macro 15 assembler

programmers reference manual

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DEC-15-LMACA-B-D

PDP-15
MACRO-15
MACRO-ASSEMBLER PROGRAM
REFERENCE MANUAL

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CONTENTS

PREFACE

The PDP-15 MACRO-Assembler program (MACRO-15) provides the user with the symbolic programming capabilities of an assembler plus the added compiler capabilities of a many-for-one macro instruction generator. This manual describes the syntax, application and operations performed by the MACRO-15 program.

In the preparation of this manual it was assumed that the reader was familiar with the basic PDP-15 symbolic instruction set as described in either the PDP-15 "System Reference Manual DEC-15-ODFFA-B-D" or the "Users Handbook, Vol. 1, Processor DEC-15-H2DA-D".

The MACRO-15 program may be operated in:

a. Disk Operating System (DOS);
b. Batch Operating Software System (BOSS);
c. ADVANCED Monitor Software System (ADSS);
d. Background/Foreground Software System (B/F);
e. RSX PLUS Software System

It is assumed in this manual that the reader is familiar with the manual describing the software system under which MACRO-15 is to be used.

The manuals involved are:

a. DOS Users Manual, DEC-15-ODUMA-B-D,
b. BOSS-15 Batch Operating Software System User's Manual, DEC-15-OBUMA-A-D,
c. ADVANCED Monitor Software System For the PDP-15/20/30/40, DEC-15-MR2B-D,
d. B/F Monitor Software System for PDP-15/30 and 15/40, DEC-15-MR3A-D,
e. RSX PLUS Reference Manual, DEC-15-IRSXA-A-D.

Differences in the use of MACRO-15 in the available monitor systems are described, where applicable, in this manual.

Technical changes made in this revision of the manual are indicated by a bar in the appropriate page margin.

CHAPTER 1
INTRODUCTION

1.1 MACRO-15 LANGUAGE

MACRO-15 is a basic PDP-15 symbolic assembler language which makes machine language programming on the PDP-15 easier, faster and more efficient. It permits the programmer to use mnemonic symbols to represent instruction operation codes, locations, and numeric quantities. By using symbols to identify instructions and data in his program, the programmer can easily refer to any point in his program, without knowing actual machine locations.

Assembled MACRO-15 programs may be run on any PDP-15 system; however, MACRO-15 symbolic programs can be assembled only on systems which have at least 8K of memory and a monitor-type software system*.

The standard output of the Assembler is a relocatable binary object program that can be loaded for debugging or execution by the Linking Loader. MACRO-15 prepares the object program for relocation, and the Linking Loader provides relocation and sets up linkages to external subroutines. Optionally, the binary program may be output either with absolute addresses (non-relocatable) or in the full binary mode (see Chapter 3 for a description of the binary output modes).

The programmer directs MACRO-15 processing by using a powerful set of pseudo-operation (pseudo-op) instructions. These pseudo-ops are used to set the radix for numerical interpretation by the Assembler, to reserve blocks of storage locations, to repeat object code, to handle strings of text characters in 7-bit ASCII code or a special 6-bit code, to assemble certain coding elements if specific conditions are met, and to perform other functions which are explained in detail in Chapter 3.

The most advanced feature of MACRO-15 is its powerful macro instruction generator. This facility permits easy handling of recurring instruction sequences, changing only the arguments. Programmers can use macro instructions to create new language elements, adapting the Assembler to their specific programming applications. Macro instructions may be recursively called up to three levels, nested to n levels, and redefined within the program. The technique of defining and calling macro instructions is discussed in Chapter 4.

*A device-dependent version of MACRO-15, called MACROI-15, is available for use with 8K DECtape systems. Refer to Appendix G.

An output listing, showing both the programmer's source code and the object program produced by MACRO-15, is printed if desired. This listing may include all the symbols used by the programmer with their assigned values. If assembly errors are detected, erroneous lines are marked with specific alphabetic error codes, which may be interpreted by referring to the error list in Chapter 5 of this manual.

Operating procedures for MACRO assembly are described in detail in Chapter 5.* (Refer to Appendix G for MACRO1 Operating Procedures.)

1.2 HARDWARE REQUIREMENTS

The MACRO-15 assembler program may be run in any configuration which meets the minimum hardware requirements for the following PDP-15 software systems:

a. Advanced Software System (ADSS-15)
b. Background/Foreground (B/F)
c. Disk Operating System (DOS-15)
d. Batch Operating Software System (BOSS-15)
e. Resource Sharing eXecutive (RSX PLUS and RSX PLUS III)

1.3 ASSEMBLER PROCESSING

The MACRO-15 assembler processes source programs in either a two-pass or three-pass operation. In the two-pass assembly operation the source program is read twice with the object program and printed listing (both optional) being produced during the second pass. During the first pass (PASS 1), the locations to be assigned the program symbols are resolved and a symbol table is constructed by the assembler. The second pass (PASS 2) uses the information computed during PASS 1 to produce the final object program.

In an optional three-pass assembly operation, PASS 2 will call in a third pass (PASS 3) portion of the assembler program. PASS 3, when called, performs a cross referencing operation during which a listing is produced which contains: (a) all user symbols, (b) where each symbol is defined, and (c) the number of each program line in which a symbol is referenced. On completion of its operation, PASS 3 calls the PASS 1 and PASS 2 portions of the assembler program back into core for further assembly operations.

*These procedures are also mentioned in the DOS-15 Keyboard Command Guide, (DEC-15-ODKCA-A-D) and the PDP-15/20 User's Guide, (DEC-15-OUGAA-A-D).

The standard object code produced by MACRO-15 is in a relocatable format which is acceptable to the PDP-15 Linking Loader, CHAIN, PATCH and TKB Utility programs. Relocatable programs that are assembled separately and use identical global symbols* where applicable, can be combined by the Linking Loader, CHAIN, and TKB into an executable object program. MACRO-15 reserves one additional word in a program for every external symbol**. This additional word is used as a pointer (called a transfer vector) to the actual data word in another program. The Linking Loader sets up these transfer vectors (when the programs are loaded) with the actual address of the global symbol.

Some of the advantages of having programs in relocatable format are as follows:

a. Reassembly of one program, which at object time was linked with other programs, does not necessitate a reassembly of the entire system.

b. Library routines (in relocatable object code) can be requested from the system device or user library device.

c. Only global symbol definitions must be unique in a group of programs that operate together.

*Symbols which are referenced in one program and defined in another.
**Symbols which are referenced in the program currently being assembled but which are defined in another program.

2.1 PROGRAM STATEMENTS

One or more statements may be written on a line of up to 76 characters where the last character is a carriage-return. Since the carriage return is a non-printing character, it is graphically represented as ↵ in this manual, e.g.,

STATEMENT↵

Several statements may be written on a single line, separated by semicolons

STATEMENT;STATEMENT;STATEMENT↵

Only the last statement may have a comments field, since semicolons are allowed in and do not delimit comments. Also, MACRO calls (a type of statement described in a later chapter) should not appear in a multi-statement line since they cause subsequence statements to be ignored.

Normally, a single statement must fit on one line. The exception to this rule is a macro call whose arguments may be continued on a subsequent line by use of the $ character. This is described in the chapter on MACROs.

A statement may contain up to four fields that are separated by a space, spaces, or a tab character. These four fields are the label (or tag) field, the operation field, the address field, and the comments field. Because the space and tab characters are not printed, the space is represented by ␣ , and the tab by →| in this manual. Tabs are set 8 spaces apart on DEC-supplied teleprinter machines, and are used to line up the fields in columns in the source program listing.

This is the basic statement format:

LABEL →| OPERATION →| ADDRESS →| /COMMENTS↵

where each field is delimited by a tab or space, and each statement is terminated by a semicolon or carriage-return. The comments field is preceded by a tab (or space) and a slash(/).

Note that a combination of a space and a tab will be interpreted by the MACRO-15 assembler as <u>two</u> field delimiters.

Example:

```
TAG  →| OP ␣ →| ADR↵ }
TAG␣ →| OP   →| ADR↵ } both are incorrect
```

These errors will not show on the listing because the space is hidden in the tab.

A MACRO-15 statement may have an entry in each of the four fields, or three, or two, or only one field. The following forms are acceptable (where the characters (s) indicate one or more of the preceding character):

```
TAG↵
TAG  →| OP↵
TAG  →| OP  →| ADDR↵
TAG  →| OP  →| ADDR␣ (s) / comments↵
TAG  →| OP␣ (s) / comments↵
TAG  →|      →|ADDR↵
TAG  →|      →|ADDR␣ (s) / comments↵
TAG  →| (s) / comments↵
     →|OP↵
     →|OP  →| ADDR↵
     →|OP  →| ADDR →| (s) / comments↵
     →|OP  →| (s) / comments↵
     →|    →| ADDR↵
     →|    →| ADDR →| (s) / comments↵
/comments↵
     →|(s) / comments↵
```

Note that when a label field is not used, its delimiting tab is written, except for lines containing only comments. When the operation field is not used, its delimiting tab is written if an address field follows, except in label only and comments only statements.

A <u>label</u> (or tag) is a symbolic address created by the programmer to identify the statement. When a label is processed by the Assembler, it is said to be defined. A label can be defined only once. The <u>operation code</u> field may contain a machine mnemonic instruction code, a MACRO-15 pseudo-op code, a macro name, a number, or a symbol. The <u>address</u> field may contain a symbol, number, or expression which is evaluated by the assembler to form the address portion of a machine instruction. In some pseudo-operations, and in macro

instructions, this field is used for other purposes, as will be explained in this manual. Comments are usually short explanatory notes which the programmer adds to a statement as an aid in analysis and debugging. Comments do not affect the object program or assembly processing. They are merely printed in the program listing. Comments must be preceded by a slash (/). The slash (/) may be the first character in a line or may be preceded by:

a. Space (␣)
b. Tab (→|)
c. Semicolon (;)

2.2 SYMBOLS

The programmer creates symbols for use in statements to represent addresses, operation codes and numeric values. A symbol contains one to six characters from the following set:

The letters A through Z
The digits 0 through 9
Two special characters, period (.) and the percent sign (%).

The first character of a symbol must be a letter, a period, or percent sign. A period may not be used alone as a symbol. The first character of a symbol must not be a digit. The letter 'X' alone may not be a symbol. ('X' has a special meaning to the Assembler, as explained later.)

The following symbols are legal:

MARK1	..1234	.A
A%	%50.99	.%
P9.3	INPUT	

The following symbols are illegal:

TAG:1	: is not a legal symbol character.
5ABC	First character may not be a digit.
X	Letter 'X' alone is illegal.
.	'.' alone is illegal as a symbol.

Only the first six characters of a symbol are meaningful to the Assembler, but the programmer may use more for his own information. If he writes,

SYMBOL1
SYMBOL2
SYMBOL3

as the symbolic labels on three different statements in his program, the Assembler will recognize only SYMBOL and will print "m" error flags on the lines containing SYMBOL1, SYMBOL2 and SYMBOL3. To the Assembler they are duplicates of SYMBOL.

2.2.1 Evaluation of Symbols and Globals

When the Assembler encounters a symbol during processing of a source language statement, it evaluates the symbol by referring to two tables: the user's symbol table and the permanent symbol table. The user's symbol table contains all symbols defined by the user. The user defines symbols by using them as labels, as variables, as macro names and globals, and by direct assignment statements. A label is defined when first used, and cannot be redefined. (When a label is defined by the user, it is given the current value of the location counter, as will be explained later in this chapter.)

All permanently defined system symbols (excluding the index register symbol, X), including system macros (except for RSX) and all Assembler pseudo-instructions use a period (.) as their first character. The Assembler also has, in its permanent symbol table, definitions of the symbols for all of the PDP-15 memory reference instructions, operate instructions, the basic EAE instructions, and some input/output transfer instructions. (See Appendix B for a complete list of these instructions.)

PDP-15 instruction mnemonic symbols may be used in the operation field of a statement without prior definition by the user.

Example:

→| LAC␣A)

LAC is a symbol whose appearance in the operation field of a statement causes the Assembler to treat it as an op code rather than a symbolic address. It has a value of 200000_8 which is taken from the operation code definition in the permanent symbol table.

The user can use instruction mnemonics or the pseudo-instruction mnemonics code as symbol labels. For example,

DZM →| DZM␣Y)

where the label DZM is entered in the symbol table and is given the current value of the location counter, and the op code DZM is given the value 140000 from the permanent symbol table. The user must be careful, however, in using these dual purpose (field dependent) symbols. Symbols in the operation field are interpreted as either instruction codes or pseudo-ops, not as symbolic labels, if they are in the permanent symbol table. System macro names cannot be duplicated by the user. In the following example, several symbols

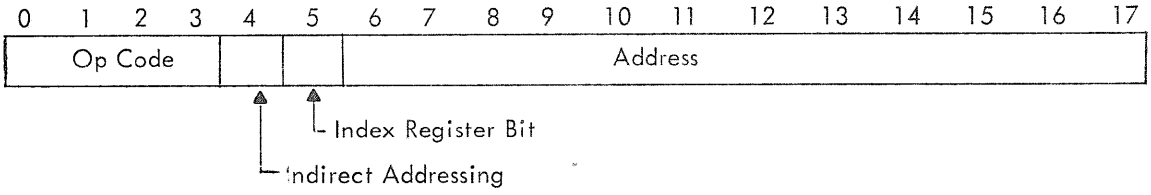
with values have been entered in the user's symbol table and the permanent symbol table. The sample coding shows how the Assembler uses these tables to form object program storage words.

User Symbol Table		Permanent Symbol Table	
Symbol	Value	Symbol	Value
TAG1	100	LAC	200000
TAG2	200	DAC	040000
DAC	300	JMP	600000
		X	010000

If the following statements are written,	the following code is generated by the Assembler
TAG1 → DAC → TAG2	040200
TAG2 → LAC → DAC	200300
DAC → JMP → TAG1	600100
→ DAC → TAG1,X	050100
→ TAG1	000100

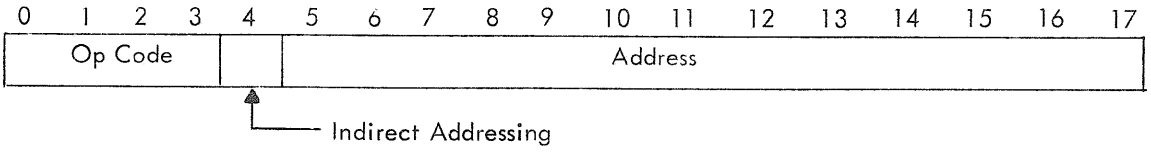
2.2.1.1 Special Symbols - The symbol X is used to denote index register usage. It is defined in the permanent symbol table as having the value of 10000. The symbol X cannot be redefined and can only be used in the address field.

2.2.1.2 Memory Referencing Instruction Format - When operating in page mode the PDP-15 uses 12 bits for addressing, 1 bit to indicate index register usage, 1 bit to indicate indirect addressing, and 4 bits for the op code.



PAGE MODE MEMORY REFERENCE INSTRUCTION

When operating in bank mode on the PDP-15, the only mode that applies to the PDP-9, 13 bits are used for addressing, there is no index register bit, 1 bit is for indirect addressing, and 4 bits are for the op code.



BANK MODE MEMORY REFERENCE INSTRUCTION

2.2.2 Variables

A variable is a symbol that is defined in the user's symbol table by using it in an address field or operation field with the number sign (#). Symbols with the # may appear more than once in a program (see items 1, 3, 4, and 5 of example given below). A variable reserves a single storage word which may be referenced by using the symbol at other points in the program with or without the #. If the variable duplicates a user-defined label, it is multiply defined and is flagged as an error during assembly.

Variables are assigned memory locations at the end of the program. The initial contents of variable locations are unspecified. The # can appear any place within the symbol character string as in the example.

Example:

Sequence	Location Counter	Source Statements	Generated Code
		→| .LOC ␣ 100	
1	100	→| LAC ␣ TA#G1	200105
2	101	→| DAC ␣ TAG3	040107
3	102	→| LAC ␣ TAG2#	200106
4	103	→| DAC ␣ T#AG3,X	050107
5	104	→| LAC ␣ #TAG2	200106
		→| .END	

2.2.3 Setting Storage Locations to Zero

Storage words can be set to zero as follows:

A →| 0; →| 0; →| 0)

In this way, three words are set to zero starting at A. Storage words can also be set to zero by statements containing only labels

A; B; C; D; E)

2.2.4 Redefining the Value of a Symbol

The programmer may define a symbol directly in the user's symbol table by means of a direct assignment statement written in the form:

SYMBOL=n)
or
SYM1=SYM2)

where n is any number or expression. There should be no spaces between the symbol and the equal sign, or between the equal sign and the assigned value, or symbol. MACRO-15 enters the symbol in the symbol table, along with the assigned value. Symbols entered in this way may be redefined. These are legal direct assignment statements: XX=28;A=1;B=2)

A symbol can also be assigned a symbolic value; e.g., A=4, B=A, or

SET=ISZ␣SWITCH)

In the previous example, the symbol B is given the value 4, and when the symbol SET is detected during assembly the object code for the instruction ISZ␣SWITCH will be generated. This type of direct assignment cannot be used in a relocatable program. Direct assignment statements do not generate storage words in the object program.

In general, it is good programming practice to define symbols before using them in statements that generate storage words. The ASSEMBLER will interpret the following sequence without trouble:

```
1                                                   .ABSP
2                          000005       Z=5
3                          000005       Y=Z
4                          000005       XX=Y
5                                       /
6              00000       200005                  LAC XX /SAME AS LAC 5
7                          000000                   .END
                         SIZE=00001     NO ERROR LINES
```

2.2.5 Forward Reference

A symbol may be defined after use. For example,

```
                                                    .ABSP
               00000       200001                   LAC Y

                           000001       Y=1
                           000000                   .END
                         SIZE=00001     NO ERROR LINES
```

This is called a forward reference, and is resolved properly in PASS 2. When first encountered in PASS 1, the LAC Y statement is incomplete because Y is not yet defined. Later in PASS 1, Y is given the value 1. In PASS 2, the Assembler finds that Y=1 in the symbol table, and forms the complete storage word.

Since MACRO-15 basic assembly operations are performed in two passes, only one-step forward references are allowed. The following example is illegal because the symbol Y is not defined during PASS 2.

```
          00100  A                                  .LOC 100
    F     00100  A    200000  A                    LAC Y
                      000001  A    Y=Z
                      000001  A    Z=1
                      000000  A                    .END

                    SIZE=00101      1 ERROR LINES
```

Forward references to internal .GLOBL symbols (see Paragraph 3.9) are illegal because the internal globals are output at the beginning of PASS 2 for library searching. Globals must be defined during PASS 1, otherwise they will be flagged. The following example is illegal:

```
1     F                                             .GLOBL A,B,C
2     F     00000  R    200000  A                   LAC     A
3                       000004  R    A=E
4           00001  R    200002  R                   LAC     D
5           00002  R    120005  E    D              JMS*    B
6           00003  R    120006  E    E              JMS*    C
7                       000000  A                   .END
            00005  R    000005  E  *E
            00006  R    000006  E  *E
                      SIZE=00007      2 ERROR LINES
```

2.2.6 Undefined Symbols

If any symbols, except global symbols, remain undefined at the end of PASS 1 of assembly, they are automatically defined as the addresses of successive registers following the block reserved for variables at the end of the program. All statements that referenced the undefined symbol are flagged as undefined. One memory location is reserved for each undefined symbol with the initial contents of the reserved location being unspecified.

Examples:

```
1                                          .ABSP
2          00100                           .LOC 100
3     U    00100     200106                LAC UNDEF1
4          00101     200104                LAC TAG#
5          00102     200105                LAC TAG#1
6     U    00103     200107                LAC UNDEF2
7                    000000                .END
                  SIZE=00110      2 ERROR LINES
```

2.3 NUMBERS

The initial radix (base) used in all number interpretation by the Assembler is octal (base 8). To allow the user to express decimal values and then restore to octal values, two radix-setting pseudo-ops (.OCT and .DEC) are provided. These pseudo-ops, described in Chapter 3, must be coded in the operation field of a statement. If any other information is written in the same statement, the Assembler treats the other information as a comment and flags it as a questionable line. All numbers are decoded in the current radix until a new radix control pseudo-op is encountered. The programmer may change the radix at any point in the program.

Examples:

Flag	Source Program	Generated Value (Octal)	Radix in Effect
	→| LAC →| 100	200100	8 } initial value is
	→| 25	000025	8 } assumed to be octal
	→| .DEC		
	→| LAC →| 100	200144	10
	→| 275	000423	10
Q	→| .OCT␣99		Octal radix takes effect even though line is flagged
	→| 76	000076	8
N	→| 99	000143	The non-octal digit forces a decimal radix for this number only

2.3.1 Integer Values

An integer is a string of digits, with or without a leading sign. Negative numbers are represented in two's complement form. The range of integers is as follows:

Unsigned	$0 \rightarrow 262143_{10}$	(777777_8) or $2^{18}-1$
Signed	$0 \rightarrow 131071_{10}$	(377777_8) or $2^{17}-1$
	$0 \rightarrow -131072_{10}$	(400000_8) or -2^{17}

An octal integer* is a string of digits (0-7), signed or unsigned. If a non-octal digit (8 or 9) is encountered the string of digits will be assembled as if the decimal radix were in effect and it will be flagged as a possible error.

Example:

Flag	Coded Value	Generated Value (Octal)	Comment
	.DEC		
	3779	007303	
	.OCT		
	-5	777773	Two's complement
	3347	003347	
N	3779	007303	Possible error, decimal assumed

A decimal integer** is a string of digits (0-9), signed or unsigned.

Examples:

Flag	Coded Value	Generated Value (Octal)	Comment
	-8	777770	Two's complement
	+256	000400	
N	-262144	000000	Error, less than $-(2^{18}-1)$

2.3.2 Expressions

Expressions are strings of symbols and numbers separated by arithmetic or Boolean operators. Expressions represent unsigned numeric values ranging from 0 to $2^{18}-1$. All arithmetic is performed in unsigned integer arithmetic

*Initiated by .OCT pseudo-op and is also the initial assumption if no radix control pseudo-op is encountered.
**Initiated by .DEC pseudo-op.

(two's complement), modulo 2^{18}. Division by zero is regarded as division by one and results in the original dividend. Fractional remainders are ignored; this condition is not regarded as an error. The value of an expression is calculated by substituting the numeric values for each element (symbol) of the expression and performing the specified operations.

The following are the allowable operators to be used with expressions:

Character		Function	
Name	Symbol		
Plus	+	Addition (two's complement)	
Minus	-	Subtraction (convert to two's complement and add)	
Asterisk	*	Multiplication (unsigned)	
Slash	/	Division (unsigned)	
Ampersand	&	Logical AND	Boolean
Exclamation point	!	Inclusive OR	Boolean
Back slash	\	Exclusive OR	Boolean
Comma	,	Exclusive OR	Boolean

Operations are performed from left to right (i.e., in the order in which they are encountered). For example, the assembly language statement A+B*C+D/E-F*G is equivalent to the following algebraic expression (((((A+B)*C)+D)/E)-F)*G.

