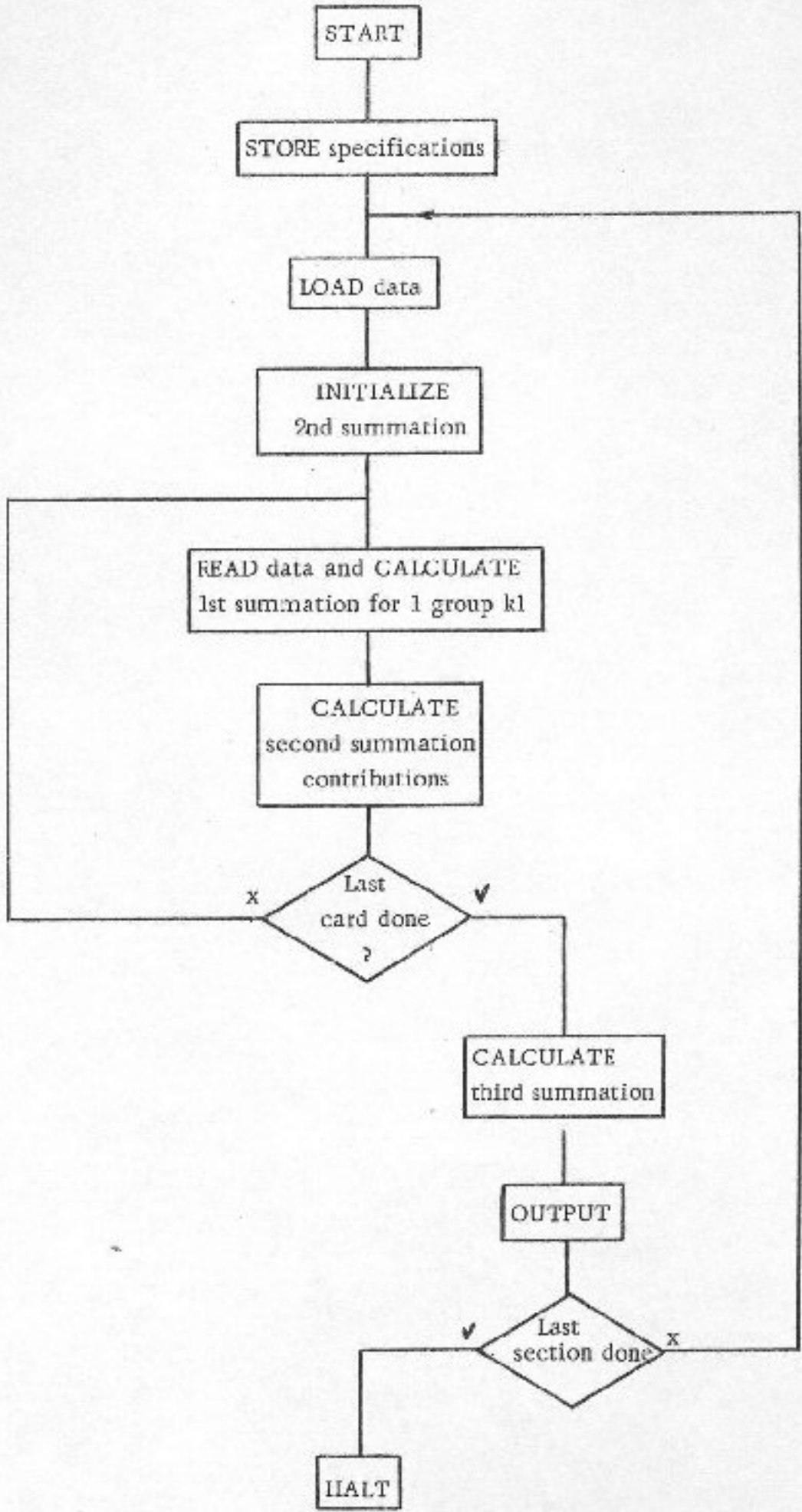
Third summation : 10.9 minutes.

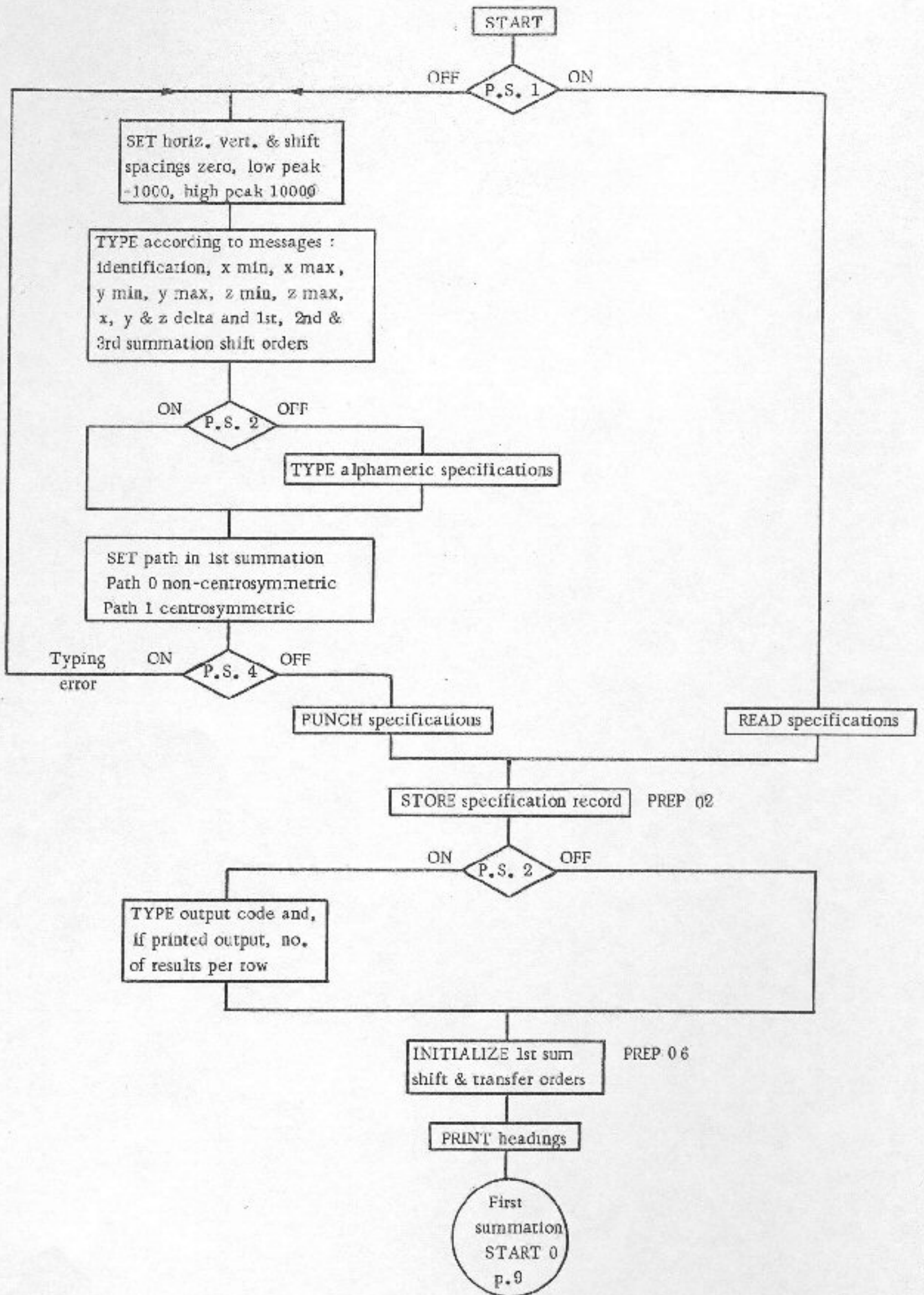
The READER NO FEED light was on continuously during the first summation (using a 250 c. p. m. card reader). It was extinguished at the end of each group kl while the second summation was being calculated.

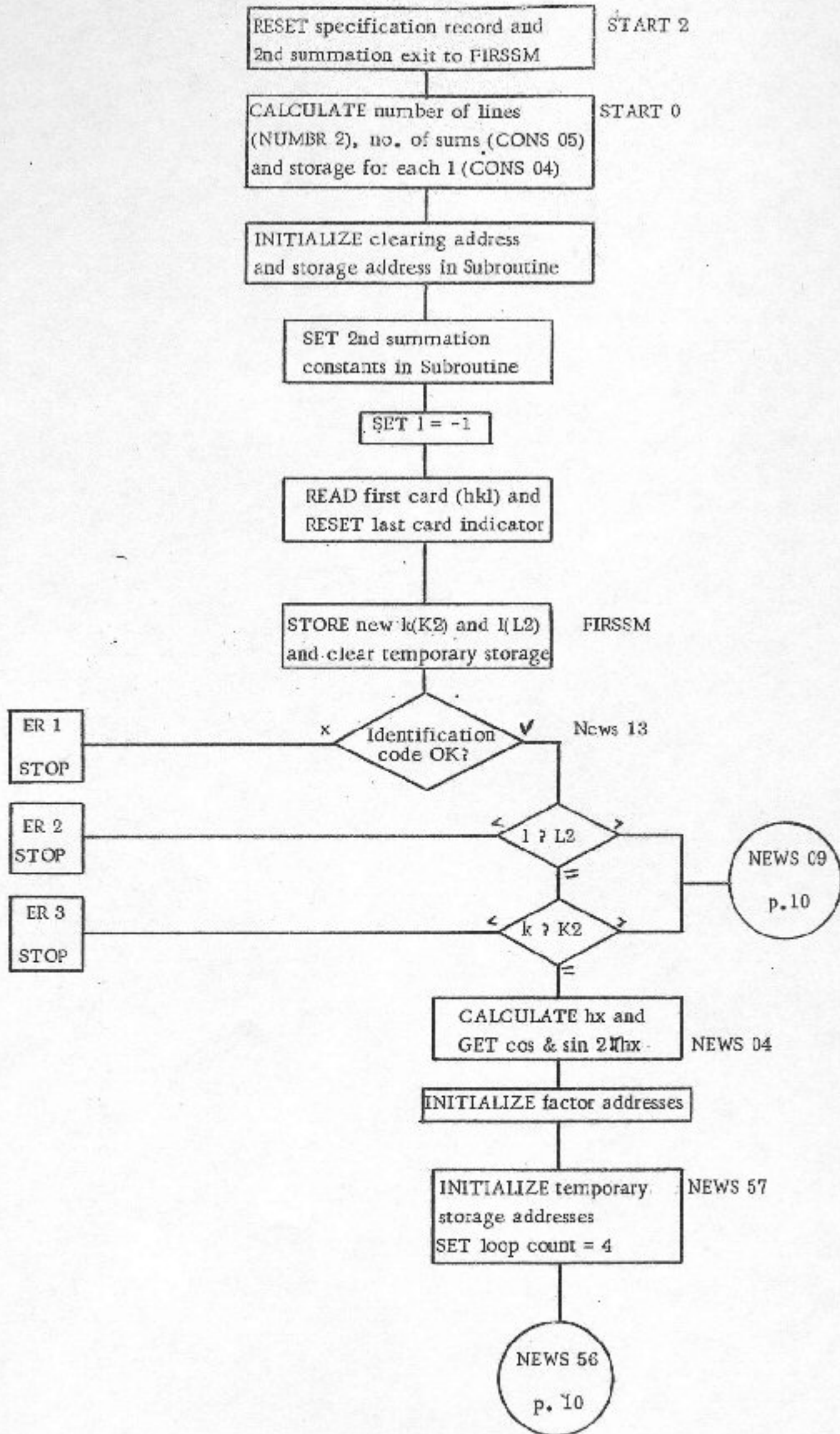
In the third summation results were punched only. Printing would greatly increase the time required.

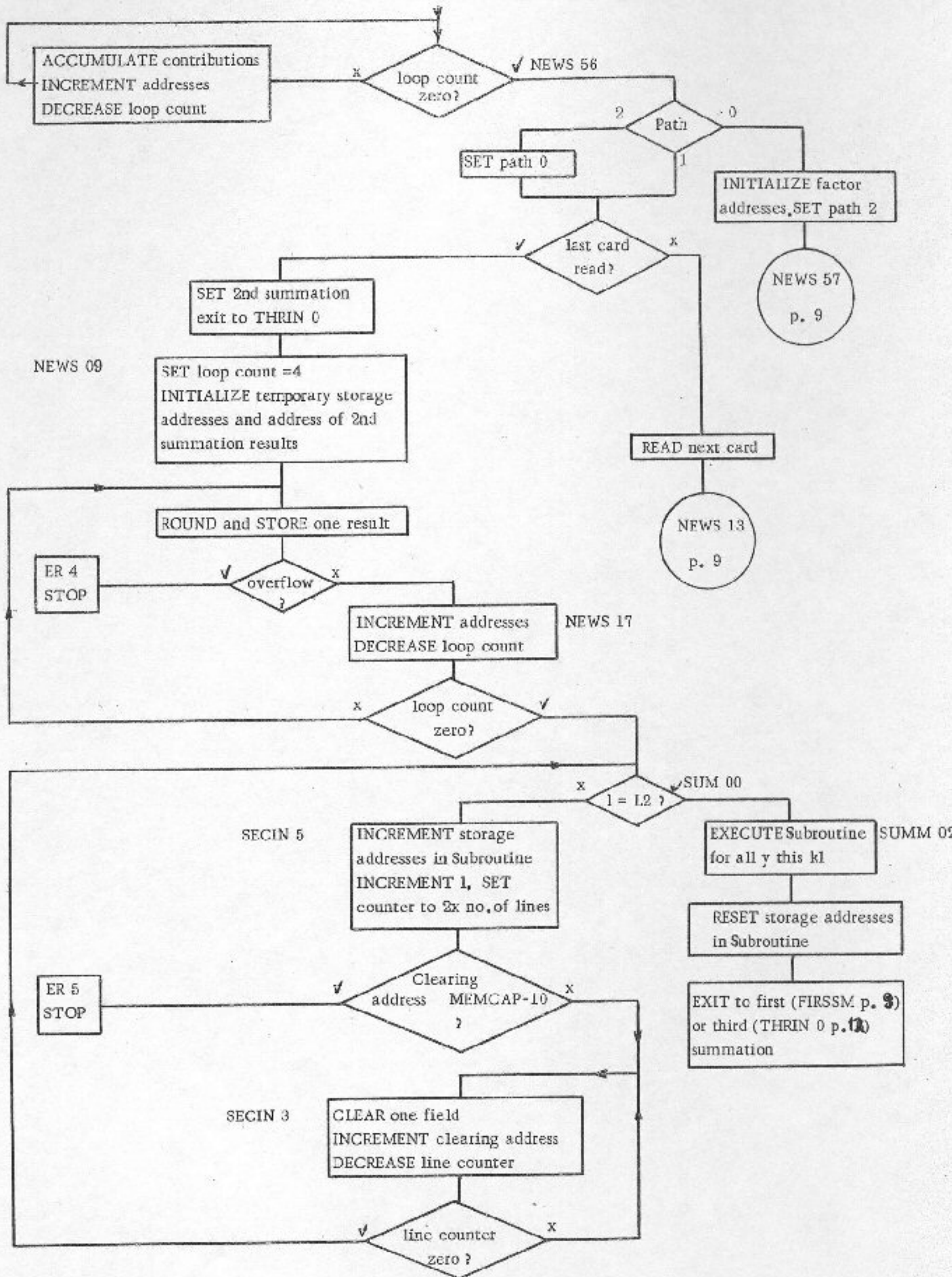
III. Flow charts.

