USER'S GUIDE TO THE EDSAC MAGNETIC TAPE SYSTEM

by

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1. General Introduction

The auxiliary store of EDSAC 2 consists of four magnetic-tape units. The transfer of information between a tape and the main store is controlled by subroutines in the reserved store. There is no buffer-store, and therefore computing is held up during information transfers. Only one tape can be used at a time; there is, however, provision for positioning one or two tapes autonomously during the operation of a program. Normally, communal tapes are used, but private tapes are available if required. The system is such as to make the tape an addressable, eraseable, store; the addressing is done by the computer as a once-for-all operation. One of the communal tapes carries most of the library subroutines and the Autocode compiler, in a section of the tape which cannot be overwritten.

2. Tapes and Tape Decks

The four tape decks are identified by the letters A,B, C and D, and the four tapes available to a programmer are numbered 1,2,3, and 4. The correspondence between tape numbers and actual tape decks in use at any time is indicated by numbers prominently displayed on the tape decks themselves. It is possible for any tape deck to be switched to correspond to any tape number, thus the duty engineer can set up any required configuration. Every tape has its number included in the labelling system, and the reserved-store routines will detect a discrepancy between the number of a particular deck and the number of the tape mounted on it. A tape deck which does not have a number displayed is out of service and cannot be used.

Power supplies to the capstans and servos of the tape units are switched individually by four switches on the control panel. Tape decks are normally switched OFF, and must be switched on as required for each program. The neon below the appropriate switch is illuminated when the deck is available to a program; there is a delay of about six seconds between switching on a deck and the deck being available. An attempt to use a tape unit which is not available will lead to the "MAGNETIC TAPE" lamp being illuminated. The program will proceed as soon as the tape deck becomes available.

3. Tape Spools

A spool will hold up to 3,600 feet of tape, though the usual length is 1,800 ft. or less. An 1,800 ft. reel can hold approximately 270,000 words, but a communal tape has a capacity of only 50,000 words. Communal

(or STANDARD) tapes are identified by coloured spools, which indicate the tape number as follows

RED	Tape 1
YELLOW	Tape 2
GREEN	Tape 3
BLUE	Tape 4

Private tapes do not have coloured spools.

Each tape has a transparent patch (called the OPTICAL MARK) approximately 15 feet from either end. These marks control the automatic loading and unloading sequence (see Section 10). Between these markers the tapes are divided magnetically into serially numbered BLOCKS, each of which can hold up to 50 words. (This does NOT mean that information transfers must be of this length - see Section 4 below.) Each block has a LABEL which includes its serial number, the tape number, and the SECTION number (see below). Block numbers, like addresses in the main store, can lie between 0 and 2047. By convention, the blocks available to the programmer are those between 200 and 1200 on standard tapes, 200 and 2000 on private tapes. The blocks before 200 are reserved for non-eraseable information, e.g. library subroutines. An attempt to read or write in a block beyond the upper limit (1200 or 2000) will cause the tape to cycle backwards and forwards indefinitely.

On a private tape it may be required to have more than 1800 blocks. This is possible, and is done by providing several SECTIONS (up to 3 on an 1800 ft. reel) each containing blocks 200 to 2000. The sections are numbered 0,1,2,... (so that a normal tape has section zero only), and the section number is included in the block label. The reserved-store sub-routines for controlling the magnetic-tape system operate within any section: to move between sections it is necessary to use a free-store library routine Z13.

4. The Reserved-Store Facilities

The reserved-store routines are described in detail in Appendix 1. The purpose of this Section is to introduce the reader to the facilities provided.

The basic operation is the transfer of a RECORD between the tape and the main store. A record consists of a set of words occupying consecutive registers in the free store, the number of words being a

natural unit for the particular program. Obviously, a program may use records of various sizes. The programmer must specify the position of the record in the free store, and its length: he must also say which tape is to be used and give the number of the block in which the record starts. If the record is of more than fifty words it will automatically be spread over the correct number of consecutive blocks. When a record is written on the tape, check sums are automatically recorded for each block, so that the accuracy of subsequent reading from the tape can be checked. This check is made automatically: if desired an automatic check can be made immediately after writing, but this slows down the transfer.

