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ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE  
**CERN** EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

An input programme for measurements of track chamber photographs

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Introduction

The data-processing necessary for the evaluation of a large number of track chamber photographs is now generally accepted as involving three stages<sup>1,2</sup>).

- (i) Selection of interesting events by scanning.
- (ii) Measurement of the photographs of these events by the use of special digitised measuring projectors whose output is in a form suitable for direct input to an electronic digital computer.
- (iii) Use of an electronic computer to carry out the calculations necessary to have the quantities of physical interest such as cross sections, angular distributions, decay spectra, etc.

This last stage involves the writing and development of computer programmes which will carry out the following tasks:-

- (i) The input of data from the measuring instruments to the computer.
- (ii) The calculations necessary for the geometrical reconstruction of each measured event.
- (iii) The calculation of kinematic quantities for each measured event.

- (iv) The calculation of statistical quantities from the analysis of large numbers of events.

The present report describes a programme written for the input of measurements of track chamber photographs to the Ferranti Mercury computer at CERN. No detailed knowledge of computer programming in general, or of Mercury in particular, is assumed; therefore no programme flow diagrams or computer instructions are given.

### I. General description

The Instruments for the Evaluation of Photographs (Iep) in use at CERN have been developed to make measurements on projected photographs of track chambers. The electronic circuits and digitisers which are part of these instruments allow coordinates to be punched on a five-hole paper tape\* (the data-tape) whenever the operator presses a record-pedal. An electric typewriter is provided by means of which additional information may be punched on the data-tape, in order that the coordinates may be identified. In what follows, and unless otherwise stated, it is assumed that all characters put on the data tape except the coded coordinates are punched by the operator using the typewriter keyboard.

The purpose of the Input Programme is to read the data-tape and store the information on it in the computer ready for the Geometrical Reconstruction Programme. The input programme must, of course, be combined with a reconstruction programme before it is of much use, and it has been written in such a way

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\* See Appendix 1 for an explanation of the punched tape code and conventions.

as to be as self-contained as possible. As a result it can be used with various reconstruction programmes and to read data-tapes from different measuring machines, without any major changes having to be made.

The information which must be read into the computer as initial data for the calculations on measurements of track chamber photographs may be divided into four classes:-

- (a) Numbers defining the geometry of an experimental arrangement, which are relevant to a whole series of measured photographs. This class of information is called Title One.
- (b) Alphabetic information and numbers concerned with the measurement and/or kinematic analysis of the types of nuclear events which have been measured. This class of information, again relevant to a whole series of measured photographs, is called Title Two.
- (c) Alphabetic information and numbers representing miscellaneous constants relevant only to a single measured nuclear event. This is called Title Three.
- (d) Numbers, representing the values of quantities actually measured on the various stereoscopic photographs of a nuclear event in the track chamber, together with alphabetic information by means of which the computer may identify the measured quantities. This is referred to as Measurements.

The operation of the input programme may be considered in two parts. Firstly it reads information from the data-tape; Secondly it has to sort, to carry out certain checks on, and to store the information in the computer memory in preparation for the calculations of the reconstruction programme.

The input programme starts with a Title Search - the data-tape is read until a title one has been found; then the information in this title is stored in the computer. When this is completed, the title search continues, reading tape until a title two is found. This is read and stored, and the title search continues. Various tests are made on title one and title two data to check for errors. Should such an error be found, the computer makes an error print, and comes to a stop, to allow the operator to decide whether the mistake will invalidate any subsequent calculations.

When a title three has been read in and stored, the input programme goes on to read in measurements, which must follow title three on the data-tape. When all the measurements of one event have been read, the reading process stops, and the input programme begins the sorting of the measurements. Various checks are made for internal consistency amongst the measurements; if any of these tests fail, the computer makes an error print, giving the necessary information to identify the error found. The programme then continues to read more tape, searching for the next title and measurements.

When the sorting is successfully completed, the geometry programme takes over; after the calculations are finished the input programme then begins with a title search to find the next event.

## II. Reading

### a) Titles

The titles must be preceded by the number of the title and an apostrophe. Thus the "warning sequence" '3' indicates that a title 3 is to follow on the data-tape.

The title search reads the data-tape looking for these warning sequences. It is arranged that titles two and three are ignored until a title one has been successfully read and stored in the computer memory, and that all titles three are ignored until a title two has been successfully read and stored. In this way it is not possible to read in any measurements until all the constants necessary for the ensuing calculations have been stored in the computer.