General flow diagram.

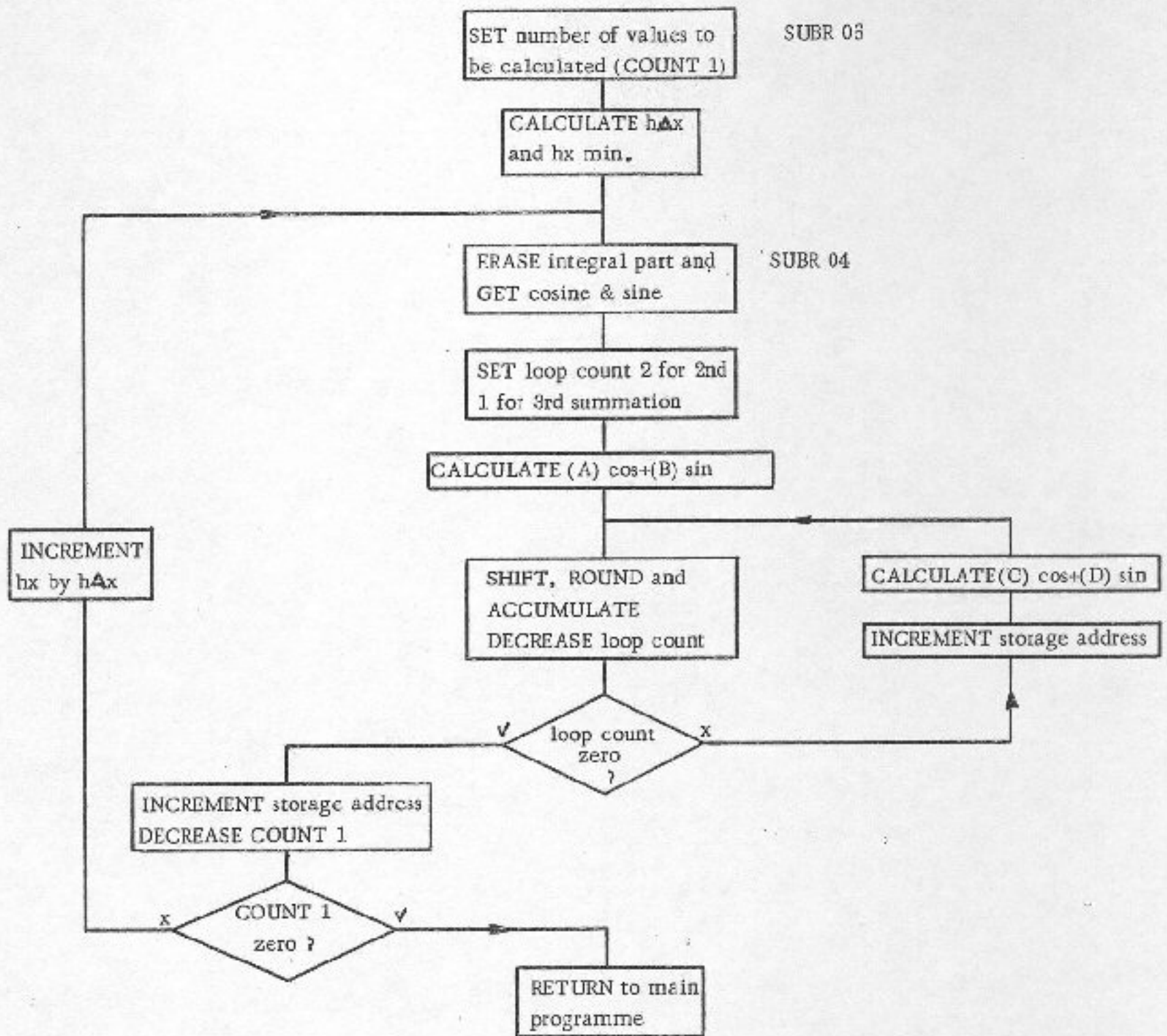


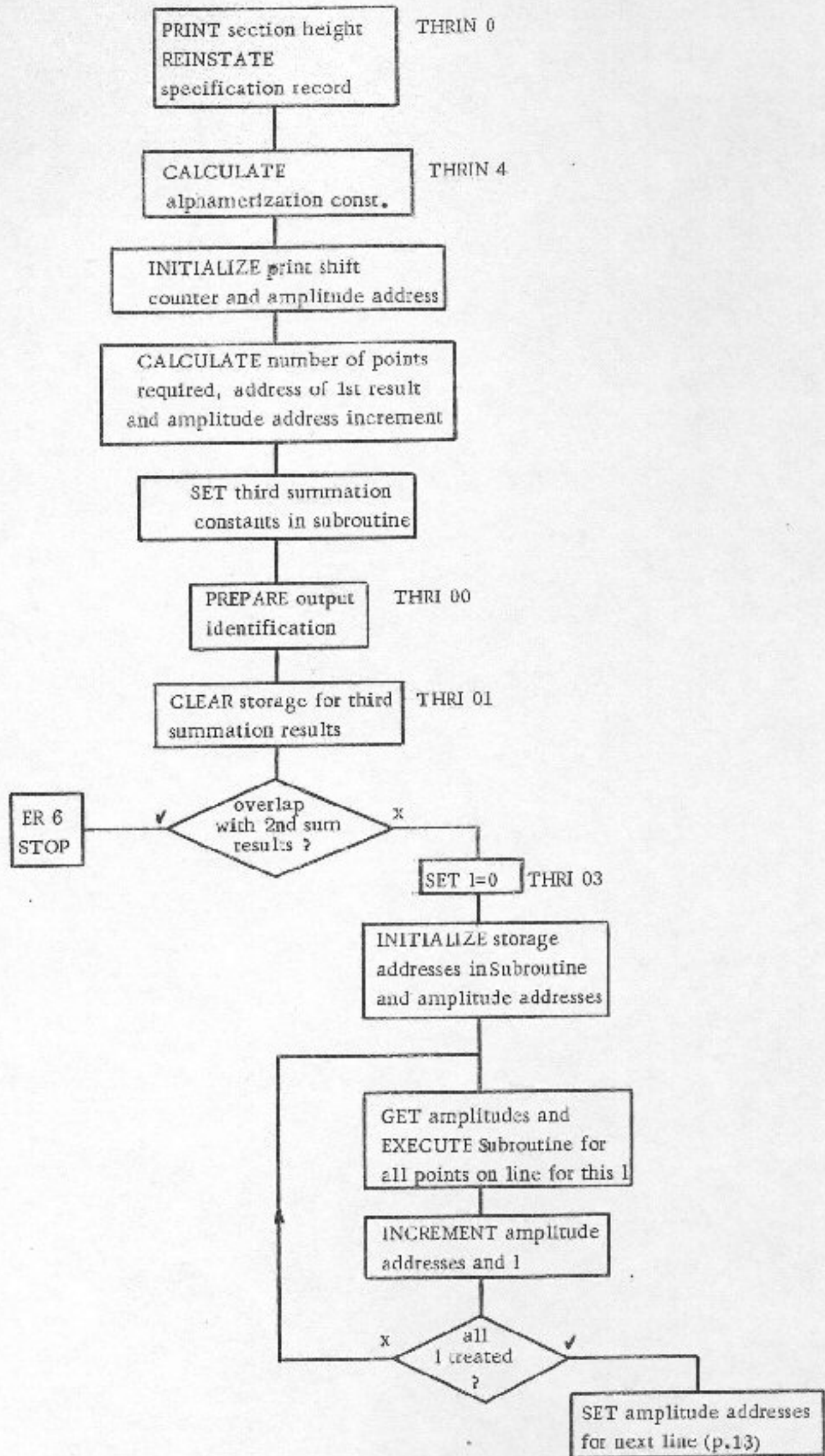


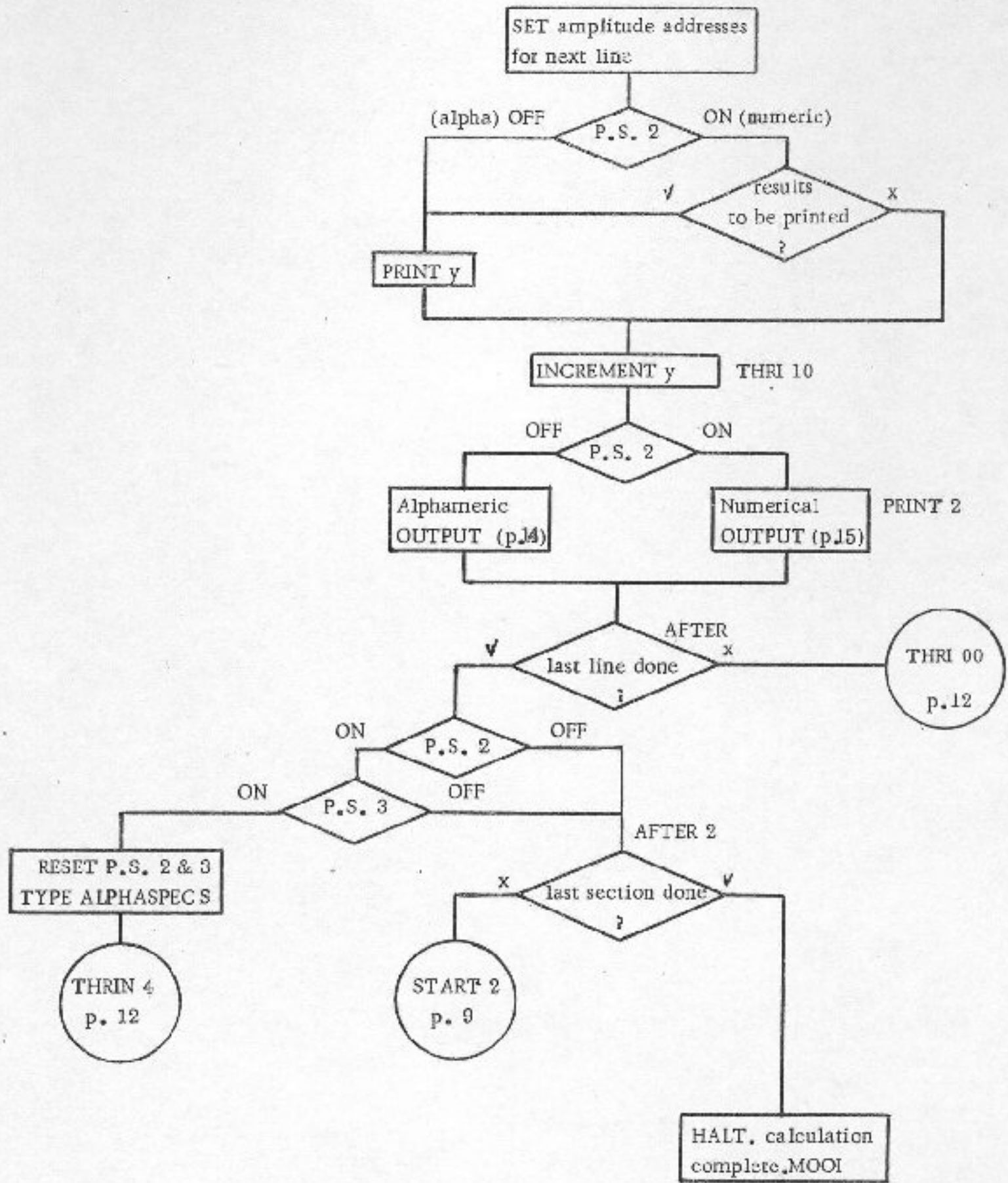


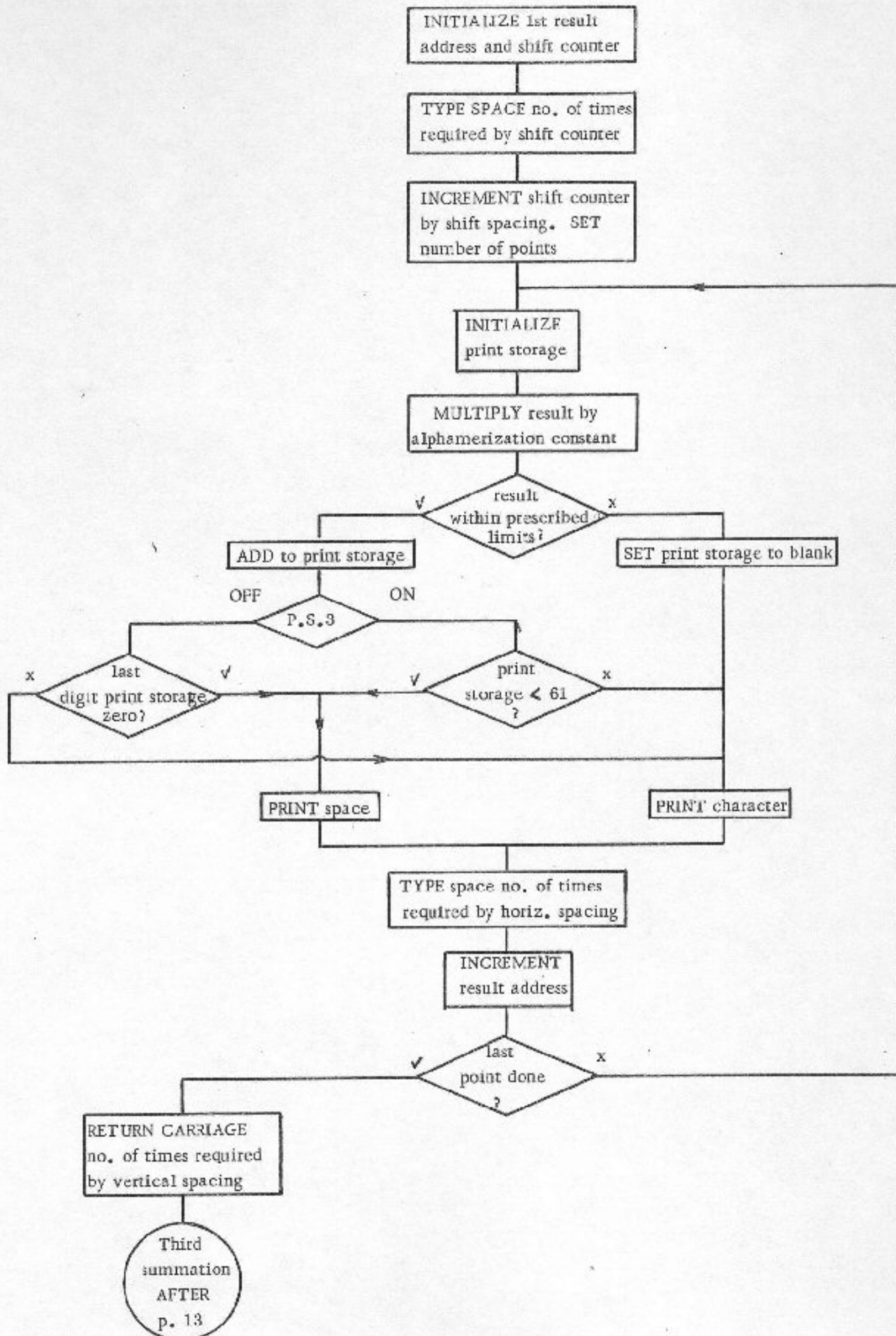


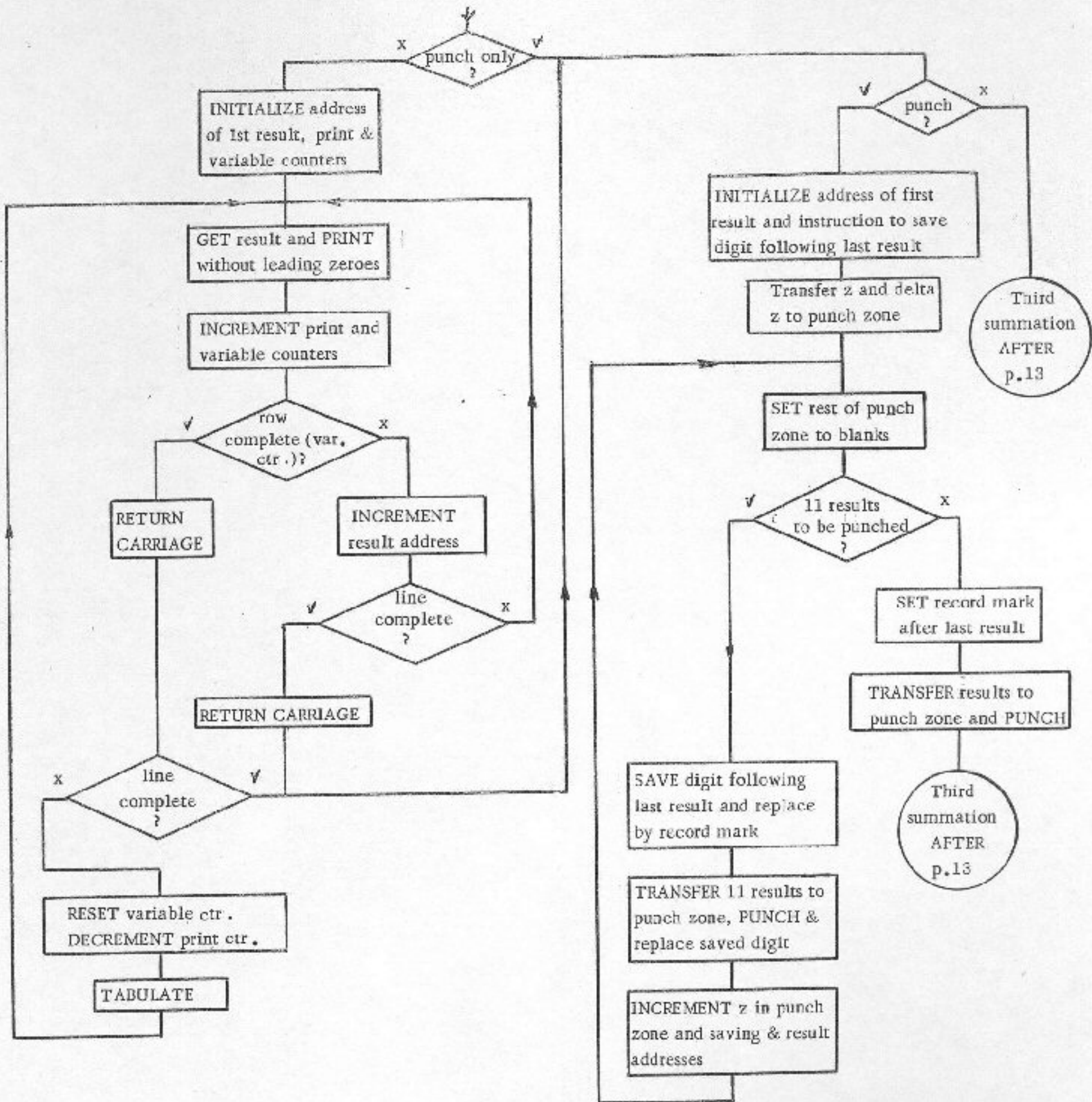
Subroutine used in second and third summations











IV. Input and Output

Note : All card zones of more than one column are X-punched in the left-most position.

Data. Each data card contains one hkl with its four (if centrosymmetric) or eight (if non-centrosymmetric) terms. The card format is :

Cols. 1- 6	Identification code	
7- 8	h	} all positive
9-10	k	
11-12	l	
13-16	A	
17-20	B	
21-24	C	
25-28	D	
29-32	E	} blank if centrosymmetric
33-36	F	
37-40	G	
38-44	H	

Negative values are denoted by an X-punch over the right-most position. The data cards must be sorted first on k, then on l.

The specifications of the summation may be introduced either via the typewriter or punched in a card. The following must be given. Identification code. The same six digit number as is punched in the data cards. A convenient system is to use the first three digits to represent the problem, the next two digits the run and the last digit 1, 2, or 3 according to whether observed, difference, or calculated data are being used.

1st, 2nd and 3rd sum minimum and maximum values. These are the bounds of the summation and will correspond to an integral number of hundredths of the unit cell edges. In the case of a projection both the first sum limits will be zero as will h.

1st, 2nd and 3rd sum delta are the increments (in hundredths of the unit cell edge) in each of the three axial directions. The last value calculated in each direction will be the largest that does not exceed the specified maximum. In the case of a projection the first sum delta will be zero.

1st, 2nd and 3rd sum shifts. The trigonometrical values are stored to four places of decimals so that, in order to conserve the position of the decimal point, it is necessary to eliminate four figures at each stage. By eliminating more or fewer figures it is possible to scale the results down or up during each summation. Thus the normal values will be 04 for all three shifts but values from 02 to 06 inclusive are possible. In order to reduce rounding errors it may be advantageous to have the input data ten times greater than

necessary and to make the third shift 05 in order to bring the results back to the correct scale. On the other hand it may be necessary to scale down by a factor of ten at some stage of the calculation to prevent overflow (see Error Indications below).

Horizontal, vertical and shift spacings are only called for if the program switches are set for alphameric output. The first two of these may each have any value from 00 to 09 which are the number of blank spaces required between successive characters and the number of blank lines between successive rows. The shift spacing (09 to 09) is the number of additional spaces to be typed at the beginning of successive rows in order to give an oblique cell. A negative shift spacing corresponds to an obtuse angle β , a positive shift spacing to an acute angle β and a shift spacing of zero to an orthogonal cell.

Low and high limits of peaks are only called for if the program switches are set for alphameric output. They determine the scale of the linear transformation used to convert each result P to the appropriate alphameric character. This is $P' = 41 + 38 \cdot (P - L) / (H - L)$ where L and H are the low and high limits called for by the programme. If P lies between L and H , P' will lie between 41 and 79 and will be printed as the corresponding alphameric character (A-9) unless it is 50, 60 or 70 when a blank will be typed. A blank will also be typed if P is outside these limits. It is possible to suppress all values less than $(H + L) / 2$ by use of program switch 3. If this is done, the value 70 will be printed as zero.

Symmetry. A 1 in this position causes the calculation of the contributions of terms $E-H$ to be skipped. The corresponding zones of the data cards may be left blank. A 0 will cause the complete calculation to be carried out.

Output. If the program switches are set for numerical output, the typewriter will call for a one digit code which determines the output medium. If the code is flagged ($\bar{0}$ or $\bar{1}$), the results will be printed and if it does not contain a digit (0 or $\bar{0}$) the results will be punched. Thus, when it is desired both to print and to punch, the code $\bar{0}$ will be used. The code 1 (no output) can be used to check that the shifts have been chosen so as to avoid overflow. This code does not affect the alphameric output which can only be typed.

