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THE MURA ASSEMBLER, MURASS

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1. Introduction

The MURA assembly program, known as MURASS, is a one-pass, block-type assembler. The duties of MURASS are to read a set of instructions and numbers written in a simple, symbolic form which will be described, translate them into the equivalent IBM 704 instructions and binary numbers, produce a deck of cards containing the translated words, and prepare a printed side-by-side listing of the symbolic words and their translation. MURASS was created for several reasons. A one-pass assembler requires less machine time than assemblers requiring multiple passes; the difference becoming quite significant in machine configurations having no tapes or drums. (It has been argued that a machine installation must have tapes and drums to avoid the expense of the otherwise long assembly times. However it can be readily shown that this argument is not economically sound for every installation). Block-type assemblers are easy to use. It is not clear that a very general symbolic address specification possesses an advantage over the simple scheme which employes relative decimal addresses terminated by a symbol specifying the base address. In fact, the former scheme because of its generality and consequently greater information content leads to more errors than the latter scheme. The automatic storage assignment feature possessed by the two-pass assemblers often makes partial assemblies extremely difficult, while a block assembler leads to easy partial assemblies. In very general multipass assemblers and compilers there is a tendency to become so far removed from the machine language that debugging becomes a much more difficult problem than it is already. For these reasons and others of a more minor nature it was felt worthwhile to construct a simple one-pass block-type

assembler for the MURA installation, and so MURASS was conceived and executed.

2. The MURASS Card Format

Figure 1 is a picture of the MURASS card. It will be noted that this card is divided into seven fields. In the fields labeled WORD 1 (Cols. 7-21), WORD 2 (Cols. 22-36), WORD 3 (Cols. 37-51) and WORD 4 (Cols. 52-66), the MURASS words to be translated into IBM 704 words are entered. The MURASS words, reading from left to right, are assembled into successive addresses, the first address being specified by the characters in the LOCATOR field (cols. 1-6). Some MURASS words, as we will see, are of a special nature not requiring assembly of the words into storage* and for these the locator field has no significance and should be left blank. The LOCATOR field and the four WORD fields are rarely completed filled. Characters are entered in these fields from left to right with no blanks between the characters within a field. This is universally true save one minor exception (see the discussion of word type N). The first character of the IDENT field is ignored by MURASS and it is desirable to leave it blank. Any characters, including blanks, may be entered in columns 68 through 72 (the remainder of the IDENT field); this set of five characters is called the Identification Number. The Identification Number identifies the program to which the words on the card belong, and it is used to partially specify symbolic block addresses. Columns 73-80 are completely ignored by MURASS and are used for card labeling. (In columns 73-76 a program classification number is placed and the last four columns are used for card sequence numbering.)

Any number of the WORD fields may be left totally blank. Words with a blank for the leading character in the field are ignored. However, the blank words must be the right-most words; the process of entering words must begin in the

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*Type L, O, and T words fall in this category.