Examples:

Assume the following symbol values:

Symbol	Value (Octal)	Comments
A	000002	
B	000010	
C	000003	
D	000005	
X	010000	Index Register Value

The following expressions would be evaluated.

Expression	Evaluation (Octal)	Comments
A+B-C,X	010007	Index Register Usage
A/B+A*C	000006	(The remainder of A/B is lost)
B/A-2*A-1+X	010003	Index Register Usage
A & B	000000	
C+A&D	000005	
B*D/A	000024	
B*C/A*D	000074	
A,X+D,X	010007	Index Register Usage Error

In the last example the expression is evaluated as follows:

Sequence of arithmetic

a. A,X = 000002 XORed with 010000 = 010002
b. A,X+D = 010002 + 000005 = 010007
c. A,X+D,X = 010007 XORed with 010000 = 000007

Note that arithmetic produces 000007 yet the value given in the example is 010007. Regardless of how the index register is used in the address field, the index register bit will always be turned on by the Assembler. In the sequence of address arithmetic above, the line would be flagged with an X because of the illegal use of the index register symbol (X).

Using the symbol X to denote index register usage causes the following restrictions:

a. X cannot appear in the TAG field — X → LAC → A
b. X cannot be used in a .DSA statement — .DSA→ A,X
c. X can be used only once in an expression (see 2.4.3) — LAC → A,X+D,X

2.4 ADDRESS ASSIGNMENTS

As source program statements are processed, the Assembler assigns consecutive memory locations to the storage words of the object program. This is done by reference to the location counter, which is initially set to zero and is incremented by one each time a storage word is formed in the object program. Some statements, such as machine instructions, cause only one storage word to be generated, incrementing the location counter by one. Other statements, such as those used to enter data or text, or to reserve blocks of storage words, cause the location counter to be incremented by the number of storage words generated.

2.4.1 Referencing the Location Counter

The programmer may directly reference the location counter by using the symbol period (.) in the address field. He can write,

```
→| JMP␣.-1
```

which will cause the program to jump to the storage word whose address was previously assigned by the location counter. The location counter may be set to another value by using the .LOC pseudo-op, described in Chapter 3.

2.4.2 Indirect Addressing

To specify an indirect address, which may be used in memory reference instructions, the programmer writes an asterisk immediately following the operation field symbol. This sets the defer bit (bit 4) of the storage word.

If an asterisk suffixes either a non-memory reference instruction, or appears with a symbol in the address field, an error will result.

Two examples of legal indirect addressing follow.

```
→| TAD* →| A
→| LAC* →| B
```

The following examples are illegal.

```
CLA*          Indirect addressing may not be specified
LAW* 17777    in non-memory reference instructions.
```

2.4.3 Indexed Addressing

To specify indexed addressing an X is used with an operator directly after the address. No spaces or tabs may appear before the operator. The Assembler will perform whatever operation is specified with the index register symbol, and then continue to evaluate the expression. At completion of the expression evaluation, if the index bit (bit 5) is not on and the location counter is pointing to page 0 of any bank, the line is flagged with a B for bank error because the address (aside from indexing modifications) must have been greater than 7777_8 (i.e., it pointed to another page). The standard code used to indicate indexing is:

```
LAC   A,X
```

The indexed addressing operation is illustrated in the following example.

Example:

```
Location  Object Code
                        .ABSP
000000    210000    A   LAC → X          /Same as LAC 0,X
000001    050005    B   DAC → A,X+1,7-1  /
000002    210001        LAC → B+X        /000001 + 010000
                        .LOC  10000      /SET to page 1
010000    210001    C   LAC   X,D
010001    210000    D   LAC   C,X
                        .END
```

Expression evaluation where A = 000000, B = 000001, C = 010000, D=010001, X=010000

NOTE: ⊕ = exclusive OR

Location	Address Field	Discussion
0	X	The value of X is added to 0. Absence of an operator always implies addition.
1	A,X+1,7-1	000000⊕010000 = 010000 010000 + 000001 = 010001 010001⊕000007 = 010006 010006 - 000001 = 010005
2	B+X	000001⊕010000 = 010001
10000	X,D	010000⊕010001 = 000001 The index bit has been turned off during expression evaluation. Because the location counter (10000) is pointing to Page 1, this line is not flagged, and the index register bit is turned on.
10001	C,X	010000⊕010000 = 000000 Same as example at Location 10000.

2.4.4 Literals

Symbolic data references in the operation and address fields may be replaced with direct representation of the data enclosed in parentheses*. This inserted data is called a literal. The Assembler sets up the address link, so one less statement is needed in the source program. The following examples show how literals may be used, and their equivalent statements. The information contained within the parentheses, whether a number, symbol, expression, or machine instruction, is assembled and assigned consecutive memory locations after the locations used by the program, unless a .LTORG pseudo-instruction appears in the program. (See section 3.2.5.) The address of the generated word will appear in the statement that referenced the literal.

*The opening parenthesis [(] is mandatory; the closing parenthesis [)] is optional.

Duplicate literals, completely defined when scanned in the source program during PASS 1, are stored only once so that many uses of the same literal in a given program result in the allocation of only one memory location for that literal. Nested literals, that is, literals within literals, are illegal and will be flagged as an error. The following is an example of a nested literal.

LAC␣(ADD␣(3))

Usage of Literal	Equivalent Statements
→| ADD␣(1)	→| ADD␣ONE ONE →| 1
→| LAC␣(TAG)	→| LAC␣TAGAD TAGAD →| TAG
→| LAC␣(DAC →| TAG)	→| LAC␣INST INST →| DAC →| TAG
→| LAC␣(JMP →| .+2)	HERE →| LAC␣INST INST →| JMP␣HERE+2

The following sample program illustrates how the Assembler handles literals.

Location Counter	Source Statement	Generated Code
	→| .LOC␣100	
100	TAG1→| LAC␣(100)	200110
101	→| DAC␣100	040100
102	→| LAC␣(JMP␣.+5	200111
103	→| LAC␣(TAG1)	200110
104	→| LAC␣(JMP␣TAG1)	200113
105	→| LAC␣(JMP␣TAG2)	200112
	TAG2=TAG1	
106	→| LAC␣(JMP␣0)	200113
107	DAC →| LAC␣(DAC →| DAC)	200114
	→| .END	
	Generated Literals	
110		000100
111		600107
112		600100
113		600000
114		040107

2.5 STATEMENT FIELDS

The following paragraphs provide a detailed explanation of statement fields, including how symbols and numbers may be used in each field.

2.5.1 Label Field

If the user wishes to assign a symbolic label to a statement in order to facilitate references to the storage word generated by the Assembler, he may do so by beginning the source statement with any desired symbol. The symbol must not duplicate a system or user defined macro symbol and must be terminated by a space or tab, or a statement terminating semicolon or carriage-return.

Examples:

TAG1;TAG2;TAG3;TAG4	A new logical line starts after each semicolon. This line is equivalent to TAG1 →| 0) TAG2 →| 0) TAG3 →| 0) TAG4 →| 0)

If there were a tab or a space after the semicolon the symbol would be evaluated as an operator instead of a tag. The sequence

TAG1; ␣ TAG2;TAG3; ␣ TAG4

is evaluated as follows:

TAG1 →\| 0)
TAG2)
TAG3 →\| 0)
TAG4)

TAG ␣ any value	
TAG ␣ (s) any value	
TAG →| ␣ (s) any value	
TAG;	These examples are equivalent to coding
TAG)	TAG →| 0)
TAG ␣ (s) (no more data on line)	in that a word of all 0s is output with the symbol TAG associated with it.

When writing numbers separated by semicolons, the first number must be preceded by a tab (→\|) or a space (␣). The sequence

TABLE ␣ 1;2;3;4;5

produces TAG errors because the first symbol of a tag cannot be numeric. The correct way to write the table sequence is as follows:

TABLE ␣ 1; ␣ 2; ␣ 3; ␣ 4; ␣ 5

Symbols used as labels are defined in the symbol table with a numerical value equal to the present value of the location counter. A label is defined only once. If it was previously defined by the user, the current definition of the symbol will be flagged in error as a multiple definition. All references to a multiply defined symbol will be converted to the first value encountered by the Assembler.

Example:

Flag	Location Counter	Statement	Storage Word Generated	Notes
M	100	A →| LAC →| B	200103	
M	101	A →| LAC →| C	200104	Error, multiple definition
D	102	→| LAC →| A	200100	First value of A referenced
	103	B →| 0	000000	
	104	C →| 0	000000	

Anything more than a single symbol to the left of the label-field delimiter is an error; it will be flagged and ignored. The following statements are illegal.

TAG+1 →\| LAS ⏎
LOC*2 →\| RAR ⏎

The line will be flagged with a "T" for tag error. The tag will be ignored but the rest of the line will continue to be processed. The only time that an error tag is not ignored is when the error occurs after the sixth character. The statement:

TAGERROR*1 ␣ NOP

will be assembled as:

TAGERR →\| NOP

and the line will be printed and flagged with a "T".

Redefinition of certain symbols can be accomplished by using direct assignments; that is, the value of a symbol can be modified. If an Assembler permanent symbol or user symbol (which was defined by a direct assignment)

is redefined, the value of the symbol can be changed without causing an error. If a user symbol, which was first defined as a label, is redefined by either a direct assignment or by using it again in the label field, it will cause an error. Variables also cannot be redefined by a direct assignment.

Examples:

Coding	Generated Value (Octal)	Comments
A=3		Sets current value of A to 3
→| LAC →| A	200003	
→| DAC →| A	040003	
A=4		Redefines value of A to 4
→| LAC →| A	200004	
B →| DAC →| A	040004	*
B=A		Illegal usage; a label cannot be redefined
→| DAC →| B	040105	
PSF=700201		To redefine possibly incorrect permanent symbol definition.

*Assume that this instruction will occupy location 105.

2.5.2 Operation Field

Whether or not a symbol label is associated with the statement, the operation field must be delimited on its left by a space(s) or tab. If it is not delimited on its left, it will be interpreted as the label field. The operation field may contain any symbol, number, or expression which will be evaluated as an 18-bit quantity using unsigned arithmetic modulo 2^{18}. In the operation field, machine instruction op codes and pseudo-op mnemonic symbols take precedence over identically named user defined symbols. The operation field must be terminated by one of the following characters:

→| or ␣ (s) (field delimiters)
) or ; (statement delimiters)

Examples:

```
TAG →| ISZ
     →| .+3 ␣ (s)
␣ (s)CMA!CML )
     →| TAG/5+TAG2; →| TAG3 )
```

The asterisk (*) character appended to a memory reference instruction symbol, in the operation field, causes the defer bit (bit 4) of the instruction word to be set; that is, the reference will be an indirect reference. If

the asterisk (*) is appended on either a non-memory reference instruction or any symbol in the address field, it will cause an error condition which will be flagged as a symbol error (S-flag). The asterisk will be ignored and the assembly process will continue.

Examples:

Assembled Value	Legal	Assembled Value	Illegal
360001	→| TAD* →| A	200001	→| LAC →| A*
220002	→| LAC* →| B	750000	→| CLA*

where A = 1 and B = 2

However, the asterisk (*) may be used anywhere as a multiplication operator.

Examples:

Legal	Illegal
→| LAC →| TAG*5	→| LAC →| TAG*4+TAD*
→| TAG*TAG1	→| A*

2.5.3 Address Field

The address field, if used in a statement, must be separated from the operation field by a tab, or space(s). The address field may contain any symbol, number, or expression which will be evaluated as an 18-bit quantity using unsigned arithmetic, modulo 2^{18}. If op code or pseudo-op code symbols are used in the address field, they must be user defined, otherwise they will be undefined by the Assembler and will cause an error message. The address field must be terminated by one of the following characters:

→| or ␣ (s)	(field delimiters)
) or ;	(statement delimiters)

Examples:

```
LAW -1          /Correctly assembled as 777777
LAW-1           /No separation from the operation field; assembled as 757777 since -1 is
                 is treated as part of the operation field.

TAG2 →| DAC →| .+3
     →|      →| TAG2/5+3 ␣ (s)
```

In the last example, the rest of the line will be automatically treated as a comment and ignored by the Assembler.

The address field may also be terminated by a semicolon or a carriage-return.

Examples:

→| JMP →| BEGIN)

→| TAD →| A; →| DAC →| B →| LAC

In the last example, a tab or space(s) is required after the semicolon in order to have the Assembler interpret DAC as being the operation field rather than the label field.

In the second line of the preceding example, the address field B is delimited by a tab. The LAC after the B →| is ignored and is treated as a comment; but, the line is flagged as questionable because only a comment field may occur on a line after the address field. If the LAC had been preceded by a slash (/), the line would have been correct.

When the address field is a relocatable expression, an error condition may occur. If the program is being assembled to run in page mode, it could not execute properly if its size exceeded 4K (4Ø96) words because it would have to load access a memory page or bank boundary. In practice, the binary loaders restrict the size to 4K-16 (4Ø8Ø) to avoid loading a program into the first 16 locations in a memory page or bank. This avoids a possible ambiguity where indirect memory references would be mistaken for autoincrement register references. Consequently, any relocatable address field whose value exceeds 4Ø95 (7777_8) is meaningless in page mode and will be flagged by the Assembler as an error.

There is a similar size restriction for programs being assembled to operate in bank mode. The Assembler flags in error any relocatable address field whose value exceeds 8191 (17777_8). The binary loaders restrict the size of bank mode programs to 8K-16 (8176) words.

When the address field is an absolute expression, an error condition will exist if the extended memory and page address bits (3, 4 and 5) do not match the corresponding bits of the address of the page currently being assembled into.

NOTE

In absolute mode, the page bits do not have to be equal if the .ABS or .FULL pseudo-ops are used instead of the .ABSP or .FULLP pseudo-ops.

Examples:

Flag	Location (octal)	Instruction	Comments
	30000	→| LAC ␣ 30100	No error message
B	30001	→| DAC ␣ 101	Will cause a bank (B) error message because the address is on a different page and bank.
B	30002	→| JMS ␣ 250	
B	30005	→| ISZ ␣ 40146	

The Linking Loader will not relocate any absolute addresses; thus, absolute addresses within a relocatable program are relative to that page in memory in which the program is loaded.

Example:

Assume that the following source line is part of a relocatable program that was loaded into bank 1 (20000_8 - 37777_8).

Source Statement	Effective Address
→| LAC ␣ 300)	20300

An exception to the above rule is the auto-index registers, which occupy location 10_8 - 17_8 in page 0 of memory bank 0. The hardware will always ensure that indirect references to 10_8 - 17_8 in any page or bank will access 10_8 - 17_8 of bank 0.

2.5.4 Comments Field

Comments may appear anywhere in a statement. They must begin with a slash (/) that is immediately preceded by

a. ␣ (s)	space(s)
b. →|	tab
c.)	carriage return/line feed (end of previous line)
d. ;	semicolon

Comments are terminated only by a carriage-return or when 76_{10} characters have been encountered in a line.

Examples:

␣ (s)/THIS IS A COMMENT (rest of line is blank)
TAG1 →| LAC ␣
/THIS IS A COMMENT
→| RTR ␣ /COMMENT)
→| RTR; →| RTR; /THIS IS A COMMENT

Observe that ; →| A/COMMENT) is not a comment, but rather an operation field expression. A line that is completely blank (containing 0 to 75 blanks/spaces) is treated as a comment by the Assembler.

A statement is terminated as follows:

↵ or ; or rest of line is completely blank.

Examples:

→| LAC ↵
→| DAC (the rest of the line is blank)
→| TAG+3
→| RTR; →| RTR; →| RTR ↵

In the last example, the statement-terminating character, which is a semicolon (;) enables one source line to represent more than one word of object code. A tab or space is required after the semicolon in order to have the second and third RTRs interpreted as being in the operation field and not in the label field.

2.6 STATEMENT EVALUATION

When MACRO-15 evaluates a statement, it checks for symbols or numbers in each of the three evaluated fields: label, operation, and address. (Comment fields are not evaluated.)

2.6.1 Numbers

Numbers are not field dependent. When the Assembler encounters a number (or expression) in the operation or address fields (numbers are illegal in the label field), it uses those values to form the storage word. The following statements are equivalent:

→| 200000␣10 ↵
→| 10+LAC ↵
→| LAC␣10 ↵

All three statements cause the Assembler to generate a storage word containing 200010. A statement may consist of a number or expression which generates a single 18-bit storage word; for example:

→| 23;␣45;␣357;␣62

This group of four statements generates four words interpreted under the current radix.

2.6.2 Word Evaluation

When the Assembler encounters a symbol in a statement field, it determines the value of the symbol by reference to the user's symbol table and the permanent symbol table, according to the priority list shown in paragraph 2.6.4.

The operation value is scanned for the following special cases:

Mnemonic	Operation Field Value
LAW	760000
AAC	723000
AXR	737000
AXS	725000
EAE instructions	64xxxx

If the operation field is not one of the special cases, the object word value is computed as follows:

If assembling for page mode:
(Operation Field +(Address Field & 7777))=Word Value
If assembling for bank mode:
(Operation Field +(Address Field & 17777))=Word Value

If the index register is used anywhere in the address field, the index register bit is set to one in the word value. If it is not used, and you are assembling with .ABSP, .FULLP or .DBREL then the index register bit is set to zero in the word value regardless of the address field value.

a. If index register usage is specified, the result of XORing bit 5 of the location counter and bit 5 of the address field value must be non-zero. (Otherwise the address without index modification was in a different page than the location counter, and the line is flagged with a B for bank error).

Example:

Flag	Location	Object Value	Tag	Source Statement	Page Addressing
				.ABSP	
	00000	210001		LAC A,X	/Page 0
	00001	740000	A	NOP	
	10000			.LOC 10000	/Page 1
	10000	210001		LAC B,X	
B	10001	210001	B	LAC A,X	
				.END	

The result of statement evaluation has produced the following results:

A,X = 10001 A = 00001

B,X = 00001 B = 10001

Note that when index register usage is specified, the index register bit may or may not be on. For B,X above, the index register bit was turned off during statement evaluation. The Assembler turns this bit on after the word is evaluated, not at statement evaluation time.

At location 10001, the result of XORing bit 5 of A,X and bit 5 of the location counter is 0. This signals the Assembler that the address reference (A) is in a different page.

b. If index register usage is not specified and the program is not assembled in bank mode*, the result of XORing bit 5 of the location counter and the address field value must be 0, otherwise the line is flagged with a B for bank error.

Example:

Flag	Location	Object Value	Tag	Source Statement
B	00000 10500 10500	210500 740000	 A	.ABSP LAC A .LOC 10500 NOP .END

c. The bank bits (3,4) of the address field value in a relocatable program must never be on. The bank bits are always lost when the address field value and the operation are combined to form the object word value.

Example:

Flag	Location	Object Value	Tag	Source Statement
B	00000 R 17777 R 17777 R 20000 R	200000 R 740000 A 740000 A	C A	LAC A /Bank bit lost .LOC C+17777 NOP NOP .END

d. The bank bits of an absolute program must equal the bank bits of the location counter. If not, the B flag alerts the programmer that he is referencing another bank.

Example:

Line	Flag	Location	Object Value	Source Statement
1				.ABSP
2		20000		.LOC 20000
3		20000	200001	LAC 1
4		20001	200001	LAC 20001
5	B	20002	210001	LAC 40001
6				.END

*See pseudo-ops .ABS, .ABSP, .FULL, .FULLP, .EBREL, .DBREL.

The address value for Lines 3 and 4 are identical. The bank bits of Line 5 do not match those of the location counter, therefore, the line is flagged.

2.6.3 Word Evaluation of the Special Cases

a. LAW - The operation field value and the address field value are combined as follows:

Operation Value + (Address Field Value & 17777) = Word Value

A validity check is then performed on the address field value as follows:

Address Field Value & 760000 = Validity Bits

If the validity bits are not equal to 760000 or 0, the line is flagged with an E to signal erroneous results.

b. AAC, AXR, AXS - The operation field value and the address field value are combined as follows.

Operation Value + (Address Field Value & 000777) = Word Value

The validity check:

Address Field Value & 777000 = Validity Bits

If the validity bits are not equal to 777000 or 0, the line is flagged with an E to signal erroneous results. The address field value for this type of instruction cannot be relocated. The line is flagged with an R if the address field value is relocatable.

c. EAE class instructions - The operation field value and the address field value are combined as follows:

Operation Value + Address Field Value = Word Value

A validity check is then performed on the word value. If the operation code bits (0 through 3) of the word value differ from those of the operation value, the line is flagged with an E error to signal erroneous results.

Example:

Line	Flag	Location	Object Word Value				
1		0	777777		LAW	17777	/17777
2		1	777777		LAW	-1	/777777
3	E	2	777777		LAW	677777	/677777
4		3	760000	A	LAW		/0
5		4	723776		AAC	-2	/777776
6	E	5	723000		AAC	-2000	/776000

If numbers are found in the operation and address fields, they are combined in the same manner as defined symbols. For example,

→| 2 →| 5 →| /GENERATES 000007

The value of a symbol depends on whether it is in the label field, the operation field, or the address field. The Assembler attempts to evaluate each symbol by running down a priority list, depending on the field, as shown below.

2.6.4 Assembler Priority List

Label Field	Operation Field	Address Field
Current Value of Location Counter	1. Pseudo-op 2. User macro in user symbol table 3. System macro table 4. Direct assignment in user symbol table 5. Permanent symbol table 6. User symbol table 7. Undefined	1. The indexing symbol, X 2. User symbol table (including direct assignments) 3. Undefined

This means that if a symbol is used in the address field, it must be defined in the user's symbol table before the word is formed during PASS 2; otherwise, it is undefined. (See section 2.2.4)

In the operation field, pseudo-ops take precedence and may not be redefined. Direct assignments allow the user to redefine machine op codes, as shown in the example below.

Example:

DPOSIT = DAC

System macros may be redefined as user macro names, but may not be redefined as user symbols by direct assignment or by use as statement labels.

The user may use machine instruction codes and MACRO-15 pseudo-op codes in the label field and refer to them later in the address field.

CHAPTER 3

PSEUDO OPERATIONS

In the discussion of symbols in the previous chapter, it was mentioned that the Assembler has in its permanent symbol table definitions of the symbols for all the PDP-15 memory reference instructions, operate instructions, the basic EAE instructions, and many commonly used IOT instructions which may be used in the operation field without prior definition by the user. Also contained in the permanent symbol table are a class of symbols called pseudo-operations (pseudo-ops) which, instead of generating instructions, generate data or direct the Assembler on how to proceed with the assembly.

By convention, the first character of every psuedo-op symbol is a period (.). This convention is used in an attempt to prevent the programmer from inadvertently using, in the operation field, a pseudo-instruction symbol as one of his own.