Number of answers in a row. With a 12" carriage typewriter there is space for up to 16 answers in a row of which the last will be repeated as the first of the following row (with the same y). It is perhaps more convenient to have 11 answers so that successive rows contain the results 0-10, 10-20, 20-30, etc.

The specification card format is :

Cols.	1- 6	Identification code
	7- 9	1st sum minimum value
	10-12	2nd sum minimum value
	13-15	3rd sum minimum value
	16-17	1st sum delta
	18-19	2nd sum delta
	20-21	3rd sum delta
	22-24	1st sum maximum value
	25-26	1st sum shift
	27-28	2nd sum shift
	29-30	3rd sum shift
	31	Symmetry
	32-33	Horizontal spacing
	34-35	Vertical spacing
	36-37	Shift spacing
	38-41	Low limit of peak
	42-46	High limit of peak
	47-49	2nd sum maximum value
	50-52	3rd sum maximum value
	53	Record mark

Even when alphameric output is not required, it is necessary to punch values for the low and high peak limits in order to prevent breakdown of the programme. During the introduction of numerical specifications via the typewriter, these values are automatically taken as -1000 and 10000.

Output format. Whatever the output medium, the identification code together with the third summation specifications will be typed as will the x-coordinate of each section calculated. In the case of typewriter output, the y-coordinate of each line is typed before the first row of each line. The number of numerical results per row or the format of alphameric results is determined by the specifications.

The format of the punched output is :

Cols.	1- 6	Identification code
	7- 9	x
	10-12	y
	13-15	z corresponding to first value on card
	16-17	Delta z
	18-21	} Up to 11 four-figure values (last figure of negative values flagged) the last of which is followed by a record mark.
	22-25	
	'	
	'	
	'	
	58-61	
	62	

The eleventh value on a card will be repeated as the first value of the following card (provided that this card is necessary to complete the line of the synthesis).

V. Example

A part of the c-axis projection of 6-azidopurine will be calculated. The relevant plane group is pgg so that :

$$\rho(xy) = \sum_h \sum_k \begin{cases} F(hk0) \cos 2\pi hx \cos 2\pi ky \cos 2\pi lz & h+k \text{ even} \\ - F(hk0) \sin 2\pi hx \sin 2\pi ky \cos 2\pi lz & h+k \text{ odd} \end{cases}$$

Thus for $h+k$ even, $F(hk0)$ is equal to the term A and for $h+k$ odd it is equal to the term B (see formula II, 2).

In the output we require as horizontal coordinate x (lines parallel to a) and vertical coordinate y . This implies a sequence of indices in each card of $0kh$. According to table II, A and B must be placed in the first and fourth fields respectively so that the data cards have the following format :

Cols.	1- 6	000522 (identification code)
	7- 8	00
	9-10	$\bar{x}x$ k
	11-12	$\bar{x}x$ h
	13-16	$\bar{x}xxx$ A
	17-20	0000
	21-24	0000
	25-28	$\bar{x}xxx$ B
	29-80	blank

The cards must be sorted first on k then on h . The values of k , h , A, B used are listed in Table V.

a. We want to calculate the projection for $y = 0.28$ (0.01) 0.47 and $z = 0.00$ (0.02) 0.30. The specifications are to be introduced via the typewriter so P.S. 1 is off. We require an alphanumerical output with the peaks only so P.S. 2 is off and P.S. 3 on. The third sum shift is set at 05 to give a convenient output scale. We require one extra space horizontally between successive characters and no extra space vertically in order to obtain the approximate dimensions of the grid ($a = 11.72 \text{ \AA}$ and $b = 17.06 \text{ \AA}$). The shift spacing is zero as the grid is orthogonal.

From a previous calculation of this projection we know that the results lie roughly between -200 and +800. If we set h at 0200 and H at 00800 only the values above $(200 + 800)/2 = 300$ would be printed with P.S. 3 on so that a large, and possibly important, part of the peak would be suppressed. By setting $L = 0550$ all values above +125 are converted to an alphanumeric character and printed.

The messages and results are shown in Fig. Va.

b. The second example is a numerical print-out (P.S. 2 on) of the same part of the projection. The only difference is that the interval along the y-axis is taken as 0.02 instead of 0.01 so that the greatest value of y calculated will be 0.46 ($0.28 + n \cdot 0.02$) instead of 0.47. As we only require the numerical output, P.S. 3 should be off.

The messages and results of this example are shown in Fig. Vb.

Table V.