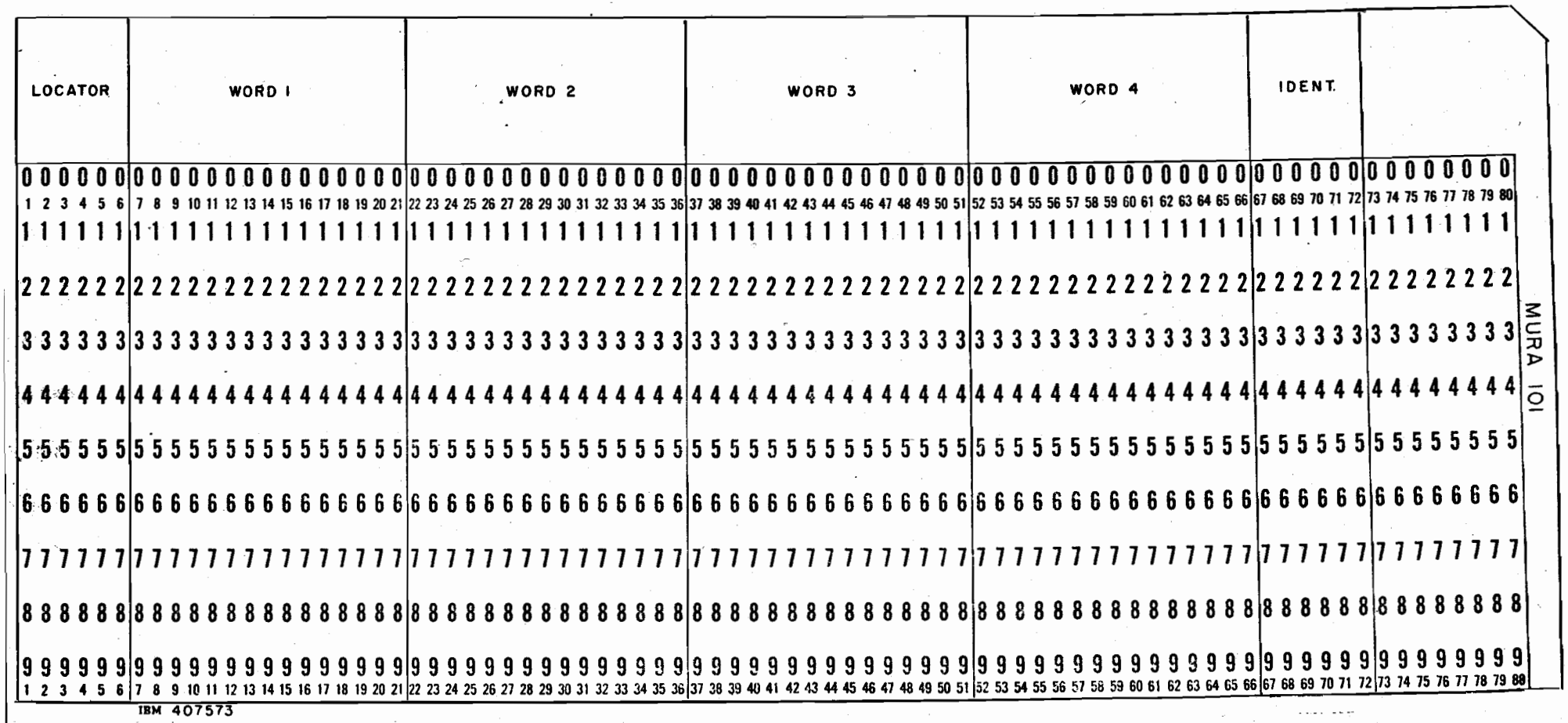

Fig. 1 - The MURASS Card

WORD 1 field and proceed consecutively. For obvious reasons it is desirable to have words entered in all of the WORD fields.

The first character in the WORD field is called the type character and defines the type of word in the field. There are eleven such characters recognized by MURASS: L, A, B, C, D, E, F, I, N, O, and T.

3. The MURASS Word Types

Word Type L

The type character L identifies this word as an entry in the block symbol table which is created by MURASS for the purpose of assigning absolute addresses and decrements to the MURASS instructions. The details of the construction of these addresses and decrements will be described later.

The absolute address of the block* defined by the type L word is written as a decimal integer immediately after the letter L. This integer is interpreted modulo $2^{15} = 32,768$. A single alphabetic letter, called the termination symbol, is placed after this integer.

MURASS operates on this word in the following way. The termination symbol, coded as a BCD character, is prefixed to the five BCD characters composing the Identification Number of the MURASS card on which this word is located. This 6-BCD-character word, called the symbolic block address, is entered in the memory location immediately following the last word stored in the block symbol table. In the succeeding storage location the absolute address of the block (i.e. the decimal integer following the type character L) is entered as an integer scaled by 2^{-35}.

Words with type character L may not be mixed with words of any other type on a MURASS card. Failure to observe this rule will result in an incorrect assembly but no program stop.

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* The address of a block is understood to mean the address of the first word in the block.

Word Type A

The type character A identifies the MURASS word as one of the five possible IBM 704 type A instructions (Cf. page 12 of the IBM 704 Manual). The MURASS word is composed of four fields following the type character which are, in order from left to right, the prefix field, the address field, the tag field, and the decrement field; Fig. 2 indicates the arrangement of the fields.

Type	Prefix	Address	Tag	Decrement

Fig. 2: The arrangement of the fields in the type A MURASS word.

The type field must of course contain the letter A.

The prefix field contains a single alphabetic letter A, B, C, D or E, which instructs MURASS to insert a corresponding binary number in the prefix field of the 704 word which is being formed from the MURASS word. Table 1 lists the MURASS prefix, the corresponding 704 binary prefix, and the corresponding symbolic mnemonic notation used by the IBM 704 Manual (and SHARE).

