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Record 1973/213

USE OF A GRAPHIC DISPLAY TERMINAL TO MATCH MAGNETIC CURVES

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SUMMARY

Sharma has described a method for calculating the total magnetic field anomaly due to two-dimensional geological structures within the earth. This Record outlines the method and its application to computer modelling studies which enable the matching of theoretical and observed magnetic anomalies to be done quickly and easily.

The main input-output device is the CSIRO 3600 graphic display terminal which can display a picture as output and can read input data drawn onto the screen with a light pen. This device is referred to as the Vista.

The original magnetic profile is read in on cards and is displayed on the Vista screen. Body cross-sections are then drawn on the screen and the theoretical profile due to these is displayed with the original profile; if the profiles do not match, the body cross-sections can immediately be changed to obtain a better match. This process can be repeated any number of times until a good match is obtained. The parameters for each body can be changed during the process, using the DD210 display console.

1. INTRODUCTION

The interpretation of magnetic anomalies may be approached in two ways: either the theoretical anomaly due to a given model is calculated and is fitted to the observed anomaly by examining a range of models considered most likely in a particular situation, or the anomaly curve is fitted automatically by least-squares fitting or similar procedures using a high-speed digital computer. The first method has been the most widely used and the method described in this report is of this type. The second method has not been widely used until recently, but with the increasing numbers of digital computers it is gaining popularity (Bott, 1967).

The earliest methods of magnetic interpretation concentrated mainly on finding the depth to the top and the susceptibility of a magnetic body, and ignored any remanent magnetism which might be present. For instance Vacquier et al. (1951) plotted the theoretical total-field contours and second vertical derivative contours over a series of rectangular prisms of infinite depth. These contours were compared with observed contours, and if a good match could be obtained the depth to the top of the body and its susceptibility could be found using a number of simple rules. A number of other authors, for instance Peters (1949), developed methods whereby the depth and susceptibility of the body could be obtained by measuring certain parameters of the observed anomaly. Of necessity, all assumed a fairly restricted model.

Parker Gay (1963) calculated the theoretical anomaly over a dyke of infinite depth and infinite length along the strike, and discovered that the two parameters, dip of dyke and dip of inducing field, could be replaced by a single variable which he called the index parameter. This led to a considerable reduction in the number of theoretical curves required to cover all possible dykes, and it became possible to calculate a complete set of such curves. Theoretical curves were compared with observed profiles, and the depth, dip, and susceptibility of the magnetic body could be found directly.

All these methods would obviously fail if the source of the anomaly did not approximate fairly closely to the regular geometric shape whose theoretical curves were calculated (Haigh, 1972). With the advent of high-speed digital computers it became practicable to calculate the anomaly due to bodies of arbitrary shape and arbitrary direction of remanent magnetization. Talwani & Heirtzler (1964) developed a program for computing the anomaly profile over infinite two-dimensional bodies of arbitrary cross-section, and a similar program was developed in the Bureau of Mineral Resources by Haigh et. al. (1972). With these methods the theoretical and observed curves must be fitted by calculating profiles over a range of probable models, and the main usage problem becomes the relatively slow input and output of the parameters for a sufficient number of models.

The present method calculates the anomaly profile over two-dimensional bodies of arbitrary cross-section using formulae developed by Sharma (1966). The problem of input and output of model parameters is tackled by the use of a graphic display computer terminal, referred to as 'Vista' in the following description. Vista consists of a television-type screen and console (Plate 1) wired so that input data can be introduced though the screen with a light pen; data read in on cards or from any other input device can also be displayed on the screen. Model parameters can be introduced while the program is running, and the calculated anomaly is immediately displayed on the screen, where it can be compared to the observed profile. Any changes required to the model can be made immediately, and by successive approximation it is usually possible to obtain a good match between the calculated and the observed profiles.

The method can be used to advantage on all types of survey from detailed exploration work to broad regional studies, and should greatly speed-up the interpretation and improve the detail obtained.

2. COMPUTING METHOD

The formulae used in the calculation of the total field anomaly were derived by Sharma (1966) who gives a general treatment covering both gravity and magnetic anomalies. The derivation given below follows Sharma very closely but is confined to magnetic anomalies, with some mathematical amplification where necessary.

We chose a right-handed system of co-ordinates (x_1, x_2, x_3) such that a two-dimensional body strikes from + 00 to - 00 in the x_2 direction. From potential theory the magnetic potential U at the point P(0, 0, 0) of a two-dimensional body with uniform magnetization vector J and area S is given by

$$U = 2\bar{J}\iint_S \log\left(\frac{1}{r}\right) ds \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

where $r = \sqrt{x_1^2 + x_3^2}$. The derivation of this formula is given in full by Kellogg (1929, page 172).

The components of the magnetic field intensity at the point P(0, 0,0) are given by differentiation of the expression for the magnetic potential (equation (1); i.e.

$$H_i = 2\sum J_k\, T_{ik} \; (i,\, k = 1,\, 2,\, 3) \qquad \ldots\ldots\ldots\ldots (2)$$

where

$$T_{ik} = \frac{\partial^2}{\partial x_i \partial x_k} \iint_S \log\left(\frac{1}{r}\right) ds. \qquad \ldots\ldots\ldots\ldots (3)$$

Now from equation (3), $T_{ik} = T_{ki}$ merely by altering the order in which the differentiation is performed. Further, the $T_{2i} = 0$ (since only two-dimensional bodies are considered), and are no longer involved in equation (3); and making use of Laplace's equation, $T_{11} = -T_{33}$. Thus for the evaluation of the vertical and horizontal components of magnetic field intensity we need only calculate the quantities T_{33} and T_{13}.

For an arbitrary surface S, the evaluation of T_{ik} in closed form is not possible. However, the analytical problem is considerably simplified by approximating the arbitrary body cross-section by a number of thin vertical or horizontal rectangular strips. This in effect, would mean division of the two-dimensional body into a number of infinitely long sheets. The evaluated expressions for the components of such a vertical sheet of small thickness Δx_1, and extending from a_3 to b_3 in the x_3 direction are derived by evaluation of equation (3) giving

$$T_{33} \overset{\Omega}{=} \Delta x_1 \left[\frac{x_3}{x_1^2 + x_3^2} \right]_{x_3 = b_3}^{a_3} \qquad \ldots\ldots\ldots\ldots (4)$$

$$T_{13} \overset{\Omega}{=} -x_1\, \Delta x_1 \left[\frac{1}{x_1^2 + x_3^2} \right]_{x_3 = b_3}^{a_3} \qquad \ldots\ldots\ldots\ldots (5)$$

Thus all the necessary components of T_{ik} are determined and magnetic anomalies in directions x_1 and x_3 can be calculated using equation (2). Values of J_k in equation (2) are determined from the direction of the magnetization vector $\bar{J}$, which may be either induced or remanent or mixed. For example, let us denote the inclination of the vector $\bar{J}$ by I and let the angle which the positive direction of x_1 axis makes with the horizontal projection of $\bar{J}$ measured clockwise with respect to the latter be D. Then J_1 and J_3 are given by

$$J_1 = J \cos I \cos D \qquad \ldots\ldots\ldots\ldots (6)$$

$$J_3 = J \sin I \qquad \text{.......... (7)}$$

If desired, the total anomaly in the direction of the Earth's field could be calculated from the sum of projections of H_1 and H_3 along the direction of total field; i.e.

$$T = H_1 \cos D \cos I + H_3 \sin I \qquad \text{.......... (8)}$$

The formulae for H_1 and H_3 can be obtained from equation (2) which gives

$$H_1 = 2(J_1 T_{11} + J_2 T_{12} + J_3 T_{13}) \qquad \text{.......... (9)}$$

But T_{12} = O if the traverse is perpendicular to the body. Hence

$$H_1 = 2(J_1 T_{11} + J_3 T_{13}) \qquad \text{.......... (10)}$$

Again $H_3 = 2(J_1 T_{31} + J_2 T_{32} + J_3 T_{33})$ .... (11)

$= 2(J_1 T_{31} + J_3 T_{33})$ since $T_{32} = 0$

Now $T_{13} = T_{31}$ and $T_{11} = - T_{33}$

so we have only two quantities to calculate.

Limitations of the method

The method has two main limitations: the lack of uniqueness of the solution, which is inherent in all potential problems, and a possible lack of two-dimensionality in the structures begin interpreted. The first can usually be overcome by consideration of geological and structural factors and of evidence from other geophysical data in the same area.

The second is more serious, for obviously many of the structures encountered will not be two-dimensional. Very little qualitative information on this subject is available, but it is reasonable to assume that if both the depth and the width of the body are less than one-quarter of its length, then departure from two-dimensionality should be fairly small. Further investigation of this matter is obviously very desirable.

Program testing

The accuracy of the program was tested by comparing the curves generated by the program with those obtained from the exact formula for a dyke of infinite depth and infinite length along the strike derived by Parker Gay (1963, equation 22):

$$F = C_F \left[\frac{(\psi_1 - \psi_2)}{R} \cos \theta_F + \frac{1}{R} \log \left(\frac{\cos \psi_2}{\cos \psi_1} \right) \sin \theta_F \right]$$

Curves for a dyke of finite depth to the bottom were obtained by taking the difference between two dykes of infinite depth with different depths to the top; comparisons of the two curves are shown in Figures 1-3. The agreement is good except for the very thin dykes, where the shape of the body when split into strips is appreciably altered, (Fig. 4). This inaccuracy is not serious as for thin bodies the scale of the screen can be increased.

The accuracy could probably be improved by altering the way in which the body is split into strips. At present the strips are of fixed width for all bodies; the first strip starts at the end of the body and strips are added on until the central value of a strip falls outside the body. The strip whose central value falls outside the body is discarded and no more strips are generated. A better way of constructing the strips would be to make the number of strips depend on the size of the body (more for small bodies) and to divide the body exactly into strips i.e. the width of a strip to be equal to:

Width of strip = (XMAX - XMIN)/ number of strips.

3. PROGRAM TOLITTLE: USER'S GUIDE

3.1 CARD DECK STRUCTURE

Figure 5 shows the card deck structure as at August 1972 and Figure 6 shows a sample data sheet.

First data card

A set of 24 alphanumeric characters which appears on the screen as an identifier (3A8).

Second data card

XGREAT: the profile distance in metres (m) required across the screen (F5.0).

RECLEVEL: the height in metres (m) at which the field profile was recorded (F5.0) (positive above sea level).

VOVERH: the vertical exaggeration required on the screen (F5.0). It is usually convenient to use vertical exaggerations in the range 1 to 5. A vertical exaggeration of 1 would be suitable for detailed exploration work and of 5 for large-scale regional work.

The use of vertical exaggerations greater than 5 causes angles to be grossly distorted. For instance a vertical exaggeration of 5 causes an angle of 10° from the horizontal to appear at about 45° and all higher angles to be correspondingly distorted.

Third data card

GLEASTO the magnetic value in nanoteslas (nT) of the bottom of the screen (F5.0).

GGREATO the magnetic value in nanoteslas (nT) of the top of the screen (F5.0).

Fourth data card

TSTN: the distance between points of calculation (F5.0). TSTN is usually selected in the range XGREAT/20 to XGREAT/50 and in any case the value of TSTN must not be less than XGREAT/100 or an array bounds error will result.

WIDTH: the width in metres (m) of the strips into which the bodies are split for the purposes of calculating the anomaly; the smaller the strips the more accurate the calculated anomaly. From experience it has been found that a value of WIDTH of XGREAT/100 is quite satisfactory; the test bodies shown in Figures 1-3 were calculated using this value of WIDTH. The value of WIDTH must not be less than XGREAT/200 or an array bounds error will result.

Fifth data card

NG: the number of points in the digitized magnetic profile (I5).

NT: the number of points in the digitized terrain profile (I5).

NT and NG are limited to 100 by array dimensions.

Following this are four sets of cards with 16F5.0 format. The first set is the digitized total magnetic field values (nT), the second set is the distances in metres of these digitized values from the origin, the third set is the digitized terrain profile in metres (+ve above sea level, -ve below sea level), and the fourth set is the distances in metres of the digitized terrain from the origin. The distances of both the magnetic and terrain profiles must be measured from the same arbitrary origin. Any units of distance may be used provided the same units are used throughout; in this Record metres are used to conform with the SI system of units. The following quantities are in distance units: XGREAT, RECLEVEL, TSTN, WIDTH, the terrain profile, the magnetic distances, and the terrain distances. The entire deck of data cards may be repeated any number of times if more than one profile is to be interpreted. The data cards for the various profiles are not separated by any intervening cards.

3.2 PROGRAM OPERATION

The program card deck is put in the input box at CSIRO's Computer Centre in the normal way, and goes onto the execution list. The job can normally be put in as a one-minute job, in which case it should appear on the screen within about 10 minutes of being fed into the card reader. However, there may be delays due to:

(1) operators taking some time to feed the job into the card reader

(2) somebody else already using the Vista

(3) the condition that the Vista is in use is not cancelled by the computer monitor.

Case (3) above can sometimes occur when the computer monitor fails while the Vista is in operation; when this has happened the job will come to the head of the execution list but will not execute. Consultant staff at the computing centre know how to rectify this fault.

The position of the job in the execution list can be found by logging in LISTQS on a DD210 console or teletype, and the status of the Vista can be found by logging LISTAPES, which among other things displays a message declaring whether or not the Vista is in use.

When the job has started, an identification panel shown in Fig. 7 (a) will appear on the screen. From here, interaction with the computer can take place in three ways, outlined in (a) to (c) below:

(a) Through the control panel on Vista. Plate 2 shows a photograph of the keyboard and Figure 8 gives the functions of the buttons. A number of options are available via the Vista keyboard.

Top row

Button 7: Photograph the screen

Button 5: Used in conjunction with the second row to move the profiles from right to left across the screen.

Middle row

The middle row is used to indicate the distance which profiles or points are required to be moved. The distances moved are in terms of the divisions marked along the axes on the screen (i.e. tenths of the distance across the screen). By itself the middle row moves the profile from left to right and in conjunction with button 5 of the top row it moves it from right to left.

The middle row of buttons is also used in conjunction with the bottom row to alter the shape of bodies already on the screen. When bodies are displayed with the final anomaly profile a small D appears in the top left-hand corner of the screen and indicates that the positions of the corners of the bodies can be altered. The distance which a corner is to be moved is specified by the buttons of the middle row (see Fig. 8) and the direction (up, down, left or right) by the bottom row. The corner to be moved is then pointed at with the light pen. This procedure can be repeated for any number of corners, and when the interrupt button is pressed the altered bodies and their anomaly profile will be displayed.

Bottom row

Button 5: Display the next profile

Buttons 4-0: Indicate the direction a corner is to be moved (see Fig. 8). Any combination of buttons 4-0 will also cause the input from the DD210 to be bypassed and the anomaly to be displayed using the values of the last parameters to be typed in.

(b) By pointing the light pen at letters displayed on the screen prior to drawing

A list of letters appears across the bottom of the screen prior to drawing (see Fig. 7b). These letters are used to select various modes of drawing; the modes are:

M Move the cross about the screen with the light pen.

P Insert a point at the position of the light pen.

V Draw a line as the cross is moved with the light pen (The line is made up of a series of smaller lines whose length is specified by the numbers displayed to the right of the letters).

B Draw a broken line

E Erase a line by pointing the light pen at the start of it

C Close the present curve (this letter appears only when the distance between the start and finish of the curve is less than a certain amount)

S Return to the 3600

F, X, Y Specify the degree of movement allowed to the cross.

F allows it to move in any direction

X allows it to move only up and down

Y allows it to move only left and right

(c) Through the keyboard of the DD210 console (Plate 3). The usual method of starting is to press the interrupt button on the Vista control panel; this is the dark single button at the top of the panel, and can be seen in Plate 2. When this is pressed the identification panel is automatically photographed and the terrain and observed magnetic profiles then appear on the screen as shown in Figure 7(b). The identification panel is used by CSIRO to identify any photographs of the screen which the user may take during the interpretation. The screen is now activated for drawing model body cross-sections with the light pen. The bodies can be drawn any shape except that they must not have indented sides (see Figures 30 and 31 in the section describing subroutine STRIPS N2) and they must be closed by pointing the light pen at the C option on the bottom of the screen. On completion of drawing the model the light pen is pointed at the S option; an R will then appear on the screen, and when the pen is pointed at this a message

*LG, CHARGECODE, BEER, PARAS,

together with the first body which was drawn will now appear on the screen.

The message indicates that the parameters for the body which is displayed on the screen can now be typed in on the DD210 console. The message is typed in on the DD210 and the small round white button (clearly visible in Plate 3) on the top left-hand side of the console is pressed. The form shown in Plate 3 will then appear on the screen and the body parameters can be typed in. Care should be taken not to type over the decimal point, which is already on the screen and indicates the exact location of the values to be typed. If the decimal point is typed over, a format error will result and the job will terminate.

The units in which the various parameters are expressed are given below together with the range of typical values.

1. Susceptibility: c.g.s. units. Susceptibility normally falls in the range 10^{-4} for sedimentary rocks to $4x10^{-3}$ for basic igneous rocks.

2. Remanent intensity: c.g.s. units x 10^{-5}.

The units of remanent intensity (c.g.s. x 10^{-5}) are chosen so that the resultant anomaly is calculated in nanoteslas, not in oersteds. Remanent intensities normally fall in the range 10^{-4} (c.g.s. units) for sedimentary rocks to 10^{-1} (c.g.s. units) for basic igneous rocks; the equivalent range of values used by the program is 10 to 10 000.

3. Remanent Declination: degrees. Remanent declinations normally fall in the range ± 15 degrees but should be in keeping with the expected declination of the Earth's field at the time a body received its remanent magnetism.

4. Remanent inclination: degrees. Remanent inclinations in the southern hemisphere usually fall in either the range 0 to -90 degrees for normally magnetized bodies or the range +90 to +180 for reversely magnetized bodies (see Fig. 9a).

5. Traverse angle: degrees. The traverse angle is the angle between the traverse across the body and true north (see Fig. 10), and may be anywhere in the range +90 east of true north to -90 west of true north. The traverse must always run from the southern half-plane to the northern half-plane (see Fig. 9b), or the polarity of the anomalies displayed on the screen will be reversed.

6. Difference from perpendicular: degrees. The difference from perpendicular is the angle between the direction of the traverse across the body and the perpendicular to the strike of the body (see Fig. 10). It is desirable that this angle be restricted to the range ± 30 degrees. The angle is measured positive clockwise, negative anticlockwise from the direction of the traverse.

7. Earth's field total intensity: nanoteslas. In the Australian region the Earth's field intensity falls in the range 39 000 nT in Papua New Guinea to 64 000 nT in southern Tasmania (Finlayson, 1973).

8. Earth's field declination: degrees. In the Australian region the declination falls in the range +14°E on the east coast to -4°W on the west coast (Finlayson, 1973).

9. Earth's field inclination: degrees. In the Australian region the inclination falls in the range -20 degrees in Papua New Guinea to -73 degrees in southern Tasmania (see Fig. 9a) (Finlayson, 1973).

When typed, the parameters are returned to the CDC 3600 by again pressing the small round top left-hand button on the DD210 console. To return to the Vista for the next model parameters, or for the model anomaly profile if parameters for all the bodies have been typed in, the interrupt button on the Vista control panel is pressed. If the parameters are the same for all models the DD210 can be bypassed by depressing any combination of the buttons 0-4 on the bottom row of the Vista control panel.

Once the model anomaly profile is displayed on the screen together with the observed anomaly profile it can be photographed by pressing button 7 on the top row of the Vista control panel. If further models are to be tried, the screen can be returned to the initial drawing stage by pressing the Vista interrupt button.

Termination of job

The job is terminated by pressing all the bottom row of buttons down except the R button and pressing the interrupt button. After termination check that the job is really terminated by typing

*LC CHARGECODE, TOLITTLE,

on the DD210 console. Unless the job is terminated, other users cannot use the Vista.

When in doubt

An operator new to the Vista might easily find himself unable to get beyond a particular point in the procedure outlined above, because an error has been made or a step in the operation forgotten. The following is a list of operations which should be attempted in this sort of situation.

1. Are the drawing options across the bottom of the screen? Point at one of them.
2. Press the breakin button.
3. Press the R. button bottom row.
4. Press the DD210 go button.
5. Press the DD210 slab button labelled 1, and then the go button.
6. Press the DD210 slab button labelled 3, and then the go button.

They may be performed in any order and at least one of them should be appropriate. However, if all these operations fail to have any effect consultant staff at the computing centre should be called in.

4. PROGRAM TOLITTLE: PROGRAMMER'S GUIDE

This chapter is designed to assist those interested in the detailed structure of the program to follow it through and enable the program listings to be understood. It is taken for granted that anyone interested in this chapter will be familiar with computer programming and CSIRO's CDC3600 system.

4.1 PROGRAM TOLITTLE, STRUCTURE

Program TOLITTLE is the driving program for the magnetic profile modelling theory outlined in Chapter 2. Associated with it are four subroutines, and the broad functions are as follows:

Program TOLITTLE:	reads card input data, defines input and output on VISTA screen, calls necessary subroutines.
Subroutine STRIPSN2:	subdivides the model into vertical strips prior to calculating the magnetic effect of each strip.
Subroutine SLOPPY:	is called from subroutine STRIPSN2 and assists in defining the boundaries of the model.
Subroutine CALAN:	calls the necessary system subroutines to enable magnetic parameters to be typed-in on the DD210 console. It then computes the geometric relation between the model and the magnetic parameters, calculates the magnetic effect of each model strip and sums the effects to give the total anomaly.
Subroutine AUTOTEST:	allows small changes to be made to the model without complete redrawing.

In reading the following reference should be made to the listing in Section 4.2 and the flowcharts in Figures 11-27.

PROGRAM TOLITTLE PART 1 (Fig. 12)

Part 1 reads in all the input data and calls CAMREADY, a system subroutine which is used to display and photograph the identification panel shown in Figure 7(a). Details of the input data are given in the main body of the report in the section on program operation.

PROGRAM TOLITTLE PART 2 (Fig. 13)

Part 2 calculates the size of the display in both distance and magnetic units, and from these computes the scales.

The depth vertically down the screen (TGREAT) and the number of nanoteslas vertically down the screen (GGREAT) are first calculated. The screen is 1024 raster units square. The raster unit is an arbitary unit controlled by the resolution of the Vista electronics. Scales for the Vista must be quoted in raster units per unit. This is the reverse of normal plotting conventions which would lead one to expect scales quoted in number of units per raster unit. For convenience a portion of the screen 1000 raster units square is used and the distance, depth, and magnetic scales (XSCALE, TSCALE, and GSCALE respectively) are worked out for this square. XINT, TINT, and GINT are used to subdivide the three axes by ten. ADJD, which is used to move the profile across the screen in part 3, is set to zero. TAKE, which is used to number each attempt at fitting, is set to zero.

Note: Text calls should not be mixed with move and vector calls etc., because in these circumstances a software fault in Vistran can cause vectors to be plotted incorrectly.

PROGRAM TOLITTLE PART 3 (Fig. 14)

Part 3 draws-in the vertical magnetic axis and subdivides it into ten intervals. The observed magnetic profile is then drawn and the magnetic axis is labelled with the number of nanoteslas per division.

CALL CLEAR, CALL AXES, and CALL DISPLAY are part of Vistran (Wallington & Knowles, 1969) and are all essential for drawing a picture on the Vista screen. CALL CLEAR allocates a storage location to all subsequent commands to draw lines, points, or text, and CALL DISPLAY displays this information. CALL AXES sets the scales and origin. The first two parameters in its parameter list are the x and y co-ordinates of the origin, and the second two parameters are the x and y scales.

CALL MOVE (x,y) moves the spot to the point (x,y). CALL VECTOR (x,y) draws a line from the current point to the point (x,y). CALL VTEXT (A,B,C) draws text where A is the text to be drawn, B is the number of characters, and C is the size and the direction in which they are to be drawn. All are fully explained by Wallington & Knowles (1969).

The Vista software imposes the condition that the point (0,0) must always be at the bottom left-hand corner of the screen. For this reason the least value of the range of the magnetic profile (GLEASTO) is subtracted from all the magnetic values, and the profile is then plotted between the limits zero and GGREATO. Similarly, the point with zero distance must always appear on the screen and the profile is moved across the screen by altering the distance co-ordinates by an amount ADJD, thus altering the effective position of zero distance. ADJD is also used as a flag to indicate whether or not the profile is being drawn for the first time.

<u>PROGRAM TOLITTLE PART 4</u> (Fig. 15)

Part four draws the depth axis, the horizontal distance axis, and the terrain profile adjusted so that it is the correct distance below the recorder level. The axes are then labelled.

Most of the devices used in part 3 are also used in part 4, and the point (0,0) must always be the bottom left-hand corner of the screen. It is convenient to have the top of the screen represent the level at which the recording was made, and to achieve this the terrain profile, which is initially pickd relative to sea level, is adjusted by an amount (TGREAT - RECLEVEL).

<u>PROGRAM TOLITTLE PART 5</u> (Fig. 16)

Part 5 clears arrays and sets flags to their initial values ready for calculating the anomaly. After calculating the anomaly due to any set of bodies, the program always returns to the start of part 5 except when the profile is moved or a new profile is required.

The array ISTART (see part 7) is set to zero. The array TOTAL is set to the central value of the magnetic range. TOTAL is filled by subroutine CALAN with the calculated anomaly values; filling TOTAL with the central value of the range means that the anomaly is displayed centred on this level.

IS, the subscript of the array ISTART, is set to one. LATEST, a flag used in part 11 to indicate that the Subroutine AUTOTEST has been called, is set to zero. ITOT, the subscript for the array TOTSTORE in subroutine CALAN, is set to zero. IN is set to the number of points at which the anomaly is calculated.

PROGRAM TOLITTLE PART 6 (Figs 17, 18)

Part 6 starts with a call to the subroutine DRAW (Wallington & Knowles, 1969), which allows bodies to be drawn onto the screen. The interrupt button may be pressed before or after drawing and options selected via the Vista keyboard (Plate 2). Options available at this stage are: terminate the program, photograph the screen, and/or move the profile backwards and/or forwards. KA, KB, and KC are set by the Vista keyboard; KA and KB are the top and middle rows respectively and may range from 0-7, these values being selected by pressing the key labelled with the value. The setting of KC employs five keys of the bottom row, which represent binary numbers, and may be used to set KC equal to decimal numbers in the range 0-63.

PROGRAM TOLITTLE PART 7 (Fig. 19)

Part 7 sorts the body co-ordinates in the array BODIES into two other arrays XC and YC. The array BODIES is returned by subroutine DRAW and contains all the co-ordinates of the draw bodies; these are, however, in raster units and are stored as a string of x and y co-ordinates. The co-ordinates are converted to the distance units being used, and the x and y co-ordinates are stored in separate arrays XC and YC. Different bodies in the array BODIES are separated by an array value representing the total number of co-ordinates (x and y) in the next body; this number is designated N in the program, and the value of N for the first body is at array location 6. A full description of the quantities in the array BODIES is given in CSIRO Technical Note No. 30 (Wallington & Knowles, 1969).

The values of KD, which are the locations in the array BODIES of the divisions between different bodies, are stored in KDSTORE. The values of IC, which are the locations in the arrays XC and YC of the start of the bodies, are stored in ICSTORE. These values are also stored in ISTART; but ISTART has one as the first member, whereas ICSTORE has zero. The two arrays are necessary as the values in ICSTORE are changed when subroutine AUTOTEST is used.

PROGRAM TOLITTLE PART 8 (Fig. 20)

Part 8 resets the values of KD and ITOT when a body has been altered by subroutine AUTOTEST. KD and ITOT must be set so that the anomaly is calculated only for the body which was altered. KD ensures that the correct body is displayed in part 9, and ITOT that the correct part of the array TOTSTORE is altered. TOTSTORE is filled by subroutine CALAN.

JSTORE, an array generated by AUTOTEST, contains the location in the arrays XC and YC of all points altered by AUTOTEST. JSTORE and ISTART are incremented and checked against each other to determine which body was altered. When a body is found that has been altered, KD and ITOT are set using the value of I presently associated with ISTART. The third "if statement" checks that JSTORE lies between the start and finish of a particular body. Once a body is found that has been altered, its anomaly is calculated and the program returns to the next value of I (statement 14). J is incremented until JSTORE(J) falls between ISTART(I) and ISTART(I+1), and then the anomaly is calculated again. The second "if statement" is required only when the first body was not altered, and it starts incrementation of I; if the second "if statement" was not present and the first body had not been altered I would never be incremented. The first "if statement" checks both JSTORE and ISTART, as either JSTORE may become zero before ISTART and the program would start looping through statement 13, or ISTART may become zero before JSTORE and then the program would start looping through statement 14.

PROGRAM TOLITTLE PART 9 (Fig. 21)

Part 9 displays the bodies one by one before their anomaly is calculated, so that the user knows for which body he is typing-in parameters. Instructions are displayed giving the message to be typed-in on the DD210 to obtain the parameter form (Plate 3). The correct body co-ordinates for display are sorted from the arrays XC and YC by using the numbers of body co-ordinates which are stored in the array BODIES. X and Y are temporary arrays and IXY is reset at the start of each new body.

PROGRAM TOLITTLE PART 10 (Fig. 22)

Part 10 extends the body by a distance equal to the width of the screen when the first and last parts do not coincide. The bodies can be extended only to the left or right, not up and down; thus a body open at the left-hand side will be extended from the two leftmost points, and similarly for a body open at the right hand side.

PROBLEM TOLITTLE PART 11 (Fig. 23)

Part 11 calls the subroutine STRIPSN2, which splits the body into strips, and the subroutine CALAN, which calculates the anomaly. NX is a flag returned from STRIPSN2 if a body has been drawn with indented sides, and causes the program to return to Part 5 statement 10 for redrawing.

PROGRAM TOLITTLE PART 12 (Fig. 24)

Part 12 displays the combined anomaly profile due to all the bodies.

PROGRAM TOLITTLE PART 13 (Fig. 25)

Part 13 displays all the bodies together with a message which identifies the traverse involved, and also a number unique to each particular interpretation. The number serves to associate the slide output with the printed output of body parameters. As well as displaying the bodies, points are inserted at all body co-ordinates; these points are detectable with the light pen and allow the shape of the body to be altered using subroutine AUTOTEST. The points are made detectable with the light pen by a call to subroutine PENABLE. Subroutine PENABLE is fully explained in CSIRO Technical Note No. 30 (Wallington & Knowles, 1969).

At the start IC is set to one less than the last value of ISTART. This is done because in part 8 IC is set to the Ith value of ICSTORE, and if I in part 8 exceeds the number of bodies, as it may do, then IC would be equal to zero and no bodies would be displayed. ISTART is one more than the number of co-ordinates because it was set so at the beginning of part 8.

PROGRAM TOLITTLE PART 14 (Figs 26, 27)

Part 14 calls subroutine AUTOTEST if any of the body shapes is to be altered, and causes actions as a result of the buttons on the keyboard being depressed.

The call to subroutine DETECT in conjunction with subroutine PENABLE allows points to be detected with the light pen; when a point has been detected, three values in the common block VISTRAN are set, LX and LY are set to the raster co-ordinates of the point detected, and LD is set to one. LD is used as a flag to indicate that subroutine AUTOTEST must be called. IATEST is used as a flag to indicate that AUTOTEST has been used; both IATEST and LD are necessary because LD equal to zero is the condition for AUTOTEST to return control to the main program. LD is set to zero when the interrupt button is pressed and points on the screen have not been detected with the light pen.

The action of the buttons on the Vista keyboard has been explained under Part 6.