The warning sequence of two apostrophes terminates any title. At the end of titles one and two, the characters ' ' cause the input programme to return to the title search. At the end of a title three the same characters cause the programme to begin to read measurements.

Title one contains the following numbers:-

- (a) A reference number to identify the data-tape.
- (b) An integer giving the number of media of refractive index  $\neq 1$  through which a light ray passes between the sensitive volume of the chamber and the camera objectives.
- (c) A series of numbers in fixed-point format (integral part, decimal point and fractional part) giving the refractive index of the medium in the chamber, and the refractive index and thickness of each medium (b).

- (d) An integer giving the number of cameras.
- (e) Fixed point numbers giving the x,y and z coordinates of the front nodal points of the camera objectives.
- (f) An integer giving the number of fiducial marks on the inside surface of the front glass of the chamber.
- (g) Fixed point numbers giving the x and y coordinates of these fiducial marks. (It is assumed they are coplanar and their plane is defined as  $z = 0$ ).
- (h) An integer giving the number of fiducial marks on the inside surface of the back of the chamber.
- (i) Fixed point numbers giving the x, y and z coordinates of these marks.
- (j) An integer giving the number of miscellaneous constants.
- (k) The miscellaneous constants (j) in fixed-point form.

Each number (integer or fixed-point) must be terminated with a comma and each fixed-point number must be preceded by its sign; there are checks in the programme to see that the correct number of integers are read and that the correct number of fixed-point numbers follow each integer. Error prints are made and the programme comes to a stop if any of these checks fail. A typical title one is given in Appendix 2.

Title two is arranged to recognise the ten warning sequences  $\pi 0, \pi 1, \dots, \pi 9$  which are intended to precede up to ten different "sub-titles" to allow up to ten different sets of supplementary information to be read into the computer. So far,

only four of these have been used, and they are:-

- (a)  $\pi$  1 precedes the Label List
- (b)  $\pi$  2 precedes the Kinematics List
- (c)  $\pi$  3 precedes the Range Energy Table
- (d)  $\pi$  4 precedes the Serial Number List

The Label List is described in Section IIc - Autolabel.

The Range Energy Table consists of a sequence of fixed-point numbers. The first of these specifies the interval of range for which the values of energy are quoted, and succeeding fixed-point numbers give these energies in order of increasing range. A total of 120 values are allowed, and a check is made to see that this is not exceeded.

The Kinematics List consists of an integer specifying the number of constants which follow, and then a series of fixed-point numbers giving values of such quantities as primary particle energy, particle masses, etc.

The Serial Number List consists of a list of the serial numbers of events whose measurements it may be required to select from a data-tape containing in addition many other measurements. (see below) A typical title two is given in Appendix 3.

Title three is very similar to title two, in that it recognises the warning sequences ?0 to ?9 of ten possible subtitles. None of them have been used so far, but they are intended for quantities such as instantaneous values of magnetic fields, changes of primary energy, etc. In addition, title three reads the serial number of the event whose measurements it precedes. This is expected to be the first item after the warning sequence 3<sup>1</sup> and may be up to 7 decimal digits long, terminated with a comma.

A search facility may be used with title three if a certain hand switch is set on the computer console. The serial number when read is compared with the entries in Serial Number List, previously read in as sub-title  $\pi$  4 in title two. If this serial number is found in the list, the entry in the list is erased, and the programme proceeds to read in the measurements of this event. If the serial number is not found in the list, the measurements immediately following are ignored and the programme passes to the title search to find the next event. This facility has been found very useful in selecting certain events from long data-tapes for special calculations.

b) Measurements

The measurement of the photographs of a nuclear event in a track chamber requires that measurements of various items be made on at least two stereoscopic photographs. The items may be points (fiducial marks, scattering points, stopping points of tracks) or tracks, and the measurement of each item will consist of one or more coordinates. These coordinates are represented on the data-tape by a number of punched tape-rows. The number of tape-rows per coordinate (the "multiplicity"  $m$ ) must be fixed, and this series of tape-rows must be preceded by the tape-row corresponding to a left hand bracket in the Mercury tape code, and must be followed by a right hand bracket. The choice of code for the coordinates is very wide, as the input programme will read in any character between the brackets; the programme checks that  $m$  and only  $m$  characters appear between the brackets. The group - ( $m$  characters) - is called a coordinate sequence. According to the kind of measuring projector being used a coordinate sequence may correspond to a pair of cartesian coordinates, or an angle, etc. When the operator

presses the record-pedal a complete coordinate sequence is punched on the data-tape.

