8080/8085

RELOCATABLE MACRO ASSEMBLER MANUAL

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The following are differences between Microtec's Assembler and the Intel Assembler described in Intel's 8080/8085 Assembly Language Programming Manual #98-301A.

- Microtec allows EBCDIC characters to be specified
- No limit to number of operands for DB or DW directives
- Only operators allowed are +,-,*,/,.LOW.,.HIGH.
- Expressions may contain no blanks. In particular the HIGH and LOW operators are delimited by periods.
- An instruction may not appear as an operand, e.g. (MOV A,B)
- Colons are not needed to terminate a label which starts in column one.
- Comments may begin with asterisks or semicolons
- The comment field on a statement need not start with a semicolon
- The following directives are not supported
  REPT
  IRP
  IRPC
- The following characters do not have any special meaning as Macro Operators
  ! ;; NUL %
- Macro Definitions may not be nested

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INTRODUCTION

Microtec has developed a Relocatable Macro Assembler for the 8080/8085 microprocessor that translates Symbolic Machine Code into relocatable object code which may then be processed by Microtec's Linking Loader. The Assembler program is written in FORTRAN IV to achieve compatibility with most computer systems. It is modular and may be executed in an overlay mode should memory restrictions make that necessary. The program is approximately 3800 FORTRAN statements in length, 20% of which are comments. The program is written in ANSI standard FORTRAN IV and no facility peculiar to any one machine was utilized. This was done in order to eliminate FORTRAN compatibility problems.

The mnemonic Operation Codes as well as Directives are identical to those utilized by Intel in their literature and in their software products. This has been done to eliminate any possible problems of program compatibility and to obviate the necessity of learning new assembly languages.

The assembler is a two pass program that builds a symbol table, issues helpful error messages, produces an easily read program listing and symbol table, and outputs a computer readable relocatable object (load) module.

The assembler features relocation, macro capability, conditional assembly, symbolic and relative addressing, forward references, complex expression evaluation, cross reference listing and a versatile set of directives.

These features aid the programmer/engineer in producing well documented, working programs in a minimum of time. Additionally, the assembler is capable of generating data in several number based systems as well as both ASCII and EBCDIC character codes.

Microtec does not present any information in this manual that will help the user understand the 8080 or 8085 microprocessor, nor has any information been included to help the user write working programs. The reader is referred to the Intel 8080/8085 Assembly Language Programming Manual #98-301A.

ASSEMBLER LANGUAGE

The assembler language provides a means to create a computer program. The features of the Assembler are designed to meet the following goals:

- Programs should be easy to create
- Programs should be easy to modify
- Programs should be easy to read and understand
- A machine readable load module to be generated

This assembler language has been developed with the following features:

- Symbolic machine operation codes (opcodes, mnemonics)
- Symbolic address assignments and reference
- Relative addressing
- Data Creation statements
- Storage reservation statements
- Assembly listing control statements
- Addresses may be generated as constants
- Character codes may be specified as ASCII or EBCDIC
- Comments and remarks may be encoded for documentation
- Cross reference table listing
- Relocatable object format

As assembly language program is a program written in symbolic machine language. It is comprised of statements. A statement is either a symbolic instruction, a directive statement, a macro statement, or a comment.

The symbolic machine instruction is a written specification for a particular machine operation expressed by symbolic operation codes and sometimes symbolic addresses or operands. Example:

```
ISAM    MOV     A,M
```

where:

ISAM - is a symbol which will represent the memory address of this instruction.

MOV - is a symbolic opcode which represents the bit pattern of the "move" instruction.

A - is a symbol, in this case a reserved symbol representing the bit pattern for the accumulator.

M - is a symbol, another reserved symbol, representing memory accessed through registers H and L.

A directive statement is a statement which is not translated into a machine instruction, but rather is interpreted as a directive to the assembler program. Example:

```
ABAT    DW      DELT
```

where:

ABAT - is a symbol. The assembler is to assign the memory address of the first byte of the two allocated bytes to this symbol.

DW - is a directive which directs the assembler program to allocate two bytes of memory.

DELT - is a symbol representing an address. The assembler is directed to place the equivalent memory address into the two allocated bytes.

Statements

Statements are always written in a particular format. This format is depicted below.

LABEL FIELD	OPERATION FIELD	OPERAND FIELD	COMMENT FIELD

The statement is always assumed to be written on an 80 column data processing card or as an 80 column card image.

The Label Field is provided to assign symbolic names to bytes of memory. If present, the label field may begin in any column if it is terminated by a colon. It may also begin in column one and not be terminated by a colon. A label may be the only field on the statement.

The Operation Field is provided to specify a symbolic operation code, a directive, or a macro call. If present this field must either begin past column one or be separated from the Label Field by one or more blanks or a colon.

The Operand Field is provided to specify arguments for the operation in the Operation Field. The Operand Field, if present, is separated from the Operation Field by one or more blanks.

The Comment Field is provided to enable the assembly language programmer to optionally place an English message stating the purpose or intent of a statement or group of statements. The Comment Field must be separated from the preceding field by one or more blanks or a semicolon.

Comment Statement

A Comment statement is a statement that is not processed by the assembler program. It is merely reproduced on the assembly listing. A comment statement is indicated by encoding an asterisk or a semicolon as the first non-blank character. Example:

```
; THIS IS A COMMENT STATEMENT
```

Logical columns 73-80 are never processed by the assembler. This field is a good place for sequence numbers, if desired.

Reserved Symbols

This assembler has internally defined twelve symbols. They are the register and segment names that Intel uses in their product descriptions. These symbols have been defined to save the user the trouble of defining them in each program. Although these symbols need not be used, they typically are used very frequently.

The user may assume the following statements have been included at the beginning of each assembled program but they will not appear on the program listing:

```
A    EQU   7          H    EQU   4
B    EQU   Ø          L    EQU   5
C    EQU   1          M    EQU   6
D    EQU   2         SP    EQU   6
E    EQU   3        PSW    EQU   6
```

In addition the following two symbols denote the "stack" and "memory" segments of a program (see Section 6).

```
STACK                    MEMORY
```

The values to which these labels have been assigned are the Intel codes for the source or the destination of the microprocessor instructions.

These reserved labels may not be used in the label field. to do so will generate an error flag.

Symbolic Addressing

When writing statements in symbolic machine language, i.e. assembler language, the machine operation code is usually expressed symbolically. For example, the machine instruction that moves data from register B into the memory location addressed by the contents of register pair H,L may be expressed as:

```
MOV    M,B
```

When translating this symbolic operation code and its arguments into machine language for the 8080, the assembler defines one byte containing 7ØH (112) at the memory location in the current Assembly Program Counter. The address of the translated byte is known because the Assembly Program Counter is always set to hold the address of the byte currently being assembled.

The user can optionally attach a label to such an instruction. For example:

```
SAVE   MOV    M,B
```

The assembler, upon seeing a valid symbol in the label field, assigns the equivalent address to the label. The equivalent address is the address contained in the Assembly Program Counter. In the given example, if the MOV instruction is to be stored in the address 127, then the symbol SAVE

would be made equivalent to the value 127 for the duration of the assembly.

The symbol could then be used anywhere in the source program to refer to the location of the instruction. The important concept is that the address of the instruction need not be known; only the symbol need be used to refer to the instruction location. Thus when jumping to the MOV instruction the user could write:

```
        JMP     SAVE
```

When the "jump" instruction is translated by the assembler, the address of the MOV instruction is placed in the address field of the JMP instruction.

It is also possible to use symbolic addresses which are near other locations to refer to those locations without defining new labels. This may be done through use of the + and - operators. For example:

```
        JMP     BEG
        JPE     BEG+4
BEG     MOV     A,B
        HLT
        MVI     C,'B'
        INR     B
```

In the above example, the instruction "JMP BEG" refers to the "MOV A,B" instruction. The instruction "JPE BEG+4" refers to the "INR B" instruction.

BEG+4 means the address of BEG plus four bytes. This type of expression is called relative symbolic addressing and given a symbolic address such as "BEG" it can be used as a landmark to express several bytes before or after the symbolic address.

Assembly Program Counter

During the assembly process the assembler maintains a FORTRAN word that always contains the address of the next memory location to be assembled. This word is called the Assembly Program Counter. It is used by the assembler to assign addresses to assembled bytes, but it is also available to the programmer.

The character "$" is the symbolic name of the Program Counter. It may be used like any other symbol, but it may not appear in the label field.

When using the "$", the programmer may think of it as expressing the idea; "$" = "address of myself." For example:

```
10    JMP   $
```

The jump instruction is in location 10. The instruction directs the microprocessor to "jump to myself." The Program Counter in this example contains the value 10 and the instruction will be translated to a "JMP 10." This could be used for example when waiting for an interrupt.

SYNTAX

The Assembler Language is a language like any other. That is, it has a character set, vocabulary, rules of grammer, and allows for individuals to define new words or elements. The rules that describe the language are termed the syntax of the language.

For an expression or statement in assembler language to be translated by the assembly program it must be written correctly in accord with the rules of syntax.

Character Set

The following list of characters are the only ones that the assembler will recognize. Use of any other characters will cause the assembler to generate an error message.

Alphabetic Characters

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Numeric Characters

0 1 2 3 4 5 6 7 8 9

Special Characters

⊬	blank character	/	slash
>	greater than	$	dollar sign
<	less then	*	asterisk
'	single quote	(	left parenthesis
,	comma	)	right parenthesis
+	plus sign	@	commercial at sign
-	minus sign	.	period

&	ampersand	:	colon
!	exclamation	;	semi-colon
"	double quote	=	equal sign
#	sharp sign	?	question mark
%	percent		

Symbols

A symbol is a sequence of characters. The first character in a symbol must be alphabetic or the special characters ? or @. Special characters except for the above two may not be used in a symbol. Imbedded blanks are not permitted. The user is cautioned not to use symbols that start with the ? character as the assembler generates "local" symbols starting with this character.

Only the first six characters of a symbol are used by the Assembler to define that symbol; the remaining characters are for documentation. The parameter that dictates the number of characters used to define a symbol may be changed in the Fortran Source code.

The Assembler's symbol table can contain up to 200 symbols. If more symbols are requred, the symbol table may be increased in size by changing a parameter in the Fortran Source code.

Symbols are used to represent arithmetic values, memory addresses, bit arrays (masks), etc. Examples of valid symbols:

```
LAB1
MASK
LOOP@NUM          (symbol used is LOOP@N)
```

Examples of invalid symbols:

ABORT*	(contains special character)
1LAR	(begins with a numeric)
PAN N	(embedded blank, symbol is PAN)

Constants

A constant is an invariant quantity. It may be an arithmetic value or a character code. There are several ways of specifying constants in this assembler language.

Decimal constants may be defined as a sequence of numeric characters optionally preceded by a plus sign or a minus sign. If unsigned, the value is assumed to be positive.

In most cases constants must be contained in one or two bytes. A one byte constant can contain an unsigned number with a value from Ø to 255. A two byte unsigned constant can range from Ø to 65535. When a constant is negative is equivalent two's complement representation is generated and placed in the field specified. A one byte two's complement negative number can range from -1 to -256. A two byte two's complement number may range from -1 to -65536.

All constants are evaluated as 16 bit quantities, i.e. modulo 65536. Whenever an attempt is made to place a constant in a field for which it is too large, an error message is generated by the assembler.

Other constants are defined utilizing a coded descriptor after the constant. A leading Ø must be added to hexadecimal constants that start with A-F. The following list indicates the available descriptors.