The following is a summary of MACRO-15 Pseudo-ops.

Pseudo-op	Section	Function
.ABS .ABSP	3.2.1 3.2.1	Object program is output in absolute, blocked, checksummed format for loading by the Absolute Binary Loader. (Neither supported with RSX PLUS, RSX PLUS III or B/F MACROA.)
.ASCII	3.8.1	Input text strings in 7-bit ASCII code, with the first character serving as delimiter. Octal codes for nonprinting control characters are enclosed in angle brackets.
.BLOCK	3.5	Reserves a block of storage words equal to the expression. If a label is used, it references the first word in the block.
.CBD .CBDR	3.18 3.19	Common Block Definition (DOS-15, RSX PLUS and RSX PLUS III only). Common Block Definition Relative (RSX PLUS and RSX PLUS III only).
.DBREL	3.2.3	Disable bank mode relocation.
.DEC	3.4	Sets prevailing radix to decimal.
.DEFIN	3.16	Defines macros. Not supported with B/F MACROA.
.DSA	3.11	Generates a transfer vector for the specified symbol.
.EBREL	3.2.3	Enable bank mode relocation.
.EJECT	3.14	Skip to head of form on listing device.
.END	3.6	Must terminate every source program. The address field contains the address of the first instruction to be executed.
.ENDC	3.13	Terminates conditional coding in .IF statements.

Pseudo-op	Section	Function
.ENDM	3.16	Terminates the body of a macro definition. Not supported by B/F MACROA.
.EOT	3.7	Must terminate physical program segments, except the last, which is terminated by .END.
.ETC	3.16	Used in macro definitions to continue the list of dummy arguments on succeeding lines. Not supported by B/F MACROA.
.FULL .FULLP	3.2.2	Produces absolute, unblocked, unchecksummed binary object programs. Used only for paper tape output. (Neither supported with RSX PLUS, RSX PLUS III or B/F MACROA.)
.GLOBL	3.9	Used to declare all internal and external symbols which reference other programs.
.IFxxx	3.13	If a condition is satisfied, the source coding following the .IF statement and terminating with an .ENDC statement is assembled.
.IODEV	3.10	Specifies .DAT slots and associated I/O handlers required by this program. (Not supported with RSX PLUS.)
.LOC	3.3	Sets the location counter to the value of the expression.
.LOCAL	3.2.4	Allows deletion of certain symbols from the user symbol table.
.LST	3.17	Continues requested assembly listing output of source lines. Lines between .NOLST and .LST are not listed.
.LTORG	3.2.5	Allows the user to specifically state where literals are to be stored. Not supported by B/F MACROA.
.NDLOC	3.2.4	Terminates deletion of certain symbols from the user symbol table contained between .LOCAL and .NDLOC.
.NOLST	3.17	Terminates requested assembly listing output of source lines of code contained between .NOLST and .LST.
.OCT	3.4	Sets the prevailing radix to octal. Assumed at start of every program.
.REPT	3.12	Repeats the object code of the next object code generating instruction. Not supported by B/F MACROA.
.SIXBT	3.8.2	Input text strings in 6-bit trimmed ASCII with first character as delimiter.
.SIZE	3.15	MACRO-15 outputs the address of last location plus the one occupied by the object program.
.TITLE	3.1	Causes the assembler to accept characters to be printed at the top of each page of assembly listing and in the Table of Contents.

3.1 PROGRAM IDENTIFICATION (.TITLE)

The program name (or any text) may be written in a .TITLE statement as shown in the following examples. The Assembler will accept up to 50_{10} characters typed until a carriage return. A form feed is output to the listing when .TITLE is encountered in the source program. The text will appear at the top of each form (page) until the next .TITLE pseudo-op. The .TITLE pseudo-op has no effect on the listing file name.

→|.TITLE␣ NAME OF PROGRAM
→|.TITLE␣ NAME OF SUBSECTION IN PROGRAM

If subsections in a program are headed by .TITLE statements, these can be used to produce a table of contents at the head of the assembly listing by use of the T option. This feature is not available in ADSS-15 and Background/Foreground.

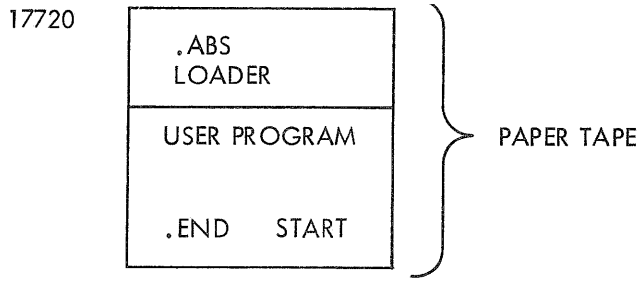
3.2 OBJECT PROGRAM OUTPUT

The normal object code produced by MACRO-15 is relocatable binary which is loaded at run time by the Linking Loader or loaded to build an executable task by CHAIN or TKB. In addition to relocatable output, the user may specify other types of output code to be generated by the Assembler.

3.2.1 .ABSP, .ABS (Not available in RSX PLUS, RSX PLUS III or B/F MACROA)*

Label Field	Operation Field	Address Field
Not used	.ABSP	NLD or␣or not specified
Not used	.ABS	NLD or␣or not specified

Both of the absolute pseudo-ops cause absolute, checksummed binary code to be output (no values are relocatable). If no value is specified in the address field and if the output device is the paper tape punch, the Assembler will precede the output with the Absolute Binary Loader (ABL), which will load the punched output at object time. The ABL is loaded, via hardware readin, into location 17720 of any memory bank. (The ABL loads only the paper tape which follows it.) If the address field of the pseudo-op contains NLD, indicating "no loader", the ABL will not precede the output.



NOTE

.ABS (P) output can be written on directoried devices. The Assembler assumes .ABS (P) NLD for all .ABS (P) output to file-oriented devices and appends an extension of ABS to the filename. This file can be punched with PIP, using Dump Mode. (There will be no absolute loader at the beginning of the tape.)

a. The .ABS, .ABSP, .FULL, and .FULLP pseudo-ops, specifying the type of output, must appear before any statements generating object code, otherwise the line will be flagged and ignored. Once one of these four pseudo-ops is specified, the user is not allowed to change output modes.

b. The NLD option provided in the address field of .ABS and .ABSP is meaningful only if the output device is paper tape.

* .ABSP and .ABS, although accepted by the Assembler, will not work properly in RSX PLUS or RSX PLUS III systems because none of the I/O handlers accept dump mode data.

A description of the absolute output format follows.

Block Heading - (three binary words)

WORD 1 Starting address to load the block body which follows.

WORD 2 Number of words in the block body (two's complement).

WORD 3 Checksum of block body (two's complement). Checksum includes Word 1 and Word 2 of the block heading.

Block Body - (n binary words)

The block body contains the binary data to be loaded under block heading control.

Starting Block - (two binary words)

WORD 1 Location to start execution of program. It is distinguished from the block heading by having bit 0 set to 1 (negative).

WORD 2 Dummy word.

If the user requests the absolute loader and the value of the expression of the .END statement is equal to 0, the ABL halts after it has loaded in the object program. To start the program the user must set the starting address in the console address switches and press START. This allows manual intervention by the user, typically to ready I/O devices prior to starting his program. If the value of the .END expression is non-zero, it is treated as the program start address to which the ABL will automatically transfer control after loading the object program.

The .ABSP pseudo-op causes all memory referencing instructions whose addresses are in a different page to be flagged as bank errors. A DBA instruction is executed by the absolute loader before control is given to the user program. Word values which have bit 5 on will signal the processor to use the index register to compute effective addresses.

The .ABS pseudo-op does not flag memory referencing instructions whose addresses are in a different page. An EBA instruction is executed, and control is given to the user in bank addressing mode. Complete bank addressing of 8K is allowed. The processor will interpret bit 5 of all memory referencing instructions as the high order address bit. A listing of the Absolute Binary Loader is given in Appendix F.

3.2.2 .FULL, .FULLP (Not available in RSX PLUS, RSX PLUS III or B/F MACROA)*

Label Field	Operation Field	Address Field	(Only useful if output is paper tape)
Not used	.FULL	Not used	
Not used	.FULLP	Not used	

The .FULL and .FULLP pseudo-ops cause full binary mode output to be produced. The program is assembled as unchecksummed absolute code and each physical record of output contains nothing other than 18-bit binary storage words generated by the Assembler. This mode is used to produce paper tapes which can be loaded via hardware readin mode. If no address is specified in the .END statement or if the address value is zero, at the

*.FULL and .FULLP, although accepted by the Assembler, will not work properly in RSX PLUS or RSX PLUS III systems because none of the I/O handlers accept dump mode data.

end of tape the assembler will punch a halt instruction with channel 7 punched in the third frame. If the .END address value is non-zero, the assembler will punch a JMP to that address, also with channel 7 of the third frame punched.

In addition, with .FULLP assembly direct memory references in page 1 to addresses in page 1 will have bit 5 set to 0 unless indexing is specified.

The only difference between the .FULL and .FULLP pseudo-ops is that memory references across page boundaries are flagged in .FULLP mode; in .FULL mode they are not.

The following specific restrictions apply to programs assembled in .FULL or .FULLP mode output.

.LOC	Should be used only at the beginning of the program
.BLOCK	May be used only if no literals appear in the program, and must immediately precede .END.

Variables and undefined symbols may be used if no literals appear in the program.

Literals may be used only if the program has no variables and undefined symbols.

The reason for these restrictions, not alleviated by the use of .LTORG, is the fact that .FULL(P) mode output contains no addressing information for storing binary words other than in sequence. The .LOC and .BLOCK pseudo-ops do not generate binary output, hence there is no way to indicate skipped locations in the output. This is also true of variables and undefined symbols.

3.2.3 .EBREL and .DBREL

Label Field	Operation Field	Address Field
Not used	.EBREL	Not used
Not used	.DBREL	Not used

The following two pseudo-ops (.EBREL and .DBREL) enable relocation mode switching. They can be used anywhere and as often as the programmer wishes in a relocatable program. In the absence of one of these mode declaration pseudo-ops, the page mode assembler assumes it is assembling 12-bit (page mode) relocatable addresses for memory reference instructions and the bank mode assembler assumes 13-bit addresses (bank mode).

A typical user program may omit the use of these pseudo-ops and simply prepare his object code by using the correct (bank or page mode) version of the assembler. For the PDP-9 there is only one correct mode, bank mode. For PDP-15 page mode programs which contain display code to be interpreted by the VT15 graphics processor, it is necessary to bracket the display code with .EBREL, .DBREL. Unlike the Central Processor, the VT15 processor runs only in bank mode; hence its instruction addresses must be relocated as 13-bit values.

Mnemonic	Description
.EBREL	Enable Bank mode RELocation Regardless of the type of Assembler being used (bank or page mode version), .EBREL causes all subsequent memory reference instruction addresses to be treated as 13-bit values, i.e., bank mode. Although in this mode, the page mode assembler will still output the "PROG>4K" warning message if the program size exceeds 4192. The 12- or 13-bit relocation is performed by the loaders. .EBREL signals the loaders to switch to 13-bit relocation by causing a dummy data word (which is not loaded) to be inserted in the binary output and having a loader code of 31_8.
.DBREL	Disable Bank mode RELocation .DBREL is the counterpart to .EBREL. It signals the loaders, with a dummy data word and loader code of 32_8 to switch to 12-bit (page mode) relocation.

NOTE

The previous mode is not saved when an .EBREL or .DBREL is encountered; for this reason, a .DBREL pseudo-op goes directly to PDP-15 (page mode) relocation rather than entering the previous mode.

3.2.4 Deletion of User Symbol Table (.LOCAL, .NDLOC)

Label Field	Operation Field	Address Field
Not used	.LOCAL	Not used
Not used	.NDLOC	Not used

The size of a program that can be assembled with MACRO-15 is determined by the number of user symbols in that program and therefore by the amount of core available at assembly time in which to store those symbols. Each user symbol requires three words of core in the assembler's symbol table. This additional core is not required at run-time (unless using a debugging program like DDT) because user symbols are not loaded into core along with the object code.

The .LOCAL and .NDLOC pseudo-ops enable deletion of certain symbols from the user symbol table. In so doing, larger programs can be assembled without increasing core size. The area between these two pseudo-ops is defined as having a number of symbols, most of which are used only in this area and which can be deleted, once this area has been passed by the assembler. The 8K PDP-15 user who writes modularized programs will find these pseudo-ops to be very powerful tools.

The assembler creates a separate symbol table (local users symbol table) when the .LOCAL pseudo-op is encountered. Only tags and direct assignments may be stored in this table. Tag symbols which have the # sign as part of the symbol are stored in the resident users symbol table (RUST). This feature is useful where a subroutine name is part of a local area but must go into the RUST because of subroutine calls from without the local area (See

Section D of the following example). Symbols which are forward references (used before defined) are stored as part of the resident users symbol table. When the .NDLOC pseudo-op is encountered the local table disappears and the resident UST is left unchanged.

An example of a program which uses the .LOCAL and .NDLOC pseudo-ops follows. The symbols that are stored in the tables are represented in the comment field in the order that they are stored during PASS 1.

```
1                .ABS
2                .LOC        100
3                CAF
4                JMS         TTYIN       /TTYIN
5       A        JMP         C           /C,A
6                LAW         -10
7                DAC         D           /D
8       KK       ISZ         D           /KK
9                JMP         A
10               LAC         KK
11               JMP         AA          /AA
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
12               .LOCAL
13      TTYIN    0                       /ALREADY STORED IN RUST (FROM LINE 4)
14               JMP         .+5
15      XXX      0                       /TEMP STORAGE OF SUBR. TTYIN: XXX(LOCAL TABLE)
16      YY       0                       /                              Y   (LOCAL TABLE)
17      Z        0                       /                              Z   (LOCAL TABLE)
18      X1       0                       /                              X1  (LOCAL TABLE)
19               KSF
20               JMP         .-1
21               KRB
22               DAC         XXX
23               DAC         YY
24               DAC         Z
25               DAC         X1
26               JMP*        TTYIN
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
27               .NDLOC
28      AA       LAC         X1          /X1,(FORWARD REF. LOCAL TABLE DISAPPEARED).
29               JMP         KK
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
30               .LOCAL
31      SYM1                             /TEMP STORAGE OF SUBR. TSUBR SYM1 (LOCAL
                                         /TABLE)
32      SYM2                             /                    SYM2 (LOCAL TABLE)
33      TSUBR#   0                       /TSUBR STORED IN RUST BECAUSE OF # SIGN.
34               LAC         SYM1
35               DAC         SYM2
36               JMP*        TSUBR
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
37               .NDLOC
38               .END
```

For purposes of illustration, lines 1-11, 12-26, 27-29, and 30-36 are broken into sections A, B, C, and D respectively. The following tables show the resident and local users symbol tables (UST) at the end of each section (PASS 1 only).

	RESIDENT UST	LOCAL UST
	-	-
SECTION	A	
	-	
	A	(NO SYMBOLS)
	AA	
	C	
	D	
	KK	
	TTYIN	
SECTION	B	
	-	
	A	X
	AA	X1
	C	Y
	D	Z
	KK	
	TTYIN	
SECTION	C	
	-	
	A	(NO SYMBOLS)
	AA	
	C	
	D	
	KK	
	TTYIN	
	X1	
SECTION	D	
	-	
	A	SYM1
	AA	SYM2
	C	
	D	
	KK	
	TTYIN	
	X1	
	TSUBR	

In Section A, the symbol TTYIN is used. TTYIN is in a local area yet it is put into the resident user symbol table because it is a forward reference. The same is true of symbol X1 from Section C. Once the .NDLOC pseudo-op is encountered, the local UST no longer exists. For that reason, the X1 reference from line 28 is a forward reference. At the end of PASS 1, X1 would be represented as an undefined symbol. When Section B is processed during PASS 2, the symbol X1 would not be stored in the local UST because it already has been put into the resident table.

LIMITATIONS

A. The .LOCAL pseudo-op causes the local UST to be built just above the Macro definitions. Consequently, the .DEFIN Macro is illegal in a local area.

B. In systems with an extra 4K of core (12K, 20K and 28K) no attempt is made to continue the local users symbol table from low core to the extra page. The housekeeping code that would be needed to do this would negate the utility of the .LOCAL pseudo-op. The likelihood of such an occurrence is small. However, should the table reach the beginning of the Assembler, assembly will terminate with the message

TABLE OVERFLOW

3.2.5 Literal Origin Pseudo-op (.LTORG) (Not available in B/F MACROA)

Label Field	Operation Field	Address Field
Not used	.LTORG	Not used

As previously stated, a literal is an item of data with its value as stated or listed. The pseudo-op .LTORG allows the user to specifically state where he wants his literal table(s) to be stored; thus enabling the user to store literal tables in different pages or banks. As many as eight literal tables are allowed. Notice in the following example that literals are not saved from one .LTORG to the next.

```
                                        .ABS
                                        .LOC    17700
17700   217703                          LAC     (1
17701   077704                          DAC*    (2
17702   217704                          LAC     (3
                                        .LOC    20000
                                        .LTORG
20000   000001  *L
20001   000002  *L
20002   000003  *L
                                        .LOC    17703
17703   740000                          NOP
17704   217711                          LAC     (1
17705   057712                          DAC     (2
                                        .LOC    20003
                                        .LTORG
20003   000001  *L
20004   000002  *L
                                        .END
```

The literals 1 and 2 are stored twice even though they appear in the same bank.

If more than eight .LTORG statements appear in a program, the excess ones will be ignored and flagged with an I error. Subsequent literals will be assigned core locations following the end of the program in the normal manner.

3.3 SETTING THE LOCATION COUNTER (.LOC)

Label Field	Operation Field	Address Field
Not used	.LOC	Predefined symbolic expression, or number

The .LOC pseudo-op sets or resets the location counter to the value of the expression contained in the address field. The symbolic elements of the expression must have been defined previously; otherwise, phase errors will occur in PASS 2. The .LOC pseudo-op may be used anywhere and as many times as required.

Examples:

Location Counter	Instruction
100	→| .LOC␣100
100	→| LAC␣TAG1
101	→| DAC␣TAG2
102	→| .LOC␣.
102	A→| LAC␣B
103	→| DAC␣C
107	→| .LOC␣A+5
107	→| LAC␣C
110	→| DAC␣D
111	→| LAC␣E
112	→| DAC␣F

A program headed by an absolute statement, e.g., .LOC 100 is an absolute binary program and the binary is output in link-loadable format.

3.4 RADIX CONTROL (.OCT and .DEC)

The initial radix (base) used in all number interpretation by the Assembler is octal (base 8). In order to allow the user to express decimal values, and then restore to octal values, two radix setting pseudo-ops are provided.

Pseudo-op Code	Meaning
.OCT	Interpret all succeeding numerical values in base 8 (octal)
.DEC	Interpret all succeeding numerical values in base 10 (decimal)

These pseudo-instructions must be coded in the operation field of a statement. All numbers are decoded in the current radix until a new radix control pseudo-instruction is encountered unless the pseudo-op occurs within a MACRO expansion (see p. 4-4). The programmer may change the radix at any point in a program.

Flag	Source Program	Generated Value (Octal)	Radix in Effect
	→| LAC 100	200100	8 } initial value is
	→| 25	000025	8 } assumed to be octal
	→| .DEC		
	→| LAC 100	200144	10

Flag	Source Program	Generated Value (Octal)	Radix in Effect
	→| 275	000423	10
	→| .OCT		
	→| 76	000076	8
N	→| 85	000125	error

If a number is encountered which contains a decimal digit while in octal mode, the number is evaluated as if the Assembler were in decimal mode, and the line is flagged with an N.

3.5 RESERVING BLOCKS OF STORAGE (.BLOCK)

.BLOCK reserves a block of memory equal to the value of the expression contained in the address field. If the address field contains a numerical value, it will be evaluated according to the radix in effect. The symbolic elements of the expression must have been defined previously, i.e., no forward referencing is allowed; otherwise, phase errors might occur in PASS 2. The expression is evaluated modulo $2^{15}(77777_8)$. The user may reference the first location in the block of reserved memory by defining a symbol in the label field. The initial contents of the reserved locations are unspecified.

Label Field	Operation Field	Address Field
User Symbol	.BLOCK	Predefined Expression

Examples:

```
BUFF →| .BLOCK␣12↵
     →| .BLOCK␣A+B+65↵
```

3.6 PROGRAM TERMINATION (.END)

One pseudo-op must be included in every MACRO-15 source program. This is the .END statement, which must be the last statement in the main program. This statement marks the physical end of the source program, and also may contain the location of the first instruction in the object program to be executed at run-time.

The .END statement is written in the general form

→| .END␣START ↵

START may be a symbol, number, or expression whose value is the address of the first program instruction to be executed. In relocatable programs to be loaded by the Linking Loader, CHAIN or TKB, only the main program requires a starting address; all other subprogram starting adresses, if specified, will be ignored.

A starting address must appear in absolute or self-loading programs; otherwise, the program will halt after being loaded and the user must manually start his program.

These are legal .END statements

→| .END␣.BEGIN+5 ↵

→| .END␣200 ↵

If no .END statement is included (or no tab or space precedes the .END) the assembler will treat it as if a .EOT was included.

3.7 PROGRAM SEGMENTS (.EOT)

If a program is physically segmented (on paper tape, DECtape or magtape), each segment except the last may terminate with an .EOT (end-of-tape) statement or with nothing at all (neither .EOT nor .END). Termination with nothing is equivalent to termination with .EOT. The last segment must terminate with an .END statement. The .EOT statement is written without label and address fields, as follows,

→| .EOT ↵

The following are typical reasons for segmenting programs:

1. A source program is prepared on three different paper tapes because one tape alone would be too large to fit in the reader.
2. A source program is split in two and stored on two DECtapes because it is larger than the capacity of a single tape.
3. To simplify program preparation, a file containing commonly used macro definitions is kept physically separate from user main programs. Thus, one does not have to include the macro definitions in each main program. Macro definition files must terminate with .EOT or nothing rather than .END.
4. Programs can be conditionally assembled for different machine configurations or different software options. This is done by defining conditional assembly parameters at assembly time. The process can be simplified if one prepares paper tapes or mass storage files defining all parameters for a given set of options. The main program and parameter file are physically segmented one from the other but can be assembled together. Parameter definition files must terminate with .EOT or nothing rather than .END.

3.8 TEXT HANDLING (.ASCII AND .SIXBT)

The two text handling pseudo-ops enable the user to represent the 7-bit ASCII or 6-bit trimmed ASCII character sets. The Assembler converts the desired character set to its appropriate numerical equivalent (see Appendix A).

Label Field	Operation Field	Address Field
SYMBOL	{ .ASCII .SIXBT }	Delimiter - character string - delimiter - <expression> .....

Only the 64 printing characters (including space) may be used in the text pseudo-instructions. See nonprinting characters, Section 3.8.5. The numerical values generated by the text pseudo-ops are left-justified in the storage word(s) they occupy with the unused portion (bits) of a word filled with zeros.

