

THE ML/I MACRO PROCESSOR

ML/I user's manual

P.J. Brown

University of Kent at Canterbury

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P.J. Brown

Preface

This manual describes ML/I in full detail with examples of its applications. It is not assumed that the reader has any previous knowledge of macro processors.

A shorter, simpler, document describing ML/I is also available. This is called "The ML/I macro processor: a simple introductory guide". A paper describing how ML/I is implemented appeared in Communications of the ACM 13, 12 (Dec. 1972), pp. 1059 - 1062; the book Macro processors and portable software (J. Wiley, 1974) contains further details.

Preface to the Fourth Edition

The Fourth Edition of the ML/I User's Manual contains few significant changes over the Third Edition. The only additions are layout keywords (including the SPACES keyword) and system variables. As well as these additions certain corrections and changes of format have been made. In particular it is assumed in this Edition that newline, not semicolon, is the closing delimiter for operation macros, since practice has shown that this is the best choice.

ML/I has remained in a stable state for some time, and there are no current plans to make extensive changes. In fact the current ML/I is really ML/II since it is the end product of a series of improvements to the original 1966 version; it has not, however, been renamed.

Table of contentsChapter 1 Introduction

- 1.1 General description
- 1.2 Organisation of the manual
- 1.3 Notation for describing syntax
- 1.4 Further points of notation
- 1.5 Improving ML/I

Chapter 2 The Environment and its constituents

- 2.1 Basic action of ML/I
- 2.2 Character set
- 2.3 Text
- 2.4 Macros and delimiter structures
 - 2.4.1 Examples of macros
 - 2.4.2 Delimiter structures
 - 2.4.3 Optional and repeated delimiters
 - 2.4.4 Macro definitions
 - 2.4.5 The difference between macros and subroutines
 - 2.4.6 Impossible replacements
- 2.5 Introduction to macro-time variables and statements
- 2.6 Inserts
 - 2.6.1 Macro variables
 - 2.6.2 Initialization of macro variables
 - 2.6.3 Subscripts and macro expressions
 - 2.6.4 Integer overflow
 - 2.6.5 Macro labels
 - 2.6.6 Macro elements
 - 2.6.7 Insert definitions
 - 2.6.8 Examples of inserts
- 2.7 Skips
 - 2.7.1 Matched skips and straight skips
 - 2.7.2 Literal brackets
 - 2.7.3 Example of a matched skip

Continued:

- 2.8 Warning markers
- 2.9 Summary of the environment
- 2.10* Normal-scan macros and straight-scan macros
- 2.11 Name environment used for examples

Chapter 3 Text Scanning and evaluation

- 3.1 Nesting and recursion
- 3.2 Call by name
- 3.3 Details of the scanning process
- 3.4 The method of searching for delimiters
- 3.5* Exclusive delimiters
- 3.6* Dynamically generated constructions

Chapter 4 Operation macros and their use in setting up the environment

- 4.1 Operation macros
- 4.2 Use of literal brackets for surrounding operation macro arguments
- 4.3 NEC macros
- 4.4* Dynamic aspects of the environment
- 4.5* Protected and unprotected inserts
- 4.6* Ambiguous use of names
- 4.7* Implications of rules for name clashes

Chapter 5 Specifications of individual operation macros

- 5.1 Specification of delimiter structures
 - 5.1.1 Keywords
 - 5.1.2 The consequences of evaluation
 - 5.1.3* Introduction to more complicated cases
 - 5.1.4* Full syntax of structure representations
 - 5.1.5* Examples of complex structure representations
 - 5.1.6 Possible errors in structure representations
- 5.2 The NEC macros
 - 5.2.1 MCWARN
 - 5.2.2 MCINS
 - 5.2.3 MCSKIP
 - 5.2.4 MCDEF
 - 5.2.5 MCNOWARN, MCNOINS, MCNOSKIP and MCNODEF
 - 5.2.6 MCWARNG, MCINSG, MCSKIPG and MCDEFG
 - 5.2.7 MCALTER

Continued:

- 5.3 System functions
 - 5.3.1 MCLENG
 - 5.3.2 MCSUB
- 5.4 Further operation macros
 - 5.4.1 MCSET
 - 5.4.2 MCNOTE
 - 5.4.3 MCGO
 - 5.4.3.1* Exact description of a GO TO
 - 5.4.4 MCPVAR

Chapter 6 Error messages

- 6.1 Examples of an error message
- 6.2 Notes on context print-outs
- 6.3 Complete list of messages
 - 6.3.1 - 6.3.13 Description of individual messages

Chapter 7 Hints on using ML/I

- 7.1 How to set up the environment
- 7.2 Possible sources of error
 - 7.2.1 Jumping over expanded code
 - 7.2.2 Generation of unique labels
 - 7.2.3 Lower case letters
 - 7.2.4 Use of newlines in definitions
 - 7.2.5 Use of redundant spaces
- 7.3 Simple techniques
 - 7.3.1 Interchanging two names
 - 7.3.2 Removing optional debugging statements
 - 7.3.3 Inserting extra debugging statements
 - 7.3.4 Deleting a macro
 - 7.3.5 Differentiation between special-purpose registers and storage locations
 - 7.3.6 Testing for macro calls
 - 7.3.7 Searching
 - 7.3.8 Bracketing within macro expressions
 - 7.3.9 Deletion from source text only
- 7.4 Sophisticated techniques
 - 7.4.1 Macro-time loop
 - 7.4.2 Examining optional delimiters
 - 7.4.3 Dynamically constructed calls
 - 7.4.4 Arithmetic expression macro
 - 7.4.5 Formal parameter names
 - 7.4.6 Intercepting changes of state
 - 7.4.7 Remembering code for subsequent insertion
 - 7.4.8 Constructions with restricted scopes
 - 7.4.9 Optimizing macro-generated code
 - 7.4.10 Macro to create a macro

Chapter 1 Introduction

1.1 General description

ML/I is a general macro processor. It is general in the sense that it can be used to process any kind of text. The text may be in any programming language or natural language, or it may be numerical data. The most important use of ML/I is to provide the user with a simple means of adding extra statements (or other syntactic forms) to an existing programming language in order to make the language more suitable for his own field of application. This process of extension may be carried to the level where the extended language could be regarded as a new language in its own right. Other uses of ML/I are program parameterization (e.g. a parameter might determine whether debugging statements are to be included in a program) and various applications in text editing or correction and data format conversion. ML/I is also suitable for use as the final pass of a compiler.

This manual does not assume the reader has any previous experience of macro processors. However, the reader who is familiar with macro processors might be interested in knowing the main features of ML/I before plunging into details. These features are:

- (a) Macros with a variable number of arguments.
- (b) Delimiters of the arguments of each macro are chosen by the user, and a macro may have several possible patterns of delimiters, each with a different meaning.
- (c) Macro-time integer variables.
- (d) Macro-time assignment and GO TO statements.
- (e) No restrictions on nesting and recursion.
- (f) Macro calls occurring anywhere in the text (i.e. calls do not have to appear in a particular field, nor do they have to be preceded by a "warning marker").
- (g) Comprehensive error messages.

1.2 Organisation of the manual

Chapters 2, 3, 4 and 5 of this manual describe ML/I in full detail. Chapter 6 describes error messages and Chapter 7 contains hints and examples. The reader may find it useful to look ahead to the examples in Chapter 7 if he has difficulty with the main text. Some Sections of this manual can be omitted

on a first reading and these are marked with an asterisk.

This manual does not describe features of ML/I that are implementation-dependent, e.g. operating instructions, character set, etc. Instead there is an Appendix which describes the implementation-dependent features for each implementation. Thus Appendix A describes the PDP-7 implementation, Appendix B the Titan one, etc. These Appendices are available separately.

A few features of ML/I as described in this manual may not be present in some implementations. In addition some implementations may include extra features. See Section 1 of the relevant Appendix for details.

1.3 Notation for describing syntax

The notation used to describe syntax should be self-explanatory. An example of its use is the following description of a hypothetical IF statement:

IF condition THEN statement;

As can be seen, a syntactic form is defined by concatenating its constituents. A constituent that is itself the name of a syntactic form is underlined. The remaining constituents are literals.

A notation borrowed from Brooker and Morris is used to indicate parts of syntactic forms that may optionally be repeated and/or omitted. In this notation a constituent or series of constituents that may optionally be omitted is written:

[constituents ?]

Constituents that may be repeated any desired number of times are written:

[constituents *]

and constituents that may be omitted or repeated are written:

[constituents *?]

Thus if the above IF statement had an optional ELSE clause, it would be written

IF condition THEN statement [ELSE statement ?] ;

and a hypothetical SUM statement which permitted any number of arguments, provided there were at least two, might be defined:

SUM argument [, argument *] ;

Lastly, when there are several alternative forms for a constituent, these are written:

(form 1)
 (form 2)
 (.)
 (:)
 (form N)

Thus an expression might be defined as:

variable [⁽⁺⁾₍₋₎ variable*?]
 (×)
 (/)

Note that the asterisk means that the syntactic forms enclosed within the brackets may be repeated; it is not required that identical text be written at each repetition.

1.4 Further points of notation

(a) When it is desired to emphasize the presence of a space, tab or newline in a piece of text, this is done by writing SPACE, TAB or NL, respectively. Note that this is simply a point of notation and the reader should be careful not to interpret an occurrence of, say, NL in a specification as requiring that he write 'N' and 'L' and underline them.

(b) An integer is said to be positive only if it is greater than zero, and negative only if it is less than zero. Integers in ML/I are represented to a decimal base.

(c) When it is necessary to emphasize that a zero is not the letter "Oh", the zero is crossed, e.g. 1/0̄. Zeros are not crossed, however, where the context makes it obvious that a zero is meant.

1.5 Improving ML/I

Readers are invited to criticize and suggest improvements in the specification of ML/I, in the description in this manual or in a particular implementation, and in particular to point out errors and ambiguities. Reports of implementation errors should be accompanied by enough material to reproduce the error and, if applicable, references to the statements in this manual that have been contravened.

Chapter 2 The environment and its constituents

2.1 Basic action of ML/I

The basic action of ML/I is as follows. The user feeds to ML/I some text and an environment. The purpose of the environment is to specify that certain insertions, deletions, expansions, translations or other modifications are to be made in the text. ML/I performs the textual changes specified by the user. This process is called evaluation of text, and the text generated as a result of the changes is called the value text. The text being evaluated is called the scanned text. In many simple applications of ML/I, the process of evaluation consists of a good deal of straight copying, the value being the same as the original, but periodically a change is made and the generated value text is different from the original scanned text.

The purpose of this Chapter is to explain the mechanisms at the disposal of the user and to give examples of their use. All the possible constituents of the environment will be described and the resultant textual changes will be explained by describing the form of the scanned text and the form of the corresponding value in each case. The mechanisms for setting up the environment will be explained in subsequent Chapters.

2.2 Character set

The character set of ML/I, i.e. the set of allowable characters in the text it processes, is implementation-defined (see Section 3 of relevant Appendix). However, the character set will normally contain a primary (upper case) set of letters A - Z, the numbers 0 - 9, and a number of characters that are not letters or numbers. Characters that are not letters or numbers are called punctuation characters. (If input is from cards the characters tab and newline will not normally physically exist as characters on the cards. However the input routine may artificially add the character "newline" at the end of each line and might possibly have some arrangement for inserting tabs as well. See Section 3 of relevant Appendix for details.) If an implementation contains both upper and lower case letters in its character set, then these are treated as entirely different sets of characters and it is not possible to use a lower case letter interchangeably with its upper case equivalent.

2.3 Text

A feature of ML/I is that it does not consider text character by character but in units of atoms. An atom is a single punctuation character or a sequence of letters and digits that is surrounded by punctuation characters (assuming an imaginary punctuation character at the beginning and end of the text). There is no restriction on the length of an atom. To take an example, the text:

```

  P I G , T A B   L A C   S P A C E   4 0 5 7
  - - - - -
  1 2 3     4     5     6

```

would be regarded as six atoms as shown.

The following definitions will be used in the rest of this manual. Text is a (possibly null) sequence of atoms. The source text is the text supplied as input to ML/I, and the output text is the text derived from evaluating the source text. The physical form of the source text and output text is implementation-defined (see Section 2 of relevant Appendix). The action of evaluating a particular piece of source text is called a process.

2.4 Macros and delimiter structures

Before defining a macro it may be useful to consider the sort of text replacement that macros are designed to achieve. PDP-7 Assembly Language will be taken as an example (but it will not be assumed the reader is necessarily familiar with this language). Assume the user wishes to introduce a new instruction of form:

```
ESUB X meaning "subtract X from the accumulator".
```

Now this instruction is not in the PDP-7 instruction set but its effect can be achieved by the three instructions:

```

CMA      complement accumulator.
ADD X    add X to accumulator.
CMA      complement accumulator.

```

The introduction of ESUB would be achieved as follows. The user would write his program as if ESUB were an extra machine instruction. Before the program was assembled it would be passed through ML/I with ESUB defined as a macro name with the above three instructions as its replacement text. ML/I would replace each occurrence of ESUB by its expanded form and the resultant output text could then be assembled normally. Each piece of text to be replaced is called a macro call and the text corresponding to X above is called the argument of the call. (Within the replacement text of ESUB it is necessary to specify that the argument of the call should be inserted immediately after ADD. This is done by a constituent of the environment called an "insert", which will be described later.)

This example serves as a simple illustration of the primary use of ML/I, namely to serve as a preprocessor to an existing piece of software to allow the user to introduce new statements of his own design into the existing language. Each new statement must be expandable in terms of the existing language.

Macros may have any number of arguments. Arguments are separated by predefined atoms or sequences of atoms called delimiters. When defining a macro, the user specifies what the delimiters are. The macro name is regarded as a delimiter and is called the name delimiter to distinguish it from the remaining delimiters, which are called secondary delimiters. The delimiter following the last argument of the call is called the closing delimiter. The general form of a macro call can, therefore, be represented as:

name delimiter [argument secondary delimiter * ?]

Arguments may be null but delimiters must consist of at least one atom.

Every time ML/I encounters in the scanned text an atom or series of atoms that has been defined as a macro name, it searches for the secondary delimiters (if any) and then replaces the entire macro call by the value of the replacement text for the macro. More details of the way macro calls are scanned are given in Sections 3.3 and 3.4.

2.4.1 Examples of macros

It may be instructive at this stage to consider a few more

examples of macros. These examples, which are listed below, are all of simple macros with fixed delimiters. Macros with more elaborate patterns of delimiters will be considered later. Note that ML/I could be used to add these macros to any desired programming language, whether high or low level.

Example 1 A macro to generate a loop, which has form

```
DO arg A TIMES arg B REPEAT
```

Here the delimiters are DO, TIMES and REPEAT. DO is the name delimiter, and TIMES and REPEAT are secondary delimiters. REPEAT is the closing delimiter. ML/I does not require that macro calls be written on a single line, and calls of this macro would tend, in practice, to span several lines of text.

Example 2 A macro of form

```
MOVE FROM arg A TO arg B;
```

The name of this macro consists of the two atoms "MOVE FROM".

Example 3 A macro to interchange two variables, which has form

```
INTERCHANGE ( arg A, arg B ) NL
```

In this example both the name and the closing delimiter consist of more than one atom. Note that ML/I does not, like some software, truncate long names such as "INTERCHANGE".

Example 4 Assume that within a program two different names, COUNT and CONT, have inadvertently been used for the same variable. Then this error could be corrected using ML/I with CONT defined as a macro with COUNT as its replacement text. Here the name delimiter, CONT, is also the closing delimiter.

The reader should, at this stage, appreciate why ML/I considers text as a sequence of atoms rather than a sequence of individual characters. If the latter were the case, ML/I would be liable to take names such as DOG and RANDOM as calls of the above macro DO since each name contains the letters "DO". As the situation stands, however, the letters "DO" would only be taken as a macro call if they were surrounded by punctuation characters.

2.4.2 Delimiter structures

The macros considered so far have had fixed delimiters. However, it is possible to have macros with any number of alternative patterns of delimiters. As a very simple example of this consider the ESUB macro. In PDP-7 Assembly Language statements are terminated with either a tab or a newline, and so it would be desirable to allow both of these as alternatives for the closing delimiter of ESUB.

In order to specify the patterns of possible delimiters of a macro the user specifies a delimiter structure. Each macro has its own delimiter structure and other constituents of the environment also have delimiter structures. A delimiter structure is a set of delimiter specifications, each of which is a sequence of one or more atoms. These sequences of atoms need not be distinct. One or more of these delimiter specifications are designated as names of the structure. The remainder are secondary delimiters. With each delimiter specification is associated a specification of its successor(s). This may be

- (a) null,
- or (b) another delimiter specification within the structure,
- or (c) a set of alternative delimiter specifications within the structure.