B - binary
O - octal
Q - octal
D - decimal
H - hexadecimal

Examples of these constants are:

```
1ØØ11B   25  ØFFH   37Q   255D   1357O
```

As ASCII or EBCDIC character constant may be specified by enclosing a single character within quote marks and preceding it with an A for ASCII ro an E for EBCDIC. If no descriptor is specified the string is assumed to be ASCII. Examples of this constant form are:

```
MVI    A,'1'
MVI    C,E'A'
ORI    'Ø'
```

A character string may be specified by using the DB or DATA directive. Character strings must follow the format described for these directives (see Section 4). Character strings may be specified as ASCII or EBCDIC in a similar manner as the character constant. Examples of the character string are:

```
A'TELETYPE CODES'
E'TERMINAL CODES'
 '   123.8'
```

Note that one byte of memory is required for each character in a string. When a string is specified in a DB or DATA directive, characters are stored in sequential bytes of memory beginning at the first available byte.

To cause the code for a single quotation mark to be generated in the character constant or string it must be specified as two single quote marks. Example:

```
'DON''T'
```

The character code for a single quotation mark will be generated once for every two marks that appear contiguously within the character string.

Expressions

An expression is a sequence of one or more symbols, constants, or other expressions separated by the arithmetic operators +,-,*,/ and the special arithmetic operators discussed later. Parenthesis are used in the normal manner to establish the correct order of the arithmetic operators. Expressions are evaluated left to right with multiplication and division being performed before addition and subtraction.

The expression must resolve to a single unique value. Consequently character strings are not permitted in expressions. All expressions are evaluated modulo 65536 and hence are all 16 bit quantities. In most cases the value of the final expression must be contained in either one or two bytes. If an attempt is made to place an expression in an one byte field and the expression is too large, an error message is generated. Examples of expressions:

```
PAM+3
(PAM+45H)/CAL
LOOP+ADDR/2
'A'+1
```

Special Arithmetic Operators

The special characters, ">", greater than and, "<", less

than, have been assigned as special arithmetic operators. They correspond to the Intel operators .LOW. and .HIGH. and are used to perform the following operations:

.LOW. or > - take low 8 bits of expression
.HIGH. or < - take high 8 bits of expression

These special operators are unary and may be used anywhere in an expression. They have precedence over all other operators, e.g. >A+B*C is not the same as >(A+B*C). Example:

```
>IASM
<IASM
 .LOW.E1+5
```

These operators have been provided to help the user define two byte addresses as individual bytes whenever that is desirable. The result of application of either of these operators is a one byte value.

The following example demonstrates the utility of these operators.

```
        LXI     H,BUFF
LOOP    MOV     A,M
        CPI     13
        JZ      MAIN
        INX     H
        MOV     L,A
        CPI     .LOW.(BUFF+40)   ;CHECK FOR END
        JZ      MAIN
        JMP     LOOP
```

DIRECTIVES

The directives or pseudo-operations are written as ordinary statements in the assembler language, but rather than being translated into equivalent machine language they are interpreted as directives to the Assembler itself.

Through use of these directives, the Assembler will reserve memory space, define bytes of data, control the listings, assign values to symbols, etc.

This section describes all directives except those primarily associated with macro assembly and relocation although some directives such as ORG apply to both absolute assembly and relocatable assembly.

The directives described in this section are:

ORG	Set Program Origin
END	End of Assembly
EQU	Equate a Symbol to an Expression
SET	Equate a Symbol to an Expression
DB	Data Definition
DATA	Data Definition (same as DB)
DW	Define Word
ACON	Address Constant (same as DW)
DDB	Define Double Byte
DS	Define Storage
EJEC	Advance Listing Form to next Page
SPAC	Space lines on listing
TITLE	Set Program Heading
LIST	List the Elements Specified
NLIST	Suppress listing of the Elements Specified
IF	Conditional Assembly Statement

ELSE	Conditional Assembly Statement Converse
ENDIF	End Conditional Assembly code

In the following descriptions, the brackets, { }, are used to indicate optionality, or if more than one item appears within the same pair of brackets, they indicate a choice.

ORG — Set Program Origin (non relocatable mode)

The ORG directive is used to inform the assembler of the memory address to which the next assembled byte should be assigned. All subsequent bytes will be assigned sequential addresses beginning with this address.

If the program does not have an ORG as the first statement, an ORG Ø is assumed and assembly will begin at location zero with absolute assembly.

Example:

```
ORG   1ØØH
```

{label}	ORG	expression

where:

label - is an optional label which if present will be equated to the given expression.

expression - a value which will replace the contents of the Assembly Program Counter and bytes subsequently assembled will be assigned memory addresses beginning with this value. Any symbols used in the expression must be previously defined.

END — End of Assembly

The END directive is used to inform the assembler that the last card of the source program has been read, as well as indicate the load module starting address. Any statements following the END directive will not be processed.

Example:

```
END   MAIN
```

END	{expression}

where:

expression - is an address that is placed in the end record of the load module and informs the loader where program execution is to begin. If expression is not specified the load address is set to zero. Specifying a load address in this directive also implies that this is a main program to the loader. If multiple load modules are combined by the Linking Loader only one module may specify a load address and hence be a main program.

EQU — Equate a Symbol to an Expression

The EQU directive is used to cause the assembler to assign a particular value to a new label. This value may be an absolute value or be a relocatable segment value (see Section 6).

Example:

```
SEVEN   EQU   7
```

label	EQU	expression

where:

label - is a symbol defined by this statement

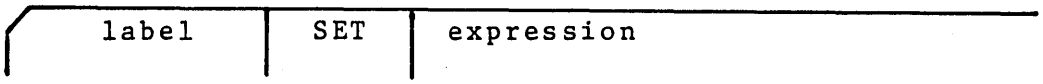
expression - is an expression whose value will be assigned to the given label for the duration of the current assembly. An attempt to reequate the same label will result in an error. Any symbols used in the expression must be previously defined. An external symbol may not be used in the expression.

SET — Equate a Symbol to an Expression

The SET directive may be used to set a symbol equal to a particular value. Unlike the EQU directive, mulitple SET directives for the same symbol may be placed in the same source program. The most recent SET directive determines the value of the symbol at any given place in the source program.

Example:

```
GO      SET     5
GO      SET     GO+10
```



where:

label - is a symbol defined by this statement

expression - is a value that will be assigned to the given label until changed by another SET directive. Any symbols used in the expression must be previously defined. An external symbol may not be used in the expression.

DB — Data Definition
DATA

The DB and DATA directives are used to define up to 70 bytes of data. The assembler will allocate one byte if an expression is given and will allocate several bytes if a character string is given. All expressions must evaluate to an one byte value or an error is generated. Negative values are stored using their two's complement representation. If an operand is a relocatable expression, it must be preceded by the .LOW. or .HIGH. operators. If neither operator is present an error is generated and the .LOW. operator is assumed.

Example:

```
ITEM    DB      +122,17,.LOW.EXP1
        DATA    6,1FH,'A'+1,32Q
OUT2    DB      A'ERR 1',7
```

{label}	DB DATA	$operand_1$,{$operand_2$}, ...

where:

label - is an optional label which will be assigned the address of the first byte defined.

$operand_i$ - is an evaluatable expression contained in one byte, a character constant or an ASCII or EBCDIC character string of up to 70 characters.

DW — Define Word
ACON

The DW or ACON directive informs the assembler to allocate two bytes per operand. Each operand is stored in successive bytes. The operands are stored with the low order 8 bits in the first byte and the high order 8 bits in the second byte. Negative values are stored using their two's complement representation.

Example:

```
ADD1    DW      1BH,40
        ACON    1000,10000
```

{label}	DW ACON	$operand_1$, {$operand_2$}, ...

where:

label - is an optional label which will be assigned the address of the first byte defined.

$operand_i$ - is an evaluatable expression contained in two bytes. A total of 70 bytes may be allocated by this directive.

DDB — Define Double Byte

This directive is similar to the DW directive except for the order in which the 16 bit value of each operand is stored. The low order 8 bits of the operand are stored in the second byte of the double byte and the high order 8 bits are stored in the first byte. Negative values are stored using their two's complement representation.

Example:

```
REV1    DDB     1000,10000
```

{label}	DDB	$operand_1$,{$operand_2$}, ...

where:

label - is an optional label which will be assigned the address of the first byte defined.

$operand_i$ - is an evaluatable expression contained in two bytes. A total of 70 bytes may be allocated by this directive.

DS — Define Storage

The DS directive is used to reserve a block of sequential bytes of storage. This directive merely cause the program counter to be advanced. Therefore, the contents of the reserved bytes are unpredicatable.

Example:

```
PAT     DS      62H
```

{label}	DS	expression

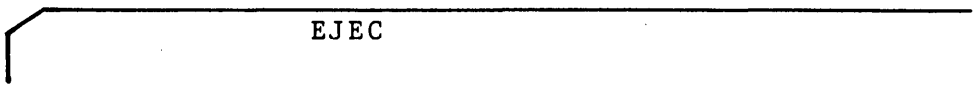
where:

label - is an optional label which will be assigned the address of the first byte allocated.

expression - a value which specifies the number of bytes to be allocated by this directive. Any symbols used in this expression must be previously defined. Expression may not contain any relocatable symbols.

EJEC — Advance Listing Form to next Page

This directive instructs the assembler to skip to the top of the next page on the listing form. Its purpose is to make program listings easier to read. Some programmers prefer to start each subroutine on a new page. The EJEC directive will not appear on the listing.

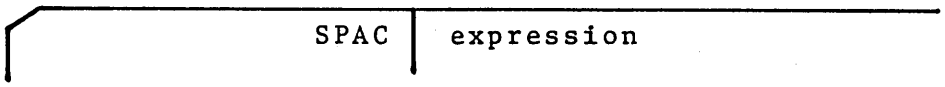


SPAC — Space lines on listing

The SPAC directive causes one or more blank lines to appear on the output listing. It enables the programmer to format the program listings for easier reading. The directive itself does not appear on the listing.

Example:

```
SPAC    7
```



where:

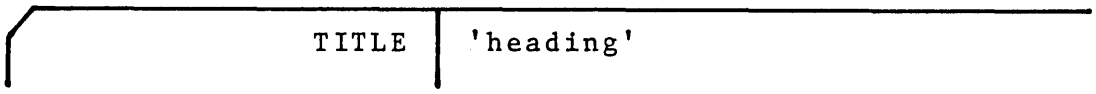
expression - evaluates to a value that determines how many lines are to be skipped. Expression may not be relocatable.

TITLE — Set Program Heading

The TITLE directive is used to print a heading at the beginning of each page of the listing. The default heading defined by the assembler and used if the programmer does not specify one via this directive is: "8080/8085 ASSEMBLER VER _._MR". For a user specified title to appear on the first page of the output listing, the TITLE directive must be the first statement in the program.

Example:

```
                    TITLE   'TEST PROGRAM'
```



where:

heading - title which will be placed at the beginning of each page. The heading may be up to 50 characters, with any additional characters not appearing in the title. The heading is delimited by single quotes but if the terminating quote is not present the first 50 characters will be used as the title. Heading may contain no characters in which case the title will be set to blanks.

LIST — List the Elements Specified

The LIST directive may be used to generate listings of the elements specified. The defaults in the assembler are that the source text, symbol table, macro expansions, and conditional assembly statements not assembled are listed and that an object module is produced. The symbol table is not placed in the object module and system generated symbols are not listed. Errors are always listed regardless of the elements specified.

Example:

```
                    LIST    X,B     produce cross reference
                                    table and put symbol table
                                    in object module
```

LIST	B,G,I,M,O,S,T,X

where:

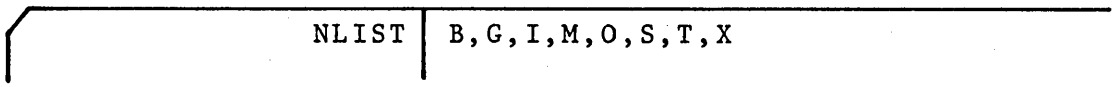
- B - specifies that the symbol table will be placed into the object module and may be used for debugging.
- G - specifies that system generated symbols (see Section 6) will be listed in the symbol table and in object module.
- I - specifies that the instructions not assembled due to conditional assembly statements will be listed (default)
- M - specifies that expanded macros will be listed in the source text (default)
- O - specifies that the object module will be produced. (default)
- S - specifies that the source test will be listed. (default)
- T - specifies that the symbol table will be listed. (default)
- X - specifies that the cross reference table will be listed. This parameter overrides the T option if specified. Thus if T and X are both specified a cross reference table will be generated. (see page 7-9)

NLIST — Suppress Listing of the Elements Specified

The NLIST directive instructs the assembler to suppress the listings of the elements specified. The listings may be enabled again by the LIST directive. Errors generated by the assembler are always listed regardless of the list flags. Thus to obtain an output listing of only errors the user should specify "NLIST S" at the beginning of the program.