3.8.1 .ASCII Pseudo-op

.ASCII denotes 7-bit ASCII characters. (It is the character set used by the operating system monitor or executive.) The characters are packed five per two words of memory with the rightmost bit of every second word set to zero. An even number of words will always be output:

First Word			Second Word		
0 6	7 13	14 17	0 2	3 9	10 16 17
1st Char.	2nd Char.	3rd Char.	4th Char.	5th Char.	0

3.8.2 .SIXBT Pseudo-op

.SIXBT denotes 6-bit trimmed ASCII characters, which are formed by truncating the leftmost bit of the corresponding 7-bit character. Characters are packed three per storage word.

0 5	6 11	12 17
1st Char.	2nd Char.	3rd Char.

3.8.3 Text Statement Format

The statement format is the same for both of the text pseudo-ops. The format is as follows.

MYTAG → { .ASCII / .SIXBT } → | delimiter | character string | delimiter | <expression>.....

3.8.4 Text Delimiter

Spaces or tabs prior to the first text delimiter or angle bracket (<) will be ignored; afterwards, if they are not enclosed by delimiters or angle brackets, they will terminate the pseudo-instruction. Also,) will terminate the pseudo-instruction.

Any printing character may be used as the text delimiter, except those listed below.

a. < as it is used to indicate the start of an expression.

b.) as it terminates the pseudo-instruction.

(The apostrophe (') is the recommended text delimiting character.) The text delimiter must be present on both the left-hand and the right-hand sides of the text string; otherwise, the user may get more characters than desired. However, ↵ may be used to terminate the pseudo-instruction.

3.8.5 Non-Printing Characters

The octal codes for non-printing characters may be entered in .ASCII statements by enclosing them in angle bracket delimiters. In the following statement, five characters are stored in two storage words.

→| .ASCII ␣'AB' <015>'CD'↵

Octal numbers enclosed in angle brackets will be truncated to 7 bits (.ASCII) or 6 bits (.SIXBT).

Example:

Source Line	Recognized Text	Comments
TAG→| .ASCII␣'ABC'	ABC	
→| .SIXBT␣'ABC'	ABC	
→| .SIXBT␣'ABC'#'/#	ABC'/	The # is used as a delimiter in order that (') may be interpreted as text.
→| .ASCII␣'ABCD'EFGE	ABCDFG	
→| .ASCII␣'AB'<11>	AB →|	<11> used to represent tab.
→| .ASCII␣'AB<11>	AB<11>	There is no delimiter after B, therefore, (<11>) is treated as text.
→| .ASCII␣<15><012>'ABC'	↵↓ABC	
→| .ASCII␣<15><12>ABC␣(s)	↵↓BC␣(s)	A is interpreted as the text delimiter. Also, since ↵ was not used to terminate the text, the ␣(s) are interpreted as text characters.

The following example shows the binary word format which MACRO-15 generates for a given line of text.

Example:

→| .ASCII →| 'ABC'<015><12>'DEF'

Generated Coding

Word Number	Octal	Binary			
Word 1	406050	1000001	1000010	1000	
Word 2	306424	011	0001101	0001010	0
Word 3	422130	1000100	1000101	1000	
Word 4	600000	110	0000000	0000000	0

3.9 GLOBAL SYMBOL DECLARATION (.GLOBL)

Label Field	Operation Field	Address Field
Not used	.GLOBL	A,B, C,D,E....

The standard output of the Assembler is a relocatable object program. The Linking Loader, CHAIN or TKB joins relocatable programs by supplying definitions for global symbols which are referenced in one program and defined in another. The pseudo-op .GLOBL, followed by a list of symbols, is used to define to the Assembler those global symbols which are either

a. internal globals - defined in the current program and referenced by other programs

b. external symbols - referenced in the current program and defined in another program

The loader (Linking Loader, CHAIN or TKB) uses this information to include in the load and then link the relocatable programs to each other.

All references to external symbols must be indirect references since PDP-15 software systems use transfer vectors for referencing external symbols. Each external symbol causes an additional word (the transfer vector word) to be reserved in the user program. The loading program will store the actual address of the external symbol in the transfer vector word. Thus, an indirect reference (through the transfer vector) will cause the external symbol location to be addressed.

Example:

```
      .GLOBL   A,B,C
A     LAC      D        /A is an internal global
D     JMS*     B        /These two instructions reference
      JMS*     C        /External symbols indirectly
      .END     D
```

The .GLOBL statement may appear anywhere within the program.

The example above is assembled as follows:

Flag	Location	Word Value	.GLOBL A,B,C
	000000 R	200001 R	A LAC D
	000001 R	120003 R	D JMS* B
	000002 R	120004 R	JMS* C
		000001	.END D
	000003 R	000003 *E	
	000004 R	000004 *E	

The real values for locations 3 and 4 will be supplied by the loading program: these two words will contain the addresses in memory of external symbols B and C.

3.10 REQUESTING I/O DEVICES (.IODEV) (not supported in RSX)

The .IODEV pseudo-op appears anywhere in the program (though standardly near the beginning) and is used to cause the Assembler to output code for the Linking Loader or CHAIN which specifies the slots in the Monitor's device assignment table (DAT) whose associated device handlers are required by the program. This is used in those systems where device handlers are brought into core at the time a program is loaded to run.

Label Field	Operation Field	Address Field
Not used	.IODEV	1,2,3...

The arguments may be numeric or symbolic. If the argument is symbolic, the symbol must be defined by a direct assignment statement.

3.11 DESIGNATING A SYMBOLIC ADDRESS (.DSA)

.DSA (designate symbol address) is used in the operation field when it is desired to create a word composed of just a transfer vector (15-bit address). It is useful when a user tag symbol is also a permanent instruction or pseudo-op symbol.

Label Field	Operation Field	Address Field
User Symbol	.DSA	Any Expression

Examples:

```
JMP  →|  LAC  →|  TAG
     →|  .DSA →|  JMP  }
     →|        →|  JMP  }
```

Equivalent methods of designating the user symbol JMP (rather than the instruction JMP) to be in the address field.

3.12 REPEATING OBJECT CODING (.REPT) (Not available in B/F MACROA)

Label Field	Operation Field	Address Field
Not used	.REPT	Count {, Increment / or_ / or; / or}

The .REPT pseudo-op causes the object code of the next sequential object code generating instruction to be repeated "count" times. Optionally, the object code may be incremented for each time it is repeated by specifying an increment. The count and increment may be represented by a numeric or symbolic value. If a symbol is used, it must be defined by an absolute direct assignment statement which must occur before the symbol is used. The repeated instruction may contain a label, which will be associated with the first statement generated. Note that arithmetic expressions in the address field are illegal.

Examples:

Source Code	Generated Object Code
→| .REPT␣5	
→| 0	000000
	000000
	000000
	000000
	000000
→| .REPT␣4,1	
→| 1	000001
	000002
	000003
	000004
→| .REPT␣3,-1	
→| 5	000005
	000004
	000003
TAG=50	
→| .REPT␣4,1	
→| JMP␣TAG	600050
	600051
	600052
	600053

NOTE

If the statement to be repeated generates more than one location of code, the .REPT will repeat only the last location. For example,

```
→| .REPT␣3
→| .ASCII␣'A'
```

will generate the following:

```
404000    5/7 A
000000
000000    last word is
000000    repeated
```

3.13 CONDITIONAL ASSEMBLY (.IF xxx and .ENDC)

It is often useful to assembly some parts of the source program on an optional basis. This is done in MACRO-15 by means of conditional assembly statements, of the form:

→| .IF... →| expression

The pseudo-op may be any of the eight conditional pseudo-ops shown below, and the address field may contain any number, symbol, or expression. If there is a symbol, or an expression containing symbolic elements, such a symbol must have been previously defined in the source program or the parameter file (except for .IFDEF and .IFUND). If not, the value of the symbol or expression is assumed to be Ø, thereby satisfying three of the numeric conditionals.

If the condition is satisfied, that part of the source program starting with the statement immediately following the conditional statement and up to but not including an .ENDC (end conditional) pseudo-op is assembled. If the condition is not satisfied, this coding is not assembled.

The eight conditional pseudo-ops (sometimes called IF statements) and their meanings are shown below.

Pseudo-op	Assemble IF x is:
→| .IFPNZ␣x	Positive and non-zero
→| .IFNEG␣x	Negative
→| .IFZER␣x	Zero
→| .IFPOZ␣x	Positive or zero
→| .IFNOZ␣x	Negative or zero
→| .IFNZR␣x	Not zero
→| .IFDEF␣x	A defined symbol
→| .IFUND␣x	An undefined symbol

In the following sequence, the pseudo-op .IFZER is satisfied, and the source program coding between .IFZER and .ENDC is assembled.

```
SUBTOT=48
TOTALL=48
→| .IFZER →| SUBTOT-TOTALL
→| LAC␣A
→| DAC␣B
→| .ENDC
```

Conditional statements may be nested. For each IF statement there must be a terminating .ENDC statement. If the outermost IF statement is not satisfied, the entire group is not assembled. If the first IF is satisfied, the

following coding is assembled. If another IF is encountered, however, its condition is tested, and the following coding is assembled only if the second IF statement is satisfied. Logically, nested IF statements are like AND circuits. If the first, second, and third conditions are satisfied, then the coding that follows the third nested IF statement is assembled.

Example:

```
→| .IFPOZ␣X          conditional 1 initiator
→| LAC →| TAG
→| .IFNZR␣Y          conditional 2 initiator
→| DAC →| TAG1
→| .ENDC             conditional 2 terminator
→| .IFDEF␣ Z         conditional 3 initiator
→| DAC →| TAG2
→| .ENDC             conditional 3 terminator
→| .ENDC             conditional 1 terminator
```

Conditional statements can be used in a variety of ways. One of the most useful is in terminating recursive macro calls (described in Chapter 4). In general, a counter is changed each time through the loop, or recursive call, until the condition is not satisfied. This process concludes assembly of the loop or recursive call.

3.14 LISTING CONTROL (.EJECT)

The following Assembler listing control is effective only when a listing is requested by Assembler control keyboard request.

Label Field	Operation Field	Address Field
Not used	.EJECT	Not used

When .EJECT is encountered anywhere in the source program, it causes the listing device that is being used to skip to top-of-form.

3.15 PROGRAM SIZE (.SIZE)

Label Field	Operation Field	Address Field
User Symbol	.SIZE	Not used

When the Assembler encounters .SIZE, it outputs one word which contains the address of the last location plus one occupied by the object program. This is normally the length of the object program (in octal). However, if a given program is 121_8 words long and has a .LOC 4ØØ statement at the head of the program, the value of the .SIZE word will be 521_8.

3.16 DEFINING MACROS (.DEFIN, .ETC, and .ENDM) (Not available in B/F MACROA)

The .DEFIN pseudo-op is used to define macros (described in Chapter 4). The address field in the .DEFIN statement contains the macro name, followed by a list of dummy arguments. If the list of dummy arguments will not fit on the same line as the .DEFIN pseudo-op, it may be continued by means of the .ETC pseudo-op in the operation field and additional arguments in the address field of the next line. The coding that is to constitute the body of the macro follows the .DEFIN statement. The body of the macro definition is terminated by an .ENDM pseudo-op in the operation field. (See Chapter 4 for more details on the use of macros.)

3.17 ASSEMBLY LISTING OUTPUT CONTROL (.NOLST and .LST)

Label Field	Operation Field	Address Field
Not used	{.NOLST / .LST}	Not used

If, while performing an assembly listing operation (L, X, or N assembly parameters), the assembler encounters a .NOLST, the listing operation will be terminated until a .LST is found. These pseudo-ops are useful when the user wishes to assemble all of a program, but only needs a listing of certain modules of the program (e.g., those which may not yet work properly). All symbols occurring between .NOLST and .LST will appear in the cross reference and symbol table listings when requested (A, V, X, or S assembly parameters).

3.18 COMMON BLOCK DEFINITION (.CBD) (DOS and RSX Systems Only)

The pseudo-op .CBD enables the programmer to declare a COMMON area of an indicated name and size and to specify the word to be set to its base address. The general format of this pseudo-op is:

Label Field	Operation Field	Address Field
User Symbol	.CBD	Name␣Size

The .CBD pseudo-op takes a COMMON name and size as arguments, reserves one word of core for the base address, and outputs loader codes and parameters to direct the Linking Loader, CHAIN or TKB programs to set a transfer vector to the base address (first element) of the named COMMON array. For example, the statement:

```
BASE .CBD ABCD 6
```

provides location BASE with the address of the first word of the COMMON area named ABCD whose size is 6. Blank COMMON is given a special name by the system software, .XX. To reference Blank COMMON in a .CBD statement, .XX should be given as the block name.

3.19 COMMON BLOCK DEFINITION RELATIVE (.CBDR) (RSX Systems Only)

The pseudo-operation .CBDR (common block definition relative) takes an offset as its only argument. The general format of this pseudo-op is:

Label Field	Operation Field	Address Field
User Symbol	.CBDR	Displacement

This pseudo-op directs the task builder to enter the starting address of the last COMMON block specified in a .CBD plus the offset given in the .CBDR into the word corresponding to the location of the .CBDR.

For example, the statements

```
BASE    .CBD    ABCD 5
BASE3   .CBDR   3
```

will cause the task builder to enter the starting address of the COMMON block ABCD into the location corresponding to the tag BASE; in addition, the location corresponding to BASE3 will contain the starting address of ABCD plus 3.

Note that .CBDR is relative to the last COMMON definition only. Any other assembler instructions or pseudo-operations may intervene between the .CBD and .CBDR.

CHAPTER 4
MACROS

When a program is being written, it often happens that certain coding sequences are repeated several times with only the arguments changed. It would be convenient if the entire repeated sequence could be generated by a single statement. To accomplish this, it is first necessary to define the coding sequence with dummy arguments as a macro instruction, and then use a single statement referring to the macro name along with a list of real arguments which will replace the dummy arguments and generate the desired sequence.

Consider the following coding sequence.

```
LAC A
TAD B
DAC C
 .
 .
 .
LAC D
TAD E
DAC F
```

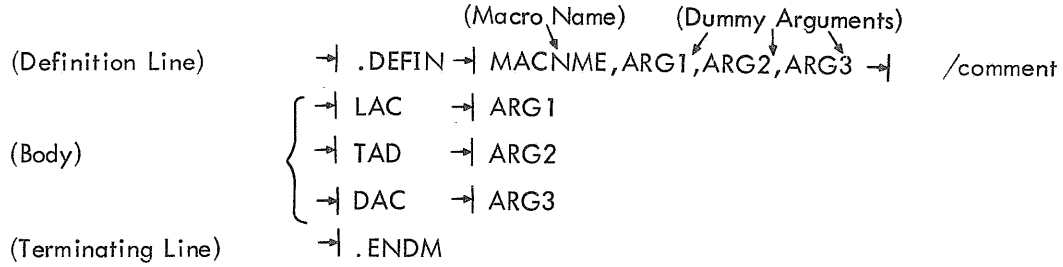
The sequence

```
LAC x
TAD y
DAC z
```

is the model upon which the repeated sequence is based. The characters x, y, and z are called dummy arguments and are identified as such by being listed immediately after the macro name when the macro instruction is defined.

4.1 DEFINING A MACRO

Macros must be defined before they are used. The process of defining a macro is as follows.



The pseudo-op .DEFIN in the operation field defines the symbol following it as the name of the macro. Next, follow the dummy arguments, as required, separated by commas and terminated by any of the following symbols.

a. space (␣)
b. tab (→|)
c. carriage return (↵)

The macro name and the dummy arguments must be legal MACRO-15 symbols. Any previous definition of a dummy argument is ignored while in a macro definition. Comments after the dummy argument list in a definition are legal.

If the list of dummy arguments cannot fit on a single line (that is, if the .DEFIN statement requires more than 72_{10} characters) it may be continued on the succeeding line or lines by the usage of the .ETC pseudo-op, as shown below.

```
→| DEFIN →|MACNME,ARG1,ARG2,ARG3   /comment
→| .ETC  →|ARG4,ARG5   /argument continuation
          :
→| .DEFIN→| MACNME
→| .ETC  →| ARG1
→| .ETC  →| ARG2
→| .ETC  →| ARG3
→| .ETC  →| ARG4
→| .ETC  →| ARG5
```

4.2 MACRO BODY

The body of the macro definition follows the .DEFIN statement. Appearances of dummy arguments are marked and the character string of the body is stored, five characters per two words in the macro definition table, until the macro terminating pseudo-op .ENDM is encountered. Comments within the macro definition are not stored.

Dummy arguments may appear in the definition lines only as symbols or elements of an expression. They may appear in the label field, operation field, or address field. Dummy arguments may appear within a literal or they may be defined as variables. They will not be recognized if they appear within a comment.

The following restrictions apply to the usage of the .DEFIN, .ETC and .ENDM pseudo-ops:

a. If they appear in other than the operation field within the body of a macro definition, they will cause erroneous results.

b. If .ENDM or .ETC appears outside the range of a macro definition, it will be flagged as undefined.

If index register usage is desirable, it should be specified in the body of the definition, not in the argument string.

```
.DEFIN      XUSE,A,B,C
LAC  A
DAC  B,X
LAC  C
.ENDM
```

If .ASCII or .SIXBT is used in the body of a macro, a slash (/) or number sign (#) must not appear as part of the text string or as a delimiter (use < 57 > to represent a slash and < 43 > to represent a number sign). Be careful when using a dummy argument name as part of the text string. For example,

```
.DEFIN   TEXT A
.SIXBT   ,A,
.SIXBT   .A.
.ENDM
```

followed by the macro call,

```
TEXT  XYZ
```

will generate the following code

```
.SIXBT   ,XYZ,
.SIXBT   .A.
```

In the first .SIXBT statement, A is recognized as a dummy argument resulting in the substitution of XYZ. In the second statement, A is not recognized as a dummy argument because the string delimiter, period, is itself a legal symbol constituent.

```
                    Definition                    Comments
→| .DEFIN  →|  MAC,A,B,C,D,E,F
→| LAC     →|  A#
→| SPA
→| JMP     →|  B
→| ISZ     →|  TMP →| /E          E is not recognized as an argument
→| LAC     →|  (C
→| DAC     →|  D + 1
→| F
→| .ASCII  →|  E
B=.
→| .ENDM
```

4.3 MACRO CALLS

A macro call consists of the macro name, which must be in the operation field, followed by a list of real arguments separated by commas and terminated by one of the characters listed below.

a. space (␣)

b. tab (→|)

c. carriage return (↵)

If the real arguments cannot fit on one line of coding, they may be continued on succeeding lines by terminating the current line with a dollar sign ($). When they are continued on succeeding lines they must start in the tag field.

Example:

```
        →| MAC →| REAL1,REAL2,REAL3,$
REAL4,REAL5
```

If there are n dummy arguments in the macro definition, all real arguments in the macro call beyond the nth dummy argument will be ignored. A macro call may have a label associated with it; this label will be assigned to the current value of the location counter.

Example:

```
(Definition)    →| .DEFIN →| UPDATE,LOC,AMOUNT
                →| LAC    →| LOC
                →| TAD    →| AMOUNT
                →| DAC    →| LOC
                →| .ENDM

(Call)          TAG→| UPDATE →| CNTR,(5      /TAG ENTERED INTO SYMBOL TABLE
                                               /WITH CURRENT VALUE OF LOCATION COUNTER
(Expansion)     TAG→| LAC    →| CNTR
                    →| TAD    →| (5
                    →| DAC    →| CNTR
```

The prevailing radix will be saved prior to expansion and restored after expansion takes place. Default assumption will be octal for the macro call. It is not necessary for the macro definition to have any dummy arguments associated with it.

Example:

```
                →| .DEFIN␣TWOS
                →| CMA
                →| TAD␣(1
                →| .ENDM
(Call)          →| TWOS
(Expansion)     →| CMA
                →| TAD␣(1
```

4.3.1 Argument Delimiters

It was stated that the list of arguments is terminated by any of the following symbols.

a. space (␣)
b. tab (→|)
c. carriage return (↵)

These characters may be used within real arguments only by enclosing them in angle brackets (<>). Angle brackets are not recognized if they appear within a comment.

Example:

```
(Definition)   →| .DEFIN␣MAC,A,B,C
               →| LAC␣A
               →| TAD␣B
               →| DAC␣C
               →| .ENDM
(Call)         →| MAC␣TAG1,<TAG2   /comment
               →| TAD␣(1)>,TAG3
(Expansion)    →| LAC␣TAG1
               →| TAD␣TAG2
               →| TAD␣(1)
               →| DAC␣TAG3
```

All characters within a matching pair of angle brackets are considered to be one argument, and the entire argument, with the delimiters (<>) removed, will be substituted for the dummy argument in the original definition.

MACRO-15 recognizes the end of an argument only on seeing a terminating character not enclosed within angle brackets.

If brackets appear within brackets, only the outermost pair is deleted. If angle brackets are required within a real argument, they must be enclosed by argument delimiter angle brackets.

Example:

```
(Definition)   →| .DEFIN →| ERRMSG,TEXT
               →| JMS →| PRINT
               →| .ASCII →| TEXT
               →| .ENDM
```

```
(Call)       →| ERRMSG →| </ERROR IN LINE/ <15>>
(Expansion)  →| JMS    →| PRINT
             →| .ASCII →| /ERROR IN LINE/<15>
```

4.3.2 Created Symbols

Often, it is desirable to attach a symbolic tag to a line of code within a macro definition. As this tag is defined each time the macro is called, a different symbol must be supplied at each call to avoid multiply defined tags.

This symbol can be explicitly supplied by the user or the user can implicitly request MACRO-15 to replace the dummy argument with a created symbol which will be unique for each call of the macro. For example,

```
→| .DEFIN →| MAC,A,?B
```

The question mark (?) prefixed to the dummy argument B indicates that it will be supplied from a created symbol if not explicitly supplied by the user when the macro is called for.

The created symbols are of the form ..0000→..9999. Like other symbols, they are entered into the symbol table as they are defined.

Unsupplied real arguments corresponding to dummy arguments not preceded by a question mark are substituted in as empty strings; and supplied real arguments corresponding to dummy arguments preceded by a question mark suppress the generation of a corresponding created symbol.

Example:

```
(Definition)  →| .DEFIN →| MAC,A,B,?C,?D,?E
              →| LAC    →| A
              →| SZA
              →| JMP    →| D
              →| LAC    →| B
              →| DAC    →| C#
              →| DAC    →| E
              D=.
              →| .ENDM
(Call)        →| MAC    →| Y#,,,,MYTAG
(Expansion)   →| LAC    →| Y#
              →| SZA
```

```
→| JMP →| ..0000
→| LAC →|
→| DAC →| ..0001
→| DAC →| MYTAG
..0000=.
```

If one of the elements in a real argument string is not supplied, that element must be replaced by a comma, as in the call above. A real argument string may be terminated in several ways as shown below:

Example:

```
→| MAC →| A,B,␣
→| MAC →| A,B,,↵
→| MAC →| A,B␣
→| MAC →| A,B↵
→| MAC →| A,B,↵
```

4.3.3 Concatenation

If a dummy argument in a definition line of the macro body is delimited by the concatenation operator '@' and immediately preceded or followed by other characters or another dummy argument, the characters that correspond to the value of the dummy argument (real argument) are combined (juxtaposed) in the generated statement with the other characters or the real argument that corresponds to the other dummy argument. This process is called concatenation.