Successors specify what to search for next when scanning. A delimiter with a null successor is a closing delimiter. As an illustration of the use of a delimiter structure consider the scanning of a macro call. During this scanning, each time a delimiter is found, the delimiter structure of the macro being called is referenced to find the successor(s) of the current delimiter and subsequent text is then scanned to try to find this successor. This process continues until a closing delimiter is found.

As an example of a delimiter structure, the delimiter structure of the ESUB macro would contain three delimiter specifications with the following information about them:

- (a) ESUB name with (b) or (c) as its successor.
- (b) TAB secondary delimiter with no successor.
- (c) NL secondary delimiter with no successor.

The rules for setting up delimiter structures (see Section 5.1) ensure that they have certain properties. Among these properties are the following:

- (a) If there is more than one name each name is represented by a different sequence of atoms.
- (b) If a delimiter specification has alternative successors each is represented by a different sequence of atoms.
- (c) The structure is connected. This means that it must be possible to reach each secondary delimiter by a sequence of successors from some name.

2.4.3 Optional and repeated delimiters

It is possible, by designing a suitable delimiter structure, to have a macro with a variable number of arguments, in particular a macro with optional arguments and/or with an indefinitely long list of arguments. For instance, suppose it is desired to implement a macro with alternative forms:

```

IF argument THEN argument
END

and IF argument THEN argument
ELSE argument
END

```

This is done by specifying that either ELSE or END is the successor of THEN. END is a closing delimiter and ELSE has successor END.

As a second example consider a macro of form:

SUM argument [$\begin{matrix} (+) \\ (-) \end{matrix}$ argument*?] ;

This macro has an indefinite number of arguments, separated by plus or minus signs. Its delimiter structure has four members as follows:

- (a) SUM name with (b), (c) or (d) as successor.
- (b) + secondary delimiter with (b), (c) or (d) as successor.
- (c) - secondary delimiter with (b), (c) or (d) as successor.
- (d) ; secondary delimiter with no successor.

2.4.4 Macro definitions

Now that the basic concepts behind macros have been introduced, it is possible to explain more exactly what makes up a macro definition. Macro definitions are the most important constituents of the environment. A macro definition consists of:

- (a) A delimiter structure. The name delimiter(s) of this structure are the macro names.
- (b) A piece of replacement text.
- (c) An integer exceeding two called the capacity, the purpose of which is explained in Section 2.6.1.
- (d) An on/off option. If this option is on, a macro is called a normal-scan macro. Otherwise it is called a straight-scan macro. The effect of this option is explained in Section 2.10.

The reader need not for the moment concern himself with (c) and (d) since nearly all macros will be normal-scan and will have capacity three.

2.4.5 The difference between macros and subroutines

There is often confusion between the purpose of macros and

the purpose of subroutines. Macros, however, always generate in-line code and so this code is inserted as many times as the macro is called. Subroutines use out-of-line code and there is only one copy of this code for a particular program. Thus macros are used only when the code to be inserted is short or highly parameterized. It would not be convenient, for instance, to use subroutines to perform the functions of any of the macros used as examples in previous Sections.

2.4.6 Impossible replacements

It is worth noting some of the types of replacement that it is not possible to perform by means of macros. Below are two examples of illegal syntax of macro calls, together with possible correct forms.

(a) Wrong arg A = arg B; since each macro call must start with a macro name.

Right SET arg A = arg B ;

(b) Wrong \$ character It is not possible to define an argument as the character (or atom) immediately following a given name. Every argument must be followed by some pre-defined delimiter.

Right \$ argument ;

2.5 Introduction to macro-time variables and statements

The form of the value of a call of such macros as the IF and SUM macros used earlier as examples would have to depend on the particular patterns of delimiters that were used in the call. For instance:

SUM ALPHA + BETA ;

must generate an entirely different set of instructions from:

SUM ALPHA - BETA - GAMMA + X + Y -Z;

and, in the case of IF, the form of the value text must depend

upon whether ELSE was present. Macros such as these, therefore, are more complicated than the ESUB case, where a fixed skeleton of code consisting of three machine instructions is substituted for each call. The only variable element in the ESUB case is the form of its argument. In the more complicated cases, where the delimiters provide a second variable element, the user has to write a little program which is executed by ML/I and tests the form of the delimiters used and generates code accordingly. In the case of SUM, which has an indefinitely long list of arguments and delimiters, this program would involve a simple repetitive loop to iterate through the list. Hence ML/I contains an elementary programming language of its own. This language contains an assignment statement, a conditional GO TO statement, labels and integer variables. All these are called macro-time entities to distinguish them from the corresponding execution-time entities, and the reader must be careful not to confuse the two. The difference is illustrated thus: the DO macro of Section 2.4.1 would generate a loop which was performed at execution-time and controlled by an execution-time variable; on the other hand the value text for the SUM macro would be generated by a macro-time loop controlled by a macro-time variable.

Macro variables and macro labels are considered in the next Section. Macro-time statements are considered in detail in Chapter 4.

2.6 Inserts

This Section describes how quantities can be inserted into text. In particular it describes how arguments of macro calls are inserted into replacement text. However, first it is necessary to consider some of the quantities, in addition to arguments, that may be inserted into text.

2.6.1 Macro variables

Macro variables are integer variables available to the user at macro-time. ML/I contains facilities for performing arithmetic on these variables, testing their values, and inserting their values into the text. They are useful as switches and for counting (e.g. in processing macros with a variable number of arguments).

There are three kinds of macro variable, namely:

- (a) permanent variables, referred to as P1, P2,....
- (b) system variables, referred to as S1, S2,....
- (c) temporary variables, referred to as T1, T2,....

Permanent and system variables have global scope; this means they can be referred to anywhere. An implementation-defined number of each is allocated at the start of each process and these remain in existence throughout. The user may allocate extra permanent variables (but not system variables) if he likes (see Section 5.4.4). The difference between permanent and system variables is that the former have no fixed meanings and are free for the user to use as he wishes, but the latter have fixed implementation-defined meanings associated with controlling the operation of ML/I. For example in a given implementation S20 might control the listing of the source text; if it was zero no listing would be produced and if it was one there would be a listing. Sections 5 and 7 of each Appendix describe the meanings of system variables (if any) and state the number of permanent and system variables that are initially allocated.

Temporary variables, on the other hand, have a more local scope. During the evaluation of the source text there are no temporary variables in existence. However, each time a macro call is made a number of temporary variables is allocated and these remain in existence while the replacement text of the macro is being evaluated. The number of temporary variables allocated at the call of a macro is given by the capacity of the macro (see Section 2.4.4). The capacity is usually three. If temporary variable N is referenced during the evaluation of the replacement text of a macro call, this is taken to mean the Nth temporary variable associated with the call. Since, as will be seen later, it is possible to have macro calls within macro calls, it is possible to have several allocations of temporary variables in existence at the same time.

2.6.2 Initialization of macro variables

The initial values of all macro variables are undefined except for the values of the first three temporary variables of each allocation, which are initialized as follows:

- T1 the number of arguments of the current macro call;
- T2 the number of macro calls so far performed by ML/I during the current process. The importance of this number is that it is unique to the current call;
- T3 the current depth of nesting of macro calls (i.e. the number of calls, including the present one, currently being processed; calls of operation macros (see Section 4.1) are not counted here, though they do count toward the setting of T2).

It is to be emphasized that these are initial values and the user is free to change them if he wishes. (In this way temporary variables are unlike system variables. If the values of system variables, even those without assigned meanings, were changed arbitrarily it might have a tragic effect.)

2.6.3 Subscripts and macro expressions

In the previous Sections macro variables were specified by a letter followed by a number (e.g. P2), but there are other possibilities. The general form of a macro variable is:

(P)
 (S) subscript
 (T)

where a subscript is an unsigned positive integer or a macro variable. The value of the subscript specifies the macro variable to be referenced. Thus if T3 has value 4, then PT3 would specify P4. As a more complicated example, if T1 had value 2 and P2 had value 6, then TPT1 would specify the sixth temporary variable.

Macro variables can be combined into macro expressions, which are used when it is desired to perform arithmetic calculations during macro generation. Examples of macro expressions are:

1, -6, 3-S1, -TT1-145/P2+P3+6

Multiplication is represented by an asterisk. The general form of a macro expression is:

$$\text{primary} \quad [\quad \begin{array}{l} (/) \\ (*) \\ (+) \\ (-) \end{array} \quad \text{primary} * ?]$$

where a primary has form:

$$[\quad \begin{array}{l} (+) * ? \\ (-) \end{array} \quad] \quad \text{operand}$$

where an operand is an unsigned integer or a macro variable. Redundant spaces can occur anywhere in macro expressions except within operands.

The result of a macro expression is the integer derived from calculating the expression by the ordinary rules of arithmetic. Unary operators are performed first, followed by the binary operators from left to right with the proviso that multiplication and division take precedence over addition and subtraction. Division is truncated to the greatest integer that does not exceed the exact result. Division by zero is detected as an error. Examples are:

- (a) $1 + 2 * 3$ has result 7.
- (b) $3 * 7/8$ has result 2.
- (c) $7/8 * 3$ has result 0.
- (d) $- 5/4$ and $5/-4$ both have result -2.
- (c) $- 4/-3 * -6$ has result - 6.

2.6.4 Integer overflow

Each implementation has a maximum absolute value which must not be exceeded by any integer derived during the calculation of a macro expression or subscript. The effect of exceeding this value is implementation-defined. See Section 5 of the relevant Appendix for details.

2.6.5 Macro labels

Since there is a facility for a macro-time GO TO, there is also a facility for placing macro-time labels. These are called macro labels. Each macro label is designated by a unique

positive integer.

2.6.6 Macro elements

Macro variables, macro labels, arguments and delimiters are collectively called macro elements. It is convenient to regard macro elements as part of the environment. The full details of how macro elements are added to the environment are explained in Section 4.4, but in essence the rule is that every time a macro is called its arguments and delimiters plus a set of temporary variables are automatically added to the environment and this supplemented environment is used to evaluate the replacement text of the call. Similarly when a macro label is encountered its position is "remembered" by adding it to the environment.

2.6.7 Insert definitions

It is now possible to define the constituent of the environment, called an insert definition, which is used for such purposes as to tell ML/I to insert a particular argument of a macro at some point in its replacement text. An insert definition consists of:

- (a) A delimiter structure. Since all inserts have fixed delimiters and exactly one argument, this delimiter structure will be a simple one. It will consist of a name with a single successor, this successor being a closing delimiter.
- (b) An on/off option. If this option is on, an insert is called protected; otherwise it is called unprotected. The use of this option, which need not be of much concern to the average reader, is described in Section 4.5.

At each point where the user wishes something to be inserted he writes the following construction, called an insert:

insert name argument delimiter

In the rest of this manual, for the purpose of examples, it will be assumed that the atom "%" is an insert name, with the atom "." as its closing delimiter. With this assumption the following are

examples of inserts (the exact meaning of these will become apparent later):

%A6. %P1. %LT2. %WA P9-16*T3.

On encountering an insert, ML/I evaluates the argument of the insert (in case it contains macro calls, etc.) and the resulting value text acts as a specification of what to insert. The value text must consist of a flag followed by a macro expression. In the first above example the flag would be A and the macro expression would be 6. The flag may be null or it may be any of the following: A, B, D, L, WA, WB or WD. Any number of redundant spaces is allowed before, after or within a flag.

The meaning of the various flags are explained below. In each explanation "N" is used to represent the value of the macro expression following the flag. More examples are given in the next Section. An attempt to insert something which does not exist (e.g. the third argument of a macro with only two arguments) results in an error. The meanings of the flags are:

- (a) A. This flag is used within the replacement text of a macro to evaluate and insert the Nth argument of a call of the macro. Any spaces at the beginning or end of the argument are deleted before it is evaluated. In the case of this flag and in cases (b) and (c) below the piece of text that is evaluated and inserted is called the inserted text.
- (b) B. As case (a) except that spaces are not deleted.
- (c) D. As case (b) except that the Nth delimiter, rather than the Nth argument, is inserted. The name of a macro is considered as delimiter zero, and the Nth delimiter is thus the delimiter following the Nth argument.
- (d) WA, WB, WD. As cases (a) to (c), respectively, except that the inserted text is not evaluated but is inserted literally, exactly as written. ('W' stands for "written".) The difference between this and the previous cases arises if the inserted text itself involves macro calls, inserts, etc. In the previous cases these are evaluated; in this case they are not.

- (e) Null. The numerical value of N, represented as a character string, is inserted. This character string contains no redundant leading zeros. It is preceded by a minus sign if N is negative; otherwise no sign is present.
- (f) L. This is used to place a macro label and is rather different from the above cases in that nothing is inserted (i.e. the value of the insert is null). The label N is, if acceptable, added to the current environment and may be the subject of a macro-time GO TO. A macro label is acceptable if it is inserted within a piece of replacement text or inserted text and has not already been defined within that text. It is legal to insert a label in the source text but since, as will be seen later, it is not possible to have a backward GO TO within the source text, such labels are not added to the environment (i.e. they are "forgotten"). Macro labels are local to the piece of text in which they occur, and there is no harm in using the same label numbers within different pieces of text. Label numbers can be chosen arbitrarily, except that they must be positive.

2.6.8 Examples of inserts

The following examples illustrate the use of inserts:

- (a) The replacement text of the ESUB macro of Section 2.4 might be written:

```
CMA
ADD  %A1.
CMA NL
```

or even:

```
CMA
ADD  %A1.
CMA  %D1.
```

The latter form would have the advantage of inserting

newline or tab according to which one was written in the call.

- (b) In the case of the DO macro of Section 2.4.1 the replacement text would involve an execution-time label. It is imperative that a different execution-time label be generated for each call of DO. This could be achieved by using the initial value of T2. The label could, for example, be written:

ZZ&T2.

In this case if two successive calls of DO occurred at the start of the source text then ZZ1 would be generated at the first call and ZZ2 at the second.

- (c) If SWITCH is a macro name with replacement text P1, then it is possible to write:

%SWITCH.

to insert the first permanent variable. The reason is that the argument of an insert is evaluated before being processed and the call of the SWITCH macro would be performed during this evaluation.

- (d) The occurrence of %A1. in the replacement text of the macro call:

MOVE FROM JACK TO JOHN;

would cause JACK to be inserted, whereas the occurrence of %B1. would cause JACK enclosed in spaces to be inserted.

- (e) If it is desired to insert the name of a macro into its replacement text this can be done by writing "%WDØ." (The reason for having this facility is that macros can have several alternative names.) In general it would be wrong to use %DØ. instead, since this form causes any macro calls within the delimiter to be performed. But delimiter zero is the macro name itself and hence an endless recursive

loop is likely. In fact when inserting delimiters it is usually better to use a "W".

- (f) This example rather jumps the gun in that it uses the macro-time statements MCSET and MCGO which have not yet been defined. However, if the reader cares to try to understand this example at this stage it may give a useful insight into the purpose of the preceding material. The example shows how the replacement text of the SUM macro could be written. (The comments at the side are for the reader's benefit and do not form part of the replacement text.)

LAC %A1.	Generate code to load accumulator with first argument.
MCSET T2 = 1	Use T2 as loop counter.
%L4.MCGO L1 IF%DT2. = +	Test if current delimiter is plus
MCGO L2 IF%DT2. = -	or minus.
MCGO LØ	If neither then exit. (LØ has a special meaning, namely "return".)
%L2. ESUB %AT2+1.	Generate code to subtract current argument.
MCGO L3	
%L1. ADD %AT2+1.	Generate code to add current argument.
%L3. MCSET T2 = T2+1	Increase T2 and continue loop.
MCGO L4	

2.7 Skips

The description so far has implied that every occurrence of a macro name in the scanned text is taken as the start of a

macro call. This would mean that the user had no easy means of getting macro names or, for that matter, insert names into his value text. Moreover, if he were unfortunate enough to use a macro name in his comments, then ML/I would take this as a macro call and would start searching for delimiters. To get round these difficulties the user places skip definitions in his environment, and by this means can cause ML/I to ignore comments and to take certain strings as literals.

A skip definition consists of:

- (a) A delimiter structure. The names of this structure are called skip names.
- (b) Three on/off options. These options are: the text option, the delimiter option and the matched option.

The action of ML/I on finding a skip name is similar to the action on finding a macro name. In both cases a search for delimiters is made until a closing delimiter is found. The text from the skip name to its closing delimiter is called a skip. A skip, therefore, has form:

skip name [argument secondary delimiter *?]

In most practical applications of skips there will be exactly one argument. The arguments of skips are treated as literals, exactly as if all macro definitions, insert definitions and warning markers (see later) had been temporarily removed from the environment during the scanning of the skip. There is no replacement text associated with a skip; instead the value of a skip is defined simply by the setting of two of its options. These options, which are independent of one another, have the following effect:

- (a) If the delimiter option is on, then the delimiters of the skip are copied over to the value text; otherwise they are not.
- (b) If the text option is on, then the arguments of the skip are copied over to the value text; otherwise they are not.