4.2 PROGRAM TOLITTLE, FORTRAN LISTING

```
C     -------               TOLITTLE PART 1
      PROGRAM TOLITTLE
      COMMON/VISTRAN/KA,KB,KC,LX,LY,LD,LT,JX,JY,NL
      COMMON/CALMAIN/TOTAL(100)
      COMMON/AUTOMAIN/XC(100),YC(100),ISTART(20) ,JSTORE(50)
      DIMENSION  BODY(200),ANPRO(200),KDSTORE(20),ICSTORE(20)
     1,GIST(100 ),DIST(100 ),X(100 ),Y(100),BODIES(500)
     1,TER(100 ),GAM(100 ),TPRO(200 ),GPRO(200 )
      DIMENSION LINETIME(3)
  100 FORMAT(16F5.0)
  102 FORMAT(3I5)
  103 FORMAT(4F10.0)
  104 FORMAT(F5.2,2F5.4)
  105 FORMAT(3F5.0)
  107 FORMAT(2F5.0)
  108 FORMAT(3A8)
C     ------------------------------------------------------------------
C     TSTN AND WIDTH ARE DISTANCE BETWEEN STATIONS AND WIDTH OF STRIPS
C     NG IS NO OF POINTS ON MAG PROFILE, NT IS NO OF POINTS ON TERRATN PROFIL
C     LINETIME IS A SET OF 24 ALPHANUMERIC CHARACTERS WHICH WILL APPEAR ON TH
C     TER(I) ARE VALVES OF TERRAIN PROFILE
C     SCREEN AS AN IDENTIFIER
C     GAM(J) ARE VALUES OF MAGNETIC PROFILE
C     DIST(I) ARE THE DISTANCES ALONG THE PROFILE OF TER(I)
C     GIST(I) ARE THE DISTANCES ALONG THE PROFILE OF GAM(J)
C     ----------------------------------------------------------------
      CALL CAMREADY(30HSEND TO J.B.CONNELLY  B.M.R    ,30)
   70 READ 108,LINETIME
      IF(EOF,60)71,72
   72 READ 105,XGREAT,RECLEVEL,VOVERH
      READ 107,GLEASTO,GGREATO
      READ 107,TSTN,WIDTH
      READ 102,NG,NT
      READ 100,(GAM(J),J=1,NG)
      READ 100,(GIST(I),I=1,NG)
      READ 100,(TER(I),I=1,NT)
      READ 100,(DIST(I),I=1,NT)

C     -------               TOLITTLE PART 2      -----------------

      TGREAT=XGREAT/VOVERH
      GGREAT=GGREATO-GLEASTO
      XSCALE=1000.0/XGREAT  $  TSCALE=1000.0/+GREAT
      GSCALE=1000.0/GGREAT
      XINT  =XGREAT/10 $ TINT=TGREAT/10  $ GINT=GGREAT/10
      ADJD=0  $ TAKE=0
```

```
C     -------         TOLITTLE PART 3          ----------------
C     ------------------------------------------------------------
   25 CALL CLEAR(GPRO, 200 )
      CALL AXES(0.0,0.0,XSCALE,GSCALE)
C     DRAW GAMMA AXIS AND LABEL IT
      ENCODE(5,150,BIF)GINT
  150 FORMAT(F5.0)
      DEB=XGREAT-10/XSCALE
      CALL MOVE(XGREAT,GGREAT)
      M=0
    6 CONTINUE
      M=M+1
      C=GGREAT-GINT*M
      CALL VECTOR(XGREAT,C)$ CALL VECTOR(DEB,C) $ CALL MOVE(XGREAT,C)
      IF(M.EQ.10)7,6
C     DRAW ORIGONAL MAGNETIC PROFILE
    7 IF(ADJD.GT.1.OR.ADJD.LT.-1)27,28
   28 DO 92 J=1,NG
   92 GAM(J)=GAM(J)-GLEASTO
   27 GIST(1)=GIST(1)+ADJD
      CALL MOVE (GIST(1),GAM(1))
      DO 98 J=2,NG
      GIST(J)=GIST(J)+ADJD
   22 CALL VECTOR(GIST(J),GAM(J))
  301 FORMAT(30X,F7.1,20X,F7.1)
C     PRINT 301,GIST(J),GAM(J)
   98 CONTINUE
      BX=XGREAT-50/XSCALE
      BY=GGREAT-300/GSCALE
      CALL MOVE(BX,BY)
      CALL VTEXT(6H1 DIV=,6,-2) $ CALL VTEXT(BIF,5,-2)
      CALL VTEXT(6HGAMMAS,6,-2)
      CALL DISPLAY(GPRO)
```

```
C    -------          TOLITTLE PART 4          ------------------
C    ----------------------------------------------------------------
      CALL CLEAR(TPRO,200 )
      CALL AXES(0.0,0.0,XSCALE,TSCALE)
C     DRAW DEPTH SCALE AND LABEL IT
      ENCODE(5,150,BAF)TINT
      DEA=10/XSCALE
      CALL MOVE(0.0,0.0)
      K=0
    1 CONTINUE
      K=K+1
      A=TINT*K
      CALL VECTOR(0.0,A) $ CALL VECTOR(DEA,A) $ CALL MOVE(0.0,A)
      IF(K.EQ.10)2,1
    2 CONTINUE
C     DRAW DISTANCE AXIS AND LABEL IT
      DEE=TGREAT-10/TSCALE
      ENCODE(5,150,BEF)XINT
      CALL MOVE(0.0,TGREAT)
      L=0
    4 CONTINUE
      L=L+1
      B=XINT*L
      CALL VECTOR(B,TGREAT) $ CALL VECTOR(B,DEE) $ CALL MOVE(B,TGREAT)
      IF(L.EQ.10)5,4
    5 IF(ADJD.GT.1.OR.ADJD.LT.-1)29,26
   26 DO 93 I=1,NT
   93 TER(I)=TER(I)+(TGREAT-RECLEVEL)
C     DRAW ORIGONAL TERRAIN PROFILE
   29 DIST(1)=DIST(1)+ADJD
      CALL MOVE (DIST(1),TER(1))
      DO 99 I=2,NT
      DIST(I)=DIST(I)+ADJD
   23 CALL VECTOR(DIST(I),TER(I))
  300 FORMAT(20X,F7.1,F80.10)
C        PRINT 300,DIST(I),TER(I)
   99 CONTINUE
      BX=20/XSCALE
      BY=300/TSCALE
      CALL MOVE(BX,BY)
      CALL VTEXT(6H1 DIV=,6,-2) $ CALL VTEXT(BAF,5,-2)
      CALL VTEXT(6HMETERS,6,-2)
      BX=300/XSCALE
      BY=TGREAT-50/TSCALE
      CALL MOVE(BX,BY)
      CALL VTEXT(6H1 DIV=,6,2) $ CALL VTEXT(BEF,5,2)
      CALL VTEXT(6HMETERS,6,2)
      CALL DISPLAY(TPRO)

C    -------          TOLITTLE PART 5          ------------------
C    ----------------------------------------------------------------
   10 CONTINUE
      DO 88 I=1,20
   88 ISTART(I)=0.0
      IS=1 $ IATEST=0   $ ITOT=0
      TAKE=TAKE+1
      IN=XGREAT/TSTN+1
      GZERO=GGREAT/2
      DO 94 I=1,IN
   94 TOTAL(I)=GZERO
```

```
C     -------          TOLITTLE PART 6          ----------------

C      ---------------------------------CONTROLS AND DRAW BODIES--------------
   62 CALL DRAW (BODIES, 500 )
      IF(KC.EQ.63)STOP
      IF  (KA.EQ.7)CALL PHOTO(32,1)
      IF(KB.EQ.0)GO TO 63
      IF(KA.EQ.5)59,60
   59 ADJD=XINT*KB
      IF(KB.EQ.1)ADJD=XINT*25
      IF(KB.EQ.2)ADJD=XINT*50
      GO TO 25
   60 ADJD=-XINT*KB
      IF(KB.EQ.1)ADJD=-XINT*25
      IF(KB.EQ.2)ADJD=-XINT*50
      GO TO 25

C     -------          TOLITTLE PART 7          ----------------
C -----------------------------------SORT OUT BODIES----------------
   63 KD=4
      IC=0
   11 N=BODIES(KD+2)
      IF(N.LE.1)GO TO 12
      KDSTORE(IS)=KD $ ICSTORE(IS)=IC
      MD=KD+3
      KD=MD+N-2
      DO 97 ID=MD,KD,2
      IC=IC+1
      XC(IC)=(BODIES(ID)-AD)/XSCALE
      YC(IC)=(BODIES(ID+1)-AD)/TSCALE
      IF(ID.NE.MD)GO TO 97
      ISTART(IS)=IC $ IS=IS+1
   97 CONTINUE
C      PRINT 400,(XC(I),I=1,IC)
C      PRINT 400,(YC(I),I=1,IC)
  400 FORMAT (X,18F7.1)
      GO TO 11
   12 ISTART(IS)=IC+1
      GO TO 36

C     -------          TOLITTLE PART 8          ----------------

   15 I=0 $ J=0
   14 I=I+1
   13 J=J+1
      IF(JSTORE(J).EQ.0.OR.ISTART(I).EQ.0)GO TO 8
      IF(JSTORE(J).GE.ISTART(I+1))17,18
   17 J=J-1  $ GO TO 14
   18 IF(JSTORE(J). GE.ISTART(I).AND.JSTORE(J).LT.ISTART(I+1))GO TO 20
      GO TO 13
   20 KD=KDSTORE(I) $ IC=ICSTORE(I)
      ITOT=(I-1)*IN
C      PRINT 310,KD,ITOT,I,J
  310 FORMAT(X,*KD=*,I5,*ITOT=*,I5,*I=*,I5,*J=*,I5)
      GO TO 9
```

```
C     -------          TOLITTLE PART 9          -----------------
C   -------------------------DISPLAY BODIES SERIALLY-------
   36 KD=4
      IC=0
    9 CONTINUE
      IXY=0
      CALL CLEAR(BODY,200)
      CALL AXES(0.0,0.0,XSCALE,TSCALE)
      N=BODIES(KD+2)
      IF(N.LE.1)GO TO 8
      MD=KD+3
      KD=MD+N-2
      DO 86 ID=MD,KD,2
      IXY=IXY+1 $ IC=IC+1
      X(IXY)=XC(IC)
      Y(IXY)=YC(IC)
      IF(ID.NE.MD)GO TO 16
      CALL MOVE(X(IXY), Y(IXY))
   16 CALL VECTOR(X(IXY),+Y(IXY))
   86 CONTINUE
      TX=100/XSCALE
      TY=300/TSCALE
      CALL MOVE(TX,TY)
      CALL VTEXT(46H*LG,CHARGECODE,BEER,PARAS,,, (FIRST TIME ONLY),46,2)
      TY=250/TSCALE
      CALL MOVE(TX,TY)
      CALL VTEXT(46HPRESS 210 GO BUTTON AND THEN VISTA RED BUTTON),46,2)
      TY=200/TSCALE
      CALL MOVE(TX,TY)
      CALL DISPLAY(BODY)

C     -------          TOLITTLE PART 10          -----------------

C     ------------------------------------------------------------
      N2=N/2
      IF(X(1).EQ.X(N2))GO TO 47
      IF(X(1).GT.X(2))GO TO 49
      X(1)=X(1)-XGREAT $ X(N2)=X(N2)-XGREAT
      GO TO 51
   49 X(1)=X(1)+XGREAT $ X(N2)=X(N2)+XGREAT
   51 X(N2+1)=X(1) $ Y(N2+1)=Y(1) $ N2=N2+1

C     -------          TOLITTLE PART 11          -----------------

C     ------------------
   47 CALL STRIPSN2(X,Y,WIDTH,N2,NX,KA)
  306 FORMAT(20X,2I5)
C      PRINT306,NX,N
      IF(NX.EQ.19)10,44
   44 CALL CALAN(WIDTH,TSTN, IN,TAKE,TGREAT,IATEST,ITOT)
      IF(IATEST.EQ.0)9,14
C     ------------------------------------------------------------
```

```
C      -------          TOLITTLE PART 12          -----------------

    8 CONTINUE
      CALL CLEAR(ANPRO,200 )
      CALL AXES(0.0,0.0,XSCALE,GSCALE)
      CALL MOVE(TSTN,TOTAL(1))
      DO 95 IV=2,IN
      KMS=IV*TSTN
      CALL VECTOR(KMS,TOTAL(IV))
C     PRINT 305,TOTAL(IV)
  305 FORMAT(20X,F7.1)
   95 CONTINUE
      CALL DISPLAY(ANPRO)

C      -------          TOLITTLE PART 13          -----------------

C      ---------------------------------------------------------
      IC=ISTART(IS)-1
      CALL CLEAR(BODY,200)
      CALL AXES(0.0,0.0,XSCALE,TSCALE)
      CALL PENABLE(1)
      DO 80 ICC=1,IC
      CALL POINT(XC(ICC),YC(ICC))
   80 CONTINUE
      CALL PENABLE(0)
      IS=1
      DO 91 ICC=1,IC
      IF(ISTART(IS).EQ.ICC)19,91
   19 IS=IS+1
      CALL MOVE(XC(ICC), YC(ICC))
   91 CALL VECTOR(XC(ICC), YC(ICC))
      ENCODE(3,152,TOF)TAKE
  152 FORMAT(F3.0)
      BX=100/XSCALE
      BY=100/TSCALE
      CALL MOVE(BX,BY)
      CALL VTEXT(LINETIME,24,3)
      BX=200/XSCALE
      BY=50/TSCALE
      CALL MOVE(BX,BY)
      CALL VTEXT(5HTAKE ,5,3) $ CALL VTEXT(TOF,3,3)
      CALL DISPLAY(BODY)
```

```
C     -------          TOLITTLE PART 14          -----------------

C     ------------------------------------------------------------
   32 CALL DETECT
      IF(LD.EQ.0)GO TO 48
      CALL  AUTOTEST(XGREAT,XSCALE,TSCALE,AD,IC,IS)
      IF(KA.EQ.7)CALL  PHOTO(32,1)
      IATEST=1
      GO TO 15
   48 IF(KC.EQ.32)GO TO 70
      IF(KA.EQ.5)39,40
   39 ADJD=XINT*KB
C       PRINT 501
      IF(KB.EQ.1)ADJD=XINT*25
      IF(KB.EQ.2)ADJD=XINT*50
      GO TO 41
   40 ADJD=-XINT*KB
      IF(KB.EQ.1)ADJD=-XINT*25
      IF(KB.EQ.2)ADJD=-XINT*50
   41 IF(KC.EQ.63)STOP
      IF  (KA.EQ.7)CALL  PHOTO(32,1)
      IF(ADJD.GT.1.OR.ADJD.LT.-1)25,10
   71 END
```

4.3 SUBROUTINE STRIPSN2, STRUCTURE

Subroutine STRIPSN2 splits the body into vertical strips as required for the calculation of the anomaly by the method of Sharma (1966). Each strip is defined by the x co-ordinate of its centre and the y co-ordinates of the top and bottom (Fig. 34). The bottom left-hand corner of the screen is always the origin.

The user when drawing a body may obviously start at any point on the body and draw either clockwise or aniclockwise; hence the program must be able to handle these different situations when splitting the body into strips. In the following example we assume that the drawing starts at B (Fig. 28) and proceeds in the order BCDA, although the program would work for any other order.

The array containing the x co-ordinates of the body (XC) is searched for maximum and minimum values (XMAX, XMIN), and at the same time the array location of XMIN (IMIN) is found. The central values of the strips are generated by dividing the interval XMIN to XMAX by the width of the strips. The first value is half a strip-width less than XMIN, and values are generated until XMAX is exceeded. The first and last values fall outside the body and contribute nothing to the anomaly as both y co-ordinates of these strips are set equal to zero.

The top and bottom co-ordinates of the strips are determined as follows(see Fig. 29). Consider the two points A and B which are drawn on the screen. The co-ordinates of A are X(IMIN), Y(IMIN); those of B are X(IMIN +1), Y(IMIN +1). The vertical lines are the central values of the strips (XS), and in particular B'Z' is the central value of the fourth strip. Construct AZ and BZ parallel to the x and y axes respectively.

Triangles ABZ and AB'Z' are similar

$$\therefore \quad B'Z' = BZ \left(\frac{AZ'}{AZ}\right)$$

and $\quad YT(4) = Y(IMIN) + B'Z'$

$$= Y(IMIN) + Y(IMIN + 1) - Y(IMIN) \frac{XS(4) - X(IMIN)}{X(IMIN - 1) - X(IMIN)} \qquad (1)$$

A similar formula applies for the co-ordinates YB of the bottom of the strip.

The subroutine starts at the point whose co-ordinates are in array location IMIN, and the slopes of the two lines radiating from this point are computed in order to decide whether the YTs or the YBs are to be computed first. The YT's and YB's are generated by the formula given above, and before each new value is calculated the corresponding value of XS is tested to see that the next body co-ordinate has not been exceeded. When XS does exceed the next body co-ordinate, the next two co-ordinates are taken and at the same time XS is tested to see that it does not exceed XMAX. If it does exceed XMAX the subroutine changes from calculating the YTs to calculating the YBs or vice versa. The generation of YTs or YBs ceases when XS becomes less than XMIN.

<u>STRIPSN2 PART 1</u> (Fig. 32)

Part 1 sarches the array X for the greatest and least x co-ordinates (XMAX, XMIN) and stores the array location of the least value (IMIN).

Part 1 also generates the central values of the strips.

<u>STRIPSN2 PART 2</u> (Fig. 33)

Part 2 calls subroutine SLOPPY, which calculates the slopes of the two lines radiating from the point with minimum x co-ordinate. The y co-ordinates of the strips are calculated starting on the section of the body between the points with array locations IMIN and IMIN+1 and working upwards. Comparison of the two slopes calculated by subroutine SLOPPY determines whether the top or bottom y co-ordinates are calculated first.

IMIN is tested to see if it is equal to N2, in which case the parameters for subroutine SLOPPY are different from the general case. IMIN will never equal 1, as the co-ordinates of the 1st and the N2th points are always the same, and owing to the way IMIN is found the N2th point will be selected as IMIN in this case. The y co-ordinates of the first and last strips are set to zero because they are not calculated in the remainder of the subroutine and, if they are not set to zero, values from previous calculations may remain in them and lead to an incorrect anomaly.

STRIPSN2 PARTS 3-6 (Figs 34,35,36,37)

Part 3-6 calculate the y co-ordinates of the strips. Parts 3 and 4 calculate the co-ordinates when the top co-ordinates are to be calculated first, and Parts 5 and 6 calculate co-ordinates when the bottom co-ordinates are to be calculated first.

All four parts transfer control to Part 7 as soon as a body with an indented side (see Figs 30, 31) is detected.

SUBROUTINE STRIPSN2 PART 7 (Fig. 38)

When a body is drawn with an indented side (see Figs 30 & 31) control is transferred to Part 7. Part 7 prints all the body parameters calculated so far and sets the flag NX to 19. Control is then returned to the main program for the redrawing of the bodies. Flowcharts for subroutine STRIPSN2 Parts 1-7 are given in Figs 32-38.

4.4 SUBROUTINE STRIPSN2, Fortr listing

```
C      ---------          STRIPSN2 PART 1
      SUBROUTINE STRIPSN2(X,Y,WIDTH,N2,NX,KC)
      COMMON/XSETC/ XS(203 ),YT(203 ),YB(203),J
      COMMON/SLIPSLOP/SLOPEA,SLOPEB
      DIMENSION X(N2),Y(N2)
C     ----------------------------------------------------------------
      NX=0
      XMIN=XMAX=X(1)
      DO 99 I=1,N2
      IF(X (I).GE.XMAX)1,2
    1 XMAX=X(I)
    2 CONTINUE
      IF(X(I).LE.XMIN)3,4
    3 XMIN=X(I)
      IMIN=I
    4 CONTINUE
   99 CONTINUE
  300 FORMAT(20X,2F20.5,2I5)
      PRINT 300,XMAX,XMIN,IMIN,N2
   41 CONTINUE
C     ----------------------------------------------------------------
      K=1
      XS(1)=XMIN-WIDTH/2
    6 K=K+1
      XS(K)=XS(K-1)+WIDTH
      IF(XS(K).GT.XMAX)5,6

C      ---------          STRIPSN2 PART 2          ------------------

    5 YT(1)=YT(K)=0
      YB(1)=YB(K)=0
      IF(IMIN.EQ.N2)7,8
    7 CALL SLOPPY(X(N2),Y(N2),X(2),Y(2),X(N2-1),Y(N2-1))
      GO TO 500
    8 CALL SLOPPY(X(IMIN),Y(IMIN),X(IMIN+1),Y(IMIN+1),X(IMIN-1),
     $Y(IMIN-1))
  500 IF(SLOPEA.GT.SLOPEB)1001,1002
C      ---------          STRIPSN2 PART 3          ------------

 1001 CONTINUE
      K=1
      KXY=IMIN-1
   14 KXY=KXY+1
      IF(KXY.EQ.N2)9,13
    9 KXY=0
      GO TO 14
   13 K=K+1
      IF(XS(K).GT.X(KXY+1))11,12
   12 YT(K)=(((Y(KXY+1)-Y(KXY))/ (X(KXY+1)-X(KXY)))* (XS(K)-X(KXY)))
     1+Y(KXY)
      GO TO 13
   11 IF(XS(K).GT.XMAX)GO TO 38
      IF(X(KXY).GT.X(KXY+1))GO TO 76
      K=K-1
      GO TO 14
   38 J=K
```

```
C     ---------           STRIPSN2 PART 4      -----------------

   15 KXY=KXY+1
      IF(KXY.EQ.N2)16,20
   16 KXY=0
      GO TO 15
   20 K=K-1
      IF(XS(K).LT.X(KXY+1))18,19
   19 YB(K)=(((Y(KXY+1)-Y(KXY))/(X(KXY)-X(KXY+1)))*(X(KXY)-XS(K)))
     1+Y(KXY)
      GO TO 20
   18 IF(XS(K).LT.XMIN)GO TO 75
      IF(X(KXY).LT.X(KXY+1))GO TO 76
      K=K+1
      GO TO 15


C     ---------           STRIPSN2 PART 5      -----------------

 1002 CONTINUE
      K=1
      KXY=IMIN-1
   23 KXY=KXY+1
      IF(KXY.EQ.N2)21,26
   21 KXY=0
      GO TO 23
   26 K=K+1
      IF(XS(K).GT.X(KXY+1))24,25
   25 YB(K)=(((Y(KXY+1)-Y(KXY))/ (X(KXY+1)-X(KXY)))* (XS(K)-X(KXY)))
     1+Y(KXY)
      GO TO 26
   24 IF(XS(K).GT.XMAX)GO TO 37
      IF(X(KXY).GT.X(KXY+1))GO TO 76
      K=K-1
      GO TO 23
   37 J=K


C     ---------           STRIPSN2 PART 6      -----------------

   27 KXY=KXY+1
      IF(KXY.EQ.N2)28,32
   28 KXY =0
      GO TO 27
   32 K=K-1
      IF(XS(K).LT.X(KXY+1))30,31
   31 YT(K)=(((Y(KXY+1)-Y(KXY))/(X(KXY)-X(KXY+1)))*(X(KXY)-XS(K)))
     1+Y(KXY)
      GO TO 32
   30 IF(XS(K).LT.XMIN)GO TO 75
      IF(X(KXY).LT.X(KXY+1))GO TO 76
      K=K+1
      GO TO 27
```

```
C     ----------          STRIPSN2 PART 7      ------------------

   76 NX=19
      PRINT 303,XMAX,XMIN,SLOPEA,SLOPEB,IMIN,N2,K,KXY
      PRINT 304,(X(I),I=1,N2)
      PRINT 304,(Y(I),I=1,N2)
      PRINT 304,(XS(I),I=1,100)
      PRINT 304,(YT(I),I=1,100)
      PRINT 304,(YB(I),I=1,100)
  303 FORMAT(X,4F20.5,4I5)
  304 FORMAT(X,18F7.1)
   75 RETURN
      END
```

4.5 SUBROUTINE SLOPPY, STRUCTURE

Subroutine SLOPPY calculates the slopes of the two lines radiating from the point with minimum x co-ordinate. XA and YA are the co-ordinates of the point with minimum x co-ordinate, XB and YB are the co-ordinates of the point with array location one greater than minimum, and XC and YC are the co-ordinates of the point with array location one less than the minimum point. When the minimum point is the last point in the body; XB and YB are the co-ordinates of the second point in the body.

XB and XC are tested to see if they are equal to XA; if either is, a small quantity is added to it in order to avoid division by zero in subsequent calculations. The slopes of the two lines are then calculated and are returned to STRIPSN2 for comparison.

4.6 Subroutine SLOPPY, Fortran listing

```
SUBROUTINE SLOPPY(XA,YA,XB,YB,XC,YC)
COMMON/SLIPSLOP/SLOPEA,SLOPEB
IF(XA.EQ.XB)XB=XA+.001
IF(XA.EQ.XC)XC=XA+.001
SLOPEA=(YB-YA)/(XB-XA)
SLOPEB=(YC-YA)/(XC-XA)
RETURN
END
```

4.7 SUBROUTINE CALAN, STRUCTURE

SUBROUTINE CALAN PART 1 (Fig.49)

Part 1 calls the system subroutines BREAKOUT and LABEL which allow parameters to be typed-in on the DD210 console. If new parameters are not required as indicated on the Vista keyboard the program goes straight to Part 5.

Values of susceptibility, number of the interpretation, remanent intensity, remanent declination, and remanent inclination are printed. The sign conventions for the parameters typed-in on the DD210 console are given in section 3.2.

SUBROUTINE CALAN PART 2 (Fig. 50)

Part 2 projects the remanent and induced vectors onto the vertical plane at right angles to the strike of the body (i.e. the x_1 x_3 plane in the theory; see Chapter 2).

The vector to be projected onto the x_1 x_3 plane is of length F and inclination I (see Fig. 40).

Projection on vertical axis = F sin I (i.e. the x_3 direction)

Projection on horizontal = F cos I

Projection of F cos I on the x_1 direction = F cos I cos Ø

Hence the vector projected in the x_1 x_3 plane has (see Fig. 41)

$$\text{Inclination} = \tan^{-1} [(F \sin I)/(F \cos I \cos \emptyset)]$$

$$= \tan^{-1} (\tan I/\cos \emptyset)$$

and magnitude $= F\sqrt{\sin^2 I + \cos^2 I \cos^2 \emptyset}$

Ø in above calculation is given by

Ø = TRAVR + DIFFR - DECR. (see Fig. 42)

(DIFFR is added because of the sign convention used) and similarly for the remanent vector.

Part 2 also takes account of the case where the traverse is not perpendicular to the strike of the body (see Fig. 43). The method of calculating the anomaly applies only to a body whose strike is at right angles to the traverse. If the traverse is not at right angles to the body, the anomaly can be worked out for the perpendiuclar direction and projected onto the traverse. This can be done only for bodies of infinite length along the strike, for which the profile is the same wherever it is taken. The spacing of the points of calculations on the traverse is (TSTN) and the spacing of the points of calculation in the x_1 dirktion is (STN). The two are related by the equation

$$STN = TSTN / \cos (DIFF)$$

<u>SUBROUTINE CALAN PART 3</u> (Figs 51,52)

Part 3 calculates the value of theta (θ), the angle between the induced and remanent inclinations. There are six possible values of theta which are shown in Figures 44 and 45. The angles are calculated using the absolute values of PRT and PVR.

<u>SUBROUTINE CALAN PART 4</u> (Fig. 54)

Part 4 calculates the magnitude of the resultant magnetic vector (see Fig. 46) and its direction (α) relative to the inclination of the present field in the x_1 x_3 plane. The cosine rule is used to calculate the magnitude of the resultant according to the formula (magnitude) $V^2 = PFT^2 + PVR^2 - PFT.\ PVR.\ \cos\theta$. The sign of θ is determined in part 3 so as to give the magnitude its correct value.

The sine rule is used to calculate the direction of the resultant, according to the formula

$$\alpha = \sin^{-1} (\sin \theta.\ PVR/V).$$

When the angle α exceeds 90° this formula will give the wrong value as the library function ASIN always selects values of $\sin^{-1}$ between -90° and + 90°. The possible values of α are shown in Figures 47 and 48 where BC = PFT; CV_1, CV_2, and CV_3 represent the different possible values of PVR; and BV_1, BV_2, and BV_3 represent the respective values of the resultant vector. We can see from Figure 48 that for $PVR < PFT$ α never exceeds 90°. However for $PVR > PFT$ (Fig. 47) α will exceed 90°. In the last case α equals 90° when $V^2 + PFT^2 = PVR^2$ and exceeds 90° when $V^2 + PFT^2 < PVR^2$. When this last condition is fulfilled the calculated value of α is replaced by the value (180-α). The sign of α is derived from the sign of θ.

SUBROUTINE CALAN PART 5 (Figs 54,55)

Part 5 calculates the anomaly. Two nested DO LOOPS are involved, the inner one running through all the strips for a particular point where the anomaly is required, and the outer one running through all the points of calculation. The outer loop increments from I to IN, where IN is the number of points at which the anomaly is to be calculated. The inner loop increments from I to J, where J is the number of strips which was computed by subroutine STRIPSN2. The top and bottom values of the strips are subtracted from TGREAT, which is the depth of the screen. This is done because the origin must be the top of the screen for the calculations, whereas bodies drawn onto the screen have the origin at the bottom. Provision for different recording levels is made in the main program by moving the terrain profile up or down by the required amount, thus giving the correct level for drawing the bodies.

Four different quantities are used for the anomaly values; they are

TOTNON: temporarily stores the anomaly values at a particular point of calculation.

TOTAL: permanent store for the values of TOTNON, accumulated for all the bodies.

TOT: permanent store for the values of TOTNON. TOT is used when bodies are changed by subroutine Autotest.

TOTSTORE: permanent store for the values of TOTNON. TOTSTORE stores all the individual values of TOTNON and they are not accumulated for all the bodies. The incrementor ITOT for TOTSTORE is set to zero in the main program. TOTSTORE is used when bodies are changed by subroutine AUTOTEST.

Flowcharts for subroutine CALAN parts 1-5 are shown in Figures 49-55.

4.8 Subroutine CALAN, Fortran listing

```
C      ---------           CALAN PART 1         -------------------

      SUBROUTINE CALAN(WIDTH,TSTN,IN,TAKE,TGREAT,IATEST,ITOT)
      COMMON/VISTRAN/KA,KB,KC,LX,LY,LD,LT,JX,JY,NL
      COMMON/CALMAIN/TOTAL(100)
      COMMON/XSETC/ XS(203),YT(203),YB(203),J
      DIMENSION A(205),B(205),X1(205), TOT(200),TOTSTORE(500)
C     ---------------------------------------------------------
      IF(KC.LE.31.AND.KC.GT.0)GO TO 2
      CALL SAVE(40)
      CALL RELEASE(40)
      CALL BREAKOUT
      CALL LABEL(40,16HCBDMR*CB    PARAS,0,0,0,7)
      REWIND 40
  302 FORMAT(25X,F5.5)
  300 FORMAT(9(20X,F7.1,/))
      READ(40,302),SUS
      READ(40,300),VR,RDEC,RINC,TRAV,DIFF,FT,DEC,DIP
  303 FORMAT(18X,17HSUSCEPTIBILITY    ,25X,1H=,F9.5,38X,6HTAKE =,F3.0/,
     6         18X,43HREMANENT INTENSITY                             =,F7.1/,
     2         18X,43HREMANENT DECLINATION                           =,F7.1/,
     3         18X,43HREMANENT INCLINATION                           =,F7.1/)
      PRINT 303,SUS,TAKE,VR,RDEC,RINC


C      ---------           CALAN PART 2         -------------------

      DECR=DEC/57.2958 $ DIPR=DIP/57.2958 $ RDECR=RDEC/57.2958
      RINCR=RINC/57.2958 $       TRAVR=TRAV/57.2958 $ DIFFR=DIFF/57.2958
      X1DIR=TRAVR+DIFFR
      STN=TSTN/COS(DIFFR)
      PIND=ATAN(TANF(DIPR)/COS(X1DIR-DECR))
      PREM=RINCR
      FR=SUS*FT
      PVR=VR*SQRT(SIN(RINCR)**2+COS(RINCR)**2*COS(RDECR-X1DIR)**2)
      PFT=FR*SQRT(SIN(DIPR)**2 +COS(DIPR)**2*COS(DECR-X1DIR)**2)


C      ---------           CALAN PART 3         -------------------

C      SORT THE SIX VALUES OF THETA

      ABSPIND=ABS(PIND)   $ABSPREM=ABS(PREM)
      IF(PIND.LE.0.0)20,30
   20 THETA=(3.14-(ABSPIND-ABSPREM))
      IF(PREM.LT.PIND)THETA=-(3.14-(ABSPREM-ABSPIND))
      IF(PREM.GT.0.0)THETA=3.14-ABSPIND-ABSPREM
      GO TO 40
   30 THETA=-(3.14-(ABSPIND-ABSPREM))
      IF(PREM.GT.PIND)THETA=(3.14-(ABSPREM-ABSPIND))
      IF(PREM.LT.0.0)THETA=-(3.14-ABSPIND-ABSPREM)
```

```
C      ---------           CALAN PART 4        -------------------

   40 V=SQRT(PFT*PFT+PVR*PVR-2*PFT*PVR*COS(THETA))
      ALPHA=ASIN(SIN(THETA)*PVR/V)
      IF(PVR.GT.PFT.AND.PVR*PVR.GT.V*V+PFT*PFT)10,11
   10 ALPHA=180/57.2958-ABS(ALPHA)
      IF(THETA.LT.0.0)ALPHA=-ALPHA
   11 ANG=PIND+ALPHA
  301 FORMAT(9F12.2,2I7)
      PRINT 301,PREM,PIND,XIDIR,PFT,PVR,V ,THETA,ALPHA,ANG,IN,J

C      ---------           CALAN PART 5        -------------------

    2 TRANS=0
      DO 99 I=1,IN
      TRANS=I*STN
      ITOT=ITOT+1
      TOT(I)=0.0
      TOTNON=0.0
      DO 98 K=1,J
      X1(K)=XS(K)-TRANS
      A(K)=TGREAT-YB(K) $ B(K)=TGREAT-YT(K)
C  501 PRINT 304,X1(K),A(K),B(K)
  304 FORMAT(20X,3F10.2)
      T13=-X1(K)*WIDTH*( 1/(X1(K)*X1(K)+A(K)*A(K))- 1/(X1(K)*X1(K)+B(K)
     1*B(K)))
      T33=-WIDTH*(A(K)/(X1(K)*X1(K)+A(K)*A(K))- B(K)/(X1(K)*X1(K)+B(K)
     1*B(K)))
      H1=V*COS(ANG) $ H3=V*SIN(ANG)
      HOR   =      2*(H1*(-T33)+H3*T13)
      VER   =      2*(H1*T13+H3*T33)
      TOTNON=TOTNON +HOR*COS(PIND)+VER*SIN(PIND)
   98 CONTINUE
      TOT(I)=TOTNON
      IF(IATEST.NE.0)TOTNON=TOTNON-TOTSTORE(ITOT)
      TOTAL(I)=TOTAL(I)+TOTNON
      TOTSTORE(ITOT)=TOT(I)
C      PRINT 310,ITOT,I,TOT(I)
  310 FORMAT(X,*ITOT=*,I5,*I=*,I5,*TOT=*,F10.5)
   99 CONTINUE
      RETURN
      END
```

4.9 SUBROUTINE AUTOTEST, STRUCTURE

SUBROUTINE AUTOTEST PART 1 (Figs 57,58,59)

Part 1 sets JSTORE(I),IROTATE and JS to their initial values and converts the detected points from raster units to actual units. The location in the array XC of the points which are detected are stored in the array JSTORE. The co-ordinates of the detected point are altered by an amount BJUMP in a sense determined by the value of KC. The magnitude of BJUMP is determined by the value of KB.

