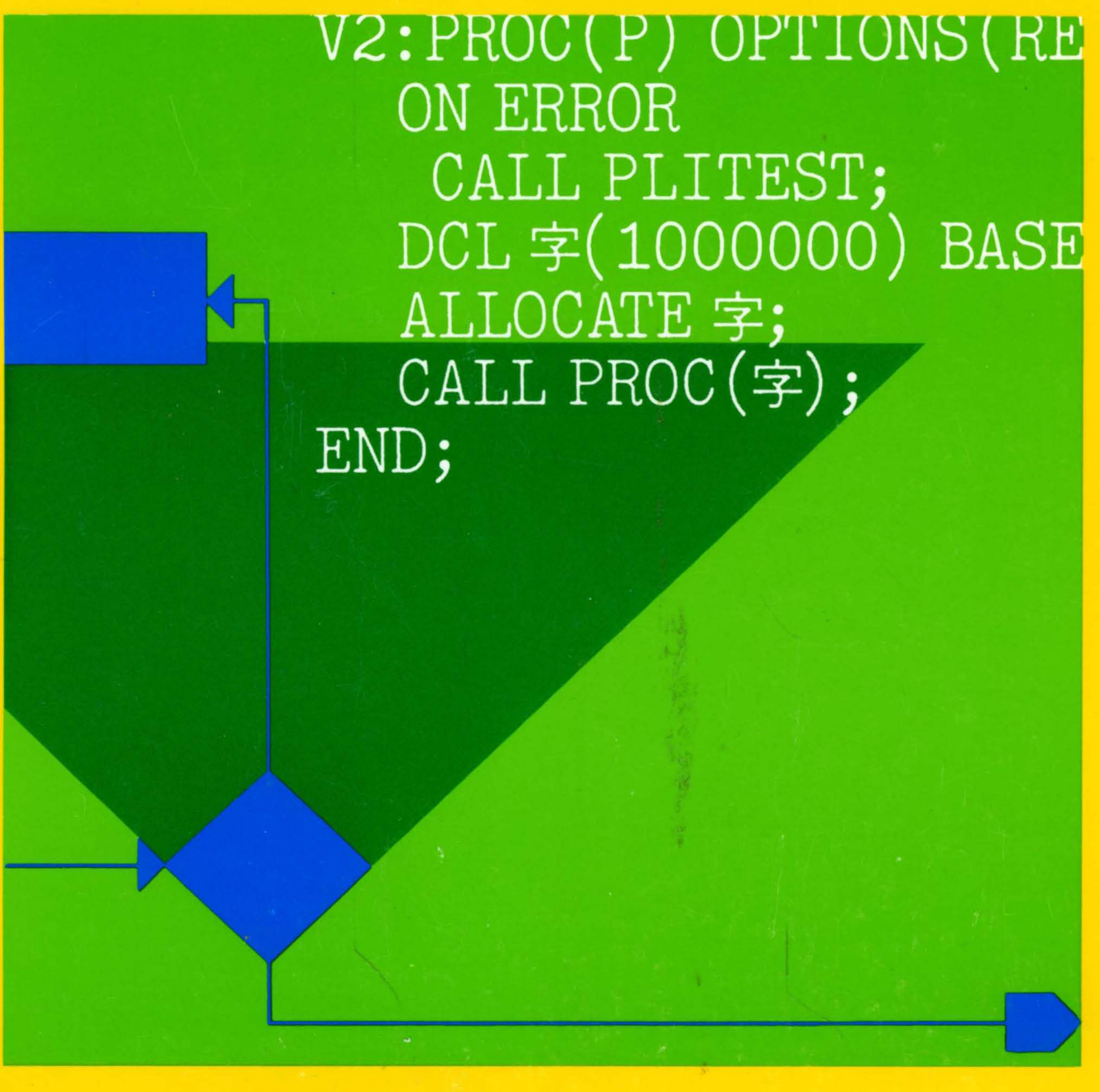
OS PL/I Version 2

Problem Determination

Release 1



```
V2:PROC(P) OPTIONS(RE
  ON ERROR
   CALL PLITEST;
  DCL 字(1000000) BASE
  ALLOCATE 字;
  CALL PROC(字);
END;
```

OS PL/I Version 2

LY27-9528-0

Problem Determination

Release 1

First Edition (December 1987)

This edition applies to Version 2 Release 1 of the following licensed programs:

- *OS PL/I Optimizing Compiler, Library, and Interactive Test Facility, Licensed Program* 5668-909
- *OS PL/I Optimizing Compiler and Library, Licensed Program* 5668-910
- *OS PL/I Library Only, Licensed Program* 5668-911

and to any subsequent releases until otherwise indicated in new editions or technical newsletters.

Changes are made periodically to this publication; before using this publication in connection with the operation of IBM systems, consult the latest *IBM System/370, 30xx, and 4300 Processors Bibliography*, GC20-0001, for the editions that are applicable and current.

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About This Book

Use *OS PL/I Version 2 Problem Determination* with the OS PL/I Optimizing Compiler Version 2. It will help you to determine problems, to formulate software search facility (SSF) search arguments and to document and submit APARs.

You can also use PLITEST, and PLITEST's interactive facilities, during run-time to diagnose problems. However, this book does not discuss using PLITEST for problem determination. In a few instances, where using PLITEST would help you significantly, PLITEST is discussed briefly. If you have PLITEST installed on your system and want more information about using PLITEST, see *OS PL/I Version 2 Programming: Using PLITEST.*

Who Might Use This Book

The primary audience for this book is all application programmers and systems programmers who write and run PL/I programs.

CMS and TSO Considerations

This book often refers to *ddnames*. In CMS, ddnames are associated to files by means of the FILEDEF command. In TSO, ddnames are associated to files by means of the ALLOC command.

How This book Is Organized

- *Chapter 1, Compiler Overview,* briefly describes how a PL/I program is compiled, link edited and run.
- *Chapter 2, Compile-Time Problem Determination,* contains the compile-time problem determination flowchart which describes various problems and recommends solutions for problems that can occur at this time.
- *Chapter 3, Compiler Output,* describes the object module generated by the compiler. It tells how PL/I organizes the object module and the form the information within it takes.
- *Chapter 4, Run-Time Organization,* describes the facilities PL/I uses during run-times such as registers, storage, load modules and the multitasking library.
- *Chapter 5, Run-Time Problem Determination,* contains the run-time problem determination flowchart which describes various problems and recommends solutions for problems that can occur at this time.
- *Chapter 6, Debugging Using Dumps,* descrıbes how to get a PL/I dump and how to interpret its contents.
- *Chapter 7, Using SSF and CSSF Search Arguments,* describes how to formulate arguments for and how to use the Software Search Facility (SSF) or the Customer Software Search Facility (CSSF).
- *Chapter 8, Submitting an APAR,* describes how to document and report suspected product problems to IBM using an APAR (Authorized Program Analysis Report).

- *Appendix A, Control Blocks,* gives information about control blocks that may be useful in problem determination.
- *Appendix B, Record-Oriented Input/Output,* describes record I/O.
- *Appendix C, Stream-Oriented Input/Output,* describes stream I/O.

Other OS PL/I Version 2 Books Available

The complete list of books in the OS PL/I Version 2 library is given in Figure 1. The figure shows what tasks each book is designed to help you with.

Task	OS PL/I Version 2 Publications	Order Number
Evaluation	General Information	GC26-4313
	Licensed Program Specifications	GC26-4314
Installation and Customization	Installation and Customization under MVS	SC26-4311
	Installation and Customization under CMS	SC26-4312
Application and System Programming	Programming Guide	SC26-4307
	Language Reference	SC26-4308
	Reference Summary	SX26-3759
	Using PLITEST	SC26-4310
	Messages and Codes	SC26-4309
Diagnosis	Problem Determination	LY27-9528

Figure 1. The OS PL/I Version 2 Library

The following books are the ones that will be most helpful while you are using this book:

OS PL/I Version 2 Programming Guide, SC26-4307, describes how to code, compile, test, and run OS PL/I programs. Information appearing in *OS PL/I Optimizing Compiler: CMS User's Guide*, SC33-0037, and *OS PL/I Optimizing Compiler: TSO User's Guide*, SC33-0029 is now contained in this book.

OS PL/I Version 2 Programming: Language Reference, SC26-4308, presents rules for writing OS PL/I source programs to be compiled by the OS PL/I Version 2 compiler.

OS PL/I Version 2 Programming: Messages and Codes, SC26-4309, lists error messages and codes that may be issued when you compile, link edit, and run OS PL/I programs. It also includes messages and codes issued by PLITEST. This book lists messages, and where needed, explanations, examples, and suggested programmer response.

Other Books You Might Need

You may want to refer to the following publications during your problem determination process:

OS/VS2 System Programming Library: Debugging Handbook, GC28-0708, GC28-0709, GC28-0710

OS/VS2 System Programming Library: Service Aids, GC28-0647

OS/VS2 System Programming Library: MVS Diagnostic Techniques, GC28-0725

OS/VS2 TSO Command Language Reference, GC28-0646

MVS/370 Message Library: System Messages, GC38-1008

MVS/Extended Architecture Command Language Reference, GC28-0646

MVS/Extended Architecture Message Library: System Messages, GC28-1156

MVS/Extended Architecture Message Library: System Codes, GC28-1157

MVS/Extended Architecture Message Library: TSO Terminal Messages, GC38-1046

MVS/Extended Architecture Diagnostic Techniques, LY28-1199

MVS/Extended Architecture System Programming Library: Service Aids, GC28-1159

MVS/Extended Architecture TSO Terminal User's Guide, GC28-1274

TSO EXTENSION Command Language Reference, SC28-1307

Virtual Machine/System Product CMS Command Reference, SC19-6209

Virtual Machine/System Product CP Command Reference, SC19-6211.

Contents

Chapter 1. Compiler Overview

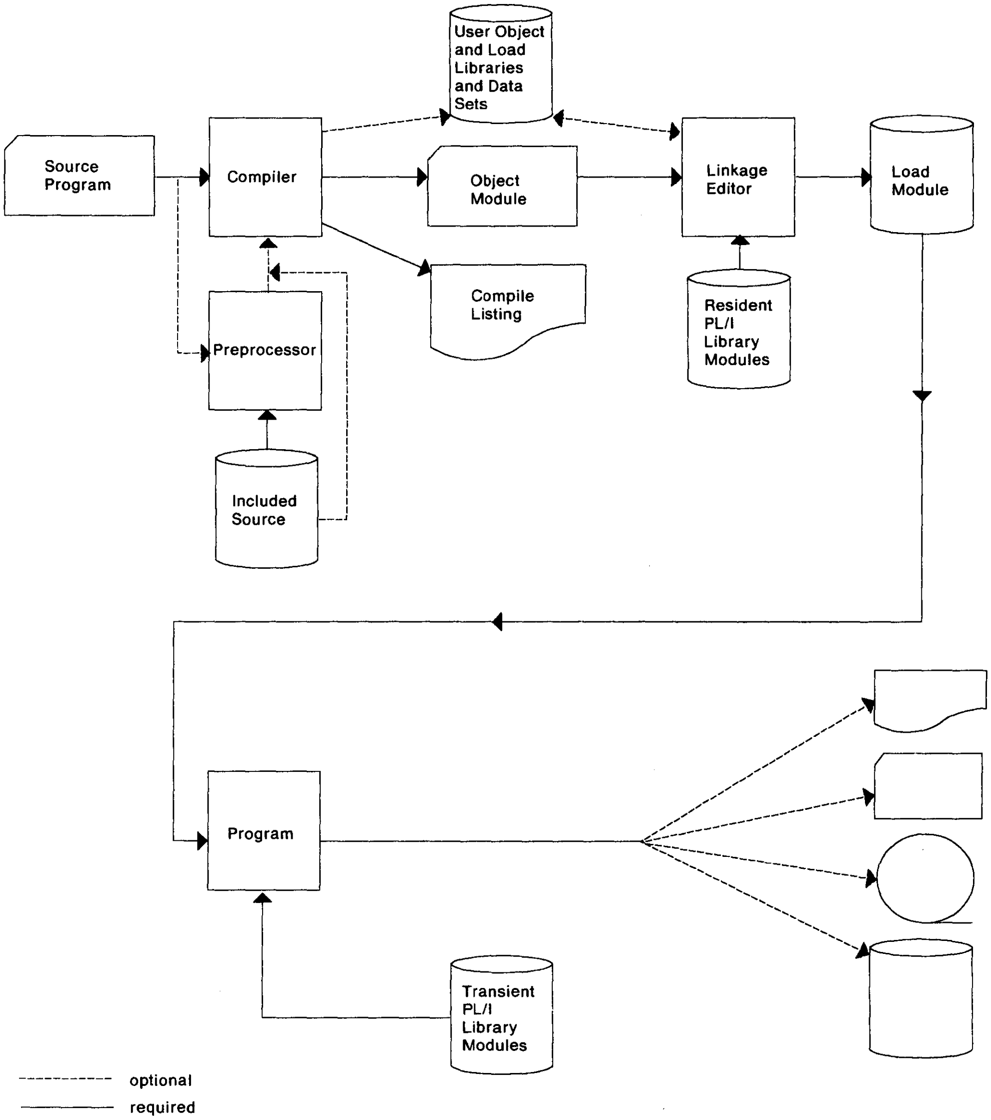


Figure 2. Compiling, Link Editing and Running

Function

The OS PL/I Optimizing Compiler Version 2 analyzes source programs written in the PL/I language and translates these source statements into a series of machine instructions that form an object module. The compiler operates as a problem state under the operating system.

Processing a PL/I Program

Figure 2 on page 1 shows the process through which a PL/I program passes from its inception to its use. There are four stages:

1. Writing the program and preparing it for the computer.
2. Compilation: Translating the program into machine instructions (that is, creating an object module).
3. Link editing: Producing a load module from the object module. This includes linking the compiled code with PL/I library modules, and possibly with other compiled programs. It also includes resolving the addresses within the code.
4. Running the load module.

The process is not necessarily a continuous one. The program may, for example, be kept in a compiled or link edited form before it is run, and also be run a number of times once compiled.

Compilation

Compilation is the process of translating a PL/I program into machine instructions. This is done by associating PL/I statements with addresses in storage and translating executable PL/I statements into a series of machine instructions. For example, the PL/I statements:

```
DCL I,J,K;
I=J+K;
```

result in the generation of machine instructions corresponding to the assembler language instructions shown below:

```
LH   7,88(0,13)  Load J into register 7
AH   7,90(0,13)  Add K to J
STH  7,96(0,13)  Place result in I
```

(The variables I, J, and K from the address in register 13 are held at offsets 96, 88, and 90, respectively.)

The OS PL/I Optimizing Compiler Version 2 does not translate all PL/I statements directly into the necessary machine instructions. Instead, certain statements are translated into calls to standard subroutines held in the resident library routines. These routines may call further library routines from the PL/I library. The following PL/I statements for example, result in a call to a resident library routine.

```
DCL X,Y;
X=SIN(Y);
```

The list below shows the code that would result from such statements:

```
LA   14,92(0,13)     Place address of Y in register 14

LA   15,96(0,13)     Place address of X in register 15

STM  14,15,80(0,3)   Place addresses in argument list

LA   1,80,(0,3)      Point register 1 at argument list

L    15,88(0,3)      Load register 15 with the address of a
                     library routine.
                     (This is held in the form of an address
                     constant generated by the compiler and
                     resolved by the linkage editor.)

BALR 14,15           Branch to the library routine, which
                     carries out the required function.
```

- Preprocessor

  The source program passes to the compiler either directly or through a preprocessor stage (see Figure 2 on page 1). The preprocessor can modify source statements in the program or insert additional source statements in the program before compilation begins. You invoke the preprocessor by specifying the compile-time option MACRO. If the compiler detects an error or the possibility of an error during the preprocessor stage, it prints a message on the pages following the input listing. Thus, there are two sets of messages: one for the preprocessor and one for the compiler. Details of preprocessor and compile-time messages are given in the *OS PL/I Version 2 Programming: Messages and Codes.*

- Compiler

  Under the control of a compile-time option, the compiler optimizes code. Some helpful compile-time options are shown in Figure 3. For more information about these options, see the *OS PL/I Version 2 Programming Guide.*

Needed Documentation	**Compile-Time Option**
Source Listing	SOURCE
Cross-reference Listing	XREF
Attribute Table	ATTRIBUTES
Aggregate Table	AGGREGATE
Storage Table	STORAGE
Compiler Options	OPTIONS

Figure 3 (Part 1 of 2). Compile-Time Options Helpful in Problem Determination

Needed Documentation	Compile-Time Option
Offset Address	OFFSET
Object Listing	LIST
Static Storage Map	MAP
Statement in Error	GOSTMT or GONUMBER
Diagnostic Message List	FLAG(I)
Margins of Source List	MARGINI
Long Form Messages	LMESSAGE
If preprocessor used	INSOURCE MDECK MACRO
Block and do-group statement listing	NEST
Sequential statement listing	STMT
PLITEST information about compiled code	TEST GOSTMT GONUMBER
Flow of control	FLOW COUNT

Figure 3 (Part 2 of 2). Compile-Time Options Helpful in Problem Determination

Link Editing

Link editing links the compiler output with external modules requested by the compiled program. These are PL/I library routines, and possibly, modules produced by further compilations. As well as linking the external modules, the linkage editor also resolves addresses within the object module.

Running

The OS PL/I Optimizing Compiler Version 2 produces code that requires a special arrangement of control blocks and registers for the correct run. This arrangement of control blocks and registers is known as the *PL/I environment*. Execution consequently becomes a three-stage process:

1. Setting up the environment. The PL/I initialization routines handle this.
2. Running the program.
3. Completing the job after the run. This consists of closing any files left open and returning control either to the supervisor or to a calling module. A termination routine handles this.

Chapter 2. Compile-Time Problem Determination

This chapter contains the compile-time problem determination chart. If you are just beginning your problem diagnosis, start by using the chart in Figure 5. Begin with Block 1 and answer the question or perform the action specified, then go to the block indicated by the answer. Some blocks describe an action to be performed and also direct you to the next block.

If you have already made a preliminary diagnosis of your problem and you are familiar with PL/I, you can use the chart index below in Figure 4 to find the information you need.

Compile-Time Subject Covered	Block Number
Abend or Program Check	26
Search Argument Generation	27
Message	28
Search Argument Generation	31
Loop	32
Search Argument Generation	33
Wait	34
Unusual or Unexpected Output	35
Search Argument Generation	36
Performance	37
Search Argument Generation	38

Figure 4. Compile-Time Problem Determination Index

Block No.	Question	Action
1	Is this a compile-time or a run-time failure?	Compile-time failure Go to 2 Run-time failure Go to 100 on page 63
2	Is this a U level message?	Yes 8 No 3
3	Is this a problem relating to a message?	Yes 8 No 4
4	Is this a loop?	Yes 8 No 5
5	Is this a wait?	Yes 8 No 6
6	Does the compilation result in some type of unusual or unexpected output?	Yes 8 No 7

Figure 5 (Part 1 of 6). Compile-Time Problem Determination Chart

Block No.	Question	Action
7	Is this a performance problem?	Yes 8 No 24
8	Has the program ever compiled before?	Yes 9 No 11
9	Has anything in the environment been changed? (Source changes, release level, maintenance fixes, compile time options, etc.)	Yes 12 No 10
10	Is the entry from:	
	U level message	Yes 26
	Message other than U level	Yes 28
	Loop	Yes 32
	Wait	Yes 34
	Unusual or unexpected output	Yes 35
	Performance	Yes 37
	Note: If you are here via the "environment changed" route, follow the major symptom code being experienced.	
11	Make sure PL/I coding rules have been followed. Check and correct any statements causing "E" or "S" level messages. If you are using the "OPTIMIZE(TIME)" or "OPTIMIZE(2)" compile option, recompile using "NOOPTIMIZE." Is the problem circumvented?	Yes 41 No 10
12	Has the source code of the program been changed? (This includes compile time options.)	Yes 15 No 13
13	Has any maintenance been applied? (PTFs, fixes)	Yes 17 No 14
14	Has the release level changed?	Yes 18 No 25
15	Check and correct any source statements causing "E" or "S" level messages. Be critical of source changes. Is the problem solved? **Note:** If the problem is solved, but you feel the message was generated in error, follow the "NO" path.	Yes END No 16
16	If you are using the "OPTIMIZE(TIME)" or "OPTIMIZE(2)" compile option, recompile using "NOOPTIMIZE." Is the problem circumvented?	Yes 41 No 10
17	Is(Are) the fix(es) or PTF(s) installed correctly? In other words, were there any system messages while installing and link editing? Search early warning microfiche or INFO/ACCESS, or ask the IBM Support Center Level 1 to search RETAIN for possible PTF errors in the form "PExxxxx".	Yes 19 No 20

Figure 5 (Part 2 of 6). Compile-Time Problem Determination Chart

Block No.	Question	Action
18	Is the release installed correctly? (Search early warning microfiche or INFO/ACCESS, or ask the IBM Support Center Level 1 to search RETAIN for any PTFs and errors applicable to this release. Search for PTF errors in the form: "PExxxxx".) Were there any SMP error messages or system messages while installing the release?	Yes 19 No 21
19	Search early warning microfiche, INFO/ACCESS, or have the IBM Support Center search RETAIN. Information about conducting a search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 22 No 10
20	Reinstall the PTF or fix and test. Is the problem solved?	Yes END No 23
21	Reinstall the release level correctly, plus any PTFs or fixes that are applicable, and test. Is the problem solved?	Yes END No 23
22	Apply applicable fix(es) from RETAIN and test. Is the problem solved?	Yes END No 23
23	Have the symptoms changed?	Yes 2 No 10
24	Something has apparently been overlooked. A failure must have occurred, and it must have been one of the previously mentioned items. Review the compiler output again. If the problem does not fit any of the stated symptoms, go to Block 41.	41
25	Obviously something has been changed. Investigate the system control program for possible changes such as fixes, PTFs, library updates or reorganization, etc.	
26	Compiler program checks will produce one of the following messages: IEL0001I U PREPROCESSOR ERROR n DURING PHASE p IEL0230I U COMPILER ERROR NUMBER n DURING PHASE p IEL0970I U COMPILER CANNOT PROCEED. ERROR n DURING PHASE p. CORRECT SOURCE AND RECOMPILE **Note:** Details of compiler error numbers and sometimes recommended programmer actions are in your *OS PL/I Version 2 Programming: Messages and Codes* manual. Go to Block 27.	27

Figure 5 (Part 3 of 6). Compile-Time Problem Determination Chart

Block No.	Question	Action
27	Search early warning microfiche, INFO/ACCESS, or have the IBM Support Center search RETAIN using the component-id 5668909, the error number from the message and phase-id from message. Information about conducting a search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 39 No 41
28	Is this an "E" or "S" level diagnostic message?	Yes 29 No 30
29	Look up the message in *OS PL/I Version 2 Programming: Messages and Codes* These messages indicate the compiler has detected error condition(s) in the source statements. Compilation may be complete, but the object program may not run correctly. Check and correct any statements in error. Rerun the program. Does the message still occur?	Yes 30 No END
30	If you are using the "OPTIMIZE(TIME)" or "OPTIMIZE(2)" compile option, recompile with "NOOPTIMIZE". Is the problem circumvented?	Yes 41 No 31
31	Search early warning microfiche, INFO/ACCESS or have the IBM Support Center search RETAIN using component-id 5668909 and MSGIELxxxxl. Information about doing your search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 39 No 41

Figure 5 (Part 4 of 6). Compile-Time Problem Determination Chart

Block No.	Question	Action
32	If a loop appears to be occurring, use a system trace facility or instruction step mode to capture all, or at least part, of the loop addresses. Then cancel the job with a dump. Find the current phase in the dump as follows: • Register 13 points to the communications area (XCOMM). • To check, look at the field at offset X'90' from register 13. This field should contain the first source input record. If register 13 has been corrupted, search for this field to locate XCOMM. • The current phase name is at offset X'4AB' from the beginning of XCOMM. This field contains two letters. Adding "IEL0" before these two letters and will give you the name of the current phase. • The phase start address is at offset X'434' from XCOMM. If you are using the "OPTIMIZE" compile option, recompile using "NOOPTIMIZE." Phase "IEL0IE" may appear to be in a loop if a large number of "BYNAME" assignments are used or if the source does an assign to a large "PICTURE" statement. Phase "IEL0IK" may appear to be in a loop sorting data names for the XREF table. Give the compiler a little more time. Other loops may be caused by: • Using a colon instead of a semicolon • Not enough storage • Not enough time. Is the problem circumvented?	Yes 41 No 33
33	Search early warning microfiche, INFO/ACCESS, or have the IBM Support Center search RETAIN using: • component-id 5668909 • LOOP and module name(s) in which loop occurs. Information about doing your search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 39 No 41
34	The only waits the compiler issues are for I/O. Wait states should be investigated from the system control viewpoint: • Check to see that the region running PL/I is not waiting for a resource owned by another region. • See if there are any system messages. If you still suspect the PL/I compiler is causing the wait, go to Block 41.	41

Figure 5 (Part 5 of 6). Compile-Time Problem Determination Chart

Block No.	Question	Action
35	Be sure all appropriate compile options are specified. If you are using the "OPTIMIZE(TIME)" or "OPTIMIZE(2)" compile option, recompile with "NOOPTIMIZE". Is the problem circumvented?	Yes 41 No 36
36	Search early warning microfiche, INFO/ACCESS, or have the IBM Support Center search RETAIN using component-id 5668909 and INCORROUT, a word describing what output is incorrect. Information about doing your search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 39 No 41
37	Performance problems usually show up after some environment change; if not a maintenance change, then perhaps a source code or compile option change. Review these items. If you are using the "OPTIMIZE(TIME)" or "OPTIMIZE(2)" compile option, recompile with "NOOPTIMIZE". Is the problem circumvented?	Yes 41 No 38
38	Search early warning microfiche, INFO/ACCESS, or have the IBM Support Center search RETAIN using component-id 5668909. Information about doing your search is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 39 No 41
39	Apply the fix(es), circumvention from RETAIN, and test. Is the problem solved?	Yes END No 40
40	Did the symptoms change?	Yes 2 No 41
41	Contact the IBM Support Center for assistance. Have available the following documentation: • Compilation listing with LIST, SOURCE, XREF, STMT, ESD, and MAP options specified • The TSO or CMS command sequence or the JCL used to run the job • Dump (if applicable) • Preprocessor input (if applicable) • List of applied fixes.	

Figure 5 (Part 6 of 6). Compile-Time Problem Determination Chart

Chapter 3. Compiler Output

This chapter describes the part of the load module generated by the compiler. The compiler output is a relocatable object module consisting of a series of 80-column records. These records contain either machine instructions, constants, or external or internal addresses that the linkage editor resolves. The records are:

TXT records
: Contain machine instructions or constants.

RLD records
: Contain internal addresses that require updating for a load module.

ESD records
: Contain external names to be resolved (bound) with other programs and data areas.

The compiler produces two main control sections:

- The program control section, holding the executable instructions translated from the PL/I program.
- The static internal control section holding constants, addresses, and static variables.

The compiler also generates a number of other control sections. These handle certain housekeeping functions or they are used for external data. This external data may have identical control sections generated for it by other compilations.

Storage for workspace and automatic variables is acquired during execution, normally by the prolog code that is executed at the start of every block.

The output from the compiler is shown in Figure 6 on page 13, and listed below:

1. *Control sections that are always generated*

   Program control section
   : Containing executable instructions.

   Static internal control section
   : Containing addresses, control blocks, constants, and STATIC INTERNAL variables.

   PLISTART
   : The entry point for the executable program phase. Passes control to initialization routine.

2. *Control sections that are generated only when required*

   PLIMAIN
   : Containing the address of the entry point of the main procedure. (Generated only for procedures with OPTIONS (MAIN).)

   PLIFLOW
   : A control section generated when the compiler FLOW option is specified.

PLICOUNT
A control section generated when the COUNT compiler option is specified.

Static external control sections
A static external control section is generated for every external variable, file, and procedure.

Plus control sections for
Each user-defined condition, and each compiler-generated subroutine used.

3. *Dummy sections*

Pseudo-register vector
A dummy section used to address files, controlled variables and FETCHable entry constants.

Program initialization uses the two control sections, PLISTART and PLIMAIN. PLISTART holds the address of the library initialization routine IBMBPIR, which is entered at the start of the program. PLIMAIN holds the address of the start of the code for the main procedure. This is the address to which the library initialization routine branches when initialization ends. It is marked "*REAL ENTRY" in the object-program listing.

A PLIMAIN control section is generated for every procedure for which OPTIONS (MAIN) is specified in the procedure statement. When two such procedures run together, control passes to the first procedure processed by the linkage editor.

Appendix A, "Control Blocks" on page 119 gives the format of PLIMAIN and PLISTART.

If you use the compile-time FLOW option, a control section called PLIFLOW is also generated. This contains code that results in the link-editing of the trace module IBMBEFL, and also contains the values of "n" and "m" specified in the option.

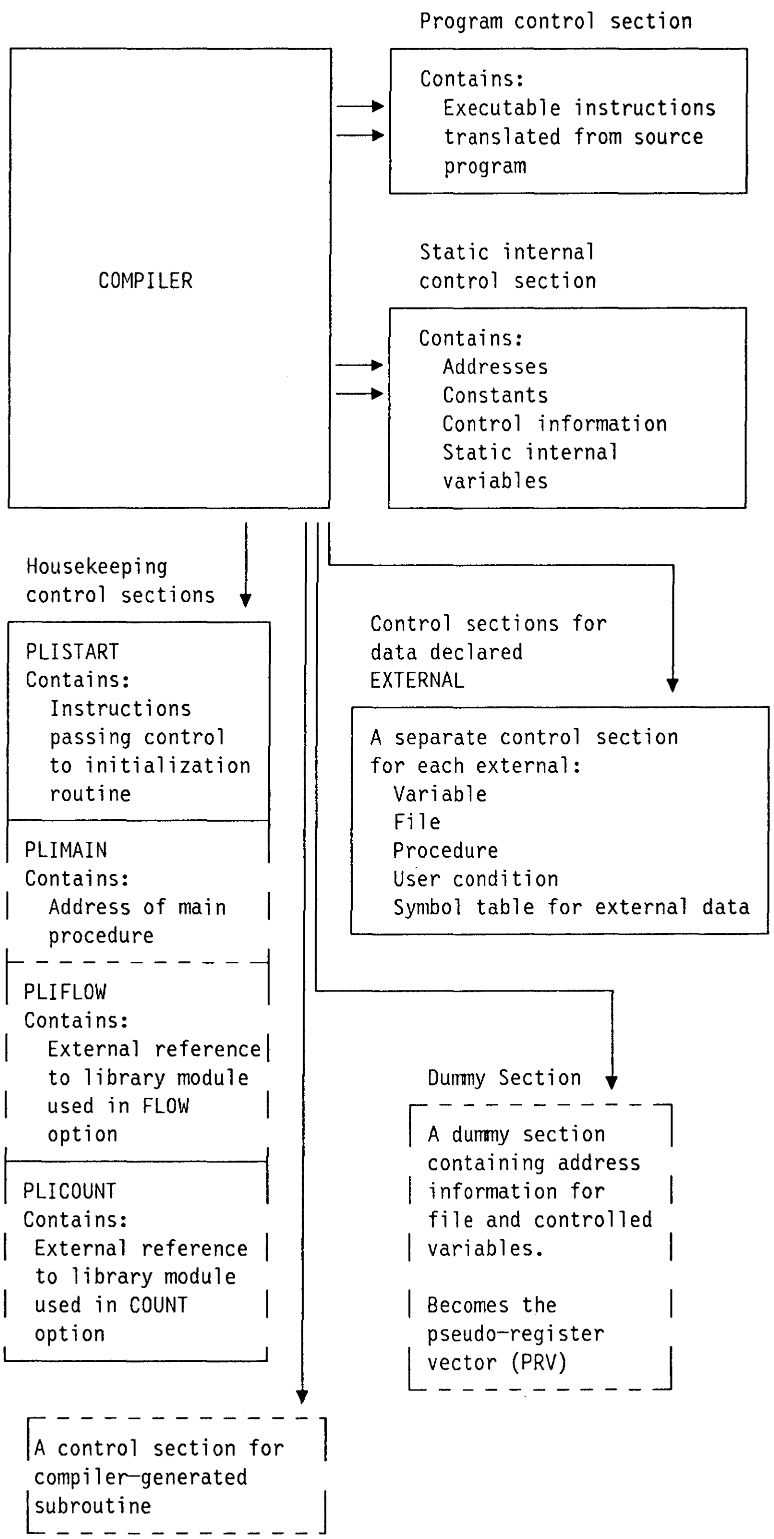

COMPILER
Program control section
Contains:
Executable instructions translated from source program
Static internal control section
Contains:
Addresses
Constants
Control information
Static internal variables
Housekeeping control sections
PLISTART
Contains:
Instructions passing control to initialization routine
PLIMAIN
Contains:
Address of main procedure
PLIFLOW
Contains:
External reference to library module used in FLOW option
PLICOUNT
Contains:
External reference to library module used in COUNT option
Control sections for data declared EXTERNAL
A separate control section for each external:
Variable
File
Procedure
User condition
Symbol table for external data
Dummy Section
A dummy section containing address information for file and controlled variables.
Becomes the pseudo-register vector (PRV)
A control section for compiler-generated subroutine

Figure 6. The Output from the Compiler

Note: Control sections surrounded with broken lines are generated only when required.