As an example of the use of a skip assume the source text contains comments that begin with the word COMMENT and end with a semicolon. In order to skip these comments the user would define COMMENT as a skip name with semicolon as its closing delimiter. In this case if the following comment occurred:

```
COMMENT THIS DO LOOP ZEROIZES ARRAY X;
```

then its value (i.e. the piece of text copied over to the value text) would be one of the following:

- (a) If both options were on, its value would be:

```
COMMENT THIS DO LOOP ZEROIZES ARRAY X;
```

- (b) If neither option was on its value would be null.

- (c) If only the delimiter option was on its value would be:

```
COMMENT;
```

- (d) If only the text option was on then its value would be:

```
THIS DO LOOP ZEROIZES ARRAY X
```

If COMMENT was not defined as a skip at all then comments would normally be copied over to the value text as in case (a). However, if in the above example DO was a macro name then ML/I would try to find the delimiters of DO and replace the call of DO by its replacement text. This is clearly undesirable. The chances are the entire source text would be scanned without finding the required delimiters. Hence the use of skips to inhibit the recognition of macro names within certain contexts.

It will be assumed in the rest of this manual that COMMENT is a skip name with semicolon as its closing delimiter.

2.7.1 Matched skips and straight skips

Assume the user has written the comment:

```
COMMENT THIS COMMENT MARKS THE HALF-WAY STAGE;
```

In this case the skip name COMMENT ~~appears~~ within an argument of the skip COMMENT. However, it is clearly undesirable that ML/I should treat the second COMMENT as a nested skip and try to match it with a semicolon. To prevent this happening COMMENT would be defined as a skip with the matched option off. This is called a straight skip.

However, there are applications of skips where it is desirable for nested skips to be recognised, and such skips have the matched option on. They are called matched skips. Examples of applications of matched skips are "strings" in Algol, which allow nested string quotes and "literal brackets", which are described later. If ML/I encounters any skip name during the scanning of a matched skip it matches the nested skip with its delimiters before matching the containing skip with its delimiters. The scanning process is described in more detail in Section 3.4. In a nest of skips the value is entirely controlled by the options associated with the outermost skip.

2.7.2 Literal brackets

It is usual to have in each environment a skip definition consisting of a name and a closing delimiter with the options set in such a way that at every occurrence of the skip the argument is copied and the delimiters deleted. Such skips are called literal brackets. It will be assumed in the rest of this manual that the name '<' with closing delimiter '>' have been defined as a pair of literal brackets. If it was required to copy a piece of text literally over to the value text, ignoring all macro calls and inserts, then the text would be written:

< text >

The process of evaluation would consist simply of removing the literal brackets. Literal brackets always have the matched option on. The reason for this will become apparent in Section 4.2.

2.7.3 Example of a matched skip

The following example, which is rather more complicated than any situation likely to arise in practice, illustrates the full implications of the rules for the matching of skips.

Example In the text:

```
< AAA < BBB COMMENT < ; CCC > DDD >
```

the initial "<" is matched with the last ">". (The occurrence of "<" after COMMENT is not recognised as a skip name since COMMENT is a straight skip.) The value of this text is:

```
AAA < BBB COMMENT < ; CCC > DDD
```

This value is independent of how the delimiter and text options for COMMENT are set.

2.8 Warning markers

Up to now, ML/I has been described as if every occurrence of a macro name not within a skip is taken as a start of a macro call. In fact this is only true if the environment is in free mode.

If he wishes, the user may place the environment in warning mode by defining one or more warning markers. Any atom or series of atoms may be defined as a warning marker. In warning mode each macro call must commence with a warning marker. Optional spaces are allowed between the warning marker and the macro name which follows it. Thus if CALL were a warning marker, the ESUB macro would be called by writing:

```
CALL ESUB X NL
```

In warning mode each occurrence of a warning marker must be followed by a macro name. Any macro name not preceded by a warning marker is not recognised as such.

The essential difference between warning mode and free mode is that in the first case all macro calls have to be specially marked by preceding them with warning markers whereas in the second case all macro names that are not to be taken as macro calls have to be specially marked by enclosing them in skips.

Note that warning markers only apply to macro calls, and must not be used to precede inserts or skips. These latter are always recognised, irrespective of the mode of the scan.

2.9 Summary of the environment

All the constituents of the environment have now been defined. To recap these are:

- (a) Macro definitions.
- (b) Insert definitions.
- (c) Skip definitions.
- (d) Warning marker definitions.
- (e) Permanent variables.
- (f) System variables.
- (g) Temporary variables.
- (h) Arguments.
- (i) Delimiters.
- (j) Macro labels.

The term construction is used as a collective name for skips, inserts and macro calls and the term name environment is used as a collective name for constituents (a), (b), (c) and (d) above since the names of these constituents are used to recognise constructions in the scanned text.

2.10* Normal-scan macros and straight-scan macros

This Section explains the difference between normal-scan macros and straight-scan macros. However, straight-scan macros have only limited uses and the reader may choose to skip this Section and assume that all macros are normal-scan.

The difference between the two types of macro arises in the scanning of macro calls. In the case of a normal-scan macro constructions nested within the call are recognised, whereas in the case of a straight-scan macro the effect is as if the name environment were temporarily removed during the scanning of the call. As an example of the use of a straight-scan macro, consider a language where comments are commenced with the word NOTE and ended with a semicolon. Assume it is desired to use ML/I to map this language into a language where comments are enclosed between the atoms "[" and "]". It is not possible to achieve

this transformation by the use of skips since the options on skips do not permit the insertion of extra characters and normal-scan macros are inadequate since it is not desired to recognise macro names within comments. Hence NOTE would be defined as a straight-scan macro. Its replacement text would be:

```
[%WA1.]
```

The replacement text of a straight-scan macro is evaluated in exactly the same way as that of a normal-scan macro.

The reader will no doubt have noticed that there is an analogy between the two types of macro and the two types of skip. In fact any straight skip can be represented as a straight-scan macro. However, straight skips are preferable, where possible, since they are slightly easier to define and much faster in execution. The analogy between normal-scan macros and matched skips is not so close. Normal-scan macros permit any constructions to be nested within calls of them whereas matched skips only allow further skips to be nested within them.

The straight-scan option can only apply to user-defined macros; it cannot apply to inserts or to operation macros (see Section 4.1).

2.11 Name environment used for examples

To avoid unnecessary repetition, a fixed name environment will be assumed in all subsequent examples. This environment consists of:

- (a) The atom "%" with closing delimiter "." as an insert definition.
- (b) The atoms "<" and ">" as literal brackets.
- (c) COMMENT as a straight skip with closing delimiter semicolon.
- (d) The DO and MOVE FROM macros of Section 2.4.1.
- (c) The ESUB macro of Section 2.4.
- (f) No warning markers.

All the macros above are taken to be normal-scan.

Chapter 3 Text scanning and evaluation

3.1 Nesting and recursion

Constructions may be nested to any desired depth, and may appear within replacement text. Furthermore, recursive macro calls are allowed. In other words, any construction is allowed with any piece of replacement text or inserted text, and a macro may be called while evaluating its own replacement text. However, constructions must be properly nested. This means that each construction must lie entirely within a single piece of replacement text, entirely within a single piece of inserted text or entirely within the source text. Apart from this obvious restriction, ML/I contains no restrictions on nesting and recursion.

As a result of nesting and recursion, the process of text evaluation is in general a recursive one. At the beginning of a process ML/I starts evaluating the source text. During this evaluation it will in general encounter a macro call. This will cause it to temporarily suspend the evaluation of the source text and start evaluating the replacement text of the call. While evaluating this replacement text, ML/I may encounter an insert, and this will cause it to suspend the evaluation of the replacement text and start evaluating some inserted text. Alternatively, it may encounter a nested macro call. Thus at any one time several pieces of text may be in the process of evaluation.

This situation is liable to lead to ambiguities in terminology, so it is necessary to clarify some of the terms that will be used. The terms "the scanned text", "the current environment" and "the current point of scan" will always refer to the text actually being evaluated, not to any piece of text whose evaluation has been temporarily suspended. ML/I is said to be evaluating inserted text if the scanned text is inserted text, and a similar definition applies to "evaluating replacement text". ML/I is said to be evaluating the source text if it is not within the evaluation of any macro calls or inserts.

3.2 Call by name

Arguments and delimiters are evaluated each time they are inserted, rather than when the call in which they occur is scanned.

In other words they are "called by name" rather than "called by value". In most cases, of course, this choice of approach makes no difference to the final result, but it does have an effect if the environment changes between the time an argument is scanned and the time it is inserted.

3.3 Details of the scanning process

When text is evaluated it is scanned atom by atom until the end is reached. All text, whether the source text, replacement text or inserted text, is scanned and evaluated in the same way. In general each atom of the scanned text is compared with all the names in the environment to see if a match can be found. However, as was seen in the previous Chapter, some types of name are not recognised under certain circumstances. The complete list of such circumstances is as follows:

- (a) No names are recognised within a straight skip or straight-scan macro call.
- (b) Apart from skip names, no names are recognised within a matched skip.
- (c) In warning mode macro names are not recognised except after warning markers. Immediately after a warning marker no names except macro names and no secondary delimiters are recognised (unless an error occurs, see Section 6.3.4).

When a construction name is found a search is made for its closing delimiter. This process is described in the next Section.

Some names in the environment may consist of more than one atom. In this case when an atom of the scanned text is found to match the first atom of the name the scanning process looks ahead to see if the remaining atoms of the name follow this atom. (This look-ahead is abandoned if the end of the current text is reached.) If a match is found scanning is resumed beyond the last atom of the name. The user can specify for each pair of atoms of a multi-atom name whether spaces between the atoms are to be ignored by the scan. Multi-atom secondary delimiters are matched in exactly the same way as multi-atom names.

Apart from these cases of multi-atom delimiters the scan always proceeds atom by atom. Each atom not within a construction is copied over to the value text. Atoms within skips may or may not be copied according to the option settings. Atoms within macro calls or inserts are never copied over to the value text since the very purpose of these constructions is to perform a replacement.

3.4 The method of searching for delimiters

When ML/I encounters a construction name, it searches for each of the secondary delimiters until the closing delimiter is found (except in the case where the construction name is its own closing delimiter, when no searching is required). In general an error message (see Section 6.3.5) is given if the end of the current piece of text is reached before the closing delimiter has been found. In this case the construction is said to be unmatched. Exclusive delimiters, however, provide a slight exception to this rule (see next Section). If, during the search for the delimiters of a construction, a nested construction is encountered, then the search for the delimiters of the outer construction is suspended until the closing delimiter of the nested construction has been found. Nested constructions can only arise within inserts, matched skips and normal-scan macros. Since arguments are called by name rather than by value, nested constructions are not evaluated when scanned over during the search for delimiters of a containing construction. Evaluation occurs only when the argument containing the nested construction is inserted.

The process of searching for closing delimiters is illustrated by the following rather pathological example (remember that the name environment of Section 2.11 applies to this and all subsequent examples).

```
DO 3 TIMES < REPEAT DO >
```

```
    ESUB REPEAT
```

```
    DO REPEAT TIMES
```

```
    REPEAT
```

```
REPEAT
```

In this example the first DO is matched with the last REPEAT, since the search for the REPEAT for this first DO is suspended during the scanning of the nested constructions <, ESUB and DO. Furthermore the occurrence of DO within the literal brackets is not recognised as a macro name.

In general, a single closing delimiter cannot terminate two separate constructions. Thus two successive REPEATs are needed in the above example to close both the DO macros. However, exclusive delimiters again provide an exception to the rule.

As a further example, if the user were foolish enough to write:

```
MOVE FROM TO TO PIG;
```

then the first TO would be taken as the delimiter of MOVE FROM. What he should write to make the second TO the delimiter is:

```
MOVE FROM < TO > TO PIG;
```

However, there is nothing wrong with writing:

```
MOVE FROM PIG TO TO;
```

In practice, if delimiter names are chosen sensibly, problems such as the above rarely arise.

3.5* Exclusive delimiters

(It is highly recommended that this Section be skipped on a first reading as it describes a rather complicated feature which is only occasionally needed.)

In the normal way, after a construction has been scanned over and replaced by its value, scanning is resumed with the atom following the closing delimiter of the construction. Hence the closing delimiter is taken as part of the construction. In a few cases, however, it is more convenient to regard the closing delimiter as external to the construction. Such a delimiter is called an exclusive delimiter. Only macros and skips may have exclusive delimiters and exclusive delimiters are always closing delimiters. After a construction with an exclusive delimiter has been dealt

with, scanning is resumed at the exclusive delimiter rather than beyond it.

Exclusive delimiters are useful when it is desired to use a single delimiter as a closing delimiter of several nested constructions. For example an IF macro might have form:

IF condition THEN nested macro call NL

where the nested macro call is terminated, like IF, by the closing newline. In this case, it would be necessary to define newline as an exclusive delimiter of any macro that could be nested within the IF macro. Then when the scan had used the newline to close the nested macro call it would re-scan it and use it again to close the IF macro.

A difficulty arises in the above example when, within the replacement text of IF, the second argument is inserted. The problem is that the nested macro call is unmatched within this argument, since its closing delimiter, the newline, lies beyond the end of the argument. ML/I resolves this problem by using the following rule; if, when inserting the Nth argument of a macro call, a construction is unmatched then the Nth delimiter is examined and if this delimiter (or a series of atoms at the start of it) is an exclusive closing delimiter which closes the apparently unmatched construction then this construction is considered as matched and processing proceeds normally. If there is a nest of unmatched constructions then this rule is successively applied to all the constructions in turn. (In fact this rule is such a natural one that the user might not realize that there is any logical problem at all.)

Note that it is quite legal to insert an exclusive delimiter in the replacement text of the macro call to which it belongs. It is even legal to define a name delimiter as an exclusive delimiter (though this is almost certain to lead to an endless loop). Furthermore it is quite legal to have both exclusive delimiters and ordinary closing delimiters within the same delimiter structure.

If a skip ends with an exclusive delimiter this closing delimiter is not taken as part of the skip and hence it is not affected by the delimiter option associated with the skip.

Exclusive delimiters are sometimes useful in simple applications where no nesting is involved. For instance it is often desirable for a skip to delete up to, but not including, the next newline.

As a more complicated example, consider a language in which macro calls were one to a line with the macro name coming first. In this case it might be convenient to give newline a double use: firstly as an exclusive delimiter of the macro on the previous line and secondly as a warning marker to precede the macro name on the next line.

The way exclusive delimiters are defined is described at the end of Section 5.1.3.

3.6* Dynamically generated constructions

The method of scanning, with the requirement that calls be properly nested, means that all the delimiters of a construction must be in the same piece of text. This rule, which is very desirable since it leads to the early detection of genuine errors, should be borne in mind by the user who wishes to generate constructions dynamically, for example to combine at macro-time separate pieces of text to build up a macro call. The rule prohibits constructions like:

```
CHOOSENAME A TO B;
```

where CHOOSENAME is a macro with replacement text MOVE FROM, or constructions like:

```
DO A %A1. B REPEAT
```

where %A1. has value TIMES. It is however, quite easy to achieve the object of these examples, namely to generate a delimiter dynamically, and the reader who is interested in doing this should refer to the example in Section 7.4.3.

Chapter 4 Operation macros and their use in setting up the environment

4.1 Operation macros

The macros considered so far have been concerned with making replacements of pieces of text. In fact, strictly speaking, they should have been called substitution macros. There is a second type of macro called an operation macro. A call of an operation macro causes a predefined system action to take place, for example the setting up of a new construction. Operation macros are an integral part of ML/I and are not, like substitution macros, defined by the user. They are, however, part of the name environment and are called in the same way as substitution macros. Examples of operation macros are MCSET (which performs macro-time arithmetic), MCDEF (which defines a macro), and MCGO (which is a macro-time conditional GO TO statement). Examples of their calls are:

```
MCSET P1 = P2 + 1
MCDEF LNG AS LENG
MCGO L6 IF %A1. = ACC
```

Chapter 5 contains complete descriptions of all the operation macros. The names of all operation macros begin with MC to minimize confusion with substitution macros. (The user is not forbidden to start his own macro names with MC, but it is probably less confusing not to.)

The arguments of all operation macros are evaluated before being processed. Thus if TEMPNO were a macro with replacement text P1, then the following would be equivalent to the previous example of MCSET:

```
MCSET TEMPNO = P2 + 1
```

In most cases a call of an operation macro does not cause any value text to be generated. No value text would be generated, for instance, in any of the examples above. However, there are two operation macros, MCSUB and MCLENG, which do cause value text to be generated. These two macros are called system functions. MCSUB is used for generating substrings of longer pieces of text and MCLENG is used to calculate the length of a piece of text.