Example:

```
                    NLIST   O       do not produce an
                                    object module
```



where:

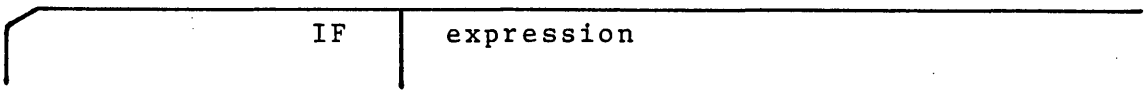
- B - specifies that the symbol table will not be placed into the object module.
- G - specifies that system generated symbols will not be listed in the symbol table or object module.
- I - specifies that the instructions not assembled due to conditional assembly statements not be listed.
- M - specifies that expanded macros not be listed.
- O - specifies that the object module will not be produced.
- S - specifies that the source text will not listed. Only those statements with errors will be listed.
- T - specifies that the symbol table will not be listed.
- X - specifies that a cross reference table will not be produced or listed.

IF — Conditional Assembly Statement

The IF directive may be used to conditionally assemble source text between the IF directive and the ELSE or ENDIF directive. If the expression in the operand field is evaluated to any non-zero value, the code will be assembled. If the expression evaluates to a value of zero the code will not be assembled. IF statements may be nested up to 16 levels and appear in the source text at any place.

Example:

```
                    IF  SYSTEM
```



where:

expression - evalutes to a value which determines whether or not the assembly between the IF and following ELSE or ENDIF will take place. Any symbols used in this expression must be previously defined. The expression may not be relocatable.

ELSE — Conditional Assembly Statement Converse

The ELSE directive is used in conjuction with the IF directive and is the converse of the IF. If the expression of the IF directive was zero, all statements between the ELSE directive and the next ENDIF are assembled. If the expression of the IF directive was non-zero, all statements between the ELSE directive and the next ENDIF are not assembled.

The ELSE directive is optional and can only appear once within in IF-ENDIF block.

Example:

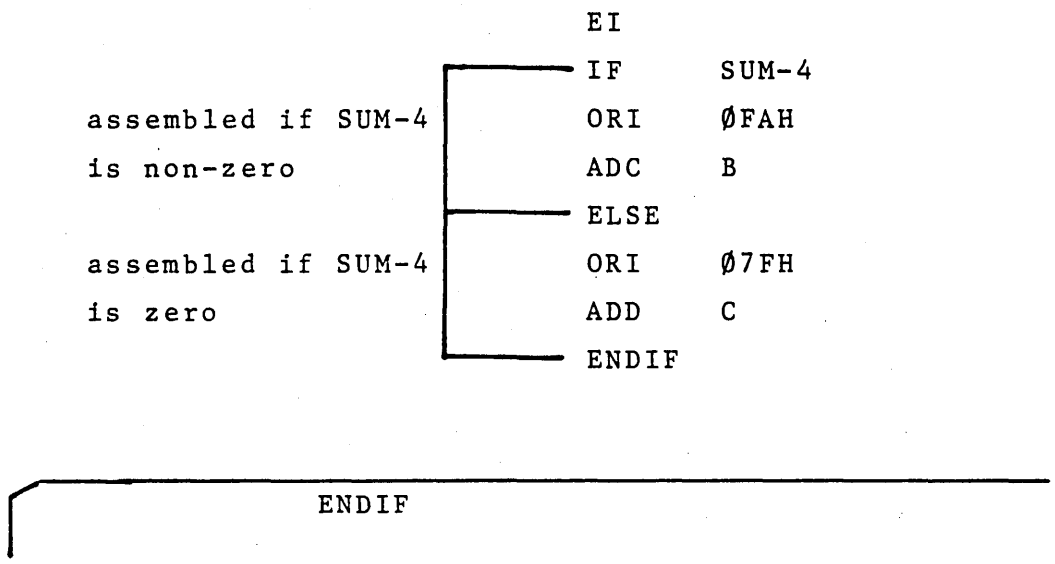
```
        IF   MAIN
        -
        ELSE
        -
        ENDIF
```

ENDIF — End Conditional Assembly Code

The ENDIF directive is used to inform the assembler where the source code subject to the conditional assembly statement ends. In the case of nexted IF statements, an ENDIF is paired with the most recent IF statement.

Example:

In the following code, if the expression SUM-4 is equal to zero, the instructions between the IF and ELSE directives will not be assembled and those between the ELSE and ENDIF will be assembled. If SUM-4 is non-zero the opposite occurs. To not list the non assembled instructions the "NLIST I" directive may be used.



MACROS

A macro is a sequence of instructions that can be inserted in the assembly source text by encoding a single instruction, the macro call. The macro definition is written only once and can be called any number of times. The macro definition may contain parameters which can be changed for each call. The macro facility simplifies the coding of programs, reduces the chance of programmer error, and makes programs easier to understand as the source code need only be changed in one location, the macro definition.

A macro definition consists of three parts; a heading, a body, and a terminator. This definition must precede any macro call. A macro may be redefined at any time with the latest definition of a macro name applying to a macro call. A standard assembler mnemonic (e.g. LXI) may also be redefined by defining a macro with the name LXI. In this case all subsequent uses of the LXI instruction in the program will cause the macro to be expanded.

Macro Heading

The heading, which consists of the directive MACRO, gives the macro a name and defines any formal parameters for the macro.

label	MACRO	{parameter list}

Label specifies the macro name and may be any user defined symbol. This name may be the same as other program defined symbols since it has meaning only in the operation field. For example, TAB could be the name of a symbol as well as a macro.

If a macro name if identical to a machine instruction or an assembler directive, the mnemonic is redefined as the macro. Once a mnemonic has been redefined as a macro, there is no way of returning that name to be a standard mnemonic. A macro name may also be redefined as a new macro with a new body.

The operand field of the MACRO line contains the name of dummy formal parameters in the order in which they occur on the macro call. Each parameter is a symbol and multiple parameters must be separated by comments. The scope of a formal parameter is limited to its specific macro definition.

Macro Body

The first line of code following the MACRO directive which is not a LOCAL directive is the start of the macro body. These statements are placed in a macro file for use when the macro is called. At expansion time, an error will be generated if another macro is defined within a macro. No statements are assembled at definition time including the Assembler directives.

Within the macro body, in any field, the name of a formal parameter listed on the MACRO line may appear. If a parameter exists, it is marked and the actual parameter from the macro call will be substituted when the macro is called. Parameters are not recognized in a comment statement or the comment field of a statement.

Macro Terminator

The ENDM directive terminates the macro definition. During a Macro definition an ENDM must be found before another MACRO statement may be used. An END statement that is found during a macro definition will terminate the macro definition as well the the assembly. The format of the ENDM is as follows:

{label}	ENDM

where:

label - is an optional symbol which becomes the symbolic address of the first byte of memory following the inserted macro.

Macro Call

A macro may be called by encoding the macro name in the operation field of the statement. The format of the macro call is shown below.

{label}	name	parameter list

where:

label - is an optional label which will be assigned a value equal to the address of the first instruction in the macro.

name - is the name of the macro called. This name should be defined by the MACRO directive or an error message will be generated.

parameter list - is a list of parameters separated by commas. These parameters may be constants, expressions. symbols, character strings or any other text separated by commas.

The parameters in the macro call are actual parameters and their names may be different than the formal parameters used in the macro definition. The actual parameters will be substituted for the formal parameters in the order in which they are written. Commas may be used to reserve a parameter position. In this case the parameter will be null. Any parameters not specified will also be null. The parameter list is terminated by a blank or a semicolon.

All actual parameters are passed as character strings into the macro definition statements. Thus symbols are passed by name and not by value. In other words the parameters are not evaluated until the macro expansion is produced. Thus SET directives within a macro may alter the value of parameters passed to the macro.

During the macro expansion, the assembler recognizes certain characters to have special meaning. The ampersand "&", is used to concatenate the text of the definition line and any actual parameters. During macro expansion, an ampersand immediately preceding or immediately following a formal parameter is removed and the substitution of the actual parameter occurs at that point. If the ampersand is not immediately adjacent to the parameter, the ampersand is not removed and remains part of the definition line. Ampersands within character strings are not recognized as concatenation operators.

The angle brackets, "< >", are used to delimit actual parameters that may contain other delimiters. When the left bracket is the first character of any parameter, all characters between it and the matching right bracket are considered part of that parameter. The outer brackets are removed when the parameter is substituted in a line. Angle brackets may be nested for use

within nested macro calls. The brackets are the only way to pass a parameter that contains a blank, comma or other delimiter. For example to use the instruction "LXI H,Ø" as an actual parameter, would require placing <LXI H,Ø> in the actual parameter list. A null parameter may consist of the angle brackets with no intervening characters.

An example of a macro call and its expansion is shown below. Note that expanded macro code is marked with plus signs.

```
Definition          GET     MACRO   X,Y,Z
                            MOV     A,X
                            RLC
                            Y
                    Z       JZ      MAIN
                            ADI     -5
                            ENDM

Call:                        -
                             -
                            CMC
                    LOOP    GET     200,<STA  DATA>,ENTRY
                            JMP     MAIN
                             -
                             -

Source Code                  -
Generated                    -
                            CMC
                     LOOP   GET     200,<STA  DATA>,ENTRY
                   +        MVI     A,200
                   +        RLC
                   +        STA     DATA
                   +ENTRY   JZ      MAIN
                            ADI     -5
                            JMP     MAIN
                             -
```

LOCAL — Define Local Symbol

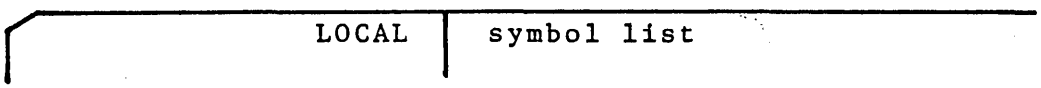
As all labels, including those within macros, are global to the complete program, a macro which contains a label and which is called more than once will cause a duplicate label error to be generated. To avoid this problem the user may declare labels within macros to be "local" to the macro. Each time the macro is called the assembler assigns each local symbol a system generated symbol of the form ??nnnn. Thus the first local symbol will be ??0001, the second ??0002, etc. The assembler does not start at ??0001 for each macro but increases the count for each local symbol encountered. The symbols defined in the LOCAL directive are treated like formal macro parameters and hence may be used in the operand field of instructions. The operand field may not contain any formal parameters defined on the MACRO directive line. As many LOCAL directives as necessary may be included within a macro definition but they must occur immediately after the MACRO directive and before the first line of the macro body. LOCAL directives that appear outside a macro definition will generate an error.

Example:

```
Definition          WAIT     MACRO    R
                             LOCAL    LAB1
                             MVI      B,R
                    LAB1     DCR      B
                             JNZ      LAB1
                             ENDM

First call
with R = 5          +        MVI      B,5
                    +??0001  DCR      B
                    +        JNZ      ??0001
```

```
Second call
with R = 0FFH          +          MVI     B,0FFH
                       +??0002    DCR     B
                       +          JNZ     ??0002
```



where:

symbol list - is a list of symbols separated by commas that are to be defined local to this macro.