A record is transferred by the orders

70 s m_1
70 t m_2
59 f 18
n k m_3

Here the record starts at register m_1 (even) in the free store and is $\frac{1}{2}m_2$ registers in length; it starts at block m_3 on tape number n, and the modifier letter k determines the operation thus:

k = r to READ FROM TAPE
t to WRITE ON TAPE
f to WRITE WITH CHECK.

When the transfer is completed, control returns to the order following the parameter n k m_3 in the store, with t set equal to the number of the next available block, i.e. the start of the next record. If the operation is that of reading from the tape, and is unsuccessful, it is automatically repeated up to a maximum of ten times, after which a report follows. If the operation is that of checked writing, failure of the check leads to the information being rewritten: only if the check is still unsuccessful is there a report. Each block within a record is checked individually. There are also reports if the tape number recorded in the block labels is not the same as the tape number called for, if an attempt is made to write into a reserved block (e.g. a library-routine block), and in certain fault conditions of the tape units.

It may be possible for a program to carry on despite a magnetic-tape

failure, provided suitable precautions have been taken elsewhere in the program. If this is so, it is obviously inconvenient for there to be a report, and the reserved-store routine is arranged so as to provide the option of by-passing the report if desired. This is done by providing two exits from the subroutine: in the event of an error, control is resumed at the order next after the program parameter, but after a successful operation this order is skipped. The error exit is selected by adding 64 to the tape number in the program parameter; the order following the program parameter will usually be an unconditional jump, or a 58 order, thus:

```
    59 f 18
  64+n k m
    58 f      jump to special error subroutine
  ------      normal exit.
```

Before reading or writing, the tape is automatically positioned at the correct block. Whilst this search is going on, calculation is held up, and therefore time can often be saved by arranging for the positioning to take place autonomously during a calculation, so that the tape is in the correct position when it is required to read or write. This positioning is initiated by the orders

```
59 f 18
n s m
```

which cause tape n to be moved so that block m will be in the correct position at the next 59 f 18 order. This movement is conducted in parallel with computation; if block m is reached whilst the calculation is still in progress the tape is automatically stopped, but no harm is done if the 59 f 18 which carries out the transfer is encountered before the tape is in position, since reading or writing will not take place until the correct block has been reached. An entry to 59 f 18 cancels any positioning which may be in progress, and stops all tapes other than the tape selected by the program parameter. When 59 f 18 is used to initiate autonomous positioning, the values of s and t on entry are irrelevant except that if s is odd it is decreased by 1, (this may be important in interludes), and that t should not have the value 0 or 1.

It is only possible in this way to position one tape at a time. It may happen that it is required to position two tapes at once, or to position one tape whilst writing on another. This can be done to a certain extent by making use of the SLAVE-TAPE facility. A slave tape

is one which is moved whenever any other tape is in motion. The slave tape is controlled by the orders

59 f 39

n f m

where n is the tape number, increased by 64 if the slave tape has to move backwards, and m is the number of blocks which the slave tape must move (NOT the required block number.) The effect of these orders is that whenever any other tape is moved (for reading, writing or positioning), the slave tape will move in the specified direction UNLESS such a movement would take it past the desired position. When the slave reaches the required position it is automatically disconnected. It is also disconnected when the store is cleared to ones, or by the orders

59 f 39

0 f 0

If a tape is designated as a slave, and before the slave movement is completed it is called by 59 f 18, this latter order over-rides the slave motion. However, the slave is not permanently disconnected, and may therefore resume its slave motion at a later stage. The slave positioning is only approximate (see Appendix 1 for details), and it is usually best to over-estimate the distance to be traversed.

In order to make good use of the slave-tape facility it is necessary to be able to discover the present position of a tape. This can be done by the orders

59 f 19

n f 0

which place in t the number of the next block on tape n. In addition, register M contains information as follows:

Digits 6,7,8 give the tape number

Digits 9 - 19 give the block number

Digits 26,27,28 give the section number.