The following example illustrates this operation.

```
(Definition)    →|.DEFIN    →| MAC, TYPE, ADDR
(Body)          →|JM@TYPE   →| ADDR
                →|.ENDM
(Call)          →|CALL      →| MAC, P,ROUT1
(Expansion)     →|JMP       →| ROUT1
(Call)          →|CALL      →| MAC, S,<SUBR1
                →|.DSA      →| ARGMNT>
(Expansion)     →|JMS       →| SUBR1
                →|.DSA      →| ARGMNT
```

The dummy argument TYPE is used to vary the mnemonic operation code of the generated statement. The character P, which is the corresponding value of TYPE in the first call to the macro, will be concatenated with the characters JM to form the mnemonic JMP. This action occurs because a dummy argument (i.e., TYPE) is delimited by the concatenation operator (i.e., is preceded by @) and is immediately preceded or followed by other characters or another dummy argument (i.e., preceded by other characters JM).

Of course, in the case where other characters are to be concatenated with the value of a dummy argument, and the first of the other characters is a MACRO-15 delimiter, it is not necessary to delimit the dummy with the concatenation operator. The following example illustrates this rule.

```
(Definition)    →| .DEFIN    →| MOVE,FROM,TO,LVL
(Body)          →| .IFUND    →| SV.@LVL
                →| SKP
    SV.@LVL     →| .BLOCK    →| 1
                →| .ENDC
                →| DAC       →| SV.@LVL
                →| LAC       →| FROM @ LVL,X
                →| DAC       →| TO @ LVL,X
                →| LAC       →| SV.@LVL
                →| .ENDM
(Call)          →| MOVE      →| UST,RUST,Ø
(Expansion)     →| .IFUND    →| SV.Ø
                →| SKP
    SV.Ø        →| .BLOCK    →| 1
                →| .ENDC
                →| DAC       →| SV.Ø
                →| LAC       →| USTØ,X
                →| DAC       →| RUSTØ,X
                →| LAC       →| SV.Ø
```

In this example concatenation is used to test the existence of a named temporary location, and output code to define it if necessary. Then the concatenation operator - MACRO-15 delimiter rule is presented by concatenating two dummy arguments and other characters beginning with a MACRO-15 delimiter. In detail, one such concatenation string is a MACRO-15 delimiter (i.e., →|), a dummy argument (i.e., FROM), the concatenation operator (i.e., @), a second dummy argument (i.e., LVL), finally followed by other characters beginning with a MACRO-15 delimiter (i.e., ,X).

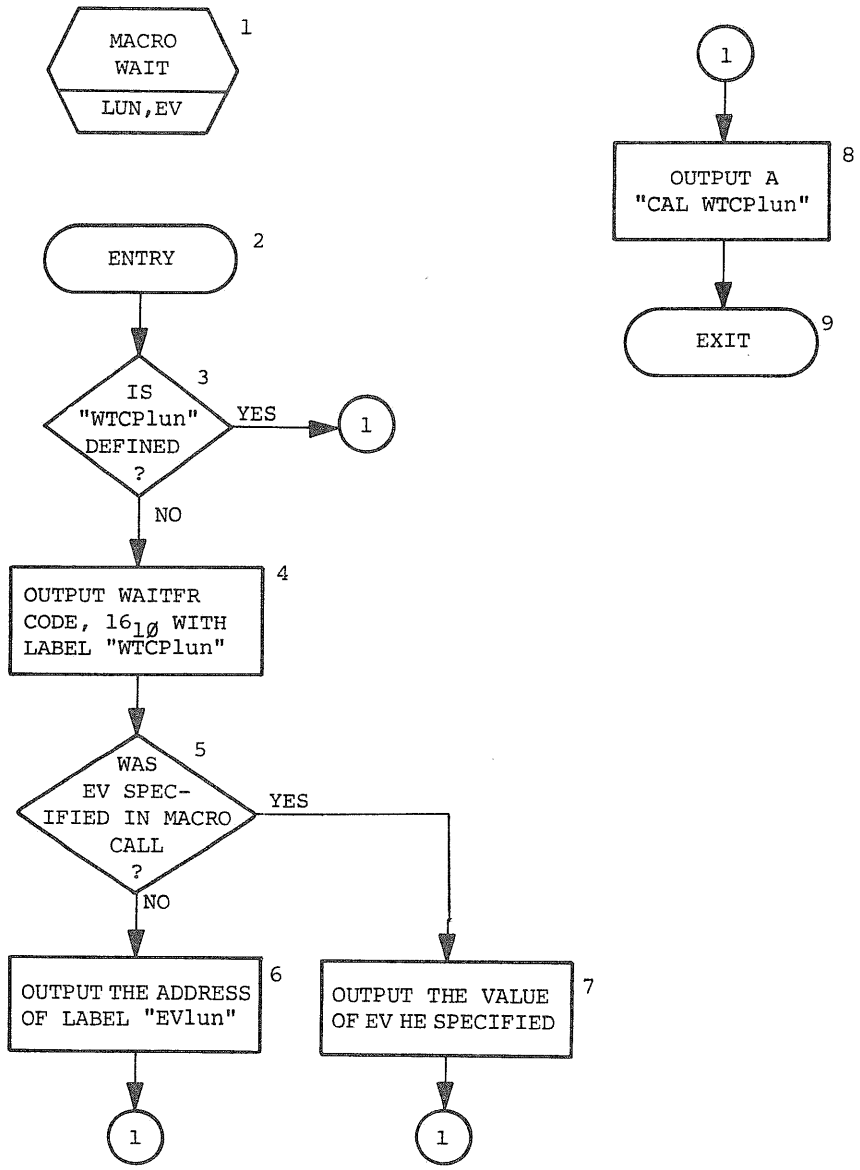
The reader may realize that the general case of real argument for dummy argument substitution performed by MACRO-15 is the application of the "other characters beginning with a MACRO-15 delimiter" rule presented above. In other words, argument substitution may be thought of as concatenation when the dummy argument is bounded by MACRO-15 delimiters, rather than a concatenation operator.

Note that one ambiguous case can arise in use of the concatenation operator when the other character string to be concatenated with an argument value is the same as a dummy argument name. The following example illustrates this problem.

```
(Definition)    →|.DEFIN    →|WAIT,LUN,EV,?TMP
(Body)          →|.DEC
                →|.IFUND    →|WTCP@LUN
                →|JMP       →| .+3
    WTCP@LUN    →|16
    TMP=EV+Ø
```

```
.IFZER      TMP
EV@LUN
.ENDC
.IFPNZ      TMP
EV
.ENDC
.ENDC
CAL         WTCP@LUN
.ENDM
```

This macro was written with the intention of satisfying the following flow diagram.



For instance, if the following call to the WAIT macro were coded (with WTCP1Ø undefined):

```
(Call)          →| WAIT      →| 1Ø
(Expansion)     →| .DEC                    (1)
                →| .IFUND    →| WTCP1Ø     (2)
                →| JMP       →| .+3        (3)
   WTCP1Ø       →| 16                      (4)
   TMP=+Ø                                  (5)
                →| .IFZER     →| TMP        (6)
                →| 1Ø                      (7)
                →| .ENDC                   (8)
                →| .IFPNZ     →| TMP        (9)
                →| .ENDC                   (10)
                →| .ENDC                   (11)
                →| CAL       →| WTCP1Ø     (12)
```

Note that according to box 6 of the preceding flow chart, under these conditions it was desired to output:

→|EV1Ø

for line 7 of the above expansion rather than what was actually generated. This discrepancy occurs because the characters EV on the appropriate line of the body of the definition are not recognized as "other characters". EV is also a dummy argument which is bounded by a MACRO-15 delimiter (i.e.,→| on the left) and the concatenation operator (i.e., @ on the right). This will cause the concatenation of the value of dummy argument EV (i.e., null) and the value of the dummy argument LUN (i.e., 1Ø), thus producing the output shown on line 7 of the expansion.

Following is a comprehensive example of the use of the concatenation operation in defining user macros: the definition of two macros, ERRMSG and MESSAGE. The purpose of ERRMSG is to cause a subroutine to be called (named ER.PRO) which will print an error message.

It has as arguments the error number (from Ø to 77_8) and an optional return address. The label of the error message to be output is created by concatenating 'ERM.' with the error number. (ERM.Ø, ERM.1, etc.) If no return address is specified, control is transferred to a label named ER.NOR by default. The second macro, MESSAGE, is used to create an IOPS ASCII line buffer with the error message to be printed, presumably via the ERRMSG macro. It also has two arguments: the error number, and the message text. The output of the macro is a properly set up header word pair labeled 'ERM.xx' where 'xx' is the specified error number, and a .ASCII statement which contains the text specified, preceded by 'ERR#xx--', where 'xx' once again is the error number. The reader should examine the example noting the use of conditional assembly parameters to accomplish macro-time error detection.

```
        .TITLE  CONCATENATION EXAMPLE FOR MACRO MANUAL
/
/MACRO 'ERRMSG' DEFINITION .  ERROR MESSAGE OUPUT MACRO.
/
/       CALLING SEQUENCE:
/
/       ERRMSG  ERRNO[,RETURN]
/
/       WHERE:
/       ERRNO = AN OCTAL NUMBER FROM 0 TO 77 REPRESENTING
/               THE ERROR CODE.
/       RETURN = (OPTIONAL) THE LOCATION TO WHICH CONTROL
/               SHOULD BE RETURNED FOLLOWING OUTPUT OF
/               THE ERROR MESSAGE.  IF NOT SPECIFIED,
/               CONTROL WILL BE GIVEN TO LOCATION 'ER.NOR'.
/
/       OUTPUT:
/
/       OUTPUT OF ERRMSG CONSISTS OF A JMS TO THE ERROR PROCESSOR
/       'ER.PRO', FOLLOWED BY A .DSA   ERM.XX WHERE XX = ERRNO.
/       ERM.XX IS ASSUMED TO BE A STANDARD IOPS ASCII LINE BUFFER
/       WHICH CONTAINS THE DESIRED MESSAGE.  IT MAY BE DEFINED USING
/       THE 'MESSAGE' MACRO (SEE BELOW).
/
/       ERROR DETECTION:
/
/       THE ERROR NUMBER ('ERRNO') IS CHECKED TO BE BETWEEN
/       0 AND 77.  OTHERWISE AN ASSEMBLER ERROR LINE IS
/       OUTPUT RATHER THAN THE CALL TO 'ER.PRO'.  THE ILLEGAL
/       ASSEMBER LINE WILL CAUSE AN 'N' ERROR (AMONG OTHERS) TO BE
/       GENERATED BY THE ASSEMBER, THUS INDICATING A 'NUMBER'
/       ERROR.
/
        .DEFIN  ERRMSG,ERRNO,RTN
        .IFNEG  ERRNO-100       /VALIDATE ERROR CODE NUMBER
        .IFPOZ  ERRNO           /TO BE 0 <= ERRNO <= 77
ZZRTNC=RTN+0                    /SETUP RETURN ADDR. IF SPECIFIED
        .IFZER  ZZRTNC
ZZRTNC=ER.NOR           /IF NO RETURN, SET TO STD. ADDR.
        .ENDC
        JMS     ER.PRO          /CALL THE ERROR PROCESSOR
        .DSA    ERM.@ERRNO      /POINT TO RIGHT MESSAGE
        JMP     ZZRTNC          /EITHER RETURN TO STD. EXIT, OR WHERE I SAID
        .ENDC
        .ENDC
        .IFNEG  ERRNO           /PUT OUT ERROR IF NECESSARY
        9       **ERROR CODE IS < 0 OR > 77**
        .ENDC
        .IFPOZ  ERRNO-100
        9       **ERROR CODE IS < 0 OR > 77**
        .ENDC
        .ENDM

/MACRO 'MESSAGE' DEFINITION.  BUILD AN ERROR MESSAGE LINE BUFFER.
/
/       CALLING SEQUENCE:
/
/       MESSAGE ERRNO,<TEXT>
/
/       WHERE:
/       ERRNO = THE ERROR NUMBER, FROM 0 TO 77 (OCTAL)
/       <TEXT> = THE MESSAGE TEXT (ENCLOSED IN ANGLE
/               BRACKETS, AS SHOWN) TO BE ASSOCIATED WITH THIS
/               'ERRNO'.
```

```
/       OUTPUT:
/
/       A STANDARD IOPS ASCII LINE BUFFER IS CREATED WITH THE NAME
/       'ERM.XX' WHERE XX = 'ERRNO' (SEE ABOVE).   THE ACTUAL MESSAGE
/       WILL HAVE THE FORMAT 'ERR#XX-- TEXT '.  WHERE XX AND TEXT ARE AS
/       ABOVE.  OF COURSE, THE LINE BUFFER HEADER PAIR WILL BE PROVIDED.
/
/       ERROR DETECTION:
/
/       'ERRNO' WILL BE CHECKED TO BE BETWEEN  0 AND 77.
/       IF THE CHECK SHOWS AN ERROR, AN ASSEMBLER ERROR
/       LINE WILL BE GENERATED RATHER THE THE MESSAGE CODE.  THE ERROR
/       LINE WILL CAUSE AT LEAST AN 'N' FLAG, INDICATING A 'NUMBER'
/       ERROR.
/
        .DEFIN  MESSAGE,ERRNO,TEXT,?A
        .IFNEG  ERRNO-100
        .IFPOZ  ERRNO
ERM.@ERRNO      A=ERM.@ERRNO/2*1000+2
        0
        .ASCII  'ERR#@ERRNO--TEXT'<15>
A=.
        .ENDC
        .ENDC
        .IFNEG  ERRNO
        9       **ERROR CODE IS < 0 OR > 77**
        .ENDC
        .IFPOZ  ERRNO-100
        9       **ERROR CODE IS < 0 OR > 77**
        .ENDC
        .ENDM
        .EJECT

            ERRMSG  4       /OUTPUT ERROR MESSAGE #4, TAKE STANDARD EXIT
*G          .IFNEG  4-100
*G          .IFPOZ  4
*G ZZRTNC=+0
*G          .IFZER  ZZRTNC
*G ZZRTNC=ER.NOR
*G          .ENDC
*G          JMS     ER.PRO
*G          .DSA    ERM.4
*G          JMP     ZZRTNC
*G          .ENDC
*G          .ENDC
*G          .IFNEG  4
*G          9       **ERROR CODE IS < 0 OR > 77**
*G          .ENDC
*G          .IFPOZ  4-100
*G          9       **ERROR CODE IS < 0 OR > 77**
*G          .ENDC
            ERRMSG  45,RECOV        /GIVE ERROR #45, AND RETURN TO LOC 'RECOV' WHEN DONE
*G          .IFNEG  45-100
*G          .IFPOZ  45
*G ZZRTNC=RECOV+0
*G          .IFZER  ZZRTNC
*G ZZRTNC=ER.NOR
*G          .ENDC
*G          JMS     ER.PRO
*G          .DSA    ERM.45
*G          JMP     ZZRTNC
*G          .ENDC
*G          .ENDC
```

```
*G
*G
*G
*G  ..0006=.
*G            .ENDC
*G            .ENDC
*G            .IFNEG  4
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ  4-100
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              MESSAGE 45,<AMBIGUOUS USE OF A COMPILER KEYWORD>
*G            .IFNEG  45-100
*G            .IFPOZ  45
*G  ERM.45    ..0009-ERM.45/2*1000+2
*G            0
*G            .ASCII  'ERR#45--AMBIGUOUS USE OF A COMPILER KEYWORD'<15>
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G            .IFNEG  45
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ  45-100
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              ERRMSG  -34,RECOV       /SHOW THAT A NEGATIVE ERROR NO. IT ILLEGAL
*G            .IFNEG  -34-100
*G            .IFPOZ  -34
*G  ZZRTNC=RECOV+0
*G            .IFZER  ZZRTNC
*G  ZZRTNC=ER.NOR
*G            .ENDC
*G            JMS     ER.PRO
*G            .DSA    ERM.-34
*G            JMP     ZZRTNC
*G            .ENDC
*G            .ENDC
*G            .IFNEG  -34
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ  -34-100
*G            9       **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              ERRMSG  456     /SHOW THAT AN ERROR NO. > 77(8) IS ILLEGAL
*G            .IFNEG  456-100
*G            .IFPOZ  456
*G  ZZRTNC=+0
*G            .IFZER  ZZRTNC
*G  ZZRTNC=ER.NOR
```

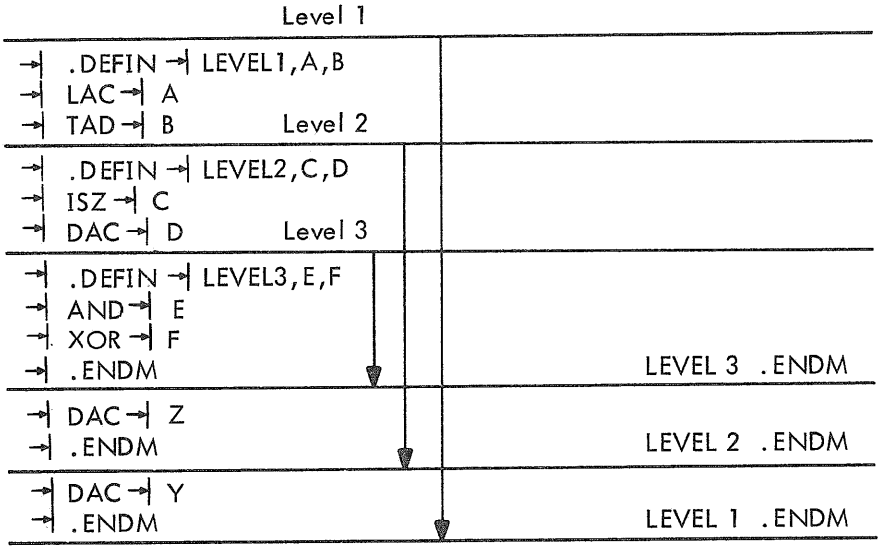
```
*G            .ENDC
*G            JMS       ER.PRO
*G            .DSA      ERM.456
*G            JMP       ZZRTNC
*G            .ENDC
*G            .ENDC
*G            .IFNEG    456
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ    456-100
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              .EJECT

              MESSAGE 4,<ILLEGAL OR UNRECOGNIZABLE SYNTAX IN STMNT>
*G            .IFNEG    4-100
*G            .IFPOZ    4
*G ERM.4      ..0006=ERM.4/2*10^0+2
*G            0
*G            .ASCII    'ERR#4--ILLEGAL OR UNRECOGNIZABLE SYNTAX IN STMNT'<15>
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G
*G ..0000=.
*G            .ENDC
*G            .ENDC
*G            .IFNEG    45
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ    45-100
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              MESSAGE -1,<THIS SHOULD GIVE A MACRO-DETECTED ERROR>
*G            .IFNEG    -1-100
*G            .IFPOZ    -1
*G ERM.-1     ..0012=ERM.-1/2*1000+2
*G            0
*G            .ASCII    'ERR#-1--THIS SHOULD GIVE A MACRO-DETECTED ERROR'<15>
*G ..0012=.
*G            .ENDC
*G            .ENDC
*G            .IFNEG    -1
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
*G            .IFPOZ    -1-100
*G            9         **ERROR CODE IS < 0 OR > 77**
*G            .ENDC
              .EJECT
```

4.4 NESTING OF MACROS

Macros may be nested; that is, macros may be defined within other macros. For ease of discussion, levels may be assigned to these nested macros. The outermost macros (those defined directly) will be called first-level macros. Macros defined within first-level macros will be called second-level macros; macros defined within second-level macros will be called third-level macros, etc. Each nested macro requires an .ENDM pseudo op to denote its termination.

Example:



At the beginning of processing, first-level macros are defined and may be called in the normal manner. Second and higher level macros are not yet defined. When a first-level macro is called, all its second-level macros are defined. Thereafter, the level of definition is irrelevant and macros may be called in the normal manner. If the second-level macros contain third-level macros, the third-level macros are not defined until the second-level macros containing them have been called.

Using the example above, the following would occur:

Call	Expansion	Comments
LEVEL1 TAG1, TAG2	LAC TAG1 TAD TAG2 DAC Y	Causes LEVEL 2 to be defined
LEVEL2 TAG3, TAG4	ISZ TAG3 DAC TAG4 DAC Z	Causes LEVEL 3 to be defined
LEVEL3 TAG5, TAG6	AND TAG5 XOR TAG6	

If LEVEL3 is called before LEVEL2 it would be an error, and the line would be flagged as undefined.

When a macro of level n contains another macro of the level n + 1, calling the level n macro results in the generation of the body of the macro into the user's program in the normal manner until the .DEFIN statement of the level n + 1 macro is encountered; the level n + 1 macro is then defined and does not appear in the user's program. When the definition of the level n + 1 is completed (.ENDM encountered), the Assembler continues to generate the level n body into the user's program until, or unless, the entire level n macro has been generated.

4.5 REDEFINITION OF MACROS

If a macro name, which has been previously defined, appears within another definition, the macro is redefined and the original definition is eliminated. For example,

```
        →| .DEFIN →| INDXSV
        →| JMS   →| SAVE
        →| JMP   →| SAVXT
SAVE →| 0
        →| LAC   →| 10
        →| DAC   →| TMP#
        →| LAC   →| 11
        →| DAC   →| TMP1#
        →| JMP*  →| SAVE
        SAVXT=.
        →| .DEFIN→|INDXSV
        →| JMS   →|SAVE
        →| .ENDM
        →| .ENDM
```

When the macro INDXSV is called for the first time, the subroutine calling sequence is generated and followed immediately by the subroutine itself. After the subroutine is generated, a .DEFIN that contains the name INDXSV is encountered. This new macro is defined and takes the place of the original macro INDXSV. All subsequent calls to INDXSV cause only the calling sequence to be generated. The original definition of INDXSV will not be removed until after the expansion is complete.

Call	Expansion
→| INDXSV	→| JMS →| SAVE
	→| JMP →| SAVXT

```
                    SAVE→| 0
                         →| LAC →| 10
                         →| DAC →| TMP#
                         →| LAC →| 11
                         →| DAC →| TMP1#
                         →| JMP* →| SAVE
                    SAVXT=.

→| INDXSV              →| JMS →| SAVE
```

4.6 MACRO CALLS WITHIN MACRO DEFINITIONS

The body of a macro definition may contain calls for other macros which have not yet been defined. However, the embedded calls must be defined before a call is issued to the macro which contains the embedded call. Embedded calls are allowed only to three levels.