(2)	(3)	(4)	(5)		k	h	A	B
k	h	A	B	(6x.0)	k	h	A	B
02	00	0752	0000		04	03	0000	0518
04	00	0514	0000		05	03	0421	0000
06	00	0189	0000		06	03	0000	0618
08	00	0257	0000		07	03	0139	0000
10	00	0181	0000		08	03	0000	0550
12	00	0076	0000		09	03	0116	0000
14	00	0110	0000		10	03	0000	0100
16	00	0052	0000		11	03	0175	0000
20	00	0021	0000		12	03	0000	0238
01	01	0107	0000		13	03	0120	0000
02	01	0000	0181		14	03	0000	0214
03	01	0476	0000		15	03	0175	0000
04	01	0000	0608		16	03	0000	0071
05	01	0317	0000		17	03	0068	0000
06	01	0000	0049		18	03	0000	0071
07	01	0184	0000		19	03	0152	0000
08	01	0000	0236		00	04	0041	0000
09	01	0621	0000		01	04	0000	0168
10	01	0000	0197		02	04	0708	0000
11	01	0236	0000		03	04	0000	0307
12	01	0000	0201		05	04	0000	0712
13	01	0294	0000		07	04	0000	0272
14	01	0000	0333		08	04	0615	0000
15	01	0336	0000		09	04	0000	0175
16	01	0000	0210		10	04	0068	0000
17	01	0091	0000		11	04	0000	0155
18	01	0000	0081		12	04	0110	0000
19	01	0100	0000		13	04	0000	0197
20	01	0000	0081		14	04	0126	0000
00	02	0233	0000		15	04	0000	0285
01	02	0000	0647		16	04	0129	0000
02	02	0110	0000		17	04	0000	0110
03	02	0000	0129		19	04	0000	0104
04	02	0573	0000		20	04	0084	0000
05	02	0000	0628		21	04	0000	0052
06	02	0230	0000		01	05	0353	0000
07	02	0000	0288		02	05	0000	0298
08	02	0052	0000		03	05	0065	0000
09	02	0000	0430		04	05	0000	0061
10	02	0421	0000		06	05	0000	0304
12	02	0223	0000		07	05	0317	0000
13	02	0000	0146		08	05	0000	0152
14	02	0230	0000		09	05	0243	0000
15	02	0000	0256		10	05	0000	0197
16	02	0116	0000		11	05	0214	0000
18	02	0068	0000		12	05	0000	0084
01	03	0188	0000		13	05	0304	0000
02	03	0000	0815		14	05	0000	0149
03	03	0556	0000		15	05	0152	0000

Table V (cont.)

k	h	A	B	k	h	A	B
T7	05	009T	0000	T7	08	0000	0084
T9	05	0058	0000	04	09	0000	0236
00	06	0132	0000	05	09	0278	0000
01	06	0000	0378	06	09	0000	0136
02	06	0314	0000	07	09	0236	0000
04	06	0061	0000	08	09	0000	0291
06	06	0184	0000	T0	09	0000	0055
07	06	0000	0125	T1	09	0097	0000
09	06	0000	0149	T4	09	0000	0065
T0	06	0110	0000	T6	09	0000	0074
T1	06	0000	0171	00	T0	0111	0000
T2	06	0298	0000	01	T0	0000	0081
T3	06	0000	0175	02	T0	0116	0000
T6	06	007T	0000	04	T0	0191	0000
T7	06	0000	0058	05	T0	0000	009T
T8	06	009T	0000	06	T0	0139	0000
T9	06	0000	0042	07	T0	0000	0100
01	07	0223	0000	09	T0	0000	0175
02	07	0000	0336	T1	T0	0000	0197
03	07	0576	0000	T2	T0	0097	0000
04	07	0000	0136	T4	T0	0055	0000
05	07	0120	0000	01	T1	0149	0000
06	07	0000	0214	02	T1	0000	0210
07	07	0320	0000	03	T1	0178	0000
08	07	0000	0107	04	T1	0000	0233
09	07	0084	0000	05	T1	0314	0000
T0	07	0000	0210	06	T1	0000	0136
T1	07	0058	0000	08	T1	0000	0126
T3	07	0230	0000	09	T1	0133	0000
T4	07	0000	0081	T1	T1	009T	0000
T5	07	0052	0000	T2	T1	0000	0110
T6	07	0000	0094	00	T2	0068	0000
T7	07	0129	0000	01	T2	0000	0078
00	08	0187	0000	03	T2	0000	0052
01	08	0000	0249	04	T2	0191	0000
02	08	0188	0000	06	T2	0087	0000
03	08	0000	0291	07	T2	0000	0104
04	08	0146	0000	08	T2	0058	0000
06	08	0078	0000	T3	T2	0000	0058
07	08	0000	0168	01	T3	0068	0000
08	08	0155	0000	04	T3	0000	0091
09	08	0000	0084	06	T3	0000	0110
T0	08	0362	0000	00	T4	0044	0000
T1	08	0000	009T	02	T4	0078	0000
T2	08	0217	0000	03	T4	0000	0087
T3	08	0000	0155	06	T4	0055	0000
T4	08	0061	0000	08	T4	0065	0000
T5	08	0000	0126	01	T5	0042	0000

Fig. Va. Numerical example.

310000300002RS

FOURIER SUMMATION PROGRAMME ERA 210.

SET PROGRAM SWITCHES

TYPE IDENT OF SPECS CARD NOW MADE(6)

TYPE 1ST SUM MIN.(3)

TYPE 1ST SUM MAX.(3)

TYPE 2ND SUM MIN.(3)

TYPE 2ND SUM MAX.(3)

TYPE 3RD SUM MIN.(3)

TYPE 3RD SUM MAX.(3)

TYPE 1ST SUM DELTA(2)

TYPE 2ND SUM DELTA(2)

TYPE 3RD SUM DELTA(2)

TYPE 1ST SUM SHIFT(2)

TYPE 2ND SUM SHIFT(2)

TYPE 3RD SUM SHIFT(2)

CENTROSYM=1, NONCENTROSYM=0 (1)

IN CASE OF TYPING ERROR SET SW4 ON
READY PUNCHOUTPUT. PUNCH ONLY=0, PRINT ONLY=T
PUNCH AND PRINT=0 (1)

TYPE NUMBER OF ANSWERS IN A ROW(3)

000522RS

000RS

000RS

0.28RS

047RS

000RS

030RS

00RS

02RS

02RS

04RS

04RS

05RS

1RS

7RS

011RS

LOAD DATA

FOURIER NO. 000522

XMIN3=.00 XMAX3=0.30 DELTA3=.02

SECTION 000

028	33	41	95	236	281	127	5	95	283	309	172
	172	19	74	123	154	166					
030	44	34	276	592	672	412	138	195	454	525	318
	318	67	59	108	147	157					
032	67	4	198	439	518	337	108	73	205	256	133
	133	24	83	94	127	164					
034	93	34	31	75	65	44	29	8	17	20	86
	86	104	41	53	122	166					
036	34	115	253	242	99	7	39	51	39	194	479
	479	592	398	107	64	124					
038	35	282	555	610	373	111	29	22	23	192	471
	471	560	350	81	69	129					
040	7	143	334	398	284	217	307	372	274	156	116
	116	75	12	78	109	138					
042	92	73	21	16	60	233	511	638	468	186	2
	2	73	90	94	117	138					
044	139	137	103	70	38	62	213	267	160	11	65
	65	84	100	138	163	146					
046	154	168	150	120	118	111	74	55	78	107	124
	124	140	167	180	173	134					

MOO1

Fig. Vb. Alphameric example.

3100003000028
FOURIER SUMMATION PROGRAMME ERA 210.

79 → 97

SET PROGRAM SWITCHES

TYPE IDENT OF SPECS CARD NOW MADE(6)	000528S
TYPE 1ST SUM MIN.(3)	000RS
TYPE 1ST SUM MAX.(3)	000RS
TYPE 2ND SUM MIN.(3)	028RS
TYPE 2ND SUM MAX.(3)	047RS
TYPE 3RD SUM MIN.(3)	000RS
TYPE 3RD SUM MAX.(3)	030RS
TYPE 1ST SUM DELTA(2)	00RS
TYPE 2ND SUM DELTA(2)	01RS
TYPE 3RD SUM DELTA(2)	02RS
TYPE 1ST SUM SHIFT(2)	04RS
TYPE 2ND SUM SHIFT(2)	04RS
TYPE 3RD SUM SHIFT(2)	05RS
TYPE HORIZ.SPACING(2)	01RS
TYPE VERT.SPACING(2)	00RS
TYPE SHIFT SPACING(2)	00RS
TYPE LOW LIMIT OF PEAKS(4)	0550RS
TYPE HIGH LIMIT OF PEAKS(5)	00800RS
CENTROSYM=1, NONCENTROSYM=0 (1)	1RS
IN CASE OF TYPING ERROR SET SW4 ON READY PUNCH	

LOAD DATA

FOURIER NO. 000522
XMIN3=.00 XMAX3=0.30 DELTA3=.02

SECTION 000

028	T U	U V /
029	S Z 1 U	/ Y 0 U
030	U 3 5 Y	S Z 1 V
031	U 3 6 Z / /	X Z U
032	S Z 1 W	S U
033	T U S	
034		
035		U W T
036	U T	S 0 3 Y
037	T Z 0 U	T 2 6 Z
038	U 2 4 X	S 0 2 W
039	U 1 3 X / / /	U V /
040	/ W Y V T V X U /	
041	S / T 0 3 Z S	
042	T 1 5 0 S	
043	/ Y 1 W	
044	T U /	
045		
046		
047		
M001		

VI. Operating Instructions

1. Set typewriter margins at 10 and, on a 12" machine, 96. Set tabs at 14, 15 and 50.
2. Set parity, I/O and overflow check switches to STOP. Set P.S. 1 ON if the specifications are to be entered via a card, OFF if they are to be typed. Set P.S. 2 OFF if alphameric output only is required in which case P.S. 3 should be OFF to print characters A-9 and ON to print characters /-9 and blanks instead of A-R. Set P.S. 2 ON if numeric output is required in which case P.S. 3 should be ON if this is to be followed by alphameric output otherwise OFF. Set P.S. 4 OFF.
3. Clear machine storage to zeroes.
4. Load the programme into storage, press START and follow the messages typed. The figures in parentheses at the end of some messages indicate the number of digits to be typed by the operator. All messages except the following have been described in the section on input.
5. Message SET P.S. 2, 3 TYPE ALPHASPECS is printed on completion of the numerical output of each section when P.S. 2 and 3 are both ON. Set P.S. 3 OFF and P.S. 3 as required to give either the full alphameric results (OFF) or only the highlights (ON). Type $\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}\bar{x}$ (RS) where the first three fields are the horizontal, vertical and shift spacings, and the last two are the low and high peak limits. A typing error may be corrected before (RS) is typed by pressing RESET, INSERT and typing 4904378 (RS). LOAD DATA will be printed at the end of each section except the last. Set P.S. 3 and 3 ON again before pressing start. Although SET P.S. 2,3, TYPE ALPHASPECS is printed after each section, the constants, once introduced, remain unchanged and it is only necessary to type (RS) on subsequent occasions.
6. Message MOOI is printed on completion of the last section.
7. Error Messages. There are six different errors indicated by the machine's typing ER n and halting. Depression of the START key will cause a MAR check. The codes are :
 - ER 1 - A data card has an identification code different from that of the specifications.
 - ER 2 - Card out of sequence with respect to l.
 - ER 3 - Card out of sequence with respect to k in a particular group l.
 - ER 4 - Overflow during the first summation ; the first sum shift constant should be increased by unity.

ER 5 - The second summation results require more space than is available ; reduce the number of lines to be calculated.

ER 6 - The second and third summations overlap one another ; reduce the number of lines to be calculated.

ARITH CHK. If an overflow occurs between the printing of LOAD DATA and of SECTION $\bar{x}xx$ the second sum shift constant must be increased by unity. If the overflow occurs after SECTION $\bar{x}xx$ has been printed the third sum shift constant should be increased.

It is desirable to verify that the overflow is due to an incorrect choice of shift constant rather than to some other cause such as a field-defining X-punch missing from a data card (which can be checked by eye). The following procedure should be followed when the 1620 stops on ARITH CHK :

1. Set the Memory Address Register Display Selector to IR-1 and press RESET, DISPLAY MAR. The Memory Address Register (MAR) should read 01938 which is the address of the instruction in the Subroutine following the accumulation instruction which caused the overflow.
2. Set the MAR Display Selector to IR-2 and press DISPLAY MAR. The MAR should now indicate 01522 or 02914 for second or third summation overflows respectively.

After making the appropriate correction it is necessary to reintroduce the programme.

8. Other possibilities of error. Two other types of error are possible, neither of these has ever been known to occur. The first is an overflow of one of the temporary storages during the first summation. As these have ten digits and the maximum contribution of one term is 99980001 (amplitude 9999 x trigonometric function 9999) this would require at least 101 values in one group kl. If this were to happen, the contents of IR 1 after ARITH CHK would be 01142.

The second error could only occur when a shift of 03 or 02 is used in the second or third summation. In these cases the one or two most significant digits of the product are cut off by a Set Flag instruction. If these digits are not zero, an incorrect value will be accumulated without any indication of error. However, it is most improbable that this will happen without the next most significant digits being sufficiently large to give overflow on accumulation of two or more values. For this reason an extra test to check for digits so lost has been omitted as it would increase the running time of the most frequently used block of the programme.