EXITM — Alternate Macro Exit

The EXITM directive provides an alternate method for terminating a macro expansion. During a macro expansion, an EXITM directive causes expansion of the current macro to stop and all code between the EXITM and the ENDM for this macro to be ignored. If macros are nested, EXITM causes code generation to return to the previous level of macro expansion. Note that an EXITM or an ENDM may be used to terminate a macro expansion, but only an ENDM may be used to terminate a macro definition.

In the following example the code following the EXITM will not be assembled if DATA is zero.

```
STORE   MACRO    DATA
         -
         -
        IF       DATA
        EXITM
         -
         -
        ENDM
```

{label}	EXITM

where:

label - is an optional label which will be given the address of the instruction assembled after the macro terminates.

RELOCATION

The object module produced by this assembler is in a relocatable format. This allows users to write programs whose final addresses will be adjusted by Microtec's Linking Loader and which may also be changed without reassembling the complete program. It also allows separate object modules to be linked together into a final program.

Relocatable programming provides many advantage for the user. Actual memory addresses are of no concern until the final load time. Large programs may be easily separated into smaller segments, developed separately, and linked together. If one segment contains an error only it need be reassembled. A library of routines may be used by many users once developed. The Loader will adjust addresses to meet each user's requirements.

To take advantage of relocatability the user should understand the concept of program segments and how separate object modules are linked together. A program segment is that part of a program which contains its own program counter and is a logically distinct section of the program. At load time the addresses for each segment may be specified separately.

This assembler provides for four program segments. The CODE segment is typically the segment that contains the actual machine instructions. In a ROM/RAM system it would be the segment that would be placed into ROM. The data area of a program is typically placed in the DATA segment. This segment usually resides in RAM. This segment could contain actual machine instructions. The STACK segment is used to contain the program stack area and resides in RAM. Typically only the main program makes references to the STACK segment and specifies

stack segment length. References are make to the stack segment with the reserved symbol STACK. The MEMORY segement is that portion of memory space not allocated to the other three segments. References are made to this segment with the reserved symbol MEMORY.

Although users may place actual code in the CODE or DATA segments, only references may be made to the STACK and MEMORY segments at assembly time.

As with non relocatable assemblers, users may also specify absolute addresses when assembling a program. In this case the object module will contain an absolute program designed to run in a particular memory location.

The object modules of the assembler are combined or linked together by a Linking Loader. The Loader converts all relocatable addresses into absolute addresses and resolves references from one module to another. Linkage between modules is provided by PUBLIC and EXTRN symbols. PUBLIC symbols are defined in one object module and made available to all other object modules via the Linking Loader. EXTRN symbols are symbols referenced in one module but defined in another module. The Linking Loader links the PUBLIC's from one module with the EXTRN's from other modules to resolve these references. A program may contain both PUBLIC and EXTRN symbols.

Relocatable Symbols

Each symbol in the assembler has associated with it a symbol type which denotes the symbol as absolute or relocatable, and the program segment to which the symbol belongs. Symbols whose values do not change value depending upon program origin are absolute symbols. Symbols whose value change when the

program origin is changed by the Linking Loader are termed relocatable symbols. The reserved symbols STACK and MEMORY discussed above are special forms of relocatable symbols. External symbols are also relocatable. Absolute and relocatable symbols may both appear in an absolute or relocatable segments.

Absolute symbols are defined as follows:

1. A symbol is in the label field when the program is assembling an absolute segment of code.
2. A symbol is defined equal to an absolute expression by the EQU or SET directives. This occurs even if the program is assembling a relocatable segment.

Relocatable symbols are defined as follows:

1. A symbol is in the label field when the program is assembling a CODE or DATA segment of code.
2. A symbol is defined equal to a relocatable expression by the EQU or SET directives.
3. The reserved symbols STACK and MEMORY are relocatable.
4. External (EXTRN) symbols are relocatable.
5. A reference to the program counter ($) while assembling a relocatable segment is relocatable.

Relocatable symbols are also classified as CODE,DATA, STACK, or MEMORY relocatable depending upon how they were defined.

Relocatable Expressions

The relocatability of an expression is determined by the relocation of the symbols that comprise the expression. All numeric constants are considered absolute. Relocatable expressions may be combined to produce an absolute expression, a relocatable expression or in certain instances illegal expressions. The following list shows those expressions

whose result is relocatable. ABS denotes an absolute symbol or constant and REL denotes a relocatable symbol.

```
ABS+REL
REL+ABS
REL-ABS
.LOW.REL
.HIGH.REL
```

Relocatable symbols that appear in expression with any other operators will cause an error, e.g. REL*REL. In addition the difference of two relocatable symbols that were defined in the same relocatable segment produces an absolute result. Any combination of two relocatable symbols from different segments including externals (EXTRN) is an error condition.

Relocation Directives

The following pages describe those directives in the assembler that pertain primarily to relocation. The nomenclature is the same as for the directives described in Section 4. The directives described are:

ASEG	Specify Absolute Segment
CSEG	Specify Code Segment
DSEG	Specify Data Segment
ORG	Specify Origin
PUBLIC	Specify PUBLIC symbols
EXTRN	Specify External symbols
NAME	Specify Module Name
STKLN	Specify Stack Length

ASEG — Specify Absolute Segment

The ASEG directive specifies to the assembler that the following statements should be assembled in the absolute mode. The ASEG remains in effect until a CSEG or DSEG directive is assembled. The starting address for the ASEG program counter is zero. At the start of assembly the program assumes an ASEG directive has been specified and assembly proceeds in the absolute mode.

{label}	ASEG

where:

label - is an optional label that will be assigned the address of the next assembled instruction.

CSEG — Specify Code Segment

The CSEG directive specifies to the assembler that the following statements should be assembled in the relocatable mode using the CODE segment program counter. Initially the CODE segment program counter is set to zero. In addition this directive may specify an operand which is passed to the Loader and has no effect on the assembly. The operand is described below.

Example:

```
                    CSEG    PAGE
```

{label}	CSEG	{},{PAGE},{INPAGE}

where:

label - is an optional label which will be assigned the address of the next instruction.

blank - specifies the code segment may be relocated to the next available byte.

PAGE - specifies that the code segment must begin on a page boundary (i.e. 0,100H,200H,...) when relocated by the Linking Loader.

INPAGE - specifies that the code segment must fit within a single page when relocated. The Loader will start the segment at the next page boundary if the segment will not fit within the current page.

If multiple CSEG directives are specified in the same assembly each must specify the same operand.

DSEG — Specify Data Segment

The DSEG directive specifies to the assembler that the following statements should be assembled in the relocatable mode using the DATA segment program counter. Initially the DATA segment program counter is set to zero. In addition, this directive may specify an operand which is passed to the Loader and has no effect on the assembly. The operand is described below.

Example:

```
                    DSEG    INPAGE
```

{label}	DSEG	{},{PAGE},{INPAGE}

where:

label - is an optional label which will be assigned the address of the next instruction.

blank - specifies the data segment may be relocated to the next availabel byte.

PAGE - specifies that the data segment must begin on a page boundary (i.e. 0,100H,200H,...) when relocated by the Linking Loader.

INPAGE - specifies that the data segment must fit within a single page when relocated. The Loader will start the segment at the next page boundary if the segment will not fit within the current page.

If multiple DSEG directives are specified in the same assembly each must specify the same operand.

ORG — Set Program Origin (relocatable mode)

The ORG directive is used to inform the assembler of the memory address to which the next assembled byte should be assigned. This directive changes the program counter of the segment which is currently being assembled, absolute, code or data. When the ORG is in a relocatable program segment the origin address must be an absolute expression or a relocatable expression which is relocatable within the current segment.

Example:

```
                    ORG     $+30H
```

{label}	ORG	expression

where:

label — is an optional label which will be equated to the given expression.

expression — a value which will replace the contents of the current segment program counter. Any symbols used in the expression must be previously defined.

PUBLIC — Specify PUBLIC symbols

The PUBLIC directive specifies a list of symbols which will be given the PUBLIC attribute. These symbols will then be made available to other modules to establish the necessary linkage between modules. Only those symbols declared PUBLIC and defined in the assembly are placed in the object module.

The PUBLIC directive may appear anywhere in the program and each symbol may be declared in only one PUBLIC directive.

Example:

```
                        PUBLIC   SCAN,LABEL,SYMBOL
```

{label}	PUBLIC	symbol list

where:

label — is an optional label which will be assigned the address of the next instruction.

symbol list — is a list of symbols separated by commas which specify the PUBLIC names available to other modules.

EXTRN — Specify External Symbols

The EXTRN directive specifies a list of symbols which will be given the EXTRN attribute. These are symbols that are referenced in this program module but defined within another program. This directive provides the linkage to those symbols through the Linking Loader.

The EXTRN directive may appear anywhere in the program and each symbol may be declared in only one EXTRN directive.

Example:

```
                    EXTRN  INPUT,OUTPUT
```

{label}	EXTRN	symbol list

where:

label - is an optional label which will be assigned the address of the next instruction.

symbol list - is a list of symbols separated by commas which specify the EXTRN names available in other modules.

NAME — Specify Module Name

The NAME directive is used to assign a name to the object module produced by the assembly. Only one NAME directive may appear in a program. The module name is a handle used by the Linking Loader when combining programs.

If no NAME directive is specified by the user the default name "MODULE" is used.

Example:

```
                                NAME    MULT
```

{label}	NAME	name

where:

label - is an optional label which will be assigned the address of the next instruction

name - is the name to be placed in the object module to denote the module name to the Loader. This name must follow all the rules of a symbol.

STKLN — Specify Stack Length

The STKLN directive allows the user to specify the length of the STACK segment generated by the Linking Loader. Typically this directive is only used in the main program but other programs may also specify a stack length. The Loader combines all STACK segments into one segment.

If the user does not specify a STKLN directive the assembler uses a default length of zero. More than one STKLN directive may be placed in a program, only the last one is used.

Example:

```
STKLN   20H
```

{label}	STKLN	expression

where:

label - is an optional label which will be assigned the address of the next instruction.

expression - an expression which indicates the length of the stack segment. This expression may not contain an relocatable symbols.

HOW TO USE THE ASSEMBLER

The Assembler

The Assembler program is usually supplied as an unlabeled unblocked magnetic tape with 80 character card image records. Other media may be requested.

The Assembler is written entirely in Fortran and is comprised of a main program and several subroutines. The main program appears first on the tape and the last subroutine is followed by a tape mark. The Assembler may be compiled from the tape.

The Assembler Installation Notes describe program installation and any modification that may have to take place for a particular computer. It is helpful to read these notes before installing the program.

Assembler Operation

The Assembler is a two pass Assembler wherein the source code is scanned twice. During the first pass the labels are examined and placed into a symbol table. Certain errors may be detected during Pass One; these will be displayed on the output listing.

During Pass Two, the object code is completed, symbolic addresses resolved, a listing and object module are produced. Certain errors, not detected during Pass One may be detected and displayed on the listing.

At the end of the Assembly process a symbol table or cross reference table may be displayed.

The following steps are taken to assemble a source program:

1. Write a program utilizing instruction mnemonics and directives. Encode the arguement fields with constants labels, symbolic addresses, etc.

2. Transfer the source program to some computer readable medium; cards, tape, etc. This medium should correspond to the input device expected by the Assembler. On some systems, device assignments may be changed during the course of an assembly by utilizing proper system control cards.

3. Include the source code as shown in the sequence in Illustration I.

4. Execute the Assembler Program.

5. Get listing and object module as output.

Assembler Listing

During Pass Two of the assembly process a program listing is produced. The listing displays all information pertaining to the assembled program; both assembled data and the users original source statements.