There are no general restrictions on the use of operation macros. They may be called from within any type of text, even from within arguments to other operation macros.

4.2 Use of literal brackets for surrounding operation macro arguments

The fact that arguments of operation macros are evaluated before being processed has several advantages but it also has its dangers, and in many cases the user will wish to inhibit this argument evaluation. Consider as an example the last argument of MCDEF, which specifies the replacement text of the macro being defined. A definition might be written:

```
MCDEF ... AS <...%A1. ...>
```

If the above literal brackets had been omitted, ML/I would have tried to insert the value of argument one at the time the macro was defined (called definition time) rather than when it was called, and an error would probably result. Occasionally, however, a user might want to do this, in particular when one macro is defined within another and the arguments of the outer one figure in the definition. Apart from cases like this it is a good plan to use literal brackets whenever specifying the replacement text of a macro.

Another reason for the usage of literal brackets arises when the replacement text involves one or more newlines, e.g.

```
MCDEF ... AS <LINE 1
LINE 2
>
```

In this case, since newline is also the closing delimiter of MCDEF, the newlines within the replacement text need to be prevented from closing the MCDEF. The literal brackets, being a construction nested within the call of MCDEF, achieve this.

It is now possible to see why literal brackets must be defined as matched skips rather than straight skips. Consider the following example, where a piece of replacement text itself contains a call of MCDEF:

```
MCDEF MAC1 AS < ...
  MCDEF MAC2 AS < ... >
  ... COMMENT > ;
>
```

It is vital that the first "<" be matched with the last ">"

and not with the occurrence of this symbol in a comment nor with the occurrence in the nested MCDEF. The definition of literal brackets as a matched skip accomplishes this.

4.3 NEC macros

Many of the operation macros have the effect of adding to or deleting from the name environment. These macros are called NEC (name environment changing) macros. The name environment is set up dynamically by calls of NEC macros during text evaluation. The initial state of the name environment is implementation-defined (see Section 2 of relevant Appendix) but it will usually contain just the operation macros. Changes in the environment affect subsequent text evaluation but have no effect on value text already generated. Constructions may be defined as either local or global. Global constructions apply to all subsequent text evaluation, whereas local constructions apply only to the text in which they are defined, together with any macros called from within this text (for exact details see next Section). A local definition occurring in the source text has the same effect as a global definition.

To start with, most users will probably not be very interested in defining new macros in the middle of text evaluation. In this case the entire name environment can be set up by a series of NEC macro calls at the start of the source text, and all the rest of the text can be evaluated using this name environment. Local definitions should be used in preference to global ones where possible since the setting up of global definitions involves more work for ML/I. (Normally global definitions are only necessary when it is desired to use one macro to set up the definition of another.) A reader who is not interested in changing the name environment dynamically can skip the next two Sections. He can, in fact, totally ignore global definitions and he need not worry about the difference between protected and unprotected inserts.

4.4* Dynamic aspects of the environment

The value of a piece of text depends upon the state of the environment when its evaluation is started. The purpose of this Section is to define the initial state of the environment when replacement text or inserted text is evaluated, and to explain the effect of dynamic changes in the name environment.

It is convenient to divide the name environment into two parts:

- (a) The global name environment, which contains the names of global constructions. Operation macro names are treated as global.
- (b) The local name environment, which contains the names of local constructions.

If a substitution macro is called or if an argument or delimiter is inserted, this cannot change the local name environment of the containing text. However, any change in the global name environment applies to the subsequent evaluation of the containing text. In other words there is a single global name environment but each piece of text in the process of evaluation has its own particular local name environment.

When a substitution macro is called, the replacement text is evaluated under the following initial environment:

- (a) the global name environment in effect when the call is made.
- (b) the local name environment in effect when the call is made.
- (c) the permanent and system variables.
- (d) the arguments and delimiters of the call.
- (e) a set of temporary variables. These are allocated when the call is made. The number allocated is given by the capacity of the macro called.
- (f) no macro labels.

When an operation macro is called, no special environment is set up and no temporary variables are allocated. The arguments of the operation macro are evaluated under the environment in force when the call was scanned. The same applies to the argument of an insert.

Before considering the initial environment for the evaluation of inserted text, it is instructive to consider an example that will illustrate the reasons behind the rules. This example involves passing arguments down from one macro to another. Assume that within the replacement text of a macro XYZ it is desired to call the MOVE FROM macro to move the second argument of XYZ into a place called TEMP. This call of MOVE FROM would be written:

```
MOVE FROM %A2. TO TEMP;
```

This call would cause the replacement text of the MOVE FROM macro to be evaluated and during this evaluation it would be necessary to insert the first argument of MOVE FROM. The insertion of this argument involves the performing of the insert "%A2.". Now in this case ML/I takes A2 to mean the second argument of XYZ, not the second argument of MOVE FROM. The initial state of the environment for the evaluation of inserted text is set to make this so. This initial environment consists of:

- (a) the current global name environment.
- (b) a local name environment. This depends on whether the insert is protected or unprotected. See next Section.
- (c) the permanent and system variables.
- (d), (e) the arguments, delimiters and temporary variables that were in the environment when the call containing the text to be inserted was encountered.
- (f) no macro labels.

The reader may have noticed that no initial environment contains any macro labels. This is because it is not possible to use the MCGO macro to jump from one piece of text to another. Thus each piece of text has its own macro labels, and macro labels are not carried down from one piece of text to another.

4.5* Protected and unprotected inserts

The difference between protected and unprotected inserts is best illustrated by an example. Consider a macro ABC whose

replacement text starts as follows:

```
MCDEF TEMP AS LMN
%A1.
```

Assume ABC is called with TEMP as its first argument. Then if "%" has been defined as a protected insert the value of %A1. is TEMP. If it has been defined as an unprotected insert the value is LMN. (MCDEF defines a local macro. If MCDEFG, which defines a global macro, had been used in place of MCDEF then the value of %A1. would always be LMN.) Hence the purpose of a protected insert is to protect the insertion of a macro's arguments or delimiters from any changes in the local environment of the macro's replacement text. It is often useful, for instance, to switch into warning mode when entering the replacement text of a macro but still to evaluate its arguments in free mode. In some applications the user may wish to define two insert names, one protected and the other unprotected. In most applications, however, it will be entirely immaterial which sort of insert is defined.

To complete the definition of the previous Section, the initial local name environment when inserted text is evaluated is as follows:

- (a) If the insert is a protected insert then it is the local name environment that was in force when the call containing the inserted text was encountered.
- (b) If the insert is an unprotected insert then it is the local name environment that was in force when the insert was encountered.

4.6* Ambiguous use of names

When defining new constructions the user should be careful to avoid certain clashes of name. It would obviously be foolish, for instance, to choose the name MCDEF for a new construction. ML/I has a fixed set of priority rules for dealing with multiply-defined names, and these are listed below. However, for the reader who is not interested in these complications the following simple rule for defining new constructions is sufficient to avoid difficulty: choose the delimiters to be different from all other environmental

names (i.e. the names of macros, inserts, skips and warning markers in the current environment). It is quite acceptable, of course, to choose the same representation for the secondary delimiters of different constructions. For example, all macros could have a newline as their closing delimiter. Furthermore it is perfectly in order to have several different names all beginning with the same atom(s); for example three separate macros could have names RETURN, RETURN TO and RETURN IF. ML/I always tries to find the longest name it can, so in this example it would only call the RETURN macro if RETRUN was not followed by TO or IF. The reader who is prepared to adopt the simple rule above can skip the rest of this Section.

A name clash is considered to occur if an atom or series of atoms of the scanned text can be interpreted in more than one way. Note that some environmental names are ignored within certain contexts (see Section 3.4 for a complete list) and thus a name can sometimes be multiply-defined without a clash occurring. For example, in warning mode it is unambiguous to have a macro name the same as an insert name since each is recognised in a different context.

When a name clash does occur, the following rules are applied in order until all ambiguity is removed:

- (a) Exclusive delimiters take precedence over everything else.
- (b) A longer delimiter takes precedence over a shorter one (as illustrated by the above RETURN example).
- (c) Secondary delimiters take precedence over environmental names.
- (d) Local environmental names takes precedence over global ones.
- (e) The most recently defined environmental name takes precedence.

4.7* Implications of rules for name clashes

Some implications of the rules in the previous Section are:

- (a) A construction may be overridden by redefining it. It is even possible to redefine a macro within its own replacement text. If it is desired to achieve the effect of deleting a macro name PQR from the environment this can be achieved by defining PQR as a skip using the MCSKIP macro of Section 5.2.3 as follows:

```
MCSKIP D, <PQR>
```

(PQR is enclosed in literal brackets to prevent it being called.) This technique can be used for all construction names. Note that when a construction is redefined its old use is not completely deleted (no storage is released) and it is possible under some circumstances to re-incarnate the old usage. For example the overriding use may have restricted scope or it may be deleted by one of the macros of Section 5.2.5, such as MCNOSKIP.

- (b) It is usually acceptable to choose a construction name to be the same as the secondary delimiter of another construction. For instance there is no harm in choosing IF as a macro name even though it is a delimiter of MCGO. The only restriction on the use of IF would be that it could not be called within the first argument of MCGO. (This restriction only applies in free mode. In warning mode there would be no restriction.)
- (c) A technique (described in Section 7.4.8) can be designed to give constructions different meanings in different scopes.
- (d) If it is desired to design a language where each macro call occupies one line, it is practicable to define newline as an exclusive delimiter of each macro and also as a warning marker or as a part of a composite macro name (for instance NL GO TO could be a macro name).
- (e) If each of GO, GO TO, and TO THE END are macro names

then

GO TO THE END

is interpreted as a call of GO TO, not as a call of GO and a call of TO THE END. This is because the rules of the previous Section are applied at each step in the scan. There is no mechanism for looking ahead and thus deciding, for instance, to take a shorter delimiter at one step in order to get a longer one later.

Chapter 5 Specification of individual operation macros

This Chapter contains descriptions of the operation macros which should be present in every implementation. In addition, each implementation may have its own particular operation macros (see Section 1 of relevant Appendix).

Arguments of operation macros are evaluated before being processed in the same way as arguments of substitution macros. Leading and trailing spaces are deleted before evaluation in all cases.

Descriptions of the operation macros have been arranged in a standard format which consists of a number of subsections. These subsections in order of occurrence are described below.

- (1) Purpose.
- (2) General form.
- (3) Examples. Examples may not be comprehensible until further subsections have been read. Each example is independent of all the others.
- (4) Restrictions. This subsection describes any restrictions on the form that the values of the arguments of the macro can take. If this subsection is omitted there are no restrictions. The notation "ARG X" is used to represent the value of the argument corresponding to arg X in the General Form.
- (5)* Order of evaluation. This subsection describes the order in which arguments are evaluated. It is omitted if the order is sequential. The order of evaluation is, of course, immaterial in all but the most pathological cases. Note that any change in the name environment caused by the call of a NEC macro does not come into effect until after all its arguments have been evaluated. It is possible for an operation macro to be aborted due to an error before all its arguments have been evaluated.

- (6) System action. This subsection describes the action performed by ML/I at a call of the macro. A reference to "the current environment" means the environment in force when the macro was called. Apart from the system functions, all operation macros have a null value.
- (7) Notes. This subsection contains nothing new, but attempts to bring out more clearly points implied by the preceding material.

Before describing the individual operation macros it is necessary to describe how to define delimiter structures, since all the operation macros which define new constructions have an argument which specifies the delimiter structure of the construction.

5.1 Specification of delimiter structures

Delimiter structures are defined by writing a structure representation, which defines all the delimiters in the structure and the successor(s) of each. The atoms that make up a delimiter are specified by a delimiter name, which is written in the following way:

$$\underline{\text{atom}} \left[\begin{array}{l} (\text{ WITH }) \\ (\text{ WITHS }) \end{array} \underline{\text{atom}} * ? \right]$$

The difference between WITH and WITHS is as follows. If two atoms are linked by WITHS, this means that any number of spaces (including none) may occur between the atoms when the delimiter is used. WITH, on the other hand, means that no intervening spaces are allowed.

As an example, the delimiter names of a macro of form:

```
COMPARE CHARACTERS argument 1 /// argument 2 ;
```

would be:

- (1) COMPARE WITHS CHARACTERS
- (2) / WITH / WITH /
- (3) ;

If, for some reason, it was desired to restrict the number of permissible spaces between COMPARE and CHARACTERS to one, then this would be specified by:

(1a) COMPARE WITH SPACE WITH CHARACTERS

Note that at least one space must be allowed between COMPARE and CHARACTERS because otherwise they would not be recognised as separate atoms. Thus, in the general case, a delimiter name is in error if two atoms are connected by WITH and neither atom is a punctuation character.

It is now necessary to consider how delimiter names are combined to form a structure representation. In the simplest case, the case of a construction with fixed delimiters, this is done simply by concatenating the delimiter names in the order in which they are to occur. Thus the complete structure representations of some of the constructions used as examples in this manual (see Section 2.11) are:

- (a) %.
- (b) < >
- (c) COMMENT;
- (d) DO TIMES REPEAT
- (e) MOVE WITHS FROM TO;

5.1.1 Keywords

Within a structure representation the atoms are separated out by layout characters, i.e. spaces, newlines, tabs, etc. (In the above examples spaces have been used.) Apart from acting as separators, layout characters are totally ignored within structure representations. Thus a problem arises when it is desired to specify a layout character as a delimiter, or as a constituent atom of a multi-atom delimiter. This problem is overcome by using layout keywords to stand for layout characters. In particular:

SPACE means a space.

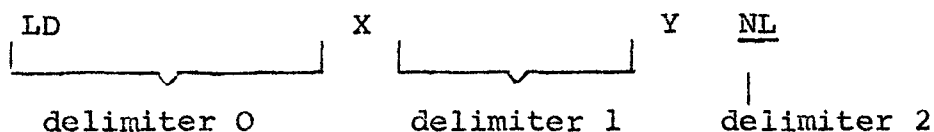
TAB means a tab .
 NL means a newline .
 SPACES means a sequence of one or more spaces .

In addition each implementation may have its own extra layout keywords. See Section 6 of the relevant Appendix for details. The characters represented by these keywords are treated as layout characters and hence, within structure representations, are exactly equivalent to newlines or spaces. Note that layout keywords only apply within structure representations.

The following are examples of delimiter structures using layout keywords

- (a) ESUB NL
- (b) SPACE
- (c) SPACE WITH SPACES (means two or more spaces)
- (d) LD WITH SPACES SPACES NL

A construction defined using (d) above, would be analysed thus:



Note how all the spaces following LD are absorbed into the name; if they had not been defined to be part of the name they would have been taken as the first delimiter.

It is permissible to use SPACES before or after WITHS; in these cases it is exactly equivalent to SPACE.

In addition to these layout keywords, there are other keywords that apply within structure representations. These are: WITH, WITHS, OPT, OR, ALL and any atom commencing with the letter 'N' followed by a digit. Keywords are reserved words and can not be used as the atoms of delimiters. However, if it is necessary to define, say, WITH as a delimiter name, then the keyword WITH could be changed to something else (e.g. '+') by using the MCALTER macro described in Section 5.2.7.

5.1.2 The consequences of evaluation

Since structure representations occur as arguments to operation macros they are evaluated before being processed. Two consequences of this, one beneficial to the user and the other a nuisance, are as follows.

The beneficial consequence is that much-used alternatives can be artificially generated. Assume, for example, that a large number of macros have the form:

```
NAME ( argument ) NL
```

where NAME varies from macro to macro. In this case it would be useful to define a macro PARENS with replacement text:

```
WITH ( ) WITH NL
```

Then a macro DOG of the above form could be defined by writing:

```
DOG PARENS
```

The mischievous consequence arises if an attempt is made to redefine a macro. Assume that a macro EMPLOYEE is defined thus:

```
MCDEF EMPLOYEE AS < J. SMITH >
```

and then subsequently an attempt is made to redefine it by writing:

```
MCDEF EMPLOYEE AS < J. BLOGGS >
```

In this second definition the structure representation is J. SMITH since EMPLOYEE is replaced by its value. Hence a macro J would be defined with secondary delimiters "." and SMITH. The end result would probably be a puzzling error message, perhaps that a delimiter of the macro J was missing.

To avoid problems such as this it is imperative to enclose a name in literal brackets if it is being redefined. The same applies if the name of one macro occurs as a delimiter of another. In fact it is not a bad rule to enclose all structure representations

in literal brackets except where constructions such as PARENS are being used. The correct way to redefine EMPLOYEE would be:

```
MCDEF < EMPLOYEE > AS < J. BLOGGS >
```

5.1.3 * Introduction to more complicated cases

The Sections which follow describe facilities for setting up more and more elaborate delimiter structures. The reader is recommended to read on until he knows enough for his own applications and then to skip the rest. Readers who are only interested in fixed delimiters may give up now.