Example:

```
→| .DEFIN →| MAC1,A,B,C,D,E
→| LAC    →| A
→| TAD    →| B
→| MAC2   →| C,D              /EMBEDDED CALL
→| DAC    →| E
→| .ENDM
→| .DEFIN →| MAC2,A,B         /DEFINITION OF EMBEDDED CALL
→| XOR    →| A
→| AND    →| B
→| .ENDM
```

The call

```
→| MAC1  →| TAG1,TAG2, (400, (777, TAG3
```

causes generation of

```
→| LAC    →| TAG1
→| TAD    →| TAG2
→| MAC2   →| (400, (777
→| XOR    →| (400
→| AND    →| (777
→| DAC    →| TAG3
```

4.7 RECURSIVE CALLS

Although it is legal for a macro definition to contain an embedded call to itself, it must be avoided because the expansion will cause more than three levels to occur.

Example:

```
→| .DEFIN →| MAC,A,B,C
→| LAC    →| A
→| TAD    →| B
→| DAC    →| C
→| MAC    →| A,B,C              /RECURSIVE CALL
→| .ENDM
```

When a call for MAC is encountered by the Assembler, it searches memory for the definition and expands it. Since there is another call for MAC contained within the definition, the Assembler goes back once again to obtain the definition; this process would never cease if more than three levels were allowed. A conditional assembly statement could be used, however, to limit the number of levels as in the following example.

Example:

```
A = 0
B = 3
      →| .DEFIN →| MAC,C,D
      →| LAC    →| C
      →| DAC    →| D
A= A + 1
      →| .IFNZR →| B-A
      →| MAC    →| SAVE, TEMP        /RECURSIVE CALL
      →| .ENDC
      →| .ENDM
```

Names and arguments of nested macros and arguments of imbedded calls may be substituted and used with perfect generality.

Example:

```
→| .DEFIN →| MAC1,A,B,C,D
→| LAC    →| A
→| ADD    →| B
→| DAC    →| C
→| .DEFIN →| D,E
→| AND    →| A
→| DAC    →| E
→| .ENDM
→| .ENDM
      :
→| .DEFIN →| MAC2,M,N,O,P,Q,?R
→| ISZ    →| M
→| JMP    →| R
→| MAC1   →| N,O,P,Q
R=.
→| .ENDM
```

The call

```
→| MAC2   →| COUNT,TAG1,TAG2,TAG3,MAC3
```

causes the generation of

```
→| ISZ    →| COUNT
→| JMP    →| ..0000
→| LAC    →| TAG1
→| ADD    →| TAG2
→| DAC    →| TAG3
..0000=.
```

It also causes the definition of MAC3

CHAPTER 5

OPERATING PROCEDURES

5.1 INTRODUCTION

Detailed descriptions of the assembler calling procedure, command string format, general operating procedures, and printouts are given in this chapter. (Refer to Appendix G for MACROI operating procedures and Appendix H for MACROA.)

5.2 CALLING PROCEDURE

5.2.1 ADSS-15 and DOS-15

In the ADSS-15 and DOS-15 systems, the MACRO-15 Assembler is called by typing MACRO↵ after the Monitor's $ request. When the Assembler has been loaded, it identifies itself by typing:

```
MACRO-15 VNN or BMACRO-15 VNN
>                >
```

on the teleprinter. The > character indicates that the Assembler is waiting for the user to type in a command string.

There are two differences between MACRO-15 (the Page Mode Assembler) and BMACRO-15 (the Bank Mode Assembler). MACRO-15 starts each assembly assuming page mode relocation (.DBREL implied) and BMACRO-15 assumes bank mode relocation (.EBREL implied). When program sizes exceed 4Ø96, MACRO-15 outputs the warning message "PROG>4K" in the assembly listing but BMACRO-15 does not. This message will appear even if the program is assembled under influence of .EBREL. This warning message has no other effect; the program will be assembled and output will be produced anyway.

5.2.2 Background/Foreground (B/F)

In B/F systems MACRO-15 is called in the same manner as for ADSS-15. It identifies itself by typing:

```
BF MACRO-15 VNN
```

for both the page and bank mode systems.

5.2.3 RSX PLUS and RSX PLUS III

In the RSX systems, MACRO-15 is invoked by typing in the Assembler's name and also the command string on the same line following the prompting message "TDV>". For example:

```
TDV>MAC BLXR←FILE↵
MACRO RSX V1A
```

The Assembler identifies itself, as just shown, only if the R option is designated in the command. The RSX version of the Assembler is equivalent to BMACRO-15 in that it assumes .EBREL to begin with and does not print "PROG>4K".

5.3 GENERAL COMMAND CHARACTERS

The following characters are frequently used in the entry and control of MACRO programs.

Character Printout

RUBOUT (Echoes\)
delete single character

CTRL U (Echoes @)
delete current line

CTRL P (Echoes↑P)
a. If the input source is physically segmented so that all but the last segment end with .EOT or nothing, the Assembler will print out the message

EOT

when the end of a segment is reached. In RSX PLUS, the Assembler does not type any such message.
b. If the source is segmented in such a way that operator intervention is required to load another segment, Macro will print

↑P

(MAC-↑P in RSX PLUS) and wait for the user to key in CTRL P (CTRL P ↵ in RSX PLUS). Except in RSX PLUS, the user response will be printed also and the line will appear as

↑P↑P

In RSX PLUS if one does not wish to load another tape, one may terminate assembly by typing CTRL Q↵.
c. At the start of PASS 2 or PASS 3 if input is on paper tape or if the source is segmented on DECtape or Magtape with segments being read via the same .DAT slot, the Assembler will request a CTRL P response as above.
d. If the Assembler is not waiting for more input, or is not waiting to start the next pass, typing CTRL P causes the Assembler to restart at PASS 1. This is true for all systems except RSX PLUS.

CTRL D (Echoes ↑D)
If the user specifies the Teleprinter as the input parameter device, he can delimit the parameter code by typing CTRL D (↑D) (followed by ↵ with the RSX Monitor). MACRO responds with EOT. MACRO immediately begins assembling the program from the device assigned to .DAT-11 (LUN 15 with RSX).

5.4 COMMAND STRING

The command string format consists of a string of options, followed by a left arrow, followed by the program name(s), followed by a terminator.

options ← filnm1,filnm2,...

The following sections describe the rules for forming proper command strings and show typical assembly examples. The character terminating the command line has significance. Terminating the line with a carriage return will cause the Assembler to re-initialize itself to PASS 1 at completion of the assembly; the Assembler is thus ready to accept another command string. Terminating the command with an ALT MODE will cause a return to the monitor at the end of assembly. In the RSX PLUS and RSX PLUS III systems these line terminators have a different meaning. Termination with carriage return causes TDV to be called; termination with ALT MODE does not. In either RSX case the Assembler exits after executing the command line. If a command string error occurs, the entire command must be retyped.

5.4.1 Program File Name

To the right of the back arrow in the command string, one or more program file names may be required, depending upon the options used and the type of I/O devices. Where several names are needed, they are separated by commas.

Program names are required for files which are to be input from or output to directoried devices. The two proper forms for a file name are

filnam␣ext

or

filnam

where

filnam = 1 to 6 character name

ext = 1 to 3 character extension

These may be formed from any of the legal printing characters shown in Appendix A and may appear in any order.

If the file name extension is omitted, the Assembler assumes SRC in default. Following are examples of single name command strings.

Examples:

User Command String	Assembler Interpretation Name	Extension
← ␣ABCDEF␣1ØØ↵	ABCDEF	1ØØ
← AB␣Ø11↵	AB	Ø11
←A↵	A	SRC
←ABCDEFG↵	ABCDEF	G
←ABCDEFG␣H↵	ABCDEF	H
←ABC␣␣VIA↵	ABC	SRC

The last three examples illustrate how the Assembler interprets improperly formed file names. If the file name is longer than six characters but is not followed by a space, the seventh, eigth and nineth characters are used as the extension. If it is followed by a space, characters beyond the sixth and before the space are ignored. If two spaces follow the file name, the extension is assumed to be SRC. In general, if too many characters are given the excess characters are ignored.

In DOS-15, RSX PLUS and RSX PLUS III systems the extension name of the main program is output (unless the O option is present) as a special code in the relocatable binary file. This enables programmers to easily identify different versions of the same program by merely assigning unique extension names. Since this special code is not legal in ADSS-15 and Background/Foreground, one may suppress it, when assembling in DOS or RSX, by specifying the O option.

Regardless of the source file extension, such as TEST ØØ1, the binary file extension will be either BIN, meaning relocatable binary, or ABS, meaning absolute binary.

5.4.2 Options

Assembler options direct the course of the assembly. They describe the types of input and output desired. Option characters are listed to the left of the back arrow. They may be listed in any order and are typically not separated one from the other (although commas and spaces, which are ignored, may be used as separators). Option characters which appear more than once and invalid characters are ignored.

Examples:

Command	Meaning
B←FILE↵	Assemble FILE SRC and produce a binary object file.
BLS←NAME↵	Assemble NAME SRC and produce a binary object file and an assembly listing followed by a symbol table listing.

Examples (Cont.):

Command	Meaning
←PROG␣ØIX↵	Assemble PROG ØIX producing no output except a list of assembly errors, if any, on the listing device assigned to .DAT -12 (LUN 16 in RSX).

The following table shows the action and the default of the options.

Option	Action	Default Action
A	Print symbols at end of PASS 2 in alphanumeric sequence on listing device.	Symbols are not printed in alphanumeric sequence.
B	Generate a binary file to DAT-13 with extension BIN or ABS, as required. (LUN 17 in RSX).	A binary file is not generated.
C	Program areas that fall between unsatisfied conditionals are not printed. It is not necessary to type the L option if this option is used.	All source lines are printed.
D	Suppress binary output and output the assembly listing onto DECtape Unit 2 with a file extension of LST (used only by MACROI).	A binary, if desired, may be output to DECtape 2. The listing is output to the teleprinter.
E	This option enables the user to have any errors occurring during assembly printed on the console printer in addition to the device assigned to .DAT -12 (LUN 16 in RSX). The L or N switch should be used with the E option. This option is particularly useful to users who assign non-printing devices to .DAT-12. Not available with ADSS-15 or B/F.	Assembly errors are not printed on the console printer.
F	Read macro definition file from .DAT -14 (LUN 18 in RSX) during PASS 1. Terminate input with .EOT or CTRL D if Teletype (CTRL D↵ if RSX). Not available with MACROA-15.	No macro definition file is processed.
G	Print only the source line of a macro expansion. It is not necessary to type the L option.	Generate printouts for macro expansions and expandable pseudo-ops (e.g., .REPT).
H	The H-option is used in conjunction with the A, V, or S options. User symbols are normally printed horizontally at the end of PASS 2, four symbols to a line. If the H-option is used the symbols will be printed one to a line.	Print symbols four to a line.
I	Ignore .EJECT's. The .EJECT pseudo-op is treated as a comment. Not available with MACROI-15 nor MACROA-15.	Skip to head of form when .EJECT is encountered.

Option	Action	Default Action
L	Generate a listing file on the requested output device, DAT-12. (LUN 16 in RSX). If the output device is directoried, then the listing file extension will be LST.	A listing file is not generated (see options N, C).
N	Number each source line (decimal). If this option is used, it is not necessary to type the L option.	Source lines are not numbered.
O	Causes the assembler to omit the source extension and the linking loader code 33 from the binary file. This option must be used when assembling programs in the DOS or RSX PLUS systems to be run in ADSS or B/F.	Loader code 33 is included in the binary output.
P	Before assembly begins, read program parameters from DAT-10 (LUN 20 in RSX). Terminate input with .EOT or CTRL D (if Teletype). The parameter file is read only once; for this reason, only direct assignments may be used.	No parameters, begin assembly immediately after command string termination.
R	Identify the Assembler version number, print END PASS 1 and END PASS 2, and print the error count on the teleprinter (RSX PLUS and RSX PLUS III only).	These items are not printed in order to speed up batch processing.
S	Same as selecting both A and V.	Symbols are not printed. (If neither option V, S nor A is requested, symbols are not printed.)
T	The T option causes a "Table of Contents" table to be generated during PASS 1. The table will contain the page number and text of all assembled .TITLE statements in the program. Not available with ADSS-15 or B/F.	A table of contents is not generated at the head of the assembly listing.
U	The assembled binary is output to DECtape Unit 1 (Used only by MACRO1).	The assembled binary may be output to DECtape Unit 2 if the B option is selected.
V	Print symbols at end of PASS 2 in value sequence on listing device.	Symbols are not printed in value sequence.
X	At completion of PASS 2, PASS3 is loaded to perform the cross-referencing operation. At completion of PASS 3 the Assembler will call in PASS 1 and 2, to continue assembling programs. If the command string was terminated by an ALT MODE, control will return to the Monitor at the end of assembly. If the L and X options are entered, the user should also enter the N option with the ADSS or B/F Systems. Without the N option the user would obtain a cross reference which would be effectively useless since the source lines of the listing are not numbered. In the DOS	A cross-reference is not provided and PASS 3 is not called in.

Option	Action	Default Action
	and RSX PLUS systems the N option is automatically entered if you enter L and X. Not available in MACROI-15.	
Z	The Z option is related to the macro definition file option F. Z has no effect if F is not also specified. FZ are used in combination when the main program is segmented into two parts. The first part, containing instructions other than simply macro definitions, must be read both during PASS 1 and PASS 2. This is the function of the Z option. (Not available with MACROI-15 or MACROA-15).	The F option, if specified, causes the Macro definition file to be read only during PASS 1.

5.4.3 Multiple Filename Commands

In the general case a command may require up to three file names, depending upon the options specified, to produce a single binary output file. As will be illustrated later on, the Assembler in RSX PLUS and RSX PLUS III systems allows multiple assemblies to be specified in a single command, which may require more than three file names. For the other software systems, the limit is three. Names may be needed to specify parameter files, macro definition files and program files. The use of these names and the manner in which they are interpreted by the MACRO Assembler are described in the following paragraphs.

NOTE

In the following descriptions any file which is processed by both PASS 1 and PASS 2 of the Assembler is also processed during PASS 3 if the cross-reference option (X) is specified.

NAME 1: PARAMETER FILE

If the P option is used and the device assigned to .DAT slot -10 (LUN 20 in RSX) has a directory, the first name is interpreted as being the parameter file name. The name of the file must be explicitly stated if it is on a directoried device. If the device assigned to the parameter file is non-directoried, the first name typed would follow the rules for name 2. The parameter file is passed over only once during PASS 1.

If the P option is not used, only two names are accepted by the command string processor. The first name then would follow the rules for name 2.

NAME 2: MACRO DEFINITION FILE

If the F option is used, the second name (or the first if the P option is not used) is interpreted as being the macro definition file or part one of a two part program (assuming the device assigned to .DAT-14

(LUN 18 in RSX) has a directory). If the device is non-directoried, the second file name (or first if the P-option is not used or doesn't require one) would follow the rules for name 3. The macro definition is normally passed over only once, during PASS 1. However, unlike the main program file, macro definitions on .DAT slot -14 are recorded in core during PASS 1. Hence, PASS 2 is unnecessary. If the Z option is used with the F option this file will be passed over twice, allowing source files in two parts on two different devices. The Z-switch has no effect if F is not specified.

If the F option is not used, the first name (second if P option is used) is interpreted as the file name of the program to be assembled.

The macro definition file may also be used as an additional parameter file. A second parameter file is useful where a program is conditionally assembled to produce different versions according to many assembly parameters.

NOTE

The RSX MACRO does not contain definitions of system directives and I/O calls. MACRO definitions for RSX are in a file called RMC.V SRC, where V changes with each release.

NAME 3: PROGRAM FILE NAME

The name of the program to be assembled. This file is processed from .DAT slot -11 (LUN 15 in RSX) and always by both PASS 1 and PASS 2. If the P and F options are not used and multiple names are typed, only the first name will be processed. If a binary output file is requested, it will be directed to .DAT slot -13 (LUN 17 in RSX). If either of the two devices has a directory, a file name must be specified. The binary file will assume the name of the program file and an extension of either BIN or ABS.

MULTIPLE NAME INTERPRETATION

Before processing, MACRO uses the .FSTAT function (SEEK in RSX) to determine whether or not the named files are on the input devices. If not, the message 'NAME ERROR' is typed. In all but the RSX and BOSS-15 systems the Assembler then expects the command string to be retyped. In RSX, the Assembler exits and calls TDV so that the command string can be given to TDV. In BOSS-15 the Assembler exits to the monitor. Assuming that enough names have been typed to satisfy the command string options, MACRO interprets the file names as follows:

a. Current name = NAME 1.
b. Was the P option used? If not, go to step f.
c. Is the device assigned to .DAT slot - 10 (LUN 20 in RSX) directoried? If not, go to step F.

d. Use the current name (NAME 1) to .SEEK the parameter file via .DAT slot -10 (LUN 20 in RSX).

e. Current name = NAME 2.

f. Was the F option used? If not, go to step j.

g. Is the device assigned to .DAT slot -14 (LUN 18 in RSX) directoried? If not, go to step j.

h. Use the current name (NAME 1 or NAME 2) to .SEEK the MACRO definition file via .DAT slot -14 (LUN 18 in RSX).

i. Current name = NAME 3 (or NAME 2 if P option not used).

j. Use the current name (NAME 1 or NAME 2 or NAME 3) to .SEEK the program file via .DAT slot -11 (LUN 15 in RSX).

RULES FOR MULTIPLE NAMES IN THE COMMAND STRING

1. Initial blanks positioned after the back arrow are ignored.
2. Files are processed sequentially. The first name after the left arrow is the first file read, the second file is next and so on.
3. Once a string of legal name characters is started, a space has the following effect on a name.
   A. The first space delimits the proper name and indicates to the command string processor that the extension name is next. The proper name is defined as the first six characters of a file name, excluding the extension.
   B. Two consecutive blanks delimit the name. An extension of 'SRC' is implied if no extension was typed.
4. A comma or line terminator delimits the name. (Same as 3B above.)
5. Any name given after the third name is ignored, except in RSX PLUS and RSX PLUS III. The RSX assembler allows multiple assemblies to be specified in a single command. Where the options require one, two or three file names, the command may contain multiples of one, two or three. Each such group of one, two or three names represents a single assembly.

RESTRICTIONS CAUSED BY MULTIPLE FILE INPUT (not relevant to RSX PLUS or RSX PLUS III)

The .FSTAT system macro is used by the MACRO Assembler to determine whether or not the input device has a directory and whether or not the argument names are on the assigned devices. For this reason, only those I/O handlers which honor or which ignore the .FSTAT function may be used with MACRO. The "A" handlers for directoried devices (e.g., DTA, DKA) honor .FSTAT. The paper tape punch and reader handlers ignore .FSTAT, but the effect is as if they accept it. Device handlers which treat .FSTAT as illegal may not be used.

5.4.4 Examples of Commands for Segmented Programs

Below are typical assembly situations which illustrate the usage of some of the assembly options and show the resulting teleprinter output. The output for RSX PLUS differs slightly from what is shown. That is explained in section 5.3.

1. Segmented Program on Paper Tape

A source main program is segmented onto three paper tapes to make loading in the reader easier. Tapes one and two terminate with an .EOT statement and tape three terminates with .END. All three segments are read from the primary input, .DAT-11 (LUN 15 in RSX). The command to Macro to produce a binary program is:

```
>B←ANYNAM↵
```

Note that tape 1 must be ready in the reader before the command string is entered. Were it not, the reader would return an end of tape condition anyway and erroneous results would be obtained. The resulting teleprinter output is shown below. The comments to the right are not part of the output; these are included here as explanatory remarks. User responses are underlined.

```
>B←ANYNAM↵
 EOT                                  /End of tape 1.
↑P↑P                                  /Ready tape 2. Type CTRL P.
 EOT                                  /End of tape 2.
↑P↑P                                  /Ready tape 3. Type CTRL P.
 END OF PASS 1
↑P↑P                                  /Ready tape 1. Type CTRL P.
 EOT                                  /End of tape 1.
↑P↑P                                  /Ready tape 2. Type CTRL P.
 EOT                                  /End of tape 2.
↑P↑P                                  /Ready tape 3. Type CTRL P.
SIZE=ØI2Ø3        NO ERROR LINES
```

2. Segmented Program on DECtape

A source main program cannot fit onto a single DECtape. It is split in two on two different DECtapes and given the same file name: MAIN SRC. The tape one file ends with .EOT; the tape two file ends with .END. The file names must be identical if both segments are to be read via the primary input, .DAT -11 (LUN 15 in RSX). Example 3 illustrates an alternate method. However, example 2 must be used if one also is to include a Macro definition file, as in example 4. The following command to Macro produces a binary program and the subsequent teleprinter output:

```
>B←MAIN↵
 EOT                                  /End of file 1. Mount second
↑P↑P                                  /DECtape on same unit. Type CTRL P.
 END OF PASS 1                        /End of file 2. Mount first
↑P↑P                                  /DECtape on same unit. Type CTRL P.
 EOT                                  /End of file 1. Mount second
↑P↑P                                  /DECtape on same unit. Type CTRL P.
SIZE=ØØ7Ø3        NO ERROR LINES
```

3. Segmented Program on Disk

This example is a variation of number 2. A two part main program resides on disk. It doesn't matter whether the two files are on the same or separate disk units. Part one terminates with .EOT; part 2, with .END. PART1 SRC will be read via the secondary input, .DAT -14 (LUN 18 in RSX); and PART2 SRC will be read via the primary input, .DAT -11 (LUN 15 in RSX). The resultant binary file, produced by the following command to MACRO, will assume the name of the second (primary) file: PART2 BIN or PART2 ABS, as the case may be:

```
>BEZ←PART1,PART2↵
 EOT                                  /End of PART1 SRC.
 END OF PASS 1                        /End of PART2 SRC.
 EOT                                  /End of PART1 SRC.
SIZE=Ø2ØØ3        NO ERROR LINES
```

Several points can be made about the differences between examples 2 and 3. First, note that CTRL P type in is not required unless input is from a device like paper tape. Next, note that example 2 is impractical on disk because it requires physically interchanging disks. Example 3 is not restricted to usage with disk, but can be used with other media as well.

4. Use of a Macro Definition File

MACDEF SRC, which terminates with .EOT, contains only Macro definitions. It is read from the secondary input, .DAT -14 (LUN 18 in RSX). The user has a main program, USEMAC 002, which terminates with .END and which calls some of these macros but does not itself define them. This is just an example. It is perfectly legal for the main program to redefine macros which also appear in the macro definition file. USEMAC ØØ2 is read from the primary input, .DAT -11 (LUN 15 in RSX). Below is the appropriate command string to produce a binary program. Note that the F option without the Z option (see example 3) instructs the Assembler to read the first file (the Macro definition file) only during PASS 1.

```
>BF←MACDEF,USEMAC ØØ2↵
 EOT                                  /End of MACDEF SRC.
 END OF PASS 1                        /End of USEMAC ØØ2.
SIZE=Ø11Ø4       NO ERROR LINES
```

Note that EOT is not printed during PASS 2 because MACDEF SRC is read only during PASS 1. The preceding example assumes that the files are on directoried devices.