VII. Programme listing

```

0001 *          *****
0002 *          THREE-DIMENSIONAL FOURIER SUMMATION PROGRAMME ERA 210.
0003 *          *****
0004 MEMCAP DS      20000          20000 00000
0005          DORG  402          00402
0006 START2 RCTY          00402 34 00000 00102
0007 CONS04 DS      5,*-5          00408 00005
0008          WATY  IDENT6          00414 39 05451 00100
0009          TR   HIGHP-4,LOWP+1  00426 31 05470 00061
0010          TFM  SUMM02+30,FIRSSM 00438 16 01540 00734
0011          H    4,4,6          00450 48 00004 00004
0012 CONS02 DS      6,*          00461 00006
0013 *
0014 *          INITIALIZATION OF SECOND SUMMATION.
0015 *
0016 STARTO S      TWOH,TWOL          00462 22 05477 00031
0017          TFM  COUNT1,0,9          00474 16 00495 00000
0018 SEC IN8 AM    COUNT1,1,10          00486 11 00495 00001
0019 COUNT1 DS     3,*-2          00495 00003
0020          CM   TWOH,0,9          00498 14 05477 00000
0021          BNH  SEC IN9          00510 47 00542 01100
0022          S    TWOH,TWOD          00522 22 05477 00038
0023          B    SEC IN8          00534 49 00486 00000
0024          DORG *-3          00542
0025 SEC IN9 TF    NUMBR2,COUNT1          00542 26 00563 00425
0026          MM   NUMBR2,2,10          00554 13 00563 00002
0027 NUMBR2 DS     3,*-2          00563 00003
0028          TF   CONS05,99          00566 26 02123 00099
0029          MM   NUMBR2,8,10          00578 13 00563 00008
0030          TF   CONS04,99          00590 26 00408 00099
0031          TFM  SEC IN3+6,R          00602 16 01620 05605
0032          TFM  SUBR02+6,R          00614 16 01932 05605
0033          S    SUBR02+6,CONS04          00626 22 01932 00408
0034          TF   DELTA,TWOD          00638 26 01661 00038
0035          TF   XMINT,TWOL          00650 26 01745 00031
0036          TFM  SUBR06+11,NUMBR2,7  00662 16 01685 00563
0037          TFM  SUBR13+11,2,10          00674 16 01829 00002
0038          BT   SUBR IN,TWOS          00686 27 02100 00047
0039          TFM  INDEX3,1,1011          00698 16 00707 00001
0040 INDEX3 DS     2,*-2          00707 00002
0041 *
0042 *          FIRST SUMMATION, SELECTION OF AMPLITUDES
0043 *          AND TRIGONOMETRIC VALUES.
0044 *
0045          RNCD H1-7          00710 36 05482 00500
0046          BLC  *+12          00722 46 00734 00900
0047 K2 DS      2,*          00733 00002
0048 FIRSSM TF    K2,K1          00734 26 00733 05491

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0049		TF	L2,L1	00746	26	00829	05493
0050		TF	MTEMP,ZERO10	00758	26	05571	05449
0051		TF	NTEMP,ZERO10	00770	26	05581	05449
0052		TF	OTEMP,ZERO10	00782	26	05591	05449
0053		TF	PTEMP,ZERO10	00794	26	05601	05449
0054	NEWS13	C	CODE,H1-2	00806	24	00025	05487
0055		BE	*+24	00818	46	00842	01200
0056	L2	DS	2,*	00829		00002	
0057		BTM	ER,100,9	00830	17	01268	00100
0058		DC	1,@,*	00841		00001	‡
0059		C	L1,L2	00842	24	05493	00829
0060		BNL	*+24	00854	46	00878	01300
0061		BTM	ER,200,9	00866	17	01268	00200
0062		DC	1,@,*	00877		00001	‡
0063		BH	NEWS09	00878	46	01306	01100
0064		C	K1,K2	00890	24	05491	00733
0065		BNL	*+24	00902	46	00926	01300
0066		BTM	ER,300,9	00914	17	01268	00300
0067		DC	1,@,*	00925		00001	‡
0068		BH	NEWS09	00926	46	01306	01100
0069		M	H1,SECTX	00938	23	05489	02387
0070		SF	98	00950	32	00098	00000
0071	ARGUM	DS	3,*	00961		00003	
0072		TF	ARGUM,99	00962	26	00961	00099
0073		MM	ARGUM,9,10	00974	13	00961	00009
0074		TFM	NEWS04+11, TABLE	00986	16	01021	04460
0075		A	NEWS04+11,99	00998	21	01021	00099
0076	NEWS04	TR	COS3-3, TABLE	01010	31	05542	04460
0077		TR	COS1-3,COS3-3	01022	31	05526	05542
0078		TF	SIN2,SIN1	01034	26	05537	05533
0079		TF	COS2,COS1	01046	26	05541	05529
0080		TF	NEWS53+11,CONS53	01058	26	01129	02097
0081	*						
0082	*						
0083	*						
0084	NEWS57	TFM	NEWS54+6,MTEMP	01070	16	01136	05571
0085		TFM	NUMB00,4,10	01082	16	01365	00004
0086	NEWS55	SM	NUMB00,1,10	01094	12	01365	00001
0087	NEWS56	BN	NEWS50,,2	01106	47	01178	01300
0088	NEWS53	M	A,COS1	01118	23	05497	05529
0089	NEWS54	A	MTEMP,99	01130	21	05571	00099
0090		A	NEWS53+11,CONS02	01142	21	01129	00461
0091		AM	NEWS54+6,10,10	01154	11	01136	00010
0092		B	NEWS55	01166	49	01094	00000
0093	NEWS50	SM	NEWS53+11,8,10	01178	12	01129	00008
0094		AM	NEWS56+6,36,10	01190	11	01112	00036
0095		B	NEWS57	01202	49	01070	00000
0096		SM	NEWS56+6,36,10	01214	12	01112	00036
0097	NEWS58	BLC	NEWS09-12	01226	46	01294	00900
0098		RNCD	H1-7	01238	36	05482	00500

FIRST SUMMATION, MULTIPLICATION AND ACCUMULATION.

0099	B	NEWS 13	01250	49	00806	00000
0100	DORG	*-3	01258			
0101	*					
0102	*	ERROR ROUTINE.				
0103	*					
0104	BNR	59007	01258	45	59007	00000
0105	DORG	*-1	01268			
0106	ER	WATY *-9	01268	39	01259	00100
0107	H		01280	48	00000	00000
0108	DORG	*-9	01282			
0109	NEWS 16	BTM ER, 400, 9	01282	17	01268	00400
0110	DC	1, @, *	01293	00001		*
0111	*					
0112	*	FIRST SUMMATION, ROUNDING AND STORING.				
0113	*					
0114	TFM	SUMMO2+30, THR INO	01294	16	01540	02198
0115	NEWS 09	TFM NUMBOO, 4, 10	01306	16	01365	00004
0116	TFM	NEWS 10+11, MTEMP	01318	16	01353	05571
0117	TFM	NEWS 12+6, M	01330	16	01408	05553
0118	NEWS 10	TF TROUND, MTEMP	01342	26	19999	05571
0119	NEWS 20	SF TROUND-7	01354	32	19992	00000
0120	NUMBOO	DS 2, *	01365	00002		
0121	NEWS 21	AM TROUND-3, 5, 10	01366	11	19996	00005
0122	NEWS 22	BNF NEWS 12, TROUND	01378	44	01402	19999
0123	NEWS 24	SF TROUND-4	01390	32	19995	00000
0124	NEWS 12	TF M, TROUND-4	01402	26	05553	19995
0125	NEWS 19	BD NEWS 16, TROUND-8	01414	43	01282	19991
0126	NEWS 17	AM NEWS 10+11, 10, 10	01426	11	01353	00010
0127	AM	NEWS 12+6, 4, 10	01438	11	01408	00004
0128	SM	NUMBOO, 1, 10	01450	12	01365	00001
0129	BNZ	NEWS 10	01462	47	01342	01200
0130	TFM	TROUND-8, 0, 10	01474	16	19991	00000
0131	*					
0132	*	SECOND SUMMATION, SELECTION OF AMPLITUDES.				
0133	*					
0134	SUMMOO	C L2, INDEX 3	01486	24	00829	00707
0135	BNZ	SEC IN 5	01498	47	01542	01200
0136	SUMMO2	BT SUBRO6, K2	01510	27	01674	00733
0137	S	SUBRO2+6, CONS04	01522	22	01932	00408
0138	B	FIRSSM	01534	49	00734	00000
0139	DORG	*-3	01542			
0140	SEC IN 5	A SUBRO2+6, CONS04	01542	21	01932	00408
0141	AM	INDEX 3, 1, 10	01554	11	00707	00001
0142	*					
0143	*	SECOND SUMMATION, PREPARATION OF STORAGE FOR NEXT SERIES.				
0144	*					
0145	TF	CLEAR 1, CONS05	01566	26	01709	02123
0146	CM	SEC IN 3+6, MEMCAP-10	01578	14	01620	19990
0147	BNH	*+24	01590	47	01614	01100
0148	BTM	ER, 500, 9	01602	17	01268	00500

0149		DC	1,@,*	01613	00001	#	
0150	SECIN3	TFM	R,0,8	01614	16	05605	00000
0151		AM	SECIN3+6,4,10	01626	11	01620	00004
0152		SM	CLEAR1,1,10	01638	12	01709	00001
0153		BNZ	SECIN3-36	01650	47	01578	01200
0154	DELTA	DS	2,*	01661		00002	
0155		B	SUMMOO	01662	49	01486	00000
0156	*						
0157	*						
0158	*						
0159	*						
0160	SUBRO6	TF	COUNT1,NUMBR2	01674	26	00495	00563
0161		M	SUBRO6-1,DELTA	01686	23	01673	01661
0162		SF	98	01698	32	00098	00000
0163	CLEAR1	DS	5,*	01709		00005	
0164		TF	ADDIN,99	01710	26	01742	00099
0165		M	SUBRO6-1,XMINT	01722	23	01673	01745
0166		SF	97	01734	32	00097	00000
0167	ADDIN	DS	2,*-3	01742		00002	
0168	XMINT	DS	3,*	01745		00003	
0169		TF	ARGUM,99	01746	26	00961	00099
0170	SUBRO4	TDM	ARGUM-2,0,11	01758	15	00959	00000
0171	SUBRO9	MM	ARGUM,9,10	01770	13	00961	00009
0172		TFM	SUBRO1+11, TABLE	01782	16	01817	04460
0173		A	SUBRO1+11,99	01794	21	01817	00099
0174	SUBRO1	TR	COS1-3, TABLE	01806	31	05526	04460
0175	SUBR13	TFM	COUNT2,2,10	01818	16	01947	00002
0176		M	COS1,M	01830	23	05529	05553
0177		TF	TROUND,99	01842	26	19999	00099
0178		M	SIN1,N	01854	23	05533	05557
0179		A	TROUND,99	01866	21	19999	00099
0180	SUBR11	SF	TROUND-7	01878	32	19992	00000
0181	SUBRO7	AM	TROUND-3,5,10	01890	11	19996	00005
0182		BNF	SUBRO2,TROUND	01902	44	01926	19999
0183	SUBR19	SF	TROUND-4	01914	32	19995	00000
0184	NUMTH1	DS	5,*	01925		00005	
0185	SUBRO2	A	R,TROUND-4	01926	21	05605	19995
0186		SM	COUNT2,1,10	01938	12	01947	00001
0187	COUNT2	DS	2,*-2	01947		00002	
0188		BZ	SUBR14	01950	46	02030	01200
0189		AM	SUBRO2+6,4,10	01962	11	01932	00004
0190		M	COS1,0	01974	23	05529	05561
0191		TF	TROUND,99	01986	26	19999	00099
0192		M	SIN1,P	01998	23	05533	05565
0193		A	TROUND,99	02010	21	19999	00099
0194		B	SUBR11	02022	49	01878	00000
0195		DORG	*-3	02030			
0196	SUBR14	AM	SUBRO2+6,4,10	02030	11	01932	00004
0197		SM	COUNT1,1,10	02042	12	00495	00001
0198		BZ	SUBRO5	02054	46	02086	01200

SUBROUTINE, MULTIPLICATION AND ACCUMULATION
USED IN SECOND AND THIRD SUMMATIONS.

0199	A	ARGUM,ADD IN	02066	21	00961	01742
0200	B	SUBR04	02078	49	01758	00000
0201	DORG	*-3	02086			
0202	SUBR05	BB A,COS 1,2	02086	42	05497	05529
0203	CONS53	DS 10,*	02097		00010	
0204	*					
0205	*	INITIALIZATION OF SUBROUTINE				
0206	*	SHIFTING AND ROUNDING ORDERS.				
0207	DS	2	02099		00002	
0208	SUBR IN	SM SUBR IN-1,10,10	02100	12	02099	00010
0209	CF	SUBR IN-1	02112	33	02099	00000
0210	CONS05	DS 5,*	02123		00005	
0211	TD	SUBR07+6,SUBR IN-1	02124	25	01896	02099
0212	SM	SUBR IN-1,1,10	02136	12	02099	00001
0213	TD	SUBR02+11,SUBR IN-1	02148	25	01937	02099
0214	TD	SUBR19+6,SUBR IN-1	02160	25	01920	02099
0215	SM	SUBR IN-1,3,10	02172	12	02099	00003
0216	TD	SUBR11+6,SUBR IN-1	02184	25	01884	02099
0217	BB		02196	42	00000	00000
0218	DORG	*-9	02198			
0219	*					
0220	*	INITIALIZATION OF THIRD SUMMATION.				
0221	*					
0222	THR IN0	RCTY	02198	34	00000	00102
0223	DIVIS1	DS 6,*-4	02205		00006	
0224	WATY	IDENT1	02210	39	05423	00100
0225	TF	IDENT4-1,SECTX	02222	26	03380	02387
0226	WNTY	IDENT4-3	02234	38	03378	00100
0227	THR IN4	RCTY	02246	34	00000	00102
0228	DIVISC	DC 6,380000,*-4	02253		00006	380000
0229	TR	HIGHP-4,LOWP+1	02258	31	05470	00061
0230	S	HIGHP,LOWP	02270	22	05474	00060
0231	TF	DIVIS1,DIVISC	02282	26	02205	02253
0232	TFM	ALPHC1,0,7	02294	16	03065	00000
0233	THR IN3	AM ALPHC1,1,10	02306	11	03065	00001
