CONTROL DATA
CORPORATION

CONTROL DATA®
CYBER 170 SERIES COMPUTER SYSTEMS
CYBER 70 SERIES COMPUTER SYSTEMS
6000 COMPUTER SYSTEMS
7600 COMPUTER SYSTEM

COMPASS VERSION 3
REFERENCE MANUAL

CPU AND PPU INSTRUCTION INDEX

CPU INSTRUCTIONS

Mnemonic Code		Operation Code (octal)	Section Number
AXi	±jk	21ijk	8.4.25
AXi	Bj,Xk	23kjk	8.4.27
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BXi	Xj-Xk	13ijk	8.4.19
BXi	-Xk	14ikk	8.4.20
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BXi	-Xk+Xj	16ijk	8.4.22
BXi	-Xk-Xj	17ijk	8.4.23
CXi	Xk	47ikk	8.4.44
DF	Xj,K	036ijK	8.4.14
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DXi	Xj-Xk	33ijk	8.4.33
DXi	Xj*Xk	42ijk	8.4.38
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GT	Bj,K	070jK	8.4.15
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IR	Xj,K	034jk	8.4.14
IXi	Xj+Xk	36ijk	8.4.35
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IXi	Xj*Xk	42ijk	8.4.39
JP	Bj±K	0210K	8.4.13
LE	Bj,Bi,K	06ijK	8.4.15
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RE	Bj+K	011jK	8.4.4
RI	Bk	0160k	8.4.9
RJ	K	0100K	8.4.3
RL	Bj±K	011jK	8.4.5
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RXi	Xj/Xk	45ijk	8.4.42
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SAi	Aj±K	501jK	8.4.45
SAi	Bj±K	511jK	8.4.45
SAi	Xj±K	521jK	8.4.45
SAi	Xj+Bk	53ijk	8.4.45
SAi	Aj+Bk	54ijk	8.4.45
SAi	Aj-Bk	55ijk	8.4.45
SAi	Bj+Bk	56ijk	8.4.45
SAi	Bj-Bk	57ijk	8.4.45
SBi	Aj±K	601jK	8.4.46
SBi	Bj±K	611jK	8.4.46
SBi	Xj±K	621jK	8.4.46
SBi	Xj+Bk	63ijk	8.4.46
SBi	Aj+Bk	64ijk	8.4.46
SBi	Aj-Bk	65ijk	8.4.46
SBi	Bj+Bk	66ijk	8.4.46
SBi	Bj-Bk	67ijk	8.4.46
SXi	Aj±K	701jK	8.4.47
SXi	Bj±K	711jK	8.4.47
SXi	Xj±K	721jK	8.4.47
SXi	Xj+Bk	73ijk	8.4.47
SXi	Aj+Bk	74ijk	8.4.47
SXi	Aj-Bk	75ijk	8.4.47
SXi	Bj+Bk	76ijk	8.4.47
SXi	Bj-Bk	77ijk	8.4.47
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MD	ℓ,k_s,c_s,k_d,c_d		8.5.2

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ADI	d	41d	9.2.10
ADM	m,d	51dm	9.2.11
ADN	d	16d	9.2.3
AJM	m,d	64dm	9.2.13
AOD	d	36d	9.2.9
AOI	d	46d	9.2.10
AOM	m,d	56dm	9.2.11
CRD	d	60d	9.2.12
CRM	m,d	61d	9.2.12
CWD	d	62d	9.2.12
CWM	m,d	63dm	9.2.12
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ERN	d	270d	9.2.8
ESN	d	7700	9.2.19
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FAN	d	76d	9.2.18
FIM	m,d	60dm	9.2.14
FJM	m,d	66dm	9.2.13
FNC	m,d	77dm	9.2.18
FOM	m,d	64dm	9.2.14
IAM	m,d	71dm	9.2.16
IAN	d	70d	9.2.15
IJM	m,d	65dm	9.2.13
IRM	m,d	62dm	9.2.14
LCN	d	15d	9.2.3
LDC	c	20dm	9.2.4
LDD	d	30d	9.2.9
LDI	d	40d	9.2.10
LDM	m,d	50dm	9.2.11
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LJM	m,d	01dm	9.2.1
LMC	c	23dm	9.2.4
LMD	d	33d	9.2.9
LMI	d	43d	9.2.10
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LMN	d	11d	9.2.3
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MAN	d	262d	9.2.6
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MXN	d	261d	9.2.6
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NJN	r	05d	9.2.1
NOM	m,d	67dm	9.2.14
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OAN	d	72d	9.2.15
ORM	m,d	66dm	9.2.14
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PSN		2400	9.2.5
RAD	d	35d	9.2.9
RAI	d	45d	9.2.10
RAM	m,d	55dm	9.2.11
RFN	d	74d	9.2.17
RJM	m,d	02dm	9.2.1
RPN	d	270d	9.2.7
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SCN	d	13d	9.2.3
SHN	r	10d	9.2.2
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SOI	d	47d	9.2.10
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STM	m,d	54dm	9.2.11
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COMPASS VERSION 3
REFERENCE MANUAL

New features, as well as changes, deletions, and additions to information in this manual are indicated by bars in the margins or by a dot near the page number if the entire page is affected. A bar by the page number indicates pagination rather than content has changed.

REVISION RECORD

REVISION	DESCRIPTION
A	Original Printing
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(7-72)	3-3, 3-5, 3-6; 4-2, 4-15, 4-19, 4-22 thru 4-28, 4-31, 4-35, 4-42, 4-51, 4-52, 4-62, 4-64, 4-66 thru 4-73
	4-75, 4-77, 4-78, 4-80, 4-82; 5-7, 5-8, 5-9, 5-16, 5-19; 6-4, 6-9, 6-10; 7-1, 7-2, 7-3; 8-9, 8-14, 8-33, 8-34
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C	Updates manual for KRONOS 2.1 and corrects typographic errors, expands a few descriptions, and adds
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	4-31, 4-35, 4-49, 4-57, 4-61, 4-81, 4-82, 4-83, 4-85; 7-2 thru 7-5; 8-6, 8-23, 8-32, 8-33, 8-43, 8-48,
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Address comments concerning this manual to:

CONTROL DATA CORPORATION
Software Documentation
215 MOFFETT PARK DRIVE
SUNNYVALE, CALIFORNIA 94086

or use Comment Sheet in the back of this manual

PREFACE

This manual is directed at programmers using the CONTROL DATA®COMPASS Assembler Version 3. This manual describes the principles, features, methods, rules and techniques of producing a COMPASS language program.

The User is assumed to be familiar with the CONTROL DATA® CYBER 170 Series Computer Systems, the CONTROL DATA® CYBER 70 Series Computer Systems, the CONTROL DATA® 6000 Series Computer Systems, or the CONTROL DATA® 7600 Computer System, and is assumed to be familiar with assemblers in general.

Readers with no previous experience with the COMPASS assembler are encouraged to direct their initial attentions to the following sections of this manual.

Chapter 1	Introduction
Chapter 2	Language Structure
Chapter 3	Program Structure, sections 3.1 through 3.3
Chapter 4	Pseudo Instructions, sections 4.1 and 4.2
Chapter 8 or 9	CPU or PPU Symbolic Machine Instructions, the chapter depending upon the machine language the user requires.
Chapter 10	Program Execution

This publication is not intended as a replacement for the related computer system reference manuals, which contain detailed information on machine instructions. Information in the related computer system reference manuals takes precedence over information in this publication should discrepencies arise between the publications.

In this manual, numbers occurring in text are decimal unless otherwise noted. Lower case letters in formats depict variables. The examples assume that assembler numeric mode is decimal and that character mode is display code unless otherwise noted. In examples, statements generated by the assembler as a result of a call or a substitution are shown in shaded print.

Other documents of interest:

CYBER 70/Model 72, 73, 74, and 6000 Series manuals

SCOPE 3.4 Reference Manual	60307200
KRONOS 2.1 Reference Manual	60407000
LOADER Reference Manual	60344200
Record Manager Reference Manual	60307300
Record Manager File Organization User's Guide	60359600
CDC CYBER 70/Model 72 Systems Description and Programming Information (vol. 1) (RM)	60347000
CDC CYBER 70/Model 73 Systems Description and Programming Information (vol. 1) (RM)	60347200
CDC CYBER 70/Model 74 Systems Description and Programming Information (vol. 1) (RM)	60347400
CDC CYBER 70/Models 72, 73, and 74 Instruction Descriptions (vol. 2) (RM)	60347300
CDC CYBER 70 Computer Systems-7030 Extended Core Storage (RM)	60347100
CDC CYBER 70/Models 72, 73, and 74 and 6000 Series Computer Systems I/O Specifications (RM)	60352500

CYBER 70/Model 76 and 7600 computer manuals

SCOPE 2 Reference Manual	60342600
CYBER 70/Model 76 Reference Manual	60367200

CYBER 170 Series Manuals

NOS 1.0 Reference Manual	60435400
CDC CYBER 170/Models 172, 173, and 174 Reference Manual	19981200
CDC CYBER 170/Model 175 Reference Manual	60420000

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INTRODUCTION 1

The CONTROL DATA COMPASS Version 3 Assembler provides the user with a versatile, extensive language for generation of object code to be loaded and executed on the central processor unit (CPU) or a peripheral processor unit (PPU). The assembler executes on the following computer systems and operating systems:

CONTROL DATA® CYBER 170 Series Computer Systems under the control of NOS 1.0

CONTROL DATA® CYBER 70 Series Models 72, 73, and 74 Computer Systems† under control of SCOPE 3.4 or KRONOS 2.1, or NOS 1.0.

CONTROL DATA® CYBER 70 Series Model 76 Computer System under control of SCOPE 2

CONTROL DATA® 6000 Series Computer Systems under control of SCOPE 3.4 or KRONOS 2.1

CONTROL DATA® 7600 Computer System under control of SCOPE 2.

From CPU source language subprograms, the COMPASS assembler generates binary point acceptable for loading and execution. Subprograms can be compiled independently for subsequent loading and execution as a single program.

From PPU source language programs, the COMPASS assembler generates absolute code to be loaded and executed on a peripheral processor unit.

Source statements consist of CPU or PPU symbolic machine instructions and pseudo instructions. The symbolic machine instructions (chapters 8 and 9) are counterparts of the binary machine instructions; they provide a means of expressing symbolically all functions of the Computer System.

The pseudo instructions are oriented towards control of the assembler itself; they control the assembler much the same as machine language instructions control the computer. The ability to control assembly places COMPASS at a level of sophistication much higher than that of the conventional assembler.

Features inherent to COMPASS include:

- Free-field source statement format — Size of source statement fields is largely controlled by user.

† References to CYBER 70/Models 72, 73, and 74, with the exception of references to CMU instructions, apply also to the 6000 Series Computer Systems. References to CYBER 70 Model 76 apply also to the 7600 Computer System.

• Control of local and common blocks	Programmer and system designate up to 255 areas to facilitate interprogram communication. In CPU programs, common areas can be defined in small core memory (CM or SCM) or extended or large core memory (ECS or LCM).
• Preloaded data	Data areas may be specified and loaded in core memory with the source program.
• Data notation	Data can be designated in integer, floating-point, and character string notation. It can be introduced into the program as a data item, a constant, or a literal.
• Address arithmetic	Addresses can be specified making extensive use of constants, symbolic addresses, and arithmetic expressions.
• Symbol equation and redefinition	Equation and redefinition of symbols allow extensive parameterization of assembly and linkage of subprograms and subroutines.
• Symbol qualification	Ability to associate a symbol qualifier with a symbol defined within a qualified sequence to render the symbol unique to the sequence. An unqualified symbol is global and can be referred to from within any sequence without qualification.
• Binary control	The programmer can specify whether binary output is to be absolute or relocatable. Absolute code can be generated for any PPU or CPU. Relocatable code can be generated for any CPU. Binary can be written as overlays or as partial records.
• Selective assembly of code sequences	Assembly-time tests allow the user to select or alter code sequences.
• Mode control	Ability to specify the base to be used for numeric notation not explicitly defined as octal or decimal, and to specify the code conversion to be applied to character data as either display code, ASCII, internal BCD, or external BCD.
• Listing control	Assembly-time control of list content.
• Micro coding	Substitution of sequences of characters defined in the program whenever the micro name is referenced. Several micros are predefined by the system for user convenience.

• Macro coding	Assembly of sequences of instructions defined in the program or on the system library whenever the macro name is referenced. Macro definitions can be redefined or purged from the operation code table.
• Operation code table	The programmer can specify or respecify the syntax of a CPU or PPU instruction. The assembler generates an entry in the operation code table for the instruction. No macro or opdef definition is associated with the entry.
• Operation code definition	Assembly of sequences of instructions defined in the program or on the system library whenever an operation code of the specified syntax is referenced.
• Code repetition	Sequences of code can be repeated during assembly or at load time.
• Remote assembly	Defers assembly of defined coding sequence until later in the assembly.
• Library routine calls	Routines can be called from the system library.
• Diagnostics	Diagnostics for source program errors are included on output listing.

1.1 OPERATING SYSTEM INTERFACE

COMPASS executes on the following equipment and operating systems:

a CYBER 70/Model 76 or 7600 CPU under control of the SCOPE 2 operating system,

a CYBER 170 Series computer system under control of NOS 1.0,

a CYBER 70/Model 72, 73, 74 or 6000-series computer system under the control of the SCOPE 3.4 or KRONOS 2.1 operating systems.

1.2 CONFIGURATION

The hardware requirements for executing COMPASS on a CPU are the minimum required for the operating system.

1.3 ASSEMBLER EXECUTION

COMPASS is called from the system library by a COMPASS control card (chapter 10) or CDC FORTRAN compilers upon encountering a COMPASS IDENT statement in the source input file. Parameters on the card specify files used during the assembler run such as the file containing source statements and the files to receive listable output and load-and-go output. The COMPASS assembler executes as a CPU program.

The operating system allocates the input/output resources as needed and performs all input/output required during the assembly.

COMPASS assembles each subprogram on the source file, in turn, in two passes. During the first pass, it reads each source language instruction, expands and edits called sequences as needed, interprets the operation code, and assigns storage.

The function of the second pass is to assign block origins, locate literals, fill in all valid symbol values and produce the assembly listing and binary output. Finally, it prepares the symbolic reference table and reinitializes itself preparatory to assembling the next subprogram.

Core requirements for tables used by the assembler are dynamically changed as requirements change during assembly. If insufficient core is available for the program, the intermediate file and cross-references are transferred to the system mass storage device and assembly continues. If any ECS/LCM space is assigned to the job, COMPASS may use it for table storage.

All nested processing of macros and similar definitions is handled in a single recursive push-down stack. COMPASS has a maximum recursion level of 400; that is, COMPASS allows nesting to a depth of 400.

1.4 RELOCATABLE OBJECT PROGRAM EXECUTION

When the assembler has completely processed the source deck, a control card (for example, LGO) can be used to call for loading and execution of a CPU object program from the load-and-go file. The loader links the newly assembled subprogram to any previously assembled subprograms and subroutines referred to by the new program and to programs on any other files specified by the programmer. After all subprograms are loaded and linked, the operating system begins program execution at a location specified by one of the subprograms. Data for the object program may be on some programmer-specified file. Normally, this loading and execution does not take place if the COMPASS assembler detects fatal errors.

LANGUAGE STRUCTURE 2

2.1 STATEMENT FORMAT

A COMPASS language source program consists of a sequence of symbolic machine instructions, pseudo instructions, and comment lines. With the exception of the comment lines, each statement consists of a location field, an operation field, a variable field, and a comments field. Each field is terminated by one or more blank characters. However, a blank embedded in a character data item, parenthesized macro parameter, or comments field does not terminate a field. The size of the variable field is restricted by the maximum statement size only. Statement format is essentially free field.

Statements are 80-to-90 column lines. When punched on cards, each card is considered a line. A single statement may be composed of as many as ten lines. Information beyond column 72 is not interpreted by COMPASS but does appear on the assembly listing. Thus, columns 73-80 can be used for additional comments or sequencing. Column 81-90 are used for sequencing by library maintenance programs; they are normally not used by the programmer. A line that contains two or more consecutive colons may be read and printed as two lines because of operating system conventions for delimiting line images.

2.1.1 FIRST COLUMN

The contents of column one designate the type of line, as follows:

, (comma)	Designates the line as a continuation of the previous line.
*(asterisk)	Designates the line as a comments line.
other	Indicates the beginning of a new statement.

2.1.2 LOCATION FIELD

The location field entry begins in column one or two of a new statement line and is terminated by a blank. If columns one and two are blank, the location field has no entry. A location field entry is usually optional. It may contain a symbol or name according to the requirements of the operation field, or a plus sign (+) or a minus sign (-) (section 3.2.4).

2.1.3 OPERATION FIELD

If the location field is blank, the operation field can begin in column three. If the location field is nonblank, the operation field begins with the first nonblank character following the location field and is terminated by one or more blanks. The operation field is blank if there are no nonblank characters between the location field and column 30. The following are legal field entries:

Central processor unit mnemonic operation code and, optionally, the variable subfields with each variable subfield preceded by a comma.

Peripheral processor unit mnemonic operation code

Pseudo instruction mnemonic operation code

Macro name

Blank

2.1.4 VARIABLE FIELD

The contents of the operation field determine if any entry is required in the variable field which consists of one or more subfields separated by commas. The variable field begins with the first nonblank character following the operation field and is terminated by one or more blanks. It is blank if there are no nonblank characters between the operation field and column 30.

A variable subfield contains one of the following:

Data item
Expression
Register designator
Name
Special element
Entry uniquely defined for the instruction

2.1.5 COMMENTS FIELD

Comments are optional and begin with the first nonblank character following the variable field or, if the variable field is missing, begin no earlier than column 30. The beginning comments column can be changed through the COL pseudo instruction (Section 4.4.5).

2.1.6 COMMENTS STATEMENT

A comments statement is designated either by an asterisk in column 1 or by blanks in columns 1-29. Comments statements are listed in assembler output but have no other effect on assembly. A statement beginning with * is not counted in line counts for IF-skipping (Section 4.9) and definition operations (chapter 5) and is not included in definitions. A statement having columns 1-29 blank is counted.

2.1.7 STATEMENT CONTINUATION

Normally, column 72 terminates a source statement that has not yet terminated. However, a statement that cannot be contained in the first 72 characters can be continued on the next line by placing a comma in column one and continuing the field in column two. A maximum of nine continuation lines is permitted for a statement. The break between lines need not coincide with a field or subfield separator; even a symbol can be split between two lines. Continuation lines beyond the ninth, and continuation lines following a terminated statement are considered comment lines.

2.1.8 CODING CONVENTIONS

Figure 2-1 illustrates a COMPASS coding form that establishes a coding convention as follows:

Column	Contents
1	Blank, asterisk,or comma
2-9	Location field entry or plus, or minus left justified
10	Blank
11-16	Operation field entry left justified
17	Blank
18-29	Variable field entry left justified
30	Beginning of comments

All examples in this manual abide by this convention.

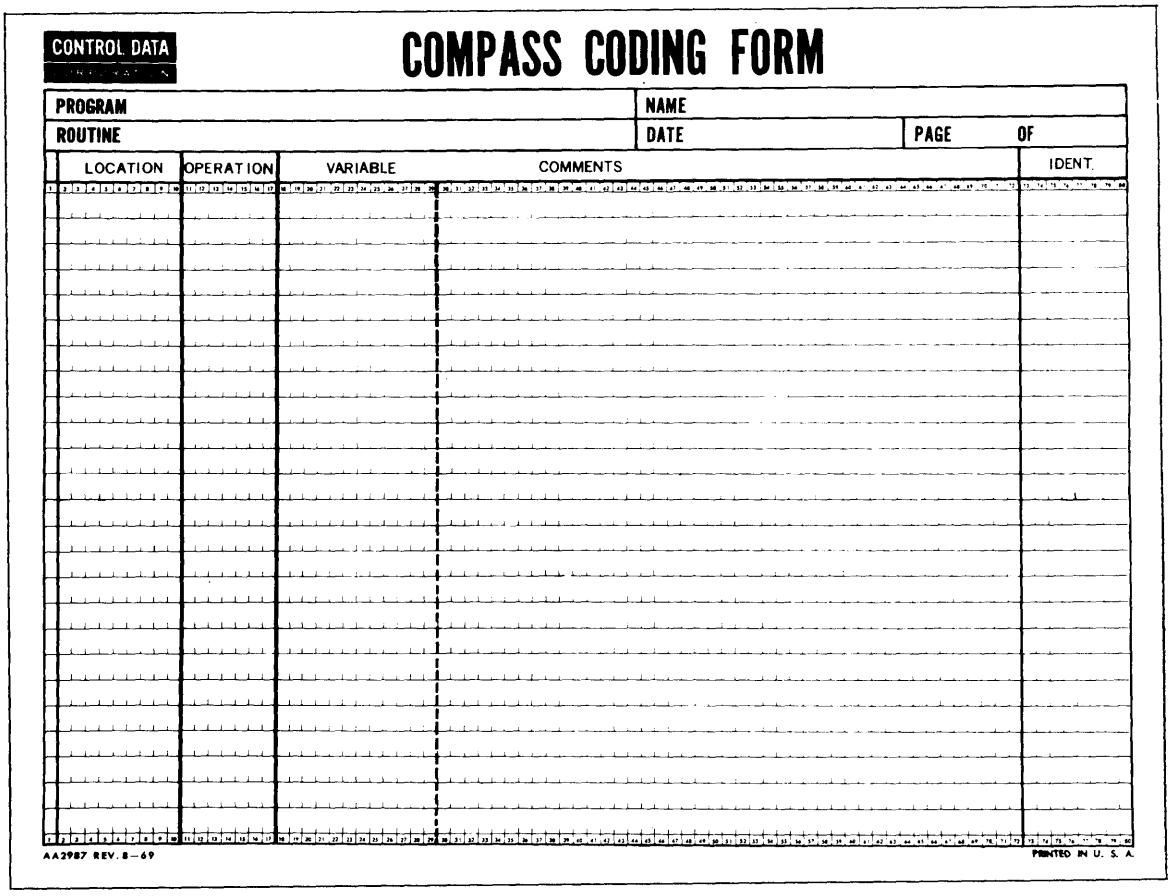


Figure 2-1. COMPASS Coding Form

2.2 STATEMENT EDITING

COMPASS reads statements in sequence from the source file. It immediately edits and interprets each statement unless (1) it is a comments statement of the type indicated by an asterisk in column one, or (2) it is part of a definition, that is, it is a statement between a macro or OPDEF header and an ENDM, between a DUP or ECHO and an ENDD, or between an RMT pair. Statements within definitions are saved for editing and interpretation when the definition is referenced or expanded. Statements within the range of a conditional (IF type) pseudo instruction are edited even when they are skipped. COMPASS performs two types of editing: concatenation, and micro substitution.

2.2.1 CONCATENATION

COMPASS examines the statement for the concatenation character ⌐→ and removes it from any field of the statement so that the two adjoining columns are linked. The most common use of the concatenation character is as a delimiter for a substitutable parameter name in a macro definition when there is no other type of delimiter already there to set off the parameter name. After the substitution takes place, the ⌐→ is superfluous and is removed by editing before the definition is interpreted.

Each removal of ⌐→ shifts the remaining columns in the statement left one character. This could become significant when comments follow a blank variable field because the comments would be shifted left and interpreted as a variable field entry rather than comments.

2.2.2 MICRO SUBSTITUTION

COMPASS examines the statement for pairs of micro marks (≠) that delimit references to micro definitions (chapter 7) and replaces each reference (including the micro marks) with the micro character string referenced. The string that replaces the reference in the statement can be a different number of characters than the reference so that after the substitution, remaining characters in the statement are shifted left or right, accordingly. If, as a result of micro substitution, column 72 of the last card read is exceeded, the assembler creates up to a maximum of nine continuation cards, beyond which it discards excess without notification on the listing. No replacement takes place if the micro name is unknown or if one of the micro marks has been omitted. The micro marks and name remain in the line. In the first case, the assembler flags a non-fatal assembly error. However, a single micro mark is not illegal and does not produce an error flag.

If the micro name is null (i.e., the two micro marks are adjacent) both micro marks are deleted and no error flag is set.

The columnar displacement caused by a micro replacement could also affect the relationship of fields to the beginning comments column. For example, it could shift the operation or variable field right beyond column 30, or could shift comments left into a blank field.

A line that contains two or more consecutive colons after editing may be printed as two lines because of operating system conventions for delimiting print lines.

2.3 NAMES

A name is a sequence of characters that identifies one of the following:

Subprogram or overlay

Block

Macro definition

Remote definition

Duplicated sequence (DUP or ECHO)

IF sequence

Micro

A comma or a blank terminates a name. Concatenation marks and pairs of micro marks are removed before the name is scanned (see section 2.2 Statement Editing).

A CPU subprogram name or overlay name is used for linkage with other subprograms. It must begin with a letter (A-Z) and is limited to seven characters maximum. Conventions imposed on names by the operating system could restrict the use of certain characters in names. There is no restriction on the first character for a PPU subprogram or overlay name. For a CYBER 70/Model 76 or 7600 PPU assembly, the name can be seven characters but for a CYBER 170 Series or a CYBER 70/Model 72, 73, 74 or a 6000 Series PPU assembly it is limited to three characters maximum. In all cases, the last character of a subprogram or overlay name cannot be a colon.

Any other type of name can consist of one to eight characters. A name does not have a value or attributes and cannot be used in an expression.

The different types of names do not conflict with each other. For example, a micro can have the same name as a macro, or a subprogram can have the same name as a block, etc.

2.4 SYMBOLS

A symbol is a set of characters that identifies a value and its associated attributes. For an ordinary symbol, the first character cannot be a $ or = or a number; a symbol can be a maximum of eight characters. A symbol cannot include the following characters.

+ - * / blank , → or ^

Other special characters must be used with care, especially in ECHO and macro definitions (chapter 5). Conventions imposed on symbols by the operating system could restrict the use of certain characters in symbols.

An external or entry point symbol is used for linkage with other subprograms and has additional restrictions (section 2.4.1 Linkage Symbols).

Concatenation marks or pairs of micro marks are removed before a symbol is examined (section 2.2 Statement Editing). In CPU assemblies, to avoid conflict with register designators, a symbol cannot normally be An, Bn, Xn, where n is a single digit from zero to seven nor can a symbol be A.x, B.x, or X.x, because x is assumed to be a data item by the assembler. However, symbols resembling register designators can be used if each use of the symbol is prefixed by =S or =X (section 2.4.2). Register designators are described further in Section 2.5.

The process of associating a symbol with a value and attributes is known as symbol definition. This can occur in five major ways.

1. A symbol used in the location field of a symbolic machine instruction or certain pseudo instructions is defined as an address having the current value of the location counter (section 3.2.2) and having an attribute defined as follows:

   a. Absolute for the absolute block

   b. Common for labeled or blank common blocks (relocatable assemblies only)

   c. Relocatable for local blocks other than absolute during pass one

   d. Absolute for local blocks during pass two of an absolute assembly

2. A symbol used in the location field of definition pseudo instructions (section 4.6) is defined as having the value and attributes derived from an expression in the variable subfield of the instruction. Certain of these pseudo instructions assign an attribute of redefinability to a symbol. Unless a symbol is redefinable, a second attempt to define it with a different value produces a duplicate definition fatal error flag.

3. An external symbol is defined outside the bounds of the current subprogram and is declared as external in the current subprogram or is defined in relation to a symbol declared as external. In either case it has the attribute of external. Unlike a systems symbol, the true value definition is not known to the current subprogram.

4. Definitions of systems symbols that take place outside of the current program can be carried over to the current program through the SST pseudo instruction. COMPASS uses the true definitions but assigns the additional attribute of systems symbol.

5. COMPASS defines a symbol by default if a reference to a symbol is preceded by =S and the symbol is not otherwise defined in the subprogram. This feature is further described in section 2.4.2 Default Symbols.

There is no restriction on the number of times that the symbol can be referred to in the subprogram.

Examples:

Legal Symbols	Illegal Symbols	
P	5A	First character numeric
R3	ABCDEFGHI	Exceeds eight characters
PROGRAM	ABE+15	Contains plus sign
	=.11	First character equal sign

2.4.1 LINKAGE SYMBOLS

A relocatable subprogram can be linked to other subprograms through linkage symbols. The two types of linkage symbols are external symbols and entry point symbols. An external or entry point symbol can be a maximum of seven characters, the first character must be a letter (A-Z), and the last character must not be a colon.

Any symbol declared as an entry point in a subprogram compiled or assembled independently of the current subprogram can be declared as an external symbol in the current subprogram. Any symbol declared as an entry point in the current subprogram can be declared as an external symbol in some other subprogram. The symbol has a zero value and an attribute of external. An external symbol can be declared either through the EXT pseudo instruction or through default (a reference to the symbol is preceded by =X, see section 2.4.2 Default Symbols).

External symbols can be defined in the subprogram relative to any external symbol declared in an EXT pseudo instruction. This is possible through use of symbol definition instructions that assign the value and attributes of an expression to a symbol. If the value of the expression reduces to an external symbol ± an integer, the location field symbol is defined as having an integer value and external attribute. Entry point symbols and external symbols are not qualified (section 2.4.5).

2.4.2 DEFAULT SYMBOLS

When a symbol reference is preceded by =S or =X and the symbol is not defined in the subprogram, COMPASS defines the symbol or declares it as an external symbol, respectively, at the end of assembly. The =X form is defined by default in relocatable assemblies only.

=Ssymbol — If symbol is not defined, COMPASS assigns an address at the end of the zero block. All subsequent references to the symbol, whether preceded by =S or not, are to the location of the word. A default symbol cannot be used where a previously defined symbol is required.

If the symbol is defined by a conventional method, COMPASS does not define it again but uses the programmer definition.

=Xsymbol — This option permits a programmer to define his symbols in a subroutine or link to them in another subprogram. If the programmer defines the symbol, the assembler uses the programmed definition. If the programmer does not define the symbol, the assembler assumes that the symbol is external as though declared in an EXT pseudo instruction. A symbol prefixed by =X must conform to the requirements for external symbols.

The system does not define a default symbol and issues an error flag if a symbol is prefixed by both =S and =X, or is prefixed by =X and is not defined conventionally in an absolute assembly. Default symbols are qualified by the qualifier in effect at the time of the =S reference.

2.4.3 PREVIOUSLY DEFINED SYMBOLS

Certain pseudo instructions require that a symbol in an expression be previously defined. This simply means that the symbol, before its use as an expression element, must be defined in a prior instruction.

2.4.4 UNDEFINED SYMBOLS

A reference to a symbol that is never defined (not even by default) causes a U error flag to be placed to the left of the instruction containing the erroneous reference.

2.4.5 QUALIFIED SYMBOLS

A symbol defined when a symbol qualifier is in effect during assembly (section 4.4.3) can be referred to outside of the qualifier sequence in which it was defined through:

/qualifier/symbol

The feature permits the same symbol to be defined in different subroutines without conflict. An unqualified symbol is global and does not require a qualifier when it is referenced, unless a qualifier is in effect, and a symbol qualified by the same qualifier has been defined. In this case, the unqualified symbol can be referenced as // symbol.

The combination of qualifier and symbol permits a value to be identified by a unique 16-character identifier. Linkage symbols are not qualified.

2.5 CPU REGISTERS

Register designators symbolically represent the 24 CPU operating registers. These registers are described more fully in chapter 8. The designators are inherent to COMPASS and cannot be changed during assembly.

In a CPU assembly, symbols of the same form as register designators may be used if each occurrence of such a symbol is prefixed by =S or =X (see section 2.4.2). However, a warning message is issued when such symbols are defined. The prefix cannot be used in the location field of machine instructions and symbol defining, data generating, BSS pseudo instructions, in the variable field of ENTRY, EXT, and SST pseudo instructions.

Register Type	Designator
Address	An or A.n
Index	Bn or B.n
Operand	Xn or X.n

For the forms An, Bn, or Xn, n is a single digit from 0 to 7. Any other value for n, for example 8, causes An, Bn, or Xn to be interpreted as a symbol rather than a register designator.

For the forms A.n, B.n, X.n, n can be a symbol or an integer. If the value of n or the value of the symbol exceeds 7, the assembler truncates it to the least significant 3 bits and issues a warning flag.

COMPASS does not recognize registers in PPU assemblies; there, the designators are acceptable as ordinary symbols.

Examples:

A1	Designates address register 1
A10	Interpreted as a symbol, not a register
A.1	Designates address register 1
A.NUM	If the value of NUM is 6, it designates address register 6
A.10	Designates address register 2; however, it produces a warning flag because the two was derived from the truncation of 12, the octal value for 10.

The following produce equivalent results. A SET pseudo instruction (section 4.6.2) defines SUM and SUB as absolute values 3 and 2, respectively. A reference to a SET-defined symbol produces the same result as if the value had been used directly. In this example, the address of ALPHA is 001000.

Code Generated

```
                    LOCATION  OPERATION  VARIABLE      COMMENTS
                    1         11         18            30
6032001000                    SB3        A2+ALPHA
```

```
                    LOCATION  OPERATION  VARIABLE      COMMENTS
                    1         11         18            30
          3         SUM       SET        3
          2         SUB       SET        2
6032001000                    SB.SUM     A.SUB+ALPHA
```

2.6 SPECIAL ELEMENTS

The following designators are reserved for use as references to special elements and cannot be used as symbols. The use of a special element in an expression causes the assembler to replace it with a value specified by the element in the expression. The control counters are discussed further in section 3.2.

Designator	Significance
* or *L	The assembler uses the value of the location counter for the block in use. The element is relocatable unless the counter in use is for the absolute block.
*O	The assembler uses the value of the origin counter for the block in use. The element is relocatable unless the counter in use is for the absolute block.
$	The assembler uses one less than the absolute value of the position counter for the block in use.

Designator	Significance
*P	The assembler uses the absolute value of the position counter for the block in use.
*F	The assembler uses an absolute value obtained as follows: 0 COMPASS was called by a COMPASS control card 1 COMPASS was called by the FORTRAN RUN compiler (earlier than Version 3.0) 2 COMPASS was called by the FORTRAN FTN compiler or the FORTRAN RUN compiler (Version 3.0 and later)

These designators are inherent to COMPASS and cannot be altered by the programmer during an assembly.

Examples:

```
|  LOCATION  |  OPERATION  |  VARIABLE  |  COMMENTS
1            11            18           30
             JP            *+1+B7
             .
             .
             .
             ZR            X3,*L-1
             .
             .
             .
             LOC           *O-RES+PPR
             .
             .
             .
             VFD           *P/
             .
             .
             .
             VFD           $/3,1/1
             .
             .
             .
             IFEQ          *F,2
```

2.7 DATA NOTATION

Data notation provides a means of entering values for calculation, increment counts, operand values, line counts, control counter values, text for printing out messages, characters for forming symbols, etc.

The two types of data notation are character and numeric. The assembler allows the user to introduce data in the program in three basic ways.

As a data item
As a constant in an expression
As a literal

2.7.1 DATA ITEMS

Character and numeric data items can be used in subfields of the DATA (section 4.8.2) and LIT (section 4.8.4) pseudo instructions or as specifications of field lengths on VFD pseudo instructions.

2.7.2 CONSTANTS

A data constant is an expression element consisting of a value represented in octal, decimal, hexadecimal, or character notation. It resembles a data item but is restricted by its use as an expression element in two ways:

1. The first character must be numeric, prohibiting the delimited type of character string (section 2.7.4) and the preradix for numeric values.

2. The field size is determined by the destination field for an expression and can be a maximum of 60 bits thus prohibiting double precision floating point numbers.

2.7.3 LITERALS

A literal is a read-only constant. It is specified as a data item in a subfield of a LIT pseudo instruction or as an element in an expression.

The method of specifying a literal in an address expression is nearly identical to that for specifying a data item in a DATA (section 4.8.2) or a LIT (section 4.8.4) pseudo instruction. The primary difference is that the literal is prefixed with an equal sign, which indicates that a literal follows.

When a literal is used as an element in an expression, the expression is evaluated using the address of the literal in the literals block rather than the value of the data item. Thus, the literal is considered relocatable. (For a discussion of the literals block, see section 3.1.3).

Conventionally, if a literal is used, it is the only element in an expression.

The first use of a literal causes the assembler to assemble the data specified by the literal, and store the data in the literals block using as many words as are required to hold the data. If the binary pattern of the prefixed type of literal or of all the literals in a LIT declared sequence matches the binary pattern of words previously entered in the literals block, an entry is not generated for the data. This process eliminates duplication of read-only data.

The LIT pseudo instruction permits symbols to be associated with literals block entries. Such entries can be referenced symbolically or through use of a prefixed literal. However, to preserve the integrity of the literals block, they should be used as read only locations.

The assembly listing includes a list of the literals block when the D list option is selected (section 4.11.1).

Example:

In the following example, using CPU instructions, the first statement creates a word in the literals block having the value 00000000000000000001. The address of that entry (for the purpose of the example) is 5555 and is used in the address field of the two statements at address 100 and the statement at the lower part of 101.

The literal in the second statement specifies a right justified character, A, which has a display code value of 1. The SB4 creates a one-word literal block entry having the value 00000000000000000002. The address of that entry is in the address field of statements at the upper half of addresses 101 and 102. In this example, the LIT sequence duplicates a sequence of entries in the literals block and does not cause new entries to be assembled.

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
		1	11	18	30
100	6120005555 +		SB2	=1	
	6130005555 +		SB3	=1RA	
101	6140005556 +		SB4	=1RB	
	5555	L	LIT	1,2	
	6120005555 +		SB2	L	
102	6130005556 +		SB3	L+1	

```
                 CONTENT OF LITERALS BLOCK.

005555   00000000000000000001            A
005556   00000000000000000002            B
```

Continuing the previous example, a LIT sequence as illustrated below, does not duplicate a sequence in the literals block and causes entries to be generated in the literals block:

Location	Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
			1	11	18	30
		5557		LIT	1,3,1RD,2	

CONTENT OF LITERALS BLOCK.

005555	000000000000000000001	A
005556	000000000000000000002	B
005557	000000000000000000001	A
005560	000000000000000000003	C
005561	000000000000000000004	D
005562	000000000000000000002	B

However, if the literals sequence in the first part of the example had been followed by a LIT that duplicates, in part, the most recent entries in the literals block, only the unduplicated part is added to the block. Thus, if the following LIT sequence had been used in place of the LIT 1,3,1RD,2, the first two words of the sequence would match the last two words of the literals block so that only two additional words would be required to complete the sequence.

Location	Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
			1	11	18	30
		5555		LIT	1,2,3,4	

CONTENT OF LITERALS BLOCK.

005555	000000000000000000001	A
005556	000000000000000000002	B
005557	000000000000000000003	C
005560	000000000000000000004	D

2.7.4 CHARACTER DATA NOTATION

Character data strings are converted to the code in use at the time the string is evaluated (section 4.4.2, CODE pseudo instruction), and placed in a field indicated by the data type (data item, constant, or literal). When no CODE instruction has been issued, conversion is to display code representation.

Format:		Example
Data Item	sign | n | type | string	-3RABC
	or	
	sign | type | d | string | d	-R*ABC*
Constant †	n | type | string	3RABC
Literal†	= | sign | n | type | string	=-3RABC
	or	
	= | sign | type | d | string | d	=-R*ABC*

= Applies to literals used as expression elements only; signifies that a literal follows.

sign Optional for data item or literal. A sign with a constant is interpreted as an element operator.

+ or omitted	The value is positive
-	The complemented (negative) value is formed

n Signifies how the string is determined:

omitted	The string is delimited by d. n cannot be omitted for a constant.
0	For data item or literal, the string consists of all characters following type to : blank or , For a constant, string consists of all characters following type to: + - * / blank , or ∧
n	For a data item or literal, n is an integer count of the number of characters in the string not counting guaranteed zeros. It is limited only by statement size. For a constant, n is an integer count of the number of characters in the string. It cannot exceed 1/6 of the number of bits in the field that will contain the expression. A truncation error is flagged for a right justified constant if the most significant bit exceeds the field. Truncated zeros do not cause an error in this case. A truncation error is flagged for a left justified constant if the least significant bit positions are truncated, even if they are zero. The string consists of the n characters following type. Regardless of base, COMPASS assumes that n is decimal.

† Expression element

type

Character string justification. The characters formed by the data item or constant are right or left justified into the destination field as follows:

Type	Significance
C	Left justified with zero fill. For data item or literal, 12 zero bits are guaranteed at the end of the string even if another word must be allocated. For a constant, the zero bits are not guaranteed; C is the same as L.
H	Left justified with blank fill
A	Right justified with blank fill
R	Right justified with zero fill
L	Left justified with zero fill
Z	Left justified with zero fill. For data item or literal, six zero bits are guaranteed at the end of the string even if another word must be allocated. For a constant, the bits are not guaranteed; Z is the same as L.

d

A delimiting character used only when n is omitted. The characters between the first occurrence of d and the second occurrence of d comprise the string. d can be any character other than ⌐→ or ≠.

string

Characters from one of the COMPASS character sets (appendix D), except for those characters that act as delimiters (see n and d), the concatenation character (⌐→), and pairs of micro marks (≠).

Concatenation marks and pairs of micro marks are removed by editing before a string is examined. A single micro mark can be used in a string.

An empty or omitted character string is defined under one of the following conditions.

1. n is 0 and type is immediately followed by a delimiter, for example, 0L
2. n is omitted and the two delimiting characters are adjacent, for example, H++

Omission of a string in a DATA pseudo instruction is legal and does not cause generation of a data word.

For a constant, an omission of the string is valid and has a zero value.

An omitted string in a LIT pseudo instruction is legal and does not cause generation of a literal for that item; however, the LIT must contain at least one non-empty data item.

An omitted string for a literal in an expression is not legal and produces an error.

It is not possible to generate empty strings using types C, Z, R or A.

Examples of character data:

In these examples, characters are converted to display code representation; all lines of code generated by DATA are printed only if the D or G list option is selected.

Data Items

Location	Code Generated
144	05222217225511165520
145	04215500000000000000
146	55555555555555555555

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		DATA	L*ERROR IN PDQ *,L..,10H	

Location	Code Generated
1100	1725
1101	2420
1102	2524

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PPU		
		.		
		.		
		.		
		DATA	0LOUTPUT	

Constants

Location	Code Generated
4722	7130000047
4723	7140000060
	5110031117
4724	6260530000
	1117240155
4725	0155555531
	1725242025
4726	2400000001
	0700000000

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SX3	1R*	
	TAG	SX4	1R.+1	
		SA1	3RCIO	
		SB6	X0+1L$	
		VFD	30/4HIOIA,6/1RA,24/0AX+1	
		VFD	42/0LOUTPUT,18/1	
		VFD	15/0LG,15/0L	

Note that the character constant in the expression in the second line consists of a decimal point (57 in display code) to which 01 is added before the value is stored. Similarly, in the third field of the first VFD, 1 is added to the display code representation of X right justified with blank fill (55555530) so that 55555531 is generated.

Literals

```
Location      Code Generated                 |  LOCATION | OPERATION | VARIABLE                  COMMENTS
                                             |  1        | 11        | 18                        30
                        100003765            |  TAG1     | LIT       | RA+-*/(A,6L)$= ,.,0C0,0L
                        100003770            |           | LIT       | 20HLITERALS
2652  5110003772 +                           |           | SA1       | =0CTENCHARCTS
                     5120003774 +            |           | SA2       | =H+LEFT JUSTIFY WITH BLANKS+
2653  5130003767 +                           |           | SA3       | =0L0
```

```
                CONTENT OF LITERALS BLOCK.

003765  0000000000454646 75051        +-*/(
003766  5253545556570000 0000    )$= ,.
003767  3300000000000000 0000    0
003770  1411240522011423 5555    LITERALS
003771  5555555555555555 5555
003772  2405160310012203 2423    TENCHARCTS
003773  0000000000000000 0000
003774  1405062455122523 2411    LEFT JUSTI
003775  0631552711241055 0214    FY WITH BL
003776  0116132355555555 5555    ANKS
```

The first LIT pseudo instruction generates three words in the literals block; the 0L item is an empty string and does not produce an entry. The second LIT pseudo instruction generates one two-word entry. The expressions in the variable fields of the SA1, SA2, and SA3 instructions each consist of a literal element. The character strings in the SA1 and SA2 literals do not duplicate former literals block entries so COMPASS generates new entries. However, since SA3 references an existing entry, COMPASS places the address of the entry in the address field of the instruction.

2.7.5 NUMERIC DATA NOTATION

Numeric data can be specified in octal or decimal notation. The value is converted to an integer or a floating point value in single or double precision.

Formats:

Data Item

sign	preradix	value	modifiers

Constant

value	modifiers

Literal

=	sign	preradix	value	modifiers

=
Applies to literals only; signifies that a literal follows.

sign
Optional for data item or literal; a sign with a constant is interpreted as an element operator.

+ or omitted	The value is positive
-	The complemented (negative) value is formed

preradix
Optional for data items and literals; cannot be used for constants. The preradix indicates the notation used for the value.

omitted	Notation can be specified by a postradix modifier or can be assumed from the assembly base. See BASE pseudo instruction.
B or O	Octal notation
D	Decimal notation

value
A series of octal or decimal digits optionally consisting of an integer, a decimal (or octal) point, and a fraction. An integer value (fixed point) does not contain a point. A floating point value (legal in CPU assemblies only) is noted by the occurrence of the point.

An octal value can be a maximum of 20 significant digits (fixed point) or 32 significant digits (floating point). An octal value cannot include 8 or 9. A decimal value cannot exceed 1.15×10^{18} (fixed point) or 7.9×10^{28} (floating point, ignoring the decimal point). Extra significant digits cause erroneous results.

If value is omitted, it is assumed to be zero.

modifiers — Associated with the value are the following optional modifiers specified in any sequence. A specific type of modifier can be specified only once. A duplicate produces an error flag.

postradix — Indicates the notation used for the value. See preradix for legal values. An error is flagged if notation contains both a preradix and a postradix.

decimal exponent — Defines a power of 10 scale factor

E±n or En or E Single precision

EE±n or EEn or EE Double precision

When the sign is plus or is omitted, the exponent (n) is positive.

When n is omitted, it is assumed to be 0. The value of n cannot exceed 32767 and is always assumed to be a decimal integer.

A fixed point value can be single precision (one word) only but a CPU floating point value can be generated in double precision (two words).

If EE is used with a fixed point value, the assembler produces a fixed point number in single precision.

The effect of the exponent is to multiply the value by 10 decimal raised to the n power.

binary scale — Defines a power of two scale factor and is specified as follows:

S±n or Sn or S

When the sign is plus or is omitted, the scale factor (n) is positive. When n is omitted, it is assumed to be 0. The value of n cannot exceed 32767 and is always assumed to be a decimal integer.

The effect of the binary scale is to multiply the value by 2 raised to the n power.

binary point position — Applies to floating point values only and is specified as follows:

P±n or Pn or P

When the sign is + or omitted, n indicates the number of bit positions the point is to be shifted to the left of bit 0. When the sign is -, n indicates the number of bits the point is to be shifted to the right.

The effect of P is to align the value so that the binary point occurs to the right of the nth bit.

The exponent is adjusted to a value of - (±n)

For example, a value with P-6 will have a biased exponent of 2006_8; a value with P10 will have an exponent of 1765_8.

If P is not specified for a floating point number or if n is omitted, the assembler generates a normalized floating point value. The P modifier permits generation of an unnormalized value.

If, as a result of P, the most significant bit of the value is shifted out of the coefficient part of the single or double precision number, the assembler generates an overflow or underflow error.

Although scale factors can exceed valid ranges, the ranges for numbers are restricted by the hardware.

Example:

> The number 1.0E4000S-1200 yields a number that is approximately 5.8 x 10^{38} and is in range of the floating point representation.

All calculations are performed in 144-bit precision. The values are rounded to 96 bits for double precision and to 48 bits for single precision floating point numbers and to 60 bits for integers.

The order in which the assembler acts on the modifiers, regardless of the sequence in which they are specified is:

1. Decimal exponent (single or double)
2. Binary scaling
3. Binary point position (CPU assemblies only)

CPU Numeric Data Items

Location	Code Generated
5000	77777777777777777742
5001	17235000000000000000
5002	16430000000000000000
5003	20000000000000000012
5004	17760000000000000002
5005	17154651767635544264
5006	17200314631463146314
5007	77777777777777777777
5010	00000000000000000000

LOCATION	OPERATION	VARIABLE	COMMENTS
1	11	18	30
POOL	DATA	-29	
NUM	DATA	1.0EE1	
	DATA	1.0E+1P0	
	DATA	3.2P1S-5E1	
	DATA	0.0151E+01	
	DATA	0.1P47,-E,DEES	

CPU Numeric Constants

Location	Code Generated
	5001 +
	555
5012	
5112	20360
	43760
	7150400000

LOCATION	OPERATION	VARIABLE	COMMENTS
1	11	18	30
ALPHA	EQU	POOL+1	
VAL	EQU	555B	
	BSSZ	100B	
	LX3	-14B	
	MX7	48	
	SX5	1S17	

CPU Numeric Literals

```
Location        Code Generated

5113  5150005151 +
                  5130005152 +
                        5153
                        5155
                        5156
                        5157

                CONTENT OF LITERALS BLOCK.

005151   2004675500023400000 4     PDA  B1   D
005152   1720431463146314631 5     OP8L:L:L:M
005153   1723500000000000000 0     OS/
005154   1643000000000000000 0     N8
005155   1720031463146314631 4     OPCL:L:L:L
005156   7777777777777777754       ;;;;;;;;;=
005157   1715465176763554426 4     OM-(¬¬2=7≠
005160   7777777777777777777       ;;;;;;;;;;
005161   0000000000000000000
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SA5	=2004675500023400000 48	
		SA3	=1.1	
	ABLE	LIT	1.0EE1	
		LIT	0.1P47	
		LIT	-D19	
		LIT	0.0151E+01,-E,DEES	

Examples of numeric data (assume default radix is decimal):

PPU Data Items

```
Location        Code Generated

300             0005
301             7766
302             0013
303             0030
304             0002
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PPU		
		•	•	
		•	•	
		•	•	
		DATA	5,-9D,+B13,14BS1,24BE-1	

PPU Constants

Location	Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
			1	11	18	30
305	0000			CON	0,+11	
306	0011					
307	4443			CON	-3334	
		31	ABC	=	25D	
		101	NUM	SET	0101	
310	7777			CON	7777	

PPU Literals

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
		1	11	18	30
311	2000 1103		LDC	=10D	
313	2100 1104		ADC	=-1	
315	2000 1105		LDC	=7777	

CONTENT OF LITERALS BLOCK.

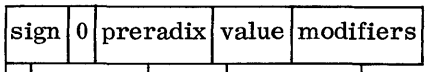
1103	0012	J
1104	7776	;;;;;;;;;;
1105	7777	;;

2.7.6 HEXADECIMAL DATA NOTATION

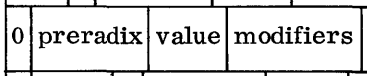
Numeric data can be specified in hexadecimal notation. The value is converted to an integer in single precision.

Formats:

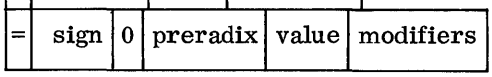
Data Item



Constant



Literal



= Applies to literals only; signifies that a literal follows.

sign Optional for data item or literal; a sign with a constant is interpreted as an element operator.

+ or omitted Value is positive.

- Complemented (negative) value is formed.

0 The zero is optional for data items and literals but must be present for constants, so the preradix will not be taken as the first character of a symbol.

preradix Must be present to indicate that a hexadecimal value follows. The preradix character is ≡ or # depending on the printer used.

value A series of hexadecimal digits. Each hexadecimal digit represents 4 bits and is either a decimal digit 0-9 or a letter A-F. The digits 0-9 represent values 0-9 and the letters A-F represent the decimal values 10-15.

The value may contain up to 26 significant hexadecimal digits. No radix point is permitted. If value is omitted, it is assumed to be zero.

modifiers The binary scale (S) modifier is optional and has the same form and meaning as for octal and decimal data (see section 2.7.5).

The binary point position (P) modifier is permitted but ignored, since it does not apply to integer values.

2.8 EXPRESSIONS

Entries in subfields of most source statements are interpreted as expressions consisting of a combination of one or more terms. Each term consists of one or more elements joined by operators. A comma or a blank terminates the expression.

An expression element can be a:

Symbol
Numeric or character constant
Special element
Register designator (CPU only)
Literal

Examples of elements:

ALPHA	A.7	3HABC
$	X3	=10HOUTPUT
*P	77BS3	

A term can be a single element or two or more elements joined by the following element operators:

*	Multiplication
/	Division

An expression can be a single term or two or more terms joined by the following term operators:

+	Addition
-	Subtraction
^	Logical minus (exclusive or)

The exclusive or operator is printed as ^ (carat) in the CDC character set or as & (ampersand) in the ASCII character set.

Rules:

1. If the last element of a term is omitted, COMPASS provides an element of zero. For example, if ABLE is a symbol, ABLE*+3 is interpreted as the value of ABLE times 0 plus 3.
2. Two successive elements are illegal. Note, however, that ** is legal because the first asterisk is interpreted as an element, the second asterisk is interpreted as an operator, and the blank is interpreted as a null element.
3. A term can contain one relocatable or external element only. Thus, **ABLE, where ABLE is a relocatable address, is illegal because ABLE and * are both relocatable.
4. The element to the left of a divisor must be absolute.
5. Division by zero results in zero with no error.
6. Two or more additive operators (+ or - or ^) in sequence are interpreted as having a term of zero value between them.
7. If an expression begins with an additive operator (+ or - or ^), COMPASS provides a term with zero value preceding the operator.

The operator that immediately precedes a register designator is the register operator, regardless of the placement of the designator in the expression. The register operator can be:

+ - * or /

Examples of expressions:

ABLE	Single term
$-29	Two terms; $ and 29
1+=3.14159EE+6	Two terms; a constant and the address of a literal. COMPASS places the literal in the literal block and uses its address in the expression.
*+3	Two terms; value of the location counter and numeric constant 3.
ABLE*4-72/NUM	Two terms, each consisting of two elements; the value of ABLE times 4, and 72 divided by the value of NUM.
10B	Single term consisting of a numeric constant.
3+A6-NUM	The components of the expression are register A6 and 3-NUM.
1R=^1R/	The character constants (= and /) are logically differenced.

2.8.1 TYPES OF EXPRESSIONS

Evaluation during assembly reduces an expression to:

An absolute value (absolute address or an integer value)

An external symbol ± a 21-bit integer

± relocatable value ± a 21-bit integer

Register designators and one of the above } CPU assembly only

Register designators } CPU assembly only

Absolute Expressions

An expression is absolute if its value is unaffected by program relocation. An expression can be absolute, even though it contains relocatable terms, under these two conditions:

1. The expression contains an even number of relocatable elements
2. The relocatable elements must cancel each other. That is, each relocatable element (or multiple thereof) in a block must be canceled by another element (or multiple thereof) in the same block. In other words, pairs of elements in the same block must have signs that oppose each other. The elements that form a pair need not be contiguous in the expression.

Examples of absolute expressions:

In the following examples, EASY and FOX are relocatable in the same block. MIKE is absolute. The control counters are for the block that contains EASY and FOX.

`EASY-FOX+MIKE`	EASY and FOX cancel each other.
`FOX-*`	FOX and the location counter cancel each other.
`MIKE+16`	The expression contains no relocatable elements.
`EASY-FOX*2+*`	EASY and the location counter cancel 2 times FOX.

Relocatable Expressions

An expression is relocatable if its value is affected by program relocation. A relocatable expression consists of a single relocatable term or, under these two conditions, a combination of relocatable and absolute terms:

1. The expression does not contain an even number of relocatable elements
2. All the relocatable elements but one must be organized in pairs that cancel each other. That is, for all but one block, each relocatable element (or multiple thereof) in a block must be canceled by another element (or multiple thereof) in the same block. The elements that form a pair need not be contiguous in the expression.
3. The uncanceled relocatable element can have three kinds of relocation:
   a. Positive program
   b. Negative program
   c. Positive common (Negative common relocation is not permitted by the loader).

Examples of relocatable expressions:

In the following examples, EASY and FOX are relocatable in the same block. MIKE is absolute. LIMA is relocatable in a different block. The control counters are for the block that contains EASY and FOX.

```
LIMA+MIKE-16

FOX-EASY+FOX

3*FOX-2*EASY

EASY-*+FOX

FOX-100B/MIKE

-MIKE*2+LIMA

=10HMESSAGE 33

-*0
```

The pairing of relocatable terms cancels the effect of relocation because both terms would be relocated by the same amount. The comparative value of the two terms remains the same regardless of program relocation.

External Expressions

An expression is external if its value depends upon the value of a symbol defined outside of the current subprogram. Either an external expression consists of a single positive external term or under the following conditions an external expression may consist of an external term, relocatable terms, and absolute terms.

1. The expression contains an even number of relocatable terms.

2. The relocatable elements must cancel each other. That is, each relocatable element (or multiple thereof) in a block must be canceled by another element (or multiple thereof) in the same block. In other words, pairs of elements in the same block must have signs that oppose each other. The elements that form a pair need not be contiguous in the expression.

Examples of external expressions:

In the following examples, XYZ and ABC are external symbols. EASY and FOX are in the same block. The control counters are for the block that contains LIMA. MIKE is absolute.

`XYZ-*+FOX-EASY+LIMA`	The pairs * and LIMA, and FOX and EASY cancel each other.
`FOX-3*EASY+2*FOX+XYZ`	The relocatable elements all cancel.
`ABC+100B`	
`XYZ+ABC`	Illegal; both are external
`-ABC+*-LIMA`	Illegal; ABC is negative
`XYZ+*O`	Illegal; *O is an unpaired relocatable element

Register Expressions

An expression is a register expression if, in a CPU assembly, it reduces to one or more register designators and an operand. The attributes of the operand can be that of an absolute, external, or relocatable expression. Use of register expressions is generally restricted to symbolic CPU machine instructions (Sections 8.4 and 8.5). If the register designator is the first element in the expression, the operator can be omitted and is assumed to be +.

Examples of register expressions:

In the following examples, XYZ is an external symbol and LIMA is a relocatable symbol.

`X3+LIMA-10B`
`LIMA+X3-10B`
`-10B+LIMA+X3`
} Produce identical results

`B1+XYZ`

`*+A.NUM`

Evaluatable Expressions

An evaluatable expression is an expression that does not contain any symbols as yet undefined. Certain pseudo instructions require that the expressions be evaluatable.

2.8.2 EVALUATION OF EXPRESSIONS

When evaluating an expression, COMPASS replaces each element with a 60-bit value. A character constant is first right or left adjusted in a field the size of the destination field and then extended to 60 bits. Signs are extended for 21-bit quantities, that is, for counters, addresses, and symbols. In division, the integral portion of the quotient is retained; any remainder is discarded. Thus, 5/2*2 results in 4.

COMPASS forms a term value by interpreting each element and operator from left to right until it reaches a + or - or ^ operator. It then notes whether or not the newly formed term contains a relocatable or external symbol or register designators. The value of the symbol is added, subtracted, or differenced from the cumulative sum of the absolute elements, relocatable elements, or external values. The assembler continues evaluating the expression until it is reduced to a symbol and/or a value. An error is flagged if the expression cannot be reduced. The expression value is truncated, if necessary, and placed in the destination field. If it is too large for the field, the system issues an error flag. The maximum field size for an expression is 60 bits.

The value of an external symbol is zero if the external symbol is defined outside of the subprogram. It is the value relative to the external used in defining the symbol if the external symbol was defined within the subprogram.

A zero value is used in place of a register designator.

For pass one evaluation, the system uses the value of a relocatable symbol relative to the block in which the symbol was defined. For pass two evaluation, the system uses a value relative to program or common block origin.

The field size for an expression depends upon the instruction and is determined as follows:

1. For a symbol definition pseudo instruction, the expression value (including character constants) is justified in a 21-bit field.

2. In a VFD pseudo instruction, the expression is placed in a field of the size specified.

3. For a CON pseudo instruction, the field size is one word (12 bits for PPU assemblies, 60 bits for CPU assemblies).

4. In a symbolic machine instruction, values of expressions are placed in address fields (18 or 6 bits for CPU assemblies; 18, 12, or 6 bits for PPU assemblies).

Some relocatable program loaders may give unexpected results if relocatable or external address values are assembled into the same field of the same word more than once, as a result of ORGing backward over the word, or by having more than one subprogram preset a common block. The ORGC pseudo instruction (see section 4.5.3) can be used to avoid such problems.

PROGRAM STRUCTURE 3

This chapter describes the general structure of a program. In some cases, it repeats information described elsewhere and correlates it so that the programmer will obtain a better understanding of how the program is assembled, loaded, and executed. Some mention is made of the SCOPE loader, but, for a complete description of the loader, refer to the reference manual for the operating system in use.

The first topic considered in this chapter is the subprogram block and how the assembler and the programmer organize the object code into blocks. Following this is a brief description of the counters that control the blocks.

Finally, there is a summary of the differences in the structure of absolute and relocatable programs and the effect of these differences on block usage.

3.1 SUBPROGRAM BLOCKS

A subprogram, whether assembled as absolute or relocatable, can be divided into subprogram areas called blocks. As assembly of a subprogram proceeds, the assembler or the user designates that object code be generated or that storage be reserved in specific blocks. By properly assigning code sequences, data, or reserved storage areas to blocks through use of ORG or ORGC, USE or USELCM, a programmer can intersperse instructions for the different blocks. The assembler assigns locations in a block consecutively as it encounters instructions destined for the block. A symbol defined within a block is not local to the block. That is, it is global and can be referred to from any other block in the subprogram. To render a symbol local to a sequence of code requires use of the QUAL pseudo instruction (Section 4.4.3).

Blocks established between two IDENT instructions, or between an IDENT and END, form a group of blocks. COMPASS recognizes a maximum of 255 blocks in a single block group, 252 of which can be user-established. When COMPASS interprets an IDENT or END pseudo instruction, it begins pass two processing of the completed block group.

All symbols are assigned absolute values, the table of block names is cleared, the list of USE, USELCM, ORG, and ORGC instructions is cleared, and block structuring restarts. For END, the symbol table is cleared before the next subprogram is assembled. If the group does not contain a USE instruction or if object code is generated (or storage reserved) before the first USE instruction, COMPASS places the code in the nominal block (identified as PROGRAM* on the listing). For an absolute program, the nominal block is the absolute block. For a relocatable program, the nominal block is the zero block. The user controls use of the nominal block and any user-established blocks through USE, USELCM, ORG, and ORGC pseudo instructions (Section 4.5). Each occurrence of a non-redundant literal constant causes an entry in the literals block; otherwise, the user has no control of this block.

3.1.1 ABSOLUTE BLOCK

The absolute block is the nominal block for an absolute assembly. It is identified by the name PROGRAM* on the listing. All code generated in the block is absolute. Each address symbol is defined during pass one as an absolute value relative to zero which is block origin. The code generated must be loaded and executed at the origin specified as the absolute block origin.

Normally, a relocatable assembly does not contain an absolute block. It may have one established, however, if the programmer issues an ORG (or ORGC) request using an absolute value. The assembler generates text tables specifying absolute block relocation. The loader loads the absolute text when it encounters the text table, without manipulating any addresses. For a relocatable assembly, an absolute block is identified on the assembly listing by the name ABSOLUTE*. There is no ECS/LCM absolute block.

3.1.2 ZERO BLOCK

The zero block has the block name 0 and is the nominal CM/SCM block for a relocatable assembly. It is a local block; that is, it is not accessible to other subprograms. Upon completion of assembly, the assembler assigns any undefined default symbols at the end of the zero block. The zero block is identified by the name PROGRAM* on the assembler listing.

An absolute program has a zero block only if the program contains default symbols. In an absolute assembly, the zero block immediately follows the absolute PROGRAM* block.

There is no ECS/LCM zero block.

3.1.3 LITERALS BLOCK

COMPASS generates literal data entries in the literals block. It is local to a subprogram. The literals block is identified by the name LITERALS* on the assembly listing. COMPASS always assigns storage to the literals block immediately following the zero block. There is no ECS/LCM literals block.

3.1.4 USER-ESTABLISHED LOCAL BLOCKS

By using USE and USELCM statements, a programmer can establish local blocks in addition to those previously described for an absolute or relocatable subprogram. At the end of assembly, COMPASS assigns an origin relative to the nominal block to each user-established local block, in the sequence in which they are established.

All of the CM/SCM local blocks are concatenated to form a single block, which is treated by the loader as a CM/SCM block whose name is unique to the subprogram. Similarly, all of the ECS/LCM† local blocks are concatenated to form a single block which is treated by the loader as an ECS/LCM block whose name is unique to the subprogram.

The length of each ECS/LCM block, including the combined local block, is rounded up, if necessary, to an integral multiple of eight 60-bit words. The maximum size of an ECS/LCM block is 1,048,568 words.