The Organization of This Chapter

The remainder of this chapter describes the contents of the static internal control section and the program control section. First the conventions used in the object program listing and the static storage map are described. Descriptions of the two control sections follow. The description of the program control section covers the conventions used in the object program code, such as register usage, method of handling flow of control, and addressing information. A short discussion of the effects of optimization completes the chapter.

Listing Conventions

Figure 7 shows all the program listing information that the compiler can produce. It also shows the relevant compile-time options and summarizes the information produced if these options are specified.

This chapter describes the contents of the static-storage map and the object-program listing. *OS PL/I Version 2 Programming Guide* gives information on the other items generated.

Name	Contents	Compiler Option
Source program	Source program statements	SOURCE
Aggregate table	Names and storage requirements of structures and arrays	AGGREGATE
Storage requirements	Names and storage requirements of all procedures	STORAGE
ESD references	Name, type, and identifier of all external references generated by the compiler[1]	ESD
Static storage	Contents of static internal and static external control sections in hexadecimal notation with comments	MAP and LIST
Table of offset and statement number	Offsets, within code, of the start of each statement	OFFSET
Object program	The contents of the program control section in hexadecimal and translated into a pseudo-assembler-language format	LIST
Variables offset MAP	The offsets of automatic and static internal variables from their defining base	MAP

Figure 7. Contents of Listing and Associated Compile-Time Options

Note to Figure 7:

[1] External references within library modules are not included.

Static-Storage Map

The *static-storage map* is a formatted listing of the contents of the static internal and static external control sections. You obtain this listing by specifying the MAP option in the PROCESS statement. The static control sections contain items grouped in the following order:

1. Address constants for entry points to procedures, and for branch instructions
2. Address constants for resident library subroutines
3. Address constants for addressing static storage beyond 4K
4. The constants pool, which contains source program constants, data element descriptors, locator/descriptors, symbol tables, declare control blocks (DCLCBs), and other control blocks
5. Static variables.

The constants pool and the static-variable sections of static storage begin on doubleword boundaries.

The static control section is listed, each line comprising the following elements:

1. Six-digit hexadecimal offset.
2. Hexadecimal text, in 8-byte sections where possible.
3. Comment, indicating the type of item to which the text refers; a comment appears against only the first line of the text for an item.

A typical static listing is shown in Figure 8 on page 17.

The following comments are used (xxx indicates the presence of an identifier):

A..	Address constant
COMPILER LABEL CL.nn	Compiler-generated label followed by CL plus number
CONDITION CSECT	Control section for programmer-named condition
CONSTANT	
CSECT FOR EXTERNAL VARIABLE	Control section for external variable
D..	Descriptor
DED..	Data element descriptor
ENVB	Environment control block
DCLCB	Declare control block
FED..	Format element descriptor
KD..	Key descriptor
ONCB	On control block
PICTURED DED..	Pictured DED
RD..	Record descriptor
SYMBOL TABLE ELEMENT	Address of symbol table
SYMBOL TABLE...xxx	Symbol table for xxx
SYMTAB DED...xxx	Symbol table DED for xxx

USER LABEL xxx — Source program label for xxx

xxx — Name of variable. If the variable is not initialized, no text appears against the comment; there is also no static offset if the variable is an array. (The static offset can be calculated from the array descriptor if required.)

```
                      SOURCE
1             EXAMPLE: PROC OPTIONS(MAIN) REORDER;
2   1                    DCL X(10),Y,Z INITIAL (0);
3   1                    GET EDIT(X,Y)(F(3),X(11));
4   1                        DO I = 1 TO Y;
5   1   1                    Z=Z*X(I);
6   1   1                    END;
7   1                    PUT EDIT(Z)(A);
8   1                END;
```

```
         STATIC INTERNAL STORAGE MAP                      STATIC EXTERNAL CSECTS

000000  E0000100          PROGRAM ADCON        000000  0000000000000000      DCLCB
000004  00000008          PROGRAM ADCON                0000000000000000
000008  0000009A          PROGRAM ADCON                000000140005E2E8
00000C  000000A4          PROGRAM ADCON                E2C9D500
000010  000000A4          PROGRAM ADCON
000014  00000000          A..IELCGIX
000018  00000000          A..IELCGIB           000000  FFFFFFFC41201000      DCLCB
00001C  00000000          A..IBMBCACA                  02D70F0000000000
000020  00000000          A..IBMBCEDB                  000000140008E2E8
000024  00000000          A..IBMBCHFD                  E2D7D9C9D5E30000
000028  00000000          A..IBMBCTHD
00002C  00000000          A..IBMBCVDY
000030  00000000          A..IBMBOCLA
000034  00000000          A..IBMBOCLC
000038  00000000          A..IBMBSAOA
00003C  00000000          A..IBMBSEDB
000040  00000000          A..IBMBSEIA
000044  00000000          A..IBMBSEIT
000048  00000000          A..IBMBSFIA
00004C  00000000          A..IBMBSIIA
000050  00000000          A..IBMBSIOA
000054  00000000          A..IBMBSIOT
000058  00000000          A..IBMBSXCA
00005C  00000000          A..STATIC
000060  08040680          DED..X
000064  500000030080      FED
00006A  6000000B          FED
00006E  58010000          FED
000072  0004              CONSTANT
000074  0001              CONSTANT
000076
000078  91E091E0          CONSTANT
00007C  00000000          CONSTANT
000080  00000009          CONSTANT
000084  00000001          CONSTANT
000088  00000000          CONSTANT
00008C  46008000          CONSTANT
000090  00000000          A..DCLCB
000094  00000000          A..DCLCB
000098  00000000          A..DCLCB
00009C  80000000          A..TEMP
0000A0  00000000          A..DCLCB
0000A4  80000000          A..TEMP
0000A8  00000152000000A4  COMPILER LABEL CL.11
```

Figure 8. Example of Static Storage Listing

Object-Program Listing

By including the option LIST in the PROCESS statement, the programmer can obtain a listing of the compiled code, known as the object-program listing. This listing consists of the machine instructions, a translation of these instructions into a form that resembles assembler language, and number of comments, such as the statement number. The format of this listing is shown in Figure 9 on page 20.

The format has blocks of code headed by the number of the statement in the PL/I program to which they are equivalent. When optimization results in code being moved out of a statement, this is indicated. Only executable statements appear in the listing. DECLARE statements are not included, because they have no direct machine-code equivalent. To simplify understanding of the listing, the names of PL/I variables are inserted, rather than the addresses that appear in the machine code. Special mnemonics are used when referring to control blocks and other items.

Statements in the object program listing are ordered by block. Statements in the outermost block are given first, followed by statements in the inner blocks. As a result, the order of statements frequently differs from that of the source program.

Every object-program listing begins with the name of the procedure. The name is defined as a constant in a DC instruction. Another constant follows this which contains the length of the procedure name. Next, the name of the procedure appears as a comment, followed by code under the heading "REAL ENTRY." At this point, the code is entered. The second section of code is the prolog, which carries out various housekeeping tasks and is described more fully later in this chapter. The message "PROCEDURE BASE." marks the end of the prolog. Following this is a translation of the first executable statement in the PL/I source program.

The comments used in the listing are as follows:

- PROCEDURE xxx—identifies the start of the procedure labeled xxx.
- REAL ENTRY —heads the initialization code for an entry point to a procedure.
- PROLOG BASE—identifies the start of the prolog code common to all entry points into that procedure.
- PROCEDURE BASE—identifies the address loaded into the base register for the procedure.
- STATEMENT LABEL xxx—identifies the position of source program statement label xxx.
- PROGRAM ADDRESSABILITY. REGION BASE—identifies the address which the program base is updated if the program size exceeds 4096 bytes and consequently cannot be addressed from one base.
- CONTINUATION OF PREVIOUS REGION—identifies the point at which addressing from the previous program base recommences.
- END OF COMMON CODE—identifies the end of code used in the execution of more than one statement.

- END PROCEDURE —identifies the end of a procedure.
- BEGIN BLOCK xxx—indicates the start of the begin block with label xxx.
- BEGIN BLOCK NUMBER xx—indicates the start of the begin block with number xx.
- END BLOCK —indicates the end of the begin block.
- STATEMENT NUMBER n—identifies the start of code generated for statement number n in the source listing.
- INTERLANGUAGE PROCEDURE xxx—identifies the start of encompassing procedure xxx
- END INTERLANGUAGE PROCEDURE xxx—identifies the end of encompassing procedure xxx.
- COMPILER GENERATED SUBROUTINE xxx—indicates the start of compiler-generated subroutine xxx.
- END OF COMPILER GENERATED SUBROUTINE—indicates the end of the compiler-generated subroutine.
- ON-UNIT BLOCK NUMBER xx—indicates the start of an ON-unit block.
- ON-UNIT BLOCK END—indicates the end of the ON-unit block.
- END PROGRAM—indicates the end of the external procedure.
- INITIALIZATION CODE FOR OPTIMIZED LOOP FOLLOWS—indicates that some of the code that follows was moved from within a loop by the optimization process.
- CODE MOVED FROM STATEMENT NUMBER n—indicates object code moved by the optimization process to a different part of the program and gives the number of the statement from which it originated.
- CALCULATION OF COMMONED EXPRESSION FOLLOWS—indicates that an expression used more than once in the program is calculated at this point.
- METHOD OR ORDER OF CALCULATING EXPRESSIONS CHANGED— indicates that the order of the code following was changed to optimize the object code.

```
000056  48 50 F 050               LH    5,80(0,15)
00005A  4B 50 E 002               SH    5,2(0,14)
00005E  91 C0 E 001               TM    1(14),X'C0'
000062  47 E0 7 076               BNO   *+20
000066  4B 50 E 002               SH    5,2(0,14)
00006A  91 40 F 026               TM    38(15),X'40'
00006E  47 80 7 076               BZ    *+8
000072  06 50                     BCTR  5,0
000074  06 50                     BCTR  5,0
000076  40 50 F 050               STH   5,80(0,15)
00007A  58 50 F 04C               L     5,76(0,15)
00007E  50 50 1 000               ST    5,0(0,1)
000082  4A 50 E 002               AH    5,2(0,14)
000086  91 C0 E 001               TM    1(14),X'C0'
00008A  47 E0 7 09E               BNO   *+20
00008E  4A 50 E 002               AH    5,2(0,14)
000092  91 40 F 026               TM    38(15),X'40'
000096  47 80 7 09E               BZ    *+8
00009A  41 55 0 002               LA    5,2(5,0)
00009E  50 50 F 04C               ST    5,76(0,15)
0000A2  58 50 1 01C               L     5,28(0,1)
0000A6  D2 03 1 01C D 04C         MVC   28(4,1),76(13)
0000AC  07 F6                     BR    6
0000AE  58 F0 7 0CC               L     15,204(0,7)
0000B2  95 60 E 000               CLI   0(14),X'60'
0000B6  47 70 7 0BE               BNE   *+8
0000BA  58 F0 7 0D0               L     15,208(0,7)
```

```
000038                           DC    AL4(0)
00003C                           DC    AL4(0)

* END OF COMPILER GENERATED SUBROUTINE


* STATEMENT NUMBER  1
000000                           DC    C'EXAMPLE'
000007                           DC    AL1(7)

* PROCEDURE                            EXAMPLE

* REAL ENTRY
000008  90 EC D 00C              STM   14,12,12(13)
00000C  47 F0 F 04C              B     *+72
000010  00000000                 DC    A(STMT. NO. TABLE)
000014  00000130                 DC    F'304'
000018  00000000                 DC    A(STATIC CSECT)
00001C  00000000                 DC    A(SYMTAB VECTOR)
000020  00000000                 DC    A(COMPILATION INFO)
000024  E8000000                 DC    X'E8000000'
000028  00010100                 DC    X'00010100'
00002C  00000000                 DC    X'00000000'
000030  00000000                 DC    X'00000000'
000034  00000000                 DC    A(ENTRY LIST VECTOR)
000038  00000000                 DC    X'00000000'
00003C  01002000                 DC    X'01002000'
```

```
PL/I OPTIMIZING COMPILER         EXAMPLE: PROC OPTIONS(MAIN) REORDER;                                         PAGE   8
```

```
000040  00000000                  DC    A(REGION TABLE)
000044  00000003                  DC    X'00000003'
000048  00000000                  DC    A(PRIMARY ENTRY)
00004C  00000000                  DC    X'00000000'
000050  00000000                  DC    X'00000000'
000054  58 30 F 010               L     3,16(0,15)
000058  58 10 D 04C               L     1,76(0,13)
00005C  58 00 F 00C               L     0,12(0,15)
000060  1E 01                     ALR   0,1
000062  55 00 C 00C               CL    0,12(0,12)
000066  47 D0 F 068               BNH   *+10
00006A  58 F0 C 074               L     15,116(0,12)
00006E  05 EF                     BALR  14,15
000070  58 E0 D 048               L     14,72(0,13)
000074  18 F0                     LR    15,0
000076  90 E0 1 048               STM   14,0,72(1)
00007A  50 D0 1 004               ST    13,4(0,1)
00007E  41 D1 0 000               LA    13,0(1,0)
000082  50 50 D 058               ST    5,88(0,13)
000086  92 80 D 000               MVI   0(13),X'80'
00008A  92 25 D 001               MVI   1(13),X'25'
00008E  92 02 D 076               MVI   118(13),X'02'
000092  D2 03 D 054 3 078         MVC   84(4,13),120(3)
000098  05 20                     BALR  2,0

* PROLOGUE BASE

* INITIALIZATION CODE FOR Z
00009A  78 40 3 07C               LE    4,124(0,3)
00009E  70 40 D 0BC               STE   4,Z
* END OF INITIALIZATION CODE FOR Z

0000A2  05 20                     BALR  2,0

* PROCEDURE BASE



* STATEMENT NUMBER  3
0000A4  41 70 D 100               LA    7,256(0,13)
0000A8  50 70 3 09C               ST    7,156(0,3)
0000AC  96 80 3 09C               OI    156(3),X'80'
0000B0  41 10 D 100               LA    1,256(0,13)
0000B4  50 10 D 0F0               ST    1,240(0,13)
0000B8  92 24 D 111               MVI   273(13),X'24'
0000BC  41 E0 3 0A8               LA    14,168(0,3)
0000C0  50 E0 D 118               ST    14,280(0,13)
0000C4  41 10 3 098               LA    1,152(0,3)
0000C8  58 F0 3 04C               L     15,A..IBMBSIIA
0000CC  05 EF                     BALR  14,15
0000CE  41 A0 2 080               LA    10,CL.10
0000D2  58 80 3 088               L     8,136(0,3)
```

```
0000D6  50 80 D 0F4              ST    8,244(0,13)
0000DA                   CL.5    EQU   *
0000DA  58 E0 3 084              L     14,132(0,3)
0000DE  5E E0 D 0F4              AL    14,244(0,13)
0000E2  89 E0 0 002              SLL   14,2
0000E6  18 4E                    LR    4,14
0000E8  41 E4 D 0C4              LA    14,VO..X(4)
0000EC  41 F0 3 060              LA    15,DED..VO..X
0000F0  58 10 D 0F0              L     1,240(0,13)
0000F4  90 EF 1 008              STM   14,15,8(1)
0000F8  05 AA                    BALR  10,10
0000FA  58 80 D 0F4              L     8,244(0,13)
0000FE  5A 80 3 084              A     8,132(0,3)
000102  50 80 D 0F4              ST    8,244(0,13)
000106  59 80 3 080              C     8,128(0,3)
00010A  47 C0 2 036              BNH   CL.5
00010E  41 E0 D 0B8              LA    14,Y
000112  41 F0 3 060              LA    15,DED..Y
000116  58 10 D 0F0              L     1,240(0,13)
00011A  90 EF 1 008              STM   14,15,8(1)
00011E  05 AA                    BALR  10,10
000120  47 F0 2 0AE              B     CL.11
000124                   CL.10   EQU   *
000124  41 E0 3 064              LA    14,100(0,3)
000128  58 10 D 0F0              L     1,240(0,13)
00012C  58 70 3 014              L     7,A..IELCGIX
000130  05 67                    BALR  6,7
000132  58 F0 3 048              L     15,A..IBMBSFIA
000136  05 EF                    BALR  14,15
000138  58 70 3 018              L     7,A..IELCGIB
00013C  05 67                    BALR  6,7
00013E  05 AA                    BALR  10,10
000140  41 E0 3 06A              LA    14,106(0,3)
000144  58 10 D 0F0              L     1,240(0,13)
000148  58 70 3 014              L     7,A..IELCGIX
00014C  05 67                    BALR  6,7
00014E  47 F0 2 080              B     CL.10
000152                   CL.11   EQU   *


* STATEMENT NUMBER  4
000152  78 00 D 0B8              LE    0,Y
000156  70 00 D 0F8              STE   0,248(0,13)
00015A  48 70 3 074              LH    7,116(0,3)
00015E  40 70 D 0C0              STH   7,I
000162  48 40 D 0C0              LH    4,I
000166  50 40 D 128              ST    4,296(0,13)
00016A  48 40 3 08C              LH    4,140(0,3)
00016E  40 40 D 128              STH   4,296(0,13)
000172  97 80 D 12A              XI    298(13),X'80'
000176  78 20 D 128              LE    2,296(0,13)
00017A  7B 20 3 08C              SE    2,140(0,3)
```

Figure 9 (Part 1 of 2). Part of an Object Program Listing

```
PL/I OPTIMIZING COMPILER         EXAMPLE: PROC OPTIONS(MAIN) REORDER;                                           PAGE   9

00017E  39 20                     CER   2,0                 000208  58 10 D 0F0               L     1,240(0,13)
000180  47 20 2 124               BH    CL.3                00020C  50 E0 1 00C               ST    14,12(0,1)
000184                    CL.2    EQU   *                   000210  58 F0 3 03C               L     15,A..IBMBSEDB
                                                            000214  05 EF                     BALR  14,15
                                                            000216  05 AA                     BALR  10,10
* STATEMENT NUMBER  5                                       000218  47 F0 2 160               B     CL.7
000184  48 90 D 0C0               LH    9,I                 00021C                    CL.8    EQU   *
000188  89 90 0 002               SLL   9,2                 00021C  58 10 D 0F0               L     1,240(0,13)
00018C  78 40 D 0BC               LE    4,Z                 000220  58 F0 3 054               L     15,A..IBMBSIOT
000190  7C 49 D 0C4               ME    4,VO..X(9)          000224  05 EF                     BALR  14,15
000194  70 40 D 0BC               STE   4,Z

                                                            * STATEMENT NUMBER  8
* STATEMENT NUMBER  6                                       000226  18 0D                     LR    0,13
000198  48 70 D 0C0               LH    7,I                 000228  58 D0 D 004               L     13,4(0,13)
00019C  4A 70 3 074               AH    7,116(0,3)          00022C  58 E0 D 00C               L     14,12(0,13)
0001A0  40 70 D 0C0               STH   7,I                 000230  98 2C D 01C               LM    2,12,28(13)
                                                            000234  05 1E                     BALR  1,14
* CODE MOVED FROM STATEMENT NUMBER 4
0001A4  48 70 D 0C0               LH    7,I                 * END PROCEDURE
0001A8  50 70 D 128               ST    7,296(0,13)         000236  07 07                     NOPR  7
0001AC  48 70 3 08C               LH    7,140(0,3)
0001B0  40 70 D 128               STH   7,296(0,13)         * END PROGRAM
0001B4  97 80 D 12A               XI    298(13),X'80'
```

Figure 9 (Part 2 of 2). Part of an Object Program Listing

In certain cases, the compiler uses mnemonics to identify the type of operand in an instruction, and, where applicable, follows the mnemonic by the name of a PL/I variable. The following prefixes are used:

A..	Address constant
ADD..	Aggregate descriptor descriptor
BASE..	Base address of a variable
BLOCK.nn	Identifier created for an otherwise unlabeled block
CL.nn	Compiler-generated label
D..	Descriptor
DED..	Data element descriptor
HOOK...ENTRY	PLITEST block entry hook
HOOK...BLOCK-EXIT	PLITEST block exit hook
HOOK...PGM-EXIT	PLITEST program exit hook
HOOK...PRE-CALL	PLITEST pre-call or function reference hook
HOOK...INFO	PLITEST Additional pre-call hook information
HOOK...POST-CALL	PLITEST post call or function reference hook
HOOK...STMT	PLITEST statement hook
HOOK...IF-TRUE	PLITEST IF true hook
HOOK...IF-FALSE	PLITEST ELSE hook
HOOK...WHEN	PLITEST WHEN true hook
HOOK...OTHERWISE	PLITEST OTHERWISE true hook
HOOK...LABEL	PLITEST label hook
HOOK...DO	PLITEST iterative DO hook
HOOK...ALLOC	PLITEST ALLOCATE controlled hook
WSP.n	Workspace, followed by decimal number of the block of allocated workspace
L..	Length of variable
LOCATOR..	Locator
RKD..	Record or key descriptor
VO..	Virtual origin (the address where element 0 would be held for a one-dimensional array, element 0, 0 for a two-dimensional array, etc.).

Static Internal Control Section

The static internal control section contains the majority of items that are not executable instructions. The contents of a typical static control section are shown in Figure 8 on page 17.

The first part of the static internal control section contains addresses. These are held in the order:

1. Addresses in static CSECT and code CSECT
2. Addresses of library modules
3. Addresses of entry points
4. Addresses of label constants that may be assigned to label variables
5. Addresses of external procedures (other than library modules)

The address section is followed by a section known as the *constants pool*. This contains the following items (if required by the program):

Constants	Constant Values Used by Compiled Code
ONCBs	Control blocks used in error handling.
Descriptors, locators and DEDs (data element descriptors)	Control information used by compiled code and library.
Symbol table address vector	Control information used in data-directed I/O.

Figure 10. Constants Pool Contents

Items are arranged according to their alignment requirements, those requiring doubleword alignment first, followed by fullword, halfword, byte, and bit.

The next section of the static internal control section holds the static variables. These are held in size order, with the smallest being first.

The final section of the static internal control section contains branch tables for those select-groups for which optimized code has been produced, the symbol table vectors and symbol table for PLITEST, the truncated statement number tables containing GOSTMT and GONUMBER data, and the TIMESTAMP data (if this option has been specified at installation time).

Program Control Section

The program control section contains the executable instructions that are a translation of the PL/I source program. The format of each program control section depends on the contents of the source program. The discussion that follows covers items that are common to all source programs.

This chapter also includes descriptions of certain library functions when they are closely allied with the subject under discussion.

Register Usage

Details of register usage during the execution of compiled code are given in Figure 11.

Register Number	Dedicated Registers	Work Registers (plus special use)	Preferred Registers	Notes
0		General		Cannot be used as base
1		General + address of parameter list		
2	Address of program base			Saved during in-line record I/O and TRT instructions
3	Address of static base			
4				Address of temporary base if DSA size greater than 3896 bytes
5		General + static back-chain on entry to procedure	Preferred register for DO-loop control variable	
6		General		
7		General		
8		General		
9		General		
10		General	Preferred register for DO-loop control when BXLE instruction is used	
11		General	Preferred register for DO-loop control when BXLE instruction is used	
12	Address of TCA			
13	Address of current DSA			
14		General + branch-and-link to library and other routines		
15		General + branch-and-link to library and other routines		

Figure 11. Register Usage in Compiled Code

The compilers use four general registers as bases for addressing various types of data; these registers are *dedicated registers*. The rest of the registers are used as required. These are *work registers*.

The dedicated registers are:

R2	Program base
R3	Static base
R12	TCA pointer
R13	DSA pointer

By arranging the dedicated registers this way, the compiled code uses five even/odd work register pairs. These registers are (0,1), (6,7), (8,9), (10,11), and (14,15).

The compiler always uses certain registers for special tasks. The compiler preferentially uses other registers for other tasks when they are available. These tasks are shown in Figure 11 on page 24.

Dedicated Registers

Register 2—Program Base Register: Register 2 is the program base register and is used for branching within the code. When the code exceeds 4K, register 2 is updated so that all branching is done on this register. Register 2 is not used during in-line I/O (when data management calls are handled by compiled code rather than by library subroutines) and during the execution of TRT instructions. During these times, the program base register contents are saved and the register used for other purposes.

Register 3—Static Base Register: Register 3 points to the start of the static internal control section. The compiler lists the items found in this control section in any particular program in the static-storage map. (See "Static Internal Control Section" on page 22). When the static control section is larger than 4K bytes, an additional base register is used.

Register 12—TCA: Offsets from register 12 are used to address the various fields in the TCA. Its format is shown in Appendix A, "Control Blocks" on page 119.

Register 13—Current DSA: Register 13 points to the current DSA. Register 13 addresses the automatic variables declared in the current procedure or block. References to offsets from register 13 which do not appear as names in the assembler language listing refer to the housekeeping fields held in every DSA. Appendix A, "Control Blocks" on page 119 shows the format of the housekeeping information in a DSA.

Register 4: When the DSA is larger than 3896 bytes register 4 is a base for compiler-generated temporaries.

Work Registers

Figure 11 on page 24 shows special or preferred uses for work registers. Registers with special uses are free and always used for the special uses. Registers with preferred uses are used when possible.

Floating-Point Registers: Floating-point registers are all used as general work registers for floating-point data.

Library Register Usage

Register usage in library modules is different from register usage in compiled code. Figure 12 shows library register usage.

In both library and compiled code usage, register 12 points at the TCA, and register 13 at the current DSA. Both library subroutines and compiled code use registers 14 and 15 to branch and link between routines.

Note: Registers 14 through 4 are normally saved by the library because most library subroutines use only these registers. You can save time by reducing save-restore requirements. However, some library routines also save one or more of registers 5 through 11.

Register	Usage
1	Work register
2	Work register
3	Program base register (dedicated)
4	Work register
5	Work register
6	Work register
7	Work register
8	Work register
9	Work register
10	Work register
11	Work register
12	TCA pointer (dedicated in both library and compiled code)
13	DSA pointer
14	Work register (always used for branch-and-link to other routines)
15	Work register (used with register 14 for branch-and-link)

Figure 12. Library Register Usage

Handling and Addressing Variables and Temporaries

Automatic Variables

The compiler allocates storage for automatic variables on a procedure or begin-block basis. If the length of the variable is known during compilation then the compiler allocates storage within the DSA of the block in which they are declared. However, if the length of the variable is not known until execution, then the compiler allocates storage in variable data areas (VDAs). VDAs are held in the last-in/first-out storage stack and are acquired in the prolog code after the DSA has been acquired. The DSA is acquired in the same way and is described in "Prolog" on page 33.

If automatic variables are used in the block in which they are declared and are held in the DSA, the compiler addresses them from register 13. If they are held in a VDA, the compiler addresses them from a separate base set up for the VDA.

Automatic variables known in any block are those that are declared in that block, or in any encompassing blocks. The method used to address automatic variables in outer blocks is a static back-chain.

The compiler-generated prolog for a procedure saves the address of the static back-chain DSA. This address can then be accessed from register 13. Frequently, the value is retained in the register and not reloaded when the variable is accessed. Typical code is:

```
L  7,96(0,13)  Pick up address of correct DSA

L  8,108(7)    Place value in register 8
```

Compiler-Generated Temporaries

Because PL/I statements can contain an unlimited number of operands, it is frequently necessary to set up fields containing intermediate results. These fields are known as *temporary variables* (temporaries) and are allocated within the DSA of the associated block, provided that the size of storage required is known at compile time. Temporaries are addressed from register 13, unless the DSA is longer than 4096 bytes. Because temporary storage is continually being reused, the same offset will not always refer to the same temporary.

Temporaries for Adjustable Variables

Where a temporary is needed to hold a value for an adjustable variable, its size is not predictable until execution. In such cases, a VDA is acquired for the temporary value.

Controlled Variables

Controlled variables are addressed through the pseudo-register vector, as described below under "The Pseudo-register Vector (PRV)" on page 29. When no allocations of the controlled variable are made, the PRV offset points to the dummy File Control Block (FCB). Otherwise, it points to the most recent allocation of the controlled variable.

Each controlled variable is headed by a four-word control block that holds the address of the previous allocation (if any), the length of the variable (including the control block), the pseudo-register vector offset, and the task invocation count. The format of this control block is shown in Appendix A, "Control Blocks" on page 119. Storage for controlled variables is allocated in separate heap storage.

Based Variables

Based variables are addressed by using the contents of the pointer on which they are based. The pointer is addressed in the usual manner, depending on its storage class. Storage for based variables which appear in an ALLOCATE statement is allocated in HEAP or in a specified AREA.

Pointers: Pointers and offsets are held as fullwords. The null pointer value is X'FF000000'.

Static Variables

Static internal variables are held in the static internal control section and are addressed from register 3.

Static external variables are held in separate control sections and are addressed from an address constant in the static internal control section.

Addressing Beyond the 4K Limit

As described above, variables can, in the simplest case, be addressed by using an offset from one of the base registers. However, as the space required for any particular type of storage can exceed the maximum offset allowed in addressing (4096 bytes), it is necessary to have a scheme to allow addressing of variables beyond this limit.

The method used is to divide storage for automatic variables, temporaries, and static variables into sections of 4096 bytes. The addresses of the second and subsequent sections are then placed in the first section. Addressing of an automatic variable beyond the 4096-byte limit is typically done by code resembling the following:

```
L  6,92(0,13)   Place address of 4K boundary in register 6.

AH 7,96(0,6)    Address variable by using offset from 4K boundary
                placed in register set up in last instruction.
```

A similar system is used for addressing any static variables which are at an offset greater than 4096 bytes. The addresses are held in the following areas:

Automatic Immediately following the housekeeping information of the DSA.

Static At the head of the first section of static storage.

Temporaries At the head of temporary storage, following bases of parameters, register save area, and addresses of any outer DSAs.

Constants and variables are held in order of size, with the smallest first. This minimizes the number of items that overflow the 4K boundary.

The Pseudo-register Vector (PRV)

Addressing Controlled Variables and Files

In order to address controlled variables, fetched procedures, and files, PL/I uses a control block called the *pseudo-register vector* (PRV). This control block is mapped by the linkage editor as a dummy section with a fullword field for each uniquely named controlled variable or file. During execution, the addresses of the storage allocated to the variables, fetched procedures, or files are placed in the PRV.

For an introduction to pseudo-registers, see *OS/VS Linkage Editor and Loader*, or *MVS/Extended Architecture Linkage Editor and Loader*.

The use of the linkage editor is necessary because controlled variables and files may be external and, consequently, it may be necessary to access them in separately compiled procedures. Other external items are compiled as CSECTs, but this is not possible for files or controlled variables because their associated storage is not allocated until execution. Controlled variables have storage allocated during the execution of an ALLOCATE statement; files are addressed from file control blocks (FCBs), which are created when the file is opened during execution. The use of the linkage editor means that FETCHed procedures cannot use controlled variables or files, except SYSPRINT.

References to controlled variables and files are compiled as assembler Q-type address constants. During link-editing, the assembler DXD facility of the linkage editor is used, and the PRV is set up as an external dummy section. The address of the PRV is placed in the TCA. Each uniquely named file or controlled variable is allocated an offset within the PRV by the linkage editor. The offset then replaces the Q-type address constants.