MURASS	704 BINARY	IBM MNEMONIC
A	001	TXI
B	011	TXH
C	111	TXL
D	010	TIX
E	110	TNX

Table 1: The 704 binary equivalents, and the IBM mnemonic equivalents of the MURASS prefixes.

The formation of the prefix is the first step in the construction of the 704 word. The other parts of the word are constructed in the order shown, reading from left to right, in Fig. 2. This first step is made by searching a table stored in the memory and finding a word designated by the MURASS prefix. This word

contains the binary prefix for the desired 704 instruction with zero in every other bit position, and having found the word it is placed in a special "working" memory location. Later, as will be described, when the address is formed it is logically added to the partially constructed 704 word in the "working" memory location, and similarly for the tag and decrement.

The address field is composed of two parts, a relative address followed by a terminating symbol. The 2's complement of the address is formed if the first character in the address field is a minus sign.

The relative address is written as a decimal integer N, and is interpreted to mean the Nth word of some block of storage. The storage block to which the relative address refers is specified by the terminating symbol and the Identification Number of the card on which the instruction being translated appears. The terminating symbol must be a letter of the alphabet or an asterisk. If the terminating symbol is alphabetic the block symbol table is searched for the symbolic block address created by prefixing the Identification Number by the terminating symbol, represented as BCD characters. When the symbolic block address is found its associated absolute block address is extracted and added to the relative address to form the absolute address for the instruction. If a minus sign preceded the relative address the 2's complement of the absolute address is formed and inserted in the address field of the 704 binary word. If a minus sign did not precede the relative address then the absolute address itself is inserted in the address field of the 704 binary word. Finally, if the terminating symbol is * the relative address itself is taken as the absolute address, the Identification Number being completely ignored, and, as in the above case, a minus sign preceding the relative address results in the 2's complement of the absolute address being inserted in the address field of the 704 binary word.

The insertion of the address in the 704 word being constructed is done as follows. The absolute address, or its 2's complement, at the completion of its construction is placed in the accumulator as an integer scaled by 2^{-35}. An extraction on bit positions 21 through 35 is made and the result is logically added to the "working" word (recall that this word contains the partically constructed 704 word). It should be obvious from this discussion that the addresses are formed modulo 32,768.*

The following rules regarding the MURASS addresses must be observed. Failure to observe these will result in a program stop (Cf. MURASS Program Stops, Section 7).

(1) There must be a terminating symbol, alphabetic letter or *, following the relative address.

(2) The total number of decimal digits in the relative address, N, plus the number of characters in the sign of the address (one or zero) cannot exceed 5. Thus the maximum N is 99999 for positive addresses and the maximum N is 9999 for negative addresses.

(3) If the terminating symbol is alphabetic then the block symbol, formed by prefixing the Identification Number with the terminating symbol, must be in the block symbol table. (This is done via word type L as explained earlier.) If the terminating symbol is * this restriction does not apply.

If the relative address is zero it may be omitted entirely; however the termination symbol must still appear (e.g. to have an absolute address of zero an asterisk is placed in the address field.)

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* Decrements are inserted in the "working" word in the same way except that an accumulator left shift of 18 places is made immediately after the extraction.

All of the above remarks pertaining to the instruction address apply to all other instruction addresses; hence in later discussion of the address of other instruction types we will refer to the above discussion.

We now discuss the MURASS tag. This is written as a single digit decimal integer T, $0 \leq T \leq 7$. MURASS forms T as a binary integer scaled by 2^{-20} and logically adds it to the 704 word being constructed. Thus T is numerically equal to the tag placed in the 704 word. If the above limits on T are not observed, that is if T = 8 or T = 9, then there will be a spillover into the decrement field; the net effect being to add one to the decrement and giving 0 or 1 in the 704 tag field. This misbehaviour will not cause a program stop. Finally, the tag, even when zero, must be written. Failure to do this will result in the first character of the decrement being interpreted as the tag. Again, this misbehaviour will not cause a program stop.

Finally we arrive at the decrement of the MURASS word. This is easily disposed of since the MURASS decrement is treated exactly like the MURASS address with the single obvious exception cited in the footnote on Page 7. Consequently, all rules pertaining to the characters in the MURASS address field apply also to the characters in the MURASS decrement field, and the reader is referred to the preceding discussion of the address. A final word of caution - the decrement must be explicitly entered in the MURASS word even if it is to have the value zero; if a decrement of zero is desired, simply place an asterisk in the MURASS decrement. Failure to observe this word of caution will result in a program stop (Cf. MURASS Program Stops, Section 7).