In order to specify the delimiter structure of a construction it is necessary to specify the name(s) of the construction and the successor(s) of each delimiter that is not a closing delimiter. In the simple cases described above the structure representation consisted of the name of the construction and then each succeeding delimiter followed by its successor until the closing delimiter. In more complicated cases it is necessary to have two other mechanisms for specifying successors, namely option lists and nodes. Furthermore it is convenient to imagine that a special symbol α occurs at the start of each structure representation and another symbol ω at the end. With this convention any successor of α is a name of the construction and any delimiter with ω as successor is a closing delimiter. The paragraphs which follow contain informal introductions to the concepts of option lists and nodes. More exact details are given in the next Section.

Option lists are used to specify that a delimiter has several optional alternatives as successor. The essential form of an option list is:

```
OPT branch 1 OR branch 2 OR ... OR branch N ALL
```

The ordering of the branches is immaterial. An example of the use of an option list is in the following structure representation for the ESUB macro:

```
ESUB OPT TAB OR NL ALL
```

If, in addition, it was decided to allow SUBTRACT as an alternative

name to ESUB, then its structure representation would be:

```
OPT ESUB OR SUBTRACT ALL OPT TAB OR NL ALL
```

In the ordinary way the successor of the delimiter at the end of a branch is taken as the delimiter following the ALL concluding the option list. In other words the branches may be thought of as coalescing at the delimiter following ALL. (Thus in the example above both ESUB and SUBTRACT have either tab or newline as alternative successors and both tab and newline have the imaginary symbol ω as successor and are therefore closing delimiters.) However, as will be seen, it is possible to override this coalescing effect by the use of nodes.

Nodes are used for defining the successor of a delimiter to be a delimiter or option list elsewhere in the structure representation. The use of nodes in structure representations is analogous to the use of labels in programming languages. As the reader will know, the statements in a programming language are written in sequence and the "successor" of each statement is normally taken as the statement which follows. However, the user can specify a different successor by the use of labels. A label is "placed" on one program statement and is then "gone to" after any program statement which requires the labelled statement as successor. In exactly the same way, nodes are used to specify the successors of delimiters.

A node is represented by a node flag followed by a positive integer. The normal node flag is the letter 'N' but this can be changed if desired using the MCALTER macro of Section 5.2.7. It will be assumed in this manual that the node flag is 'N'. A node is placed by writing its name before any delimiter name or option list. A node can be "gone to" only from the end of a branch of an option list or at the end of a structure representation. A "go to" is indicated simply by placing the name of the appropriate node at the desired point. (Although the name of a node is used both to place it and to go to it, there is no ambiguity, owing to the different context in which each occurs.) As a simple example of the use of nodes, consider the structure representation of a SUM macro which allows any number of arguments separated by plus or minus signs and terminated

by a semicolon. A typical call of SUM would be:

```
SUM A + B - C + D ;
```

The structure representation of SUM is:

```
SUM N1 OPT + N1 OR - N1 OR ; ALL
```

This is interpreted thus. SUM is followed by either a plus sign, a minus sign or a semicolon. Node N1 is placed before the option list. The successor of both plus and minus is defined by going to N1, and N1 is associated with the alternatives plus, minus and semicolon. The successor of semicolon, on the other hand, is taken as the delimiter which follows ALL, which is ω . Hence the semicolon is a closing delimiter.

There are no particular restrictions on the use of nodes. Any number of nodes may be placed within a structure representation provided, of course, that they have different numbers. Any positive integers may be chosen to designate nodes; no particular sequence is required. Node numbers are local to the structure representation in which they occur and hence there is no relation between the nodes of one structure representation and those of another. Thus the same node numbers may be used in each case. There are no restrictions on the scope of a "go to"; thus it may dive into an option list or alternatively come out of one.

The node $N\emptyset$ (N zero) has a special usage, namely to denote an exclusive delimiter. Node $N\emptyset$ may be gone to but it may not be placed. If the successor of a delimiter is specified by $N\emptyset$ then this delimiter is taken as an exclusive delimiter. Apart from $N\emptyset$, it is illegal to go to a node without placing it.

5.1.4 * Full syntax of structure representations

Before describing the general form of a structure representation it is necessary to describe a number of syntactic sub-components. These are:

- (a) A nodeplace represents the placing of a node and is specified by the node flag followed by an unsigned

positive integer.

- (b) A nodego represents the action of going to a node and is also specified by the node flag followed by an unsigned integer. (In this case and case (a) above any redundant leading zeros are ignored.)
- (c) A delspec represents the specification of a delimiter or an option list and is of form:

$$[\text{nodeplace ?}] (\text{delimiter name} (\text{OPT branch} [\text{OR} [\text{nodeplace ?}] \text{branch *?}] \text{ALL}))$$

where a branch is of form:

$$\text{delimiter name} [\text{delspec * ?}] [\text{nodego ?}]$$

(The reader may like to look ahead to the examples in the next Section at this point.) Note that each branch must begin with a delimiter name, called the branch name. The branch names are the possible alternative successors of the delimiter preceding the option list, and must all be different. Thus no sequence of atoms must match more than one branch name, and the following option list is therefore incorrect:

$$\text{OPT X WITH SPACE WITH Y ... OR X WITHS Y ... ALL}$$

since "X Y" could be the name of either branch.

As was seen from the preceding example of the SUM macro, nodeplaces immediately preceding an option list associate the node with all the options of the list. The syntax forbids a nodeplace immediately after OPT and a nodeplace immediately following OR has a special meaning in that it associates the node not only with the delimiter name that follows it but also with the names of all subsequent branches of the option list. As an example, assume that the SUM macro was extended to allow the user the option of assigning the answer by writing, for example:

SUM X = Y + Z; to calculate Y + Z and assign the answer X,
 or SUM Y + Z; to calculate Y + Z and leave the answer in
 an accumulator.

Here SUM has an optional first argument delimited by an equals sign. Its structure representation could be written:

SUM OPT = N1 OR N1 + N1 OR - N1 OR ; ALL

In this case N1, which is placed after the first OR, is associated with the alternatives plus, minus and semicolon.

Now that the sub-components have been described it is possible to give the general form of a structure representation. This is:

[delspec *] [nodego ?]

One last point should be made about the writing of structure representations. This concerns minimizing the amount of storage that is needed to store a delimiter structure. The storage used is a function of the number of delimiter names in the structure. Thus it is advisable to try to link a structure together in such a way that it contains the minimum number of delimiters. As an example of redundancy, consider the following structure representation:

BUMP OPT TIMES ; OR ; ALL

This represents a construction of form:

BUMP [argument TIMES ?] argument ;

Note that the semicolon is repeated within the structure representation of BUMP. However, this repetition can be avoided by writing the structure representation in the following improved way:

BUMP OPT TIMES N1 OR N1 ; ALL

5.1.5 * Examples of complex structure representations

This section contains the general forms of some possible constructions together with the structure representation of each.

Example 1

General form Either BUY arg A # arg B . arg C;

or BUY arg A POUNDS arg B \$ arg C D arg D;

Structure representation BUY OPT \$. OR POUNDS S D ALL;

In the second form, if it is desired to allow the S and D fields optionally to be omitted, then the structure representation could be written:

BUY OPT \$. ; OR POUNDS OPT S N1 OR N1 D ; OR ; ALL ALL

Here N1 is associated with the possibilities D and semicolon. In this form the semicolon is mentioned three times. The structure representation is therefore improved by writing it in the following form, where semicolon only occurs once:

BUY OPT \$. N2 OR POUNDS OPT S N1 OR N1 D N2 OR N2 ; ALL ALL

(The diagram in the next Section may be an aid to understanding this.)

Example 2

General form [/ argument * ?] END

Structure representation N1 OPT / N1 OR END ALL

This macro has two possible names: "/" and "END".

Example 3

General form (LOAD)
 (LOAD Q) arg A, arg B NL
 (STORE)

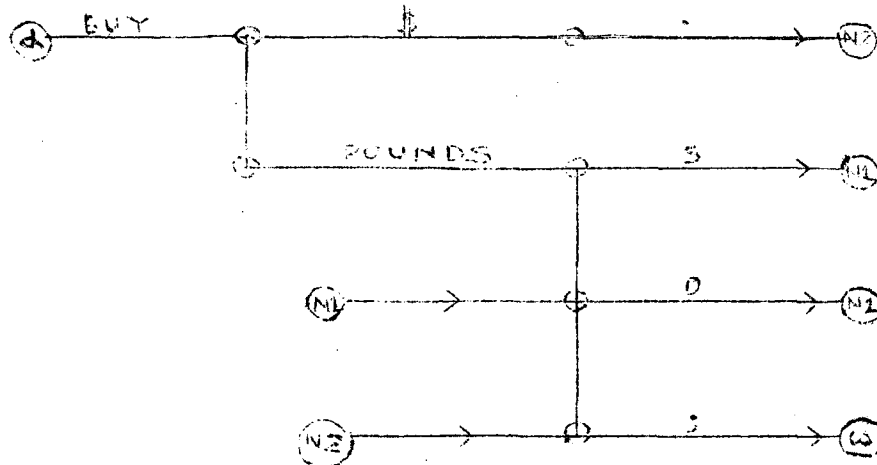
where the newline is an exclusive delimiter.

Structure representation OPT LOAD OR LOAD WITHS Q OR STORE ALL, NL NØ

5.1.6 Possible errors in structure representations

Great care must be taken in writing structure representations as errors can have very unfortunate results. In complex cases it may be useful to use a diagram. For example the following

represents the BUY macro of the previous Section in its final improved form.



Special points to be watched in writing structure representations are the use of keywords and the possible differences between the structure representation as written and its evaluated form. Remember that keywords cannot be used as delimiter names.

If NL/I does reject a structure representation as illegal (giving the message of Section 6.3.6), then the following are some of the possible causes:

- (a) Illegal syntax, for example : unmatched OPT, node after OPT, two nodes in succession, branch without a name, placing of node zero, names such as N1A.
- (b) Keyword used as delimiter.
- (c) Undefined or multiply-defined node.
- (d) Two branches with the same name.
- (e) Misuse of WITH or WITHS e.g. GO WITH TO, X WITHS N1.
- (f) Structure with no closing delimiter.
- (g) Unconnected structure. For example the delimiter D is not connected to the main structure in the following case:

NOGOOD N1 OPT A N1 OR B N1 ALL D

5.2 The NEC macros

The operation macros which change the name environment are listed in this Section.

5.2.1 MCWARN

<u>Purpose</u>	Definition of a local warning marker.
<u>General form</u>	MCWARN <u>arg A</u> <u>NL</u>
<u>Examples</u>	(a) MCWARN \$ (b) MCWARN CALL WITHS THIS WITHS MACRO
<u>Restrictions</u>	ARG A must be a structure representation consisting simply of a single delimiter name.
<u>System action</u>	ARG A is added to the current environment as a local warning marker and the current environment is placed in warning mode.

5.2.2 MCINS

<u>Purpose</u>	Definition of a local insert.
<u>General form</u>	MCINS [<u>arg A</u> , ?] <u>arg B</u> <u>NL</u>
<u>Examples</u>	(a) MCINS * . (b) MCINS U, INSERT HERE
<u>Restrictions</u>	ARG A, if it exists, must consist of the letter 'P' or the letter 'U'. Redundant spaces are allowed. ARG B must be a structure representation of form: <u>delimiter name</u> <u>delimiter name</u>
<u>System action</u>	A new local insert definition is added to the current environment. The delimiter structure of the new insert is represented by ARG B and the option is defined as "protected" unless ARG A exists and consists of the letter 'U'. In this latter case it is defined as "unprotected".
<u>Notes</u>	(a) Unprotected inserts are only needed for sophisticated applications of ML/I and users with simple applications can safely omit <u>arg A</u> .

5.2.3 MCSKIP

Purpose Definition of a local skip.

General form MCSKIP [arg A, ?] arg B NL

Examples (a) MCSKIP MT, ()
defines "(" and ")" as literal brackets.

(b) MCSKIP N WITH. WITH B WITH. ;
deletes comments that commence with N.B.
and end with a semicolon.

(c) MCSKIP DT, ' '

(d) MCSKIP NONL NL

(e) MCSKIP T, NOPUNCT N1 OPT, N1 OR. N1 OR END ALL
causes all commas and periods between NOPUNCT and
END to be deleted.

(f) MCSKIP STATIC
deletes all occurrences of STATIC. Note that
the delimiter structure of a skip can specify
any number of delimiters, although usually
there will be one, as in this example, or two.

Restrictions ARG A, if it exists, must have form:

$$\left[\begin{array}{l} (M) \\ (D) \\ (T) \end{array} * ? \right]$$

Redundant spaces are allowed. ARG B must be
a structure representation.

System action A new local skip definition is added to the
current environment. The delimiter structure
of the new skip is represented by ARG B, and
the matched option, the text option and the
delimiter option are set if ARG A contains
the letter M, T. or D, respectively. If
arg A is omitted none of the options is set.

Notes

- (a) The letters in ARG A may be in any order.
- (b) If arg A is omitted and arg B contains a comma, then this comma should be enclosed in literal brackets to prevent it being taken as a delimiter of MCSKIP.

5.2.4 MCDEFPurpose

Definition of a local macro.

General formMCDEF [arg A VARS ?] arg B (AS)
(SSAS) arg C NLExamples

(a) MCDEF ARRSIZE AS 6

(b) MCDEF ESUB NL
AS < CMA
ADD %A1.
CMA

>

is a definition of the ESUB macro used in examples.

(c) MCDEF 6 VARS CALCULATE AS ...

(d) MCDEF (OPT + OR - OR * ALL) AS <%D1. %A1. %A?.>
This macro converts fully parenthesized algebraic notation to Polish Prefix notation. Thus, for example, it would convert ((PI*26)-LENGTH) to -* PI 26 LENGTH.(e) MCDEF PARENS AS WITH () WITH NL
defines the PARENS macro used in Section 5.1.2.(f) MCDEF NOTE ; SSAS < [%WA1.] >
is the definition of the straight-scan macro NOTE used as an example in Section 2.10. "SSAS" stands for "straight-scan AS".(g) MCDEF CALL NL NØ AS ...
defines a CALL macro with newline as an exclusive delimiter.Restrictions

ARG A, if it exists, must be a macro expression and ARG B must be a structure representation.

Order of evaluationarg A, arg C, arg B.System action

A new local macro definition is added to the current environment. The delimiter structure of this new macro is represented by ARG B, the replacement text is specified by ARG C and the

capacity (i.e. the number of temporary variables) is the greater of the result of ARG A and three. The capacity is three if ARG A is omitted. The new macro is set up as a normal-scan macro if MCDEF is called with delimiter AS and as a straight-scan macro if the delimiter SSAS is used.

Notes

- (a) The replacement text is normally enclosed in literal brackets to delay evaluation until macro call time and to ensure that any newlines within the replacement text are not taken as the closing delimiter of MCDEF.
- (b) If it is desired that the replacement text be treated as a literal when the macro is called as well as when it is defined, then it is necessary to enclose the replacement text in double literal brackets (see example in Section 7.3.1).

5.2.5 MCNOWARN, MCNOINS, MCNOSKIP and MCNODEF

- Purpose Deletion of local constituents of the current environment.
- General form
- (a) MCNOWARN
 - (b) MCNOINS
 - (c) MCNOSKIP
 - (d) MCNODEF
- System actions These macros respectively delete all local warning markers, all local insert definitions, all local skip definitions and all local macro definitions from the current environment. In addition, MCNOWARN causes the current environment to be placed in free mode unless there are any global warning markers.
- Notes
- (a) Note that these macros do not have newline as a closing delimiter.
 - (b) In current implementations no storage is released if a constituent of the environment is deleted by one of these macros.
 - (c) See the example in Section 7.3.4 for a method of deleting individual constructions from the environment.
 - (d) If MCNOWARN is to be meaningful it must be preceded by a warning marker.
 - (c) MCNODEF does not cause the operation macros to be deleted from the environment since these latter are global.

5.2.6 MCWARNG, MCINSG, MCSKIPG and MCDEF

<u>Purpose</u>	Global equivalents of MCWARN, MCINS, MCSKIP and MCDEF.
<u>General form</u>	Similar to those of the corresponding local macros.
<u>Examples</u>	<p>(a) MCWARNG MACRO</p> <p>(b) MCINSG /.</p> <p>(c) MCSKIPG DT, TEXT::</p> <p>(d) MCDEF %A1. WITH(,)AS<...></p>
<u>Restrictions</u>	The restrictions on the forms of arguments are the same as for the corresponding local macros.
<u>System actions</u>	As for the corresponding local macros except that the newly-defined constituents are global rather than local.
<u>Notes</u>	<p>(a) If a global NEC macro is called in the source text, the effect is the same as if the corresponding local macro had been called (except for certain differences if the name is multiply-defined). Global constructions are not, however, deleted by the macros MCNOWARN etc. described in Section 5.2.5. For reasons of efficiency the user is recommended to use local macros where possible.</p> <p>(b) If a call of MCWARNG occurs, all subsequent text processing will be in warning mode, since it is impossible to delete a global warning marker.</p>

5.2.7 MCALTERPurpose

Alteration of the secondary delimiters of operation macros or of the keywords used in structure representations.