59 f 19 can thus be used to check that the correct tape has been mounted on a deck, and that it is positioned in the correct section. In the program parameter following 59 f 19, the modifier letter and the address are ignored.

5. Store Dumping

It is often useful to be able to preserve on magnetic tape the contents of the free store and some portions of the reserved store. If this can be done it is possible to restart a program by replacing the original contents in these stores; the operation of preserving is called a STORE DUMP and the converse operation is conveniently described as an UNDUMP. Store dumping can be used either as a safety precaution during a long run, so that the program can be restarted with minimum waste of time in the event of a machine failure, or as a means of breaking up a long run into shorter periods.

A store dump is initiated by the orders

```
59 f 38
n f m
```

Here n is a tape number and m is the number of the first of 23 consecutive blocks. This records on the tape the entire free store except register 2046, and relevant information from the reserved store (e.g. parameters and page-layout counts) using checked writing. The information dumped can be recovered by the orders

```
59 f 38
n r m
```

where n and m have the same significance as above. The effect of this is to restore the program in the free store, to replace the contents of the relevant portions of the reserved store, then to resume the program as if the original store dump had just taken place, i.e. on the order following the n f m in the program. The undumping orders will usually be on a jiffy tape, e.g. 59 f 38

```
n r m
s2
```

read in by the Set Start key. When the program is resumed after dumping, the contents of registers M, L, K, s and t will NOT be the same as they were when the dump took place, and overflow, if it was set, will have been reset. This means that the dump order must be so placed in the program that the contents of these registers are immaterial. It is of course possible to preserve the contents of the accumulator and modifiers by storing their values before dumping and recovering them after dumping. Also, input channel 1 and output channel 1 will have been selected by the SET START key. If other input or output channels are in use, the dumping orders should be followed by a 106 order so

that, after an undump, the correct configuration can be restored.

In addition to store dumping by means of a 59 f 38 placed at a suitable point in a program, it is often desirable to be able to dump a program at an arbitrary point, e.g. to allow a short program test to be carried out. This can be done by using subroutine Z10, which works in conjunction with the interrupt facility.
Z10 preserves the contents of M,L,K,s and t, and the overflow warning, and normally dumps the store into the library section of the standard tape 1, though it can be altered to dump in any required position. When using this facility to break into a program, there are various matters which require consideration. Most important, the program which comes on must not itself be dumped in the same blocks. Equally, it must not use the same output devices as the original program, and if the original program was using magnetic tape, the substitute program must not destroy any information on the tapes. This imposes limits on the compatibility of programs, but it is good practice to include subroutine Z10 in a program if storage permits, so that in case of necessity it can be interrupted. If it is required to dump the main store, library routine A4 must be used instead of Z10.

6. Library Subroutines

Many of the library subroutines are stored on the standard tape 1, in the blocks with numbers less than 200. Any attempt to write in these blocks (except when store dumping by use of Z10) leads to a report. For purposes of magnetic-tape storage the subroutines are specially numbered (see list in Appendix 3), and they can be transferred to the free store in two ways.

(i) During program input. The directive

```
q/
```

causes subroutine number q to be transferred to the free store with its first order in the register specified by p1. It is ESSENTIAL that p1 should be EVEN, it is therefore advisable to use the directive

```
rq/
```

unless p1 has been set explicitly. If it is desired to label the first order of the subroutine by a parameter, p90, say, the sequence

```
rp90 = p1
q/
```

is recommended. After the transfer, p1 is automatically set to the address of the next available register provided that the Assembly Routine is being used. If the old program input routine is being used, the

directive p1 = 9p1 must be punched on the tape unless p1 is reset explicitly. If q is greater than 199, or if there is a reading failure, there will be an input report.

(ii) During operation of a program. The orders

```
70 s m  (m EVEN)
59 f 18
 1 r q
```

will cause subroutine number q to be placed in the store starting at register m. The value of t is irrelevant: the correct number of words is read automatically.