Controlled variables and files are addressed via the PRV regardless of whether they are external or internal. The compiler prefixes internal items with the name of their procedures so that their names are unique. Figure 13 on page 30 summarizes the use of the PRV.

During compilation

1. Each controlled variable or file reference is compiled as a Q-type address constant that will be used as an offset within the PRV.
2. The compiler generates a DXD instruction for every item requiring pseudo-register addressing.

During link editing

1. The number of unique names requiring pseudo-register addressing is calculated and placed in a field that can be accessed by a CXD instruction.
2. Each reference to a name generated as a Q-type address constant is replaced by the appropriate offset from the start of the PRV.

During program initialization

1. The length required for the PRV is obtained by use of a CXD instruction. Storage for the PRV is then obtained in the program management area. The address of the PRV is placed in the TCA.
2. The address of the dummy FCB is placed in every field of the PRV.

During execution

1. When storage is allocated to the FCB or controlled variable, the address of the storage is placed in the associated field in the PRV. Comparison with the dummy FCB address can then be made, to determine whether storage has been allocated for the item.

Figure 13. Use of the Pseudo-register Vector (PRV)

The Location of the PRV

The pseudo-register vector is held in the program management area, and is addressed from the TCA.

Under Multitasking: Whenever a new task is attached, the PRV of the attaching task is copied into the program management area of the attached task. This means that, at the point when the task is attached, the files and controlled variables addressed from the subtask will be the same as those in the parent task. However, because each task has its own PRV, either task may change the addresses without affecting the other.

Initialization of the PRV

To simplify implicit opening, the PRV is initialized with every field set to point to a control block known as the *dummy FCB*. Use of this control block as if it were a genuine FCB results in control being passed to the open routines: the file is opened, and a real FCB is created. The address of the real FCB is then placed in the PRV.

Pseudo-register fields for controlled variables are also initialized to point to the dummy FCB, so that the controlled variable allocation mechanism can determine whether an allocation was made, by comparing the PRV value with the address of the dummy FCB. (The address of the dummy FCB is held throughout the program in the TCA, so that the comparison can be made.)

Program Control Data

Program control data comprises pointer, offset, file, area, entry, event, task, and label data.

Pointer and offset data items are each held in fullword. The data item in both cases consists of an address that is held right-adjusted in the field, padded on the left with zeros. For both data types, the null value is represented by hexadecimal X'FF000000'.

A file variable is held as a fullword containing the address of the declare control block (DCLCB); the DCLCB corresponds to a file constant.

The formats of area, entry, event, task, and label data are given in Appendix A, "Control Blocks" on page 119.

Handling Data Aggregates

PL/I *data aggregates* are structures and arrays, and include both arrays of structures and structures of arrays.

Array elements are addressed from the *virtual origin* of an array. This is the point at which the element whose subscripts are all zeros is held, or would be held if there had been such an element included in the array. Each element can be accessed by using a multiplier for each dimension. The multiplier is the distance between elements in a cross-section of an array.

For example, in an array B(9,9) the multiplier for the first dimension is the distance between elements B(1,1) and B(2,1); the multiplier for the second dimension is the distance between elements B(1,1) and B(1,2).

If the bounds of the array and the length of the elements of the array are known during compilation, the values of multipliers can be calculated and placed as constants in the static internal control section. For accessing an element with a constant subscript, the offset from the virtual origin can be calculated during compilation. If the subscript value is a variable, the multiplier must be picked up from static storage during execution and the value calculated.

If the bounds or extents of an array are not known during compilation, a control block known as an *array descriptor* is set up. This control block is used to hold necessary information about bounds, multipliers, etc. The information is placed in the array descriptor during execution.

Structures are treated in a similar manner. Where all information about a structure is known, it is mapped during compilation and offsets to each item from the start of the structure are known to compiled code. If a structure cannot be mapped during compilation, it is mapped during execution, and the offsets within the structure are placed in a control block known as a *structure descriptor*. To access an item in the structure, compiled code finds the offsets and calculates the address of each element from them.

Arrays of Structures and Structures of Arrays

Arrays of structures and structures of arrays are held as they are declared.

The array of structures

```
1 S(2),
  2 B,
  2 C;
```

are held in the order

S(1).B	S(1).C	S(2).B	S(2).C

B and C are known as *interleaved arrays*, because the elements within each array are not contiguous.

The structure of arrays

```
1 S,
  2 B(2),
  2 C(2);
```

are held in the order

S.B(1)	S.B(2)	S.C(1)	S.C(2)

Elements are accessed as array elements in both cases. In the array of structures shown above, both B and C are treated as separate arrays with their own virtual origins and multipliers. The difference would be in the value of the multipliers. When possible, the values of multipliers are calculated during compilation. When adjustable bounds or extents are involved, the necessary data for both arrays of structures and structures of arrays is placed in a structure descriptor.

Array and Structure Assignments

Assignments between structures and arrays of the same format are done by MVC instructions. Provided an array is not interleaved, an assignment is made to it as a whole, and the elements are not moved one at a time. Similarly, structures that are contiguous and have the same format are moved as a whole.

Handling Flow of Control

In PL/I, five types of statement can result in nonconsecutive flow of control. These statements are:

CALL statements
END statements
RETURN statements
Function references
GOTO statements

The first four of these are concerned with the block structure of the PL/I program and involve passing control from one block to another. GOTO statements can result in branches to code that is either in the current block, or in any other active block.

Consecutive flow of control also ceases when an error or program interrupt occurs.

Activating and Terminating Blocks

BEGIN, CALL, END, and RETURN statements, and function references all result in the activation or termination of blocks. The block structure of PL/I is implemented by means of a hierarchy of DSAs.

Each block (begin block, procedure block, or ON-unit block) executes on its own program base that is set up at the end of the prolog code for each block. This base is marked in the object code listing with:

```
*     PROCEDURE BASE
```

In the PL/I optimizing compiler, blocks are always called by means of a BALR instruction on registers 14 and 15. Within the prolog code, the registers are stored in the DSA of the calling block, and a new DSA is set up to hold the automatic variables of the new block plus a certain amount of environmental information such as the enablement or disablement of certain conditions.

When a block is terminated, the registers of the calling block are restored, and a branch is made on register 14. This immediately returns control to the instruction after the BALR issued in the preceding block. The DSA of the called block is automatically discarded because all fields in the DSA, including the pointer to the next available byte of free storage, were addressed from register 13. Because register 13 has been altered, the values that apply to the calling block automatically become current when the calling block's registers are restored.

Prolog and Epilog Code

Except for certain single statement ON-units, every PL/I begin block or procedure block has a prolog and an epilog. The prolog prepares the environment for the associated block and acquires storage for automatic variables, compiler-generated temporaries, and workspace. The epilog frees the storage acquired for the block, restores the registers of the caller, and returns control to the caller.

Prolog

The prolog appears on the object-program listing between REAL ENTRY and PROCEDURE BASE or BLOCK BASE. Every prolog has to acquire a dynamic save area (DSA) for the new block. (The DSA is a register save area concatenated with housekeeping information, plus storage for automatic variables and temporaries.) Other jobs that may be done in the prolog code are:

- Initialization of automatic variables that have the INITIAL attribute.
- Initialization of pointers and locators that have the INITIAL attribute.
- Movement of parameter addresses passed to the procedure to the correct location.

- Acquisition of storage for adjustable variables.
- Initialization of certain items for argument lists.
- Setting-up certain interrupt-handling information such as ONCBs and enable cells.

An example of prolog code is shown in Figure 14 on page 35. More information about constants is in the ″Communicating with Assembler Language Programs″ chapter in the *OS PL/I Version 2 Programming Guide*.

```
STM   14,12,12(13)          Store registers of calling program.
B     *+72                  Branch around constants.
DC    A(STMT. NO. TABLE)    Constant
DC    F'360'                Constant - length required for new DSA.
DC    A(STATIC CSECT)       Constant - address of static internal
                              CSECT
DC    A(SYMTAB VECTOR)      Constant
DC    A(COMPILATION INFO)   Constant
DC    X'A9000000'           Constant
DC    X'00010101'           Constant
DC    X'00000000'           Constant
DC    X'00000000'           Constant
DC    A(ENTRY LIST VECTOR)  Constant
DC    X'00000000'           Constant
DC    X'02008000'           More of the same
DC    A(REGION TABLE)       ....
DC    X'00000004'           ....
DC    A(PRIMARY ENTRY)      ....
DC    X'00000000'           ....
DC    X'00000000'           ....
L     3,16(0,15)            Set up R3 as static base.
L     1,76(0,13)            R1 to hold old NAD
L     0,12(0,15)            Compare with EOS in TCA
ALR   0,1                   Add old NAB (in R1) and length required
                              for DSA (in R0).
CL    0,12(0,12)            Compare with EOS in TCA.
BNH   *+10                  Branch around library call if new DSA
                              fits in segment.
L     15,116(0,12)          Load address of stack overflow routine
                              (IBMBPGR) from TCA.
BALR  14,15                 Branch to overflow routine.
L     14,72(0,13)           Load address of LWS from old DSA.
LR    15,0                  Set up new NAB address.
STM   14,0,72(1)            Set LWS, NAB, and end-of-prolog NAB in
                              DSA.
ST    13,4(0,1)             Place back-chain in new DSA.
LA    13,0(1,0)             Point register 13 to new DSA.
ST    5,88(0,13)            Set up static back-chain.
MVI   0(13),X'80'           Set up housekeeping flags - see
MVI   1(13),X'24'             Appendix A, "Control Blocks" on page 119.
MVC   84(4,13),120(3)       Set up enable cells.

Other code as required      Other tasks may be carried out at this point,
                              such as initialization of variables with
                              the initial attribute, acquiring a VDA for
                              adjustable variables, and setting up
                              certain error-handling fields.
BALR  2,0                   Set R2 as program base.
```

Figure 14. Typical Prolog Code

After saving the registers, the prolog tests to see if there is enough room for the DSA in the current segment of storage. This is done by adding the length of the new DSA, calculated at compile time, to the address of the next available byte.

If the result is greater than the end-of-segment pointer (EOS) placed in the TCA during initialization, the library overflow routine (IBMBPGR) is called to try to acquire a further segment from the free-area chain.

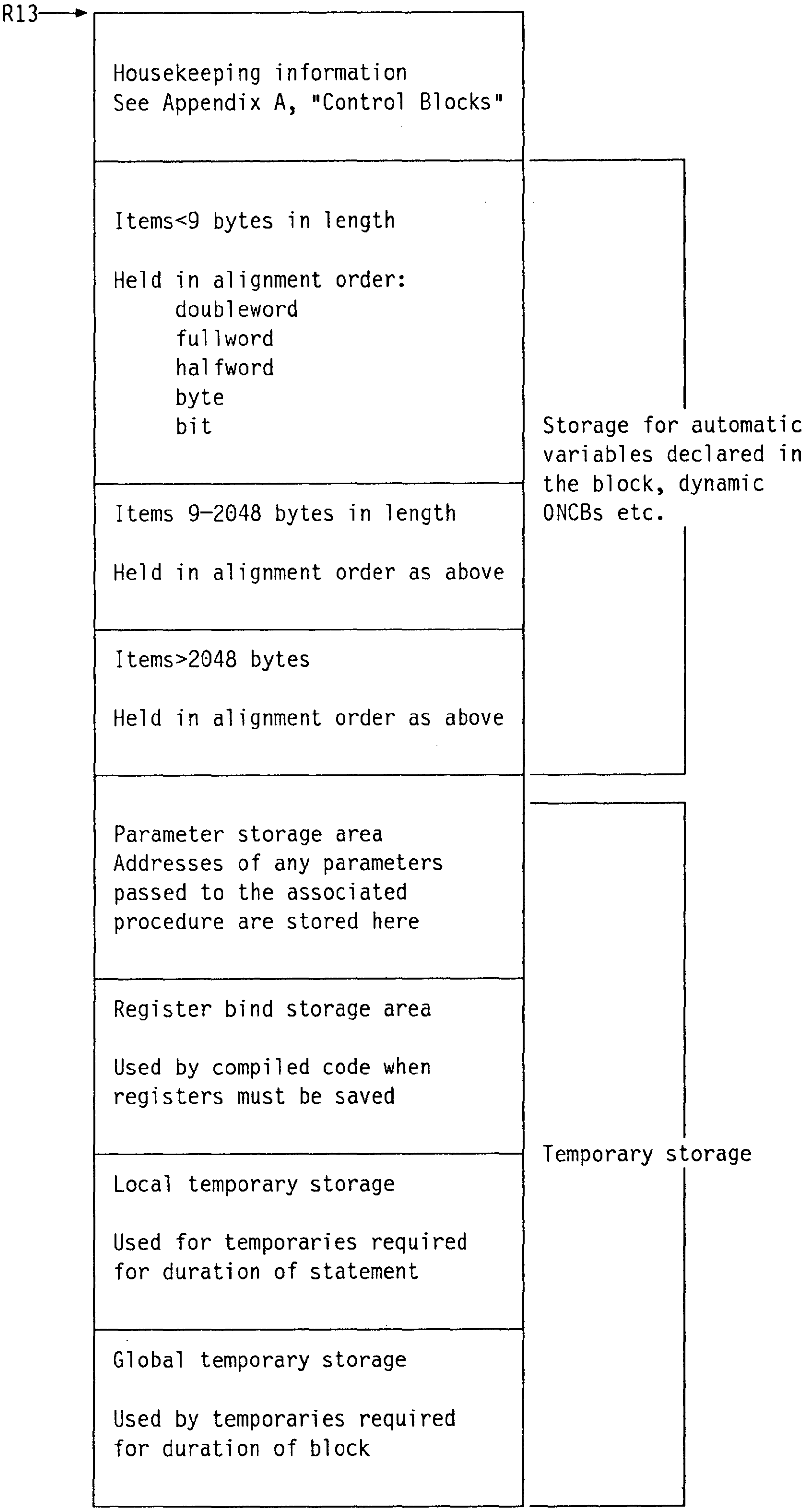
If space for the DSA is available, the next-available-byte pointer (NAB) is updated to point at the first 8-byte boundary beyond the end of the new DSA. The remaining instructions set up housekeeping fields and point registers at various standard fields, including register 13 to the start of the new DSA, and register 4 to the start of storage for temporaries. The final BALR instruction establishes register 2 as the program base register.

Two back-chains are set up. The *dynamic back-chain*, which points to the DSA of the calling or preceding block, and the *static back-chain*, which points to the DSA of the statically encompassing block. For the main procedure, the dynamic back-chain points to the dummy DSA, and the static back-chain is set to zero. The address of the statically encompassing block is passed in register 5.

Static back-chains are used in tracing the scope of names and the enablement of PL/I conditions.

For PL/I procedures with COBOL or FORTRAN in the OPTIONS option, the prolog is considerably different from the one described above.

The format of the DSA is shown in Figure 15 on page 37; full details are shown in Appendix A, "Control Blocks" on page 119.



R13

Housekeeping information
See Appendix A, "Control Blocks"

Items<9 bytes in length

Held in alignment order:
doubleword
fullword
halfword
byte
bit

Items 9—2048 bytes in length

Held in alignment order as above

Items>2048 bytes

Held in alignment order as above

Storage for automatic variables declared in the block, dynamic ONCBs etc.

Parameter storage area
Addresses of any parameters passed to the associated procedure are stored here

Register bind storage area

Used by compiled code when registers must be saved

Local temporary storage

Used for temporaries required for duration of statement

Global temporary storage

Used by temporaries required for duration of block

Temporary storage

Figure 15. Contents of Typical Compiled Code DSA

Epilog

Epilog code consists of the instructions generated for END or RETURN statements. These instructions restore the registers to the values that were held when the current block was called. The register values are those stored in the previous DSA. Typical epilog code is shown in Figure 16.

```
Epilog code for main procedure

LR   0,13          Save current DSA address
L    13,4(0,13)    Back-chain
L    14,12(0,13)   Pick up value of R14
LM   2,12,28(13)   Restore registers 2 through 12
BALR 1,14          Branch to initialization routine retaining
                   current address in Rl

Epilog code for subroutine or begin block

L    13,4(0,13)    Back-chain
LM   14,12,12(13)  Restore registers of preceding block
BR   14            Return
```

Figure 16. Epilog Code

The completion of a main procedure results in the raising of the FINISH condition, and this may result in the execution of an ON-unit.

Consequently, the address of the current DSA and the address of the current statement must be retained (the DSA is needed to search for the ON-unit; the address of the current statement is needed if a SNAP trace is requested in the FINISH ON-unit). Epilog code for a main procedure therefore takes a different form to that generated for a subroutine.

CALL Statements

CALL statements are executed by picking up the address of the block to be called from static storage. A BALR instruction is then carried out on registers 14 and 15. If arguments are being passed to the called procedure, an argument list is set up in temporary storage, the first bit of the last argument is set to '1', and register 1 is pointed at the argument list.

This example is for a call to an external procedure without parameters.

```
00005E  1B 11         SR    1,1         No parameters, so clear Regl
000060  1B 55         SR    5,5         External proc, so no static back-chain
000062  58 F0 3 024   L     15,36(0,3)  Pick up address of procedure
000066  05 EF         BALR  14,15       Branch to procedure
```

Function References

Function references are compiled in exactly the same way as CALL statements. If the function returns a value, an extra field is placed as the last argument in the list. The returned value is placed in this field when the function is completed. In those cases where the compiler builds the parameter list in internal static, the typical code might be:

```
0001FE  41 90  6 0B4    LA  9,B
000202  50 90  3 0BC    ST  9,188(0,3)
000206  41 90  6 0B0    LA  9,A
00020A  50 90  3 0C0    ST  9,192(0,3)       Set up parameter list
00020E  18 56           LR  5,13             Load static back-chain address
000210  41 10  3 0BC    LA  1,188(0,3)       Point register 1 at parameter
                                             list
000214  58 F0  3 008    L   15,A...DOUBLE    Place address of function
                                             (DOUBLE) in R15
000218  05 EF           BALR 14,15           Branch to function
```

Return Statement

RETURN statements are executed in a similar way to END statements, but result in the termination of a procedure rather than a block. Consequently, before the restoration of the registers, a back-chain must be made to correct DSA. A back-chain is made through any BEGIN blocks. The depth of nesting can be determined during compilation, so the back-chain can be loaded the required number of times before the branch is made.

Typical code would be:

```
0003F0  58 D0  D 004    L    13,4(0,13)   Pick up DSA back-chain
0003F4  98 EC  D 00C    LM   14,12,12(13) Restore registers
0003F8  07 FE           BR   14           Branch to procedure
```

Note: If the procedure in which the RETURN statement occurs is a main procedure, the code will take the form compiled for an END statement for an external procedure.

GOTO Statements

Depending on whether the GOTO statement branches to a label within the block or external to the block, then the branching has different implications. If the label is outside the block, the branch implies that one or more blocks must be terminated. If the label in the GOTO statement is a label variable, it is not always possible to determine during compilation whether the label will be in the same block as the GOTO statement. Consequently, interpretive code is used for label variables.

For GOTO statements to a label constant within the block, the compiler produces a straightforward branch instruction. For GOTO statements that may pass control to another block, compiled code calls the interpretive code.

This interpretive code is held in the TCA. The compiled code branches to the interpretive code to implement a GOTO that may transfer control out of the block. This TCA code determines whether it is one of a small number of special cases, and, if it is, calls a library routine—IBMBPGO. In other circumstances, the GOTO code in the TCA handles the branch and any block termination involved.

GOTO within a Block

The optimizing compiler produces code that assumes that the registers retained across the execution of a labeled statement will be 2, 3, 12, and 13. These are the program base, the static base, the address of the TCA, and the address of the current DSA. All other register values may be different when control passes through the labeled statement on different occasions.

The enablement of conditions may differ in the GOTO statement and in the labeled statement. Within a block, the enablement status may be varied only for the duration of a single statement. The GOTO therefore resets the block enablement status before the branch is taken. If the labeled statement has a different enablement status from the block, it will be automatically reset in the labeled statement.

The enablement of conditions is recorded by enable cells. Two sets are used: the *block* enable cells retain the enablement situation at the start of the block, which can consequently be restored at any time; the *current* enable cells hold the enablement situation that is current, which, as explained earlier, may differ from that at the start of the block.

A GOTO within block normally takes the form of a simple branch instruction plus any alteration of the enablement bits that may be necessary to reset the enablement situation to that at the start of the block. Typical code is:

```
000F1A  47 F0  2 0C8   B   INPUT     Branch to correct address in
                                     compiled code (label name is
                                     "INPUT")
```

The optimizing compiler attempts to retain the same block base for all branches within a block. However, this is not always possible and, if the code for the block is longer than 4096 bytes, it may be necessary to set up a new base when a GOTO statement is executed. As all labels are stored with both their address and their base this presents no problem. The address of the label and the value of its base form the value of the label constant. The value of the base is placed in register 2, and a branch is made to the label address.

When a GOTO to a label within the block is made, there is no need to reset registers 3, 4, 12, or 13 as these are not altered within a block. When OPTIMIZE (TIME) is specified an attempt is made to retain other register values across labels.

Labeled statements within a block have an effect on optimization in that, apart from the bases and block addresses mentioned above, values cannot normally be retained in registers beyond a labeled statement.

GOTO Out of Block

GOTO statements that transfer control from a block have to overcome the problems described above, plus problems of block termination.

For a GOTO out of block or to a label variable, compiled code makes a call to the GOTO code in the TCA, which is held at offset 128 (decimal). Through registers 14 and 15 the GOTO code receives either the contents of the label variable or the equivalent information for a label constant. This equivalent information is the address where the label constant is held and the address of the DSA of the block in which the label appears.

The GOTO code restores registers 3 and 4 from the DSA passed to it, loads register 2 from the second word of the label constant, and loads register 13 from register 15. It then branches to the appropriate point in code which is picked up from the address of the label constant, passed in register 14.

The enablement situation at the start of the block has to be restored, and this is done by setting the current enable cells in the DSA to the value of the block enable cells. If the current enable cells indicate that CHECK is enabled, a search is made for qualified CHECK ONCB, so that the enable cells may be set to the start-of-block situation in this ONCB.

In a similar manner, it may be necessary to restore the NAB value to that at the start of the block. This will be necessary if the statement that left the block acquired a VDA. The start-of-block NAB value is retained in the DSA and is known as the end-of-prolog NAB. If a VDA has been acquired, the fact is flagged in the flag byte of the DSA, and the GOTO places the end-of-prolog NAB value in the current NAB field.

Such action is never required within a block, as VDAs are only acquired for the duration of one statement and are never used for GOTO statements. Typical code would be:

```
GOTO label-constant (out of block)

000226 18 E6        LR  15,6          Place address of DSA in R15
000228 41 E0  3 088 LA  14,136(0,3)   Place address of label
                                      constant in R14
00022C 47 F0  C 080 B   128(0,12)     Branch to GOTO code in TCA
```

GOTO Label Variable

GOTO label variable statements are treated in different ways depending on whether optimization has been specified.

For NOOPTIMIZE, they are all treated as GOTO out of block; for OPTIMIZE (TIME), a check is made to determine whether they could be out-of-block branches. The check is made by testing a label list, which is a list of the label constants to which the label variable may be assigned. If the programmer has supplied a label list, it is used. Otherwise, a list is generated containing all the label constants that are assigned to label variables. If a branch to any of the labels in the list could result in a GOTO out-of-block, all GOTO statements referring to the label variable are treated as GOTO out-of-block situations. Typical code would be:

```
GOTO label-variable

0000D0 98 EF  D 0A8  LM  14,15,168(13)  Load R14 and R15 with label
                                        variable
0000D4 47 F0  0 080  B   128(0,12)      Branch to GOTO code in TCA
```

Errors When Using Label Variables

Although it is invalid PL/I, it is possible for a GOTO statement using a label variable to result in transfer of control to an inactive block. The optimizing compiler has no method of checking such errors, and the consequences are unpredictable. Such errors can occur because a label variable is not reset when the block containing the label constant to which it refers is terminated. When an attempt is made to GOTO a label variable, the address of the DSA is passed in register 14. The GOTO code verifies this address to be the address of an active DSA, and acts accordingly. Three possibilities arise:

1. The original DSA has not been overwritten, and the program will execute.
2. The DSA of another active block has overwritten the original DSA. The results are then unpredictable, as the code branched to will be accessing an incorrectly mapped DSA.
3. The original DSA has been overwritten with other information. Again, the results are not predictable. When PL/I determines that the data in the DSA is not another DSA, ERROR condition code 9002 is raised.

It should be noted that, because of the method used to allocate DSAs, the chances of one DSA starting at the same address as a previous DSA are high.

GOTO-Only ON-Units

Certain ON-units are not executed as separate program blocks. Instead, the required action is taken under the control of the error handler. ON-units containing only a GOTO statement (GOTO-only ON-units) are handled in this way.

The error handler accesses ON-units through control blocks known as ON control blocks (ONCBs). The ONCB for a GOTO-only ON-unit is specially flagged, and the last word of the ONCB is initialized to hold an offset. At this offset in the DSA of the block containing the ON-unit, the address of the label information is held. For a label variable, the offset contains the address of the label variable; for a label constant, the offset contains the address of a label temporary that is initialized to the value of the label constant. The initialization is done during the execution of the prolog of the block that contains the ON-unit.

The error handler loads the information in the label variable or the label temporary into registers 14 and 15, and calls the GOTO code in the TCA.

Interpretive GOTO Routines

If the test in the GOTO code in the TCA reveals that an abnormal situation exists, the interpretive GOTO routine is called. This routine is a subroutine of the program initialization routine.

Two abnormal cases can arise:

GOTO out of SORT exit routine
GOTO from an event I/O ON-unit (certain cases only)

When either of these situations could occur a flag is set in the TCA. Sort exits are also flagged in the DSA of the procedure involved.

The SORT exit DSA requires special action because the GOTO will involve the termination of SORT if it transfers control to another block.

The GOTO during an event I/O ON-unit can cause the termination of a number of WAIT statements. This involves removing information about these statements from the various chains that are set up during event I/O.

If CHECK enablement has to be changed because of a GOTO, the interpretive GOTO routine calls the library routine IBMBPGO to reset check enablement.

Argument and Parameter Lists

In PL/I, a *parameter list* is a list of the items a program expects to receive; an *argument* list is a list of the items that are passed by the calling routine.

Between PL/I routines, addresses are always passed rather than the arguments themselves. For strings, structures, arrays, and areas, the addresses of locators are passed rather than the addresses of the arguments themselves.

When arguments are passed to routines whose entry points are declared with the ASSEMBLER, COBOL, or FORTRAN attributes, the address of the data itself must be passed.

Arguments are passed in an argument list addressed by register 1. For nonreentrant, nonrecursive code, the list is set up in static storage and completed by the compiler if the values are are known at compile time. If the procedure is reentrant, recursive, or fetched, the list is moved into the temporary storage area in the DSA before the call is made; otherwise the parameter list is moved into automatic storage.

The addresses passed in the argument list are moved into the parameter storage area, which is held at the head of temporary storage and is addressed by register 4. (See Figure 14 on page 35) Parameters are then accessed by picking up the addresses from this area.

Dummy arguments, when they are required, are set up by the calling program. Consequently, the called program can treat all arguments in the same manner.

Library Calls

Library calls occur in object program. All library calls that appear in the object listing are to resident PL/I library modules. Transient PL/I library routines are called by routines in the resident library routines.

The number of library calls used depends on the source program and the level of optimization specified. For OPTIMIZE (TIME), the minimum number of library calls will be made. If NOOPTIMIZE is specified, library calls will be made where this will speed compilation.

Figure 17 on page 44 shows examples of sequences used for calling library modules. The majority of library calls can easily be recognized by the appearance in the listing of the letters "IBM," followed by five letters specifying the module name and entry point. To call a module, its address is loaded into register 15, and a BALR instruction is carried out on registers 14 and 15.

Example 1. Call to library routine that has been link-edited and whose address is held in the static internal control section.

The arguments passed are addressed by register 1.

```
LA   1,40(0,4)       Point R1 at argument list
LA   14,VO..U(11)    Load address of argument in register
LA   15,DED..VO..    Load address of argument in register
     U(11)
STM  14,15,0(1)      Store into argument list
L    15,A..IBMBSLO   Pick up address of routine from static
                     internal control section and place in R15
BALR 14,15           Branch and link to routine
```

Example 2. Call to library routine whose address is held in TCA

```
L    15,116(0,12)    Load address of routine held in TCA
BALR  14,15          Branch and link to routine
```

Figure 17. Examples of Library Calling Sequences

Setting-Up Argument Lists

Before a call is made to a library module, an argument list must normally be set up. This is done in one of several ways, depending on the library module. The majority of library calls require the method shown in Figure 17, example 1. This consists of loading the list into sequential registers starting at register 14, and then using a store-multiple instruction to place the arguments into an area of static storage, whose address is then loaded into register 1. Argument lists are set up as far as possible during compilation and, where necessary, completed during execution.

Addressing the Subroutines

As can be seen in example 1 of Figure 17, library addresses are generally held in static storage and addressed as an offset from register 3. However, the addresses of certain library routines are held in the TCA or the TCA appendage and addressed from register 12. They are addressed either directly or indirectly as shown in example Figure 17. The names of these routines do not appear on the listing; however, they can be identified by their offset from the start of the TCA (see Figure 18 on page 45).

Offset from Start of TCA (Register 12) Decimal	Offset from Start of TCA (Register 12) Hex	Name of Module Entry Point	Use
72	48	IBMBPGRD	Stack overflow routine to get VDA
84	54	IBMBEFL	FLOW module
108	6C	IBMBPGRA	Get non-LIFO dynamic storage
112	70	IBMBPGRB	Free non-LIFO dynamic storage
116	74	IBMBPGRC	Stack overflow routine for prolog
120	78	IBMBERRB	Error handler software interrupt
264	108	IBMBJWTA	WAIT module
268	10C	IBMBTOCA	Completion pseudovariable routine
272	110	IBMBTOCB	Event variable assignment routine

Figure 18. Offsets Where Addresses of Library Modules Are Held in the TCA

DO-Loops

Where possible, DO-loops are carried out by means of a BXLE instruction, because this is more efficient than using a simple BCT instruction. BXLE DO-loops can be used where the control variable cannot be altered except at the head of the loop, and where it is not subsequently accessed after the completion of the loop. BXLE DO-loops cannot be used for the outer of a number of nested DO-loops. For outer loops, other branch instructions are used. Code for a number of typical DO-loops is shown below. Note that the code will differ according to the content of the loop.

Source program

```
DO I = 1 to 10;
  DO J = 1 to 10;
       .
       .
       .
       .
       .
       .
  END;
END;
```

Object program

1. *Code for outer do-loop*

```
        LH       5,596(0,3)     Pick up 1 from constants pool
        STH      5,I            Place 1 in I
  CL.1  EQU      *
         .
         .
         .
         .
         .
        LH       5,I
        AH       5,596(0,3)     Increment and
        STH      5,I            store in I
        C        5,598(0,3)     Compare I and constant 10
                                in static storage
        BNH      CL.1
```

2. *Code for inner do-loop*

```
        LH       5,596(0,3)     Place 1 in first operand
        LH       10,596(0,3)    Place 1 in second operand
        LH       11,598(0,3)    Place 10 in comparand
  CL.2  EQU      *
         .
         .
         .
         .
         .
        BXLE     5,10,CL.2      Increment, test, and branch if necessary.
```

Compiler-Generated Subroutines

The compiler uses internal subroutines to carry out certain functions. These have the advantage over library modules, because they can be tailored for the most common case. When special cases arise, the library routines are called. Compiler-generated subroutines have the further advantage that they are internal to compiled code and consequently need not follow the standard operating system calling sequence.

Compiler-generated subroutines are used for the following purposes:

IELCGIA	Stream I/O input—provides address of source of next edit-directed data or format item
IELCGIB	Stream I/O input—housekeeping after transmission of data item
IELCGOG	Stream I/O output—provides address of target of next edit-directed data or format item
IELCGOH	Stream I/O output—updates FCB, counts data item, and frees VDA if one was used
IELCGOC	Stream I/O—processes X format items
IELCGMV	Move long (registers 6,7,8,9)
IELCGCL	Compare long (registers 1,6,7,8,9)
IELCGCB	Compare long bits

IELCGON	Dynamic ONCB chaining
IELCGRV	Revert VDA chaining
IELCGBB	Test for '0' bits
IELCGBO	Test for '1' bits

Compiler-generated subroutines are held in separate control sections and are printed at the head of the object-program listing when they are used in a program.