General form

MCALTER arg A TO arg B NL

Examples

(a) MCALTER

TO ;

MCALTER AS TO : ;

After these two calls of MCALTER, Example

(a) of Section 5.2.4 would be written :

MCDEF ARRSIZE : 6;

(b) MCALTER WITH TO +
MCDEF JOIN + (WITH) AS ...
MCALTER + TO WITH

Here WITH is changed to + and then back to WITH again in order to define a macro "JOIN(" with delimiter WITH.

(c) MCALTER N TO 9

(d) MCALTER SPACE TO BLANK

Restrictions

ARG A and ARG B must be single atoms. ARG A must be either a secondary delimiter of one or more operation macros or one of the keywords used in structure representations. ARG B must not be longer than the system name of any delimiter or keyword matched by ARG A. If ARG A is the node flag (i.e. the letter 'N' or whatever has replaced it) then ARG B must be a letter or a digit.

Order of evaluation arg B, arg A.

System action

ARG B is substituted in place of ARG A wherever ARG A occurs as a secondary delimiter of an operation macro or as a keyword.

Notes

- (a) MCALTER cannot be used to change the names of operation macros.
- (b) It is very dangerous to change a keyword or delimiter to become the same as another keyword, for instance:

MCALTER UNLESS TO IF

The effect of an alteration such as the above on subsequent processing is undefined, since it depends upon the order in which delimiters are scanned.

- (c) In the unlikely event of a call of MCALTER specifying several replacements some of which are valid, and some of which are invalid because of the length of ARG B, then the number of valid replacements that are performed before the call is aborted is undefined.
- (d) In the MCGO macro (and in any other macro where the action taken depends upon the form of the delimiters), the delimiters are examined immediately the macro is called and no call of MCALTER within an argument can affect the action of the containing macro.
- (e) Since the operation macros are global, the effect of MCALTER is also global.
- (f) It has been assumed in examples throughout this manual (apart from this Section) that no calls of MCALTER have occurred.
- (g) Since MCALTER has a global effect, it is not recommended to use it locally to a piece of replacement text. If it is used locally, MCALTER must be called again before leaving the replacement text in order to cancel the changes that have been made.

5/23

- (h) A layout keyword can be MCALTERED to be the same as the character it represents, e.g.

```
MCALTER NL TO <  
>
```

This will effectively delete the layout keyword, e.g. after the above MCALTER, newline would stand for itself within structure representations - it would not act as a separator.

5.3 System functions

The operation macros which return values are listed in this Section. Note that these macros do not have a newline as the closing delimiter.

5.3.1 MCLENG

Purpose

Function to find the length of a character string.

General form

MCLENG (arg A)

The left parenthesis is part of the macro name. It may optionally be preceded by spaces.

Examples

(a) MCLENG (%A1.)

(b) MCLENG(%A1.%D3.PIG)

System action

The value of this function is the number of characters in ARG A. This number is represented as a character string in the way described in Section 2.6.7 (e).

5.3.2 MCSUBPurpose

Function to access a substring.

General form

MCSUB (arg A, arg B, arg C)

The left parenthesis is part of the macro name. It may optionally be preceded by spaces.

Examples

(a) MCSUB (ABC/XYZ, 3, 6)

This function has value C/XY.

(b) MCSUB (ARGUMENT, -2, 0)

This function has value ENT, since non-positive results of ARG B and ARG C specify offsets from the end of ARG A.

(c) MCSUB (%D2., 1, 1)

The value of this function is the first character of the inserted delimiter.

(d) MCSUB (%A3. Y%D3., 1, P3 - T6 + 7)

Order of evaluation

arg A, arg B, arg C. However, arg C is not evaluated if VB (see below) is greater than L (see below) or is less than one.

System action

Let L be the number of characters in ARG A, let RB be the result of ARG B, and let VB be derived from these values by the following rule:

$$VB = \begin{cases} RB & \text{if } RB > 0 \\ L + RB & \text{otherwise} \end{cases}$$

Let VC be derived from the result of ARG C by a similar rule. The value of a call of MCSUB depends upon whether VB and VC describe a valid substring of ARG A. This occurs if:

$$1 \leq VB \leq VC \leq L$$

If this relation does not hold the value of MCSUB is null. If the relation holds the value of MCSUB is the substring of ARG A from character position VB up to and including character position VC, the first character of ARG A being taken as character position one.

Notes

- (a) In the case where the relation holds, the value of MCSUB consists of $VC - VB + 1$ characters.
- (b) The value of MCSUB is not itself evaluated. Thus the value of Example (b) would be ENT even if ENT was a macro.

5.4 Further operation macros

The remaining operation macros, i.e. those not falling into the previous categories, are described below.

5.4.1 MCSET

<u>Purpose</u>	Macro-time assignment statement.
<u>General form</u>	MCSET <u>arg A</u> = <u>arg B</u> <u>NL</u>
<u>Examples</u>	(a) MCSET P10 = 3 (b) MCSET T6 = -4 (c) MCSET TT3 = TP4 - 109 + 25/P1 (d) MCSET T%A1.=%A1. + 17 where the value of the inserted argument is a positive integer.
<u>Restrictions</u>	ARG A must be the name of a macro variable in the current environment. (ARG A may contain redundant spaces at the beginning or the end.) ARG B must be a macro expression.
<u>System action</u>	The result of ARG B is assigned to the macro variable designated by ARG A.

5.4.2 MCNOTE

Purpose Generation of user's own error and debugging messages.

General form MCNOTE arg A NL

Examples (a) MCNOTE %A3. IS ILLEGAL ARGUMENT
 (b) MCNOTE OCCURENCE NUMBER %P1. OF <CONT>

System action ARG A is printed on the debugging file (see Chapter 6) as if it were a system message. A newline is inserted in front of it and it is followed by a printout of the context of the call of MCNOTE.

Notes (a) If example (b) occurred in line 3 of a macro CONT, then the printout might be:

OCCURENCE NUMBER 33 OF CONT
 DETECTED IN
 LINE 3 of MACRO CONT WITH NO ARGUMENTS
 CALLED FROM
 LINE 267 OF SOURCE TEXT

(b) Notes (d) and (f) of Section 6.2 do not apply to the printing of ARG A.

5.4.3 MCGOPurpose

Macro-time GO TO statement or conditional.
GO TO statement.

General forms

- (a) MCGO arg A NL
- (b) MCGO arg A (IF) arg B (=) arg C NL
 (UNLESS) (BC)
 (EN)
 (GE)
 (GR)

The meanings of the respective mnemonic second delimiters are:
Belongs to Class, Equals Numerically,
Greater than or Equals and Greater than.

Examples

- (a) MCGO L1
 (b) MCGO LT1
 (c) MCGO L6 IF%D1. = +
 (d) MCGO L0 UNLESS P3 - T5 GE - 6
 (e) MCGO L T3 - P7 + 4 UNLESS %A6. BC N

This tests whether argument six is a number
 (Belongs to the Class of Numbers).

Restrictions

ARG A must consist of the letter "L" (optionally preceded by redundant spaces) followed by a macro expression. The result of this macro expression must never be negative and, furthermore, it must not be zero if MCGO is called from the source text. If the second delimiter is BC then ARG C, which is the name of a class, must consist of one of the following letters:

- I (for identifier)
 L (for letter)
 N (for number)

together with any desired number of spaces. If the second delimiter is EN, GE or GR then ARG B and ARG C must both be macro expressions.

Order of evaluation arg B, arg C, arg A. In Form (b), arg A is evaluated only if the condition holds.

System action for form (b) ARG B and ARG C are compared to yield a true or false value. If the second delimiter is EN, GE or GR, then numerical comparison is performed; otherwise character comparison is performed. The method of comparison depends on the second delimiter in the following way:

- (a) =. A true value results only if ARG B and ARG C are identical strings of characters.
- (b) BC. If ARG C is the letter I, then a true value results only if ARG B is of form:

$$\left[\begin{array}{l} \text{(letter) *} \\ \text{(digit)} \end{array} \right]$$

If ARG C is the letter L, then a true value results only if ARG B is of form:

$$\left[\underline{\text{letter}} * \right]$$

If ARG C is the letter N, then a true value results only if ARG B is of form:

$$\left[\begin{array}{l} (+) *? \\ (-) \end{array} \right] \quad \left[\underline{\text{digit}} * \right]$$

- (c) EN, GE, GR. In these cases a true value results only if the result of ARG B is, respectively, numerically equal to, greater than or equal to, or greater than the result of ARG C.

If the comparison yields a false value and the second delimiter is IF or if the comparison yields a true value and the second delimiter is UNLESS, then no further action takes place. Otherwise the system action for Form (a) is now performed.

System action for form (a) Let N be the result of the macro expression in ARG A. If N is positive, then

the point of scan is changed to the point associated with macro label N. (See next Section for a fuller description.) If N is zero, then processing of the current piece of text is abandoned and evaluation proceeds as if the end of the current piece of text had been reached. Thus when N is zero a MCGO serves a similar function to the RETURN statement found in many high-level languages. This 'RETURN' facility may be used within inserted text or replacement text but not within the source text.

Notes

- (a) Note that leading and trailing spaces are removed before arg B and arg C are evaluated. If it is required that these spaces take part in the comparison, they should be enclosed in literal brackets.
- (b) If it is desired to achieve the effect of a backward GO TO in the source text then the required loop must be defined as the replacement text of a macro call. See Section 7.4.1 for an example.
- (c) Sections 7.3.9 and 7.3.5 contain examples of the use of MCGO.
- (d) The user should be very careful to differentiate between the two relational operators "=" and EN. Note that the relation "P1 EN P2" is true if the first two permanent variables have the same value whereas "P1 = P2" is, of course, never true. Note that "%P1. = %P2." is equivalent to "P1 EN P2".

5.4.3.1* Exact description of GO TO

The following is a more exact description of the action of ML/I in performing a GO TO when N is positive.

If label N, which is called the designated label, is

present in the current environment then the action of ML/I is simply to change the point of scan to the point associated with the designated label. Otherwise a forward search for the designated label is performed, starting at the current point of scan. If a macro call or skip is encountered during this search, the search is suspended until the end of the macro call or skip is found. Each time an insert is encountered outside a call or skip, the argument is evaluated and the search ends when an insert which "places" label N is found (or, in the error case, at the end of the current piece of text). No value text is generated during a search and no macro calls are performed (except conceivably during the evaluation of the argument of an insert). At the end of the search the action of ML/I is concluded by setting the point of scan as the point immediately after the designated label.

Any labels encountered in the forward search (including the designated one) are added to the current environment provided that the rules of Section 2.6.7 (f) are satisfied.

If an error is detected during a forward search then the appropriate error message is printed in the normal way.

5.4.4 MCPVAR

Purpose

Allocation of extra permanent variables.

General form

MCPVAR arg A NL

Example

(a) MCPVAR 100

Restrictions

ARG A must be a macro expression.

System action

Let N be the result of ARG A. If N is greater than the current number of permanent variables then the number of permanent variables is increased to N ; otherwise no action is taken. The values of the new permanent variables are set to zero and the values of the previously allocated ones remain unchanged.

Chapter 6 Error messages

ML/I detects all errors and prints a message at every occurrence. An error message consists of a statement describing the particular error that has been detected with a print-out of the current context. This print-out enumerates all the macro calls and insertions of arguments or delimiters that are currently being processed, together with a line number to indicate the state of the scan in each case. Error messages are printed on an implementation-defined medium (see Section 4 of relevant Appendix) called the debugging file. This is normally a printer or on-line typewriter.

6.1 Example of an error message

An example of an error message is the following. Assume the user has written:

```
MCSET Y10 = 56
```

in the source text. Then the following message would be given:

```
ERROR(S)
ARGUMENT HAS ILLEGAL VALUE, VIZ "Y10"
DETECTED IN
MACRO MCSET WITH ARGUMENTS
1) Y10
2) 56
CALLED FROM
LINE ... OF SOURCE TEXT
```

6.2 Notes on context print-outs

The printout of the context should be largely self-explanatory but the following points should be noted.

(a) The line number is one greater than the number of newlines so far encountered in the piece of text to which it refers. Line numbers refer to scanned text, not to value text.

(b) If a macro call or insert straddles more than one line of text, then the line numbers of both the beginning and the end of the call or insert are printed (e.g. CALLED FROM LINES 6 TO 21 OF SOURCE TEXT).

(c) When the arguments of a call are enumerated, the text of each argument rather than its value is printed.

(d) If a piece of text in an error message consists of a single layout character, then the corresponding layout keyword, enclosed in parentheses is used in its place, for example:

DELIMITER (NL) OF MACRO X NOT FOUND

In addition a null piece of text is represented by (NULL).

(e) Any multi-atom delimiter occurring in an error message is printed in full. A space is printed between two adjacent atoms if spaces are permitted between the atoms (i.e. if WITHS has been used rather than WITH in their definition).

Note (d) above applies to each atom. As an example, a message involving the multi-atom macro name "MCSUB(" would read:

MACRO MCSUB (CALLED FROM ...

(f) There is an implementation-defined number 2N (see Section 4 of the relevant Appendix) which is the maximum length of a piece of text that can be inserted in an error message. If a piece of text is too long, the first N-4 characters and the last N-4 characters are printed, separated by three dashes and some spaces.

(g) If the text of an error message is about to overflow a line, then a newline is artificially inserted.

6.3 Complete list of messages

This Section contains a complete list of all the error messages produced by ML/I.

6.3.1 Illegal macro element

Message flag number IS ILLEGAL MACRO ELEMENT

Description The number, which is the value of the subscript or macro expression associated with the flag, is either too large or too small. Alternatively, macro elements of the type designated by the flag do not exist in the current environment (e.g. there are no arguments or temporary variables in the source text).

System action The current operation macro or insert is aborted.

6.3.2 Arithmetic overflow

Message ARITHMETIC OVERFLOW

Description Overflow has occurred during the evaluation of a macro expression or subscript. This message occurs when an attempt is made to divide by zero. It may also occur under other circumstances but these are implementation-defined (see Section 5 of relevant Appendix).

System action The current operation macro or insert is aborted.

6.3.3 Illegal input character

Message ILLEGAL INPUT CHARACTER

Description A character of the source text is not in the character set of the implementation.

System action The illegal character is replaced by a fixed implementation-defined character called the error character (see Section 4 of relevant Appendix). A typical error character is the question mark.

6.3.4 Illegal macro name

Message ILLEGAL MACRO NAME AFTER WARNING, VIZ 'atom'

Description

A warning marker is followed, possibly with intervening spaces, by the given atom which is not a macro name (nor the start of a multi-atom macro name). If this error occurs within an argument the above message is printed both when the argument is originally scanned and also each time it is inserted.

System action

The warning marker is treated as if it had not been recognised as an environmental name, and the atom which follows is treated as if no warning marker had occurred. Thus, for example, a skip name following a warning marker will be treated as such.

6.3.5 Unmatched constructionMessage

DELIMITER name [OR name*?] OF (MACRO) name
 (SKIP)
 (INSERT)
 IN LINE number OF CURRENT TEXT NOT FOUND

Description

The given construction which starts in the given line of the current piece of text is not complete. Note that the line number is relative to the current piece of text. When the error was detected the scan was searching for the given delimiter (or for one of the given alternative delimiters). The error is detected only when the scan reaches the end of the source text or the end of a piece of inserted text or replacement text.

Possible causes

A mismatch of the delimiters of a construction nested within the given one can cause this error since delimiter matching is liable to get "out of phase" as a result. Alternatively, an incorrect specification of a delimiter structure can cause delimiters to be matched in a way not intended by the user and, again, the error may be in a nested construction rather than in the given one.

System action In the call and insert cases, the effect is as if the text from the macro or insert name to the current point of scan was deleted. In the skip case, text skipped over is treated in the normal way and the skip is artificially terminated.

6.3.6 Illegal syntax of argument value

Message ARGUMENT number HAS ILLEGAL VALUE, VIZ 'value'

Description The given value of an argument to an operation macro or insert has not the required syntax. For operation macro arguments see appropriate "Restrictions" subsection of Sections 5.2, 5.3 or 5.4, or if the argument is (supposed to be) a structure representation then see Section 5.1.6. For arguments to inserts see Section 2.6.7.

System action The current operation macro or insert is aborted.

6.3.7 Redefined label

Message LABEL number IS MULTIPLY-DEFINED

Description An attempt has been made to re-define a label that has already been defined within the current text.

System action The new definition is ignored.

