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USER GUIDE FOR LBL TELETYPE AND VISTA TRANSPORT *

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ABSTRACT

LBL's version of the ion optic code TRANSPORT for designing charged particle beam transport systems is available from the data cell and can be run interactively from a remote teletype terminal or a remote teletype and vista console.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

INTRODUCTION

TRANSPORT is a computer code for the calculation of charged particle beam transport systems. The theory behind Transport and a detailed description of its data input and operation are described elsewhere [1], [2]. The purpose of this report being to acquaint the TRANSPORT user to the method of remote terminal submission and use of teletype options to guide TRANSPORT in the solution of beam problems via the teletype and input and output medium.

The various versions of TRANSPORT are available from the LBL-data cell via a LIBCOPY from the Library TRANSPORT. If the user is off the site he must use TRAN4 from a remote teletype terminal. If the user is on the hill he may use either TRAN4 or the vista version TRAN3.

---

1) "LBL version of TRANSPORT", A.C. Paul, 1971, UCID-3525

2) "TRANSPORT 360", Karl L. Brown, Sam K. Howry, 1970, SLAC-91

Availability of Berkeley TRANSPORT

Currently there is some computer time at the University of California Berkeley Laboratory which is being made available to federal agencies, institutions and firms which have federal contracts or grants. For information concerning the LBL computing facility contact either

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Data Input

The control cards for the teletype and vista transports are shown in Table 1. The data input file is TAPE5, so any data to be entered from the input file must be copied to TAPE5. The teletype version of transport will read its data from either TAPE5 or directly from the teletype, this decision being made at execution time by the user from the teletype. The data is either the standard Berkeley data, or standard data plus names. Either may be in field free format. Table 2 shows an example of TRANSPORT data for use with the teletype version.

The data input for transport consists of a series of data decks, each beginning with a title card followed by an option card, and ending with a 73. card. The data between the option card and the 73. card is chosen from the various possible elements which describe the beam line

and are described in UCID-3525. Any number of data decks may be stacked together. A date and case number card must not be used with either of the interactive TRANSPORTS, TRAN3 or TRAN4.

Data Array and Names

The data appearing between the option card and the 73. card serially fills a singly dimensioned data array, with each number specified, located in the data array at position given by the data array counter, I. The data may subsequently be altered by reference to its I count value. Alternatively, each data input card may be given a name (if not explicitly by the user, the code will generate a unique name for each data card) which then can be used to alter or refer to the various parameters of that line in the data array. The names are restricted to six or less alphanumeric characters, the first of which must be alphabetic.

For each name there corresponds an I, the I of the type code. The data is stored in the data array in the order the cards are encountered, consequently the names are in that order also. In this report, we will often refer to name pairs (e.g., namel, name2) where namel must refer to a smaller or equal I count than name2, that is, the data line for namel proceeds the data line for name2 or namel equals name2. Names and I counts may be mixed, i.e., Namel, Name2 could be replaced by Namel, I2 where I2 is the index counter value of Name2.

Starting a Teletype or Vista Job

A teletype job may be submitted through a card reader or through the BRF (Berkeley Remote Facility).[1] In either case, the control and data cards are identical, only the submittal device differs.

When submitting via a card reader, the user simply connects his teletype to the job and waits for it to start execution.

When submitting via the BRF, the user first connects his teletype to the BRF, enters the editor, and types in his control and data cards as shown in Table 3. These entries may be saved via a STORE for future use by retrieval with a ↑LOAD from the BRF, see the BRF manual. In any case, after entry of his data he submits his job by ↑SUBMIT. He may then disconnect his teletype from the BRF and connect it to his job and await its start of execution.

When the program begins execution it prints "PROGRAM EXECUTING--TYPE READY, STOP OR ABORT", the appropriate response by the user to start his program being READY. Table 4 shows the first set of exchanges between the computer and the user starting his teletype run. The arrows indicate user enteries in response to the questions printed by the teletype.

After the first data deck has been read and is stored in the data array, the teletype will print "NEXT" indicating it is ready for the next option to be entered. The "NEXT" printing can be suppressed via an option as described later.

---

1) The Berkeley Remote Facility, J. Burkhard, E. Romascan, UCID-3339 (1969)

Teletype Input Options

Table 5 gives a summary of the teletype input options to be used with Teletype TRANSPORT, TRAN4. Table 6 gives a summary of the Teletype input options to be used with the vista TRANSPORT, TRAN3. On the following pages each of these summarized options will be explained in detail and occur in alphabetic order. Those which may only be used with TRAN4 will be designated by TRAN4 parenthetically attached to the option, similarly, those options which may only be used with TRAN3 will have TRAN3 parenthetically attached to the option in the write up which follows. If during execution of either TRAN3 or TRAN4 a non-existent or illegal option is requested, no harm is done as the code will simply say - no such option. All options which follow which do not have parenthetical attachments may be used with both TRAN3 and TRAN4. Some of the options have abreviated forms which may be used when desired although they are less descriptive.

ABORT

This entry will terminate the job executing the control cards following the "EXIT" card.

ALINE or AL

The ALINE (ADD LINE) option allows the teletype user to add new data lines and elements to his data array. The entries consist of the location or name of the line after which the new line is to be added, followed by the new line. Example, consider adding a 13.1 data line after the DRFT4, Table 7. This could be accomplished by one of the following entries:

```
ALINE, 29, 13. 1.
ALINE, 29, 13. 1. NAME1
ALINE, DRFT4, 13. 1.
ALINE, DRFT4, 13. 1. NAME1
```

If the name NAME1 of the new data line is not entered, the code will generate a unique name for the new data line.

ALTER or A

The alter option allows the user to change or alter any element in his data array. There are two general schemes that can be employed, one uses the location of the element to be changed by designation of the "storage index" I, within the data array, the other uses the unique "name" of the data line and the location of the element to be changed within this line. Example, consider changing the field strength of the second quadruple in a data set to -8.75 kg. This quadruple occupies, say, locations 19 through 22 in the data array and has the name QV. The alteration can be accomplished by any of the equivalent entries:

```
ALTER, 21 -8.75
ALTER, QV, 3, -8.75
ALTER, QV, 1, 3, -8.75
```

The general scheme is

```
        ALTER, I, change
or      ALTER, NAME, J. change
or      ALTER, NAME, N, J. change
```

where NAME is the name of the data line. N would only be used if more than one data line has the same name and only the Nth line is to be altered (see page 21).

BEAM (TRAN3) or B

During a Vista run, the user may wish to flip back and forth between his data displays and his beam line. This is accomplished by

MDATA and BEAM entries on the teletype. If the beamline display is to be started fresh, removing any rays, matrices, or scale changes, this is accomplished by a BEAM option followed by a CANCL option.

BLINE (TRAN4) or BL

Standard transport execution output may be printed on the teletype by entering the indices or names in ordered pairs. The output requested will be generated after each go or solve option entered. If the output is to be cancelled enter BLINE with no indices or names. Names and indices may be mixed, but indices, names or mixtures must always have the first value of each pair refer to a lower or equal (same) data element than the second value of each pair.

```
BLINE
BLINE, I11, I12, I21, I22, .... etc.
BLINE, NAME1, NAME2, NAME3, NAME4, etc.
BLINE, I11, NAME2, NAME3, I22, ... etc.
BLINE, I11, I11, NAME1, NAME1, ... etc.
```

CANCL (TRAN3) or C

When a request is made which cannot be acted upon for some reason an error message may appear on the VISTA screen requesting you to hit "C" for cancellation of the request. No other entry will be accepted. Data input then resumes in normal fashion.

DLINE or D

The DLINE (Delete Line) option allows the teletype user to remove a data line from his data array. A group of lines may be removed together by specifying the name or index of the first line and the name or index of the last line bracketing all lines to be removed.

```
DLINE, I
DLINE, NAME
DLINE, I1, I2
DLINE, NAME1, NAME2
DLINE, I1, NAME2
etc.
```

FIN

This option terminates the run. The control cards after a "FIN." control card will be executed, otherwise the job is done.

FIX

This option removes variables in the data array by zeroing the vary codes of each type code and negating all constraints. The fix option operating on the data shown in column 1 produces the result shown in column 2. It operates on all the data in the data array.

1.	1.
5.02	5.
3.	3.
5.01	5.
3.	3.
10.1	-10.1
10.2	-10.2
3.	3.
10.	-10.

If it is only desired to fix the data between two points in the data array the entry would be

```
FIX, NAME1, NAME2
FIX, I1, I2
```

FORCE

Many checks are made on the data entered via the teletype to see that it is legitimate data. Occasionally one may wish to make an illegitimate entry for which no checks will be performed. This can be accomplished via the force entry giving the data array index and the new value of this element of the data array.

FORCE, I, X.

Use this option with extreme care.

GO or G

Entrance of GO causes execution of the data in the data array. No optimization will be performed. No teletype output will be generated when using this option with TRAN3 (VISTA). The output for TRAN4 will always start with the statement "Executing case number--" and end with the line "Length = --". Any other output is at the specific request of the user via a previous BLINE entry or the data in the data array controlling teletype output such as:

13.	-1.	Output Beam matrix and vectors
13.	-4.	Output the RC accumulated transformation matrix from last update
13.	-8.	Output the RC2 matrix
13.	-27.	Output vectors only
13.	-45.	Output the RPL matrix for polygons

The 13. N. data entry request output on the normal off line printer irrespective of the sign of N if such output has not been prohibited via a suppress entry when first starting to job. A negative N means output on the teletype is requested.