3.1.5 LABELED COMMON BLOCKS

A labeled common block is a storage area that can be preset with data accessible to one or more relocatable subprograms. These blocks are designated during assembly as being in CM/SCM or ECS/LCM through the USE and USELCM pseudo instructions respectively, where the name of the block is the name enclosed by slant bars; that is, /name/. The tables are designed so that the loader can allocate space in memory for the first subprogram that is loaded that declares the block. Thus, the first subprogram that names a block sets the maximum size of the block. Each subprogram, as it is loaded, can link to allocated blocks or can cause new blocks to be allocated. The contents of a labeled common block can be generated by any of the subprograms having access to it.

If an absolute subprogram attempts to establish a labeled common block by using a USE /name/ or USELCM /name/ instructions COMPASS treats the block as a local block having the slant-bar enclosed name.

3.1.6 BLANK COMMON BLOCKS

A blank common block is a storage area that cannot be preset with data. That is, the loader does not load information into the area before the program is executed.

For a relocatable program, the CM/SCM and ECS/LCM blank common blocks are allocated space by the loader after all subprograms are loaded, according to the largest block area declared by any of the subprograms. A CM/SCM blank common block is established through use of the USE pseudo instruction (section 4.5.1). An ECS/LCM blank common block is established through use of the USELCM pseudo instruction (section 4.5.2). A blank common block has no name. A USE // indicates blank common in CM/SCM; A USELCM // indicates blank common in ECS/LCM.

† SCOPE 2 does not currently allow LCM local blocks.

If no relocatable program declares a blank common block, there is none. If an absolute program contains a USE // or USELCM // instruction, COMPASS treats the block as a local block named // and data can be stored in this block.

Only CPU programs can use the USELCM pseudo instruction.

3.1.7 REDUNDANT BLOCK NAMES

A CPU subprogram may have two blocks with the same name and the same memory type if they have different block types (local or common). Furthermore, a CPU subprogram may have two blocks with the same name and the same block type if they have different memory types (CM/SCM or ECS/LCM). Thus, altogether, there may be up to four different blocks with the same name.

3.2 BLOCK CONTROL COUNTERS

For each block used in a subprogram, COMPASS maintains three counters, an origin counter, a location counter, and a position counter. When a block is first established or its use is resumed, COMPASS uses the counters for that block. During pass one, the origin and location counters are initially zero. During pass two, as the assembler constructs the program, it assigns an initial value to each local block origin counter and location counter. Thus, expressions containing relocatable symbols are not necessarily evaluated the same in pass one and pass two.

3.2.1 ORIGIN COUNTER

The origin counter controls the relative location of the next word to be assembled or reserved in the block. It is possible to reserve blank storage areas simply by using either the ORG, ORGC, or BSS pseudo instructions to advance the origin counter; ORG and ORGC also permit the programmer to reset the counter to some lower location in the block or to change blocks. BSS allows the programmer to decrement the counter but not to change blocks. The origin counter is incremented by one for each word assembled or skipped forward and decremented by one for each word skipped in the reverse direction.

When the special element *O is used in an expression, the assembler replaces it by the current value of the origin counter for the block in use.

3.2.2 LOCATION COUNTER

The location counter is normally the same value as the origin counter and is used by the assembler for defining symbolic addresses within the block. The counter is incremented whenever the origin counter is incremented. It is possible through the LOC pseudo instruction to adjust the location counter so that it differs from the origin counter. This may be desirable when the code being assembled is to be loaded at one location and subsequently moved and executed at another location. In this case, the programmer resets the location counter to reflect the actual location at which execution is to occur. As another example of its use, the programmer assembling a large table may reset the location counter to zero so that on the listing, the addresses alongside each word of the table reflect the word's position in the table rather than in the block. Note that use of this technique does not alter the placement of code in the block. (For an example of these applications, see the LOC pseudo instruction, section 4.5.5.) When either of the special elements * or *L is used in an expression, the assembler replaces it by the current value of the location counter for the block in use.

3.2.3 POSITION COUNTER

Assume that bits are numbered 59-00, from left to right within a 60-bit CPU word and numbered 11-00 within a 12-bit PPU word. Then, the position counter is initially 60 and 12, respectively, and indicates the number of bits remaining in the word. The position counter, which is decremented by one for each completed bit of an assembled word, becomes 00 when the word is completed, and is reset to 60 or 12 when a new operation is started.

For a CPU assembly, the 15-bit and 30-bit CPU instructions cause the position counter to normally have values of 60, 45, 30, and 15 reflecting the placement in the word for the next instruction or data word to be generated. For a PPU assembly, the normal value is 12.

The normal pattern of advancement for the position counter can be altered through use of the VFD and POS pseudo instructions.

When the special element *P is used in an expression, the assembler replaces it with the current value of the position counter.

When the special element $ is used in an expression, the assembler replaces it with the current value minus one of the position counter for the block in use; that is, it returns the next available bit position.

3.2.4 FORCING UPPER

In a CPU assembly, if any of the following conditions is true, the assembler packs parcels remaining in a partially completed word with no-operation instructions (section 8.1), sets the position counter to 60, and increments the origin and location counters before it assembles code for the next instruction:

Insufficient room remains in a partially filled word for the next instruction or data to be generated.

The current statement is a machine instruction, or a VFD pseudo instruction, with a location symbol or + in the location field.

The current statement is an RE, WE, PS, XJ, CC, CU, DM, or IM instruction for a CYBER 170 Series or CYBER 70/Model 72, 73, 74, or 6000 Series. (The programmer can negate this force upper by placing a minus sign in the location field of the instruction.)

The current statement is an END, BSS, BSSZ, DATA, DIS, CON, SEGMENT, SEG, IDENT, ORGC, LOC, ORG, or MD pseudo instruction.

The assembler forces upper after it assembles code for one of the following:

JP
RJ
Unconditional EQ
Unconditional ZR
ES (CYBER 70/Model 76 or 7600)
MJ (CYBER 70/Model 76 or 7600)
PS (CYBER 170 Series, CYBER 70/Model 72, 73, 74 or 6000 Series)
XJ (CYBER 170 Series, CYBER 70/Model 72, 73, 74 or 6000 Series)
IM (CYBER 70/Model 72 and 73)

This post force upper does not occur immediately, but is deferred until the assembler encounters the next machine instruction or data generating, storage allocating, or binary control pseudo instruction in the same USE block. The programmer can negate the force upper following the instruction by placing a minus sign in the location field of the next instruction. Thus, pseudo instructions following one of the above machine instructions and referencing the origin, location, or position counter will use the value before the force upper.

In a PPU assembly, no forcing upper occurs; the assembler ignores a + in the location field on any instruction other than a VFD. A plus or minus in the location field of a VFD in PPU assemblies forces the VFD data to begin at the next full word.

3.3 RELOCATABLE PROGRAM STRUCTURE

A CPU relocatable program consists of one or more subprograms that can be assembled separately, either in the same computer run or in independent runs. The subprogram can all be written in COMPASS source language, or can be written in any other source language available in the product set of the operating system as long as the compiler or assembler produces relocatable binary output in a form acceptable to the loader. A COMPASS language subprogram is composed of instructions beginning with an IDENT pseudo instruction and ending with an END pseudo instruction.

The COMPASS assembler repertoire includes pseudo instructions that facilitate relocatable subprogram linkage. Through these linkages, subprograms loaded together can transfer control to each other and can access common storage locations.

Upon completion of assembly of a relocatable subprogram, COMPASS assigns each local block an origin relative to the zero block (Figure 3-1). Output is in the form of tables for the Relocatable Loader. Each local block thus becomes an extension of the zero block. The length of the subprogram given on the assembly listing is the sum of the final values of the origin counters for the local blocks, including the zero block and literals block, but not the absolute block. Any absolute text is simply inserted at the absolute location relative to RA (S).

COMPASS binary output for a relocatable subprogram consists of one section for each LCC pseudo instruction (if any) in the source program, followed by one section containing the subprogram loader tables.

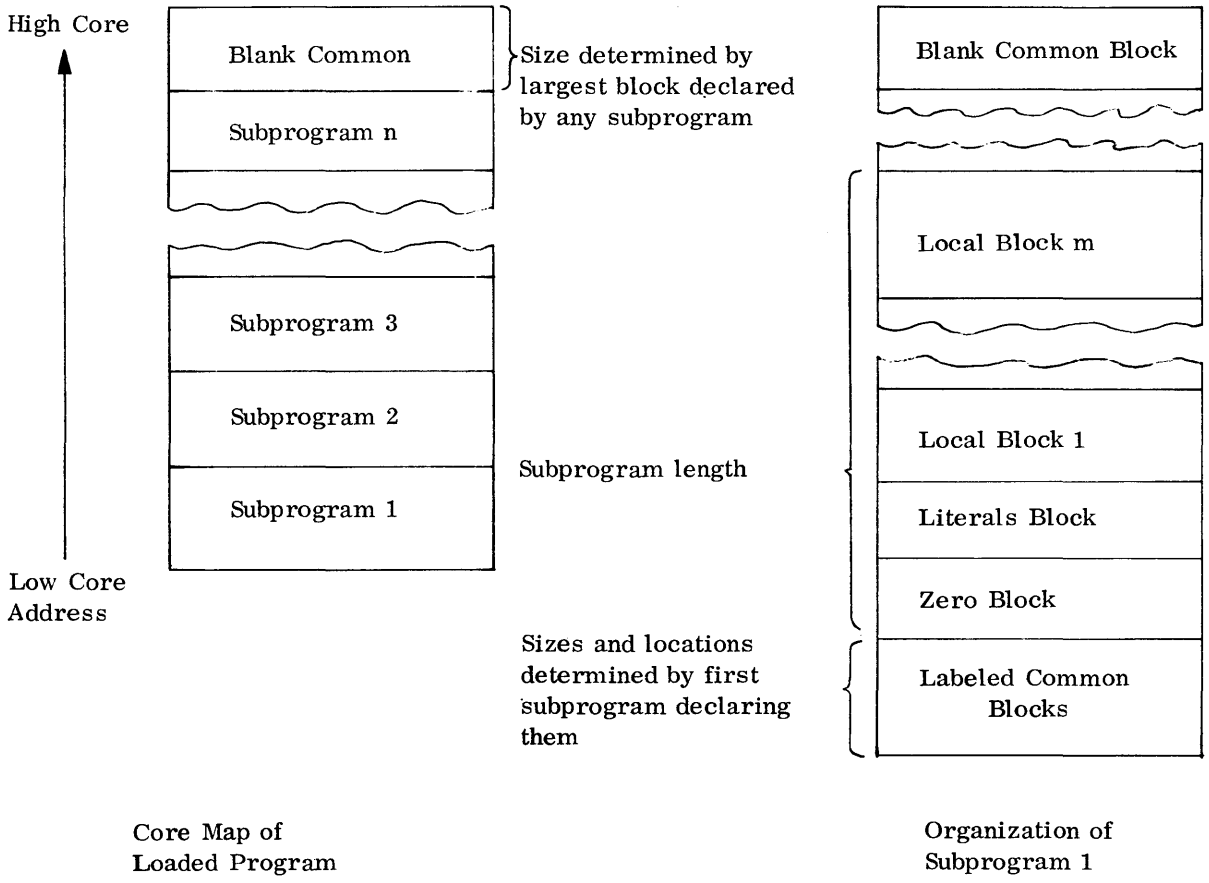


Figure 3-1. Relocatable Program Structure

3.4 ABSOLUTE PROGRAM STRUCTURE

An absolute program consists of code that is not relocatable and must be loaded at specific core locations. Because the absolute loader performs no address manipulation, absolute code can be loaded more rapidly than relocatable code.

The programmer has the option of constructing his absolute program as a single unit, or of dividing it into overlays. Each overlay consists of data, information, or instructions that are needed at different times. Dividing a program into overlays allows several routines to occupy the same core storage consecutively so that total storage requirements for a program are reduced.

During assembly of an absolute program or overlay, COMPASS creates a core image of the absolute code. During pass two, it assigns each block an origin relative to the absolute block. Any relocatable symbol is reassigned an absolute address; each block effectively becomes an extension of the absolute block. Figure 3-2 illustrates the structure of an absolute program that is not divided into overlays.

The binary output for the program consists of a section for each overlay. Note that the section for an absolute program that is not divided into overlays has the same format as the main overlay of a program divided into overlays. The user has the option of writing part of a binary section at a time by using either a SEG pseudo instruction or an IDENT (other than the first IDENT) with a blank variable field.

An absolute section has three parts:

1. 77_8 prefix table (PRFX)
2. 50_8 or 51_8 overlay table, or a 6000 or 7600 PPU header table
3. Core image of the program

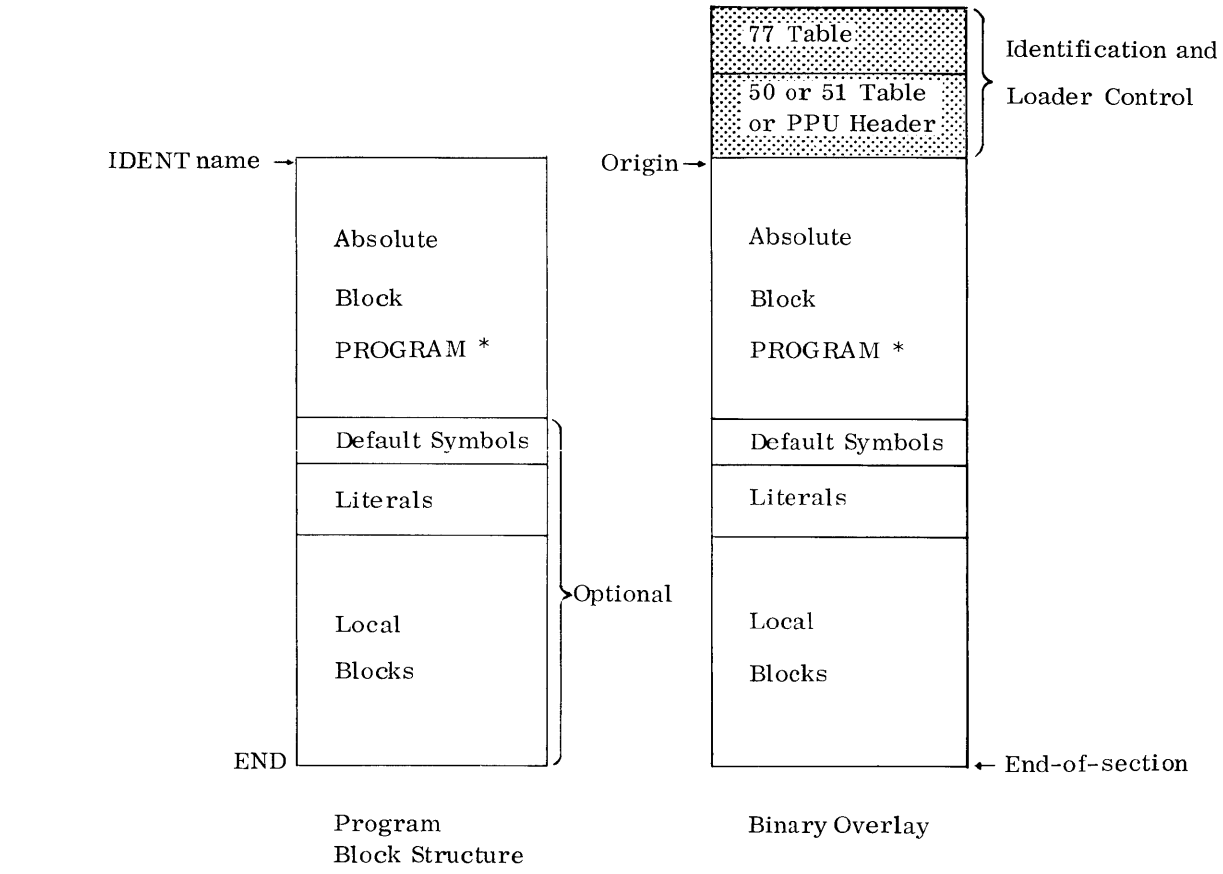
The table formats are described more fully in the Loader Reference Manual.

The amount of binary written as a result of the binary control instruction (IDENT, SEGMENT, SEG, or END) is subject to whether or not an entire block group is written.

If a complete block group is being written (everything between an IDENT and an END or between two IDENT instructions), the core image of the program or overlay ends with the maximum origin counter value for the last block established, that is, with the last word address.

If only a portion of the binary for the block group is being written, it consists of the core image of the program or overlay ending with the value of the current origin counter.

END, SEGMENT, and a nonblank IDENT complete on overlay and write an end of section. SEGMENT and IDENT write header information for the overlay to follow.



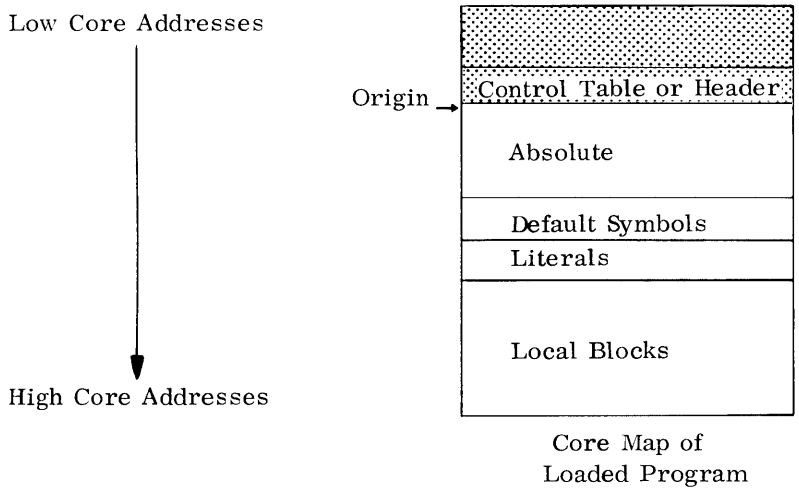


Figure 3-2. Absolute Program Structure

3.4.1 ABSOLUTE OVERLAYS

When an absolute program contains more than the one IDENT † pseudo instruction or contains SEGMENT pseudo instructions, COMPASS does not prepare just one section of a core image of the program as it is assembled, but, instead, generates a section for each overlay.

Dividing the program into overlays permits core to be sequentially overlayed by different subroutines and data during program execution, reducing the maximum core requirements for the program.

For a CPU assembly, the overlay generated is either primary or secondary as determined by the IDENT or SEGMENT pseudo instruction. The portion of the program following the first IDENT is normally the main overlay and is identified by the level numbers 0,0. Secondary overlays can be generated subsequent to the main overlay. A secondary overlay is identified by the level numbers x,y, where x is nonzero.

Conventionally, the main overlay is the first one loaded and contains calls to the operating system loader to load one or more overlays as they are required during object time execution. Any overlay can call the loader to load another overlay. Control transfers to an entry in the overlay or returns to the calling overlay according to the format of the call. (For detailed information concerning CPU loader calls, refer to the Loader Reference Manual.)

Because overlays are not all in core concurrently during program execution and because the sequence in which overlays are loaded and executed is beyond the scope of the assembler, it is the user's responsibility to assure that an overlay does not refer to symbols, instructions, or data that is not concurrently in core.

Although PPU overlays are not identified by level numbers, they resemble CPU overlays in all other respects.

Overlays generated by using IDENT pseudo instructions differ in certain respects from overlays generated by using SEGMENT instructions, as described below.

Binary formats for overlays are described in the Loader Reference Manual.

IDENT-Type Overlays

The portions of the program from IDENT to IDENT, and IDENT to END comprise the overlays. IDENT provides the programmer with the option of specifying the overlay level numbers with each overlay, including the overlay generated by the first IDENT.

If no level number is provided for a CPU assembly, the first overlay is numbered 0,0 and any overlay after that is numbered 1,0. IDENT allows each overlay to be assigned unique numbers. Thus, the loader has a means of locating a specified overlay when several overlays are written on the same file.

---

† IDENT instructions described in this section are assumed to have nonblank parameters. The special case of the blank IDENT is described in Section 3.4.3.

The first IDENT causes COMPASS to generate the program or overlay identification information that precedes the absolute section. Upon encountering a second IDENT instruction before an END instruction, COMPASS generates output consisting of a core image of the overlay starting with the overlay origin specified on the previous IDENT and normally ending with the maximum origin counter value of the last block declared in the overlay, that is, it normally ends with the last word address. An IDENT subsequent to a SEG or SEGMENT, however, generates binary that ends at the location specified by the current origin counter. Following the core image, COMPASS writes an end of section and the overlay identification information specified by the new IDENT for the overlay to follow.

For an IDENT-type overlay, COMPASS completes all blocks, including the literals block. Block structuring starts fresh with each overlay. This means that each overlay can use the same block names used by other overlays, and each overlay can contain a literals block. The USE table and control counters are all reinitialized. The origin specified for an IDENT-type of overlay can be any place in a previously generated overlay. This is possible because IDENT causes the assembler to assign an absolute address to each symbol in the symbol table. It can do this because the sizes of all the blocks are known.

Figure 3-3 illustrates a CPU program consisting of a main overlay and a secondary overlay. The main overlay uses the absolute block and block A. Default symbols and literals cause the assembler to generate a zero block and the literals block. Following the second nonblank IDENT instruction, the program overlay origin is set back into the block A. The overlay generates a new literals block and new blocks A, C, and D.

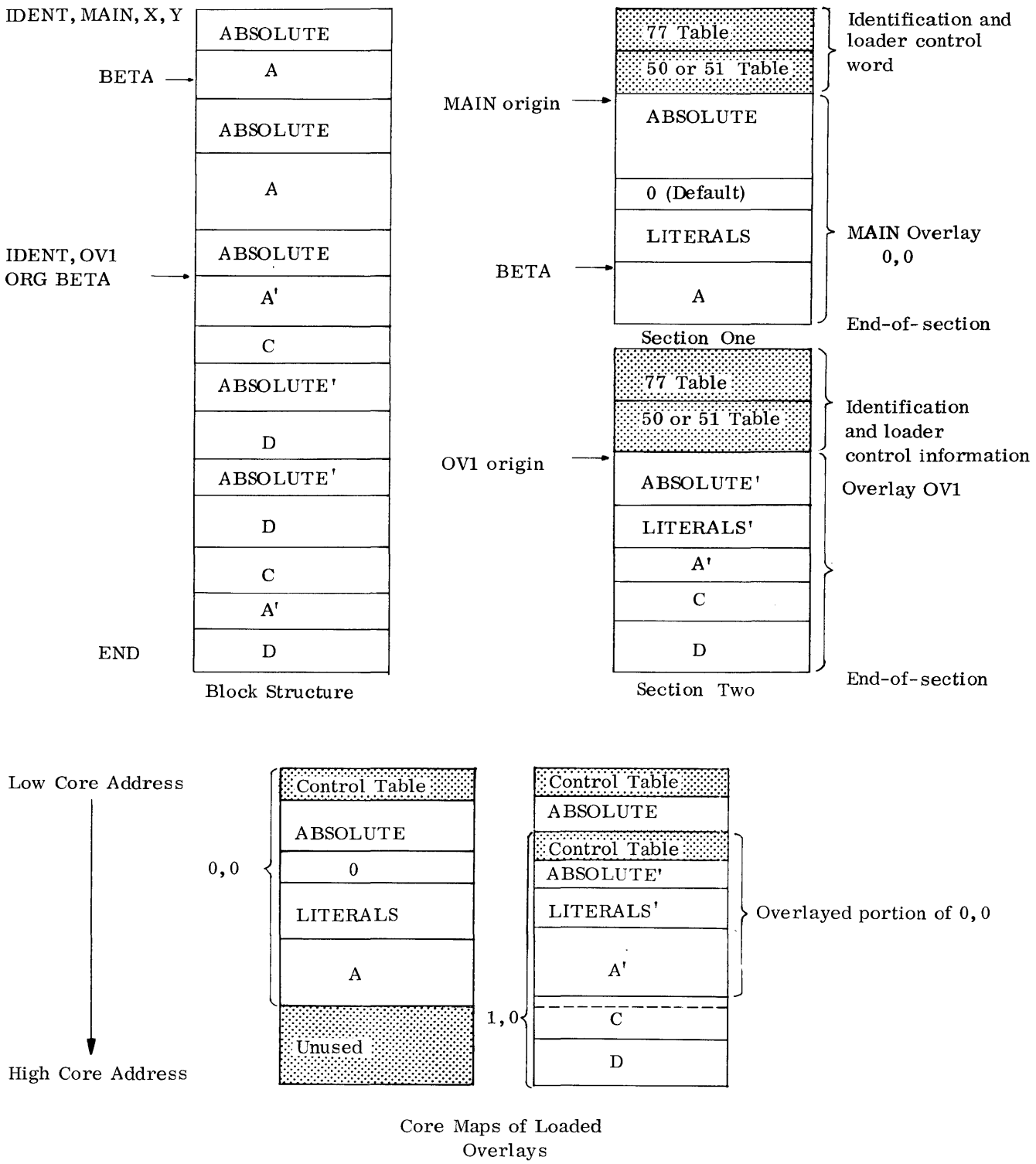


Figure 3-3. IDENT-Type Overlay Structure

SEGMENT-Type Overlays

The portions of the program from the IDENT that identifies the program to SEGMENT, from SEGMENT to SEGMENT, and from SEGMENT to END comprise the overlays. SEGMENT provides the programmer with the option of specifying the overlay level number with each overlay.

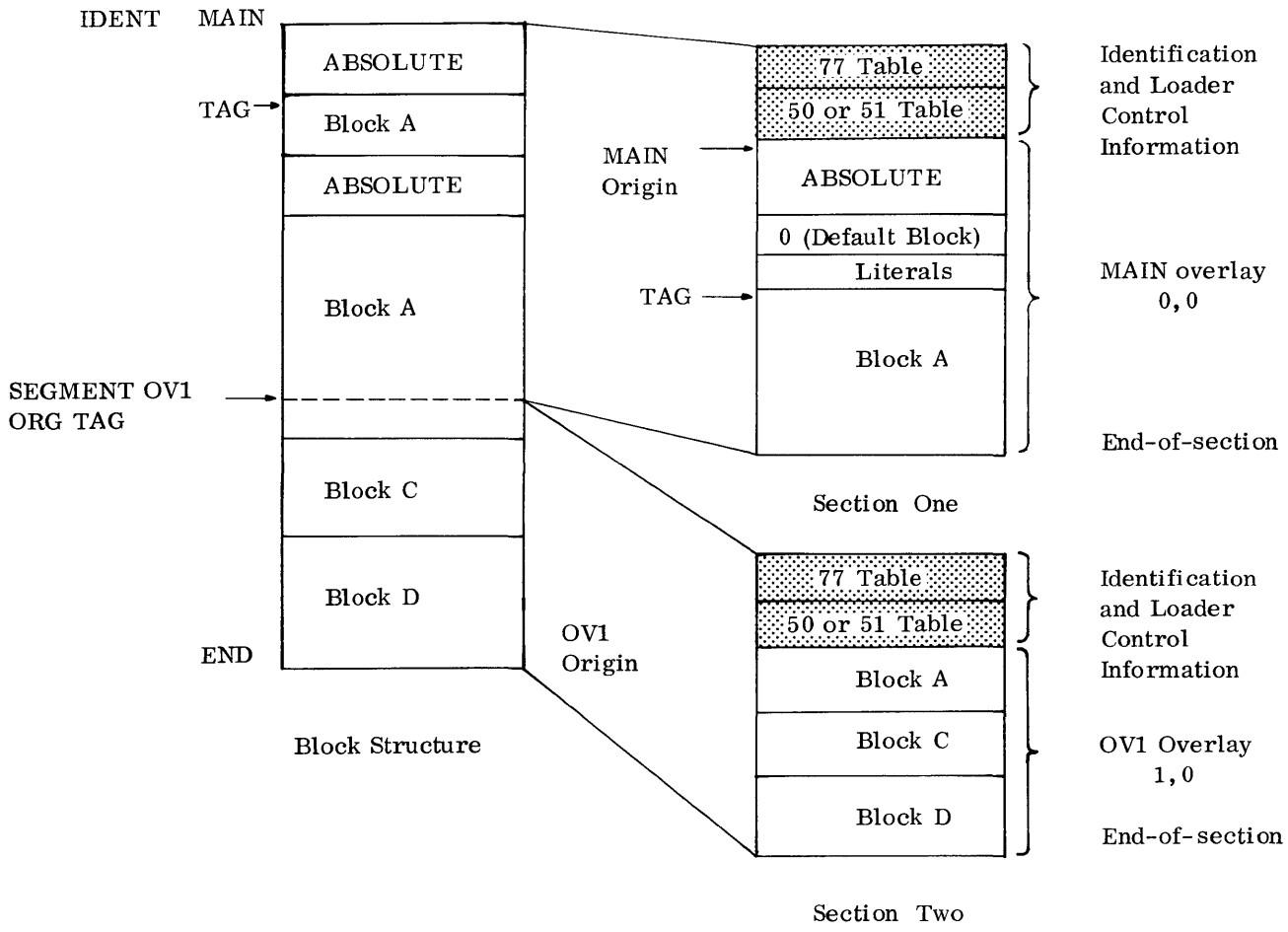
If no level number is provided for a CPU overlay, the first overlay is numbered 0,0 and any overlay after that is numbered 1,0. SEGMENT allows each overlay to be assigned a unique number. Thus, the loader has a means of locating a specified overlay when several overlays are written on the same file.

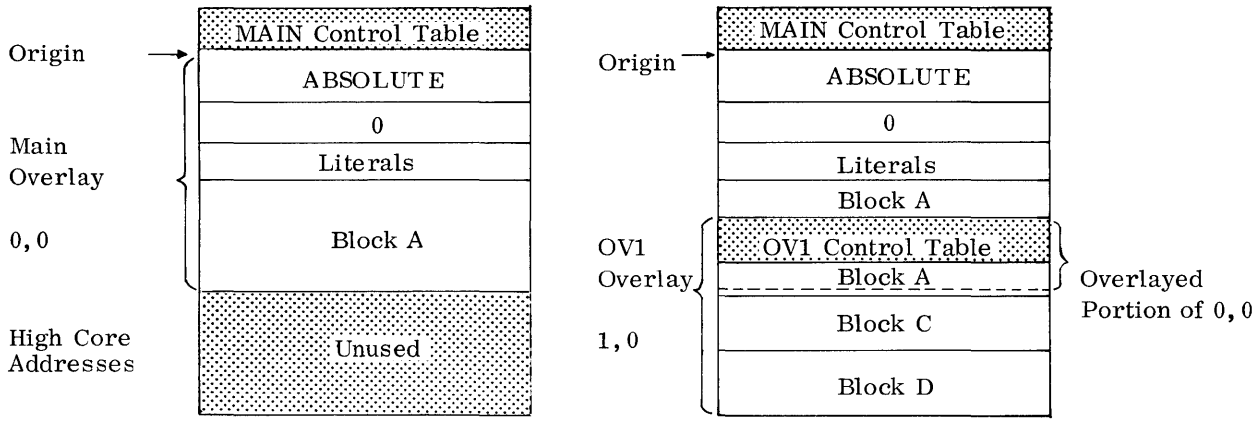
Upon encountering a SEGMENT instruction, COMPASS generates output consisting of a core image of the overlay starting with the overlay origin specified on the previous SEGMENT (or IDENT, for the first overlay), and ending with the current origin counter value of the block in use at the time the SEGMENT was encountered. Following this, COMPASS writes an end-of-section and overlay identification information for the overlay to follow.

For SEGMENT, the last block used in the overlay is incomplete. The literals block is in the overlay that contains the end of the absolute block. It is the responsibility of the user to assure that all blocks other than the one in use are complete. The origin of the new overlay can be defined using symbols in the block in use only. SEGMENT does not clear the symbol table or reinitialize the USE table.

Each new SEGMENT-created overlay must use unique block names because blocks established in previous overlays cannot be resumed and because the block names remain in the USE table due to the incompleteness of the block group.

Figure 3-4 illustrates a program consisting of a main overlay and a secondary overlay. The main overlay uses the absolute block, the literals block, and block A. Default symbols cause the generation of a zero block. Following the SEGMENT, an ORG instruction sets the overlay origin back into block A, the block in use when the SEGMENT was encountered. The 1,0 overlay establishes new blocks C and D.





Core Maps of Loaded Overlays

Figure 3-4. SEGMENT-Type Overlay Structure

3.4.2 MULTIPLE ENTRY POINT OVERLAYS

When a CPU program or overlay that calls an overlay is assembled independently of the overlay called, it may be desirable for the called overlay to identify more than one entry point. Thus, ENTRY pseudo instructions are permitted within an absolute assembly and cause the generation of a 51_8 overlay table. This table consists of a control word and a list of overlay entry points. The calling program can examine the list and link to any of the entry points. The 51_8 table occupies the area below the overlay origin and uses one more word than the number of entries in the table. For the format of the 51_8 table, refer to the Loader Reference Manual.

3.4.3 PARTIAL BINARY

When a CPU absolute program or an overlay contains SEG pseudo instructions or IDENT pseudo instructions for which the parameters are omitted (blank), COMPASS writes a partial binary section consisting of the binary generated since the previous IDENT, SEGMENT, or SEG instruction. However, it does not write an end of section or a new 77_8 table. A SEGMENT, nonblank IDENT, or END instruction completes the binary section.

SEG-Type Partial Binary

By writing partial binary using SEG, the programmer can reduce the assembler storage requirements. A fatal error is issued if the user attempts to store data into a block previously written out or into a block that will be written out later.

When the SEG is encountered, COMPASS writes binary beginning with the first block established in that portion of binary and ending with the final count specified by the origin count for the current block.

SEG does not write a complete block group. The portion of the binary that contains the end of the absolute block contains the literals block, if there is one. The symbol table and USE table are not reinitialized.

Figure 3-5 illustrates how the binary for an absolute program can be written in three separate binary writes to reduce the amount of core required to assemble the program. The resulting absolute section is loaded and executed as a single program or overlay.

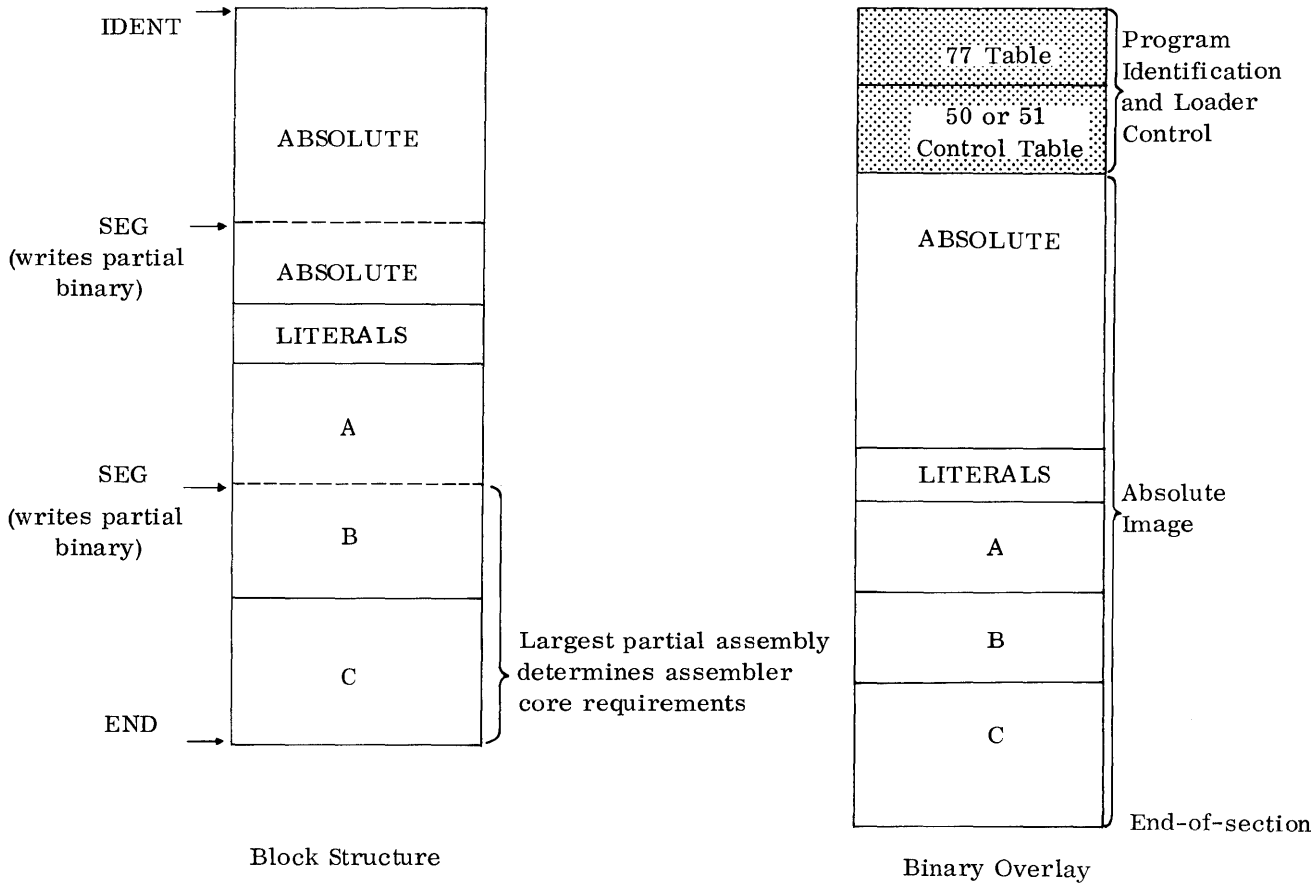


Figure 3-5. SEG-Type Partial Binary

IDENT-Type Partial Binary

An IDENT with a blank variable field causes all binary accumulated since the previous IDENT, SEG, or SEGMENT to be written out without an end of section or a new 77_8 prefix table. The USE table and the block counters are reinitialized. Each symbol in the symbol table is assigned an absolute address. The blocks in each partial binary section generated in this manner are allocated as if the partial binary section were a new subprogram with its own absolute block, literals block, and local blocks. This allows portions of a program to be self-contained units even though they are not overlays but are loaded as a single unit. The origin of an absolute block for a new portion is the last word address plus one of the last block of the previous portion.

The core image written by a blank IDENT starts with the origin of the absolute block and normally ends with the maximum origin counter value of the last block declared in the block group, that is, it normally ends with the last word address. If part of the block group has already been written by a SEG or SEGMENT, however, the end of the binary is specified by the value of the origin counter for the current block.

COMPASS completes all blocks. The literals block is terminated. Block structuring starts fresh with each IDENT. Each new partial binary section created by a blank IDENT can use the same block names as are used by the other blank IDENT-created partial binary sections and non-blank IDENT-created overlays and each IDENT can contain a literals block but the blocks with the same names are independent of each other.

An attempt to write into or to reset the origin counter to a location in a partial binary section written separately causes a range error.

Figure 3-6 illustrates how the binary for an overlay can be written in three discrete partial binary sections to reduce the amount of core required to assemble the program and divide the program into self-contained units. The resulting absolute section is loaded and executed as a single overlay.

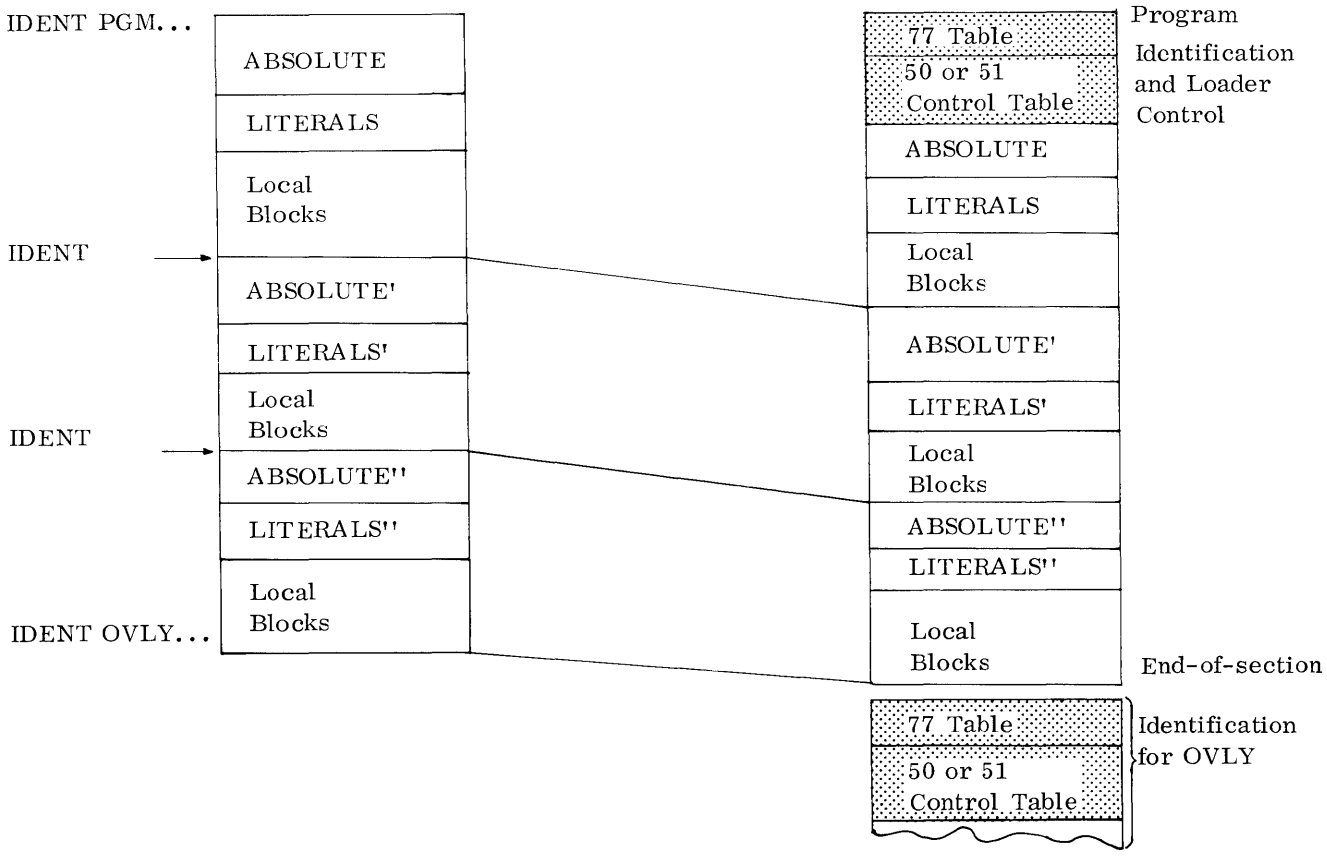


Figure 3-6. IDENT-Type Partial Binary

PSEUDO INSTRUCTIONS 4

4.1 INTRODUCTION TO PSEUDO INSTRUCTIONS

This chapter and chapters 5, 6, and 7 describe the pseudo instructions available in the COMPASS language. It is impossible to write a program in the COMPASS language without using some of the more basic pseudo instructions. The programmer who is new to the language should give special attention to these instructions.

Pseudo Instruction	Section	CPU Relocatable	CPU Absolute	PPU Absolute
IDENT	4.2.1	X	X	X
ABS	4.3.1	-	X	-
PPU or PERIPH	4.3.3 or 4.3.4	-	-	X
ORG	4.5.3	-	X	X
ENTRY	4.7.1	X	-	-
BSS	4.5.4	X	X	X
CON	4.8.6	X	X	X
END	4.2.2	X	X	X

4.1.1 TYPES OF PSEUDO INSTRUCTIONS

Pseudo instructions discussed in this chapter are classed according to application as follows:

Subprogram identification (IDENT and END)

Binary control (ABS, MACHINE, PERIPH, PPU, IDENT, SEGMENT, SEG, LCC, STEXT, COMMENT, and NOLABEL)

Mode control (BASE, CHAR, CODE, COL, B1= 1, B7= 1, and QUAL)

Block counter control (USE, USELCM, ORG, ORGC, BSS, LOC, and POS)

Symbol definition (EQU and=, SET, MAX, MIN, MICCNT, and SST)

Subprogram linkage (ENTRY, ENTRYC, and EXT)

Data generation (BSSZ and blank operation code, DATA, DIS, LIT, VFD, CON, R=, REP, REPC, and REPI)

Assembly control (ELSE, ENDIF, IFtype, IFop, IF, IFC, IFPL, IFMI, and SKIP)

Error control (ERR and ERRxx)

Listing control (LIST, EJECT, SPACE, TITLE, TTL, NOREF, CTEXT, ENDX, and XREF)

Later chapters describe pseudo instructions that involve definition operations, alterations to the operation code table, and micros. In general, pseudo instructions can be summarized according to where they can be placed in a subprogram.

4.1.2 REQUIRED PSEUDO INSTRUCTIONS

Two pseudo instructions, IDENT and END, are required for any assembly. IDENT must be the first source statement; END signals the termination of source statements for a subprogram.

4.1.3 FIRST STATEMENT GROUP

Certain pseudo instructions establish basic characteristics of the assembly and provide the assembler with required information. These instructions comprise the first statement group which must precede any symbol definition, storage allocation, or object code generation. The following instructions, if used, must be in the first statement group.

ABS
MACHINE
PERIPH
PPU
STEXT

4.1.4 PERMISSIBLE ANYWHERE INSTRUCTIONS

The following pseudo instructions are permissible anywhere, including in the first statement group.

BASE	CPSYN	ENDM	MICCNT	OPSYN	SPACE
B1=1	DECMIC	HERE	MICRO	PPOP	SST
B7=1	EJECT	IFC	NIL	PURGDEF	TITLE
CHAR	ELSE	IRP	NOLABEL	PURGMAC	TTL
CODE	END	LIST	NOREF	QUAL	XREF
COMMENT	ENDD	MACRO	OCTMIC	RMT	
CPOP	ENDIF	MACROE	OPDEF	SKIP	

Comments lines and references to macro definitions are also permitted anywhere.

CPU or PPU symbolic machine instructions and all other pseudo instructions cannot be placed in the first statement group. The first use of one of these instructions terminates the first statement group.

4.2 SUBPROGRAM IDENTIFICATION

Subprogram identification pseudo instructions designate subprogram beginning and end. When two or more subprograms are assembled in a single COMPASS run called through COMPASS control statement, the end of the source decks is indicated by a 7/8/9 card.

4.2.1 IDENT — SUBPROGRAM IDENTIFICATION

An IDENT pseudo instruction of the following form is the first statement of a subprogram recognized by the assembler. Usually, any lines preceding the first IDENT or between an END and IDENT are assumed to be comments. However, when COMPASS has been called by some other language processor such as FORTRAN, the assembler returns control to the processor when the statement following END is not IDENT. For a relocatable subprogram, COMPASS flags any subsequent use of IDENT before END as an error. For an absolute subprogram, a second form of IDENT described under BINARY CONTROL is available for overlay generation.

The format of IDENT varies according to the type of assembly.

CPU Relocatable Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name

CPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin,entry,ℓ_1,ℓ_2

7600 PPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin,entry,ppu

6000 Series PPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin

name — Name of the subprogram or overlay. The parameter is required. For a CPU relocatable or absolute assembly, name can be 1-7 characters, of which the first must be alphabetic (A-Z) and the last must not be a colon.

For a CYBER 70/Model 76 or 7600 PPU assembly, name can be 1-7 characters. For a CYBER 170 Series or CYBER 70/Model 72, 73, 74 or 6000-Series PPU assembly, name can be 1-3 characters. In either case, there is no restriction on the first character, but the last character must not be a colon.

origin — An expression specifying the first word address of the absolute program or overlay. The overlay loader table and all code assembled starting at this address and ending with the next SEGMENT, nonblank IDENT, or END instruction comprises the overlay. For a single entry point CPU program the load address for the overlay is origin-1. The word at origin -1 is overlayed by the 50_8 loader control table. For a multiple entry point CPU program, the load address for the absolute overlay is origin-wc-1, where wc is the number of entry points in the 51_8 loader table.

For a PPU subprogram, the load address is origin-5. Five 12-bit PPU words are overlayed by the 60-bit loader table.

Data can be generated in locations starting with origin and above, but not below origin. The origin subfield does not serve the same function as ORG nor does it replace ORG for setting the origin counter.

If the origin field is null for an absolute subprogram, the assembler uses address 000000 RA(S) as the origin for a CPU program and 0000 as the origin for a PPU program.

For a relocatable subprogram, the subfield is ignored. The loader automatically relocates the first subprogram to be loaded starting at RA(S)+100_8, the second subprogram starting at the first available location following the first subprogram, etc.

entry — For a CYBER 70/Model 76 or 7600 PPU assembly or for an absolute CPU assembly, this subfield contains an expression specifying the subprogram entry address, which can be symbolic.

ℓ_1, ℓ_2 — Absolute expressions specifying the level numbers of the overlay. ℓ_1 is the primary level (0-63) and ℓ_2 is the secondary level (0-63). When the first IDENT identifies the main overlay, ℓ_1 and ℓ_2 can be omitted. If ℓ_1 is omitted, it is set to 00. If ℓ_2 is omitted, it is set to 00.

Because the first IDENT precedes any use of the BASE pseudo instruction, the level numbers on this IDENT are evaluated as decimal unless specifically designated as octal by a post radix.

ppu — Absolute expression specifying the number of the PPU on which this program is to be loaded. On the first IDENT, this number is evaluated as decimal unless specifically designated as octal.

A location field symbol, if present, is ignored.

If the COMPASS assembler is called from within a FORTRAN compilation rather than by a COMPASS control card, IDENT must be in columns 11-15.

When the subprogram does not include a TITLE instruction, COMPASS uses the IDENT variable field entry as the main subprogram title on the assembly listing.

Example:

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                 11         18              30
          IDENT   CT,CONTROL,CONTROL
          ABS               ABSOLUTE CPU PROGRAM
          ORG     110B
CONTROL   BSS     0         DEFINES SYMBOL CONTROL
          END
```

Absolute CPU program CT will be loaded at origin address 00110_8.

4.2.2 END — END OF SUBPROGRAM

An END pseudo instruction must be the last instruction of each subprogram. It causes the assembler to terminate all counters, conditional assembly, macro generation, or code duplication. Before terminating assembly, COMPASS assembles any waiting remote text (see RMT).

For a relocatable subprogram, the assembler combines all local blocks into a relocatable subprogram block, generates the relocatable binary tables and produces the listing.

For an absolute assembly, the assembler assigns each block an origin relative to absolute zero, combines all blocks into an absolute subprogram or overlay, generates the absolute binary section and produces the listing.

END can also be used to signal the end of source statements from an external source (see XTEXT). In this case, it does not terminate the subprogram.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	END	trasym

sym — Optional last word address symbol; if present, COMPASS defines it as the total subprogram length, including the literals block and all local blocks. The value is the last word address plus one.

trasym — A symbol specifying the entry point to which control transfers for a relocatable subprogram. This symbol must be declared as an entry point in a subprogram -- not necessarily the subprogram being assembled. At least one subprogram must specify a transfer address or the loader signals an error. If more than one subprogram indicates a transfer address, the loader uses the last one encountered.

For an absolute assembly, trasym is ignored.

Example:

```
 | LOCATION | OPERATION | VARIABLE | COMMENTS
1|          |11         |18        |30
 |          | IDENT     | PROG1    |
 |          | ENTRY     | BEGIN    |
 |          |  .        |  .       |
 |          |  .        |  .       |
 |          |  .        |  .       |
 | BEGIN    | SB1       | 1        |
 |          |  .        |  .       |
 |          |  .        |  .       |
 |          |  .        |  .       |
 |          | END       | BEGIN    |
```

4.3 BINARY CONTROL

Pseudo instructions that allow the user extensive control of binary output produced by the assembler are summarized below and described fully in this section.

ABS	Specifies CPU absolute binary output
MACHINE	Specifies processor type
PPU	Specifies CYBER 70/Model 76 or 7600 PPU binary output
PERIPH	Specifies CYBER 170 Series, CYBER 70/Model 72, 73, 74, or 6000 Series PPU binary output
IDENT	Begins absolute overlay or writes partial binary section
SEGMENT	Begins absolute overlay
SEG	Writes partial binary section
STEXT	Generates system text overlay
COMMENT	Inserts comments into the 77_8 prefix table
NOLABEL	Suppresses header information on binary output
LCC	Passes loader control information to the relocatable loader

4.3.1 ABS — ABSOLUTE CPU PROGRAM

An ABS instruction declares a CPU program to be absolute. If used, it must be in the first statement group.

The following instructions are illegal in an absolute program:

EXT
LCC
REP
REPC
REPI

A symbol can be prefixed by =X if it is also defined conventionally; in this case, the =X has no significance because a conventional definition takes precedence (Section 2.4.2).

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	ABS	

Symbols in the location and variable fields, if present, are ignored. If a program contains both ABS and PERIPH (or PPU), the PERIPH (or PPU) instruction takes precedence.

Example:

```
 |  LOCATION  | OPERATION | VARIABLE          | COMMENTS
1|            |11         |18                 |30
 |            | IDENT     | CT,CONTROL,CONTROL|
 |            | ABS       |                   |ABSOLUTE CPU PROGRAM
 |            |  .        |  .                |
 |            |  .        |  .                |
 |            | ORG       | 110B              |
 |  CONTROL   | BSS       | 0                 |DEFINES SYMBOL CONTROL
 |            |  .        |  .                |
 |            |  .        |  .                |
 |            |  .        |  .                |
 |            | END       |                   |
```

4.3.2 MACHINE - DECLARE OBJECT PROCESSOR TYPE

The MACHINE pseudo instruction specifies the type of computer system on which the object program can be executed successfully and optionally specifies hardware features needed by the object program. If used, MACHINE must be in the first statement group.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	MACHINE	type, hf_1, hf_2, hf_3, . . . , hf_n

A location field symbol, if present, is ignored.

type — Character string designating object processor type. The subfield can be any length and may contain any characters other than blank or comma. The first character identifies processor type, as follows:

6 — The object program is restricted to the following computer systems: CYBER 170 Series, CYBER 70/Model 72, 73, or 74, or 6000 Series. All machine instructions unique to the CYBER 70/Model 76 or 7600 Computer Systems are undefined.

7 The object program is restricted to a CYBER 70/Model 76 Computer System or to a 7600 Computer System. With the exception of the PS instruction (often used for subroutine entry points in CPU assemblies), all instructions unique to the following computer systems are undefined: CYBER 170 Series, CYBER 70/ Models 72, 73, and 74, and 6000 Series.

In a CPU assembly, if the MACHINE pseudo instruction is omitted, or the type subfield is blank, or its first character is not 6 or 7, then all CPU instructions are defined, and the target and valid fields of the PRFX table in the object program are blanks. If the type subfield is present and its first character is 6 or 7, the valid field contains 6X or 7X. If the type subfield is at least two characters, the first character is 6 or 7, and the second character is a digit (0-9), the target field contains those two characters.

In a PPU assembly, if the MACHINE pseudo instruction is omitted, or the type subfield is blank, or its first character is not 6, or 7, then: if the PERIPH pseudo instruction is present, MACHINE 6 is assumed; if the PPU pseudo instruction is present, MACHINE 7 is assumed. The target field of the PRFX table contains blanks, and the valid field contains 6P or 7P.

hf_i Optional subfield, a character string designating an optional hardware feature required for successful execution of the object program. The subfield may be any length and may contain any characters other than blank or comma. It has no effect on assembly of the program. The first character of the subfield is placed in the hardware-instruction-dependencies field in the PRFX table in the object program.

Recommended mnemonic letters are:

C Compare/Move Unit

D Distributive Data Path

I Integer Multiply Instruction

L ECS/LCM

R Interlock Register

X Central and Monitor Exchange Jumps

Up to nine hf_i subfields are processed; any additional subfields are ignored. If the hf_i subfields are omitted, the comma following type can also be omitted.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		MACHINE	6,CMU,LCM,XJ	

4.3.3 PPU - CYBER 70/MODEL 76 OR 7600 PPU PROGRAM

A PPU instruction declares a program to be a CYBER 70/Model 76 or 7600 absolute PPU program rather than a CPU program. If used, PPU must be in the first statement group. For a description of binary format generated as a result of this instruction, refer to the Loader Reference Manual.

Floating point constants and the following instructions are illegal in a PPU assembly:

ENTRY	SEGMENT
ENTRYC	USELCM
EXT	R=
LCC	B1=1
REP	B7=1
REPC	
REPI	
SEG	

If the program contains both a PPU and a PERIPH pseudo instruction, the PPU takes precedence. PPU programs permit symbols of the form used for CPU register designators; they are normal symbols having no special significance. The following instructions are legal but are not applicable in a PPU assembly:

OPDEF
CPOP
CPSYN
PURGDEF

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	PPU	J

J — A character string beginning with J supplied in the variable field alters the way that COMPASS assembles the variable expression on UJN, ZJN, NJN, MJN, or PJN instructions.

If J is not specified, COMPASS first tests the range of the expression against the short jump limit (±31). If the value is in range, COMPASS assembles the jump using the value of the expression. If the value is out of range, COMPASS performs a second test, this time using the expression value minus the location counter value. If the value is now in range, COMPASS assembles the instruction using the expression value minus the location counter value. However, if it is out of range, a fatal error is flagged.

Selection of the J option causes COMPASS to always subtract the value of the location counter from the value of the expression.

As a result, COMPASS is able to differentiate between an expression value that is an absolute address in the short jump range from an expression value that is a true relative address.

A symbol in the location field, if present, is ignored.

Example:

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
			PPU		
			•		
			•		
740		TAG	BSS	20B	
760	0357		UJN	TAG-*	EXPRESSION < 37B

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
			PPU	JUMP	
			•		
			•		
740		TAG	BSS	20B	
760	0357		UJN	TAG	EXPRESSION-* < 37B

4.3.4 PERIPH - CYBER 170 SERIES OR CYBER 70/MODELS 72, 73, 74 OR 6000 SERIES PPU PROGRAM

A PERIPH instruction declares a program to be a CYBER 170 Series or CYBER 70/Model 72, 73, 74, or 6000 Series absolute PPU program rather than a CPU program. If used, PERIPH must be in the first statement group. For a description of binary output produced as a result of this instruction, refer to the Loader Reference Manual.

Floating point constants and the following instructions are illegal in a PPU assembly:

ENTRY	LCC	REPI	R=
ENTRYC	REP	SEG	B1=1
EXT	REPC	USELCM	B7=1

A symbol can be prefixed by =X if it is also defined conventionally.

PPU programs permit symbols of the form used for CPU register designators; they are normal symbols having no special significance. The following instructions are legal but are not applicable to PPU assemblies:

OPDEF
CPOP
CPSYN
PURGDEF

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	PERIPH	J

J — A character string beginning with J supplied in the variable field alters the way that COMPASS assembles the variable field expression on UJN, ZJN, MJN, or PJN instructions.

If J is not specified, COMPASS first tests the range of the expression value against the short jump limit (±31). If the value is in range, COMPASS assembles the jump using the value of the expression. If the value is out of range, COMPASS performs a second test, this time using the expression value minus the location counter value. If the value is now in range, COMPASS assembles the instruction using the expression value minus the location counter value. However, if it is out of range, a fatal error is flagged.

Selection of the J option causes COMPASS to always subtract the value of the location counter from the value of the expression.

For an example illustrating how to use J, see the PPU pseudo instruction.

A symbol in the location field, if present, is ignored.

4.3.5 IDENT - IDENTIFY AND GENERATE OVERLAY

Two or more IDENT pseudo instructions are permitted in CPU absolute or PPU assemblies. Second and subsequent IDENT instructions having nonblank variable fields cause generation of overlays. IDENT differs from SEGMENT in the way it generates overlays. First, it allows the specification of overlay numbers. Second, the USE table and all block counters are reinitialized. The symbol table is not cleared; all symbols are reassigned absolute addresses relative to absolute zero. Thus, an ORG to a previously defined symbol restarts the absolute block at the symbolic address. The third difference is that normally the end of the overlay is determined by the last word address, the maximum origin counter value of the last block established in the overlay. A preceding SEG or SEGMENT can alter this, however (Section 3.4).

For a CPU assembly, an IDENT with a blank variable field causes a partial binary write. The output is not terminated by an end of section or a new 77_8 table. However, the USE table and the block counters are reinitialized and each symbol in the symbol table is assigned an absolute address.

Following an IDENT, COMPASS assumes that all blocks, including the literals block are complete. Block structuring starts fresh with the new overlay or portion of binary. Thus, each new overlay or partial can use the same block names as are used by other overlays or partial and each can have a literals block.

For a blank IDENT, an attempt to write into or reset the origin counter to a location in a partial section written separately causes a range error. Following the IDENT, the origin of the new absolute block is the next word after the binary written out, that is, it is lwa+1.

The format of the IDENT varies according to the type of assembly as follows:

CPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin,entry,ℓ_1,ℓ_2

or

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	

7600 PPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin,entry,ppu

6000 Series PPU Absolute Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IDENT	name,origin

name — Name of the overlay. For a CPU program, 1-7 characters, the first of which must be alphabetic (A-Z); for CYBER 170 Series or a CYBER 70/Model 72, 73, or 74 or a 6000 Series PPU program, 1-3 characters; for a CYBER 70/Model 76 or 7600 PPU program, 1-7 characters. In all cases, the last character must not be a colon. A name is a loader linkage symbol required for overlays.

origin — An expression specifying the first word address of the overlay. The overlay control word and all code assembled starting with this address and ending with the next SEGMENT, nonblank IDENT, or END instruction comprises the overlay. For a single entry point CPU program, the load address for the overlay is origin-1. The word at origin-1 is overlayed by the 50_8 loader table. For a multiple entry point CPU program, the load address for the overlay is origin-wc-1, where wc is the number of entry points listed in the 51_8 loader table.

For a PPU subprogram, the load address is origin-5. Five 12-bit PPU words are overlayed by the 60-bit loader control table. Data can be generated in locations starting with origin and above, but not below origin. The origin subfield does not serve the same function as ORG nor does it replace ORG for setting the origin counter. The origin of an overlay can be below the origin specified on any other IDENT or SEGMENT.

entry — An expression specifying the overlay entry address. When the overlay is called, control optionally transfers to this address.

ℓ_1, ℓ_2 — Absolute expressions specifying the level numbers of the overlay for CPU programs only. ℓ_1 is the primary level ($00\text{-}77_8$), ℓ_2 is the secondary level ($00\text{-}77_8$). If base is M, ℓ_1 and ℓ_2 are assumed to be octal. If ℓ_1 and ℓ_2 are not specified, ℓ_1 is set to 01 and ℓ_2 is set to 00.

ppu — An absolute expression specifying the number of the PPU in which the overlay is to be loaded. If base is M, ppu is assumed to be octal.

A location field symbol, if present, is ignored.

The binary is written on the file specified by the B parameter on the COMPASS control card. END dumps the last overlay or completes a partially written section.

Examples:

The following program uses IDENT for overlay creation. Symbols T.OVL, O.DMP1, etc. are defined on a system text overlay.

```
                 LOCATION  OPERATION  VARIABLE              COMMENTS
                 1         11         18                    30
D.M              |         IDENT     DMP.1,T.OVL,O.DMP1    |
                 |         ABS       |                     |
                 |         BASE      M                     |
                 |         COMMENT   10/07/70.CONTROL CARD CALL.DMP.
                 |         LIST      G                     |
                 |         SST       |                     OVERLAY
                 |         ORG       T.OVL                 DMP1
                 |         QUAL      DMP1                  |
                 DMP       SX0       B1                    |
                 |         .         .                     |
                 |         .         .                     |
                 |         .         .                     |
                 |         QUAL      DMP2                  |
                 |         IDENT     DMP2,T.OVL,O.DMP2     |
                 |         ORG       T.OVL                 OVERLAYS DMP2
                 UBW2      SX0       B6+1                  THROUGH DMP8
                 |         .         .                     |
                 |         .         .                     |
                 |         .         .                     |
                 |         QUAL      DMP9                  |
                 |         IDENT     DMP.9,T.OVL,O.DMP9    OVERLAY
                 |         ORG       T.OVL                 DMP9
                 |         SX0       O.DMP2+F.MDE          |
                 |         .         .                     |
                 |         .         .                     |
                 |         .         .                     |
                 |         END       |                     END OVERLAY DMP9
```

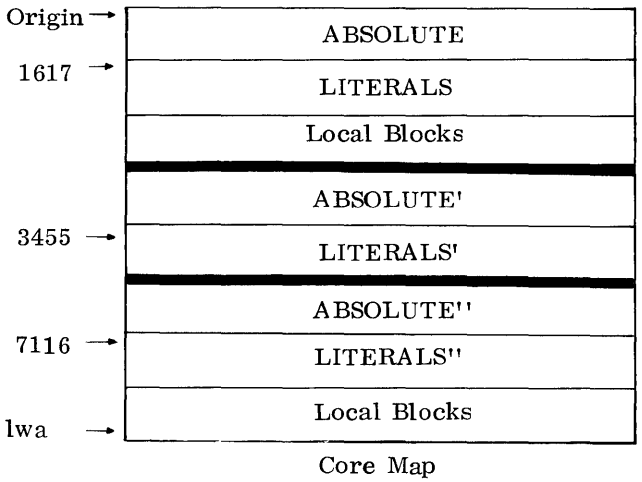
The following program uses IDENT instructions having blank variable fields.