Optimization and Its Effects

Optimization produces the most efficient possible object program. The OS PL/I Optimizing Compiler adopts a threefold approach:

1. It attempts to compile each statement in the most efficient manner.
2. It modifies the resulting code for each block, in an attempt to make it more efficient (for example, by maintaining values in registers and by using common control blocks for similar items).
3. It examines the source program to discover whether statement flow can be reorganized to produce a more efficient program (for example, by moving code out of loops).

The effect of specifying the compiler option OPTIMIZE (TIME) is that the compiler loads and calls the optimization phases, and executes optimization code in other phases.

When NOOPTIMIZE is specified, the optimization phases are not called; no attempt is made to study the flow of the program, and the examination of compiled code for possible improvements is not undertaken on a global basis. More library calls will generally be made if NOOPTIMIZE is specified.

Examples of Optimized Code

A number of the more noticeable effects of optimization are shown below. These show code sequences which may prove difficult to understand without knowledge of the objectives of optimization. Where possible, the examples of code are expansions of the examples shown in the *OS PL/I Version 2 Programming Guide*. The examples do not cover all optimization carried out by the compiler.

Elimination of Common Expressions

Elimination of common expressions is handled by avoiding multiple calculations of the same expression, the value being retained either in temporary storage or in a register. In the examples shown below, the common expression is "B+C." In the first example, the value is held in a register. In the second. it is held in temporary storage, because the value to which it is first assigned is altered. In certain circumstances, the code could be compiled to move the value from the variable to which it was originally assigned to the second variable.

Example 1: Value held in register: *Source program*

```
2    A=B+C;
3    If X<Y THEN X=Y;
4    D=B+C;
```

```
* STATEMENT NUMBER  2
00005E  78 00 D 0BC               LE    0,B
000062  7A 00 D 0C0               AE    0,C
000066  70 00 D 0B8               STE   0,A


* STATEMENT NUMBER  3
00006A  78 60 D 0C4               LE    6,X
00006E  79 60 D 0C8               CE    6,Y
000072  47 B0 2 020               BNL   CL.2
000076  78 60 D 0C8               LE    6,Y
00007A  70 60 D 0C4               STE   6,X


* STATEMENT NUMBER  4
00007E                    CL.2    EQU   *

* CALCULATION OF COMMONED EXPRESSION FOLLOWS
00007E  70 00 D 0CC               STE   0,D
```

Example 2: Value held in temporary storage: *Source program*

```
2          A=B+C;
3          IF X<Y THEN A=6;
4          D=B+C;
```

Note: "A" may be altered before subsequent use of expression.

Object program

```
* STATEMENT NUMBER  2
00005E  78 00 D 0BC               LE    0,B
000062  7A 00 D 0C0               AE    0,C
000066  38 20                     LER   2,0
000068  70 20 D 0B8               STE   2,A


* STATEMENT NUMBER  3
00006C  78 60 D 0C4               LE    6,X
000070  79 60 D 0C8               CE    6,Y
000074  47 B0 2 022               BNL   CL.2
000078  78 20 3 01C               LE    2,28(0,3)
00007C  70 20 D 0B8               STE   2,A


* STATEMENT NUMBER  4
000080                    CL.2    EQU   *

* CALCULATION OF COMMONED EXPRESSION FOLLOWS
000080  70 00 D 0CC               STE   0,D
```

Movement of Expressions Out of Loops

When expressions cannot be altered inside a section of code that may be executed a number of times, the expression is moved out of the loop to a position where it will be executed only once, regardless of the number of times that the loop is executed. The process is known as movement of invariant expressions. The most obvious example is in DO-loops. However, the compiler analyzes the source program for other types of loop and also moves code from these.

Example 1 shows code moved from a DO-loop. Example 2 shows code moved from a loop that has been detected by the compiler. It should be noted that code moved out of loops frequently involves conversion and is not obvious in the source program.

Example 1: DO-loop

Source program

```
2        Do I=1 TO N;
3        J=3;
4        END;
```

Object program

```
 * STATEMENT NUMBER  2
 00005E  48 E0 D 0BA                  LH    14,N
 000062  18 BE                        LR    11,14
 000064  48 A0 3 018                  LH    10,24(0,3)
 000068  18 5A                        LR    5,10
 00006A  40 50 D 0B8                  STH   5,I
 00006E  19 5B                        CR    5,11
 000070  47 20 2 026                  BH    CL.3
 000074                       CL.2    EQU   *


 * STATEMENT NUMBER  3
 000074  48 60 3 01A                  LH    6,26(0,3)
 000078  40 60 D 0BC                  STH   6,J
```

Example 2: Compiler-detected loop

Source program

```
2        L: IF X>Y THEN GOTO BED;          /*LOOP BEGINS*/
3             J=I-N;
4             X=X+J;
5             GO TO L;                     /*LOOP ENDS*/
6      BED:   A=X;
```

Object program

```
 * STATEMENT NUMBER  2

 * STATEMENT LABEL          L
 00005E  78 00 D 0B8                  LE    0,X
 000062  79 00 D 0BC                  CE    0,Y
 000066  47 20 2 038                  BH    BED
```

```
* STATEMENT NUMBER  3
00006A  48 60 D 0C6              LH    6,I
00006E  4B 60 D 0C8              SH    6,N
000072  40 60 D 0C4              STH   6,J


* STATEMENT NUMBER  4
000076  50 60 D 0E0              ST    6,224(0,13)
00007A  48 60 3 01C              LH    6,28(0,3)
00007E  40 60 D 0E0              STH   6,224(0,13)
000082  97 80 D 0E2              XI    226(13),X'80'
000086  78 60 D 0E0              LE    6,224(0,13)
00008A  7B 60 3 01C              SE    6,28(0,3)
00008E  3A 60                    AER   6,0
000090  70 60 D 0B8              STE   6,X


* STATEMENT NUMBER  5
000094  07 F2                    BR    2


* STATEMENT NUMBER  6

* STATEMENT LABEL        BED
000096  70 00 D 0C0              STE   0,A
```

Elimination of Unreachable Statements

If the source program contains statements that can never be executed because they are unconditionally branched around, these statements will be ignored by the compiler.

In the example below, the statements between 5 and 8 can never be reached. Consequently, no code is compiled for these statements, and a compiler diagnostic message is issued to indicate that this is the case.

Example

Source program

```
5  GOTO LABEL;
6    IF A<B THEN
        IF B<C THEN
           IF A<X THEN
           B=B*C;
7    ELSE C=B*C;
8 LABEL:  X=X+1;
```

Object program

```
* STATEMENT NUMBER  5
00008A  47 F0 2 028      B   LABEL

* STATEMENT NUMBER  8

* STATEMENT LABEL  LABEL
00008E  78 60 D 0AC      LE  6,X
000092  7A 60 3 018      AE  6,24
                              (0,3)
000096  70 60 D 0AC      STE 6,X
```

Compiler message reads:

```
"6,6,6,7 STATEMENT MAY NEVER BE
EXECUTED. STATEMENTS IGNORED."
```

Simplification of Expressions

Certain expressions are simplified for speedier execution. For example, multiplication is simplified to addition, as in the following example.

Example: Multiplication into addition

Source statement

```
 2    X=3*B
```

Object program

```
* STATEMENT NUMBER  2
000062  78 20 D 0A4      LE  2,B
000066  3A 22            AER 2,2
00006A  7A 20 D 0A4      AE  2,B
00006E  70 20 D 0A0      STE 2,X
```

or

```
6    X=3*B**2
```

Object program

```
* STATEMENT NUMBER  6
0000E2  78 40 D 0BC      LE   4,B    Load B
0000E6  3C 44            MER  4,4    B**2
0000E8  38 64            LER  6,4
0000EA  3A 66            AER  6,6    2*B**2
0000EC  3A 64            AER  6,4    3*B**2
0000EE  70 60 D 0B8      STE  6,X
```

Modification of DO-Loop Control Variables

When the DO-loop control variable is used for accessing array elements, it is frequently modified to simplify addressing of the array elements.

If, as in the example in Figure 19 on page 53, the elements of the array are four bytes long, it simplifies addressing to increment the loop control variable by 4 rather than by 1. When this is done, the increment becomes the distance between the start of successive array elements. Provided that the original value of the loop control variable is the same as that of the first bound of the array, the loop control variable in turn becomes the offset of the element from the virtual origin of the array.

If the loop control variable is altered, this means that the increment and final value must also be altered. Thus the loop in the example instead of being incremented from 1 to 10 by 1, is incremented from 4 to 40 by 4. Note that the value of the loop control variable is set at the start of the loop but is not incremented. If the value of the loop variable is required after the loop has been executed, this type of optimization cannot take place.

In the example, the control variable is held in register 5 using a BXLE instruction. The array elements are addressed by using register 5 as the offset from the virtual origins of arrays C and B. As register 5 starts the loop with the value of 4 and is incremented by 4 for each iteration of the loop, this gives the correct address. Both arrays begin 4 bytes from their virtual origins, and each array element is 4 bytes long.

Source program

```
    2   DCL C(10) FLOAT DECIMAL (6);
    3   DCL B(10) FLOAT DECIMAL (6);
    4    DO I=1 TO 10;
    5     C (I)=B(I);
    6     END;
```

Object Program

```
 * STATEMENT NUMBER  4
 00005E  48 60 3 018       LH   6,24(0,3)    Pick up 1 from static
 000062  40 60 D 0B8       STH  6,I          Place in I

 * INITIALIZATION CODE FOR OPTIMIZED LOOP FOLLOWS

 * CODE MOVED FROM STATEMENT NUMBER 5
 000066  48 E0 3 01A       LH   14,26(0,3)   Load 4 into R14 from static
 00006A  48 80 3 01C       LH   8,28(0,3)    Load 40 into R8 from static
 00006E  18 B8             LR   11,8         Load 40 into R11 for BXLE
 000070  18 AE             LR   10,14        Load 4 into R10
 000072  18 5E             LR   5,14         Load 4 into R5

 * CONTINUATION OF STATEMENT NUMBER  4
 000074           CL.2     EQU   *


 * STATEMENT NUMBER  5
 000074  78 05 D 0BC        LE    0,VO..B(5)    Pick up VO..B+R5
 000078  70 05 D 0E4        STE   0,VO..C(5)    Place in VO..C+R5


 * STATEMENT NUMBER  6
 00007C  87 5A 2 016        BXLE  5,10,CL.2     Increment R5 by 4, test
                                                for end of loop, and
                                                branch or continue
```

Figure 19. Modification of DO-Loop Control Variable

Branching around Redundant Expressions

If a series of tests are to be made and action taken if any of the tests proves positive, the compiler takes the requisite action as soon as the first positive test is found.

In the example in Figure 20 on page 54, a test is first made to see if A=D. If so, the value of Y+Z is assigned to X without a further test being made to see if C=D. Note that the last test is for inequality, so that if the variables are equal, control will continue with the code that assigns the value to X.

Source program

```
    2           IF (A=D) | (C=D) THEN
                    X=Y+Z;
```

Object program

```
* STATEMENT NUMBER 2
000062  78  00  D 0A0     LE   0,A        Pick up A
000066  79  00  D 0A4     CE   0,D        Compare A and D
00006A  47  80  2 018     BE   CL.3       Branch if equal
00006E  78  40  D 0A8     LE   4,C        Pick up C
000072  79  40  D 0A4     CE   4,D        Compare C and D
000076  47  70  2 024     BNE  CL.2       Branch if not equal
00007A               CL.3 EQU  *
00007A  78  60  D 0B0     LE   6,Y
00007E  7A  60  D 0B4     AE   6,Z        X=Y+Z
000082  70  60  D 0AC     STE  6,X
000086               CL.2 EQU  *
```

Figure 20. Branching Around Redundant Expressions

Rationalization of Program Branches

When the length of a program is greater than 4096 bytes and, consequently, it cannot be addressed from one base register, an attempt is made to update the base at the most efficient point, so that there will be as few changes of program base as possible during execution. The aim is to avoid any program branches which move from the scope of one base register to the scope of another.

The program base register is register 2, and this is updated when necessary. As register 2 is required for in-line record I/O and TRT instructions, the program base is saved and restored after such use.

Use of Common Constants and Control Blocks

Constants and control information used more than once are generated only once in static storage. Thus for the statements X=768, Y=768, the constant value of 768 will be picked up from the same address in both cases. Similarly, compiler-generated control descriptors are generated only once if a number of variables require identical control information.

The process of avoiding duplication is known as *commoning*. It should be noted that constants may not be commoned if they are not used in the same way. In the example in Figure 21 on page 55, constant '123' is stored in a different form for assignment, multiplication, and exponentiation.

Source program

```
    2          X=123;                        /*COMMONED ITEM*/
    3          Y=123*Z;
    4          V=V**123;
    5          A=123;                        /*COMMONED ITEM*/
```

Object program

```
 00005E  78 00 3 01C         LE    0,28(0,3)  /*COMMONED ITEM*/
 000062  70 00 D 0B8         STE   0,X


 * STATEMENT NUMBER  3
 000066  78 20 D 0C0         LE    2,Z
 00006A  7C 20 3 01C         ME    2,28(0,3)
 00006E  70 20 D 0BC         STE   2,Y


 * STATEMENT NUMBER  4
 000072  41 70 D 0C4         LA    7,V
 000076  50 70 3 024         ST    7,36(0,3)
 00007A  50 70 3 02C         ST    7,44(0,3)
 00007E  96 80 3 02C         OI    44(3),X'80'
 000082  41 10 3 024         LA    1,36(0,3)
 000086  58 F0 3 014         L     15,A..IBMBMXSA
 00008A  05 EF               BALR  14,15


 * STATEMENT NUMBER  5
 00008C  78 00 3 01C         LE    0,28(0,3)
 000090  70 00 D 0C8         STE   0,A        /*COMMONED ITEM*/
```

Figure 21. Use of Common Constants

Chapter 4. Run-Time Organization

This chapter tells you about the facilities of PL/I that are used at run-time and how they are organized. Topics covered are the task communications area, various registers, dynamic storage allocation, use of storage, load modules and their naming conventions and the multitasking library.

Communications Area

The facilities offered by PL/I language, particularly the error-handling facilities, imply that certain items must be accessible at all times during the run. To simplify accessing such items, a standard communications area is set up for the duration of the run. This area is known as the task communications area (TCA), and register 12 is usually addresses it throughout the run.

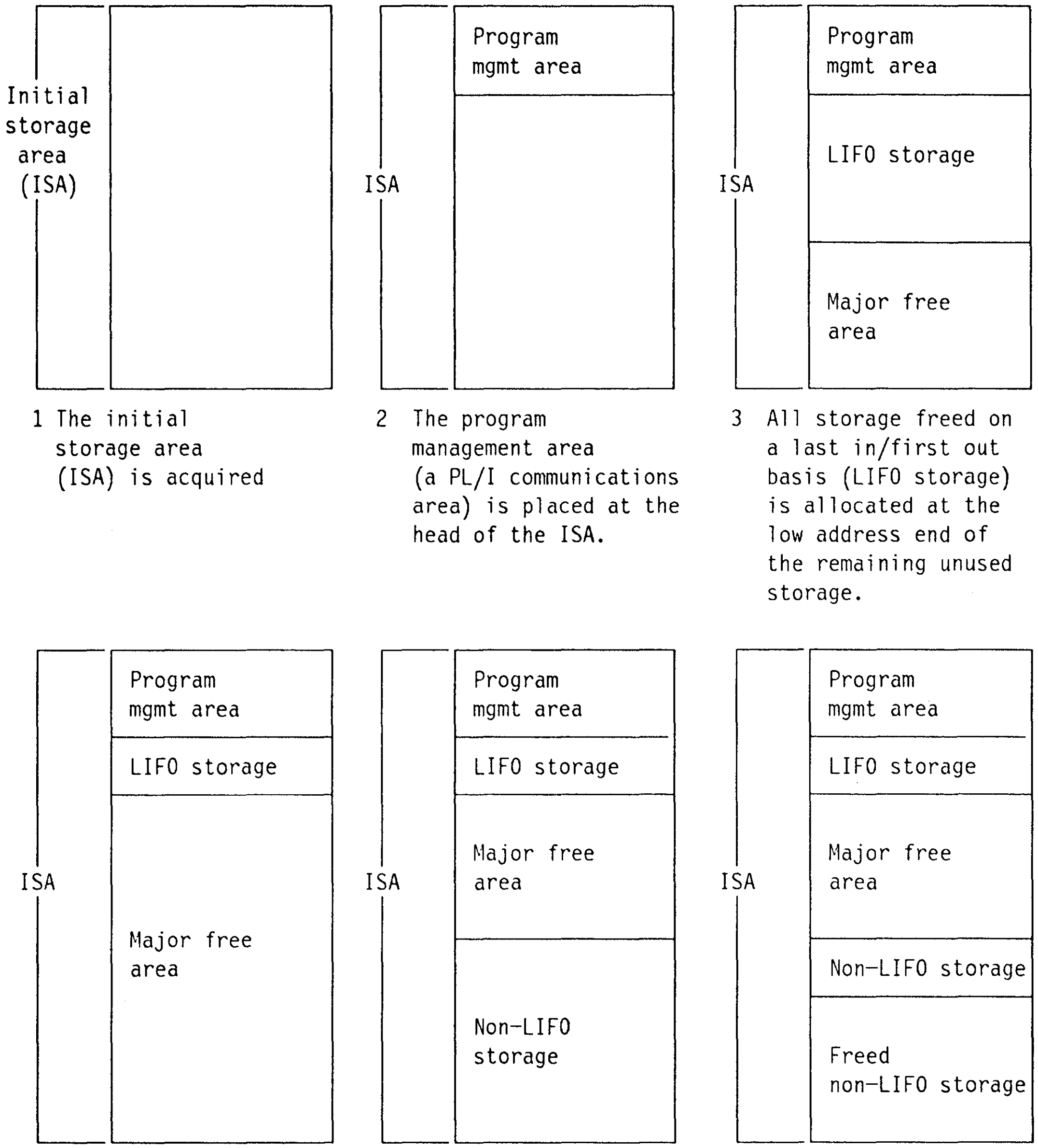
Dynamic Storage Allocation

The principles of the dynamic storage scheme are illustrated in Figure 22 on page 58.

The allocation and freeing of AUTOMATIC storage on a block-by-block basis implies a facility for the reuse of such storage. This technique of inter-block communications uses for each block a save area that contains register save information, AUTOMATIC variables, and housekeeping information.

This area is known as dynamic storage area (DSA). It consists of the standard operating system save area concatenated with certain housekeeping information and with storage for AUTOMATIC variables. DSAs are held contiguously in a last-in/first-out (LIFO) storage stack and are freed and allocated by the alteration of pointer values.

When a block is entered, the registers of the preceding block are stored in the previous DSA and a new DSA is acquired. A back-chain pointer to the previous DSA is placed in the new DSA. This arrangement allows access to information in previous blocks. Register 13 points to the head of the DSA for the current block. The code that carries out this and any other block initialization is known as the *prolog code.* To obviate the need for special coding in the main procedure, a dummy DSA is set up by an initialization routine. Register 13 points at this dummy DSA on entry to the main procedure.



1 The initial storage area (ISA) is acquired

2 The program management area (a PL/I communications area) is placed at the head of the ISA.

3 All storage freed on a last in/first out basis (LIFO storage) is allocated at the low address end of the remaining unused storage.

4 When LIFO storage is freed, the most recently allocated element is the first to be freed. It is freed by being reabsorbed into the major free area.

5 Elements not freed on a last in/first out basis (non-LIFO storage) are allocated at the high address end of the free storage, or in a separate area known as HEAP.

6 When non-LIFO storage is freed, it is, where possible, absorbed into the major free area. Where this is not possible it is placed on a chain of free storage. The head of this chain is held at a fixed offset in the program management area. Areas on this chain are reused where possible.

Figure 22. Use of PL/I Dynamic Storage without Heap Storage

In addition to AUTOMATIC variables, certain other types of storage are allocated and freed dynamically. Items not freed on a last-in/first-out basis are kept in a second storage area called *non-LIFO* storage. If items within this area are freed, they are placed on a free-area chain. The storage scheme is handled partly by a compiled code and partly by a library routine.

In the LIFO storage stack, compiled code acquires and frees space.

HEAP storage is an area that is used for dynamically allocated storage, or controlled and dynamically based variables, in the program. This storage is separate from the ISA. It is controlled by the HEAP run-time option.

Contents of a Typical Load Module

The contents of a typical load module are shown in Figure 23 on page 60. The contents are:

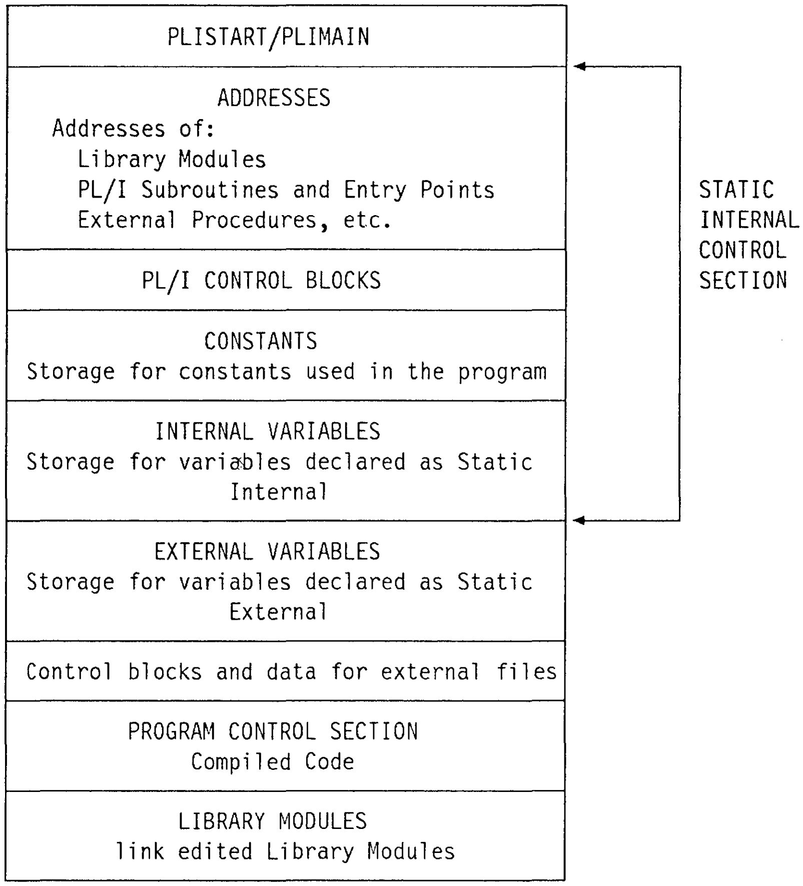
- Object module (the executable machine instructions previously generated).
- Link edited routines. These routines include library routines, many of which are included in every executable program phase. These are the initialization routines. Other resident routines are included as required.

As well as the executable machine instructions, the program requires certain control information and addresses.

The Overall Use of Storage

Figure 24 on page 61 illustrates the overall use of storage. The program acquires an area known as the *initial storage area* (ISA) for program management and PL/I dynamic storage. The initialization routines set up the program management area which includes the TCA and the dummy DSA discussed above. PL/I dynamic storage allocations use the remainder of the ISA. The LIFO stack starts beyond the end of the program management area and expands, as necessary, toward the end of the ISA. Storage for I/O buffers and library routines is acquired by issuing GETMAIN macro instructions.

Non-LIFO dynamic storage starts at the end of the ISA and expands toward the LIFO stack. If you use HEAP storage, then separate storage areas are acquired.



PLISTART/PLIMAIN

ADDRESSES
Addresses of:
Library Modules
PL/I Subroutines and Entry Points
External Procedures, etc.

PL/I CONTROL BLOCKS

CONSTANTS
Storage for constants used in the program

INTERNAL VARIABLES
Storage for variables declared as Static Internal

EXTERNAL VARIABLES
Storage for variables declared as Static External

Control blocks and data for external files

PROGRAM CONTROL SECTION
Compiled Code

LIBRARY MODULES
link edited Library Modules

Figure 23. Diagram of an Executable Program

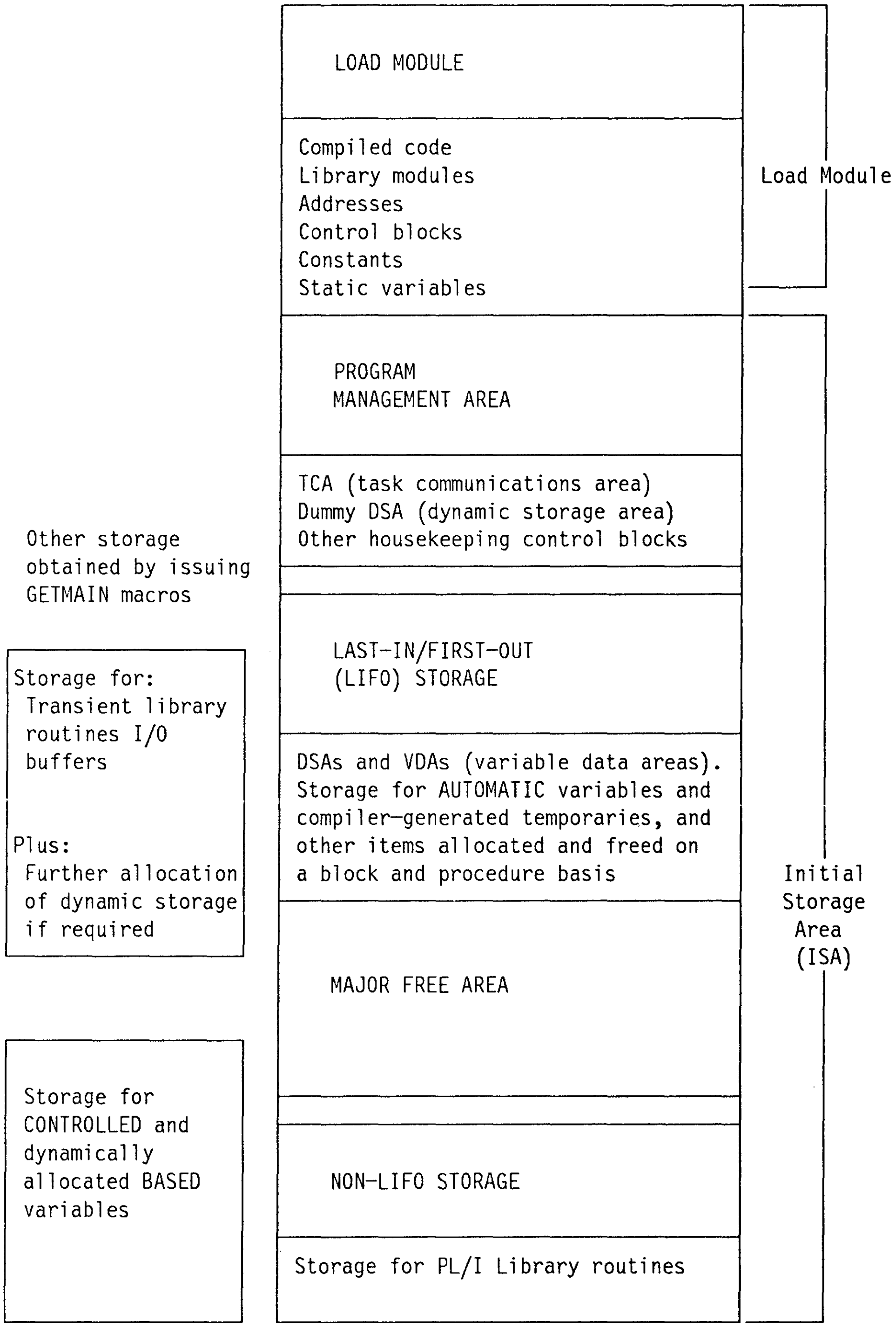


Figure 24. Use of Storage

Library Module Naming Conventions

PL/I library modules are named according to the conventions in this section. Usually the EBCDIC name is coded into the module close to its start. This allows the name of the routine to be easily seen in a dump.

The first three or four letters of the PL/I Library module name indicate where the module belongs. These initial letters and their locations follow.

IBMB	PL/I Library
IBMO	Usually PLITEST but sometimes the PL/I Library
AQA	PLITEST
IBMF	PL/I Library, CICS support
IBMT	PL/I Library, Multitasking support

Note: Some CICS modules are link edited into the load module DFHSAP.

DUMP Eye Catchers and PLITEST

You will see module eye catchers in your dump. PL/I provides these to aid your problem diagnosis. Each eye catcher is a four-letter character string followed by the last date the module was compiled. The fourth letter of the module name and the mnemonic make up this character string.

For example, the eye catcher

```
BOPB 06/15/85
```

is for the module IBMBOPBA, which was last compiled on 06/15/85.

These same conventions are true in PLITEST.

The Multitasking Library

Two data sets hold the resident library modules, SYS1.PLIBASE and SYS1.PLITASK. SYS1.PLIBASE holds all modules needed to run non-multitasking programs. SYS1.PLITASK holds the multitasking versions of all modules that differ for multitasking and non-multitasking environments.

Both the multitasking and non-multitasking modules have the same link-edit names for their entry points. Multitasking modules have a fourth letter *T*; non-multitasking modules have a fourth letter *B* in their control names.

The use of the same link-edit name permits the compiler to generate the same code for library calls, regardless of whether the program is a multitasking or non-multitasking one. In order for multitasking programs to be link edited and run in a multitasking environment, the data set SYS1.PLITASK must precede SYS1.PLIBASE in input to the linkage editor.

Chapter 5. Run-Time Problem Determination

This chapter contains the run-time problem determination chart. If you are just beginning your problem diagnosis, use the chart in Figure 26. Begin with the first block, Block 100, answer the question or perform the action specified, then go to the block indicated by the answer. Some blocks describe an action to be performed and also direct you to the next block.

If you have already made a preliminary diagnosis of your problem and you are familar with PL/I, you can use the chart index below in Figure 25 to find the information you need.