MATRX (TRAN3) or MA

The request for a Display of a transformation matrix will also give a display of the beam matrix, 12 additional numbers and a plot of two selected phase plane projections. The required Teletype input is

MATRX, LOC, N, IJKL or
MATRX, LOC, IJKL

where LOC is the data index counter or Name of the element with length (may be zero) preceeding the matrix generating data request card (see below) and will normally be shown on the beam line as an asterisked (*) integer. Should no such tag be visible the number may be chosen from the data display index. N will normally be entered, only when the matrix generating request is contained within the limits of a repeat option (9. N. to 9. 0.), N matrices are generated, then it is mandatory to enter N so as to select which matrix is desired for display with the given LOC. IJKL is the designation of the two phase plane projections IJ and KL where $1 \leq M \leq 6$, M=I,J,K, and L. The vectors will also be displayed on the phase plane projections if they are within the scale limits of the projections or can be forced to be displayed by causing the scale phase planes to always include the vectors by use of the 13. 31 or 13. 32 data options.

The matrix generating request cards can be used to store up to a maximum of ten locations for displays of the transfer matrix, beam matrix and vectors. The location of these cards can be changed to generate matrix information at different locations from the teletype. The information is stored during execution of transport.

The matrix generating cards are:

13.	4.	display	RC	matrix	
13.	4.X	"	R3	"	
13.	8.	"	R	"	
13.	24.	"	R2	"	
13.	42.	"	RC	"	suppressing second order printout
13.	48.	"	R	"	" " " "

In second order transport the vectors displayed may be defined as second order matrix elements by the 13. Nijk data card. This card defines vector position N to be the T(ijk) second order matrix element where (N+1)/2 is the vector number with N odd (horizontal N even (vertical).

MDATA (TRAN3) or M

Often the data array is so large that the VISTA screen will not accomodate the entire array. The entry of MDATA flips between the "pages" of the data in a circular fashion, the first of the data following the last of the data. The data displayed gives the index counter, name, and data lines for the data array.

LABLE (TRAN4) or L

This option allows the user to enter the parameters that should appear in the table printed when the table option is selected. The table may consist of any combination of up to 19 of the following parameters:

LABLE	DEFAULT	MEANING
TYPE	"	prints type code and number of each data line
LC	"	accumulated length
xBEAM	"	horizontal beam projection
yBEAM	"	vertical beam projection
xCENT	-	horizontal beam centroid shift
yCENT	-	vertical beam central shift
xAPE	-	horizontal apertures
yAPE	-	vertical aperture
x1	-	horizontal ray 1
y1	-	vertical ray 1

LABLE	DEFAULT	MEANING
x2	-	horizontal ray 2
y2	-	vertical ray 2
.	-	.
.	-	.
.	-	.
x6	-	horizontal ray 6
y6	-	vertical ray 6

If the LABLE option is not used, or used with no parameter list the default lables will be used in the table. A typical entry to give the accumulated length, horizontal and vertical beam and horizontal beam centroid shift and the vertical extent of vector 5 would be:

LABLE, LC, xBEAM, yBEAM, xCENT, Y5

All subsequent table request will then produce tables given these parameters in that order.

MOVE

This option allows the user to move a group of data within the data array

MOVE, NAME1, NAME2, NAME3

Here the data lines Name1 to Name2 are moved to follow Name3. If only one data line is to be moved the entry would be

MOVE, NAME1, NAME3

NAME or NA

The Name option allows the user to rename his data array with the standard Name convention internally generated by the code. The Names will be generated by the type of data element given below and an incremental counter appended, i.e., Q1, Q2, Q3 etc. for quadrupoles, NAME Q.

STANDARD NAME	ICONNT	TYPE	MEANING
BEAM1	(27)	1.000	BEAM
FF1	(35)	2.000	FRINGE FIELD TO BENDING MAGNET
L1	(38)	3.000	DRIFT SPACE
BM1	(44)	5.000	QUADRUPOLE
SLIT1	(48)	6.000	SLIT
AXIS1	(52)	7.000	AXIS CENTROID SHIFT
ALIN1	(59)	8.000	MISS-ALIGNMENT
REP1	(67)	9.000	REPEAT
CON1	(69)	10.000	CONSTRAINT
ACC1	(74)	11.000	ACCELERATION
TIL1	(79)	12.000	PHASE SPACE TILTS
IO1	(95)	13.000	INPUT-OUTPUT
AUX1	(97)	14.000	AUXILIARY MATRIX
UNIT1	(109)	15	UNITS
DA1	(113)	16.000	DATA INPUT
SEC1	(116)	17.000	SECOND ORDER
SEX1	(120)	18.000	SEXTUPOLE
SOL1	(124)	19.000	SOLINOID
ROT1	(127)	20.000	ROTATION
STRY1	(129)	21.000	STRAY FIELD
VEC1	(134)	22	VECTORS
SEP1	(136)	23.000	SEPARATOR
PLOT1	(143)	24.000	PLOT OPTIONS
MAT1	(150)	25.000	MATRIX INPUT
SC1	(154)	26.000	SPACE CHARGE
BUN1	(159)	27.000	BUNCHER

If only 1 name is to be changed it may be done by entering

NAME, I, NEWNAME
NAME, NAME, NEWNAME.

NCASE

An entry of NCASE requests the input of a new data case. This case can come from off-line by reading tapes, or from on-line teletype entry of an entire data set, in which case the teletype requests the entry of a title, option, and standard data. The user then enters the standard data, with or without names with no further requests from the teletype. When he is through entering his data he enters a 73. and normal teletype options then become effective.

If the data is read from TAPE5 and an end of file is encountered, an error diagnostic will be printed and the data case can then be entered via the teletype. All input is in field free format.

The run number will be sequentially advanced unless a second entry is made, e.g., NCASE, YES. Then a request of entrance of the date, and case number will be made. The acceptable entries are:

NCASE
NCASE, YES

PDATA or PD

The data stored in the Data array may be printed on the teletype via the PDATA option. If the print time will be longer than 2 minutes, a warning will be issued and the user can then cancel the print command or accept it. The data printed will consist of the standard transport data Lines preceeded by the storage index, and data Line name. A portion of the data array may be printed by entering the index or names of the section to be printed. The permissible enteries are:

PDATA	PRINT ENTER DATA ARRAY
PDATA, N	PRINT LINE WITH INDEX N=1,2,--300
PDATA, NAMEN	PRINT LINE OF NAME NAMEN
PDATA, N1, N2	PRINT ALL DATA BETWEEN N1 AND N2
PDATA, NAME1, NAME2	PRINT ALL DATA BETWEEN NAME1 AND NAME2

OUTPT

The off-line output generated by transport may be turned on or off by entering

OUTPT, YES
OUTPT, NO

PULL

This option allows a user to "PULL" a group of elements out of any one of the four data array's (DATA, SAVE, SAVE2, SAVE3) into a buffer. Each subsequent ALINE or DLINE option specifies the location in the data array where the pulled data is to be placed. In this way a set of data elements may be conveniently placed at many locations of the data array. Any entry other than ALINE or DLINE following the PULL option concludes the PULL option and subsequent ALINE's and DLINE's have their usual meanings. Example:

```
PULL, M, NAME1, NAME2
ALINE, N1, N2, N3, .....
DLINE, N1, N2, N3, .....
ALINE, N1
.
.
.
```

M is the array from which the data NAME1 to NAME2 is to be pulled

M=0	DATA array
M=1	SAVE1 array
M=2	SAVE2 array
M=3	SAVE3 array

Name2 does not have to be entered if only one element is to be pulled from array M.

The parameter list for ALINE and/or DLINE are the names or index counts where the Pulled data is to be inserted.

PUNCH

The punch option writes the DATA array onto TAPE7. This tape may be listed on the output file or punched to cards after the RUN is over by the following control cards:

```
FIN.
REWIND (TAPE7)
COPYSBF (TAPE7, OUTPUT)
COPY (TAPE7/RB, PUNCH)
```

Tape7 could also be copied to some common file and used as input (Tape5) for some subsequent RUN.

RAY (TRAN3) or R

After execution of transport any vectors tracked may be added by the RAY option on to the beamline display. The first six vectors may all be added together or they may be added one or more at a time. The possible teletype entries are:

```
RAY
RAY, N1
RAY, N1, N2, N3 ...
```

The RAY option would display all vectors on the beam line. If a series of one to six numbers follow, then these are the vectors which would be added to the beamline display. Only the first six vectors in Transport data array may be displayed on the VISTA screen.

RECAL or RE

The data and vectors saved via the save option may be recalled via the RECAL option. The recalled data can come from one of three arrays and may or may not be swapped between the chosen array and the data array depending on the input parameters entered.

```
RECAL
RECAL, 1
RECAL, 2
RECAL, 3
RECAL, N, SWAP
```

Where N = 1, 2, or 3. RECAL and RECAL, 1 gives the same results, namely recall of the data saved in the SAVE array via a SAVE, 1 entry. The

swap entry exchanges the data between the data array and the SAVEN array.