In order that the computer programme may identify the measurements of the various items, each must be associated with a "label". The labels consist of 2 characters, either of which may be a letter, A to Z, or a decimal digit, 0 to 9. The convention adopted is that measurements of a point are labelled by two identical characters, measurements of a line by two different characters. The acceptable labels are then classified as follows:-

- (i) Two identical figures, labels of type 22, specify the measurement of a fiducial mark. (In this case fiducial mark No. 2).
- (ii) Two identical letters, labels of type AA, specify the measurements of a well-defined point on the photograph (say the apex A of a scattering event).
- (iii) Two different letters, labels of type AB, specify the measurement of the line between points A and B (say the track of a secondary particle produced in a scattering at the point A, and which stops in the chamber at the point B).
- (iv) A letter followed by figure, labels of type A2, specify the measurement of a line passing through the point A (say the track of a secondary particle produced in a scattering at the point A, and which does not stop inside the chamber).
- (v) Two different figures, labels of type 23, specify the measurement of a line whose ends are not specifically measured (say the track of a non-interacting particle which passes completely through the chamber).

To be accepted by the input programme a measurement must be made up of an acceptable label, and one or more coordinate sequences immediately following on the data-tape. A label not immediately preceding a coordinate sequence is ignored, as is an isolated coordinate sequence.

At the beginning of the measurements relevant to photograph 1, 2, 3 or 4 the labels +1, +2, +3 or +4 must appear on the data-tape. For reasons of symmetry in the programme, these labels have to be "accepted" in the same sense as other labels. They must therefore be followed by a coordinate sequence, though the contents of the sequence are ignored.

The end of measurements for a given event is indicated by two apostrophes `' '`. When these have been read, the input programme begins the sorting of the measurements.

A variety of error-correction marks are available for corrections to be made on the data-tape.

- (i) Erase  $\times$  allows any tape-row punched in error to be ignored by overpunching with the erase tape-row. Between the brackets of a coordinate sequence, however,  $\times$  is not ignored and so this facility is not available.
- (ii) Pi  $\pi$ , if immediately after a coordinate sequence, causes this sequence to be ignored.
- (iii) Query `?` allows everything on the data-tape back to the closing bracket of the last accepted coordinate sequence to be ignored.
- (iv) Minus `-` causes the last accepted measurement to be ignored (label plus coordinate sequences).

- (v) Comma , causes all measurements of the present photograph to be ignored.
- (vi) Dot . cancels all the present event, its measurements and its title three.

The input programme stores the measurements in the following way. As the measurements are read in, the coordinates (obtained by suitable de-coding of the coordinate sequences) are entered serially in a list called Number Store, in exactly the order they are on the data-tape. At the same time a count (gamma) is kept, which starts at zero as the measurements of an event begin, and which is advanced by one after each entry is made in number store. In computer terminology gamma is the "address" of number store entries\*. Recording the value of gamma as each new label is read allows the entries in number store to be associated with their label. In fact in order to identify all the entries in number store, two index lists are made up as the measurements are read in. These are Photograph List and Initial List.

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\* Number Store may be imagined as a list of coordinates, one coordinate per line; with each line is associated a number, starting at 0 for the first line, 1 for the second line, 2 for the third line etc. This number is gamma, and it provides a convenient way of referring to the coordinates entered in number store, or more generally to entries in any list.  $\gamma = 3$  for instance specified the coordinate in the fourth line of number store; i.e., the "address" of this coordinate relative to the start of number store is 3.

warning sequence  $\pi$ 1 must precede the labels, and the set of labels corresponding to events of type 0 or type 1, etc., is preceded by the characters /0 or /1 etc.. Up to ten different types may be specified. After the decimal digit the programme expects to read the set of labels appropriate to the type of event specified and in the same order that the various items of the events will be measured.