If rotation is required, statement No. 2 + 1 transfers control to Part 3. LAGAIN is a flag used in Part 2.

SUBROUTINE AUTOTEST PART 2 (Fig. 60)

Part 2 stores the x and y co-ordinates (ROTATEX1, ROTATEY1) of the final position of a point to be rotated and also stores its array location (J1). The flag IROTATE is set to 1 to indicate that the next point detected will form the axis of rotation.

At the closure of a body there are two coincident points and if these points are pointed at with the light pen only one of them will be detected. To remedy this, DO LOOP 98 checks whether the detected point is either the first or last point of a body and, if it is, sets J equal to the array location of the other closure point. The flag IROTATE is set to zero and the flag LAGAIN, which indicates that a closure point has been detected, is set to 1. The program is then returned to Part 1 so that the second closure point can be moved to the same place as the first.

Subroutine DETECT allows points on the screen to be detected and if no points are detected sets LD to zero, in which case control is returned to the main program. Only points which have been prepared by a call to subroutine PENABLE can be detected.

SUBROUTINE AUTOTEST PART 3 (Figs 61,62)

Part 3 rotates a line of points. To rotate, two points are detected with the appropriate buttons on the Vista keyboard depressed. The first point detected is moved by an amount BJUMP in Part 1; the second point detected forms th axis of rotation, and all intermediate points are repositioned half way between the axis of rotation and the new position of the first point detected. The intermediate points, although they are no longer essential to define the shape of the body, are retained to avoid changing the total number of points making up the body. If the total number of points in the body are changed, then the array locations of the start and finish of the bodies in the array ISTART (see TOLITTLE Parts 7 and 8) would be incorrect.

There are two paths, one long and one short, between any two points on the boundary of a body (Fig. 56). The short path is assumed to be rotating, and all points on this path are replaced by the intermediate values (XHALF,YHALF). One of two different ways of replacing these points must be adopted depending on whether or not the short path contains the closure point. If the short path does not contain the closure point then the array locations of the intermediate points will have numerical values between those of the two detected points. But if the short path contains the closure point then the array locations of the intermediate parts will have numerical values, both between that of the closure point and the higher of the two detected points and between that of the closure point and the lower of the two detected points.

To determine whether or not the closure point is in the short path, the absolute difference between the two array locations is compared to the total number of points in the body minus this difference (statement No. 100 + 3), and if the absolute difference is the larger of the two quantities than it can be shown that the closure point is in the short path.

Flowcharts for AUTOTEST Parts 1-3 are shown in figures 57-62.

4.10 Subroutine AUTOTEST, Fortran listing

```
---------          AUTOTEST PART 1          -----------------

      SUBROUTINE AUTOTEST(XGREAT,XSCALE,TSCALE,AD,IC,IS)
      COMMON/VISTRAN/KA,KB,KC,LX,LY,LD,JX,JY,NL
      COMMON/AUTOMAIN/XC(100),YC(100),ISTART(20),JSTORE(50)
      DO 990 I=1,50
 990  JSTORE(I)=0.0
      IROTATE=0 $ JS=1
   7  XD=(LX-AD)/XSCALE $ YD=(LY-AD)/TSCALE
      IF(KB.NE.0)BJUMP=XGREAT/(KB*10)
 301  FORMAT (/,2F20.5)
       PRINT 301,XD,YD
-----------------------------SEARCH FOR MATCH-----
      DO 99 J=1,IC
      IF(XC(J).GT.(XD-1).AND.XC(J).LT.(XD+1))5,99
   5  IF(YC(J).GT.YD-1.AND.YC(J).LT.YD+1)GO TO 2
  99  CONTINUE
--------------------------------WHICH OPTION REQD-------
   2  JSTORE(JS)=J $ JS=JS+1
      IF(IROTATE.EQ.1)GO TO 1000
      LAGAIN=0
       PRINT 300,XC(J),YC(J),IC
 300  FORMAT (/,2F20.5,I5)
   1  IF(KC.EQ.1) GO TO 10
      IF(KC.EQ.2) GO TO 20
      IF(KC.EQ.4) GO TO 30
      IF(KC.EQ.8) GO TO 40
      IF(KC.EQ.17)GO TO 10
      IF(KC.EQ.18)GO TO 20
      IF(KC.EQ.20)GO TO 30
      IF(KC.EQ.24)GO TO 40
      GO TO 2000
--------------------------------OPTIONS------------
  10  YC(J)=YC(J)-BJUMP
      IF(KC.LT.17)GO TO 50
      GO TO 60
  20  YC(J)=YC(J)+BJUMP
      IF(KC.LT.17)GO TO 50
      GO TO 60
  30  XC(J)=XC(J)-BJUMP
      IF(KC.LT.17)GO TO 50
      GO TO 60
  40  XC(J)=XC(J)+BJUMP
      IF(KC.LT.17)GO TO 50
```

```
C   ---------        AUTOTEST PART 3            ----------------

C   ----------------------------STORE END ROTATE------------

   60 J1=J $ IROTATE=1
      ROTATEX1=XC(J) $ ROTATEY1=YC(J)

C   ---------------------------CHECK FOR CLOSURE POINT------------

   50 IF(LAGAIN.EQ.1)GO TO 2000
      DO 98 I=1,IS
      IF(J.EQ.ISTART(I))GO TO 52
      IF(J.EQ.ISTART(I)-1)GO TO 53
   98 CONTINUE
      GO TO 2000
   52 J=ISTART(I+1)-1
      GO TO 54
   53 J=ISTART(I-1)
   54 IROTATE=0   $  LAGAIN=1
      GO TO 1

C   --------------------------------DETECT----------------

 2000 CALL DETECT
      IF(LD.EQ.0)RETURN
      GO TO 7
```

```
C      ---------         AUTOTEST PART 5        ----------------

C -----------------------------------ROTATE-----------------

 1000 J2=J   $ IROTATE=0
      ROTATEX2=XC(J)  $ ROTATEY2=YC(J)
      IF(J1.GT.J2)GO TO 70
      J11=J1  $  J22=J2  $  GO TO 71
   70 J11=J2  $  J22=J1
   71 ABSJ1J2=J22-J11
      IF(ABSJ1J2.LE.1)GO TO 2000

C     -------------------------FIND NO. POINTS IN CURVE-------------

      DO 97 I=1,IS
      IF(ISTART(I).GT.J11)GO TO 100
   97 CONTINUE
  100 JN=ISTART(I)-ISTART(I-1)
C ------------------------------CONTINUE----------------------------
      XHALF=(ROTATEX1+ROTATEX2)/2
      YHALF=(ROTATEY1+ROTATEY2)/2
C -----------------------------------------------------------------
      IF(ABSJ1J2.GT.JN-ABSJ1J2)110,120
  110 IF(LAGAIN.EQ.1)GO TO 120
  111 J22=J22+1
      IF(J22.EQ.J11)GO TO 2000
      DO 96 I=1,IS
      IF(J22.EQ.ISTART(I)-1)GO TO 113
   96 CONTINUE
      GO TO 114
  113 XC(J22)=XHALF  $  YC(J22)=YHALF
      J22=ISTART(I-1)
  114 XC(J22)=XHALF  $  YC(J22)=YHALF
      GO TO 111
  120 J11=J11+1  $  J22=J22-1
      DO 95  I=J11,J22
C      PRINT 305,XHALF,YHALF,I
  305 FORMAT(/,2F10.5,I5)
      XC(I)=XHALF  $  YC(I)=YHALF
   95 CONTINUE
      GO TO 2000
      END
```

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Plate 1 The Vista in use

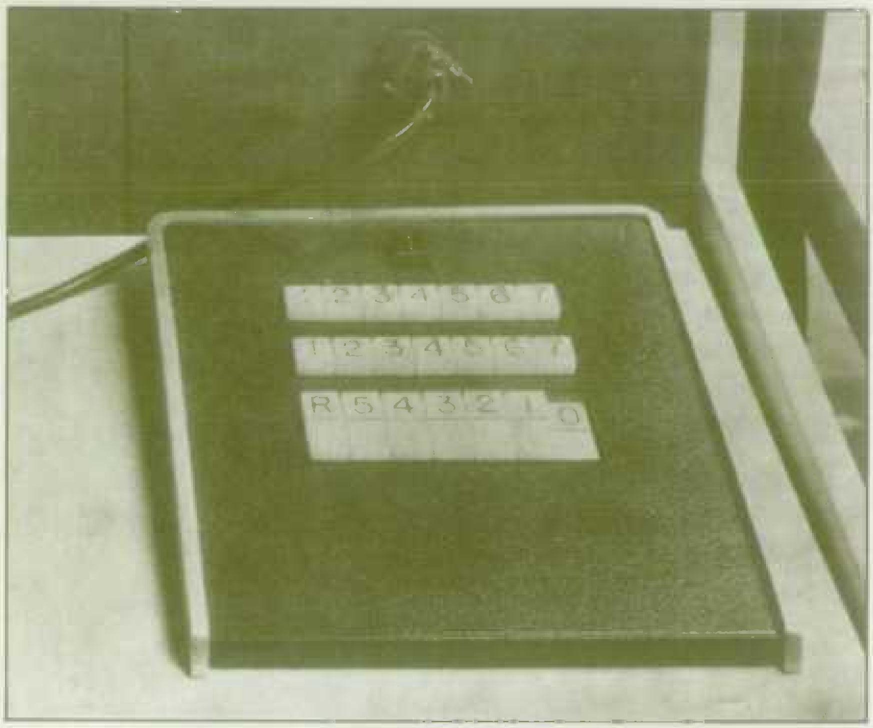


Plate 2 Photograph of Vista control panel

Plate 3 DD210 keyboard and display onto which parameter values are typed

Fig. 1

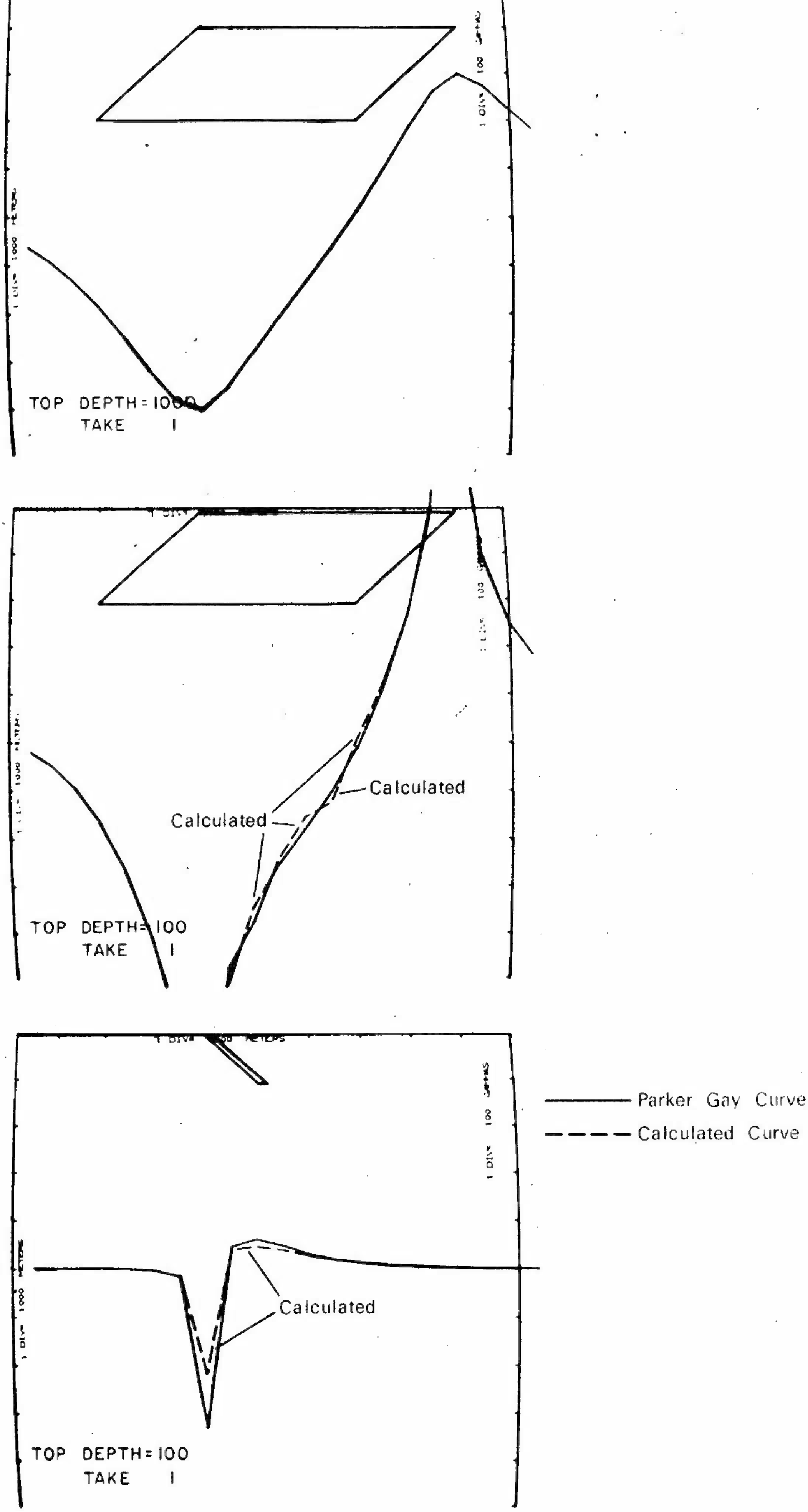

TOP DEPTH=1000
TAKE 1
Calculated
Calculated
TOP DEPTH=100
TAKE 1
Calculated
TOP DEPTH=100
TAKE 1
Parker Gay Curve
Calculated Curve

Fig. 2

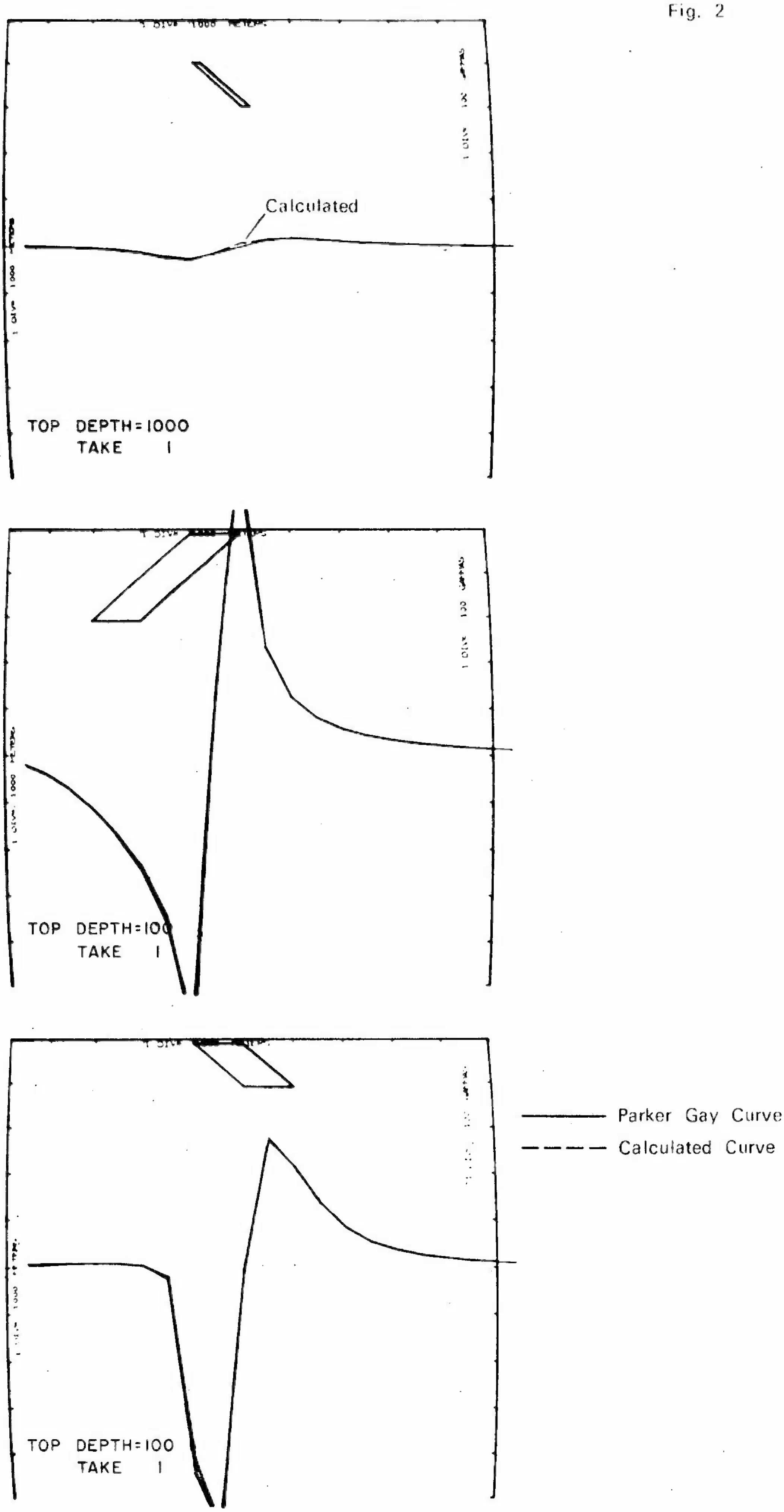
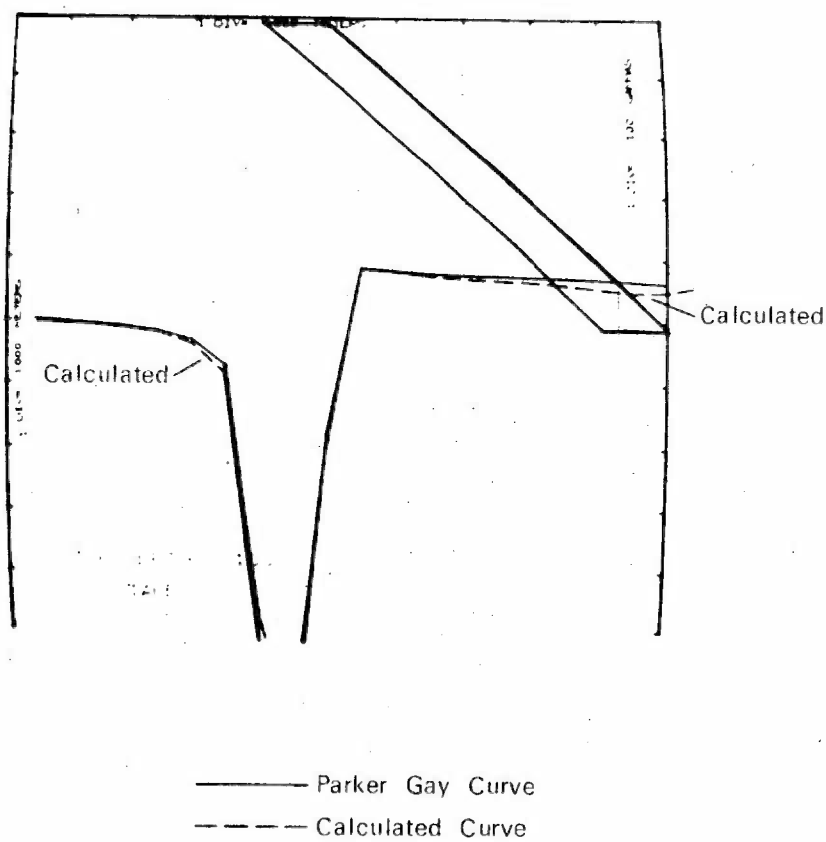

Calculated
TOP DEPTH=1000
TAKE 1
TOP DEPTH=100
TAKE 1
TOP DEPTH=100
TAKE 1
Parker Gay Curve
Calculated Curve

Fig. 3



G/60-32-24A

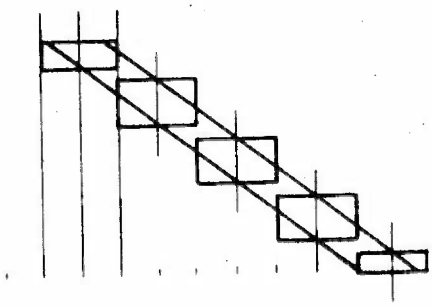


Fig. 4 Thin dyke split into strips

```
*JOB,CBCMR*CB,TOLITTLE,1
*DESC,BK
*EQUIP,67=TV
*DRLOCATE,28,CBC*****,BEER
*DFCOPDR,28,CBC*****,BEER
*RELEASE,28
*EQUIP,40=(,PARAS),SV
*FILE,40
     SUSCEPTIBILITY =+      .
       REMANENT AMP =+      .
       REMANENT DEC =+      .
       REMANENT INC =+      .
     TRAVERSE ANGLE =+      .
      DIFF FROM PERP=+      .
        TOTAL FIELD =+      .
          FIELD DEC =+      .
          FIELD INC =+      .

ALL QUANTITIES ARE MEASURED FROM TRUE
NORTH,EXCEPT FIELD INC AND REMANENT INC
WHICH ARE POSITIVE DOWN AND NEGATIVE UP
*FILEEND
*FTN,X,L
      PROGRAM TOLITTLE
      COMMON/VISTRAN/KA,KB,KC,LX,LY,LD,LT,JX,JY,NL
                 .
                 .
                 .
                 .
                 .
                 .

      SUBROUTINE AUTOTEST(XGREAT,XSCALE,TSCALE,AD,IC,IS)
                 .
                 .

      GO TO 2000
      END
        SCOPE
*LOAD
*RUN,1,2000
TRAV 124
4000    0    4
-500  500
 200   40
  25   44
 235  264  276  215   15 -340 -235 -213  110  136  146   45  -14   75
 388  -63 -160   -3 -306 -423 -269   69  -30
   0  387  528  915 1056 1840 1927 2224 2521 2817 3422 3725 3933 4170 4
4766 5220 5523 5977 6431 6962 7228 7494 8025
-200  300    0  -35  -70  -90 -120 -163 -196 -163 -167 -172 -249 -208 -
-215 -249 -215 -187 -217 -214 -235 -187 -217 -214 -189 -198 -198 -197 -
-198 -198 -197 -185 -245 -185 -163 -166 -216 -166 -151    0
-2100-2100-1100 -300  528  968 1056 1349 1492 1349 1927 2432 2609 2521 2
4081 3725 4081 4615 4917 5402 4978 4615 4917 5402 5523 5614 6431 6590 6
5614 6431 6590 6697 6829 6697 6962 7228 7093 7228 7493 8163
*EOF
*EOP
```

Fig. 5 Card deck structure

BMR DATA CODING FORM

NAME | DATE | SHEET OF

1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-79
TRAV	124														
4000	0	4				XGREAT, RECLEVEL, VOVERH									
-500	500					GLEASTO, GGREATO									
200	40					TSTN, WIDTH									
25	44					NG, NT									
235	264	276	215	15	-340	-235	-213	110	136	146	45	-14	75	-59	17
383	-63	-160	-3	-306	-423	-269	69	-30							
0	387	528	915	1056	1840	1927	2224	2521	2817	3422	3725	3933	4170	4466	461
4766	5220	5523	5977	6431	6962	7228	7494	8025							
-200	300	0	-35	-70	-90	-120	-163	-196	-163	-167	-172	-249	-208	-211	-21
-215	-249	-215	-187	-217	-214	-235	-187	-217	-214	-189	-198	-198	-197	-268	-26
-198	-198	-197	-185	-245	-185	-163	-166	-216	-166	-151	0				
-2100	-2100	-1100	-300	528	968	1056	1349	1492	1349	1927	2432	2609	2521	2817	372
4081	3725	4081	4615	4917	5402	4978	4615	4917	5402	5523	5614	6431	6590	6484	582
5614	6431	6590	6697	6829	6697	6962	7228	7093	7228	7493	8163				
TRAV	126														
ETC.															

Fig. 6 Sample data sheet

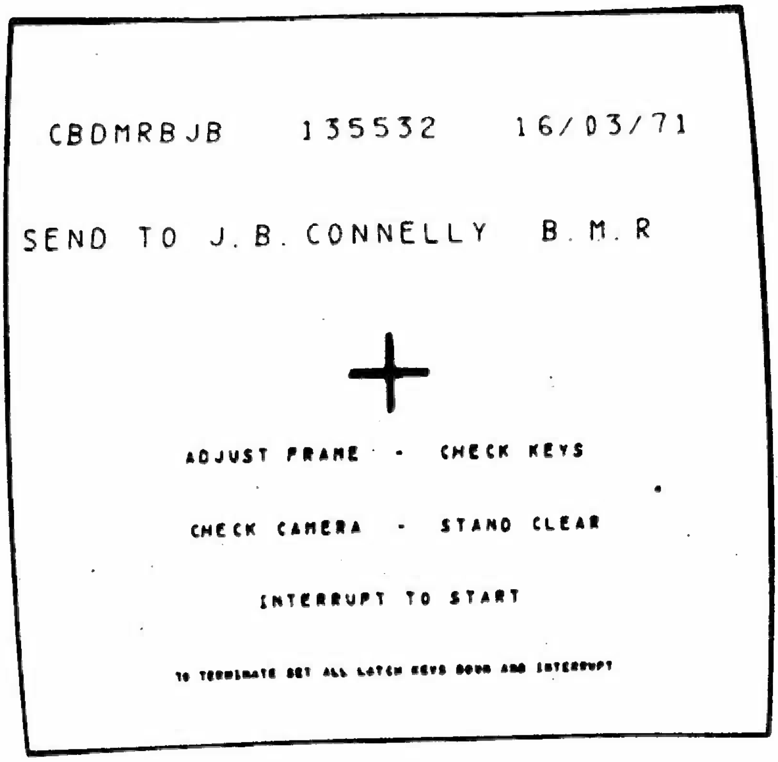


Fig. 7 (a) Identification panel

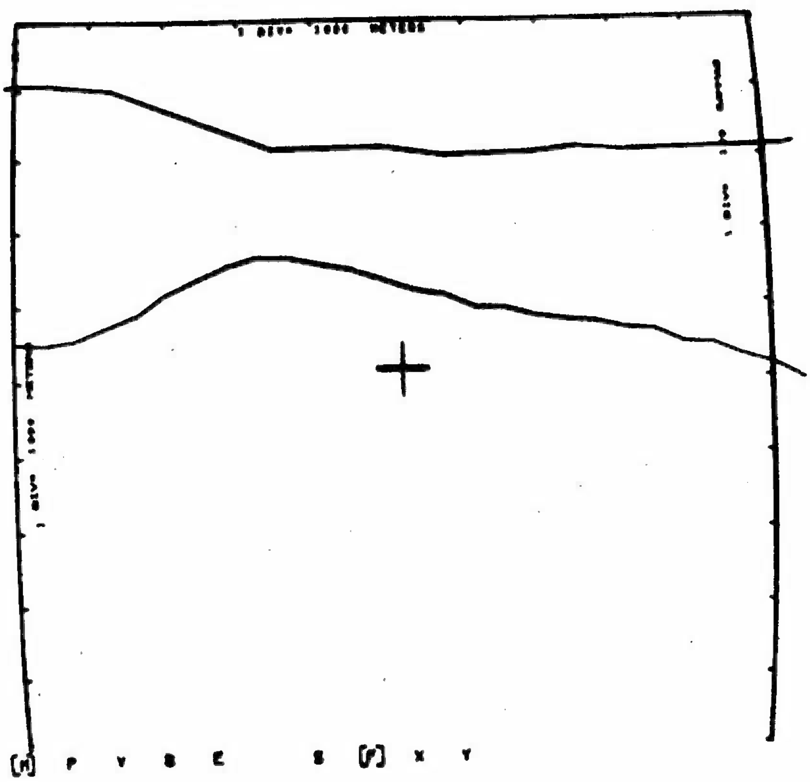


Fig. 7 (b) Screen ready for drawing

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				NEGATIVE MOVE		PHOTOGRAPH
1	2	3	4	5	6	7

PROFILE DIVISIONS MOVED =	25	50	3	4	5	6	7
	1	2	3	4	5	6	7
POINT DIVISIONS MOVED =	1.0	0.5	0.33	0.25	0.2	0.17	0.14

Used to indicate distance points and profiles are to be moved

R	5	4	3	2	1	0
	SELECT NEW PROFILE	ROTATE	RIGHT	LEFT	UP	DOWN

Used to indicate which direction a point is to be moved
Any combination of these buttons will cause the DD210 parameter form to be bypassed

Fig. 8 Vista control panel (functions)

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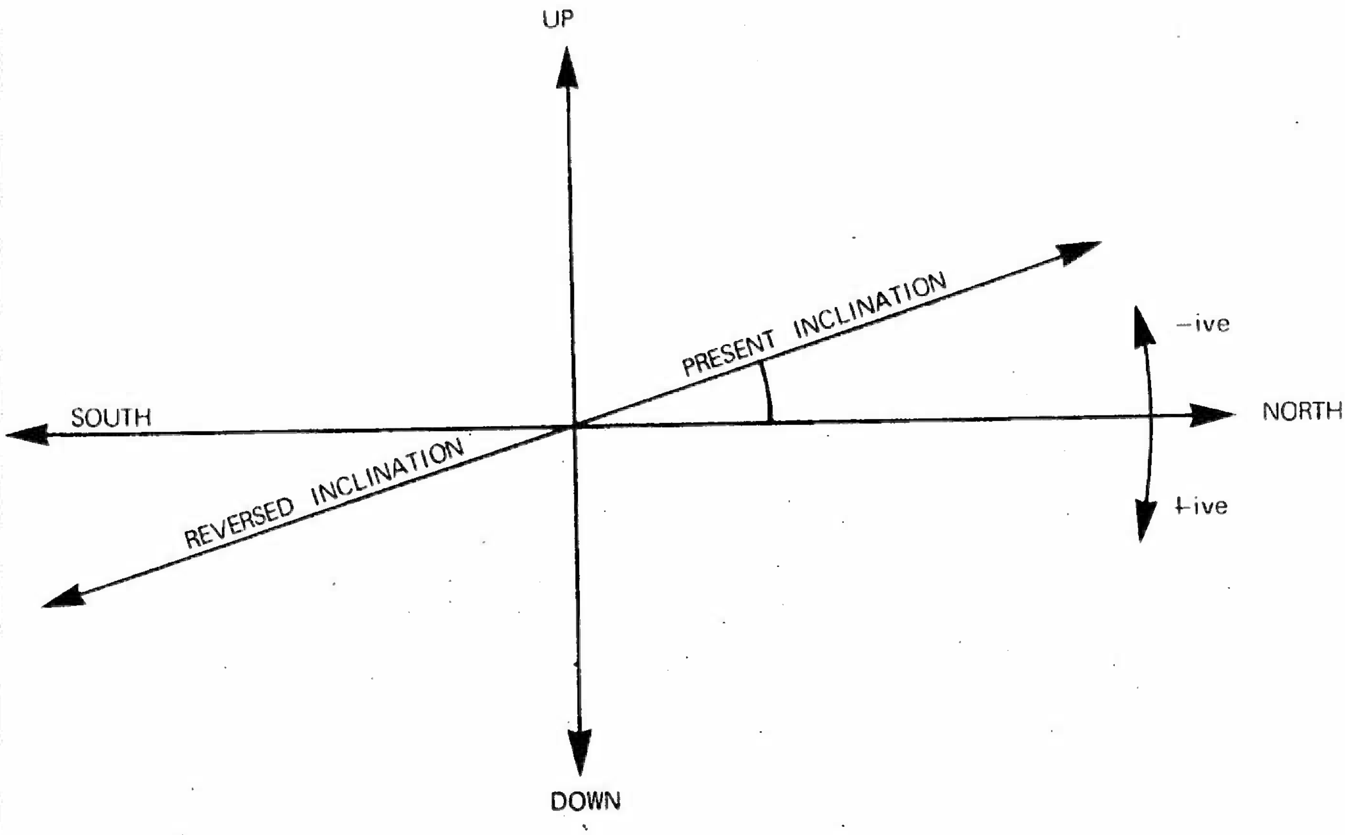

Fig. 9 (a) Sign convention of the angles of inclination of the Earth's present and remanent magnetic fields