7. The Autocode Compiler

This may be called down from the standard tape 1 and started by the special directive

```
144 / ≠ 2 c.r., l.f.
```

8. The Assembly Routine

This may be called down from the standard tape 1 and started by the special directive

```
25 / s 2  c.r., l.f.
```

9. Miscellaneous Information

(a) Transfer time. The average transfer time is 0.8 msec per word, i.e. 40 msec for a 50-word block. The tape is traversed at 100 in. per second, and thus takes about 90 seconds to traverse from

block 200 to block 2000.

(b) Writing rings. If it is desired to prevent the accidental overwriting of information on a private tape, the private tape reel can be fitted with a writing ring. This is an iron ring which fits on the back of the tape spool. When the spool is mounted on a deck the green "NOT RECORDING" indicator at the right-hand side of the deck is illuminated, and if an attempt is made to write on the tape the machine stops with the yellow "NOT WRITING" indicator on the control panel illuminated. The tape continues to move until the Run key is raised and the Set Start key is operated.

(c) Stopping a tape. A tape can always be stopped in emergency by raising the Run key and operating Set Start key. N.B. A tape should NOT be stopped by switching the power off.

(d) If the numbers on top of a tape deck are illuminated in red, this means that the block-mark protection circuit has been turned off. No harm is done by using the deck in this condition, but as a safety precaution the red lamp should normally be switched off, by the switch at the side of the number panel, thus replacing the block-mark protection.

(e) If an attempt is made to use a non-available tape unit (i.e. non-existent, or switched off, or switched to "Manual") the machine will stop with the "Magnetic Tape" lamp on the control panel illuminated. This also happens if the tape reaches the optical mark at either end, or if there are no block marks on the tape.

(f) If the Run key is raised whilst information is being written on magnetic tape the machine will not stop until the writing of the current block has been completed.

(g) All magnetic-tape routines in the reserved store change the contents of M,L, and t; all except 59 f 39 disturb K also. 59 f 18 and 19 preserve s unless it is odd, in which case it is decreased by unity. 59 f 39 preserves s intact, 59 f 38 destroys it. All reset overflow.

(h) Block 0 does not exist on any tape and an attempt to use it will usually cause the tape to run away. Therefore, if a block number is to be set in the course of a program, it is desirable to insert initially a bogus block number in the program parameter rather than to leave it zero, so that, if by some error the correct value is not inserted, the program will not attempt to find block 0. Thus 59 f 18, 1 r -1 is preferable to 59 f 18, 1 r 0.

(j) The TRACE facility can be used with programs that use the magnetic tape system.

(k) When a positioning operation finishes, the sign digit of register 2 in the reserved store changes from a 1 to a 0. Thus the orders

```
110 f 2
55 r -1
```

will delay a program until positioning has finished. Note that this detects the end of positioning: the fact that the sign degit of 2 is a 1 does not necessarily mean that positioning is in progress.

As long as a slave movement is uncompleted the sign digit of register 126 in the reserved store is a zero, hence the orders

```
110 f 126
55 f
```

can be used to sense the completion of the slave movement.

10. Changing Magnetic Tapes

The tape which is being loaded or unloaded is always on the right-hand side of the unit.

To UNLOAD a tape, press the right-hand of the two "Unload" buttons for the appropriate unit, holding the button down until the "Unload" indicator is illuminated. The unit will automatically unload onto the right-hand reel, and finally the red "Off" indicator will be illuminated. If the tape has a transparent leader this should be slipped out from under the head before unclipping from the left-hand spool.

To LOAD a tape, mount the tape on the right-hand hub, with the unit "Off". Press the left-hand of the two Load buttons associated with the unit: the spools will now rotate freely. Turn the left-hand spool until the spring catch is at "Twelve o'clock", and thread the tape across the bridge, under the head, securing it by the catch on the left-hand reel. Rotate this

reel clockwise until the transparent leader is clear of the bridge, then close the doors. The tape will load, and the green "Remote" indicator will come on.

The MANUAL buttons cause the tape to move to the left or right, respectively; after manual operation it is necessary to press the "Remote" button to return the unit to machine control. Note that the tape can only pass the optical mark during unload; at any other time the tape is stopped when the mark is reached.