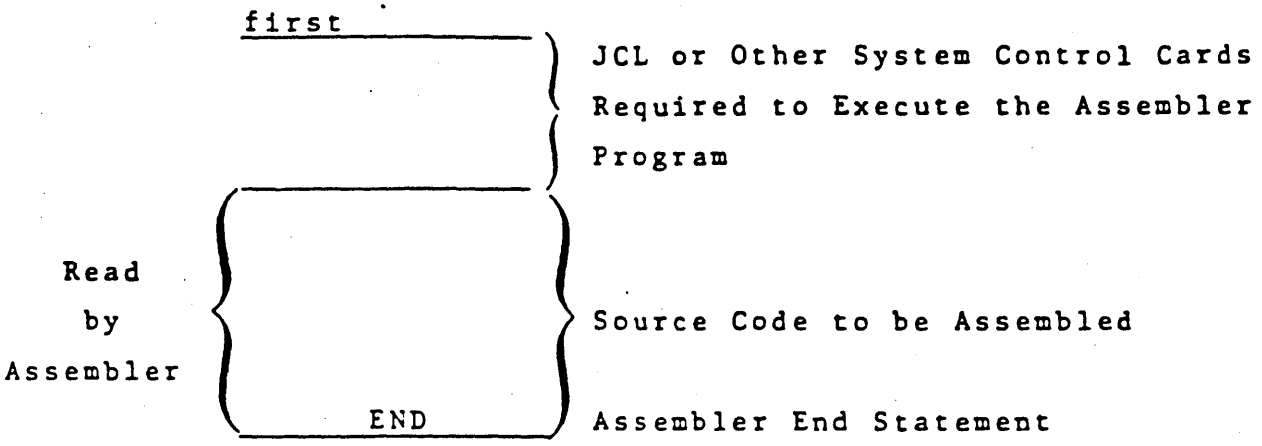
The listing may be used as a documentation tool through the inclusion of the comments and remarks that describe the function of the particular program segment.

The main purpose of the listing is to convey all pertinent information about the assembled program, i.e. the memory addresses and their contents. The load module, also produced during Pass Two, contains the address and content information but in a format that can be read only with great effort.

CARD ORDER

Illustration I

Read the Input Stream



The illustration on page 7-6 is a sample of a typical program listing. Referring to the listing illustration, the following information is pertinent:

- The assembler may detect error conditions during the assembly process. The column titled "ERR" will contain the error code(s) should the assembler detect one or more errors in the associated line or source code. An explanation of the individual error codes is given in Appendix A.

- The column titled "LINE" contains decimal numbers which are associated with the listing line numbers. The maximum number of lines is a source program is 9999.

- The column titled "ADDR" contains a value which represents the first memory address of the data shown in bytes one to four on a given line or the value of an EQU or SET directive. The hexadecimal number under B1 represents one byte of data to be stored in the memory address. If there is a number under B2 it represents data to be stored in the given memory address plus one. Columns B3 and B4, if they contain a number, similarly represent data to be stored in the memory address plus two or three.

- To the right of the data bytes are the relocation types of any relocatable operands. The types are as follows: C - code, D - data, S - stack, M - memory, E - external.

- The users original source statements are reproduced without alteration to the right of the above information. Macro expansions are preceded with a plus sign.

- At the end of the listing the assembler prints the message "ASSEMBLER ERRORS = " with a cumulative count of errors. The assembler substitutes three bytes of NOP's when it cannot translate a particular opcode and so provides room for patching the program if desired.

- A symbol table or cross reference table is generated at the end of each assembly listing that lists all symbols utilized in alphabetic order along with any relocatable symbol types.

```
       1                                   * INPUT IS FREE FORMAT
       2                                            NAME      SAMPLE                    ;SET PROGRAM NAME
       3                                            LIST      X                         ;GET A CROSS REFERENCE TABLE
       4                                            PUBLIC    STOR1,STOR2               ;DECLARE PUBLICS
       5                                            EXTRN     E1,E2                     DECLARE EXTERNALS
       6                                   * EXAMPLE OF MACRO CAPABILITY
       7                                   MAC1     MACRO     X,Y
       8                                            SUI       22
       9                                            MOV       X,Y
      10                                            CMA
      11                                            LXI       X,'A'
      12                                            ENDM
      13                                   ;
      14                                   ; EXAMPLE OF VARIOUS ASSEMBLER ERRORS
      15                                   ;
 O    16  0000  00 00 00                   STAR     RAC                                 UNDEFINED OPCODE
 V    17  0003  C6 2C                               ADI       300                       ILLEGAL VALUE
 U    18  0005  40                                  MOV       C,F                       UNDEFINED SYMBOL
M     19                                            EQU       15                        MISSING LABEL
L     20  0006  00 00 00                   AB+C     RAL       LABEL ERROR
 S    21  0009  40                                  MOV       C D                       SYNTAX ERROR
 S    22  000A  C3 00 00                            JMP       STAR++5                   SYNTAX ERROR
 R    23  000D  0A                                  LDAX      H                         ILLEGAL REGISTER FOR LDAX
 F    24  000E  D6 16                               SUI       22,                       FORMAT ERROR
D     25  0010  2F                         STAR     CMA                                 MULTIPLE DEFINED LABEL
 A    26  0011  06 00                               MVI       D,                        ARGUMENT ERROR
 E    27  0013  01 00 00                            LXI       H,SUB*5                   RELOCATION ERROR
      28                                   * ASSEMBLER DIRECTIVES
      29                                            DSEG                                ;SET DATA SEGMENT
      30                                            ORG       100                       ;SET ORIGIN
      31  0001                             ONE      EQU       1                         EQUATE 1 AND ONE
      32  0064  38 30 38 30                         DB        '8080/8085'               DEFINE A STRING
      33  0068  2F 38 30 38
      34  006C  35
      35  006D                             SUM:     DS        5                         RESERVE STORAGE
      36  0072  00 00                      STOR1:   DW        STAR                      DEFINE A WORD
      37  0074  17                         STOR2    DB        23,48                     DEFINE DATA
      38  0075  30
      39                                            CSEG                                ;SET CODE SEGMENT
      40                                   * EXAMPLE OF THE VARIOUS INSTRUCTIONS
      41  0000  78                         BEG:     MOV       A,B
      42  0001  76                                  HLT
      43  0002  0E 42                               MVI       C,'B'                     LOAD ASCII CHARACTER B
      44  0004  04                                  INR       B
      45  0005  BE                                  CMP       M
      46  0006  C3 04 00       E                    JMP       E1+4                      ;EXTERNAL REFERENCE
      47  0009  17                                  RAL
      48  000A  C3 00 00       C                    JMP       BEG
      49  000D  31 00 00       S                    LXI       SP,STACK
      50  0010  CD 40 00       C                    CALL      $+48                      LOCATION COUNTER REFERENCE
      51  0013  C9                         SUB      RET
      52  0014  DB 15                               IN        25Q                       OCTAL CONSTANT
      53  0016  11 72 00       D                    LXI       D,SUM+5
      54  0019  32 78 00       D                    STA       SUM+1011B                 BINARY CONSTANT
```

```
 55  001C  EB                          XCHG
 56  001D  06 6D          D            MVI     B,>SUM              ;LOWER 8 BITS
 57  001F  0E 00          D            MVI     C,.HIGH.SUM         ;UPPER 8 BITS
 58                             *
 59                             *
 60  0001                       CONTRL  SET 1
 61  0021  80                   MAIN    ADD     B
 62  0022                               MAC1    B,C                 CALL MACRO MAC1
 63  0022  D6 16                *       SUI     22
 64  0024  41                   *       MOV     B,C
 65  0025  2F                   *       CMA
 66  0026  01 41 00             *       LXI     B,'A'
 67  0029  4E 4F 50                     DATA    'NOP',0
 68  002C  00
 69                                     NLIST   M                   DON'T EXPAND NEXT CALL
 75                                     IF      CONTRL=1            CONDITIONAL ASSEMBLY
 76                                     MVI     A,6
 77                                     XCHG
 78                                     ELSE
 79  0034  21 22 00                     LXI     H,22H
 80  0037  C3 21 00          C          JMP     MAIN
 81                                     ENDIF
 82                                     IF      CONTRL
 83  003A  3E FF                        MVI     A,-1
 84  003C  EB                           XCHG
 85                                     ELSE
 86                                     LXI     H,0FFFFH
 87                                     JMP     MAIN
 88                                     ENDIF
 89  003D                               END

ASSEMBLER ERRORS =   12
```

CROSS REFERENCE

LABEL		VALUE	REFERENCE				
A		0007	0				
B		0000	0				
BEG	C	0000	-41	48			
C		0001	0				
CONTRL		0001	-60	75	82		
D		0002	0				
E		0003	0				
E1	E	0000	5	46			
E2	E	0001	5				
H		0004	0				
L		0005	0				
M		0006	0				
MAIN	C	0021	-61	80			
MEMORY	M	0000	0				
ONE		0001	-31				
PSW		0006	0				
SP		0006	0				
STACK	S	0000	0				
STAR		0000	-16	22	-25	36	
STOR1	D	0072	4	-36			
STOR2	D	0074	4	-37			
SUB	C	0013	27	-51			
SUM	D	006D	-35	53	54	56	57

The Object Module

As part of the Pass Two processing, the assembler produces an object module. The object module is a machine readable computer output in the form of punched cards, paper tape, etc. The output module contains specifications for loading the memory of the target microprocessor and provide the necessary linkage to link object modules together.

The object module is normally punched out on the device specified. However, through use of the LIST and NLIST directives all or part of the output may be deleted.

The object module is produced as a series of card images on the output punch device. The object module is compatible with Intel's relocatable format although it is produced in a readable as opposed to binary format.

The object module may be loaded into Microtec's Linking Loader which will then convert it to an absolute program in Intel's standard hexadecimal format. This may then be loaded into a development system or used to program a PROM.

A program is available from Microtec which will convert the output of this assembler into a format directly usable by Intel's MDS LINK and LOCATE commands. This program is provided on a diskette and executes on the Intel MDS system.

A sample object module is shown on the following page. This is the object module of the sample program shown on the preceding pages.

```
1620000272000 6STOR1*00740006STOR2*00F1
0634000000000000000C62C400000004^C300000AD6162F060001000065
061A00026400383038302F3830383SA6
0610000272000000017302F
0634000100007876OE4204BEC3040017C30000310000CD4000C9DB152D
220C00030B00110083
240A0003030E00BE
200C000300000700CA
0616000116001172003278OOE8B5
240E00020317001A0098
060C00011D00066D5D
240A0002011E00B1
063E00011F000E0080D616412F0141004E4F5000D616532F11410021220OC321009C
22080003380098
240A0002022000AE
060E00013A003EFFE889
040A0000010000F1
0E0200F0
```

Cross Reference Format

The cross reference option is normally turned off. To turn is on use "LIST X", to turn it off again use "NLIST X" (see LIST and NLIST directives). The assembler will produce either a cross reference table or a symbol table. The cross reference table will be produced if "LIST X" has been specified. References may only be accumulated during particular portions of the program by turning the cross reference option on and off. However, to get the listing of cross references, the option must be turned on before the END statement. Typically the "LIST X" directive will be one of the first statement in the source and never turned off.

An example of the cross reference output is as follows:

LABEL		VALUE	REFERENCE		
A		0007	0		
ABC		F45A	-4	15	35
MAIN	C	0000	35		
TABLE		051C	-6	34	-54

LABEL and VALUE are self explanatory. Any flags on the left of the value are the relocation types of the symbol. Under REFERENCE, a value preceded by a minus sign indicates that the symbol was defined on that line. A value of Ø as the only entry on the line indicates this is an internal system symbol (e.g. A,B,C, ...). Line numbers not preceded by a minus sign indicate a reference to the symbol. Note that for SET symbols, move than one definition may appear for a given symbol as in TABLE above.

APPENDIX A

ASSEMBLER ERROR CODES

If errors in the source code are detected during the assembly process, an indication of the type of error is printed on the listing on the same line as the statement in error.

The following list should serve as a guide to diagnose the error. The listing always displays a total error count.

A - Argument error. The argument is missing or contains an illegal character.