Run-Time Subject Covered	Block Number
Abend or Program Check	125
System Dump	126
Formatted PL/I Dump	129
Interrupt Type and Location	132
Source Statement Processed	139
Finding Registers	142
Search Argument Generation	143
Loop	144
Search Argument Generation	148
Wait	149
Unusual or Unexpected Output	150
Bad Output Data	154
Bad File Record	156
Search Argument Generation	160
Performance	161

Figure 25. Run-Time Problem Determination Index

Block No.	Question	Action
100	Is this an abend?	Yes 106 No 101
101	Is this a problem relating to a message?	Yes 106 No 102
102	Is this a loop?	Yes 106 No 103
103	Is this a wait?	Yes 106 No 104
104	Is this unusual or unexpected output?	Yes 106 No 105
105	Is this a performance problem?	Yes 106 No 124

Figure 26 (Part 1 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action

106	Add to the program the following block:
	`ON ERROR BEGIN;`
	`   ON ERROR SNAP SYSTEM;`
	`   PUT DATA;`
	`END;`
	Recompile and rerun the program. If the problem is solved, END. If the problem still exists: has the program ever worked before?
		Yes 107
		No 109

107	Has anything in the environment changed? Look for source code changes, system control program (SCP) changes, PTFs, release fixes, etc.	Yes 111 No 108
108	Is the entry from: MESSAGE LOOP WAIT UNUSUAL or UNEXPECTED OUTPUT PERFORMANCE **Note:** If you are here via the "environment changed" route, follow the major symptom code being experienced.	 Yes 125 Yes 144 Yes 149 Yes 150 Yes 161
109	Has the source code been checked for accuracy and all "E" or "S" level compiler messages corrected?	Yes 108 No 110
110	Correct the conditions causing the "E" or "S" level messages. Recompile and test the program. Is the problem solved? Note: If the problem is solved, but you feel the message was generated in error, follow the "NO" path.	Yes END No 120
111	Has the source code of the program been changed?	Yes 115 No 112
112	Has any maintenance been applied to the PL/I compiler and/or libraries?	Yes 116 No 113
113	Has the PL/I compiler release level changed?	Yes 118 No 114

Figure 26 (Part 2 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
114	You probably do not have a PL/I problem. In getting to this block, you have indicated that the program has compiled and run successfully before. Now you should investigate the system control program for changes that could have affected this program. **Note:** System control program refers to the operating system. If you still believe this to be a PL/I problem, go to Block 108 and follow the major symptom code.	See Note
115	Were there any messages at compile time that could have caused this problem? If so, correct those conditions. Recompile and test the program. Is the problem solved?	Yes END No 120
116	Is(Are) the fix(es) or PTF(s) installed correctly? **Note:** Check early warning microfiche or have the IBM Support Center check SSF for errors on all PTFs and fixes applied. Use the keyword PExxxxx for PTF errors.	Yes 121 No 117
117	Reinstall the PTF or fix correctly and test. Is the problem solved?	Yes END No 120
118	Is the release level installed correctly? **Note:** Search early warning microfiche or have the IBM Support Center search SSF for any PTFs and errors applicable to this release. Are there any messages from the link edit steps?	Yes 121 No 119
119	Reinstall the release level correctly, plus any PTFs or fixes that are applicable, and test. Is the problem solved?	Yes END No 120
120	Have the symptoms changed?	Yes 100 No 121
121	Search early warning microfiche or have the IBM Support Center do an SSF search. For more information about doing an SSF search, see Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 122 No 108
122	Apply applicable fix(es) from hit(s) and test. Is the problem solved?	Yes END No 123
123	Have the symptoms changed?	Yes 100 No 108
124	Something has apparently been overlooked. A failure must have occurred and it must have been one of the previously mentioned types. Review the symptoms again. If the problem does not fit any of the stated symptoms, go to Block 164.	164

Figure 26 (Part 3 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
125	Do you have a system dump rather than a PL/I formatted dump? Review the section on run-time dump analysis that precedes these charts.	Yes 126 No 129
126	To reduce the possibility of a user error, rerun the program with the SIZE, SUBSCRIPTRANGE, STRINGSIZE, and STRINGRANGE conditions enabled. Were any of these conditions raised? **Note:** For instructions, see *OS PL/I Version 2 Programming: Language Reference.*	Yes 127 No 129
127	This probably means you have a programming problem. Correct the code that caused the condition, and rerun the program. Is the problem solved?	Yes END No 128
128	Have the symptoms changed?	Yes 100 No 129
129	Do you have an IBMxxxx message?	Yes 130 No 131
130	The IBMxxxx message will give you the following information: Message number ON-code number Condition raised (if applicable) Statement number being processed (if "GOSTMT" was specified) Offset of statement being processed (You can use the table of offsets to find the statement number from this.) Procedure name being run Go to Block 131.	131
131	Do you already know the type and location of the interrupt?	Yes 142 No 132
132	Do you have a system dump rather than a PL/I formatted dump?	Yes 136 No 133
133	Does the PL/I dump have trace information? **Note:** Find the words "***CALLING TRACE***".	Yes 134 No 135

Figure 26 (Part 4 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
134	To find the type of interrupt: 1. For an example of trace information in a dump, see "Housekeeping Information in All Dumps" on page 92. 2. The ON-code (1) type of ON-unit, (2) and reason for entry, (3) as well as who called the error handler (4) are given in the trace information. 3. The ON-code is your type of interrupt. To find the interrupt locations: 1. Find IBMBERR's DSA (see "Housekeeping Information in All Dumps" on page 92). 2. Chain back one DSA (X'04' in each DSA holds the address of the previous DSA). 3. The address of the interrupt is at X'0C' in this DSA. To find the register contents on interrupt: 1. If the interrupt was an abend, there will be no register information available unless SPIE and STAE were in effect. 2. If the interrupt was a software detected interrupt, the contents of registers 14 through 11 at the time of interrupt are at offset X'08' in the previous DSA. 3. If the interrupt was a program check, registers 0 through 11 are at offset X '14' in the previous DSA, and registers 14 and 15 are at X'5C' in the DSA for IBMBERR. Go to Block 137. **Note:** IBMBERR could be IBMFERR.	137

Figure 26 (Part 5 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
135	To find the type of interrupt: find and interpret the on communication area (ONCA) which will give you the ON-code. 1. Find IBMBERR's DSA. (Register 13 has the current DSA address. Offset X'04' in each DSA holds the address of the previous DSA. IBMBERR's DSA has X'EEEE' in the second halfword of the first word.) 2. Locate the halfword at offset X'54' of this DSA, which contains the error code. If this error code is X'0C' or X'0D' then locate the address of the LWS at offset X'48' from IBMBERR's DSA and locate the pointer to the current ONCA. (Offset X'02' in the LWS.) 3. From the current ONCA, chain back to the previous ONCA (the chain back field is the first fullword of each ONCA). 4. Locate the 2-byte error code at X'04'. 5. Using Figure 32 on page 86, find the base number associated with the first byte of the error code. 6. Translate the right-hand five bits (of the second byte of the error code) to decimal. 7. Add this value to the base number to get the ON-code. 8. Look up the ON-code in the *OS PL/I Version 2 Programming: Language Reference*. If you have a system dump, go to Block 136. **Note:** IBMBERR could be IBMFERR.	136
135 (cont'd)	To find the interrupt location: 1. Register 13 holds current DSA address. 2. Offset X'04' in each DSA holds address of previous DSA. 3. Chain back to the DSA before the error handler's DSA. 4. The interrupt address is at offset X'0C' in this DSA. Go to Block 137.	137
136	If possible, obtain a PL/I dump, then go to block 133. If you cannot obtain a PL/I dump but you do have a system dump, you will find the interrupt address in the second word of the PSW in the system dump. Go to Block 137.	133 137

Figure 26 (Part 6 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
137	Compare the interrupt address to the link map. Is the address within a library module or outside the link map? If the address is outside the link map, the interrupt probably occurred in a transient library module. If the address is within the link map, the interrupt occurred in a resident library module. Remember the module name for your early warning microfiche or SSF search. Go to Block 138.	138
138	Now you know the type of the interrupt and, if you have a message or a PL/I dump with trace information, you should also know what source statement was being run. Go to Block 142. If you have a system dump, or no trace information, or for some other reason you do not know the source statement being run, go to Block 139.	142 139
139	LIST option in effect: OFFSET option in effect.	Yes 140 Yes 141

Figure 26 (Part 7 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
140	1. Locate the error handler DSA. (Register 13 has the current DSA address. X'04' in each DSA holds the address of the previous DSA. IBMBERR's DSA has X'EEEE' in the first word.) 2. Chain back until a procedure DSA is found. (Procedure DSAs have bits 4 and 5 set to '00'B.) 3. Chain back one more DSA. **Note:** IBMBERR could be IBMFERR. 4. Note the address held at offset X'10' (register 15 for the procedure in which the interrupt occurred). 5. Subtract this entry point address from the interrupt address to obtain an offset. If the interrupt occurred in a library module, subtract the entry point address from the entry point address of the procedure (Register 14). 6. This offset should then be added to the offset of the REAL ENTRY of the procedure in which the interrupt occurred as given in the object listing. (For main procedures, this will be the length of the procedure name plus one, rounded up to the next multiple of four.) 7. In the object listing, this offset points to the assembler instruction after the instruction that caused the interrupt. The PL/I statement number is given in the listing preceding the code with which it is associated. Sometimes the statement statement number may not be exact, if the OPT (TIME) option is specified. Go to Block 142.	142
141	1. Obtain the offset address of the interrupt as described in steps 1 through 5 in Block 140. 2. Use this offset with the offset and Statement Table in the listing to find the statement number. Go to Block 142.	142
142	If your ON-code was 8094, 8095, or 8096, you may want to know the contents of the registers at the time of the program check. Refer to Chapter 6, "Debugging Using Dumps" on page 75 for more information. Go to Block 148 if your major symptom code is loop. Otherwise, go to Block 143.	148 143

Figure 26 (Part 8 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
143	Search early warning microfiche or have the IBM Support Center do an SSF search. More information doing an SSF searches is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 162 No 164
144	If a loop appears to be occurring, use the instruction step mode, if possible, to capture all, or at least part, of the loop addresses. Then cancel the job with a dump. Is the loop in the user program area? Note: Use the link map to determine this.	Yes 145 No 146
145	If the loop is within the user program, it is probably a program logic error. Correct the situation and rerun the program. If you still believe the problem to be in PL/I, go to Block 148.	148
146	Find the module name(s) in which the loop occurs. Use the link map to determine this. If the loop addresses are outside the link map, the loop is probably occurring in a transient library module. If it is in the link map, remember the name. **Note:** The control blocks portion of an ABDUMP (SNAP) contains information on the entry point address and length of transients loaded. Go to Block 147.	147
147	You may want to know which source statement is being processed. Go to Block 138.	138
148	Search early warning microfiche or have the IBM Support Center do an SSF search using: • component-id 5668909 • EXEC • LOOP • module name(s) (if applicable) • type of statement being processed (if applicable—search without it first). Any hits?	Yes 162 No 164
149	Usually wait states are caused by the system control program, not by PL/I. Get a dump and determine what is being waited for.. To do this, locate the ECB/CCB pointed to by register 1. If you still believe the problem is in PL/I, search early warning microfiche or have the IBM Support Center do an SSF search, using: • component-id 5668909 • EXEC • WAIT. Any hits?	Yes 162 No 164

Figure 26 (Part 9 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
150	Rerun the program with the following conditions enabled: SIZE, SUBSCRIPTRANGE, STRINGSIZE, STRINGRANGE. Were any of these conditions raised?	Yes 151 No 153
151	Correct the code that raised these conditions and rerun the program. Is the problem solved?	Yes END No 152
152	Have the symptoms changed?	Yes 100 No 153
153	If you do not have a dump, you may want to get one by calling PLIDUMP at appropriate places in the program. See Chapter 6, "Debugging Using Dumps" on page 75 for more information. Is your problem due to bad output data, such as on an output report?	Yes 154 No 155
154	You need to look at your variable fields in the dump. First, determine the types of variables you are working with. They will be one of the following types: static, automatic, controlled, based, area. "Finding Variables" on page 107 explains how to find these variables in a dump. Go to Block 155.	155
155	Is your problem related to a bad file record?	Yes 156 No 160
156	You need to look at the file information in the dump. Do you have a PL/I dump with file information formatted?	Yes 157 No 158
157	The FCB, ENVB, DCB, and for VSAM the IOCB and ACB will be formatted for each open file. Go to Block 159.	159
158	An offset from register 3 points to the DCLCB. The first word in the DCLCB points to the FCB. The offset from register 3 can be found in the static storage map in the compile listing. The maps of the file control blocks are in Appendix A, "Control Blocks" on page 119. Go to Block 159.	159
159	Check the file attributes in the dump with those in the source program to be sure they are the same. One common error in overlay programs is not specifying the exact attributes in an overlay for a file as were specified in the root. Go to Block 160.	160

Figure 26 (Part 10 of 11). Run-Time Problem Determination Chart

Block No.	Question	Action
160	Search early warning microfiche or have the IBM Support Center do an SSF search. Information about doing an SSF searches is in Chapter 7, "Using SSF and CSSF Search Arguments" on page 113. Any hits?	Yes 162 No 164
161	Performance problems usually show up after some environment change or when using some function you have not used before. Try to identify this. Search early warning microfiche or have the IBM Support Center do an SFF search using: • component-id 5668909 • EXEC • PERFM. If you can, also include a description of the action being performed. Any hits?	Yes 162 No 164
162	Apply the fix(es) from SSF and test. Is the problem solved?	Yes END No 163
163	Have the symptoms changed?	Yes 100 No 164
164	Contact the IBM Support Center for assistance. Have available the following documentation: • Compilation listing with LIST and MAP options specified • Job control statements • Linkage Editor map • Run-time dump (if applicable)	

Figure 26 (Part 11 of 11). Run-Time Problem Determination Chart

Chapter 6. Debugging Using Dumps

The OS PL/I Optimizing Compiler allows you to obtain a run-time dump by calling PLIDUMP. Using SYSABEND or SYSUDUMP in the JCL does not normally result in a dump after a program interrupt or, except in certain exceptional cases, after an ABEND. This is because SPIE/ESPIE and STAE/ESTAE routines result in all interrupts, and the majority of ABENDs, being passed to the PL/I error handler.

Certain types of program error can, however, result in overwriting of the control information used by the error handling routines. When this occurs, an ABEND will be issued that results in system action. This ABEND has a user code of 4000. Provided that a SYSABEND or SYSUDUMP DD statement was included in the JCL, an ABEND dump will then be generated.

ABEND dumps are possible under these circumstances.

1. When an interrupt occurs during the execution of one of the error handling routines.
2. When housekeeping control blocks have been overwritten after an ABEND in the program.
3. If the NOSPIE or NOSTAE option has been used.
4. An error occurred in the program and the user has coded the User Exit module.

The first two of these situations are most probably caused by overwriting of control information by the PL/I program. The first can be identified because a message is sent to the console that reads 'INTERRUPT IN ERROR HANDLING ROUTINES PROGRAM TERMINATED', and the ABEND code will be 4000.

It is always possible for the programmer to ask an operator to request a stand-alone dump at any point in the program. The need to do this should, however, occur only infrequently.

For information about compiled code register usage and library register usage see Figure 11 on page 24 and Figure 12 on page 26.

Considerations

A DD statement with the ddname PLIDUMP or PL1DUMP, a FILEDEF command in CMS, or an ALLOCATE command in TSO must be supplied to define the data set for the dump.

The data set defined by the PLIDUMP DD statement must have DSORG=PS specified or assumed by default, and must have one of the following attributes:

- Correct DCB parameters for a system SNAP dump
- Allocated to disk
- Allocated to SYSOUT
- Allocated to the terminal or unit-record device.

To get a formatted dump, ON ERROR must CALL PLIDUMP.

How to Use This Chapter

This chapter contains information on how to obtain and interpret dumps, and on how to identify compiled code, data, and control blocks within a dump. Some knowledge of the compiler's housekeeping scheme, described in Chapter 3, "Compiler Output" is assumed. A summary of how to use this chapter when debugging is given in Figure 27 on page 77.

This chapter is divided into seven sections:

- **"Section 1: How to Obtain a PL/I Dump"** .

  This section explains how to obtain a hexadecimal dump of a PL/I program. It also gives some suggestions on the use of various compiler and PL/I options that may prove useful when debugging.

- **"Section 2: Suggested Debugging Procedures"** .

  This section describes two ways of debugging a PL/I program using a dump. The first shows a PL/I dump that was called from an ERROR ON-unit; the second shows debugging with a system dump that was probably generated because the housekeeping control blocks were overwritten.

- **"Section 3: Locating Specific Information"** .

  This section describes how to find various data areas and other information. It is indexed and numbered for quick reference.

- **"Section 4: Special Considerations for Multitasking"** .

  This section describes the special considerations that must be taken into account when debugging a program that uses multitasking.

- **"Section 5: Special Considerations for CICS"** .

  This small section tells you about the differences between the PL/I-CICS run-time environment and the PL/I batch and multitasking environments.

- **"Section 6: User Exit Considerations"** .

  This section describes the user exit and how to use it.

- **"Section 7: SYSTEM Option Considerations"** .

  This section gives you some information about the SYSTEM option and refers you to the *OS PL/I Version 2 Programming Guide* for more details.

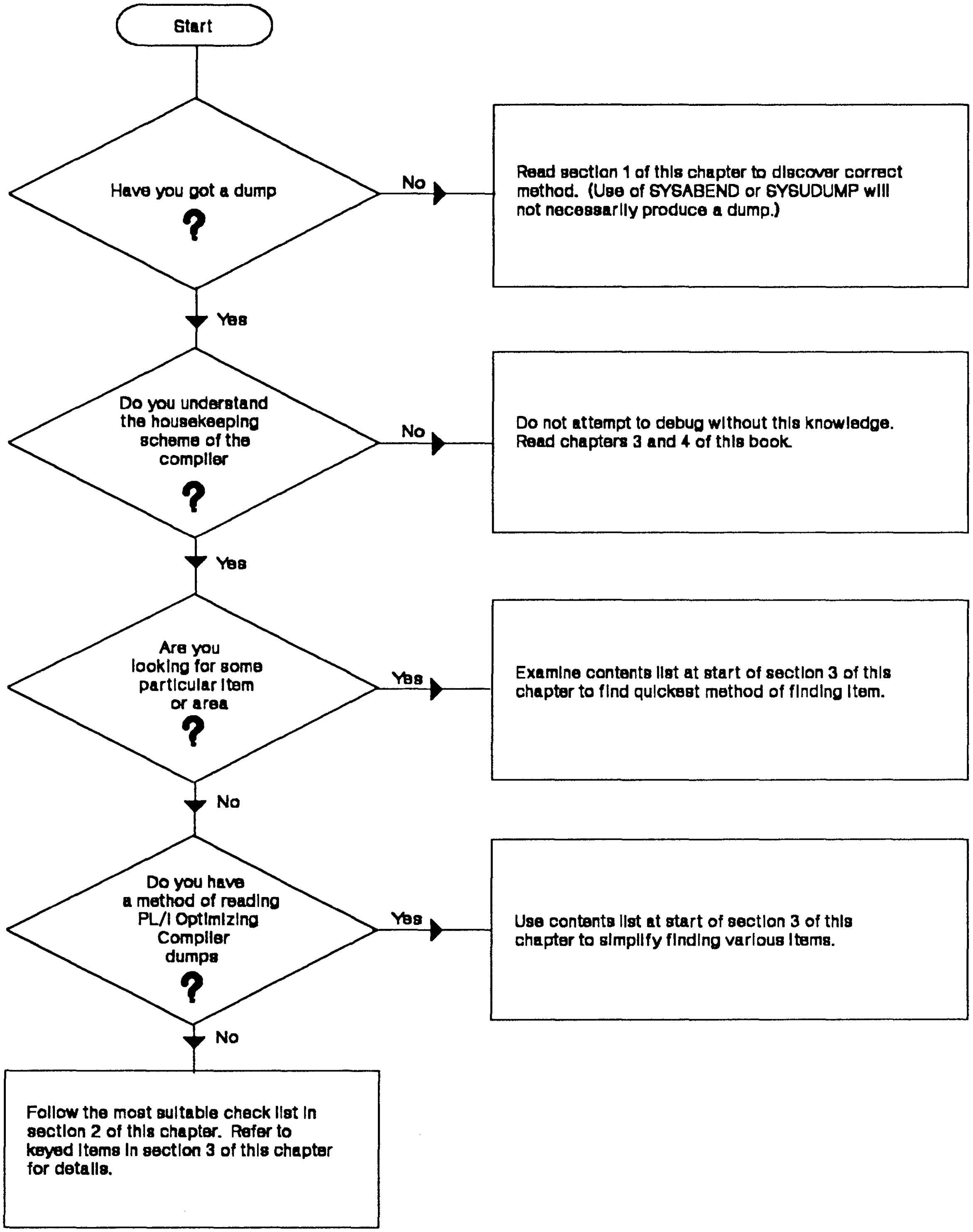

Start
Have you got a dump ?
No
Read section 1 of this chapter to discover correct method. (Use of SYSABEND or SYSUDUMP will not necessarily produce a dump.)
Yes
Do you understand the housekeeping scheme of the compiler ?
No
Do not attempt to debug without this knowledge. Read chapters 3 and 4 of this book.
Yes
Are you looking for some particular item or area ?
Yes
Examine contents list at start of section 3 of this chapter to find quickest method of finding item.
No
Do you have a method of reading PL/I Optimizing Compiler dumps ?
Yes
Use contents list at start of section 3 of this chapter to simplify finding various items.
No
Follow the most suitable check list in section 2 of this chapter. Refer to keyed items in section 3 of this chapter for details.

Figure 27. How to Use this Chapter When Debugging

If you are familiar with system dump methods, read "Section 1: How to Obtain a PL/I Dump" on page 78 before requesting a dump. PL/I uses methods that do not follow OS. Use the next two sections when debugging. If you know what not follow OS. Use the next two sections when debugging. If you know what you are looking for, go directly to "Contents" on page 92. This section directs you to numbered sections that give details of how to find particular items. If you have no preferred scheme of your own, you can follow the recommended procedures in "Section 2: Suggested Debugging Procedures" on page 87. It cross-refers to the items in "Section 3: Locating Specific Information," so that the details of the steps involved can be quickly found.

Section 1: How to Obtain a PL/I Dump

In order to get a formatted PL/I dump, you must include a call to PLIDUMP in your program.

CALL PLIDUMP

The statement CALL PLIDUMP may appear wherever a CALL statement is used. It has the following form:

```
CALL PLIDUMP
   (character-string-expression 1, character-string-expression 2);
```

Character-string-expression 1 is a "dump options" character string consisting of one or more of the following dump option characters:

T Trace. A calling trace through all active DSAs is generated. When an ON-unit DSA is encountered, the values of the relevant condition built-in functions are given. The reason for the entry to the ON-unit is also given if the ERROR or FINISH conditions are raised as standard system action for another condition.

NT No trace. A calling trace is not given.

F File information. A complete set of attributes for all open files is given, plus the contents of all accessible buffers.

NF No file information required.

S Stop. The program will be terminated after the dump.

C Continue. Execution of the program continues after the dump.

H Hexadecimal. A SNAP hexadecimal dump of the region will be given. If trace information is requested, the TCA and DSA addresses will be given.

If file information is requested, the addresses of the FCBs will be given and the contents of all accessible buffers will be printed in hexadecimal notation as well as in character.

NH No hexadecimal dump required.

B Blocks. The contents of the TCA, TIA, DSAs, FCBs, and file buffers are printed in hexadecimal notation.

NB No block information required.

K Produce a hexadecimal dump of the TIOAS and TWA (CICS control blocks) if they exist

NK No dump of CICS blocks.

Tasking Options

A *All*, which results in a dump of all active tasks including the control task.

O *Only*, which results in a dump of the current task and a dump of the control task.

E *Exit*, which results in the termination of the task after the dump.

The default options are TFCANHNB. That is, trace information, file information, no block information, no hexadecimal dump, all tasks, and continuation after the information is output.

Options are read from left to right. Invalid options are ignored, and, if contradictory options are coded, the rightmost options are taken.

Character-string-expression 2 is a user identifier character string of up to 90 characters chosen by the PL/I programmer. It is printed at the head of the dump. If the character string is omitted, nothing is printed.

If PLIDUMP is called a number of times in a program, a different user identifier should be used on each occasion. This simplifies identification of the point at which the dump was called.

Suggested Coding

For PLIDUMP to produce a dump, a DD card for PLIDUMP must be included in the JCL. PLIDUMP can be called from anywhere in a program, but the normal method used when debugging will be to call PLIDUMP from an ON-unit. As continuation after the dump is one of the options available, PLIDUMP can be used as a SNAP dump to get a series of dumps of main storage throughout the running of the program.

By including the statement CALL PLIDUMP ('HB','dump identifier'); in an ERROR ON-unit, it is possible to obtain a hexadecimal dump, with control blocks identified and formatted, should an error occur. If an ERROR ON-unit is being included in a program, care should be taken that there are no further ON ERROR statements which might override the ON-unit requesting a dump.

Suggested code for use when debugging with a dump is given in Figure 28 on page 80.

1 2 3

```
*PROCESS LIST MAP GOSTMT FLOW (n,m);
4  (SIZE, SUBSCRIPTRANGE, STRINGRANGE):
   DUMPER: PROC;
   ON ERROR CALL PLIDUMP ('HB', 'ERROR ON-UNIT DUMP');
                  .
                  .
   END;           .  5
```

1 These options give compiled code listing and static storage map, essential for interpreting any dump. MAP results in the generation of a table showing offsets of static and automatic variables from their defining bases.

2 Permits trace of statement numbers in original source program, and simplifies program checking.

3 Provides trace of last n branch-out/branch-in points in up to m blocks if SNAP or PLIDUMP with trace is used.

4 Prefix options. The use of these PL/I checkout options is strongly urged. Since, however, they cause an increase both in the size of object code and in execution time, it may be necessary to restrict their use to suspected blocks or statements.

5 Two arguments can be passed to PLIDUMP. They are the dump options character string and the dump identifier. The format ot the call statement is:

CALL PLIDUMP (character-string-expression 1, character-string-expression 2);

Dump options character string
(Default is 'TFCANHNB')

T	Trace information required
NT	No trace information required
F	File information required
NF	No file information required
S	Stop after dump
C	Continue after dump
H	Hexadecimal information required
NH	No hexadecimal information required
B	Control block information required
NB	No control block information required
A	Dump all tasks
O	Dump current task only
E	Exit from task after dump
K	Produce a hexidecimal dump of TIOAS and TWA
NK	No dump of CICS blocks

Dump identifier character string

Printed at head of dump. May be up to 90 characters long.

Figure 28. Code for Debugging

Avoiding Recompilation

If an ERROR ON-unit containing a call to PLIDUMP is to be included in an existing program, it is necessary to recompile the program. This course is advisable as it allows other diagnostic aids, such as SUBSCRIPTRANGE, to be included. However, if recompilation is not desirable, a PL/I dump can be obtained by using a small bootstrap routine that contains an ERROR ON-unit calling PLIDUMP. This routine can be compiled and then link-edited with the object module of the program that needs to be dumped. The ON-unit will then be inherited by the program that requires a dump, and a dump will be generated when an error occurs. A suitable bootstrap program is shown in Figure 29. When using this method, the bootstrap must be link-edited as the MAIN procedure; it should therefore be passed to the linkage editor before the program that requires dumping, since that program will also have the MAIN option. If the program that requires dumping expects to be passed parameters, the bootstrap procedure should use an identical parameter list in its PROCEDURE statement, and should include an identical argument list in the CALL statement used to invoke the inner procedure.

Note: You can call PLIDUMP without recompiling your program by using PLITEST. You can use the run-time TEST option to have PLITEST easily gain control of your program. Once PLITEST has control, it can do a number of things, including issuing a CALL PLIDUMP. For more information about this method of calling PLIDUMP, see *OS PL/I Version 2 Programming: Using PLITEST*.

```
BOOTSTRAP:  PROC OPTIONS (MAIN);

            DCL program* ENTRY EXTERNAL;

            ON ERROR CALL PLIDUMP ('HB',
            'BOOTSTRAP');

            CALL program*;

            END;
```

See text before using this method.

Figure 29. Suggested Method of Obtaining a Dump when Recompilation is Particularly Undesirable

Note to Figure 29:

* Insert the name of the program to be dumped at the points marked "program*" in this example.

If the program that requires dumping already has an ERROR ON-unit, this will override the ERROR ON-unit in the bootstrap program. However, if you are using PLITEST, PLITEST gains control prior to the ON-units in the program.

In certain circumstances, a dump can still be obtained.

1. If the reason for the entry to the ON-unit is the occurrence of a PL/I condition, an ON-unit for this condition in the bootstrap program will result in a dump before the ERROR ON-unit is run.

(For example, if the CONVERSION condition was occurring in the program to be dumped, a CONVERSION ON-unit could be included in the bootstrap program. Such an ON-unit would be entered before the ERROR condition was raised.)

2. Provided that the ERROR ON-unit does not include a GOTO out of the ON-unit, a FINISH ON-unit can be used. Since the standard system action for the ERROR condition is to raise the FINISH condition, the dump will be generated after the ERROR ON-unit has been executed.

There is no point in including SUBSCRIPTRANGE or other prefixes in the bootstrap routine, because these are not inherited by called programs.

IBM does not recommend the bootstrap method unless you have particularly strong reasons for avoiding recompilation.

Contents of a PL/I Dump

The appearance of a typical dump produced by the PLIDUMP modules with the options TFHBA is shown in Figure 30 on page 84. The contents of particular sections follow.

Headings

The dump is headed by the line

```
***PL/I DUMP***
```

This is followed by the user identifier, if any, given as the second character string in the argument list of PLIDUMP.

Trace Information

A request for trace information results in the following output:

1. A trace of every procedure, begin block, and ON-unit that is active at the time of the call to PLIDUMP. For procedures, the procedure name and statement number from which the procedure was called are given. The offset of the statement is given as well as the entry point address and DSA address. Also, if the entry point used is not the main entry point and the statement number option was specified, the main entry name is given.

   For multitasking programs, the name of the task variable, its status, and the absolute priority of the task are printed. If no task variable is supplied, 'NONE' is printed as the name of the task variable. A dummy task variable will have been supplied.

2. For ON-units, the values of any relevant condition built-in functions are given. The type of ON-unit is given and, where the cause of entry into the ON-unit is not self-explanatory, the cause of entry is also given (for example, if an ERROR ON-unit was entered because of a conversion error, this fact is given in the trace information). The ON-unit type is specified, using a 3- or 4-letter abbreviation. A list of these abbreviations is given in Figure 31 on page 84.

3. When a hexadecimal dump is requested, the entry point address of each active block is also given, together with the address of its associated DSA.