Word Type B

The type character B identifies the MURASS word as one of the 81 possible IBM 704 type B instructions (Cf. Page 12 of the IBM 704 Manual). The MURASS word is composed of three fields following the type character which are, in order from left to right, the operation field; the address field and the tag field; Fig. 3 indicates

the arrangement of the fields.

Type	Operation	Address	Tag

Fig. 3: The arrangement of the fields in the type B MURASS word.

The type field must of course contain the letter B.

The operation field contains the standard IBM 704 symbolic mnemonic operation code letters as given in the 704 Manual. Thus, the letters CLA are entered in the operation field for the clear and add instruction, ADD for the add instruction, etc..

Following the procedure for the type A word, the first step in the construction of the 704 word is the formation of the appropriate bit pattern for the operation specified by the three letter symbolic mnemonic operation. This first step is made by searching a table stored in the memory and finding a word designated by the MURASS operation. This word contains the correct bit pattern for the desired 704 operation with zero in bit positions 12 through 35, and having found the word it is placed in the "working" memory location. Subsequently the address and tag will be logically added to this word to finally form the desired 704 instruction.

The MURASS address field for the type B instruction is treated exactly like the address field for the type A instruction; hence all rules regarding the address are the same.

The rules regarding the MURASS tag for the type B instruction are identical to the rules for the tag in the type A instruction with one exception, namely, the tag may be omitted. If the tag is omitted then zero will be in the tag field of the 704 word.

Word Type C

The MURASS word with type character C is, with the exception of the prefix field, identical in form and treatment to the MURASS type A word. The prefix differs in that a single octal digit is placed in the MURASS prefix field and the resultant 704 word has this octal digit in its prefix field. If an 8 or 9 is inadvertently placed in the MURASS prefix field the resultant prefix of the 704 word will be 0 or 1 respectively (i.e. the prefix if treated modulo 8). Such an error does not cause a program stop. A prefix must be specifically entered. Failure to do this will result in the first character of the address being treated as the prefix and a program stop is possible.*

This word type is particularly useful when a constant with a special value for the prefix is desired.

Word Type D

The MURASS word with type character D is, with the exception of the operation field, identical in form and treatment to the MURASS type B word. The operation field differs in that a four digit octal number is placed in it rather than the three letter mnemonic for an operation, and the resultant 704 word has this four digit octal number in its operation field.

The octal number, n, placed in the operation field of the 704 word is obtained from the arithmetic process

$$n = e_3 8^3 + e_2 \times 8^2 + e_1 8 + e_0 \text{ (modulo } 2^{12})$$

where the octal number in the MURASS operation field is

$$e_3 e_2 e_1 e_0 \quad (0 \leq e_i \leq 7)$$

If an e_i is accidentally given the non-octal value 8 or 9, the erroneous result is predictable from the above equation. Such an error will not cause a program stop.

*This would be a program stop indicating a missing terminating symbol (Cf. MURASS Program Stops, Sec. 7).

All four octal digits must be entered in the MURASS operation field. Failure to observe this rule can result in a program stop. *

Word Type E

The type character E identifies the MURASS word as an octal number. This octal number is composed of 12 octal digits immediately following the type character. The resultant 704 word will contain this octal number.

Leading zeros cannot be omitted, all 12 digits must be explicitly specified. Failure to obey this rule or the entry of non-octal digits will not cause a program stop.

Word Type F

The type character F identifies the MURASS word as a fixed point fraction. The MURASS fixed point fraction is written as a decimal number, with sign if negative and without sign if positive, immediately following the type character. The decimal point is assumed to lie immediately to the left of the first decimal digit. The fraction should contain no more than eleven decimal digits and must not exceed 0.99999999998. Digits beyond the eleventh will be ignored if the former rule is not observed, and a divide check stop (at location 3432_8) will occur if the latter rule is not observed. If no character at all follows the F the resultant 704 word is zero, and if a minus sign only follows F the resultant 704 word is minus zero.

Examples of Type F MURASS words and the resultant 704 words are given in Table 2.

MURASS Word	704 Word (Octal)
F5	200000000000
F75	300000000000
F-0625	420000000000
F99999999998	377777777777

Table 2: Type F MURASS words and the corresponding 704 word formed by MURASS.