C - Macro Substitution error. When substituting actual macro parameters for formal macro paramters, the 80 column source line limit was exceeded.

D - Duplicate Label error. The label in the statement has previously appeared in the label field. A label on SET directive previously appeared in a statement other than a SET or a label on a statement other than a SET statement now appears on a SET statement. A label appears more than once in an EXTRN or PUBLIC directive or a symbol defined in an EXTRN directive appears in the label field of some statement.

E - Relocation error. The instruction contains an operand that violates a rule of relocation. An operand that should be absolute is relocatable or an EQU or SET directive make reference to an external symbol.

F - Format error. The instruction has been written in a format which is not permitted. This error usually indicates a trailing comma and the instruction is assembled properly.

L - Label error. A label contains an invalid character of starts with a numeric character.

M - Missing Label. This statement requires a label.

N - Macro Nesting error. When nesting macros the available number of levels was exceeded.

O - Opcode error. The opcode mnemonic has not been recognized as a valid mnemonic, directive, or a macro call. Also a macro defined within another macro or conditional statements nested too deeply. ELSE, ENDIF, or ENDM used without preceding IF or MACRO. LOCAL directive used outside of MACRO body or more than one NAME directive in a program.

R - Register error. The register expression could not be evaluated or when evaluated was greater than 7 or less than 0. The register field was not found or a specified register is not valid for the given opcode.

S - Syntax error. A rule of syntax has been violated in the statement. Parenthesis are not nested properly or possibly two operators appear in sequence.

T - Table overflow. Symbol table is full - assembly continues. An attempt was made to define too many macros or too many parameters in nested macro calls.

U - Undefined symbol. There is a symbolic name in the operand field which has never been in the label field. The symbol should have been previously defined for certain directives and was not but may have been defined after the directive.

V - Value error. An evaluated expression or constant is out of range for the field of the actual machine instruction in which it is to be contained. A one byte value is relocatable but was not preceded by a .LOW. or .HIGH. operator. In this case it is forced .LOW.

CROSS REFERENCE OVERFLOW AT ____. The cross reference file has been filled. Assembly continues and references are not accumulated past this line. This message appears in the cross reference table listing. Enlarge cross reference file space or turn references off for sections of the program.

APPENDIX B

ASCII AND EBCDIC CODES

The Assembler will recognize only the following characters. The equivalent codes are expressed in hexadecimal notation.

CHARACTER	ASCII	EBCDIC	CHARACTER	ASCII	EBCDIC
Ø	3Ø	FØ	V	56	E5
1	31	F1	W	57	E6
2	32	F2	X	58	E7
3	33	F3	Y	59	E8
4	34	F4	Z	5A	E9
5	35	F5			
6	36	F6	blank	2Ø	4Ø
7	37	F7	!	21	5A
8	38	F8	"	22	7F
9	39	F9	#	23	7B
			$	24	5B
A	41	C1	%	25	6C
B	42	C2	&	26	5Ø
C	43	C3	'	27	7D
D	44	C4	(	28	4D
E	45	C5	)	29	5D
F	46	C6	*	2A	5C
G	47	C7	+	2B	4F
H	48	C8	,	2C	6B
I	49	C9	-	2D	6Ø
J	4A	D1	.	2E	4B
K	4B	D2	/	2F	61
L	4C	D3			
M	4D	D4	:	3A	7A
N	4E	D5	;	3B	5E
O	4F	D6	<	3C	4C
P	5Ø	D7	=	3D	7E
Q	51	D8	>	3E	6E
R	52	D9	?	3F	6F
S	53	E2	@	4Ø	7C
T	54	E3			
U	55	E4			

APPENDIX C

8080/8085 OPERATION CODES

The following table illustrates the proper format for writing 8080/8085 instructions. The operation code mnemonics listed are the only valid opcodes for the assembler.

These symbols are used in the table.

D,S - indicates a source or destination register which is one of the following: A,B,C,D,E,H,L,M

RP - indicates a register pair which may be one of the following: B,D,H,SP

PSW - indicates the Program Status Word

exp_8 - indicates an 8 bit value

exp_{16} - indicates a 16 bit value

ddd
sss - the bit pattern representing one of the registers denoted by D or S above. The bit patterns are as follows:

B - 000	C - 001	D - 010
E - 011	H - 100	L - 101
M - 110	A - 111	

rp - the bit pattern representing one of the register pairs denoted by RP above. The bit patterns are as follows:

B - 00	D - 01	H - 10	SP - 11

* - new instruction of 8085

When two states are shown for an instruction, the first number is if the condition is not satisfied and the second number is if the condition is satisfied.

SYMBOLIC OPCODE	FIRST BYTE MACHINE CODE	NUMBER OF BYTES	NUMBER OF STATES	
			8080	8085
Data Transfer				
MOV D,S	01dddsss	1	5	4
MOV D,M	01ddd110	1	7	7
MOV M,S	01110sss	1	7	7
MVI D,exp_8	00ddd110	2	7	7
MVI M,exp_8	00110110	2	10	10
LXI RP,exp_{16}	00rp0001	3	10	10
LDA exp_{16}	00111010	3	13	13
STA exp_{16}	00110010	3	13	13
LHLD exp_{16}	00101010	3	16	16
SHLD exp_{16}	00100010	3	16	16
LDAX RP	00rp1010	1	7	7
STAX RP	00rp0010	1	7	7
XCHG	11101011	1	4	4
Arithmetic Group				
ADD S	10000sss	1	4	4
ADC S	10001sss	1	4	4
SUB S	10010sss	1	4	4
SBB S	10011sss	1	4	4
ADI exp_8	11000110	2	7	7
ACI exp_8	11001110	2	7	7
SUI exp_8	11010110	2	7	7
SBI exp_8	11011110	2	7	7
INR D	00ddd100	1	5	4
DCR D	00ddd101	1	5	4
INX RP	00rp0011	1	5	6
DCX RP	00rp1011	1	5	6
DAD RP	00rp1001	1	10	10
DAA	00100111	1	4	4
Logical Group				
ANA S	10100sss	1	4	4
XRA S	10101sss	1	4	4
ORA S	10110sss	1	4	4
CMP S	10111sss	1	4	4
ANI exp_8	11100110	2	7	7
XRI exp_8	11101110	2	7	7
ORI exp_8	11110110	2	7	7
CPI exp_8	11111110	2	7	7
RLC	00000111	1	4	4
RRC	00001111	1	4	4
RAL	00010111	1	4	4
RAR	00011111	1	4	4
CMA	00101111	1	4	4
CMC	00111111	1	4	4
STC	00110111	1	4	4

SYMBOLIC OPCODE	FIRST BYTE MACHINE CODE	NUMBER OF BYTES	NUMBER OF STATES	
			8080	8085
Branch Group				
JMP exp_{16}	11000011	3	10	10
JNZ exp_{16}	11000010	3	10	7/10
JZ exp_{16}	11001010	3	10	7/10
JNC exp_{16}	11010010	3	10	7/10
JC exp_{16}	11011010	3	10	7/10
JPO exp_{16}	11100010	3	10	7/10
JPE exp_{16}	11101010	3	10	7/10
JP exp_{16}	11110010	3	10	7/10
JM exp_{16}	11111010	3	10	7/10
CALL exp_{16}	11001101	3	17	18
CNZ exp_{16}	11000100	3	11/17	9/18
CZ exp_{16}	11001100	3	11/17	9/18
CNC exp_{16}	11010100	3	11/17	9/18
CC exp_{16}	11011100	3	11/17	9/18
CPO exp_{16}	11100100	3	11/17	9/18
CPE exp_{16}	11101100	3	11/17	9/18
CP exp_{16}	11110100	3	11/17	9/18
CM exp_{16}	11111100	3	11/17	9/18
RET	11001001	1	10	10
RNZ	11000000	1	5/11	6/12
RZ	11001000	1	5/11	6/12
RNC	11010000	1	5/11	6/12
RC	11011000	1	5/11	6/12
RPO	11100000	1	5/11	6/12
RPE	11101000	1	5/11	6/12
RP	11110000	1	5/11	6/12
RM	11111000	1	5/11	6/12
RST A	11aaa111	1	11	12
PCHL	11101001	1	5	6
Stack, I/O and Machine Control Group				
PUSH RP	11rp0101	1	11	12
PUSH PSW	11110101	1	11	12
POP RP	11rp0001	1	10	10
POP PSW	11110001	1	10	10
XTHL	11100011	1	18	16
SPHL	11111001	1	5	6
IN exp_8	11011011	2	10	10
OUT exp_8	11010011	2	10	10
EI	11111011	1	4	4
DI	11110011	1	4	4
HLT	01110110	1	7	5
NOP	00000000	1	4	4
RIM	00100000	1	*	4
SIM	00110000	1	*	4

APPENDIX D

HEXADECIMAL NOTATION

Hexadecimal notation is a convenient way to express binary information. Each hexadecimal digit may be though of as representing the information in four binary bits.

The assembled code is expressed in hexadecimal notation on the output listing. Hexadecimal is the name of the base 16 number system.

DECIMAL	HEXADECIMAL	BINARY
Ø	Ø	ØØØØ
1	1	ØØØ1
2	2	ØØ1Ø
3	3	ØØ11
4	4	Ø1ØØ
5	5	Ø1Ø1
6	6	Ø11Ø
7	7	Ø111
8	8	1ØØØ
9	9	1ØØ1
1Ø	A	1Ø1Ø
11	B	1Ø11
12	C	11ØØ
13	D	11Ø1
14	E	111Ø
15	F	1111

Appendix E

HEXADECIMAL-DECIMAL CONVERSION TABLE

This table allows conversions to b made between hexadecimal and decimal numbers. The ta has a decimal range of 0 to 4095. To convert larger numbers add the following values to the table values.

Hexadecimal	Decimal
1000	4096
2000	8192
3000	12228
4000	16384
5000	20480
6000	24576
7000	28672
8000	32768
9000	36864
A000	40960
B000	45056
C000	49152
D000	53248
E000	57344
F000	61440

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
000	0000	0001	0002	0003	0004	0005	0006	0007	0008	0009	0010	0011	0012	0013	0014	0015
010	0016	0017	0018	0019	0020	0021	0022	0023	0024	0025	0026	0027	0028	0029	0030	0031
020	0032	0033	0034	0035	0036	0037	0038	0039	0040	0041	0042	0043	0044	0045	0046	0047
030	0048	0049	0050	0051	0052	0053	0054	0055	0056	0057	0058	0059	0060	0061	0062	0063
040	0064	0065	0066	0067	0068	0069	0070	0071	0072	0073	0074	0075	0076	0077	0078	0079
050	0080	0081	0082	0083	0084	0085	0086	0087	0088	0089	0090	0091	0092	0093	0094	0095
060	0096	0097	0098	0099	0100	0101	0102	0103	0104	0105	0106	0107	0108	0109	0110	0111
070	0112	0113	0114	0115	0116	0117	0118	0119	0120	0121	0122	0123	0124	0125	0126	0127
080	0128	0129	0130	0131	0132	0133	0134	0135	0136	0137	0138	0139	0140	0141	0142	0143
090	0144	0145	0146	0147	0148	0149	0150	0151	0152	0153	0154	0155	0156	0157	0158	0159
0A0	0160	0161	0162	0163	0164	0165	0166	0167	0168	0169	0170	0171	0172	0173	0174	0175
0B0	0176	0177	0178	0179	0180	0181	0182	0183	0184	0185	0186	0187	0188	0189	0190	0191
0C0	0192	0193	0194	0195	0196	0197	0198	0199	0200	0201	0202	0203	0204	0205	0206	0207
0D0	0208	0209	0210	0211	0212	0213	0214	0215	0216	0217	0218	0219	0220	0221	0222	0223
0E0	0224	0225	0226	0227	0228	0229	0230	0231	0232	0233	0234	0235	0236	0237	0238	0239
0F0	0240	0241	0242	0243	0244	0245	0246	0247	0248	0249	0250	0251	0252	0253	0254	0255