RESPN

The response option allows the user to turn on or off the teletype response of "NEXT" signifying the waiting of next data or option input from the teletype. The allowed entries are:

RESPN, YES
RESPN, NO

SAVE or SA

Three auxiliary data arrays may be used to store the data in the data array and vectors for subsequent retrieval. They are the SAVE (the same as SAVE1) SAVE2 and the SAVE3 arrays. The following entries will store the data and vectors in current use into the designated save arrays.

SAVE
SAVE, 1
SAVE, 2
SAVE, 3

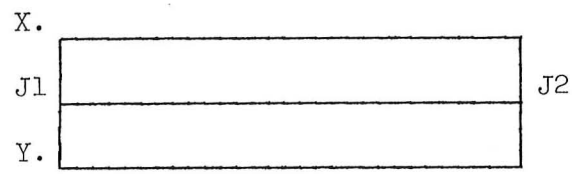
When no numeric is entered, the default is 1, i.e. the SAVE and SAVE, 1 option give identical results. The data saved will only be changed by another SAVE command, except for the SAVE3 array which is used during a segmentation (SEGMT).

SCALE (TRAN3) or SC

The beam line display obtained after a GO or SOLVE command may not show sufficient detail of a portion of the beam line. The scale option allows the user to insert the starting and ending point of the display and the horizontal and vertical scales. The data to be given via teletype is:

SCALE, J1,J2,X.,Y.

Here J1, J2 are the data storage index or name of data line. This data will produce a plot



Extending from J1 to J2 with maximum horizontal (x) scale of X and maximum vertical (Y) scale of Y. Any field may be void, i.e., if only the horizontal scale is to be changed the data can be given as

SCALE,,,X.

If only the longitudinal section is to be altered the data can be given as

SCALE, J1, J2

Should the user wish to restore the original scale he may enter SCALE with no other parameters. If the scale option has been selected by error, the cancel option may be used. Normally J1 and J2 will be the data array index counter such as display on the bottom of the beam line or along the left edge of the data display. Should the entered J1 and J2 not be correct the code will take the next larger correct value.

SEGMT or SE

Many beam lines are a series of connected sections which can be considered to feed one another but otherwise independent. Often the problem of "many variables and constraints" can be simplified by calculating each section or segment of the beam line independently, using the output of the preceeding section or segment as input to the next section. This calculational procedure reduces the time and output

since already solved sections are not recalculated as one optimizes each segment of his beam system individually.

The complete data set describing the entire beamline set is read. The user may segment the data by entering the section of the data which is to be calculated as the first segment. The first segment may start at any place on the beam, not necessarily at the beginning. The starting point and ending point being designated by the SEGMT option. Selection of the segmentation option via the teletype does three things, 1) saves the entire data array in the SAVE3 array, 2) processes all data cards and performs all beam calculations from the beginning of the original data up to the starting point of the segment, and 3) replaces the data stored in the data array by the data delimited between the starting and ending points selected.

The allowed inputs being of the form:

```
SEGMT, NAME1, NAME2
SEGMT, I1, I2
SEGMT, I1, NAME2
```

All subsequent operations are upon this data now displayed and the calculations use as starting values of the σ, RC, RC2, R3 matrices and vectors the values calculated and saved for the beginning of this segment.

Example: Consider a beam line consisting of a quadrupole to produce a point to parellel beam and another quadrupole to produce a focus at a target.

The original data set is shown in column 1.

Title Option	Title Option			Title Option	Title Option	3.
15.		1.	1.	15.	15.	5.01
15.	15.	5.01	5.	15.	15.	3.
1.	15.					
5.01		10.	-10.		1.	
10.	1.			1.	5.	10.
	5.01			5.	-10.	
3.	10.			-10.		
5.01					3.	
	3.			3.		
3.	5.01			5.01	5.01	
					3.	
10.	3.			3.	10.	
73.	10.			10.		
	73.			73.	73.	

Column two shows a box around the data to be segmented by the teletype. The segmentation command is given and column 3 is produced after the constant, 15. data elements, are processed. Now a SOLVE command causes optimization of the quadrupole processing only the 1., 5.01, and 10. data element. After optimization the quadrupole can be fixed and the constraint negated by using the FIX option. This will fix all variables by zeroing out the vary codes and negate all 10. data cards as shown in column 4. This data can be stored in the saved data by using the save option. Whatever data is on the data array will replace the data in the appropriate section of the SAVE3 array regardless of the number on lines inserted or deleted. The entire data array can now be recalled (RECAL) as shown in column 5. A box shows the data to be segmented as the next section as shown in column 6. Selection of the segment option causes calculation of the data from the 15. element up to the first drift space with the result of this calculation being saved and used as initial conditions for the segment delimited by the box. The data

transferred to the data array as shown in column 7. The user is now ready to optimize this segment and proceeds in an analogous fashion for all subsequent segment of his beam line.

SNAPB (TRAN3) or SB

The beam line displayed on the VISTA screen will be copied to disc file SNAP via the SNAPB (SNAP beam line) option. After the program is terminated, SNAP may be copied to film in order to generate a microfilm copy of the beam displays.

SNAPD (TRAN3) or SD

The data displayed on the screen of the VISTA will be copied to disc file SNAP via the SNAPD (SNAP Data) option. The data can then be transferred to microfilm as described under SNAPB and shown in section

SOLVE or I

Entrance of the Solve options causes an optimization of any variables in the data array subject to the constraints in the data array. After completion of the optimization and automatic execution of the data (GO option) is issued. One of two optimization routines may be used, standard optimization or variable matrix optimization as specified by the data in the data array. Unless specifically requested, standard optimization is used. The output generated during optimization being:

```
EXECUTING CASENO        1-1
ACTUAL VALUE OF VARIABLES
(X2) variable1.  Variable2....
SOLVED (X2)
```

If the data deck contains a 16. 29. -1. data line specifying variable **matrix** optimization the output generated would be:

```
EXECUTING CASENO  1-2
VARMIT
0 - 1 (X2)  V1.  V2. ...
6 - 10(X2)  V1.  V2. ...
.
.
.
.
SOLVED (X2)
```

The output giving the iteration cycle, the number of times transport was executed to evaluate the chi-square, the current value of chi-square, and the value the variables currently have. This output line is printed every 5th cycle. If more or less output is desired the request can be made as a second parameter, e.g.

SOLVE,N

will generate a output line every Nth cycle.

TABLE (TRAN4) or TA

A table may be printed after execution of transport giving the type codes, accumulated length, **beam ellipsoid**^{X,Y} projections, centroid X,Y shifts and apertures encountered along the beam line by entering the TABLE request. If vectors are also being tracked, the X,Y positions of the first four vectors may also be printed. Since a complete TABLE may take considerable time to print, facility is provided for entry of pairs of indexes or names bracketing the sections of beam line which should appear in the TABLE. The possible entries might be:

```
TABLE
TABLE, I1, I2                          I1 ≤ I2
TABLE, NAME1, NAME2
TABLE, I1, I2, I3, I4, -----           I1 ≤ I2, I3 < I4,000
TABLE, I1, NAME2, NAME3, NAME4, NAME5, I6, ---
etc.
```

Where I1, etc. are the data location index and the names are the names of various data lines, as given by the data option. The first name of each pair must precede or equal the second name in the data structure, as the corresponding I of each pair is smaller than or equal to the second I.

TITLE or TI

This option allows the user to change the title of his data. The title appears at various places on the off-line output and so can be used for making appropriate comments for the various runs. The data entry is

TITLE, NEW TITLE ETC.

TLOC (TRAN4)

Often a user wishes to produce a table (TABLE option) at certain locations along his beam line many times during his teletype run. In order to releive him of the necessity of entering the locations for which the table will be generated a default list may be defined via the TLOC option such that any entry of TABLE with no parameter list will use the default list as locations.

TLOC, NAME1, NAME2,.....

VECT or V

The vectors stored in the vector array may be added, altered, deleted or printed via the VECT option. If no vectors are in the data array they may be entered via the aline option, not the VECT, aline option. Thereafter, all reference or changes of vectors is via the VECT option. Typical input lines might be:

```
VECT, ALINE, N, X. XP. Y. YP. S. DP. COMP.
VECT, ALTER, N. CHANGES
VECT, ALTER, N, K, CHANGES
VECT, DLINE, N1
VECT, DLINE, N1, N2
VECT, PRINT, N1, N2
```

In adding a vector, one need only enter the numbers up to the last non-zero entry, the other parameters being automatically set to zero. The VECT, ALINE option will automatically increment the vector counter in the data array (number after the 22. element in the data array). To delete a vector one enters the vector number to be deleted. If more than one sequential vector is to be deleted, one enters the first and last vector number to be deleted.

To alter a vector already in data storage, one selects the vect, alter option. The vector space X, X', Y, Y', S, dp, β can be assigned a numeric equivalence 1,2,3,4,5,6 and 7. Then to change the value of S, dp, which are the 5th and 6th positions one enters

VECT, ALTER, 5, S. DP.

Up to 40 vectors can be transformed by transport. However only the first four may appear in the table of TRAN4. All vectors will be printed at each location requesting the σ-matrix (13. -1.) on the teletype version and any location requesting the vectors (13. -27.).

ERROR Messages and checks

The input routines make numerous checks for legitimate data input. Should a check not be satisfied an error message will be generated as listed below with the most common errors generating the message. Generally, the user only needs to retry the input after correcting the error.