*This would be a program stop indicating a missing terminating symbol (Cf. MURASS Program Stops, Sec. 7).

The decimal to binary conversion of the fraction is performed with maximum accuracy, the error being less than or equal to $\pm 2^{-36}$.

Word Type I

The type character I identifies the MURASS word as a fixed point integer. The MURASS fixed point integer is written as a decimal number, with sign if negative and without sign if positive, immediately following the type character. The decimal point is assumed to lie immediately to the right of the last decimal character. The integer should not exceed $2^{35} - 1$ (=34, 359, 738, 367) but if it does it will be interpreted modulo 2^{35}, and no program stop will occur. If no character at all follows I the resultant 704 word will be zero, and if a minus sign only follows I the resultant 704 word is minus zero.

Examples of type I MURASS words and the resultant 704 words are given in Table 3.

MURASS Word	704 Word (Octal)
I5	000000000005
I-100	400000000144
I1000	000000001750
I-34, 359, 738, 367	777777777777

Table 3: Type I MURASS words and the corresponding 704 word formed by MURASS.

The decimal to binary conversion of the integer is exact.

Word Type N

The type character N identifies the MURASS word as a floating point number. In contrast with the other MURASS numbers (type characters E, F and I) it has three fields, rather than two. The arrangement of the fields is indicated in Fig. 4.

Type	n	exp

Fig. 4: Arrangement of the fields in the MURASS floating point number, $n \times 10^{exp}$.

The type field contains the character N. The number represented by this MURASS word is $n \times 10^{exp}$ from which MURASS constructs the equivalent 704 floating point number in normalized form. The field designated by n in Fig. 4 contains a decimal number n, where $1 \leq n < 10$, and is written as a sequence of decimal digits with the decimal point assumed to be located between the first and second digits. A minus sign precedes the first digit if a negative floating point number is represented and the sign is omitted for a positive floating point number. n must contain no more than 9 decimal digits. Failure to observe this rule will not cause a program stop, but an incorrect number will result. The field labeled exp contains a decimal integer with absolute magnitude less than or equal to 37*, with sign for a negative exponent and without sign for a positive exponent. Failure to observe this rule does not cause a program stop but may result in an incorrect number. If the exponent is too small the MQ overflow light will be turned on. If no entry is made in the exponent field the exponent is interpreted as zero.

Examples of type N MURASS words and the resultant 704 words are given in Table 4.

MURASS Word	704 Word (Octal)
N5 -1	200400000000
N-625 -2	575400000000
N1 3	212764000000
N170141181 38	377777777777
N146936795 -39	000400000000

Table 4: Type N MURASS words and the corresponding 704 words formed by MURASS.

The magnitude of the error resulting from the conversion from floating decimal to floating binary does not exceed 2^{-28} in the fractional part of the floating binary 704 word.

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*In some cases the exponent may be 38 or -39; see Table 4.

A special rule must be observed when a type N word is placed on the MURASS card, namely, there must be a blank separating the fields n and exp. This is the only exception to the universal MURASS rule which says that no blank can appear between the characters of a MURASS word on the MURASS card. Failure to place a blank between n and exp can lead to an erroneous number but no program stop.

Word Type O

The appearance of the type character O in a MURASS word is a signal to produce entries on an Origin Card. There are special rules applying to MURASS cards containing type O words. Type O MURASS words must appear in pairs on a MURASS card in the WORD 1 and WORD 2 fields, and a second pair may be placed in the WORD 3 and WORD 4 fields. The WORD 1 and WORD 2 fields must be occupied before entries can be made in the WORD 3 and WORD 4 fields. Finally, no MURASS words of any other type may appear on the card. Failure to observe these rules will result in an incorrect assembly but no program stop.

The arrangement of the fields in a type O word is identical to that for the type A word shown in Fig. 2. Entries into these fields are made according to the following prescription:

(1) Enter the letter O in the type field.

(2) Enter the digit zero in the prefix field, or a 4 if the last or 10th origin pair (see below).

(3) Enter the nominal address in the address field.

(4) Enter the digit zero in the tag field.

(5) Enter an asterisk in the decrement field.

For the second type O word of the pair:

(6) Enter the letter O in the type field.

(7) Enter the digit zero in the prefix field.

(8) Enter the operating address in the address field.

(9) Enter the digit zero in the tag field.

(10) Enter the loading address in the decrement field.

All of the rules applying to the composition and treatment of the characters in the address and decrement fields of a type A word apply also to the type O word.