```
                    LOCATION    OPERATION   VARIABLE        COMMENTS
                    1           11          18              30
                                IDENT       VVV,110B,ENT
                                ABS
                                ORG         110B
                    ENT         SX0         1
                                .           .
                                .           .
                                .           .
1617                            LIT         1,2,3
                                .           .
                                .           .
                                .           .
                                IDENT
                                .           .
                                .           .
                                .           .
3455                            LIT         2,3
                                .           .
                                .           .
                                .           .
                                IDENT
                                .           .
                                .           .
                                .           .
7116                            LIT         1,2
                                .           .
                                .           .
                                .           .
                                END
```

First Partial Binary

Second Partial Binary

Third Partial Binary



Core Map

4.3.6 SEGMENT - GENERATE BINARY SEGMENT

The SEGMENT pseudo instruction produces overlays at assembly time. It has many of the features of IDENT and is included primarily to provide another way of handling literals. Use of SEGMENT is intended for 6000 Series CPU absolute or PPU assemblies. For a relocatable subprogram, a SEGMENT pseudo instruction causes BSSZ code and the FILL, REPL, and LINK relocatable tables to be written on the binary output file.

The first SEGMENT causes all binary accumulated since the IDENT to be dumped as the main (0, 0) overlay. Each subsequent SEGMENT generates a new overlay with the specified level numbers. END dumps the last overlay. When COMPASS encounters a SEGMENT pseudo instruction, it does not clear the symbol table or block declarations. All blocks other than the block in use must be complete. For a CPU assembly, the literals block must be in one overlay only but that overlay can be any overlay.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	SEGMENT	origin,entry,l_1,l_2

name — Name of overlay. For a CPU program, 1-7 characters, first of which must be alphabetic (A-Z); for a PPU subprogram, 1-3 characters. In all cases, the last character must not be a colon. It is a required loader linkage symbol.

origin — A relocatable expression specifying the first word address of the overlay. It can only be an address in the block in use. The overlay loader table and all code assembled starting at this address and ending with the next SEGMENT, nonblank IDENT, or END instruction comprises the overlay.

For a CPU program the load address for the record is origin-1. The word at origin-1 is overlayed by the 50_8 loader table.

For a PPU subprogram, the load address is origin-5. Five 12-bit PPU words are overlayed by the 60-bit loader table. Data can be generated in locations starting with origin and above, but not below origin. The origin subfield does not serve the same function as ORG nor does it replace ORG for setting the origin counter. The origin of an overlay can be below the origin specified on any other IDENT or SEGMENT.

entry — An expression specifying the overlay entry address. It is used for CPU assemblies only. When the overlay is called, control optionally transfers to this address.

l_1,l_2 — Absolute expressions specifying the level numbers of the overlay for CPU programs only. l_1 is the primary level (00-77_8), l_2 is the secondary level (00-77_8). If base is M, l_1 and l_2 are assumed to be octal. If l_1 and l_2 are not specified, l_1 is set to 01 and l_2 is set to 00.

Example:

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1               11         18              30
                IDENT      SAM,ENTA
                ABS
                ORG        110B
ENTA            BSS        0               ENTRY POINT
                .          .
                .          .
                .          .
OVLOC           BSS        0               OVERLAY LOAD POINT
                .          .
                .          .
                .          .
SEG1            SEGMENT    STRT,ENTB
                ORG        OVLOC
                BSS        1               LOADER TABLE
STRT            BSS        0               FIRST WORD OF OVERLAY
                .          .
                .          .
                .          .
ENTB            BSS        0               EXECUTION BEGINS HERE
                .          .
                .          .
                .          .
                END                        END OF OVERLAY
```

SEG1 is loaded as an overlay upon a call for the loader from the program. The first word of the overlay is loaded at OVLOC +1, following the loader table. The entry point to the overlay and the first executable instruction is at ENTB. The overlay, when executed occupies the area of the main program beginning at OVLOC.

4.3.7 SEG - WRITE PARTIAL BINARY

The SEG pseudo instruction permits the generation of a CPU absolute subprogram or overlay in less core than would otherwise be required for assembly. It is illegal in PPU and relocatable assemblies.

SEG causes COMPASS to write on the binary output file all binary information accumulated since the previous IDENT, SEGMENT, or SEG pseudo instruction. It does not write an end of section or begin a new PRFX table. A SEGMENT, IDENT, or END instruction completes the binary section.

SEG does not affect the location and origin counters. The user cannot resume use of a block established prior to the SEG, except for the block in use when the SEG was encountered. An attempt to reset the origin counter so as to resume a block already written out causes an R error. Also, since the block group is incomplete and the names of the blocks already written out are still in the USE table, no new blocks can be established using the same block names as were used prior to the SEG.

The literals block is written in the portion that contains the end of the absolute block.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	SEG	

Symbols in the location field and variable field, if present, are ignored.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		IDENT	NAME,ORIGIN,ENTRY	
		ABS		
		USE	A	
		•	•	
		•	•	
		•	•	
		SEG		
		USE	B	
		•	•	
		•	•	
		•	•	
		SEG		
		•	•	
		•	•	
		•	•	
		END		

4.3.8 STEXT - GENERATE SYSTEM TEXT RECORD

As a result of an STEXT pseudo instruction, binary output for the subprogram consists of all symbols, micros, and opcodes (macros, opdefs, and machine and pseudo instructions), written in overlay format at the end of pass one. The STEXT instruction must be in the first statement group.

The system text overlay becomes available in other assemblies through use of the G or S option on the COMPASS control card (chapter 10). Through this feature, information in the system text overlay need be processed only once for all COMPASS programs using the same system text. System text overlays cannot be generated and used in the same assembly batch; system text overlays generated by one COMPASS control card call can be used only by assemblies performed by later COMPASS control card calls.

The symbols included in the system text overlay written are all symbols defined in the assembly except those for which at least one of the following is true:

The symbol value is relocatable or external.

The symbol is qualified.

The symbol is redefinable (i.e., defined by SET, MAX, MIN, or MICCNT).

The symbol is defined by statements read by XTEXT or occurring between CTEXT and ENDX.

The symbol is defined by SST (i.e., is a system symbol input to the present system text assembly).

The symbol is 8 characters beginning with ↑ ↓.

All defined micros are included in the system text overlay.

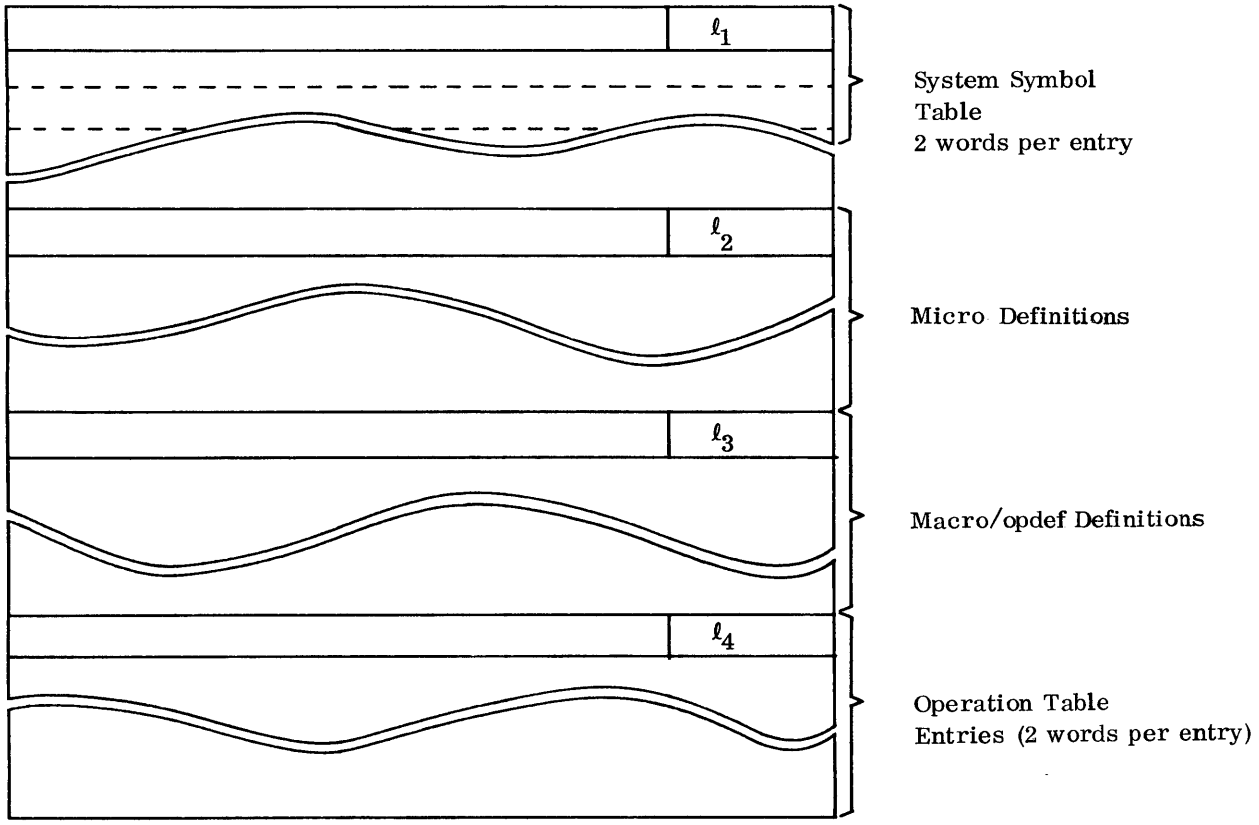
All program-defined opcodes are also included. Machine and pseudo instructions automatically defined by COMPASS, and opcodes defined by system text input (if any) to the assembly, are not included.

When a system text overlay is used as input to an assembly through the G or S option on a COMPASS control card, all of the micros and opcodes in the system text are automatically defined at the start of each assembly; however, the symbols in the system text are defined only for those assemblies that contain the SST pseudo instruction.

A system text overlay on the library is an absolute overlay that has the following control table:

59 48	42	36	00
5000	01	01	000000000000

Format of Text:



ℓ_i = Number of words in each part of overlay

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
rname	STEXT	

rname — Name assigned to overlay; 1-7 alphanumeric characters, of which the first must be a letter (A-Z) and the last must not be a colon. It is placed in the prefix table that precedes the overlay.

If rname is blank, COMPASS uses the name from the IDENT instruction and generate the system text only. Otherwise, the system text is generated in addition to the relocatable or absolute binary and precedes the binary output on the binary file.

An entry in the variable field, if present, is ignored.

Example:

```
|  LOCATION  | OPERATION | VARIABLE  | COMMENTS
1            11          18          30
             IDENT       SYSTEXT
             STEXT
             BASE        MIXED
MPRS         EQU         100         ┐
 •           •           •           │
                                     SYSTEM CONSTANTS, SYMBOLS,
                                     AND COMMUNICATIONS AREAS
 •           •           •           │
 •           •           •           ┘
TRTS         EQU         7777
IXX/X        OPDEF       I,J,K       ┐
 •           •           •           │
 •           •           •           SYSTEM-DEFINED MACROS
 •           •           •           AND OPDEFS
             ENDM                    │
SYSCOM       MACRO       N           │
 •           •           •           │
 •           •           •           │
 •           •           •           ┘
             ENDM
DATE         MICRO       1,10,*...*  ┐
 •           •           •           │
 •           •           •           SYSTEM-DEFINED MICROS
 •           •           •           ┘
             END
```

4.3.9 COMMENT—PREFIX TABLE COMMENT

The COMMENT pseudo instruction inserts the character string specified in the variable field into the eighth through fourteenth words of the PRFX table in the object program. The prefix table, and thus the comment, is ignored by the loader but identifies the section. If a subprogram contains more than one COMMENT instruction, the new comments are appended to the table for the most recent binary control card. If the subprogram contains a NOLABEL instruction, the COMMENT instruction is meaningless. COMMENT instructions following SEG and blank IDENT pseudo instructions are ignored without notification.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	COMMENT	string

string — COMPASS searches the columns following the blank that terminates the operation field. If it does not find a nonblank character before the default comments column (see COL pseudo instruction), it takes the characters starting with the default comments column minus one. Otherwise, the character string begins with the first nonblank character following the operation field. In either case, the last character of the string is the last nonblank character of the statement. 1 to 10 blanks are appended on the right so that the string is followed by at least one blank and the length of the string is a multiple of 10 characters. If the variable and comment fields are all blanks, the string consists of 10 blanks. If the string length is more than 70 characters, all characters beyond the 70th are lost.

A location field symbol, if present, is ignored. Refer to section 4.3.5 for an example.

4.3.10 NOLABEL — DELETE HEADER TABLE

The NOLABEL instruction modifies the format of the binary output produced by COMPASS for an absolute assembly by optionally suppressing header information. It is particularly convenient for generating deadstart programs which must be loaded at location zero or for writing Chippewa format CPU programs.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	NOLABEL	I

I — Optional; if the variable field contains a character string beginning with an I, COMPASS suppresses all prefix (77_8) tables, but retains the other program header tables.

If the I option is omitted, COMPASS suppresses all of the following:

Prefix tables (77_8)
Overlay control tables (50_8)
Multiple entry point tables (51_8)
PPU header control tables

A location field symbol, if present, is ignored. NOLABEL is illegal in a relocatable CPU assembly.

4.3.11 LCC — LOADER DIRECTIVE

The LCC pseudo instruction provides a means of including loader directives with the tables for a relocatable program.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	LCC	directive

directive — First nonblank character following LCC to the first blank. For directive formats, refer to the Loader Reference Manual.

A location field symbol, if present, is ignored.

COMPASS writes a directive as a section in packed display code for subsequent interpretation by the loader. COMPASS does not edit the directive; the loader recognizes illegal forms at load time.

4.4 MODE CONTROL

Mode control pseudo instructions influence the basic operating characteristics of the assembler. Specifically, the instructions allow the programmer to alter the way in which the assembler:

Interprets binary data	BASE pseudo instruction
Generates character data	CODE pseudo instruction
Interprets the beginning of comments on statements	COL pseudo instruction
Qualifies symbols or does not qualify them	QUAL pseudo instruction
Interprets the R= instruction	B1=1 or B7=1 pseudo instruction

In each case, the assembler has a default mode which it uses if one of these instructions is never used.

4.4.1 BASE — DECLARE NUMERIC DATA MODE

The BASE pseudo instruction declares the mode of interpretation for numeric data for which a base radix is not explicitly defined. Use of the BASE pseudo is optional; if BASE is not used in a subprogram, COMPASS evaluates unspecified numeric data as decimal.

An alternate application of BASE is to define the previous base as a micro.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	BASE	mode

mname — Optional 1-8 character micro name by which the previous BASE mode can be referenced in subsequent BASE instructions. If mname is present, the value of the micro named mname is (re)defined to be a single letter D, M, or O, corresponding to the BASE mode in effect prior to this BASE instruction.

mode

Blank, in which case the base remains unchanged, or 1-8 characters, the first of which designates the new base as follows:

O — Octal assembly base; any subsequent use of a data item not specifically identified by an O, D, or B prefix or suffix is evaluated as octal. For example, the constants 15 and 15B are evaluated as 15_8; constant 15D is evaluated as 17_8. Any item containing an 8 or 9 without a D radix is flagged as erroneous. Exceptions are scale factors, character counts, shift counts (S modifier), and binary point positions, which are always considered decimal.

D — Decimal assembly base; any subsequent use of a data item not specifically identified by an O, D, or B prefix or suffix is evaluated as decimal.

M — Mixed assembly base; any subsequent use of a data item not specifically identified by an O, D, or B is evaluated as decimal if it is one of the following. Otherwise, it is evaluated as octal.

- VFD bit count
- IF, ELSE, or SKIP line count
- MICRO, OCTMIC, or DECMIC character count
- B, C, or I subfield in REP or REPI
- DUP or ECHO line count
- Character count
- Shift counts (S modifier)
- Scale factors
- Binary point position
- COL column number
- DIS word count
- SPACE line count

* — Use base in effect prior to current base. The assembler records occurrences of BASE pseudo instructions and maintains a table of the most recent 50 occurrences. Each BASE * resumes use of the most recent entry and removes it from the list. When the subprogram contains more BASE * instructions than there are entries in the stack, COMPASS uses a decimal base.

other — If the variable field is not blank and does not contain one of the above, COMPASS sets an error flag.

Examples:

This example illustrates the affect of BASE on a VFD instruction that defines a 48-bit field containing 10_8.

```
Code Generated

                    D+0
0000000000000010

                    0+D
                   0000
000000000010

                    D+M
                00000000
00000010
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS
|  1          |           11|        18|        30
|             |  BASE     | 0        |
|             |  VFD      | 60/10    |
|             |  .        | .        |
|             |  .        | .        |
|             |  BASE     | D        |
|             |  VFD      | 48/8     |
|             |           |          |
|             |  .        | .        |
|             |  .        | .        |
|             |  BASE     | M        |
|             |  VFD      | 48/10    |
```

The following example illustrates the micro capability of BASE:

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS
|  1          |           11|        18|        30
D+M |  SAVEB   | BASE      | M        | SAVE BASE IN USE
    |  .       | .         | .        |
    |  .       | .         | .        | CODE USING BASE M
    |  .       | .         | .        |
    |          | BASE      | *SAVEB*  | RESTORE SAVED BASE
M+D |          | BASE      | D        | RESTORE SAVED BASE
    |  .       | .         | .        |
    |  .       | .         | .        |
    |  .       | .         | .        |
```

4.4.2 CHAR-DEFINE OTHER CHARACTER DATA CODE

The CHAR pseudo instruction defines character data codes to be used when the CODE O (for Other) mode is in effect.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	CHAR	exp1,exp2

exp1 — Evaluatable absolute expression whose value is 00 to 77_8. The value of exp1 is the display code value of the character to be redefined.

exp2 — Evaluatable absolute expression whose value is 00 to 77_8. The value of exp2 is the new code other value of the character designated by exp1.

A location field symbol, if present, is ignored.

Initially, all code other values are the same as display code. CHAR need be used only for those characters whose code other values are different from display code. Characters may be redefined as many times as desired by subsequent CHAR pseudo instructions.

Example:

```
          LOCATION  OPERATION  VARIABLE SUBFIELDS
00↛63               CHAR       0,63B     INTERCHANGE COLON AND
63↛00               CHAR       63B,0     PERCENT FOR CODE OTHER
```

4.4.3 CODE — DECLARE CHARACTER DATA CODE

The CODE pseudo instruction declares that until the next CODE pseudo instruction is encountered all constants, character strings, and character data items are to be generated in the specified code. Character data can be generated in ASCII†, display, external BCD, or internal BCD, codes. If no CODE instruction is used, COMPASS generates display code. Codes are given in appendix D.

An alternative application of CODE is to define the previous code as a micro.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	CODE	char

mname Optional 1-8 character micro name by which the previous CODE mode can be referenced in subsequent CODE instructions. If mname is present, the value of the micro named mname is (re)defined to be a single letter A, D, E, or I, corresponding to the CODE mode in effect prior to this CODE instruction.

char The first character of a string indicates the code conversion:

- A ASCII six-bit subset
- D Display
- E External BCD
- I Internal BCD
- O Other code, defined by CHAR pseudo instructions.
- * Use code in effect prior to current code. The assembler records occurrences of CODE pseudo instructions and maintains a table of the most recent 50 occurrences. Each CODE * resumes use of the most recent entry and removes it from the list. When the subprogram contains more CODE * instructions than there are entries in the stack, COMPASS generates display code.

†American Standard Code for Information Interchange.

Example:

Code Generated

```
1725242025240000000
                 D↱A
5765646065640000000
                 A↱E
4624234724230000000
                 E↱I
4664634764630000000
                 I↱D
1725242025240000000
                 D↱I
4664634764630000000
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		DATA	OLOUTPUT	
		CODE	ASCII	
		DATA	OLOUTPUT	
		CODE	EXTERNAL BCD	
		DATA	OLOUTPUT	
		CODE	INTERNAL BCD	
		DATA	OLOUTPUT	
		CODE	DISPLAY	
		DATA	OLOUTPUT	
		CODE	*	
		DATA	OLOUTPUT	

4.4.4 QUAL — QUALIFY SYMBOLS

The QUAL pseudo instruction signals the beginning of a sequence of code in which all symbols defined in it are either qualified or are unqualified (global). If no QUAL is in a subprogram, all symbols are defined as global.

An alternative application of QUAL is to define the previous qualifier as a micro.

Within a QUAL sequence in which a symbol is defined, a symbol reference need not be qualified. Used outside the sequence, the symbol must be referenced as/qualifier/symbol. Thus, a symbol and a qualifier become a unique identifier local to the sequence in which the symbol was defined. The same symbol used with a different qualifier is local to a different QUAL sequence. If a symbol is defined with no qualifier as well as being defined as qualified, a reference to the symbol within the QUAL sequence is assumed to be a reference to the qualified symbol rather than to the global symbol. In this case, a reference to the global symbol must be written as // symbol.

Default symbols and linkage symbols are not qualified.

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	QUAL	qualifier

mname Optional 1-8 character micro name by which the previous qualifier can be referenced in subsequent QUAL instructions or symbol references. If mname is present, the value of the micro named mname is (re)defined to be the 0-8 characters comprising the qualifier in effect prior to this QUAL instruction.

qualifier — A symbol qualifier or * or blank, as follows:

qualifier — 1-8 character name, the first character of which cannot be $ or = or numeric. The qualifier cannot contain the characters

+ - * / , or ^

A blank terminates the qualifier.

Any symbol defined subsequent to this QUAL up to the next QUAL must be referenced from outside the QUAL sequence as

/qualifier/symbol

The current qualifier appears as the third sub-subtitle on the assembly listing (section 11.1).

* — The assembler resumes using the qualifier in use prior to the current qualifier. The assembler records occurrences of QUAL pseudo instructions and maintains a table of the most recent 50 occurrences. Each QUAL * resumes use of the most recent entry and removes if from the list. When the subprogram contains more QUAL * instructions than there are entries in the stack, COMPASS uses the null (global) qualifier.

blank — A blank variable field causes any symbols defined up to the next QUAL to be global. A global symbol does not require a qualifier.

NOTE

The first attempt to redefine a global symbol from within a QUAL sequence results in A and U errors. The symbol is defined local to the QUAL sequence with a zero value. To avoid fatal errors, precede any redefinition instruction (SET, MAX, MIN, or MICCNT) within a QUAL sequence with a blank QUAL and follow it with a QUAL *.

Examples:

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1                11         18             30
                 QUAL       PASS1
      BCDE       SX6        F              BCDE QUALIFIED BY PASS1
                 .          .
                 .          .
                 EQ         LOC1
                 QUAL       PASS2
      BCDE       EQU        LOC2           BCDE QUALIFIED BY PASS2
                 QUAL                      SYMBOLS GLOBAL FROM NOW ON
                 .          .
                 .          .
                 .          .
      GLOB       BSS        0              GLOB IS GLOBAL
                 .          .
                 .          .
                 RJ         /PASS1/BCDE    JUMP TO PASS1 ROUTINE
                 .          .
                 .          .
                 RJ         /PASS2/BCDE    JUMP TO PASS2 ROUTINE
```

Location	Code Generated
10044	
10054	7777777777777777776
10055	
10065	7777777777777777776

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1                11         18             30
      TAB        MACRO      BLOCK,KWAL
                 USE        BLOCK
                 QUAL       KWAL
      TAG1       BSS        10B
      TAG2       VFD        60/-1
                 USE        *
                 QUAL       *
                 ENDM
                 .          .
                 .          .
                 .          .
                 TAB        ONE,ONE
                 USE        ONE
                 QUAL       ONE
      TAG1       BSS        10B
      TAG2       VFD        60/-1
                 USE        *
                 QUAL       *
                 ENDM
                 TAB        TWO,TWO
                 USE        TWO
                 QUAL       TWO
      TAG1       BSS        10B
      TAG2       VFD        60/-1
                 USE        *
                 QUAL       *
                 ENDM
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS
|1 |          | 11        | 18       | 30
|  |          | QUAL      | Z        |
|  | Z1       | BSS       | 0        | Z1 QUALIFIED BY Z
|  |          | .         | .        | .
|  |          | .         | .        | .
|  |          | .         | .        | .
|  |          | QUAL      | B        | EQUATE SYMBOLS SO THAT
|  | Z1       | =         | /Z/Z1    | Z1 IN Z CAN BE REFERRED
|  |          |           |          | TO AS Z1 IN B
```

4.4.5 B1 = 1 AND B7 = 1 — DECLARE THAT B REGISTER CONTAINS ONE

The B1=1 and B7=1 pseudo instructions declare that in this CPU subprogram, the contents of the B1 register or the B7 register, respectively, are one. These instructions do not produce code; they alter the way in which code is generated by the R= instruction (Section 4.8.7) and define the symbol B1=1 or B7=1. If more than one instruction is used, the assembler uses the last one encountered.

Formats:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	B1=1 B7=1	

A symbol in the location or variable field is ignored.

Note that loading the respective B register with one is the user's responsibility.

For an example of use, refer to R= (Section 4.8.7).

4.4.6 COL — SET COMMENTS COLUMN

The COL pseudo instruction sets the column number at which the comments field can begin when the variable field is blank. If no COL instruction is used in the subprogram, COMPASS uses 30.

LOCATION	OPERATION	VARIABLE SUBFIELDS
	COL	n

n — An absolute evaluatable expression designating the column number; $n \geq 12$. When base is M, n is assumed to be decimal. If n is less than 12, COMPASS sets the column at 12. If n is zero or blank, COMPASS sets the column to 30, the default column.

A location field symbol, if present, is ignored.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
44		COL USE	36	RETURN TO BLOCK 0

In this example, subsequent statements for which the variable field is blank cannot have comments beginning before column 36.

4.5 BLOCK COUNTER CONTROL

Counter control pseudo instructions establish local blocks, labeled common blocks, and blank common blocks in addition to the absolute, zero, and literal blocks established by the assembler; they control use of all program blocks, and provide the user with a means of changing origin, location, and position counters.

4.5.1 USE — ESTABLISH AND USE BLOCK

USE establishes a new block or resumes use of an already established block. The block in use is the block into which code is subsequently assembled. A user may establish up to 252 blocks.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	USE	block

block — Identifies block to be used, as follows:

0 or blank	Nominal block (absolute or 0)
//	Blank common block; for a relocatable subprogram, this block cannot contain data. The only storage allocation instructions that can follow are BSS and ORG. The BSSZ instruction is illegal because it presets the block to zeros.
/name/	Labeled common block. A name can be a maximum of 7 characters and cannot include blank or comma. The first and last characters must not be colons. Conventions imposed by the loader or other assemblers or compilers could further restrict the use of names.
name	Local block. A name can be 1-8 characters, excluding blank or comma. Use of this name enclosed by brackets does not cause the block to become a labeled common block. For example, USE A and USE /A/ are different blocks.
*	Block in use prior to current USE, USELCM, ORG, or ORGC. See discussion following.

A location field symbol, if present, is ignored.

The nominal program block contains the entire program if no USE or USELCM is encountered.

Redundancy between block names is permitted as follows:

A labeled common block designated by /0/ can coexist with the program block designated by 0. Blank common designated by // can coexist with a labeled common block designated as ////.

A CPU subprogram may have two blocks with the same name and the same memory type if they have different block types (local or common). Furthermore, a CPU subprogram may have two blocks with the same name and the same block type if they have different memory types (CM/SCM or ECS/LCM). Thus, altogether, there may be up to four different blocks with the same name.

When a block is first established, its origin and location counters are zero and its position counter is either 60 (CPU subprogram) or 12 (PPU subprogram). When a different block than that in use is indicated, COMPASS saves the values of the current origin and position counters along with an indicator as to whether the next instruction is to be forced upper. If the most recently assembled instruction under the block is one that forces the next instruction upper, the first instruction assembled upon resumption of the block is forced upper. When the designated block has been previously established, COMPASS resumes assembly in the block using the last known values for the origin and position counters. The value of the location counter is not saved. Upon resumption of the block, it is set to the value of the origin counter. If a LOC had been used previously, resetting of the location counter to produce the desired results is the responsibility of the programmer.

The assembler records occurrences of USE, USELCM, ORG, and ORGC pseudo instructions (except USE * and USELCM *) and maintains a USE table of the most recent 50 occurrences. Each USE * and USELCM * resumes use of the most recent entry and removes it from the table. When the subprogram contains more USE * or USELCM * instructions than there are entries in the stack, COMPASS uses the nominal block.

Examples:

```
Location        Code Generated

                                    USE
13   0100000000                     RJ      ALPHA       BLOCK 0 IN USE
                                    USE     DATA1       BLOCK DATA1 IN USE
35   1720400000000000000    SAP     DATA    1.0
                                    USE     *           RESUME USE OF BLOCK 0
14   5130000000                     SA3     SAM
```

Note that the SA3 is forced upper because the RJ causes a force upper of the next instruction in the block.

```
Location        Code Generated

                                    USE     TABLE       USE TABLE LOCAL BLOCK
2615   00                           VFD     6/0
                                    USE     *           RESUME PREVIOUS BLOCK
                                    .       .           .
                                    .       .           .
                                    .       .           .
                                    USE     TABLE       RESUME USING TABLE
       30002600 +                   VFD     6/1RX,18/S
                                    USE     *           RESUME PREVIOUS BLOCK
```

Note how separate blocks can be used to facilitate packing of partial-word bytes into a table residing in a block other than the one primarily being used.

4.5.2 USELCM - ESTABLISH AND USE ECS/LCM BLOCK

The USELCM pseudo instruction establishes or resumes use of a block assigned to extended core storage (ECS) or large core memory (LCM). For all ECS/LCM blocks in an absolute CPU assembly, and for the ECS/LCM blank common block in a relocatable assembly, data generating instructions (including BSSZ) and symbolic machine instructions are illegal; only storage reservation pseudo instructions (BSS, ORG and ORGC) are allowed. The USELCM pseudo instruction is illegal in PPU assemblies.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	USELCM	block

block: Identifies block to be used, as follows:

0 or blank	Illegal.
//	Blank common block. A subprogram can have two blank common blocks if one of them is in ECS/LCM.
/name/	Labeled common block. The name can be a maximum of 7 characters and cannot include blank or comma. The first and last characters must not be colons. The loader or other assemblers or compilers could further restrict the use of names.
name	Local block. † The name can be 1-8 characters, excluding blank or comma. Use of this name enclosed by brackets does not cause the block to become a labeled common block. For example, A and /A/ are different blocks. All of the local ECS/LCM blocks are concatenated to form a single block, which is treated by the loader as an ECS/LCM common block whose name is unique to the subprogram.
*	Block in use prior to current USE, USELCM, ORG, or ORGC.

A location field entry, if present, is ignored.

The length of each ECS/LCM block, including the combined local block, is rounded up, if necessary, to an integral multiple of eight 60-bit words. The maximum size of an ECS/LCM block is 1,048,568 words.

Further rules for USELCM are the same as for USE.

† SCOPE 2 does not currently allow local blocks in LCM.

Examples:

```
 |  LOCATION | OPERATION | VARIABLE      | COMMENTS
 1           | 11        | 18            | 30
             | BASE      | 0             |
             |           |               |
             | USELCM    | LCM           | ESTABLISH AND USE LCM BLOCK
 LCMC        | BSS       | 0             | DEFINE SYMBOL LCMC
 BLOC1       | BSS       | 100           | RESERVE 100 WORDS
 BLOC2       | BSS       | 200           | RESERVE 200 WORDS
             | USE       | *             | RESUME PREVIOUS BLOCK
             | .         | .             |
             | .         | .             |
             | ORG       | BLOC1+1000B   |
 BLOC3       | BSS       | 20            | RESERVE 20 MORE WORDS
             | USE       | *             | RESUME PREVIOUS BLOCK
```

4.5.3 ORG AND ORGC - SET ORIGIN COUNTER

ORG indirectly indicates the block to be used for assembly of subsequent code and specifies the value to which the origin and location counters are to be set. COMPASS makes an entry in the USE table and saves the current origin and position counter values.

ORGC † indirectly indicates the block to be used for assembly of subsequent code and specifies the value to which the origin and location counters are to be set. COMPASS makes an entry in the USE table and saves the current origin and position counter values. In a PPU or absolute assembly, ORGC is the same as ORG. In a relocatable CPU assembly, ORGC is the same as ORG if the USE block specified by the address expression is not a common block; otherwise, code following an ORGC is ignored by the linking loader if that common block was first declared by a previously loaded subprogram.

† Not supported by SCOPE 2 Loader.

Formats:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	ORG	exp
	ORGC	exp

exp Expression specifying the address to which the origin and location counters are to be set. Following ORG or ORGC, the assembly resumes at the upper position of the location specified. COMPASS determines the block as follows:

1. If the expression contains a symbolic address, COMPASS uses the block in which the symbol was defined.

2. COMPASS uses the current block if the value of the expression is *, *L, or *O. If the origin and location counters are the same value, and no code has been assembled in the current location, the only effect of *, *L, or *O is to force the next instruction upper. If a word is partially assembled, however, the code already assembled into the location is lost.

   If the counter values differ, * or *L sets the origin counter to agree with the location counter value; *O sets the location counter to the origin counter value.

3. An absolute expression causes use of the absolute block. In a relocatable assembly, this is the only way to establish the absolute block. All symbols defined in the absolute block are absolute.

Any symbols in the expression must be already defined in the assembly and must not result in a negative relocatable value. It is not possible to ORG or ORGC into the literals block.

A location field symbol, if present, is ignored.

Once an ORGC pseudo instruction has established the conditional loading indication for a given common block, it is in effect whenever assembly in that block is resumed by subsequent USE or USELCM pseudo instructions, and can be cleared only by an ORG pseudo instruction specifying that block.

```
|  LOCATION  | OPERATION | VARIABLE      | COMMENTS
1            11          18              30
             USE         ALPHA
             .           .               .
             .           .               .
             .           .               .
ABC          DATA        20,100,1000     LOCATED IN ALPHA
             .           .               .
             .           .               .
             USE         BETA
XYZ          BSS         0               LOCATED IN BETA
             .           .               .
             .           .               .
             .           .               .
             ORG         ABC             SETS ALPHA COUNTERS TO ABC
             .           .               AND RESUMES USE OF ALPHA
             .           .               .
             BSS         1000
             .           .               .
             .           .               .
             ORG         50              SETS ABSOLUTE BLOCK COUNTER
             .           .               TO 50 AND BEGINS ITS USE
             .           .               .
             ORG         XYZ+100         SETS BETA COUNTERS TO XYZ+100
             .           .               .
             .           .               .
             .           .               .
             USE         *               RESUMES ABSOLUTE BLOCK
             .           .               .
             .           .               .
             .           .               .
             USE         *               RESUMES BLOCK ALPHA
             .           .               .
             .           .               .
             .           .               .
             USE         *               RESUMES BLOCK BETA
             .           .               .
             .           .               .
             .           .               .
             .           .               .
             USE         *               RESUMES BLOCK ALPHA
             .           .               .
             .           .               .
             .           .               .
             USE         *               RESUMES NOMINAL BLOCK
             .           .               .
```

```
      LOCATION  OPERATION  VARIABLE      COMMENTS
1                 11         18          30
          USE     /DATA/
DATA      BSS     0
          ORGC    DATA
          DATA    1,2,3               CONDITIONALLY PRESET DATA


          USE     ANYBLOCK
          CON     3RXYZ               UNCONDITIONAL DATA
          USE     *
FOUR      DATA    4                   RETURN TO /DATA/ STILL
          DATA    5,6                 CONDITIONALLY SKIPPING

          ORG     FOUR
          ZR      X1,ERROR            UNCONDITIONALLY LOADED
          RJ      SUB4                INSTRUCTIONS
          .
          .
          .
```

4.5.4 BSS—BLOCK STORAGE RESERVATION

The BSS instruction reserves core in the block in use by adjusting the origin and location counters. It does not generate data to be stored in the reserved area. A primary application is for reserving blank common storage. It can also be used to reserve an area to receive replicated code (see REP, REPC, and REPI, section 4.8.8).

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	BSS	aexp

sym — If present, sym is defined as the value of the location counter after the force upper occurs. It is the beginning symbol for the storage area.

aexp — Absolute expression specifying the number of storage words to be reserved. All symbols must be previously defined; aexp connot contain external symbols. The value of the expression can be negative, zero, or positive and the value is added to both the origin counter and the location counter. A BSS 0 or an erroneous expression causes a force upper and symbol definition but no storage is reserved.

Example:

```
    LOCATION  OPERATION  VARIABLE      COMMENTS
1             11         18            30
          USE      //
COMMON    BSS      1000B         RESERVE 512 WORDS OF BLANK COMMON
          USE      *
          .        .             .
          .        .             .
          .        .             .
          SA6      COMMON+500B
          .        .             .
          .        .             .
          .        .             .
TAG       BSS      0             DEFINE SYMBOL TAG
          .        .
```

4.5.5 LOC — SET LOCATION COUNTER

A LOC pseudo instruction sets the value of the current location counter to the value in the variable field expression. The location counter is used for assigning address values to location symbols. Changing the location counter permits code to be generated so that it can be loaded at the location controlled by the origin counter and moved and executed at the location controlled by the location counter. Thus, any addresses defined while the location counter is different from the origin counter will be correctly relocated only after the code is moved.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	LOC	exp

exp — Relocatable expression specifying the address to which the location counter is to be set. Any symbols in the expression must be already defined in the assembly and must not result in negative relocation.

A location field symbol, if present, is ignored.

Following a LOC, if the value of the location counter differs from the origin counter, the location field is flagged with an L on the listing until a LOC *O, USE, ORG, ORGC, or USELCM instruction resets the location counter to the value of the origin counter.

A LOC instruction does not cause the assembler to switch from the current block to another. LOC causes the next instruction in the block to be forced upper. The only effect of LOC * or LOC *L is to force upper. Because COMPASS does not save the value of the location counter when it switches blocks, a USE, ORG, ORGC, or USELCM for a different block effectively resets the location counter to the origin counter value. When use of the block is resumed, it is the responsibility of the user to reset the location counter to produce the desired results.

Example:

In the following example, the first LOC is used to generate PPU code that is to be loaded into one PPU and transmitted to a different PPU for execution. The second LOC is used so that on the listing the address field contains the table ordinal rather than a load address. At the end of the table, a LOC instruction changes the location counter to resume counting under the first LOC. At the end of the program, LOC *O returns the location counter to the value of the origin counter.

Location	Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
			1	11	18	30
		1	T1	EQU	1	
		0	CH	EQU	0	
7100				ORG	7100	
7100			RES	BSS	0	
L 100				LOC	100	
L 100	2400		PPR	PSN	0	
L 101	2400			PSN	0	
L 102	2400			PSN	0	
L 103	6100	0100		EIM	PPR,CH	
			•	•	•	
			•	•	•	
			•	•	•	
L 205			PPRA	BSS	0	
L 0				LOC	0	
L 0	0100			CON	PPR	
L 1	0114			CON	STM	
L 2	0121			CON	DPM	
L 3	0132			CON	EXR	
L 4	0136			CON	CHS	
L 5	0147			CON	DMP	
L 6	0240			CON	END	
L 7	1000			CON	1000	
			•	•	•	
			•	•	•	
			•	•	•	
L 215				LOC	*O-RES+PPR	
L 215				BSS	240-*	
L 240			END	BSS		
7240				LOC	*O	

4.5.6 POS — SET POSITION COUNTER

The POS pseudo instruction sets the value of the position counter for the block in use to the value specified by the expression in the variable field.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	POS	aexp

aexp — An absolute evaluatable expression having a positive value less than or equal to the assembly word size (60 for CPU, 12 for PPU). A negative value, or a value greater than 60 (or 12), causes an error. The value indicates the bit position within the current word at which the assembler is to assemble the next code generated. Use caution, because if the new position counter value is greater than the old position counter value, part of the word is reassembled. (New code is ORed with previously assembled data.) If the new position counter value is less than the old position counter value, the assembler generates zero bits to the specified bit position. If the value of aexp is zero, COMPASS assembles the next code in the following word.

A location field symbol, if present, is ignored.

CAUTION

If the POS instruction is used on a word containing relocatable or external addresses, undefined results may occur with no diagnostics.

The POS instruction does not alter the origin and location counters. The position counter is never 0 at the beginning of an instruction. At the beginning of a new operation, if a data value has been stored into bit 0 (the rightmost bit) of a word, COMPASS increments the origin counter and the location counter and resets the position counter to 60 (or 12).

A POS *P has no effect whereas a POS $ subtracts one from the counter.

4.6 SYMBOL DEFINITION

The pseudo instructions EQU, =, SET, MAX, MIN, and MICCNT permit direct assignment of 21-bit values to symbols. The values can be absolute, relocatable, or external. Register designators are not valid in the expressions. Subsequent use of the symbol in an expression produces the same result as if the value had been used as a constant. In the listing of the symbolic reference table, a reference to an EQU, =, SET, MAX, MIN, or MICCNT instruction is flagged with a D. Symbols defined using EQU and = cannot be redefined; symbols defined using any of the other symbol definition instructions can be redefined.

4.6.1 EQU OR = – EQUATE SYMBOL VALUE

An EQU or = pseudo instruction permanently defines the symbol in the location field as having the value and attributes indicated by the expression in the variable field.

Formats:

	LOCATION	OPERATION	VARIABLE SUBFIELDS
	sym	EQU	exp
or			
	sym	=	exp

sym — A location symbol is required. See section 2.4 for symbol requirements.

exp — An evaluatable expression. Any symbols in the expression must be previously defined or declared as external. The expression cannot contain symbols prefixed by =S or =X unless the symbols have also been defined conventionally. If the expression is erroneous, COMPASS does not define the location symbol but flags an error.

Examples:

```
                LOCATION  OPERATION  VARIABLE          COMMENTS
                1         11         18                30
20437           OPS       =          20437B
   74           LINP      =          74B
    3           CH        EQU        3
   74           PAGESIZ   =          LINP
64271           LGOPS     EQU        *-OPS
```

4.6.2 SET — SET OR RESET SYMBOL VALUE

A SET pseudo instruction defines the symbol in the location field as having the value and attributes indicated by the expression in the variable field. A subsequent SET using the same symbol redefines the symbol to the new value and attributes. SET can be used to redefine symbols defined by SET, MAX, MIN, or MICCNT, only.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	SET	exp

sym — A location symbol is required. See section 2.4 for symbol requirements.

exp — An evaluatable expression. The expression cannot include symbols as yet undefined and cannot contain symbols prefixed by =S or =X unless the symbols are also defined conventionally.

If the expression is erroneous, COMPASS does not define the symbol but issues a warning flag.

The symbol in the location field cannot be referred to prior to its first definition.

Examples:

```
                LOCATION  OPERATION  VARIABLE  COMMENTS
                1         11         18        30
17              A         EQU        15        A HAS VALUE OF 15
74              B         SET        *P        B HAS VALUE OF POSITION COUNTER
22              C         SET        A+3       C HAS VALUE A+3 OR 18
76              B         =          B+2       ILLEGAL, B IS DOUBLY DEFINED
24              C         SET        C+2       LEGAL, C CHANGES FROM 18 TO 20
                D         SET        F+A       ILLEGAL, F AS YET UNDEFINED
                          BSS        AA        ILLEGAL, REFERENCE PRECEDES
                                               FIRST DEFINITION
20              AA        SET        16
```

4.6.3 MAX — SET SYMBOL TO MAXIMUM VALUE

The MAX pseudo instruction defines the symbol in the location field as having the value and attributes indicated by the largest (most positive) value of the expressions in the variable field. A subsequent SET, MAX, MIN, or MICCNT using the same symbol redefines the symbol to the new value. Conversely, MAX can be used to redefine symbols defined by these instructions.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	MAX	$exp_1, exp_2, \ldots, exp_n$

sym — A location field symbol is required. See section 2.4 for symbol requirements.

exp_i — An evaluatable expression. Any symbols in the expression must be previously defined. The expression cannot contain symbols prefixed by =S or =X unless the symbols are also defined conventionally.

The expressions should have similar attributes. No test is made for attributes. The test for maximum value is made in pass one. In testing for the maximum value in pass one, COMPASS uses values for relocatable symbols relative to block origins.

NOTE

During pass two, the expression selected in pass one is used. The relocatable symbols have been reassigned values relative to program origin and these values are used for the final value of the expression selected in the first pass.

If any of the expressions are erroneous, COMPASS does not define the symbol but issues a warning flag. The symbol in the location field cannot be referred to prior to its first definition.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
5	PT3	EQU	5	
6	PT31	EQU	6	
2	PT32	EQU	2	
6	SYM	MAX	PT3,PT31,PT32	

4.6.4 MIN — SET SYMBOL TO MINIMUM VALUE

A MIN pseudo instruction defines the symbol in the location field as having the value and attributes indicated by the minimum or least positive value of the expressions in the variable field. A subsequent SET, MAX, MIN, or MICCNT using the same symbol redefines the symbol to the new value. Conversely, MIN can be used to redefine symbols defined by these instructions.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	MIN	$exp_1, exp_2, \ldots, exp_n$

sym — A location symbol is required (section 2.4).

exp_i — An evaluatable expression. Any symbols in the expression must be previously defined. The expression cannot contain symbols prefixed by =S or =X unless the symbols are also defined conventionally.

The expressions should have similar attributes; no test is made for attributes.

The test for minimum value is made in pass one. In testing for the minimum value in pass one. COMPASS uses values for relocatable symbols relative to block origins.

NOTE

During pass two, the expression selected in pass one is used. The relocatable symbols have been reassigned values relative to program origin and it is these values that are used for the final value of the expression which was selected in the first pass.

If any of the expressions are erroneous, COMPASS does not define the symbol but issues a warning flag.

The symbol in the location field cannot be referred to prior to its first definition.

4.6.5 MICCNT — SET SYMBOL TO MICRO SIZE

The MICCNT pseudo instruction defines the symbol in the location field as having a value equal to the number of characters in the value of the micro named in the variable field. A subsequent SET, MAX, MIN, or MICCNT using the same symbol redefines the symbol to the new value. Conversely, MICCNT can be used to redefine symbols defined by these instructions.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	MICCNT	mname

sym — A location symbol is required (Section 2.4).

mname — Name of a previously defined micro; it may be a system micro or may have been defined through MICRO, OCTMIC, DECMIC, or BASE. If mname has not been previously defined, the location symbol is not defined (or redefined) and a warning flag is issued.

Example:

```
                LOCATION  OPERATION  VARIABLE              COMMENTS
                1         11         18                    30
                MSG       MICRO      1,,*STRING*           DEFINE 6-CHARACTER MICRO
                          .          .                     .
                          .          .                     .
                          .          .                     .
6               MSIZE     MICCNT     MSG                   MSIZE EQUALS 6
                          .          .                     .
                          .          .                     .
                          .          .                     .
                MSG       MICRO      1,,*ALPHANUMERIC ≠MSG≠*  19 CHAR. MICRO
                MSG       MICRO      1,,*ALPHANUMERIC STRING*  19 CHAR. MICRO-
23              MSIZE     MICCNT     MSG                   MSIZE EQUALS 19
```

4.6.6 SST — SYSTEM SYMBOL TABLE

An SST pseudo instruction defines system symbols, with the exception of the symbols noted, as if the symbols had been defined in the subprogram.

When a system text overlay is used as input to an assembly through the G or S option on a COMPASS control card, all micros and opcodes in the system text overlay are defined automatically at the start of each assembly; however, the symbols in the system text overlay are defined only for assemblies that contain the SST pseudo instruction.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	SST	$sym_1, sym_2, \ldots, sym_n$

sym_i One or more symbols on the file that are not to be defined.

A location field symbol, if present, is ignored.

Refer to page 10-11 for an example of use.

4.7 SUBPROGRAM LINKAGE

Pseudo instructions ENTRY, ENTRYC, and EXT do not define symbols but either declare symbols defined within the subprogram as being available outside the subprogram or declare symbols referred to in the subprogram as being defined outside the subprogram.

4.7.1 ENTRY AND ENTRYC - DECLARE ENTRY SYMBOLS

The ENTRY pseudo instruction specifies which of the symbolic addresses defined in the subprogram can be referred to by subprograms compiled or assembled independently; ENTRY lists entry points to the current subprogram. ENTRY is illegal in PPU assemblies.

The ENTRYC † pseudo instruction conditionally specifies which of the symbolic addresses defined in the subprogram can be referred to by subprograms compiled or assembled independently; ENTRYC lists conditional entry points to the current subprogram. ENTRYC is illegal in PPU assemblies and is synonymous with ENTRY in absolute CPU assemblies. In a relocatable assembly, an entry point symbol declared by ENTRYC is ignored by the linking loader if the value of the symbol is relative to a common block and that common block was first declared by a previously loaded subprogram.

Formats:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	ENTRY	$sym_1, sym_2, \ldots, sym_n$
	ENTRYC	$sym_1, sym_2, \ldots, sym_n$

sym_i Linkage symbol; 1-7 characters of which the first must be alphabetic (A-Z) and the last must not be a colon. The symbol cannot include the following characters:

+ - * / blank , or ∧

Each symbol must be defined in the subprogram as nonexternal (cannot begin with =X or be listed on an EXT pseudo instruction). Entry point symbols must be unqualified (Section 2.4.5).

A location symbol, if present, is ignored.

A list of all entry points declared in the subprogram precedes the assembly listing. An asterisk appears to the right of each conditional entry point.

†Not supported by SCOPE 2 Loader.

Example:

Location	Code Generated
110	
110	
110	5120000100
	73720
111	5110000002

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		IDENT	CT,CONTROL,CONTROL	
		ABS		
		ENTRY	MODE	
		ENTRY	ONSW	
		ENTRY	OFFSW	
		ENTRY	ROLLOUT	
		ENTRY	SETPR	
		ENTRY	SETTL	
		ENTRY	SWITCH	
		ORG	110B	
	CONTROL	BSS	0	
	MODE	SA2	ACTP	
		SX7	X2	
		SA1	?	
		•	•	
		•	•	
		•	•	

4.7.2 EXT — DECLARE EXTERNAL SYMBOLS

The EXT pseudo instruction lists symbols that are defined as entry points in independently compiled or assembled subprograms for which references can appear in the subprogram being assembled. The EXT pseudo instruction is illegal in an absolute subprogram.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	EXT	$sym_1, sym_2, \ldots, sym_n$

sym_i Linkage symbol, 1-7 characters of which the first must be alphabetic (A-Z) and the last must not be a colon. The symbol cannot include the following characters;

+ - * / blank , or ^

These symbols must not be defined within the subprogram. External symbols are unqualified.

A location field symbol, if present, is ignored.

An external reference is flagged with an X in the address field in the listing of code generated. All external symbols are listed in the header information for the assembly listing.

4.8 DATA GENERATION

The instructions described in this section are the only pseudo instructions that generate data. All other program data is generated through symbolic machine instructions. An instruction that generates data cannot be used in a blank common block. The pseudo instructions that generate data are:

BSSZ	Generates zeroed words
blank operation field	Generates one zeroed word
DATA	Generates one or more words of data
DIS	Generates one or more words of data
LIT	Generates literals block entries
VFD	Places expression values in user-defined fields
CON	Places expression values in full words
R=	For use in macros; R= assumes that either (B1)=1 or (B7)=1 and generates increment instructions accordingly
REP, REPC, or REPI	Does not actually generate object code at assembly time but causes the relocatable loader to repeatedly load a sequence of code into a reserved blank storage area.

4.8.1 BSSZ AND BLANK OPERATION FIELD—RESERVE ZEROED STORAGE

The BSSZ instruction reserves zeroed core in the block in use. The origin and location counters are adjusted by the requested number of words and the assembler generates data words of zero to be loaded into the reserved area. An instruction that contains a symbol in the location field but has a blank operation field has the same effect as a BSSZ of one word.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	BSSZ	aexp

sym — If present, sym is defined as the value of the location counter after the force upper occurs. The symbol identifies the beginning of the reserved storage area.

aexp — Absolute evaluatable expression specifying the number of zeroed words of storage to be reserved. The expression cannot contain external symbols or result in a relocatable or negative value.

A BSSZ 0 or an erroneous expression causes a force upper and symbol definition but no storage is reserved.

A BSSZ or group of BSSZ instructions of six or more words produces an REPL table in object code to reduce the physical size of the object program (appendix B).

For a blank operation field the listing shows one zero word of data; for a BSSZ instruction the listing shows the word count.

4.8.2 DATA — GENERATE DATA WORDS

The DATA pseudo instruction generates one or more complete 60-bit or 12-bit data words in the current block for each item listed in the variable field.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	DATA	$item_1, item_2, \ldots, item_n$

sym — If present, sym is assigned the value of the current location counter after the force upper occurs. It becomes the symbolic address of the first item listed.

$item_i$ — Character, octal numeric, or decimal numeric data item, according to specifications described in section 2.7. Floating point notation is illegal in PPU assemblies. Items are separated by commas and terminated by a blank. A literal cannot be used as an item.

A DATA pseudo instruction always forces upper. A blank item does not cause generation of a data word.

Unless the D list option is selected, only $item_1$ appears on the listing.

Examples:

```
Location        Code Generated

552   140717000000000000000
553   400000000000000000000
554   031715201114050000000
555   172524202524000000000
556   000000000000000000000
557   172051463146314631460
560   164031463146314631460
```

```
      LOCATION   OPERATION   VARIABLE          COMMENTS
1                11          18                30
      OPTB       DATA        0LLGO
      OPT        DATA        1BS59
      OPTT       DATA        0LCOMPILE
      OPTD       DATA        0LOUTPUT,0
      OPTY       DATA        1.3EE
```

```
Location        Code Generated

                                D.0
1250            7070
1251            7770
1252            0000
1253            0034
1254            5501
1255            0000
1256            0506
1257            0123
1260            7773
1261            0401
1262            2401
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PERIPH		
		BASE	0	
		.	.	
		.	.	
	DAT	DATA	7070,-7,0,1R1	
		DATA	2C A,0LEF	
		DATA	0123,-4	
		DATA	H*DATA*	

4.8.3 DIS—GENERATE WORDS OF CHARACTER DATA

The DIS pseudo instruction generates words containing character data. The instruction can be used conveniently when a character data string is to be used repeatedly. Unless the D list option is selected only the first word of character data appears on the listing. The instruction has two formats:

Format one:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	DIS	n, string

sym — If present, sym is assigned the location counter value after the force upper occurs. It is the symbolic address of the first word containing the character string.

n — An absolute evaluatable expression specifying an integer number of words to be generated. When base is M, COMPASS assumes that n is decimal.

string — Character string

For a CPU program, COMPASS takes 10 times n characters from the string and packs them as they occur 10 characters per word into n words. For a PPU program, COMPASS takes two times n characters from the string and packs them as they occur two characters per word into n words. If the statement ends before 10 x n (or 2 x n) characters, the remainder of the requested words are filled with blanks. If n is 0, COMPASS assumes the instruction is in format two.

Format two:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	DIS	,dstringd

sym — If present, sym is assigned the location counter value after the force upper occurs. It is the symbolic address of the first word containing the character string.

d — Delimiting character

string — Character string; any character other than delimiting character

In this form, the string must be bounded by delimiters. The comma is required. The characters between the two delimiting characters are packed into as many CPU or PPU words as are needed to contain them. Twelve zero bits are guaranteed at the end of the character string even if COMPASS must generate an additional word for them. If COMPASS detects the end of the statement before it detects a second delimiting character, it produces a fatal error.

Examples:

```
Location     Code Generated

  561   0705160522012405535
  562   5503202555271722042 3
  563   0705160522012405535
  564   5503202555271722042 3
  565   0000000000000000000
```

```
      LOCATION   OPERATION  VARIABLE        COMMENTS
1                11         18              30
      ONE        DIS        2,GENERATE 2    CPU WORDS

      TWO        DIS        ,*GENERATE 2    CPU WORDS*
```

```
Location        Code Generated

                                    D.M
1402            0705
1403            1605
1404            2201
1405            2405
1406            5534
1407            3355
1410            2020
1411            5527
1412            1722
1413            0423
1414            0705
1415            1605
1416            2201
1417            2405
1420            5534
1421            3355
1422            2020
1423            5527
1424            1722
1425            0423
1426            0000
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PPU		
		BASE	M	
		DIS	10,GENERATE	10 PP WORDS
		DIS	,*GENERATE	10 PP WORDS*

4.8.4 LIT — DECLARE LITERAL VALUES

A LIT pseudo instruction generates data words in the literals block. This instruction and the = prefix to a data item provide the only means of generating data in the literals block. The LIT pseudo instruction assures sequential entries for a table of values.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	LIT	$item_1,item_2,\ldots,item_n$

sym — If present, sym is assigned the value of the literals block location counter

$item_i$ — At least one and not more than 100 words of character, octal numeric, or decimal numeric data items. Section 2.7.3 contains specifications. Items are separated by commas and terminated by a blank. Floating point data items are illegal in PPU assemblies.

COMPASS enters data items into the literals block in the order specified.

If the converted binary values for all the data items listed with a single LIT match an existing literal block sequence, they are not duplicated. If, however, any item in the list does not match an entry in the block, the entire sequence is generated. A literal item subsequently referred to through an = prefix is not duplicated. A null item (e.g. H** or 0L) does not cause a word to be generated.

Examples:

```
Location  Code Generated      LOCATION  OPERATION  VARIABLE                COMMENTS
                                1         11         18                      30
                  611           POOL      LIT        3.1,1.59265,2.7182182,57.2957795EE1
                        CONTENT OF LITERALS BLOCK.
000611  1721614631463146314631463146    0Q[-Y-Y-Y-
000612  1720627557644177627l    0P]≥.≠6;]↓
000613  1721533735113601442 6    0Q$42I3A9V
000614  1731436365144066312l    0Y8!↗L5♥YQ
000615  1651333303354057656 6    N(00C25.↗♥
```

```
Location  Code Generated      LOCATION  OPERATION  VARIABLE                COMMENTS
                                1         11         18                      30
                  7447          N2        LIT        1R1,7070,7,0
                  7453                    LIT        2C  A,0LEF
                  7456                    LIT        H*LITERALS*
                        CONTENT OF LITERALS BLOCK.

7447    0034                          1
7450    7070                          ↑↑
7451    0007                          G
7452    0000
7453    5501                          A
7454    0000
7455    0506                          EF
7456    1411                          LI
7457    2405                          TE
7460    2201                          RA
7461    1423                          LS
```

4.8.5 VFD — VARIABLE FIELD DEFINITION

The VFD instruction generates data in the current block by placing the value of an expression into a field of the specified size.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	VFD	$item_1/exp_1, item_2/exp_2, \ldots, item_n/exp_n$

sym — For a CPU assembly, the location field can contain sym, plus, minus, or blank, as follows:

- sym — If a symbol is provided in the location field, a force upper occurs and the value of the location counter following the force upper is assigned to the symbol. The symbol identifies the first word of data generated by the VFD.
- \+ — Causes a force upper. Data generation begins in a new word.
- \- — COMPASS generates zero bits to the next quarter word boundary, at which point the first field begins.
- blank — COMPASS begins the first field at the current value of the position counter.

For a PPU assembly, if the location field contains a plus, minus, or a symbol, data generation begins in a new word. If the location field is blank, the first field begins at the current value of the position counter.

$item_i$ — An unsigned constant or previously defined symbol having a value specifying a positive integer number of bits for the field to be generated; maximum field size is 60 bits for both CPU and PPU assemblies (60 being the maximum number of significant bits for an expression value). When base is M, $item_i$ is assumed to be decimal notation.

exp_i — An absolute, relocatable, or external expression, the value of which will be inserted into the field specified by $item_i$. The expression is evaluated using the specified field size. Character constants are right or left adjusted in the field according to the type of justification indicated. In a relocatable CPU assembly, no field that contains a relocatable or external address expression can cross a 60-bit word boundary, and no 60-bit word can have more than four fields that contain relocatable or external address expressions.

Each field is generated as it occurs. For a CPU assembly, if the next instruction that generates code in the block is not a VFD with a blank location field, and the last VFD field in the current VFD ends to the left of a quarter word boundary, COMPASS inserts zero bits up to the next quarter word boundary. These zero bits do not show on the assembly listing. Remaining parcels are then filled with no-operation instructions.

When a VFD instruction that does not have a location field entry immediately follows another VFD in the same block, no padding with zeros or forcing upper occurs; fields are generated sequentially as they are specified.

Following a VFD, the position counter contains the number of bits remaining to be assembled in the last word in which data was generated by the VFD.

Examples:

```
Location    Code Generated

                                  31
566     2401020000023000551
567     0000005665555555555
570     777777774
                  000000000000
571     1117240155015555531
572     0000001505232301070 5
573     031117000000033
```

```
|  | LOCATION | OPERATION | VARIABLE                          | COMMENTS
|1 |          | 11        | 18                                | 30
|  | ALPHA    | SET       | 25
|  | TABLE    | VFD       | 36/3CTAB,6/19,18/TABLOC
|  |          | VFD       | 30/*-1,30/5H      ,ALPHA/-0
|  |          | VFD       | *P/
|  |          | VFD       | 30/0HIOTA,6/1RA,24/0AX+1
|  |          | VFD       | 60/0RMESSAGE,30/3LCIO,15/0R0
```

```
Location    Code Generated

                                  0rM
1310            3334
1311            3536
1312            3740
1313            4142
1314            4344
1315            0010
1316            0011
1317            7765
1320            0707
```

```
|  | LOCATION | OPERATION | VARIABLE                          | COMMENTS
|1 |          | 11        | 18                                | 30
|  |          | PPU       |
|  |          | BASE      | M
|  | N4       | VFD       | 60/10R0123456789
|  | A11      | VFD       | 12/10,12/11,12/-12,12/-7070
```

4.8.6 CON — GENERATE CONSTANTS

The CON pseudo instruction generates one or more full words of binary data in the block in use. It differs from DATA in that it generates expression values rather than data items and differs from VFD in that the field size is fixed.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	CON	$exp_1, exp_2, \ldots, exp_n$

sym — If present, sym is assigned the value of the location counter after the force upper occurs.

exp_i — An absolute, relocatable, or external expression the value of which will be inserted into a field having a size of one word. For PPU assembly, floating point is not allowed; for CPU assembly, double precision is not allowed.

Examples:

```
      Location        Code Generated

      1460            0000
      1461            0006
      1462            0003
      1463            2204
      1464            0024
      1465            0000
      1466            0006
      1467            0003
      1470            2172
      1471            0024
```

```
      Location        Code Generated

          574
    L       0
    L       0   0000000000000000055
    L       1   0000000000000000062
    L       2   0000000000000000064
    L       3   0000000000000000060

    L      75   0000000000000000066
    L      76   0000000000000000076
    L      77   0000000000000000055
          674
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS |
|1 |          | 11        | 18       | 30       |
|  | MSG1     | CON       | 0        |          |
|  |          | CON       | 6        |          |
|  |          | CON       | 3        |          |
|  |          | CON       | FAIL     |          |
|  |          | CON       | 20       |          |
|  | MSG2     | CON       | 0        |          |
|  |          | CON       | 6        |          |
|  |          | CON       | 3        |          |
|  |          | CON       | PASS     |          |
|  |          | CON       | 20       |          |
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS |
|1 |          | 11        | 18       | 30       |
|  | TAD      | RSS       | 0        |          |
|  |          | LOC       | 0        |          |
|  |          | CON       | 1R       | 00       |
|  |          | CON       | 1R]      | 01       |
|  |          | CON       | 1R≠      | 02       |
|  |          | CON       | 1R=      | 03       |
|  |          | .         | .        | .        |
|  |          | .         | .        | .        |
|  |          | .         | .        | .        |
|  |          | CON       | 1R∨      | 75       |
|  |          | CON       | 1R¬      | 76       |
|  |          | CON       | 1P       | 77       |
|  |          | LOC       | *0       |          |
```

4.8.7 R = — CONDITIONAL INCREMENT INSTRUCTION

The R= pseudo instruction generates a CPU increment unit instruction depending on the contents of the variable subfields and on whether or not the subprogram earlier contained a B1=1 or B7=1 pseudo instruction (Section 4.4.4).

Use of R= augments macro definitions and increases optimization of object code. It is illegal in a PPU program.

The A list option controls listing of substituted instructions.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	R=	reg,exp

sym — Optional, if present, sym is assigned the value of the location counter after the force upper occurs. This force upper occurs whether the R= generates an instruction or not.

reg — A register designator (A, X, or B) and a digit (0-7) which COMPASS concatenates with S to form the instruction operation code.

exp — Operand register or value expression. If the second subfield is the same two characters as reg, no instruction is generated.

If the expression value is 0, the variable field is B0.

If the B1=1 instruction has been assembled prior to this instruction and the expression value is 1, 2, or -1. the variable field of the instruction is B1, B1+B1, or -B1, respectively.

If the B7=1 instruction has been assembled prior to this instruction and the expression value is 1, 2, or -1, the variable field for the instruction is B7, B7+B7, or -B7, respectively.

In all other cases, the variable field is the register or value indicated by the expression.