ERROR IN RAY OPTION, TRY AGAIN

ERROR IN TTY ENTRY, TRY AGAIN

NO SUCH OPTION, TRY AGAIN

DATA ERROR, NO EXECUTION.

Check of data array has found a data error such as zero quadrupole aperture, zero partical momentum etc. the I count of the data line in question is printed and return made to the user.

FIRST INDEX MUST BE LESS THAN 2nd INDEX TRY AGAIN.

Pdata, I1, I2 was submitted with I1 >I2.

MAXIMUM NUMBER OF ELEMENTS IS 300, DATA NOT ACCEPTED.

YOU HAVE REQUESTED MORE THAN 2.5 MINUTE OUTPUT, SHOULD I PROCEED.

VARIABLE LIMITS ENCOUNTERED IN ALTER --OR--

Tried to move more than 6 times

NO RAYS IN DATA ARRAY, USE ALINE.

MISCELLANEOUS

When using the "add to beam" option the zero data element must be entered as a separate data line when input is from TAPE5

1. .01 0. .02 .174 .02 -.34 -.0674 ADDBM

0.

and must be entered as a single line when entered via a ALINE.

ALINE, NAME, 1. .01 0. .02 .174 .02 -.34 -.0674 0. ADDBM

When adding a correlation input the data may be on one or two lines on TAPE5,

12. .2 0. 0. 0. 0. .937 0. 0. 0. .99 0. 0. .45 0. 0.

or

12. .2 0 0 0 0 .937 0.

0 0 .99 0 0 .45 0 0.

are acceptable input. If the second group of eight entries are zero, the following may be used;

12. .019 0. 0. 0. 0. .937 0.

0.

where the last entry will have zero fill on all unspecified fields. When using the ALINE input the entry may only be made on one line

ALINE, NAME, 12. .2 0. 0. 0. 0. .937 0. 0. 0. .99 0. 0. .45 0. 0. COR1

SEVERAL DATA LINES WITH THE SAME NAME

If two or more data lines have identical names, they will be altered or deleted together, e.g., if QUADH of Table 7 is to have a 5.50 cm aperture the single entry of "ALTER,QUADH,4,5.5" will change both apertures of the divided quadrupole. The ALINE option used with a duplicate name data will insert the new line after the first appearance of the name, for example, adding a 13. 1. line after the first QUADH data line would be given by

ALINE, QUADH, 13. 1.

To add this line after the nth occurance of the multipally named data, n must be specified after the name, e.g., to add the 13. 1. line after the second QUADH data line, one would use:

ALINE, QUADH, 2, 13. 1.

If only the nth multiply named line is to be deleted, n follows the name, e.g., to delete the second quadrupole QUADH one would enter

DLINE, QUADH, 2

It is not possible to use a multiply named data element as one parameter of a multiple delete, i.e., the following card is illegal.

DLINE, QUADH, I03

While all data with name QUADH can be deleted by entering

DLINE, QUADH

To alter the Jth position of the Nth multiple named line requires the input of N after the Name, i.e.,

ALTER, NAME, N, J, X.

When several data lines have the same name and are to be used via a parameter list for the options listed below, the data line which first occurs with the given name will be used. If a different (other than the first occurance of the name) data line is desired the name must be entered as a double entry; name, N, where N is the number of the occurance. In this way, the pairs of names used in the BLINE or TABLE options may in fact be three of four entries per pair, or the names used with the other options, such as PDATA etc. can be two entires per name.

Option		
ALINE,	NAME,NEWLINE	NAME,N,NEWLINE
ALTER,	NAME,CHANGE	NAME,N,CHANGE
BLINE,	NAME1,NAME2....	NAME1,N,NAME2 or NAME1,N,NAME2,N or NAME1,NAME2,N
DLINE,	NAME1,NAME2	"
FIX,	NAME1,NAME2	"
NAME,	NAME1,NEWNAME	"
PDATA,	NAME1,NAME2	"
PULL,	M,NAME1,NAME2	"
SEGMT,	NAME1,NAME2	"
TABLE,	NAME1,NAME2,....	"
TLOC,	NAME1,NAME2,....	"

BEAMLINE DISPLAY (TRAN3)

After execution of the GO or SOLVE options the beam line will be displayed on the VISTA screen. The display will be automatically scaled to show the entire beam envelope and all magnet apertures. The paraxial trajectory runs down the center of the display from left to right with the horizontal display above and the vertical display below. By construct, a vector which crosses the axis is reflected at the point of crossing masking the sign change. No such ambiguity is encountered by the envelope since it is always positive by definition. Above the display is given the accumulated length while below the display is given the data index number for elements possessing sufficient length. Should matrix data be available at a given location an (*) will follow the data index number. Matrix data will be generated for the first ten data cards requesting matrix output, 13.4., 13.4x, 13.8., 13.24., 13.48. Should the length of certain elements be sufficiently small so that adjacent numbers are crowded it will be necessary to scale in order to produce it or the number may be found from the data display.

Additional beam line display options are RAY and MATRX. These options allow the display of the vectors and matrices along with the beam envelope. Once a beam line display has been scaled, rayed and/or matrixed it will so remain until explicitly altered or cancelled by the user. This may be accomplished by the BLINE, C entry.

Data Display (TRAN3)

The data deck is displayed along with the addition of the data index I, NAME on the left and the accumulated length on the right of

the usual transport data. The data displayed may be altered, deleted or added thereto by selection of the appropriate option. The normal display has the following format:

Data Index	Description	Normal Transport Data								Accumulated Length
1.	UNIT	15.	1.	1.	1.					
5.	UNIT	15.	1.	1N	2.54					
10.	BEAM	1.	.25	2.5	.25	2.5	0.	0.	2.5	
18.	DRIFT	3.	2.							2.000E+00
20.	QUAD	5.	.35	10	4					2.350E+00
24.	OUTPUT	13.	4.							
		etc.								

The data so displayed may be operated upon by the appropriate selection of options.

In addition several parameters will be printed along with certain data types which pertain to the data as it existed on the last execution. These parameters are listed below according to type code:

Type Code	Description	Parameter List
4.	Bending Magnet	Bending angle, radius of curvature
5.	Quadrupole	horizontal, vertical focal length
10.	Constraint	Fit

OUTPUT (TRAN4)

Output from the teletype transport will be generated on the teletype by any of the following TRAN4 options:

PDATA ..... see TABLE 7
BLINE and GO or SOLVE ..... see TABLE 9
TABLE ..... see TABLE 8

Additional output will be generated during execution if any of the following data cards are included in the transport data array:

13. 5. and 13. 6. or 13. 7.	see TABLE 10
13. -1.	see TABLE 11
13. -4	see TABLE 11
13. -4.x	similar to 13. -4.
13. -8.	similar to 13. -4.
13. -24.	similar to 13. -4.
13. -27.	similar to 13. -1.
13. -45	similar to 13. -4.

TRANSPORT OPTIMIZER

Two optimizers are available, the standard optimizer[1)] and the VARMIT[2)] optimizer. The standard optimizer is fast but often will not find a solution for a complicated problem. If it fails to solve the problem the user can instruct transport to use the Varmit optimizer by inserting several cards in his data deck. Varmit is relatively slow requiring 30 to 60 seconds for complicated problems, but finds a solution if one exists in the neighborhood of the starting point. The Varmit optimizer is called into operation by including the data card

16. 29. -1.

in the data deck. Varmit moves down hill until it finds a minimum. The optimization is terminated when one of the following conditions exist.

1) The rms deviation in the constraints (F) is less than the desired value (E),

2) The improvement in F was less than FE31 in three tries,

---

1) TRANSPORT, C. H. Moore, S. R. Howry, H. S. Butler, unpublished (1965)

2) Variable Metric Method for Minimization, W. C. Davidon, ANL-5990 (1959)

4) More than 6 consecutive moves were made,

5) The program hit the limits of the variable 15 times while trying to find the minimum.

The user can input the values of E, FE31 and MAX via the cards

```
16.  27.  E.
16.  26.  FE31.
16.  31.  MAX.
```

the default values are E=1., FE31 = .001 and MAX = 200.

TABLE 1

CONTROL CARDS AND DECK STRUCTURE FOR THE BERKELEY TELETYPE AND VISTA VERSIONS OF TRANSPORT. THE TRANSPORT DATA SETS MAY BE STACKED MANY DEEP

```
TRAN4,12,500,65000.ACCNO. J. Q. USER
LIBCOPY(TRANSPORT,TRAN4,TRAN4)
COPY(INPUT,1R,NULL,1F,TAPE5/RBR)
REWIND(TRAN4)
TTY.
TRAN4.
EXIT.
DMP.
EOR
TRANSPORT DATA DECK TITLE 1
 0
....
....
....    TRANSPORT DATA
....
....
73.
EOR
```

```
VISTA,17,500,75000.ACCNO. J. Q. USER
LIBCOPY(TRANSPORT,TRAN3,TRAN3)
COPY(INPUT,1R,NULL,1F,TAPE5/RBR)
REQUEST TAPE99,TV.  VISTA 41
REWIND(TRAN3)
TTY.
TRAN3.
EXIT.
DMP.
FIN.
COPY(SNAP/RB,FILM/RBR)
RETURN(TAPE99)
EOR
TRANSPORT TITLE CARD 1
 0
....
....
....    TRANSPORT DATA
....
....
73.
EOR
```

TABLE 2

EXAMPLE OF FIELD FREE FORMAT INPUT OF TRANSPORT DATA SHOWING USER NAMED DATA SET AND USER UNNAMED DATA SET.