In order that the Origin Cards produced by this program be acceptable for the MURA "Relocatable to Absolute Translator, MU RAT 1," Library Subroutine, the paris of origin words must be given consecutively in order of increasing nominal address, and the last pair, and every 10th pair, if there are more than 10 pairs, must have a 4 entered in the prefix of the first word of the pair.

Word Type T

The type character T when encountered by MURASS results in the produc tion of a Transfer Card. The type T MURASS word has two fields, the type field which contains the letter T, and an address field which contains the transfer address. The characters in the address field are interpreted exactly like those in the address field of the type A instruction.

Only one type T word may be entered on a card. It must be entered in the WORD 1 field and the other fields must be empty. Failure to observe these rules will result in an incorrect assembly but no program stop.

4. The LOCATOR

A brief description of the properties of the LOCATOR field on the MURASS card was given earlier in Section 2. A complete description is given in this section.

The LOCATOR field has no significance, and is in fact ignored by MURASS on cards which contain type L, O or T words. For uniformity in the assembly

listing, described later, it is customary to leave the LOCATOR field blank on such cards. However, this is not necessary, and whatever does appear in the LOCATOR field will also appear on the assembly listing without any effect on the logical operation of MURASS.

The LOCATOR field is significant on cards which contain type A, B, C, D, E, F, I, and N words. On such cards the LOCATOR field contains an address written in the standard form described in detail above for the type A word. This address is the loading address for the first word on the card and successive words have successive loading addresses.

The address in the LOCATOR field on successive MURASS cards affect the format of the output, both the listing and the binary cards, as we shall see in the next section.

5. The Cards Produced by MURASS

Three types of cards are produced by MURASS; absolute binary cards, relocatable binary cards, and origin cards.

MURASS absolute Binary Cards

The format for these cards is identical with that for the standard SHARE absolute binary cards, with the exception that bit positions 9L6, 9L7, 9L8 and 9L9 are always punched out. Thus, the format of the absolute binary cards is as follows:

(1) 1's in 9L6 - 9L9 inclusive.

(2) Word count in 9L13 - 9L17 inclusive.

(3) Initial loading address in 9LA.

(4) Check sum in 9R.

(5) Successive words in card positions 8L, 8R, 7L, 7R, etc.

(6) The maximum number of words on a card is 20; hence 12L and 12R will never be occupied.

We consider now the steps taken in the formation of the binary card. Successive MURASS symbolic cards are read and the words contained thereon translated into the 704 binary words and stored in a block of storage called the binary word bank. This will continue until one of the following situations arises:

(a) The binary word bank contains 20 words.

(b) The address, β, specified by the LOCATOR on the card just encountered (but not yet translated) and α, the one on the preceding card (already translated) are such that $\beta - \alpha \neq 4$.

(c) The Identification Number on the card just encountered (but not yet translated) is not identically equal to the Identification Number on the preceding card (already translated).

(d) A card containing type L words is encountered and the preceding card did not contain type L words.

(e) A card containing type O words is encountered and the preceding card did not contain type O words.

(f) A card containing a type T word is encountered.

(g) A card <u>not</u> containing type L words is encountered and the preceding card did contain type L words.

(h) A card <u>not</u> containing type O words is encountered and the preceding card did contain type O words.

(i) A MURASS absolute binary card is encountered.

(j) An end of file condition for the card reader is detected.

In all situations, except (g), the contents of the binary word bank are punched onto an absolute binary card and a corresponding page of the listing is printed, following which the translation and reading process is resumed. In (g), since no binary cards are produced corresponding to type L words, just a page of the listing for the type L words is prepared.

In situation (f), above, not only are the present contents of the binary word bank

punched onto a card, but in addition a transfer card is prepared, and a corresponding page of the listing is printed. The transfer card has the transfer address in 9LA and no other entries.

In situation (h) an origin card is produced. The format for this origin card is discussed later.

We note from (i) above that MURASS does accept MURASS absolute binary cards. It will read such cards and reproduce them identically and prepare a page of listing showing the 24 octal words on the corresponding card. These binary cards may appear anywhere, in any order, within the deck of cards that is being read by MURASS.