Examples:

1. R= used with B1=1

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		B1=1		
		R=	B3,2	
[illegible]		[illegible]	[illegible]	
		R=	B3,3	
[illegible]		[illegible]	[illegible]	

2. R= used with B1≠1

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	TAG	R=	X5,-1	
[illegible]	[illegible]	[illegible]	[illegible]	

3. Expression is same as register designator:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	REG	MICRO	1,,*B5*	
		R=	B5,≠REG≠	
		R=	B5,B5	

No instruction is generated; SB5 B5 would be a no operation instruction.

4.8.8 REP, REPC, AND REPI - GENERATE LOADER REPLICATION TABLE

The REP, REPC, and REPI instructions cause the assembler to generate an REPL loader table so that when the subprogram being assembled is loaded, the loader will load one or more copies of a data sequence. For the REPI instruction, the loader generates the copies immediately upon encountering the table; for REP, the replication takes place at the end of loading. For REPC† the loader ignores the REPL table if the destination data address is in a common block that was first declared by a previously loaded subprogram; otherwise, the loader generates the copies immediately upon encountering the tables.

Replication of object code is valid in relocatable assemblies only. It is particularly useful for setting one or more blocks of storage to a given series of values or for generating tables.

Data to be replicated must not contain any external references or common block relocatable addresses. For REPC and REPI, data must be in previously assembled text.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	REP REPC † REPI	S/saddr, D/daddr, C/rep, B/bsz, I/inc

A location field symbol, if present, is ignored.

The variable field subfields can be in any order.

S/saddr — Relocatable expression specifying first word address of code to be copied. The S/saddr subfield must be provided. If it is zero, or omitted, the assembler flags the instruction as erroneous and does not generate an REPL loader table.

D/daddr — Relocatable expression specifying the destination of the first word of the first copy. If D/daddr is omitted, the assembler sets daddr to zero, and, when daddr is zero, the loader uses saddr plus bsz for the destination address.

Note that room for the repeated data must be reserved in the destination block.

† Not supported by SCOPE 2 Loader.

C/rep — Absolute expression specifying the number of times code is to be copied. When base is M, COMPASS assumes that rep is a decimal value. If C/rep is omitted, the assembler sets rep to zero. When rep is zero or one, the loader makes one copy.

B/bsz — Absolute expression specifying the number of words to be copied (block size). When base is M, COMPASS assumes that bsz is decimal.

If B/bsz is omitted, the assembler sets bsz to zero. When bsz is zero or one, the loader copies one word.

I/inc — Absolute expression specifying the increment size in words. When base is M, COMPASS assumes that inc is in decimal.

The increment size is the number of words between the first word of each copy. When inc is zero or omitted, the loader uses bsz as the increment size. The loader writes the first copy starting at daddr, the second starting at daddr+inc, the third at daddr + 2 x inc, etc. until the rep count is exhausted.

The origin and location counters for the block containing the daddr are not advanced by a value of inc x rep. Storage reservation for replicated code is the responsibility of the user.

Rules for replication:

1. The S subfield cannot be omitted
2. Room must be reserved for the copies in the destination block (for example, through ORG, ORGC, or BSS)
3. REP, REPC, and REPI can be used in relocatable assemblies only
4. Data to be replicated must not contain any external references or common block relocatable addresses
5. For REPC and REPI, data must be in previously loaded text

Example:

```
Location        Code Generated                  LOCATION  OPERATION  VARIABLE          COMMENTS
                                                1         11         18                30
                                  10            RC        =          10
                                                          USE        NEWP
5017    0000000000000000015       BA        DATA       15,20,7070B,1,5,3.14
5020    0000000000000000020
5021    0000000000000007070
5022    0000000000000000001
5023    0000000000000000005
5024    1721630000000000000
                                  13            I         EQU        *-BA+5
                                                          USE        DBLOCK
5251                              DA        BSS        RC*I
                                                          USE        *
                                                          REPI       S/BA,D/DA,B/I-5,C/RC,I/I
```

4.9 CONDITIONAL ASSEMBLY

The following pseudo instructions permit optional assembly or skipping of source code. A special form, SKIP, causes unconditional skipping. COMPASS provides IF test instructions that:

Test for assembly environment (IFtype)
Compare values of two expressions (IFop)
Compare values of two character strings (IFC)
Test the attribute of a single symbol or an expression (IF)
Test the sign of an expression (IFPL and IFMI)

Immediately following the test instruction are instructions that are assembled when the tested condition is true and skipped when the condition is false. Skipping is terminated either by a source statement count on the IF instruction, or by an ENDIF, an ELSE, or an END.

The statement count, when used, is decremented for instruction lines only; comment lines (identified by * in column one) are not counted. Determining the IF range with a statement count produces slightly faster assembly than using the ENDIF.

The results of an IF test are determined by the values of expressions in pass one; the value of a relocatable symbol is relative to the USE block in which it was defined. The value of an external symbol is 0 if the symbol was declared as external. If the symbol was defined relative to a declared external, the value is the relative value.

4.9.1 ENDIF — END OF IF RANGE

An ENDIF causes skipping to terminate and assembly to resume. When the sequence containing the ENDIF is being assembled, or is controlled by a statement count, the ENDIF has no effect other than to be included in the count.

Skipped instructions such as macro references are not expanded. Thus, any ENDIF that would have resulted from an expansion is not detected.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	ENDIF	

ifname Name of an IF, SKIP, or ELSE sequence; or blank

Skipping of a sequence initiated by an IF, SKIP, or ELSE that is assigned a name can be terminated by an ENDIF specifying the sequence by name, or by any unnamed ENDIF. Any ENDIF terminates skipping of an unnamed sequence that is not controlled by a source line count. A named ENDIF terminates the named IF, SKIP, or ELSE and any unnamed IF, SKIP, or ELSE sequences in effect that are not under line count control.

4.9.2 ELSE — REVERSE EFFECTS OF IF

Through the ELSE instruction, COMPASS provides the facility to reverse the effects of an IF test within the IF range. An ELSE detected during skipping causes assembly to resume at the instruction following the ELSE. An ELSE detected while a sequence is being assembled initiates skipping of source code following the ELSE. Skipping continues until:

1. A statement count specified on the ELSE is exhausted
2. A second ELSE is detected for the sequence
3. An ENDIF is detected for the sequence

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	ELSE	ℓnct

ifname — Name of an IF, SKIP, or ELSE sequence, or blank.

ℓnct — Optional absolute evaluatable expression specifying integer number of source lines to be skipped. It has no effect if the ELSE resumes assembly. When the base is M, COMPASS assumes that ℓnct is decimal.

An ELSE specifying the sequence by name or any unnamed ELSE terminates skipping of a sequence initiated by an IF, SKIP, or an ELSE that has an assigned name. Skipped instructions such as macro references are not expanded; any ELSE that would have resulted from the expansion is not detected.

4.9.3 IFTYPE - TEST OBJECT PROCESSOR TYPE

IFtype pseudo instructions test for the type of processor that will execute the object program, as declared by MACHINE, and PERIPH or PPU pseudo instructions.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	IFtype	ℓnct

ifname Optional 1-8 character name.

type Mnemonic specifying type of object processor.

Type	Condition Causing Assembly
CP	Any central processor unit
CP6	Neither PERIPH nor PPU nor MACHINE 7 has been specified. CPU code is assembled for a CYBER 170 Series, CYBER 70/ Model 72, 73, or 74 or 6000 Series Computer System.
CP7	Neither PERIPH nor PPU nor MACHINE 6 has been specified. That is, CPU code is assembled for a CYBER 70/Model 76 or a 7600 Computer System.
PP	Any peripheral processor unit
PP6	One of the following is true: 1. PERIPH has been specified but MACHINE 7 has not been specified. 2. PPU and MACHINE 6 have both been specified. PPU code is assembled for a CYBER 170 Series, CYBER 70/Model 72, 73, or 74 or a 6000 Series Computer System.
PP7	One of the following is true: 1. PPU has been specified but MACHINE 6 has not been specified. 2. PERIPH and MACHINE 7 have both been specified. That is, PPU code is assembled for a CYBER 70/ Model 76 or a 7600 Computer System.

ℓnct	Optional absolute evaluatable expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.

2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.

3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect.

Example:

Code Generated

```
                                  IDENT   XYZ
                                  MACHINE 6
                                  .
                                  .
0                                 BSS     123
                                  IFGP6   2
173  0130000000                   XJ      0
                                  ELSE    1
                                  MJ      0
```

4.9.4 IFOP – COMPARE EXPRESSION VALUES

An IFop pseudo instruction compares the values of two expressions according to the relational mnemonic specified and assembles instructions in the IF range when the comparison is satisfied.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	IFop	$exp_1, exp_2, fnct$

ifname — Optional 1-8 character name

op — Specifies comparative test:

op	Condition causing assembly
EQ	Equality, the expressions are equal in all respects. That is, they not only have the same numeric value but have the same attributes as well. For example, both are names that are common relocatable, or absolute, or external, etc.
NE	Inequality, the expressions are not equal in all respects. They differ in value or in some attribute.
GT	The first expression is greater in value than the second expression. No other attributes are tested.
GE	The first expression is greater than or equal in value to the second expression. No other attributes are tested.
LT	The first expression is less in value than the second expression. No other attributes are tested.
LE	The first expression is less than or equal in value to the second expression. No other attributes are tested.

For these tests, positive zero and negative zero are equal.

exp_i — An expression. When the value of exp is tested, exp can include only previously defined symbols and the result can be absolute, relocatable, or external. If an undefined symbol is used, the expression value is set to zero, the IF instruction is flagged as erroneous, and assembly continues with the next instruction.

ℓnct — Optional absolute evaluatable expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal. When ℓnct is blank, the comma can be omitted.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.
2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.
3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect.

Example:

A demonstration of one use of IF statements in a PPU program:

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1                 11         18              30
                  IF       DEF,LOOP
                  IFLT     *-LOOP,40B
                  ZJN      LOOP
                  ELSE     2
                  NJN      *+3
                  LJM      LOOP
                  .
                  .
                  .
```

This code assembles a zero jump to the symbol LOOP if LOOP has been defined within 37_8 words (the range of a short jump) prior to the occurrence of this code. Otherwise, the NJN and LJM are assembled.

4.9.5 IFPL AND IFMI – TEST SIGN OF EXPRESSION

The IFPL and IFMI pseudo instructions test the sign of an expression and assemble instructions in the IF range according to whether the sign of the value is plus (PL) or minus (MI). The pseudo instructions allow positive zero to be distinguished from negative zero.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	IFPL	exp,ℓnct
ifname	IFMI	exp,ℓnct

ifname — Optional 1–8 character name

exp — An expression. It can include only previously defined symbols and the result can be absolute, relocatable, or external. If an undefined symbol is used, the instruction is flagged as erroneous and assembly continues with the next instruction.

ℓnct — Optional absolute expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal. When ℓnct is blank, the comma can be omitted.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.
2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.
3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect.

The condition tested for by IFPL is satisfied if the value of exp is greater than or equal to plus zero; the condition for IFMI is satisfied if the value of exp is less than or equal to minus zero.

Example:

The following opdef defines the CPU instruction MXi jk so that the address value is 60 if the expression value is negative zero or a positive non-zero multiple of 60, otherwise it is the address expression value modulo 60.

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                 11       18                30
|
|     MXQ       OPDEF      REG,VAL
|               LOCAL      A
|     A         SET        VAL
|
|     A         SET        A-A/60D*60D
|               IFPL       A,3
|               IFEQ       A,0,3
|               IFLE       VAL,0,1
|               SKIP       1
|     A         SET        A+60D
|               VFD        6/43B,3/REG,6/A
|               ENDM
|
|
|
```

Example of call:

```
                Code Generated
                                  LOCATION  OPERATION  VARIABLE          COMMENTS
                                  1         11         18                30
                                            MX6        -52
                7777713           ↑↓000001            SET       -52
                7777713           ↑↓000001            SET       ↑↓000001-↑↓000001/600*600
                                            IFPL       ↑↓000001,3
                                            IFEQ       ↑↓000001,0,3
                                            IFLE       -52,0,1
                                            SKIP       1
                     10           ↑↓000001            SET       ↑↓000001+60D
43610                                       VFD        6/43B,3/6,6/↑↓000001
                                            ENDM
```

4.9.6 IF - TEST SYMBOL OR EXPRESSION ATTRIBUTE

The IF pseudo instruction tests a symbol or an expression for a specific attribute and assembles instructions in the IF range if the test is satisfied.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	IF	att,exp,lnct

ifname Optional 1-8 character name

att Specifies attribute test. A minus prefix to the attribute causes assembly on the false rather than the true condition.

att	Condition causing assembly
SET	The symbol given in the second subfield was defined by a SET, MAX, MIN, or MICCNT
-SET	The symbol given in the second subfield was defined other than by a SET, MAX, MIN, or MICCNT
ABS	The expression in the second subfield reduces to a value that is not relocatable or external
-ABS	The expression in the second subfield reduces to either a relocatable or an external address
REL	The expression in the second subfield reduces to a local or common relocatable address
-REL	The expression in the second subfield does not reduce to a local or common relocatable address
REG	The expression in the second subfield contains one or more register names
-REG	The expression in the second subfield does not contain a register name
COM	The expression in the second subfield reduces to a common relocatable address (any blank or labeled common block)
-COM	The expression in the second subfield is not a common relocatable address (any blank or labeled common block)
EXT	The expression in the second subfield contains one or more external symbols
-EXT	The expression in the second subfield does not contain an external symbol
LCM	The expression reduces to an LCM address
-LCM	The expression does not reduce to an LCM address
LOC	The expression reduces to a program relocatable address
-LOC	The expression does not reduce to a program relocatable address

DEF	All the symbols in the expression in the second subfield are defined
-DEF	One or more of the symbols in the expression in the second subfield is undefined
MIC	The name in the second subfield is a micro
-MIC	The second subfield does not contain a micro name
SST	The second subfield does not contain a system symbol
-SST	The second subfield contains a system symbol

exp — For SET, SST, -SET, and -SST, exp must be a single defined symbol. For MIC and -MIC, exp must be a name. For any other test, it is an expression. The expression can include symbols as yet undefined if att is DEF, -DEF, REG, -REG, EXT, or -EXT only. If an undefined symbol is used with any other attribute, the expression value is set to zero, the instruction is flagged as erroneous, and assembly continues with the next instruction.

ℓnct — Optional absolute evaluatable expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal. When ℓnct is blank, the comma can be omitted.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.
2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.
3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect.

Examples

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1               11         18              30
      ABLE      BSS        20
        .       .          .
        .       .          .
        .       .          .
      TEST      IF         REL,ABLE+15
        .       .          .
        .       .          .
        .       .          .
      TEST      ENDIF
                IF         COM,DTA,2       ERRONEOUS, DTA AS YET UNDEFINED
                .          .
                .          .
                .          .
                USE        //
      DTA       BSS        1
```

4.9.7 IFC - COMPARE CHARACTER STRINGS

The IFC pseudo instruction compares two character strings according to the operator specified and assembles instructions in the IF range if the comparison is satisfied.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	IFC	op,dstring$_1$dstring$_2$d,ℓnct

ifname — Optional 1-8 character name

d — Delimiting character. Characters between the first and second occurrence of this character constitute the first character string; characters between the second and third occurrence constitute the second character string.

op — Specifies comparative test:

op	Condition causing assembly
EQ or -NE	string$_1$ has the same value as string$_2$
NE or -EQ	string$_1$ does not equal string$_2$
GT or -LE	string$_1$ is greater than string$_2$
GE or -LT	string$_1$ is greater than or equal to string$_2$
LT or -GE	string$_1$ is less than string$_2$
LE or -GT	string$_1$ is less than or equal to string$_2$

string$_i$ — Character string. When IFC is within a macro definition, each character string can be a formal parameter.

ℓnct — Optional absolute evaluatable expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal. When ℓnct is blank, the comma can be omitted.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.
2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.

3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect

Each character in $string_1$ is compared with the corresponding character in $string_2$ progressing from left to right until an inequality is found or both strings are exhausted. When one string is shorter than the other, it is padded with a character that has a value less than any other character in the string.

The truth condition is based on the relative magnitudes of the characters in the strings.

Examples:

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                11         18               30
      TEST1     IFC        EQ,$ABC$ABC$      ABC EQUALS ABC
      TEST2     IFC        LT,*AB*ABC*       AB IS LESS THAN ABC
      TEST3     IFC        GT,XAXX           A IS GREATER THAN NULL
                IFC        -GE,*Z*8*,3       Z IS LESS THAN 8
```

The IFC in the following example checks for an empty parameter string.

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                11         18               30
      XX        MACRO      P1,P2
                IFC        EQ,**P2*,1
      P         ERR                          FLAG ERROR
                .
                .
                .
                ENDM
```

The following example illustrates a character string terminated incorrectly. When COMPASS reaches end of statement without finding a third asterisk, the asterisk omitted following P1 causes an error flag.

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                11         18               30
                IFC        EQ,*OD*P1,2$P2
```

4.9.8 SKIP — UNCONDITIONALLY SKIP CODE

The SKIP instruction causes COMPASS to unconditionally skip the instructions in the SKIP range. It resembles an IF for which there is no true condition.

Format

LOCATION	OPERATION	VARIABLE SUBFIELDS
ifname	SKIP	ℓnct

ifname — Optional 1-8 character name

ℓnct — Optional absolute evaluatable expression specifying an integer count of the number of statements to be skipped. When base is M, COMPASS assumes that ℓnct is decimal.

The ifname and ℓnct parameters are related as follows:

1. If a count is supplied, it takes precedence over any ENDIF but not over an ELSE. The only effect of an ENDIF in a count controlled sequence is to be included in the count. Skipping terminates when the count is exhausted or when an ELSE with a matching or blank name is encountered, whichever occurs first.

2. If neither a count nor a name is supplied, the IF range is terminated by an ENDIF, whether named or unnamed, or by an unnamed ELSE, whichever is encountered first. A named ELSE has no effect.

3. If a name but no count is supplied, the IF range is terminated by an ENDIF or ELSE with a matching name or by an unnamed ENDIF or ELSE. An ENDIF or ELSE with a name that does not match has no effect.

4.10 ERROR CONTROL

The ERR and ERRxx pseudo instructions described in this section either conditionally or unconditionally set an error flag.

4.10.1 ERR — UNCONDITIONALLY SET ERROR FLAG

An ERR pseudo instruction produces an assembly error but does not affect other code. Usually, it is used in conjunction with a conditional assembly pseudo instruction to force an error into the assembly based on an assembly time test. One application is to use a test and ERR to detect illegal macro parameters.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
flag	ERR	

flag — A single alphanumeric character denoting the error type. The flag is placed in the listing to the left of the line for ERR. The flag can denote a fatal or nonfatal error. A fatal error causes COMPASS to suppress generation of the binary deck unless the D mode option is selected on the COMPASS control card. If no flag is specified, or the character is not one of those given in section 11.7, COMPASS uses P.

A variable field entry, if present, is ignored.

Example:

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1                 11         18             30
      NNN       MACRO      P1,P2,P3,P4
                IFEQ       P1,0
      A         ERR
                .          .
                .          .
                .          .
                ENDM
                .          .
                .          .
                .          .
                NNN        0,A,B,C
```

4.10.2 ERRxx — CONDITIONALLY SET ERROR FLAG

An ERRxx pseudo instruction produces an assembly error when a condition detected during the second pass of the assembler is true.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
flag	ERRxx	aexp

flag — A single alphanumeric character denoting the error type. The flag is placed in the listing to the left of the line for ERR. The flag can denote a fatal or nonfatal error. A fatal error causes COMPASS to suppress generation of the binary deck unless the D mode option is selected on the COMPASS control card. If no flag is specified, or the character is not one of those given in section 11.7, COMPASS uses P.

xx — Defines condition under which aexp value is erroneous.

xx	Error Condition
NG or MI	Value of expression is negative
NZ	Value of expression is nonzero
PL	Value of expression is positive
ZR	Value of expression is zero

aexp — Absolute expression. It cannot contain external symbols or references to blank common. The test is made in pass two of the assembler. Relocatable addresses are assigned values relative to program origin rather than to the block in which they are defined.

NOTE

ERRxx is the only conditional instruction for which the test is made in pass two. Therefore, this is the only pseudo instruction that can be used to determine PPU overflow if the PPU program has literals and USE blocks.

Example:

Test for memory overflow in PPU assembly

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
			PERIPH		
			•		
			•		
7447		LASTTAG	BSS	0	
	7777447	R	ERRPL	LASTTAG-7777	
7462			END		

4.11 LISTING CONTROL

The instructions described in this section permit extensive control of the assembly listing format.

4.11.1 LIST — SELECT LIST OPTIONS

The LIST pseudo instruction controls the content and format of the assembler listing. LIST instructions are disabled under either of the following conditions:

When the list parameter (L) on the COMPASS control card (section 10.1.2) is zero, or

When the list option parameter (LO) on the COMPASS control card is used and is other than LO=0.

Use of the LIST pseudo instruction is optional. If it is not used in the subprogram, COMPASS list output is according to the L and LO parameters on the COMPASS control card. If the LO parameter is omitted or LO=0, the list options are as if L, B, N, and R only are selected and the listing contains heading information, assembly text, assembler statistics, an error directory (upon occurrence of an error only), and a symbolic reference table. Formats of this output are described in detail in chapter 11 and brief summaries are given below.

Heading information	Program length, origin, and length of each block, entry points and external symbols.
Assembly text	Line, and assembly results of each line assembled (not skipped) from the input device (excludes code generated by RMT, DUP, ECHO, XTEXT, or a macro or opdef expansion). For data generating pseudo instructions DATA, DIS, BSSZ that produce more than one word of object code, only the first word is listed. For VFD and CON all words of object code are listed. For R=, only the pseudo instruction is listed. Each occurrence of the LIST instruction is listed.
Assembler statistics	Amount of storage used, counts of assembled statements, defined symbols, invented symbols, and references to symbols.
Error directory	Lists fatal and nonfatal errors and summarizes the causes of each.
Symbolic reference table	List of all symbols defined in the program according to symbol qualifier, if any, followed by an index to every reference to the symbol in the listed statements.

Formats:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	LIST or LIST	$op_1, op_2, \ldots, op_n$ *

A location field symbol, if present, is ignored.

op_i

A list option represented by a single letter or a letter prefixed by a minus sign. The unprefixed letter selects the option; the prefixed letter cancels the option. Options are separated by commas and terminated by a blank.

A List statements actually assembled

When A is not selected, a line containing concatenation and micro substitution marks is listed with the marks in it exactly as presented to the assembler. When the A option is selected, however, the assembler lists the line before and after the editing takes place. Selecting A also causes the listing of lines of code resulting from the R= pseudo instruction.

B List binary control statements

When B is selected, the listing includes SEG, SEGMENT, IDENT, and END pseudo instructions.

C List listing control statements

When C is selected, the listing includes EJECT, SPACE, TTL, and TITLE pseudo instructions. A listing instruction that causes an EJECT is listed as the first line of the new page after the EJECT takes place

D Include details

Selection of the D option causes listing of the following items not normally listed:

Second and subsequent lines of DATA and DIS
Code assembled remotely when HERE or END causes its assembly
Literals block
Default symbols

E Include echoed lines

Selection of E causes listing of all iterations of code duplicated as a result of DUP and ECHO.

F List IF-skipped lines

When F is selected, the listing includes all lines skipped by IF, IFop, IFC, IFPP, IFCP, SKIP, and ELSE. In addition, the Symbolic Reference Table contains references to symbols in IF statements.

G List generated code

Selection of this option causes listing of all code generating lines regardless of list controls other than L. Instructions listed include symbolic machine instructions and BSS, BSSZ, CON, DATA, DIS, R=, and VFD.

L Master list control

This option is normally selected. When L is canceled, the long list contains error flagged lines, an error directory, and LIST pseudo instructions only, regardless of selection of any other options on LIST.

M List macros and opdefs

Selection of M causes all lines generated by calls to macros and opdefs other than those defined by the system to be listed.

N List nonreferenced symbols
This option is normally selected. Cancellation of this option causes any non-system symbol for which no reference has been accumulated (e.g., all occurrences are in IF statements with the F option deselected, or are between CTEXT or ENDX with the X option deselected) to be omitted from the symbolic reference table.

R Accumulate and List references
This option is normally selected. When R is canceled, COMPASS does not accumulate references. R should not be canceled if a complete symbolic reference table is desired. If R is canceled at the end of assembly, no symbolic reference table is produced.

S List systems macros and opdefs
Selection of S causes all lines generated by calls to systems-defined macros and opdefs to be listed.

T List nonreferenced system symbols
Selection of this option causes a symbol defined through SST to be included in the symbolic reference table even if there are no accumulated references.

X List XTEXT lines

Selection of the X option causes listing of all statements assembled as a result of an XTEXT pseudo instruction. CTEXT and ENDX provide a means of alternately turning this external designator off and on.

$ A dollar sign in the variable field selects all options.

* An asterisk in the variable field causes selection of the options in effect prior to the current selection. The assembler records occurrences of LIST pseudo instructions and maintains a table of the most recent 50 occurrences. Each LIST * resumes use of the most recent entry and removes it from the list. When the subprogram contains more LIST * instructions than there are entries in the stack, COMPASS selects the default list options (B, L, N, and R).

For list options A, C, D, E, F, M, S, and X, all applicable options must be selected for a specific line to be listed. For example, listing of an expansion resulting from a DUP within a macro requires selection of both M and E. Similarly, an expansion causes by an XTEXT within a system macro call is listed only when both X and S are selected. To obtain a listing showing ⌐ and ≠ marks removed from external text inside a DUP range requires that A, X, and E all be selected.

Example:

```
                                    LOCATION  OPERATION  VARIABLE      COMMENTS
                                    1         11         18            30
                                              LIST       A
                                              DATA       1.3*EE
0   17205146314631463146              DATA       1.3EE
                                      LIST       D
                                      DATA       1.3*EE
2   17205146314631463146              DATA       1.3EE
3   16403146314631463146
                                      LIST       -A,-D
4   17205146314631463146              DATA       1.3*EE
                                      LIST       *
                                      DATA       1.3*EE≠≠
6   17205146314631463146              DATA       1.3EE
7   16403146314631463146
```

4.11.2 EJECT—EJECT PAGE AND BEGIN NEW SUB-SUBTITLE

The EJECT pseudo instruction advances printer paper to a new page before printing. Then, page headings are printed and listing continues. EJECT has no effect, other than setting the sub-subtitle, if it is generated by DUP, ECHO, RMT, XTEXT, or a macro or opdef expansion, and the corresponding LIST options are not all selected.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	EJECT	

name — New program sub-subtitle for the page will be printed in character positions 70-79 of the second line of the page. A blank name clears the sub-subtitle.

An entry in the variable field, if present, is ignored.

4.11.3 SPACE — SKIP LINES AND BEGIN NEW SUB-SUBTITLE

The SPACE pseudo instruction spaces the assembler listing. When a page is full, an eject occurs and listing resumes on the next page. A SPACE immediately following an EJECT is ignored. SPACE has no effect, other than setting the sub-subtitle, if it is generated by a DUP, ECHO, RMT, XTEXT, or a macro or opdef expansion, and the corresponding LIST options are not all selected.

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	SPACE	scnt,rcnt

name — New subprogram sub-subtitle will be printed in characters 70-79 on the second line of the next page heading. A blank name clears the sub-subtitle.

scnt — An absolute expression specifying a positive integer number of spaces between the most recent line and the next line of printout. If base is M, scnt is assumed to be decimal. If scnt is omitted or zero, no line is skipped.

rcnt — An absolute expression specifying a positive integer number of lines that must be remaining on the page following spacing. If base is M, rcnt is assumed to be decimal.

If scnt + rcnt exceeds the number of lines on the page before spacing occurs, the SPACE acts like an EJECT. Note that either the eject occurs or the number of spaces are skipped but not both.

Blank cards can also be used to space the listing.

4.11.4 TITLE — ASSEMBLY LISTING TITLE

The first TITLE pseudo instruction establishes the title that will be printed on each page of the listing. A subsequent TITLE instruction generates a subtitle and causes a page eject. If the subprogram does not include a TITLE instruction, COMPASS prints the variable field of the first IDENT pseudo instruction as the title. A TITLE instruction without a character string produces an untitled listing. A name in the location field introduces a new subprogram sub-subtitle.

A TITLE instruction has no effect when LIST option X is deselected and the TITLE instruction is in text read by XTEXT or is between CTEXT and ENDX instructions. All other TITLE instructions (except the first which sets the main title) cause a page eject, even when generated by a macro expansion, unless LIST option L is deselected.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	TITLE	string

name — New subprogram sub-subtitle to be printed in character positions 70-79 on the second line of the page. A blank name clears the sub-subtitle.

string — COMPASS searches the columns following the blank that terminates the operation field. If it does not find a nonblank character before the default comments column (see COL pseudo instruction), it takes the characters starting with the default comments column minus one up to the end of the statement. Otherwise, the title or subtitle begins with the first nonblank character following TITLE and continues to the end of the statement or to 62 characters. Any characters beyond the 62nd are lost. A blank string produces an untitled listing.

Example:

```
      LOCATION  OPERATION  VARIABLE      COMMENTS
1                 11         18          30
          IDENT   MTD
          LIST    C
          TITLE   MT DRIVER
          .
          .
          .
          TITLE   I/O ROUTINES
          .
          .
          .
```

First page: MT DRIVER

Subsequent pages: MT DRIVER
I/O ROUTINES

4.11.5 TTL — NEW ASSEMBLY LISTING TITLE

The TTL pseudo instruction introduces a new main title to be printed on each page of the listing, and clears the subtitle.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	TTL	string

string — COMPASS searches the columns following the blank that terminates the operating field. If it does not find a nonblank character before the default comments column (see COL pseudo instruction), it takes the characters starting with the default comments column minus one up to the statement end. Otherwise, the title begins with the first nonblank character following TTL and continues to the end of the statement or to the 62nd character. Any characters beyond the 62nd are lost. A blank string produces an untitled listing.

name — New sub-subtitle to be printed in character positions 70-79 on the second line of the pages. A blank name clears the sub-subtitle.

TTL does not cause a page eject.

4.11.6 NOREF — OMIT SYMBOL REFERENCES

The NOREF pseudo instruction causes the symbols named in the variable field to be suppressed from the symbolic reference table.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	NOREF	$sym_1, sym_2, \ldots, sym_n$

sym_i — One or more symbols defined in the subprogram. If a symbol qualifier is in effect when the NOREF is encountered, the symbols are assumed to be qualified by the qualifier in use. Alternatively, sym_i can be a non-blank qualifier symbol enclosed by slant bars, /qualifier/, in which case all symbols qualified by the specified qualifier are suppressed from the sumbolic reference table.

A location field symbol, if present, is ignored.

4.11.7 CTEXT AND ENDX — DISABLE/ENABLE LISTING OF COMMON DECK TEXT

The CTEXT pseudo instruction sets the XTEXT flag for list control.

NOTE

When the flag is set, external text is listed only if the X list option is selected.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	CTEXT	string

name — If X list option is selected, name (optional) is treated as a sub subtitle; otherwise it is ignored.

string — If the variable field is nonblank and the X list option is selected, the CTEXT is treated as a subtitle. The CTEXT instruction generates a subtitle and causes a page eject. If X is not selected, the CTEXT does not affect titling.

The subtitle begins with the first nonblank character following CTEXT or in the default comments column (see COL pseudo instruction) minus one, whichever comes first, and continues to the end of the statement or to 62 characters. Any characters beyond the 62nd are lost.

The ENDX pseudo instruction clears the XTEXT flag for list control and causes listing to resume, starting with the instruction after ENDX, when the X list option has not been selected.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	ENDX	

Entries in the location field or variable field, if present, are ignored.

4.11.8 XREF—REFERENCE SYMBOLIC ADDRESS

The XREF pseudo instruction provides the options of having the symbolic reference table contain references to symbols according to (1) location counter address, (2) page and line number, or (3) both. For the format of the symbolic reference table, refer to section 11.8.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	XREF	string

string — An optional character string, the first character of which indicates how symbols are to be referenced.

- A — The symbolic reference table lists addresses only. Flags are not included.
- B — The symbolic reference table lists references to symbols according to page number, line, and address. Flags are included.
- P — The symbolic reference table lists references to symbols according to page and line numbers. Flags are included.

A location field symbol, if present, is ignored.

If the string is omitted or if no XREF is issued, the symbolic reference table contains references according to page and line numbers and includes flags. The last XREF encountered in a subprogram determines the form of the listing for the entire subprogram.

DEFINITION OPERATIONS 5

This chapter describes pseudo instructions that involve definition operations. These pseudo instructions cause sequences of instructions to be saved for these reasons:

They can be assembled from an external source (XTEXT).

Assembly can be delayed until later in the subprogram (RMT).

They can be assembled repeatedly (DUP and ECHO).

They can be referred to for assembly (MACRO, MACROE or OPDEF).

Any instructions other than END, including other definitions or calls, can be in the body of a definition.

Each request for assembly of one of the saved sequences of code, such as a reference to a macro, causes an entry in the assembler recursion stack. The most recent entry in the stack points to the source of statements (the definition) to be assembled. When the definition contains an inner, nested, reference to a saved definition, the stack pointer is changed so that the source of statements is the innermost definition. The stack allows nesting of definitions to a maximum level of 400. When the end of a definition is reached, the assembler switches to the preceding entry in the stack. When the stack is empty, the assembler resumes assembly of the next statement in the input source deck. A nested definition must be wholly contained by its next outer definition.

Definitions are saved compressed but otherwise unedited (with micro and concatenation marks). Editing occurs each time the definition is processed. Compression removes blanks and replaces them with coded bytes as follows:

A single space is represented by 55_8; it is not compressed. Two or more embedded spaces are replaced in the image as follows:

2 spaces replaced by 5555_8
3 spaces replaced by 0002_8
4 spaces replaced by 0003
. . .
. . .
. . .
64 spaces replaced by 0077_8
65 spaces replaced by 007755_8
66 spaces replaced by 00775555_8
67 spaces replaced by 00770002_8, etc.

Trailing spaces are considered as embedded and are included in the image. The 00 character (colon) is represented by the 12-bit code 0001. A 12-bit zero byte marks the end of the statement.

The listing identifies the source of statements and the recursion level for all definition operations.

For XTEXT, DUP, and ECHO, assembly occurs as soon as a definition is saved. Unless the definition contains a USE, USELCM, or ORG instruction, code is assembled into the block in use when the XTEXT, DUP, or ECHO is encountered. For RMT, macros, and opdefs, however, definition and assembly take place in two steps. The block in use at definition time does not determine where code in the definition will be assembled. That is, code is assembled into the block in use when the definition is assembled if the definition does not itself contain a USE, USELCM, or ORG.

Similarly, for XTEXT, DUP, and ECHO, any qualifier in effect when the pseudo instruction is encountered applies to symbols defined in the sequence (assuming the sequence does not contain a QUAL). For RMT, macros, and opdefs, however, because definition and assembly take place in two steps, the qualifier in use at definition time does not affect symbols in the definition. The qualifier, if any, in effect when the definition is assembled is applied to the symbols defined in the sequence.

A qualifier applies to symbols only. It does not apply to block names or to the names of DUP, ECHO, RMT, or macro definitions, nor to any substitutable parameter names.

In definitions having substitutable parameters, it is possible to use a different block name, different qualifier, or different symbols with each expansion simply by declaring either the qualifier symbol, block name, or symbols to be qualified as substitutable parameters. (For an example, refer to example 7 under Macro Call.)

5.1 EXTERNAL TEXT (XTEXT)

The XTEXT pseudo instruction provides a means of obtaining source statements from a file other than that being used for input. COMPASS transfers the text from the external source and assembles it before taking the next statement from the interrupted source of statements. The file may be a sequential file, an indexed file with named records, or an UPDATE or MODIFY random-access program library file.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
file	XTEXT	rname

file — Name of a file containing source statements. If file is omitted, COMPASS assumes the file named in the X parameter on the COMPASS control card (Section 10.1.2). If no X parameter was specified, COMPASS assumes OLDPL.

rname — If rname is blank, COMPASS assumes that the file is sequential; it rewinds the file and reads the first section. If rname is not blank, it is the name of the section to be read. The file must be a SCOPE 3 indexed file with named records,† a record indexed file with named records, a random-access program library file in UPDATE format, or a random-access program library file in MODIFY †format.

Text records may be in any of the following formats.

1. Normal text. If the first line contains rname starting in column 1, it is skipped.
2. A common deck in an UPDATE or MODIFY † random-access program library file. If the file is in UPDATE format, the first line (*COMDECK rname) is always skipped.
3. An UPDATE or MODIFY † compressed compile file section.

COMPASS reads source statements to an end-of-section mark or an END pseudo instruction.

5.2 REMOTE ASSEMBLY

Definition and assembly of remote code takes place in two steps. A pair of RMT pseudo instructions delimit code that is to be saved for later assembly. Later, a HERE pseudo instruction directs COMPASS to assemble a specific sequence of remote code or to assemble all unlabeled remote code. An END instruction causes any unlabeled remote code to be assembled.

5.2.1 RMT — SAVE REMOTE CODE

A RMT pseudo instruction signals the beginning or the end of a sequence of code to be assembled remotely.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
rmtname	RMT	

rmtname — Optional 1-8 character name identifying the remote sequence. It is significant on the beginning RMT only. The field is ignored for a terminating RMT. If supplied, rmtname can be used on a subsequent labeled HERE. If the sequence is unlabeled, an unlabeled HERE or END causes its assembly.

A variable field entry, if present, is ignored.

† MODIFY is not supported by SCOPE 2.

Any instruction legal when the remote lines are called for assembly is legal between the RMT pair. If expansion of an RMT reveals a second RMT pair implicit to the saved definition, assembly of the first pair must occur through a HERE instruction so that the inner pair will be expanded by an END. Similarly, if the assembly of the second pair reveals yet a third RMT pair, the second pair must be assembled through a HERE rather than the END, etc.

Any labeled remote code present when END is processed is discarded without notice.

5.2.2 HERE — ASSEMBLE REMOTE CODE

A HERE pseudo instruction causes the labeled remote sequence to be assembled or unlabeled saved remote sequences to be assembled. In the absence of a USE, USELCM, IDENT, or an ORG within the saved sequence, the remote code is assembled under the block in use at the time the HERE is encountered. In the absence of a QUAL within the saved sequence, symbols are qualified under the qualifier in use at the time the HERE is encountered. RMT code is assembled only once. After it is assembled, it is no longer saved. A HERE encountered when there is no remote text saved has no effect on assembly.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
rmtname	HERE	

rmtname — Optional; the name of a previously saved RMT sequence. Only the named sequence will be assembled at this time.

A variable field entry, if present, is ignored.

If unlabeled remote sequences still remain to be assembled when the END card signaling the end of assembly is encountered, COMPASS assembles them before it terminates assembly. However, any RMT pairs that might have resulted from the assembly are lost. Also, any remaining labeled remote code is lost.

Examples:

The following example illustrates use of RMT within a macro definition. Following the last call to the macro, a HERE causes all saved unlabeled RMT sequences to be assembled.

Location	Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
		1		11	18	30
				MACRO	TABLE,TNAM,EQIV	
				IFC	EQ,**EQIV*	
			TNAM	EQU	*-ORIGINS	
			O.TNAM	CON	BUCKET	
				ELSE	2	
			TNAM	EQJ	EQIV	
			O.TNAM	EQU	O.EQIV	
				RMT		
			L.TNAM	EQU	TNAM+SIZES	
				RMT		
				•		
				•		
				•		
				ENDM		
				•		
				•		
				•		
4727			INTER	TABLE		
				IFC	EQ,***	TABLE
	1331		INTER	EQU	*-ORIGINS	TABLE
4727	0000000000000032304		O.INTER	CON	BUCKET	TABLE
				ELSE	2	TABLE
						TABLE
				RMT		TABLE
			L.INTER	EQU	INTER+SIZES	TABLE
				RMT		TABLE
				ENDM		TABLE
4730			LASTAB	TABLE		
				IFC	EQ,***	TABLE
	1332		LASTAB	EQU	*-ORIGINS	TABLE
4730	0000000000000032304		O.LASTAB	CON	BUCKET	TABLE
				ELSE	2	TABLE
						TABLE
				RMT		TABLE
			L.LASTAB	EQU	LASTAB+SIZES	TABLE
				RMT		TABLE
				ENDM		TABLE
4731			NRTAB	TABLE	LASTAB	
				IFC	EQ,**LASTAB*	TABLE
				ELSE	2	TABLE
	1332		NRTAB	EQU	LASTAB	TABLE
	4730		O.NRTAB	EQU	O.LASTAB	TABLE
						TABLE
				RMT		TABLE
			L.NRTAB	EQU	NRTAB+SIZES	TABLE
				RMT		TABLE
				ENDM		TABLE
				•		
				•		
				•		
				HERE		
	4672		L.INTER	EQU	INTER+SIZES	*RMT*
	4673		L.LASTAB	EQU	LASTAB+SIZES	*RMT*
	4673		L.NRTAB	EQU	NRTAB+SIZES	*RMT*

In the following example, assembly of the RMT sequence is caused by the END statement.

```
                    LOCATION  OPERATION  VARIABLE              COMMENTS
                    1         11         18                    30
                              RMT
                    FLD       DECMIC     BUF+BUFL-WSA+ENDS
                    PRS       LIT        C*≠FLD≠ DECIMAL REQUIRED.*
                              RMT
                              LIST             C
                    FLD       DECMIC     BUF+BUFL-WSA+ENDS          *RMT*    1
                    PRS       LIT        C*≠FLD≠ DECIMAL REQUIRED.* *RMT*    1
1[illegible]2       PRS       LIT        C*25759 DECIMAL REQUIRED.* *RMT*    1
```

5.3 CODE DUPLICATION

This section describes two pseudo instructions (DUP and ECHO) that cause a sequence of code to be assembled repeatedly. For a DUP sequence, each assembly is identical with the first, and the number of repetitions is specified or is indefinite. For an ECHO sequence, each assembly resembles a macro reference. Actual parameters supplied in a list are substituted for formal parameters on each repetition of the code sequence. The number of repetitions is determined by the number of actual parameters provided on the ECHO instruction.

Every inner DUP or ECHO sequence must lie totally within the range of the next outer DUP or ECHO, or a fatal E error is flagged.

5.3.1 DUP — SIMPLE DUPLICATION

The DUP pseudo instruction specifies repeated assembly of the statements immediately following. The range of the DUP is specified either by a source statement count on the DUP instruction or by an ENDD.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
dupname	DUP	rep,ℓnct

dupname — Optional name of the DUP sequence; 1-8 characters. When supplied, it can be used in an ENDD. When no name is supplied, the range of the DUP is determined by a statement count or by any ENDD.

rep — Absolute evaluatable expression specifying the integer number of times statements in the DUP range are to be assembled. If rep is null or zero, the instructions in the range are not assembled; that is, code is skipped. When base is M, COMPASS assumes that rep is decimal.

NOTE

A very large (unobtainable) repeat count in conjunction with a STOPDUP instruction can be used for indefinite duplication of code.

ℓnct — An evaluatable expression specifying an integer count of the number of statements to be assembled repeatedly. When base mode is M, COMPASS assumes that ℓnct is decimal. The count is decremented for statements only; comment lines (identified by * in column one) are not counted. On each iteration, the assembler copies the source statements and then assembles them. Thus, any recursive statements within the sequence are counted before they are expanded.

The dupname and ℓnct parameters are related.

1. If a count is supplied, it takes precedence over any ENDD. The only effect of an ENDD is to be included in the count. Under count control, a name is irrelevant.
2. If neither a count nor a name is supplied, the DUP range is terminated only by an unnamed ENDD.
3. If a name but no count is supplied, the DUP range is terminated by an ENDD with a matching name or by an unnamed ENDD. An ENDD with a name that does not match does not effect the range.

5.3.2 ECHO — ECHOED DUPLICATION

The ECHO instruction specifies repeated assembly of the instructions immediately following. On each iteration, the assembler copies the source statements substituting an actual parameter in the list for each formal parameter until the shortest list is exhausted, and then assembles the statements. ECHO offers many of the features of macros but does not require separate definition and reference. The range of the ECHO instruction is specified either by a source statement count specified on the ECHO instruction, or by an ENDD. The statement count, when used, is decremented for instructions only;

comment lines, identified by * in column one, are not part of the definition and are not counted.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
dupname	ECHO	ℓnct, p_1=(list$_1$), p_2=(list$_2$), . . . , p_n =(list$_n$)

dupname — Optional name of the ECHO sequence; 1-8 characters. When supplied, it can be used in an ENDD. When no name is supplied, the range of the ECHO is determined by a statement count or by any ENDD.

ℓnct — Optional absolute evaluatable expression specifying an integer count of the number of source statements to be assembled repeatedly. If base mode is M, the count is assumed to be decimal. If ℓnct is zero or omitted, the comma must be present and the ECHO range is defined by an ENDD.

Any recursive statements, such as macro references, are counted before they are expanded.

If the count exceeds the range of an outer DUP or ECHO sequence, a fatal E error is flagged.

The dupname and ℓnct parameters are related.

1. If a count is supplied, it takes precedence over any ENDD. The only effect of an ENDD in a count-controlled sequence is for it to be included in the count. Under count control a name is irrelevant.
2. If neither a count nor a name is supplied, the ECHO range is terminated only by an unnamed ENDD.
3. If a name but no count is supplied, the ECHO range is terminated by an ENDD with a matching name or by an unnamed ENDD. An ENDD with a name that does not match does not terminate the sequence.

p_i — Names of not more than 63 formal substitutable parameters. Each name is 1-8 characters, the first of which must be alphabetic. A name cannot be END, LOCAL, ENDD, IRP, or ENDM. A second or later occurrence of a parameter name is ignored. A name that begins with a number is ignored.

The separator between p_i and (list$_i$) is conventionally an = but can be any of the following:

+ - * / ( ) $ = , or .

COMPASS recognizes a substitutable parameter name within a definition when it is between any two of the following:

: + - * / ( ) $ = blank , . ≠ or ↦

The substitutable parameter name can occur in any field within a definition.

Before the ECHO definition is stored, COMPASS replaces each use of a substitutable name. Otherwise, it saves the definition unedited, i.e., with micro and concatenation marks. Use of the semicolon is restricted in the definition because the assembler, when it expands the definition, interprets it as a substitutable parameter flag (77_8).

The character ↱ flags the occurrence of a name not bounded by any other special character and, thus, not otherwise recognized. When it expands the definition, COMPASS substitutes an actual parameter value from the list for the substitutable parameter and removes the ↱ so that the adjacent items are concatenated.

Because the assembler replaces the first substitutable parameter with 7701, the second with 7702, etc. the programmer can use the display characters ;A, ;B, etc. directly in place of his substitutable parameter names in the definition and achieve the same results as if the assembler had replaced the name with the flag. (Example 8, Section 5.4.3 illustrates a similar application of this technique.)

($list_i$) Actual parameter list in the form $a_1, a_2, \ldots, a_n$ where a_i is substituted for p_i on the first assembly of the ECHO sequence, a_2 is substituted on the second assembly, etc. until the shortest list is exhausted. Two consecutive commas are interpreted as a null parameter. An explicit zero, if desired, must be entered. An actual parameter can contain a set of embedded parameters enclosed by parentheses. However, the embedded parentheses must be properly paired. The assembler removes the outer pair of parentheses before substituting the embedded set in a line. A parenthetical item can contain blanks or commas.

If there are no parameters or any of the lists are null, COMPASS assembles the ECHO sequence zero times, effectively skipping it.

5.3.3 STOPDUP — STOP DUPLICATION

The STOPDUP instruction allows premature termination of a DUP duplication before the repeat count is reached or of an ECHO duplication before the shortest list is exhausted. Assembly is completed to the end of the range for the current iteration and then continues with the next source statement. Only the innermost duplication is affected.

A STOPDUP outside of a DUP or ECHO range has no effect on assembly. If a DUP or ECHO is nested, STOPDUP terminates only the innermost DUP or ECHO.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	STOPDUP	

An entry in the location or variable field is ignored.

5.3.4 ENDD — END DUPLICATION SEQUENCE

The ENDD pseudo instruction terminates a DUP or ECHO sequence when the statement count is unspecified on the DUP or ECHO.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
dupname	ENDD	

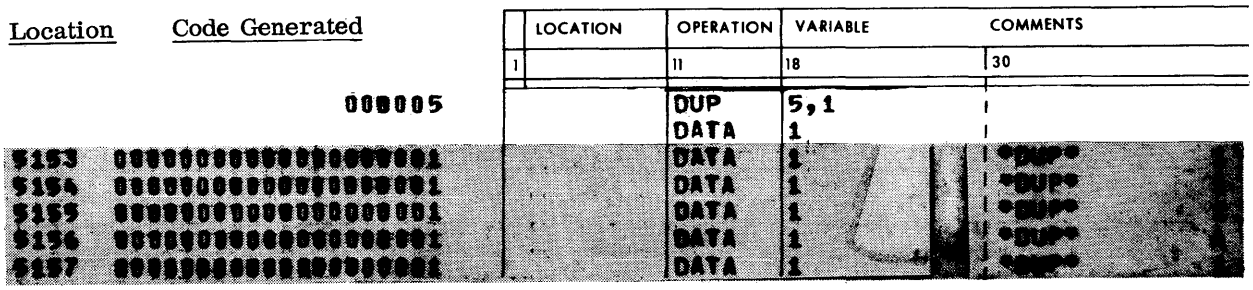
dupname — Name of a DUP or ECHO sequence, or blank. A named DUP or ECHO sequence can be terminated by an ENDD specifying the sequence by name, or by any unnamed ENDD. An unnamed DUP or ECHO sequence that is not controlled by statement count is terminated only by an unnamed ENDD. An ENDD does not terminate a sequence controlled by a statement count. The ENDD is included in the count but has no other effect.

An ENDD outside the range of a DUP or ECHO has no effect on assembly.

Examples:

In the following examples, the statements that result from expansion are shown faded. They are listed only when the E list option is selected. Source statements are shown in bold characters.

1. This example illustrates use of a simple DUP instruction.



2. This example illustrates a nested DUP instruction with one of the DUP duplications terminated by a STOPDUP.

```
1         LOCATION    OPERATION   VARIABLE          COMMENTS
1                     11          18                30
          GO          MACRO
          TAG         MICRO       NO,1,/#ALPHABET#/
                      IFC         EQ,/#TAG#/E/,1          ASSEMBLE STOPDUP WHEN TAG=E
                      STOPDUP
          NO          SET         NO+1                    NO IS 6 IN LAST ITERATION
          GO          ENDM
          ALPHABET    MICRO       1,,/ABCDEFGHIJK/
          NO          SET         1
                      DUP         -1                      UNOBTAINABLE ITERATION COUNT
                      GO
                      ENDD
                      GO                                                          *DUP*
          TAG         MICRO       NO,1,/#ALPHABET#/                               GO
          TAG         MICRO       NO,1,/ABCDEFGHIJK/                              GO
                      IFC         EQ,/#TAG#/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      IFC         EQ,/A/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      STOPDUP                                                     GO
          NO          SET         NO+1                    NO IS 6 IN LAST ITERATION GO
                      ENDM                                                        GO
                      ENDD                                                        *DUP*
                      GO                                                          *DUP*
          TAG         MICRO       NO,1,/#ALPHABET#/                               GO
          TAG         MICRO       NO,1,/ABCDEFGHIJK/                              GO
                      IFC         EQ,/#TAG#/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      IFC         EQ,/B/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      STOPDUP                                                     GO
          NO          SET         NO+1                    NO IS 6 IN LAST ITERATION GO
                      ENDM                                                        GO
                      ENDD                                                        *DUP*
                      .           .
                      .           .
                      .           .
                      .           .
                      GO                                                          *DUP*
          TAG         MICRO       NO,1,/#ALPHABET#/                               GO
          TAG         MICRO       NO,1,/ABCDEFGHIJK/                              GO
                      IFC         EQ,/#TAG#/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      IFC         EQ,/E/E/,1          ASSEMBLE STOPDUP WHEN TAG=E GO
                      STOPDUP                                                     GO
          NO          SET         NO+1                    NO IS 6 IN LAST ITERATION GO
                      ENDM                                                        GO
                      ENDD                                                        *DUP*
```

3. This example illustrates nested ECHO instructions. A statement count terminates the second level ECHO. The ENDD terminates the first level. Notice how COMPASS assembles each copy before it begins the next iteration.

```
Location  Code Generated  LOCATION  OPERATION  VARIABLE          COMMENTS
1         11              11        18         30
                                    PPU
                                    .
                                    .
                                    .
                          STM       PPOP       5,5415B
                                    LIST       M,D,E
                                    ECHO       ,CM=(X,Y,Z)
                                    ECHO       2,P1=(A,B,C)
                                    LDN        CM
                                    STM        P1
                                    ENDD
                                    ECHO       2,P1=(A,B,C)   *ECHO*  1
                                    LDN        X              *ECHO*  1
                                    STM        P1             *ECHO*  1
1452      1450                      LDN        X              *ECHO*  2
1453      5415 0036                 STM        A              *ECHO*  2
1455      1450                      LDN        X              *ECHO*  2
1456      5415 0037                 STM        B              *ECHO*  2
1460      1450                      LDN        X              *ECHO*  2
1461      5415 0040                 STM        C              *ECHO*  2
                                    ENDD                      *ECHO*  1
                                    ECHO       2,P1=(A,B,C)   *ECHO*  1
                                    LDN        Y              *ECHO*  1
                                    STM        P1             *ECHO*  1
1463      1460                      LDN        Y              *ECHO*  2
1464      5415 0036                 STM        A              *ECHO*  2
1466      1460                      LDN        Y              *ECHO*  2
1467      5415 0037                 STM        B              *ECHO*  2
1471      1460                      LDN        Y              *ECHO*  2
1472      5415 0040                 STM        C              *ECHO*  2
                                    ENDD                      *ECHO*  1
                                    ECHO       2,P1=(A,B,C)   *ECHO*  1
                                    LDN        Z              *ECHO*  1
                                    STM        P1             *ECHO*  1
1474      1470                      LDN        Z              *ECHO*  2
1475      5415 0036                 STM        A              *ECHO*  2
1477      1470                      LDN        Z              *ECHO*  2
1500      5415 0037                 STM        B              *ECHO*  2
1502      1470                      LDN        Z              *ECHO*  2
1503      5415 0040                 STM        C              *ECHO*  2
                                    ENDD                      *ECHO*  1
1505      5415 1524                 STM        TAG
```

5.4 MACROS AND OPDEFS

A macro or opdef definition is a sequence of source statements that are saved and then assembled whenever needed through a macro or opdef call. A macro call consists of the occurrence of the macro name in the operation field of a statement. It usually includes parameters to be substituted for formal parameters in the macro code sequence so that code generated can vary with each assembly of the definition.

An opdef call differs from a macro call in that the assembler interprets the call by examining the format or syntax of the instruction rather than the contents of the operation field alone. The instruction comprising the opdef call usually includes parameters to be substituted for parameters in the code sequence. There are some differences in the way parameters are substituted, however, as is further described under Opdef Call.

Use of a macro or an opdef requires two steps, definition of the macro or opdef sequence, and calling of the definition.

A definition consists of three parts: heading, body, and terminator.

Heading

A macro definition is headed by a MACRO or MACROE pseudo instruction stating the name of the macro and identifying substitutable parameters in the body of the macro.

An opdef definition is headed by an OPDEF pseudo instruction stating the syntax of the calling instruction and identifying substitutable parameters in the body of the macro.

The heading optionally includes one or more LOCAL instructions identifying symbols local to the definition.

Body

The body begins with the first statement in a definition that is not a LOCAL statement or a comment line. A comment line can be either identified by * in column one or can have columns 1-29 blank. (Following the first statement of the macro body, only comments identified by * in column 1 are ignored.)

Use of the semicolon is restricted because when a definition is expanded a semicolon is interpreted as a substitutable parameter mark or a local symbol flag.

The body consists of a series of symbolic instructions. All instructions other than END, including other macro and opdef definitions and calls are legal within a definition. However, a definition within a definition is not defined until the outer definition is called. Therefore, an inner definition cannot be called before the outer definition is called.

A name of a substitutable parameter listed in the heading can occur in any field within the body. A reference to a substitutable parameter is recognized when it is between two of the following characters in an expression or field:

: + - * / ( ) $ = blank , . ≠ or ⌐→

The character ⌐→ flags the occurrence of a name not bounded by any other special

character, and, thus, not otherwise recognized. On a call, the assembler substitutes an actual parameter value for the substitutable parameter and removes the ⌐→ so that the adjacent items are concatenated.

NOTE

The programmer can legally use the characters . ( ) : $ and = in symbols but when he does, he must be careful that these characters are not interpreted as delimiters in macro definitions (example 4 under macro calls).

The macro body optionally contains IRP pseudo instructions that allow iterative assembly of a sequence within the body such that each iteration uses a different parameter value.

Terminator — An ENDM pseudo instruction terminates a macro or opdef definition.

Definition Processing — A macro or opdef can be defined anywhere in a subprogram before it is called. When COMPASS encounters a definition, it places the name of the macro or the syntax of the opdef along with the number of substitutable parameters and local symbols in the assembler operation code table. Before the definition is saved, COMPASS replaces each occurrence of a parameter name or local symbol with a 77xx (where xx is a number assigned to the substitutable parameter or local symbol).

On the call, each use of a substitutable parameter (each 77xx) is replaced by its actual parameter; each use of a local symbol is replaced by a unique symbol generated by the assembler. Usually, symbols replaced in this way have no meaning outside the definition. However, if the macro includes an RMT sequence which contains local symbols, the local symbols will have meaning where the remote code is assembled outside of the definition.

5.4.1 ENDM — END MACRO DEFINITION

An ENDM terminates a macro or opdef definition.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	ENDM	

mname — Name of a macro sequence, syntax of an OPDEF sequence, or blank.

An ENDM specifying a macro by name terminates the named macro definition and any unterminated macro or opdef definitions within it. An unnamed ENDM terminates all unterminated definitions. An ENDM outside the range of any macro sequence has no effect other than to be included in statement counts.

Example:

```
|  LOCATION  | OPERATION | VARIABLE          | COMMENTS
1            11          18                  30
|            |           |                   |
|  JAY       | MACRO     | P1,P2,P3          |
|            |  .        |                   |
|            |  .        |                   |
|            |  .        |                   |
|  KAY       | MACROE    | PK2,PK2,PK3,PK4   |
|            |  .        |                   |
|            |  .        |                   |
|            |  .        |                   |
|  JPX/XQ    | OPDEF     | OP1,OP2,OP3       |
|            |  .        |                   |
|            |  .        |                   |
|            |  .        |                   |
|  KAY       | ENDM      |                   | TERMINATES KAY AND
|            |  .        |                   | THE OPDEF DEFINITION
|            |  .        |                   |
|            |  .        |                   |
|            | ENDM      |                   | TERMINATES JAY
|            |           |                   |
```

5.4.2 MACRO — MACRO HEADING

A MACRO pseudo instruction notifies the assembler to place the instructions forming the body of the macro in a table of macro definitions for assembly upon call and place the macro name in the operation code table.

The MACRO pseudo instruction has two forms:

Format one:

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	MACRO	parameters

Format two:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	MACRO	mname,parameters

The blank location field identifies the second format.

mname — A legal name other than END, ENDD, IRP, LOCAL, or ENDM. 1-8 characters.

A name that is identical to a PPU symbolic machine instruction, pseudo instruction, or macro already in the operation code table redefines the instruction. The most recent definition applies for the macro call. A redefinition causes an informative flag to be issued but the new definition holds.

parameters — Names of substitutable parameters. The order in which names are listed determines the order in which parameters must occur in the macro call. Each name is 1-8 characters, the first of which must be alphabetic. A name cannot be END, IRP, LOCAL, ENDD or ENDM. A name that begins with a number, or a second or later occurrence of a parameter name in the list is ignored.

Any of the following special characters separate parameters in the list:

+ - * / ( ) $ = , or .

These characters have no meaning other than as separators. A blank terminates the list of parameters. Also, any of these characters can be used to separate the mname from parameters in format two.

The total number of unique parameter names and local symbols must not exceed 63 for any one macro definition.

Format one does not require parameters.

Format two requires at least one substitutable parameter. This parameter is termed the location argument because the location field entry in the macro call is its substituted value. Omission of the location argument from a MACRO instruction in format two causes the assembler to issue a fatal error and ignore the definition.

The assembler ignores a blank parameter produced by two concurrent separators or by a separator at the end of the list.

For an example of definition and calls, refer to Macro Calls.

Examples of macro instructions:

1. Legal MACRO instructions:

```
    LOCATION    OPERATION   VARIABLE            COMMENTS
1               11          18                  30
    ABC         MACRO       P1,P2,P3
                MACRO       DEF*LOC*ONE*TWO*TEN
    MESSAGE     MACRO       A
```

2. MACRO instructions having identical parameter lists.

```
    LOCATION    OPERATION   VARIABLE            COMMENTS
1               11          18                  30
    SUM         MACRO       X=Y+Z+X             SECOND X PARAMETER IS IGNORED
    SUM         MACRO       X(Y+Z)
    SUM         MACRO       X=Y+Z
    SUM         MACRO       X,Y,(Z+X)           NULL PARAMETER AND SECOND
                                                X ARE IGNORED
    RAO         MACRO       X
    RAO         MACRO       X=X+1               SECOND X AND NUMERIC
                                                PARAMETER ARE IGNORED
```

3. Illegal use of format two:

```
    LOCATION    OPERATION   VARIABLE            COMMENTS
1               11          18                  30
                MACRO       ABC                 NO SUBSTITUTABLE PARAMETER
                MACRO       ABC,,FP             NULL PARAMETER FIELD
                MACRO       ABC,16,FP           NUMERIC PARAMETER FIELD
```

5.4.3 MACRO CALLS

A macro headed by a MACRO pseudo instruction can be called by an instruction in the following format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	mname	$p_1,p_2,\ldots,p_n$

sym — Optional; depends on definition (see discussion following)

p_i — Parameter list composed of alphanumeric strings. Parameters are separated by commas and terminated by a blank. Two consecutive commas constitute a null parameter. An explicit zero, if desired, must be entered.

Each parameter must be in its correct relative position depending on the sequence in which its formal substitutable name is given in the MACRO pseudo instruction.

When the definition MACRO is in format one, the first parameter in the call is substituted wherever the first substitutable parameter occurs in the definition, the second parameter in the call is substituted wherever the second substitutable parameter occurs in the definition, etc. When the definition MACRO is in format two, the location field entry in the call is substituted wherever the first substitutable parameter occurs in the definition, the first parameter in the variable field of the call is substituted wherever the second substitutable parameter occurs in the definition, etc.

If null parameters are interspersed with legal parameters, the correct positions must be established with commas. When the list terminates before the last possible parameter, all remaining parameters are considered null.

When the first character of a parameter is a left parenthesis, the assembler considers all the characters between it and the matching right parenthesis as an embedded parameter or as an iterative parameter. It is an iterative parameter when the substitutable parameter has been named in an IRP pseudo instruction (Section 5.4.9). Otherwise, it is an embedded parameter.

The assembler removes the outer pair of parentheses before substituting the enclosed character string in a line. Embedded parenthetical items must be properly paired. A parenthetical item can contain blanks and commas.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		MESSAGE	(=C*PROGRAM ABORT.*)	

After substitution, spacing between fields is the same as it was before substitution. One effect is that a null actual parameter replacing a formal parameter in a variable field effectively moves the comments field to the left. Then, when the line is assembled, the comments could be erroneously interpreted as a variable subfield.

Processing of a location symbol and forcing upper of the first macro instruction depend on the MACRO form used for the definition.

If the macro is defined using format one, that is, the macro name is in the location field, a location symbol on the macro call line forces the first word of generated code upper. The location field symbol is assigned the current value of the location counter. A location field (if any) on the line in the definition that generates the code is assigned the same address. If the location field of the macro call does not contain a symbol, the location and position counters are not affected by the call.

When the macro is defined using format two, that is, the macro name is in the variable field and the first parameter is a location argument, the location symbol of the call is substituted for the first parameter or location argument. The fact that this argument came from the location field rather than the variable field has no special significance in the macro expansion. In the macro call, the location field argument cannot be more than 8 characters. Parentheses are not given the special meaning used in the variable field of a macro call line.

Example:

1. An illustration of concatenation

```
Location  Code Generated   LOCATION  OPERATION  VARIABLE      COMMENTS
                          1         11         18            30
                          MACK      MACRO      P1,P2
                                    S*P1       P1+1R*P2
                                    .
                                    .
                                    .
                                    ENDM
                                    .
                                    .
                                    .
                                    MACK       A2,A
                                    S*A2       A2+1R*A          MACK    1
7763  5022000001                    SA2        A2+1RA           MACK    1
                                    ENDM                        MACK    1
```

2. An illustration of nested definitions and calls

```
 | LOCATION | OPERATION | VARIABLE | COMMENTS
 1          |           11         18         30
   NAME1      MACRO
    .          .
    .          .
    .          .
   NAME2      MACRO
               .
               .
               .
   NAME2      ENDM
               .
               .
               .
               NAME2                AT THIS TIME, THIS LINE
               .                    IS PART OF A DEFINITION
               .                    RATHER THAN BEING A CALL.
               .
               .
   NAME1      ENDM
               .
               .
               .
               NAME1                NAME1 IS CALLED AND EXPANDED.
               .
               .
               .
               NAME2                CALL TO NAME2 IS VALID
```

3. The following example illustrates two calls to a definition headed by a MACRO in format two using the location argument. The macro is named TABLE; its substitutable arguments are TABNAM, VALUE1, and VALUE2, where TABNAM is the location argument.