INPUT OF NAMED DATA FROM INPUT FILE

```
 0
1.   1.   17.   1.   17.   0.   0.   .3106   BEAM
3.   2.5  DRFT1
13.   2.   IO1
5.   1.25   10.6   4.   QH
3.   .25   DRFT2
5.   1.25   -9.657   4.   QV
3.   6.75   DRFT3
5.   1.25   10.657   4.   QH
3.   .25  DRFT4
5.   1.25   -9.875   4.   QV
3.   .975   DRFT5
13.   1.   IO2
13.   4.   IO3
6.   2.   1.25   2.54   SLITX
3.   .95   DRFT6
73.
```

TRANSPORT DATA INPUT, FIELD FREE FORMAT NO NAMES

```
 0
1.   1.   17.   1.   17.   0.   0.   .3106
 3.   1.
5.   1.25   10.65   4.
3.   .25
5.   1.25   -9.675   4.
3.   6.25
13.   1.
13.   4.
6.   2.   1.25   2.54
73.
```

TABLE 3

Example showing the connecting to the BRF and storing TRANSPORT control cards and data deck.

```
>BRF!
CONNECTED
 BRF 3.1  *07/07/72. 15.25.01. *A. ENTER NAME,ACCOUNT
PAUL,490491!
OK
↑EDIT!
OK
1 TRAN4,17,500,65000.490491,A.C.PAUL!
2 FLOOR(3X)!
3 LIBCOPY(TRANSPORT,TRAN4,TRAN4)!
4 TTY.!
5 COPY(INPUT,1R,NULL,1F,TAPE5/RBR)!
6 TRAN4.!
7 DMP.!
8 EOR!
9 TEST INPUT OF NAMED DATA!
10 0!
11 1. 1. 17. 1. 17. 0. 0. .311 BEAM!
12 3. 2.5 DRFT1!
13 13. 2. !
14 5. 1.25 10.6 4. QH
15 3. .25 DRFT2!
16 5. 1.25 -9.657 4. QV!
17 3. 6.750 DRFT3!
18 5. 1.25 10.657 4. QH!
19 3. .25 DRFT4!
20 5. 1.25 -9.875 4. QV!
21 3. .975 DRFT5!
22 13. 1. !
23 13. 4. !
24 6. 2. 1.25 2.54 !
25 3. .95 DRFT6!
26 73.!
27 EOR!
30 EOR!
↑STORE,TRAN4!
STORE IN PROCESS
STORE SUCCESSFUL
>DC.
```

TABLE 4

Loading of a TRANSPORT job from the BRF and the beginning intercourse between the program and the user. Arrows indicate usual user response to program generated questions.

```
>BRF!
CONNECTED
 BRF 3.1  *07/07/72. 15.40.55. *A. ENTER NAME,ACCOUNT
PAUL,490491!
OK
↑LOAD,TRAN4!
LOAD IN PROCESS
LOAD COMPLETE, ENTERING ↑EDIT
OK
↑SUBMIT!
 15.50.55. SUBMITTED TRAN400  REMOTE
OK
>DC.!
OK
>CT.TRAN400!
CONNECTED - IN 6600A INPUT Q PRIORITY = 76
**BKY51**A*07/07/72.7617 N
+++ TT 064 CONNECTED
 OUTPUT  CC 77 0145 0273
FLOOR(3X)
LIBCOPY(TRANSPORT,TRAN4,TRAN4)
 TRAN4   DA 00
TTY.
COPY(INPUT,1R,NULL,1F,TAPE5/RBR)
 TAPE5   DB 02
TRAN4.
PROGRAM EXECUTING -- TYPE READY, STOP OR ABORT
READY!
DO YOU WANT TTY INSTRUCTIONS PRINTED
NO!
TELETYPE INPUT OPTIONS ARE
ALINE  ALTER  DLINE  FIN    FIX    FORCE  GO
MOVE   NAME   NCASE  OUTPT  PDATA  PUNCH  PULL
RECAL  RESPN  SAVE   SEGMT  SOLVE  TITLE  VECT
BLINE  LABLE  TABLE  TLOC
-----------
DO YOU WANT OFF-LINE PRINT
YES!
ENTER DATE
7/7/72!
ENTER CASENUMBER
1!
IS DATA TO BE ENTERED OFF-LINE
YES!
TEST INPUT OF NAMED DATA
0     NUMBER OF DATA ELEMENTS I1=   46
NEXT
PDATA!
```

TABLE 5

Teletype option summary table. The left most column gives abbreviations that may be used if desired.

```
 TRAN4 (7/5/72)
REFERENCE UCID-3525 AND UCID-3564

      ABORT
AL    ALINE,NAME1, NEW LINE.
A     ALTER,NAME,N,CHANGE
BL    BLINE,N1,N2,N3,N4......
D     DLINE,N1,N2
-     FIN
F     FIX,NAME1,NAME2
-     FORCE,N,X.
G     GO
L     LABLE,LAB1,LAB2.....
         LABS=LABLES FOR TABLE OPTION
MV    MOVE,NAME1,NAME2,NEWLOC
         ,NAME,NEWLOC
NA    NAME     ALL DATA
         ,NAME,NEWNAME
-     NCASE
-     OUTPT
PD    PDATA,NAME1,NAME2
-     PULL,M,NAME1,NAME2
        M=0 DATA, M=1 SAVE, M=2 SAVE2, M=3 SAVE3
-     PUNCH
RE    RECAL
         ,N
         ,N,SWAP
-     RESPN,YES
         ,NO
SA    SAVE,N
SE    SEGM1,NAME1,NAME2
I     SOLVE
TA    TABLE,N1,N2,N3,N4....
T     TITLE,NEWTITLE
-     TLOC,N1,N2,N3,N4....
V     VECT,ALTER,N,M,CHANGE
         ,ALINE,N,NEWVECTOR.
         ,DLINE,N1,N2
         ,PRINT,N1,N2
```

TABLE 6

Vista version option summary table. Left most column indicates abbreviation for options which may be used if desired.

```
 TRAN3 (7/5/72)
REFERENCE UCID-3525 AND UCID-3564

A     ALTER,NAME,POSITION,CHANGE
AL    ALINE,NAME,NEWLINE.....
B     BEAM
C     CANCL
D     DLINE,NAME1,NAME2
-     FIN
F     FIX
-     FORCE,N,X.
G     GO
MA    MATRX,LOC,PLANES
      MATRX,LOC,N,PLANES
M     MDATA
MV    MOVE,NAME1,NAME2,NEWLOC
          ,NAME,NEWLOC
NA    NAME  ALL DATA
          ,NAME1,NEWNAME
-     NCASE
-     OUTPT
PD    PDATA,NAME1,NAME2
-     PULL,M,NAME1,NAME2
        M=0 DATA, M=1 SAVE, M=2 SAVE2, M=3 SAVE3
-     PUNCH
R     RAYS          DISPLAY ALL
      RAYS,1,4,5  DISPLAY 1,4 AND 5
RE    RECAL  OR RECAL,2
      RECAL,1,SWAP  OR RECAL,2,SWAP
SA    SAVE  OR SAVE,2
SB    SNAPB
SC    SCALE,NAME1,NAME2,X,Y
      SCALE,C
SD    SNAPD
SE    SEGMT,NAME1,NAME2
T     TITLE,NEW TITLE
I     SOLVE
V     VECT,ALTER,N,M,CHANGE
      VECT,ALINE,N,NEWVEC....
      VECT,DLINE,N1,N2
      VECT,PRINT,N1,N2
```

TABLE 7

Output of a PDATA option for data shown. Left most column gives data name. Number in parenthesis are the index counter I for the ITYPE codes, followed by the data line.

```
------------------
0TRANSPORT TEST CASE
 0
I01    (  1) 13.000   5.000
BEAM1  (  3)  1.000   1.000   5.000    .750   3.500   0.      0.       .375
       ( 11)  22    1
              0.      0.       0.       0.       0.       1.0000   0.
L1     ( 13)  3.000   1.000
QH     ( 15)  5.020    .375    .612   2.500
QV     ( 19)  5.030    .375   -.633   2.500
L2     ( 23)  3.000    .750
BM1    ( 25)  4.000   1.100  10.000   0.
DRFT4  ( 29)  3.000   1.000
QV     ( 31)  5.030    .375   -.633   2.500
QH     ( 35)  5.020    .375    .612   2.500
L3     ( 39)  3.000    .750
I02    ( 41) 13.000   6.000
CON1   ( 43) 10.000   2.000   1.000   0.       .001
CON2   ( 48) 10.000   4.000   3.000   0.       .001
I03    ( 53) 13.000  -1.000
I04    ( 55) 13.000  -4.000
SLIT1  ( 57)  6.000   2.000   1.000   1.000
L4     ( 61)  3.000   1.000
------------------
```

TABLE 8

Output generated by the TABLE option. The column headings may be selected by the LABLE option for the desired locations.

TABLE,BEAM1,L4!