As the labels are read, the programme compiles a Label List containing the labels in the order they appear on the data-tape, and a Label Index with one entry for each type specifying the number of labels appropriate to the type, and where they are to be found in label list. A total of 118 labels may be read, with no restriction on how they are distributed amongst the various types. Photograph labels are not allowed in the label lists. Various checks are made during the compiling of the label list and index to see that only acceptable labels are used and the permissible number of types or labels is not exceeded. Error prints are made if an error is found.

If an event is to be measured using autolabel, this is indicated in title three. The serial number of the event is no longer terminated with a comma but with an oblique stroke, followed by the type number. After reading this, the input programme checks in the label index that labels for such a type-number exist in the label list.

The start of the coordinate sequences of each item must be marked by an oblique stroke when autolabel is used; a single conveniently placed button allows the operator to punch this character on the data-tape, without interrupting the measuring process. A measurement will be accepted in autolabel if it is made up of an oblique stroke immediately followed by one or more coordinate sequences. The input programme keeps a record of the number of

such measurements it has read for each photograph of an event by counting the oblique strokes read. It finds, using the label index, the corresponding label in the label list, and this label is then entered in the initial list. Thus when the fourth oblique stroke is read, the fourth label in the label list is selected as identifying the coordinate sequence immediately following on the data tape.

It is possible to change any label for a given event by punching the oblique stroke followed by the required label punched from the typewriter keyboard just before the coordinate sequence(s). In this case the required label will be entered in the initial list instead of the label in the label list corresponding to that particular oblique stroke. The oblique stroke count however is advanced by one, so the net effect is as if the required label had been substituted for one in the label list for that particular event.

If it is required to insert the measurement of an item for which there is no label included in the label list, this may be done by putting the required label followed by its coordinate sequence(s) on the data-tape ensuring that the label is not immediately preceded by an oblique stroke. In this way the coordinates will be entered in the number store and the required label in the initial list without the oblique stroke count being altered. The net effect is as if the required label had been inserted in the label list for a particular event.

If it is required to jump round a label in the list (if, for instance the item is not to be measured on a certain photograph) this may be done by putting two oblique strokes followed by the coordinate sequence(s) of the next item. The oblique stroke count is advanced by one for each stroke, but the label corresponding to the second stroke is entered in initial list as identifying the coordinate sequence. Putting three strokes in succession allows

two labels in the list to be ignored, and so on.

### III. Sorting

The sorting of the measurements begins by making up a Type Index for each possible type of label. Each label written in initial list is examined, and according to its type the number of the entry in initial list where the label is to be found is written into the appropriate type index. The five indices made up are Fiducial Mark, (label of type 22), Point (AA), Line type 1 (AB), Line type 2 (A3) and Line type 3 (23).

The second part of the sorting process compiles the Reconstruction Lists, one for each label read in with the measurements. Using the type indices to show where labels of each type are to be found in initial list, an ordered set of reconstruction lists is made up; the fiducial mark lists are made up first, followed by lists for all the measured points and finally for all lines. Each reconstruction list is headed by the label to which it refers. One entry is made in a reconstruction list for each photograph. It contains the address of the entry in the number store where the coordinates for the label and photograph in question begin ( $\gamma'$ ), together with the number ( $n$ ) of coordinates relevant to the particular label. If an item is not measured on a photograph, both entries for that photograph are made zero.

During the sorting process, checks are made to see that any one label is not used twice in the same photograph, that no label is used without being preceded by a photograph number, and that there are not measurements for more photographs than the number of cameras read in by title one. Should any of these tests reveal an error the computer prints out the error and returns to reading tape, looking for the next event.

In figure 2 is shown the complete set of lists made up by the programme for the very simple event whose measurements are shown in figure 1. The information on the data-tape is shown in figure 1, where (1 89) for instance represents a coordinate sequence, containing in suitable code a series of tape-rows representing the coordinate pair  $x = 1$ ,  $y = 89$  of a point measured by the digitised measuring projector

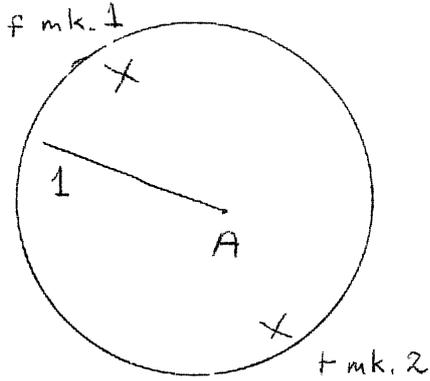
Using the 300 character per second tape reader on Mercury, the input programme will read and sort the measurements of a 3-prong star on three photographs, in about two to five seconds, depending on the number of coordinates measured per track.