4. When the compiler FLOW option is in effect, the flow statement table is given.

5. If a hexadecimal dump is requested, the address of the TCA is printed at the head of the trace.

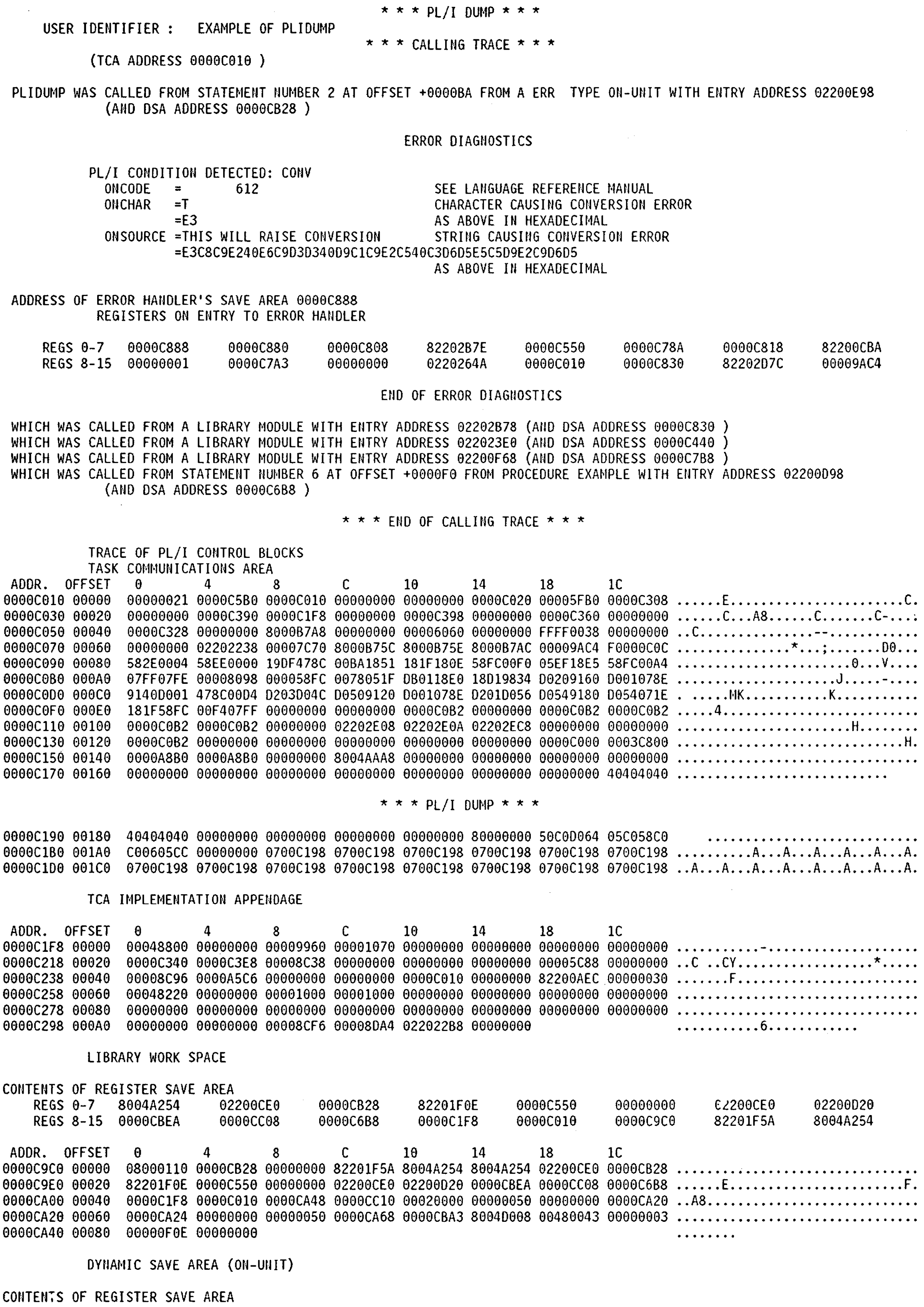
6. If either a hexadecimal dump or control block information has been requested, and any ERROR ON-units are traced, the following information is also included:

   a. The address of IBMBERRs DSA

   b. The contents of the general and floating point registers at the time IBMBERR was called

   c. If there was an interrupt, the address of the interrupt

   d. A trace of library DSAs back to the last compiled code DSA.



```
                                              * * * PL/I DUMP * * *
      USER IDENTIFIER :   EXAMPLE OF PLIDUMP
                                            * * * CALLING TRACE * * *
           (TCA ADDRESS 0000C010 )

  PLIDUMP WAS CALLED FROM STATEMENT NUMBER 2 AT OFFSET +0000BA FROM A ERR  TYPE ON-UNIT WITH ENTRY ADDRESS 02200E98
              (AND DSA ADDRESS 0000CB28 )

                                                    ERROR DIAGNOSTICS

           PL/I CONDITION DETECTED: CONV
             ONCODE   =       612                   SEE LANGUAGE REFERENCE MANUAL
             ONCHAR   =T                            CHARACTER CAUSING CONVERSION ERROR
                      =E3                           AS ABOVE IN HEXADECIMAL
             ONSOURCE =THIS WILL RAISE CONVERSION   STRING CAUSING CONVERSION ERROR
                      =E3C8C9E240E6C9D3D340D9C1C9E2C540C3D6D5E5C5D9E2C9D6D5
                                                    AS ABOVE IN HEXADECIMAL

  ADDRESS OF ERROR HANDLER'S SAVE AREA 0000C888
            REGISTERS ON ENTRY TO ERROR HANDLER

      REGS 0-7   0000C888     0000C880     0000C808     82202B7E     0000C550     0000C78A     0000C818     82200CBA
      REGS 8-15  00000001     0000C7A3     00000000     0220264A     0000C010     0000C830     82202D7C     00009AC4
                                                 END OF ERROR DIAGNOSTICS

  WHICH WAS CALLED FROM A LIBRARY MODULE WITH ENTRY ADDRESS 02202B78 (AND DSA ADDRESS 0000C830 )
  WHICH WAS CALLED FROM A LIBRARY MODULE WITH ENTRY ADDRESS 022023E0 (AND DSA ADDRESS 0000C440 )
  WHICH WAS CALLED FROM A LIBRARY MODULE WITH ENTRY ADDRESS 02200F68 (AND DSA ADDRESS 0000C7B8 )
  WHICH WAS CALLED FROM STATEMENT NUMBER 6 AT OFFSET +0000F0 FROM PROCEDURE EXAMPLE WITH ENTRY ADDRESS 02200D98
              (AND DSA ADDRESS 0000C6B8 )

                                             * * * END OF CALLING TRACE * * *

           TRACE OF PL/I CONTROL BLOCKS
           TASK COMMUNICATIONS AREA
  ADDR.  OFFSET   0        4        8        C        10       14       18       1C
 0000C010 00000  00000021 0000C5B0 0000C010 00000000 00000000 0000C020 00005FB0 0000C308 ......E.......................C.
 0000C030 00020  00000000 0000C390 0000C1F8 00000000 0000C398 00000000 0000C360 00000000 ......C...A8......C.......C-....
 0000C050 00040  0000C328 00000000 8000B7A8 00000000 00006060 00000000 FFFF0038 00000000 ..C...............--............
 0000C070 00060  00000000 02202238 00007C70 8000B75C 8000B75E 8000B7AC 00009AC4 F0000C0C ...............*...;.......D0...
 0000C090 00080  582E0004 58EE0000 19DF478C 00BA1851 181F180E 58FC00F0 05EF18E5 58FC00A4 .......................0...V....
 0000C0B0 000A0  07FF07FE 00008098 000058FC 0078051F DB0118E0 18D19834 D0209160 D001078E .....................J.....-....
 0000C0D0 000C0  9140D001 478C00D4 D203D04C D0509120 D001078E D201D056 D0549180 D054071E . .....MK...........K...........
 0000C0F0 000E0  181F58FC 00F407FF 00000000 00000000 0000C0B2 00000000 0000C0B2 0000C0B2 .....4..........................
 0000C110 00100  0000C0B2 0000C0B2 00000000 02202E08 02202E0A 02202EC8 00000000 00000000 .......................H........
 0000C130 00120  0000C0B2 00000000 00000000 00000000 00000000 00000000 0000C000 0003C800 ..............................H.
 0000C150 00140  0000A8B0 0000A8B0 00000000 8004AAA8 00000000 00000000 00000000 00000000 ................................
 0000C170 00160  00000000 00000000 00000000 00000000 00000000 00000000 00000000 40404040 ............................

                                              * * * PL/I DUMP * * *

 0000C190 00180  40404040 00000000 00000000 00000000 00000000 80000000 50C0D064 05C058C0     ............................
 0000C1B0 001A0  C00605CC 00000000 0700C198 0700C198 0700C198 0700C198 0700C198 0700C198 ..........A...A...A...A...A...A.
 0000C1D0 001C0  0700C198 0700C198 0700C198 0700C198 0700C198 0700C198 0700C198 0700C198 ..A...A...A...A...A...A...A...A.

           TCA IMPLEMENTATION APPENDAGE

  ADDR.  OFFSET   0        4        8        C        10       14       18       1C
 0000C1F8 00000  00048800 00000000 00009960 00001070 00000000 00000000 00000000 00000000 ...........-....................
 0000C218 00020  0000C340 0000C3E8 00008C38 00000000 00000000 00000000 00005C88 00000000 ..C ..CY..................*.....
 0000C238 00040  00008C96 0000A5C6 00000000 00000000 0000C010 00000000 82200AEC 00000030 .......F........................
 0000C258 00060  00048220 00000000 00001000 00001000 00000000 00000000 00000000 00000000 ................................
 0000C278 00080  00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 ................................
 0000C298 000A0  00000000 00000000 00008CF6 00008DA4 022022B8 00000000                   ...........6............

           LIBRARY WORK SPACE

 CONTENTS OF REGISTER SAVE AREA
     REGS 0-7   8004A254     02200CE0     0000CB28     82201F0E     0000C550     00000000     C2200CE0     02200D20
     REGS 8-15  0000CBEA     0000CC08     0000C6B8     0000C1F8     0000C010     0000C9C0     82201F5A     8004A254

  ADDR.  OFFSET   0        4        8        C        10       14       18       1C
 0000C9C0 00000  08000110 0000CB28 00000000 82201F5A 8004A254 8004A254 02200CE0 0000CB28 ................................
 0000C9E0 00020  82201F0E 0000C550 00000000 02200CE0 02200D20 0000CBEA 0000CC08 0000C6B8 ......E.......................F.
 0000CA00 00040  0000C1F8 0000C010 0000CA48 0000CC10 00020000 00000050 00000000 0000CA20 ..A8............................
 0000CA20 00060  0000CA24 00000000 00000050 0000CA68 0000CBA3 8004D008 00480043 00000003 ................................
 0000CA40 00080  00000F0E 00000000                                                       ........

           DYNAMIC SAVE AREA (ON-UNIT)

 CONTENTS OF REGISTER SAVE AREA
```

Figure 30. An Example of PLIDUMP

Abbreviation	Condition Name
AREA	AREA
CHCK	CHECK
COND	CONDITION (programmer-named condition)
CONV	CONVERSION
ENDF	ENDFILE
ENDP	ENDPAGE
ERR	ERROR
FIN	FINISH
FOFL	FIXEDOVERFLOW
KEY	KEY
NAME	NAME
OFL	OVERFLOW
REC	RECORD
SIZE	SIZE
STRG	STRINGRANGE
STRZ	STRINGSIZE
SUBG	SUBSCRIPTRANGE
TMIT	TRANSMIT
UFL	UNDERFLOW
UNDF	UNDEFINEDFILE
ZDIV	ZERODIVIDE

Figure 31. Abbreviations for Condition Names Used in PLIDUMP Trace Information

File Information

A request for file information results in the following output:

1. The default and declared attributes of all open files are given.

2. Buffer contents of all buffers are given. If a hexadecimal dump has been requested, the contents of the buffers are given in both hexadecimal and character notation. If no hexadecimal dump is requested, the contents are given in character notation only.

3. The contents of the FCBs, DCBs, DCLCBs, IOCBs, and exclusive file blocks are given in formatted hexadecimal notation, if either the 'H' or 'B' option is also included.

Byte 1	PL/I Condition, If Any	Base No.
X'02'	ZERODIVIDE	320
X'03'	FIXEDOVERFLOW	310
X'04'	SIZE	340
X'05'	CONVERSION	600
X'06'	OVERFLOW	300
X'07'	UNDERFLOW	330
X'08'	STRINGSIZE	150
X'09'	STRINGRANGE	350
X'0A'	SUBSCRIPTRANGE	520
X'0B'	AREA	360
X'0C'	ERROR	009
X'0D'	FINISH	004
X'0E'	CHECK	510
X'0F'	CONDITION	500
X'10'	KEY	050
X'11'	RECORD	020
X'12'	UNDEFINEDFILE	080
X'13'	ENDFILE	070
X'14'	TRANSMIT	040
X'15'	NAME	010
X'16'	ENDPAGE	090
X'17'		-
X'18'		-
X'19'	PENDING	100
X'1A'	ATTENTION	400
X'CD'		9250
X'CF'	ERROR	1000
X'D3'		9200
X'D5'		3500
X'D7'		4050
X'D9'		5050
X'DF'		5000
X'E1'	ERROR	9050
X'E3'		1000
X'E5'		4000
X'E7'		xxxx
X'E9'		4050
X'EB'	ERROR	0003
X'ED'		1000
X'EF'	ERROR	1550
X'F1'		1500
X'F3'		2000
X'F5'		3768
X'F7'	ERROR	3000
X'F9'	ERROR	3800
X'FB'		3900
X'FD'		9000
X'FF'		8090

Figure 32. Error Code Field Lookup Table

Hexadecimal Dump

The hexadecimal dump is produced by the execution of a SNAP macro instruction. Thus the normal SNAP dump is produced.

It should be noted that the PSW will contain the address of an instruction in IBMBKMR, one of the modules used to implement PLIDUMP. This will bear no relation to the error in the dumped program.

If the program is not multitasking, the SNAP macro specifies all register save areas, subpools, task control blocks, and, provided the O (Only) option is not included in the PLIDUMP options, the trace table.

For a dump of a multitasking program the contents are:

In the control task

- Register save areas
- Subpools
  - Trace table
  - Control blocks

In the other tasks

- Register contents
- Register save areas
  - Subpools
  - Jobpack Area
  - Linkpack Area

Block Option

When the block option is used, the contents of the TCA, the TIA (TCA appendage), and the DSAs in the LIFO stack (that is, all active DSAs) are printed in hexadecimal and character format. The absolute address is printed in the left hand column; the offsets within the block are then printed. This is followed by the contents of the block, first in hexadecimal and then in character notation. For DSAs, the type of DSA is shown; that is, library DSA, procedure DSA, ON-unit DSA, or dummy DSA. The contents of the FCBs, DCLCBs, and IOCBs for any open files are printed in a similar format.

In a dump of a multitasking program, the contents of the tasking appendage are also printed.

If the option A(all) is used in a multitasking program, the TCA, TIA, DSAs and tasking appendage of all directly ascending tasks will be printed. FCBs, IOCBs, DCLCBs will be printed after files open in any task if the option A is used.

Section 2: Suggested Debugging Procedures

The main difficulty in reading a dump of a PL/I program is knowing where to start. The signposts known to assembler language programmers are of little help. There are, however, five main sources of information to be considered when using a dump to debug a PL/I program. They are:

1. The statement number and the address where the error occurred (if a dump was requested after an error).
2. The type of error (if a dump was requested after an error).
3. The values in the general registers when the dump was requested or when the error occurred.
4. The chain of DSAs.
5. The TCA.

The first two of these items hold equivalent information to that held in the PSW in a system dump. The last three items enable the housekeeping to be checked and the location of the control blocks and the program variables to be discovered. The methods of locating other information, given in "Section 3: Locating Specific Information" on page 92, refer to the key areas shown above. The object program listing allows you to study the instructions that are being carried out and to find various control blocks in static storage. The linkage editor map allows you to identify particular parts of the executable program phase and to identify the routine associated with each DSA. The object program listing is produced by the LIST compiler option; the linkage editor map, by MAP.

Note: The PSW in the SNAP dump should not be consulted. This will give the address at which the SNAP macro instruction was issued. This is an address in one of the PLIDUMP modules and is not relevant to the error in the problem program. Instead, look at the trace information.

Debugging Overlaid Storage

Storage overlay is one of the most common errors you usually debug with a dump. In PL/I applications, overlay problems can be divided into these categories:

- Are you using a subscript outside the declared bounds (SUBSCRIPTRANGE)?
- Did you attempt to assign a string to a target with a shorter maximum length (STRINGSIZE)?
- Does one of the arguments to a SUBSTR reference fail to comply with the rules described for the SUBSTR built-in function (STRINGRANGE)?
- Were significant high-order (left-most) binary or decimal digits lost during an assignment to a variable, an intermediate result, or on an input/output operation (SIZE)?
- Are you reading a variable-length file into a variable?
- Are you using a pointer variable?

By understanding these problem areas before you proceed through the dump, you can isolate the problem much faster.

The first four categories are associated with the indicated PL/I conditions, all of which are disabled by default. If you suspect one of these problems is in your program, use a condition prefix on the suspected statement or use the condition prefix on the BEGIN or PROCEDURE statement that defines the block containing the suspected statement.

The fifth category occurs when you read a data record into a variable that is too small. This type of problem only happens with variable-length files, and can often be isolated by examining the data in the file information, and the data in the buffer.

The last category occurs when you misuse a pointer variable. This type of storage overlay is particularly difficult to isolate.

There are a number of ways pointer variables can be misused:

1. When a READ statement with the SET option is executed, a value is placed in a pointer. If you then execute a WRITE statement or another READ SET option with another pointer, you will overlay your storage if you try to use the original pointer.
2. When you attempt to use a pointer to allocated storage that has already been freed, you can also cause a storage overlay.
3. When you attempt to use a pointer, set with the ADDR built-in function, as a base for data with different attributes, you can cause a storage overlay.

Debugging Procedures

The best approach to a dump depends on the problem to be solved and must therefore be left largely in the hands of the programmer. However, two suggested courses of action are given in this section:

1. When PLIDUMP has been called from an ERROR or other ON-unit
2. When only a system ABEND dump has been generated.

Other possible situations are when you request a dump a specified point in the program, or when you request a stand-alone dump. No attempt is made to suggest a course of action in these circumstances. However, in such cases, the main storage situation can be investigated by following the methods itemized in "Section 3: Locating Specific Information" on page 92.

Throughout each of the two recommended procedures given in the following paragraphs, there are cross-references to the methods given in "Section 3: Locating Specific Information." The cross-references consist of the keys by which the methods are identified; for example, H6, D5. These keys are listed in "Housekeeping Information in All Dumps" on page 92.

PL/I Dump Called from ON-Unit

If a PL/I dump is called from an ERROR ON-unit, it can be assumed that the housekeeping system of the program is working. If it were not working, the dump would probably not have been generated.

A large amount of diagnostic information is available at the head of the dump. An error message is generated, which provides a useful starting point. First, examine the type of the error and the point where it occurs. Next, examine the ONCODE and other condition built-in function values, along with the trace information. We suggest the following procedure:

1. Examine the error by means of the ONCODE and any other relevant built-in function values. These values are given in the trace information. (The meanings of codes are given in the *OS PL/I Version 2 Programming: Language Reference.*)
2. Find the location of the error (P1 on page 92) and the block in which the error occurred (H12 on page 93). If the error occurred in a library module, see H14 on page 93. This information is normally available from the head of the PLIDUMP in the trace information.
3. Examine the trace to see if it appears as expected.
4. Examine the information in the file buffers, and check that file attributes are as expected. This information will be printed in the dump heading.

5. Check the values of any variables involved in the interrupt (V1-V6).
6. Check values of registers to see if dedicated registers are pointing to correct areas (H8 and H9). Distinguish between compiled code and library register usage.
7. If SUBSCRIPTRANGE or STRINGRANGE is not enabled, check that the error was not caused by one of these conditions.
8. Check housekeeping (H1-H16) starting with the area most directly concerned with type of statement in which the error occurred.
9. Check values of all variables in the program (V1-V6).
10. Check the logic of code being executed from object listing.

System ABEND Dump

Provided a SYSABEND or a SYSUDUMP card is included in the JCL, a system ABEND dump will be generated when there is a failure of the error-handling modules, or of the module that prints the PL/I hexadecimal dump. It should be noted that the failure of these modules is more likely to be caused by the overwriting of essential information than by an error in the modules themselves.

Because ABENDs caused by overrunning the specified time (SYSTEM 322) do not enter the STAE/ESTAE exit, these will cause dumps to be generated in normal circumstances.

An ABEND dump will not normally be produced for program checks, because a program check exit is set by the PL/I housekeeping routines, so that the system returns all program checks to the error handler. In the error handler itself, the program check exit is reset so that a program check interrupt results in a dump.

Thus, an ABEND is produced if:

- The program interrupt exit was reset during the program.

  This exit is normally set by the program initialization routines to prevent a dump.
- The program interrupt exit was never set at all. This possibility is extremely unlikely.
- The program check exit itself is not working, and the SPIE/ESPIE macro in the initialization routines did not successfully set the program check exit.

The most probable of these suggested causes is that the program check exit was reset by the program. The program interrupt exit is always reset for the duration of error handling or PLIDUMP, to prevent looping should an interrupt occur.

If an interrupt occurs during error handling, an ABEND with a code of 4000 is produced. This results in a dump if SYSABEND or SYSUDUMP cards were provided. An interrupt in the error-handling routines indicates either that the error-handling routines are at fault, or, more probably, that some of the control information of the error-handling routines was overwritten during the execution of the program.

The most practical solution may be to recompile the program with SUBSCRIPTRANGE, STRINGSIZE, and STRINGRANGE enabled. Then rerun the program with the NOSPIE and NOSTAE run-time options. These PL/I conditions check for possible overwriting by subscripts or substrings that are beyond the bounds of the referred variable.

If a 4000 ABEND must be run, execute with NOSPIE and NOSTAE.

However, having obtained an ABEND dump, the following debugging procedure may be adopted.

1. Determine whether the dump was caused by an interrupt in the error-handling routines or a housekeeping error discovered during the analysis of an ABEND. If the cause was an interrupt in the error handler, a message will have been sent to the console before the ABEND was issued, and the ABEND will have a code of 4000, if the interrupt occurred in one of the error-handling routines. Note that codes 322 and 122 may also give system dumps, and that the use of NOSPIE or NOSTAE can result in the generation of a dump.
2. Locate the instruction causing the interrupt. This is done by looking for the PSW (O1).
3. Inspect this instruction to see if it appears to have been overwritten, bearing in mind the cause of the interrupt; for example,
   a. Do the registers used in the instruction contain incorrect information, picked up because of overwriting?
   b. Is it a branch to a protected address?
4. Inspect the TCA(O5) to ensure that all error-handling addresses are correct.
5. Investigate the housekeeping fields, starting with the DSA chain (H1-H3), then the chain of ONCAs (H5,H6).
6. Investigate the error that caused entry into the error handler. This can be done by examining the contents of IBMBERR's DSA (H7) and the associated ONCA (H6). See whether incorrect information passed to the error handler could be causing a failure.
7. Check for uninitialized variables (particularly pointers), and incorrect passing of parameters.
8. If none of the above produces a solution, an error in the error-handling modules is a possibility. If you decide to call IBM for assistance at this point, see Chapter 8, "Submitting an APAR" on page 115. The cause of the original entry to the error handler may already be known, and can perhaps be avoided by altering the source program so that the error does not occur. It must be emphasized that the cause of entry into the PL/I error handler was *not* the cause of the system dump.
9. If the interrupt is not in the error handler, or one of the routines it calls, the highest probability is still that the program check exit was altered in the error handler and that an invalid branch was then made from one of the addresses in the TCA because of overwriting. Therefore, you should carefully check the TCA. (See Appendix A, "Control Blocks" on page 119 for more information about the TCA.) If this fails to produce results, return to stage 2 of the above procedure.

Section 3: Locating Specific Information

This section tells you how to find information in a dump. The section is organized in modular form for easy reference. You should look through the list below to discover the items in which you are interested. Suggested methods of debugging a PL/I program from a dump are given in "Section 2: Suggested Debugging Procedures" on page 87. Unless you are experienced in using dumps, or are looking for some particular item, use the procedures in "Section 2: Suggested Debugging Procedures," rather than attempting to find various items through the information in this section.

Note: In CMS, storage is not divided into subpools. However, the information is still in the dump.

Contents

Key Areas of a PL/I Dump

Key Areas of an ABEND Dump

Stand-Alone Dumps

Housekeeping Information in All Dumps

H11	Finding the task variable
H12	Block structure of program (static back-chain)
H13	Forward chain in DSAs
H14	Action if error is in a library module
H15	Discovering contents of parameter lists
H16	Finding main procedure DSA
H17	Finding the relationships between tasks
H18	Finding the tasking appendage
H19	Finding the TCA from the tasking appendage
H20	Following the heap free-area chain
H21	Following the heap storage chain

Finding Variables

V1	Automatic variables
V2	Static variables
V3	Controlled variables
V4	Based variables
V5	Area variables
V6	Variables in areas

Control Blocks and Fields

C1	Quick guide to identifying control fields

Key Areas of a PL/I Dump

P1: Statement Number and Address Where Error Occurred (Dump Called from ON-Unit Only)

Information required is the point at which the condition that caused entry to the ON-unit occurred. This is identified in the trace information. If no trace information is generated, the method suggested for ABEND dumps can be employed. If the condition occurred in compiled code, the machine instruction being executed can be identified on the object program listing. This is done by subtracting the address of the program control section from the address of the interrupt and looking at this offset in the object program listing. The instruction thus found will be the one *after* the instruction that was last executed.

Note: If PLIDUMP is called a number of times in a program, a different user identifier should be used with each CALL statement so that the point at which the dump was requested is obvious.

P2: Type of Error (Applies to Dump Called from ON-Unit Only)

The type of error is identified in the trace information, in terms of the type of ON-unit entered and the reason for entry. The ONCODE is also given, thus providing further indication of the cause of the condition. If the dump was called from an ERROR ON-unit, an error message should have been generated before the dump. This again will give the cause of the error.

If no trace information has been generated, the type of error can be discovered from the error code appearing in the ONCA associated with the interrupt. The method for finding the ONCA is described in H5.

P3: Register Contents at Time of Error or Dump Invocation

If trace information has not been generated, the contents of the registers can be found from the save area in the DSA. The register contents required will depend on the situation. If PLIDUMP was called from an ON-unit, the register contents at the time the condition was raised will be most useful, unless the condition was raised in a library module. If the condition was raised in a library module, the contents of the registers at the point where the library call was made will probably prove more useful.

For a dump called from an ON-unit, the method of finding the register contents is as follows:

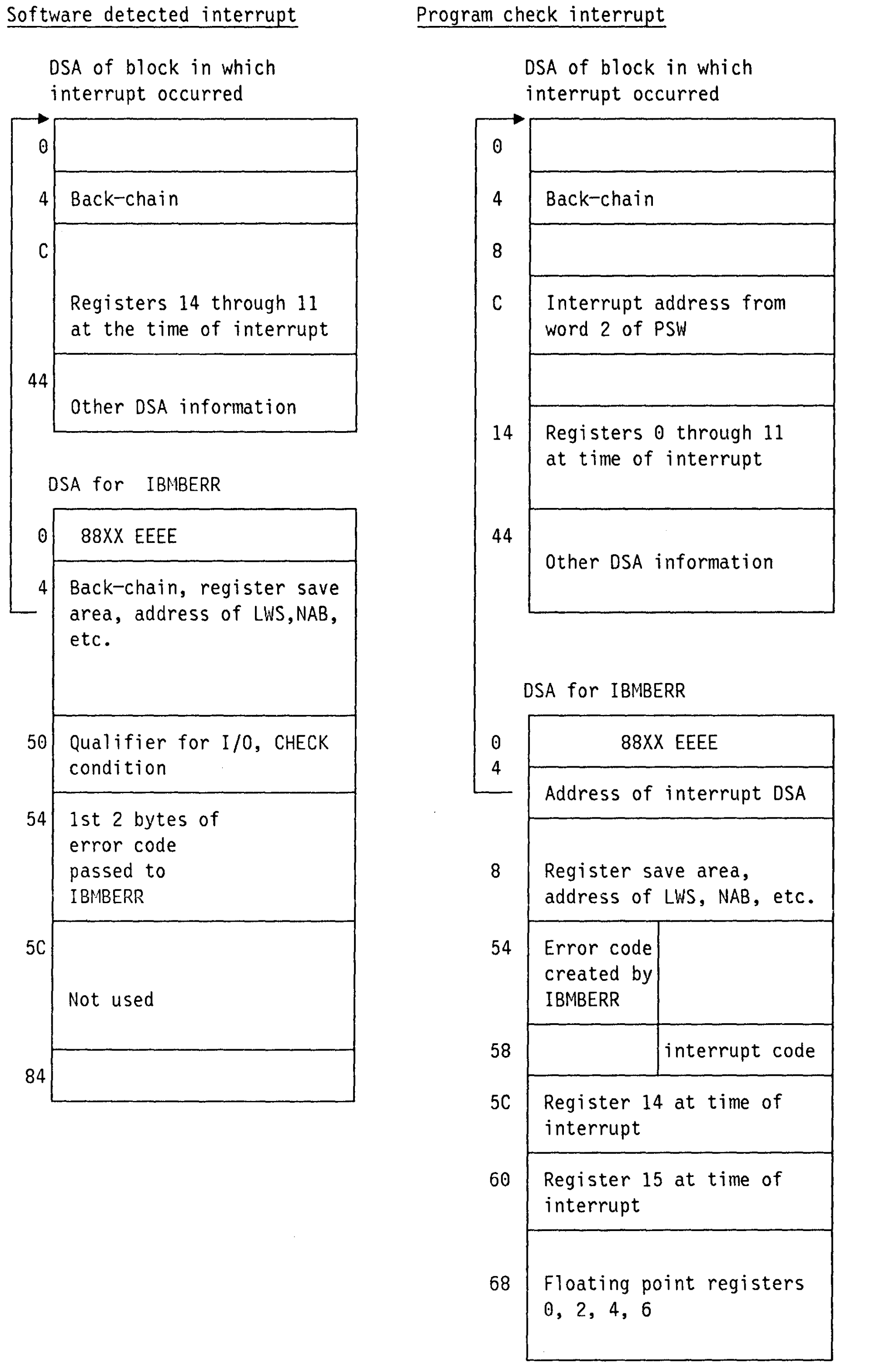
1. Find the DSA of IBMBERR. The value of register 13 will be found in the chainback field at offset 4 of this DSA.
2. If the interrupt was a program check interrupt (see Figure 34 on page 95), the contents of registers 14 and 15 will also be stored in the DSA, register 14 at offset '5C'(92) and register 15 at offset '60'(96) from the head of the DSA.
3. Registers 0 through 11 will be stored in the save area of the previous DSA, starting at offset '14'(20).
4. If the interrupt was a software interrupt, the registers will be stored at offset 'C'(12) of the DSA before IBMBERR's DSA in the order 14 through 11. See Figure 34 on page 95.

Discovering If Interrupt Was Program Check Interrupt: If trace information is available, a check can be made on whether IBMBERRA or IBMBERRB was called. IBMBERRA is entered after program check interrupts, IBMBERRB after software interrupts. If no trace information is available, the simplest method of discovering if the interrupt was a program check interrupt is to inspect bit 7 in byte X'56'(86) in IBMBERR's DSA. This is set to 0 for program check interrupts, and to 1 for other interrupts.

Finding Register Values If Interrupt Occurred in Library Routine: If the ON-unit was entered from a library module, a search back through the DSA chain to the first compiled code DSA should be made. This can be discovered from the trace information or by following the back-chain from IBMBERR's DSA (offset 4 in each DSA) until a procedure block, begin block, or ON-unit DSA is found. This may be determined from flag bits 4 and 5 of DSA, as follows:

Bit 4	Bit 5	DSA
0	0	Procedure block
1	0	Begin block
1	1	ON-unit

Figure 33. DSA Flag Bits 4 and 5


Software detected interrupt
DSA of block in which interrupt occurred
0
4 Back-chain
C
Registers 14 through 11 at the time of interrupt
44
Other DSA information
DSA for IBMBERR
0 88XX EEEE
4 Back-chain, register save area, address of LWS,NAB, etc.
50 Qualifier for I/O, CHECK condition
54 1st 2 bytes of error code passed to IBMBERR
5C Not used
84
Program check interrupt
DSA of block in which interrupt occurred
0
4 Back-chain
8
C Interrupt address from word 2 of PSW
14 Registers 0 through 11 at time of interrupt
44 Other DSA information
DSA for IBMBERR
0 88XX EEEE
4 Address of interrupt DSA
8 Register save area, address of LWS, NAB, etc.
54 Error code created by IBMBERR
58 interrupt code
5C Register 14 at time of interrupt
60 Register 15 at time of interrupt
68 Floating point registers 0, 2, 4, 6

Floating point registers are saved only if interrupt relates directly to a PL/I condition, and return may be made to the point of interrupt

Figure 34. The Contents of IBMBERR's DSA After a System Detected and a PL/ I Interrupt

The value of register 12 can only be discovered in a DSA prior to a compiled code DSA, as it is not stored by library routines when they are entered. This means that the dummy DSA always contains the value of register 12. Register 12 should point to the TCA, whose address is also given in the head of trace information.

No Trace Information Generated: If no trace information has been generated, the register values on taking the dump will be printed at its head. The address of the DSA for PLIDUMP will be in register 13. The back-chain can then be followed to find the DSA for IBMBERR. The DSA for IBMBERR can be recognized if an ON-unit is involved, because it will be the DSA before the ON-unit DSA. IBMBERR's DSA is always headed by a flag word of hexadecimal X'8800EEEE', meaning that it is a library DSA in LIFO storage. To identify IBMBERR's DSA for certain, register 15 of the previous block's DSA must be inspected to see if it points to the module IBMBERR.

P4: The DSA Chain

The addresses of the DSAs are given in a PL/I dump if trace information and a hexadecimal dump are requested. If trace information is not requested, the address of the DSA for the dump routine can be obtained from register 13 at the head of the dump. The chainback field is held in the second word of the DSA. When the dummy DSA is reached, this chainback field will be set to zero. The DSA chain passes through DSAs in LIFO storage and DSAs in LWS (library workspace).

See H1 and Figure 35 on page 97 for details of how to follow the DSA chain.