6.3.8 Undefined label

Message LABEL number REFERENCED IN LINE number OF CURRENT TEXT NOT FOUND

Description A call of MCGO references an undefined label. This error is detected when the scan reaches the end of a piece of text (since it performs a search for the missing label). If any constructions are unmatched, the message(s) of Section 6.3.5 are printed with this message.

Possible causes An attempted backward MCGO in the source text or an attempted MCGO from one piece of text to another can cause this error. Alternatively, it can be caused by an unmatched construction within the scope of a forward MCGO.

System action The effect is as if the designated label had been found at the very end of the current piece of text.

6.3.9 Storage exhausted

Message PROCESS ABORTED FOR LACK OF STORAGE [POSSIBLY DUE TO other messages?]

Description ML/I has used up all its available storage. If the current text is the source text then the following additional information is given: if there are any constructions currently unmatched, or if a search is being made for a label as a result of a forward MCGO, then the messages of Sections 6.3.5 and 6.3.8 are printed with this message.

Possible causes Storage is taken up by macro variables, by the name environment, by a macro call or insert in the source text, and by nested calls and/or inserts. Hence an unmatched macro call in the source text or a call with a very long argument can cause this error. Alternatively, it can be caused by an endless or very deep recursive nest, by the name environment being too big, or by a combination of all these factors.

System action The current process is aborted.

6.3.10 System error

Message SYSTEM ERROR

Description There has been a machine error, an operating error or an error in the implementation of ML/I.

System action The current process is aborted.

6.3.11 Subsidiary message

Message (MACRO) name ABORTED DUE TO ABOVE ERROR
(INSERT)

Description This message occurs as a subsidiary message every time an error causes the operation macro or insert currently being performed to be aborted. Any construction that has been aborted is given a null value.

6.3.12 Statistics

Typical message AT END OF PROCESS: number LINES, number CALLS

Description The occurrence of this message is implementation-defined (see Section 4 of relevant Appendix). It is usually printed at the end of a process and sometimes at intermediate stages as well. The number of lines of source text that have so far been scanned, together with the total number of macro calls performed (the value used as an initial setting of T2) is printed.

6.3.13 Implementation-defined messages

Description Each implementation may have its own particular messages. See Section 4 of relevant Appendix for details.

Chapter 7 Hints on using ML/I

7.1 How to set up the environment

Where possible it is best to write all the NEC macro calls to set up the environment at the start of the source text. The name environment will normally contain an insert definition and it is a good idea to define this first. Choose some atom(s) as the insert name that will not occur naturally in the source text. Next define skips to cause comments and literals in the source text to be skipped over. Also define a pair of literal brackets, again choosing atoms that do not occur naturally in the source text. Thus do not use "<" and ">" if these symbols are used to represent "less than" and "greater than". Finally, define the required macros, not forgetting to enclose arguments in literal brackets where necessary. It may be useful to have a systematic convention for macro names, for example starting every macro name with the same letter. However, due to the randomizing technique used in the internal working of many implementations of ML/I, it is not advisable to choose macro names all of the same length and all ending with the same character, as this would slow down execution.

7.2 Possible sources of error

The following Sections illustrate some areas where the user of ML/I should take special care.

7.2.1 Jumping over expanded code

If macros are used in an assembly language, great care must be taken with instructions of the form "jump to location counter + N", since there may be macros within the scope of the jump which expand into several machine instructions. The same applies to machine instructions of the form "skip one instruction". For this reason it is helpful to choose macro names that cannot be confused with the names of machine instructions.

7.2.2 Generation of unique labels

If a macro generates code which involves an execution-time label, then a different label must be generated at each

call of the macro. The technique described in Section 2.6.8(b) can be used for this purpose. The same applies, in some cases, to execution-time temporary variables.

7.2.3 Lower case letters

Note that in implementations where the character set includes both upper and lower case letters, only upper case letters may be used for vocabulary words of ML/I. This applies to the names and secondary delimiters of operation macros, to keywords and to insert flags. Further note that, for example, "PIG", "Pig" and "pig" are three different atoms.

7.2.4 Use of newlines in definitions

Remember that layout characters within replacement text are treated like any other characters. They should therefore be used with great care as they affect the format of the output text. Thus:

```
MCDEF LOAD AS <LD>
      LOAD X
```

would generate:

```
LD X
```

whereas:

```
MCDEF STORE
AS <ST
>
      STORE Y
```

would generate:

```
ST
Y
```


Moreover:

```
MCDEF JUMP AS
<B>
    JUMP LB6
```

would generate:

```
B
    LB6
```

since JUMP would be defined as a null macro.

7.2.5 Use of redundant spaces

As a general rule extra spaces are ignored within text that forms an instruction to ML/I but are treated like any other character within text that ML/I manipulates.

Spaces may be chosen as construction names, but in any context where spaces are ignored they are ignored even if space is a construction name. In particular, spaces are ignored after warning markers so, when in warning mode, it is not possible to have a macro name commencing with a space.

Below is a list of some of the places where spaces are ignored:

- (a) At the beginning or end of an argument to an operation macro (before evaluation).
- (b) Ditto for an argument to a substitution macro, provided the insert flag B is not used.
- (c) After a warning marker.
- (d) Within a macro expression (except within variable names or constants).
- (e) Within the argument to an insert (except within variable names or constants).
- (f) Within the values of those operation macro arguments that specify options.

Within structure representations one or more spaces act as a separator.

7.3 Simple techniques

This Section illustrates a few techniques for solving some simple problems. In general, only one solution is given but there are often several equally good solutions. In some cases a problem has been described in terms of the use of ML/I as a preprocessor to a particular language, but in each case the problem has counterparts in other applications.

7.3.1 Interchanging two names

Problem It is desired to interchange the names PIG and DOG in a piece of text.

Solution The complete name environment is set up as follows:

```
MCSKIP MT, < >
MCDEF PIG AS <<DOG>>
MCDEF DOG AS <<PIG>>
```

and the desired result is achieved by evaluating the given text under this environment.

- Notes
- (a) In this example there is no necessity to have an insert definition in the environment.
 - (b) Notice that two pairs of literal brackets are used to surround the pieces of replacement text. One pair is stripped off at definition time and the second at replacement time. If the brackets were omitted, ML/I would endlessly replace one name by the other.

7.3.2 Removing optional debugging statements

Problem It is desired to include a number of extra statements in a FORTRAN program in order to aid in debugging its execution. These are to be removed when the program is debugged. Each statement ends with a newline.

Solution Some unique atom, say DEBUG, is written at the beginning of each debugging statement. Before the FORTRAN program is compiled it is passed through ML/I. If it is desired to include the debugging statements then the following skip definition is placed in the name environment:

```
MCSKIP DEBUG
```

This causes each occurrence of DEBUG to be deleted. When it is desired to delete the debugging statements then the following skip definition is used:

```
MCSKIP DEBUG NL
```

7.3.3 Inserting extra debugging statements

Problem It is desired in a PDP-7 Assembly Language program for a particular variable COW, to replace every occurrence of DAC COW (deposit accumulator at COW) by a call to a subroutine (which perhaps prints the value assigned to COW). This call has form JMS TYP COW.

Solution MCDEF DAC WITHS COW AS <JMS TYP COW>

7.3.4 Deleting a macro

Problem It is desired to delete the macro GONE from the current environment.

Solution The following skip accomplishes this:

```
MCSKIP D, <GONE>
```

Notes

- (a) The literal brackets prevent GONE being called during the evaluation of the second argument of the above MCSKIP.
- (b) Strictly speaking the macro GONE is overridden rather than deleted (see Section 4.7(a)).

7.3.5 Differentiation between special-purpose registers and storage locations

Problem It is desired to define an INTERCHANGE macro for PDP-7 Assembly Language so that, as well as being used to interchange the values of two storage locations it can be used to interchange the accumulator with a storage location. In the latter case "ACC" is written as the first argument of the call.

Solution Assuming the existence of a MOVE FROM macro, which moves the value of one storage location into another, the definition of INTERCHANGE is written:

```
MCDEF INTERCHANGE WITH ( , ) WITH NL
AS <MCGO L1 IF %A1. = ACC
MOVE FROM %A2. TO TEMP; MOVE FROM %A1. TO %A2.;
MOVE FROM TEMP TO %A1.;
MCGO LØ
%L1. DAC TEMPAC
MOVE FROM %A2. TO TEMP; MOVE FROM TEMPAC TO %A2.;
LAC TEMP
>
```

7.3.6 Testing for macro calls

Problem It is desired to find out whether an argument of a macro call itself involves any macro calls, inserts or skips.

Solution Compare the written form of the argument with its evaluated form. (It is assumed that any construction occurring within the argument would cause these two forms to be different.) The following is an example of how the test might be written:

```
MCGO L1 IF %A1. = %WA1.
```

Alternatively, if it was only required to test if the argument involved any macro calls, the test might be written:

```
MCGO L1 IF MCODEF%A1. = %A1.
```

provided that % had been defined as an unprotected insert.

7.3.7 Searching

Problem It is desired to search the source text to find all occurrences of given atoms.

Solution Define macros such as:

```
MCDEF X
AS <MCNOTE HERE IS <X>
>
```

It is best to send the output text itself to a null channel so that the only printed output is the MCNOTE message.

7.3.8 Bracketing within macro expressions

Problem Parentheses cannot be used within macro expressions.

Solution Use nested inserts. For example to insert the value of $(P1 + 6) / (P3 - 2)$ write:

```
%%P1+6./%P3-2..
```

7.3.9 Deletion from source text only

Problem It is desired to delete a given atom only if it occurs in the source text.

Solution Use temporary variable three, e.g.:

```
MCDEF X AS <MCGO LØ IF T3 EN 1
%WDØ.>
```

7.4 * Sophisticated techniques

This Section illustrates some techniques which may be of value to the more sophisticated user.

7.4.1 Macro-time loop

Problem A macro-time iteration statement is required in order to generate repetitive text.

Solution

The macro MCFOR defined below serves this purpose. It allows the step size to be optionally omitted; in this case a step size of one is assumed. MCFOR should be regarded as a "black box" by the reader who finds the definition below hard to understand. The part labelled "L2" is to deal with a negative step size.

```
MCDEF MCFOR = OPT STEP N1 OR N1 TO ALL NL REPEAT
AS<MCSET %A1. = %A2.
MCSET T3 = 1
MCGO L1 IF T1 EN 4
MCSET T3 = %A3.
MCGO L1 IF T3 GR Ø
%L2. MCGO LØ IF %AT1-1. GR %A1.
%AT1.MCSET %A1. = %A1. + T3
MCGO L2

%L1. MCGO LØ IF %A1. GR %AT1-1.
%AT1.MCSET %A1. = %A1. + T3
MCGO L1
>
```

Examples

- (a) MCFOR P1 = 1 TO 20
 JMP LAB%P1.
 REPEAT
 would generate the twenty instructions
 JMP LAB1, ... , JMP LAB20.
- (b) MCFOR P6 = 20 STEP - 1 TO 1
 JMP LAB%P6.
 REPEAT
 would generate the above twenty instructions
 in reverse order.
- (c) MCSET P2 = 1
 MCFOR P1 = 1 TO 10
 %P2.MCSET P2 = P2+P2
 REPEAT
 would generate the first ten powers of two.

Notes

- (a) The controlled variable must be a permanent

variable. (If it were a temporary variable, MCFOR would try to use its own temporary variables rather than those of the calling environment thus causing an error.)

- (b) The initial value, step size, and final value must be macro expressions not involving temporary variables.
- (c) MCFOR is a substitution macro, not an operation macro.
- (d) Calls of MCFOR may be nested.
- (e) MCFOR can be used to perform loops within the source text, thus surmounting the restriction that backward MCGOs within the source text are not allowed.

7.4.2 Examining optional delimiters

Problem An IF macro has form:

```

                (GE)
IF  arg A  (GR)  arg B  THEN ...
                (LT)
                (=)
                (etc.)

```

Within the replacement text of IF, it is desired to examine the form of the first delimiter and go to L1 if the delimiter is GE, to L2 if it is GR, etc. This problem can obviously be solved by writing a large number of conditional MCGO statements but this would make the IF macro very slow and cumbersome.

Solution The various possible delimiters can be defined as macros thus:

```
MCDEF GE AS 1
```

```
MCDEF GR AS 2
```

etc.

and then the requisite switch statement can be written:

```
MCGO L%D1.
```

Notes

- (a) The definition of the delimiters of IF as macros does not affect the scanning of a call of the IF macro since the use of an atom as a delimiter takes precedence over its use as a macro name.
- (b) It is necessary to place the definitions of GE etc. after the definition of IF or else to enclose the structure representation of IF within literal brackets.
- (c) This technique will not, as it stands, work for name delimiters. However, see Section 7.4.8.

7.4.3 Dynamically constructed calls

Problem It is required to implement a WHILE macro of form:

```

      (GE)
      (GR)
  WHILE arg A (LT) arg B DO
      (=)
      (etc.)

```

arg C

END

Within the replacement text of this macro it is desired to call the IF macro with the first delimiter of this call of IF the same as the delimiter that occurred in the call of WHILE. However, as was seen in Section 3.6, it is not possible to do this by writing:

```
IF ... %D1. ... THEN ...
```


Solution It is necessary to use a temporary macro definition to build up the text for the required call of IF and then to call the temporary macro. This could be achieved thus:

```
MCDEF <TEMP>AS<IF> ... %WD1. ... THEN ...
TEMP
```

- Notes
- (a) WD1 was used rather than D1 since GE etc. are macros and it is not desired to call them at this stage.
 - (b) Note that the insert %WD1. is not enclosed in literal brackets and is thus inserted when TEMP is defined. Thus if this delimiter were GR, then the replacement text of TEMP would be:


```
IF ... GR ... THEN ...
```

 and calling TEMP would then accomplish the required call of IF.
 - (c) TEMP is enclosed in literal brackets when it is defined in case there is already a TEMP macro in existence. This might arise, for example, if the WHILE macro was called recursively.
 - (d) TEMP should be a local macro rather than a global one so that the storage it occupies is released when an exit is made from the WHILE macro.
 - (e) This general technique can be used in all cases where it is required to build up a call dynamically. The next Section contains a further example of the technique.

7.4.4 Arithmetic expression macro

Problem A macro whose name is "(" has been designed so that, when supplied an arithmetic expression as argument, it generates assembly code to calculate the value of the expression and to place the resultant value in an accumulator. This macro

will be referred to as "the parenthesis macro".
A typical call of the parenthesis macro might be:

```
(PIG +(Y/6)*Z - 16)
```

This involves a nested call of the same macro. The arguments of the outer call are PIG, (Y/6), Z and 16, and the delimiters are +, * and -. It is desired to use this macro to implement a SET macro, which allows a macro expression as argument. Calls of SET might be:

```
SET DOG = Y
```

```
SET VAR = (VAR + 6)/13 - PIG
```

Solution

The solution to this problem is not to give the SET macro a complicated delimiter structure but rather to regard it as a macro with two arguments. The second argument is then passed down to the parenthesis macro, which breaks it down into operators and operands. The SET macro is defined:

```
MCDEF SET = NL
AS <MCDEF TEMP AS <(>%WA2.<)>
TEMP
[instruction to store the result in %A1.]
>
```

Notes

- (a) Notice the use of TEMP to build up a call of the parenthesis macro. In the second of the above examples of SET, for instance, TEMP would be defined as:

```
((VAR+6)/13 - PIG)
```

When TEMP was called, it would result in a call of the parenthesis macro with arguments (VAR+6), 13 and PIG.

- (b) It would have been wrong to call the parenthesis macro from within SET by writing simply (%A2.), since this would have been interpreted as a call with one argument.

7.4.5 Formal parameter names

Problem It is desired to use the name TAXRATE for the first formal parameter of the macro DEDUCT.

Solution The first part of the definition of DEDUCT is written:

```
MCDEF DEDUCT ... AS <MCDEF TAXRATE AS %A1.
...
```

Thereafter within the replacement text of DEDUCT, TAXRATE can be written in place of "%A1."

7.4.6 Intercepting changes of state

Problem It is desired in PDP-7 Assembly Language to generate some decimal constants within the replacement text of a macro SIZE. However, PDP-7 Assembly Language has two statements, OCTAL and DECIMAL, to control the base to which constants are to be written, and this might vary between calls of SIZE. Furthermore, it is desired that a call of SIZE should not change the base behind the user's back.

Solution A permanent variable, say P10, is used as a switch, the value zero being used to indicate an octal base. The following is written at the start of the source text:

```
MCSET P10 = 0
MCDEF OCTAL AS <MCSET P10 = 0
%WD0.>
MCDEF DECIMAL AS <MCSET P10 = 1
%WD0.>
```

and the definition of SIZE is written:

```
MCDEF SIZE AS <MCSET T1 = P10
DECIMAL
:
MCGO L0 IF T1 EN 1
OCTAL
>
```

thus ensuring that the base is returned to its original state.