0234	S	DIVIS1,HIGHP	02318	22	02205	05474
0235	BNN	THR IN3	02330	46	02306	01300
0236	NAMPL2	DS 2,*	02341		00002	
0237	TFM	SHIFTC,0,9	02342	16	03857	00000
0238	BNF	*+72,SHFTSP	02354	44	02426	00056
0239	TF	*+35,NUMBR2	02366	26	02401	00563
0240	SM	*+23,1,10	02378	12	02401	00001
0241	SECTX	DS 3,*-2	02387		00003	
0242	MM	SHFTSP	02390	13	00056	00000
0243	SF	97	02402	32	00097	00000
0244	MULT01	DS 5,*	02413		00005	
0245	S	SHIFTC,99	02414	22	03857	00099
0246	TFM	THR104+11,R	02426	16	02889	05605
0247	TFM	THR105+11,S	02438	16	02901	05609
0248	S	THREEH,THREEL	02450	22	05480	00034

0249		TFM	COUNT1,1,9	02462	16	00495	00001
0250	THR IN1	S	THREEH,THREED	02474	22	05480	00040
0251		BN	THR IN2	02486	47	02518	01300
0252	REGIS1	DS	2,*	02497		00002	
0253		AM	COUNT1,1,10	02498	11	00495	00001
0254		B	THR IN1	02510	49	02474	00000
0255		DORG	*-3	02518			
0256	THR IN2	TF	NUMBR3,COUNT1	02518	26	03854	00495
0257		MM	NUMBR3,4,10	02530	13	03854	00004
0258		TF	NUMTH1,99	02542	26	01925	00099
0259		TF	NAMPL2,INDEX3	02554	26	02341	00707
0260		AM	NAMPL2,1,10	02566	11	02341	00001
0261		M	CONSO4,NAMPL2	02578	23	00408	02341
0262		SF	95	02590	32	00095	00000
0263	NUMTH2	DS	5,*	02601		00005	
0264		SM	99,8,10	02602	12	00099	00008
0265	COUNT4	DS	3,*-2	02611		00003	
0266		TF	NUMTH2,99	02614	26	02601	00099
0267		TF	DELTA,THREED	02626	26	01661	00040
0268		TF	XMINI,THREEL	02638	26	01745	00034
0269		TFM	SUBRO6+11,NUMBR3	02650	16	01685	03854
0270		TFM	SUBR13+11,1,10	02662	16	01829	00001
0271	COUNSH	DS	3,*-2	02671		00003	
0272		TFM	SUBRO2+6,MEMCAP-7	02674	16	01932	T9993
0273		BT	SUBR IN,THREES	02686	27	02100	00049
0274		TF	IDENT4-1,TWOL	02698	26	03380	00031
0275		TF	PUNCH+8,SECTX	02710	26	05490	02387
0276		TF	PUNCH+16,THREED	02722	26	05498	00040

0277 *

0278 * THIRD SUMMATION, PREPARATION OF STORAGE FOR NEXT LINE.

0279 *

0280	THR100	TF	PUNCH+11,IDENT4-1	02734	26	05493	03380
0281		TFM	THR101+6,MEMCAP-7	02746	16	02788	T9993
0282		TF	COUNT1,NUMBR3	02758	26	00495	03854
0283	THR102	SM	THR101+6,4,10	02770	12	02788	00004
0284	THR101	TFM	MEMCAP-7,0,8	02782	16	19993	00000
0285		SM	COUNT1,1,10	02794	12	00495	00001
0286		BNZ	THR102	02806	47	02770	01200
0287		C	THR101+6,SECIN3+6	02818	24	02788	01620
0288		BNL	*+24	02830	46	02854	01300
0289		BTM	ER,600,9	02842	17	01268	00600
0290		DC	1,@,*	02853		00001	‡
0291	THR103	TFM	REGIS1,0,10	02854	16	02497	00000
0292	THR107	S	SUBRO2+6,NUMTH1	02866	22	01932	01925

0293 *

0294 * THIRD SUMMATION, SELECTION OF AMPLITUDES.

0295 *

0296	THR104	TF	M,R	02878	26	05553	05605
0297	THR105	TF	N,S	02890	26	05557	05609
0298	THR106	BT	SUBRO6,REGIS1	02902	27	01674	02497

0349	IDENT4	DC	4,@,*-4	03381	00004	000‡
0350		B	PRT017	03386	49 03430	00000
0351		DORG	*-3	03394		
0352	PRT019	CM	WRALPH,61,10	03394	14 03133	000‡1
0353		BN	PRT018	03406	47 03374	01300
0354	PRT016	WATY	WRALPH	03418	39 03133	00100
0355	PRT017	TF	SPACEC,HORSP	03430	26 03473	000‡2
0356	PRT014	SM	SPACEC,1,10	03442	12 03473	00001
0357		BN	PRT012	03454	47 03486	01300
0358		SPTY		03466	34 00000	00101
0359	SPACEC	DS	2,*-4	03473	00002	
0360		B	PRT014	03478	49 03442	00000
0361		DORG	*-3	03486		
0362	PRT012	AM	PRT011+11,4,10	03486	11 03209	000‡4
0363		SM	COUNT4,1,10	03498	12 02611	000‡1
0364		BNZ	PRT011-12	03510	47 03186	01200
0365		TF	RETURC,VERTSP	03522	26 03565	000‡4
0366	PRT013	CM	RETURC,1,1011	03534	14 03565	000‡1
0367		BE	AFTER	03546	46 04330	01200
0368		RCTY		03558	34 00000	00102
0369	RETURC	DS	2,*-4	03565	00002	
0370		SM	RETURC,1,10	03570	12 03565	000‡1
0371	PUNPRT	DS	1,*-3	03578	00001	
0372		B	PRT013	03582	49 03534	00000
0373		DORG	*-3	03590		
0374	*					
0375	*		NUMERICAL PRINTING AND PUNCHING.			
0376	*					
0377	PRINT2	BNF	PRINT3,PUNPRT	03590	44 03986	03578
0378		SPTY		03602	34 00000	00101
0379	PRINC1	DS	3,*-7	03606	00003	
0380	PRINC2	DS	3,*-4	03609	00003	
0381		TFM	PRT031+11,MEMCAP-7	03614	16 03697	19993
0382		S	PRT031+11,NUMTH1	03626	22 03697	01925
0383		TFM	PRINC1,0,9	03638	16 03606	00000
0384		TFM	PRINC2,0,9	03650	16 03609	00000
0385	PRT032	TFM	PRT022+11,WRNUM-4	03662	16 03745	03748
0386	PRT028	TFM	*+9,4,10	03674	16 03683	000‡4
0387	PRT031	TF	WRNUM-1,MEMCAP-7	03686	26 03751	19993
0388		CF	WRNUM-4	03698	33 03748	00000
0389	PRT029	SM	PRT028+9,1,10	03710	12 03683	000‡1
0390		BZ	PRT027	03722	46 03778	01200
0391	PRT022	BD	PRT027,WRNUM-4	03734	43 03778	03748
0392		SPTY		03746	34 00000	00101
0393	WRNUM	DC	5,@,*-5	03752	00005	0000‡
0394		AM	PRT022+11,1,10	03758	11 03745	000‡1
0395		B	PRT029	03770	49 03710	00000
0396		DORG	*-3	03778		
0397	PRT027	TF	PRT020+6,PRT022+11	03778	26 03796	03745
0398	PRT020	WNTY	WRNUM-4	03790	38 03748	00100

0299	*							
0300	*			THIRD SUMMATION, INCREMENTING.				
0301	*							
0302		A	THR104+11, CONSO4		02914	21	02889	00408
0303		A	THR105+11, CONSO4		02926	21	02901	00408
0304		AM	REGIS1, 1, 10		02938	11	02497	00001
0305		C	REGIS1, NAMPL2		02950	24	02497	02341
0306		BNZ	THR107		02962	47	02866	01200
0307		S	THR104+11, NUMTH2		02974	22	02889	02601
0308		S	THR105+11, NUMTH2		02986	22	02901	02601
0309		BNC2	*+24		02998	47	03022	00200
0310		BNF	THR110, PUNPRT		03010	44	03034	03578
0311		WNTY	IDENT4-3		03022	38	03378	00100
0312	THR110	A	IDENT4-1, TWOD		03034	21	03380	00038
0313		BC2	PRINT2		03046	46	03590	00200
0314	*							
0315	*			ALPHANUMERICAL PRINTING, PLOTTING.				
0316	*							
0317		TBTY			03058	34	00000	00108
0318	ALPHC1	DS	6, *-4		03065		00006	
0319	PRINT1	TFM	COUNSH, 0, 9		03070	16	02671	00000
0320		TFM	PRT011+11, MEMCAP-7		03082	16	03209	19993
0321		S	PRT011+11, NUMTH1		03094	22	03209	01925
0322	PRT002	C	COUNSH, SHIFTC		03106	24	02671	03857
0323		BE	PRT001		03118	46	03162	01200
0324		SPTY			03130	34	00000	00101
0325	WRALPH	DAC	2, A@, *-8		03133		00002X2 A†	
0326		AM	COUNSH, 1, 10		03142	11	02671	00001
0327		B	PRT002		03154	49	03106	00000
0328		DORG	*-3		03162			
0329	PRT001	A	SHIFTC, SHFTSP		03162	21	03857	00056
0330		TF	COUNT4, NUMBR3		03174	26	02611	03854
0331		TFM	WRALPH, 41, 10		03186	16	03133	00041
0332	PRT011	TF	MULT01, MEMCAP-7		03198	26	02413	19993
0333		TDM	MULT01-4, 0, 11		03210	15	02409	00000
0334		CF	MULT01-3		03222	33	02410	00000
0335		S	MULT01, LOWP		03234	22	02413	00060
0336		M	ALPHC1, MULT01		03246	23	03065	02413
0337		BNF	PRT015, 99		03258	44	03290	00099
0338	PRT005	TFM	WRALPH, 0, 10		03270	16	03133	00000
0339		B	PRT004		03282	49	03350	00000
0340		DORG	*-3		03290			
0341	PRT015	AM	96, 5, 10		03290	11	00096	00005
0342		CM	95, 38, 10		03302	14	00095	00038
0343		BP	PRT005		03314	46	03270	01100
0344		SF	94		03326	32	00094	00000
0345		A	WRALPH, 95		03338	21	03133	00095
0346	PRT004	BC3	PRT019		03350	46	03394	00300
0347		BD	PRT016, WRALPH		03362	43	03418	03133
0348	PRT018	SPTY			03374	34	00000	00101

0399		AM	PRINC1,1,10	03802	11	03606	00001
0400		AM	PRINC2,1,10	03814	11	03609	00001
0401	PRT030	CM	PRINC2,16,9	03826	14	03609	00016
0402		BNE	PRT023	03838	47	03930	01200
0403	PRT026	RCTY		03850	34	00000	00102
0404	NUMBR3	DS	3,*-7	03854		00003	
0405	SHIFTC	DS	3,*-4	03857		00003	
0406		C	PRINC1,NUMBR3	03862	24	03606	03854
0407		BE	PRINT3	03874	46	03986	01200
0408		TFM	PRINC2,0,9	03886	16	03609	00000
0409		SM	PRINC1,1,10	03898	12	03606	00001
0410		TBTY		03910	34	00000	00108
0411		B	PRT032	03922	49	03662	00000
0412		DORG	*-3	03930			
0413	PRT023	AM	PRT031+11,4,10	03930	11	03697	00004
0414		C	PRINC1,NUMBR3	03942	24	03606	03854
0415		BE	PRT026	03954	46	03850	01200
0416		SPTY		03966	34	00000	00101
0417		B	PRT032	03978	49	03662	00000
0418		DORG	*-3	03986			
0419	PRINT3	BD	AFTER,PUNPRT	03986	43	04330	03578
0420		TFM	PNCHO1+11,MEMCAP-10	03998	16	04213	T9990
0421		S	PNCHO1+11,NUMTH1	04010	22	04213	01925
0422		TF	PNCHO2+11,PNCHO1+11	04022	26	04189	04213
0423		AM	PNCHO2+11,44,10	04034	11	04189	00044
0424		TF	PUNCH+14,THREEL	04046	26	05496	00034
0425		TF	PUNCH+16,THREED	04058	26	05498	00040
0426	PNCHO6	TFM	PNCHO5+6,PUNCH+17	04070	16	04088	05499
0427	PNCHO5	TDM	PUNCH+17	04082	15	05499	00000
0428		DNB	1,*	04093		00001	
0429		AM	PNCHO5+6,1,10	04094	11	04088	00001
0430		CM	PNCHO5+6,PUNCH+79	04106	14	04088	05561
0431		BNH	PNCHO5	04118	47	04082	01100
0432		CM	PNCHO2+11,MEMCAP-10	04130	14	04189	T9990
0433		BNL	PNCHO7	04142	46	04282	01300
0434		TF	PNCHO3+6,PNCHO2+11	04154	26	04196	04189
0435		TF	PNCHO4+6,PNCHO2+11	04166	26	04232	04189
0436	PNCHO2	TD	PNCHO3+10,MEMCAP-1	04178	25	04200	19999
0437	PNCHO3	TDM	MEMCAP-1	04190	15	19999	00000
0438		DC	1,@,*	04201		00001	‡
0439	PNCHO1	TR	PUNCH+17	04202	31	05499	00000
0440		WNCD	PUNCH	04214	38	05482	00400
0441	PNCHO4	TD	MEMCAP-1,PNCHO3+10	04226	25	19999	04200
0442		A	PUNCH+13,THREED	04238	21	05495	00040
0443		AM	PNCHO1+11,40,10	04250	11	04213	00040
0444		AM	PNCHO2+11,40,10	04262	11	04189	00040
0445		B	PNCHO6	04274	49	04070	00000
0446		DORG	*-3	04282			
0447	PNCHO7	TD	MEMCAP-10,400	04282	25	19990	00400
0448		TF	*+23,PNCHO1+11	04294	26	04317	04213

0449	TR	PUNCH+17	04306	31	05499	00000
0450	WNCD	PUNCH	04318	38	05482	00400
0451	*					
0452	*	THIRD SUMMATION, TEST FOR NEXT LINE.				
0453	*					
0454	AFTER	C TWOH, IDENT4-1	04330	24	05477	03380
0455		BNL THR100	04342	46	02734	01300
0456		BNC2 AFTER2	04354	47	04410	00200
0457		BNC3 AFTER2	04366	47	04410	00300
0458		WATY MESS05	04378	39	05361	00100
0459		RNTY HURSP-1	04390	36	00051	00100
0460		B THRIN4	04402	49	02246	00000
0461		DORG *-3	04410			
0462	*					
0463	*	TEST FOR NEXT SECTION.				
0464	*					
0465	AFTER2	A SECTX, ONED	04410	21	02387	00036
0466		C ONEH, SECTX	04422	24	00043	02387
0467		BNL START2	04434	46	00402	01300
0468		WATY IDENT8	04446	39	05413	00100
0469		H	04458	48	00000	00000
0470		DORG *-9	04460			
0471	*					
0472	*	TABLE OF COSINES AND SINES.				
0473	*					
0474	TABLE	DS *+1	04460	00000		
0475		DC 4,9999	04463	00004	9999	
0476		DC 5,@	04468	00005	0000‡	
0477		DC 4,9980	04472	00004	9980	
0478		DC 5,628@	04477	00005	0628‡	
0479		DC 4,9921	04481	00004	9921	