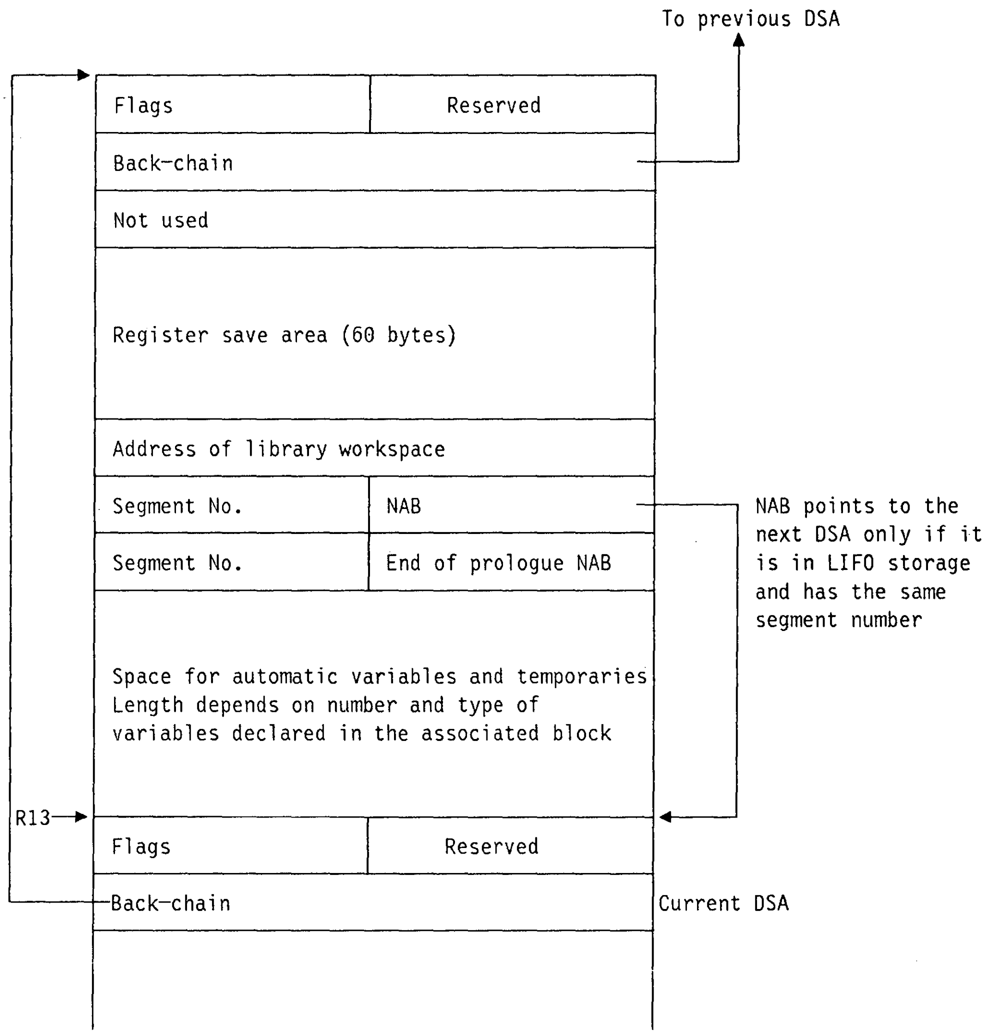

To previous DSA
Flags
Reserved
Back-chain
Not used
Register save area (60 bytes)
Address of library workspace
Segment No.
NAB
NAB points to the next DSA only if it is in LIFO storage and has the same segment number
Segment No.
End of prologue NAB
Space for automatic variables and temporaries Length depends on number and type of variables declared in the associated block
R13
Flags
Reserved
Back-chain
Current DSA

Figure 35. The Chaining of DSAs

P5: The TCA

The address of the TCA is given in a PL/I dump. If 'B' (block option) is specified in the dump-options character string, the complete TCA (including the appendage) is printed separately from the body of the dump.

The TCA is addressed by register 12. If NOTRACE is specified, the TCA is in subpool 1, preceded by the characters ZTCA.

P6: Timestamp

If the TSTAMP installation option is specified in your installation, the date and time of compilation are in the last 16 bytes of the static control section. The first word gives the offset to the information. The static control section is addressed by register 3. If the BLOCK option is specified, the timestamp is printed at the head of the static blocks.

Key Areas of an ABEND Dump

O1: Address of Interrupt

If the ABEND code is 4000, the address of the interrupt can be found from the second word of the PSW, which gives the address of the instruction following the point of interrupt. The PSW is held in subpool 5.

The associated statement number in the source program can normally be found by finding the last compiled code DSA, and finding the point at which the exit was made (register 14 in the save area). The address of the program control section in the link-edit map can then be subtracted from this address; the offset compared to the listing gives the appropriate statement number.

Finding the statement number is not likely to prove useful because of the circumstances in which a system dump is generated. The address found will usually be the address at which the error handler was entered before the program check exit was altered. The reason for entry into the error handler is *not* the cause of the dump. If the ABEND code is not 4000, see "O6: Finding the Program Interrupt Element (PIE/EPIE)."

O2: Type of Interrupt

The type of interrupt can be found from the first word of the PSW.

O3: Register Contents at the Point of Interrupt

Registers 14 through 2 appear in the PIE (program interrupt element). Registers 3 through 13 are those printed in the save area trace. See O6 for finding the PIE.

O4: The DSA Chain

Register 13 should point at the most recent DSA. The back-chain can be followed from offset '4' of each DSA. See Figure 36 on page 103.

O5: The TCA

Register 12 should point at the TCA.

O6: Finding the Program Interrupt Element (PIE/EPIE)

The program interrupt element (PIE) or extended program interrupt element (EPIE) is found in subpool 5. The PIE/EPIE is followed by registers 3 through 13 and then the STAE/ESTAE work area. The STAE/ESTAE work area holds the last problem program PSW.

This is the value required for finding the original cause of the ABEND if the ABEND code is other than 4000.

Stand-alone Dumps

S1: Finding Key Areas in Stand-Alone Dumps

The programmer should attempt to find the various PL/I key areas (TCA, DSA chain, etc.) discussed above.

Housekeeping Information in All Dumps

H1: Following the DSA Back-chain

Each DSA holds a back-chain address in the second word. This word holds the address of the previous DSA. The end of the chain is marked by the dummy DSA whose first word contains the flag hexadecimal '82'. The back-chain in the dummy DSA points to the external save area or is zero if the program was called from the system. (See P4 or D4 for finding the DSA chain.)

For programs using multitasking, the DSA back-chain leads to the dummy DSA of the major task. The DSA of the block in which the task was attached is not included in the chain. To find this DSA, the 'static' back-chain held at offset X'58'(88) can be used *provided* the procedure attached as a task is internal to the attaching block. If the procedure is not internal, the NAB value X'4C'(76) in the DSA before it will *normally* point to the required DSA.

(For the relationship of NAB and DSA chaining, see H13.)

H2: Associating Instruction with Correct Statement and Program Block

Statement Number and Program Block: The statement number and entry point associated with the interrupt will normally be given in a PLIDUMP. However, if they have to be found, the programmer should follow the method used by the error message modules.

Statement Number: It must first be established whether the GOSTMT option is in effect. This will be indicated in the listing for the compilation. If the listing is not available it will be flagged in the compiled code DSA. (Flag bit 13 of the DSA flags is set to '1'B.) If this bit is not set, the table of offsets and statement numbers may be available; if this is not available, statement numbers and offsets must be deduced from the object program listing. The method of using the table of offsets is described under "Using the Table of Offsets" on page 101. If both statement numbers and the table of offsets are available, it will probably be faster to use the table of offsets rather than the statement number table.

The statement number is found by use of the DSA chain as described below:

1. Find the chain of DSAs. The most recent DSA should be addressed by register 13.
2. If the DSA found is not a compiled code DSA (in a compiled code DSA, flag bits 4 and 5 are set to '00'B, '01'B, or '11'B), the interrupt was not in compiled code. (See Figure 33 on page 94.) If the interrupt was in compiled code, the interrupt address can be directly associated with a statement number.

   If the interrupt was not in compiled code, the address at which compiled code was left must be discovered and this address associated with a statement number. To find the address at which compiled code was left:

a. Chain back along the DSA chain until a compiled code DSA is reached (flag bits 4 and 5 set to '00', '01', or '11'B). For more information, see Figure 33 on page 94.

b. The register 14 address saved in the DSA (offset 12 X'C') will be the point to which the library module or other module would have returned if the call had been successfully completed.

The address thus found is the address to be associated with a statement number.

3. Chain back one DSA to the DSA before the compiled code DSA that has been discovered in step 1 on page 99 or step 2 on page 99. The register 15 value in this DSA (offset 16 X'10') is the entry point of the block. If this appears to give an invalid result, check to see whether the DSA is one of those used in interlanguage communication (flag bit 7 set to '1'B and bit 0 of flags 2 (offset X'76') set to '1'B). If this is the case, chain back one more DSA and try again.

4. At offset 8 from the entry point of the block, the address of the statement number table will be held.

5. Calculate the offset between the value in the first word of the statement number table and the address for which a statement number is required. If the address for which a statement number is required is less than the address in the first word of the statement number table, then either an invalid branch has been made, or a compiler-generated subroutine is being executed. If it is possible that a compiler-generated subroutine is being executed, return to the compiled code DSA and attempt to find a statement number associated with the values held first in register 6; if this gives an invalid or improbable result, then in register 14. If the second word in the statement number table is less than the offset between the address for which a statement number is required and the first word of the statement number table, it is not within the program control section and an erroneous branch has been made out of the program.

6. If the offset is more than X'7FFF', the statement number will be held in the second or subsequent sections of the table. Obtain the number given by translating the offset into binary and ignoring the last 15 bits and step down this number of sections of the table. (For example, if the offset was X'8FFF', translate to binary = '1000 1111 1111 1111'B, ignore last 15 binary digits = 1; therefore, step down one section of the table. If the offset was X'18FFF', the binary would be '0001 1000 1111 1111'B. Ignoring the 15 right-hand bits leaves '11'B; therefore, step down three sections of the table.)

   The address of the second section of the table is held at offset X'8' in the table, the address of the third section is held at the head of the second section, the address of the fourth section at the head of the third section, and so forth.

7. When the correct section of the table has been identified, search for the first offset in the table that is greater than or equal to the offset for which you are searching. Following this offset, the statement number is given in 2-byte hexadecimal format.

Procedure Name: To find the entry point name, a back-chain is made beyond the first *procedure* DSA found on the chain. Register 15 in the save area before this procedure DSA will point to the entry point of the procedure. (Procedure DSAs have flag bits 4 and 5 set to '00'B. The register 15 value is held at offset 16 X'10'.)

The entry is preceded by a one-byte field that holds the number of characters in the name. This one byte field is in turn preceded by the entry point name.

Using the Table of Offsets: Statement numbers can also be found by comparing them with the offsets in the offset and statement number table generated by the compiler when the OFFSET option is specified.

Offsets are held from each primary entry point of a procedure or ON-unit. To use the table of offsets, find the entry point used by the program in the manner described above. Find the primary entry point for the procedure. (If the primary entry point was not used, look at the object program listing to see the relationship between the entry point used and the primary entry point.) Note that, the offsets given are from the point marked *REAL ENTRY in the object program listing. This point is one byte after the end of the primary entry point name.

If the interrupt occurred in an ON-unit, it may be necessary to discover the type of ON-unit entered before it can be identified. This is done by inspecting the DSA before the DSA of the ON-unit. This DSA is for IBMBERR. The first byte of the error code is held in this DSA at offset 84 (X'54'). Compare this byte with the values in Figure 32 on page 86. This error code is given an associated PL/I condition. It is the ON-unit for this condition that is entered. If there is more than one ON-unit for the condition, the ON-unit entered must be deduced by studying the dump, and source and object listings. If the register 15 value appears to be invalid, this may be caused by rechaining in interlanguage processing. If this is possible, chain back one more DSA and try again. (To check if this has occurred, see step 3 on page 100.)

H3: Following Calling Trace

The calling trace can be followed because branches within the program are always made on registers 14 and 15. Hence register 15 in each DSA points to the address that was branched to from that block. Register 14 points to the address to which control passed when the block was completed. By finding the entry point name (see "H2: Associating Instruction with Correct Statement and Program Block" on page 99), it is possible to follow the calling trace.

H4: Associating DSA with Block

DSAs are associated with code by finding the register values in the preceding DSA register save area (H8) and using the fact that all branches are made via registers 14 and 15. Register 14 in any DSA points to the instruction after the point at which control left that block. Register 15 points to the address at which the next block was entered. The block in the source program can be identified by statement numbers or entry point, described in "H2: Associating Instruction with Correct Statement and Program Block" on page 99.

H5: Finding Relevant ONCA

When an interrupt has occurred in the error handler and a system dump has been produced, it is possible to discover the information that the error handler would have used to generate appropriate error messages. The ONCA holds values for the condition built-in functions. The appropriate ONCA can be found in the following manner.

1. Find the DSA before that of IBMBERR (follow back the DSA chain until register 15 in the save area points to IBMBERR). See H1, H3, H7. If this is a library DSA (flag bits 4 and 5 set to '10') go to 3, below.
2. Find the LWS addressed from this DSA. The address is held at offset X'48'(72).
3. Find the offset from the LWS to the ONCA. This is held at offset 2 in the LWS.
4. Add the offset to the address of the library DSA in LWS.

H6: Following the Chain of ONCAs

ONCAs are used to hold condition built-in function values. They are chained together, one being provided for every level of interrupt. The chainback field is in the first word of the ONCA. The dummy ONCA is marked by a chainback field of zero.

H7: Finding Information from IBMBERR's DSA

The information held in IBMBERR's DSA is used by the error message modules for information about the error. If the messages have not been generated, the information can be deduced from the DSA. The contents of IBMBERR's DSA are shown in Figure 34 on page 95. See H4 for associating DSAs with correct code. IBMBERR's DSA can be identified by X'EEEE' in bytes 2 and 3.

H8: Finding and Interpreting Register Save Areas

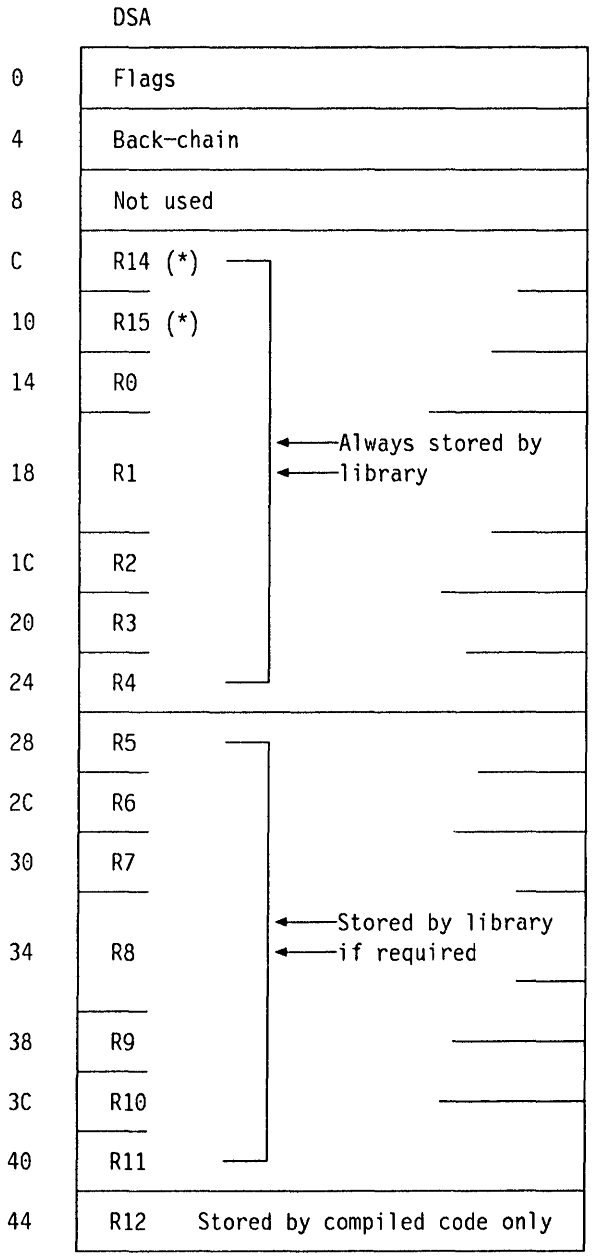
Register save areas are held at offset X'C'(12) in all DSAs, including DSAs in LWS. Offsets and registers are shown in Figure 36 on page 103. Each DSA holds the register values as they were on exit from its block.

H9:Register Usage

A summary of register usage, showing which registers are always used for a particular purpose, is given in Figure 11 on page 24.

H10: Following the ISA Free-Area Chain

The ISA free-area chain connects the areas of non-LIFO dynamic storage that have been used and freed, but have not been absorbed into the major free area. The chain starts at offset X'1C' (28) in the implementation-defined appendage, which is addressed from offset X'28'(40) in the TCA. The end of the chain is marked with a zero entry.



(*) Not stored if hardware interrupt occurs

Figure 36. The Register Save Area in the DSA

H11: Finding the Task Variable

The task variable is held in the TCA at offset X'24'(36).

H12: Block Structure of Program (Static Back-chain)

The block structure of the program can be followed from the address held at offset X'58'(88) in each compiled code DSA. This address holds the address of the compiled code DSA of the statically encompassing block. The chain thus formed is known as the static back-chain.

H13: Forward Chain in DSAs

The forward chain in DSAs is not supported by the compiler. However, a forward chain through the LIFO stack can normally be followed by use of the NAB pointer. The NAB pointer is held at offset X'4C'(76) from the head of each DSA. The last pointer in the chain points to the major free area. If the NAB pointer contains anything except '00' in its first byte, the chain cannot be followed, because it is not contained in a single LIFO segment. The address required is held in the last three bytes of NAB; the first byte contains the segment number (see C1). The forward chain includes only those DSAs in the LIFO stack and does not include any DSAs in LWS.

H14: Action If Error Is in a Library Module

The fact that the interrupt or the error was discovered during the execution of a library module suggests that a check must be made on the data that is being passed to the module.

To discover the contents of a parameter list, see H15.

H15: Discovering Contents of Parameter Lists

Parameters are passed in a list of words pointed to by register 1, except during stream I/O. To find the position of a parameter passed to a program, find the value of register 1 in the save area of the DSA (see "H4: Associating DSA with Block" on page 101) of the calling block. Register 1 will then locate the parameter list. If the list is in static storage, this can be compared with the static storage listing. The name of the called routine can be discovered (H3). The correct parameters for PL/I library routines are given in the appropriate library Program Logic Manual.

H16: Finding Main Procedure DSA

The main procedure DSA can be found by following the back-chain of DSAs to the dummy DSA. The address of the main procedure DSA will be given by the last 3 bytes of NAB in the dummy DSA. NAB is held at offset X'4C'(76) in the dummy DSA. The address of the dummy DSA is held at offset X'24'(36) in the TCA appendage, which is addressed from offset X'28'(40) in the TCA. The dummy DSA can be recognized by the presence of X'82' in the flag byte and the character value ZDSA before it.

Library routines store at least registers 14 through 4, and up to registers 14 through 11; compiled code routines store registers 14 through 12. Thus the address of register 12 can always be found in the dummy DSA, although it may not be in other DSAs. The contents of the register save area in the DSA of the block that called IBMBERR are slightly different from normal if the interrupt was a hardware interrupt. See Figure 34 on page 95 for a diagram of IBMBERR's DSA.

H17: Finding the Relationship between Tasks

The relationship between tasks can be discovered from the chains in the tasking appendage. The chain held at offset X'28'(40) points to the tasking appendage of the most recently attached subtask.

The chain at offset X'24'(36) points to the task with the same attaching task that was attached before the task being inspected (elder sibling). If there is no such task, the field is set to zero.

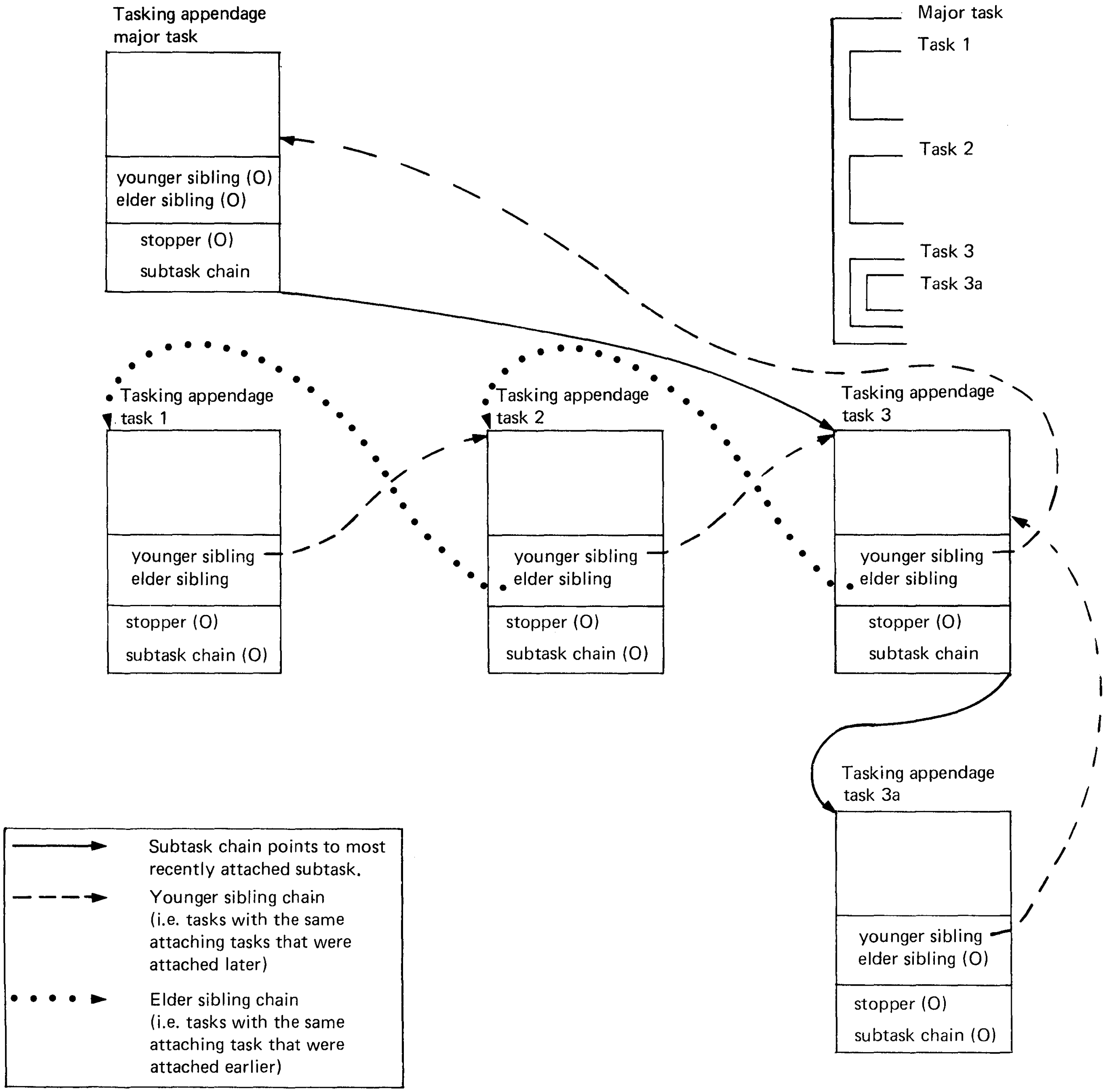
The chain at offset X'20'(32) points to the subsequently attached task with the same attaching task (younger sibling). If there is no younger sibling, this chain points to an offset within the tasking appendage of the parent task. An attempt to continue along the chain results in a zero field being met. (See Figure 37.)

To Find the Parent Task: Search along the chain held at offset X'20'(32) in each tasking appendage. When this field is zero, the tasking appendage of the parent task has been reached. The start of this tasking appendage is at an offset of X'-8'(-8) from the address held in the pointer of the previous tasking appendage. (See Figure 37.)

To Find All Subtasks of a Task: The address of the most recently attached subtask is held at offset X'28'(40) in the tasking appendage. Other subtasks can be found by following the chain held at offset X'24'(36) in the tasking appendage until a zero field is reached. This will be the end of the chain and is the first of the active subtasks to be attached by the task. (See Figure 37.)

To Find Sibling Tasks: Previously attached sibling tasks (elder sibling) can be found by following the chain held at offset X'24'(36) in the tasking appendage.

Subsequently, attached sibling tasks (younger siblings) can be found by following the chain held at offset X'20'(32) in the tasking appendage. When a zero field in this chain is reached, the parent task has been found. The most recently attached sibling task is the last one whose chain field does not hold a zero value. The word after the zero value will point to the tasking appendage of this task. (See also Figure 37 on page 106).



Note: Because tasks are chained in both directions, all relationships be quickly found.
Following the 'younger sibling chain' leads to the attaching task. When the attaching task is reached, the offset that should be the offset to the younger sibling is to the stopper. Thus it is known that the attaching task has been reached.

Figure 37. The Chaining of Tasks Through Their Tasking Appendages

H18: Finding the Tasking Appendage

The address of the tasking appendage is held at offset X'2C'(44) in the TCA and at offset X'50'(80) in the dummy DSA of the attaching task.

H19: Finding the TCA from the Tasking Appendage

The TCA is addressed from X'2C'(44) in the TCA tasking appendage.

H20: Following the heap free-area chain

The heap free-area chain connects the areas of heap storage that are available to satisfy ALLOCATE requests.

The chain starts at offset X'78'(120) in the implementation-defined appendage, which is addressed from offset X'28'(40) in the TCA. The end of the chain is marked with a zero.

H21: Following the heap storage chain

The heap storage chain connects all areas obtained by GETMAIN macro instructions for use as heap storage. The chain starts at offset X'74'(116) in the implementation-defined appendage, which is addressed from offset X'28'(40) in the TCA. The end of the chain is marked with a zero.

Finding Variables

The value of the variables in the program at the point of interrupt can be discovered by using the compiled code listing as a guide to their addresses, and then finding these addresses in the dump. The method used depends on the type of variable.

V1: Automatic Variables

Automatic variables can be found by using an offset from the DSA of the block in which they were declared. This information appears in the variables offset map generated when the compiler MAP option is used. If the compiler MAP option has not been used, the information can be deduced from compiled code. (For finding the DSA associated with a block, see "H4: Associating DSA with Block" on page 101.)

V2: Static Variables

Static variables are normally addressed by an offset from register 3. This offset is given in the variables offset map generated when the compiler MAP option is used. If the compiler MAP option has not been used, the offset can be deduced by studying the listing of compiled code. The value of register 3 can be found in the save area of the DSA. (For finding the DSA associated with a block, see "H4: Associating DSA with Block" on page 101.)

V3: Controlled Variables

Controlled variables are addressed by an anchor word that is held in the pseudo-register vector. This anchor word can be identified from compiled code, while the PRV offset can be found in the dump. The address of the controlled variable must be obtained from the PRV in the dump because it is not filled-in until the ALLOCATE statement is executed.

The address in the pseudo-register vector is the address of the data or, in certain circumstances, of a descriptor or a locator/descriptor. These fields are described in Appendix A, "Control Blocks" on page 119. The data is preceded by a control block—the controlled variable control block. The address of the previous allocation is held at an offset of -8 from the address in the PRV. If there is no previous allocation, the address is set to zero.

V4: Based Variables

Based variables are located by finding the value of the defining pointer. This value is found by using one of the methods described above to find static, automatic, or controlled variables. If the pointer is itself based, its defining pointer must be found and the chain followed until the correct value is found.

Typical code would be the following:

For X BASED (P), with P AUTOMATIC

```
58 60 D 088        L 6,P

58 E0 6 000        L 14,X
```

P is held at offset X'88' from register 13, and this address points at X.

Care must be taken when examining a based variable to ensure that the pointers are still valid.

V5: Area Variables

Area variables are located in one of the ways described above, according to their storage class.

Typical code would be:

For area variable A declared AUTOMATIC

```
41 60 D 088        LA 6,A
```

The area would start at offset X'88' from register 13.

V6: Variables in Areas

Variables in areas are found by locating the area and then using the offset to find the variable.

Control Blocks and Fields

For simplicity, the methods of finding various control blocks are placed in an alphabetic table. Details of the control blocks are available in Appendix A, "Control Blocks" on page 119.

As well as control blocks, various other items are included in the list. Where necessary, cross-reference is made to other sections in this chapter.

C1: Quick Guide to Identifying Control Fields

Control Field	Identification
Automatic Variables	See "Variables"
Back-chain DSA back-chain ONCA back-chain	offset X'4' in DSA offset X'0' in ONCA
BOS Beginning of segment	Offset X'8' from TCA
Controlled variables	see "Variables"
DCLCB Declare control block	Deduced from object program listing
DCB	addressed from offset X'14'(20) in FCB
ENVB Environment block	offset X'C'(12) in DCLCB
DED Data element descriptor	deduced from object program listing
Diagnostic statement table	addressed from offset X'8' from entry point of main procedure
DFB Diagnostic file block	addressed from offset X'40'(64) in TCA
DSA Dynamic storage area	addressed by register 13 (see P3 and D3)
EOS End of segment	offset X'C'(12) in TCA
Event variable	deduced from object program listing and knowledge of parameter lists of I/O and wait modules
FCB File control block	identified in PL/I dumps. Addressed via PRV and DCLCB
Flow statement table	addressed from offset X'4C'(76) in TCA
Filename	addressed from offset X'10'(16) in FCB
ISA Free-area chain	offset X'1C' (28) in implementation-defined appendage, which is addressed from offset X'28'(40) in TCA
Heap free-area chain	offset X'78' (120) in the implementation-defined appendage
Heap storage chain	offset X'74' (116) in the implementation-defined appendage
Locator/descriptor	deduced from object program listing
LWS Library workspace	addressed from offset X'48'(72) in every DSA
NAB Next available byte	offset X'4C'(76) in DSA

Figure 38 (Part 1 of 2). Quick Guide to Identifying Control Fields

Control Field	Identification
ONCA ON-communications area	the offset of the associated ONCA is held in a halfword at offset X'2' in each section of LWS
ONCB ON-control block start of dynamic ONCB chain	offset X'60'(96) in DSA
first static ONCB	offset X'5C'(92) in DSA
ON-cells	addressed from offset X'70'(112) in DSA
Parameter lists	object program listing and static storage map
Register values	See P3 and O3
Symbol table	Static listing
Symbol table vector	Static listing
Statement number table	see diagnostic statement table
Static storage	addressed by register 3 in compiled code. See P3 and O3.
Segment number	first two bytes of BOS, or NAB. '00'=1, 'FF'=2, etc.[1]
Tasking appendage	addressed from X'2C'(44) in the TCA.
Task variable	addressed from X'24'(36) in the TCA.
TCA Task communications area	addressed by register 12. See P3 and D3.
Variables	
automatic	offset from DSA of block in which they are declared. As shown in variables offset map. See V1.
based	address of the pointer must be deduced from the object program listing. This gives the address of the variable. See V2.
controlled	PRV offset referenced in compiled code holds latest allocation of the variable. A back-chain through the previous allocation can be made using the header chain. See V3.
static	offset from register 3 is shown in variable offset map. See V4.
area	as for other variables depending on storage class. See V5.
Variables in areas	find address of area. Find variable from offset within areas shown in compiled code. See V6.

Figure 38 (Part 2 of 2). Quick Guide to Identifying Control Fields

Note: [1] Except when the first two bytes of NAB are filled with zeros, the first two bytes of BOS are always less than the first two bytes of NAB when a segment needs to be freed.

Section 4: Special Considerations for Multitasking

The major difference between a dump of a multitasking program and the dump of any other PL/I program is that certain relevant items are held within the control task. For this reason, the control task is always dumped as well as the current task.

The contents of the dump of a tasking program depend on the dump options specified. If A (all) is used, all the tasks will be dumped. If O (only current task) is specified, the control task and the current task will be dumped.

The dump is carried out within the control task and this prevents access to the tasking housekeeping during the execution of the dump. However, this does not prevent access by other tasks to PL/I variables which may be dumped. Subtasks of the current task can access and alter values within the ISA of the current task. Consequently, the values of the variables printed cannot be guaranteed to be those that were current at the invocation of the dump.

The DSA chaining differs slightly when a program is multitasking. The back-chain passes through the dummy DSA of the task and ends at the dummy DSA of the major task. The DSA of the block in which the task was attached is *not* included in the back-chain.

Compiled code and the static control sections generated by the compiler are always held in storage associated with the control task.

Section 5: Special Considerations for CICS

The PL/I-CICS run-time environment is different from either the PL/I batch environment or the PL/I multitasking environment. This is because system services such as program management, storage management, and error handling are requested through the EXEC CICS interface.

As a result of these differences, when you prepare a PL/I program for execution under CICS, you must take special action during the compile and the link edit steps. You can find information about these actions in the *OS PL/I Version 2 Programming Guide.*

The CICS environment user exit is IBMFXITA. This user exit, if it determines that an ABEND is required, supplies a four-character EBCDIC ABEND code. The User exit is discussed detail in *OS PL/I Version 2 Installation and Customization under MVS.*

CICS ABEND codes are different from PL/I ABEND codes. CICS ABEND codes are listed in the *OS PL/I Version 2 Programming Guide.*

Section 6: User Exit Considerations

IBM supplies a user exit you can modify. You can invoke it during initialization and termination. The IBM-supplied name of the user exit is IBMBXITA. (The CICS User exit name is IBMFXITA.)