Note

This technique is also useful for the following problem: the user has written a macro SUBS to generate code for subscripted vectors and it is necessary that SUBS generates different code for the two following calls:

- (a) LAC SUBS (V, 1) Load accumulator from element.
- (b) DAC SUBS (V, 1) Store accumulator in element.

The problem is solved by using the above technique to cause LAC and DAC to set a switch which the SUBS macro can then test to find out which instruction preceded its call.

7.4.7 Remembering code for subsequent insertion

Problem

It is desired to design two macros, REMEMBER and INSERT, to enable the user to remember text for subsequent insertion. These macros are used in the following way. REMEMBER is called with a piece of text as argument. REMEMBER does not generate any code but remembers its argument for subsequent insertion. When the INSERT macro is called all the pieces of text that have been remembered are inserted.

Solution

A sequence of global macros I1, I2, ... IN is used, the value of N being given by a permanent variable, say P1Ø. Each macro represents a piece of text that is to be remembered. The definitions of REMEMBER and INSERT would be written:

```

MCSET P1Ø = Ø
MCDEF REMEMBER;
AS <MCSET P1Ø = P1Ø + 1
MCDEFG I&P1Ø. AS %A1.
>
MCDEF INSERT AS <MCFOR P1 = 1 TO P1Ø
RECALL I&P1.
REPEAT>

```

where MCFOR is the macro of Section 7.4.1 and RECALL is a macro defined thus:

```
MCDEF RECALL NL
AS <MCDEF TEMP AS%A1.
TEMP>
```

Notes

- (a) The above solution tries to minimize the amount of storage used. It would have been possible to do without the RECALL macro, but this would have involved redefining TEMP N times within the MCFOR loop and so, albeit temporarily, using up rather more storage.
- (b) Note that the macros I1 etc. must be global whereas the macro TEMP should be local.
- (c) An apparently promising technique for this problem which fails because of excessive use of storage is the following. The entire remembered text is maintained by redefining the INSERT macro as below each time REMEMBER is called:

```
MCDEF REMEMBER; AS <MCDEFG<INSERT> AS INSERT%A1.
>
```

The trouble with this approach is that old versions of INSERT can never be released, thus using up a very considerable amount of storage.

7.4.8 Constructions with restricted scopes

Problem

It is desired to assign different meanings to a macro X within different scopes. One meaning is to apply within the replacement text of a set of macros M1, ..., MN whereas another meaning is to apply elsewhere.

Solution

One solution is to redefine X as a local macro within each of M1 to MN, but this is tiresome if N is large and slower than the method below even

if N is one. A better solution is to place the two following definitions at the start of the source text:

```
MCDEFG X ... AS <replacement to be used in M1 to MN>
```

```
MCDEF <X ... > AS <replacement to be used elsewhere>
```

The second definition overrides the first. Within the macros M1 to MN the first definition can be re-incarnated by writing MCNODEF, which deletes the second definition. Any macros besides X that were used within M1 to MN should also be defined as global.

Notes

- (a) This technique can be used in a variety of applications. It is the best solution in almost all situations where a macro or set of macros has restricted scope, but where this scope does not consist simply of the replacement text of a single macro. Even in the latter case the technique is useful as it is faster than setting up the local definitions every time a macro is called.
- (b) This technique can be used to extend the technique described in Section 7.4.2 to make it work for name delimiters. For example, if a macro had alternative names A and B and, within the replacement text of this macro, it was desired to insert the number 206 if the name was A and the number 15 if the name was B then this could be achieved, assuming "%" to be an unprotected insert, by writing:

```
MCDEFG A AS 206
```

```
MCDEFG B AS 15
```

```
MCDEF <OPT A OR B ALL ...>AS< ... MCNODEF%DØ. ...>
```

7.4.9 Optimizing macro-generated code

Problem It is desired to optimize the code generated by ML/I, in particular to cut down possible inefficiencies at the boundary between successive macros.

Solution There are basically two approaches to producing optimal code:

- (a) Code can be optimized as it is produced. Typically this would involve using the permanent variables to maintain some sort of indication of the previous instruction(s) generated.
- (b) A second pass can be made through the macro generated code, to search for various inefficient sequences of instructions.

Except in simple cases, the second method is usually the better. In many machines considerable optimization can be performed by maintaining where possible an indication of the contents of the accumulator(s) or other special-purpose registers and thus cutting out redundant loading instructions. This can be done by defining macros to map into numbers all the variables used in the code being generated. A permanent variable, say P1, could be used to indicate whether the accumulator was known to contain the current value of a particular execution-time variable. If so, P1 could contain the number of the variable, otherwise it could be zero. P1 would need to be zeroized when a label was placed, a subroutine was called, etc. This might be achieved by defining a macro with many alternative names, covering all the situations where the accumulator was clobbered. The macro might be:

```
MCDEF OPT , OR JMS OR ADD OR ... ALL AS<MCSET P1 = 0
%WD0.>
```

7.4.10 Macro to create a macro

Problem This problem illustrates the use of a macro to set up the definition of another macro. The

7/18

problem is as follows. It is desired to design a macro EQUATE which equates one vector to part of another. Thus the call:

```
EQUATE VEC1 TO VEC2 OFFSET 3
```

would cause each subsequent reference to an element of VEC1, which has form, say:

```
VEC1 (subscript)
```

to be translated into a reference to the corresponding element of VEC2, namely:

```
VEC2 (subscript +3)
```

Solution

```
MCDEF EQUATE TO OFFSET NL  
AS <MCDEFG%A1. WITH( ) AS%A2.(<%A1.>+%A3.)  
>
```

Examples

(a) The call:

```
EQUATE VEC1 TO VEC2 OFFSET 3
```

would be equivalent to writing the definition:

```
MCDEFG VEC1 WITH( ) AS <VEC2(%A1.+3)>
```

Notes

(a) The main source of error in this sort of problem is to confuse the arguments of the macro that creates the definition with the arguments of the new macro being defined. The rule is that the latter should be enclosed doubly in literal brackets. Hence in the replacement text of EQUATE, the arguments within single literal brackets are the arguments of EQUATE, which are inserted when the new macro is defined, and the argument within double literal brackets is the argument of the new macro, which is inserted when the new macro is called.

Supplement 1: startlines and stop markers

This supplement describes two new features that have been recently added to ML/I. The features are available in version AIC of ML/I. For those interested in how these features are implemented a separate document is available.

New feature 1: startline

It is often useful, when processing text where a line is a logical entity (e.g. as in most assembly languages and some high-level languages), to define newline as a macro name. This causes subsidiary problems because

- (a) the first and last line of the text need to be treated specially.
- (b) as well as being a macro name, newline may also be a closing delimiter.

To remedy this, ML/I contains a new feature whereby the input routine can be made, on option, to insert an invisible layout character called "startline" at the start of each line of text. The option is controlled by the variable S1: if S1 is one, startline characters are inserted; if S1 is not one, they are not. Initially S1 is zero. ML/I treats startline like any other layout character. Its layout keyword is SL.

Startlines are ignored in the output text from ML/I. However they are not ignored in value text and the user is recommended to set S1 to one after his macros have been read in. (One reason for this is illustrated by the following example:

```
MCDEF TEST OPT ; OR NL ALL
AS < MCGO LI IF %WD1.=<
>
...
```

If S1 was one while this macro was being read in, then a startline would appear before the ">" character. In this case the test after the IF, which should test if delimiter one is a newline, would in fact test if delimiter one was a newline followed by a startline. The test would therefore always fail.) If, as is very often the case, startline on its own is a construction name, the above recommendation is virtually imperative.

Since startlines are invisible on a listing, any occurrence of a startline in an error message is replaced by (SL).

Example

The following macros would list all labelled statements in an assembly language program. It is assumed the assembler is such that statements are one to a line and a line is labelled if the first character is not a space.

```
MCSKIP SL WITH SPACE NL
```

```
MCDEF SL NL
```

```
AS<8VAL.
```

```
>
```

```
MCSET S1 = 1
```

New feature 2: stop markers

An annoying feature of previous versions ML/I was that if a delimiter of a macro call in the source text was accidentally omitted or wrongly specified, then the remainder of the source text might be scanned over in searching for the missing delimiter.

To remedy this, ML/I now contains a new construction called a stop marker. Stop markers are defined by means of the operation macro MCSTOP, which has a similar syntax to MCWARN. Stop markers are only recognized when ML/I is searching for a delimiter of a construction in the source text. Outside of this context, stop markers are not part of the environment. If it encounters a stop marker, ML/I gives a message to signal that the current construction(s) are unmatched. The text from the construction name up to (but not including) the stop marker is ignored, and scanning is resumed at the stop marker itself. For example if the source text read:

```
MCDEF  IF  THEN  NL
AS< ... >
MCSTOP NL
IF X = Y  THIN  GO  TO  Z
```

ML/I would take the final newline as a stop marker and would give the error message

```
DELIMITER THEN OF MACRO IF IN LINE ... NOT FOUND
```

Stop markers obey the normal rules for name clashes (see Section 4.6 of User's Manual). Hence if, in the above example, THIN were replaced by THEN, then the final newline would be treated as a delimiter of IF rather than a stop marker and there would be no error message. An implication of this is that if the following definition were added to the above text

```
MCSKIP  DT,COMMENT  N1  OPT  NL  N1  OR ; ALL
then    COMMENT    XXX
        YYY
        ZZZ;
```

would not cause an error since all newlines would be treated as

delimiters, not stop markers. In general, therefore, it is possible (though tortuous in all but the simplest cases) to define constructions that may be arbitrarily long even if stop markers have been defined.

Note that stop markers override the normal scope rules in that they are recognized within skips and within straight-scan macros. They are treated as local constructions. (There is no MCSTOPG.)

Stop markers will stop forward MCGOs in the source text, as well as unmatched constructions.

Experience with stop markers has shown that in 9 out of 10 applications of ML/I it is a good idea to include

```
MCSTOP NL
```

in the environment. It is best to make this the last definition since calls of MCDEF may legally straddle several lines.

ML/I User's Manual 4th EditionSupplement 2: controlled line numbers and optional warning markers

This supplement describes two new features that have been added to ML/I. The features are available in version AID of ML/I. For those interested in how these features are implemented a separate document is available.

New feature 3: controlled line numbers

In many uses of ML/I some predefined macros are applied to a piece of text. If errors occur, the line numbers in the error messages do not correspond to a listing of the text being processed. For example if the macros occupy 93 lines then ML/I takes the first line of the text to be processed as line 94. This can be very confusing to a user of a package of macros that is unknown to him.

To remedy this, the source text line number has been made accessible to the user by placing it in S2.

S2 is initially 0 and ML/I increases it by one at the start of each line of the source text (including the first), and assigns the new value of S2 to ML/I's internal line count that is used in error messages.

Writers of packages of macros should, at the end of their macros, reset S2 to zero (or whatever value makes the first line of the text to be processed line one - differences can occur when newline is part of a construction name as ML/I is sometimes looking ahead).

The value of S2 is also useful for other purposes, e.g. for generating unique labels or for use in comments in generated output.

New features 4: optional warning markers

If S3 is one, the error message that is normally given if a warning marker is not followed by a macro name is suppressed.

This is useful if macro calls in the source text are only to be recognised in certain positions, e.g. following a tab or at the start of a line. In such examples the characters tab or startline could be defined as warning markers, and, assuming that not all occurrences need to be followed by macro calls, S3

could be set to one.

Note that if a warning marker is not followed by a macro name it is treated as if it were not a construction name at all and is thus normally copied over to the value text. This applies irrespective of whether S3 is being used to suppress the error message.

The following example illustrates how optional warning markers work

```
MCDEF PIG AS POG
MCINS %.
MCSET S3=1
MCWARN +
+PIG,PIG,MCSET+%S3.+NOTMAC+++
```

would generate the value text

```
POG,PIG,MCSET+1+NOTMAC+++
```

ML/I User's Manual 4th Edition

Supplement 3: An extra option

This supplement describes a new feature that is available in version AIE of ML/I.

New Feature 5: option on MCNOTE

If S4 has the value one, MCNOTE suppresses all the contextual information it normally gives. All that is output is the value of the argument of MCNOTE, preceded and followed by a newline. For example

```
MCSET S4 = 1
MCNOTE MESS 1
MCNOTE ERROR IN LINE %S2.
```

would produce the message

```
MESS 1
ERROR IN LINE .....
```

If S4 has value zero the normal contextual information is printed.

INDEX/1

I N D E X

- A (as insert flag) 2/14
- ALL 5/6
- Ambiguous name 4/6
- ARG 5/1
- arg 5/1
- Argument 2/3
- Atom 2/2

- B(as insert flag) 2/14
- Branches 5/6

- Call (of macro) 2/3
- Call by name 3/1
- Capacity 2/7, 2/10, 5/17
- Character set 2/1
- Clashing names 4/6
- Closing delimiter 2/3
- Construction 2/12
- Current environment 3/1
- Current point of scan 3/1

- D (as insert flag) 2/14
- Debugging file 6/1
- Definition time 4/3
- Delimiter 2/3 et seq
- Delimiter option (on skip) 2/18, 3/15
- Delimiter structure 2/5, 5/2 et seq
- Dynamically generated construction 3/6

- Environment 2/1, 2/22, 3/1
- Error causes 7/2
- Error messages 6/1 et seq
- Errors in structure representations 5/11
- Evaluation 2/1, 3/1 et seq
- Examples (conventions used) 2/23
- Exclusive delimiters 3/4, 5/8
- Expressions (macro expressions) 2/11

- Flag (for insert) 2/14
- Free mode 2/21

- Global construction 4/3
- Global name environment 4/4

- Initial environment 4/3, 4/4
- Insert 2/9 et seq, 5/14
- Insert name 2/13
- Inserted text 2/14

- Keyword 5/3

- Label 2/12, 5/31
- Layout keyword 5/3, 5/23
- Literal brackets 2/20, 4/2
- Local construction 4/3
- Local name environment 4/4

- Macro 2/2 et seq, 5/17
- Macro call 2/3
- Macro element 2/13
- Macro expression 2/11
- Macro label 2/12, 5/31
- Macro name 2/3
- Macro-time statement 2/8
- Macro-time variable 2/8, 2/9
- Matched (option on skip) 2/18, 2/19, 5/15
- MCALTER 5/21
- MCDEF 5/17
- MCDEFG 5/20
- MCGO 5/29
- MCINS 5/14
- MCINSG 5/20
- MCLENG 5/24
- MCNODEF 5/19
- MCNOINS 5/19
- MCNOSKIP 5/19
- MCNOTE 5/28
- MCNOWARN 5/19
- MCPVAR 5/33
- MCSET 5/27

INDEX/2

MCSKIP 5/15	.	Structure representation
MCSKIPG 5/20	.	5/2 <u>et seq</u>
MCSUB 5/25	.	Subroutine 2/8
MCWARN 5/13	.	Subscript 2/11
MCWARNG 5/20	.	Substitution macro 4/1
	.	Successor 2/5
NØ (node zero) 5/8	.	Syntax (for describing
Name clash 4/6	.	ML/I) 1/2
Name delimiter 2/3	.	System function 4/1, 5/24
Name environment 2/22	.	System variable 2/10
NEC macro 4/3	.	
Nesting 3/1	.	Tab 2/1
Newline 2/1, 7/2	.	TAB 5/4
NL 5/4	.	<u>TAB</u> 1/3
<u>NL</u> 1/3	.	Temporary variable 2/10
Node 5/6 <u>et seq</u>	.	Text 2/2
Normal-scan macro 2/22	.	Text (option on skip) 2/18,
Notation 1/3, 5/1	.	5/15
	.	
Operation macro 4/1	.	Unmatched construction 3/3
OPT 5/6	.	Unprotected insert 2/13, 4/5
Optional delimiter 2/5	.	
OR 5/6	.	Value text 2/1
Output text 2/2	.	Variable 2/8
Overflow 2/12	.	
	.	WA (as insert flag) 2/14
Permanent variable 2/10	.	Warning marker 2/21, 5/13
Process 2/2	.	Warning mode 2/21
Protected insert 2/13, 4/5	.	WB (as insert flag) 2/14
Punctuation character 2/1	.	WD (as insert flag) 2/14
	.	WITH 5/2
Recursion 3/1	.	WITHS 5/2
Repeated delimiter 2/5	.	
Replacement text 2/3	.	
	.	
Scanned text 2/1, 3/1	.	
Scanning 3/2	.	
Secondary delimiter 2/3	.	
Skip 2/17 <u>et seq</u> , 5/15	.	
Skip name 2/18	.	
Source text 2/2	.	
Space character (use of) 7/3	.	
SPACE 5/3	.	
<u>SPACE</u> 1/3	.	
SPACES 5/4	.	
Straight skip 2/19	.	
Straight-scan macro 2/22	.	