NAME	TYPE	LC	XBEAM	YBEAM	X1	Y1
BEAM1	1.003	0.	1.000	.750	0.	0.
L1	3.013	1.000	1.118	.828	0.	0.
QH	5.015	1.375	1.060	1.010	0.	0.
QV	5.019	1.750	1.025	1.174	0.	0.
L2	3.023	2.500	1.329	1.196	0.	0.
BM1	4.025	3.600	1.338	1.268	.453	0.
DRFT4	3.029	4.600	.971	1.368	1.224	0.
QV	5.031	4.975	1.029	1.222	1.705	0.
QH	5.035	5.350	1.110	1.052	2.140	0.
L3	3.039	6.100	1.052	1.034	2.449	0.
L4	3.061	7.100	1.154	1.065	2.862	0.

TABLE 9

BLINE option output generated by subsequent GO option at locations specified and saved by the BLINE option.

```
BLINE,L1,L2,BM1,BM1!
G!
 EXECUTING CASENO   2-23
L1     ( 13)
 DRIFT 3.0     1.000 M
QH     ( 15)
 QUAD  5.02     .375 M      .6116 KG   2.50 CM   (   1.43 M  )
QV     ( 19)
 QUAD  5.03     .375 M     -.6326 KG   2.50 CM   (  -1.26 M  )
L2     ( 23)
 DRIFT 3.0      .750 M
BM1    ( 25)
 BEND 4.000  1.100 M   10.000 KG    .00 (  50.385 D) (   1.251 M  )
 LENGTH   7.100M
```

TABLE 10

Example of the polygon calculation generated when 13.5. and 13.6. or 13.7. data cards are included in the data set.

```
 EXECUTING CASENO   2-20
POLYGON AT 13.5.0 DELTAP=   0.     PC          P=     .375 GEV/C
 1      1.5617    9.3830 5.015 5.019      1.3360    4.1015 5.019 5.031
 2      1.5472    9.4858 5.019 5.019     -2.0885   11.7660 5.031 5.035
 3       .6883   13.6808 5.019 5.031     -2.3311   12.2327 5.035 5.035
 4       .0237   13.0946 5.031 5.035     -3.9687   14.6870 5.015 5.035
 5       .0010   13.0501 5.035 5.035     -3.3963    8.9625 5.015 5.019
 6     -2.9425    4.4252 5.015 5.035     -3.2810    8.1051 5.019 5.019
 7     -1.5617   -9.3830 5.015 5.019     -1.3360   -4.1015 5.019 5.031
 8     -1.5472   -9.4858 5.019 5.019      2.0885  -11.7660 5.031 5.035
 9      -.6883  -13.6808 5.019 5.031      2.3311  -12.2327 5.035 5.035
10      -.0237  -13.0946 5.031 5.035      3.9687  -14.6870 5.015 5.035
11      -.0010  -13.0501 5.035 5.035      3.3963   -8.9625 5.015 5.019
12      2.9425   -4.4252 5.015 5.035      3.2810   -8.1051 5.019 5.019
APERTURES
HORIZONTAL POLYGON AREA=  96.8443 CM MR
   CENTER AT    0.     CM       0.     MR
VERTICAL POLYGON AREA=  80.9516 CM MR
   CENTER AT      -.000 CM        .000 MR
 LENGTH   7.100M
```

TABLE 11

Output generated by the 13.-1. data entry giving the beam and vectors and the 13.-4. data entry giving the RC transformation matrix.

```
EXECUTING CASENO   2-22
53    0.       1.052 CM    LENGTH     6.100 M    (I03    )
      0.       4.754 MR     -.000
      0.       1.034 CM     0.     0.
      0.       2.538 MR     0.     0.      .000
      0.       1.243 CM     -.349   .937 0.     0.
      0.       0.    PC     0.     0.     0.     0.     0.
53L=    6.100
1(A)     2.449    4.125    0.       0.       -.136    1.000    0.
```

```
EXECUTING CASENO   2-13

= 55 TRANSFORM 1   (I04    )
   -.79491      .13770     0.          0.          0.          2.44932
  -3.11278     -.71877     0.          0.          0.          4.12542
   0.          0.           .17705      .29306     0.          0.
   0.          0.         -3.35601      .09315     0.          0.
   -.43448     -.23286     0.          0.          1.00000     -.13640
   0.          0.          0.          0.          0.          1.00000
LENGTH    7.100M
```