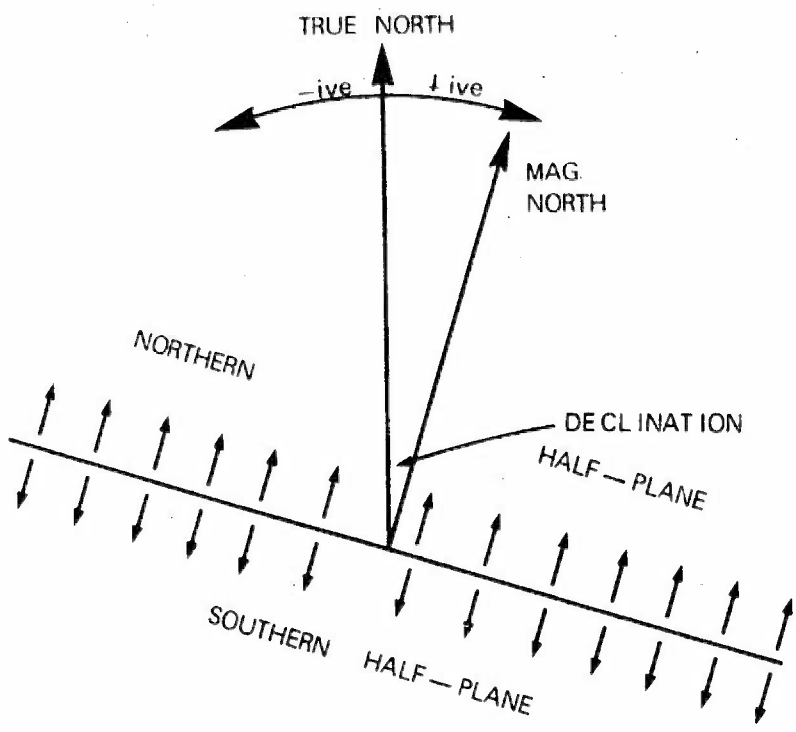

Fig. 9 (b) Definition of the northern and southern half–planes

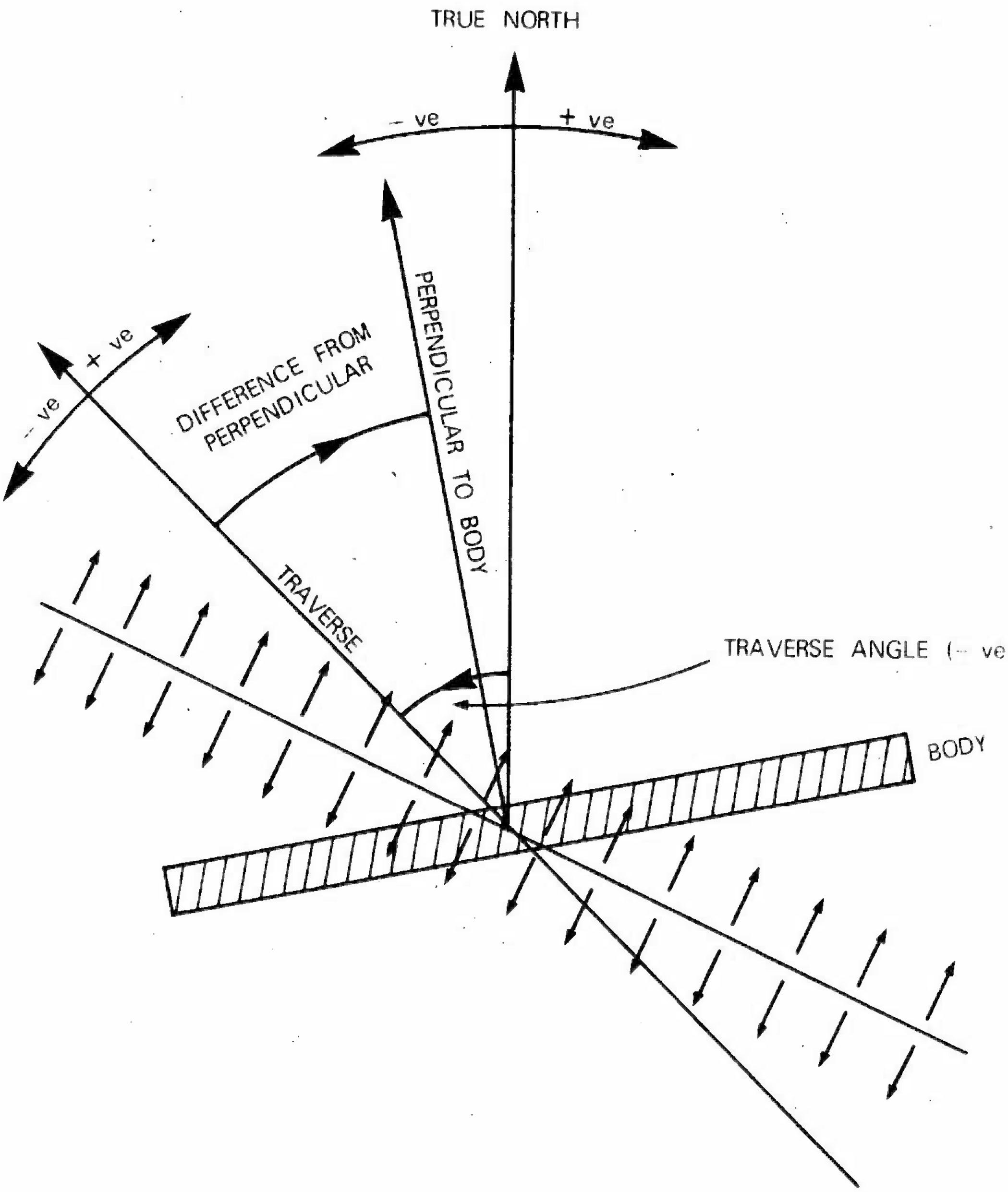

Fig. 10 Traverse angle and difference from perpendicular

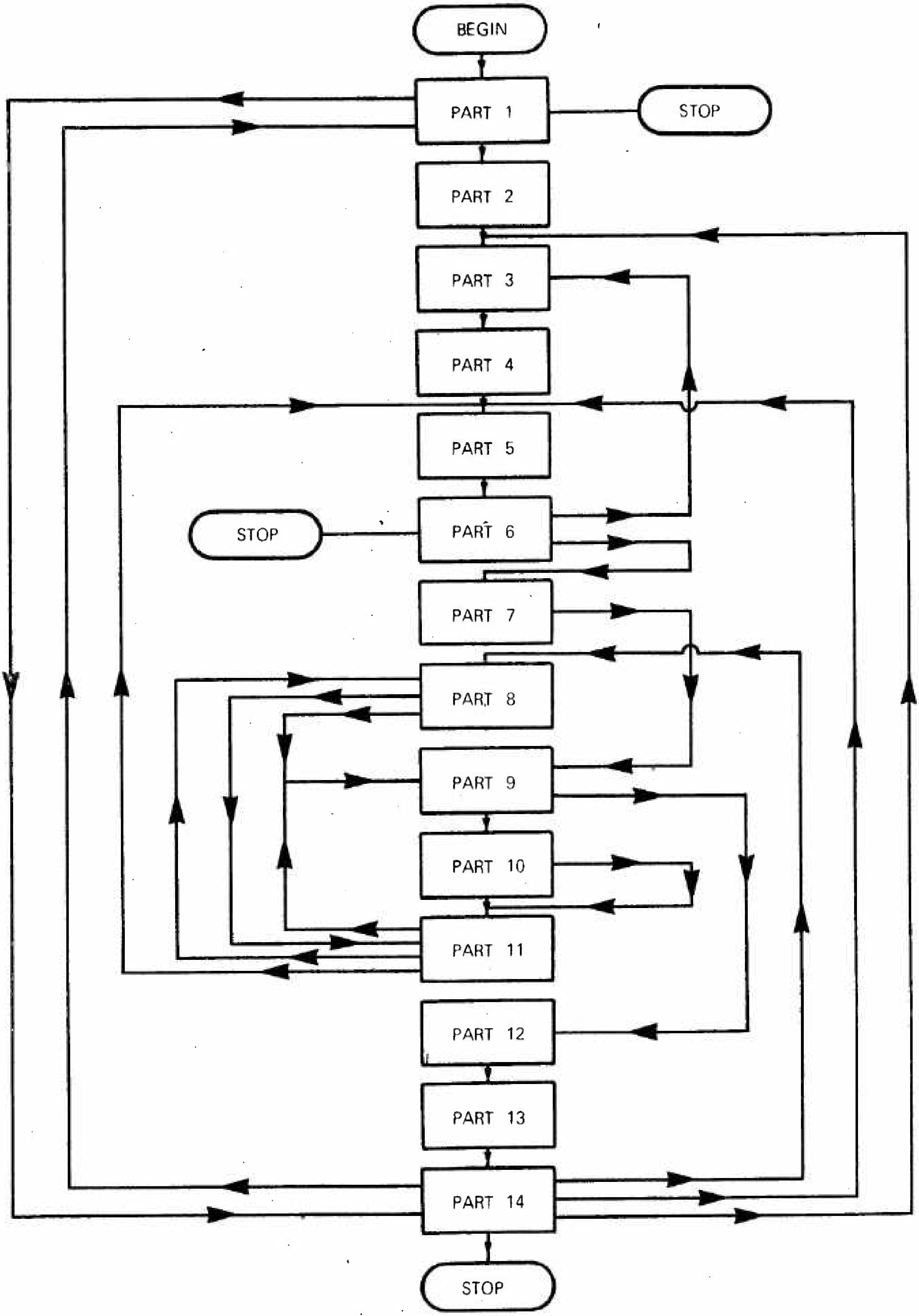

Fig. 11 Relation between the parts of TOLITTLE

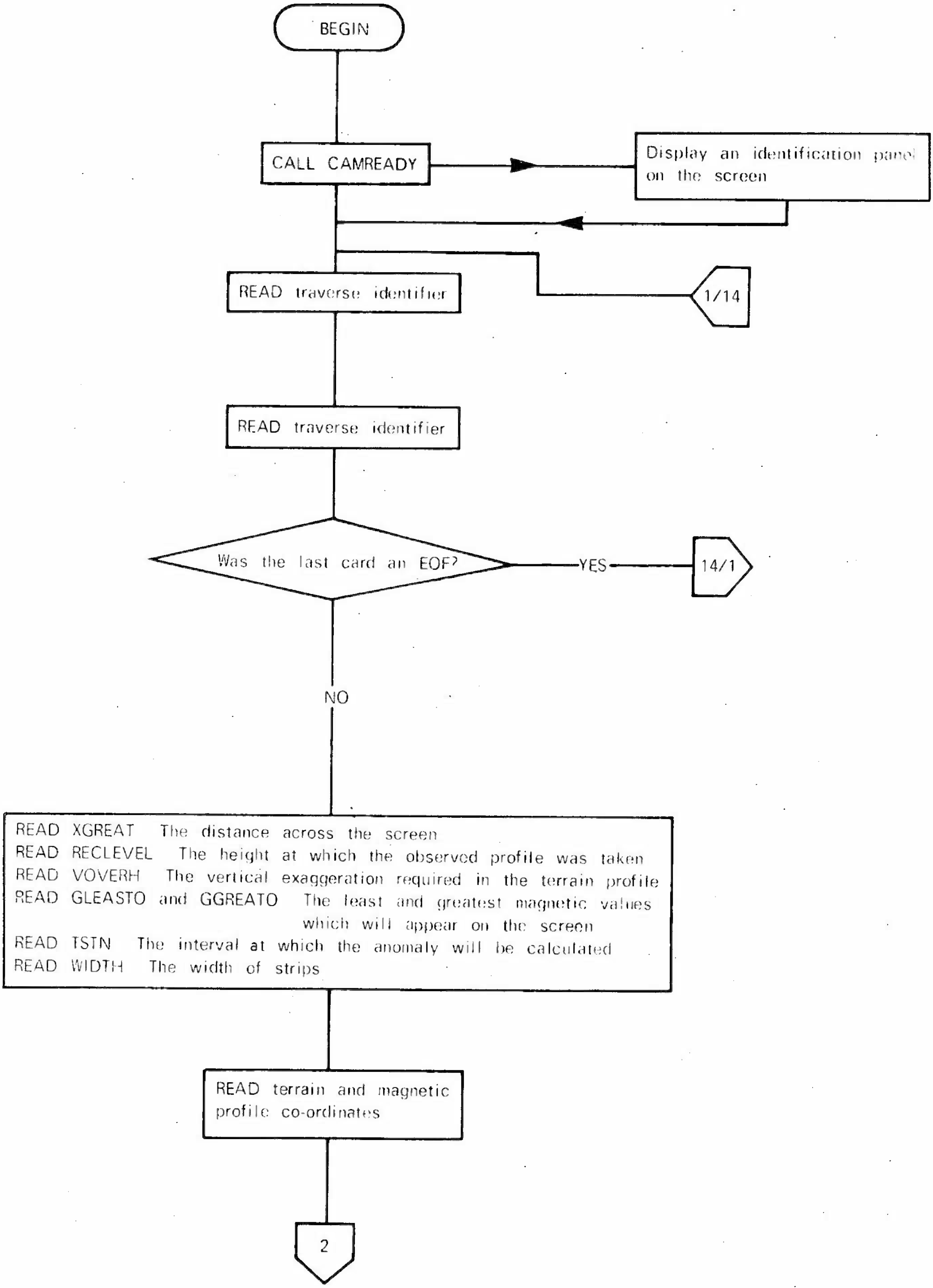

Fig. 12 Flowchart for program TOLITTLE, Part 1

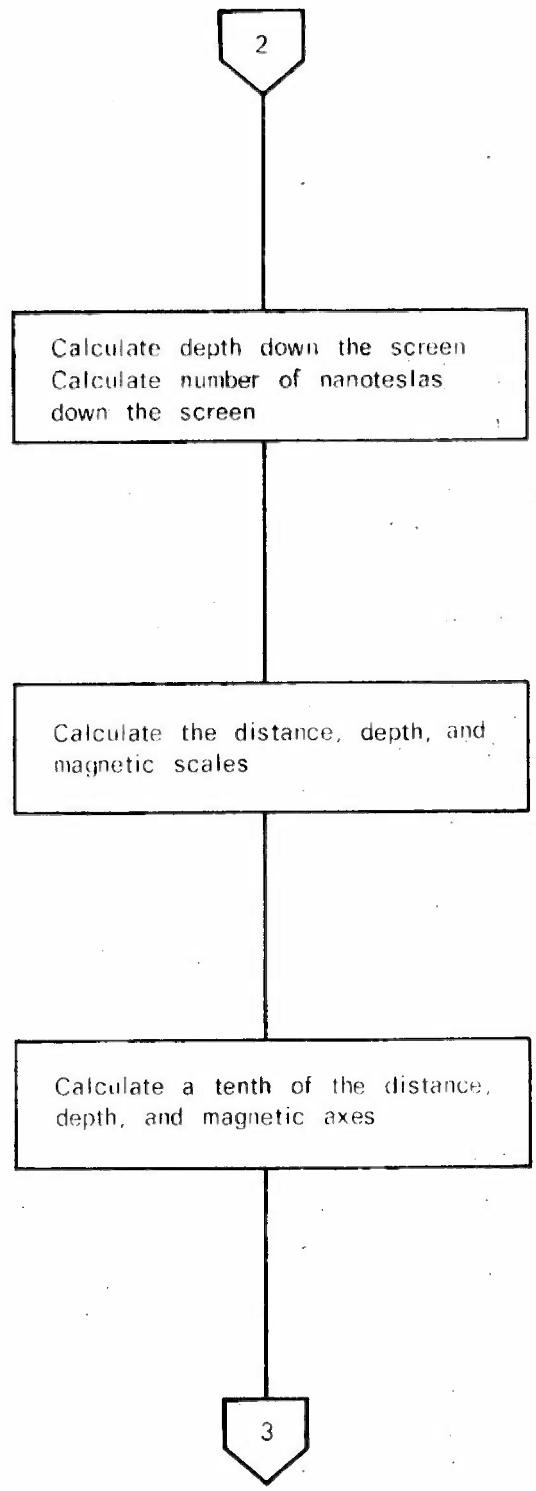

Fig. 13 Flowchart for program TOLITTLE, Part 2

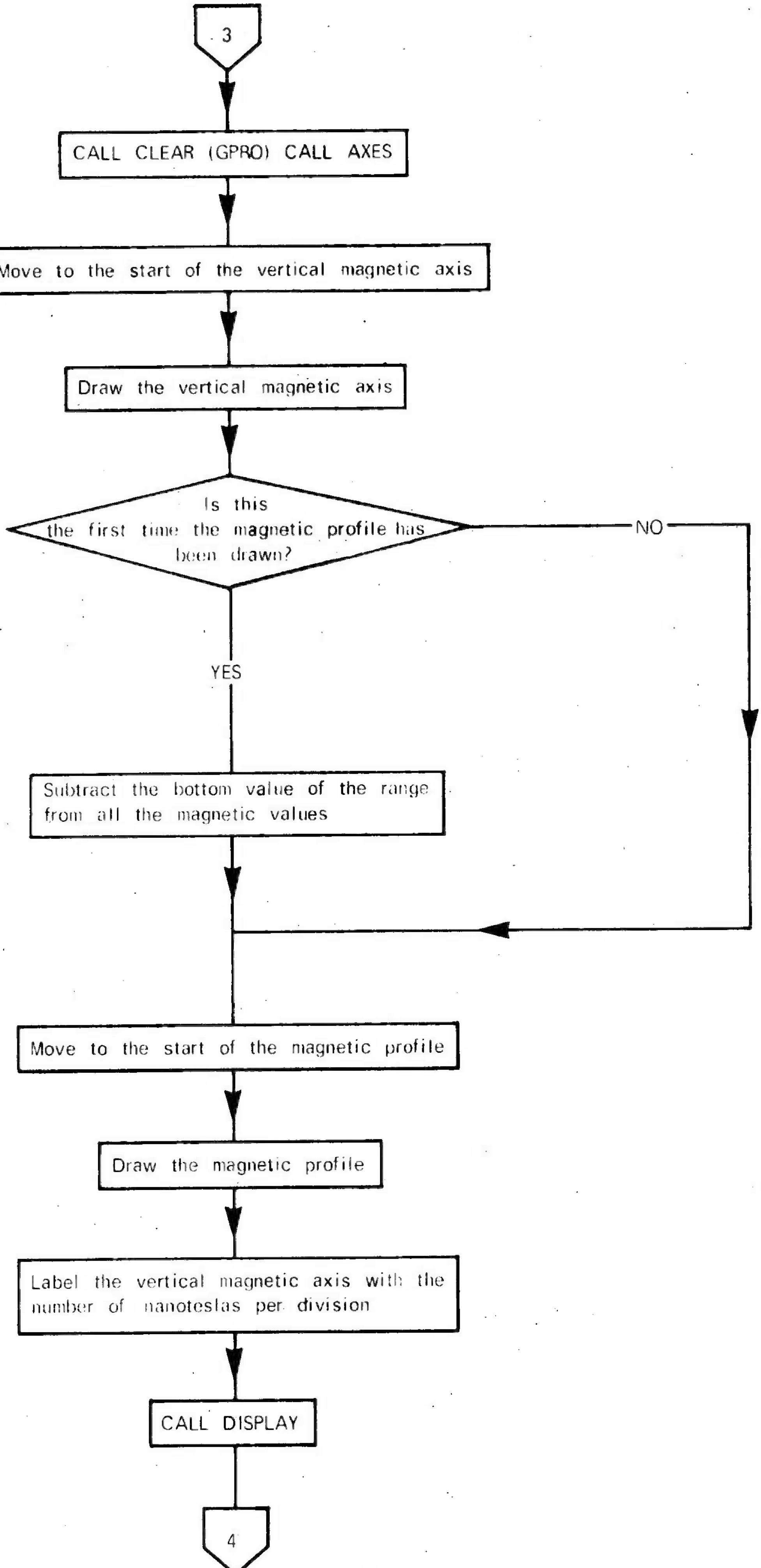

Fig. 14 Flowchart for program TOLITTLE Part 3

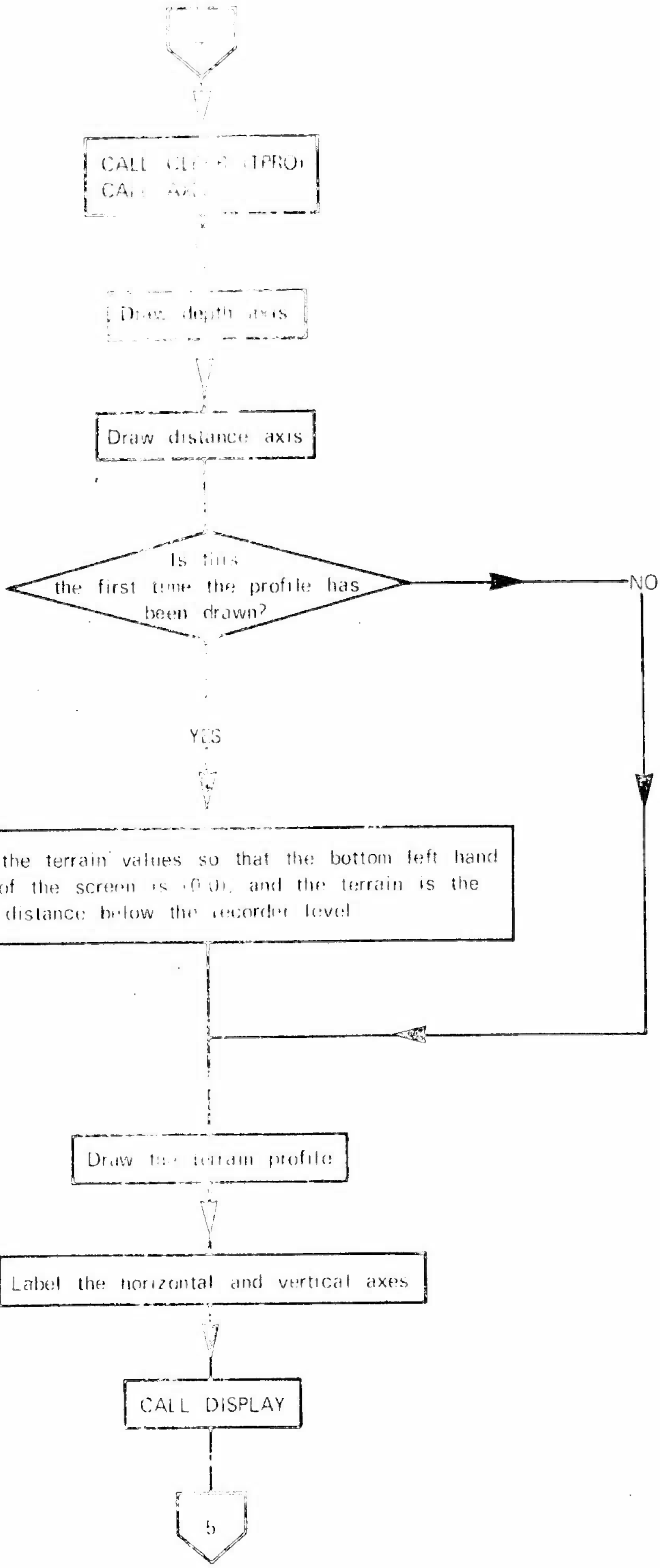

Fig. 15 Flowchart for program TOLITTLE. Part 4

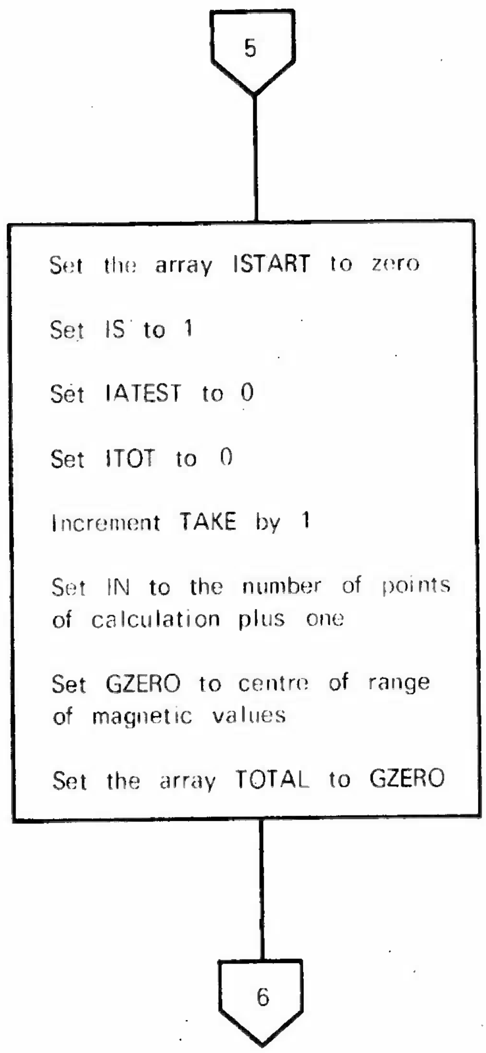

Fig. 16 Flowchart for program TOLITTLE, Part 5

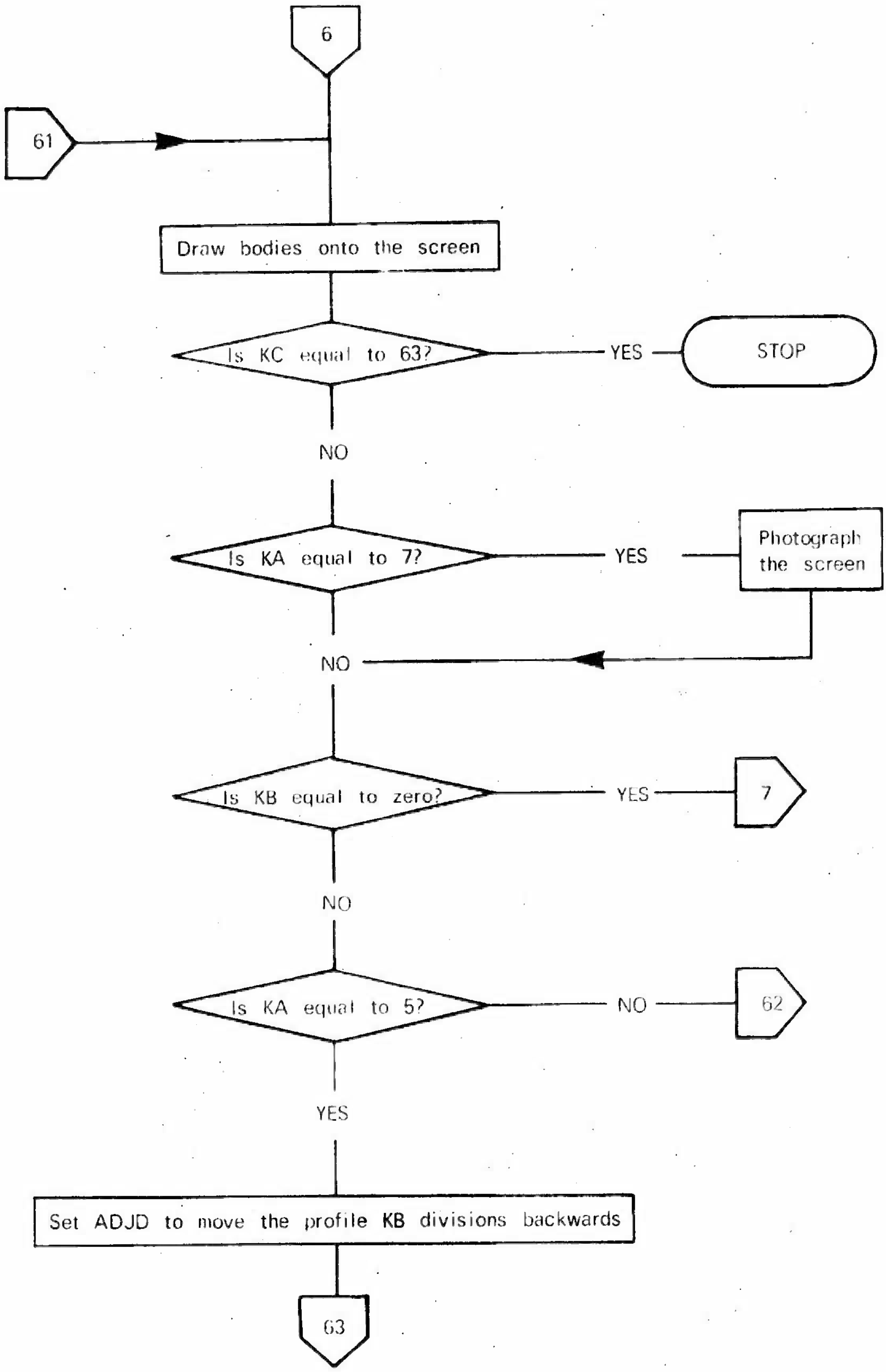

Fig. 17 Flowchart for program TOLITTLE, Part 6

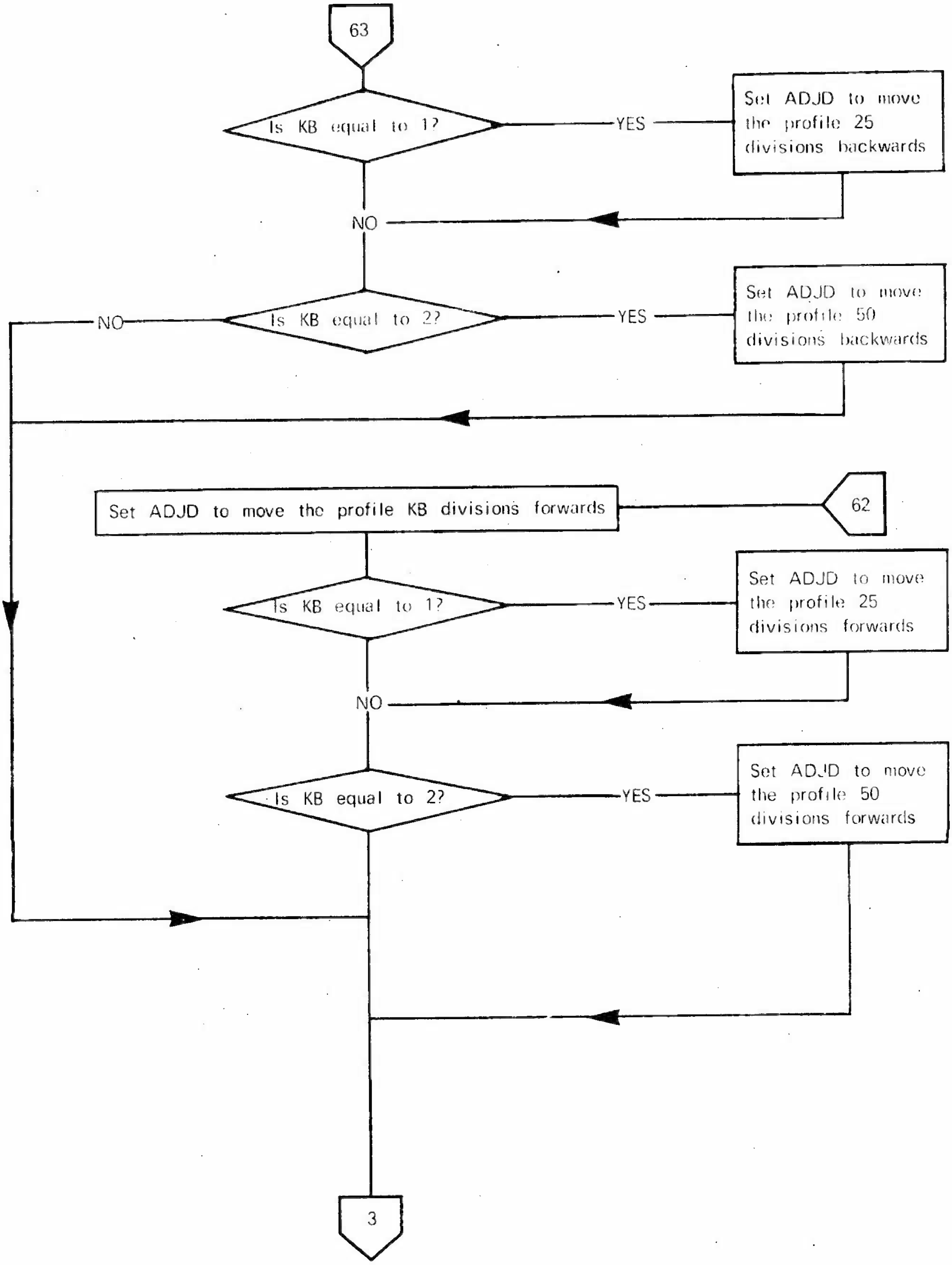

Fig. 18 Flowchart for program TOLITTLE, Part 6 cont.