HEXADECIMAL-DECIMAL INTEGER CONVERSION (Cont'd)

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
A00	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	257
A10	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	259
A20	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	260
A30	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	262
A40	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	263
A50	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	265
A60	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	267
A70	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	268
A80	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	270
A90	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	271
AA0	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	273
AB0	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	275
AC0	2752	2753	2754	2755	2756	2757	2758	2759	2760	4761	2762	2763	2764	2765	2766	276
AD0	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	278
AE0	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	279
AF0	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	281
B00	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	283
B10	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	284
B20	2848	2849	2850	3851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	286
B30	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	287
B40	2880	2881	2882	2883	2884	2885	2866	2887	2888	2889	2890	2891	2892	2893	2894	289
B50	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	291
B60	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	292
B70	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	294
B80	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	295
B90	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	297
BA0	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	299
B80	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	300
BC0	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	302
BD0	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	303
BE0	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	305
BF0	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	307
C00	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	308
C10	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	310
C20	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	311
C30	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	313
C40	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	315
C50	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	316
C60	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	318
C70	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	319
C80	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	321
C90	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	323
CA0	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	324
CB0	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	326
CC0	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	327
CD0	3280	3281	3282	3283	3284	3285	3286	3287	3288	3289	3290	3291	3292	3293	3294	329
CE0	3296	3297	3298	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	3309	3310	331
CF0	3312	3313	3314	3315	3316	3317	3318	3319	3320	3321	3322	3323	3324	3325	3326	333

HEXADECIMAL-DECIMAL INTEGER CONVERSION (Cont'd)

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
D00	3328	3329	3330	3331	3332	3333	3334	3335	3336	3337	3338	3339	3340	3341	3342	3343
D10	3344	3345	3346	3347	3348	3349	3350	3351	3352	3353	3354	3355	3356	3357	3358	3359
D20	3360	3361	3362	3363	3364	3365	3366	3367	3368	3369	3370	3371	3372	3373	3374	3375
D30	3376	3377	3378	3379	3380	3381	3382	3383	3384	3385	3386	3387	3388	3389	3390	3391
D40	3392	3393	3394	3395	3396	3397	3398	3399	3400	3401	3402	3403	3404	3405	3406	3407
D50	3408	3409	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420	3421	3422	3423
D60	3424	3425	3426	3427	3428	3429	3430	3431	3432	3433	3434	3435	3436	3437	3438	3439
D70	3440	3441	3442	3443	3444	3445	3446	3447	3448	3449	3450	3451	3452	3453	3454	3455
D80	3456	3457	3458	3459	3460	3461	3462	3463	3464	3465	3466	3467	3468	3469	3470	3471
D90	3472	3473	3474	3475	3476	3477	3478	3479	3480	3481	3482	3483	3484	3485	3486	3487
DA0	3488	3489	3490	3491	3492	3493	3494	3495	3496	3497	3498	3499	3500	3501	3502	3503
DB0	3504	3505	3506	3507	3508	3509	3510	3511	3512	3513	3514	3515	3516	3517	3518	3519
DC0	3520	3521	3522	3523	3524	3525	3526	3527	3528	3529	3530	3531	3532	3533	3534	3535
CC0	3536	3537	3538	3539	3540	3541	3542	3543	3544	3545	3546	3547	3548	3549	3550	3551
DE0	3552	3553	3554	3555	3556	3557	3558	3559	3560	3561	3562	3563	3564	3565	3566	3567
DF0	3568	3569	3570	3571	3572	3573	3574	3575	3576	3577	3578	3579	3580	3581	3582	3583
E00	3584	3585	3586	3587	3588	3589	3590	3591	3592	3593	3594	3595	3596	3597	3598	3599
E10	3600	3601	3602	3603	3604	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614	3615
E20	3616	3617	3618	3619	3620	3621	3622	3623	3624	3625	3626	3627	3628	3629	3630	3631
E30	3632	3633	3634	3635	3636	3637	3638	3639	3640	3641	3642	3643	3644	3645	3646	3647
E40	3648	3649	3650	3651	3652	3653	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663
E50	3664	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	3675	3676	3677	3678	3679
E60	3680	3681	3682	3683	3684	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	3695
E70	3696	3697	3698	3699	3700	3701	3702	3703	3704	3705	3706	3707	3708	3709	3710	3711
E80	3712	3713	3714	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725	3726	3727
E90	3728	3729	3730	3731	3732	3733	3734	3735	3736	3737	3738	3739	3740	3741	3742	3743
EA0	3744	3745	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	3756	3757	3758	3759
EB0	3760	3761	3762	3763	3764	3765	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775
EC0	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786	3787	3788	3789	3790	3791
ED0	3792	3793	3794	3795	3796	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	3807
EE0	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817	3818	3819	3820	3821	3822	3823
EF0	3824	3825	3826	3827	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	3838	3839
F00	3840	3841	3842	3843	3844	3845	3846	3847	3848	3849	3850	3851	3852	3853	3854	3855
F10	3856	3857	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	3868	3869	3870	3871
F20	3872	3873	3874	3875	3876	3877	3878	3879	3880	3881	3882	3883	3884	3885	3886	3887
F30	3888	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	3899	3900	3901	3902	3903
F40	3904	3905	3906	3907	3908	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	3919
F50	3920	3921	3922	3923	3924	3925	3926	3927	3928	3929	3930	3931	3932	3933	3934	3935
F60	3936	3937	3938	3939	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	3950	3951
F70	3952	3953	3954	3955	3956	3957	3958	3959	3960	3961	3962	3963	3964	3965	3966	3967
F80	3968	3969	3970	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	3981	3982	3983
F90	3984	3985	3986	3987	3988	3989	3990	3991	3992	3993	3994	3995	3996	3997	3998	3999
FA0	4000	4001	4002	4003	4004	4005	4006	4007	4008	4009	4010	4011	4012	4013	4014	4015
FB0	4016	4017	4018	4019	4020	4021	4022	4023	4024	4025	4026	4027	4028	4029	4030	4031
FC0	4032	4033	4034	4035	4036	4037	4038	4039	4040	4041	4042	4043	4044	4045	4046	4047
FD0	4048	4049	4050	4051	4052	4053	4054	4055	4056	4057	4058	4059	4060	4061	4062	4063
FE0	4064	4065	4066	4067	4068	4069	4070	4071	4072	4073	4074	4075	4076	4077	4078	4079
FF0	4080	4081	4082	4083	4084	4085	4086	4087	4088	4089	4090	4091	4092	4093	4094	4095

ASSEMBLER INSTALLATION NOTES

These notes are designed to help the user install the Assembler and perform any modifications needed for a particular computer. The notes are separated into six sections: Program Installation; Program Modifications; Program I/O; Memory Requirements and Overlays; Cross Reference Notes; and NOVA Modifications.

A. Program Installation

1. The Assembler should be compiled once and its object module stored on some secondary device (disk). Compile the program in the usual manner, assigning it a name which can be refered to by an Execute or Run command for the computer. If upon loading the compiled program it is discovered that not enough main memory is available to hold the entire program, refer to the section describing Overlay Structures.

B. Program Modifications

1. Some computers do not accept the full ASCII character set. Therefore, some of the characters defined in Subroutine INIT may by illegal and give a compilation error. If this is the case on your computer, the illegal characters must be replaced by legal characters. If the characters are not used in the microprocessor assembly language (e.g. double quote), they may be replaced with blanks. If the illegal characters are used in the assembly language (e.g. greater than sign), replace each illegal character with a unique legal character and use the new character in place of the old, illegal character. The character arrays that need to be changed are in Subroutine INIT and are marked with comments.

2. The variable IBIT corresponds to the number of bits per word in the host computer. IBIT is initially set to 16. This variable determines how many characters are packed into one host computer word for symbols stored in the Assembler symbol table. The user may want to increase this variable if his machine has a longer word length. Increasing IBIT will allow a larger number of symbols to be stored in a fixed amount of memory. When initially installing the program, it is suggested that IBIT be left at 16 until the program is known to be operating correctly.

3. To increase the size of the symbol table and thus the number and length of the symbols the symbol table can hold, the user must change certain variables. The variables that must be changed depend on the number of bits per host computer word (see 2), the number of symbols in the symbol table, and the number of characters used to define a symbol. The variables that define these parameters are described below.

IBIT - number of bits per host computer word (set by user)
MLAB - maximum lable length in characters (set by user)
ICCNT - number of characters per host computer word (calculated)
IWORD - number of computer words per symbol (calculated)
LTAB - length of symbol table (set by user)

The user must change the following variables to reflect the size of the symbol table and the length of a symbol. The arrays are in COMMON, and therefore, the dimensions need to be changed in every Subroutine.

ITAB(IWORD,LTAB)
ITABV(LTAB)
ITABS(LTAB)
NAME(IWORD)

where: IWORD = 1+(MLAB-1)/ICCNT
ICCNT = IBIT/8

4. To increse the number of macros that may be defined, the following variables must be modified:

```
MXMAC - maximum macro count (set by user)
MDISK(MXMAC)
MPARC(MXMAC)
MCNAM(IWORD,MXMAC)
```

5. The number of columns of the input source statement that is written to the output listing is defined by the variable MLCOL in Subroutine INIT. MLCOL should be set to the maximum width of the users printer output device minus 35 (width-35). The maximum value of MLCOL is 80 which corresponds to the full source statement. The default value of MLCOL is 72.

C. Program Input/Output

1. The logical I/O device assignments assumed in the Assembler Program are:

```
IPCH  = 4  (object module device, typcially punch device)
ICRD  = 5  (input device, typically card reader)
IPRT  = 6  (listing device, typically a printer)
IMFLE = 7  (intermediate source file, disk or tape)
MCFLE = 8  (macro source file, disk)
```

These device assignments may have to be changed for your system. This may be done in either the Job Control Stream or in the program itself. If the device assignments are to be changed in the program, the variables may be found in Subroutine INIT.

2. Reading and writing to a bulk storage device such as a disk is not standard in FORTRAN. There are however, two usual methods to perform this operation. Method 1 uses a DEFINE FILE statement and standard READ and WRITE statements as follows:

```
DEFINE FILE 7(1000,95,U,IMREC)
WRITE(IMFLE'IMREC) LIST
READ (IMFLE'IMREC) LIST
```

where: IMFLE = 7 - is the file number of logical device
1000 - is the maximum number of records
95 - is the record size in words
U - indicates a binary record
IMREC - indicates the record number (associated variable)
LIST - list of variables to read or write

Method 2 uses a CALL to an executive or system routine to process the disk read or write. For a typical computer this is as follows:

```
CALL EXEC(#,CODE,IBUF,CNT,NAME,IMREC)
```

where: # - indicates the type of call, read or write
CODE - indicates binary or formatted I/O, etc.
IBUF - start of variables to read or write
NAME - is typically a dimensioned array which contains the name of the disk file. This name is then used in the Job Control Stream to allocate disk storage.
IMREC - disk record number

The Assembler Program uses Method 1 above as the standard method. However, statements for Method 2 are included in the program as comment statements for informative purposes.

3. All Program I/O activity except for generation of the output listing is done in Subroutine INOUT. This includes the reads and writes of the Intermediate files, reading the source input, and writing the output object module.

4. There are alternative ways of passing relocatable object modules from the Assembler to the Loader. The relocatable object modules could be written to a card punch, paper tape punch, or a tape unit by the Assembler, and read back by the Loader. Or, the relocatable modules could be saved on disk files by the Assembler. If object

modules are passed from the Assembler to the Loader via disk files, the user must chose how to name the relocatable object module files generated by the Assembler. Three alternative methods are:

a. The Assembler produces the object module on the same file during each assembly. The user must rename the file before another assembly is performed. Usually this can be easily done with a RENAME command in the assembler's Job Control Stream.

b. The Assembler writes the object module to a logical unit number, IPCH, but an ASSIGN Control card is used to equate the logical unit number with a disk file name. The user can vary the file name on the ASSIGN Control card with each assembler run.

c. The Assembler can read the object module file name from an input device and open the specified disk file from the assembler program. If this is done, the file name must be read into an array with a pointer to the array in the system call that opens the file, or in the calls that read and write from the file.