#### Acknowledgements

This version of the Iep Input Programme is the result of development work over the last two years, to which various members of the Iep Group in STS Division have contributed by discussion and experience gained in using this and earlier version of the input programme. Particularly to be acknowledged is the work of Drs. N.E. Hoskin and L.H. Underhill of AWRE Aldermaston who, during tenure of CERN fellowships in 1958, prepared a similar input programme for the IBM 704 computer<sup>3)</sup>. Dr. A. Brenner was associated with the development of the autolabel scheme, and Mr. Böck programmed the title three serial number search, as well as some modifications to the initial list and number store storage.

References

1. CERN Report CERN 58-24 "Summary of Proceedings of an International Meeting on Instruments for the Evaluation of Photographs", by G.R. Macleod and Miss J. Snow, CERN, Geneva, October 1958.
2. "Proceedings of an International Conference on High Energy Accelerators and Instruments CERN 1959", Session 6 pp 523-557 Ed. by L. Kowarski, CERN, Geneva, December 1959.
3. Internal CERN Report "Tape Punching Conventions for Iep", August 1958, by N.E. Hoskin and L.H. Underhill.



Single incident particle A1  
 stopping in the chamber at A.  
 Two fiducial marks 1 and 2 on  
 the chamber front glass. Two  
 stereoscopic photos of this event.

Data-tape for measurement of this event

3'	Title three warning sequence
12345,	Serial number
''	Title closure
+1(1 89)	Photo 1 warning sequence
11(1 89)	Label and measurement of fiducial mark 1
AA(70 48)	Label and measurement of point A
A1(38 53)(27 54)(10 57)(-4 58)	- " - track A1
22(77 2)	- " - f.mk. 2
+2(77 2)	Photograph 2 begins
11(12 98)	
A1(-9 65)(20 54)(42 48)(62 41)	Labels and measurements of photo 2
AA(71 39)	
22(61 -9)	
''	End-of-measurement sequence

Fig. 1 Data-tape for the simple event above

Photograph List

J	$\beta$
1	0
2	4

Initial List

$\beta$	uv	J	$\gamma$
0	11	1	2
1	AA	1	4
2	A1	1	12
3	22	1	14
4	11	2	16
5	A1	2	24
6	AA	2	26
7	22	2	28

Number Store

$\gamma$	Coords	$\gamma$	Coords
0	1	14	12
1	89	15	98
2	70	16	-9
3	48	17	65
4	38	18	20
5	53	19	54
6	27	20	42
7	54	21	48
8	10	22	62
9	57	23	41
10	-4	24	71
11	58	25	39
12	77	26	61
13	2	27	-9

Type Indices

Fiducial Mark	Points	Lines Type
0	1	1
3	6	2
4		5
7		

Reconstruction Lists

uv
$\gamma', n$ for J=1
$\gamma', n$ for J=2

11	0	2
	14	2

22	12	2
	26	2

AA	2	2
	24	2

A1	4	8
	16	8

Fig. 2  
The various lists made up for the event of figure 1.

TAPE	VALUE	PRINTER	
		FIGS.	LETS.
•	0	FIG.	SHIFT.
••	1	1	a
•••	2	2	b
••••	3	*	c
•••••	4	4	d
••••••	5	(	e
•••••••	6	)	f
••••••••	7	7	g
•••••••••	8	8	h
••••••••••	9	π	i
•••••••••••	10	=	j
••••••••••••	11	-	k
•••••••••••••	12	π	l
••••••••••••••	13	L.F.	m
•••••••••••••••	14	SP	n
••••••••••••••••	15	•	o
•••••••••••••••••	16	o	p
••••••••••••••••••	17	v	q
•••••••••••••••••••	18	v	r
••••••••••••••••••••	19	3	s
•••••••••••••••••••••	20	4	t
••••••••••••••••••••••	21	5	u
•••••••••••••••••••••••	22	o	v
••••••••••••••••••••••••	23	/	w
•••••••••••••••••••••••••	24	φ	x
••••••••••••••••••••••••••	25	9	y
•••••••••••••••••••••••••••	26	+	z
••••••••••••••••••••••••••••	27	LET.	SHIFT.
•••••••••••••••••••••••••••••	28	•	•
••••••••••••••••••••••••••••••	29	,	?
•••••••••••••••••••••••••••••••	30	C.R.	π
••••••••••••••••••••••••••••••••	31	*	*

Note: On the CERN Iep typewriters  
the character È replaces ?  
and À replaces π.