The following precautions should be observed when changing tapes.

(a) The tape reel removed from the unit MUST be placed in its polythene bag IMMEDIATELY, and the tape and bag placed in its can as soon as possible.

(b) The new reel must be securely locked on its hub before automatic loading starts.

(c) The doors of the tape unit must not be left open any longer than is necessary for changing the tape reel.

(d) Tape reels must be held by the handle, NEVER by the rim, and should never be laid down except in a polythene bag.

A cupboard for the storage of magnetic-tape cans is situated by the line printer.

11. Programming with magnetic tape

(a) Layout of records on tape.

The simplest procedure is to put records head to tail on the tape. The book-keeping involved is trivial, since after each record is written (or read), t contains the address of the block at which the next record can begin. However, if records are to be read successively, with an appreciable amount of computation (i.e. more than 100 msec) between each two read operations, the maximum transfer rate will be obtained by arranging that the last block of the record contains not more than 30 words, or by leaving an empty block if the last block of the record is full. In this way there is time for the tape to come to rest and to restart subsequently without overshooting the beginning of the next record.

If it is required to read or write in the next block of a sequence

after more than 20 msec of computation, and if the previous block of the sequence contains its full 50 words, time can be saved by including a positioning instruction immediately after the last block is used, i.e. before the computation.

If a record extends over several blocks, it is possible to read or write in any of the constituent blocks individually, and it is therefore possible to make an alteration in the middle of a long record without reading it into the main store in its entirety.

It is wasteful to write sparse information on the tape without first packing it in the free store.

(b) Errors and Checks.

When a record is read from the tape, the transfer is checked block by block, and the reading of each block may be repeated up to ten times. There is no guarantee, however, that the information read is the same as that originally written on the tape, since another user may have overwritten some of the blocks. This can be guarded against by storing the overall check sum, which is left in M after a record has been written, and adding it (fixed point,) to the content of the M after reading the record. If the information is the same in both cases this sum will be zero. If a record is transferred incorrectly, it is most likely that the error or errors occur in only one block. If the special error exit of the magnetic-tape control routine is selected, the positions of the blocks containing errors are indicated by the binary ones in M; digit M_i is a one if the ith block contained an error (i = 1,2,3...).

If information written on the tape is to be read frequently, or if it is the result of many minutes of calculation, it is worthwhile using the checked writing facility of 59 f 18. However, since checked writing increases the transfer time by a factor of three, the programmer should consider whether the extra protection is worth the reduction in speed.

(c) Recovery after errors.

In a long program, particularly one using magnetic tape, it is important that provision should be made for restarting the program, in the event of a machine error, without wasting all the previous time. Restart procedures will normally be by way of a store-undump (see Section 5). If store dumping is to be employed with a program which uses magnetic tape, it is essential to arrange that, in the event of a store undump, the relevant information is still available on tape. This will usually mean that the program should be designed to take data from one tape and

write the results of the calculation on another, only destroying the original data when it is certain that the whole of the current stage of the calculation has been completed successfully.

An alternative to store dumping, for purely magnetic-tape errors, is to use some form of error-correcting scheme for magnetic transfers. There are many such schemes; they all involve using the error-exit facility to send control to a recovery routine in the event of an error. Two simple schemes are as follows.

(i) The simplest possible technique is to write everything twice. This is reasonable if the information is to be written rarely and read repeatedly. A very convenient scheme is to write the information in duplicate on two tapes, tapes 1 and 2, say. The program takes information from tape 1, and keeps tape 2 in step by means of the slave tape facility. In the event of an error the transfer is repeated from tape 2; it is unlikely that the same error will occur on an entirely separate tape. If, however, this second attempt should fail, a definite indication, e.g. a stop order, should be provided. The programming required for this scheme is simple, and is outlined below.

MAIN PROGRAM	RECOVERY PROGRAM
59 f 39	80 s p97(96
2 f 100 (see below)	79 sr 4
70 s -(99	80 s p99
70 t -(98	80 t p98
59 f 18	59 f 18
65 r -(97	66 r -1
50 f p96	101 f 1
------(95	50 f p95

This is almost self-evident, except for the slave control. The parameter 2 f 100 is an arbitrary value: due to the idiosyncracies of the slave control routine (see Appendix 1) it is desirable always to specify a slave distance in excess of that required.