5. Parameter File on Paper Tape

A main program, MAIN SRC, which terminates with .END is conditionalized to produce different binary code based on the values or existence of certain assembly parameters. It is read via the primary input, .DAT -11 (LUN 15 in RSX), which, for this example, is assigned to DECtape. A paper tape containing parameter definitions (direct assignments) terminates with .EOT and is read via the auxiliary input, .DAT -1Ø (LUN 2Ø in RSX). The following command to Macro produces a binary program:

```
>BP←MAIN↵
 EOT                                  /End of parameter tape.
 END OF PASS 1                        /End of MAIN SRC.
SIZE=ØØ6Ø2       NO ERROR LINES
```

Note, although input is partly from paper tape, a CTRL P response is unnecessary because the parameter tape is read only during PASS 1.

6. Multiple File Assemblies in RSX

Using the Assembler in RSX PLUS or RSX PLUS III, several assemblies, using the same set of options for each, may be specified in a single command. Unless the R option is used, no printout on the teleprinter will occur to signal the various stages of assembly. Below are listed two typical commands in RSX.

```
>MAC BL←P1,P2␣ØØ3, P3,P4↵
```

This requests four assemblies. A separate binary and listing are produced for P1 SRC, P2 ØØ3, P3 SRC and P4 SRC.

```
>MAC PB←PAR1,FIL1,PAR2,FIL2↵
```

This requests two assemblies. A separate binary is produced for FIL1 SRC and FIL2 SRC. The parameter file PAR1 SRC is applied to the assembly of FIL1 SRC and PAR2 SRC to that of FIL2 SRC.

5.5 ASSEMBLY LISTINGS

If the user requests a listing via the command string, the Assembler will produce an output listing on the requested output device. The top of the first page of the listing will contain the name of the program as given in the command string. The body of the listing will be formatted as follows:

Line Number	Error Flags	Location	Address Mode	Object Code	Address Type	Line Type	Source	Statement
XXXX	XXX	XXXXX	[R]	XXXXXX	[R] [A] [E]	*G *L *R *E	X	X

where:

Line Number = Each source line and comment line is numbered (decimal); generated lines are not included. Lines are not numbered unless the X or N option is specified.

Flags = Errors encountered by the assembler

Location = Relative or absolute location assigned to the object code.

Address Mode = Indicates the type of user address.

A = absolute
R = relocatable

Line Type = *G = Generated *L=Literal *R=Repeated *E=External

Object Code = The contents of the location (in octal)

Address Type = Indicates the classification of the object code.

A = absolute
R = relocatable
E = external

The object codes assigned for literals and external symbols are listed following the program.

5.6 SYMBOL TABLE OUTPUT

At the end of PASS 2, the symbol table may be output to the listing .DAT -12 (LUN 16 in RSX) device. If the A option is used, the table will be printed in alphanumeric sequence; if the V option is used, the symbol table will be printed in numeric value sequence; if the S option is used, the symbol table will be output in both alphanumeric and numeric sequence. The format is as follows:

Symbol	Value	Type
SYMBL1	XXXXX	E
SYMBL2	XXXXX	R
DIRECT	XXXXXX	A

The Xs represent the octal value assigned to the symbol. This is the location where the symbol is defined, except for external symbols. For these, the value is the location of the transfer vector, whose contents are set at program load time with the actual value of the symbol. Note that for SYMBL1 and SYMBL2 there are five Xs but that there are six Xs for the symbol DIRECT. Symbols having six octal numbers to represent their values are the result of direct assignments.

The symbol table shows the type of symbol:

A = absolute
R = relocatable
E = external

Locations assigned to variables immediately follow the last object code producing statement in the assembled program. Locations assigned for literals not under .LTORG influence and transfer vectors are listed immediately following the variables; if no variables are used in the program, literals and transfer vectors immediately follow the program output.

```
PAGE    1     SAMPLE.SRC      SAMPLE PROGRAM

                                        .TITLE SAMPLE PROGRAM
                                /
                                / SAMPLE SUBROUTINE, NOT CLAIMED TO WORK OR TO HAVE ANY PRACTICAL
                                / VALUE, USED TO ILLUSTRATE THE OUTPUT ON AN ASSEMBLY LISTING.
                                / THESE LINES ARE COMMENTS.
                                /
                                / THIS LISTING WAS OBTAINED USING BMACRO-15 IN DOS-15 WITH THE
                                / FOLLOWING COMMAND OPTIONS TO MACRO:  LSX
                                /
                  000005 A      OUT=5                           /.DAT SLOT 5.
                                        .IODEV  OUT
                                        .GLOBL  PRINT,SAVE,RESTOR
                                /
                                        .IFUND  WIDTH           /CONDITIONAL ASSEMBLY.
                                        .DEC
                                WIDTH=72                        /DECIMAL NUMBER.
                                        .OCT
                                        .ENDC
                  000040 A      BUFSIZ=WIDTH*4/5*2+2            /DIRECT ASSIGNMENT.
                                /
          00000 R 000000 A      PRINT   0                       /SUBROUTINE ENTRY POINT.
          00001 R 040116 R              DAC     ACSAV#          /VARIABLE.
          00002 R 200123 R              LAC     (SAVBUF)        /LITERAL.
          00003 R 120122 E              JMS*    SAVE            /EXTERNAL CALL.
          00004 R 220116 R              LAC*    ACSAV           /BUFFER ADDRESS.
          00005 R 741200 A              SNA
    U     00006 R 600117 R              JMP     NOBUFF          /UNDEFINED SYMBOL (MISSPELLED).
    F     00007 R 040003 A              DAC     WRITE+3         /UNDEFINED SYMBOL BECAUSE OF
          00010 R 723777 A              AAC     -1              /2 FORWARD REFERENCES.
          00011 R 060124 R              DAC*    (10)            /AUTOINDEX REGISTER.
          00012 R 777740 A              LAW     -BUFSIZ
          00013 R 040115 R              DAC     COUNT
          00014 R 735000 A              CLX
          00015 R 220010 A      LOOP    LAC*    10
          00016 R 050055 R              DAC     BUF,X           /INDEX REGISTER REFERENCE.
          00017 R 440115 R              ISZ     COUNT
          00020 R 600015 R              JMP     LOOP
          00021 R 600024 R              JMP     CHANGE
          00022 R 200125 R      NOBUF   LAC     (ERRMSG)
    U     00023 R 040123 R              DAC     WRIT+3          /UNDEFINED (MISSPELLED).
          00024 R 740000 A      CHANGE  NOP
                                        .INIT   OUT,1,0         /SYSTEM MACRO CALL.
          00025 R 001005 A *G           CAL+1*1000 OUT&777
          00026 R 000001 A *G           1
          00027 R 000000 A *G           0+0
          00030 R 000000 A *G           0
          00031 R 200126 R              LAC     (JMP AROUND)
          00032 R 040024 R              DAC     CHANGE
                                /
                                        .EJECT                  /PAGE EJECT.
```

```
PAGE  2     SAMPLE SRC      SAMPLE PROGRAM

 47                  000033 R     WRITE=AROUND                        /FORWARD REFERENCE.
 48          000033 R             AROUND   .WRITE  OUT,2,XX,0         /SYSTEM MACRO CALL.
             000033 R 002005 A *G          CAL+2*1000 OUT&777
             000034 R 000011 A *G          11
             000035 R 740040 A *G          XX
                      *G                   .DEC
             000036 R 000000 A *G          -0
 49                                        /
 50                                        .WAIT   OUT                 /SYSTEM MACRO CALL.
             000037 R 000005 A *G          CAL OUT&777
             000040 R 000012 A *G          12
 51          000041 R 000123 R             LAC     (SAVBUF)
 52          000042 R 120121 E             JMS*    RESTOR              /EXTERNAL CALL.
 53          000043 R 000116 R             LAC     ACSAV
 54          000044 R 620000 R             JMP*    PRINT
 55                                    /
 56                                    / THE NEXT LINE CONTAINS THREE STATEMENTS.
 57                                    /
 58          000045 R 003002 A     ERRMSG  003002; 0; .ASCII /ERROR/<15>
             000046 R 000000 A
             000047 R 424452 A
             000050 R 247644 A
             000051 R 064000 A
             000052 R 000000 A
 59          000052 R                      .LOC    .+1                 /CHANGE LOCATION COUNTER.
 60          000052 R         A    SAVBUF  .BLOCK  3                   /MQ, XR AND LR.
 61          000055 R         A    BUF     .BLOCK  BUFSIZ
 62          000115 R 000000 A     COUNT   0
 63                                    /
 64                                    / FOLLOWING THE .END STATEMENT ARE THREE LOCATIONS (NOT SHOWN)
 65                                    / FOR ONE VARIABLE (ACSAV) AND TWO UNDEFINED SYMBOLS (NOBUFF
 66                                    / AND WRITE, THE LATTER BECAUSE OF A DOUBLE FORWARD REFERENCE).
 67                                    / FOLLOWING THAT (SHOWN) ARE TWO EXTERNAL TRANSFER VECTORS
 68                                    / AND FOUR LITERALS.
 69                                    /
 70                  000000 A                .END
             000121 R 000121 E *E
             000122 R 000122 E *E
             000123 R 000052 R *L
             000124 R 000010 A *L
             000125 R 000045 R *L
             000126 R 000033 R *L
          SIZE=000130          3 ERROR LINES
```

```
ACSAV   000115 R     BUF     000055 R     BUFSIZ  000040 A
CHANGE  000124 R     ERRMSG  000045 R     LOOP    000015 R
NOBUF   000022 R     OUT     000005 A     PRINT   000000 R
RESTOR  000121 R     SAVBUF  000052 R     WIDTH   000011 A
WRIT    000120 R     WRITE   000033 R

PRINT   000000 R     .       000035 A     LOOP    000015 R
CHANGE  000124 R     ACSAV   000033 R     WRITE   000033 R
ERRMSG  000045 R     SAVBUF  000052 R     BUF     000055 R
COUNT   000115 R     ACSAV   000116 R     NOBUFF  000117 R
RESTOR  000121 R     SAVE    000122 R     NOBUF   000022 R
                                          BUFSIZ  000040 A
                                          WIDTH   000011 A
                                          WRIT    000120 R
```

SAMPLE CROSS REFERENCE

```
ACSAV   000115   22      25      58
ACSAV   000033   33      47      48*
BUF     000055   26      41*
BUFSIZ  000040   10*     51      61
CHANGE  000124   30      41*     44
COUNT   000115   22      40      62*
ERRMSG  000045   35      52*
LOOP    000015   24*     27
NOBUF   000022   25*
NOBUFF  000117   27
OUT     000005   10*     11      42      48      50
PRINT   000000   12      21*     54
RESTOR  000121   10      52
SAVBUF  000052   23      51      60*
SAVE    000122   12      24
WIDTH   000011   14      16*     19
WRIT    000120   45
WRITE   000033   28      47*
```

5.7 RUNNING INSTRUCTIONS

Once the Assembler has identified itself, it is ready to perform an assembly. Proceed as follows:

a. Place the source program to be assembled on the appropriate input device.

b. Type the command string.

5.7.1 Paper Tape Input Only

The following steps are required when the source program is encountered in the paper tape reader:

a. At the end of a source tape segment which is not terminated with a .END statement or at the beginning of PASS 2 or PASS 3, the Assembler types

↑P

b. Place the proper source tape in the reader and, if the computer is a PDP-9, push the tape-feed button to clear the EOT flag.

c. In all systems except RSX PLUS or RSX PLUS III type CTRL P to continue. For the latter, type CTRL P).

5.7.2 Cross-Reference Output

At the end of PASS 2, PASS 3 will be performed by the Assembler for the cross-referencing operation if the X option is requested. At completion, the assembler will be restarted (except in RSX systems) to permit additional assemblies if the command string is terminated by a CARRIAGE RETURN (↵) entry.

When a cross reference output is requested, the symbols are listed in alphabetic sequence. The first address after the symbol is the location where the symbol is defined or its 6-digit value if it is a direct assignment. All subsequent locations represent the line number (decimal) where the symbol was referenced. The line number with the asterisk is that in which the symbol is defined. Leading zeros are suppressed for the cross-reference symbol table. Nine line numbers are printed on one line and subsequent line numbers are continued on the next line.

Example:

```
PAGE      1      PRGA      CROSS REFERENCE
A         1        XXXXX   XXXXX*..  ....XXXXX
                   XXXXX   XXXXX
B         5000     XXXXX*
SYMBOL    100      XXXXX*
```

Cross referencing can be a useful tool even without the aid of a line printer. It is possible to put the source assembly listing with line numbers onto a directoried device, such as, DECtape, and the cross reference table (by a separate assembly) on a teleprinter. Then, desired lines in the "LST" file can be accessed by using the EDITOR.

LIMITATIONS

A. Before cross reference output can begin, PASS3 of the Assembler must first have read the entire source file(s) and stored the reference line numbers in core memory. Should available core be too limited, the Assembler will output the following message to the listing:

CORE EXHAUSTED AT LINE DDDD

where D is a decimal digit. Then the Assembler outputs all the references found up to that point.

B. For programs with more than 9999 lines of source code, line numbers begin again at ØØØØ on line 1ØØØØ. In the cross-reference listing, 1ØØØØ is represented as :ØØØ, 11ØØØ as ;ØØØ, and so on. These special characters are simply those which follow the numerals in the ASCII character set (Appendix A). Below is a list of characters and their meanings.

:	1Ø
;	11
<	12
=	13
>	14
?	15

C. To conserve core space, PASS3 of the Assembler does not maintain a permanent symbol table. Consequently, if user defined symbols are identical to permanent symbols, references to the permanent symbols will be included in the cross reference. For example:

```
        LAC  A
        TAD  LAC
        .
        .
        .
LAC     5
```

Three references to LAC will be listed.

D. Conditionals (.IFxxx through .ENDC) are treated during PASS3 as if they are always satisfied. Consequently, although a conditional might not be satisfied during PASS1 and PASS2, references within to defined user symbols will appear in the cross-reference output.

Note that undefined symbols which are referenced in .IFDEF and .IFUND statements remain undefined; hence, these do not appear in the cross reference.

5.8 PROGRAM RELOCATION

The normal output from the MACRO-15 Assembler is a relocatable object program, which may be loaded into any part of memory regardless of which locations are assigned at assembly time. To accomplish this, the address portion of some instructions must have a relocation constant added to it. This relocation constant is added at load time by the Linking Loader, CHAIN or TKB; it is equal to the difference between the memory location that an instruction is actually loaded into and the location that was assigned to it at assembly time. The Assembler determines which storage words are relocatable (marking them with an R in the listing), which are absolute (making these non-relocatable words with an A) and which are external (marking these with an E). The rules that the Assembler follows to determine whether a storage word is absolute or relocatable are as follows.

a. If the address is a number (not a symbol), the address is absolute.

b. If the address is a symbol which is defined by a direct assignment statement (i.e., =) and the right-hand side of the assignment is a number, all references to the symbol will be absolute.

c. If a user symbol is defined within a block of coding that is absolute, the value of that symbol is absolute.

d. Variables, undefined symbols, external transfer vectors, and literals get the same relocation as was in effect when .END was encountered in PASS 1.

e. If the location counter (.LOC pseudo-op) references a symbol which is not defined in terms of a relocatable address, the symbol is absolute.

f. All others are relocatable.

The following table depicts the manner in which the Assembler handles expressions which contain both absolute and relocatable elements.

(A=absolute, R=relocatable)

A+A=A	A-R=R	R+R=R and flagged as possible error
A-A=A	R+A=R	R-R=A
A+R=R	R-A=R	

If multiplication or division is performed on a relocatable symbol, it will be flagged as a possible relocation error.

If a relocatable program exceeds 4K, and the assembler is a page mode version, the following warning message will be typed at the end of PASS 2:

PROG > 4K

5.9 SYSTEM ERROR CONDITIONS AND RECOVERY PROCEDURES

5.9.1 ADSS-15, DOS-15 and BOSS-15

Printout	Recovery Procedure
IOPS 4	Device is not ready. Ready the device and, if it is an I/O BUS device, not a UNIBUS device, type CTRL R (↑ R)
IOPS Ø-3 IOPS 5-77	Unrecoverable I/O error. Except in BOSS-15, type CTRL P to restart MACRO or type CTRL C to return to the Monitor.

5.9.2 BACKGROUND/FOREGROUND

Printout	Recovery Procedure
"DEVICE" NOT READY	Ready "DEVICE" and then type CTRL R (↑ R)
.ERR Ø-777	Most of these errors are unrecoverable. Those which are recoverable do not require operator intervention. For terminal errors type CTRL P to restart MACRO or type CTRL C to return to the Monitor.

5.9.3 RSX PLUS and RSX PLUS III

Printout	Recovery Procedure
MAC-I/O ERROR LUN xx yyyyyy	is produced on LUN 13: xx represents the Logical Unit Number (decimal) and yyyyyy the octal Event Variable value indicating the cause of the error. Control is automatically returned to TDV.

5.9.4 Restart Control Entries (not relevant to RSX)

CTRL P	Restart Assembler, if running
CTRL C	Return to Monitor

5.10 ERROR DETECTION BY THE ASSEMBLER

MACRO-15 examines each source statement for possible errors. The statement which contains the error will be flagged by one or several letters in the left-hand margin of the line, or, if the lines are numbered, between the line number and the location. The following table shows the error flags and their meanings.

Flag	Meaning
A	Error in direct symbol table assignment - assignment ignored
B	1. Memory bank error (program segment too large) 2. Page error - the location of an instruction and the address it references are on different memory pages (error in page mode only)
D	Statement contains a reference to a multiply-defined symbol - the first value is used
E	1. Symbol not found in user's symbol table during PASS 2 2. Operator combined with its operand may produce erroneous results
F	Forward reference - symbol value is not resolved by PASS 2
I	Line ignored: 1. Relocatable pseudo-op in .ABS program 2. Redundant pseudo-op 3. .ABS pseudo-op in relocatable program 4. .ABS pseudo-op appears after a line has been assembled 5. A second .LOCAL pseudo-op appears before a matching .NDLOC pseudo-op 6. An .NDLOC appears without an associated .LOCAL pseudo-op 7. Too many .LTORG pseudo-ops (more than 8) 8. .IODEV pseudo-op in .ABS or .FULL program
L	Literal error: 1. Phase error - literal encountered in PASS 2 does not equal any literal found in PASS 1 2. Nested literal (a literal within a literal)
M	Multiple symbol definition - first value defined is used
N	Error in number usage (digit 8 or 9 used under .OCT influence)
P	Phase error: 1. PASS 1 symbol value not equal to PASS 2 symbol value (PASS 2 value ignored) 2. A tag defined in a local area (.LOCAL pseudo-op) is also defined in a non-local area
Q	Questionable line: 1. Line contains two or more sequential operators (e.g., LAC A+*B) 2. Bad line delimiter - address field not terminated with a semicolon, carriage return or a comment 3. Bad argument in .REPT pseudo-op 4. Unrecognizable symbol with .ABS(P) pseudo-op
R	Possible relocation error
S	Symbol error - illegal character used in tag field
U	Undefined symbol
W	Line overflow during macro expansion
X	Illegal use of macro name or index register

In addition to flagged lines, there are certain conditions which will cause assembly to be terminated prematurely.

Message	Meaning
SYNTAX ERR	Bad command string, control returns to TDV (RSX only)
?	Bad command string, retype (not RSX)
NAME ERROR	File named in command string not found. In all systems except BOSS-15 and RSX, the Assembler will restart and accept another command string. RSX MACRO will return to TDV. BOSS-15 will return to the Monitor.
TABLE OVERFLOW	Too many symbols and/or macros
CALL OVERFLOW	Too many embedded macro calls
CORE EXHAUSTED AT LINE nnnn	PASS 3 error - too many symbol references

APPENDIX A

CHARACTER SET

Printing Character	7-bit ASCII	6-bit Trimmed ASCII	Printing Character	7-bit ASCII	6-bit Trimmed ASCII
@	100	00	Form Feed	014	
A	101	01	Carriage Return	015	
B	102	02	ALT MODE (ESC)	175	
C	103	03	Rubout	177	
D	104	04	(Space)	040	40
E	105	05	!	041	41
F	106	06	"	042	42
G	107	07	#	043	43
H	110	10	$	044	44
I	111	11	%	045	45
J	112	12	&	046	46
K	113	13	'	047	47
L	114	14	(	050	50
M	115	15	)	051	51
N	116	16	*	052	52
O	117	17	+	053	53
P	120	20	,	054	54
Q	121	21	-	055	55
R	122	22	.	056	56
S	123	23	/	057	57
T	124	24	0	060	60
U	125	25	1	061	61
V	126	26	2	062	62
W	127	27	3	063	63
X	130	30	4	064	64
Y	131	31	5	065	65
Z	132	32	6	066	66
[*	133	33	7	067	67
\	134	34	8	070	70
]*	135	35	9	071	71
↑*	136	36	:*	072	72
←*	137	37	;	073	73
Null	000		<	074	74
Horizontal Tab	011		=	075	75
Line Feed	012		>	076	76
Vertical Tab	013		?	077	77

*Illegal as source, except in a comment or text. Any characters not in this table are illegal to MACRO-15 and are flagged and ignored.

APPENDIX B

PERMANENT SYMBOL TABLE

Operate	
OPR	740000
NOP	740000
CMA	740001
CML	740002
OAS	740004
RAL	740010
RAR	740020
IAC	740030
HLT	740040
XX	740040
SMA	740100
SZA	740200
SNL	740400
SML	740400
SKP	741000
SPA	741100
SNA	741200
SZL	741400
SPL	741400
RTL	742010
RTR	742020
SWHA	742030
CLL	744000
STL	744002
CCL	744002
RCL	744010
RCR	744020

CLA	750000
TCA	740031
CLC	750001
LAS	750004
LAT	750004
GLK	750010
LAW	760000

EAE	
EAE	640000
LRS	640500
LRSS	660500
LLS	640600
LLSS	660600
ALS	640700
ALSS	660700
NORM	640444
NORMS	660444
MUL	653122
MULS	657122
DIV	640323
DIVS	644323
IDIV	653323
IDIVS	657323
FRDIV	650323
FRDIVS	654323
LACQ	641002
LACS	641001
CLQ	650000
ABS	644000

GSM	664000
OSC	640001
OMQ	640002
CMQ	640004
LMQ	652000

IOT	
IOT	700000
IORS	700314
DBK	703304
DBR	703344
IOF	700002
ION	700042
CAF	703302
RES	707742

Memory Reference	
CAL	000000
DAC	040000
JMS	100000
DZM	140000
LAC	200000
XOR	240000
ADD	300000
TAD	340000
XCT	400000
ISZ	440000
AND	500000
SAD	540000
JMP	600000

Automatic Priority* Interrupt	
RPL	705512
SPI	705501
ISA	705504

Index Instructions Which Take an Immediate Nine-bit Operand	
AAC	723000
AXR	737000
AXS	725000

Index and Limit Register Instructions Which do not use Operands	
CLLR	736000
PAL	722000
PAX	721000
PLA	730000
PLX	731000
PXA	724000
PXL	726000
CLX	735000

Mode Switching	
EBA	707764
DBA	707762

Index Register Value	
X	10000

*Not part of the permanent symbol table in B/F MACROA.