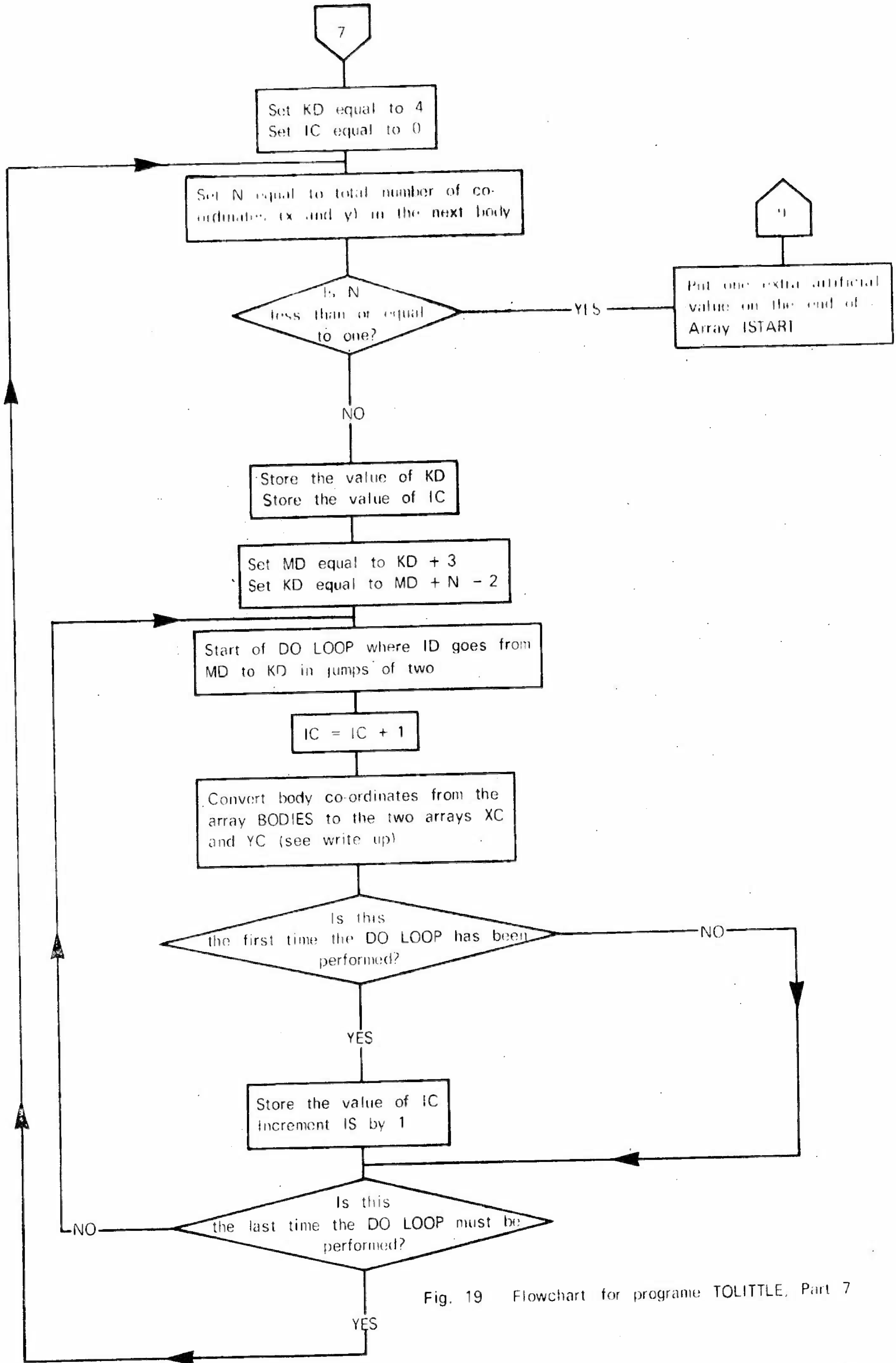

Fig. 19 Flowchart for programe TOLITTLE, Part 7

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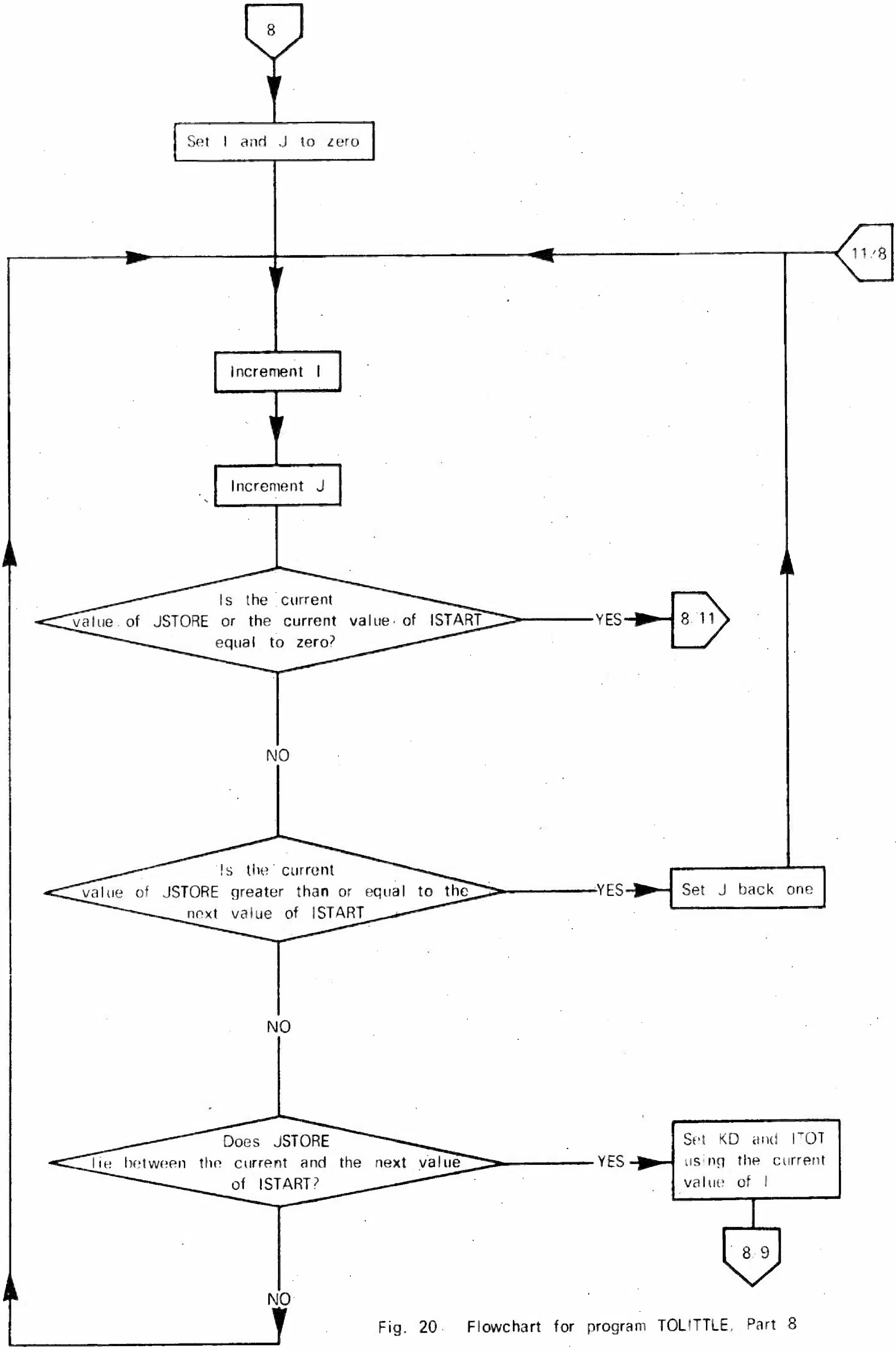