TABLE 12

```
UCID-3525                    TRANSPORT VERSION 10                    UCID-3525
                                  A. C. PAUL
                               JANUARY 5 1972
QUESTIONS CONSERNING THIS CODE SHOULD BE DIRECTED TO A.PAUL EX 6141
VERSION  TYPE                   FIELD LENGTH  SOURCE OF PROGRAM
TRAN2 / 1ST ORDER            /  60K        / LIBCOPY(TRANSPORT,X,TRAN2 )
TRAN22/ 2ND ORDER            /  75K        / LIBCOPY(TRANSPORT,X,TRAN22)
TRAN4 / 1ST ORDER TTY        /  65K        / LIBCOPY(TRANSPORT,X,TRAN4 )
TRAN42/ 2ND ORDER TTY        /  75K        / LIBCOPY(TRANSPORT,X,TRAN42)
TRAN3 / 1ST ORDER VISTA      /  75K        / LIBCOPY(TRANSPORT,X,TRAN3 )
TRAN32/ 2ND ORDER VISTA      / 130K        / LIBCOPY(TRANSPORT,X,TRAN32)
-----------------------------------------------------------------------
      10        20        30        40        50        60        70
456789012345678901234567890123456789012345678901234567890123456789012
COORDINATE SYSTEM OF TRANSPORT
   +Z DIRECTION OF PARTICLE MOTION
   +Y VERTICAL DISPLACEMENT UPWARD
   +X HORIZONTAL DISPLACEMENT (USE LEFT OR RIGHT HAND RULE)
   NEGATIVE PARTICLES/ USE LEFT HAND RULE AND LEFT HAND COORDINATES
       +X AXIS HORIZONTAL DISPLACEMENT TO RIGHT LOOKING ALONG  +Z
   POSITIVE PARTICLES/ USE RIGHT HAND RULE AND RIGHT HAND COORDINATES
       +X AXIS HORIZONTAL DISPLACEMENT TO LEFT LOOKING ALONG +Z

   TITLE AND DATE CARD FORMAT(8A10)
   CASE NUMBER CARD FORMAT(F10.3)
   OPTION CARD FORMAT(1XI1)
   BEAM ELEMENTS FORMAT   (8F10.3)
      EXCEPT A 15. ELEMENT(2F10.3,A6,4XF10.3)
   FIRST DATA CARD MUST BE DATE CARD WITH A COMMENT ON IT
   SECOND DATA CARD MUST BE A CARD WITH ANY FLOATING POINT NUMBER C
       THIS NUMBER WILL BE SEQUENTIALLY INCREASE FOR EACH DATA CASE
      THE ABOVE TWO CARDS APPEAR ONLY ONCE IN THE DATA DECK STRUCTURE
      THEN MAY FOLLOW ANY NUMBER OF DATA SETS BEGINING WITH A TITLE
      CARD,OPTION CARD AND TRANSPORT DATA TERMINATED WITH A 73. CARD
-----------------------------------------------------------------------
   BEAM ELEMENTS
      TYPECODE-MEANING                  TYPE---PARAMETER LIST FOR TYPE---
        1.  BEAM                         1. X. XP. Y. YP. DS. DP/P. P.
            ADD TO BEAM.  IF A BLANK CARD FOLLOWS A 1. CARD THE PARAM
            ADD QUADRATICALLY TO THE DIAGONAL ELEMNETS OF THE BEAM
            MATRIX.  THE MOMENTUM IS CHANGED BY P. I.E. PO=PO+P
*           IF EREST.NE.0 (SEE 16. 18. CARD) P IS ENERGY
        2   MAGNET POLE FACE ROTATION 2. T. B2.
               ANGLE WITH SAME SIGN AS B IS VERTICALLY FOCUSING
               IN THE SEQUENCE 4. 2. 4. 2. 4.=4.(2. 4.)(2. 4.)
               B2 IS FIELD INTO WHICH MAGNET FRINGE FIELD EXTENDS
        3   DRIFT SPACE                  3.  L.
        4   BENDING MAGNET               4.  L.  B.  INDEX.
               FOR VERTICAL BEND USE NEGATIVE L, + FIELD IS UPWARD.
               SEE TYPE 16. 21. FOR INPUT OF BEND ANGLE OPTION
        5   QUADRUPOLE                   5.  L.  B.  HALF-APERTURE
               + B IS HORIZONTALLY FOCUSING FOR POSITIVE PARTICLES
        6   SLIT                         6. J.  X.  Y.
                THE SLIT IS NOW MODIFIED SO AS NOT TO CHANGE THE BEAM
                J=1  X=1.  UPDATE BEAM
                J=0  X=2.  INITIATE RC2 MATRIX
                J=0  X=3.  INITIALIZE R3 MATRIX
                J=1  X=HORIZONTAL HALF WIDTH OF SLIT
                J=2   X AND Y ARE THE RECTANGULAR HALF APERATURES
                     ASSOCIATED WITH THE FOLLOWING ELEMENT OF LENGTH L
                J=3  X=VERTICAL HALF WIDTH OF SLIT
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        J=4    X AND Y ARE THE RECTANGULAR HALF APERTURES
        J=5    X AND Y ARE THE ELLIPTICAL HALF APERTURES
        J=6   X AND Y ARE THE ELLIPTICAL HALF APERTURES
              ASSOCIATED WITH THE FOLLOWING ELEMENT OF LENGTH L
 7   CENTROID SHIFT                7.  DX. DTX. DY. DTY. DS. DDP
 8   MAGNET ALIGNMENT              8. X. TX. Y. TY. S. TS. NMP.
      N=0 UNCERTAINTY IN POSITION, N=1 DELIBERATE DISPLCACMENT
      M=0 ORIGINAL AXIS FOR SUCCEEDING MAGS. M=1 NEW MISALIGNED
      P=0 USE R MATRIX, P=1 USE RC MATRIX, P=2 USE RC2 MATRIX.
 9   REPETITION                    9.  J.
        J=NUMBER OF TIMES REPEATED, J=0 END OF REPEATED DATA
        REPEATS MAY BE NESTED FOUR DEEP
10   CONSTRAINT                    10  J.  K.  X.  SD.
        J=0  K=1   BEAM INTENSITY CONSTRAINT
        J=0  K=0   SYSTEM LENGTH  CONSTRAINT
       -(J+20),K   AUXILARY MATRIX RC2(J,K) CONSTRAINT
       -(J+10),K   BETATRON PHASE ANGLE CONSTRINAT, -11,2
       -J,K        TRANSFORMATION MATRIX RC(J,K) CONSTRAINT
       J,K.GT.0    BEAM MATRIX CONSTRAINT SI(J,K)
       J+10,K      CORRELATION OF BEAM RJK=SI(J,K)/SQRT(   )
        J.GT.K.LT.10 COVARIANCE OF BEAM CONSTRAINT SI(J,K)
        J=K.GT.0   AND .LT.10 PHASE PROJECTION SQRT(SI(J,J))
        J=ABCD     K=Y STORAGE RING CONSTRAINT
                        Y*R(A,B)+R(C,D)=X +- SD
        LOWER LIMIT CONSTRAINT  10.1 J. K. VALUE. SD.
        UPPER LIMIT CONSTRAINT  10.2 J. K. VALUE. SD.

11   ACCELERATOR(ENERGY GAIN)  11. L. DE. PHASE. WAVELENGTH.
*    DE IS MOMENTUM CHANGE IF EREST=0 (SEE 16. 18 CARD)
*    PHASE IN DEGREES, WAVELENGTH IN UNITS OF UNIT(5)
12   BEAM INPUT CORRELATION    12.  15 NUMBERS
        SI(J,K) FOR J.NE.K AND J=2,6, K=1,J-1.
13   OUTPUT CONVENTIONS        13. J.
        1  TEMPARARY OVERRIDE OF ELLIPSE OUTPUT SUPPRESION
       -2    SUPPRESS BEAM ELLIPSE OUTPUT ON FIRST RUN THRU
        2    SUPPRESS BEAM ELLIPSE OUTPUT
        3    PERMANENT OVERRIDE OF ELLIPSE OUTPUT SUPPRESION
        4    RC MATRIX PRINT OUT
        4.X  VISTA MATRIX OUTPUT OF R3 (ACCUM MATRIX FROM 1.)
        5    START PHASE SPACE APERTURE CALCULATION
        6    PRINT OUT APERTURE PHASE SPACE
        7    ENERGY SPECTRUM FOR APERTURE CALCULATION
        8    PRINT OUT R() MATRIX
       10    CONDITIONAL QUADRUPOLE APERTURE CONSTRAINT
       11    CALCOMP ENVELOPE TRACE    ( NOT AVAILABLE)
       12    CALCOMP LAYOUT            ( NOT AVAILABLE)
       20    ALIGNMENT OPTION
       21    ALIGNMENT OPTION
       22    ALIGNMENT OPTION
       24    RC2 MATRIX PRINT OUT
       25    SUPPRESS VECTOR TRACKING OUTPUT
       26    PERMANENT OVERRIDE OF VECTOR OUTPUT SUPPRESSION
       27    TEMPORARY OVERRIDE OF VECTOR OUTPUT SUPPRESION
       28    TURN OFF PRINTING OF APERTURES TABLES.
       29    TURN OFF APERTURE PLOTS AT SOURCE 13. 5.
       30    TURN ON APERATURE PLOTS AT TARGET 13. 6.
       31    HORIZONTAL VECTORS WITHIN LIMITS OF PHASE SPACE
       32    VERTICAL VECTORS WITHIN LIMITS OF PHASE PLOTS
       40    PRINT R AND RC MATRIX AFTER EACH ELEMENT WITH L
       42    PRINT 1ST ORDER RC MATRIX, NO 2DN ORDER OUTPUT
       43    PRINT POLYGON MATRIX WITH ORIGIN AT 13. 5. LOC.
       46    TURN OFF PROJECTIONS ON A TABLE(19.,20. TYPE)
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        48      PRINT 1ST ORDER R MATRIX, NO 2ND ORDER OUTPUT
        49      PRINT DC/DV MATRIX DURING OPTION 3 ON TELETYPE
      NIJK      VISTA T(IJK) SECOND ORDER TO VECTOR POSITION N
14    ARBITRARY MATRIX            14. X. X. X. X. X. X. J.
15    UNIT CHANGE                 15. J.  DIM  X.
      A SET OF 15. CARDS MUST BE PRECEEDED BY A 15. N. M. CARD
      WHERE N IS THE NUMBER OF 15. CARDS FOLLOWING, N MAY BE 0.
      IF M.NE.0 THE UNITS ARE RESTORED TO STANDARD VALUE BEFORE
      PROSESSING THE N FOLLOWING 15. CARDS.
          J  SIGNIFICANCE                 STANDARD VALUE
          1  HOR AND VERT EXTENT           CM
          2  HOR AND VERT DIVERGENCE       MILLIRADIANS
          3  VERTICAL EXTENT               CM
          4  VERTICAL DIVERGENCE           MILLIRADIANS
          5  PULSE BEAM LENGTH             CM
          6  MOMENTUM SPREAD               PERCENT
          7  NOT USED
          8  LENGTH                        METERS
          9  MAGNETIC FIELD                KILOGAUSS
         10  MASS                          ELECTRON MASSES
         11  MOMENTUM OR ENERGY            GEV/C
16    PARAMETER INPUT             16.  J.  X.
          1     BDB  QUADRATIC TERM IN BENDING FIELD
          2     DB  ERROR IN BENDING FIELD
          3     SM  MASS OF PARTICLES
          4     HORIZONTAL HALF APERTURE
          5     VERTICAL HALF APERTURE  (EFFECTS POLEFACE MATRIX
          6     ACCUMULATED LENGTH, LC.
          7     FR1  ENTRANCE FRINGE FIELD POLE ROT. FACTOR
          8     FR2  EXIT FRINGE FIELD POLE ROT.FACTOR