```
Location  Code Generated   | LOCATION | OPERATION | VARIABLE          | COMMENTS
                           1          |  11       |  18               |  30
                                      | MACRO     | TABLE,TABNAM,VALUE1,VALUE2
                           TABNAM     | VFD       | 60/VALUE1,60/VALUE2
                                      | ENDM      |
                                      |  .        |
                                      |  .        |
                                      |  .        |
                           SPVAL      | TABLE     | 1.0,2.0           | CALL ONE
4741 1720600000000000000   SPVAL      | VFD       | 60/1.0,60/2.0     |          TABLE
4742 1721400000000000000   SPVAL      |           |                   |          TABLE
                                      | ENDM      |                   |
                                      |  .        |                   |
                                      |  .        |                   |
                                      |  .        |                   |
4743                                  | TABLE     | 1.0               | CALL TWO
4743 1720400000000000000   SPVAL      | VFD       | 60/1.0,60/        |          TABLE
4744 0000000000000000000   SPVAL      |           |                   |          TABLE
                                      | ENDM      |                   |
```

4. An illustration of embedded parameters:

Definition:

```
      LOCATION    OPERATION   VARIABLE        COMMENTS
1                 11          18              30
      XAM         MACRO       A,B
                  LDM         A
                  LJM         B
                  ENDM
```

Call:

```
      LOCATION    OPERATION   VARIABLE        COMMENTS
1                 11          18              30
                  XAM         (SUM,10B),(SAM,IND3)
```

Expansion:

```
Location    Code Generated      LOCATION    OPERATION   VARIABLE        COMMENTS
                                1                       11          18              30
7303        5010 7245                       LDM         SUM,10B
7305        0117 7243                       LJM         SAM,IND3
                                            ENDM
```

5. The following example illustrates use of R= in macros:

```
      LOCATION    OPERATION   VARIABLE        COMMENTS
1                 11          18              30
      ONSW        MACRO       N
                  R=          X1,N
                  SX2         11B
                  RJ          =XCPM=
                  ENDM
      OFFSW       MACRO       N
                  R=          X1,N
                  SX2         12B
                  RJ          =XCPM=
                  ENDM
```

6. The following example illustrates a character in a symbol erroneously being interpreted as a delimiter for a parameter.

```
          LOCATION  OPERATION  VARIABLE        COMMENTS
1                   11         18              30
ABC       MACRO     Z,VAL,P5
Z         SET       VAL
          SA7       Z.ALPHA
          .         .
          .         .
          .         .
          ENDM
ABC       MACRO     IOTA,1,3
IOTA        SET       1
          SA7       IOTA.ALPHA      ILLEGAL SYMBOL. TOO LONG
          ENDM
```

7. The following example illustrates changing of control blocks and symbol qualifiers through substitutable parameters in a macro. (The same call could be used by using micros to change actual parameters.)

```
          LOCATION  OPERATION  VARIABLE        COMMENTS
1                   11         18              30
TAB       MACRO     BLOCK,KWAL
          USE       BLOCK
          QUAL      KWAL
TAG1      BSS       10B
TAG2      VFD       60/-1
          USE       *
          QUAL      *
          ENDM
          TAB       ONE,ONE
          USE       ONE                       TAB
          QUAL      ONE                       TAB
TAG1      BSS       10B                       TAB
TAG2      VFD       60/-1                     TAB
          USE       *                         TAB
          QUAL      *                         TAB
          ENDM                                TAB
          TAB       TWO,TWO
          USE       TWO                       TAB
          QUAL      TWO                       TAB
TAG1      BSS       10B                       TAB
TAG2      VFD       60/-1                     TAB
          USE       *                         TAB
          QUAL      *                         TAB
          ENDM
```

8. The following example illustrates a technique that an experienced programmer may wish to use to save time in processing of definitions. Remember that the assembler replaces the first substitutable parameter with 7701, the second with 7702, etc. Note that 7701 is ;A in display characters, 7702 is ;B, etc. This means that the programmer can use the display characters directly in place of his substitutable parameter names in the body of the definition and achieve the same results as if the assembler had made the substitution when it saved the definition. At the time the definition is assembled, the assembler replaces each 77xx with the actual parameter whether the code was inserted by the assembler when it saved the definition or by the programmer when he coded the definition.

```
                                  |  LOCATION  |  OPERATION  |  VARIABLE                COMMENTS
                                  |  1         |  11         |  18                      30
                                  |            |             |
                                  |  CHAR      |  MACRO      |  ASCII,INTERNAL,EXTERNAL,BCD
                                  |            |  CON        |  ;D;C;B;A
                                  |            |  ENDM       |
                                  |            |  .          |
                                  |            |  .          |
                                  |            |  .          |
                          D=0     |            |  BASE       |  0
                                  |            |             |
                                  |            |  CHAR       |  43,10,10,30 8
7771  0000000000030101043         |            |  CON        |  30101043                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
7772                              |            |  CHAR       |  44,11,11,31 9
7772  0000000000031111164         |            |  CON        |  31111164                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
7773                              |            |  CHAR       |  45,60,20,13 +
7773  0000000000013206045         |            |  CON        |  13206045                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
7774                              |            |  CHAR       |  46,40,40,15 -
7774  0000000000015404046         |            |  CON        |  15404046                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
7775                              |            |  CHAR       |  47,54,54,12 *
7775  0000000000012545447         |            |  CON        |  12545447                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
7776                              |            |  CHAR       |  50,21,61,17 /
7776  0000000000017612190         |            |  CON        |  17612190                CHAR  1
                                  |            |  ENDM       |                          CHAR  1
```

5.4.4 MACROE — EQUIVALENCED MACRO HEADER

A MACROE pseudo instruction can be used instead of a MACRO instruction to notify the assembler to place the instructions forming the body of the macro in a table of macro definitions for assembly upon call, to place the macro name in the operation code table, and to save the list of parameter names so that actual parameters supplied in the macro call can be listed by name in any sequence in the macro call.

The MACROE pseudo instruction has two forms:

Format one:

LOCATION	OPERATION	VARIABLE SUBFIELDS
mname	MACROE	parameters

Format two:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	MACROE	mname, parameters

The blank location field identifies the second format.

mname — A legal name other than END, ENDD, IRP, LOCAL, or ENDM. It can be 1-8 characters. A name that is identical to a PPU symbolic machine instruction name, pseudo instruction, or macro instruction already in the operation code table redefines the instruction. The most recent definition is the one that applies for the macro call. A redefinition causes an informative flag to be issued but the new definition holds.

parameters — Names of substitutable parameters. Unlike MACRO, the order in which names are listed does not determine the order in which parameters can occur in the macro call. Each name is 1-8 characters, the first of which must be alphabetic. A name cannot be END, ENDD, LOCAL, IRP, or ENDM. A name that begins with a number, or a second or later occurrence of a parameter name in the list is ignored. Any of the following special characters separate parameters in the list:

+ - * / ( ) $ = , or .

These characters have no meaning other than as separators. A blank terminates the list of parameters. The total number of unique parameter names and local symbols must not exceed 63 for any one macro definition. Also, any of these can be used to separate the mname from parameters in format two.

Format one does not require parameters.

Format two requires at least one substitutable parameter. This parameter is termed the location argument because the location field entry in the macro call is its substituted value. Omission of the location argument from a MACRO instruction in format two causes the assembler to issue a warning flag and ignore the definition.

The assembler ignores a blank parameter produced by two concurrent separators or by a separator at the end of the list.

For an example of definition and calls, refer to Equivalenced Macro Call.

5.4.5 EQUIVALENCED MACRO CALL

A macro definition headed by a MACROE pseudo instruction can be called by an instruction of the following format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	mname	$p_1=a_1,p_2=a_2,\ldots,p_n=a_n$

mname — Name of MACROE definition

sym

Optional symbol. A symbol in the location field causes the location counter to be forced upper. The symbol is then assigned the value of the location counter. A location field symbol on the first line in the definition that generates code is assigned the same address. If the location field of the macro call does not contain a symbol, the manner of the force upper is a function of the first-code-generating line in the macro expansion.

$p_i=a_i$

An equivalenced parameter. Each p is the name of a substitutable parameter. The a_i is an actual parameter to be substituted for p_i. The parameters need not be listed in the same order as they are listed on the MACROE instruction. Equivalenced parameters in the list are separated by commas and terminated by a blank.

A null value is substituted for any parameter omitted from the list.

When the first character of an actual parameter is a left parenthesis, the assembler considers all the characters between it and the matching parenthesis as an embedded parameter or as an iterative parameter. It is an iterative parameter when the substitutable parameter has been named in an IRP pseudo instruction (section 5.4.9, IRP). Otherwise, it is an embedded parameter. The assembler removes the outer pair of parentheses before substituting the enclosed character string in a line. Embedded parenthetical items must be properly paired. A parenthetical item can contain blanks and commas.

After substitution, spacing between fields is the same as it was before substitution. One effect is that a null actual parameter replacing a formal parameter in a variable field effectively moves the comments field to the left. Then, when the line is assembled, the comments could be erroneously interpreted as a variable subfield.

Processing of a location symbol and forcing upper of the first macro instruction depend on the MACROE form used for the definition.

If the macro is defined using format one, that is, the macro name is in the location field, a location symbol on the macro call line forces the first word of generated code upper. The location field symbol is assigned the current value of the location counter. A location field (if any) on the line in the definition that generates the code is assigned the same address. If the location field of the macro call does not contain a symbol, the location and position counters are not affected by the call.

When the macro is defined using format two, that is, the macro name is in the variable field and the first parameter is a location argument, the location symbol of the call is substituted for the first parameter or location argument. The fact that this argument came from the location field rather than the variable field has no special significance in the macro expansion.

CAUTION

After substitution, spacing between fields is the same as it was before substitution.

Example:

Location Code Generated

```
                                    LOCATION  OPERATION  VARIABLE          COMMENTS
                                    1         11         18                30
                                    SAM       MACROE     A,B,C
                                              CON        A
                                              CON        B
                                              CON        C
                                              ENDM
                                              .
                                              .
                                              .
5007                                          SAM        A=1,C=5,B=0
5007  000000000000000001                      CON        1                 SAM 1
5010  000000000000000000                      CON        0                 SAM 1
5011  000000000000000005                      CON        5                 SAM 1
                                              ENDM                         SAM 1
```

5.4.6 OPDEF — DEFINE CPU OPERATION

An OPDEF pseudo instruction notifies the assembler to place instructions in the body of the definition in a table of definitions for assembly upon call and place the instruction syntax in the operation code table. There is no way of removing the definition from the table. It can, however, be bypassed through redefinition, or disabled through CPSYN. If the syntax duplicates a CPU instruction already in the table, the OPDEF definition takes precedence.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
syntax	OPDEF	parameters

syntax

The syntax consists of a mnemonic operator and variable field descriptors. The mnemonic operator consists of two letters. The first can be any letter. The second letter can be a register designator: A, B, or X in which case the operation field of the opdef call is recognized as cAn, cXn, or cBn (c is a unique character; n is 0-7); or the second letter can be any other letter, in which case the operation field of the opdef call is recognized simply by a two-letter mnemonic, such as EQ.

The variable field descriptors define the order of appearance of all registers, expressions, and subfield separators that comprise the variable field of the opdef call. It consists of none, one, two, or three of the following 22 subfield descriptors. Q represents an expression. An r represents a register letter (A, B, or X). A comma separates two descriptors; a blank terminates the syntax.

void	Q
r	rQ
-r	-rQ
r_1+r_2	r_1+r_2Q
$-r_1+r_2$	$-r_1+r_2Q$
r_1*r_2	r_1*r_2Q
$-r_1*r_2$	$-r_1*r_2Q$
r_1/r_2	r_1/r_2Q
$-r_1/r_2$	$-r_1/r_2Q$
r_1-r_2	r_1-r_2Q
$-r_1-r_2$	$-r_1-r_2Q$

For example, $-r_1*r_2$ would be written as -X*B to describe -X3*B1 whereas rQ would be written as BQ to describe B2+ALPHA.

The first descriptor immediately follows the mnemonic operator.

parameters

A substitutable parameter for each register designator (r) and expression designator (Q) in the syntax in the order in which they occur in the syntax (and, consequently, in the calling instruction). Parameters can be separated by any of the characters:

+ - * / ( ) $ = , or .

A blank terminates the list.

The assembler ignores a blank parameter produced by two concurrent separators or by a separator at the end of the list. A second or later occurrence of a parameter name in the list is ignored.

Examples:

1. Listed below are some instructions that could be defined through OPDEF and the syntax entries that would describe them:

Calling Instruction		Opdef Syntax
Operation	Variable Subfields	
JP†	K††	JPQ
JP†	Bn±K	JPBQ
JP	Bn±Bn±K	JPB±BQ
JP	Bn, K	JPB, Q
JP	Xn/Xn±K	JPX/XQ
NE†	Bn, Bn, K	NEB, B, Q
LJ	Bn-Bn, An-Xn, K	LJB-B, A-X, Q
BXn†	-Xn*Xn	BX-X*X
SBn†	Xn+Bn	SBX+B
LXn†	Bn, Xn	LXB, X
JP†	Bj+K	JPBQ
NE†	Bj, Bk, K	NEB, B, Q
BXi†	-Xk*Xj	BX-X*X
SBi†	Xj+Bk	SBX+B
SBi†	Bj+Xk	SBB+X

† Legal COMPASS CPU instructions
†† K represents an expression.

2. The following complete definition redefines single-address long jump JP as the EQ jump, which is faster than JP on the 6600 Computer System.

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      JPQ       OPDEF      P1
                EQ         P1
                ENDM
```

Each subsequent JP instruction that matches the syntax JPQ is assembled as an EQ. A JP instruction having a different syntax, such as the following, is not affected.

Location	Code Generated
10002	0233000005 +

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  JP         B3+ALPHA
```

3. The following definition traps all floating point double-precision subtraction instructions (DXi Xj-Xk) and jumps to an error-check routine for debugging. I, J, and K are substitutable parameters used within the definition.

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      DXY-Y     OPDEF      I,J,K
                .
                .
                .
                PJ         CKOUT
                ENDM
```

4. The following sequence causes RXi K to be defined as AXi K. It does not affect the standard RXi instructions involving registers.

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      RXQ       OPDEF      P1,P2
                AX.P1      P2
                ENDM
```

5.4.7 OPDEF CALL

An opdef call resembles a CPU mnemonic machine instruction. The mnemonic code, quantity and sequence of registers, arithmetic operators, and expressions (excluding operators within the expressions) must match the syntax described in the OPDEF for the definition to be called.

NOTE

If the Q in a descriptor is combined with register letters, a plus or minus must precede an expression in the call.

OPDEF Syntax	Call		
JPQ	JP	K	Not combined
JPBQ	JP	Bn+K	Combined
JPB,Q	JP	Bn,K	Not combined
JPX/XQ	JP	Xn/Xn+K	Combined

An OPDEF call can occur any place after the definition is saved. In substituting parameters, the assembler uses only the register values given in the call. It does not substitute the register designators.

A location symbol on the opdef call line forces the first word of generated code upper. The location field symbol is assigned the current value of the current location counter after the force upper. A location field on the line in the definition that generates code is assigned the same value. If the location field of the opdef call does not contain a symbol, the manner of the force upper is a function of the first code-generating instruction in the expansion. If the call location field and the code-generating instruction field both contain symbols they are assigned the same value.

Only a line having the correct syntax calls the definition.

Examples:

The following opdef defines an instruction having the syntax IXX/X. On the call, the assembler substitutes 3, 4, and DIV (not X3, X4, and X. DIV) for P1, P2, and P3, respectively.

Location	Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
				1 11 18 30	
		IXX/X	OPDEF	P1,P2,P3	
			PX.P2	X.P2	
			PX.P3	X.P3	
			NX.P2	X.P2,B4	
			NX.P3	X.P3,B4	
			FX.P1	X.P2/X.P3	
			UX.P1	X.P1,B4	
			LX.P1	X.P1,B4	
			ENDM		
			IX3	X4/X.DIV	
10161 27404			PX.4	X.4	IX3
27606			PX.DIV	X.DIV	IX3
24444			NX.4	X.4,B4	IX3
24646			NX.DIV	X.DIV,B4	IX3
10162 44346			FX.3	X.4/X.DIV	IX3
26343			UX.3	X.3,B4	IX3
22343			LX.3	X.3,B4	IX3
			ENDM		IX3

The following OPDEF selectively traps the SXi Xj+Bk instructions.

Definition:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	SXX+B	OPDEF	I,J,K	
		•		
		•		
		•		
		ENDM		

Statements that call the definition:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SX3	X1+B2	
		•		
		•		
		•		
	SYM	SX.NN	X6+B.XXX	

Statements that do not call the definition:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SX5	X4	NO B DESIGNATOR OR +.
		SX6	B3+X4	REGISTERS INTERCHANGED
		SX.Y	B3	NO X DESIGNATOR OR OPERAND
		SY	X4+B4	MNEMONIC CODE NOT SX.

5.4.8 LOCAL—LOCAL SYMBOLS

One or more LOCAL instructions that list symbols local to the definition optionally follows the MACRO, MACROE, or OPDEF pseudo instruction. The only lines that can separate the first header statement from LOCAL are comment lines.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	LOCAL	symbols

symbols — List of local symbols. Each symbol must begin with an alphabetic character. Symbols must be separated by and must not include the following characters:

+ - * / ( ) $ = , or .

A blank terminates the list. The maximum number of local symbols and substitutable parameters is 63. COMPASS ignores the use of a substitutable parameter name in the local symbol list.

A location field symbol, if present, is ignored.

A symbol in the list is considered local to the macro; that is, it is known only within the macro definition. On each expansion of the macro, COMPASS creates a new symbol for each local symbol and substitutes it for each occurrence of the local symbol in the definition (other than in comment lines identified by * in column 1). Thus, invented symbols replace LOCAL-named symbols wherever they appear in a macro difinition in a manner similar to the way substitutable parameters are replaced.

A user passes a local symbol to inner macro definitions or inner macro calls when he does not declare the symbol local in any of the inner definitions saved or called. That is, a symbol declared local in a macro can be referred to in any inner macro that does not also declare it as local (see example 2).

A symbol not defined as local is accessible from outside the macro definition. An invented symbol is qualified if defined while in a QUAL block. It is not listed in the symbolic reference table. Blanks are preserved in a line containing a substituted symbol; COMPASS makes no attempt to change the structure of the line.

On the listing, each invented symbol is shown as ↑↑sym, where sym is unique for each local symbol in the subprogram. For example, if the symbol A is declared local to the macro, the subprogram can define a different symbol A elsewhere.

Examples:

1. In the following example, C is local to macro ABC and is passed to inner macro definitions. In the definition, each occurrence of formal parameter A is replaced by the parameter mark 7701; each occurrence of B by the parameter mark 7702, and each occurrence of C by the parameter mark 7703. Then, when ABC is called, COMPASS assigns invented symbol ↑↑000001 to C and replaces each occurrence of 7703 in definitions ABC and XYZ.

```
 LOCATION  OPERATION  VARIABLE          COMMENTS
 1         11         18                30
 ABC       MACRO      A,B
           LOCAL      C
 C         BSS        10B
   .         .
   .         .                                    DEFINITION
   .         .                                    OF ABC
 XYZ       MACRO      D
           SA1        C                 DEFINITION
             .                          OF XYZ
             .
           ENDM
           ABC        3,4
 ↑↑000001            BSS     10B
 XYZ       MACRO      D                           EXPANSION      ABC
           SA1        ↑↑000001          DEFINITION  OF ABC       ABC
                                        OF XYZ                   ABC
           ENDM                                                  ABC
```

2. In the following example, C is local to each level. Note how this example differs from the preceding one.

```
                LOCATION    OPERATION   VARIABLE        COMMENTS
1                           11          18              30
                BCD         MACRO       A,B
                            LOCAL       C
                C           BSS         10B
                .           .                           } DEFINITION
                .           .                           } OF BCD
                .           .
                YZA         MACRO
                            LOCAL       C
                            SA1         C               DEFINITION
                            .                           OF YZA
                            .
                C           BSSZ        1
                            ENDM
```

On the call to BCD, the assembler replaces each occurrence of C with the invented symbol, ↑↑000002 including the use of the symbol in the LOCAL instruction for macro XYZ.

```
                LOCATION    OPERATION   VARIABLE        COMMENTS
1                           11          18              30
                            BCD         5,6             EXPANSION OF BCD
10279           ↑↑000002    BSS         10B             BCD
                YZA         MACRO                       BCD
                            LOCAL       ↑↑000002        BCD
                            SA1         ↑↑000002        BCD
                ↑↑000002    BSSZ        1               BCD
                            ENDM                        BCD
```

Finally, on a call to YZA, ↑↑000002 is defined as local and the assembler replaces each ↑↑000002 with another invented symbol. Thus, each reference to C in the source code SA1 instruction does not result in a reference to the BSS in the outer macro.

```
                LOCATION    OPERATION   VARIABLE        COMMENTS
1                           11          18              30
10205                       YZA                         EXPANSION OF YZA
10205  5110010206 +         SA1         ↑↑000003        YZA
10206           ↑↑000003    BSSZ        1               YZA
                            ENDM                        YZA
```

5.4.9 IRP — INDEFINITELY REPEATED PARAMETER

An IRP pseudo instruction in a macro definition signals the beginning or end of a sequence of code to be assembled repeatedly with one parameter varied with each repetition.

It has two formats:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	IRP	parameter
	IRP	

The first form introduces the sequence and names the substitutable parameter; the second form terminates the repeated sequence. In either form, a location field symbol, if present, is ignored.

The parameter name must be listed as a substitutable parameter on the MACRO or MACROE pseudo instruction for the definition.

On the macro call, the indefinitely repeated parameter consists of one or more subparameters enclosed by parentheses and separated by commas. The assembler assembles the sequence for each subparameter; the number of copies of the sequence depends on the number of subparameters (none at all when the actual parameter is null). When the list of subparameters is exhausted, the assembler continues with the next line in the definition. If the named substitutable parameter does not occur between the two IRP instructions, the assembler repeats the code unchanged for each subparameter provided in the call. An IRP outside of the range of a macro has no effect on assembly other than to be included in statement counts.

IF-skips of IRP sequences should be controlled by instruction bracket names rather than statement counts because IRP expansions are done even when an IF-skip is used and because the number of statements generated by IRP is variable.

Anything that can be done with an IRP pair can be done with ECHO and ENDD. IRP is faster at assembly time but ECHO is more flexible (it is not expanded during IF-skips, allows multiple arguments, and can be nested). IRP should be used when greater speed is desired and the expanded capabilities of ECHO are not needed.

Examples:

1. Repeat sequence within macro

```
                                    LOCATION  OPERATION  VARIABLE          COMMENTS
                                    1         11         18                30
                                    ZAB       MACRO      ARG,B             }
                                              IRP        ARG               }
                                              SA1        ARG               }
                                              SX6        X1+B    REPEATED  } DEFINITION
                                              SA6        ARG     SEQUENCE  } OF ZAB
                                              IRP                          }
                                              ENDM                         }
                                              .
                                              .
10207                                         ZAB        (J,K,L),CON
                                              IRP        J,K,L
10207  5110010127 +                          SA1        J
                  7261010133 +                SX6        X1+CON
10210  5160010127 +                          SA6        J
                  5110010131 +                SA1        K
10211  7261010133 +                          SX6        X1+CON
                  5160010131 +                SA6        K
10212  5110010132 +                          SA1        L
                  7261010133 +                SX6        X1+CON
10213  5160010132 +                          SA6        L
                                              IRP
                                              ENDM
```

2. Assign symbol at every 100_8 words of zeroed storage:

```
      LOCATION  OPERATION  VARIABLE        COMMENTS
1                11         18              30
                 USE        STORAGE
      BUF        MACRO      P1
                 IRP        P1
      P1         BSSZ       100B
                 IRP
                 ENDM
                 BUF        (P,Q,R,S,T)
                 IRP        P,Q,R,S,T
                 BSSZ       100B
                 BSSZ       100B
                 BSSZ       100B
                 BSSZ       100B
                 BSSZ       100B
                 IRP
                 ENDM
```

5.5 SYSTEM MACRO AND OPDEF DEFINITIONS

Definitions of such general usefulness that they should be available to any program without each program defining them can be placed on the system text file as system macros or can be placed on a file accessible through an XTEXT pseudo instruction.

System macros provide for such system functions as reading and writing files and specifying parameters for file environment tables, etc. Systems macro definitions are available to COMPASS for each assembly. The programmer can use a macro call for a system macro at any time in his programs. Descriptions of system macros are given in the operating system reference manual.

Systems definitions can include any legal macro or opdef definition. An expansion of a call for a system definition is not normally included on the assembler listing. Use of the S option of the LIST pseudo instruction(Section 4.11.1) enables listing of expansions of system definitions.

OPERATION CODE TABLE MANAGEMENT 6

The COMPASS operation code table contains the information that COMPASS requires for interpreting legal operation field entries for COMPASS instructions.

When assembly begins, the operation code table contains these entries.

Pseudo instructions (except LOCAL)
CPU symbolic instructions (Section 8.4)
CMU symbolic instructions (Section 8.5)
PPU symbolic instructions (Chapter 9)
System macro and opdef definitions

The MACRO, MACROE, and OPDEF pseudo instructions (Chapter 5) cause entries to be made in this table. In addition, the programmer has the capability of creating entries through the following instructions discussed later in this chapter:

CPOP	CPU operation
PPOP	PPU operation
OPSYN	Synonymous PPU or pseudo operation or macro
CPSYN	Synonymous CPU operation or opdef

If a new entry redefines an instruction already in the table, the obsolete entry is not physically removed from the table. Instead, it is saved so that the table can be reconstructed between assemblies. COMPASS reconstructs the operation code table using all the original system macros, opdefs, pseudo instructions, and symbolic machine instructions. No programmer-created entry is preserved from assembly to assembly. The number of entries in the table is limited to 4123.

The only pseudo instruction that logically removes entries from the operation code table are PURGMAC and PURGDEF.

Entries in the operation code table are in two distinct formats permitting a logical division of the table. One type of entry permits identification of an instruction by finding a match for the contents of the operation field, thus, it provides mnemonic recognition. The other type of entry is looked at only if the search for a mnemonic operator fails to yield a match during a CPU assembly.

This type of entry provides for recognition of an instruction according to its syntax. COMPASS analyzes the statement to be interpreted, determines the syntax of the operation and variable subfields, and again searches the table.

Instructions recognized in the mnemonic search and the information provided to the assembler for each instruction are as follows:

Pseudo instructions	The entry contains addresses to routines that perform pass one and pass two operations
PPU symbolic instructions	The entry describes the format of the instructions to be assembled
Instructions described through PPOP	The entry describes the format of the instruction to be assembled
Macro instructions	The entry directs the assembler to the location of the saved definition
Instructions described through OPSYN	The entry is a copy of the synonymous entry

For a PPU assembly, a failure to find an entry for a mnemonic operator causes an operation code error. For a CPU assembly, however, if the search for the mnemonic operator does not yield a match, COMPASS searches the operation code table again for an entry with a matching syntax. Instructions recognized in the syntactical search and the information provided to the assembler for each instruction are as follows:

CPU symbolic instructions	The entry describes the format of the CPU instruction to be assembled
Instructions described through CPOP	The entry describes the format of the CPU instruction to be assembled
Instructions defined through OPDEF	The entry directs the assembler to the location of the definition
Instructions described through CPSYN	The entry is a copy of the synonymous instruction The action taken depends on the synonymous entry

If, following the second search of the operation code table, the statement still has not been identified, the assembler takes the following action:

For a PPU assembly, it generates a 24-bit instruction of which the first 12 bits are zero.

For a CPU assembly, it generates a 30-bit zero instruction.

Although OPSYN and CPSYN pseudo instructions provide a means of rendering more than one instruction synonymous, only instructions of the same type can become synonymous. The logical division of the table between the two types of entries prevents mnemonically identified instructions from being made synonymous with syntactically identified instructions.

When a MACRO, MACROE, PPOP, or OPSYN creates an entry for a mnemonic name that is already in the table for a different instruction, the new entry takes precedence over the old entry. Similarly, when a OPDEF, CPOP, or CPSYN redescribes a syntax already in the table for a different instruction, the new entry takes precedence over the old entry. As a result, the order of precedence for operation field recognition is, from highest to lowest:

1. Programmer-created entries for mnemonically identified instructions

2. System macros, pseudo instructions, PPU symbolic machine instructions, and CMU instructions other than the IM instruction.
3. Programmer-created entries for syntactically identified instructions
4. CPU symbolic instructions and the CMU IM instruction

Example:

The following example illustrates a special case in which a macro name takes precedence over one form of a machine instruction, i.e., the form using SB4 as an operation code.

```
      LOCATION  OPERATION  VARIABLE   COMMENTS
1                 11         18       30
      SB4       MACRO      P1,P2      DEFINE MACRO NAMED SB4
                .
                .
                .
                ENDM
                .
                .
                .
                SB4        A1+ABLE    CALL TO MACRO.  NOT CPU INSTRUCTION
                .
                .
                .
                SB3        A1+ABLE    MACHINE INSTRUCTION

      SB4       OPSYN      NIL        DISABLES MACRO BUT DOES NOT
                .                     RESTORE NORMAL USE OF SB4
                .                     AS AN OPERATION CODE.  EVEN IF
                .                     IT WERE REDEFINED WITH OPDEF
                .                     IT WOULD NOT BE RECOGNIZED.
                .                     THE MACRO FORM ALWAYS TAKES
                .                     PRECEDENCE.
                .
                PURGMAC    SB4        RESTORES NORMAL USE OF SB4
```

6.1 MNEMONICALLY IDENTIFIED INSTRUCTIONS

Mnemonically identified instructions include all pseudo instructions, macro instructions, and PPU symbolic instructions whether system or programmer defined. PPOP, OPSYN, NIL, and PURGMAC provide the programmer with a means of creating or removing operation code table entries that are in the mnemonically identified format.

6.1.1 PPOP — PPU OPERATION CODE

The PPOP pseudo instruction defines the operation and variable fields of a PPU symbolic machine instruction and creates an operation code table entry for the instruction. COMPASS generates an octal machine instruction of the defined format whenever the PPU instruction described by the PPOP instruction is used. If the operation code table already contains an entry for the name, the new definition takes precedence over the old during assembly of the subprogram or until it is redefined. No error is flagged. Any illegal parameter in PPOP causes COMPASS to ignore the PPOP and issue a 7-type error flag.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
name	PPOP	ctl, val, type

name — Mnemonic name, 1-8 characters

ctl — Control of instruction assembly

ctl	Significance
0	Illegal; if used, COMPASS ignores the PPOP
1	24-bit instruction with 12-bit address and no indexing
2	12-bit instruction with signed relative address or absolute address (e.g., UJN)
3	24-bit instruction with 18-bit address (e.g., LDC)
4	12-bit instruction with 6-bit address (e.g., LDN)
5	24-bit instruction with 12-bit address and optional indexing (e.g., LDM)
6	12-bit instruction with signed relative address (e.g., SHN)
7	24-bit instruction with 12-bit address and required second field (e.g., IAM)

val — An evaluatable expression specifying the 4-octal digit operation code value; usually, only the two leftmost digits are significant. If the assembly base is M, the field is assumed to be octal.

type — An evaluatable expression specifying an integer value that COMPASS interprets as follows:

6	Restrict the instruction being defined to the CYBER 170 Series, CYBER 70/Models 72, 73, and 74; COMPASS sets an error flag if the instruction being defined is used in a CYBER 70/Model 76 PPU assembly.
7	Restrict the instruction being defined to the CYBER 70/Model 76; COMPASS sets an error flag if the instruction being defined is used in a CYBER 170 Series, CYBER 70/Model 72, 73, or 74 PPU assembly.
other or omitted	The instruction is not restricted to either machine type. If the base is M, type is assumed to be octal. If type is omitted, the comma preceding it can be omitted also.

Example:

Code Generated			LOCATION	OPERATION	VARIABLE	COMMENTS
		1		11	18	30
				PERIPH		
	0*0			BASE	0	
				•		
				•		
				•		
	15		LA	EQU	15	
	40		C	EQU	40	
			STM	PPOP	5,5400+LA	
				•		
				•		
				•		
7311	5415 0040			STM	C	

6.1.2 OPSYN — SYNONYMOUS MNEMONIC OPERATION

The OPSYN pseudo instruction makes a name in the location field of the OPSYN synonymous with the macro, pseudo instruction or PPU mnemonic name specified in the variable field. The size of the operation code table is the only limit to the number of instructions that can be made synonymous.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
$name_1$	OPSYN	$name_2$

The name in the variable subfield must be previously defined as a standard instruction code. After an OPSYN, either name produces equivalent results. If the location field specifies a previously defined macro or operation code, the new definition takes precedence over the old without notification. Thus, a macro defined by a name that is subsequently used in an OPSYN location field is not called when the macro name is used in the operation field. The instruction actually called is the instruction named in the variable subfield of the OPSYN. On the other hand, the old macro definition is not lost and can be restored by purging the new definition with PURGMAC.

Example:

1. An operation named CALL is synonymous with RJM.

```
          LOCATION  OPERATION  VARIABLE   COMMENTS
1                   11         18         30
          CALL      OPSYN      RJM
                    .
                    .
                    .
                    CALL       =XSUBR=    PRODUCES SAME RESULTS
                                          AS IF IT WERE AN RJM
```

2. In the following example, a programmer wishes to use a macro named LJM for part of the program and use the real LJM for the remainder of the program.

```
          LOCATION  OPERATION  VARIABLE   COMMENTS
1                   11         18         30
          LJM.      OPSYN      LJM        SAVE ORIGINAL DEFINITION AS LJM.
                    PURGMAC    LJM        PURGE ORIGINAL DEFINITION
                    .
                    .
                    .
          LJM       MACRO      XX
                    .
                    .
                    .
          LJM       ENDM
                    .
                    .                     CODE USING LJM MACRO
                    .
          LJM       OPSYN      LJM.       RESTORES ORIGINAL LJM
                    .
                    .                     CODE USING ORIGINAL LJM
                    .
```

6.1.3 NIL — DO NOTHING PSEUDO INSTRUCTION

The NIL pseudo instruction resembles a no-op; it produces no code and conveys no information to the assembler. It is primarily designed for disabling a macro; it cannot be used with CPSYN. The following instructions could be used in place of NIL as nil instructions:

ENDM
ENDD
ENDIF
IRP

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	NIL	

A location field symbol if present is ignored.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	MACK	OPSYN	NIL	
		•		
		•		
		•		
	TAG	MACK	A,B,6,73	
		•		

The assembler interprets each call to MACK as a NIL instruction. TAG is not defined because it becomes the location field symbol for NIL when the statement is assembled.

6.1.4 PURGMAC—PURGE MACROS

The PURGMAC pseudo instruction provides a means of disabling operation code entries for the named instructions for the duration of the current assembly.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	PURGMAC	$name_1, name_2, \ldots, name_n$

$name_i$ Names of mnemonic operation codes for macro definitions, pseudo instructions, or PPU instructions.

A location field symbol if present is ignored.

6.2 SYNTACTICALLY IDENTIFIED INSTRUCTIONS

Syntactically identified instructions apply to CPU assemblies only. The CPOP and CPSYN pseudo instructions create operation code table entries for instructions that are to be identified through recognition of their syntax, rather than through the contents of the operation field only.

6.2.1 CPOP — CPU OPERATION CODE

The CPOP pseudo instruction describes the syntax of a new CPU symbolic machine instruction and creates an operation code table entry for the instruction. An instruction of the defined format is generated whenever the CPU instruction described by the CPOP instruction is used. If the operation code table already contains an entry for the instruction, the new definition takes precedence over the old during assembly of the subprogram. Any illegal parameter in CPOP causes COMPASS to ignore the CPOP and issue an error flag.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sytx	CPOP	ctl, val, reg, type

sytx

The syntax consists of a mnemonic operator and variable field descriptors. The mnemonic operator consists of two letters. The first can be any letter. The second letter can be a register designator: A, B, or X, in which case, the operation field of the instruction is recognized as cAn, cXn, or cBn, (c is a unique character; n is 0-7); or the second letter can be any other letter, in which case the operation field of the instruction is recognized simply by a two-letter mnemonic, such as EQ.

The variable field descriptors define the order of appearance of all registers, expressions, and subfield separators that comprise the variable field of the instruction being described. It consists of none, one, two, or three of the following 22 subfield descriptors. Q represents an expression. An r represents a register letter (A, B, or X). A comma separates two descriptors; a blank terminates the syntax.

void	Q
r	rQ
-r	-rQ
r_1+r_2	r_1+r_2Q
$-r_1+r_2$	$-r_1+r_2Q$
r_1*r_2	r_1*r_2Q
$-r_1*r_2$	$-r_1*r_2Q$
r_1/r_2	r_1/r_2Q

$-r_1/r_2$	$-r_1/r_2Q$
r_1-r_2	r_1-r_2Q
$-r_1-r_2$	$-r_1-r_2Q$

For example, to describe -X3*B1, the descriptor, $-r_1*r_2$, would be written as -X*B whereas, to describe B2+ALPHA, the descriptor rQ would be written as BQ.

ctl — Control of instruction assembly.

ctl	Significance
0	15-bit instruction
1	30-bit instruction
2	15-bit instruction, force upper before assembly
3	30-bit instruction, force upper before assembly
4	15 bit instruction, force upper after assembly
5	30-bit instruction, force upper after assembly
6	15-bit instruction, force upper before and after assembly
7	30-bit instruction, force upper before and after assembly

val — An evaluatable expression specifying a 9-bit operation code; if the base is M, val is assumed to be octal.

reg — Three octal digits specifying the order from left to right into which register numbers are to be inserted into the i, j, k portions of a 15-bit instruction, or into the i and j portions of a 30-bit instruction. If the assembly base is M, reg is assumed to be octal.

1	Register number obtained from operation field
2	Number of second register or only register in variable field
3	Number of first of two registers in variable field
0	Set field to 0

type — An evaluatable expression specifying an integer value that COMPASS interprets as follows:

6	Restrict the instruction being defined to the 6000 Series, CYBER 170 Series, and CYBER 70/Models 72, 73, and 74; COMPASS sets an error flag if the instruction being defined is used when MACHINE 7 has been specified.
7	Restrict the instruction being defined to the 7600 or the CYBER 70/Model 76; COMPASS sets an error flag if the instruction being defined is used when MACHINE 6 has been specified.
other or omitted	The instruction is not restricted to a machine type.

If base is M, type is assumed to be octal. If type is omitted, the comma preceding it can be omitted also.

Example:

Code Generated

```
                    SAX+B   CPOP  0,5308,1328  DEFINES SAI  XJ+BK
                    SXXQ    CPOP  1,7208,1208  DEFINES SXI  XJ+K
                            .
                            .
                            .
            53731           SA7   X3+B1
722 7231000003      TAG     SX3   X1+3
```

6.2.2 CPSYN — SYNONYMOUS CPU INSTRUCTION

The CPSYN pseudo instruction renders an instruction with the syntax given in the location field synonymous with the instruction having the syntax specified in the variable field. The only limit to the number of CPU instructions that can be made synonymous is the size of the operation code table (4123 entries).

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
$sytx_1$	CPSYN	$sytx_2$

$sytx_1$ Syntax of a CPU instruction (see CPOP for legal forms). If this syntax is already in the operation code table, the table entry for $sytx_2$ takes precedence over the old table entry for $sytx_1$ without notification.

$sytx_2$ Syntax of a CPU instruction for which there must be an entry in the operation code table. Following the CPSYN, an instruction in either $sytx_1$ or $sytx_2$ produces an octal instruction of the format described by the entry for $sytx_2$.

6.2.3 PURGDEF—PURGE CPU OPERATION CODE

The PURGDEF pseudo instruction provides a means of disabling syntactically-identified operation code entries for the duration of the current assembly.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
	PURGDEF	sytx

sytx Syntax of a CPU instruction (see CPOP for legal forms).

A location field symbol, if present, is ignored.

MICROS 7

The COMPASS micro capability enables the programmer to symbolically refer to a defined character string. When used in conjunction with IFC, DUP, STOPDUP, and SET pseudo instructions, micro strings provide for varied manipulation of character strings -- testing for a particular character, counting characters, concatenation of strings, etc.

Use of a micro definition requires two steps: definition of the character string, and substitution. In this discussion, substitution rather than definition is discussed first so that the reader has a better understanding of how a definition is used when it is described.

7.1 MICRO SUBSTITUTION

Wherever a micro name between micro marks (≠) occurs in a statement other than a comment line (* in column 1), the assembler substitutes the micro before it interprets the statement. If column 72 of the last card read is exceeded as a result of micro substitution, the assembler creates up to a maximum of 9 continuation cards, beyond which it discards excess characters without notification on the listing. No replacement takes place if the micro name is unknown or if one of the micro marks has been omitted. If the micro name is unknown, the assembler flags a nonfatal assembly error. If the micro name is null, (that is, the two micro marks are adjacent), then

1. Both micro marks are deleted, and
2. No error flag is set

Example:

A micro identified as NAM is defined as the 7 characters:

```
ADDRESS
```

A reference to NAM is in the variable field of a line:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	LOC	SA1	≠NAM≠+4	

However, before the line is interpreted, COMPASS substitutes the definition for NAM producing the following line:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
	LOC	SA1	ADDRESS+4	

NOTE

Unless the A option of the LIST pseudo instruction is enabled, the listing depicts the instruction as it was before the substitution took place.

7.2 MICRO DEFINITION

Pseudo instructions specifically designed for the purpose of defining micros are: MICRO, OCTMIC and DECMIC. In addition, the following pseudo instructions optionally define micros: BASE, CODE, and QUAL. Also, system or built-in micros are automatically defined by COMPASS at the start of each subprogram assembly.

7.2.1 MICRO — DEFINE MICRO

The MICRO pseudo instruction defines a character string and assigns a name to that string.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
micname	MICRO	n_1,n_2,dstringd

micname — Name by which definition is called; 1-8 characters

n_1 — Absolute evaluatable expression specifying starting character in string; when the base is M, COMPASS assumes that n_1 is decimal.

n_2 — Absolute evaluatable expression specifying number of characters; when the base is M, COMPASS assumes that n_2 is decimal.

dstringd — Delimited character string. The delimiter d is a character not used in the string.

Counting the first character after d as character 1, the assembler forms the string by extracting n_2 characters starting with character n_1. If the second delimiting character occurs before count n_2 is exhausted, the defined string terminates at that point. If n_1 is greater than zero and n_2 is omitted, zero, or negative, the defined string includes all the characters from n_1 to the closing delimiter (see second example).

If n_1 is omitted, zero, or negative, the defined string is empty; no substitution takes place when the micro name is referred to. That is, n_2 and the character string are ignored.

A previously defined micro can be a part of a micro definition; one micro can be defined as a substring of another (see third example).

A micro can combine previously defined micros or can be a subset of another. Also, a micro defined originally as one character string can be redefined subsequently with a different character string. After the redefinition, the original character string is inaccessible.

If n_1 or n_2 is negative, the assembler generates a 7-type error.

Examples:

1. The following MICRO defines NAME as the 19 characters beginning with A and ending with G.

```
    LOCATION  OPERATION  VARIABLE              COMMENTS
1             11         18                    30
    NAME      MICRO      1,19,*ALPHANUMERIC STRING*
```

2. This example illustrates a blank character count. The defined string begins with A and is terminated by the closing delimiter.

```
      LOCATION   OPERATION  VARIABLE              COMMENTS
1                11         18                    30
      MICKY      MICRO      1,,*ALPHANUMERIC STRING*
```

3. One micro can be defined as a substring of another.

```
      LOCATION   OPERATION  VARIABLE              COMMENTS
1                11         18                    30
      NAM1       MICRO      1,25,*MAJOR ALPHANUMERIC STRING*
        .          .          .
        .          .          .
        .          .          .
      NAM2       MICRO      7,,*≠NAM1≠*  SAME STRING AS IN EXAMPLES 1 AND 2
```

4. One micro can combine others.

```
      LOCATION   OPERATION  VARIABLE              COMMENTS
1                11         18                    30
      NAM1       MICRO      1,12,$ALPHANUMERIC$
      NAM2       MICRO      1,7,X STRINGX
      NAM3       MICRO      1,,+≠NAM1≠≠NAM2≠+     COMBINES NAM1 AND NAM2
```

5. A micro name can be redefined.

```
      LOCATION   OPERATION  VARIABLE              COMMENTS
1                11         18                    30
      MSG        MICRO      1,6,*STRING*
        .          .          .
        .          .          .                  CODE USING FIRST DEFINITION
        .          .          .
      MSG        MICRO      1,19,*ALPHANUMERIC ≠MSG≠*
        .          .          .
        .          .          .                  CODE USING SECOND DEFINITION.
        .          .          .                  FIRST DEFINITION IS INACCESSIBLE.
```

6. Micro substitution takes place before a line is assembled or examined for syntax. Thus, the following is possible.

```
      LOCATION   OPERATION  VARIABLE              COMMENTS
1                11         18                    30
      NAM        MICRO      1,25,* LOC      SA1     ADDRESS+*
                   .
                   .
                   .
≠NAM≠1
      LOC        SA1        ADDRESS+1
```

7.2.2 DECMIC — DECIMAL MICRO

Using a decimal conversion, the DECMIC pseudo instruction converts the expression into a character string to be saved under the name specified.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
micname	DECMIC	aexp,n

micname — Name by which definition is called; 1-8 characters

aexp — Absolute evaluatable expression

n — Optional absolute evaluatable expression specifying number of characters in the defined string. The defined string is a maximum of 10 characters regardless of the magnitude of n. When base is M, COMPASS assumes that n is decimal

If n is omitted or has a zero value, the micro contains the number of characters indicated by the conversion to a maximum of 10 characters. If the converted expression has more than n (or 10) digits, the most significant digits are truncated. If the value has fewer than n digits, the string is right justified and filled with leading zeros. All numbers are treated as positive.

Example:

```
      LOCATION  OPERATION VARIABLE          COMMENTS
1                 11      18                30
      V         DECMIC  8,6
      SYMBL     MICRO   1,,*≠V≠ STORAGE NEEDED*
      SYMBL     MICRO   1,,*001024 STORAGE NEEDED*
```

7.2.3 OCTMIC — OCTAL MICRO

Using an octal conversion, the OCTMIC pseudo instruction converts the value of the expression into a character string to be saved under the name specified.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
micname	OCTMIC	aexp,n

micname — Name by which definition is called; 1-8 characters

aexp — Absolute evaluatable expression

n — Optional absolute evaluatable expression specifying number of characters in the string. The defined string is a maximum of 10 characters regardless of the magnitude of n. When base is M, COMPASS assumes n as a decimal. If n is omitted or has a zero value, the micro contains the number of characters indicated by the conversion to a maximum of 10 characters.

If the converted expression has more than n (or 10) digits, the most significant digits are truncated. If the value has fewer than n digits, the string is right justified and filled with leading zeros. All numbers are treated as positive.

Example:

```
 |  LOCATION |OPERATION| VARIABLE          COMMENTS
1|           |11       |18                 30
 |V1         |OCTMIC   |B,6
 |
 |
 |
 |S1         |MICRO    |1,,*≠V1≠ ADDITIONAL STORAGE NEEDED*
 |S1         |MICRO    |1,,*002000 ADDITIONAL STORAGE NEEDED*
```

7.3 PREDEFINED MICRO NAMES

Several standard micros are predefined by the COMPASS assembler. They are available for every assembly. The programmer simply writes the micro reference as desired.

These micros are automatically defined at the beginning of each assembly, and have the default values specified below until they are redefined by the programmer; thereafter, the programmer's definition holds until the start of the next assembly.

7.3.1 DATE

The DATE micro contains the current date in 10 characters in the following form as obtained from the operating system:

Δ yr/mo/dy.

The micro reference is ≠DATE≠.

7.3.2 JDATE

The automatic value of the JDATE micro is five digits yyddd, where yy is the year and ddd is the day of year at the time of assembly. Thus, JDATE is the Julian date form of DATE.

The micro reference is ≠JDATE≠.

7.3.3 TIME

The TIME micro contains the current time of day in 10 characters in the following form as obtained from the operating system:

Δ hr.min.sec.

The micro reference is ≠TIME≠.

Example:

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		TITLE	PROGRAM ASSEMBLED ON ≠DATE≠ AT≠TIME≠	

7.3.4 BASE

The automatic value of the BASE micro is a single letter D, M, or O, corresponding to the number base currently in effect(specified by the most recent BASE pseudo instruction); it is initially D.

The micro reference is ≠BASE≠.

7.3.5 CODE

The automatic value of the CODE micro is a single letter A, D, E, or I, corresponding to the character code currently in effect (specified by the most recent CODE pseudo instruction); it is initially D.

The micro reference is ≠CODE≠.

7.3.6 QUAL

The automatic value of the QUAL micro is 0 to 8 characters comprising the qualifier symbol currently in effect (specified by the most recent QUAL pseudo instruction); it is null initially and whenever the blank qualifier is in effect.

The micro reference is ≠QUAL≠.

7.3.7 SEQUENCE

The automatic value of the SEQUENCE micro is 18 characters comprising the sequence field (card columns 73-90) of the first line of the COMPASS source statement most recently read from the main source input file. Thus, if the current statement was read from the main source input file, SEQUENCE is the sequence field of the first line of the statement. However, if the current statement is generated (i.e., part of a macro call expansion, DUP expansion, etc.) or is read from a different file via the XTEXT pseudo instruction, then SEQUENCE is the sequence field of the first line of the statement most recently read from the main source input file.

The micro reference is ≠SEQUENCE≠.

7.3.8 MODLEVEL

The automatic value of the MODLEVEL micro is the value (up to 9 characters) specified by the ML parameter on the COMPASS control card. If no ML parameter is present, the automatic value of the MODLEVEL micro is equal to that of the JDATE micro. When COMPASS is called by a compiler to process embedded COMPASS subprograms, the automatic value of the MODLEVEL micro is supplied by the calling compiler. The MODLEVEL micro is intended to be used when assembling a compiler (or COMPASS itself), to provide the compiler modification level to be placed in word 6 of each PRFX table in the binary output written by the compiler.

The micro reference is ≠MODLEVEL≠.

7.3.9 PCOMMENT

The automatic value of the PCOMMENT micro is the value specified by the PC parameter on the COMPASS control card, with characters truncated from the right or blanks appended to the right, as necessary, so that the micro's length is exactly 30 characters. If no PC parameter is present, the automatic value of the PCOMMENT micro is 30 blanks. When COMPASS is called by a compiler to process embedded COMPASS subprograms, the automatic value of the PCOMMENT micro is supplied by the calling compiler. The PCOMMENT micro is intended to be used in a COMMENT pseudo instruction to specify words 8 - 10 of the PRFX table in the binary output. It may also be used, in conjunction with the *F special symbol, to determine compiler options (debug mode, rounded arithmetic, etc.) in effect at the time of assembly.

The micro reference is ≠PCOMMENT≠.

CPU SYMBOLIC MACHINE INSTRUCTIONS 8

COMPASS recognizes symbolic notation for all CYBER 170 Series Central Processor Unit Instructions, all CYBER 70 Series Central Processor Unit Instructions, all 7600 Central Processor Unit Instructions and all 6000 Series Computer Systems Central Processor Unit instructions.

The assembler identifies each symbolic instruction according to its syntax and generates a one parcel 15-bit instruction or a two parcel 30-bit instruction. The object code for an instruction is generated in the block in use when the instruction is encountered.

8.1 MACHINE INSTRUCTION FORMATS

Figures 8-1 and 8-2 illustrate the formats for CPU 15-bit and 30-bit instructions generated by the assembler.

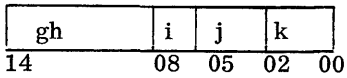


Figure 8-1. CPU 15-Bit Instruction Format

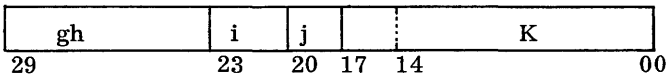


Figure 8-2. CPU 30-Bit Instruction Format

gh	6-bit instruction code
ghi	9-bit instruction code
i	3-bit code specifying one of eight designated registers (e.g., Ai)
j	3-bit code specifying one of eight designated registers (e.g., Bj)
k	3-bit code specifying one of eight designated registers (e.g., Bk)
K	18-bit integer value used as an operand, address of an operand, or branch destination address.
jk	6-bit integer value specifying a shift count or mask count

Figure 8-3 illustrates possible arrangements of one and two parcel instructions in a 60-bit CPU instruction word. Generally, the assembler does not allow a two-parcel instruction to begin in the fourth parcel of a word. However, the assembler may generate a 30-bit instruction in a fourth parcel when all of the following are true:

1. The assember is at the fourth parcel (position counter is 15)

2. The instruction does not include K. Note that if K is included in the syntax and reduces to zero, it requires 30 bits because the evaluation of K takes place in the second pass whereas the space for the instruction is reserved in the first pass.

3. The instruction does not have a location field symbol or is not otherwise forced upper.

When a two parcel instruction begins in the last parcel of a word, the CYBER 170/Model 175, CYBER 70/Model 76 or 7600 executes it as if the instruction word had a fifth parcel containing all zeros. On the CYBER 170/Model 172, 173, or 174, CYBER 70/Model 72 or 73, or 6400, this condition causes an error exit. On the 6600 or CYBER 70/Model 74, the CPU takes the first parcel of the current instruction.

Before it assembles an instruction that must begin in the first parcel (forced upper) and after it assembles an instruction that requires the instruction following it to be forced upper, the assembler completes a word as follows:

Lower 15 bits remain	They are packed with a one parcel NO (pass) instruction
Lower 30 bits remain	They are packed with a two parcel SB0 B0+K instruction
Lower 45 bits remain	They are packed with a NO instruction and an SB0 B0+K instruction

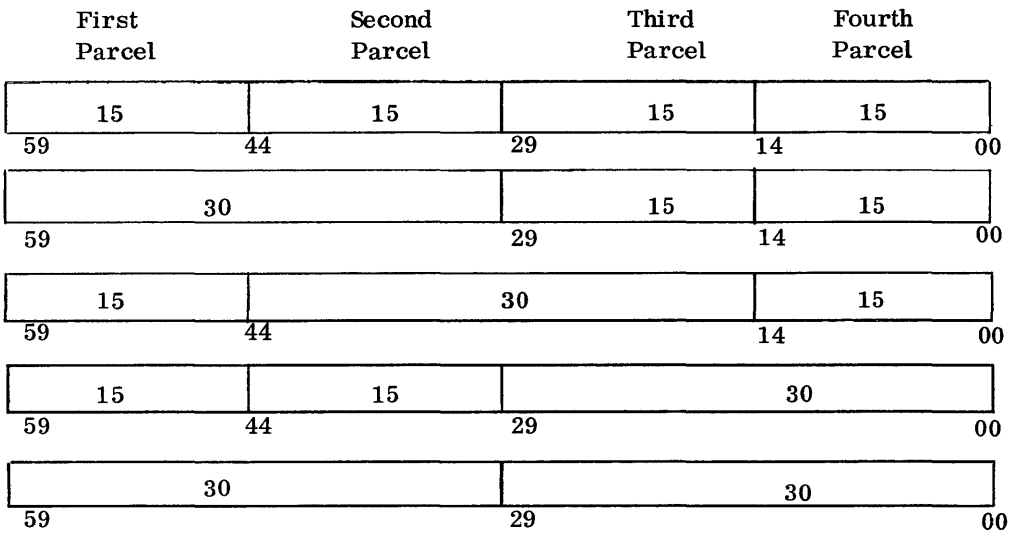


Figure 8-3. Arrangements of Instructions in a 60-bit CPU Word

8.2 INSTRUCTION EXECUTION

8.2.1 6600/6700AND CYBER 70/MODEL 74 EXECUTION

After an exchange jump start by a PPU and CPU program, CPU instructions issue automatically in the original sequence, to an 8-word instruction stack. The stack can hold a program loop consisting of up to 26 15-bit instructions and one 30-bit instruction.

Instructions are read from the stack one at a time and issued to the functional units (table 8-1) for execution. A scoreboard reservation system in CPU control keeps a current log of which units and operating registers are reserved for computation results from functional units.

Each functional unit executes several instructions, but only one at a time. Some branch instructions require two units, the second unit receives direction from the branch unit.

The rate of issuing instructions varies from the maximum of one instruction every 100 nanoseconds (one minor cycle). Sustained issuing at this rate may not be possible because of functional unit and CM conflict or because of serial rather than simultaneous operation of units. Program run time can be decreased by efficient use of the units. Instructions that are not dependent on previous steps may be arranged or nested in program areas where they may be executed concurrently with other operations to eliminate dead spots in the program and increase the instruction issue rate.

The following steps summarize instruction issuing and execution:

- An instruction is issued to a function unit when:

  Specified functional unit is not reserved

  Specified result register is not reserved for a previous result

- Instructions are issued to functional units at minor cycle intervals when no reservation conflicts are present.
- Instruction execution starts in a functional unit when both operands are available. Execution is delayed when an operand is a result of a previous step which is not complete.
- No delay occurs between the end of a first unit and the start of a second unit which is waiting for the results of the first.
- After a branch instruction no further instructions are issued until instruction has been executed. In the execution of a branch instruction, the branch unit uses:

  Increment unit to form the instructions that branch to K + Bi and branch to K if Bi ...

  Long add unit to perform the instructions that branch to K if Xj ...

  Time spent in the long add or increment units is part of total branch time.

Read central memory access time is computed from the end of increment unit time to the time an operand is available in X operand register. Minimum time is 500 nanoseconds assuming no central memory bank conflict.

† The 6700 also includes a 6400-type central processor unit

TABLE 8-1. CYBER 70/Model 74 and 6600/6700 FUNCTIONAL UNITS

UNIT	GENERAL FUNCTION
Branch	Handles all jumps or branches from the program.
Boolean	Handles the basic logical operations of transfer, logical product, logical sum, and logical difference.
Shift	Executes operations basic to shifting. This includes left (circular) and right (end-off sign extension) shifting, and normalize, pack, and unpack floating point operations. The unit also includes a mask generator.
Floating Add	Performs single or double precision floating point addition and subtraction on floating point operands.
Long Add	Performs addition and subtraction of two 60-bit fixed point operands
Floating Multiply	Performs single or double precision floating point multiplication on floating point operands
Floating Divide	Performs single precision floating point division of floating point operands; also counts the number of 1 bits in a 60-bit word.
Increment	Performs one's complement addition and subtraction of 18-bit operands.

8.2.2 CYBER 170/MODELS 172, 173, 174, CYBER 70/ MODELS 72, 73 AND 6200/6400/6500 EXECUTION

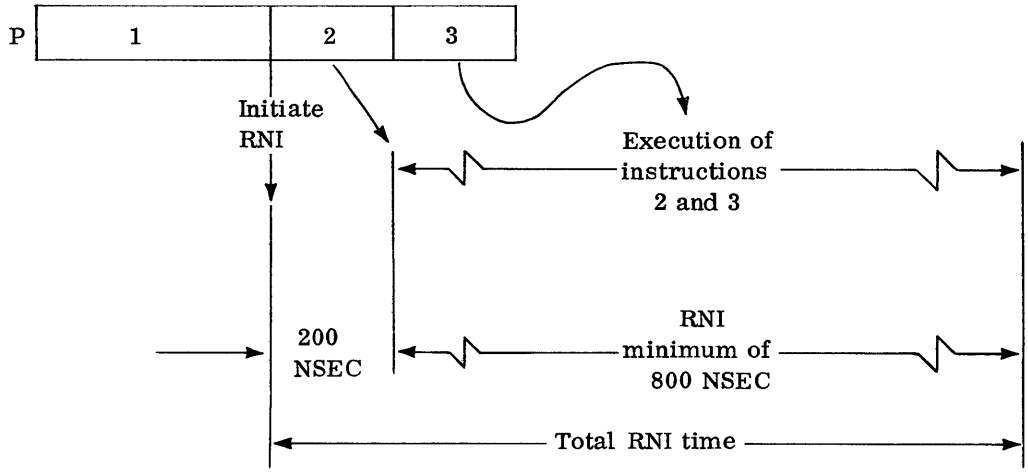
The CYBER 170/Models 172, 173, 174, CYBER 70/Models 72 and 73, and 6200, 6400, and 6500 systems CPU has a unified arithmetic unit, rather than separate functional units as in the 6600 system. Instructions in the CPU are executed sequentially.

For efficient coding in the central processor unit:

Always attempt to place jump instructions in the upper portion of the instruction word to avoid both the additional time for RNI (2 minor cycles) and the possibility of a memory bank conflict with (P + 1).

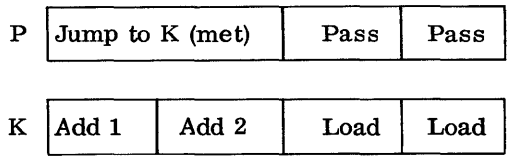
Where possible, place load/store instructions in the lower two portions to avoid lengthening execution times.

Reading the next instruction words of a program from central memory, RNI, is partially concurrent with instruction execution. RNI is initiated between execution of the first and second instructions of the word being processed. Initiating RNI operation requires two minor cycles; the remainder of the RNI is parallel in time with execution of the remaining instructions in the word:



In calculating execution times, two minor cycles are added to each instruction word in a program to cover the RNI initiation time. Exceptions are the return jump and the jump instructions (in which the jump condition is met) when they occupy the upper position of the instruction word. Since the times for these instructions already include the time required to read the new instruction word at the jump address, no additional time is consumed (Appendix A).

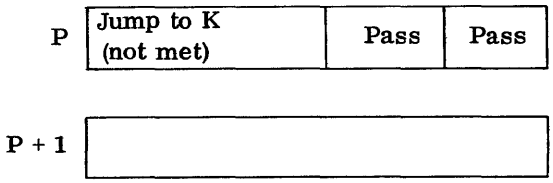
Example:



Instruction	Minor Cycles Required
Jump	13
Add 1	5
RNI Initiation	2
Add 2	5
Load	12
Store	10
Total Time	47 Minor Cycles

After RNI is initiated (between the first and second instructions of the word), a minimum of eight minor cycles elapses before the next instruction word is available for execution. Even if the lower order positions of the word should require less than eight minor cycles, a minimum of eight minor cycles is allowed.

Example:



8.2.3 CYBER 170/MODEL 175, CYBER 70/MODEL 76, AND 7600 EXECUTION

Execution of an arithmetic or logical machine instruction takes place in one of nine functional units in the computation section of the CYBER 170/Model 175, CYBER 70/Model 76 or 7600 CPU. Each is a specialized unit with algorithms for a portion of the CPU instruction execution. Table 8-2 lists the general function of each unit. A number of functional units may be in operation at the same time.

TABLE 8-2. CYBER 170/Model 175, CYBER 70/Model 76 and 7600 FUNCTIONAL UNITS

UNIT	GENERAL FUNCTION
Boolean	Handles the basic logical operations of transfer, logical product, logical sum, and logical difference. It also performs the pack and unpack floating point operations.
Shift	Executes operations basic to shifting. This includes left (circular) and right (end-off sign extension) shifting, and mask generation.
Normalize	Performs the normalize operations.
Floating Add	Performs single or double precision floating point addition or subtraction on floating point operands.
Long Add	Performs integer addition or subtraction of two 60-bit fixed point operands.
Floating Multiply	Performs single or double precision floating point multiplication on floating point operands.
Floating Divide	Performs single precision floating point division of floating point operands.
Population Count	Counts the number of 1 bits in a 60-bit word.
Increment	Performs one's complement addition and subtraction of 18-bit operands.

A functional unit receives one or two operands from operating registers at the beginning of instruction execution and delivers the result to the operating registers after performing the function. The functional units do not retain any information for reference in subsequent instructions. The units operate in three-address mode with source and destination addressing limited to the operating registers.

Except for the floating multiply and divide units, all functional units have one clock period segmentation. This means that the information arriving at the unit, or moving within the unit, is captured and held in a new set of registers at the end of every clock period. It is therefore possible to start a new set of operands for unrelated computation into a functional unit each clock period even though the unit may require more than one clock period to complete the calculation. This process may be compared to a delay line in which data moves through the unit in segments to arrive at the destination in the proper order but at a later time. All functional units perform their algorithms in a fixed amount of time. No delays are possible once the operands have been delivered to the front of the unit.

The floating multiply unit has a two clock period segmentation. Operands may enter the multiply unit in any clock period providing there was no multiply operation initiated in the preceding clock period.

The floating divide unit is the only functional unit in which an iterative algorithm is executed. There is little segmentation possible in this unit. However, to increase execution speed, the beginning of a new divide operation can follow a previous divide operation by 18 clock periods for a gain of 2 clock periods.

Instructions involving storage references for operands or program branching are difficult to time. Program branching within the instruction stack causes no storage references and small program loops can therefore be precisely timed.

8.3 OPERATING REGISTERS

Twenty-four registers minimize memory references for arithmetic operands and results:

Function	Identity	Length	Number
Operand Registers	X0 - X7	60 Bits	8
Address Registers	A0 - A7	18 Bits	8
Index Registers	B0 - B7	18 Bits	8

A register is reserved if it is the destination of an instruction that has been initiated but has not been completed. A register is free in the clock period (or minor cycle) following the store into it.

8.3.1 X REGISTERS

Eight 60-bit X registers in the computation section of the CPU designated X0, X1,...,X7 are the principal data handling registers for computation. Data flows from these registers to the SCM (CM) and the LCM (not ECS). Data also flows from SCM (CM) and LCM (not ECS) into these registers. All 60-bit operands involved in computation must originate and terminate in these registers.

Operands and results transfer between SCM (CM) and these registers as a result of placing SCM (CM) into corresponding address registers.

On the CYBER 70/Model 76 and 7600, the X registers also serve as address registers for referencing single words from LCM. X0 is used as the LCM relative starting address in a block copy operation.

8.3.2 A REGISTERS

Eight 18-bit A registers in the computation section of the CPU, designated as A0, A1,..., A7, are essentially SCM (CM) operand address registers. With the exception of A0 and X0, A registers are associated one-for-one with the X registers. Placing a quantity into an address register A1 - A5 causes an immediate SCM (CM) read reference to that relative address and sends the SCM (CM) word to the corresponding operand register X1 - X5. Similarly, placing a value into address register A6 or A7 causes the word in the corresponding X6 or X7 operand register to be written into that relative address of SCM (CM).

The A0 and X0 registers operate independently of each other and have no connection with SCM (CM). A0 is used as the relative SCM (CM) starting address in a block copy operation and for scratch pad or intermediate results.

8.3.3 B REGISTERS

Eight 18-bit B registers in the computation section of the CPU designated as B0, B1,...,B7 are primarily indexing registers for controlling program execution. Program loop counts can be incremented and decremented in these registers.

Program addresses may be modified on the way to an A register by adding or subtracting B register quantities. The B register also holds shift counts for pack and normalize operations and the channel number for channel status requests.

B0 always contains positive zero; that is, B0 is held clear. Often as a programming convention, B1 or B7 contains positive 1. See the B1=1, the B7=1, and the R= pseudo instructions.

8.4 SYMBOLIC NOTATION

This section describes notation used for coding symbolic CPU machine instructions. Instructions are listed according to octal sequence. Instructions unique to a computer system are identified as such. These instructions can be assembled on any machine but will execute properly on the noted machine only. For details and special conditions arising during instruction execution, refer to the relevant hardware system reference manual.

The location field of a symbolic machine instruction optionally contains a location symbol. When the symbol is present, it is assigned the value of the location counter after the force upper (if any) occurs.

The operation field of a symbolic CPU machine instruction contains a mnemonic operator, the last two characters of which are often a register designator.

The variable field contains one, two, or three subfields. For 15-bit instruction, subfields take the forms:

r -r r,r	r is a register designator
r op r -r op r	op is a register operator + - * /
±jk	jk is an absolute expression specifying a shift count or mask bit count. If the expression value is in the range -60 to -0, inclusive, COMPASS adds 60 to it. If it is less than -60 or greater than 63, COMPASS sets a warning flag and uses the low-order 6 bits of the expression value.

For a 30-bit instruction, subfields take the forms:

K	The single subfield contains an absolute, relocatable, or external expression that does not include a register.
r op K	The single subfield contains an absolute, relocatable, or external expression that includes a register designator; op is an expression operator: + - * /
r,K	One subfield contains a register designator, the other subfield contains an absolute, relocatable, or external expression that does not include a register designator.
r,r,K	Two subfields contain register designators; a third contains an absolute, relocatable, or external expression that does not include a register.

In the formats and examples, K reduces to an 18-bit value that represents one of the following in pass two:

An absolute address or a word count

An external symbol ± an integer value

An address that is relocatable relative to the program origin or common block origin.

An address of a literal

If K is negative, the assembler inserts the one's complement of the integer value in the K portion of the instruction.

In the descriptions of the formats, ±K designates that the evaluation of all non-register elements can result in a positive or negative value for the expression (see section 2.8.2 Evaluation of Expressions). Use of ±K to represent the integer portion of the expression does not imply that the first term operator in the expression is an expression operator. If you consider that a and b are terms in expression K, then +K indicates that the sum of the values of a and b is positive and -K indicates that the sum of the values is negative. Thus, -K does not mean that a-b would become -a+b.

In the following example, the symbol XRAY has the value 407_8. The first term operator (-) forms the value 777370_8. Subtracting 1 from this results in 777367_8 or a -K (-410_8).

Code Generated

```
13  7212777367
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SX1	X2-XRAY-1	

Unless otherwise noted, subfields can be in any order. COMPASS also allows an added degree of flexibility by allowing the variable subfields of an instruction to be written in the operation field with each subfield preceded by a comma. For example:

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		UX1	B2,X3	

can be written

Code Generated

```
26123
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		UX1,B2	X3	

The instructions are identical to the assembler.

Similarly, the following instructions are regarded as identical. Use of this feature is optional.

	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
0423010641		EQ	B2,B3,K	
0423010641		EQ,B2	B3,K	
0423010641		EQ,B2,B3	K	
0423010641		EQ,B2,B3,K		

8.4.1 PROGRAM STOP OR EXCHANGE JUMP INSTRUCTION (CYBER 170 SERIES, CYBER 70/MODEL 72, 73, 74, AND 6000 SERIES)

The CEJ/MEJ Panel Switch determines whether this instruction causes the central processor unit to halt or to execute an exchange jump. The DISABLE position disables the central exchange jump or the monitor exchange jump. In this case, the instruction is illegal for a CYBER 170/Model 175. For all other systems, PS halts the central processor unit at the current step in the program. An exchange jump is necessary to restart the central processor unit. The ENABLE position enables the jump capabilities for all systems. In this case, PS causes an exchange jump to monitor address (MA) in the exchange package.

The contents of the location field become a sub-subtitle on the assembler listing. The assembler forces upper before and after assembling a PS instruction.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Branch

Operation	Variable	Description	Size	Octal Code
PS		Program stop or exchange jump to (MA)	30 bits	00000 00000
PS	K	Program stop or exchange jump to (MA)	30 bits	0000K

Example:

Code Generated

0000000000

	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
		PS		

8.4.2 ERROR EXIT INSTRUCTION (CYBER 70/MODEL 76 OR 7600)

ES execution is treated as an error condition and the machine sets the program range condition flag in the PSD register. The condition flag then generates an error exit request which causes an exchange jump to address (EEA). All instructions issued prior to this instruction are run to completion. Any instruction following this instruction in the current instruction word is not executed. When all operands have arrived at the operating registers as a result of previously issued instructions, an exchange jump occurs to the exchange package designated by (EEA).

The i, j, and k designators, which are ignored by the computation section, are set to zero by the assembler. The program address stored in the exchange package on the terminating exchange jump is advanced one count from the address of the current instruction word (P=P+1). This is true regardless of which parcel of the current instruction word contains the error exit instruction.

The error exit instruction is not intended for use in user program code. The program range condition flag is set in the PSD register to indicate that the program has jumped to an area of the SCM field which may be in range but is not valid program code. This should occur when an incorrectly coded program jumps into an unused area of the SCM field or into a data field. The program range condition flag is also set on the condition of a jump to address zero. These conditions can be determined on the basis of the register contents in the exchange package. The existence of an error exit condition resulting from execution of this instruction can thus be deduced.

The location field of an ES instruction becomes a sub-subtitle on the assembler listing.

Format: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
ES		Error exit to EEA	15 bits	00000
ES	K	Error exit to EEA	15 bits	00000

Example:

Code Generated

```
00000
```

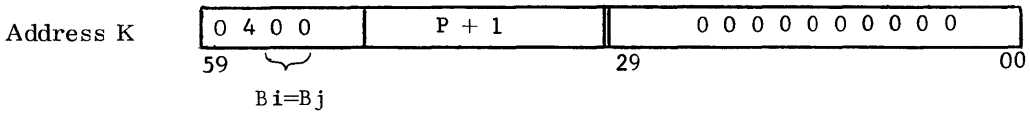
```
      ES
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30

8.4.3 RETURN JUMP INSTRUCTION

When this instruction is executed, an unconditional jump to the current address plus one [(P)+1)] is stored in the upper half of relative address K in SCM and control then transfers to K+1 for the next instruction. The lower half of the stored word is all zeros. The instruction always branches out of the instruction stack and voids all instructions currently in the instruction stack.