Fig. 3 The tape code for the Ferranti Mercury computer

Appendix 1 - Tape-rows, Symbols and characters.

The Mercury tape-code is shown in fig. 3. Each row of perforation across the paper tape may have any combination of holes from none to five. One such row is called a "tape-row". The first column in fig. 3 shows a diagrammatic representation of the tape with all 32 possible tape-rows. The second column shows the numerical value of each row, if it is regarded as a 5-bit binary number where a hole represents 1 and no-hole 0.

Each tape-row is associated with two symbols (shown in columns three and four of figure 3, with the exception of tape-rows zero and 27. These two tape-rows are reserved for the following interpretive role. If the zero tape-row is punched on the tape, then each tape-row punched afterwards is taken to represent the cooresponding symbol in the Figure Shift column (column three in fig. 3). As soon as the tape-row 27 is found on the tape, then all succeeding tape-rows are interpreted as representing the symbols in the Letter Shift column (column four fig. 3). A punched tape is "read" by being passed through the photo-electric tape-reader on Mercury, in the same direction as it is punched. From the point of view of the programme, "reading a tape" means examining the 5-bit binary numbers corresponding to each tape-row. By means of the tape-reader these numbers may be stored in the memory of the computer. When tape following a figure shift tape-row (but before a letter shift tape-row) passes through the computer tape-reader, the tape is said to be "read on figure shift". Tape following a 27 tape-row and before a zero tape-row is "read on letter shift".

For the perforation of data-tapes from the digitised measuring instruments, an electric typewriter is arranged with a coding diode-matrix so that when any key is depressed, the tape-row

corresponding to the symbol of that key is punched. An electronic circuit ensures that the appropriate shift tape-row is punched on the tape whenever the key pressed requires a change of shift. This allows labels and titles to be put on the tape. The measured coordinates are punched out directly from the digital circuits by operating a pedal.

The term "character" is rather loosely used to mean either the symbol, or its corresponding tape-row, or both. With luck the context makes it clear which is meant. "The character A is put on the tape" means that "the tape-row of binary value 1, on letter shift, is punched on the tape". No distinction is made between capital or small letters, and letter or figure shift does not correspond to the shift-key (upper or lower case) on a typewriter.

Appendix 2 - A typical Title One

1'	Warning characters
12015,	Reference Number
1,	Number of media (one front glass)
+1.093,	Liquid refractive index
+1.517,	Glass refractive index
+80.0,	Glass thickness
3,	Number of cameras
+67.9, -152.2, +77.3,	x-coordinates of cameras 1, 2, 3
+128.6, -9.5, -131.1,	y-coordinates of cameras 1, 2, 3
+1128.0, +1128.0, +1128.0,	z-coordinates of cameras 1, 2, 3
3,	Number of front fiducial marks
+100.8, +0.1, -99.2,	x-coordinates of front marks 1, 2, 3
+0.68, -99.87, +0.53,	y-coordinates of front marks 1, 2, 3
0,	Number of back fiducials (zero, therefore no coordinates follow)
3,	Number of constants
+2.0,	Allowable tolerance on fiducial mark measurements
+50.0,	Allowable tolerance on photograph measurements (in digitiser fringes)
+100000.0,	Maximum calculable radius of curvature
''	Terminating sequence

Coordinates may be in cms or mms, but must be consistent.

Appendix 3 - A typical Title Two

2'	Warning characters for title
$\pi 1$	Warning characters for sub-title (Label List)
/1	Event type 1
11 22 AA A1 A2 A3 33 44	Labels in order of measurement for type 1
/3	Event type 3
11 22 AA A1 AF FF AG GG 33 44	Labels for type 3
$\pi 3$	Next sub-title (Range/energy table)
+4.0,	Step length in mms
+0.00, +6.70, .....	n values of energy for successive
.....	ranges from 0 to
.....+68.00, +68.50,	(n-1)x(step-length)
$\pi 2$	Next sub-title (Kinematics List)
+250.0, +938.213, ...+1.0,	Various kinematic constants, order and number depending upon kinematic programme
''	Terminating sequence

Appendix 4 - Error Correction Marks

π or Å erases last coordinate sequence which was part of an accepted measurement. It must immediately follow the coordinate sequence to be effective. Its effect is cumulative until all coordinate sequences of a measurement have been erased and the label has been "de-accepted". The label is not erased.