(ii) The second method to be described is a more elaborate one, which is capable in principle of correcting any number of errors in a single block, provided that all the other blocks are correct. Suppose that the record consists of an integral number of 50-word blocks (if necessary, the last block of the record is filled with dummy information). We arrange to write an additional check block, in which the ith word is the sum of the ith word in each preceding block. (This sum should be formed fixed point, ignoring overflow.) The first step in the event

of error is to locate the block containing the error(s), and to check that all the other blocks are correct. This is done as follows, using the information left in M at the error exit from 59 f 18. If the record starts at block m_o, the orders

```
90 sr 0
 3 s  0
70 s  m_o
```

place in s the number of the block containing the first error. The orders

```
66 t 2
53 f --
```

now check that there are no more errors - if there are the 53 order will cause a jump. If there is only one erroneous block then, by forming the sums of the ith words and comparing them with the sums found in the check block, the error(s) can be corrected. This procedure is facilitated by placing in the check block the complements of the sums rather than the sums themselves. This method of error-correction becomes less effective as the number of blocks in the record increases, due to the method of forming the check sums. It would be much better to form them with end-around-carry, but this adds to the complexity of the programming, and is probably not worth the effort.

APPENDIX 1.

SPECIFICATIONS OF PERMANENT SUBROUTINES FOR MAGNETIC-TAPE CONTROL

(1) 59 f 18. General magnetic-tape control.

Followed by a program parameter:

F k m where F = tape number
m = block number and
k = f for checked write
= t for unchecked write
= r for read
= s for position.

On entry, s specifies the first register of the transfer and $\frac{1}{2}$t the number of words to be transferred. If s is odd, unity is subtracted from it. t can have any value: if t > 100 the information is automatically written into or read from the appropriate number of consecutive (50-word) blocks. On exit, t contains the number of the next available block and M contains an overall check sum: the check sum on reading is the fixed-point complement of the check sum obtained when writing, if the transfer is correct.

If the transfer is found to be incorrect the machine repeats the operation up to a maximum of ten times, then prints the program parameter F k m and normally reports with t=5. Alternatively, a special error exit can be selected by adding 64 to the tape number in the program parameter.

In this case exit is normally to the order next but one after the program parameter, but if an error occurs, the program parameter is printed (setting page layout as for a report), then exit is to the order following the program parameter. On this error exit the ith digit of M is a one if the ith block of the sequence was incorrectly transferred, and the other digits of M are zeros. t does NOT indicate the number of the next block available.

Irrespective of whether or not the error exit is selected, there will be reports, identified by the value of t, if

(a) ten successive block labels are faulty (t=9)
(b) writing in the selected block is not permitted (t=4)
(c) the tape number does not agree with the tape number called for (t=3)
(d) the block is of zero length (t=4).

NOTES

1. The function F in the program parameter is treated modulo 8.
2. If t=0 on entry there will be a report as if on a block of zero length.
3. K is changed: overflow is reset.
4. If, following a magnetic tape transfer, the old program input routine is entered, parameter 3 will appear set to the tape number and parameters 4 and 5 may appear to be used but not set. This means that they CANNOT BE RESTORED BY AN EXPLICIT DIRECTIVE UNLESS THEY ARE FIRST UNSET by means of the directive = 4. It is therefore recommended that programs using the old input routine should not use parameters 3, 4 and 5.
   NOTE PARTICULARLY that it is quite permissible to use parameters 4 and 5 if the Assembly Routine is used.
5. If a record starts at register m and is n words in length, the condition $m+2n < 2048$ must be satisfied. If it is not satisfied the record will not in fact be transferred correctly, though it may appear to have been transferred.

(2) 59 f 19. Read block label.

Followed by a program parameter:

F k m where F is a tape number (modulo 8) and k and m are irrelevant.