After the instruction is executed the octal word at K is:



This instruction is intended for transferring control to a subroutine between execution of the current instruction word and the following instruction word. Instructions appearing after the return jump instruction in the current instruction are not executed. The called subroutine must exit at address K in CM (SCM). A jump to address K of the branch routine returns the program to the original sequence. The assembler sets the unused j designator to zero.

A force upper occurs after the instruction is assembled.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Branch
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RJ	K	Return jump to K	30 bits	0100K

Example:

Code Generated

```
0100005250 +
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
          RJ      HELP
```

8.4.4 ECS INSTRUCTIONS (CYBER 170 SERIES, CYBER 70/MODELS 72, 73, 74 OR 6000 SERIES)

These instructions initiate either a read or write operation to transfer (Bj) + K 60-bit words between extended core storage (ECS) and central memory (CM). The initial ECS address is (X0) + RA_{ECS}; the initial CM address is (A0) + RA_{CM}.

The assembler forces upper before assembling an RE or WE instruction.

Three error conditions cause an error exit to the lower-order 30 bits of the instruction word containing the RE or WE instructions. These 30 bits should always hold a jump to an error routine. The conditions are:

1. Parity error(s) when reading ECS. If a parity error is detected, the entire block of data is transferred before the exit is taken.

2. The ECS bank from/to which data is to be transferred is not available because the bank is in maintenance mode, or the bank has lost power. If either of these conditions exists on an attempted read or write, an immediate error exit is taken.

3. An attempt to reference a nonexistent address. On an attempted write operation, no data transfer occurs and an immediate error exit is taken. If the attempted operation is a read, and addresses are in range, zeros are transferred to central memory. This is a convenient high-speed method of clearing blocks of central memory.

For additional information about these instructions, refer to the CONTROL DATA® CYBER 70 Computer System 7030 Extended Core Storage Reference Manual, Publication No. 60347100.

Formats: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RE	Bj	Read extended core storage	30 bits	011j0 00000
RE	K	Read extended core storage	30 bits	0110K
RE	Bj+K	Read extended core storage	30 bits	011jK
WE	Bj	Write extended core storage	30 bits	012j0 00000
WE	K	Write extended core storage	30 bits	0120K
WE	Bj+K	Write extended core storage	30 bits	012jK

The length of the block is determined by adding the quantity K to the contents of register Bj. Either quantity may be used as an increment or decrement. The result is an 18-bit integer which is truncated to a 10-bit quantity. Thus, a maximum block size is 1777_8. (For example, if the result of the add is 003000_8, the instruction transfers 1000_8 words.) No error indications are given when this occurs unless the field length is exceeded causing a block range error. If the block length is zero, the instruction becomes a do-nothing instruction; the condition is not error flagged.

Relative source or destination addresses begin at (A0) in the SCM and at the relative LCM address determined from the lowest order 19 bits of (X0). If (X0) is negative, the 19 bits are treated as a positive integer. If the sum of $(X0_{18-00})$ and the block count exceeds the (FLL), the copy is not executed and the LCM block range condition flag is set in the PSD register. Similarly, if the sum of (A0) and the block exceeds (FLS), the copy is not executed and the SCM block range condition flag is set in the PSD register.

Any error condition occurring during execution of a block copy instruction causes a flag to be set in the PSD register but does not interrupt the block copy instruction. No further instructions are issued during block transfer of data. Instructions already issued are completed; all other activity, with the exception of I/O word requests, stops.

Formats: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RL	Bj	Block copy (Bj) words from LCM to SCM	30 bits	011j0 00000
RL	K	Block copy (K) words from LCM to SCM	30 bits	0110K
RL	Bj±K	Block copy (Bj) ± K words from LCM to SCM	30 bits	011jK
WL	K	Block copy (K) words from SCM to LCM	30 bits	0120K
WL	Bj	Block copy (Bj) words from SCM to LCM	30 bits	012j0 00000
WL	Bj±K	Block copy (Bj) ± K words from SCM to LCM	30 bits	012jK

Example:

Code Generated

```
0115001000
0110002000
0124777677
```

```
      LOCATION   OPERATION   VARIABLE      COMMENTS
1                 11          18            30
      ,          PL          1000B+B5      ,
      ,          RL          2000B         ,
      ,          WL          B4-100B       ,
```

8.4.6 EXCHANGE JUMP INSTRUCTION (CYBER 170 SERIES, CYBER 70/MODELS 72, 73, 74, AND 6000 SERIES)

This instruction unconditionally exchange jumps the central processor, regardless of the state of the monitor flag bit. Instruction action differs, however, depending on whether the monitor flag bit is set or clear.

This instruction is not legal for a CYBER 170/Model 175 if the MEJ/CEJ switch is in the DISABLE position or if the instruction does not reside in parcel 0 of the instruction word.

Operation is as follows:

1. Monitor flag bit clear: The starting address for the exchange is taken from the 18-bit Monitor Address register. This starting address is an absolute address. During the exchange, the monitor flag bit is set.

2. Monitor flag bit set: The starting address for the exchange is the 18-bit result formed by adding K to the contents of register Bj. This starting address is an absolute address. During the exchange, the monitor flag bit is cleared.

For additional information, refer to the Standard Option 10104-A/B/C/D Central and Monitor Exchange Jumps for 6600 Reference Manual, Pub. No. 60203200.

The assembler forces upper before and after assembling an XJ instruction.

Formats: Functional Unit: Branch

Operation	Variable	Description	Size	Octal Code
XJ		Exchange jump to MA if in program mode	30 bits	01300 00000
XJ	Bj	Exchange jump to (Bj); flag set	30 bits	013j0 00000
XJ	K	Exchange jump to K; flag set	30 bits	0130K
XJ	Bj+K	Exchange jump to (Bj) + K; flag set	30 bits	013jK

Examples:

Code Generated

```
0130000000
0130001000
0135000600
```

```
      LOCATION  OPERATION  VARIABLE      COMMENTS
1                 11         18          30
      
                  XJ
                  XJ         1000B
                  XJ         B5+600B
```

8.4.7 EXCHANGE EXIT INSTRUCTION (CYBER 70/MODEL 76 OR 7600)

The normal termination for an exchange package execution interval is through execution of an exchange instruction (MJ). The exit mode flag in the PSD register determines the source of the exchange package.

This instruction has priority over all other types of exchange jump requests. If an I/O interrupt request or an error exit request occurred prior to execution of this instruction, it is denied and the exchange jump specified by the MJ is executed. The rejected interrupt request is not lost, however. The conditions that caused it are reinstated when the exchange package enters its next execution interval.

The MJ instruction voids the instruction word stack. Any instructions remaining in the stack are not executed.

The system makes no protective tests on the exchange jump address.

Exit Mode Flag Set: When the exit mode flag is set, the MJ instruction causes the current program sequence to terminate with an exchange jump to a relative address in the SCM field for the current program. The exchange package is located at relative address (Bj) $\pm$ K. An overflow of the lowest order 16 bits of this result causes an error condition that is not sensed in the hardware. Should a program erroneously execute an exchange exit instruction with an overflow condition, the exchange jump sequence begins at the absolute SCM address corresponding to the lowest order 16 bits of this sum. This 30-bit form of MJ is privileged to a monitor program.

Exit Mode Flag Not Set: When the exit mode flag is not set, the object program terminates the execution interval with a 15-bit form of the MJ instruction. The normal exit address (NEA) is the absolute address of the exchange package. This is an absolute address in SCM and is generally not in the SCM field for the current program. This form of the MJ instruction has a blank variable field; the assembler sets the j and k designators to zero.

This instruction is used for calling a system monitor program for input/output, monitor calls, etc.

All operating register values, program addresses, and mode selections are preserved in the exchange package for the object program so that the object program can be continued at a later time. The program address in the object program exchange package is advanced one count from the address of the instruction word containing the exchange exit instruction. The monitor program normally resumes the object program at this address.

The assignment of (NEA) is a responsibility of the system monitor program. If (NEA) has more than 16 bits of significance, the upper bits are discarded and the lower 16 bits are used as the absolute address in SCM for the exchange jump. A force upper occurs after the instruction is assembled.

Formats: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
MJ		Exchange exit to NEA if exit flag clear	15 bits	01300
MJ	Bj	Exchange exit to (Bj) if exit flag set	30 bits	013j0 00000
MJ	Bj±K	Exchange exit to (Bj) ± K if exit flag set	30 bits	013jK
MJ	K	Exchange exit to K if exit flag set	30 bits	0130K

Examples:

Code Generated

```
01300
0134000500
0135777477
0130000600
```

```
      LOCATION   OPERATION   VARIABLE          COMMENTS
1                11          18                30
                 MJ
                 MJ          B4+500B
                 MJ          -300B+B6
                 MJ          600B
```

8.4.8 DIRECT LCM TRANSFER INSTRUCTIONS (CYBER 70/MODEL 76 OR 7600)

A single word transfer either reads one 60-bit word from LCM and enters this word into an X register or writes one 60-bit word directly into LCM from an X register.

The execution time for transferring a word from LCM to an X register depends on whether the requested word already resides in one of the bank operand registers. A read LCM instruction for a word not currently residing in a bank operand register will require 17 clock periods for delivering a field of eight 60-bit words to the designated X register. A read LCM instruction for a word already residing in a LCM bank operand register as a result of a previous instruction will require three clock periods to deliver the requested word to the designated X register. Thus, although the first 60-bit word will require 17 clock periods, the second through eighth words in the same LCM word require three clock perods each. This means that consecutive LCM operands are available, on an average, every five clock periods as opposed to SCM operands at eight clock periods.

The LCM address is determined from (Xk_{18-00}). Even if (Xk) is negative, the 19 bits are treated as a positive integer. If the address exceeds the field length (FLL), the word transfer does not take place and the LCM direct range condition flag is set in the PSD register. Xj is either the source or destination register.

Instructions are buffered to the extent that each issues in one minor cycle unless a previous LCM reference is in process. When an RX instruction issues, the LCM busy flag is set and remains set until the requested word is delivered.

For a write (WX) instruction, if the word cannot be entered immediately in the proper bank operand register, it is held in the LCM write register until the bank operand register is free.

Formats: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RXj	Xk	Read LCM at (Xk) and set Xj	15 bits	014jk
WXj	Xk	Write (Xj) into LCM at (Xk)	15 bits	015jk

Examples:

Code Generated

```
01465
01570
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      RX6       X5
      WX7       X0
```

8.4.9 RESET INPUT CHANNEL BUFFER INSTRUCTION (CYBER 70/MODEL 76 OR 7600)

This instruction is exclusively a 7600 instruction. It initiates a new record transmission from a PPU to SCM. This instruction prepares the input channel (Bk) buffer for a new record transmission from a PPU to SCM. The instruction clears the input channel buffer address and resets the input channel assembly counter to the first 12-bit position in the SCM word.

This instruction is intended to be privileged to an input routine, that is, one that terminates a record of incoming data and prepares for the next record.

The input routine removes the data in the input channel buffer and then executes this instruction to prepare the buffer for the next incoming record. This instruction is effective only if the monitor mode flag is set in the program status register. If the monitor mode flag is cleared, this instruction becomes a pass instruction. When this instruction issues, it will execute the required channel functions without regard to the current status or activity at the input channel buffer.

The lowest order four bits of (Bk) are used in this instruction. The higher order bits are ignored. If higher order bits are set in (Bk) the lowest order four bits are masked out and used to determine the channel number. If (Bk) is zero, this instruction becomes a pass instruction.

Two or more consecutive RI instructions referring to different channels will issue in consecutive clock periods with no interference resulting in the multiplexer. If two consecutive instructions refer to the same channel, they repeatedly perform the same function but do not cause interference in the multiplexer.

Format: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RI	Bk	Reset input channel (Bk) buffer	15 bits	0160k

Example:

Code Generated

```
01607
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  RI         B7
```

8.4.10 SET REAL-TIME CLOCK INSTRUCTION (CYBER 70/MODEL 76 OR 7600)

This instruction reads the contents of the CPU clock period counter (real-time clock) and places them in Bj. The 18-bit clock counter advances one count in two's complement mode for each clock period. The 2^{17} bit is the overflow bit. The CPU is interrupted when the overflow bit is set. When the interrupt is handled, the bit is cleared. It permits measurement of CPU execution.

Format: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
TBj		Set Bj to current clock time	15 bits	016j0
TBj	K	Set Bj to current clock time; K is ignored.	15 bits	016j0

Example:

Code Generated

```
01670
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  TB7
```

8.4.11 RESET OUTPUT CHANNEL BUFFER INSTRUCTION (CYBER 70/MODEL 76 OR 7600)

This instruction initiates a new record transmission from SCM to PPU. It clears the output channel (Bk) buffer address and disassembly counter, transmits a record pulse over the output channel data path to the PPU, and initiates an SCM reference for the first word to be transmitted.

This instruction is intended for execution in an output routine to initiate a new record transmission over an output channel data path. The output channel buffer is normally inactive when this instruction is executed. The output channel buffer is loaded with the data for the next record, and this instruction is executed to initiate the transmission. The record pulse is transmitted along with the word pulse as soon as the first word of data from the SCM is entered in the output channel disassembly register.

This instruction is effective only if the monitor mode flag is set in the program status register. If the monitor mode flag is cleared, this instruction becomes a pass instruction. When this instruction issues, it will execute the required channel functions without regard to the current status or activity at the output channel.

The lowest order four bits of (Bk) are used in this instruction. The higher order bits are ignored. If higher order bits are set in (Bk), the lowest order four bits are masked out and used to determine the channel number. If (Bk) is zero, this instruction becomes a pass instruction.

Normally, the output channel buffer is inactive when this instruction is executed, the program having checked for completion of the previous record before issuing an RO. The program can detect the end of record in two ways. First, it can compare the output channel buffer address with a known record length. The alternative is to obtain a response from the peripheral unit over the corresponding input channel data path. If data is moving over the output channel data path when an RO is issued, the RO instruction takes priority, with a resulting loss of data in the previous record. Two or more consecutive RO instructions referring to different channels will issue in consecutive clock periods with no interference resulting in the multiplexer. If two consecutive instructions refer to the same channel, they transmit a record pulse over the output path and restart the buffer repeatedly. A data word may or may not be transmitted depending on the timing of the instructions and conflicts that occur.

Format: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
RO	Bk	Reset output channel (Bk) buffer	15 bits	0170k

Example:

Code Generated

01705

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		RO	35	

8.4.12 READ CHANNEL STATUS INSTRUCTIONS (CYBER 70/MODEL 76 OR 7600)

These instructions copy the contents of the input or output channel buffer address register indicated by masking (Bk_{03-00}) and enter the value in Bj. The instructions are used for monitoring the progress of an input channel buffer or an output channel buffer.

A channel buffer area is divided into fields by the threshold testing mechanism. The first half of the buffer area constitutes one field and the last half of the buffer area the other field. An I/O multiplexer interrupt request is generated by the threshold testing mechanism whenever the channel buffer address is advanced across a field boundary. This occurs at the center of the buffer area and at the end of the buffer area.

The IBj instruction is the only vehicle for a program to determine whether an I/O multiplexer interrupt request was generated by a buffer threshold test or by a record flag. The program must retain the input channel buffer address from one interrupt period to the next. If the buffer address is in the same field as for the previous interrupt, the interrupt request was from a record flag. If the buffer address is in the opposite field from the previous interrupt, the interrupt request was from a threshold test.

The lowest order four bits of (Bk) are used in these instructions. The higher order bits are ignored. If higher order bits are set in (Bk) the lowest order four bits are masked out and used to determine the channel number. If (Bk) = 0, the IBj instruction reads the contents of the CPU clock period counter. However, the OBj instruction places all zeros into Bj.

Two or more IBj instructions or OBj instructions may occur in consecutive program instruction locations referencing the same or different channels. These instructions may issue in consecutive clock periods providing the Bj register reservations do not cause a delay. No interference will result in the multiplexer in these situations.

If correct results are to be obtained, an IBj instruction must not immediately follow an RI instruction nor may an OBj instruction immediately follow an RO instruction. A delay of one clock period is sufficient.

Formats: Functional Unit: None

Operation	Variable	Description	Size	Octal Code
IBj	Bk	Bj ← Read input channel (Bk) status	15 bits	016jk
OBj	Bk	Bj ← Read output channel (Bk) status	15 bits	017jk

Example:

Code Generated

```
01664
01756
```

```
      LOCATION   OPERATION   VARIABLE   COMMENTS
1                11          18         30
      IB6        B4
      OB5        B6
```

8.4.13 UNCONDITIONAL JUMP INSTRUCTION

This instruction adds the contents of index register Bi to K and branches to the relative CM (SCM) address specified by the sum. The remaining instructions, if any, in the current instruction word are not executed. The branch address is K when i is zero.

Addition is performed in an 18-bit one's complement mode. On a CYBER 170 Series, a CYBER 70/ Model 72, 73, or 74 or 6000 Series system this instruction voids the stack. On a CYBER 70/Model 76 or 7600, the instruction word stack is not altered by execution of this instruction. The instruction is intended to allow computed branch point destinations. It is the only CPU instruction in which a computed parameter can specify a program branch destination address. All other jump instructions have pre-assigned destination addresses at execution time.

The assembler sets the unused j designator to 0. A force upper occurs after the instruction is assembled.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Branch
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: None

Operation	Variable	Description	Size	Octal Code
JP	Bi+K	Jump to (Bi)+K	30 bits	02iiK
JP	Bi	Jump to (Bi)	30 bits	02ii0 00000
JP	K	Jump to K	30 bits	0200K

Example:

Code Generated

```
0255000004 +
0277000000
```

```
      LOCATION  OPERATION  VARIABLE      COMMENTS
1                 11         18            30
          JP      B5+GOTO
          JP      B7
```

8.4.14 X-REGISTER CONDITIONAL BRANCH INSTRUCTIONS

These instructions cause the program sequence to branch to K or to continue with the current program sequence depending on the contents of operand register Xj. The decision is not made until the Xj register is free. These instructions do not void the stack.

The following rules apply to tests made in this instruction group:

1. The ZR and NZ operations test the full 60-bit word in Xj. The words 00.....00 and 77.....77 are treated as zero. All other words are non-zero. Thus, these instructions are not a valid test for floating point zero coefficients. However, they can be used to test for underflow of floating point quantities.

2. The PL and NG operations examine only the sign bit (2^{59}) of Xj. If the sign bit is zero, the word is positive; if the sign bit is one, the word is negative. Thus, the sign test is valid for fixed point words or for coefficients in floating point words.

3. The IR and OR operations examine the upper-order 12 bits of Xj.

   On the 7600, the following quantities are detected as being out of range:

   3777x.....x (positive overflow)
   4000x.....x (negative overflow)
   1777x.....x (positive indefinite)
   6000x.....x (negative indefinite)

   All other words are in range. An underflow quantity is considered in range. The value of the coefficient is ignored in making this test.

   On a 6000-Series computer system, 3777x...x and 4000x...x are out of range; all other words are in range.

4. The DF and ID operations examine the upper-order 12 bits of Xj. Both positive and negative indefinite forms are detected:

   1777x.....x and 6000x.....x are indefinite

   All other words are definite. The value of the coefficient is ignored in making this test.

5. An error exit occurs on a 6000 series or a CYBER 70/Model 72, 73, or 74 system when an indefinite or out of range value is used as an operand of an arithmetic instruction. Such error exits may be avoided by using DF, ID, IR or OR instructions to test for such values before using them as operands.

   On a 7600 or CYBER 70/Model 76 system, an error exit occurs as soon as indefinite or out of range value is produced as the result of an arithmetic instruction. The DF, ID, IR and OR instructions are useful only when a MODE control statement is used to suppress such error exits.

Formats:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Branch
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: None

Operation	Variable	Description	Size	Octal Code
ZR	Xj,K	Branch to K if (Xj) = 0	30 bits	030jK
NZ	Xj,K	Branch to K if (Xj) $\neq$ 0	30 bits	031jK
PL	Xj,K	Branch to K if (Xj) sign is plus	30 bits	032jK
NG	Xj,K	Branch to K if (Xj) sign is minus	30 bits	033jK
MI	Xj,K	Branch to K if (Xj) sign is minus	30 bits	033jK
IR	Xj,K	Branch to K if (Xj) in range	30 bits	034jK
OR	Xj,K	Branch to K if (Xj) out of range	30 bits	035jK
DF	Xj,K	Branch to K if (Xj) definite	30 bits	036jK
ID	Xj,K	Branch to K if (Xj) indefinite	30 bits	037jK

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
0305002363 +		ZR	X5,ZERO	
0313002364 +		NZ	X3,NONZERO	
0324002365 +		PL	X4,PLUS	
0331002366 +		NG	X1,NEG	
0331002366 +		MI	X1,NEG	
0340002367 +		IR	X0,INRANGE	
0351002370 +		OR	X1,OUTRNGE	
0365002371 +		UF	X5,DEFINT	
0377002372 +		IU	X7,INDEFNT	

8.4.15 B-REGISTER CONDITIONAL BRANCH INSTRUCTIONS

These instructions test an 18-bit word from register Bi against an 18-bit word from register Bj for the condition specified. They branch to address K on a successful test. Otherwise, the program sequence continues at the next instruction. The decision is not made until both B registers are free. For the tests against zero (all zeros), the assembler sets either the i or the j designator to 0 indicating B0.

The following rules apply in the tests made by these instructions:

1. Positive zero is recognized as unequal to negative zero, and
2. Positive zero is recognized as greater than negative zero, and
3. A positive number is recognized as greater than a negative number.

The 06 and 07 instructions are intended for branching on an index threshold test. The tests are made in a 19-bit one's complement mode. The (Bi) and the (Bj) are sign extended one bit to prevent erroneous results caused by exceeding the modulus of the comparison device. The (Bj) is then subtracted from the (Bi). The branch decision is based on the sign bit in the 19-bit result.

For these instructions, Bi and Bj must be specified in the order indicated below.

These instructions do not void the stack.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Branch
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: None

Operation	Variable	Description	Size	Octal Code
ZR †	K	Branch to K	30 bits	0400K
ZR	Bi, K	Branch to K if (Bi) = 0	30 bits	04i0K
EQ †	K	Branch to K	30 bits	0400K
EQ	Bi, K	Branch to K if (Bi) = 0	30 bits	04i0K
EQ	Bi, Bj, K	Branch to K if (Bi) = (Bj)	30 bits	04ijK
NE	Bi, K	Branch to K if (Bi) $\neq$ 0	30 bits	05i0K
NE	Bi, Bj, K	Branch to K if (Bi) $\neq$ (Bj)	30 bits	05ijK
NZ	Bi, K	Branch to K if (Bi) $\neq$ 0	30 bits	05i0K
PL	Bi, K	Branch to K if (Bi) $\geq$ 0	30 bits	06i0K
GE	Bi, K	Branch to K if (Bi) $\geq$ 0	30 bits	06i0K
GE	Bi, Bj, K	Branch to K if (Bi) $\geq$ (Bj)	30 bits	06ijK
LE	Bj, Bi, K	Branch to K if (Bj) $\leq$ (Bi)	30 bits	06ijK
LE	Bj, K	Branch to K if (Bj) $\leq$ 0	30 bits	060jK
NG	Bi, K	Branch to K if (Bi) < 0	30 bits	07i0K
MI	Bi, K	Branch to K if (Bi) < 0	30 bits	07i0K

† The assembler forces the position counter upper after assembling the instructions.

Formats (cont'd):

Operation	Variable	Description	Size	Octal Code
GT	Bj, Bi, K	Branch to K if (Bj) > (Bi)	30 bits	07ijK
GT	Bj, K	Branch to K if (Bj) >0	30 bits	070jK
LT	Bi, K	Branch to K if (Bi) <0	30 bits	07i0K
LT	Bi, Bj, K	Branch to K if (Bi) < (Bj)	30 bits	07ijK

Examples:

Code Generated

```
0450005221 +
0405005222 +
0453005223 +
0400005223 +
0515005224 +
0560005225 +
0620005226 +
0645005227 +
0650005230 +
0676005231 +
0770005232 +
0730005233 +
0767005234 +
0705005235 +
0712005236 +
```

```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1               11         18                30
      ZR        B5,BZERO
      EQ        B0,B5,EQUAL
      EQ        B5,B3,JUMP
      EQ        JUMP
      NE        B1,B5,NOTEQ
      NZ        B6,BNOTZR
      PL        B2,BPLUS
      GE        B4,B5,GEQ
      GE        B5,GEB0
      LE        B6,B7,LTHAN
      NG        B7,BNEG
      MI        B3,B3LT0
      GT        B7,B6,B7GT
      GT        B5,B5GT0
      LT        B1,B2,BLTB
```

8.4.16 TRANSMIT INSTRUCTION

This instruction transfers the 60-bit word in operand register Xj to register Xi. It is essentially a copy instruction intended for moving data from X register to X register as quickly as possible. No logical function occurs. The assembler sets the k designator to the value specified for j.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	Xj	Transmit (Xj) to Xi	15 bits	10ijj

Example:

Code Generated

```
10622
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PX6	X2	

8.4.17 LOGICAL PRODUCT INSTRUCTION

This instruction forms the logical product (AND function) of 60-bit words from operand registers Xj and Xk and places the product in operand register Xi. Bits of register Xi are set to 1 when the corresponding bits of the Xj and Xk registers are 1 as in the following example:

(Xj) = 0101
(Xk) = 1100
(Xi) = 0100

This instruction is intended for extracting portions of a 60-bit word during data processing. If the j and k designators have the same value, the instruction becomes a transmit instruction.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	Xj*Xk	Logical product of (Xj) and (Xk) to Xi	15 bits	11ijk

Example:

Code Generated

```
11563
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PX5	X5*X3	

8.4.18 LOGICAL SUM INSTRUCTION

This instruction forms the logical sum (inclusive OR) of 60-bit words from operand registers Xj and Xk and places the sum in operand register Xi. A bit of register Xi is set to 1 if the corresponding bit of the Xj or Xk register is a 1 as in the following example:

(Xj) = 0101
(Xk) = 1100
(Xi) = 1101

This instruction is intended for merging portions of a 60-bit word into a composite word during data processing. If the j and k designators have the same value, the instruction degenerates into a transmit instruction.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	Xj+Xk	Logical sum of (Xj) and (Xk) to Xi	15 bits	12ijk

Example:

Code Generated

12767

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PX7	X6+X7	

8.4.19 LOGICAL DIFFERENCE INSTRUCTION

This instruction forms the logical difference (exclusive OR) of 60-bit words from operand registers Xj and Xk and places the difference in operand register Xi. A bit in register Xi is set to 1 if the corresponding bits in the Xj and Xk registers are unlike as in the following example:

(Xj) = 0101
(Xk) = 1100
(Xi) = 1001

This instruction is intended for comparing bit patterns or for complementing bit patterns during data processing. If the j and k designators have the same value the result will be a word of all zeros written into register Xi.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	Xj-Xk	Logical difference of (Xj) and (Xk) to Xi	15 bits	13ijk

Example:

Code Generated

13601

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		PX6	X0-X1	

8.4.20 COMPLEMENT INSTRUCTION

This instruction extracts the 60-bit word from operand register Xk, complements it, and transmits this complemented quantity to operand register Xi. It is intended for changing the sign of a fixed point or floating point quantity as quickly as possible.

The assembler sets the unused j designator of the instruction to k.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	-Xk	Transmit complement of (Xk) to Xi	15 bits	14ikk

Example:

Code Generated

```
14311
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  BX3        -X1
```

8.4.21 LOGICAL PRODUCT AND COMPLEMENT INSTRUCTION

This instruction forms the logical product (AND function) of the 60-bit quantity from operand register Xj and the complement of the 60-bit quantity from operand register Xk, and places the result in operand register Xi. Thus, bits of Xi are set to 1 when the corresponding bits of the Xj register and the complement of the Xk register are 1 as in the following example:

```
(Xj) = 0101
Complemented (Xk) = 0011
(Xi) = 0001
```

This instruction is intended for extracting portions of a 60-bit word during data processing. If the j and k designators have the same value, a logical product is formed between two complementary quantities. The result will be a word of all zeros.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	-Xk*Xj	Logical product of (Xj) and complement of (Xk) to Xi	15 bits	15ijk

Examples:

Code Generated

```
15432
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  BX4        -X2*X3
```

8.4.22 COMPLEMENT AND LOGICAL SUM INSTRUCTION

This instruction forms the logical sum (inclusive OR) of the 60-bit quantity from operand register Xj and the complement of the 60-bit word from operand register Xk, and places the result in operand register Xi. Thus, bits of Xi are set to 1 if the corresponding bit of the Xj register is one or the corresponding bits of the Xk register is a 0 as in the following example:

(Xj) = 0101

(Xk) = 1100

(Xi) = 0111

This instruction is intended for merging portions of a 60-bit word into a composite word during data processing. If the j and k designators have the same value the result is a word of all ones.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	-Xk+Xj	Logical sum of (Xj) and complement of (Xk) to Xi	15 bits	16ijk

Example:

Code Generated

16654

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		BX6	-X4+X5	

8.4.23 COMPLEMENT AND LOGICAL DIFFERENCE INSTRUCTION

This instruction forms the logical difference (exclusive OR) of the quantity from operand register Xj and the complement of the 60-bit word from operand register Xk, and places the result in operand register Xi. Thus, bits of Xi are set to 1 if the corresponding bits of Xj and register Xk are alike as in the following example:

(Xj) = 0101

(Xk) = 1100

(Xi) = 0110

This instruction is intended for comparing bit patterns or for complementing bit patterns during data processing. If the j and k designators have the same value, a logical difference is formed between two complementary quantities. The result is a word of all ones.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Boolean
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
BXi	-Xk-Xj	Logical difference of (Xj) and complement of (Xk) to Xi	15 bits	17ijk

Example:

Code Generated

```
17731
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  BX7        -X1-X3
```

8.4.24 LOGICAL LEFT SHIFT jk PLACES INSTRUCTION

This instruction shifts the 60-bit word in operand register Xi left circular jk places if expression jk is positive or left circular 60+jk places if jk is negative. Bits shifted off the left end of operand register Xi replace those shifted from the right end.

The 6-bit shift count jk allows a complete circular shift of (Xi).

In COMPASS notation, jk is an absolute expression. If it is positive, COMPASS places the lower 6 bits on the value in the jk fields. If it is negative, COMPASS adds 60 to jk and places the result in the jk fields. Thus, a negative value effectively designates a logical right shift. A positive value designates a left shift.

If the negative shift count is less than -60, the assembler generates a 7-type error.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
LXi	jk	Logical shift (Xi) by ± jk places	15 bits	20ijk

Example:

Code Generated

```
20325
20362
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  LX3        25B
                  LX3        -12B
```

8.4.25 ARITHMETIC RIGHT SHIFT jk PLACES INSTRUCTION

This instruction shifts the 60-bit word in operand register Xi right jk places if expression jk is positive and right 60+jk places if expression jk is negative. The rightmost bits of Xi are discarded and the sign bit is extended.

If the shift count is equal to the 60-bit register length, the result contains 60 copies of the sign bit. If the operand is positive, a positive zero results. If the operand is negative, a negative zero results.

In COMPASS notation, jk is an absolute expression. If it is positive, COMPASS places the lower 6 bits of the value in the jk fields. If it is negative, COMPASS adds 60 to jk and places the result in the jk fields. Thus, a negative value effectively designates the number of high order bits of the operand that are to be retained. If the negative shift count is less than -60, a 7-type error is generated.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
AXi	jk	Arithmetic shift (Xi) by ± jk places	15 bits	21ijk

Example:

Code Generated

```
21537
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1     11        18         30
      AX5       378
```

8.4.26 LOGICAL LEFT SHIFT (Bj) PLACES INSTRUCTION

This instruction shifts the 60-bit quantity from operand register Xk the number of places specified by the quantity in index register Bj and places the result in operand register Xi.

1. If (Bj) is positive, (that is, bit 17 of Bj = 0), the quantity from Xk is shifted left circular. The low order 6 bits of (Bj) specify the shift count. The higher order bits are ignored.

2. If (Bj) is negative, (that is, bit 17 of Bj = 1), the quantity from Xk is shifted right (end off with sign extension). For the CYBER 170 Series, the CYBER 70 Series/Models 72, 73, and 74, and the 6000 Series, the one's complement of the low order 11 bits of (Bj) specify the shift count. The higher order bits are ignored. If the shift count is 59 to 63 (decimal), the result stored in the Xi register consists of 60 copies of the operand sign bit. If the shift count is 64 (decimal) or greater, the result register Xi is cleared to 60 zeros. For the CYBER 70/Model 76 and the 7600, the one's complement of the low order 12 bits of (Bj) specify the shift count. The higher order bits are ignored. If the shift count is 59 (decimal) or greater, the result stored in the Xi register consists of 60 copies of the operand sign bit.

If – Bj is specified, the assembler converts the instruction to an arithmetic right shift. The (Bj) might be the result of an unpack instruction, in which case it is the unbiased exponent and (Xi) is the coefficient. This instruction is used for shifting a coefficient from a floating point number to the integer position after an unpack operation.

CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift

Format: CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
LXi	Xk, Bj	Logically shift (Xk) by (Bj) places to Xi	15 bits	22ijk
LXi	Bj,Xk	Logically shift (Xk) by (Bj) places to Xi	15 bits	22ijk
LXi	Xk	Transmit (Xk) to Xi	15 bits	22i0k
LXi	Bj	Logically shift (Xi) by (Bj) places to Xi	15 bits	22iji
LXi	-Bj,Xk	Arithmetic right shift (Xk) by (Bj) places to Xi	15 bits	23ijk
LXi	Xk,-Bj	Arithmetic right shift (Xk) by (Bj) places to Xi	15 bits	23ijk
LXi	-Bj	Arithmetic right shift (Xi) by (Bj) places to Xi	15 bits	23iji

Example:

Code Generated

```
22675
22534
22302
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      |         |LX6       |X5,B7    |
      |         |          |         |
      |         |LX5       |B3,X4    |
      |         |          |         |
      |         |LX3       |X2       |
      |         |          |         |
```

8.4.27 ARITHMETIC RIGHT SHIFT (Bj) PLACES INSTRUCTION

This instruction shifts the 60-bit quantity from operand register Xk the number of places specified by the quantity in index register Bj and places the result in operand register Xi.

1. If (Bj) is positive (that is, bit 17 of Bj = 0), the quantity from register Xk is shifted right (end off with sign extension). For the CYBER 170 Series, CYBER 70/Model 72, 73, 74 and 6000 Series Computer Systems, the low order 11 bits of (Bj) specify the shift count. The higher order bits are ignored. If the shift count is 59 to 63 (decimal) the Xi register contains 60 copies of the (Xk) sign bit. If the shift count is 64 (decimal) or more, the Xi register is zeroed. For the CYBER 70/Model 76 or 7600 Computer Systems, the low order 12 bits of (Bj) specify the shift count. The higher order bits are ignored. If the shift count is 64 (decimal) or more the Xi register contains 60 copies of the sign of the operand.

2. If (Bj) is negative (that is, bit 17 of Bj = 1), the quantity from register Xk is shifted left circular. The complement of the lower order 6 bits of Bj specify the shift count. The higher order bits are ignored.

If -B is specified, the assembler converts the instruction to a logical left shift. This instruction is intended for use in data processing where the amount of shift is derived in the computation. This instruction is also useful for adjusting the coefficient of a floating point number while it is in its unpacked form.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
AXi	Xk, Bj	Arithmetic shift of (Xk) by (Bj) places to Xi	15 bits	23ijk
AXi	Bj, Xk	Arithmetic shift of (Xk) by (Bj) places to Xi	15 bits	23ijk
AXi	Xk	Transmit (Xk) to Xi	15 bits	23i0k
AXi	Bj	Arithmetic shift of (Xi) by (Bj) places to Xi	15 bits	23iji
AXi	-Bj, Xk	Logically shift (Xk) by (Bj) places to Xi	15 bits	22ijk
AXi	Xk, -Bj	Logically shift (Xk) by (Bj) places to Xi	15 bits	22ijk
AXi	-Bj	Logically shift (Xi) by (Bj) places to Xi	15 bits	22iji

Example:

Code Generated

```
23764
23211
23502
23424
```

```
      LOCATION   OPERATION   VARIABLE    COMMENTS
1                 11          18          30
      AX7         X4,B6
      AX2         B1,X1
      AX5         X2
      AX4         B2
```

8.4.28 NORMALIZE INSTRUCTION

This instruction normalizes the floating point quantity from operand register Xk and places it in operand register Xi. Normalizing consists of shifting the coefficient the minimum number of positions required to make bit 47 different from bit 59. This places the most significant bit of the coefficient in the highest order position of the coefficient portion of the word. The exponent portion of the word is then decreased by the number of bit positions shifted. The number of shifts required to normalize the quantity is entered in index register Bj.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
NXi	Xk	Normalize (Xk) to Xi	15 bits	24i0k
NXi	Bj, Xk	Normalize (Xk) to Xi; shift count to Bj	15 bits	24ijk
NXi	Xk, Bj	Normalize (Xk) to Xi; shift count to Bj	15 bits	24ijk
NXi		Normalize (Xi) to Xi	15 bits	24i0i
NXi	Bj	Normalize (Xi) to Xi; shift count to Bj	15 bits	24iji

Example:

Code Generated

```
24575
24505
24552
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                11         18        30
          NX5       X5,B7
          NX5
          NX5,B5    X2
```

8.4.29 ROUND AND NORMALIZE INSTRUCTION

This instruction performs the same operation as the NXi instruction with the exception that the quantity from operand register Xk is rounded before it is normalized. Rounding is accomplished by placing a 1 round bit immediately to the right of the least significant coefficient bit. The resulting coefficient is increased by one-half the value of the least significant bit. Normalizing a zero coefficient places the round bit in bit 47 and reduces the exponent by 48. Note that the same rules apply for underflow, overflow, infinite, and indefinite results.

If (Xk) is an infinite quantity (3777x...x or 4000x...x) or an indefinite quantity (1777x...x or 6000x...x), no shift takes place. The contents of Xk are copied into Xi, and Bj is set to zero.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
ZXi	Xk	Round and normalize (Xk) to Xi	15 bits	25i0k
ZXi	Bj, Xk	Round and normalize (Xk) to Xi; shift count to Bj	15 bits	25ijk
ZXi	Xk, Bj	Round and normalize (Xk) to Xi; shift count to Bj	15 bits	25ijk
ZXi	Bj	Round and normalize (Xi) to Xi; shift count to Bj	15 bits	25iji
ZXi		Round and normalize (Xi) to Xi	15 bits	25i0i

Example:

Code Generated

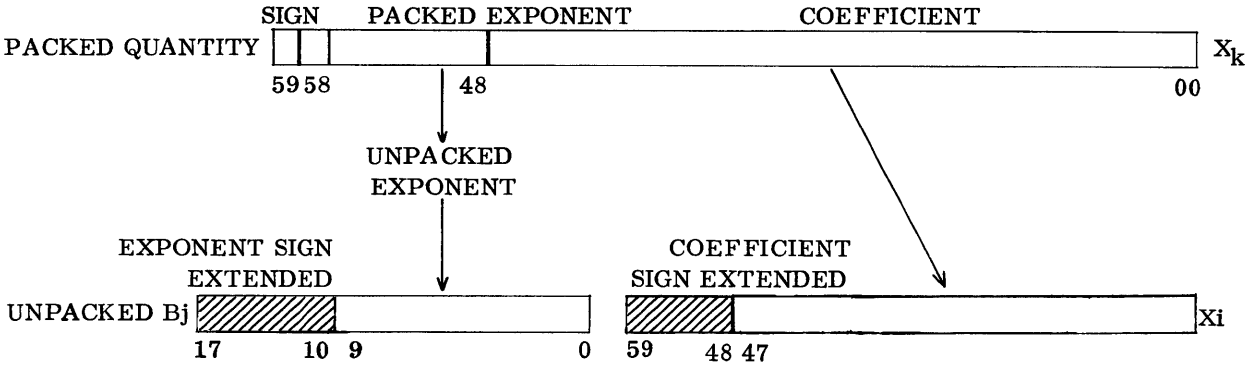
```
25474
25404
25361
```

```
      LOCATION   OPERATION   VARIABLE   COMMENTS
1                11          18         30
           ZX4         X4,B7
           ZX4
           ZX3,B6      X1
```

8.4.30 UNPACK INSTRUCTION

This instruction unpacks the floating point quantity from operand register Xk and sends the 48-bit coefficient to operand register Xi and the 11-bit exponent to index register Bj. The exponent packing is removed during unpack so that the quantity in Bj is the true one's complement representation of the exponent. The contents of Xk need not be normalized.

The exponent and coefficient are sent to the low-order bits of the respective registers as shown below:



Special operand formats are treated in the same manner as normal operands.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
UXi	Xk	Unpack (Xk) to Xi	15 bits	26i0k
UXi	Bj, Xk	Unpack (Xk) to Xi and Bj	15 bits	26ijk
UXi	Xk, Bj	Unpack (Xk) to Xi and Bj	15 bits	26ijk
UXi		Unpack (Xi) to Xi	15 bits	26i0i
UXi	Bj	Unpack (Xi) to Xi and Bj	15 bits	26iji

Example:

Code Generated

```
26777
26342
26707
26777
```

```
      LOCATION   OPERATION   VARIABLE   COMMENTS
1                11          18         30
           UX7         X7,B7
           UX3,X2      B4
           UX7
           UX7         B7
```

8.4.31 PACK INSTRUCTION

This instruction packs a floating point number in operand register Xi. The coefficient of the number is obtained from operand register Xk and the exponent is obtained from index register Bj. The exponent is packed by toggling bit 2^{10} during the pack operation. The instruction does not normalize the coefficient.

Exponent and coefficient are obtained from the proper low-order bits of the respective registers and packed in reverse order as shown in the illustration for the unpack instruction. Thus, bits 58-48 of Xk and bits 17-11 of Bj are ignored. There is no test for overflow or underflow. No flags are set in the PSD register by this instruction.

Note that if (Xk) is positive, the packed exponent occupying Xi_{58-48} is obtained from Bj_{10-00} by complementing bit 10; if (Xk) is negative, bit 10 is not complemented but bits 09-00 are complemented.

The j designator may be set to zero in this instruction to pack a fixed point integer into floating point format without using one of the active B registers (exponent = 0).

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Boolean

Operation	Variable	Description	Size	Octal Code
PXi	Xk	Pack (Xk) to Xi	15 bits	27i0k
PXi	Xk, Bj	Pack (Xk) and (Bj) to Xi	15 bits	27ijk
PXi	Bj, Xk	Pack (Xk) and (Bj) to Xi	15 bits	27ijk
PXi		Pack (Xi) to Xi	15 bits	27i0i
PXi	Bj	Pack (Xi) and (Bj) to Xi	15 bits	27iji

Example:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
27565		PX5	X5,B6	
27671		PX6,B7	X1	
27505		PX5		
27565		PX5	B6	

8.4.32 UNROUNDED SP FLOATING POINT ADD INSTRUCTIONS

These instructions form the unrounded sum or difference of the floating point quantities from operand registers Xj and Xk and pack the result in operand register Xi. The packed result is the upper half of a double precision sum or difference.

At the start both arguments are unpacked, and the coefficient of the argument with the smaller exponent is entered into the upper half of the accumulator. The coefficient is shifted right by the difference of the exponents. The other coefficient is then added to or subtracted from the upper half of the accumulator. If overflow occurs, the result is right-shifted one place and the exponent of the result increased by one. The upper half of the accumulator holds the coefficient of the result, which is not necessarily in normalized form. The exponent and upper coefficient are then repacked in operand register Xi.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Add
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Add

Operation	Variable	Description	Size	Octal Code
FXi	Xj+Xk	Floating point sum of (Xj) and (Xk) to Xi	15 bits	30ijk
FXi	Xj-Xk	Floating point difference of (Xj) minus (Xk) to Xi	15 bits	31ijk

Examples:

Code Generated

```
30745
31213
```

```
      LOCATION   OPERATION   VARIABLE      COMMENTS
1                 11          18            30
      ----------  ----------  ------------  ------------
                  FX3         X4+X5
                  FX2         X1-X3
```

8.4.33 DP FLOATING POINT ADD INSTRUCTIONS

These instructions form the sum or difference of two floating point numbers as in the single precision instructions, but pack the lower half of the double precision result with an exponent 48 less than the upper sum. The result is not necessarily normalized.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Add
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Add

Operation	Variable	Description	Size	Octal Code
DXi	Xj+Xk	Floating DP sum of (Xj) and (Xk) to Xi	15 bits	32ijk
DXi	Xj-Xk	Floating DP difference of (Xj) and (Xk) to Xi	15 bits	33ijk

Examples:

Code Generated

```
32323
33414
```

```
      LOCATION   OPERATION   VARIABLE      COMMENTS
1                 11          18            30
      ----------  ----------  ------------  ------------
                  DX3         X2+X3
                  DX4         X1-X4
```

8.4.34 ROUNDED SP FLOATING POINT ADD INSTRUCTIONS

These instructions form the rounded sum or difference of the floating point quantities from operand registers Xj and Xk and pack the upper portion of the double precision result in operand register Xi. These instructions are intended for use in floating point calculations involving single precision accuracy.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Add
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Add

Operation	Variable	Description	Size	Octal Code
RXi	Xj+Xk	Rounded floating sum of (Xj) and (Xk) to Xi	15 bits	34ijk
RXi	Xj-Xk	Rounded floating difference of (Xj) minus (Xk) to Xi	15 bits	35ijk

Examples:

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
34534		RX5	X3+X4	
35653		RX6	X5-X3	

8.4.35 LONG ADD (FIXED POINT) INSTRUCTIONS

These instructions form the 60-bit one's complement integer sum or integer difference of quantities from operand registers Xj and Xk and store the result in operand register Xi. An overflow condition is ignored.

The instructions are intended for addition or subtraction of integers too large for handling in the increment unit. They are also useful for merging and comparing data fields during data processing.

For an addition, if both operands are zero, the result is zero. If either zero operand is positive zero (all 0's), the result is a positive zero quantity. If both operands are minus zero (all 1's), the result is a negative zero quantity.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Long Add
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Long Add

Operation	Variable	Description	Size	Octal Code
IXi	Xj+Xk	Integer sum of (Xj) and (Xk) to Xi	15 bits	36ijk
IXi	Xj-Xk	Integer difference of (Xj) minus (Xk) to Xi	15 bits	37ijk

Example:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
36545		IX5	X4+X5	
37631		IX6	X3-X1	

8.4.36 UNROUNDED SP FLOATING POINT MULTIPLY INSTRUCTION

This instruction multiplies two floating point quantities obtained from operand registers Xj (multiplier) and Xk (multiplicand) and packs the upper product result in operand register Xi.

In this operation, the exponents of the two operands are unpacked from the floating point format and are added with a correction factor of 48 to form the exponent for the result. The coefficients are multiplied as signed integers to form a 96-bit integer product. The upper half of this product is then extracted to form the coefficient of the result. The result is a normalized quantity only when both operands are normalized; the exponent in this case is the sum of the exponents plus 47 (or 48). The result is not normalized when either or both operands are not normalized.

Formats:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Multiply
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Multiply

Operation	Variable	Description	Size	Octal Code
FXi	Xj*Xk	Floating point product of (Xj) and (Xk) to Xi	15 bits	40ijk

Example:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
40011		FX0	X1*X1	

8.4.37 ROUNDED SP FLOATING POINT MULTIPLY INSTRUCTION

This instruction multiplies the floating point number from operand register Xk (multiplicand), by the floating point number from operand register Xj. The upper product result is packed in operand register Xi. (No lower product is available.) The multiply operation is identical to that of the single precision instruction except that a rounding bit is added in bit position 46 of the 96-bit product. The upper half of the product is then extracted to form the coefficient for the result. An alternate output path is provided with a left shift of one-bit position to normalize the result coefficient if the original operands were normalized and the double precision product has only 95 bits of significance. The exponent for the result is decremented by one count in this case.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Multiply
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Multiply

Operation	Variable	Description	Size	Octal Code
RXi	Xj*Xk	Rounded floating point product of (Xj) and (Xk) to Xi	15 bits	41ijk

Example:

Code Generated

41232

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		RX2	X3*X2	

8.4.38 DP FLOATING POINT MULTIPLY INSTRUCTION

This instruction multiplies two floating point quantities obtained from operand registers Xj and Xk and packs the lower product in operand register Xi. The two 48-bit coefficients are multiplied together to form a 96-bit product. The lower-order 48 bits of this product (bits 47-00) are then packed together with the resulting exponent. The result is not necessarily normalized. The exponent of this result is 48 less than the exponent resulting from an unrounded single precision instruction using the same operands.

This instruction is intended for use in multiple precision floating point calculations. It may also be used to form the product of two integers providing the resulting product does not exceed 48 bits of significance. The operands must be packed in floating point format before executing this instruction. The results must be unpacked to obtain the integer product.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Multiply
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Multiply

Operation	Variable	Description	Size	Octal Code
DXi	Xj*Xk	Floating point DP product of (Xj) and (Xk) to Xi	15 bits	42ijk

Example:

Code Generated

```
42 345
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		DX3	X4 * X5	

8.4.39 INTEGER MULTIPLY INSTRUCTION

The CPU integer multiply instruction is, to COMPASS, synonymous with the double precision floating point multiply instruction. Regardless of how it is written in COMPASS, the 42ijk instruction is executed as follows: If each operand register has all zeros or all ones in its leftmost 12 bits, the 47-bit integer product is formed in Xi with sign extension in its leftmost 12 bits. (Exception: if each operand has bit 2^{47} different from its sign bit, the result is shifted left one bit position.) Otherwise, a double precision floating point multiplication is performed. Thus, there is no need to pack exponents into the operands, and unpack the result, for an integer multiply. COMPASS provides the alternate symbolic representations IXi Xj*Xk and DXi Xj*Xk for the 42ijk instruction as an aid to program readability, so the programmer can indicate whether the instruction is being used for integer multiplication.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Multiply
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Multiply

Operation	Variable	Description	Size	Octal Code
IXi	Xj*Xk	Integer product of (Xj) and (Xk) to Xi	15 bits	42ijk

Example:

Code Generated

```
42234
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		IX2	X3*X4	

8.4.40 MASK INSTRUCTION

This instruction clears register Xi and forms a mask in it. A positive value for expression jk defines the number of 1's in the mask as counted from the highest order bit in Xi. A negative value for expression jk defines the number of 0 bits (unmasked) counted from the low order bit in Xi. The completed masking word consists of 1's in the high order bit positions of the word and 0's in the remainder of the word.

The contents of operand register i are zero when jk is zero. The contents of operand register i are all ones when jk is 60.

This instruction is intended for generating masks for logical operations. Used with the shift instruction, this instruction creates an arbitrary field mask faster than by reading a pre-generated mask from storage.

In COMPASS notation, if the value of absolute expression jk is positive, the assembler inserts it into the jk field of the assembled instruction. If the value of absolute expression jk is negative, the assembler adds 60 to the expression value and places the sum in the jk field of the assembled instruction.

A negative jk value less than -60 results in a 7-type assembly error.

An MXi 0 is the fastest instruction for clearing an X register.

Format: CYBER 70/Model 74 or 6600 Functional Unit: Shift
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Shift

Operation	Variable	Description	Size	Octal Code
MXi	jk	Form mask in Xi, $\pm$ jk bits	15 bits	43ijk

Example:

Code Generated

43042

43360

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		MX0	42B	
		MX3	-14B	

8.4.41 UNROUNDED SP FLOATING POINT DIVIDE INSTRUCTION

This instruction divides two normalized floating point quantities obtained from operand registers Xj (dividend) and Xk (divisor) and packs the quotient in operand register Xi.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Divide
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Divide

Operation	Variable	Description	Size	Octal Code
FXi	Xj/Xk	Floating point divide of (Xj) by (Xk) to Xi	15 bits	44ijk

Example:

Code Generated

```
44631
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      FX6       X3/X1
```

8.4.42 ROUNDED SP FLOATING POINT DIVIDE INSTRUCTION

This instruction divides the floating quantity from operand register Xj (dividend) by the floating point quantity from operand register Xk (divisor) and packs the rounded quotient in operand register Xi.

Format: CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Divide
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Floating Divide

Operation	Variable	Description	Size	Octal Code
RXi	Xj/Xk	Rounded floating point division of (Xj) by (Xk) to Xi	15 bits	45ijk

Example:

Code Generated

```
45724
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
      RX7       X2/X4
```

8.4.43 PASS INSTRUCTION

The no-operation (pass) instruction is not associated with a functional unit. This instruction is a do-nothing instruction used typically to pad the program between steps. An integer value in the variable field (optional) is inserted into the lower 9 bits of the instruction. The assembler automatically pads the remainder of a word whenever a force upper occurs; in this case, the programmer is not required to insert the NO.

Format:

CYBER 70/Model 74 or 6600/6700 Functional Unit: None
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: None

Operation	Variable	Description	Size	Octal Code
NO		Pass	15 bits	46000
NO	n	Pass	15 bits	46n

Example:

Code Generated

```
46000
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
          NO
```

8.4.44 POPULATION COUNT INSTRUCTION

This instruction counts the number of 1 bits in operand register Xk and stores the count in the lower order 6 bits of operand register Xi. Bits 59-06 are cleared.

If Xk is a word of all ones, a count of 60 (decimal) is delivered to the Xi register. If Xk is a word of all zeroes, a zero word is delivered to the Xi register.

The assembler sets the unused j designator to k.

Formats:

CYBER 70/Model 74 or 6600/6700 Functional Unit: Floating Divide
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Population Count

Operation	Variable	Description	Size	Octal Code
CXi	Xk	Count of number of 1's in (Xk) to Xi	15 bits	47ikk

Example:

Code Generated

```
47700
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
          CX7       X0
```

8.4.45 SET A REGISTER INSTRUCTIONS

These instructions are intended for fetching operands from storage for computation and for delivering results back into storage. The instructions have two destination registers: the Ai register which receives the address formed from the operands and either the Xi register or a CM (SCM) storage location.

If the i designator is nonzero, a storage reference is made using the lower 15, 16, or 17 bits of the resulting sum or difference as the relative storage address depending on machine size. The upper bits are ignored. The type of storage reference is a function of the i designator value.

i = 0; no storage reference

i = 1, 2, 3, 4, or 5; contents of CM (SCM) relative address (Ai) to register Xi

i = 6 or 7; contents of register Xi stored at CM (SCM) relative address (Ai)

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Increment
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Increment

Operation	Variable	Description	Size	Octal Code
SAi	Aj+K	Set Ai to (Aj) ± K	30 bits	50ijK
SAi	K	Set Ai to K	30 bits	51i0K
SAi	Bj+K	Set Ai to (Bj) ± K	30 bits	51ijK
SAi	Xj+K	Set Ai to (Xj) ± K	30 bits	52ijK
SAi	Xj	Set Ai to (Xj)	15 bits	53ij0
SAi	Xj+Bk	Set Ai to (Xj) + (Bk)	15 bits	53ijk
SAi	Bk+Xj	Set Ai to (Xj) + (Bk)	15 bits	53ijk
SAi	Aj	Set Ai to (Aj)	15 bits	54ij0
SAi	Aj+Bk	Set Ai to (Aj) + (Bk)	15 bits	54ijk
SAi	Bk+Aj	Set Ai to (Aj) + (Bk)	15 bits	54ijk
SAi	Aj-Bk	Set Ai to (Aj) - (Bk)	15 bits	55ijk
SAi	-Bk+Aj	Set Ai to (Aj) - (Bk)	15 bits	55ijk
SAi	Bj	Set Ai to (Bj)	15 bits	56ij0
SAi	Bj+Bk	Set Ai to (Bj) + (Bk)	15 bits	56ijk
SAi	-Bk	Set Ai to (B0) - (Bk)	15 bits	57i0k
SAi	Bj-Bk	Set Ai to (Bj) - (Bk)	15 bits	57ijk
SAi	-Bk+Bj	Set Ai to (Bj) - (Bk)	15 bits	57ijk

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
5010000001		SA1	A0+1	
5100777774		SA0	-3	
5121000003		SA2	3+B1	
5231777771		SA3	X1-6	
53411		SA4	X1+B1	
54541		SA5	A4+B1	
54641		SA6	A4+B1	
54540		SA5	A4	
55641		SA6	-B1+A4	
56711		SA7	B1+B1	
57721		SA7	B2-B1	

8.4.46 SET B REGISTER INSTRUCTIONS

These instructions perform one's complement addition and subtraction of 18-bit operands and store an 18-bit result in index register Bi.