Examples

(asterisk \* represents a complete coordinate sequence)

AA\* AB\*\*\*\*\* \*Å      AA\* AB\*\*\*\*\*ÅÅÅÅ  
AA\* AB\*\*\*\*\* 3 Å      AA\* AB\*\*\*\*\*ÅÅÅÅÅÅ

The section underlined is erased. In the third example Å has no effect.

? or È erases all characters back to the last accepted measurement, which is not erased. Overrules the error marks minus, comma and dot.

Examples

AB\*\* A2 - A3, 46W./2 È  
AB\*\* 2 È È È

- Minus erases last accepted measurement. Cumulative until last accepted photograph label which it cannot erase.

Examples

+2\* AB \*\*\*\*\* AA\* -  
+2\* AB \*\*\*\*\* AA\* - -  
+2\* AB \*\*\*\*\* AA\* - - - - -

, comma erases all of present photograph: cumulative until previous title closure sequence which it cannot erase.

Examples

3'1234,' ' +1\* AA\* AB\*\*\* +2\* AA\* AB\*\*\*,  
 3'1234,' ' +1\* AA\* AB\*\*\* +2\* AA\* AB\*\*\*,,  
 3'1234,' ' +1\* AA\* AB\*\*\* +2\* AA\* AB\*\*\*\*,.,.,.

. Dot

erases all measurements of an event, title three included. It simply returns control to title search which searches for the next event. If several dots put in succession, only first is effective, next ignored. Measurements must be terminated as usual with ' ' to make dot effective.

All error marks must be followed by an accepted photograph label, an accepted measurement, or an end-of-measurement sequence before they become effective.

All error marks are available with autolabel. When a comma is used it is not however possible to add any autolabel measurements to the previous photo, e.g.

/\*/\*\* +3\*/\*\*/\*, +2\*/\*/\*\* is permitted  
 /\*/\*\* +3\*/\*\*/\*, /\*\*/\* +2\*/\* is not permitted

Only one minus correction mark may follow an auto-label measurement preceded by several oblique strokes.

/\*/\*\* - /\* is permitted    /\*/\*\* - - - /\* is not permitted

X Erase

Any character punched in error may be ignored on input if it is overpunched with tape-row 31 (five holes). Not to be used between the brackets of a coordinate sequence.

Appendix 5 - Error Prints

Error prints in titles are followed, after the title closure sequence has been read, by a hoot - low note, as many high notes as the title number, low note - and a stop. After all other error prints control passes to title search without any hoot or stop.

a. Title One errors

- All prints preceded by the print ERROR which starts on a new line.

- If an incorrect number of fixed point numbers is found after an integer, one of the following prints is made

TOO MANY FIXED POINT NUMBERS BETA =        or

FIXED POINT NUMBERS NOT COMPLETED BETA =

followed by a value of  $\beta$  showing which integer is concerned.

$\beta = 0$ , reference number;  $\beta = 1$  number of media;  $\beta = 2$  cameras;

$\beta = 3$  front fiducials;  $\beta = 4$  back fiducials;  $\beta = 5$  constants.

- If the number of integers is incorrect, prints out

> 6 INTEGERS READ BETA =        or

< 6 INTEGERS.

- If the reference number overflows, the print

> 6 DIGITS IN REFERENCE NUMBER is made.

b. Title Two and sub-title errors

- All preceded by ERROR T2 on new line.
- If more than ten sub-titles are used, prints

>10 WARNING SEQUENCES ALPHA =

with a value of  $\alpha$ , which counts the sub-titles read in.

- In label-list sub-title  $\pi 1$ , following prints are available.

TYPE NUMBER MISSING if / not followed by decimal digit.

LABEL ODD if number of label characters is not even, or if a photograph label is used.

LBLST >59 BETA = if label list overflows, with value of  $\beta$  showing at which label this occurred.

- In kinematics list  $\pi 2$ , one error print possible; R42 if an incorrect number of constants found.