Places in M the next block label on the tape, and places in t the number of this block. Changes the content of K and resets overflow. Reports with t=9 if ten successive block labels are found to be faulty.

See note 4 of 59 f 18 above.

(3) 59 f 38. Store dumping and undumping.

Followed by a program parameter:

F k m where F is a tape number (modulo 8),
m is the number of the first of 23 consecutive blocks to be used, and
k = f for dump
= r for undump.

In a store dump the contents of the free store (except register 2046) and relevant parts of the reserved store (e.g. parameters, and digit and page layouts) are written on the selected tape; the program is then resumed at the order following the program parameter.

In a store undump the free store and relevant portions of the reserved store are reinstated to the conditions immediately before the dump order, and control is resumed as if emerging from the dump routine.

However, when the program is so resumed, the contents of M, L, K, s and t, will differ from what they were when the dump order was executed.

Reports may occur as for 59 f 18.

The error exit facility is not available.

(4) 59 f 39. Slave tape

Followed by a program parameter:

F f m m is the number of blocks the slave has to travel
F is the tape number, plus 64 if the slave has to move backwards.

The slave will move whenever any other tape is moved under control of 59 f 18 or 59 f 38, provided that such movement would not take it past the desired position.

When m blocks have been traversed the slave is automatically disconnected: it is also disconnected when the store is cleared. M and L are changed, overflow is reset; nothing else is disturbed.

The distance moved by the slave tape is usually less than specified; however, the slave will never finish further away from the desired position than it started.

The exact rules governing slave operation are as follows:

(a) If the master tape is positioning, either autonomously or as part of a data transfer, the slave tape moves the same distance (within one block) unless this movement would take it past the desired position.

(b) Whilst data is being transferred, the slave moves approximately 4/5 of the specified distance, or less if the blocks on the master contain fewer than 50 words.

(c) If an autonomous positioning operation is cut short by a reading or writing operation, the distance moved by the slave will be curtailed accordingly.

(d) If a tape which has been selected as a slave is moved under control of 59 f 18 or 59 f 38, such motion will over-ride the slave motion required, but the distance traversed will be taken account of by the slave tape control.

APPENDIX 2

MAGNETIC TAPE REPORTS.

Order	Value of t	Significance	Probable Cause (excepting machine errors)
59 f 18 59 f 19 59 f 38	9	Ten successive block labels incorrectly read	Tape has been moved beyond block 1200 or 2000 of last section
59 f 18 59 f 38	4	Block not available for writing	(i) Trying to write in a block below 200 (except when using Z10). (ii) 59 f 18 entered with t = 0.
59 f 18 59 f 38	3	Wrong tape number	Wrong tape mounted on deck
59 f 18	5	Check-sum failure	(i) Trying to read from a block in which nothing has been written (ii) Length of record on reading differs from length of record written. (The report is preceded by the program parameter, which indicates the type of operation.)
59 f 38	5	Check-sum failure	Undumping without previously dumping.

APPENDIX 3

Routine	Number	Routine	Number	Routine	Number
A1	92	Q1	118	V19	83
2	93	2	119	20	59
3	85	3	120	21	58
		4	121	22	56
B2	100	5	122	23	54
3	101	6	96	24	52
4	102	7	97	25	50
		8	98		
F2	103	10	114	Z5	141
4	104			6	142
5	87	R1	123	8	143
6	106			11	88
		V1	124	12	90
G1	105	3	125	13	86
3	107	4	126		
		7	127		
J1	108	8	128		
		9	130		
K1	109	10	131		
2	110	11	132		
		12	134		
M1	111	14	135		
		16	137		
P3	115	17	94		

(ii) Store dumping

Subroutine Z10 is incorporated in programs by starting the program tape with the directives

99/s9
25/s2

The effect of these is to place Z10 in locations 2006 to 2045 inclusive then to enter the assembly routine. If it is desired to read constants by the asterisk facility, p2 should be set to a suitable value (say 1952) by an explicit directive.

A program which has been dumped by Z10 on the standard tape 1 may be undumped by reading the directive 99/s3.
Directive 99/s2 places Z10 in the store, then enters the old program input routine.