0480		DC 5,1253@	04486	00005	1253‡	
0481		DC 4,9823	04490	00004	9823	
0482		DC 5,1874@	04495	00005	1874‡	
0483		DC 4,9686	04499	00004	9686	
0484		DC 5,2487@	04504	00005	2487‡	
0485		DC 4,9511	04508	00004	9511	
0486		DC 5,3090@	04513	00005	3090‡	
0487		DC 4,9298	04517	00004	9298	
0488		DC 5,3681@	04522	00005	3681‡	
0489		DC 4,9048	04526	00004	9048	
0490		DC 5,4258@	04531	00005	4258‡	
0491		DC 4,8763	04535	00004	8763	
0492		DC 5,4818@	04540	00005	4818‡	
0493		DC 4,8443	04544	00004	8443	
0494		DC 5,5358@	04549	00005	5358‡	
0495		DC 4,8090	04553	00004	8090	
0496		DC 5,5878@	04558	00005	5878‡	
0497		DC 4,7705	04562	00004	7705	
0498		DC 5,6374@	04567	00005	6374‡	

0499	DC	4,7290	04571	00004	7290
0500	DC	5,6846@	04576	00005	6846‡
0501	DC	4,6846	04580	00004	6846
0502	DC	5,7290@	04585	00005	7290‡
0503	DC	4,6374	04589	00004	6374
0504	DC	5,7705@	04594	00005	7705‡
0505	DC	4,5878	04598	00004	5878
0506	DC	5,8090@	04603	00005	8090‡
0507	DC	4,5358	04607	00004	5358
0508	DC	5,8443@	04612	00005	8443‡
0509	DC	4,4818	04616	00004	4818
0510	DC	5,8763@	04621	00005	8763‡
0511	DC	4,4258	04625	00004	4258
0512	DC	5,9048@	04630	00005	9048‡
0513	DC	4,3681	04634	00004	3681
0514	DC	5,9298@	04639	00005	9298‡
0515	DC	4,3090	04643	00004	3090
0516	DC	5,9511@	04648	00005	9511‡
0517	DC	4,2487	04652	00004	2487
0518	DC	5,9686@	04657	00005	9686‡
0519	DC	4,1874	04661	00004	1874
0520	DC	5,9823@	04666	00005	9823‡
0521	DC	4,1253	04670	00004	1253
0522	DC	5,9921@	04675	00005	9921‡
0523	DC	4,628	04679	00004	628
0524	DC	5,9980@	04684	00005	9980‡
0525	DC	4,0	04688	00004	0000
0526	DC	5,9999@	04693	00005	9999‡
0527	DC	4,-628	04697	00004	628
0528	DC	5,9980@	04702	00005	9980‡
0529	DC	4,-1253	04706	00004	1253
0530	DC	5,9921@	04711	00005	9921‡
0531	DC	4,-1874	04715	00004	1874
0532	DC	5,9823@	04720	00005	9823‡
0533	DC	4,-2487	04724	00004	2487
0534	DC	5,9686@	04729	00005	9686‡
0535	DC	4,-3090	04733	00004	3090
0536	DC	5,9511@	04738	00005	9511‡
0537	DC	4,-3681	04742	00004	3681
0538	DC	5,9298@	04747	00005	9298‡
0539	DC	4,-4258	04751	00004	4258
0540	DC	5,9048@	04756	00005	9048‡
0541	DC	4,-4818	04760	00004	4818
0542	DC	5,8763@	04765	00005	8763‡
0543	DC	4,-5358	04769	00004	5358
0544	DC	5,8443@	04774	00005	8443‡
0545	DC	4,-5878	04778	00004	5878
0546	DC	5,8090@	04783	00005	8090‡
0547	DC	4,-6374	04787	00004	6374
0548	DC	5,7705@	04792	00005	7705‡

0549	DC	4,-6846	04796	00004	6846
0550	DC	5,7290@	04801	00005	7290‡
0551	DC	4,-7290	04805	00004	7290
0552	DC	5,6846@	04810	00005	6846‡
0553	DC	4,-7705	04814	00004	7705
0554	DC	5,6374@	04819	00005	6374‡
0555	DC	4,-8090	04823	00004	8090
0556	DC	5,5878@	04828	00005	5878‡
0557	DC	4,-8443	04832	00004	8443
0558	DC	5,5358@	04837	00005	5358‡
0559	DC	4,-8763	04841	00004	8763
0560	DC	5,4818@	04846	00005	4818‡
0561	DC	4,-9048	04850	00004	9048
0562	DC	5,4258@	04855	00005	4258‡
0563	DC	4,-9298	04859	00004	9298
0564	DC	5,3681@	04864	00005	3681‡
0565	DC	4,-9511	04868	00004	9511
0566	DC	5,3090@	04873	00005	3090‡
0567	DC	4,-9686	04877	00004	9686
0568	DC	5,2487@	04882	00005	2487‡
0569	DC	4,-9823	04886	00004	9823
0570	DC	5,1874@	04891	00005	1874‡
0571	DC	4,-9921	04895	00004	9921
0572	DC	5,1253@	04900	00005	1253‡
0573	DC	4,-9980	04904	00004	9980
0574	DC	5,628@	04909	00005	628‡
0575	DC	4,-9999	04913	00004	9999
0576	DC	5,@	04918	00005	0000‡
0577	DC	4,-9980	04922	00004	9980
0578	DC	5,-628@	04927	00005	628‡
0579	DC	4,-9921	04931	00004	9921
0580	DC	5,-1253@	04936	00005	1253‡
0581	DC	4,-9823	04940	00004	9823
0582	DC	5,-1874@	04945	00005	1874‡
0583	DC	4,-9686	04949	00004	9686
0584	DC	5,-2487@	04954	00005	2487‡
0585	DC	4,-9511	04958	00004	9511
0586	DC	5,-3090@	04963	00005	3090‡
0587	DC	4,-9298	04967	00004	9298
0588	DC	5,-3681@	04972	00005	3681‡
0589	DC	4,-9048	04976	00004	9048
0590	DC	5,-4258@	04981	00005	4258‡
0591	DC	4,-8763	04985	00004	8763
0592	DC	5,-4818@	04990	00005	4818‡
0593	DC	4,-8443	04994	00004	8443
0594	DC	5,-5358@	04999	00005	5358‡
0595	DC	4,-8090	05003	00004	8090
0596	DC	5,-5878@	05008	00005	5878‡
0597	DC	4,-7705	05012	00004	7705
0598	DC	5,-6374@	05017	00005	6374‡

0599	DC	4,-7290
0600	DC	5,-6846@
0601	DC	4,-6846
0602	DC	5,-7290@
0603	DC	4,-6374
0604	DC	5,-7705@
0605	DC	4,-5878
0606	DC	5,-8090@
0607	DC	4,-5358
0608	DC	5,-8443@
0609	DC	4,-4818
0610	DC	5,-8763@
0611	DC	4,-4258
0612	DC	5,-9048@
0613	DC	4,-3681
0614	DC	5,-9298@
0615	DC	4,-3090
0616	DC	5,-9511@
0617	DC	4,-2487
0618	DC	5,-9686@
0619	DC	4,-1874
0620	DC	5,-9823@
0621	DC	4,-1253
0622	DC	5,-9921@
0623	DC	4,-628
0624	DC	5,-9980@
0625	DC	4,0
0626	DC	5,-9999@
0627	DC	4,628
0628	DC	5,-9980@
0629	DC	4,1253
0630	DC	5,-9921@
0631	DC	4,1874
0632	DC	5,-9823@
0633	DC	4,2487
0634	DC	5,-9686@
0635	DC	4,3090
0636	DC	5,-9511@
0637	DC	4,3681
0638	DC	5,-9298@
0639	DC	4,4258
0640	DC	5,-9048@
0641	DC	4,4818
0642	DC	5,-8763@
0643	DC	4,5358
0644	DC	5,-8443@
0645	DC	4,5878
0646	DC	5,-8090@
0647	DC	4,6374
0648	DC	5,-7705@

05021	00004	7290
05026	00005	6846‡
05030	00004	6846
05035	00005	7290‡
05039	00004	6374
05044	00005	7705‡
05048	00004	5878
05053	00005	8090‡
05057	00004	5358
05062	00005	8443‡
05066	00004	4818
05071	00005	8763‡
05075	00004	4258
05080	00005	9048‡
05084	00004	3681
05089	00005	9298‡
05093	00004	3090
05098	00005	9511‡
05102	00004	2487
05107	00005	9686‡
05111	00004	1874
05116	00005	9823‡
05120	00004	1253
05125	00005	9921‡
05129	00004	0628
05134	00005	9980‡
05138	00004	0000
05143	00005	9999‡
05147	00004	0628
05152	00005	9980‡
05156	00004	1253
05161	00005	9921‡
05165	00004	1874
05170	00005	9823‡
05174	00004	2487
05179	00005	9686‡
05183	00004	3090
05188	00005	9511‡
05192	00004	3681
05197	00005	9298‡
05201	00004	4258
05206	00005	9048‡
05210	00004	4818
05215	00005	8763‡
05219	00004	5358
05224	00005	8443‡
05228	00004	5878
05233	00005	8090‡
05237	00004	6374
05242	00005	7705‡

0649	DC	4,6846	05246	00004	6846
0650	DC	5,-7290@	05251	00005	7290‡
0651	DC	4,7290	05255	00004	7290
0652	DC	5,-6846@	05260	00005	6846‡
0653	DC	4,7705	05264	00004	7705
0654	DC	5,-6374@	05269	00005	6374‡
0655	DC	4,8090	05273	00004	8090
0656	DC	5,-5878@	05278	00005	5878‡
0657	DC	4,8443	05282	00004	8443
0658	DC	5,-5358@	05287	00005	5358‡
0659	DC	4,8763	05291	00004	8763
0660	DC	5,-4818@	05296	00005	4818‡
0661	DC	4,9048	05300	00004	9048
0662	DC	5,-4258@	05305	00005	4258‡
0663	DC	4,9298	05309	00004	9298
0664	DC	5,-3681@	05314	00005	3681‡
0665	DC	4,9511	05318	00004	9511
0666	DC	5,-3090@	05323	00005	3090‡
0667	DC	4,9686	05327	00004	9686
0668	DC	5,-2487@	05332	00005	2487‡
0669	DC	4,9823	05336	00004	9823
0670	DC	5,-1874@	05341	00005	1874‡
0671	DC	4,9921	05345	00004	9921
0672	DC	5,-1253@	05350	00005	1253‡
0673	DC	4,9980	05354	00004	9980
0674	DC	5,-628@	05359	00005	628‡
0675	MESS05	DAC	26,SET PS2,3.TYPE ALPHASPECS@		
05361	00026X2	SET	PS2,3.TYPE ALPHASPECS‡		
0676	IDENT8	DAC	5,M001@	05413	00005X2 M001‡
0677	IDENT1	DAC	9,SECTION @	05423	00009X2 SECTION ‡
0678	ZER010	DC	10,0	05449	00010 0000000000
0679	IDENT6	DAC	10,LOAD DATA@	05451	00010X2 LOAD DATA‡
0680	HIGHP	DS	5	05474	00005
0681	TWOH	DS	3	05477	00003
0682	THREEH	DS	3	05480	00003
0683		DS	1	05481	00001
0684	PUNCH	DS	1	05482	00001
0685		DS	5	05487	00005
0686	H1	DS	2	05489	00002
0687	K1	DS	2	05491	00002
0688	L1	DS	2	05493	00002
0689	A	DS	4	05497	00004
0690	B	DS	4	05501	00004
0691	C	DS	4	05505	00004
0692	D	DS	4	05509	00004
0693	E	DS	4	05513	00004
0694	F	DS	4	05517	00004
0695	G	DS	4	05521	00004
0696	H	DS	4	05525	00004
0697	COS1	DS	4	05529	00004

0698	SIN1	DS	4	05533	00004
0699	SIN2	DS	4	05537	00004
0700	COS2	DS	4	05541	00004
0701	COS3	DS	4	05545	00004
0702	SIN3	DS	4	05549	00004
0703	M	DS	4	05553	00004
0704	N	DS	4	05557	00004
0705	O	DS	4	05561	00004
0706	P	DS	4	05565	00004
0707		DORG	(0+1)	05562	
0708	MTEMP	DS	10	05571	00010
0709	NTEMP	DS	10	05581	00010
0710	OTEMP	DS	10	05591	00010
0711	PTEMP	DS	10	05601	00010
0712	TROUND	DS	10, MEMCAP-1	19999	00010
0713	R	DS	4	05605	00004
0714	S	DS	4	05609	00004
0715		DORG	20	00020	
0716	CODE	DS	6	00025	00006
0717	ONEL	DS	3	00028	00003
0718	TWOL	DS	3	00031	00003
0719	THREEL	DS	3	00034	00003
0720	ONED	DS	2	00036	00002
0721	TWOD	DS	2	00038	00002
0722	THREED	DS	2	00040	00002
0723	ONEH	DS	3	00043	00003
0724	ONES	DS	2	00045	00002
0725	TWOS	DS	2	00047	00002
0726	THREES	DS	2	00049	00002
0727	SYM	DS	1	00050	00001
0728	HORSP	DS	2	00052	00002
0729	VERTSP	DS	2	00054	00002
0730	SHFTSP	DS	2	00056	00002
0731	LOWP	DS	4	00060	00004
0732	*				
0733	*				
0734	*				
0735	*				
0736	*				
0737	*				
0738	*				
0739		DORG	15082	15082	
0740	START	RCTY		15082	34 00000 00102
0741		WATY	MESS75	15094	39 18493 00100
0742		H		15106	48 00000 00000
0743		BC1	PREP01	15118	46 16414 00100
0744		TR	15032, NCIALPH-1	15130	31 15032 18801
0745		RCTY		15142	34 00000 00102
0746		WATY	MESS70	15154	39 18159 00100
0747		TBTY		15166	34 00000 00108

THE REMAINDER OF THE PROGRAMME IS USED ONLY ONCE FOR
INITIALIZATION AND PREPARATION OF THE SPECIFICATIONS
OF THE CALCULATION.

IT IS ERASED BY THE SECOND SUMMATION RESULTS.

18493
13387
5100

0748	RNTY	15001
0749	SF	15001
0750	RCTY	
0751	WATY	MESS50
0752	TBTY	
0753	RNTY	15007
0754	SF	15007
0755	RCTY	
0756	WATY	MESS51
0757	TBTY	
0758	RNTY	15022
0759	SF	15022
0760	RCTY	
0761	WATY	MESS52
0762	TBTY	
0763	RNTY	15010
0764	SF	15010
0765	RCTY	
0766	WATY	MESS53
0767	TBTY	
0768	RNTY	15047
0769	SF	15047
0770	RCTY	
0771	WATY	MESS54
0772	TBTY	
0773	RNTY	15013
0774	SF	15013
0775	RCTY	
0776	WATY	MESS55
0777	TBTY	
0778	RNTY	15050
0779	SF	15050
0780	RCTY	
0781	WATY	MESS56
0782	TBTY	
0783	RNTY	15016
0784	SF	15016
0785	RCTY	
0786	WATY	MESS57
0787	TBTY	
0788	RNTY	15018
0789	SF	15018
0790	RCTY	
0791	WATY	MESS58
0792	TBTY	
0793	RNTY	15020
0794	SF	15020
0795	RCTY	
0796	WATY	MESS59
0797	TBTY	

15178	36	15001	00100
15190	32	15001	00000
15202	34	00000	00102
15214	39	17339	00100
15226	34	00000	00108
15238	36	15007	00100
15250	32	15007	00000
15262	34	00000	00102
15274	39	17381	00100