The Assembler program currently writes the object module to a logical device. If the user wishes to open a disk file for the object module from the program, the user must add the necessary code.

5. As previously mentioned, the object module is written to logical device 4. The object record that is written to this unit is contained in array IPBUF which is padded out with blanks to 72 positions. The variable IPLEN indicates how many positions actually contain load information and should be used in a write statement to a sequential file or a paper tape unit to conserve space. This is the output statement used in subroutine

INOUT by the Assembler. When writing to an I/O device that requires fixed length records (many disk units), use the complete 72 positions of array IPBUF. The DEFINE FILE statement shown as a comment in the main program for unit 4 and the disk write statements described in 2 above may have to be used. The object module disk file write may be formatted or unformatted (binary) as long as the read statement in the Loader performs a similar operation.

6. Some examples are shown below of system calls that open disk files and equate the logical device number 4 to the disk file name. If your computer uses these or similar statements they should be placed where the DEFINE FILE statement for logical device 4 is in the main program.

NOVA

```
CALL OPEN(4,"OBJECT",3,IER)
```

PDP-11

```
CALL ASSIGN(4,"OBJECT")
```

On some computers it is easier to assign room for and name a disk file in the Job Control Stream preceding the assembly. No call OPEN is required for a file that already exists, and equating the file to a logical device is not necessary. The name of the file is placed in an array in subroutine INOUT and the array name is placed in an executive call.

HP 2100

```
:ST,B,OBJECT,50                              (in Control Stream)
CALL EXEC(15,1091,IPBUF,72,NAMEP,IOREC)      (in INOUT, NAMEP contains
                                              name of file)
```

7. Some systems require disk space to be allocated for the temporary files used by the assembler, by placing statements in

Job Control Stream. Check to see if this is necessary for your system. The intermediate file (IMFLE) is used to store the source between passes of the Assembler. The macro file (MCLFE) is used to store the macro definitions. If Macros are not used the file associated with MCFLE need not be allocated (however, see section on cross reference tables). It should be noted, that the intermediate disk file could be replaced by any sequential file, such as a magnetic tape file. However, the macro file requires a random access device. If IMFLE is a sequential file, then a REWIND IMFLE statement should be placed in the main program after the CALL PASS1 statement.

8. To avoid a system error if the user fails to place an END directive at the end of the assembly program, the user may detect the end of file on the input device and force an END statement to be placed in the source input. If the READ statement for your particular Fortran allows the End of File condition be be stated, the user may include the following code in Subroutine INOUT.

```
100   READ(ICRD,1000,END=110) IN
      RETURN
110   DO 120 I=1,80
      IN(I) = IBLNK
120   CONTINUE
      IN(6) = ICHRE
      IN(7) = ICHRN
      IN(8) = ICHRD
      RETURN
```

D. Memory Requirements, Overlays, and Chaining

1. If core size is limited, the Assembler programs may have to be Overlayed. One Overlay structure is shown below.

Main	1st Overlay	2nd Overlay
MAIN	INIT	PASS2
SCAN	PASS1	LOUT
LABEL	OPCOD	OUT
SYMBL	MSCAN	ROUT
CONST	MCDEF	SYMTA
INOUT	MCREF	XREFT
		AHEX
		VHEX

A second structure which requires more overlays but reduces memory requirements even more is to place INIT in its own overlay. All routines shown in the 1st overlay above except for INIT in another overlay. PASS2,LOUT,OUT,ROUT and XREFT in another overlay, and SYMTA in a final overlay. In this case AHEX and VHEX should be placed in the Main segment.

2. If a chaining facility is available, the routines shown above in the Main Program may be compiled and loaded with each group of routines in the two overlays, creating two separate programs. The chain command may be used to call in the second program. If this is done, COMMON must usually be saved in the first program on a file and restored in the second program. On some computers this is automatically done by the chaining facility.

3. To aid those users who need to form their own Overlays or to Segment their programs, the following list shows each routine in the Assembler and all the routines that call it.

```
MAIN   -
INIT   - MAIN
INOUT  - PASS1,PASS2,MCDEF,MCREF,ROUT,SYMTA,XREFT
PASS1  - MAIN
PASS2  - MAIN
OPCOD  - PASS1,MCDEF
LABEL  - INIT,PASS1,SCAN
SYMBL  - PASS1,OPCOD,LABEL,MCDEF,MSCAN
SCAN   - PASS1,PASS2
CONST  - SCAN
MCDEF  - PASS1
MCREF  - PASS1
MSCAN  - PASS1,MCDEF
LOUT   - PASS2
OUT    - PASS2
ROUT   - OUT
SYMTA  - MAIN
XREFT  - PASS2,LABEL,SYMTA
VHEX   - LOUT,ROUT
AHEX   - LOUT,SYMTA
```

E. Cross Reference

The cross reference table is accumulated in a memory array and when the array is filled the table is stored on a disk file. However, the variable IXPAG in subroutine INIT may be set to 0, in which case if the memory array becomes full, the table will not be written to disk and further references will not be accumulated but assembly will continue.

2. The standard cross reference table array size is 512 words. Each reference requires 2 words, hence 256 references may be accumulated in memory. To avoid using disk this array may be increased. The variables to change are described below.

3. The number of reference table arrays (memory array of 512 words) that will be written to disk is set at 25. Hence 256*25 references can be accumulated with the standard program. This may also be increased.

4. The disk file that is used to store cross references (if necessary) is the same as the file used for macros. If necessary for some reason, another file may be assigned. The cross reference read and write statements in INOUT may then have to be changed.

5. To increase the page size (memory array) of the cross reference table or total number of pages produced or to not use the disk to store references, the following variables must be changed.

MXREF - size of cross reference memory. The number of references on a page is (MXREF/2). MXREF should be divisible by 128.

IXTAB - cross reference array. Should be set to IXTAB(MXREF)

IXPAG - total number of pages of size MXREF that will be written before accumulating references stops. If IXPAG=0 then no pages will be written to disk and references will only be accumulated in memory.

F. NOVA Modifications

When installing the Assembler on a NOVA Computer, it is suggested that Fortran V be used. If Fortran IV is used, some additional program modificaitons have to be made.

1. Most versions of NOVA Fortran fill an H data specificaiton statement with zeros and not blanks, as is typically done. Therefore, characters read in under A formats must have the padded blanks stripped off. Insert the following statements after Fortran Statement 100 in INOUT.

```
      DO 105 I=1,80
      IN(I) = IN(I).AND.-256
105   CONTINUE
```

2. All variables initialized in DATA statements must be placed in Labeled COMMON. The variables are local to each Subroutine, so unique dummy labels may be used for the COMMON Block names.

3. The DEFINE FILE statements in the Main program must be replaced with CALL OPEN statements similar to those shown below.

```
CALL OPEN(7,"IDUM1",3,IER)
CALL OPEN(8,"IDUM2",3,IER,228)
```

The number of bytes per record must be included for random access files.

4. The Assembler Macro file must be random access, so a call to FSEEK must preceed each Macro and Cross Reference file access. Use Binary READ and WRITE statements for the intermediate files. To implement the above, change the Fortran source code in INOUT as follows:

```
200   READ BINARY (IMFLE) IMBUF
300   CALL FSEEK (MCFLE,MCREC)
      READ BINARY (MCFLE) MCBUF
400   CALL FSEEK (MCFLE,MCREC)
      READ BINARY (MCFLE) MCORE
500   WRITE BINARY (IMFLE) IMBUF
600   CALL FSEEK (MCFLE,MCREC)
      WRITE BINARY (MCFLE) MCBUF
700   CALL FSEEK (MCFLE,MCREC)
      WRITE BINARY (MCFLE) (IXTAB(J),J=1,128)
```

5. Several characters cannot be used in Hollerith Data Specifications since they are not in the NOVA assembler's legal character set. These include right and left parenthesis, percent sign, quote mark, question mark, etc.. Check you Assembly Language Manual for the legal character set. The greater than and less than sign are probably also illegal even though they are listed as legal. In Subroutine INIT, replace all illegal characters with their internal representations as they would appear in a 1H Data format.

```
      DATA NALPH( 1),NALPH( 2),NALPH( 3),NALPH( 4) /1H0,1H1,1H2,1H3/
      DATA NALPH( 5),NALPH( 6),NALPH( 7),NALPH( 8) /1H4,1H5,1H6,1H7/
      DATA NALPH( 9),NALPH(10),NALPH(11),NALPH(12) /1H8,1H9,1HA,1HB/
      DATA NALPH(13),NALPH(14),NALPH(15),NALPH(16) /1HC,1HD,1HE,1HF/
      DATA NALPH(17),NALPH(18),NALPH(19),NALPH(20) /1HG,1HH,1HI,1HJ/
      DATA NALPH(21),NALPH(22),NALPH(23),NALPH(24) /1HK,1HL,1HM,1HN/
      DATA NALPH(25),NALPH(26),NALPH(27),NALPH(28) /1HO,1HP,1HQ,1HR/
      DATA NALPH(29),NALPH(30),NALPH(31),NALPH(32) /1HS,1HT,1HU,1HV/
      DATA NALPH(33),NALPH(34),NALPH(35),NALPH(36) /1HW,1HX,1HY,1HZ/
      DATA NALPH(37),NALPH(38),NALPH(39),NALPH(40) /1H ,1H!,8704,1H#/
      DATA NALPH(41),NALPH(42),NALPH(43),NALPH(44) /9216,9472,1H&,9984/
      DATA NALPH(45),NALPH(46),NALPH(47),NALPH(48) /10240,10496,1H*,1H+
      DATA NALPH(49),NALPH(50),NALPH(51),NALPH(52) /1H,,1H-,1H.,1H//
      DATA NALPH(53),NALPH(54),NALPH(55),NALPH(56) /1H:,1H;,15360,1H=/
      DATA NALPH(57),NALPH(58),NALPH(59) /15872,16128,1H@/
      DATA NBLNK,NQUOT,NPLUS,NMIN,NGRAT,NLESS
     1  /1H ,9984,1H+,1H-,15872,15360/
      DATA NDOLR,NCOMM,NAST,NSEMI,NCOLN/9216,1H,,1H*,1H;,1H:/
      DATA NCHRA,NCHRD,NCHRE,NCHRF,NCHRL /1HA,1HD,1HE,1HF,1HL/
      DATA NCHRM,NCHRO,NCHRR,NCHRS,NCHRT /1HM,1HO,1HR,1HS,1HT/
      DATA NCHRU,NCHRV,NCHRB,NCHRX,NCHRW /1HU,1HV,1HB,1HX,1HW/
      DATA NMULT,NDIV,NRPAR,NLPAR /1H*,1H/,10496,10240/
      DATA NCPER,NCAT,NSHRP,NAMP /9472,1H@,1H#,1H&/
      DATA NTITL( 1),NTITL( 2),NTITL( 3),NTITL( 4) /1H6,1H8,1H0,1H0/
      DATA NTITL( 5),NTITL( 6),NTITL( 7),NTITL( 8) /1H ,1HM,1HA,1HC/
      DATA NTITL( 9),NTITL(10),NTITL(11),NTITL(12) /1HR,1HO,1H ,1HA/
      DATA NTITL(13),NTITL(14),NTITL(15),NTITL(16) /1HS,1HS,1HE,1HM/
      DATA NTITL(17),NTITL(18),NTITL(19),NTITL(20) /1HB,1HL,1HE,1HR/
      DATA NTITL(21),NTITL(22),NTITL(23),NTITL(24) /1H ,1HV,1HE,1HR/
```