APPENDIX C

MACRO-15 CHARACTER INTERPRETATION

Character Name	Character Symbol	Function
Space	␣	Field delimiter. Designated by ␣ in this manual.
Horizontal tab	→|	Field delimiter. Designated by →| in this manual.
Semicolon	;	Statement terminator
Carriage return	↵	Statement terminator
Plus	+	Addition operator (two's complement)
Minus	-	Subtraction operator (addition of two's complement)
Asterisk	*	Multiplication operator or indirect addressing indicator
Slash	/	Division operator or comment initiator
Ampersand	&	Logical AND operator
Exclamation point	!	Inclusive OR operator
Back slash	\	Exclusive OR operator
Opening parenthesis	(	Initiate literal
Closing parenthesis	)	Terminate literal
Equals	=	Direct Assignment
Opening angle bracket	<	Argument delimiter
Closing angle bracket	>	Argument delimiter
Comma	,	An argument delimiter in macro definitions or an exclusive OR operator.
Question mark	?	Created symbol designator in macros
Quotation mark	"	Text string indicator
Apostrophe	'	Text string indicator
Number Sign	#	Variable indicator
Dollar sign	$	Real argument continuation
Line feed	non-printing	not applicable
Form feed	non-printing	
Vertical tab	non-printing	
Commercial At	@	Concatenation operator in macro definitions

Character Name	Character Symbol	Function
Null	Blank Character	Ignored by the Assembler
Delete	Blank Character	Ignored by the Assembler

Illegal Characters

Only those characters listed in the preceding table are legal in MACRO-15 source programs, all other characters will be ignored and flagged as errors. The following characters, although illegal as source, may be used within comment lines and in text preceded by .ASCII or .SIXBT pseudo-ops.

Character Name	Symbol
Left bracket	[
Right bracket	]
Up arrow	↑
Left arrow	←
Colon	:

APPENDIX D

SUMMARY OF MACRO-15 PSEUDO-OPS

Pseudo-op	Section	Format	Function
.ABS .ABSP	3.2.1 3.2.1	→|.ABS→|NLD↵ →|.ABSP→|NLD↵	Object program is output in absolute, blocked, checksummed format for loading by the Absolute Binary Loader. Not supported in RSX PLUS, RSX PLUS III or B/F MACROA.
.ASCII	3.8.1	label*→|.ASCII␣/text/< octal >↵	Input text strings in 7-bit ASCII code, with the first character serving as delimiter. Octal codes for nonprinting control characters are enclosed in angle brackets.
.BLOCK	3.5	label*→|.BLOCK→|exp↵	Reserves a block of storage words equal to the expression. If a label is used, it references the first word in the block.
.CBD	3.18	label*→|.CBD␣NAME␣CODE↵	Sets up a COMMON area having the name and size specified. The first element in the COMMON area is also given (base address). (DOS and RSX Systems only.)
.CBDR	3.19	label*→|.CBDR␣arg↵	Enters the starting address of the last common block specified in a .CBD plus the argument into the location of the .CBDR (RSX PLUS Systems only).
.DBREL	3.2.3	→|.DBREL↵	Disable bank mode relocation.
.DEC	3.4	→|.DEC↵	Sets prevailing radix to decimal.
.DEFIN	3.16	→|.DEFIN␣macro name, args↵	Defines macros. Not supported in B/F MACROA.
.DSA	3.11	label*→|.DSA␣exp↵	Generates a transfer vector for the specified symbol.
.EBREL	3.2.3	→|.EBREL↵	Enable bank mode relocation.
.EJECT	3.14	→|.EJECT↵	Skip to head of form on listing device.
.END	3.6	→|.END␣START↵	Must terminate every source program. START is the address of the first instruction to be executed.
.ENDC	3.13	→|.ENDC↵	Terminates conditional coding in .IF statements.
.ENDM	3.16	→|.ENDM↵	Terminates the body of a macro definition. Not supported in B/F MACROA.
.EOT	3.7	→|.EOT↵	Must terminate physical program segments, except the last, which is terminated by .END.

* All pseudo-ops shown with a label generate binary output code.

Pseudo-op	Section	Format	Function
.ETC	3.16	→|.ETC␣args,args↵	Used in macro definition to continue the list of dummy arguments on succeeding lines. Not supported in B/F MACROA.
.FULL	3.2.2	→|.FULL↵	Produces absolute, unblocked, uncheck-summed binary object programs. Used only for paper tape output. Not supported in RSX PLUS, RSX PLUS III or B/F MACROA.
.FULLP	3.2.2	→|.FULLP↵	
.GLOBL	3.9	→|.GLOBL␣sym,sym,sym↵	Used to declare all internal and external symbols which reference other programs. Needed by Linking Loader.
.IFxxx	3.13	→|.IFxxx␣exp↵	If a condition is satisfied, the source coding following the .IF statement and terminating with an .ENDC statement is assembled.
.IODEV	3.10	→|.IODEV␣.DAT numbers↵	Specifies .DAT slots and associated I/O handlers required by this program. Not supported in RSX PLUS or RSX PLUS III.
.LOC	3.3	→|.LOC␣exp↵	Sets the location counter to the value of the expression.
.LOCAL	3.2.4	→|.LOCAL↵	Allows deletion of certain symbols from the user symbol table.
.LST	3.17	→|.LST↵	Continue requested assembly listing output of source lines. Lines between .NOLST and .LST are not listed.
.LTORG	3.2.5	→|.LTORG↵	Allows the user to specifically state where literals are to be stored. Not supported in B/F MACROA.
.NDLOC	3.2.4	→|.NDLOC↵	Terminates deletion of certain symbols from the user symbol table contained between .LOCAL and .NDLOC.
.NOLST	3.17	→|.NOLST↵	Terminates requested assembly listing output of source lines of code contained between .NOLST and .LST.
.OCT	3.4	→|.OCT↵	Sets the prevailing radix to octal. Assumed at start of every program.
.REPT	3.12	→|.REPT␣count, n↵	Repeats the object code of the next object code generating instruction Count times. Optionally, the generated word may be incremented by n each time it is repeated. Not supported in B/F MACROA.
.SIXBT	3.8.2	label →|.SIXBT␣/text/ < octal > ↵	Input text strings in 6-bit trimmed ASCII, with first character as delimiter. Numbers enclosed in angle brackets are truncated to one 6-bit octal character.
.SIZE	3.15	label →|.SIZE↵	MACRO-15 outputs the address of last location plus one occupied by the object program.

Pseudo-op	Section	Format	Function
.TITLE	3.1	→|.TITLE␣any text string↵	Causes the assembler to accept up to 50_{10} typed characters. During source program assembly operations, a .TITLE causes a form feed code to be output to place the text starting with .TITLE at the top of a page.

APPENDIX E
SUMMARY OF SYSTEM MACROS

System macros (Monitor commands) are defined in the Monitor manuals, and are summarized here for the convenience of the PDP-15 programmers.

System macros are predefined to MACRO-15, but not in RSX, which uses a macro definition file apart from the Assembler itself. The file's name is RMC.XX, where XX is the version number which may change over time. To use a system macro, the programmer writes a macro call statement, consisting of the macro name and a string of real arguments.

To initialize a device and device handler

→| .INIT␣ds,f,r

where ds = .DAT slot number in octal

f = 0 for input files; 1 for output files

r = user restart address*

To read a line of data from a device to a user's buffer

→| .READ␣ds,m,l,w

where ds = .DAT slot number in octal

m = a number, 0 through 4, specifying the data mode:

0 = IOPS binary
1 = Image binary
2 = IOPS ASCII
3 = Image alphanumeric
4 = Dump mode

l = line buffer address

w = word count of the line buffer in decimal, including two-word header

To write a line of data from the user's buffer to a device

→| .WRITE␣ds,m,l,w

where ds = .DAT slot number in octal

m = a number, 0 through 4, specifying the data mode:

0 = IOPS binary
1 = Image binary

*Meaningful only when device associated with .DAT slot ds is the Teleprinter. Typing CTRL P on the keyboard will force control to location r.

2 = IOPS ASCII
3 = Image alphanumeric
4 = Dump mode

l = line buffer address

w = word count of line buffer in decimal, including the two-word header

To detect the availability of a line buffer

→| .WAIT␣ds

where ds = .DAT slot number in octal. After the previous .READ, .WRITE, or .TRAN command is completed, .WAIT returns control to the user at the instruction following the .WAIT expansion.

To detect the availability of a line buffer and transfer control to ADDR if not available

→| .WAITR␣ds, ADDR

where ds = .DAT slot number (octal radix)

ADDR = Address to which control is transferred if buffer is not available.

To close a file

→| .CLOSE␣ds

where ds = .DAT slot number in octal

To set the real-time clock to n and start it.

→| .TIMER␣n,c

where n = number of clock increments in decimal. Each increment is 1/60 second (in 60-cycle systems) or 1/50 second (in 50-cycle systems)

c = address of subroutine to handle interrupt at end of interval

To return control to the Monitor.

→| .EXIT)

MASS STORAGE COMMANDS FOR DECTAPE, MAGNETIC TAPE, AND DISK

To search for a file, and position the device for subsequent .READ commands

→| .SEEK␣ds,d

where ds = .DAT slot number in octal

d = address of user directory entry block

To examine a file directory, find a free directory entry block and transfer the block to the device

→|.ENTER␣ds,d,p

where ds = .DAT slot number in octal
d= address of user directory entry block
p= protection code

The third argument, the protection code, is recognized only by the DOS-15 assemblers; in other systems it is ignored.

To clear device directory to zero

→|.CLEAR␣ds

where ds = .DAT slot number in octal

To rewind, backspace, skip, write end-of-file, or write blank tape on nonfile-oriented magnetic tape

→|.MTAPE␣ds,xx

where ds = .DAT slot number in octal

xx = a number, 00 through 07, specifying one of the functions shown below

00 = Rewind to load point*
02 = Backspace one record*
03 = Backspace one file
04 = Write end-of-file
05 = Skip one record
06 = Skip forward one file
07 = Skip to logical end-of-file

or a number, 10 through 16, to describe the tape configuration

10 = Even parity, 200 bpi
11 = Even parity, 556 bpi
12 = Even parity, 800 bpi
14 = Odd parity, 200 bpi
15 = Odd parity, 556 bpi
16 = Odd parity, 800 bpi

To read from, or write to any user file-structured mass storage device

→|.TRAN␣a,d,b,l,w

where a = .DAT slot number in octal
d = transfer direction:
0=Input forward
1=Output forward
2=Input reverse (DECtape only)
3=Output reverse (DECtape only)
b = device address in octal, such as block number for DECtape
l = core starting address
w = word count in decimal

*May be used with any non-directoried mass storage device.

To delete a file

→| .DLETE␣ds,d

where ds = .DAT slot number in octal

d = starting address of the three-word block of storage in user area containing the file name and extension of file to be deleted from the device.

To rename a file

→| .RENAM␣ds,d

where ds = .DAT slot number in octal

d = starting address of two three-word blocks of storage in user area containing the file names and extensions of the file to be renamed, and the new name, respectively.

To determine whether a file is present on a device

→| .FSTAT␣ds,d

where ds = .DAT slot number in octal

d = starting address of three-word block in user area containing the file name and extension of the file whose status is desired.

BACKGROUND/FOREGROUND MONITOR SYSTEM COMMANDS

To read a line of data from a device to a user's buffer in real-time

→| .REALR␣ds,n,l,w,ADDR,p

where ds = .DAT slot number in octal

m = Data mode specification

0 = IOPS binary
1 = Image binary
2 = IOPS ASCII
3 = Image Alphanumeric
4 = Dump mode

l = Line buffer address

w = word count of line buffer in decimal, including the two-word header

ADDR = 15-bit address of closed subroutine that is given control when the request made by .REALR is completed.

p = API priority level at which control is to be transferred to ADDR:

0 = mainstream
4 = level of .REALR
5 = API software level 5
6 = API software level 6
7 = API software level 7

To write a line of data from user's buffer to a device in real time

→| .REALW␣ds,m,l,w,ADDR,p

where ds = .DAT slot number in octal

m = Data mode specification

0 = IOPS binary
1 = Image binary
2 = IOPS ASCII
3 = Image Alphanumeric
4 = Dump mode

l = line buffer address

w = word count of line buffer in decimal, including the two-word header

ADDR = 15-bit address of closed subroutine that is given control when the request made by .REALW is completed

p = API priority level at which control is to be transferred to ADDR

0 = mainstream
4 = level of .REALW
5 = API software level 5
6 = API software level 6
7 = API software level 7

To indicate, in a FOREGROUND job, that control is to be relinquished to a BACKGROUND job

→| .IDLE

To set the real-time clock to n and start it

→| .TIMER␣n,c,p

where n = number of clock increments in decimal. Each increment is 1/60 of a second (1/50 in 50 Hz systems)

c = address of subroutine to handle interrupt at end of interval

p = API priority level at which control is to be transferred to c

0 = mainstream
4 = level of .TIMER
5 = API software level 5
6 = API software level 6
7 = API software level 7

To exit from all real-time subroutines which were entered via .REALR, .REALW, .TIMER, or real-time CTRL P requests.

.RLXIT addr

where addr = The 13-bit entry point address of the real-time subroutine from which an exit is to be made.

DOS SYSTEM MACROS

The following macros are implemented in the Disk Operating System only.

To open a file for random access via .RTRAN macros.

→| .RAND␣ds,namptr)

where ds = .DAT slot number in octal

namptr = name pointer, points to the first word of a 3-word representation (.SIXBT) of the file name and extension of the file to be opened

To enable random access to the blocks of a file previously opened by a .RAND I/O macro.

→| .RTRAN␣ds,d,relblk,bufadd,beg,cnt)

where ds = .DAT slot (octal radix)

d = direction:

if d=0, direction is input
if d=1, direction is output

relblk = block number (octal radix) relative to beginning of the file...first block is block 1, etc.

bufadd = address of I/O buffer in user's core space.

beg = first physical word of physical block to be read or written... ignored for disk pack...must be octal radix, 0< beg <375.

cnt = number of words, starting with beg, to be read or written... ignored for disk pack...must be DECIMAL radix, 1< cnt <(253-beg).

To request a buffer from the buffer pool

→| .GTBUF)

To return a buffer to the buffer pool which was obtained via the .GTBUF macro.

→| .GVBUF)

To obtain access to files on the disk under UFDs other than that of the current user.

→| .USER␣nn,uic)

where nn = .UFDT slot number

uic = UIC

To request the system loader (.SYSLD) to load and start a specified system program from within a user program.

→| .OVRLA␣namptr↵)

where namptr = pointer to the first address of the two-word .SIXBT representation of the name of the program to be loaded.

WARNING

All I/O operations should be completed before .OVRLA macro is issued.

APPENDIX F

SOURCE LISTING OF THE ABSOLUTE BINARY LOADER

```
                /***ABSOLUTE BINARY LOADER ***
                /       .FULL
700004          CLOF=700004
700112          RRB=700112
700144          RSB=700144
700101          RSF=700101
017720          LDSTRT=17720
703302          BINLDR CAF                      /CLEAR FLAGS
700004                 CLOF                     /CLOCK OFF
700012                 IOF+10                   /INTERRUPT OFF
705504                 ISA                      /TURN OFF API
740000          LODMOD NOP                      /(EBA), (DBA), (NOP)
707702                 707702                   /PDP-9 COMPATIBILITY (EEM)
017726          LDNXBK=17726
157775                 DZM  LDCKSM              /CHECKSUMMING LOCATION
117753                 JMS  LDREAD
057776                 DAC  LDSTAD              /GET STARTING ADDRESS
741100                 SPA                      /BLOCK HEADING OR
617747                 JMP  LDXFR               /START BLOCK
117753                 JMS  LDREAD
057777                 DAC  LDWDCT              /WORD COUNT (2'S COMPLEMENT)
117753                 JMS  LDREAD
017736          LDNXWD=17736
117753                 JMS  LDREAD
077776                 DAC* LDSTAD              /LOAD DATA INTO APPROPRIATE
457776                 ISZ  LDSTAD              /MEMORY LOCATIONS
457777                 ISZ  LDWDCT              /FINISHED LOADING
617736                 JMP  LDNXWD              /NO
357775                 TAD  LDCKSM
740200                 SZA                      /LDCKSM SHOULD CONTAIN 0
740040                 HLT                      /CHECKSUM ERROR HALT
617726                 JMP  LDNXBK              /PRESS CONTINUE TO IGNORE
017747          LDXFR=17747
057777                 DAC  LDWDCT
457777                 ISZ  LDWDCT
617763                 JMP  LDWAIT              /EXECUTE START ADDRESS
740040                 HLT                      /NO ADDRESS ON .END STATEMENT
017753          LDREAD=17753                    /MANUALLY START USER PROGRAM
```

```
000000              0
700144              RSB
357775              TAD   LDCKSM
057775              DAC   LDCKSM
700101              RSF
617757              JMP   LDREAD+4
700112              RRB
637753              JMP*  LDREAD
                  /THE LAST FRAME OF EVERY .ABS(P) PROG IS GARBAGE.
017763            LDWAIT=17763
117753              JMS   LDREAD          /PASS OVER LAST FRAME (PDP-9
637776              JMP*  LDSTAD          /COMPATIBILITY).
006235            FNDLDR=.
003500            HRMWD   003500; 0       /HEADER
000000
000261              261;    277           /HRM START
000277
000320              320;    0
000000
017775            LDCKSM=17775
017776            LDSTAD=17776
017777            LDWDCT=17777
                  /       .END BINLDR
                  /*** END OF LOADER ***
```

APPENDIX G
MACROI-15 ASSEMBLER
ADVANCED MONITOR SYSTEM

ADSS-15 8K DECtape systems cannot utilize MACRO-15 if a binary output on DECtape is desired, since the combined size of MACRO-15, the Resident Monitor, and the required DECtape device handler (DTB.) is greater than 8K. DECtape (DTC.) input/paper tape output also leads to core overflow. If, however, paper-tape input/paper-tape output is desired, MACRO-15 may be used. Device handlers PRB, PPC, or PPB (for .ABS or .FULL programs) may be used as required.

The MACROI-15 assembler, which is a device-dependent version of MACRO-15, does permit DECtape I/O on an 8K machine. This is possible because MACROI, though identical to MACRO in function, uses self-contained DECtape and Teleprinter I/O routines. This results in a core load which operates in 8K and allows approximately 390_{10} locations for the User's Symbol Table.

DEVICE ASSIGNMENTS

Since MACROI is device-dependent, the user may not use the Monitor ASSIGN command. The assembler performs I/O in the manner described below (as modified by the D and U options):

a. The user's source program is input from DECtape Unit 1.

b. The assembled binary is output to DECtape Unit 2*.

c. The assembly listing is output to the Teletype.

d. The parameter file is input from the Teletype if the P option is used.

e. MACRO definitions are accepted from DECtape unit 1 during PASS 1 (F option). This file must be named .MACRO SRC.

OPERATION

The operating features of MACROI are the same as described in Chapter 5 for MACRO, with the following exceptions:

Calling Procedure

MACROI is called by typing MACROI↵ after the Monitor's $ request. When the assembler has been loaded, it identifies itself by typing:

MACROI	Vnn	(in page mode systems)
BMACROI	Vnn	(in bank mode systems)

*If you want .ABS paper tape output, you cannot PIP this binary to paper tape because you will get 9 empty frames every 252 words. You must use MACRO as described above.

on the Teletype and then waits for a command string.

NOTE

The command line editing function CTRL U deletes the entire line and echoes ↑U and a carriage return/line feed operation on the Teleprinter.

Additional Options

The following options may be used in the command string to MACROI along with the other normal MACRO options (excluding I, X and Z):

Option	Action	Default Action
D	Suppress binary output and output the assembly listing on DECtape Unit 2. (file extension: LST)	A binary, if desired, may be output to DECtape 2. The listing is output to the Teleprinter.
U	The assembled binary is output to DECtape Unit 1.	The assembled binary is output to DECtape Unit 2 if B option is selected.

Error Conditions

MACROI performs I/O error checking, and outputs the following messages:

Message	Meaning
IOPS 0	Illegal CAL
IOPS 1	CAL* Illegal
IOPS 3	Illegal Interrupt
IOPS 4	DECtape unit not ready - type CTRL R when ready.
IOPS 12	Unrecoverable DECtape Error
IOPS 13	File Not Found
IOPS 14	Directory Full
IOPS 15	DECtape Full
IOPS 23	Illegal Word Pair Count
IOPS 61	Input Parity Error While Reading Directory or File Bit Map

All of the above error messages, except IOPS 4, are terminal. Type CTRL P to restart MACROI or type CTRL C to call in the Monitor. A more complete description of IOPS errors may be found in the Monitor System Manuals or User's Guides listed in the Preface of this manual.

APPENDIX H
MACROA-15 ASSEMBLER
BACKGROUND/FOREGROUND SYSTEM

An abbreviated version of the MACRO-15 assembler is provided in addition to MACRO-15, for Background/Foreground systems. MACROA is somewhat smaller than MACRO and can be used where Background core space is at a premium.

MACROA exists because MACROI (see Appendix G) cannot be used in the Background. (It issues IOT instructions for one.)

DEVICE ASSIGNMENTS

MACROA uses the same .DAT slots as does MACRO excluding .DAT -14, namely:

-13 Binary Output
-12 Assembly Listing
-11 Source Input
-1Ø Parameter Input

OPERATION

The operating features of MACROA are the same as described in Chapter 5 for MACRO, with the following exceptions:

Calling Procedure

MACROA is called by typing MACROA↵ after the Monitor's $ request. When the assembler has been loaded, it identifies itself by typing:

BF MACROA-15 Vnn

on the Teletype and then waits for a command string. Only one name is accepted in the command string. This means that the F and Z options are illegal and that parameter file input is allowed only from Teletype or paper tape.

Unrecognized Assembly Options

The F, Z and I options are illegal to MACROA.

Unrecognized Pseudo-Operations

The following pseudo-ops are illegal to MACROA:

.ABS	.ABSP	.FULL	.FULLP
.REPT	.LTORG	.DEFIN	.ENDM
.ETC			

Unrecognized API Instructions

MACROA does not contain in its permanent symbol table the definitions of API instructions.

INDEX

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MACRO-15 Assembler
Reference Manual
DEC-15-LMACA-B-D

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