It follows from the above remarks that a properly ordered MURASS deck (successively increasing LOCATORS and all cards with the same IDENT together) will yield the minimum number of binary cards. However, any MURASS cards containing word types A, B, C, D, E, F, I, and N in any combination may be ordered in any way and a proper set of binary cards will result; the only difference being that the binary words are distributed over a larger number of binary cards than when the MURASS cards are in the proper order. The cards containing type L words may also be mixed in any order with the exception that the symbolic block addresses that they define must not be referred to until they have been previously defined by a type L word. Failure to observe this rule will cause a program stop (Cf. MURASS Program Stops, Sec. 7) indicating an undefined termination symbol. It is therefore good practice to put all cards containing type L words at the beginning of the MURASS deck. Cards containing type O words must be arranged in order of increasing nominal address. Failure to do this will not result in a program stop but the origin cards produced will have correspondingly disordered nominal addresses and will be unsuited for use with MU RAT1 .

The card containing a type T word may appear anywhere in the deck. However, it will always appear among the binary cards in the order corresponding to its appearance in the MURASS deck and since it is customary to have the transfer card

at the end of the binary deck it is good practice to place the card containing the type T word at the end of the MURASS deck.

MURASS Relocatable Binary Cards

The format for the MURASS relocatable binary cards is identical with that for the standard SHARE relocatable binary cards. Thus, the format of the relocatable binary cards is as follows:

(1) 9L1 is punched.

(2) Word count in 9L13-9L17 inclusive.

(3) Nominal initial loading location in 9LA.

(4) Indicator bits are in the 8-row starting from the left.

(5) The following one and two-bit codes are used to indicate the type of field:

0 absolute field

10 relocatable direct field

11 relocatable complemented field

(6) Words to be loaded are in 7L, 7R, 6L, 6R, etc., with a maximum of 20 words allowed on the card.

The steps involved in the reading of MURASS cards and the preparation of relocatable binary cards are like those discussed for the absolute binary cards. There is however one additional situation which will cause the punching of a card. When the number of indicator bit positions that have been used is 67 to 70 (which could conceivably occur for 17 words), then the contents of the binary word bank are punched onto two relocatable binary cards: the first card will contain the words in the first portion of the binary word bank up to the point where the aforementioned condition on the indicator bit positions is met; any remaining words in the binary word bank are punched on a second card. In this instance the contents of the two cards will appear on the same page of the printed listing.

MURASS Origin Cards

The format for the MURASS origin cards is as follows:

(a) 9L3 is punched,

and in rows 8, 7, 6, etc. (indicated by N below),

(b) nominal address in the left address field (NL21 - NL35),

(c) loading address in the right decrement field (NR3 - NR17),

(d) operating address in the right address field (NR21 - NR35),

(e) LS is punched in the last row used.

The origin cards will be suitable for use with MU RAT1 if the type O words in the MURASS deck are in order of increasing nominal address, as mentioned earlier.

6. The Listing Produced by MURASS

On the listing there appears the complete contents of every MURASS card that has been read and the complete contents of every binary card (absolute, relocatable, or origin) that has been produced. There is a one-to-one correspondence between the pages of the listing and the cards produced. * Each line of the listing corresponds to a single word on the binary card. On the same line there appears the corresponding MURASS word, and the nominal address of the word. The detailed format is most easily described by an example.

Let us consider the assembly of a program with identification number LB304, containing just two termination symbols, A and T. Assume that we want the block with symbolic address ALB304 to be at 100_{10} and the block with symbolic address TLB304 to be at zero. A MURASS card with the two appropriate type L words is

*An exception to this occurs in the unusual circumstance of indicator bit overflow, the contents of the two cards appearing on one page of the listing. (See page 19.)

made and placed at the beginning of the MURASS deck. The page of the listing corresponding to this card is shown in Fig. 5. The columns have been labeled for the purposes of this discussion only. In the IDENT column the identification number, entered in cols. 68-72 of the IDENT field of the MURASS card, appears. The LOCATOR field of the MURASS card has been left blank; hence nothing appears in the column labeled LOCATOR. L100A was entered in the WORD 1 field of the card and appears on the first line of the column labeled MURASS WORD. L0T was entered in the WORD 2 field of the card and appears on the second line in the MURASS WORD column. The space separating the type character from the rest of the word is a property of the printer board wiring and does not exist on the MURASS card.

In Fig. 6 is shown the first page of the listing assembled with the above type L words, when absolute binary cards are produced. Entries appear in the IDENT and LOCATOR columns just once per MURASS card and appear on the same line as the MURASS WORD in the WORD 1 field of the card.