Operands are obtained from address (A), index (B), and operand (X) registers as well as from the instruction itself (K = 18-bit operand). Operands obtained from an Xj operand register are the truncated lower 18 bits of the 60-bit word. The highest order bits are ignored; an overflow condition is also ignored.

If the i designator is a zero, the instruction is a do-nothing instruction.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Increment
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Increment

Operation	Variable	Description	Size	Octal Code
SBi	Aj+K	Set Bi to (Aj) ± K	30 bits	60ijK
SBi	K	Set Bi to K	30 bits	61i0K
SBi	Bj+K	Set Bi to (Bj) ± K	30 bits	61ijK
SBi	Xj+K	Set Bi to (Xj) ± K	30 bits	62ijK
SBi	Xj	Set Bi to (Xj)	15 bits	63ij0
SBi	Xj+Bk	Set Bi to (Xj) + (Bk)	15 bits	63ijk
SBi	Bk+Xj	Set Bi to (Xj) + (Bk)	15 bits	63ijk
SBi	Aj	Set Bi to (Aj)	15 bits	64ij0
SBi	Aj+Bk	Set Bi to (Aj) + (Bk)	15 bits	64ijk
SBi	Bk+Aj	Set Bi to (Aj) + (Bk)	15 bits	64ijk
SBi	Aj-Bk	Set Bi to (Aj) - (Bk)	15 bits	65ijk
SBi	-Bk+Aj	Set Bi to (Aj) - (Bk)	15 bits	65ijk
SBi	Bj	Set Bi to (Bj)	15 bits	66ij0
SBi	Bj+Bk	Set Bi to (Bj) + (Bk)	15 bits	66ijk
SBi	-Bk	Set Bi to (B0) - (Bk)	15 bits	67i0k
SBi	Bj-Bk	Set Bi to (Bj) - (Bk)	15 bits	67ijk
SBi	-Bk+Bj	Set Bi to (Bj) - (Bk)	15 bits	67ijk

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
6011777772		SB1	A1-5	
6110777772		SB1	-5	
6121000011		SB2	3+B1+6	
6231000100		SB3	X1+100B	
63427		SB4	X2+B7	
64541		SB5	A4+B1	
64540		SB5	A4	
65641		SB6	-B1+A4	
65643		SB6	A4-B3	
66711		SB7	B1+B1	
67751		SB7	B5-B1	

8.4.47 SET X REGISTER INSTRUCTIONS

The SXi instructions perform one's complement addition and subtraction of 18-bit operands and store an 18-bit result into the lower 18 bits of operand register Xi. The sign of the result is extended to the upper 42 bits of operand register Xi. An overflow condition is ignored.

Operands are obtained from address (A), index (B), and operand (X) registers as well as the instruction itself (K = 18-bit operand). Operands obtained from an Xj register are the truncated lower 18 bits of the 60-bit word. The highest order bits are ignored.

Formats: CYBER 70/Model 74 or 6600/6700 Functional Unit: Increment
CYBER 170/Model 175, CYBER 70/Model 76 or 7600 Functional Unit: Increment

Operation	Variable	Description	Size	Octal Code
SXi	Aj+K	Set Xi to (Aj) ± K	30 bits	70ijK
SXi	K	Set Xi to K	30 bits	71i0K
SXi	Bj+K	Set Xi to (Bj) ± K	30 bits	71ijK
SXi	Xj+K	Set Xi to (Xj) ± K	30 bits	72ijK
SXi	Xj	Set Xi to (Xj)	15 bits	73ij0
SXi	Xj+Bk	Set Xi to (Xj) + (Bk)	15 bits	73ijk
SXi	Bk+Xj	Set Xi to (Xj) + (Bk)	15 bits	73ijk
SXi	Aj	Set Xi to (Aj)	15 bits	74ij0
SXi	Aj+Bk	Set Xi to (Aj) + (Bk)	15 bits	74ijk
SXi	Bk+Aj	Set Xi to (Aj) + (Bk)	15 bits	74ijk
SXi	Aj-Bk	Set Xi to (Aj) - (Bk)	15 bits	75ijk
SXi	-Bk+Aj	Set Xi to (Aj) - (Bk)	15 bits	75ijk
SXi	Bj	Set Xi to (Bj)	15 bits	76ij0
SXi	Bj+Bk	Set Xi to (Bj) + (Bk)	15 bits	76ijk
SXi	-Bk	Set Xi to (B0) - (Bk)	15 bits	77i0k
SXi	Bj-Bk	Set Xi to (Bj) - (Bk)	15 bits	77ijk
SXi	-Bk+Bj	Set Xi to (Bj) - (Bk)	15 bits	77ijk

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
7000005233 +		SX0	BNEG+A0+1	
7110775755		SX1	-2022B	
7121000005		SX2	B1+5	
7233777744		SX3	X3-33B	
73442		SX4	X4+B2	
74553		SX5	A5+B3	
74540		SX5	A4	
75641		SX6	-B1+A4	
75604		SX6	A0-B4	
76776		SX7	B7+B6	
77751		SX7	B5-B1	

8.5 CMU SYMBOLIC MACHINE INSTRUCTIONS

The Compare/Move Unit (CMU) is a standard CPU hardware component of the CYBER 70 Series Model 72 and Model 73, and the CYBER 170/Models 172, 173 and 174. It provides CPU instructions for moving and comparing data fields that consist of strings of 6-bit characters. Data fields can span word boundaries and can begin and end at any character position within a word. A data field is specified by its length in characters and the location of its leftmost character (according to word address and character position). Data fields cannot be in the operating registers nor in ECS.

Each 60-bit word of a data field contains 10 character positions numbered 0 to 9 from left to right (high order to low order).

COMPASS provides symbolic forms of the four CMU instructions plus a pseudo instruction used to generate a descriptor word to be referenced by the indirect move instruction. Of the four instructions, the indirect move (IM) instruction is the only one that syntactically resembles other CPU instructions. The other three instructions have formats dissimilar to CPU instructions and are generated through COMPASS pseudo instructions. All of these instructions must begin at the top of a 60-bit word; COMPASS automatically forces upper before each of them unless the location field contains a minus sign. All but IM are 60 bits in length. IM is 30 bits, but the hardware requires that the instruction be in the upper half of its word. The lower half of the word is not executed. COMPASS automatically forces upper following IM, unless the next instruction has a minus sign in its location field.

8.5.1 IM - INDIRECT MOVE

The indirect move instruction moves the contents of a data field to another location. It is a 30-bit instruction that specifies the address of a descriptor word which, in turn, contains the length and address of the data fields.

The descriptor word is fetched from storage location (Bj)+ K. If the data field length is zero, the instruction is executed as a pass but the execution time is longer. Otherwise, the content of the source field is moved to the destination field. If the two fields overlap, the results are undefined. The X0 register is used for intermediate storage during execution of the instruction, and is cleared upon completion of the instruction.

Operation	Variable	Description	Octal Code
IM	K	Move data according to word at K	4640K
IM	Bj±K	Move data according to word at (Bj)± K	464jK
IM	Bj	Move data according to word at (Bj)	464j 000000

8.5.2 MD - INDIRECT MOVE DESCRIPTOR WORD

The MD pseudo instruction generates a descriptor word for use by the indirect move (IM) instruction.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	MD	ℓ, k_s, c_s, k_d, c_d

sym — If present, sym is assigned the value of the location counter after the force upper occurs. It becomes the symbolic address of the descriptor word.

ℓ — Absolute address expression specifying the field length in characters (0-8191). The upper 9 bits (ℓ) are placed in bits 56-48 of the descriptor word; the lower 4 bits (ℓ) are placed in bits 29-26.

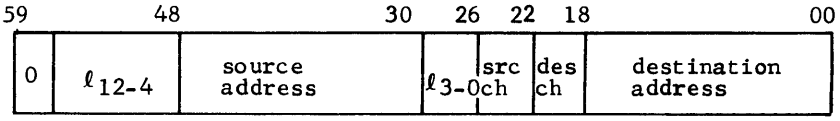
k_s — An expression specifying the first word address of the source field in CM/SCM.

c_s — An absolute expression (0-9) specifying the starting character position of the source field within the word at location k_s. Characters are numbered from left to right.

k_d — An expression specifying the first word address of the destination field in CM/SCM.

c_d — An absolute expression (0-9) specifying the starting character position of the destination field within the word at location k_d.

Indirect Move Descriptor Word format:



Example:

Code Generated

```
                                  LOCATION   OPERATION   VARIABLE          COMMENTS
                                  1          11          18                30
                                  |          |           |                 |
00760050004005a07000              DWORD      MD          1000,BUFFA,0,BUFFB,5
                                                         |
                                                         |
                                                         |
4640010665                                   IM          DWORD
                                                         |
```

BUFFA is at address 2000; BUFFB is at address 3000

8.5.3 DM - DIRECT MOVE

The direct move (DM) pseudo instruction generates a CMU instruction that moves the contents of a data field to another data field. The machine instruction occupies one full word and cannot be split between words. The instruction includes its own data field descriptor.

If the data field length is zero, the instruction is executed as a pass, but the execution time is longer. Otherwise, the contents of the source field are moved to the destination field. If the two fields overlap, the results are undefined. The X0 register is used for intermediate storage during execution of the instruction and is cleared upon completion of the instruction.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	DM	ℓ, k_s, c_s, k_d, c_d

sym — If present, sym is assigned the value of the location counter after the force upper occurs. It becomes the symbolic address of the instruction word.

ℓ — Absolute address expression specifying the field length in characters (0-127).

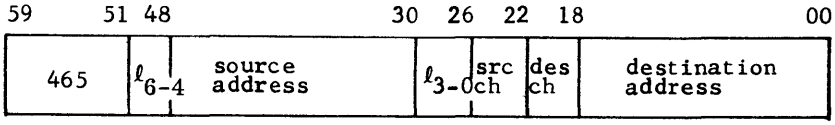
k_s — An expression specifying the first word address of the source field in CM/SCM.

c_s — An absolute expression (0-9) specifying the starting character position of the source field within the word at location k_s.

k_d — An expression specifying the first word address of the destination field in CM/SCM.

c_d — An absolute expression (0-9) specifying the starting character position of the destination field within the word at location k_d. Characters are numbered from left to right.

Octal format of instruction:



Example:

Code Generated

```
4657005006743500700C
```

```
      LOCATION  OPERATION  VARIABLE              COMMENTS
1                 11        18                    30
                  CM        127,BUFFA,C,BUFFB,5
```

8.5.4 CC - COMPARE COLLATED

The compare collated (CC) pseudo instruction generates a CMU instruction that compares the contents of two data fields, one character at a time, from left to right, until a pair of corresponding characters is found to have unequal collating values or until the data fields are exhausted. It is a 60-bit instruction that occupies one full word. It cannot be split between two words. The instruction includes its own data field descriptor. Register A0 contains the first word address of a table in storage that contains the collating values to be used in comparing characters. The result of the comparison is placed in register X0.

The first word address of the collating table is obtained from register A0. The contents of the data fields are compared from left to right, one character at a time from each field, until two unequal characters are found. The collating value of each character is obtained from the collating table. If these values are equal, the compare continues until another character pair is unequal or until all characters have been compared. If the collating values are unequal, the two data fields are unequal and the field with a larger collating value is the greater of the two fields. The collating values are treated as 6-bit unsigned integers. Note that two unequal characters could have the same collating value and would compare equal.

Upon instruction completion, register X0 contains a 60-bit signed integer as follows:

(Field A)>(Field B)	$(X0) = \ell - n > 0$
(Field A)= (Field B)	$(X0) = 0$
(Field A)<(Field B)	$(X0) = n - \ell < 0$

n is the number of pairs of characters that compared equal. If $\ell = 0$, then (X0) is 0.

The format of the collating table for six-bit characters is:

	59	53	47	41	35	29	23	27	11	0
(A0)	00	01	02	03	04	05	06	07		
(A0)+1	10	11	12	13	14	15	16	17		
⋮										
(A0)+7	70	71	72	73	74	75	76	77		

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	CC	ℓ, k_a, c_a, k_b, c_b

sym — If present, sym is assigned the value of the location counter after the force upper occurs. It becomes the symbolic address of the instruction.

ℓ — Absolute address expression specifying the field length in characters (0 - 127)

k_a — An expression specifying the first word address of the first data field in CM.

c_a — An absolute expression specifying the starting character position of the first data field within the word at location k_a. Characters are numbered from left to right.

k_b — An expression specifying the first word address of the second data field in CM.

c_b — An absolute expression (0-9) specifying the starting character position of the second data field within the word at location k_b.

Octal format of instruction:

59 51	48 30	26 22	18 00
466	ℓ_{6-4} first string address	ℓ_{3-0} fs ch	ss ch second string address

Example:

Code Generated

```
5100003120
4667005000740500 7000
```

	LOCATION	OPERATION	VARIABLE	COMMENTS
1		11	18	30
		SA0	TABLE	
		CC	127,BUFFA,0,BUFFB,5	

8.5.5 CU - COMPARE UNCOLLATED

The compare uncollated (CU) pseudo instruction generates a CMU instruction that compares the contents of two data fields, one character at a time, from left to right, until a pair of corresponding characters are found to have unequal values or until the data fields are exhausted. The machine instruction is a 60-bit instruction that occupies one full word and cannot be split between two words. It includes its own data field descriptor. The result of the comparison is placed in register X0.

Execution resembles the CC instruction except that A0 and the collating table are not used. Instead, the characters are compared directly with each character regarded as a 6-bit unsigned binary integer. Register X0 is set in the same manner as by the CC instruction.

Format:

LOCATION	OPERATION	VARIABLE SUBFIELDS
sym	CU	ℓ, k_a, c_a, k_b, c_b

sym — If present, sym is assigned the value of the location counter after the force upper occurs. It becomes the symbolic address of the instruction.

ℓ — Absolute address expression (0-127) specifying the field length in characters.

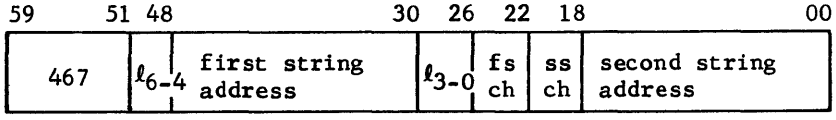
k_a — An expression specifying the first word address of the first data field in CM.

c_a — An absolute expression (0-9) specifying the starting character position of the first data field within the word at location k_a. Characters are numbered from left to right.

k_b — An expression specifying the first word address of the second data field in CM.

c_b — An absolute expression (0-9) specifying the starting character position of the second data field within the word at location k_b.

Octal format of Instruction:



Example:

Code Generated

```
467700500074050007000
```

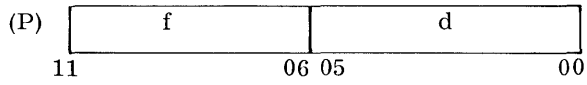
```
      LOCATION  OPERATION  VARIABLE          COMMENTS
1                11         18                30
                  CU         127,BUFFA,0,BUFFB,5
```

PPU SYMBOLIC MACHINE INSTRUCTIONS 9

The COMPASS assembler recognizes symbolic notation for peripheral processor unit (PPU) instructions. When a PPU or PERIPH pseudo instruction is in the first statement group, the assembler identifies each symbolic instruction by name and generates a one word (12 bit) or two word (24 bit) object code machine instruction under control of the current origin, location, and position counters. All PPU code is absolute. Numeric data must be in integer notation. Floating point notation is illegal.

9.1 MACHINE INSTRUCTION FORMATS

An assembled instruction has a 12-bit or 24-bit format. The 12-bit format has a 6-bit operation code f and a 6-bit operand d. A PPU accomplishes program indexing and manipulates operands in several modes. The 12-bit and 24-bit instruction formats provide for 6-bit, 12-bit, or 18-bit operands and 6-bit or 12-bit addresses. Figures 9-1 and 9-2 illustrate the 12-bit instruction format and the 24-bit instruction format, respectively.



Direct Mode:

d = memory address of operand

Indirect Mode:

d = memory address of the address of the operand

No Address Mode:

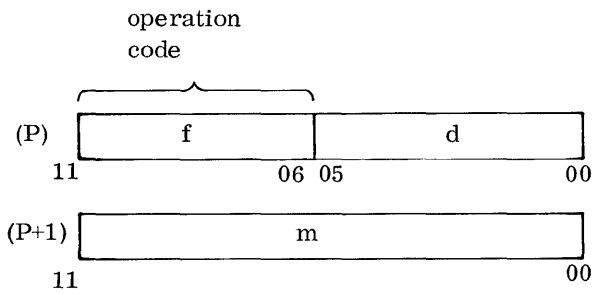
d = 6-bit operand, shift count, or relative address

Other:

d = special value; e.g., channel designator

Figure 9-1. PPU 12-bit Instruction Format

The 24-bit format uses the 12-bit quantity m, which is the contents of the next program address (P + 1), with d or the contents of d to form an 18-bit operand or a 12-bit operand address.



Indexed Mode:

d = address of the index for modifying the address of the operand

m = base address of the operand

(d) + m = address of operand

Constant Mode:

dm = 18-bit operand

Other:

dm = special values; e.g., d = channel designator and m = 12-bit address of word count on IAM and OAM instructions

Figure 9-2. PPU 24-bit Instruction Format

9.2 SYMBOLIC NOTATION

This section describes notation used for coding symbolic PPU machine instructions. Instructions are described in octal operation code sequence which generally reflects the mode of addressing. Instructions unique to a computer system are identified as such.

The location field of a symbolic PPU machine instruction optionally contains a location symbol. When the symbol is present, it is assigned the value of the location counter.

The operation field of a symbolic PPU machine instruction contains a three-character name.

The variable field contains one or two subfields. Each subfield contains an absolute or relocatable expression that reduces to a 6-bit, 12-bit, or 18-bit value.

Designators used in this section are listed in Table 9-1.

Generally, the third character of the instruction mnemonic (N, D, M, C, or I) indicates the mode of addressing:

- N No operand address reference
- D Direct operand address: d contains operand
- M Memory address m or m + (d) contains operand
- C 18-bit constant
- I Indirect; operand address is (d)

TABLE 9-1. PERIPHERAL PROCESSOR INSTRUCTION DESIGNATORS

Designator	Use
A	18-bit A register
c	An expression that reduces to an 18-bit operand value.
d	A 6-bit operand or operand address expression.
m	A 12-bit expression value used with d or (d) to form an 18-bit operand or 12-bit operand address.
P	12-bit Program Address register
Q	12-bit Q register
r	An expression that reduces to a 6-bit value ($-37_8 \leq r \leq 37_8$) specifying relative address or shift count
( )	Contents of a register or location
(( ))	Refers to indirect addressing

Some of the instructions provide similar functions using different modes of addressing. They can be grouped according to function as shown below:

Function	Description
Data transmission	The following instructions either load data into the A register or store data from it. A load instruction loads a 6-bit, 12-bit, or 18-bit value as indicated by the instruction; any remaining upper bits of A are zeroed, except for the LCN instruction for which remaining bits are set to one. A store instruction stores the lower 12 bits of the A register contents into a memory location indicated by the instruction. The contents of A are not altered.

Instruction	Octal Code	Section
LDN	14	9.2.3
LCN	15	9.2.3
LDC	20	9.2.4
LDD	30	9.2.9
STD	34	9.2.9
LDI	40	9.2.10
STI	44	9.2.10
LDM	50	9.2.11
STM	54	9.2.11

Function (cont'd)	Description (cont'd)

Arithmetic

A PPU arithmetic instruction adds or subtracts a 6-bit, 12-bit, or 18-bit quantity from the contents of the A register and enters the result in A.

Instruction	Octal Code	Section
ADN	16	9.2.3
SBN	17	9.2.3
ADC	21	9.2.4
ADD	31	9.2.6
SBD	32	9.2.6
ADI	41	9.2.7
SBI	42	9.2.7
ADM	51	9.2.8
SBM	52	9.2.8

Logical

A logical instruction forms a logical value in A using the contents of A as one of the operands and a 6-bit, 12-bit, or 18-bit value indicated by the instruction as the second operand. When the second operand is fewer than 18 bits, the remaining upper bits of A are unaltered, except for the LPN instruction for which the upper 12 bits are zeroed.

Formation of a logical difference is equivalent to setting each bit in A that is unlike the corresponding bit in the second operand. For example,

```
Initial (A)    =0101
Operand        =1100
Final (A)      =1001
```

Formation of a logical product is equivalent to setting a bit in A when the original setting of the bit in A and the corresponding bit in the second operand are both one's.

For example,

```
Initial (A)    =0101
Operand        =1100
Final (A)      =0100
```

A selective clear sets a bit zero in the A register wherever a bit is set in the second operand. For example,

```
Initial (A)    =0101
Operand        =1100
Final (A)      =0001
```

Function (cont'd)	Description (cont'd)

Logical (cont'd)

Logical instructions include the following:

Instruction	Octal Code	Section
LMN	11	9.2.3
LPN	12	9.2.3
SCN	13	9.2.3
LPC	22	9.2.4
LMC	23	9.2.4
LMD	33	9.2.9
LMI	43	9.2.10
LMM	53	9.2.11

Replace

A replace instruction performs an arithmetic operation and returns the results to the A register and the memory location from which one operand was obtained. The lower 12 bits of the result replaces the operand obtained from a memory location.

Instruction	Octal Code	Section
RAD	35	9.2.9
AOD	36	9.2.9
SOD	37	9.2.9
RAI	45	9.2.10
AOI	46	9.2.10
SOI	47	9.2.10
RAM	55	9.2.11
AOM	56	9.2.11
SOM	57	9.2.11

9.2.1 BRANCH INSTRUCTIONS

For branch instructions, the r subfield is a numeric value that indicates the number of locations to be jumped (maximum 31). When r is positive ($01-37_8$), the jump is forward r locations. When r is negative (76_8-40_8), the jump is backward 77_8-r locations. In the following tests, negative zero (777777) is nonzero. For conditional instructions, when the test condition is true, the jump takes place. When the condition is not met, execution continues with the next instruction.

CAUTION

The jump count must not be 00 or 77. If it is, execution loops on the jump instruction.

The J option of the PPU instruction (Section 4.3.3) and the PERIPH instruction (Section 4.3.4) cause the value of the location counter to be subtracted from the value of the symbolic address (tag) before it is placed in the d field of the object code instruction.

Formats:

Operation	Variable	Description	Size	Octal Code
LJM	m,d	Long jump to m+(d); if d = 0, m is not modified	24 bits	01dm
RJM	m,d	Return jump to m+(d); Store P+2 at m+(d) and jump to m+(d)+1.	24 bits	02dm
UJN	r†	Unconditional jump to P± r locations	12 bits	03d
UJN	tag	Unconditional jump to tag	12 bits	03d
ZJN	r†	Zero jump; jump to P±r locations if (A) = 0	12 bits	04d
ZJN	tag	Zero jump to tag	12 bits	04d
NJN	r†	Nonzero jump; jump to P±r locations if (A) ≠ 0	12 bits	05d
NJN	tag	Nonzero jump to tag	12 bits	05d
PJN	r†	Positive jump; jump to P±r locations if (A)≥0	12 bits	06d
PJN	tag	Positive jump to tag	12 bits	06d
MJN	r†	Minus jump; jump to P±r locations if (A)< 0	12 bits	07d
MJN	tag	Minus jump to tag	12 bits	07d

†If PPU J or PERIPH J option has been selected, r is not valid. The contents of the variable field must be a symbolic address (tag).

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
0100 1362		LJM	START	
0271 0000		PJM	0,CTO	
0371		UJN	TAG1-*	
0404		ZJN	+4	
0525		NJN	TAG3	
0667		PJN	TAG2-*	
0726		MJN	TAG4	

In the above examples, the LJM instruction is at address 0014_8. TAG1 is address 0012_8, TAG2 has a value of 13_8, TAG3 has a value of 25_8, and TAG4 has a value of 26_8.

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
		PPU	J	
0347		UJN	TAG1	
0404		ZJN	TAG3	In this example, the UJN is at address 0040. TAG1 is address 0010, TAG2 is 0011, TAG3 is address 0045, and TAG4 is address 0046.
0556		NJN	TAG2+10	
0602		PJN	-1+TAG4	
0743		MJN	TAG1	

9.2.2 SHIFT INSTRUCTION

The SHN instruction shifts the contents of the A register right or left r places. If r is positive (+1 to +31), the shift is left circular r places; if r is negative (-31 to -1), the shift is end off r places to the right with no sign extension. No shift takes place when r is ± 0. The assembler places the value of the r expression in the d field. If -31 >r >31 , the assembler generates an address error.

Format:

Operation	Variable	Description	Size	Octal Code
SHN	r	Shift (A) by + (left) or - (right) r bits	12 bits	10d

Examples:

1. Shift contents of A left circular 6 places

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
1006		SHN	6	

2. Shift contents of A right end off 6 places

Code Generated

	LOCATION	OPERATION	VARIABLE	COMMENTS
			6	
1071	SCNT	SCT	6	
		SHN	-SCNT	

9.2.3 NO ADDRESS MODE INSTRUCTIONS

In this mode, during instruction execution, the contents of the d field are interpreted as a 6-bit positive operand. This mode eliminates the need for storing many constants in core.

Formats:

Operation	Variable	Description	Size	Octal Code
LMN	d	Logical difference (A)-d→A	12 bits	11d
LPN	d	Logical product (A)*d →A	12 bits	12d
SCN	d	Selective clear (A)	12 bits	13d
LDN	d	Load d→A	12 bits	14d
LCN	d	Load complement d→A	12 bits	15d
ADN	d	Add (A)+d→A	12 bits	16d
SBN	d	Subtract (A)-d→A	12 bits	17d

Examples:

Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
		1	11	18	30
1112			LMN	12B	
1207			LPN	7	
1321			SCN	21B	
	15	AA	SET	15B	
1415			LDN	AA	
1514			LCN	AA-1	
1601			ADN	1	
1702			SBN	2	

9.2.4 CONSTANT MODE INSTRUCTIONS

In this mode, during instruction execution, the contents of the d and m fields are taken directly as an operand. This mode also eliminates the need for storing many constants. The assembler reduces absolute or relocatable expression c to an 18-bit value and stores the upper six bits in d and the lower 12 bits in m.

Format:

Operation	Variable	Description	Size	Octal Code
LDC	c	Load c →A	24 bits	20dm
ADC	c	Add (A)+c →A	24 bits	21dm
LPC	c	Logical product (A)*c →A	24 bits	22dm
LMC	c	Logical difference (A)-c →A	24 bits	23dm

Examples:

Code Generated

```
2070 7070
                0
2177 7776
2207 0707
             70707
2307 0707
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS
| 1 |          | 11        | 18       | 30
|  |          | LDC       | 7070707
|  | VAL      | =         | 0
|  |          | ADC       | VAL-1
|  |          | LPC       | 0707070
|  | MASK     | SET       | 0707070
|  |          | LMC       | MASK
```

9.2.5 NO OPERATION INSTRUCTION

The PSN instruction specifies that no operation is to be performed. It provides a means of padding a program.

Format:

Operation	Variable	Description	Size	Octal Code
PSN		No operation (Pass)	12 bits	2400

Example:

Code Generated

```
2400
```

```
|  | LOCATION | OPERATION | VARIABLE | COMMENTS
| 1 |          | 11        | 18       | 30
|  |          | PSN       |
```

Other octal operation codes (not generated by COMPASS) that act as pass instructions are:

CYBER 170 Series, CYBER 70/ Models 72, 73, 74 and 6000 Series	CYBER 70/Model 76 and 7600
00	25
25	26
	27
	75
	76

9.2.6 EXCHANGE JUMP INSTRUCTIONS (CYBER 170 SERIES, CYBER 70/MODEL 72, 73, 74, AND 6000 SERIES)

The EXN instruction transmits an 18-bit (absolute) address of which only 17 bits are used from the A register to the CPU with a signal notifying the CPU to execute an exchange jump. The address in A is the starting location of the 16-word exchange package which contains information about the CPU program to be executed. The 18-bit initial address must be entered in A before the EXN instruction is executed. The CPU replaces the file with similar information from the interrupted CPU program. The PPU is not interrupted.

The MXN instruction conditionally exchange jumps to the CPU and initiates CPU monitor activity. If the monitor flag bit is clear, this instruction sets the flag and initiates the exchange. If the monitor flag bit is set, this instruction acts as a pass instruction. The starting address for this exchange is the 18-bit address in the PPU A register. This address must be entered in A before the MXN instruction is executed.

Execution of MAN resembles MXN. However, the exchange package address is taken from the 18-bit Monitor Address (MA) register in CPU d, rather than from the PPU A register.

In a system with dual central processors, d can be 0 or 1 and specifies which CPU the exchange jump will interrupt. In single processor systems, this value is not interpreted.

Formats:

Operation	Variable	Description	Size	Octal Code
EXN	d	Exchange jump to CPU d	12 bits	260d
MXN	d	Monitor exchange jump CPU d to (A)	12 bits	261d
MAN †	d	Monitor exchange jump CPU d to (MA)	12 bits	262d

† CYBER 170 Series and CYBER 70/Models 72, 73 and 74 only.

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
2601		EXN	1	
2610		MXN	0	
2623		MAN	3	

9.2.7 READ PROGRAM ADDRESS INSTRUCTION (CYBER 170 SERIES , CYBER 70/MODELS 72, 73, 74 OR 6000 SERIES)

This instruction transfers the contents of the CPU P register to the PPU A register; this allows the PPU to determine whether the CPU is in execution. In a dual central processor system, the lowest order bit of the instruction format specifies which CPU P register is to be examined. This bit is not interpreted for a single central processor system. The largest value that (P) can be is 17 bits. An ECS transfer is in progress when bit 17 of this instruction is set; however, bit 17 of the P register is not set.

Format:

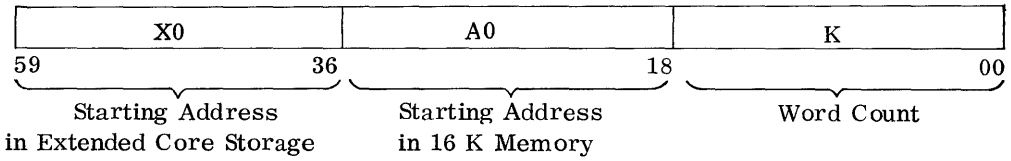
Operation	Variable	Description	Size	Octal Code
RPN	d	Read program address CPU d → A	12 bits	270d

Example:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
2700		RPN		

9.2.8 6416 PPU INSTRUCTIONS

COMPASS assembles the following instructions for execution on a 6416 computer system only. The ETN instruction initiates memory transfer operations by transmitting an 18-bit address from the PPU A register to the 6416 16K memory. This address points to a word having the following format:



Expression d of this instruction specifies the transfer to be performed:

If d is 0, K words are transferred from ECS to 16K memory.

If d is 1, K words are transferred from 16K memory to ECS.

Note that addresses contained in the word are absolute addresses. Operating systems may require relocation (adding RA to an address) and field length testing, e. g., Is address + RA FL? The Exchange Jump package contains RA and FL values for central memory and for extended core storage. The 6416 has no hardware for automatic relocation and field length testing; it is therefore incumbent upon the program to perform these functions whenever required by an operating system.

The ERN instruction examines the status of the data trunk between 16K memory and the extended core coupler. If the data trunk is busy (a transfer is in progress), a 1 is placed in the most significant bit position of the A register. If the trunk is free (not busy), the A register remains cleared. The d portion of this instruction is ignored.

After execution of this instruction the program would typically test the A register for a sign before executing an instruction that initiates an ECS operation.

Formats:

Operation	Variable	Description	Size	Octal Code
ETN	d	Extended core transfer	12 bits	260d
ERN	d	Read extended core coupler status	12 bits	270d

Examples:

Code Generated

```
2600
2700
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
      1         11         18        30
          ETN
          ERN
```

9.2.9 DIRECT ADDRESS MODE INSTRUCTIONS

In this mode, during instruction execution, the contents of the d field specify the address of the operand. During assembly, the assembler reduces absolute or relocatable expression d to a 6-bit value that specifies one of the first 100_8 addresses in core memory (0000 - 0077_8). During instruction execution, (d) is treated as a positive 12-bit quantity.

Format:

Operation	Variable	Description	Size	Octal Code
LDD	d	Load (d)→A	12 bits	30d
ADD	d	Add (A) + (d)→A	12 bits	31d
SBD	d	Subtract (A) - (d)→A	12 bits	32d
LMD	d	Logical difference (A) and (d) →A	12 bits	33d
STD	d	Store (A)→d	12 bits	34d
RAD	d	Replace add (d) + (A)→d and A	12 bits	35d
AOD	d	Replace add (d) + 1→d and A	12 bits	36d
SOD	d	Replace subtract one (d) - 1→d and A	12 bits	37d

Examples:

Code Generated

```
3012
3103
3240
3327
3401
3555
3612
3713
```

```
      LOCATION  OPERATION  VARIABLE      COMMENTS
1               11         18            30
      LDD       TAG1
      ADD       TAG2-100
      SBD       400
      LMD       TAG1+15B
      STD       1
      RAD       55B
      AOD       TAG1
      SOD       TAG2
```

9.2.10 INDIRECT ADDRESS MODE INSTRUCTIONS

In this mode, during instruction execution, d specifies an address, the contents of which specify the address of the desired operand. Thus, d specifies the operand address indirectly.

During assembly, the assembler reduces absolute or relocatable expression d to a 6-bit value that specifies one of the first 100_8 addresses in core memory (0000 - 0077_8).

On the 7600 (or CYBER 70/Model 76), the address formed permits referencing of all memory locations but one (0000 - 7776_8).

On a 6000 Series Computer System (as well as CYBER 170 Series or CYBER 70/Model 72, 73 or 74) PPU, the address formed in indirect address mode permits referencing of all memory locations, including address 7777_8.

Formats:

Operation	Variable	Description	Size	Octal Code
LDI	d	Load ((d))→A	12 bits	40d
ADI	d	Add (A) + ((d))→A	12 bits	41d
SBI	d	Subtract (A) - ((d))→A	12 bits	42d
LMI	d	Logical difference (A) - ((d))→A	12 bits	43d
STI	d	Store (A)→(d)	12 bits	44d
RAI	d	Replace add ((d)) + (A)→(d) and A	12 bits	45d
AOI	d	Replace add one ((d)) + 1→(d) and A	12 bits	46d
SOI	d	Replace subtract one ((d)) - 1→(d) and A	12 bits	47d

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
4012		LDI	TAG1	
4103		ADI	TAG2-10	
4240		SBI	40B	
4327		LMI	TAG1+15B	
4401		STI	1	
4555		RAI	55B	
4612		AOI	TAG1	
4713		SOI	TAG2	

9.2.11 INDEXED DIRECT ADDRESS MODE INSTRUCTIONS

In this mode, during instruction execution, the value formed by m+(d) is used as the address of the operand. During assembly, the assembler reduces absolute or relocatable expression d to a 6-bit value that specifies one of the first 100_8 addresses in core memory (0000 - 0077_8). The value of absolute or relocatable expression m is a 12-bit base address.

NOTE

The address formed in indexed addressing permits referencing of all memory locations but one ($0000-7776_8$). Although m and/or (d) can have a value of 7777_8, the computer system does not permit m+(d) to reference address 7777_8.

When in indexed direct address mode, if d is nonzero the contents of address d are added to m to produce a 12-bit operand address (indexed addressing). If d is zero, m is taken as the operand address.

Formats:

Operation	Variable	Description	Size	Octal Code
LDM	m,d	Load (m+(d))→A	24 bits	50dm
ADM	m,d	Add (m+(d))→A	24 bits	51dm
SBM	m,d	Subtract (m+(d))→A	24 bits	52dm
LMM	m,d	Logical difference (A) - (m+(d))→A	24 bits	53dm
STM	m,d	Store (A)→m+(d)	24 bits	54dm
RAM	m,d	Replace add (m+(d)) + (A)→m+(d) and A	24 bits	55dm
AOM	m,d	Replace add one (m+(d)) + 1→m+(d) and A	24 bits	56dm
SOM	m,d	Replace subtract one (m+(d)) - 1→m+(d) and A	24 bits	57dm

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
5077 0203		LDM	TAG6,77B	
5106 0202		ADM	TAG5,6	
5200 0202		SBM	TAG5	
5315 7000		LMM	7000B,15B	
5410 0272		STM	TAG5+70B,TAG1-2	
5500 0342		RAM	140B+TAG5,0	
5600 0173		AOM	-10B+TAG6	
5712 0203		SOM	TAG6,TAG1	

9.2.12 CENTRAL READ/WRITE INSTRUCTIONS (CYBER 170 SERIES, CYBER 70/MODELS 72, 73, 74 OR 6000 SERIES)

The CRD instruction transfers a 60-bit word from central memory to five consecutive PPU locations. The 18-bit address of the central memory location must be loaded into A prior to executing this instruction. (Note that this is an absolute address.) The 60-bit word is disassembled into five 12-bit words beginning at the left. Location d receives the first 12-bit word. The remaining 12-bit words go to successive locations. The (A) are not altered.

The CRM instruction reads a block of 60-bit words from central memory. The content of location d gives the block length. The 18-bit address of the first central word must be loaded into A prior to executing this instruction. (Note that this is an absolute address.) During the execution of the instruction, (P) goes to processor address 0 and P holds m. Also, (d) goes to the Q register where it is reduced by one as each central word is processed. The original content of P is restored at the end of the instruction.

(A) is advanced by one to provide the next central memory address after each 60-bit word is disassembled and stored. The contents of the Q register are also reduced by one. The block transfer is complete when (Q)=0. The block of central memory locations proceeds from address (A) to address (A) + (d) -1. The block of processor memory locations proceeds from address m to m+5(d)-1.

Each central word is disassembled into five 12-bit words beginning with the high-order 12 bits. The first word is stored at processor memory location m. The content of P (which is holding m) is advanced by one to provide the next address in the processor memory as each 12-bit word is stored. If P overflows, operation continues as P is advanced from 7777_8 to 0000_8. These locations will be written into as if they were consecutive.

The CWD instruction assembles five successive 12-bit words into a 60-bit word and stores the word in central memory. The 18-bit address word designating the central memory location must be in A prior to execution of the instruction. (Note that this is an absolute address.)

Location d holds the first word to be read out of the processor memory. This word appears as the higher order 12 bits of the 60-bit word to be stored in central memory. The remaining words are taken from successive addresses.

The CWM instruction assembles a block of 60-bit words and writes them in central memory. The content of location d gives the number of 60-bit words. The content of the A register gives the beginning central memory address. (Note that this is an absolute address.) During the execution of this instruction (P) goes to processor address 0, and P holds m. Also, (d) goes to the Q register, where it is reduced by one as each central word is assembled. The original content of P is restored at the end of the instruction.

The content of P (the m portion of the instruction) gives the address of the first word to be read out of the processor memory. This word appears as the higher order 12 bits of the first 60-bit word to be stored in central memory.

The content of P is advanced by one to provide the next address in the processor memory as each 12-bit word is read. If P overflows, operation continues as P is advanced from 7777_8 to 0000_8. These locations will be read from as if they were consecutive.

(A) is advanced by one to provide the next central memory address after each 60-bit word is assembled. Also, Q is reduced by one. The block transfer is complete when (Q)=0.

Formats:

Operation	Variable	Description	Size	Octal Code
CRD	d	Central read from (A) to d	12 bits	60d
CRM	m,d†	Central read from (d) CM words beginning at CM (A)→ PPU m	24 bits	61dm
CWD	d	Central write from d to (A)	12 bits	62d
CWM	m,d†	Central write (d) words beginning at PPU m→ CM (A)	24 bits	63dm

†Expression d is required.

Example:

Code Generated

```
6015
6125 0012
6232
6350 0012
```

```
      LOCATION  OPERATION  VARIABLE     COMMENTS
1                11         18           30
          CRD    15B
          CRM    TAG1,25B
          CWD    32B
          CWM    TAG1,50B
```

9.2.13 I/O BRANCH INSTRUCTIONS (CYBER 170 SERIES, CYBER 70/MODELS 72, 73, 74, AND 6000 SERIES)

The following instructions are conditional long jump instructions, each of which tests for a condition on channel d. When the condition is true, the jump to address m takes place. When the condition is not met, execution continues with the next instruction. These instructions are exclusively 6000-series PPU instructions. The d expression is required.

For the FJM instruction, an input channel is full when the input equipment has sent a word to the channel register and sets the full flag. The channel remains full until the PPU accepts the word and clears the flag. An output channel remains full when a PPU sends a word to the channel register and sets the full flag. The channel is empty when the output equipment accepts the word and notifies the PPU.

Formats:

Operation	Variable	Description	Size	Octal Code
AJM	m,d	Jump to m if channel d active	24 bits	64dm
IJM	m,d	Jump to m if channel d inactive	24 bits	65dm
FJM	m,d	Jump to m if channel d full	24 bits	66dm
EJM	m,d	Jump to m if channel d empty	24 bits	67dm

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
6402 0012		AJM	TAG1,2	
6502 0013		IJM	TAG2,CHAN-2	
6604 0025		FJM	TAG3,4	
6704 0026		EJM	TAG4,CHAN	

9.2.14 I/O BRANCH INSTRUCTIONS (CYBER 70/MODEL 76 AND 7600)

The following instructions are conditional long jump instructions each of which tests a condition on channel d. When the condition is true, the jump to address m takes place. When the condition is not met, execution continues with the next instruction. These instructions are exclusively 7600 PPU instructions. The d expression is required.

Formats:

Operation	Variable	Description	Size	Octal Code
FIM	m,d	Jump to m on channel d input word flag	24 bits	60dm
EIM	m,d	Jump to m if no input word flag on channel d	24 bits	61dm
IRM	m,d	Jump to m on channel d input record flag	24 bits	62dm
NIM	m,d	Jump to m if no input record flag on channel d	24 bits	63dm
FOM	m,d	Jump to m on channel d output word flag	24 bits	64dm
EOM	m,d	Jump to m if no output word flag on channel d	24 bits	65dm
ORM	m,d	Jump to m on channel d output record flag	24 bits	66dm
NOM	m,d	Jump to m if no output record flag on channel d	24 bits	67dm

Examples:

Code Generated		LOCATION	OPERATION	VARIABLE	COMMENTS
		1	11	18	30
6005 1365			FIM	TAG5,5	
6102 1365			FIM	TAG5,2	
6201 1366			IRM	TAG6,1	
	4	CHAN	SET	4	
6304 1366			NIM	TAG6,CHAN	
6415 7000			FOM	7000B,15B	
6500 1525			EOM	140B+TAG5,0	
6601 1266			ORM	-100B+TAG6,CHAN-3	
6705 1366			NOM	TAG6,CHAN+1	

9.2.15 A REGISTER INPUT/OUTPUT INSTRUCTIONS

The following instructions transfer a word to or from channel d and the lower 12 bits of the A register.

On the CYBER 70/Model 76 or 7600, the IAN instruction is not executed until the input channel d word flag is set. If the flag is not set when the instruction is read, execution halts until an external signal sets the flag. The input channel d record flag does not affect the IAN execution. The IAN instruction clears the input channel d word flag and record flag and transmits a resume signal over the input cable after the word is entered in the A register.

On the CYBER 70/Model 76 or 7600, the OAN instruction is not executed while the output channel d word flag is set. If the flag is set, execution stops until an external resume signal clears the flag. This instruction sets the output channel d word flag and transmits a work pulse over the output channel cable.

On a CYBER 170 Series, CYBER 70/Model 72, 73, or 74 or 6000-series machine, executing either of these instructions when the channel is inactive causes the peripheral processor unit to become inoperative until some other peripheral processor activates the channel or the system is deadstarted.

Formats:

Operation	Variable	Description	Size	Octal Code
IAN	d	Input: channel d to A	12 bits	70d
OAN	d	Output: (A) to channel d	12 bits	72d

Examples:

Code Generated	LOCATION (1)	OPERATION (11)	VARIABLE (18)	COMMENTS (30)
7003		IAN	3	
7204		OAN	CHAN	

9.2.16 BLOCK INPUT/OUTPUT INSTRUCTIONS

The following instructions transfer a block of 12-bit words on channel d to or from a starting PPU memory location specified by m. The number of words transferred is specified by the contents of the A register which is reduced by one as each word is transferred. The operation is completed when (A) = 0 or the channel becomes inactive (CYBER 170 Series, CYBER 70/Model 72, 73, 74 or 6000 only).

On a CYBER 170 Series, CYBER 70/Model 72, 73, 74 or 6000-series machine, the input operation is complete when (A) = 0 or the data channel becomes inactive. If the operation is terminated by the channel becoming inactive, the next location in the processor memory is set to all zeros. The word count is not affected by this empty word. Therefore, the contents of the A register gives the block length minus the number of real data words actually read in.

During execution of either of these instructions, address 0000 temporarily holds P, while the P register holds m. The contents of P advances by one to give the address for the next word as each word is transferred.

NOTE

If this instruction is executed on a CYBER 170 Series, CYBER 70/Model 72, 73 or 74 or 6000-series machine when the data channel is inactive, no operation is accomplished and the program continues at P + 2. However, the location specified by m is set to all zeros for the IAM instruction.

On a CYBER 70/Model 76 or 7600 the IAM instruction is not executed until the input channel d word flag is set. If the flag is not set when the instruction is read, execution halts until an external signal sets the flag. The presence of an input channel d record flag is ignored for the first word of the block but terminates the block input at any word after the first. In this case, the next location in the PPU block input storage area contains a noise word; any remaining locations are unaltered. Note that the storage location can be incremented through location 7776_8 to 0000_8 on a 7600 (or CYBER 70/Model 76), or location 7777 through 0000 on a 6000-series machine (or a CYBER 170 Series, CYBER 70/Model 72, 73, or 74), which could destroy existing data or a program.

On a CYBER 70/Model 76 or 7600, the OAM instruction is not executed until the output channel d word flag is cleared. If the flag is set when the instruction is read, execution halts until a resume pulse clears the flag. An output channel d record flag does not affect OAM execution.

Formats:

Operation	Variable	Description	Size	Octal Code
IAM	m,d †	Input: (A) words to m from channel d	24 bits	71dm
OAM	m,d †	Output: (A) words to channel d from m	24 bits	73dm

†Expression d is required.

Examples:

Code Generated	LOCATION	OPERATION	VARIABLE	COMMENTS
	1	11	18	30
7103 1364		IAM	TAG,3	
7304 1364		OAM	TAG,4	

9.2.17 SET OUTPUT RECORD FLAG INSTRUCTION (CYBER 70/MODEL 76 AND 7600)

The RFN instruction sets the output channel d record flag and transmits a record pulse over the cable. The instruction ignores the previous status of the channel d flags; the instruction is executed even if the output channel d record flag is set.

Format:

Operation	Variable	Description	Size	Octal Code
RFN	d	Set output record flag on channel d	12 bits	74d

Example:

Code Generated

```
7406
```

```
      LOCATION  OPERATION  VARIABLE  COMMENTS
1                 11         18        30
                  RFN        6
```

9.2.18 CHANNEL FUNCTION INSTRUCTIONS (CYBER 170 SERIES, CYBER 70/MODELS 72, 73, 74, AND 6000 SERIES)

The ACN instruction activates the channel specified by d. This instruction must precede the IAN, IAM, OAM, or OAN instructions. Activating a channel alerts the input/output equipment for the exchange of data. Activating an already active channel causes the PPU to become inoperative until another PPU or an external equipment deactivates the channel, or the system is deadstarted.

The DCN instruction deactivates the channel specified by expression d. It stops the input/output equipment and terminates the buffer. Deactivating an already inactive channel causes the PPU to become inoperative until deadstart or until the channel is activated. Avoid disconnecting the channel before first sensing for channel empty, deactivating a channel before stopping the associated processor, or deactivating a channel before placing a useful program into the associated processor. After deadstart, PPUs wait on an input channel. Deactivating a channel after deadstart causes an exit to address 0001 and execution of the program.

The FAN instruction sends the external function code from the lower 12 bits of the A register on channel d.

The FNC instruction sends the external function code specified by m on channel d. For this instruction, expression d is required.

Execution of a FAN or FNC instruction when the channel is active causes the PPU to become inoperative until another PPU or an external equipment deactivates the channel, or the system is deadstarted.

Formats:

Operation	Variable	Description	Size	Octal Code
ACN	d	Activate channel d	12 bits	74d
DCN	d	Disconnect channel d	12 bits	75d
FAN	d	Function (A) on channel d	12 bits	76d
FNC	c,d	Function c on channel d	24 bits	77dm

Examples:

```
                    LOCATION  OPERATION  VARIABLE  COMMENTS
                    1         11         18        30
7405                          ACN        5
7504                          DCN        CHAN
7605                          FAN        CHAN+1
7705 0020                     FNC        20B,5
```

9.2.19 ERROR STOP INSTRUCTION (CYBER 70/MODEL 76 AND 7600)

The ESN instruction halts execution of the peripheral processor program and indicates a program error condition to the monitor control unit. The PPU must be restarted by a deadstart sequence from the MCU, only.

Format:

Operation	Variable	Description	Size	Octal Code
ESN	d	Error Stop	12 bits	7700

Example:

Code Generated

```
                    LOCATION  OPERATION  VARIABLE  COMMENTS
                    1         11         18        30
7700                          ESN
```

PROGRAM EXECUTION 10

COMPASS can be called from the library and placed in execution through a COMPASS call card or through an IDENT statement (Section 4.2.1) in a FORTRAN source deck. When COMPASS is called through FORTRAN, parameters are ordinarily specified on the RUN or FTN card and are the same as for the FORTRAN program.

10.1 CONTROL STATEMENTS

Normally, assembly of COMPASS source programs or the execution of CPU binary object decks is done from a job file. A file is usually submitted in the form of card decks or card images. The first section of the file must contain the control statements described in this section. Other optional statements are described in the operating system reference manual. Following the control statement section are one or more sections containing source statements and data. A control statement key word begins with the first non-blank character on the card. A comma or a left parenthesis or blank begins a parameter string. Parameters in the string are separated by commas. A period or right parenthesis terminates a parameter string. Comments optionally follow the terminator. Within the parameter strings, blanks are ignored. Ordinarily, a parameter can contain only letters and digits. When a parameter is enclosed between dollar signs, all characters are permitted and blanks are not ignored. Within such a dollar-sign delimited parameter, two consecutive dollar signs represent a single dollar sign.

10.1.1 JOB STATEMENT

A job statement of the following format must be the first statement in the deck. The parameters following name can be in any order or can be omitted. For any omitted field a default value is supplied which is an installation option.

Format:

```
name,Tt,CMscm,EClcm.
```

name 1-7 letters or digits by which the job is identified. The first character must be a letter.

Tt CPU time limit in octal seconds ($1-7777_8$), must be sufficient to process all control cards for the job, including assembly and execution.

CMscm Estimate of maximum amount of SCM or CM required for execution (1 - 6 octal digits). The estimate for COMPASS is a minimum of 40000.

ECIcm Estimate of maximum amount of LCM or ECS in octal thousands, required for assembly or execution ($1 - 1400_8$). The estimate for COMPASS is a minimum of none.

COMPASS notes storage used in the job dayfile. For subsequent runs, the field lengths can be decreased accordingly.

Examples:

```
JOB1,P2,T100,CM40000,EC30.
```

```
TESTER.
```

10.1.2 COMPASS CALL STATEMENT

The following statement causes the COMPASS assembler to be loaded from the library and executed. Parameters specify modes and files.

Format:

```
COMPASS(p1,p2,...,pn)
```

The optional parameters, p, may be in any order within the parentheses. A parameter can be omitted or can be in one of the following forms.

mode

mode = 0

mode = lfn

Mode is one or two characters as described below; lfn is a 1 - 7 character name of a file or a character string.

Mode	Significance
A - Abort mode	
A	Abort job at end of run to EXIT(S) statement if any assembly errors occurred.
omitted	Do not abort job for assembly errors
B - Binary output	
omitted or B	Binary on the load-and-go file (LGO)
B=0	No binary output
B=lfn	Binary on the named file
D - Debug mode	
D	Binary is generated on the file indicated by B parameter in spite of assembly errors and regardless of the abort mode (A parameter) D is ignored if B=0
omitted	Assembly errors inhibit binary output. In abort mode (A parameter present), no binary output is written at all for a subprogram containing assembly errors. Otherwise (A parameter omitted), the message ERRORS IN ASSEMBLY is written to the file indicated by the B parameter for each subprogram containing assembly errors.
F - FORTRAN mode; establishes value of special element *F	
omitted or F	*F is 0
F=number	*F is number (one decimal digit)
F=name	*F is a number corresponding to name as follows: COMPASS = 0 RUN = 1 FTN = 2
G - Get system text	
Omitted or G=0	Load no system text from a sequential binary file
G	Load the first system text overlay, if any, from file named SYSTEXT
G=lfn	Load the first system text overlay, if any, in the specified sequential binary file
G=lfn/ovl	Search the specified sequential binary file for a system text overlay whose name is ovl and load the first such overlay

Mode	Significance

I - Source of assembler input

omitted	Source deck is on INPUT file
I	Source deck is on COMPILE file in either compressed or expanded format.
I=0	Illegal
I=lfn	Source deck is on named file

L - Full List

omitted or L	List output on OUTPUT file
L=lfn	List output on named file. When the full list is on a different file than the short list, the listing for each subprogram is preceded by a one-word header consisting of an asterisk and the first six characters of the subprogram name. This header identifies the subprogram as a convenience for sorting and cataloging. Also see O option.
L=0	No full list will be generated

LO-List options; selects or deselects a maximum of nine of the list options A, B, C, D, E, F, G, L, M, N, R, S, T, or X

omitted or LO=0	Same as selecting B, L, N, and R only
LO	Selects list options C, F, G, and X, and deselects R
LO=$c_1 c_2 \ldots c_n$	A list of up to nine characters. Inclusion of B, L, N, or R deselects the corresponding option. Otherwise, inclusion of a character selects the option. For options, refer to LIST pseudo instruction, section 4.11.1.
LO=$$$$	Selects all list options

ML-Initial Value of MODLEVEL Micro

omitted or ML	MODLEVEL is defined equal to JDATE at the start of each assembly
ML=string	MODLEVEL is defined as string (nine characters maximum) at the start of each assembly

N - No eject; suppresses ejects caused by normal listing control. The only page ejects are at the beginning of new subprograms.

N	No eject
omitted	Normal ejects

O - Short list; suppressed if full list is directed to the same file or if no assembly errors occur. However, if the full list and short list are on different files (for example, the full list is written on OUTPUT and the short list is written on the named file), the short list will be augmented by the addition of any error lines originating with a macro call.

omitted or O	List output on OUTPUT file
O=lfn	List output on named file
O=0	No short list will be generated

P - Continue page

P	Page numbering continues from subprogram to subprogram.
omitted	Page numbering begins with 1 at the start of each subprogram

PC- Initial Value of PCOMMENT Micro

omitted or PC	PCOMMENT is defined as 30 blanks at the start of each assembly
PC=string	PCOMMENT is defined as string at the start of each assembly. Characters are truncated from the right or blanks are appended to the right, as necessary, so that the length of the micro value is exactly 30 characters.

S - System Text Name

omitted	If there are no G parameters other than G=0, load the overlay named SYSTEXT from the job's current global library set.
S=0	Load no system text from a library
S	Load system text overlay named SYSTEXT from job's current global library set
S=ovl	Load the system text overlay named ovl from the job's current global library set
S=lib/ovl	Load the system text overlay named ovl from the library named lib, which may be a user library file or a system library

X - Source of external text (XTEXT) when location field of XTEXT pseudo instruction is blank.

omitted	External text OLDPL file
X=lfn	External text on named file
X=0	Illegal
X	External text on OPL file.

Examples:

COMPASS(B,D,S=OVI)	Reads source from INPUT, writes the binary output to LGO, and the listing to OUTPUT. Assemble in debug mode with system text from overlay OVI in the global library set.
COMPASS(LO=ASGXD)	Disables LIST pseudo instruction and sets LIST options A, S, G, X, and D.
COMPASS.	Uses the standard default options.

MULTIPLE SYSTEM TEXT OVERLAYS

COMPASS 3 allows up to seven system text overlays to be used for an assembler run. They are specified by G and S parameters on the COMPASS control card. Each G parameter (except G=0) specifies loading of a system text overlay from a sequential binary file, and each S parameter (except S=0) specifies loading of a system text overlay from a user library file or a system library. The G and S parameters can be used in any combination and in any order, and can be intermixed freely with other parameters, provided the total number of system text overlays specified does not exceed seven. COMPASS loads the system text overlays in the order in which the G and S parameters occur on the COMPASS card. If a system macro, micro, or symbol is defined by more than one system text, only the last definition is used.

Examples:

```
COMPASS(I,S,S=PFMTEXT,G=MYTEXT)
```

Reads source from file COMPILE and gets system text from overlays SYSTEXT and PFMTEXT in the global library set, and from the local file MYTEXT.

```
COMPASS(G=FILE/SCPTEXT,S=MYLIB/TEXT)
```

Get system text from overlay SCPTEXT on the file FILE, and from overlay TEXT in library MYLIB.

10.1.3 LGO CONTROL STATEMENT

An LGO control statement calls for the loading and execution of CPU binary output produced by the assembler when the B option on the COMPASS card is selected. When binary output is on some file other than LGO, the card is replaced by a program call card for that file. The file is automatically rewound before loading. The LGO file is temporary; it is released at job termination.

Formats:

```
LGO(p1,p2,p3,...,pn)
```

or

```
LGO.
```

10.1.4 PROGRAM CALL STATEMENT

The program call statement directs the operating system to search for a file or CPU program that has the name specified on the card, load it into the user's small core memory, and execute it as a CPU program.

Formats:

```
name(p1,p2,...,pn)

name.
```

name Program name

p_i Parameters in a format acceptable to the program being called

When the operating system locates the file, it begins loading it from the current file position and, when loading is complete, executes the program as a CPU program.

10.1.5 7/8/9 CARD

The card that separates sections in the job deck is characterized by having rows 7, 8, and 9 punched in column one. The level is assumed zero unless columns 2 and 3 contain an octal level number punched in Hollerith code. The remainder of the columns optionally contain comments.

As an example, a deck consisting of a control card section and a COMPASS source input section would include two 7/8/9 cards. The first terminates the control cards and the second terminates COMPASS input.

10.1.6 6/7/8/9 CARD

The card that signals the end of the job deck is characterized by having rows 6, 7, 8 and 9 punched in column one. Columns 2-80 optionally contain comments.

10.1.7 ACCOUNT CARD

The control card format is:

```
ACCOUNT, usernum, passwrd.
```

usernum User (account) number

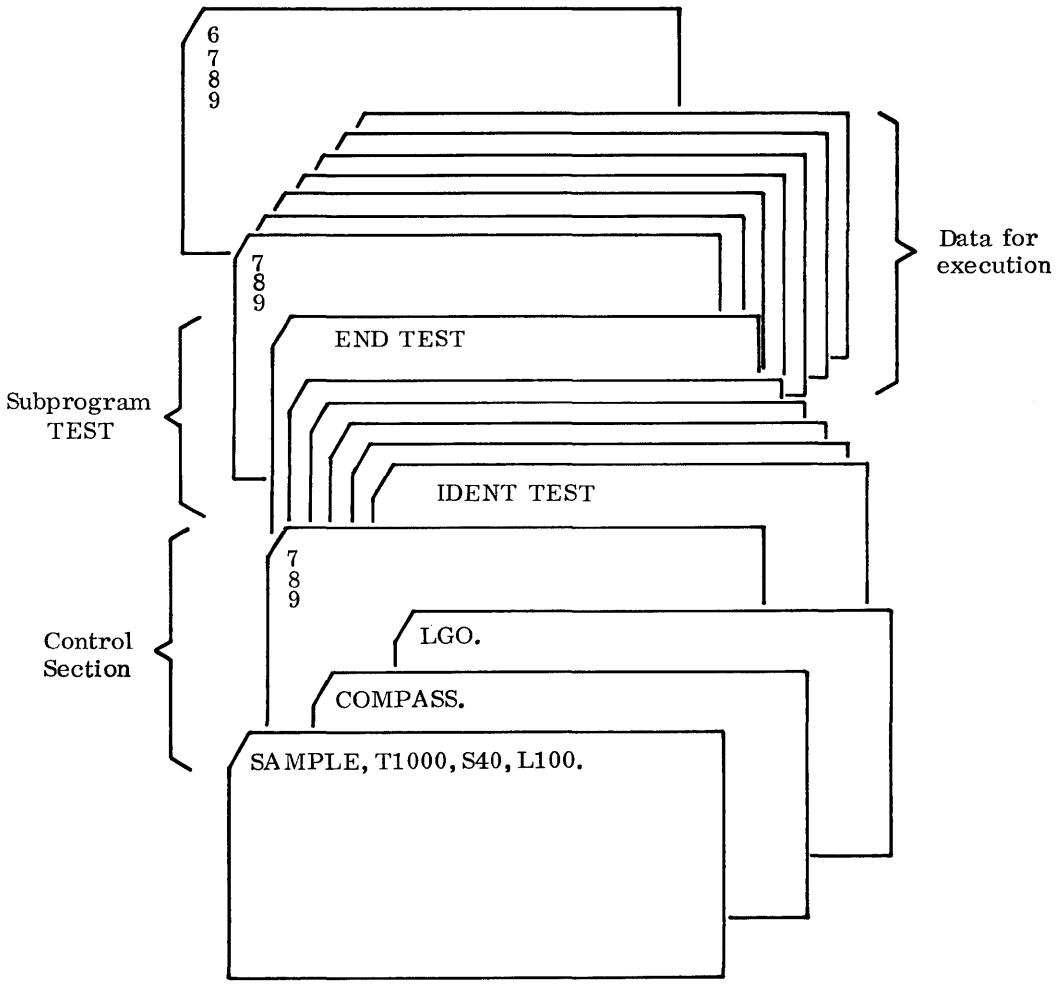
passwrd User password

The ACCOUNT card, required by some operating systems, follows the job card and specifies the user number and password. The user number is used in system bookkeeping and defines the user's file catalog area. The user can specify a different permanent file catalog during job processing by issuing another ACCOUNT card.

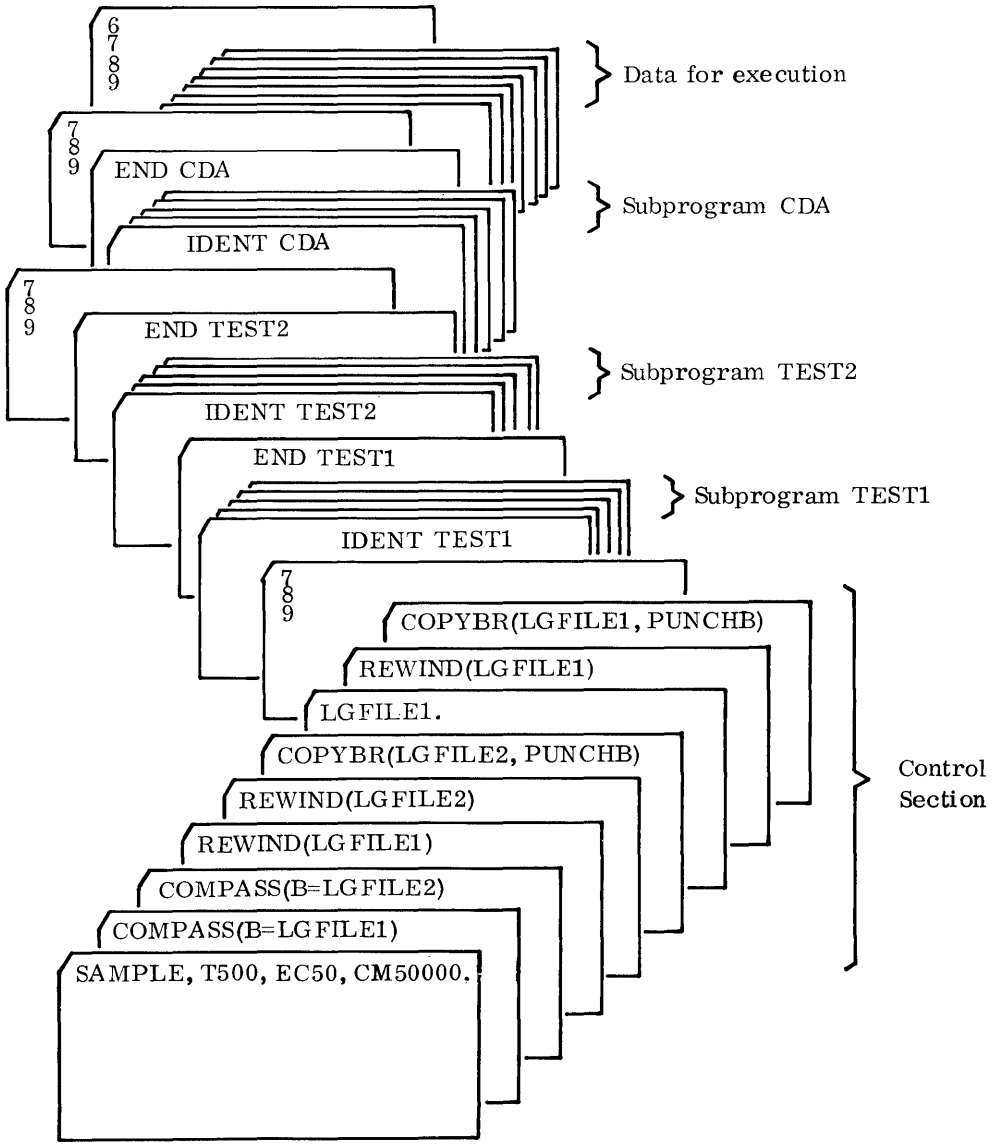
The samples which follow do not have ACCOUNT cards.