          9     RDL   L=L+GAUSS(RDL) FOR DRIFT SPACES
         10     RDB   B=B(1+GAUSS(RDB)) FOR QUADRUPOLE FIELDS
         11     RDT   TH=TH+GAUSS(RDT) FOR BEAM ROTATIONS
         12     RAB1  POLE FACE ENTRANCE RADIUS
         13     RAB2  POLE FACE EXIT RADIUS
         14     CAUSES COMP OF VECTOR TO BE LENGTH WHEN LOST BY
                INTERSECTION WITH APERATURES, + HOR, - VERTICAL
         15     FOCLTL
         16     APFILL (FRAC QUAD APE USED IN RECT APE APPROX)
         17     LENGTH, L.
         18     EREST(REST ENERGY)  IN ENERGY UNITS (15.  11.)
         19     MATRIX TO WHICH BETATRON FUNCTION APPLIES
                1. RC,  2. RC2,  3. R,  4. R3
         20     BEAM.  CAUSES BEAM ELLIPSE TOBE DEFLECTED BY
                       PARTICLE SEPARATOR
         21     X=0  BENDING MAGNET INPUT 4. L. B. N.
                X=1. BENDING MAGNET INPUT 4. A. B. N.
                X=2. BENDING MAGNET INPUT 4. L. A. N.
                     WHERE A= ANGLE OF BEND IN DEGREES
         22     X=1. WEDGE MAGNETS, X=2. RECTANGULAR MAGNETS
         23     VEC  =0 NO SPACE CHARGE ON VECTORS. =1 S.C. ON V
         27     SIZE  STOP VARMIT ITERATION WHEN RMSDEV=SIZE
         28     ISTEP SIZE OF RANDOM STEO=.5*1)**(ISTEP-1)*FUNCT
         29     IREAD=-1 VARMIT,=0 STANDARD,=1 BOTHVAR THEN STAN
         30     IWRITE =0,1,2,3,4  OUTPUT CONTROL
         31     ICLOCK=MAX NUMBER OF ITERATIONS
         32     ICNVRG= NUMBER OF ITERATIONS WITH LT .1PC IMPRVT
         33     MAXIMUM NUMBER OF RANDOM STARTS DURING OPTIMIZTN
*     17    SECOND ORDER                17.  1.  0.  3.  (TRAN22/TRAN32)
      18    SEXTUPOLE                   18. L.  B.  HALF-APERTURE.
      19    SOLENOID                    19. L.  B.
      20    BEAM ROTATION               20. T.
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21    ALIGNMENT OPTION              21. J. LMIN. LMAX.
      IF J.LT.0 CHANGE OF VARIABLE CONVERGENCE LIMITS, SEE
      INTERNAL CONSTRAINTS ON VARIABLES.
      IF J=0, BEAM CARD INPUTS BETATRON FUNCTIONS WITH HORIZTAL
      EMITTANCE/PI=LMIN AND VERTICAL EMITTANCE/PI=LMAX.
      1. BX. AX. BY. AY. ). ). P./ WHERE GX=(1+AX**2)/BX ETC.
22    VECTOR(RAY) INPUT             22. X. XT. Y. YT. DS. DP/P. COMP
         COMP=0  NORMAL BEAM  OF VELOCITY BETA0
*        COMP=B  B=BETA OF PARTICLES TO BE DEFLECTED BY SEPARATR
         COMP=LENGTH WHEN LOST IF A 15. 14. DATA CARD IS USED.
         COMP.LE.1. FIRST ORDER VECTOR INPUT
         COMP=2 FIRST ORDER INPUT, 2ND ORDER VECTOR=FIRST**2
         COMP.GT.2 FIRST ORDER VECTOR INPUT FOLLOWED BY COMP
           2ND ORDER PAIRS, I.E. JK,V(JK), .....ETC.
         MAXIMUM OF 40 FIRST ORDER OR 6 SECOND ORDER VECTORS
23    VELOCITY SEPARATOR            23. L. V. AH. AV. BETA0. BETA1.
         BETA0 IS VELOCITY OF VECTORS WITH COMP=0
*        POSTIVE LENGTH DEFLECTS COMP.NE.0 PARTICLES HORIZONTALY
*        NEGATIVE LENGTH DEFLECTS COMP.NE.0 PARTICLES VERTICALLY
         V IS THE ELECTRIC POTENTIAL ON THE SEPARATOR PLATES
24    PLOTS                         24. J. XS. YS. ZS. V1. V2.
            IF XS=YS=0. SET PLOT AND GRAPH SCALES FROM DATA
            J.LT.0 PAGE EJECT FOLLOWING PLOTTING IS SUPPRESSED
         J=0 GRAPH BEAM LINE SHOWING BEAM, APERTURES, AND VECTORS
            V1 TO V2.  ZS IS LENGTH PER PLOT LINE, IF ZERO MAKE
            GRAPH OF 2 PAGE LENGTH
         J=1 TARGET SIZE FOR CALC. OF SOLID ANGE ACCEPTANCE
            XS=HOR.SIZE, YS=XP SIZE, ZS=VERT.SIZE, V1=YP SIZE.
         J=4 ENERGY SPECTRUM FOR P=XS TO P=YS IN STEPS OF ZS.
         J=5 XS,YS HORIZONTAL, ZS,V1 VERTICAL SCALES AT 13. 5.
         J=6 XS,YS HORIZONTAL, ZS,V1 VERTICAL SCALES AT 13. 6.
         J=X IF X.GT.10 PLOT PHASE PLANES GIVEN BY X. E.G. X=AB
            PLOT PHASE PLANE AB, IF X=ABCDEF PLOT PHASE PLANES
            AB,CD,EF. WHERE AB=12, CD=34, EF=16. ETC.
            V2=PLOTSYM=0 SYMETRIX, =1. NONSYMETRIX SCALES
*     25  SECOND ORDER MATRIX        25. MA. INPUTTYPE. PARM.
*        THIS OPTION IS AVAILABLE ON TRAN22 AND TRAN32 TAPES
*        AND ALLOWS INPUT OF FIRST AND SECOND ORDER MATRICES
*        INTO FOUR DISTINCT ARRAYS WHICH CAN BE USED AT OTHER
*        LOACATIONS IN THE BEAM LINE WHEN INPUTTYPE=0 (UCID 3448
*        FORMAT FOR MATRIX ELEMENTS IS 8E10.3 (WILL READ 8F10.)
26    SPACE CHARGE                  26. STEP. AMPS. PRNTFREQ. RFFREQ
         SPACE CHARGE CALCULATION BY IMPULSE APPROX EVERY STEP
         STEP=LENGTH INCREMENT AT WHICH SPACE CHARGE FORCE ACTS
         AMPS=AVERAGE CURRENT IN AMPERES
         PRNTFREQ=OUTPUT EVERY PRNTFREQ STEPS OF EACH REGION
         RFFREQ= R.F. BUNCH FREQ IN MC, =0 IF DC BEAM
27    RF BUNCHER                   27. L. V. RFPHASE. RFFREQ.
      L MUST=0, V(MEGAVOLTS), RFPHASE(0 OR 180 DEG), RFFREQ(MC)
73    END CASE                      73.
73    END ALL CASES                 73. 73.
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OPTION=0      STANDARD DATA INPUT.  TYPE CODE PLUS PARAMETER LIST
OPTION=1      INPUT BEAM, BEAM CORRELATIONS AND PARTICLE VECTORS
              ONLY TO BE USED WITH PREVIOUSLY DEFINED BEAM LINE.
              OPTION 1 TERMINATED BY OPTION CARD OR BLANK AND 73.
OPTION=2      CHANGE SINGLE DATA ELEMENT BY READING VALUE OF INDEX
              I OF DATA TO BE CHANGED FOLLOWED BY THE NEW VALUE.
              READING OF THIS SPECTIAL I. X. CARD INPUT CONTINUES
              UNTILL A BLANK CARD IS ENCOUNTERED.  THIS CAUSES  A
              RESUMPTION OF STANDARD (OPTION=0) DATA INPUT.
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                A 73. TERMINATOR MAY ONLY BE USED AFTER A BLANK CARD
OPTION=3        THIS OPTION ALLOWS THE PARAMETERS OF THE PRECEEDING
                DATA DECK TO BE STEEPED
*               EITHER RANDOMLY OR WITHIN A GIVEN GRID IN GIVEN STEPS
*               (UCID-3470) MAXIMUM OF 4 PARAMETERS MAY BE CYCLED
*               THE INPUT CONSISTS OF THE VARIABLE NUMBER, MIMIMUM
*               VALUE, MAXIMUM VALUES, STEP SIZE, RANDOM FLAG, AND NO
*               OF SUBSEQUENT RUNS WITH OPTIMIZATION AT THE MIMUMUM O
*               CHI SQUARE VALUES FOUND IN THE OPTION 3 SEARCH
*               IF NON-VARIABLE DATA IS TOBE STEPPED, THEN THE DATA
*               INPUT CONSISTS OF -I,VMIN,VMAX,STEP WHERE I IS THE
                INDEX VALUE OF THE DATA IN THE DATA ARRAY
*               -I.1 ALL SUCH PARAMETERS ARE CYCLED TOGETHER
*               -I.2 PARAMETER ASSIGNED THE VALUES SPECIFIED ON CARD
OPTION=4        THIS OPTION TRANSFORMS THE BEAM AND VECTORS USEING
                THE RC ACCUMULATED MATRIX FROM THE END OF PREVIOUS
                CASE.  PHASE PLOTS WILL BE MADE AT THE LAST 24. 1234.
                LOCATION.  TERMINATED BY BLANK CARD AND 73.
STACKING OF OPTIONS
    OPTION 1,2,3,4        OPTION 1,4          OPTION 1,2,0
     0                     1                   1
    DATA(1)               DATA(1)             DATA(1)
     2                     4                   2
    DATA(2)               BLANK CARD          DATA(2)
     3                    73.                  0
    DATA(3)                                   DATA(0)
     4                                        73.
    BLANK CARD
    73.
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INTERNAL CONSTRAINTS ON VARIABLES
        ELEMENT JTYPE   VARIABLES LOWER   UPPER   LOWER    UPPER
        BEAM    1       1.111111  .01     1000.   ETC.
        POLE    2       2.1       -50.    60.
        DRIFT   3       3.1       .1      1000.
        BEND    4,5,6   4.011     -18.    18.     -500.    500.
        QUAD    7,8     5.11      .01     10.     -20.     20.
        EXTRA   9,10,11
        ALIGN   12,13   8.111111  -1.     1.      -50.     50.
                                  REPEAT THREE MORE TIMES
        AUX     14      14.111111 NONE    NONE
        SOL     15      19.11     NONE    NONE    NONE     NONE
        ROT     16      20.1      -360.   360.
        THESE LIMITS CAN BE CHANGED BY A CARD OF THE FOLLOWING TYP
        21. -JTYPE. LOWER LIMIT.  UPPER LIMIT.

SYMBOLS CORRESPONDING TO VECTORS USED IN PHASE SPACE PLOTTING
1(A)    6(F)    11(L)   16(Q)   21(V)   26(-)   31(=)   36([)
2(B)    7(G)    12(M)   17(R)   22(W)   27(/)   32(,)   37(])
3(C)    8(H)    13(N)   18(S)   23(Y)   28())   33(0)   38(≠)
4(D)    9(J)    14(O)   19(T)   24(Z)   29(()   34(*)   39(→)
5(E)   10(K)    15(P)   20(U)   25(+)   30($)   35(≡)   40(<)
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