Thus, the first MURASS card of this program has

(1) LB304 in cols. 68-72 of the IDENT field.

(2) A in the locator field; more specifically A is in the first column of this field or col. 1 of the card.

(3) BTPL1*4 in the WORD 1 field; more specifically, the word occupies cols. 7-13.

(4) BSXD11A1 in the WORD 2 field; more specifically, the word occupies cols. 22-29.

(5) BLXA11A1 in the WORD 3 field; more specifically, the word occupies cols. 37-44.

(6) BSTOT in the WORD 4 field; more specifically, the word occupies cols. 52-56.

IDENT	LOCATOR	MURASS WORD
LB304		L 100A
LB304		L 0T

Fig. 5: A typical page of a listing containing Type L words

IDENT	LOCATOR	MURASS WORD	OCTAL WORD	LOADING ADDRESS
			0 07424 0 00144	
			3 45152 3 51242	
LB304	A	B TPL1*4	0 12000 4 00001	00144
		B SXD11A1	4 63400 1 00157	00145
		B LXA11A1	0 53400 1 00157	00146
		B STOT	0 60100 0 00000	00147
LB304	4A	B CLA25A1	0 50000 1 00175	00150
		B LRS35*	0 76500 0 00043	00151
		B MPRT	4 20000 0 00000	00152
		B ADD26A1	0 40000 1 00176	00153
LB304	8A	A D5A11*	2 00001 1 00151	00154
		B LXD11A1	4 53400 1 00157	00155
		B TRA2*4	0 02000 4 00002	00156
		B HTR13*	0 00000 0 00015	00157
LB304	12A	F 00000000016	0 00000 0 00005	00160
		F 00000000209	0 00000 0 00110	00161
		F 00000002505	0 00000 0 01535	00162
		F 00000027557	0 00000 0 22375	00163
LB304	16A	F 00000275573	0 00000 2 70736	00164
		F 00002480159	0 00003 2 00320	00165
		F 00019841270	0 00032 0 03200	00166
		F 00138888889	0 00266 0 26603	00167

Fig. 6: A typical page of a listing produced by MURASS in an assembly onto absolute binary cards

In the OCTAL WORD column there appear the octal words on the first card of the absolute binary deck in the order 9L, 9R, 8L, 8R, 7L and so on; 11L, 11R, 12L and 12R which are not indicated are blank, the top blank portion of the card being always omitted from the listing. The MURASS word to the left of the OCTAL word is the one from which the OCTAL word was constructed. Note that the OCTAL word 9L (containing the MURASS absolute binary card identifying bits in cols. 9L6-9L9, the word count, and initial loading address) and 9R (containing the check sum) have no corresponding MURASS word. In the LOADING ADDRESS column the octal loading address of the corresponding octal word appears.

An assembly onto relocatable binary cards would look like Fig. 6 except that there would be no MURASS words corresponding to the 8L and 8R words of the card since they now contain indicator bits and the OCTAL word for BTPL1*4 would appear in the 7L portion of the relocatable binary card with the other words following in order.

7. MURASS Program Stops

A list of MURASS program stops is given in the table below.

Instruction	Location	Sense Light Condition	Meaning of Stop
HTR 1750_8	10677_8	1 on	Missing terminating symbol, or 6 characters in relative address
HTR 1750_8	10723_8	2 on	Undefined block address
HTR 1750_8	3114_8	3 on	Undefined operation for Type A word
HTR 1750_8	3173_8	3 on	Undefined operation for Type B word
HTR 1750_8	2762_8	1 and 2 on	Check Sum error on binary card read-in
HTR 10045_8	10132_8		Echo Check Failure
HTR 1750_8	5670_8 to 5767_8		Improper Type character
HTR 1750_8	2637_8		End of File. This is the normal stop at the end of an assembly

Table 5: MURASS Program Stops

8. Operator's Notes

1. SENSE SWITCH 1 down gives an assembly onto absolute binary cards.
2. SENSE SWITCH 1 up gives an assembly onto relocatable binary cards.
3. SENSE SWITCHES 2, 3, 4, 5 and 6 are not used.
4. Use the MURASS BOARD in the printer.
5. Use the standard SHARE 72-72 straight wired boards in card reader and card punch.
6. The MURASS program starts at location 1000_{10} (1750_8). A transfer to this location at any time after the MURASS program has been read into the memory will initiate a new assembly.
7. After an Echo Check Stop pressing the start button will result in another attempt to print correctly.