Fig. 20 Flowchart for program TOLITTLE, Part 8

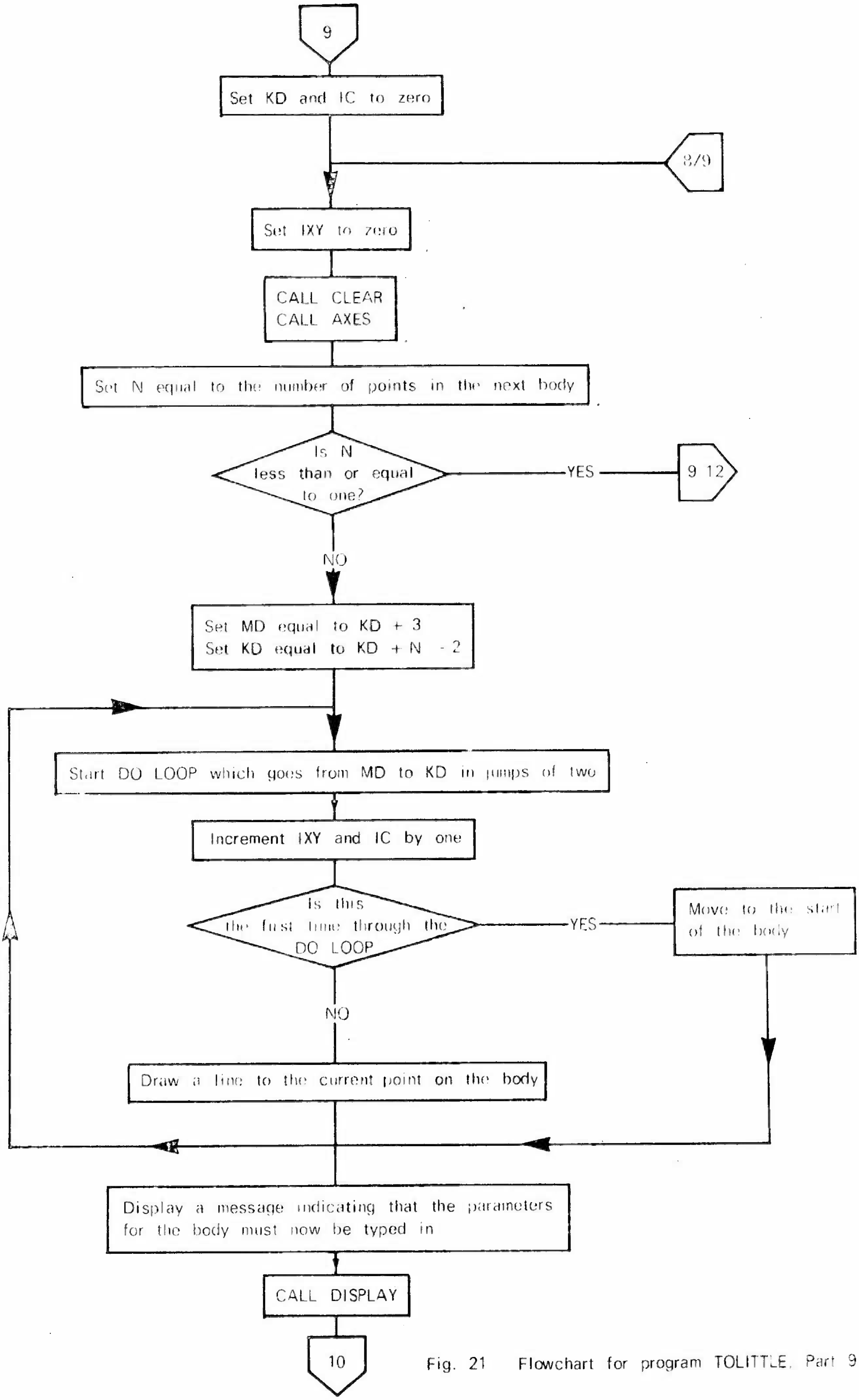

Fig. 21 Flowchart for program TOLITTLE, Part 9

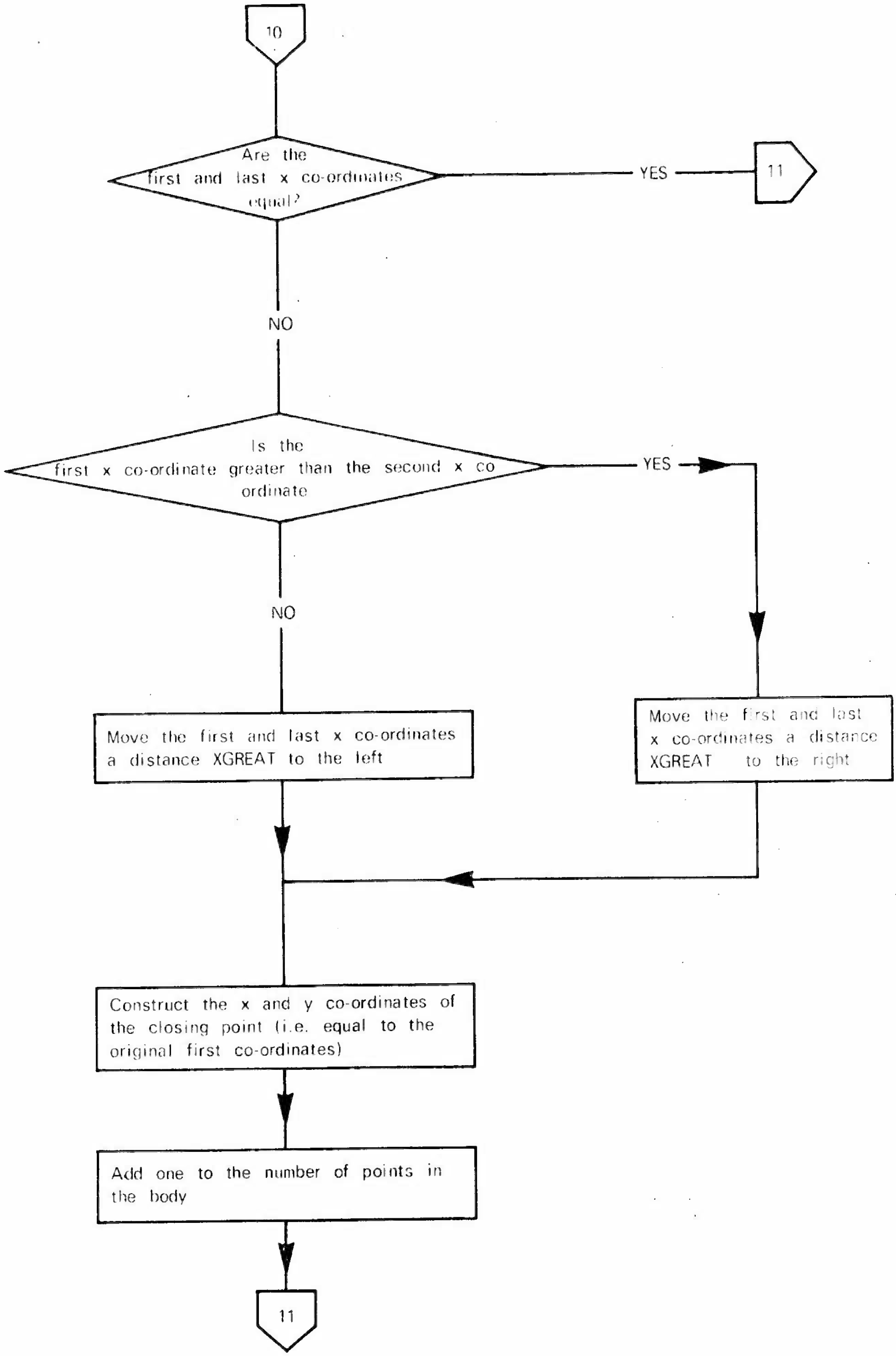

Fig. 22 Flowchart for program TOLITTLE. Part 10

To accompany Record No. 1973/213

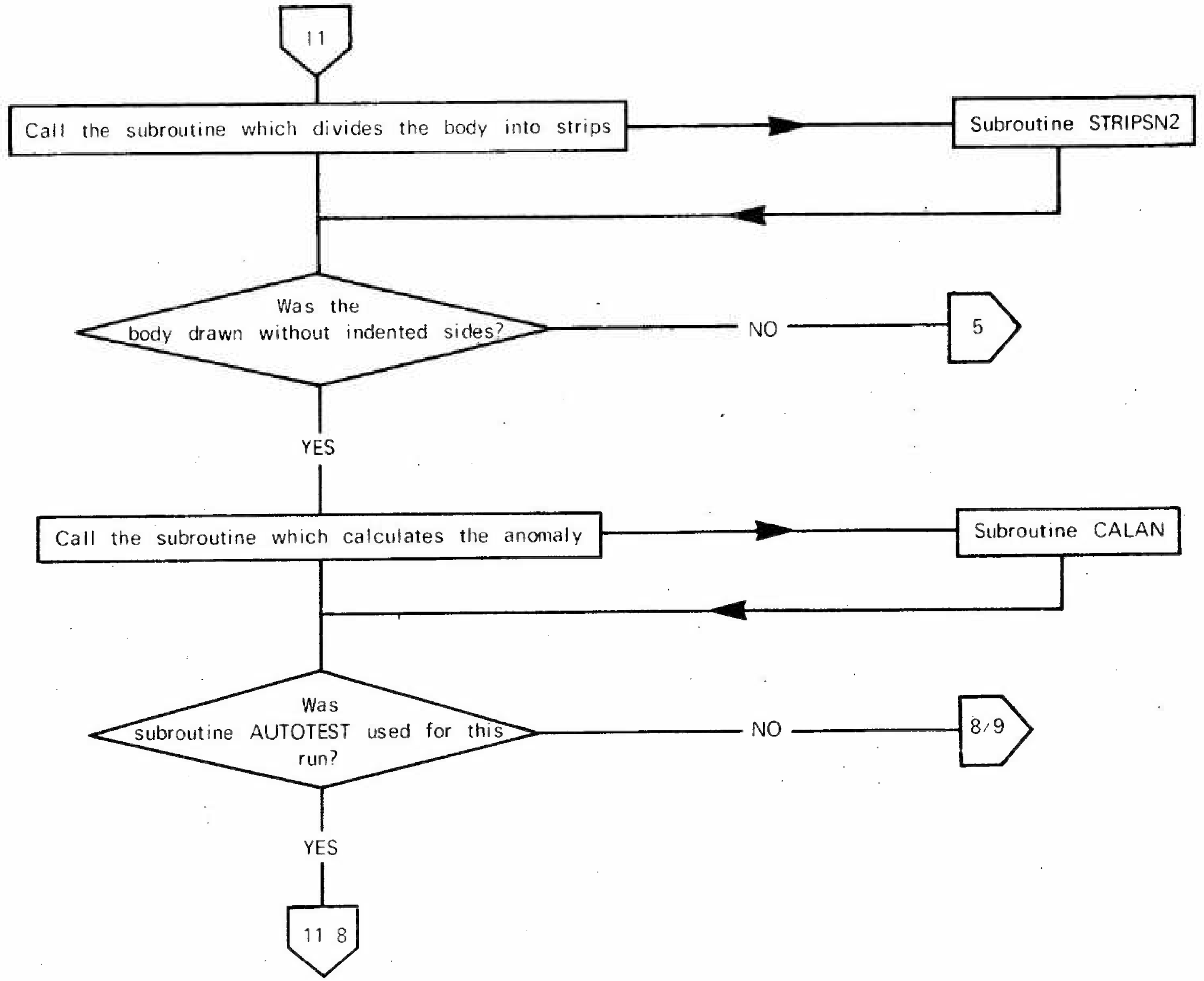

Fig. 23 Flowchart for program TOLITTLE. Part 11

G460-32-47A

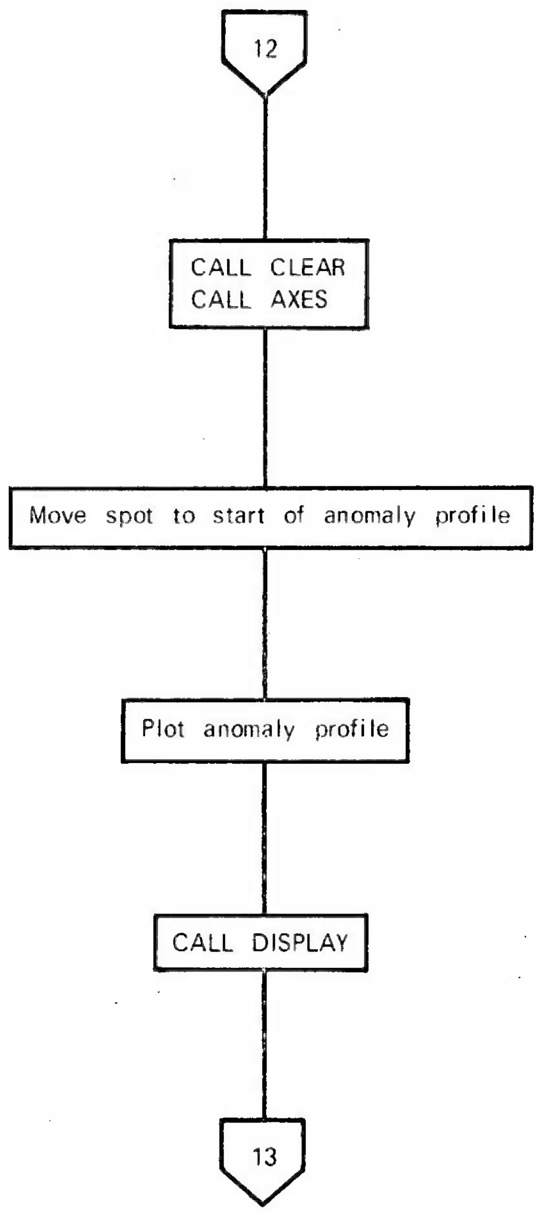

Fig. 24 Flowchart for programe TOLITTLE, Part 12

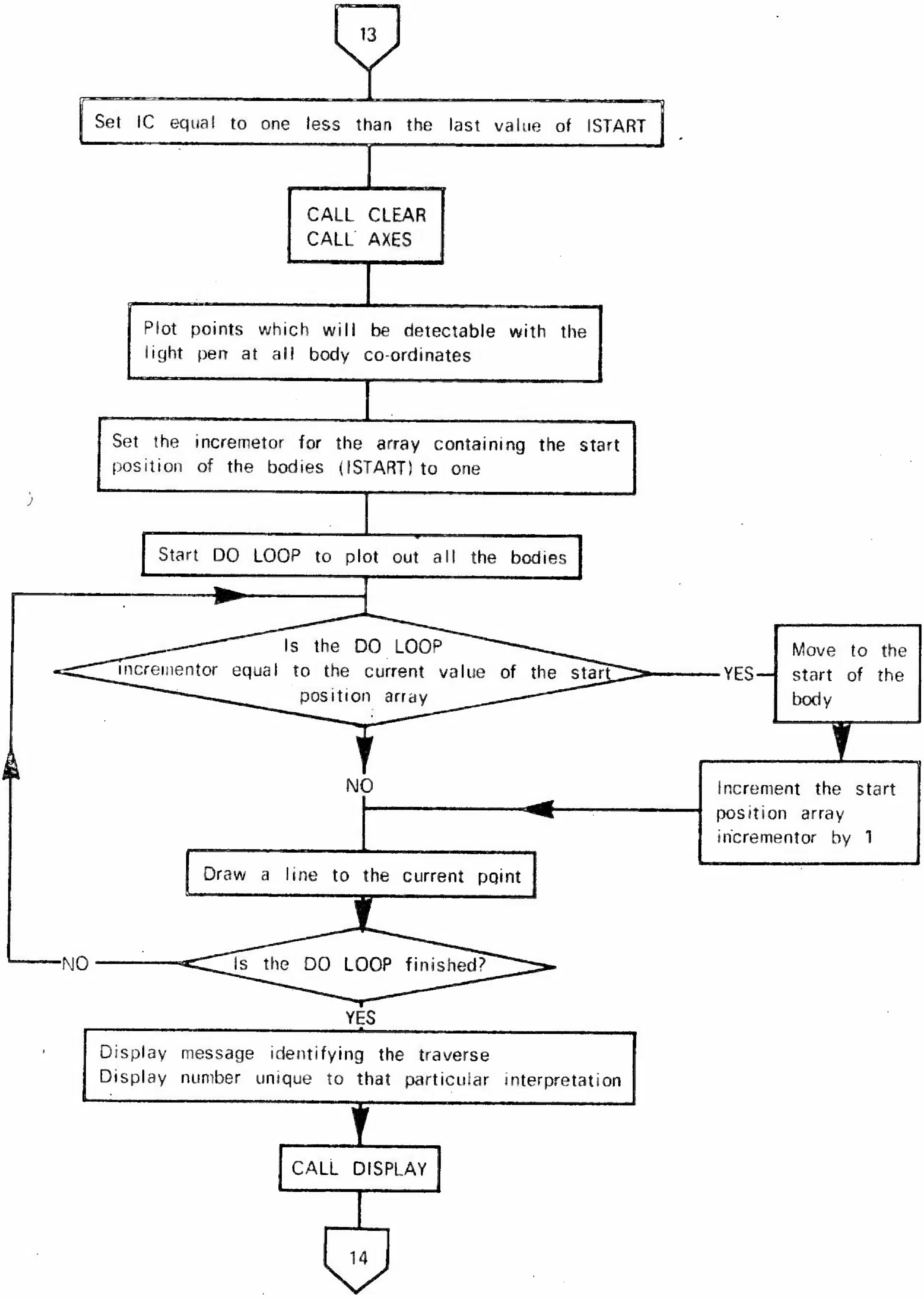

Fig. 25 Flowchart for program TOLITTLE, Part 13

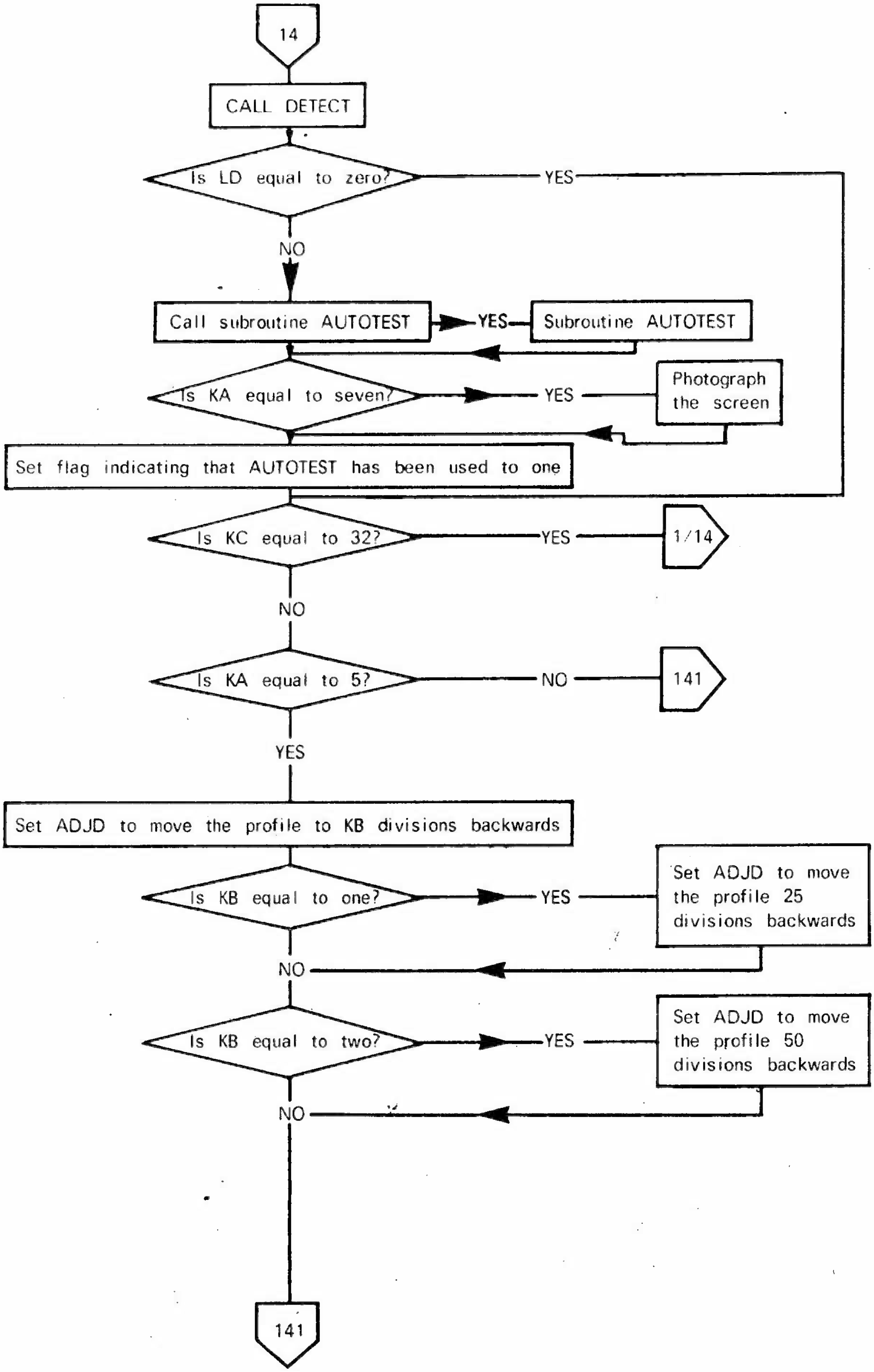

Fig. 26 Flowchart for program TOLITTLE, Part 14

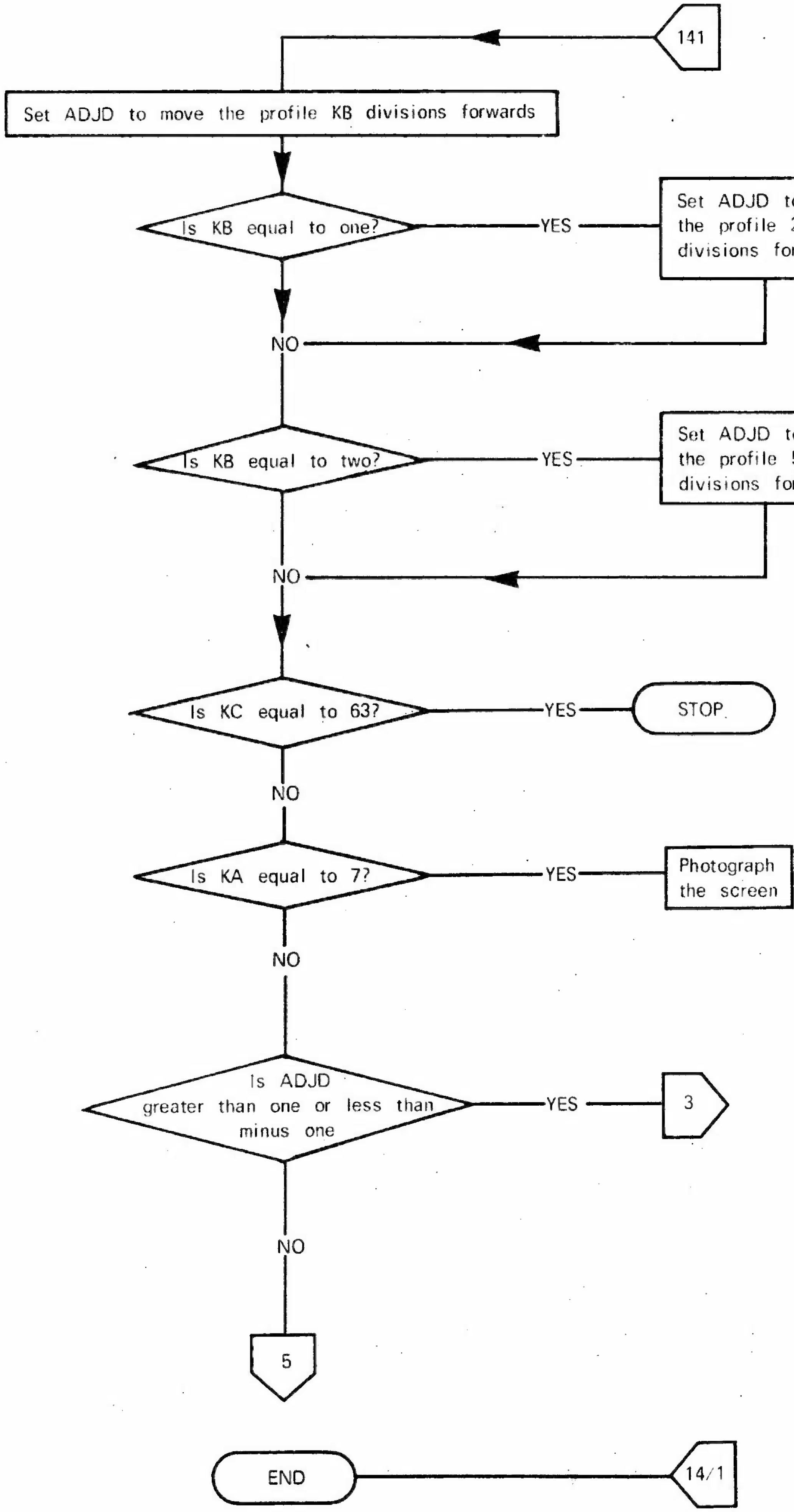

Fig. 27 Flowchart for program TOLITTLE. Part 14 cont

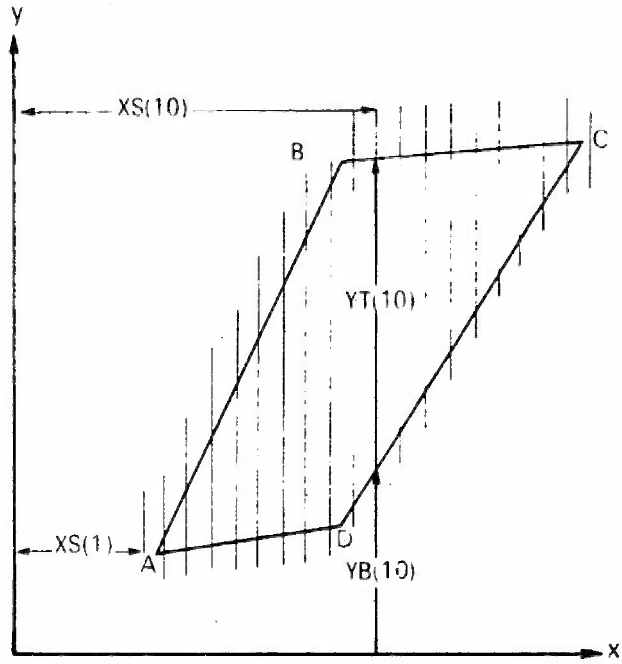

Fig. 28 Method of splitting a body into strips

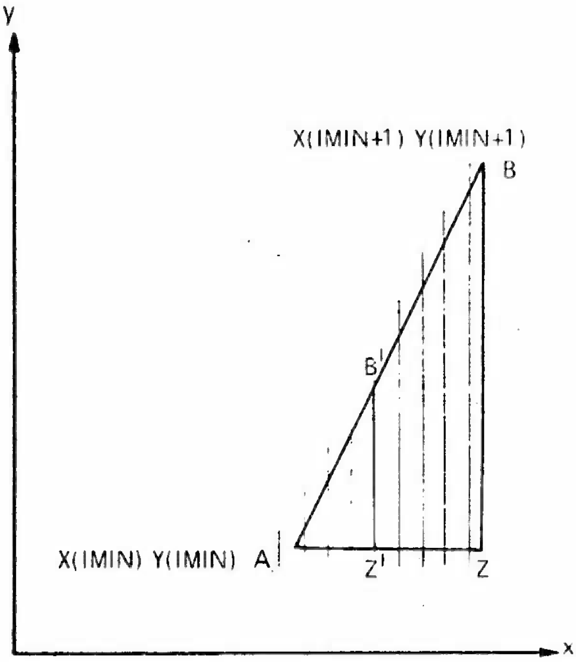

Fig. 29 Method of calculating the y coordinates of a strip

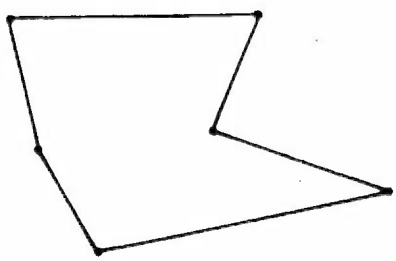

Fig. 30 Body with indented side

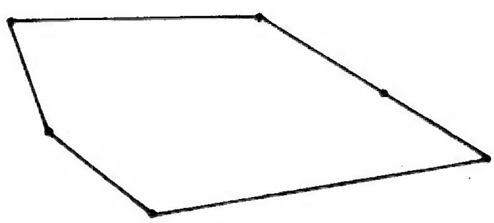

Fig. 31 Body without indented side

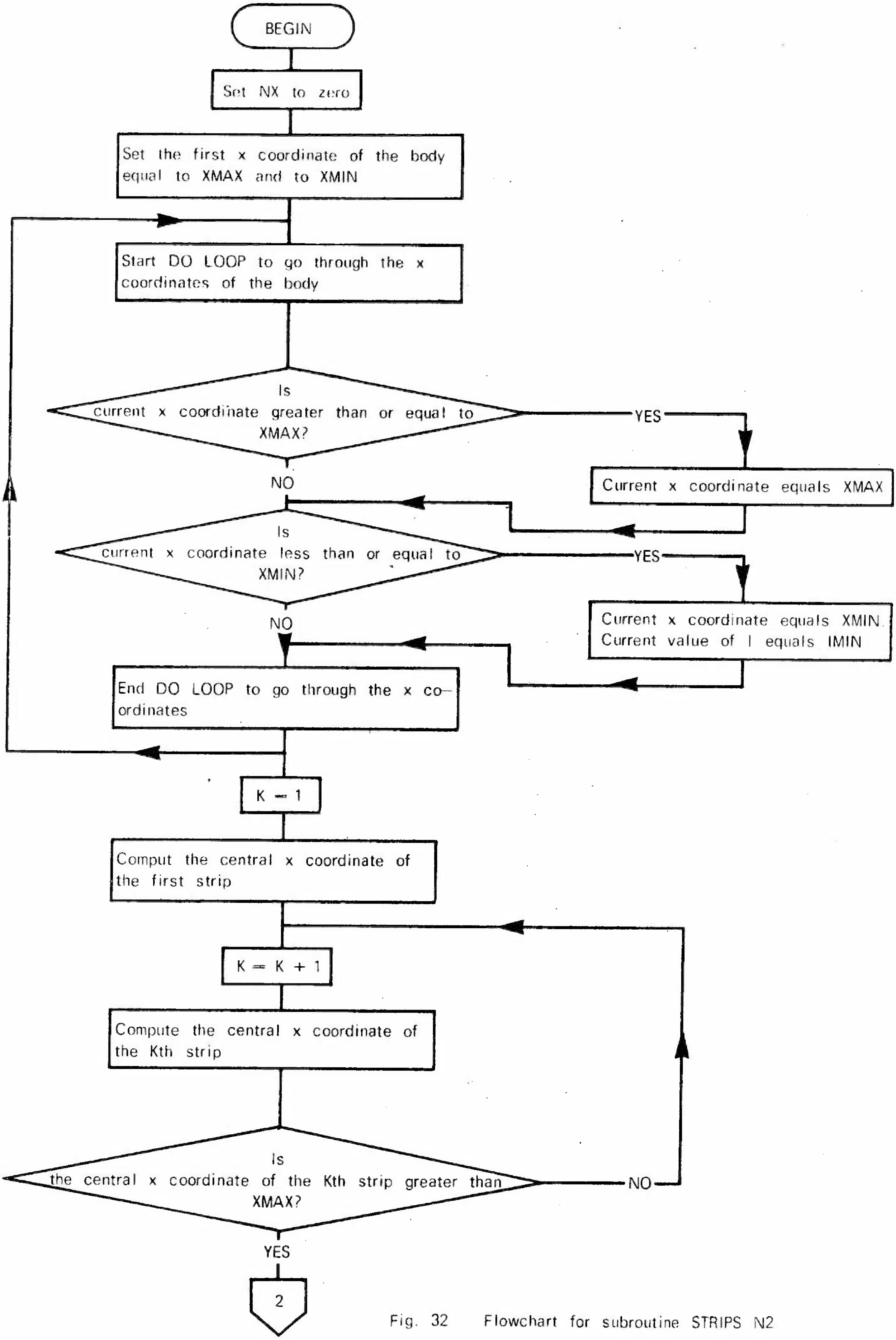

Fig. 32 Flowchart for subroutine STRIPS N2

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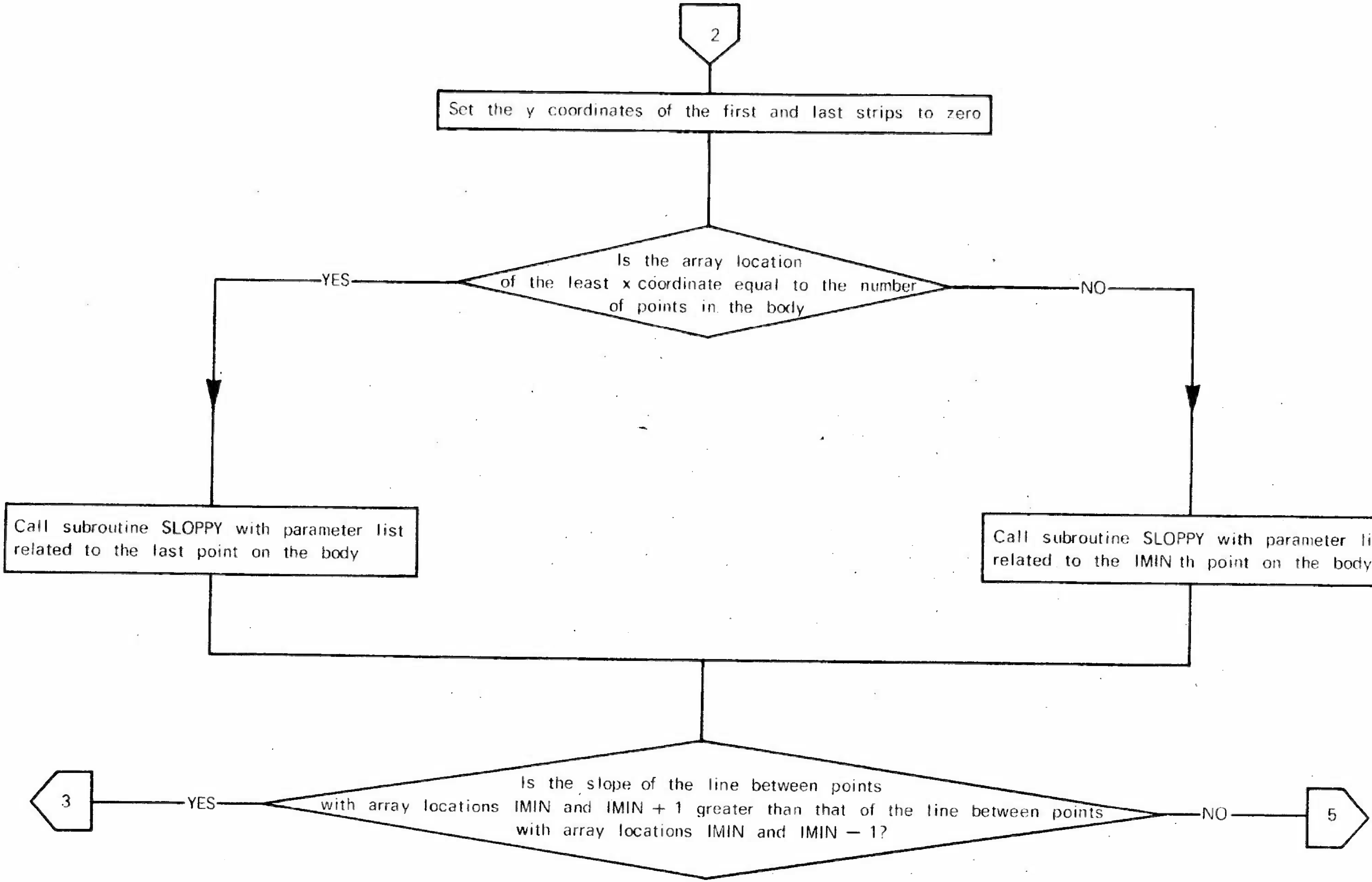


Fig. 33 Flowchart for subroutine STRIPS N2

G460-32-37A

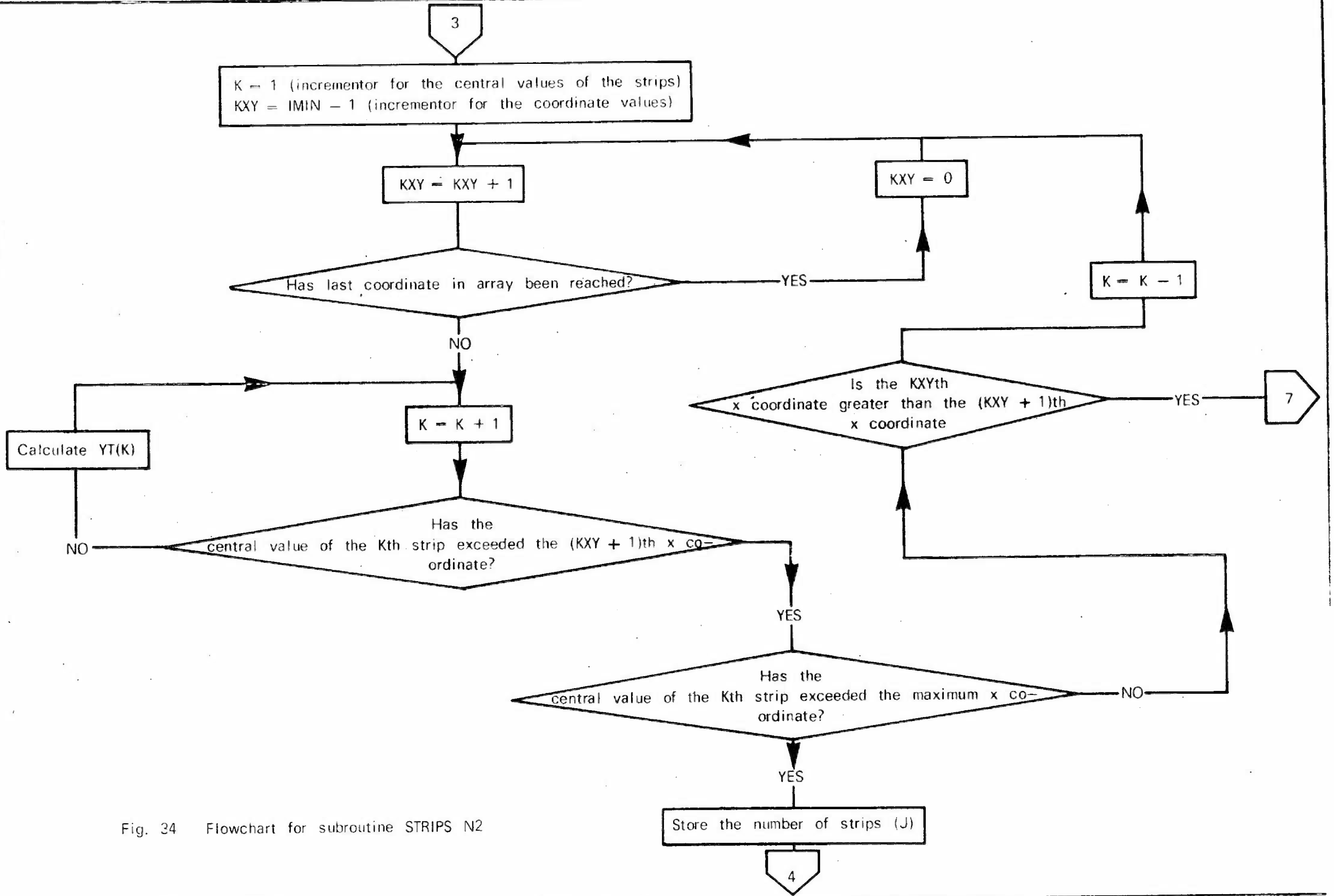


Fig. 34 Flowchart for subroutine STRIPS N2

To accompany Record No 1973/213

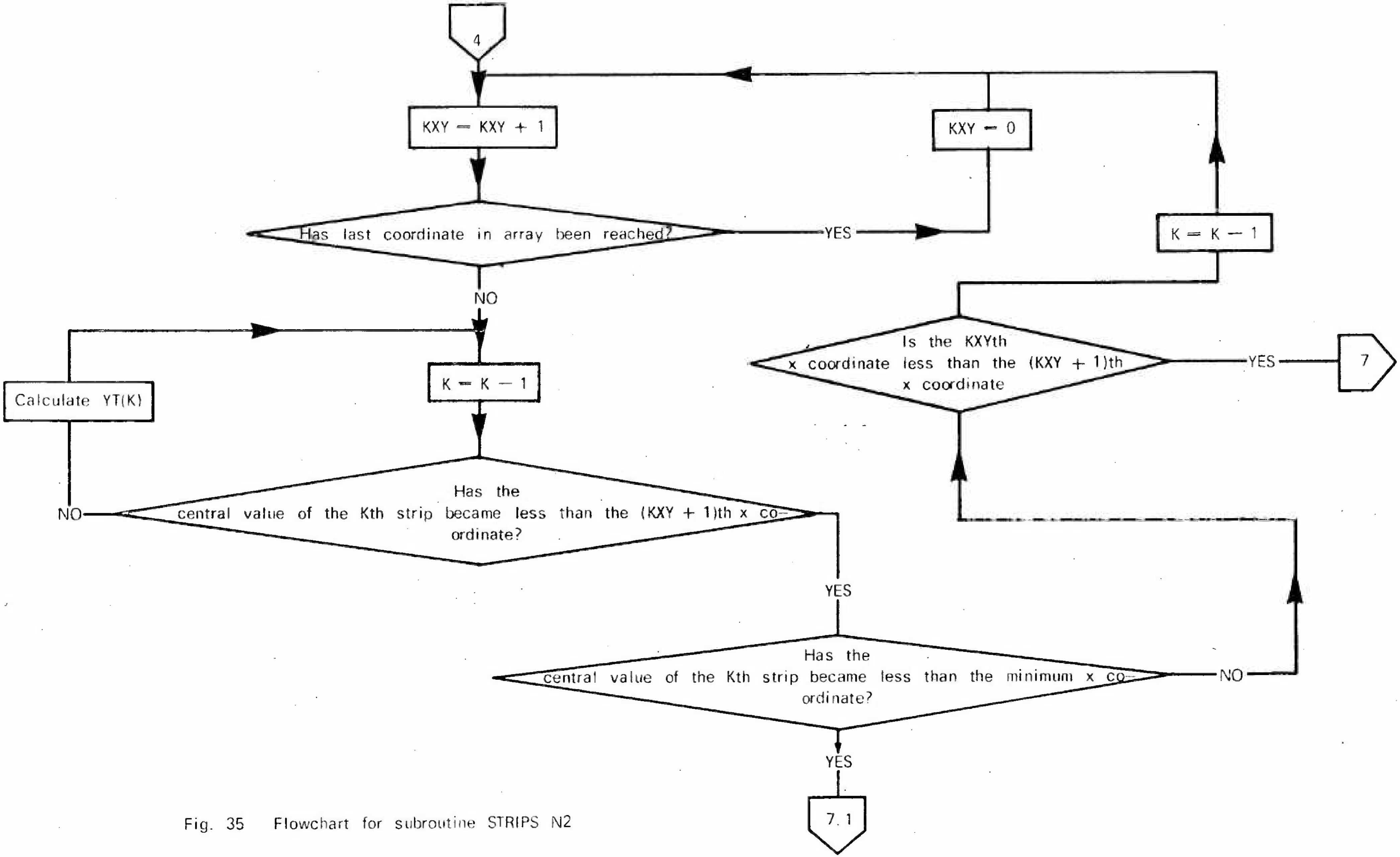


Fig. 35 Flowchart for subroutine STRIPS N2

G400-32-56A

To accompany Record No. 1973 213

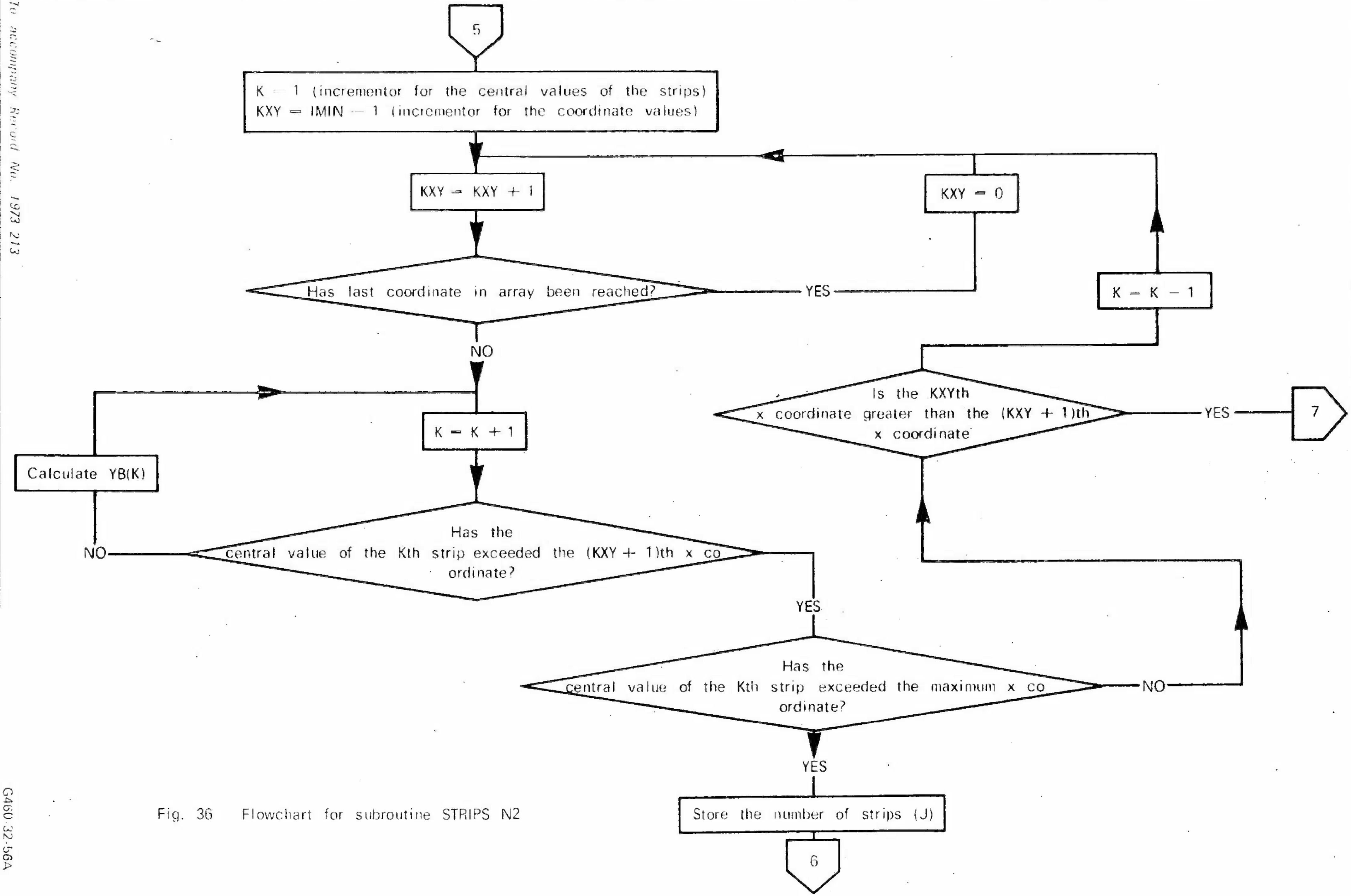


Fig. 36 Flowchart for subroutine STRIPS N2

G460 32-56A

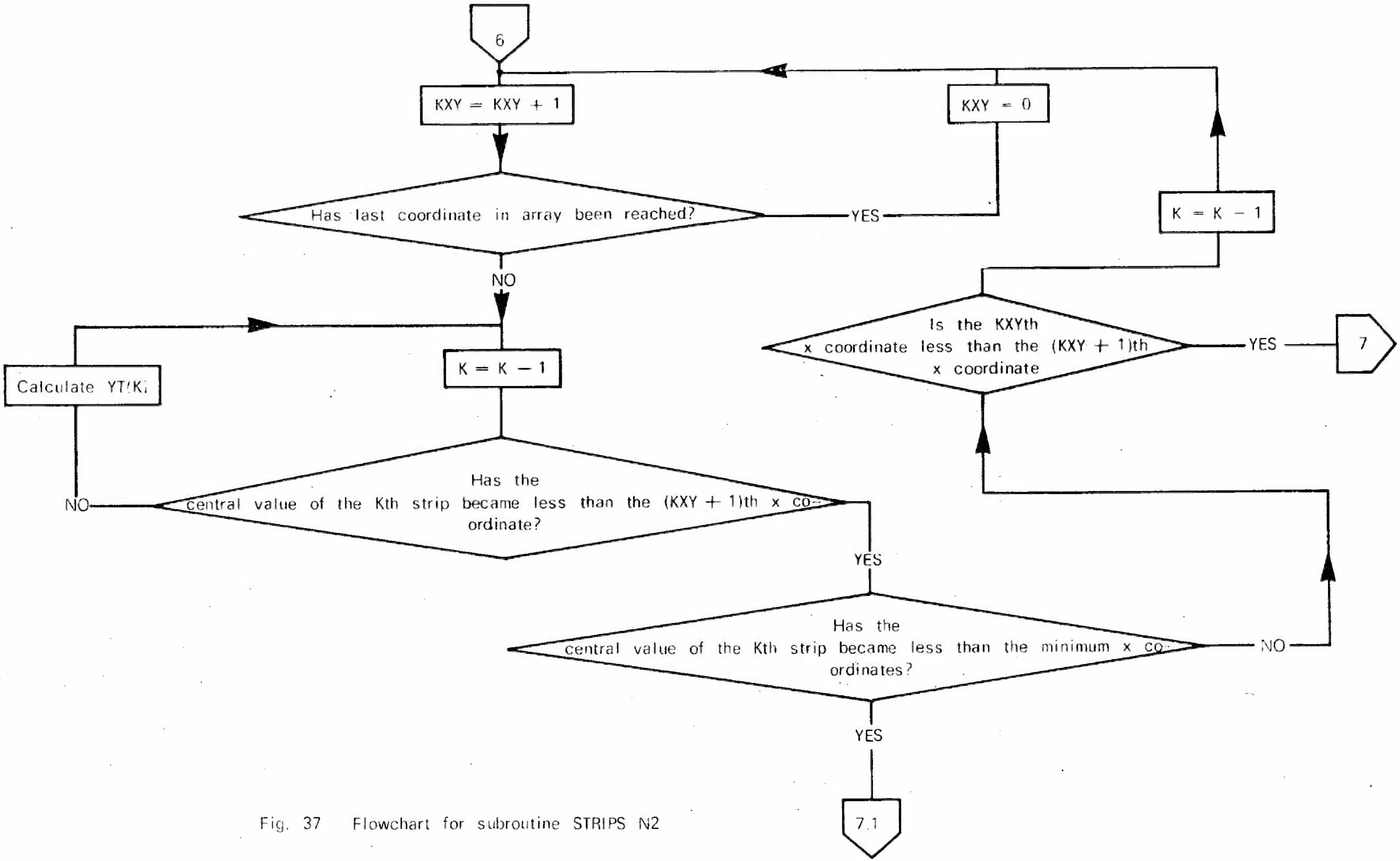


Fig. 37 Flowchart for subroutine STRIPS N2

To accompany Record No. 1973/213

G460 32 57A

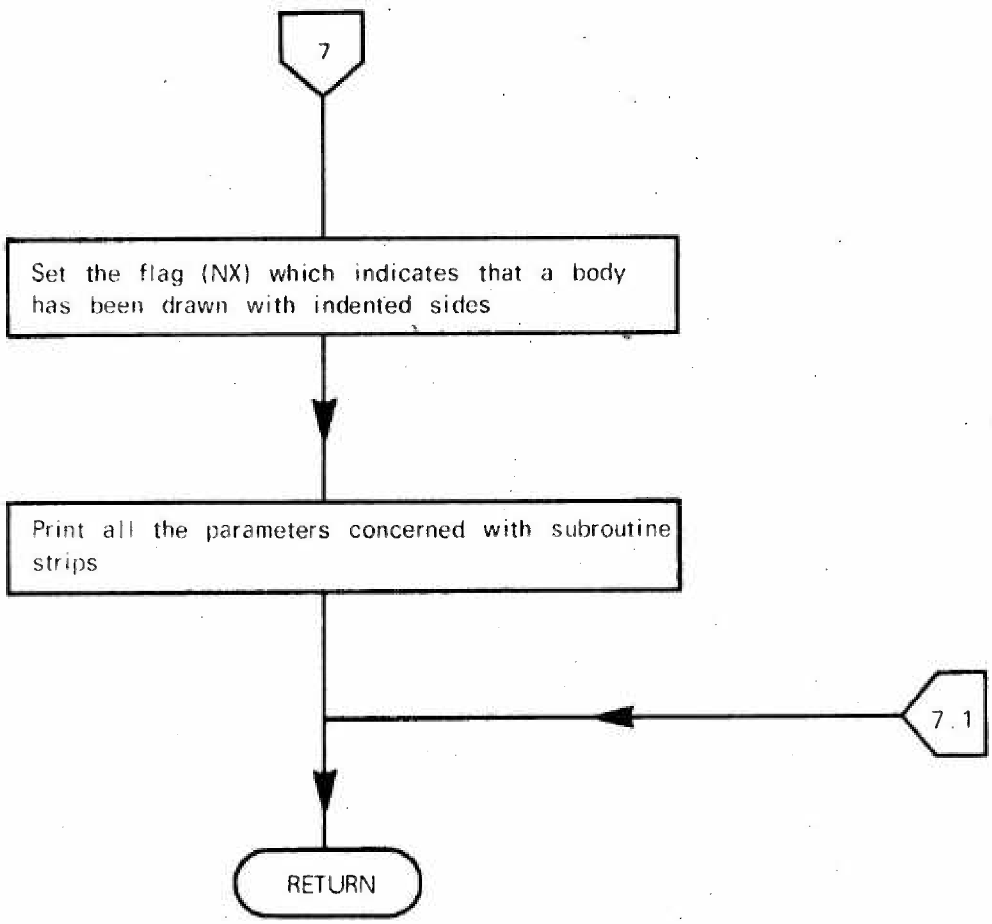


Fig. 38 Flowchart for subroutine STRIPS N2

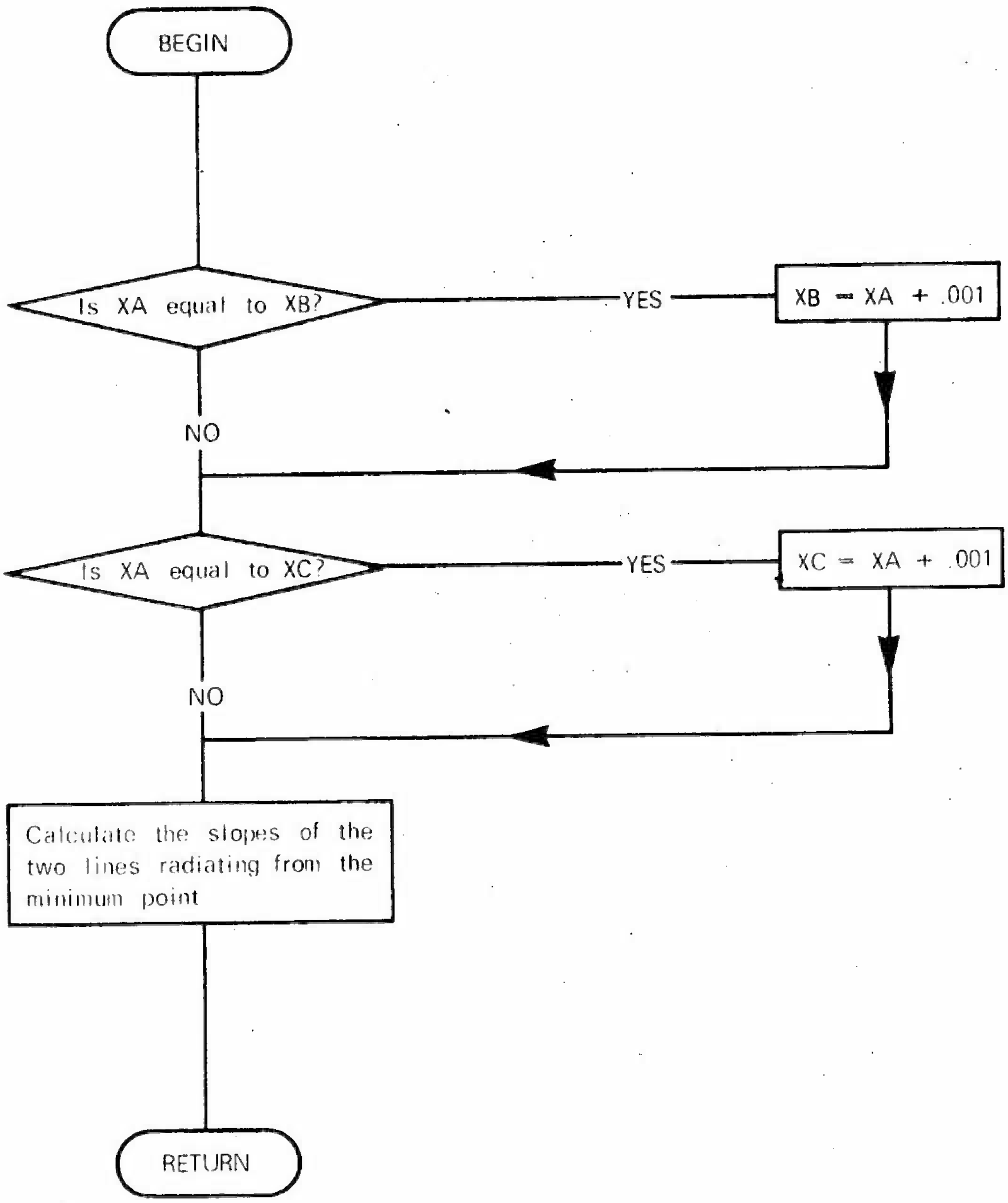


Fig. 39 Flowchart for subroutine SLOPPY

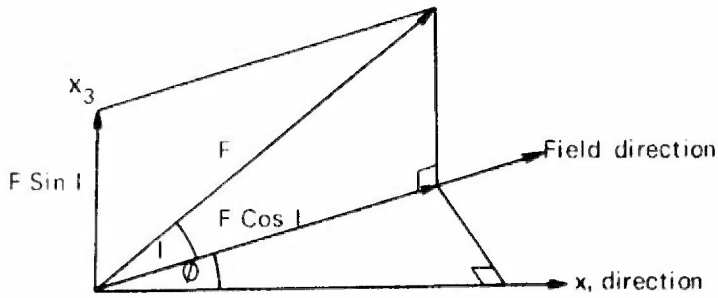


Fig. 40 Method of projecting the remanent and induced vectors onto the x_1x_3 plane