15286	34	00000	00108
15298	36	15022	00100
15310	32	15022	00000
15322	34	00000	00102
15334	39	17423	00100
15346	34	00000	00108
15358	36	15010	00100
15370	32	15010	00000
15382	34	00000	00102
15394	39	17465	00100
15406	34	00000	00108
15418	36	15047	00100
15430	32	15047	00000
15442	34	00000	00102
15454	39	17507	00100
15466	34	00000	00108
15478	36	15013	00100
15490	32	15013	00000
15502	34	00000	00102
15514	39	17549	00100
15526	34	00000	00108
15538	36	15050	00100
15550	32	15050	00000
15562	34	00000	00102
15574	39	17591	00100
15586	34	00000	00108
15598	36	15016	00100
15610	32	15016	00000
15622	34	00000	00102
15634	39	17635	00100
15646	34	00000	00108
15658	36	15018	00100
15670	32	15018	00000
15682	34	00000	00102
15694	39	17679	00100
15706	34	00000	00108
15718	36	15020	00100
15730	32	15020	00000
15742	34	00000	00102
15754	39	17723	00100
15766	34	00000	00108

0798	RNTY	15025
0799	SF	15025
0800	RCTY	
0801	WATY	MESS60
0802	TBTY	
0803	RNTY	15027
0804	SF	15027
0805	RCTY	
0806	WATY	MESS61
0807	TBTY	
0808	RNTY	15029
0809	SF	15029
0810	BC2	PREP05
0811	RCTY	
0812	WATY	MESS62
0813	TBTY	
0814	RNTY	15032
0815	SF	15032
0816	RCTY	
0817	WATY	MESS63
0818	TBTY	
0819	RNTY	15034
0820	SF	15034
0821	RCTY	
0822	WATY	MESS64
0823	TBTY	
0824	RNTY	15036
0825	SF	15036
0826	RCTY	
0827	WATY	MESS66
0828	TBTY	
0829	RNTY	15038
0830	SF	15038
0831	RCTY	
0832	WATY	MESS65
0833	TBTY	
0834	RNTY	15042
0835	SF	15042
0836	PREP05	RCTY
0837	WATY	MESS68
0838	TBTY	
0839	RNTY	15031
0840	RCTY	
0841	WATY	MESS77
0842	H	
0843	BC4	START+48
0844	RCTY	
0845	TD	15053,400
0846	WATY	MESS71
0847	H	

15778	36	15025	00100
15790	32	15025	00000
15802	34	00000	00102
15814	39	17767	00100
15826	34	00000	00108
15838	36	15027	00100
15850	32	15027	00000
15862	34	00000	00102
15874	39	17811	00100
15886	34	00000	00108
15898	36	15029	00100
15910	32	15029	00000
15922	46	16234	00200
15934	34	00000	00102
15946	39	17855	00100
15958	34	00000	00108
15970	36	15032	00100
15982	32	15032	00000
15994	34	00000	00102
16006	39	17899	00100
16018	34	00000	00108
16030	36	15034	00100
16042	32	15034	00000
16054	34	00000	00102
16066	39	17943	00100
16078	34	00000	00108
16090	36	15036	00100
16102	32	15036	00000
16114	34	00000	00102
16126	39	18043	00100
16138	34	00000	00108
16150	36	15038	00100
16162	32	15038	00000
16174	34	00000	00102
16186	39	17987	00100
16198	34	00000	00108
16210	36	15042	00100
16222	32	15042	00000
16234	34	00000	00102
16246	39	18097	00100
16258	34	00000	00108
16270	36	15031	00100
16282	34	00000	00102
16294	39	18599	00100
16306	48	00000	00000
16318	46	15130	00400
16330	34	00000	00102
16342	25	15053	00400
16354	39	18233	00100
16366	48	00000	00000

0848		WNCD	15001	16378	38	15001	00400
0849		TR	20,15001	16390	31	00020	15001
0850		B	PREP02	16402	49	16462	00000
0851	PREP01	RCTY		16414	34	00000	00102
0852		WATY	MESS72	16426	39	18257	00100
0853		H		16438	48	00000	00000
0854		RNCD	20	16450	36	00020	00500
0855	PREP02	TR	HIGHP-4,LOWP+1	16462	31	05470	00061
0856		TF	SECTX,ONEL	16474	26	02387	00028
0857		BNC 2	PREP06	16486	47	16798	00200
0858	PREP04	RCTY		16498	34	00000	00102
0859		WATY	MESS73	16510	39	18305	00100
0860		WNTY	MESS76-1	16522	38	18372	00100
0861		RCTY		16534	34	00000	00102
0862		WATY	MESS78	16546	39	18375	00100
0863		WNTY	MESS79-1	16558	38	18408	00100
0864		WATY	MESS80	16570	39	18411	00100
0865		TBTY		16582	34	00000	00108
0866		RNTY	PUNPRT	16594	36	03578	00100
0867		BNF	PREP08,PUNPRT	16606	44	16762	03578
0868		RCTY		16618	34	00000	00102
0869		WATY	MESS74	16630	39	18423	00100
0870		TBTY		16642	34	00000	00108
0871		RNTY	PRT030+9	16654	36	03835	00100
0872		SF	PRT030+9	16666	32	03835	00000
0873		BD	PREP06,PUNPRT	16678	43	16798	03578
0874		B	PREP12	16690	49	16774	00000
0875	PREP09	RCTY		16702	34	00000	00102
0876		WATY	MESS81	16714	39	18669	00100
0877		H		16726	48	00000	00000
0878		BC4	PREP04	16738	46	16498	00400
0879		B	PREP06	16750	49	16798	00000
0880	PREP08	BD	PREP09,PUNPRT	16762	43	16702	03578
0881	PREP12	RCTY		16774	34	00000	00102
0882		WATY	MESS71	16786	39	18233	00100
0883	PREP06	RCTY		16798	34	00000	00102
0884		SM	ONES,10,10	16810	12	00045	00070
0885		CF	ONES	16822	33	00045	00000
0886		TD	NEWS21+6,ONES	16834	25	01372	00045
0887		SM	ONES,1,10	16846	12	00045	00001
0888		TD	NEWS24+6,ONES	16858	25	01396	00045
0889		TD	NEWS12+11,ONES	16870	25	01413	00045
0890		SM	ONES,3,10	16882	12	00045	00003
0891		TD	NEWS20+6,ONES	16894	25	01360	00045
0892		SM	ONES,1,10	16906	12	00045	00001
0893		BNN	*+24	16918	46	16942	01300
0894		TDM	NEWS19+1,1	16930	15	01415	00001
0895		TD	NEWS19+11,ONES	16942	25	01425	00045
0896		BD	PREP03,SYM	16954	43	16978	00050
0897		B	PREP07	16966	49	16990	00000

0898	PREP03	TFM	NEWS56+6, NEWS58	16978	16	01112	01226
0899	PREP07	TD	IDENT3+60, THREED	16990	25	18595	00040
0900		TD	IDENT3+58, THREED-1	17002	25	18593	00039
0901		TD	IDENT3+38, THREEH	17014	25	18573	05480
0902		TD	IDENT3+36, THREEH-1	17026	25	18571	05479
0903		TD	IDENT3+32, THREEH-2	17038	25	18567	05478
0904		TD	IDENT3+16, THREEL	17050	25	18551	00034
0905		TD	IDENT3+14, THREEL-1	17062	25	18549	00033
0906		RCTY		17074	34	00000	00102
0907		WATY	IDENT6	17086	39	05451	00100
0908		H		17098	48	00000	00000
0909		RCTY		17110	34	00000	00102
0910		RCTY		17122	34	00000	00102
0911		TF	CODE1, CODE	17134	26	18799	00025
0912		WATY	MESS82	17146	39	18769	00100
0913		CF	CODE1-5	17158	33	18794	00000
0914		WNTY	CODE1-5	17170	38	18794	00100
0915		RCTY		17182	34	00000	00102
0916		WATY	IDENT3	17194	39	18535	00100
0917		RCTY		17206	34	00000	00102
0918		CM	ONED, 0, 10	17218	14	00036	00000
0919		BNE	*+24	17230	47	17254	01200
0920		TFM	ONED, 1, 10	17242	16	00036	00001
0921		CM	TWOD, 0, 10	17254	14	00038	00000
0922		BNE	*+24	17266	47	17290	01200
0923		TFM	TWOD, 1, 10	17278	16	00038	00001
0924		CM	THREED, 0, 10	17290	14	00040	00000
0925		BNE	*+24	17302	47	17326	01200
0926		TFM	THREED, 1, 10	17314	16	00040	00001
0927		B	STARTO	17326	49	00462	00000
0928	MESS50	DAC	21, TYPE 1ST SUM MIN.(3)@	17339	00021X2	TYPE 1ST SUM MIN.(3)	
0929	MESS51	DAC	21, TYPE 1ST SUM MAX.(3)@	17381	00021X2	TYPE 1ST SUM MAX.(3)	
0930	MESS52	DAC	21, TYPE 2ND SUM MIN.(3)@	17423	00021X2	TYPE 2ND SUM MIN.(3)	
0931	MESS53	DAC	21, TYPE 2ND SUM MAX.(3)@	17465	00021X2	TYPE 2ND SUM MAX.(3)	
0932	MESS54	DAC	21, TYPE 3RD SUM MIN.(3)@	17507	00021X2	TYPE 3RD SUM MIN.(3)	
0933	MESS55	DAC	21, TYPE 3RD SUM MAX.(3)@	17549	00021X2	TYPE 3RD SUM MAX.(3)	
0934	MESS56	DAC	22, TYPE 1ST SUM DELTA(2)@	17591	00022X2	TYPE 1ST SUM DELTA(2)	
‡							
0935	MESS57	DAC	22, TYPE 2ND SUM DELTA(2)@	17635	00022X2	TYPE 2ND SUM DELTA(2)	
‡							
0936	MESS58	DAC	22, TYPE 3RD SUM DELTA(2)@	17679	00022X2	TYPE 3RD SUM DELTA(2)	
‡							
0937	MESS59	DAC	22, TYPE 1ST SUM SHIFT(2)@	17723	00022X2	TYPE 1ST SUM SHIFT(2)	
‡							
0938	MESS60	DAC	22, TYPE 2ND SUM SHIFT(2)@	17767	00022X2	TYPE 2ND SUM SHIFT(2)	
‡							
0939	MESS61	DAC	22, TYPE 3RD SUM SHIFT(2)@	17811	00022X2	TYPE 3RD SUM SHIFT(2)	
‡							
0940	MESS62	DAC	22, TYPE HORIZ.SPACING(2)@	17855	00022X2	TYPE HORIZ.SPACING(2)	
‡							


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0941 MESS63 DAC 22,TYPE VERT. SPACING(2)@ 17899 00022X2 TYPE VERT. SPACING(2)
‡
0942 MESS64 DAC 22,TYPE SHIFT SPACING(2)@ 17943 00022X2 TYPE SHIFT SPACING(2)
‡
0943 MESS65 DAC 28,TYPE HIGH LIMIT OF PEAKS(5)@
17987 00028X2 TYPE HIGH LIMIT OF PEAKS(5)‡
0944 MESS66 DAC 27,TYPE LOW LIMIT OF PEAKS(4)@
18043 00027X2 TYPE LOW LIMIT OF PEAKS(4)‡
0945 MESS68 DAC 31,CENTROSYM=1,NONCENTROSYM=0 (1)@
18097 00031X2 CENTROSYM=1,NONCENTROSYM=0 (1)‡
0946 MESS70 DAC 37,TYPE IDENT OF SPECS CARD NOW MADE(6)@
18159 00037X2 TYPE IDENT OF SPECS CARD NOW MADE(6)‡
0947 MESS71 DAC 12,READY PUNCH@ 18233 00012X2 READY PUNCH‡
0948 MESS72 DAC 24,LOAD SPECIFICATION CARD@
18257 00024X2 LOAD SPECIFICATION CARD‡
0949 MESS73 DAC 34,OUTPUT. PUNCH ONLY=0, PRINT ONLY=@
18305 00034X2 OUTPUT. PUNCH ONLY=0, PRINT ONLY=‡
0950 MESS76 DC 2,1@ 18373 00002 T‡
0951 MESS78 DAC 17,PUNCH AND PRINT=@ 18375 00017X2 PUNCH AND PRINT=‡
0952 MESS79 DC 2,@ 18409 00002 0‡
0953 MESS80 DAC 6, (1)@ 18411 00006X2 (1)‡
0954 MESS74 DAC 35,TYPE NUMBER OF ANSWERS IN A ROW(3)@
18423 00035X2 TYPE NUMBER OF ANSWERS IN A ROW(3)‡
0955 MESS75 DAC 21,SET PROGRAM SWITCHES@ 18493 00021X2 SET PROGRAM SWITCHES
0956 IDENT3 DAC 32,XMIN3=.00 XMAX3=0.00 DELTA3=.00@
18535 00032X2 XMIN3=.00 XMAX3=0.00 DELTA3=.00‡
0957 DNB 27,15080 15080 00027
0958 MESS77 DAC 35,IN CASE OF TYPING ERROR SET SW4 (IN@
18599 00035X2 IN CASE OF TYPING ERROR SET SW4 (IN‡
0959 MESS81 DAC 50,NO OUTPUT. SET SW4 (ON TO CORRECT,OFF TO CONTINUE.@
18669 00050X2 NO OUTPUT. SET SW4 (ON TO CORRECT,OFF TO CONTINUE.‡
0960 MESS82 DAC 13,FOURIER NO. @ 18769 00013X2 FOURIER NO. ‡
0961 CODE1 DS 6 18799 00006
0962 DC 1,@ 18800 00001 ‡
0963 NOALPH DC 2,0 18802 00002 00
0964 DC 2,0 18804 00002 00
0965 DC 2,0 18806 00002 00
0966 DC 4,-1000 18810 00004 T000
0967 DC 6,10000@ 18816 00006 T0000‡
0968 DEND START 15082
END OF PASS2

```

VIII. Maintenance

The core layout is as follows :

00020-00057	Specifications
00100-00400	Arithmetic tables
00402-04459	Programme
04460-05359	Trigonometric tables
05360-05601	Constants and working storage
05602-19989*	Storage for second and third summation results
19990*-19999*	Working storage used in scaling and rounding off
15001-18316	Initialization programme.

Addresses marked* are given for a 20K machine. Processing the symbolic programme for a larger machine will cause these addresses to be augmented. There is no space available for modifications to the programme unless the size of the second summation is limited when space will become available up to location 19585*. Such limitation could be achieved by modifying the instruction at 01578 to 14 01620 xxxxx where xxxxx + 1 is the beginning of a patch.

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