- In serial number list  $\pi 4$

SERIAL NUMBER TOO LONG if more than 6 decimal digits.

SERIAL NUMBER LIST TOO LONG if more than 159 serial numbers read.

c. Title Three Errors

- All prints preceded by ERROR T3 on a new line.
- If serial number overflows prints

> 7 DIGITS IN SERIAL NUMBER

- If title is closed without serial number having been terminated, prints

NO SERIAL

- If serial number is terminated with / but not followed by decimal digit prints

TYPE NUMBER MISSING

d. Measurement errors

- All preceded by ERROR on new line
- If an incorrect number of characters is found in a coordinate sequence, prints

IEP SQCE uv J =

the label uv identifies the measurement where the error is to be found and the value of J gives the photograph number. If autolabel is in use uv is replaced by / $\nu$  where  $\nu$  is the value of the oblique stroke count when the fault was found.  $\nu$  is punched in binary.

- If no entries have been made in label list for the type number specified with the serial number in title three, prints

LBLST  $\nu$  NO ENTRIES, where  $\nu$  is the type number.

- If the oblique stroke count exceeds the number of labels in the list for the type in question, then prints

LBLST EXCEEDED.

e. Sorting errors

- All preceded by ERROR on new line

- LABEL uv J = .

If J = 0, the label uv has been given without a photograph number. If J > the number of cameras, too high a camera number has been specified.

- LABEL uv USED TWICE. J = .

If the label uv occurs more than one in photo J.

- LABEL uv ENTERED J = , ,

with values of J specifying the photographs for which uv already been entered in reconstruction list. This print is made if

measurements are given on more cameras that have been specified in title one.

- If the number of reconstruction lists exceeds the allowed value for any type of item, the following print is made showing where the overflow occurred.

RCLST EXCEEDED LABEL uv.

Appendix 6 - Coordinate sequences

000.00	Figure shift, if necessary.	∅		
001.01	Left hand bracket (			
xxx.xx	5-bit binary number of value	a )	} X-coordinate	
xxx.xx	"	b )		
xxx.xx	"	c )		
xxx.xx	"	d )		most significant
xxx.xx	"	e )		
xxx.xx	"	f )	} Y-coordinate	
xxx.xx	"	g )		
xxx.xx	"	h )		most significant
001.10	Right hand bracket )			

↑  
motion of tape

In the above sketch of the tape . represents the sprocket hole, 0 represents no-hole and 1 represents a hole punched in the tape. x may be a hole or no-hole. The 5-bit characters used to code the XY coordinates are read as pure binary numbers, left to right in the sketch. Four characters are used for Y and four for X, and the coordinates are given by

$$X = d \cdot 32^3 + c \cdot 32^2 + b \cdot 32 + a$$

$$Y = h \cdot 32^3 + g \cdot 32^2 + f \cdot 32 + e$$

Thus X and Y may have values from 0 to  $2^{20}-1$

The multiplicity defining the number of characters to be read between brackets, and the decoding routine which converts these characters to binary-numbers in the computer may be readily changed to allow other coding schemes to be used for coordinate sequence.

Appendix 7 - Limits to storage

The limits on information which may be stored are as follows:

- Title 1    - reference number of up to 6 decimal digits  
          - coordinates of up to 4 cameras  
          -       "       "       "       "       6 front fiducials  
          -       "       "       "       "       4 back fiducials  
          - 9 refractive indices  
          - 8 thicknesses  
          - 8 miscellaneous constants
- Title 2    - up to 10 sub-titles  $\pi 0$  to  $\pi 9$   
          -  $\pi 1$  up to 10 type numbers, with a maximum total of  
              118 labels  
           $\pi 2$  seventeen constants  
           $\pi 3$  up to a maximum of 120 entries in the range energy  
              table.  
           $\pi 4$  up to a maximum of 159 serial numbers, each number  
              of up to 6 decimal digits.
- Title 3    - serial number up to 7 decimal digits  
          - up to ten type numbers /0 to /9  
          - up to ten sub-titles ?0 to ?9

Measurements

- measurements on up to 4 photographs
- up to a maximum of 10 fiducial marks on each photo
- up to a maximum of 20 points on each photo
- up to a maximum of 30 tracks on each photo
- up to a total maximum of 2500 numbers may be read in for each event (or 1250 x-y coordinate pairs).