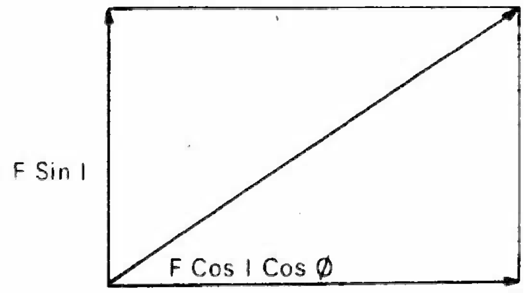


Fig. 41 Components of the projected vectors in the x_1x_3 plane

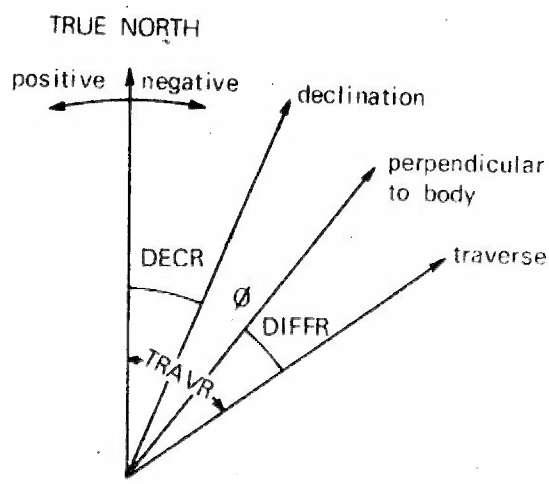


Fig. 42 Relarionship of Ø to the input parameters

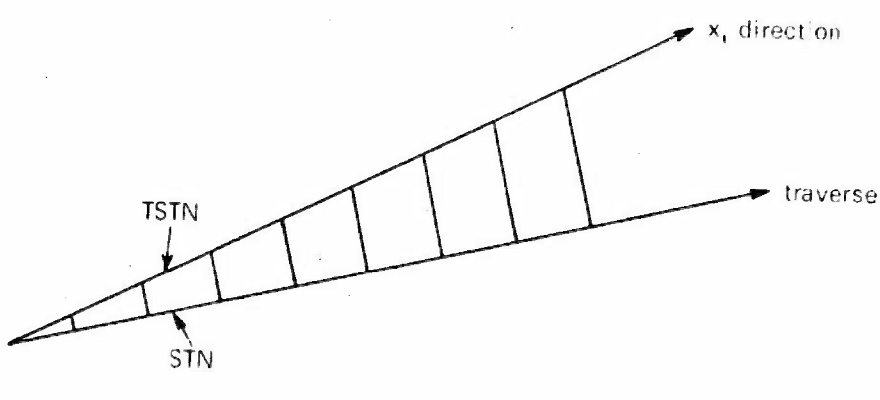


Fig. 43 Relationship between TSTN and STN

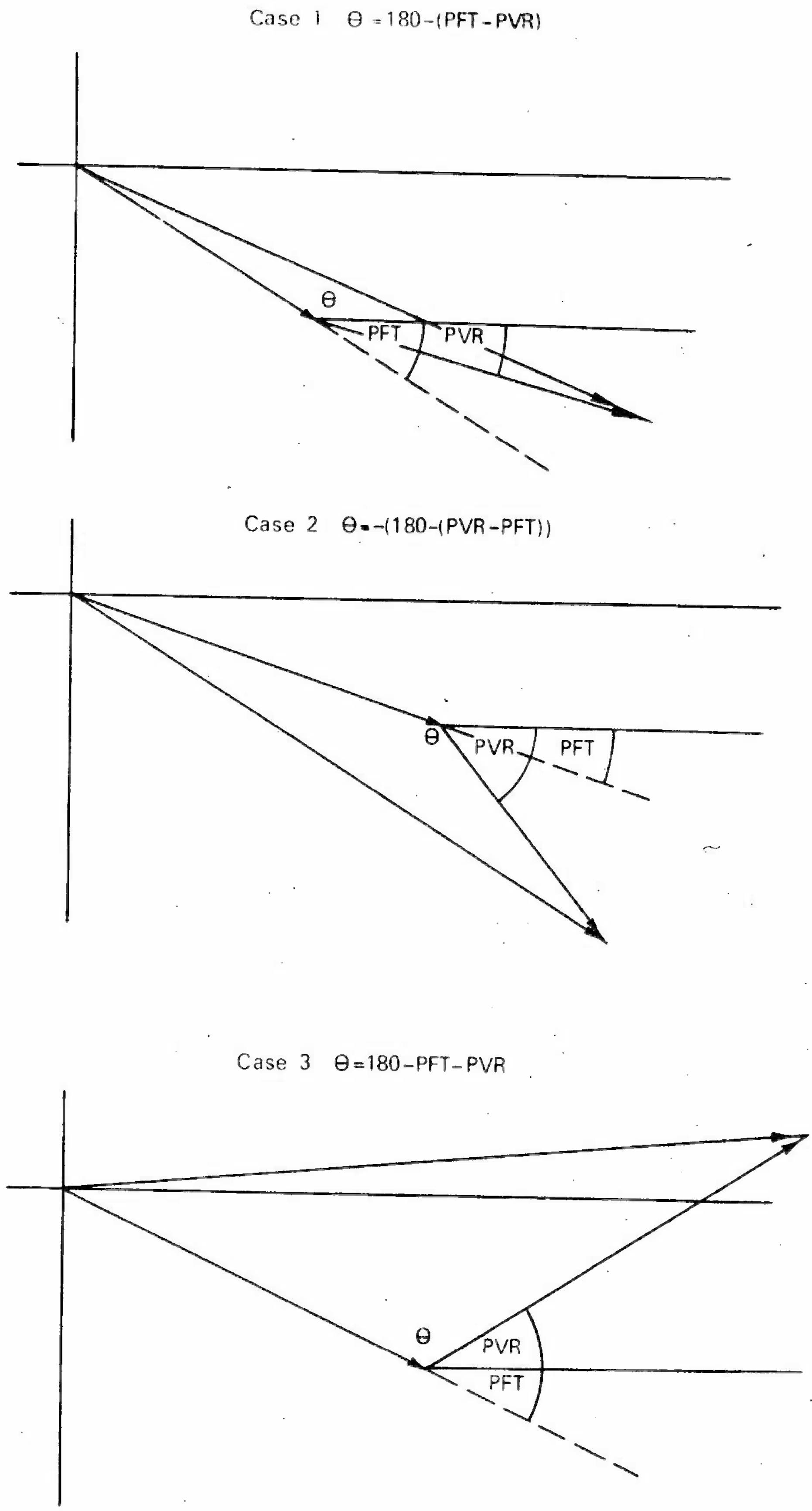
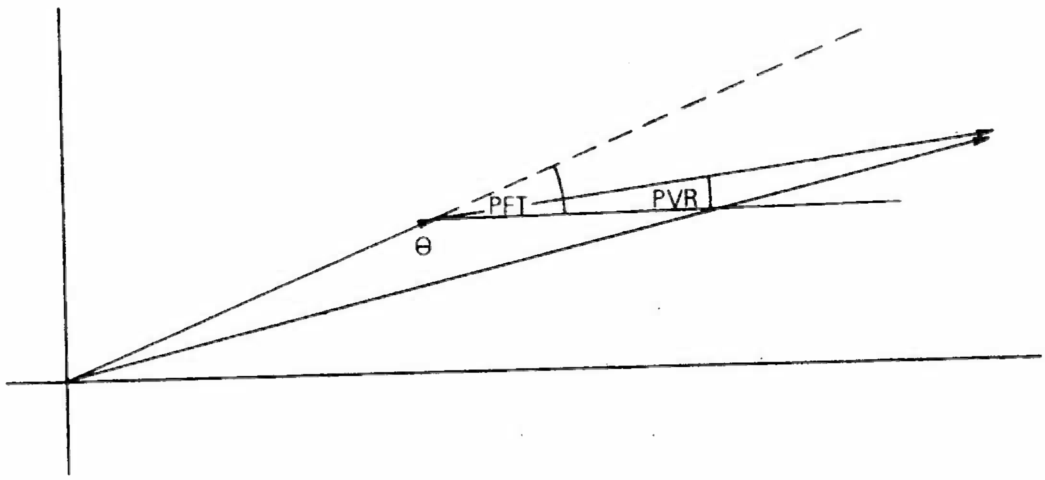
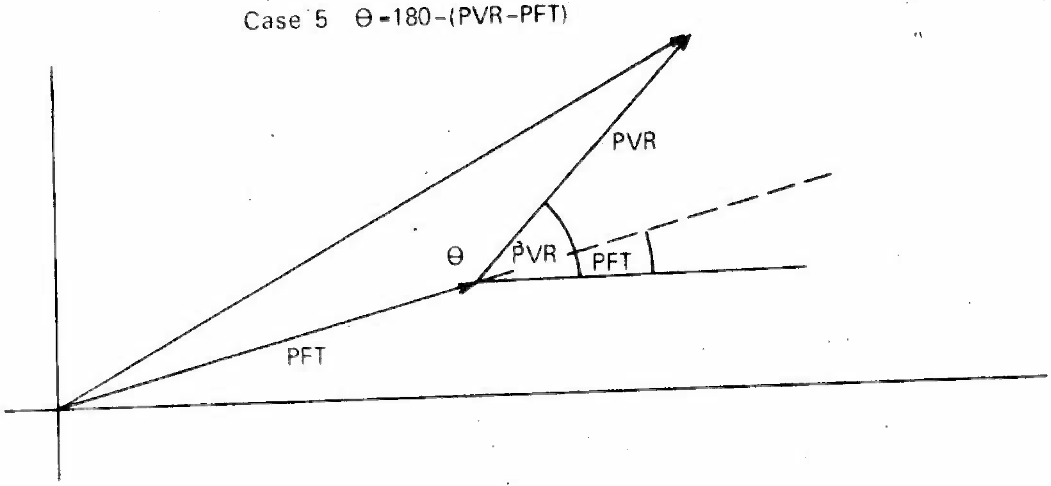


Fig. 44 Configuration of the induced and remanent vectors for the first three possible values of Θ

Case 4 Θ=-(180-(PFT-PVR))



Case 5 Θ=180-(PVR-PFT)



Case 6 Θ=-(180-PFT-PVR)

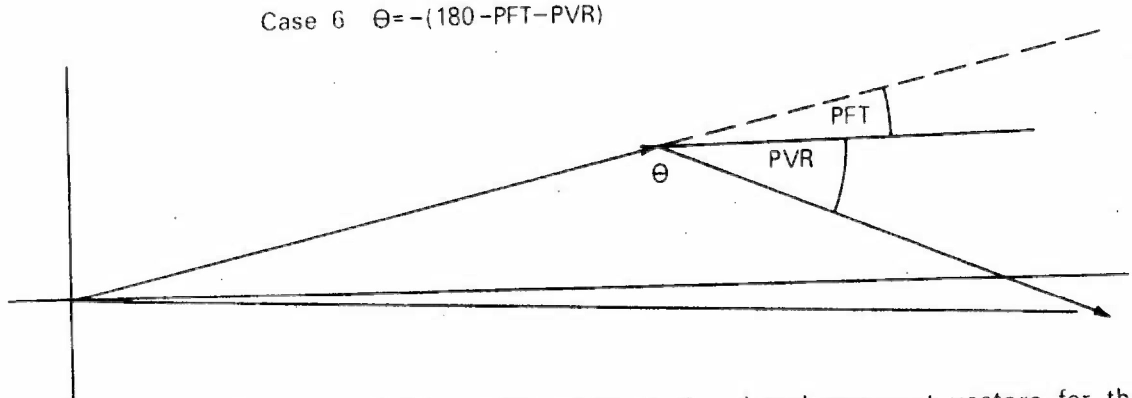


Fig. 45 Configuration of the induced and remanent vectors for the second three values of Θ

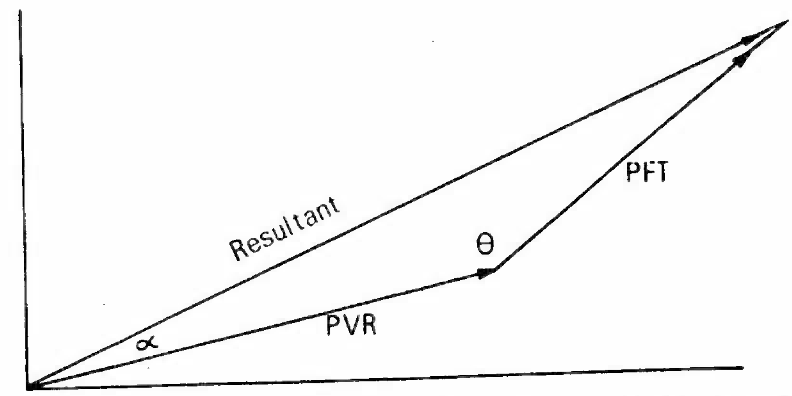


Fig. 46 Relationship of ∝ to PVR, PFT, and Θ

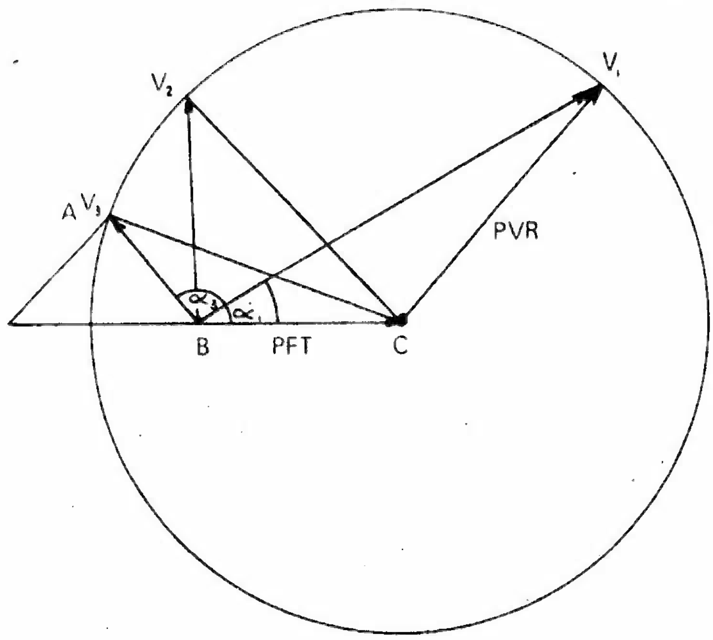


Fig. 47 Circle giving all possible values of ∝ when PVR > PFT

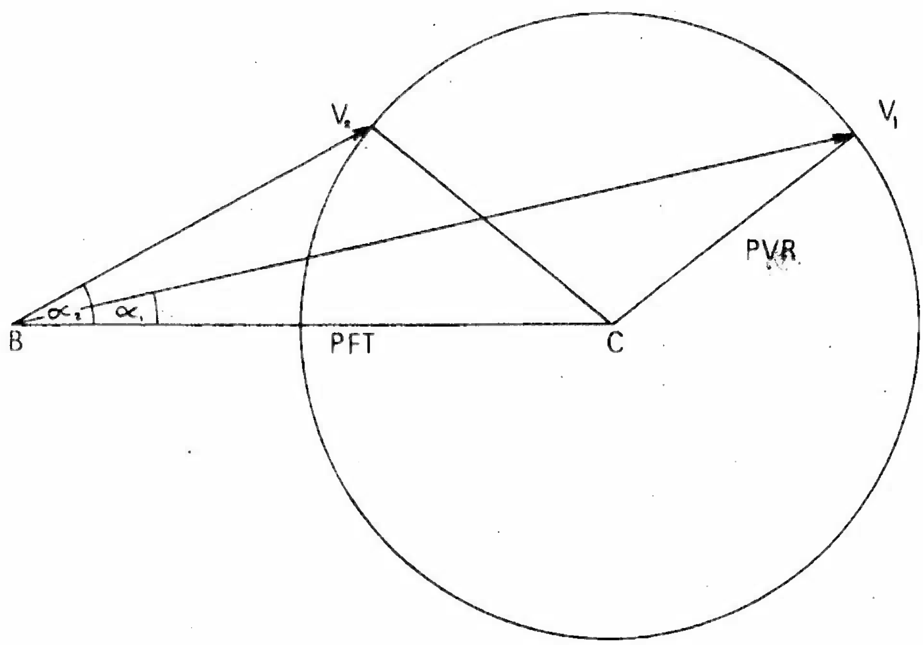


Fig. 48 Circle giving all possible values of ∝ when PVR < PFT

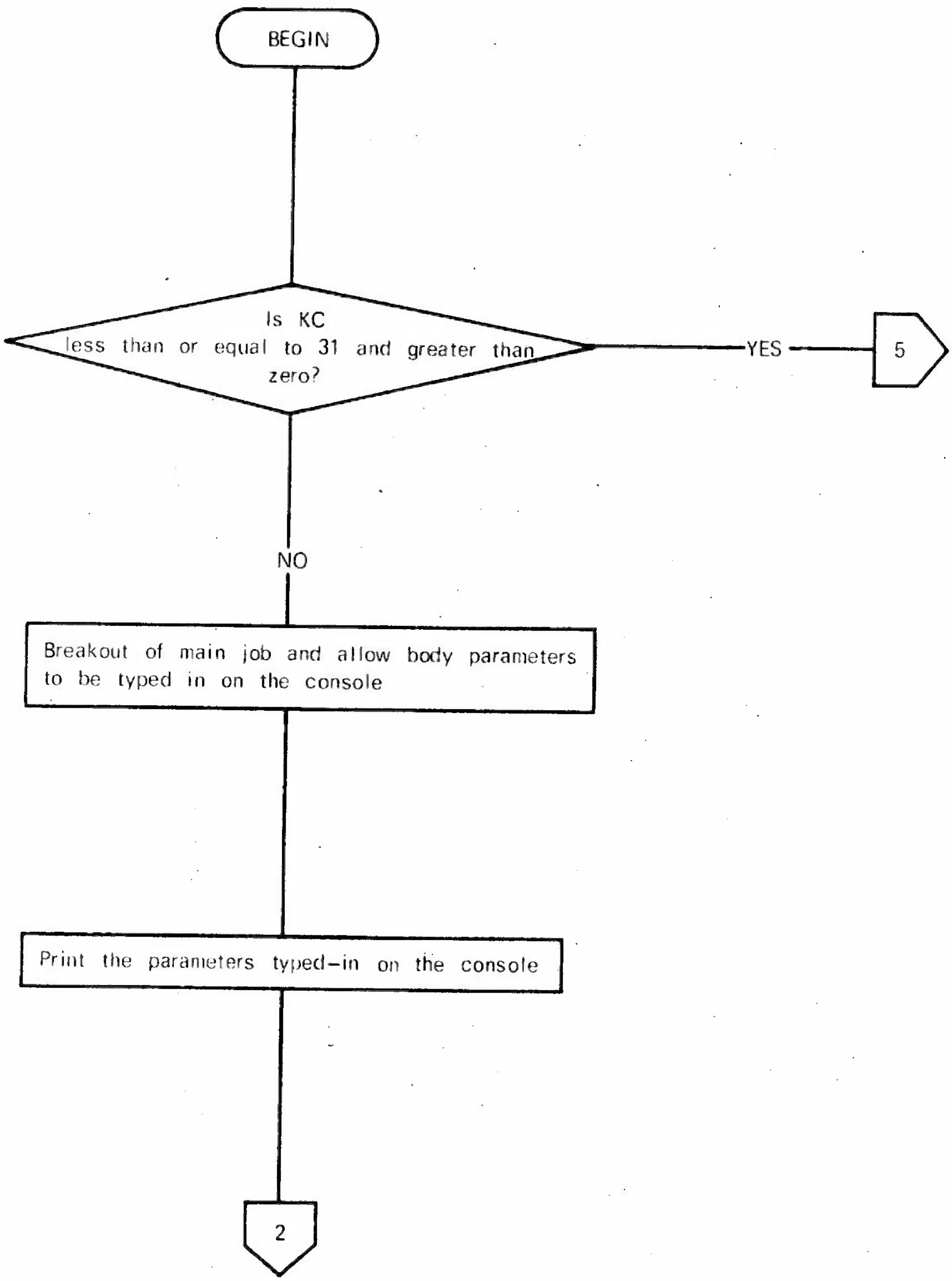


Fig. 49 Flowchart for subroutine CALAN, Part 1

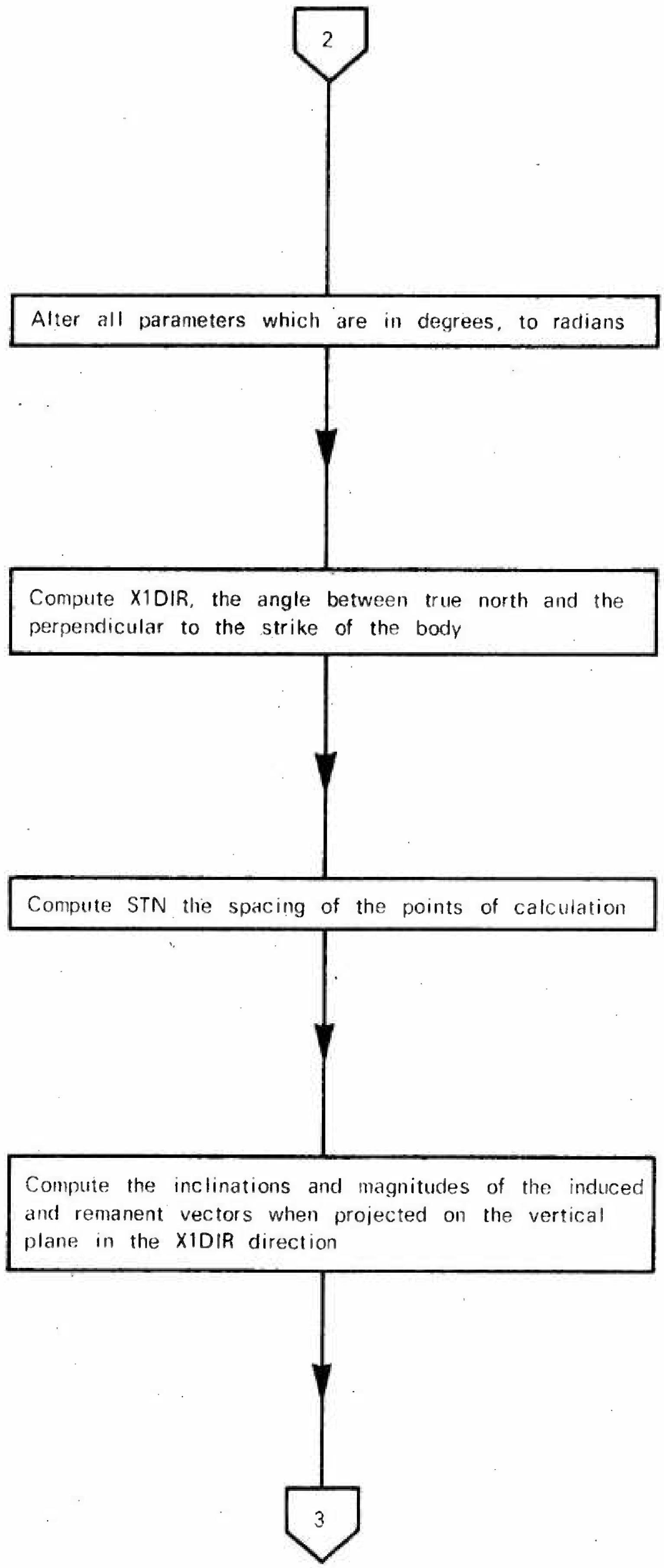


Fig. 50 Flowchart for subroutine CALAN, Part 2

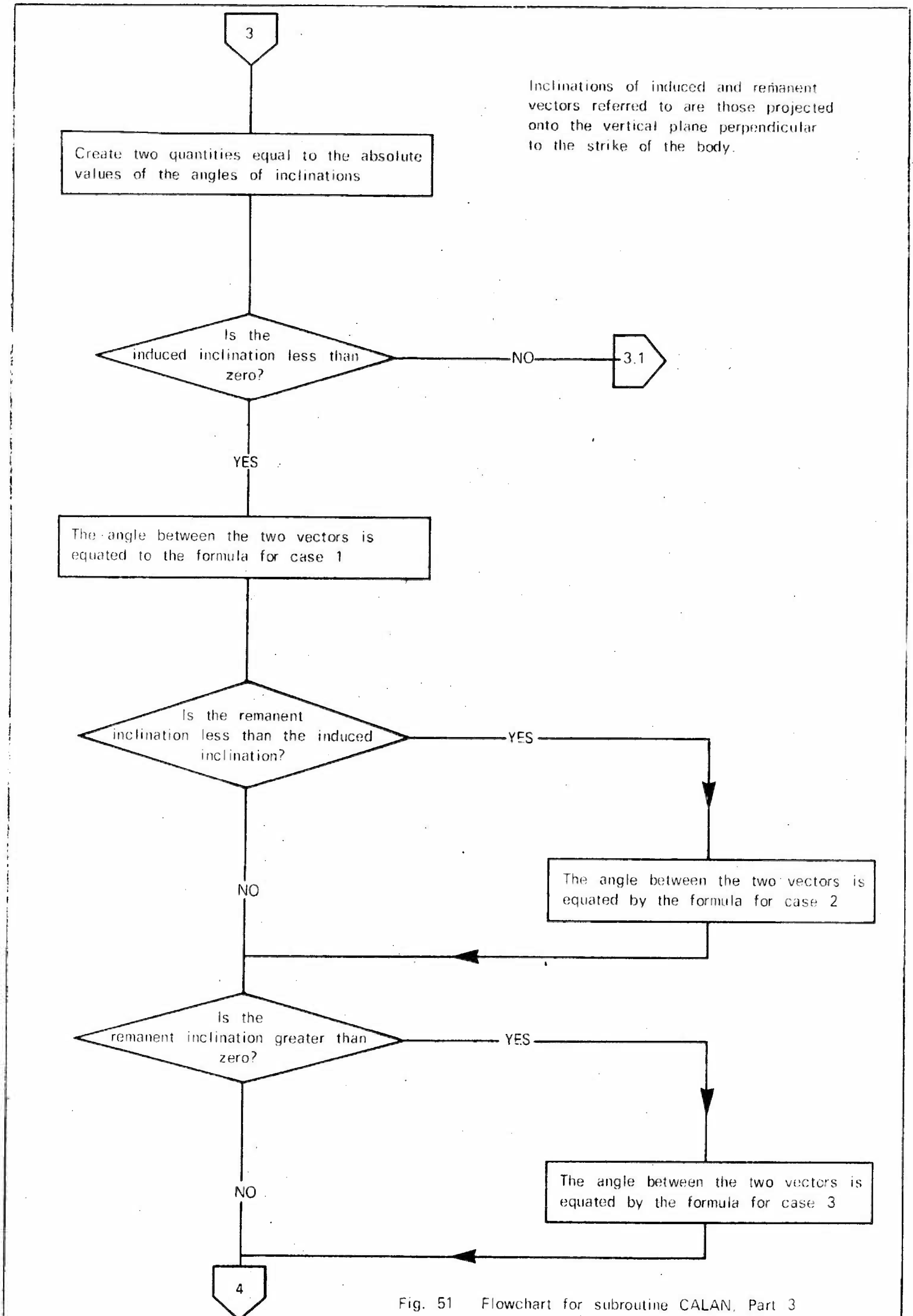


Fig. 51 Flowchart for subroutine CALAN, Part 3

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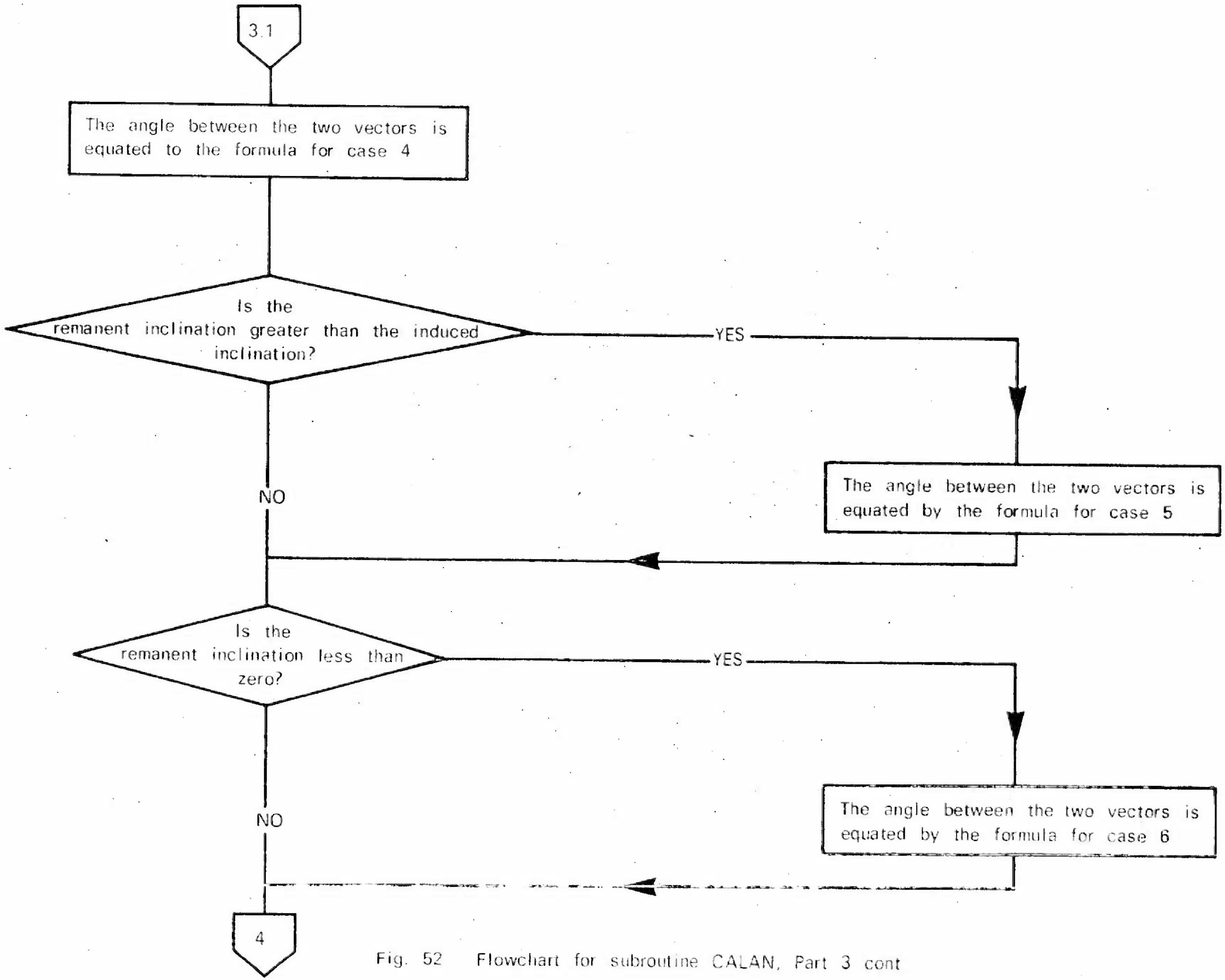