10.2 SAMPLE DECKS

The following job calls for assembly of the source program and execution of the binary object program produced by the assembly. COMPASS reads source statements from file INPUT, writes the listing on OUTPUT, and writes a binary object deck on file LGO. Control statement LGO calls for execution of the binary object program, which obtains its data from file INPUT.



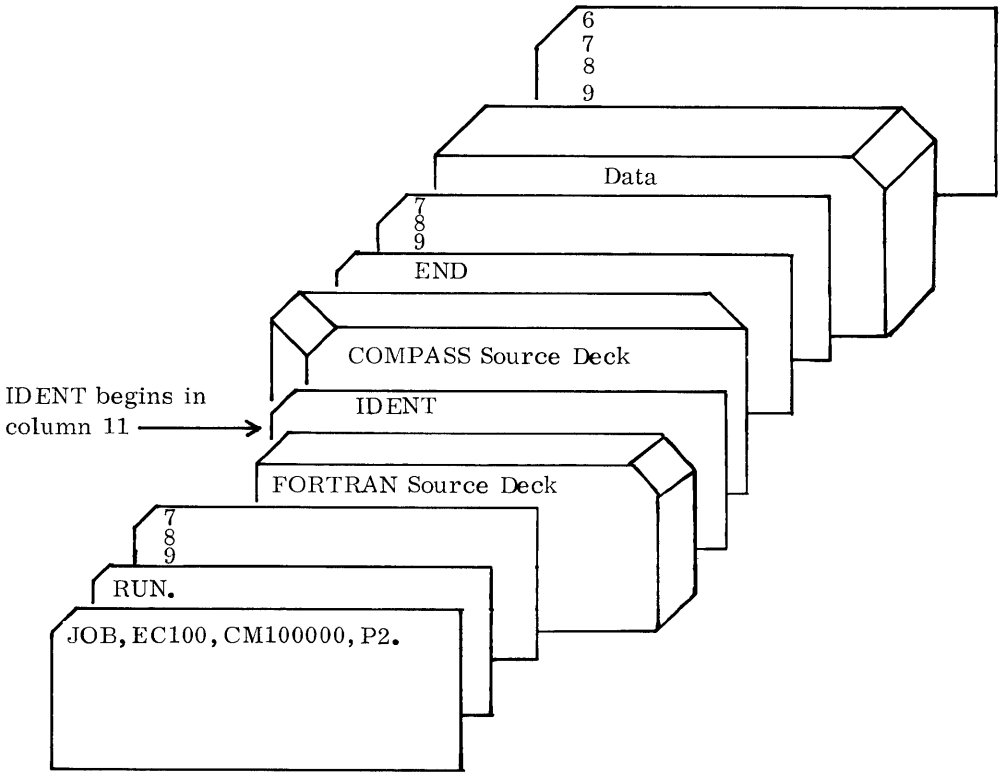
In the following job, the COMPASS assembler is called twice. During the first assembly, binary object decks for subprograms TEST1 and TEST2 are written on file LGFILE1. The source decks for these subprograms are in the second section of the INPUT file. During the second assembly, COMPASS writes a binary object deck for subprogram CDA on file LGFILE2. Each assembler run produces a full listing. Following the second assembly, both files containing binary output are repositioned to the beginning of the file. Then, the COPYBR program is called to copy the contents of LGFILE2 to a punch file (PUNCHB). The LGFILE1 statement then calls for the loading and execution of subprograms TEST1 and TEST2 from LGFILE1. Following successful execution of the subprograms, the file is rewound and copied to the punch file, after which the job terminates.



In the following example, COMPASS is called from within a FORTRAN program. The source program follows the FORTRAN program in the same section.

No parameters on the RUN card cause:

1. Loading and execution of the RUN compiler
2. Object program CM/SCM and ECS/LCM fields to be set
3. Source decks on INPUT
4. Listings to be written on OUTPUT
5. Binary object programs to be written on LGO
6. No cross reference list to be produced

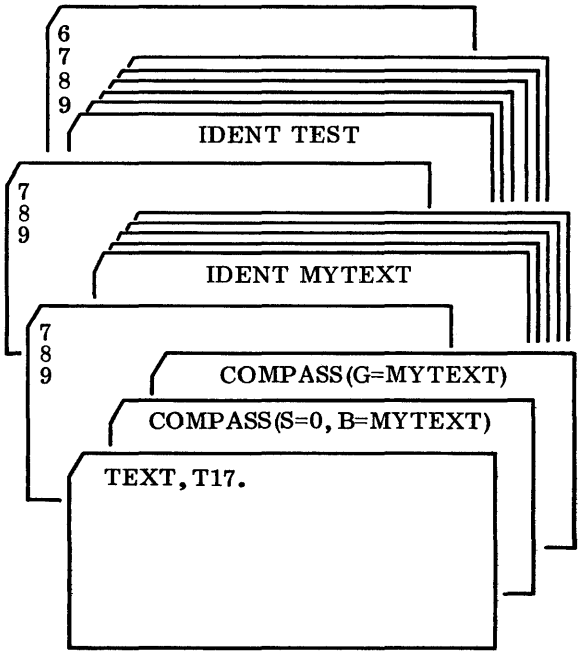


The following sample programs illustrate how to assemble and use a system text overlay.

```
                        IDENT   MYTEXT

                        STEXT

          1     ONE     EQU     1               CONSTANT ONE
         36     HALF    EQU     30              POS CONSTANT

                SHIFT   MACRO   ALPHA,BETA      POSITIONING MACRO

                        IFC     NE,$ALPHA$X2$,1
                        SA2     ALPHA

                        IFC     NE,$BETA$B2$,1
                        SB2     BETA

                        LX6     X2,B2

                        ENDM

                        END
```

```
                                IDENT   TEST
                                ENTRY   TEST
                                SST

6110000001              TEST    SB1     ONE             CONSTANT ONE FROM TEXT

          5120000004 +          SA2     INBUF           PICK UP VALUE FROM STORAGE

6120000036                      SHIFT   X2,HALF         POSITION  WORD IN X6

5160000006 +                    SA6     OUTBUF          RETURN NEW WORD TO STORAGE

          7160247021            ENDRUN

                    2   INBUF   BSS     2
                    1   OUTBUF  BSS     1

                                END     TEST
```

The deck for this job could be set up as follows:



LISTING FORMAT 11

This section describes assembly listing format. Control of the contents of the listing is described in section 4.11 Listing Control, and in section 10.1.2 COMPASS Control Statement.

11.1 PAGE HEADING

Each page of the assembly listing contains a title line and a subtitle line in the following format:

<table>
<tr><td>title</td><td colspan="2">COMPASS Version</td><td>date</td><td>time</td><td>PAGE x</td></tr>
<tr><td>subtitle</td><td>sub-sub
title</td><td>block
name</td><td>symbol
qual</td><td colspan="2"></td></tr>
</table>

title	Up to 62 characters taken from the first TITLE pseudo instruction or from a TTL pseudo instruction or, in lieu of these, from the IDENT instruction
date	Date of assembly
time	Time of assembly in hours, minutes and seconds
PAGE x	Page number of listing. Pagination begins with 1 for each END instruction unless the P option is selected on the COMPASS control card
subtitle	Up to 62 characters taken from second and subsequent TITLE pseudo instructions or a CTEXT pseudo instruction
sub-subtitle	Up to 10 characters taken from the most recent EJECT, SPACE, TITLE, or TTL pseudo instruction or the location field of an ES or PS machine instruction. If the instruction that introduces the new sub-subtitle also causes a page eject, the instruction immediately follows the heading (assuming the C list option is also selected).
block name	Name of the block in use at beginning of page
symbol qual	Qualifier in use (see QUAL pseudo instruction) at beginning of page

11.2 HEADER INFORMATION

The first page of the assembly listing for each subprogram contains a summary of binary control cards (optional), a list of all the blocks established for the subprogram, and lists of entry points and external symbols.

11.2.1 BINARY CONTROL CARD SUMMARY

A binary control card summary in the following format is generated for each IDENT instruction when the

COMPASS control card or the LIST instruction selects the B list option:

ADDRESS	LENGTH	BINARY CONTROL CARDS.
$addr_1$	ℓ_1	$binary\ card_1$
$addr_2$	ℓ_2	$binary\ card_2$
.	.	.
.	.	.
.	.	.
$addr_n$	ℓ_n	$binary\ card_n$

$binary\ card_i$ The binary card that caused generation of the binary for the overlay, partial binary, or subprogram. The list includes SEG, SEGMENT, and END instructions.

$addr_i$ The origin address for the subprogram, overlay, or partial binary written out as a result of the binary card

ℓ_i The length of the subprogram, overlay or partial binary

Example:

```
ADDRESS LENGTH              BINARY CONTROL CARDS.
    101    271              IDENT  COMPASS,LOVER,CMP
    372   5241              SEG
   5633   1242              SEG
   7075   4145              SEG
  13242   5175              SEG
  20437   1352              SEG
  22011                     END    COMPASS
```

11.2.2 BLOCK USAGE SUMMARY

A block usage summary of the following format is generated in the assembly listing under control of the B list option:

BLOCKS	TYPE	ADDRESS	LENGTH
$name_1$	t_1	$baddr_1$	$b\ell_1$
$name_2$	t_2	$baddr_2$	$b\ell_2$
⋮	⋮	⋮	⋮
$name_n$	t_n	$baddr_n$	$b\ell_n$

$name_i$ Name of the block used in the subprogram, as follows:

PROGRAM*	For a relocatable assembly, indicates the zero block. For an absolute assembly, the first PROGRAM* indicates the absolute block, the second indicates the default symbols block.
ABSOLUTE*	Appears in a relocatable assembly only and indicates the use of an absolute block.
LITERALS*	Identifies the literals block.
other	Identifiers a local, labeled common, or blank common block.

type The type of the block as follows:

ABSOLUTE	All addresses in the block are relative to absolute zero. For an absolute assembly, all blocks are ABSOLUTE.
+ LOCAL	Addresses in the block are relative to the origin assigned to block zero. The + is present for an ECS/LCM block.
+ COMMON	Addresses in the block are relative to the origin of the common block. The + is present for an ECS/LCM block.

$baddr_i$ Beginning address of the block according to type.

$length_i$ Number of words in the block.

Examples:

```
BLOCKS      TYPE       ADDRESS      LENGTH

PROGRAM*    ABSOLUTE         0        5416
LITERALS*   ABSOLUTE      5416         215
CONTROL     ABSOLUTE      5633        1242
PSEUDO      ABSOLUTE      7075        4145
SUBS        ABSOLUTE     13242        5175
BUFFERS     ABSOLUTE     20437       11140


BLOCKS      TYPE       ADDRESS      LENGTH

ABSOLUTE*   ABSOLUTE         0          62
PROGRAM*    LOCAL            0          35
DATA1       LOCAL           35           1
LCM        +LOCAL            0           5
TABLE      +LOCAL            5           5
TABLE      +COMMON           0         123
TABLE       LOCAL           36           1
TABLE       COMMON           0           1
//          COMMON           0        1000
```

11.2.3 ENTRY POINT LIST

If the subprogram declares entry points, a list of entry point symbols in the following format follows the block usage summary.

ENTRY POINTS.

sym_1* +$addr_1$ +$block_1$	sym_{n+1}* +$addr_{n+1}$ +$block_{n+1}$	sym_{2n+1}* +$addr_{2n+1}$ +$block_{2n+1}$
sym_2* +$addr_2$ +$block_2$	sym_{n+2}* +$addr_{n+2}$ +$block_{n+2}$	sym_{2n+2}* +$addr_{2n+2}$ +$block_{2n+2}$
.	.	.
.	.	.
.	.	.
sym_n* + $addr_n$ +$block_n$	sym_{2n}* +$addr_{2n}$ +$block_{2n}$	sym_{3n}* +$addr_{3n}$ +$block_{3n}$

Where n is one-third the number of entry points. The asterisk to the right of sym_i is present if sym_i is a conditional entry point (declared by ENTRYC). The + to the left of $addr_i$ is present if $block_i$ is an ECS/LCM block. The + to the right of $addr_i$ is present if addr is relocatable. $Block_i$ is blank or a common block name surrounded by slashes.

If the symbol is undefined, $addr_i$ is *******.

Example:

```
 ENTRY POINTS.

 SNAP1          1345+            CALL        72+            REORDER        2375+
 SNAP2          1352+            GOTO       156+            RPF            2461+
 SNAP3          1357+            IF         224+            RPH            2463+
 JUMPVEC   *       0+/JUMPVEC/   LABEL      372+            LCM       +       0+
 BEGIN             0+            READ       435+            LCMB      *+      1 0+/LCMA/
 BYTESIZ           6             RECORD      24+/DATA/
```

11.2.4 EXTERNAL SYMBOL LIST

If external symbol references are declared in the subprogram, a list of the following format follows the list of entry point symbols:

EXTERNAL SYMBOLS.

sym_1	sym_{n+1}	sym_{2n+1}	sym_{3n+1}	. . .	sym_{7n+1}
sym_2	sym_{n+2}				
sym_3	sym_{n+3}				
⋮	⋮				
sym_n	sym_{2n}				

Where n is one-eighth the number of external symbols.

Example:

```
 EXTERNAL SYMBOLS.

 ERMSG     CONEXIT  XDECPI    SYMBOL  COGOTO    CPC
```

11.3 OCTAL AND SOURCE STATEMENT LISTING

The contents of the octal and source statement listing depends on the options selected.

The list is 130 characters wide with fields assigned as shown in figure 11-1.

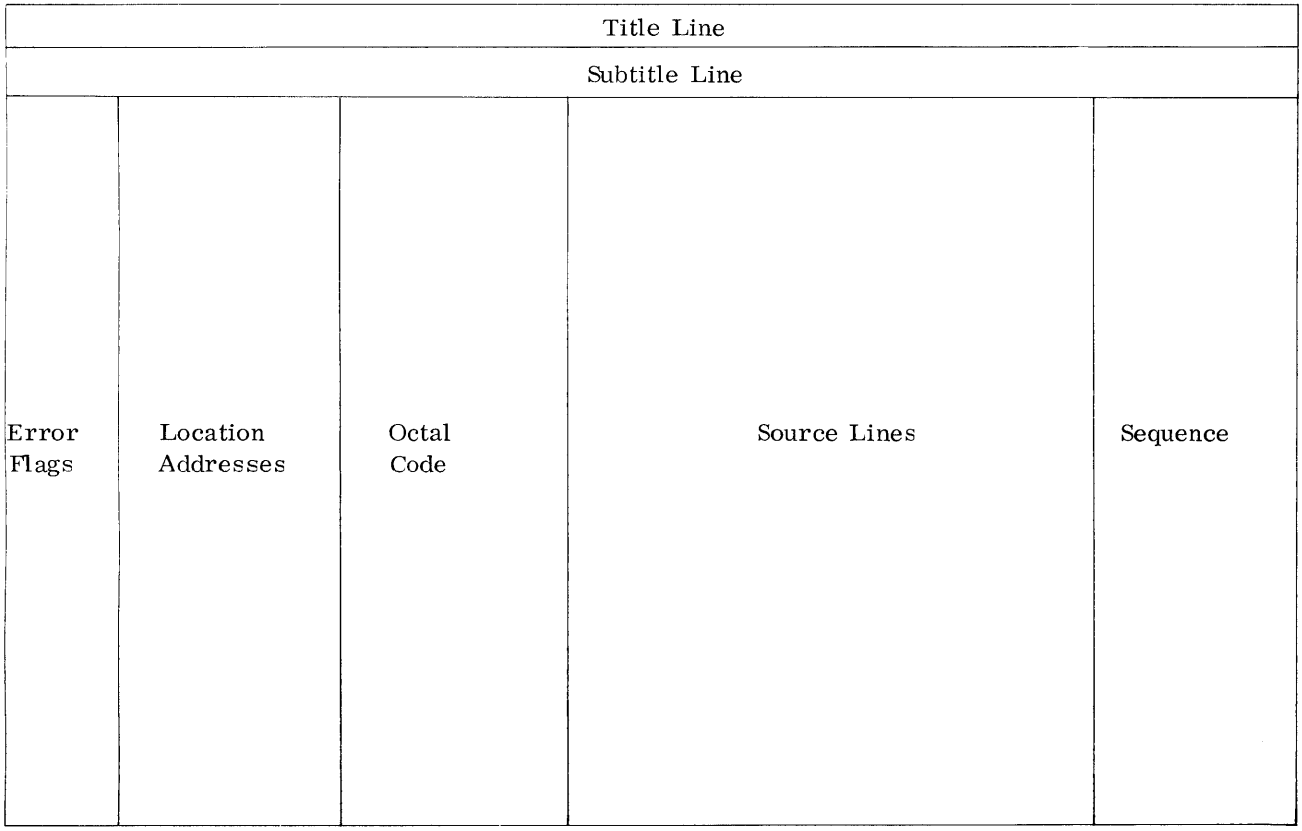


Figure 11-1. Format of Octal and Source Statement Listing

Error Flags — Error flags indicating that errors of the type indicated have been detected on the source line or in a subsequent statement that is not listed. These flags are described more fully under Error Directory. Lines containing errors are always listed.

Location Addresses — The value of the location counter with leading zeros suppressed. If no code is generated or no location symbol is defined by the statement, this field is blank. If at the time the value is assigned, the value of the location counter differs from the value of the origin counter, an L precedes the address.

Octal Code — The actual code generated by this statement. Depending on options selected, the listing shows just the first word or all words generated for data generation instructions. The field does not include NO instructions (46000_8) packed for a force upper or zeros packed for a completed parcel on a VFD. A 24-bit PPU instruction is shown two words of data per line.

If the word contains an address, the octal code is flagged as follows:

- `-` Negative relocatable address
- `+` Positive relocatable address
- `C` Common relocatable address
- `X` External address

For a statement that does not generate code, this field is normally blank. Exceptions are as follows:

For a LIT instruction the field contains the address of the first word of the literals generated.

For a COL instruction, the field contains the new beginning-of-comments column number.

For a symbol defined through SET, MAX, MIN, EQU, =, or MICCNT, this field contains the octal value of the symbol right justified with leading zeros suppressed.

For an instruction resulting in a change of base, the notation $b_1 \vdash\!\!\rightarrow b_2$ is right justified in the field. b_1 indicates the old base and b_2 indicates the new base.

For an instruction resulting in a change of code conversion, the notation $c_1 \vdash\!\!\rightarrow c_2$ is right justified in the field. c_1 indicates the old code and c_2 indicates the new code.

For a DUP instruction, the field contains the repeat count.

For a BSS or BSSZ instruction, the field contains the octal value of the word count right justified with leading zeros suppressed. If the word count is zero the field is blank.

For a DECMIC or OCTMIC instruction, the field contains the octal value of the expression right justified with leading zeros suppressed.

Source Code — Source statement image (columns 1-72)

Sequence — Columns 73-90 of the card image or an identifier for an expansion of a definition operation as follows:

Macro	macro name
Remote code	*RMT*
Duplicated code	*DUP*
Echoed code	*ECHO*
XTEXT	file name
OPDEF	Operation field of opdef call, e.g., SB1

The recursion level is indicated in the right half of the field.

Example:

```
COMPASS 3.71210 - CYBER 70/ COMPREHENSIVE ASSEMBLER.          COMPASS 3.71210      08/20/71  16.25.44.      PAGE    82
COMMON AND UTILITY SUBROUTINES.                               ALC

                                **        ALC - TABLE MANAGER AND ALLOCATOR.                                    COMPASS  1695
                                *         ALLOCATOR WILL MOVE TABLES TO ACQUIRE ROOM.  ALSO MAY DUMP            COMPASS  1696
                                *         INTERMEDIATE OR CROSS-REFERENCES ONTO SCRATCH FILE.                   COMPASS  1697
                                *         ENTRY  (A0) = TABLE INDEX.                                           COMPASS  1698
                                *                (X1) = CHANGE (+ OR -) TO TABLE SIZE.                         COMPASS  1699
                                *         EXIT   (X2) = ORIGIN OF TABLE.                                       COMPASS  1700
                                *                (X3) = NEW LENGTH OF TABLE.                                   COMPASS  1701
                                                                                                              COMPASS  1702
                                                                                                              COMPASS  1703
  5466  5020003462              ALCX      SA2    ORIGINS+A0  RECLAIM VALUES FOR EXIT REPLY                     COMPASS  1704
              5030003516                  SA3    SIZES+A0                                                      COMPASS  1705
                                                                                                              COMPASS  1706
  5467  0000000000              ALC       PS                 RETURN EXIT                                     COMPASS  1707
  5470  6120000034              ALC1      S32    NTABLES     PRESET INDEX REGISTERS                          COMPASS  1708
              5020003462                  SA2    ORIGINS+A0  CURRENT ORIGIN                                  COMPASS  1709
  5471  54322                             SA3    A2+B2       CURRENT LENGTH                                  COMPASS  1710
          54421                           SA4    A2+B1       NEXT TABLE ORIGIN                               COMPASS  1711
              36613                       IX6    X1+X3       NEW SIZE                                        COMPASS  1712
                  37042                   IX0    X4-X2       TEST IF ROOM FOR EXPANSION                      COMPASS  1713
  5472  37006                             IX3    X0-X6                                                       COMPASS  1714
            0330005474                    NG     X0,ALC2     JUMP TO RE-ALLOCATE CORE                        COMPASS  1715
                  54630                   SA6    A3          STORE NEW SIZE                                  COMPASS  1716
  5473  0400005466                        EQ     ALCX        EXIT                                            COMPASS  1717
                                                                                                              COMPASS  1718
                                *         MOVE TABLES.                                                        COMPASS  1719
                                                                                                              COMPASS  1720
  5474  5120003172              ALC2      SA2    SIZCORE     SEE IF ENOUGH ROOM                              COMPASS  1721
              10411                       BX4    X1                                                          COMPASS  1722
                  67721                   S37    B2-B1                                                       COMPASS  1723
  5475  67771                   ALC3      S37    B7-B1                                                       COMPASS  1724
          5157003516                      SA5    SIZES+B7                                                    COMPASS  1725
                  36445                   IX4    X4+X5                                                       COMPASS  1726
  5476  0570005475                        NZ     B7,ALC3     LOOP                                            COMPASS  1727
              5130003345                  SA3    PASS                                                        COMPASS  1728
  5477  63730                             S37    X3                                                          COMPASS  1729
          37024                           IX0    X2-X4                                                       COMPASS  1730
              63440                       S34    X4          (B4) = TOTAL LENGTH                             COMPASS  1731
                  67707                   S37    -B7         [illegible]                                     COMPASS  1732
            0330005533                    [illegible]
```

11.4 LITERALS

When the D list option has been selected, the assembly listing includes a listing of the literals block following the default symbols listing. Following each literal address is the octal contents of the word and a display code conversion of the contents of the word.

Examples:

```
                    CONTENT OF LITERALS BLOCK.

0101121   1745577375300000000     0+.>>X
0101122   1665000000000000000     N
0101123   1505232301070555636     MESSAGE 33
0101124   5504050311150114552     DECIMAL R
0101125   0521251122050457000     EQUIRED.
0101126   5522052125112205040     REQUIRED
0101127   0000000000000000000
0101130   2022170722011555010     PROGRAM AB
0101131   1722245700000000000     ORT.


                    CONTENT OF LITERALS BLOCK.

7315      0034                      1
7316      7070                      ↑↑
7317      0007                      G
7320      0000
7321      5501                      A
7322      0000
7323      0506                      FF
7324      1411                      LI
7325      2405                      TE
7326      2201                      RA
7327      1423                      LS
```

11.5 DEFAULT SYMBOLS

When the D list option is selected, a list of default symbols immediately precedes the literals block.

Example:

```
                                DEFAULT SYMBOLS DEFINED BY COMPASS

000000 X                        MSG=
005461                          TAG1
005462                          TAG2
005463                          ABC
005464                          SYM
```

11.6 ASSEMBLER STATISTICS

Assembler statistics are printed at the end of the octal and source statement listing or, if the D list option is selected, following the default symbols. Information includes the following:

Amount of storage used (octal)

Number of source statements

Number of symbols defined

Number of invented symbols

Number of symbol references

Machine on which COMPASS executed and assembly time

Number of errors encountered during assembly

Number of lost references, that is, references to symbols that have been omitted from the symbolic reference table.

11.7 ERROR DIRECTORY

The assembly listing includes an error directory if any errors are detected during assembly. The directory begins a new page identified with the subtitle ERROR DIRECTORY. Each type of error that occurred is called out with a two-line message of the following format:

```
x   TYPE ERROR                  description
        OCCURRED ON PAGES        p1,   p2,   p3, ... pn
```

Types and descriptions are given in Tables 11-1 and 11-2. Errors flagged with an alphabetic character are fatal. A fatal error causes suppression of binary output. Nonfatal warning flags are numeric; they are informative only.

TABLE 11-1. FATAL ERRORS

Error Type	Definition
A	ADDRESS FIELD BAD. Indicates any of a number of possible errors in a variable subfield entry. For example: CODE character not A, D, E, I, O, or * Symbol or name greater than 8 characters Expression does not reduce to one external term, relocatable terms do not cancel properly, instruction disallows register designators, instruction requires absolute expression, etc. Data error; 8 or 9 encountered in octal data, modifier not S, P, O, E, D, or B No data in variable field of LIT instruction No symbol following an =S or =X prefix Relative jump out of range (-31>r >31) on PPU instruction BASE character not O, M, D, or * Register illegal in CON instruction Unable to locate synonymous instruction for OPSYN or CPSYN. Micro count less than zero or greater than ten NOLABEL character not I Negative relocation on ORG POS value less than 0 or greater than word size. Erroneous OPDEF reference
D	DOUBLY DEFINED SYMBOL. THE FIRST DEFINITION HOLDS. Symbol previously defined or declared external
E	ECHO, DUP, RMT, OR MACRO ILLEGALLY NESTED. Definition not wholly within next outer definition
F	NUMBER OF ENTRIES EXCEEDS PERMISSIBLE AMOUNT. LIT generates more than 100 words Data missing or erroneous on XTEXT file More than 63 formal parameters and local names in macro definition More than 255 blocks

TABLE 11-1. FATAL ERRORS (cont'd)

Error Type	Definition
L	LOCATION FIELD BAD. Required location field entry is erroneous Format two macro definition has no substitutable parameters
N	NEGATIVE RELOCATION ON ENTRY POINT.
O	OPERATION FIELD BAD. Instruction unrecognizable, out of sequence (e.g., ABS or PPU not in first statement group or instruction is illegal for binary mode), or relational mnemonic on IF statement is erroneous. Location symbol begins beyond column two.
P	CONSULT LISTING FOR REASON BEHIND P-ERROR User-generated error flag (ERR or ERRxx instruction)
R	DATA ORIGIN OUTSIDE BLOCK OR IN BLANK COMMON. Range error
U	UNDEFINED SYMBOL. VALUE ASSUMED 0. Reference to a symbol that is not defined; for example, IF statement line count, DIS word count, unrecognizable attribute on IF statement, and undefined qualifier
V	BIT COUNT ERROR ON VFD (MUST BE $0 \leq$ COUNT ≤ 60). VFD field size erroneous

TABLE 11-2. INFORMATIVE ERRORS

Error Type	Description
1	LOCATION SYMBOL BAD. SYMBOL NOT DEFINED. Location field entry erroneous. The instruction does not require an entry.
2	ADDRESS ERROR ON SYMBOL DEFINITION Erroneous variable field entry. The location field symbol is not defined.
3	DUPLICATE MACRO DEFINITION. NEW ONE OVERRIDES. Macro, opdef, or synonymous operation redefines operation code
4	BAD FORMAL PARAMETER NAME IGNORED. Macro or ECHO formal parameter name repeated or illegal
5	CPU OPERATION SYNTAX INCORRECTLY SPECIFIED. OPDEF, CPOP, CPSYN, or PURGDEF specifies illegal syntax
6	LOCATION FIELD MEANINGLESS. Entry in location field is ignored
7	ADDRESS VALUE EXCEEDS FIELD SIZE, RESULT TRUNCATED. Value of expression exceeds size of destination field BSS address expression value is negative MICRO starting character position or character count is negative
8	MISSING OR EXTRA ADDRESS SUBFIELD. Variable subfield entry missing or superfluous
9	MICRO SUBSTITUTION ERROR. NO SUBSTITUTION Micro reference unrecognized

11.8 SYMBOLIC REFERENCE TABLE

The assembler generates a symbolic reference table (figure 11-2) if the L list option is on at the end of assembly. The table is not complete if the option was turned off at any time during the assembly. The table lists symbols according to the qualifier, if any, under which they were defined. The global symbols are listed first. A new heading of the following form introduces each new list of qualified symbols.

SYMBOL QUALIFIER = qualifier

The qualifiers are in the order declared in the subprogram. Symbols are listed alphabetically.

When symbol references are lost because table space has been exceeded, the subtitle line includes notification in the form n LOST REFERENCES.

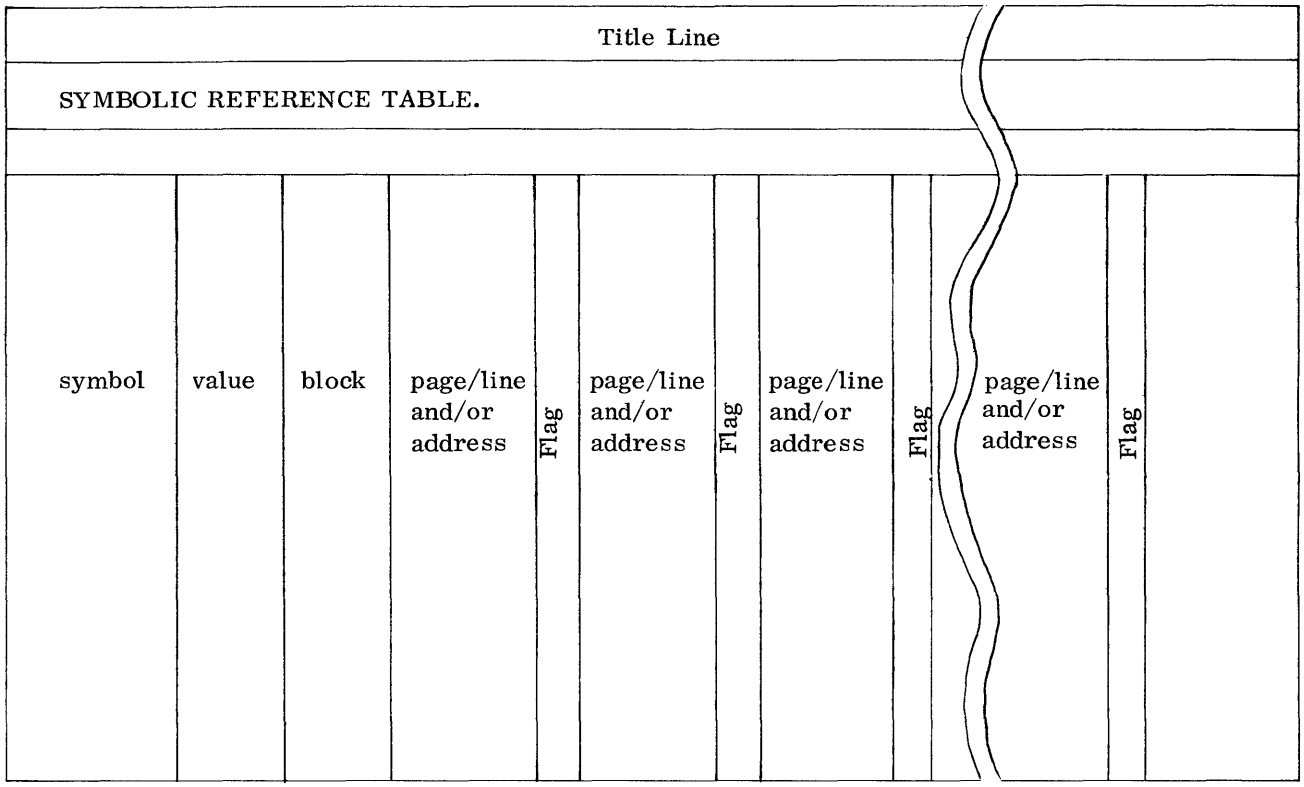


Figure 11-2. Format of Symbolic Reference Table

symbol	Alphabetical list of symbols defined under the qualifier
value	Absolute value of the symbol or the address assigned to this symbol relative to the block named
block	If the symbol was defined by the SST pseudo instruction, block is the system text file or overlay name. Otherwise, this field is blank in an absolute assembly or, in a relocatable assembly, it contains the name of the block containing the symbol.

page/line — From left to right and from top to bottom, a list of indices sequenced according to page number. Each index points to a statement containing references to the symbol or defining the symbol.

address — When the XREF pseudo (section 4.11.8) has been used, the page line field contains the location counter address of the instruction containing the reference. Page and line numbers are optionally included with the address.

flag — Identifies page/line index to a statement that defines the symbol or uses it in an IF statement as follows:

- D Definition statement; EQU, =, SET, MAX, MIN, or MICCNT
- E ENTRY or ENTRYC pseudo instruction
- F Symbol used in conditional test
- I Symbol used for indirect storage (applies only to PPU or PERIPH assemblies)
- L Symbol used in location field of the statement
- S Symbol used for storage
- X EXT pseudo instruction

When XREF A is in effect, the table does not include the flags.

Example:

```
COMPASS 3.71210 - CYBER 70/ COMPREHENSIVE ASSEMBLER.          COMPASS 3.71210      .8/26/71  16.25.44.      PAGE   551
SYMBOLIC REFERENCE TABLE.                                     DEBUG

SNTEMP     5115                72/12 L   74/51 S   74/53     76/22 S   76/24
SNUMB      5421                73/48     74/03     74/12     74/39     74/42     75/44     75/50     78/54 L
SNUMB1     5416                78/48 L   78/53     78/56
SNWLIN     5423                73/28     73/41     74/05     74/52     76/23     79/08 L   79/41
SNWLIN1    5425                79/14 L   79/16
SNWLIN2    5427                79/13     79/17 L
SNX        5134                72/16 L   72/39 S   74/10     77/14     77/34
                               72/32 S   72/42 S   74/16     77/30     77/38



                                        SYMBOL QUALIFIER =  DATA

AF         6675                115/39 L  116/46    121/37    131/52    132/19    132/32
CCS        7326                132/44    133/03    133/18    133/31    133/44    134/02    135/48 L  136/ 6
CCS1       7332                135/52    135/54 L
CCS2       7323                135/38 L  136/01
CSA        7254                117/32    121/20    133/01 L
CSC        7257                117/26    121/17    133/16 L
CSM        7250                117/20    121/14    132/42 L
CSL        7263                117/17    121/11    133/42 L
CSR        7266                117/11    121/08    133/57 L
CSZ        7261                117/ 8    121/05    133/29 L
DCS        7222                117/09    117/12    117/18    117/21    117/27    117/33    131/33 L
DCS1       7225                131/42 L  131/46
DL         6674                115/38 L  126/36    134/20
DO         6673                115/37 L  115/46 S  116/35    126/35    134/19
DV         6653                115/16 L  120/26 S  122/41    123/56    124/27    132/05
EF         6661                115/21 L  122/21    125/11    126/33    127/05 S
ERR        6715                116/30 L  121/35    122/04    123/03    126/36    127/07    131/51    132/16
                               116/53    121/51    122/07    125/39    126/11    128/19    132/18
                               118/57    122/01    122/10    125/50    126/44    128/41    132/11
ES         6662                115/22 L
ESC        7141                122/22    128/04 L
EV         6663                116/23 L  122/43    123/07 S  123/42
FC         6660                115/19 L  120/35 S  122/49
FW         6676                115/40 L  135/03    135/17
GCS        7270                132/49    133/08    133/21    133/34    133/47    134/05    134/19 L
GCS1       7275                134/34 L  134/37
GCS2       7277                134/32    134/39 L
GCS3       7300                134/41 L  134/44
GCS4       7303                134/40    134/45 L
GCS5       7304                134/48 L  134/51
GCS6       7306                134/46    134/53 L
GCS7       7307                134/53    134/55 L
GCS8       7316                135/02    135/11    135/15 L
INT        7135                125/48    126/55 L
LRS        6740                117/15    117/24    117/30    119/06 L
NCS        7233                121/06    121/09    121/12    121/15    121/18    121/21    132/05 L
                               132/21
```

CHARACTER SETS A

NOTES

1. The terms upper case and lower case apply only to the case conversions, and do not necessarily reflect any true case.
2. When translating from display code to ASCII/EBCDIC the upper case equivalent character is taken.
3. When translating from ASCII/EBCDIC to display code, the upper case and lower case characters fold together to a single display code equivalent character.
4. All ASCII and EBCDIC codes not listed are translated to display code 55 (space).
5. Where two display code graphics are shown for a single octal code, the leftmost graphic corresponds to the CDC 64-character set (system assembled with IP CSET set to C64.1), and the rightmost graphic corresponds to the CDC 64-character ASCII subset (system assembled with IP CSET set to C64.2).
6. In a 63-character set system, the display code for the : graphic is 63. The % character does not exist, and translations from ASCII/EBCDIC % or ENQ yield blank (55_8). The display code value 00 is undefined in 63-character set systems.
7. Twelve or more zero bits at the end of a 60-bit word are interpreted as an end-of-line mark rather than two colons. An end-of-line mark is converted to external BCD 1632 and internal BCD 1672 by operating systems when writing 7-track magnetic tape in even parity (coded) mode, and converted back to 0000 when reading.
8. This code is changed to 12 when written on a 7-track magnetic tape in even parity (coded) mode.
9. 11-0 and 11-8-2 are equivalent on input. The character will be punched as 11-0 on output.
10. 12-0 and 12-8-2 are equivalent on input. The character will be punched as 12-0 on output.
11. 12-8-7 and 11-0 are equivalent on input. The character will be punched as 12-8-7 on output.
12. 12-8-4 and 12-0 are equivalent on input. The character will be punched as 12-8-4 on output.
13. CODE pseudo selects 6-bit octal code as follows:

A	ASCII
D	Display Code (default)
E	External BCD
I	Internal BCD

CODE D (default) CODE E CODE I CODE A

Display Code		Hollerith Punch (026)	BCD		ASCII							EBCDIC			
						Upper Case			Lower Case			Upper		Lower	
Octal (13)	Char.		Ext. (13)	Int. (13)	6-Bit Octal (13)	Hex.	Char.	Punch (029)	Hex.	Char.	Punch	Hex.	Char.	Hex.	Char.
00	:(7)	8-2	00(8)	12	32	3A	:	8-2	1A	SUB	9-8-7	7A	:	3F	SUB
01	A	12-1	61	21	41	41	A	12-1	61	a	12-0-1	C1	A	81	a
02	B	12-2	62	22	42	42	B	12-2	62	b	12-0-2	C2	B	82	b
03	C	12-3	63	23	43	43	C	12-3	63	c	12-0-3	C3	C	83	c
04	D	12-4	64	24	44	44	D	12-4	64	d	12-0-4	C4	D	84	d
05	E	12-5	65	25	45	45	E	12-5	65	e	12-0-5	C5	E	85	e
06	F	12-6	66	26	46	46	F	12-6	66	f	12-0-6	C6	F	86	f
07	G	12-7	67	27	47	47	G	12-7	67	g	12-0-7	C7	G	87	g
10	H	12-8	70	30	50	48	H	12-8	68	h	12-0-8	C8	H	88	h
11	I	12-9	71	31	51	49	I	12-9	69	i	12-0-9	C9	I	89	i
12	J	11-1	41	41	52	4A	J	11-1	6A	j	12-11-1	D1	J	91	j
13	K	11-2	42	42	53	4B	K	11-2	6B	k	12-11-2	D2	K	92	k
14	L	11-3	43	43	54	4C	L	11-3	6C	l	12-11-3	D3	L	93	l
15	M	11-4	44	44	55	4D	M	11-4	6D	m	12-11-4	D4	M	94	m
16	N	11-5	45	45	56	4E	N	11-5	6E	n	12-11-5	D5	N	95	n
17	O	11-6	46	46	57	4F	O	11-6	6F	o	12-11-6	D6	O	96	o
20	P	11-7	47	47	60	50	P	11-7	70	p	12-11-7	D7	P	97	p
21	Q	11-8	50	50	61	51	Q	11-8	71	q	12-11-8	D8	Q	98	q
22	R	11-9	51	51	62	52	R	11-9	72	r	12-11-9	D9	R	99	r
23	S	0-2	22	62	63	53	S	0-2	73	s	11-0-2	E2	S	A2	s
24	T	0-3	23	63	64	54	T	0-3	74	t	11-0-3	E3	T	A3	t
25	U	0-4	24	64	65	55	U	0-4	75	u	11-0-4	E4	U	A4	u
26	V	0-5	25	65	66	56	V	0-5	76	v	11-0-5	E5	V	A5	v
27	W	0-6	26	66	67	57	W	0-6	77	w	11-0-6	E6	W	A6	w
30	X	0-7	27	67	70	58	X	0-7	78	x	11-0-7	E7	X	A7	x
31	Y	0-8	30	70	71	59	Y	0-8	79	y	11-0-8	E8	Y	A8	y
32	Z	0-9	31	71	72	5A	Z	0-9	7A	z	11-0-9	E9	Z	A9	z
33	0	0	12	00	20	30	0	0	10	DLE	12-11-9-8-1	F0	0	10	DLE
34	1	1	01	01	21	31	1	1	11	DC1	11-9-1	F1	1	11	DC1
35	2	2	02	02	22	32	2	2	12	DC2	11-9-2	F2	2	12	DC2
36	3	3	03	03	23	33	3	3	13	DC3	11-9-3	F3	3	13	TM
37	4	4	04	04	24	34	4	4	14	DC4	11-9-4	F4	4	3C	DC4

CODE D (default)

CODE E

CODE I

CODE A

Display Code		Hollerith Punch (026)	BCD		ASCII							EBCDIC			
						Upper Case			Lower Case			Upper		Lower	
Octal (13)	Char.		Ext. (13)	Int. (13)	6-Bit Octal (13)	Hex.	Char.	Punch (029)	Hex.	Char.	Punch	Hex.	Char.	Hex.	Char.
40	5	5	05	05	25	35	5	5	15	NAK	9-8-5	F5	5	3D	NAK
41	6	6	06	06	26	36	6	6	16	SYN	9-2	F6	6	32	SYN
42	7	7	07	07	27	37	7	7	17	ETB	0-9-6	F7	7	26	ETB
43	8	8	10	10	30	38	8	8	18	CAN	11-9-8	F8	8	18	CAN
44	9	9	11	11	31	39	9	9	19	EM	11-9-8-1	F9	9	19	EM
45	+	12	60	20	13	2B	+	12-8-6	0B	VT	12-9-8-3	4E	+	0B	VT
46	-	11	40	40	15	2D	-	11	0D	CR	12-9-8-5	60	-	0D	CR
47	*	11-8-4	54	54	12	2A	*	11-8-4	0A	LF	0-9-5	5C	*	25	LF
50	/	0-1	21	61	17	2F	/	0-1	0F	SI	12-9-8-7	61	/	0F	SI
51	(	0-8-4	34	74	10	28	(	12-8-5	08	BS	11-9-6	4D	(	16	BS
52	)	12-8-4	74	34	11	29	)	11-8-5	09	HT	12-9-5	5D	)	05	HT
53	$	11-8-3	53	53	04	24	$	11-8-3	04	EOT	9-7	5B	$	37	EOT
54	=	8-3	13	13	35	3D	=	8-6	1D	GS	11-9-8-5	7E	=	1D	IGS
55	space	space	20	60	00	20	space	space	00	NUL	12-0-9-8-1	40	space	00	NUL
56	,	0-8-3	33	73	14	2C	,	0-8-3	0C	FF	12-9-8-4	6B	,	0C	FF
57	.	12-8-3	73	33	16	2E	.	12-8-3	0E	SO	12-9-8-6	4B	.	0E	SO
60	≡ # (5)	0-8-6	36	76	03	23	#	8-3	03	ETX	12-9-3	7B	#	03	ETX
61	[	8-7	17	17	73	5B	[	12-8-2	1C	FS	11-9-8-4	4A	¢	1C	IFS
62	]	0-8-2	32	72	75	5D	]	11-8-2	01	SOH	12-9-1	5A	!	01	SOH
63	% (6)	8-6	16	16	05	25	%	0-8-4	05	ENQ	0-9-8-5	6C	%	2D	ENQ
64	≠ "	8-4	14	14	02	22	"	8-7	02	STX	12-9-2	7F	"	02	STX
65	┌─	0-8-5	35	75	77	5F	_	0-8-5	7F	DEL	12-9-7	6D	_	07	DEL
66	∨ !	11-0 (9)	52	52	01	21	!	12-8-7 (11)	7D	}	11-0	4F	|	D0	}
67	∧ &	0-8-7	37	77	06	26	&	12	06	ACK	0-9-8-6	50	&	2E	ACK
70	↑ '	11-8-5	55	55	07	27	'	8-5	07	BEL	0-9-8-7	7D	'	2F	BEL
71	↓ ?	11-8-6	56	56	37	3F	?	0-8-7	1F	US	11-9-8-7	6F	?	1F	IUS
72	<	12-0 (10)	72	32	34	3C	<	12-8-4 (12)	7B	{	12-0	4C	<	C0	{
73	>	11-8-7	57	57	36	3E	>	0-8-6	1E	RS	11-9-8-6	6E	>	1E	IRS
74	≤ @	8-5	15	15	40	40	@	8-4	60	`	8-1	7C	@	79	`
75	≥ \	12-8-5	75	35	74	5C	\	0-8-2	7C	¦	12-11	E0	\	6A	¦
76	¬ ∧	12-8-6	76	36	76	5E	∧	11-8-7	7E	~	11-0-1	5F	¬	A1	~
77	;	12-8-7	77	37	33	3B	;	11-8-6	1B	ESC	0-9-7	5E	;	27	ESC

HEXADECIMAL–OCTAL CONVERSION TABLE

		First Hexadecimal Digit															
		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Second Hexadecimal Digit	0	000	020	040	060	100	120	140	160	200	220	240	260	300	320	340	360
	1	001	021	041	061	101	121	141	161	201	221	241	261	301	321	341	361
	2	002	022	042	062	102	122	142	162	202	222	242	262	302	322	342	362
	3	003	023	043	063	103	123	143	163	203	223	243	263	303	323	343	363
	4	004	024	044	064	104	124	144	164	204	224	244	264	304	324	344	364
	5	005	025	045	065	105	125	145	165	205	225	245	265	305	325	345	365
	6	006	026	046	066	106	126	146	166	206	226	246	266	306	326	346	366
	7	007	027	047	067	107	127	147	167	207	227	247	267	307	327	347	367
	8	010	030	050	070	110	130	150	170	210	230	250	270	310	330	350	370
	9	011	031	051	071	111	131	151	171	211	231	251	271	311	331	351	371
	A	012	032	052	072	112	132	152	172	212	232	252	272	312	332	352	372
	B	013	033	053	073	113	133	153	173	213	233	253	273	313	333	353	373
	C	014	034	054	074	114	134	154	174	214	234	254	274	314	334	354	374
	D	015	035	055	075	115	135	155	175	215	235	255	275	315	335	355	375
	E	016	036	056	076	116	136	156	176	216	236	256	276	316	336	356	376
	F	017	037	057	077	117	137	157	177	217	237	257	277	317	337	357	377
Octal		000 – 037		040 – 077		100 – 137		140 – 177		200 – 237		240 – 277		300 – 337		340 – 377	

ASSEMBLY-TIME I/O

SCOPE 2

COMPASS 3 under SCOPE 2 uses the Record Manager for all of its I/O operations. Thus, COMPASS 3 can read and write files with a variety of external formats. For each of the files used by COMPASS, the default format, and the combinations of file format description parameters that may be specified in FILE control cards to override the defaults, are given below.

Main Source Input File

The main source input file may be a normal source input file or a compressed compile file; COMPASS determines which it is by inspecting the data in the file. A normal source input file under SCOPE 2 comprises the following:

File Organization (FO)	sequential (SQ)
Block Type (BT)	unblocked
Maximum Block Length (MBL)	none
Record Type (RT)	control word (W)
Maximum Record Length (MRL)	100 chars.
Conversion Mode (CM)	NO
Label Type (LT)	unlabeled (UL)

The only other formats that may be specified by FILE control statements are as follows (X=allowed, -=not allowed):

Block Type	Record Type		
	F	W	Z
unblocked	X	X	–
C	X	X	X
I	–	X	–

File Organization (FO) must be sequential (SQ).

Maximum Record Length (MRL) must not exceed 160 characters.

Label Type (LT) may be any value supported by the operating system.

Although the maximum record length may be as large as 160 characters, only the first 90 characters of each record are reproduced in the listing output files.

If the file is a compressed compile file (written by UPDATE in X mode or MODIFY† in A mode), COMPASS sets the file format description parameters to resemble normal input; however, MRL = 5120 characters.

Listing Output Files

The default format under SCOPE 2 comprises the following:

File Organization (FO)	sequential (SQ)
Block Type (BT)	unblocked
Maximum Block Length (MBL)	none
Record Type (RT)	control word (W)
Maximum Record Length (MRL)	137 chars.
Conversion Mode (CM)	NO
Label Type (LT)	Unlabeled (UL)

The only other formats that may be specified by FILE control statements are as follows (X=allowed, -=not allowed):

Block Type	Record Type		
	F	W	Z
unblocked	X	X	–
C	X	X	X
I	–	X	–

File Organization (FO) must be sequential (SQ).

Maximum Record Length (MRL) must not exceed 137 characters.

Label Type (LT) may be any value supported by the operating system.

Binary Output File

FILE control statements can be used under SCOPE 2 to specify the format of binary output files for any of the operating systems, such that a program can be assembled under SCOPE 2 and the object program executed under a different system if so desired.

---

†MODIFY is not available under SCOPE 2.

File Characteristics	SCOPE 2	NOS/SCOPE 3/KRONOS
File Organization (FO)	sequential (SQ)	sequential (SQ)
Block Type (BT)	unblocked	character count (C)
Maximum Block Length (MBL)	none	5120 chars.
Record Type (RT)	control word (W)	SCOPE logical record (S)
Maximum Record Length (MRL)	1,310,710 chars.	none
Conversion Mode (CM)	NO	NO
Label Type (LT)	Unlabeled (UL)	ANY

No other formats are allowed, except that the label type (LT) may be any value supported by the operating system used for assembly. The format shown above under SCOPE 2 is the default binary output file format under that system.

Scratch Files

COMPASS uses two scratch files named ZZZZZRL and ZZZZZRM, when table storage space overflows. Regardless of what may be specified by FILE control cards, COMPASS sets the file format description parameters for these files under SCOPE 2 as follows:

File Organization (FO) = sequential (SQ).

Conversion Mode (CM) = NO.

For file ZZZZZRL:

Block Type (BT) = unblocked
Maximum Block Length = 5120 characters.

Record Type (RT) = undefined (U) Maximum Record Length = 2550 chars.

For file ZZZZZRM:

Block Type (BT) = character count (C), Maximum Block Length = 5120 characters

Record Type (RT) = SCOPE logical (S), no Maximum Record Length

ALL OPERATING SYSTEMS

System Text Input Files

A user library file designated by an S parameter on the COMPASS control card must have the standard library file format for the system on which COMPASS is being used. COMPASS uses the operating system overlay loader to access these files.

For a sequential binary (non-library) file designated by a G parameter on the COMPASS control card, the default and permitted formats are the same as those given above for the COMPASS binary output file.

XTEXT Input Files

A file read by COMPASS when processing an XTEXT pseudo instruction may have any of several formats. COMPASS determines the file format (a) by whether the XTEXT pseudo instruction variable field is empty and (b) by inspecting the data in the file.

If the variable field is empty, the File Organization (FO) must be sequential (SQ). COMPASS rewinds the file and reads until end of section or a COMPASS END statement is encountered, whichever comes first. The default and permitted formats under SCOPE 2 are the same as those given above for the main source input file.

If the XTEXT variable field is non-empty, the file organization may be any of three non-standard types:

Record Indexed with name index (under SCOPE 2 only)

SCOPE 3.3 style random file with name index (not supported under SCOPE 2)

UPDATE or MODIFY† random program library file

In each case, COMPASS sets the file format description parameters to the appropriate values; no FILE control card is needed.

The record indexed file organization is actually the word addressable (WA) file organization with a set of format conventions superimposed on it. Such a file can be created by a FORTRAN program using the library subroutines OPENMS, STINDX, WRITMS, and CLOSMS with a name index, or by a COBOL program specifying ORGANIZATION IS STANDARD, SYMBOLIC KEY IS data-name. When COMPASS detects such a file under SCOPE 2, it sets the file format description parameters as follows (no FILE card is needed):

File Organization (FO) = word addressable (WA).

Block Type (BT) = unblocked

Record Type (RT) = control word (W), Maximum Record Length (MRL) = 160 chars.

Conversion Mode (CM) = NO

COMPASS positions the file at the record pointed to by the index entry containing the name given in the XTEXT statement variable field, and then reads records sequentially until end of section or a COMPASS END statement is encountered, whichever comes first.

The SCOPE 3.3 style random file with name index is permitted for compatibility with previous versions of COMPASS. When COMPASS detects such a file, it searches the file index and positions the file at the beginning of the specified section, and then reads sequentially until end of section or a COMPASS END statement is encountered, whichever comes first. Such files cannot be used with SCOPE 2.

An UPDATE or MODIFY† random program library file is processed similarly. The name in the variable field of the XTEXT statement must be the name of a common deck. When COMPASS detects such a file under SCOPE 2, it sets the file format description parameters as follows (no FILE control card is needed):

---

†MODIFY is not available under SCOPE 2.

File Organization (FO) = word addressable (WA).

Block Type (BT) = unblocked

Record Type (RT) = control word (W), Maximum Record Length (MRL) = 5120 characters

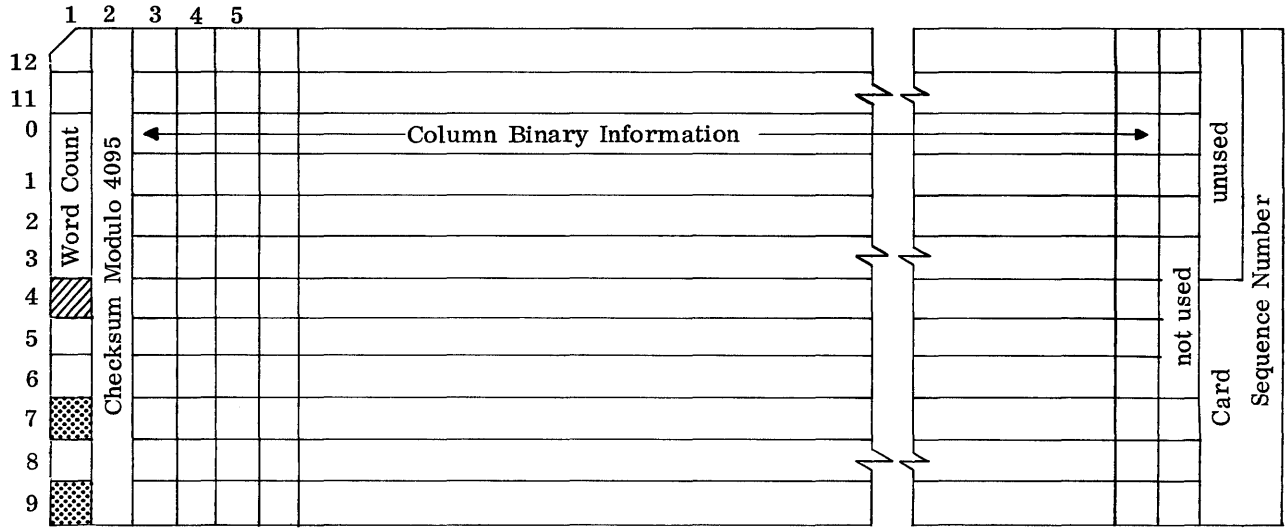
Conversion Mode (CM) = NO

COMPASS positions the file at the first card image of the designated section (common deck). The first active card image (the *COMDECK card) is skipped. COMPASS then reads card images sequentially, ignoring inactive card images, until end of section or a COMPASS END statement is encountered, whichever comes first.

BINARY CARD FORMATS C

Column 1

7,8,9 levels 0 to 16	End of section
6,7,9	End of partition (KRONOS/NOS only)
6,7,8,9 or 7,8,9 level 17	End of information
7,9	Binary card
7 and 9 not both in column 1	Coded card



A binary card can contain up to 15 60-bit CPU words starting at column 3. Column 1 also contains a count of 60-bit words in rows 0, 1, 2, and 3 plus a check indicator in row 4. If row 4 of column 1 is zero, column 2 is used as a checksum for the card on input; if row 4 is one, no check is performed on input.

Column 78 of a binary card is not used, and columns 79 and 80 contain a binary serial number. If a section is punched, each card has a checksum in column 2 and a serial number in columns 79 and 80, which sequences it within the logical record.

HINTS ON USING COMPASS D

1. Within a macro definition:

   a. Use comment cards having * in column one. These are not saved whereas other types of comments are saved.

   b. Whenever possible minimize the number of lines of code.

   c. IRP is faster than either ECHO or DUP.

   d. Use the substitutable parameter flags ;A, ;B, etc., for macros to avoid a second line.

   e. Within macros, use symbols such as .1, .2, etc. instead of local symbols.

   f. If possible, avoid recursive macro structure to increase assembly speed.

   g. If a macro call is the cause of an error, direct full list output to a file other than OUTPUT (L=filename) to obtain a list of the erroneous macro call with the error listing.

2. In IF sequences:

   a. Use line counts rather than ENDIF to terminate sequences.

   b. Use SKIP rather than IFPP to skip code.

3. Micros:

   a. Micro replacement is time consuming.

   b. Avoid using local symbols for micros.

   c. Use ≠ ≠ for a null substitution.

4. Minimize SYSTEXT size.

5. To reduce core requirements, use SEG cards in absolute programs.

6. Use NOREF for symbols for which listing is not required.

7. Use QUAL for all overlays.

DAYFILE MESSAGES E

The dayfile messages that can be issued by COMPASS are listed below, with an explanation for each.

ASSEMBLING xxxxxxx

This message is displayed at the system operator's console only; it is not written to the dayfile. COMPASS updates the display whenever it processes an IDENT statement with a non-blank variable field.

ASSEMBLY ABORTED - ECS READ ERROR.

This message can occur only when COMPASS is used on a CYBER 170 or CYBER 70/Model 72, 73, or 74, and only when the job has an ECS field length. In this case, COMPASS may store some of its internal tables in ECS, and issues the above message (and aborts the job) when an ECS error persists through four attempts to read the data. For the CYBER 70/Model 76, LCM errors are handled by the operating system.

ASSEMBLY ABORTED - ECS WRITE ERROR.

This message can occur only when COMPASS is used on a CYBER 170 or CYBER 70/Model 72, 73, or 74, and only when the job has an ECS field length. In this case, COMPASS may store some of its internal tables in ECS, and issues the above message (and aborts the job) when an error occurs in writing data to ECS; no retry attempt is made. For the CYBER 70/Model 76, LCM errors are handled by the operating system.

ASSEMBLY ABORTED - PASS n TABLE
OVERFLOW ASSEMBLING xxxxxxx

An irrecoverable table overflow condition has occurred in assembly pass n (1 or 2) while processing the indicated program. COMPASS allocates memory space dynamically to all of its internal tables, so that when one overflows, all do. When the tables do not all fit in the available SCM space, COMPASS stores some of them in the job's ECS/LCM field length (if any) and some others go to mass storage scratch files. COMPASS issues the above message, and aborts the job, when insufficient SCM exists after all such possibilities have been exhausted.

ASSEMBLY COMPLETE. nnnnnnB {CM / SCM} USED.
xxxx.xxx CPU {SECONDS ASSEMBLY TIME. / SEC. nnnnnnB {ECS / LCM} USED.}

COMPASS issues this message when it has completed processing of all source programs on the input file and did not detect any fatal errors. nnnnnn is the octal number of SCM words needed; i.e., the minimum field length needed to perform the assemblies successfully. It may be larger than the actual field length; in this case, it is the minimum field length needed to avoid lost references. The second line, which can be suppressed by an installation parameter, gives the total central processor time used by COMPASS, in seconds to three decimal places. If any ECS/LCM was used, this is shown in the second line.

ASSEMBLY ERRORS. nnnnnnB {CM / SCM} USED.
xxxx.xxx CPU {SECONDS ASSEMBLY TIME. / SEC. nnnnnnB {ECS / LCM} USED.}

COMPASS issues this message when it has completed processing of all source programs on the input file and detected at least one fatal error. If the A option was specified on the COMPASS control card, COMPASS aborts the job after issuing this message. nnnnnn and the second line are as in the ASSEMBLY COMPLETE message.

BAD CONTROL CARD ARGUMENT - xx

The COMPASS control card contains an unrecognized or invalid argument. The offending argument is named in the message. See Chapter 10 for details.

CANT LOAD COMP3$

The operating system loader reported a fatal error when COMPASS attempted to load its primary overlay. This message should be preceded by an explanatory message from the loader.

COMPASS NEEDS AT LEAST nnnnnB SCM.

The job's SCM field length is too small for COMPASS. nnnnnn is the octal number of words needed by COMPASS before it can begin processing. This can vary depending on the version of COMPASS used and the listing and binary output options specified on the control card. This is an absolute minimum, and does not include whatever space may be required for system text, local macro and micro definitions, etc.

nnnnnnnnn ERRORS IN xxxxxxx

COMPASS issues this message for each source program in which fatal errors are detected.

IDENT CARD MISSING.

COMPASS issues this message for each source program in which an END statement is encountered before an IDENT statement is found. This is a fatal error.

IMPROPER SYSTEM TEXT FORMAT.
BAD SYSTEM TEXT - x=yyyyyyy/zzzzzzz

A system text overlay does not have the internal format required by this version of COMPASS. This may be caused by a system error. COMPASS ignores the bad overlay but does not abort the job. The second line identifies the offending overlay in the same form in which it is specified in the COMPASS control card; x=yyyyyyy/zzzzzzz may be any of the following:

G=filenam
G=filenam/overlay
S=overlay
S=library/overlay

INPUT FILE EMPTY OR MISPOSITIONED.

COMPASS encountered end of data when it attempted to read the first line from the source input file. After issuing this message, COMPASS generates an END card which in turn causes the IDENT CARD MISSING message and a fatal error.

INSUFFICIENT STORAGE FOR SYSTEM TEXT.
BAD SYSTEM TEXT - x=yyyyyyy/zzzzzzz

COMPASS issues this message, but does not abort the job, when an irrecoverable table overflow occurs during system text loading, before the first assembly is begun. The second line identifies the system text being loaded at the time. A substantial increase the job's SCM field length may be needed.

nnnnnnnn LOST REFERENCES IN xxxxxxx

COMPASS issues this message for each source program whose symbolic cross-reference table does not fit in the job's SCM field length for sorting just before it is printed. Rather than aborting the job, COMPASS discards some of the references. The ASSEMBLY COMPLETE message gives the field length needed to avoid lost references.

MORE THAN 7 SYSTEM TEXTS SPECIFIED.

COMPASS issues this message, and aborts the job, when the G and S parameters on the COMPASS control card specify a total of more than seven system text overlays.

NO CONTROL CARD TERMINATOR.

COMPASS read continuation control cards and encountered end of section before finding a) or . not in a $-delimited string. This is not a fatal error.

RECURSION DEPTH EXCEEDED 400.

COMPASS maintains a push-down stack for source input control, with one entry for each active DUP ECHO, HERE, XTEXT, or macro call. The maximum depth of this stack is set by an installation parameter; it is 400 in the released system. When this limit is exceeded, COMPASS sets a fatal error and clears the stack (so that the next statement will be read from the source input file) but does not abort the job. This is usually caused by a source program error in which a macro calls itself indefinitely.

SYSTEM TEXT NOT FOUND.
BAD SYSTEM TEXT - x=yyyyyyy/zzzzzzz

COMPASS issues this message, but does not abort the job, when it cannot load the system text overlay identified in the second line. For an overlay loaded from a library (S parameter), this message should be preceded by an explanatory message from the operating system loader. For an overlay loaded from non-library file (G parameter), COMPASS could not find the overlay on the file.

nnnnnnnnn WARNING MESSAGES IN xxxxxxx

COMPASS issues this message for each source program in which non-fatal errors are detected.

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Legend

CP	Absolute or relocatable CPU program
CPA	Absolute CPU program
CPR	Relocatable CPU program
PP	Absolute PPU program

† Looked for during IF skipping.

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