Fig. 52 Flowchart for subroutine CALAN, Part 3 cont

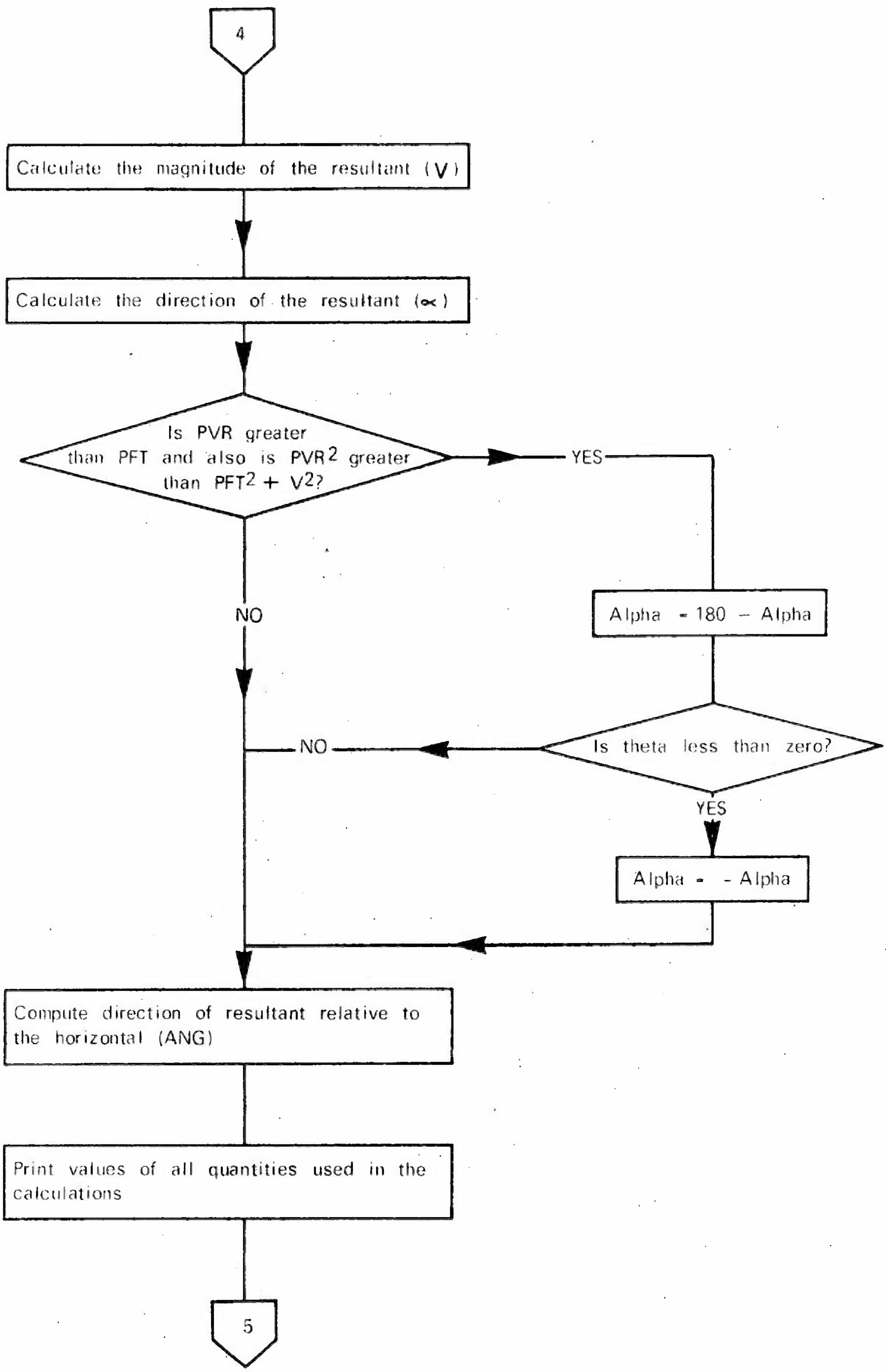

Fig 53 Flowchart for subroutine CALAN, Part 4

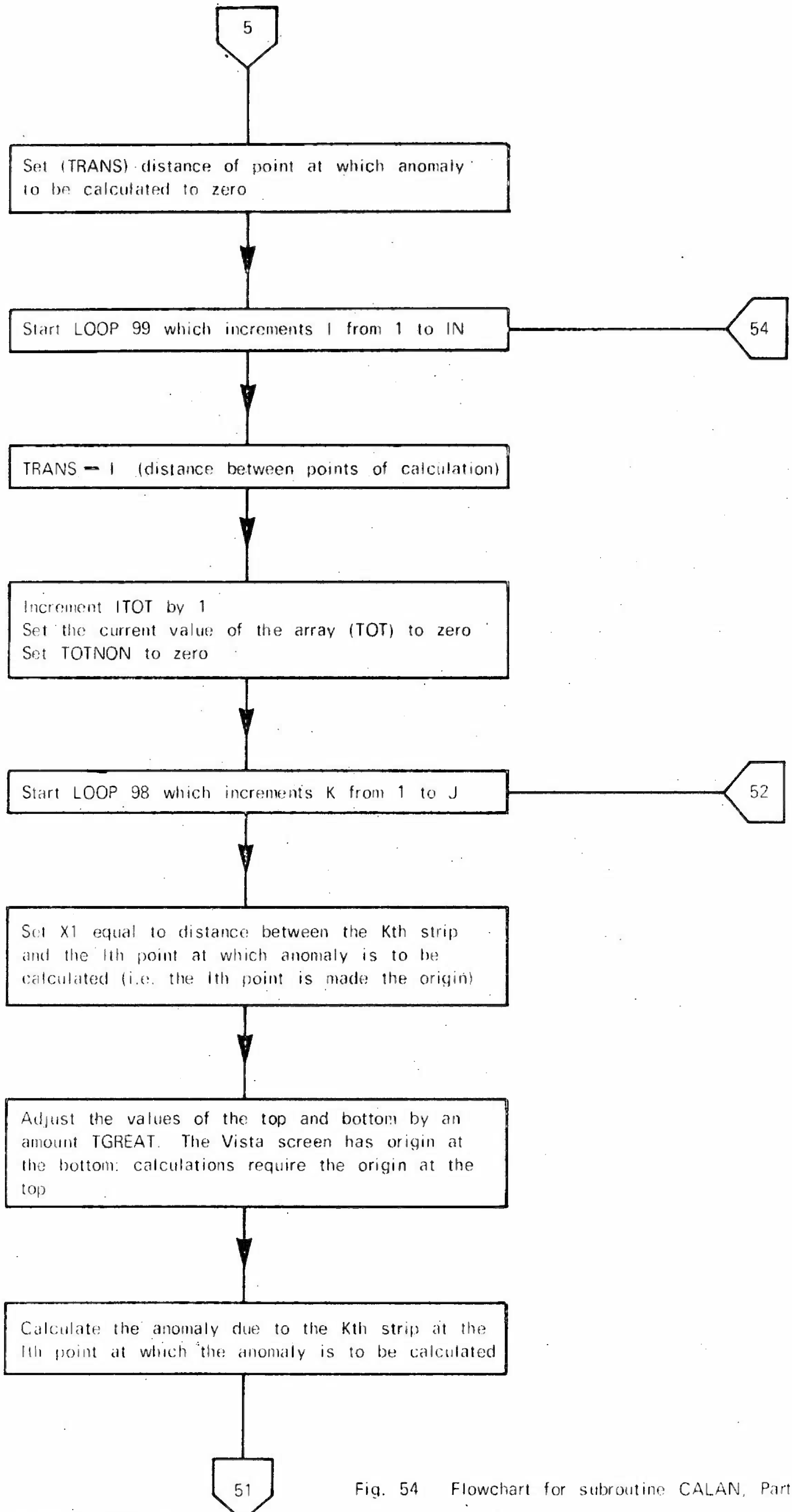

Fig. 54 Flowchart for subroutine CALAN, Part 5

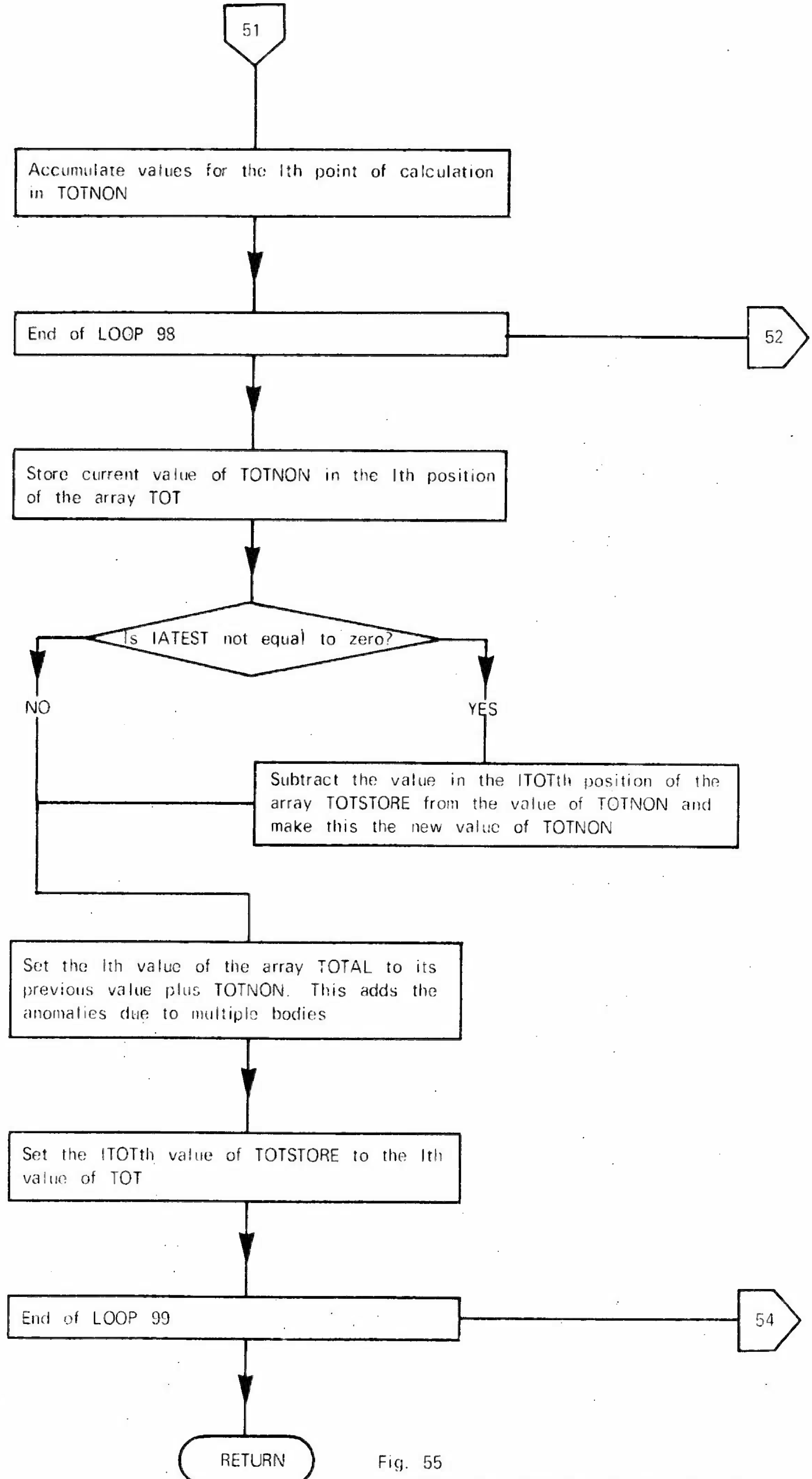

Fig. 55
Flowchart for subroutine CALAN, Part 5 cont

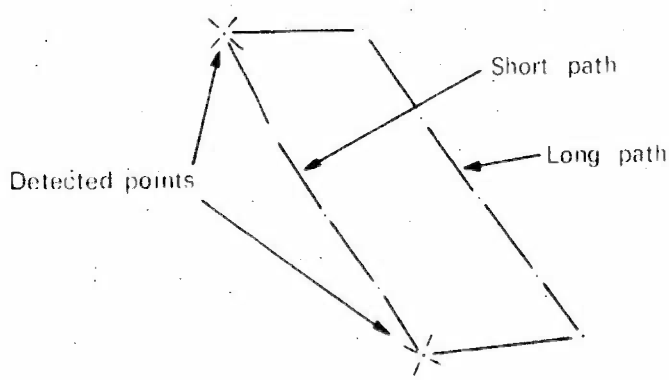

Fig. 56 Short and long paths between two points which have been detected on a body

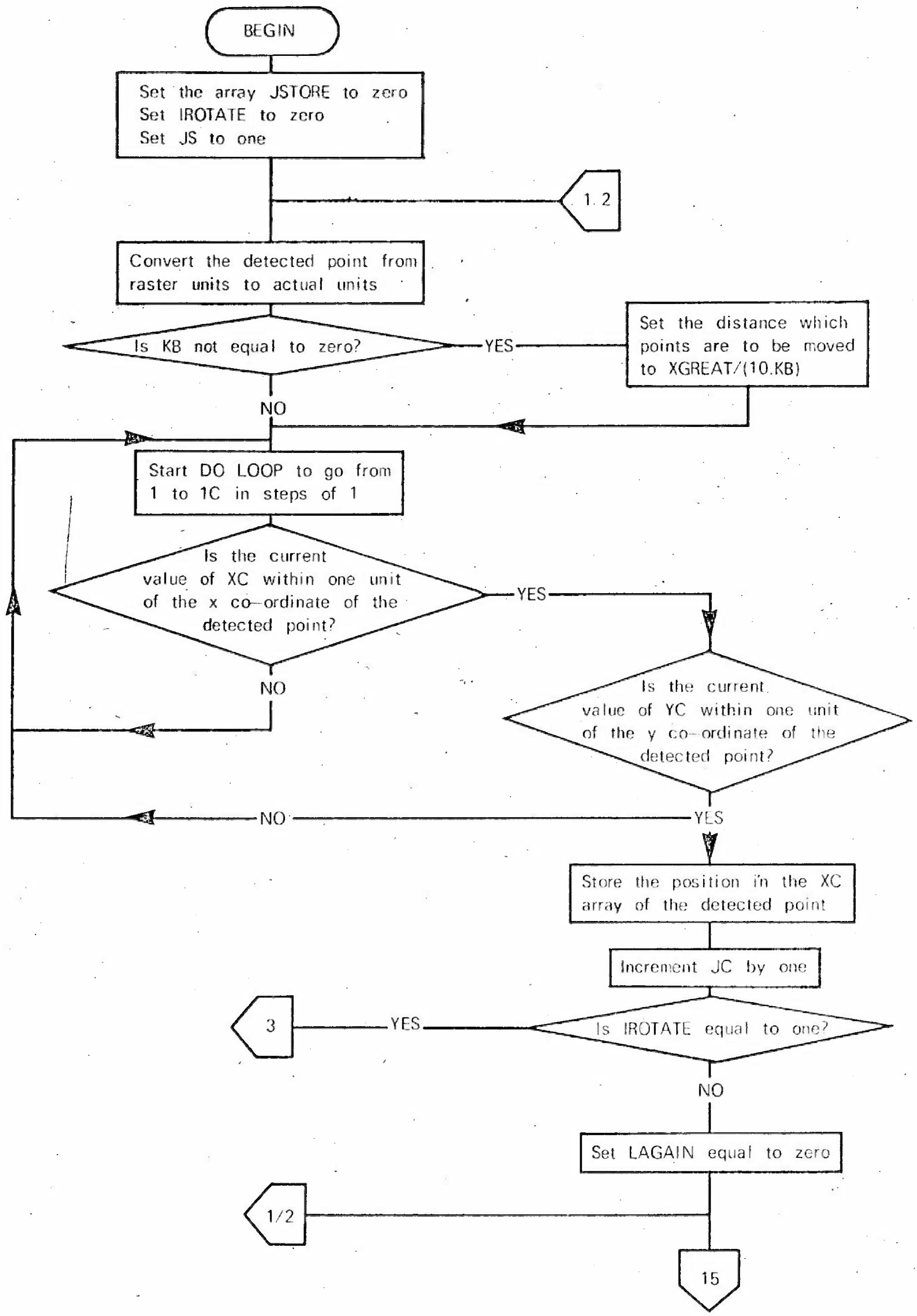

Fig. 57 Flowchart for subroutine AUTOTEST, Part 1

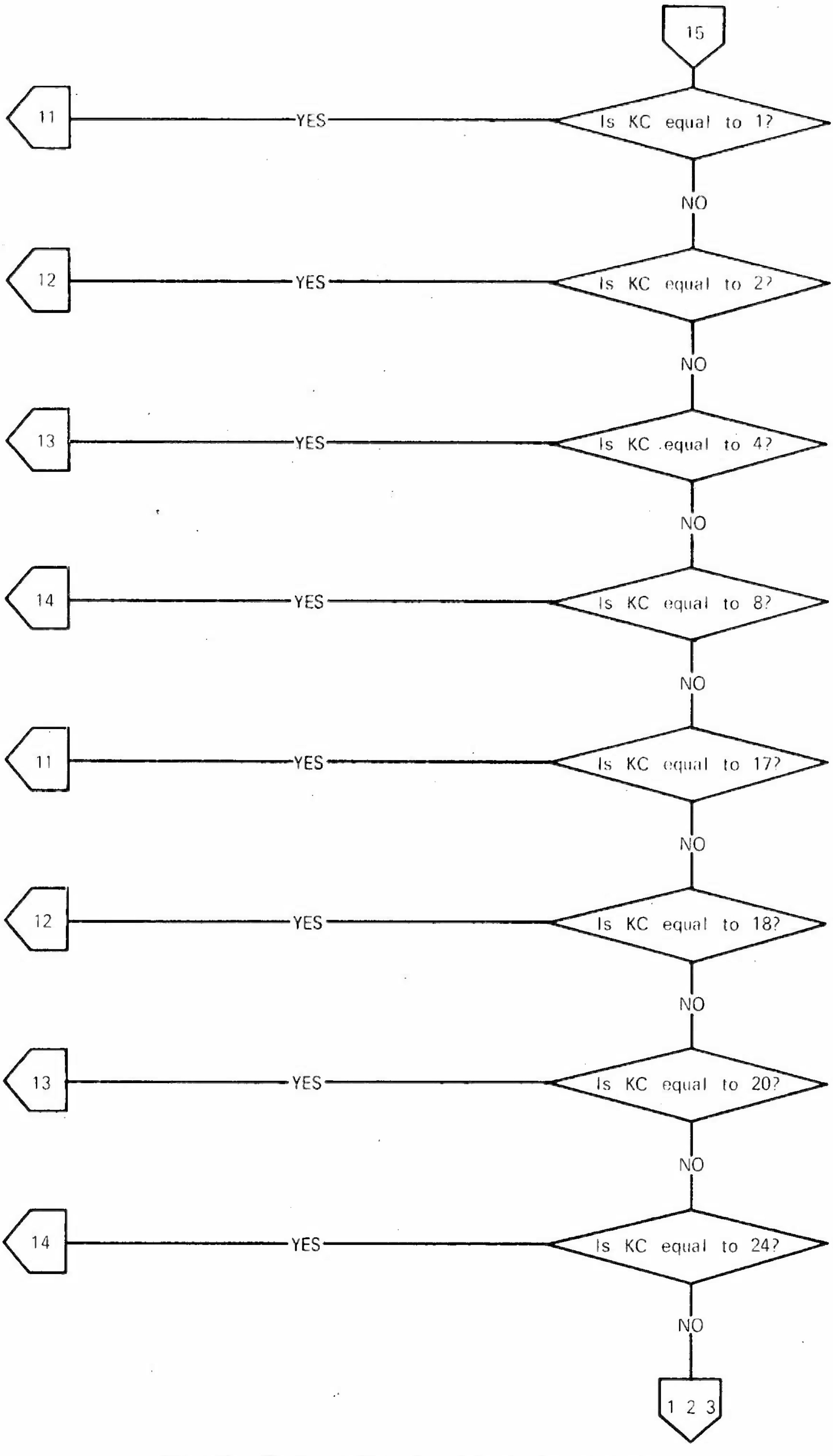

Fig. 58 Flowchart for subroutine AUTOTEST, Part 1 cont

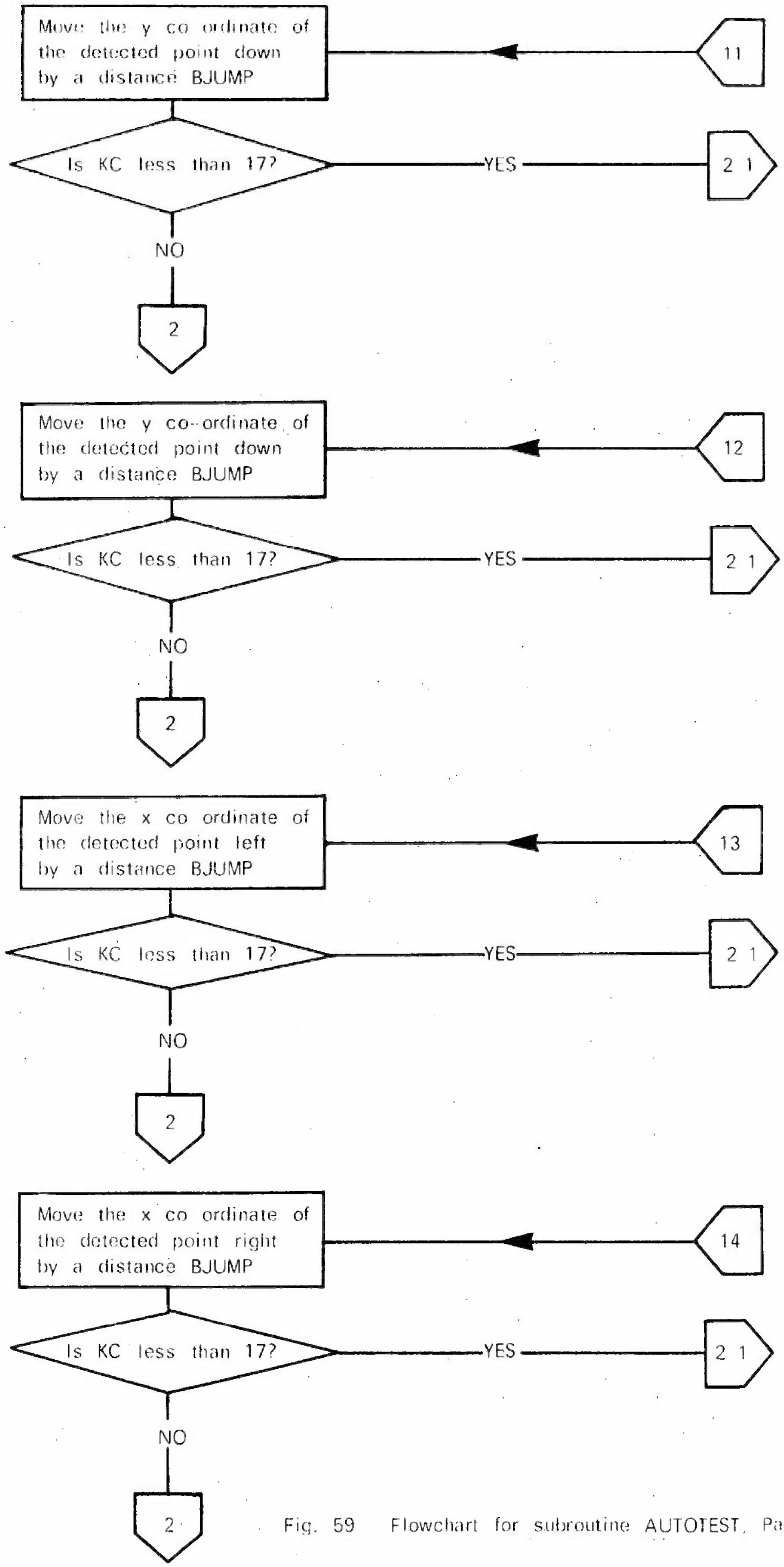

Fig. 59 Flowchart for subroutine AUTOTEST, Part 1 cont

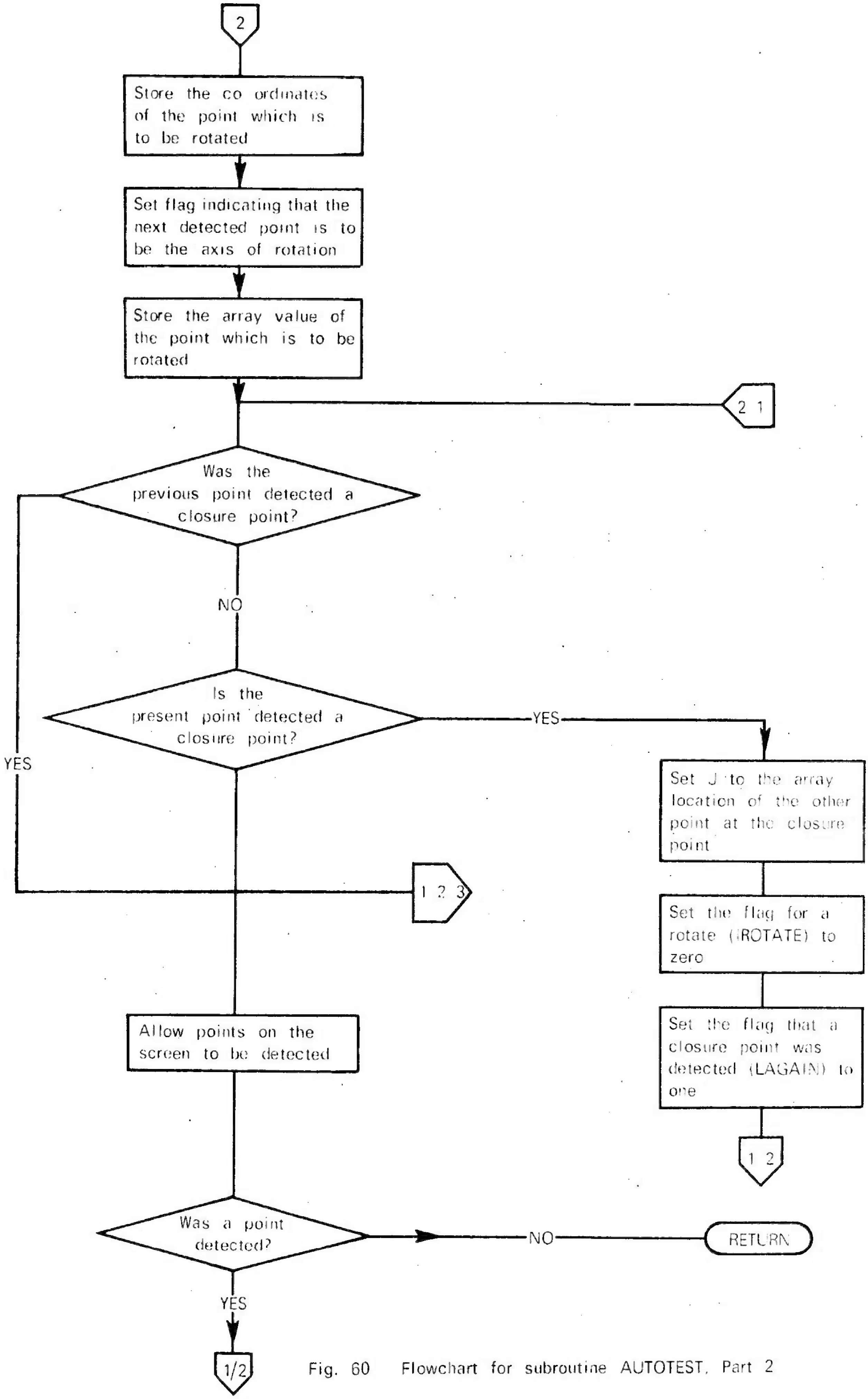

Fig. 60 Flowchart for subroutine AUTOTEST, Part 2

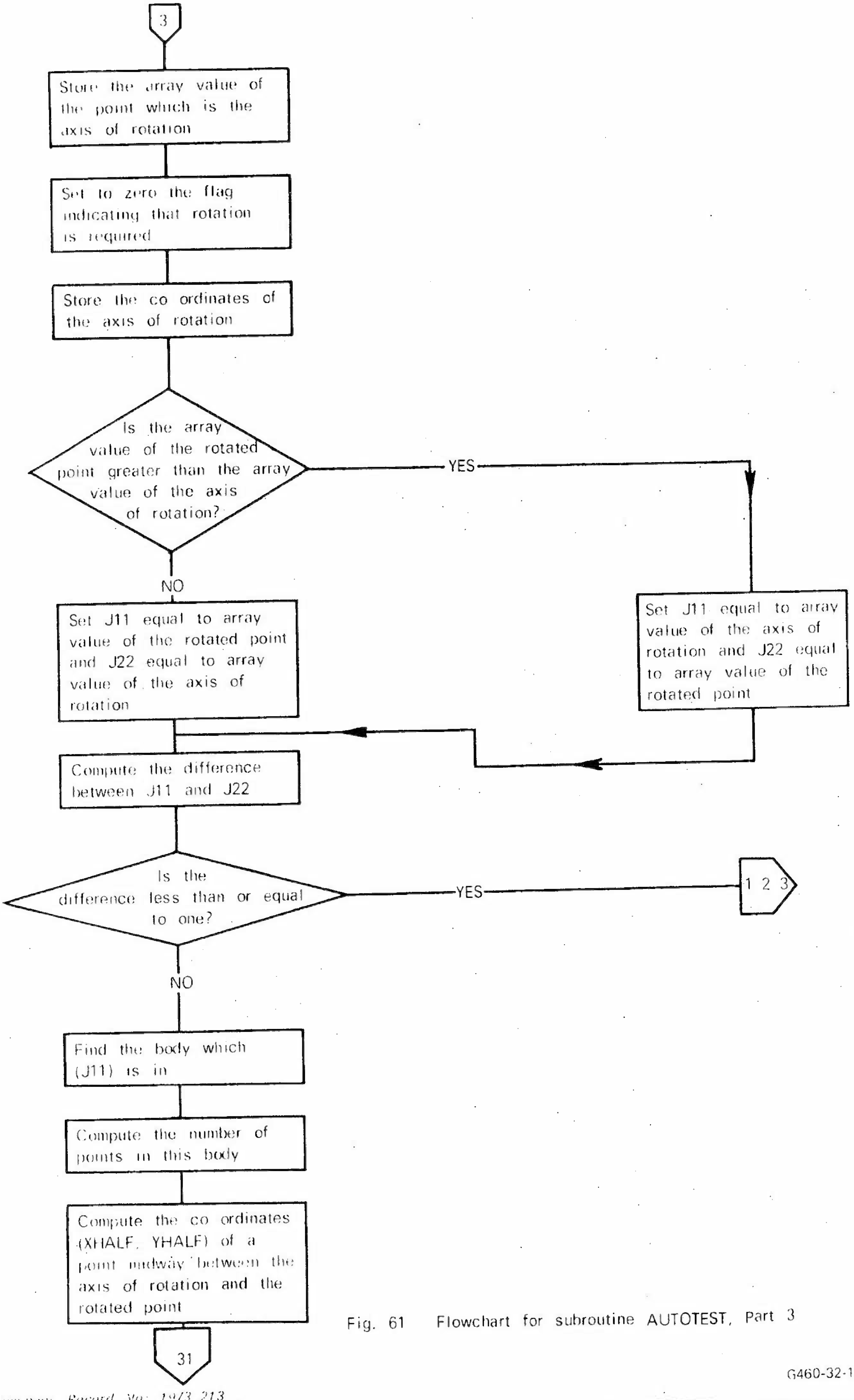

Fig. 61 Flowchart for subroutine AUTOTEST, Part 3

G460-32-10A

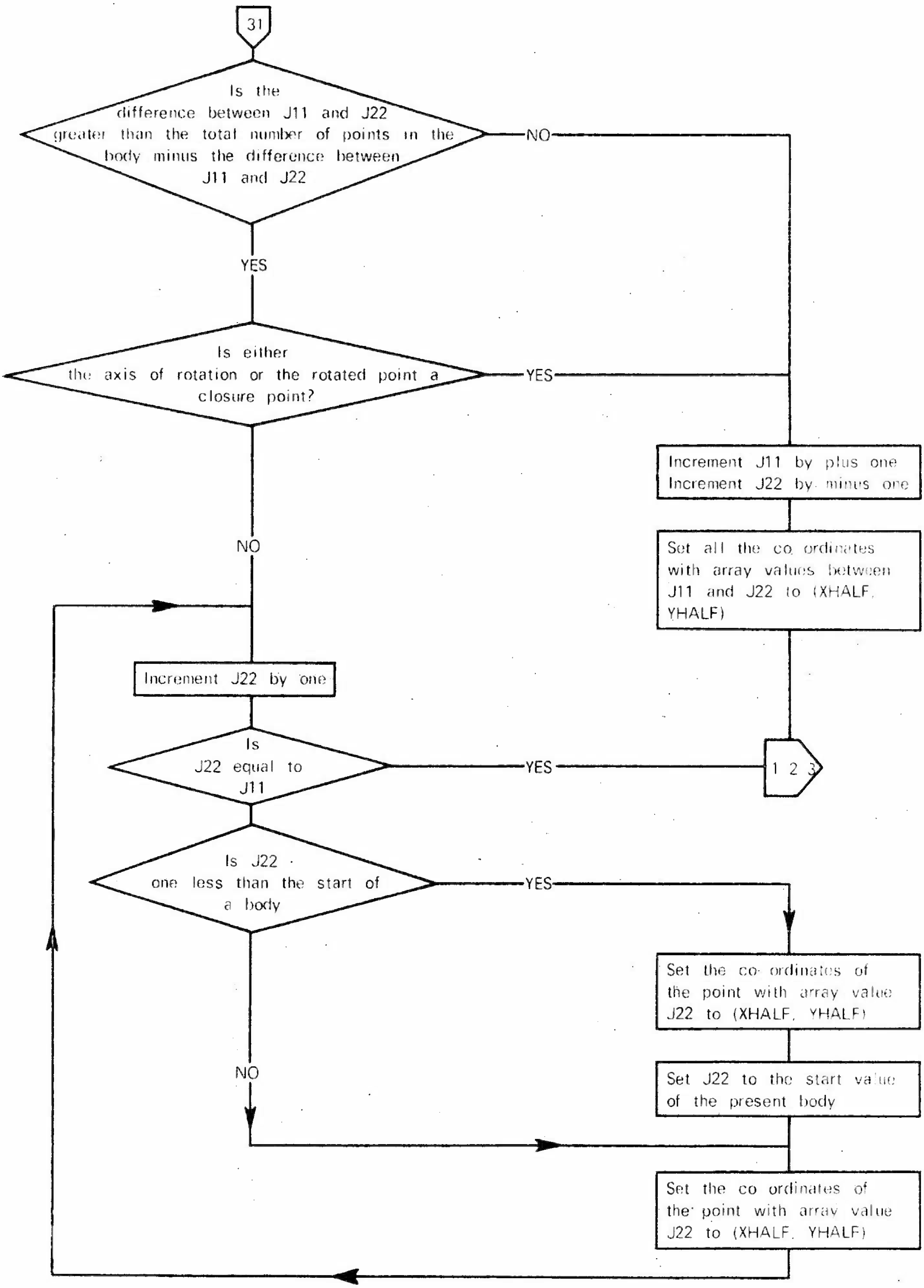

Fig. 62 Flowchart for subroutine AUTOTEST, Part 3 cont