The user exit can request the program to ABEND, if it is invoked with the initialization or the termination function code.

If you invoke the user exit during initialization, neither the PL/I environment nor PL/I error handling facilities are established yet. But if you invoke the user exit with the termination function code, the PL/I environment is established. Then if the user exit experiences a program check, and you have enabled error handling facilities, the program will give an ABEND 4044.

Section 7: SYSTEM Option Considerations

The SYSTEM compile-time option determines the format of the parameter list to the MAIN procedure. The SYSTEM option does not necessarily determine the system or sub-system on which you are running. If you try to pass a type of the parameter list that is different from the type specified by the SYSTEM option, you will get unpredictable results. For more information see the *OS PL/I Version 2 Programming Guide*.

You can find the SYSTEM specification in a main PL/I procedure in a constants section toward the beginning of the compiled code. For more information about the location and representation of the the SYSTEM option in the constants section see the section, "Retaining the PL/I Environment - PLIMAIN" in the *OS PL/I Version 2 Programming Guide*.

Chapter 7. Using SSF and CSSF Search Arguments

Use SSF and CSSF search arguments to look for IBM-supported fixes that apply to your problem. By formulating your own search arguments, you can find information about a reported problem and use that information to correct your own problem. If no other problems have been reported, you can discover you have a new problem that you should bring to the attention of IBM software support.

When you search, you use the the Software Support Facility (SSF) or Customer Software Support Facility (CSSF, a subset of the SSF data base that is searched if MVS INFO/ACCESS is installed). Your search checks the SSF or CSSF data base to determine if your problem has been reported. These data bases contain data associated with APARs (Authorized Program Analysis Reports), PTFs (Program Temporary Fixes), and PSP (Preventive Service Planning) buckets.

If you find a fix in your search, you can order it through the Support Center, retrieve the fix from Info/Access, or pull the fix from Data Link.

Formulating the Search Argument

You formulate a search argument using keywords, which are a set of numbers, a set of characters, or a combination of both.

If you have access to RETAIN, you can formulate a search argument like this:

```
p; 5668910 ABEND0C1 IBMBERRA
```

If you have access to INFO/ACCESS, your search argument is constructed through using panels. In either case, your search compares all words in the search argument to all records in the area selected. (For more information on using INFO/ACCESS see the *Information Access User's Guide*.)

Your search arguments should contain standard forms of keywords (explained below) and specific keywords related to the problem. Common words such as "and," "the," "register," etc., do not comprise an effective search argument. Your search argument compares all the records in "file" of the "library" within the "facility" that has been selected. Each equal comparison is called a "hit."

You must have a meaningful search argument. If you have an overly general search, an excessive number of hits result, most of which have no bearing on the problem. In a similar way, if you have an overly descriptive search argument no hits may be found.

You must include specific facts about a problem to form an effective search argument.

Using Standardized Keywords

To help you in your search, certain keywords in SSF have been standardized by IBM to reduce the number of ways a word can be spelled. For example, in "ONCODExxxx," "xxxx" represents the ON-code number, as in "ONCODE8095". Another example is "MSGIELxxxxI" where "xxxx" represents the message number, as in "MSGIEL0230I". Note that each example is a single word.

Your search argument should consider all possibilities. (For example, MSGIEL0230I could be IEL0230I or IEL0230.)

Chapter 8. Submitting an APAR

Proper documentation is essential when submitting an APAR. The documentation you provide to IBM must be in the proper form and detail so that IBM programming service personnel can reproduce the problem at the IBM programming service location. You must supply the source program with the APAR to enable the problem to be reproduced and analyzed. The service personnel will be able to resolve the problem faster if you reduce the source program to the smallest, least complex form that still contains the problem.

If you are submitting the APAR because a previous APAR was returned, supply the additional requested documentation and be sure to indicate the number of the previous APAR.

Materials to Submit

If you are submitting an APAR for the first time, supply the materials, listed below, that apply to your problem. Submitting all the required materials avoids having the APAR returned to you for additional information, leading to a faster resolution of your problem.

The following checklist summarizes the materials that you must submit with an APAR. A complete description of each of the types of material follows the checklist.

Materials	When Required
Original Source or Failing Test Case	Always
JCL	MVS only
Load Libraries	Run-time problems only
Input Data Sets	Run-time problems only
PL/I Compiler	Only when requested
PL/I Library	Only when requested
Compiler Listing	Always
JCL Listing	MVS only
CMS Terminal Session Log	CMS only
Linkage Editor Listing	Run-time problems only
Run-Time Dump	Run-time problems only
Applied PTFs and Fixes	Always, or specify no fixes applied

Figure 39. Summary of Requirements for APAR Submission

Note: If you supply machine-readable material on a tape reel, describe how the tape was created.

Original Source Information

You must supply source information in one of three forms:

- Your original source
- The machine-readable source
- A small, but re-creatable, failing test case.

Note: If you do not supply one of these three, IBM Programming Service will probably return your APAR.

If you send machine-readable source, submit the information on a nonlabelled tape. Along with the tape, send a hard copy listing of how the tape was created. Carefully pack and clearly identify machine-readable information. Make sure the APAR number is on the tape, so that it can be identified if it is separated from the rest of the material submitted with the APAR.

Depending on the options and conditions you have, the machine-readable source is different. These are listed in the following table. Also, the machine-readable source should not have any %NOPRINT statements, unless they are relevant to the problem.

Options and Conditions	**Machine-Readable Source**
NOINCLUDE NOMACRO	The source is the data set assigned to SYSIN for the compile step.
INCLUDE MACRO Preprocessor failure	The source is the data set assigned to SYSIN for the compile step and the source statement library or libraries referenced in %INCLUDE statements in the program.
INCLUDE MACRO	The source is the SYSPUNCH data set produced by the compiler when the MDECK compiler option is specified.

Figure 40. Machine-Readable Sources

Load Libraries Information

If the failure occurs at run-time and the source called one or more previously compiled modules, then in addition to your original source, you must supply the load libraries containing these modules in machine-readable form.

Input Data Sets Information

If the failure occurs at run-time, you must provide enough input data with your APAR to allow the re-creation of the failure.

PL/I Compiler and PL/I Library

You do not need to send these unless you are specifically asked for them. IBM programming service personnel need them only if they cannot recreate your problem using programming service's own library and compiler.

Compiler Listing

If you think you have a compiler failure, then all listings that you supply must relate to a specific run of the compiler. Do not send information that is derived from separate compilations or runs. These may mislead the programming support personnel.

With your APAR, always send the listing which results from the compilation of the original source. Perform the compilation with the following compiler options in effect unless the opposite option is required to show the failure or unless the option masks the failure.

```
ATTRIBUTES   LMESSAGE          OPTIONS
ESD          MAP               SOURCE
FLAG (I)     MARGINI ('|')     STMT
LIST         NEST              XREF
```

In addition to the above options, you may also need to do the following:

- If your compilation is performed with either the INCLUDE or MACRO compile-time options and you have a preprocessor failure, specify the INSOURCE compile-time option as well.
- If your problem is a run-time problem, you must specify the GOSTMT compile-time option.

JCL Listing

In MVS, you must provide listings of job control statements used to run the program. If you are having problems with a batch job, show any cataloged procedures you are using in expanded form by specifying MSGLEVEL=(1,1) in the JOB statement.

CMS Terminal Session Log

If your failure occurs while compiling or running a program under CMS, supply the full details of the virtual machine environment. The best way to do this is:

1. Immediately before you invoke the compiler to reproduce the problem, issue the following commands:

   ```
   QUERY SET
   QUERY TERMINAL
   QUERY VIRTUAL
   QUERY SEARCH
   QUERY DISK *
   QUERY FILEDEF
   QUERY LIBRARY
   QUERY INPUT
   QUERY OUTPUT
   ```

2. Invoke the compiler using the PLIOPT command, specifying the compiler options required to produce the relevant output, preferably on a line printer, or, alternatively, at a typewriter terminal.

Submit the entire terminal listing, from LOGON to LOGOFF. If a display terminal is used, spool console input/output using the

```
CP SPOOL CONSOLE START
```

command to provide the full details of all input entered and of all responses received.

Linkage Editor Listing

If your problem is a run-time failure, specify the XREF linkage editor option. Submit the linkage editor map. This map, produced when the failing program is link edited, is essential for the analysis of the storage dump.

Run-Time Dump

If your problem occurs during the run of a PL/I program, supply a storage dump with your APAR. If at all possible, provide a formatted PL/I dump produced by the PL/I error-handling facilities by including the following statement in an ERROR ON-unit that is entered when the program fails:

```
CALL PLIDUMP ('TFHB');
```

If for some reason a formatted PL/I dump cannot be obtained, supply a storage dump obtained by using the system SYSUDUMP or SYSABEND facilities or by using a stand-alone dump program. If you think you have a run-time failure, the listings must relate to the relevant link editing and execution steps.

Note: Do not send information that is derived from separate compilations or runs. These may mislead the programming support personnel.

Applied Fixes

Also supply with your APAR a list of any program temporary fixes (PTFs) and local fixes applied to either the compiler or to the library. If no fixes have been applied, indicate this specifically with your APAR.

Appendix A. Control Blocks

This appendix provides information on the format of the control blocks that may be used during the execution of a program compiled by the OS PL/I Optimizing Compiler. Brief details of the function of each control block, together with when it is generated and where it can be located, are also given.

Except where explicitly stated all offsets from the start of a block are byte offsets and are given in hexadecimal notation.

The controls blocks and the pages they can be found on are listed below.

- "Area Locator/Descriptor" on page 120.
- "Area Variable Control Block" on page 121.
- "Aggregate Descriptor Descriptor" on page 122.
- "Aggregate Locator" on page 124.
- "Array Descriptor" on page 125.
- "CICS Appendage" on page 128.
- "Controlled Variable Block" on page 130.
- "Data Element Descriptor (DED)" on page 132.
- "FORMAT DEDs (FEDs)" on page 138.
- "Declare Control Block (DCLCB)" on page 140.
- "Dynamic Storage Area (DSA)" on page 142.
- "Entry Data Control Block" on page 146.
- "Environment Block (ENVB)" on page 147.
- "Event Variable Control Block" on page 151.
- "File Control Block (FCB)" on page 152.
- "Fetch Control Block (FECB)" on page 163.
- "Input/Output Control Block (IOCB)" on page 164.
- "Label Data Control Block" on page 170.
- "Library Workspace (LWS)" on page 171.
- "ON Communications Area (ONCA)" on page 172.
- "ON Control Block (ONCB)" on page 175.
- "PLIMAIN" on page 177.
- "PLISTART Parameter List" on page 178.
- "Record Descriptor (RD)" on page 180.
- "String Locator/Descriptor" on page 181.
- "Structure Descriptor" on page 182.
- "Task Communication Area (TCA)" on page 190.
- "Symbol Table (SYMTAB)" on page 183.
- "TCA Implementation Appendage (TIA)" on page 196.
- "TCA Tasking Appendage (TTA)" on page 200.
- "Task Variable (TV)" on page 202.

Area Locator/Descriptor

Function

Holds the address and length of the area variable for passing to other routines or for execution time reference if the area has an adjustable length.

When Generated

As far as possible during compilation. If necessary, completed during execution.

Where Held

Static internal control section or AUTOMATIC storage.

How Addressed

From an offset from registers 3 or 13 known to compiled code

	0	1	2	3	4
0	A(Area Variable)				
4	Length				

A(Area Variable): Is the address of the area variable control block.

Length: Is the total length including both the control block and the area variable.

Area Descriptor

The area descriptor is the second word of the area locator/descriptor. It is used in structure descriptors, when areas appear in structures, and in the controlled variable "description" field when an area is controlled.

Area Variable Control Block

Function

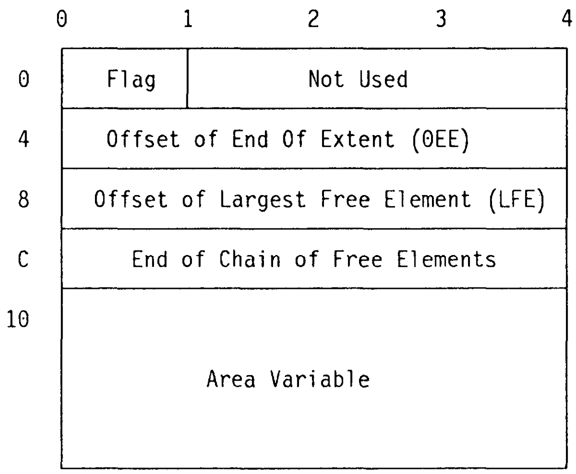
Used to control storage allocation within the area variable.

When Generated

When the area variable is initialized. This depends on the storage class of the area.

Where Held

At the head of the area variable.



	0	1 2 3 4
0	Flag	Not Used
4	Offset of End Of Extent (OEE)	
8	Offset of Largest Free Element (LFE)	
C	End of Chain of Free Elements	
10	Area Variable	

Free Elements: If there are free elements in the area variable, they are headed by two words. The first word gives the length of the element, the second word gives the offset to the next smaller free element. If there is no smaller free element, the second word is set to zero.

Flag	X'1'	Area variable does contain free elements.

Aggregate Descriptor Descriptor

Function

Contains information needed to map a structure or an array of structures during execution. Used for structures that contain adjustable extents or the REFER option.

When Generated

As far as possible during compilation. Adjustable values are filled in during execution.

Where Held

Static internal control section or AUTOMATIC storage.

How Addressed

From an offset from registers 3 or 13 known to compiled code.

General Format

An aggregate descriptor descriptor consists of a series of fullword fields one for each structure element and one for each base element in the structure.

Structure Element

0		1	2	3			
0	F 1	Offset	Level	F 2	F 3	F 4	Dimension

Byte 0, Bit 0: 0 indicates a Structure Element

Flag Bits

1	(located in Byte 0, Bit 1): Not applicable to structure elements
2-4	(located in Byte 3, Bits 0-2): Not applicable to structure elements

Offset: (14 bits): The offset within the aggregate descriptor descriptor to the entry for the containing structure. The offset is held in multiples of four bytes. The first element of the structure (the major structure element) has its offset field set to all '1'B.

Level: Logical level of identifier in structure

Dimension: (5 bits): Real dimensionality of identifier

Base Element

0			1	2	3			
1	F 1	Alignment	Length	Level	F 2	F 3	F 4	Dimension

Byte 0, Bit 0: 1 indicates a Base Element

Flag Bits

1 (located in Byte 0, Bit 1): Last element in structure indicator

0 = Not last element
1 = Last element

2-4 (located in Byte 3, Bits 0-2)

If Flag 2 = 1, element is an AREA
If Flag 3 = 1, element is a BIT string
If Flag 4 = 1, element is a GRAPHIC string

Alignment: (6 bits): Alignment stringency

Bit value	Decimal value	Alignment
000000	0	bit
000111	7	byte
001111	15	halfword
011111	31	fullword
111111	63	doubleword

Length: Length (in bytes) of data. Length is zero for strings and AREAs, whose length is held in descriptors.

Level: Logical level of identifier in structure

Dimension: (5 bits): Real dimensionality of identifier

Aggregate Locator

Function

Used to pass the address of an array or structure and its associated descriptor to a called routine. Also to associate the aggregate with its descriptor during execution.

When Generated

During compilation.

Where Held

Static internal control section or AUTOMATIC storage.

How Addressed

From an offset from registers 3 or 13 known to compiled code.

```
     0         1         2         3         4
     ┌─────────────────────────────────────────┐
   0 │        Address of data aggregate        │   Word 1
     ├─────────────────────────────────────────┤
   4 │          Address of descriptor          │   Word 2
     └─────────────────────────────────────────┘
```

Array Descriptor

Function

Contains information about the extent of an array. For arrays of area variables or strings, an area or string descriptor is attached to the array descriptor.

The array descriptor is used to pass information about an array to called routines, or to hold information about an array with adjustable extents.

When Generated

As far as possible during compilation. If the array has adjustable extents, it is completed during execution when the values are known.

Arrays of structures make use of structure descriptors to hold similar information.

Where Held

Static internal control section or AUTOMATIC storage.

How Addressed

From an offset from registers 3 or 13 known to compiler code, or from an aggregate locator.

Arrays of Strings or Areas

For arrays of strings or areas, the descriptors are completed by string or area descriptors concatenated to the array descriptor. String and area descriptors are the second word of string and area descriptor/locator pairs.

For bit string arrays, the bit offset from the byte address is held in the string descriptor.

General Format

PL/I Version 1: The first word in the array descriptor is the RVO (relative virtual origin). This is followed by two words for each dimension of the array, containing the multiplier and high and low bound for each dimension.

	0 1	2 3 4
0	RVO (AO-VO)	
4	Multiplier	
8	High bound	Low bound
C	Multiplier 2	
10	High bound 2	Low bound 2
	etc. **Note:** Two full words containing multiplier and high and low bound are included for each array dimension.	

PL/I Version 2: The first word in the array descriptor is the RVO (relative virtual origin). This is followed by three words for each dimension of the array, containing the multiplier and high and low bound for each dimension.

	0 1 2 3 4
0	RVO (AO-VO)
4	Multiplier
8	High bound
C	Low bound
10	Multiplier 2
14	High bound 2
18	Low bound 2
	etc. **Note:** Three full words containing multiplier and high and low bound are included for each array dimension.

RVO: Relative virtual origin, the distance between the virtual origin (VO) and the actual origin (AO). Virtual origin is the point at which the element in the array whose subscripts are all zeros is, or would be, held. Actual origin is the start of the first element in the array.

RVO is held as a bit value for arrays of unaligned bit strings, but otherwise as a byte value. Bit offsets are given in the string descriptor. Actual origin and virtual origin are also held as byte values.

High bound: The highest subscript in any dimension.

Low bound: The lowest subscript in any dimension.

Multiplier: The multiplier is the offset between any two elements marked by the change of subscript number in any dimension.

For example for the array DATA(10,10), the multiplier for the first dimension is the offset between DATA(1,1) and DATA(2,1) etc. The multiplier for the second dimension is the offset between DATA(1,1) and DATA(1,2). The offset is measured from the start of the one element to the start of the next.

Multipliers are byte values except for bit string arrays, in which case they are bit values.

CICS Appendage

Function

Holds information needed during operation under CICS/OS/VS.

When Generated

During program initialization under CICS/OS/VS.

Where Held

In the program management area at the head of the ISA.

How Addressed

From TCIC offset X'124' in TCA.

	0	1	2	3 4		
0	A(CICS TCA)				TCTCA	
4	A(CICS CSA)				TCCSA	
8	A(IBMFSTVA) or 0				TCSTV	
C	A(Msg Output Bootstrap)				TCTMS	
10	A(Report/Count Bootstrap)				TCTCR	
14	Terminal ID				TCTRM	
18	Transaction ID				TCTRN	
1C	PL/I Mask	CICS Mask	Command Workspace			
20	Temp1				TCTP1	
24	Temp2				TCTP2	→TCTMP
28	Temp3				TCTP3	
2C	A(DFHSAP, PL/I-CICS Nucleus Interface)				TCSAP	
30	A(PL/I to CICS Macro Interface)				TCMAC	
34	A(PL/I Program Exec. Interface Block)				TCEIB	
38	ABEND Code				TCABD	
3C	Interrupt Code				TCINT	→TCPSW
40	Return Address				TCRTN	
44	(PL/I Acquired Storage Chain)				TCSCH	
48	A(Buffer), Message/Count/Rep Records				TCBUF	
4C	Used as Exec. Interface DSA (184 bytes)				TCEIS	
104	User's Exec. Interface Block Copy (76 bytes)				TCEIC	

TCTMP: This area is used as a temporary workspace by PL/I. It is comprised of the TCTP1, TCTP2, and TCTP3 fields.

TCPSW: This area holds the Program Status Word (PSW) at the time of an interrupt. The field, TCINT, holds the interrupt code; TCRTN holds the return address.

Controlled Variable Block

Function

To hold information about the controlled variable.

When Generated

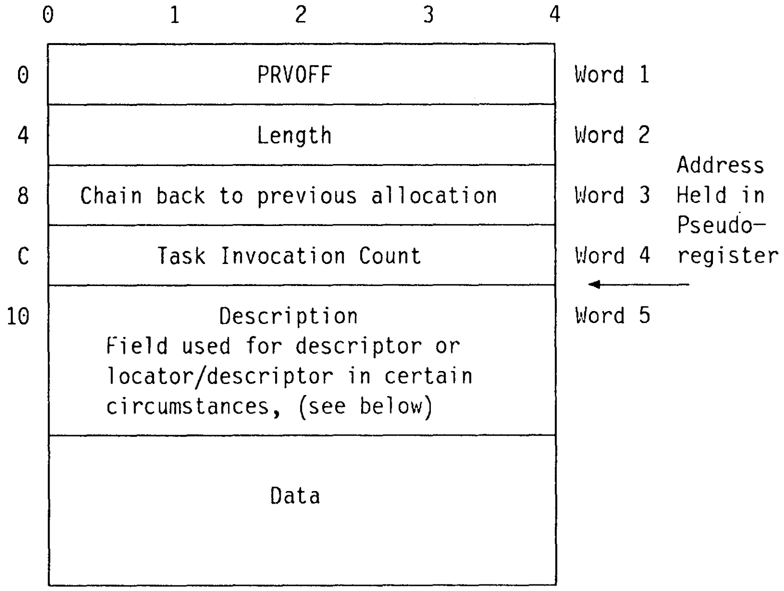
When the variable is allocated.

Where Held

At the head of the controlled variable.

How Addressed

From an offset in the PRV. (The PRV address is held at offset X'4' in the TCA.)


0
1
2
3
4
0
PRVOFF
Word 1
4
Length
Word 2
8
Chain back to previous allocation
Word 3
C
Task Invocation Count
Word 4
Address Held in Pseudo-register
10
Description
Field used for descriptor or locator/descriptor in certain circumstances, (see below)
Word 5
Data

PRVOFF: Offset within pseudo-register vector associated with the controlled variable.

Length: Length of the total allocation including the four words of the heading.

Chain back: Address of word 5 of previous allocation, set to address of dummy FCB if first allocation

Task invocation count: A method of identifying which task the controlled variable is attached to. A controlled variable cannot be freed within a task unless the task invocation count of the variable is the same as that in the TCA.

Description: If the item is one that requires a descriptor/locator or a locator, this is placed at the head of the data. If the item is a structure or array and the extents are *unknown* at compile time, the descriptor will also be placed before the data.

Thus for:

Strings and areas
The controlled variable is headed by a *locator/descriptor*.

Structures and arrays
The controlled variable is headed by a *locator*.

Structures and arrays with adjustable extents
The controlled variable is headed by a *locator* followed by a *descriptor*.

All other data
The *description field is not used* and the data itself starts at offset X'10'(16).

Data Element Descriptor (DED)

Function

Used to convey description of data elements to library conversion, stream I/O routines, check condition routines, and PLITEST.

When Generated

During compilation.

Where Held

Static internal control section or external symbol table csect.

How Addressed

From an offset from register 3 known to compiled code or from a pointer in the symbol table.

Format of DEDs

All DEDs are headed by two bytes that indicate the data type. These two bytes are followed by as many bytes as are required to complete the description of the data.

For arithmetic items, DEDs are completed by such items as scale and precision. For pictured items, a representation of the picture is included in internal form.

Flag 1: Also known as Code Byte and Look up Byte, define the data type.

Hex Value	**Data Type**
X'00'	FIXED BINARY
X'04'	FIXED DECIMAL
X'08'	FLOAT
X'0C'	FREE DECIMAL (an internal form)
X'10'	FIXED PICTURE BINARY
X'14'	FIXED PICTURE DECIMAL
X'18'	FLOAT PICTURE BINARY
X'1C'	FLOAT PICTURE DECIMAL
X'20'	non-VARYING CHARACTER
X'24'	non-VARYING BIT
X'28'	VARYING CHARACTER
X'2C'	VARYING BIT
X'30'	CHARACTER PICTURE
X'40'	BINARY constant
X'44'	DECIMAL constant
X'48'	BIT constant
X'50'	F/E Format
X'54'	P Format (arithmetic)
X'58'	A/B/P Format (character)
X'5C'	C Format
X'60'	X-Format

Hex Value	Data Type
X'64'	COL Format
X'68'	SKIP Format
X'6C'	LINE Format
X'70'	PAGE Format
X'80'	LABEL
X'84'	ENTRY
X'88'	AREA
X'8C'	TASK
X'90'	OFFSET
X'94'	POINTER
X'98'	FILE
X'9C'	EVENT
X'A0'	GRAPHIC Fixed
X'A8'	GRAPHIC Varying

Flag 2: completes the definition, if necessary.

Bits 0&1 =	00	A-format item
	01	B-format item
	10	Character picture format item
	11	GRAPHIC
Bit 2 =	0	Fixed constant
	1	Float constant
Bit 3 =	0	Not extended float
	1	Extended float
Bit 4 =	0	F-format/fixed picture
	1	E-format/float picture
Bit 5 =	0	Declared binary
	1	Declared decimal
Bits 4&5 =	11	Then DED is for character
Bit 6 =	0	Short precision
	1	Long precision
Bit 7 =	0	Real *or* length specified (A or B format) aligned bit string.
	1	Complex (also set if E, F, or P in C-format) *or* no length specified (A or B format) *or* unaligned bit string.

All bits for which neither value is defined are set to '0'B. :cc 20

DED for STRING Data

```
    0         1         2
   ┌─────────┬─────────┐
 0 │ Flag 1  │ Flag 2  │
   └─────────┴─────────┘
```

DED for FLOAT Data

	0	1	2	3
0	Flag 1	Flag 2	precision	

DED for FIXED Data

	0	1	2	3	4
0	Flag 1	Flag 2	precision	scale±128	

DED for PICTURE STRING Data

	0	1	2	3	4
0	Flag 1	Flag 2	L1		
4	L2		Picture in Internal Form		

Flag 1: (X'30')

L1: Length of field with insertion characters

L2: Length of field without insertion characters

Internal Code: The internal code for string pictures is as follows:

Code	**Picture(hex)**
A	X'00'
9	X'04'
X	X'1C'

DED for PICTURE DECIMAL Arithmetic Data

	0	1	2	3	4
0	Flag 1	Flag 2	Precision	Scale Factor+128	
4	Length of Picture	Length of Data	Flag 3	Flag 4	
	Picture in internal code				

Flag 1: (X'14' or X'1C')

Flag 3: Describes the mantissa subfield.

Bit 0 = Always set to zero
Bit 1 = 1 Drifting S in subfield
Bit 2 = 1 Drifting + in subfield
Bit 3 = 1 Drifting – in subfield
Bit 4 = 1 Drifting $ in subfield
Bit 5 = 1 Total suppression in subfield
Bit 6 = 1 * in subfield
Bit 7 = Always set to zero

Flag 4: Describes the exponent subfield. It has the same format as Flag Byte 3.

Internal codes for pictures

Code	Picture
00	9
04	Y
08	Z
0C	*
10	E
14	K
18	T
1C	I
20	R
24	CR
28	DB
2C	B
30	S (t)
34	S (d)
38	S (s)
3C	+
40	+ (d)
44	+ (s)
48	– (t)
4C	– (d)
50	– (s)
54	$ (t)
58	$ (d)
5C	$ (s)
60	/ (t)
64	/ (d)
68	/ (s)
6C	. (t)
70	. (d)
74	. (s)
78	, (t)
7C	, (d)
80	, (s)
84	V

Note: Abbreviations for internal codes:

(t) = terminal
(d) = drifting

(s) = static
After E or K, the next byte contains the number of digits in the exponent.

Scale Factor: The scale factor of a picture DED is the number of digit positions after the "V" (0 if there is no "V") added to the number in the F specification, if any.

Rule for Setting Bit 5 in Flag Bytes 3 and 4: Bit 5 is set if no 9, Y, T, I, or R is present. This applies before any Z, S, etc. has been translated to a 9.

Rules for Translating Pictures into Encoded Pictures

1. Characters 9, Y, E, K, T, I, R, CR, DB, B, and V are translated directly.
2. Characters Z and * are translated directly if they do not follow a V. If either follows a V, it is translated into the code for character 9.
3. An S, +, −, or $ is translated to a static S, +, −, or $ if it is the only one of its kind in the subfield.
4. If more than one S appears in a subfield, the S′s are translated into drifting S′s.

Except when:

a. It appears immediately before a Y, 9, V, T, I or R. In this case it is translated into the code for a terminal S.

b. It appears anywhere after a V. In this case it is translated into the code for a 9.

The same rule applies for the +, −, or $.

5. A "/", a ",", or a "." is treated as drifting, if:

a. It is in a subfield containing either one or more Z or asterisk, or more than one +, s, −, or $.

and if:

b. It is not immediately preceding a Y, 9, V, T, I, or R. In this case it is translated into terminal form.

DED for Program Control Data

Program control DEDs are used to describe program control constants and program control variables. Program control DEDs may be 2 or 4 bytes in length.

	0	1	2
0	Flag 1	Flag 2	Further Bytes as Required

Flag 1 Also known as the look up byte. Defines the data type.

X'80'   Label variable, 2-byte DED.

X'84' Entry variable, 4-byte DED. The byte at offset 2 contains a code indicating the entry type.

Offset 2	Entry Type
X'10'	PL/I
X'7'	FORTRAN
X'5'	COBOL
X'16'	OPTIONS(ASM).

X'88' Area variable, 2-byte DED.

X'8C' Task variable, 2-byte DED.

X'90' Offset variable, 2-byte DED.

X'94' Pointer variable, 2-byte DED.

X'98' File variable, 2-byte DED.

X'9C' Event variable, 2-byte DED.

X'B0' Label constant, 2-byte DED.

X'B4' Entry constant, 4-byte DED. The byte at offset 2 contains a code indicating the entry type.

Offset 2	Entry Type
X'10'	PL/I
X'7'	FORTRAN
X'5'	COBOL
X'16'	OPTIONS(ASM).

X'B8' File constant, 2-byte DED.

X'BC' CONDITION condition name, 2-byte DED.

Flag 2: Flag 2 is used only by Flag 1 look up bytes X'B0' and X'B4'.

Bit 0 With Flag 1 look up byte X'B0' indicates a label on a FORMAT statement.

With Flag 1 look up byte X'B4' indicates whether this entry is fetchable.

Bits 1-7 Unused.

FORMAT DEDs (FEDs)

For the meaning of the flag bytes, see "Data Element Descriptor (DED)" on page 132.

DED for F and E FORMAT Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	W		
4	D	X			

Flag byte 1 = X'50'

W Total length of the format field
D Number of decimal places
X Precision + 128 for F-format number of significant figures for E-format

DED for G FORMAT Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	Length		

Flags

Flag 1 = X'A0' For G-format
Flag 2 = X'C0'

Length is optional.

DED for PICTURE FORMAT Arithmetic Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	W		
4	Copy of DED as for arithmetic picture				

Flag 1: (X'54')

W: Total length of the format field

DED for PICTURE FORMAT Character Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	W		
4	Copy of DED as for arithmetic picture				

Flag 1: (X'58')

W: Total length of the format field

DED for C FORMAT Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	W		
4	FED for real part		FED for imag. part		

Flag 1: (X'5C')

Note: The complex bit (bit 7) in Flag 2 is set in both the real part and the imaginary part FED.

W: Total length of the format field

DED for CONTROL FORMAT Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	Parameter		

Flag 1: (X'60, 64, 68, 6C or 70')

Parameter Length of item (X format), column number (COL format), number of lines to skip (SKIP format), line number (LINE format), is omitted for PAGE format.

DED for STRING FORMAT Items (FED)

	0	1	2	3	4
0	Flag 1	Flag 2	Length		

Flag 1: (X'58')

The difference between A, B, and P (character) formats is given by bits 0 and 1 of Flag 2. The length field may be omitted for A and B format items.

Declare Control Block (DCLCB)

Function

Addresses file via PRV, holds declared file attributes, filename, and address of ENVB.

When Generated

During compilation.

Where Held

In a separate static control section for external files, or in a static internal control section for internal files.

How Addressed

The address is generated by the linkage editor for external files; It is addressed by an offset from register 3 for internal files.

<table>
<tr><th></th><th colspan="2">0 1 2 3 4</th><th></th></tr>
<tr><td>0</td><td colspan="2">Pseudo-Register Offset</td><td>DFCB</td></tr>
<tr><td>4</td><td colspan="2">Declared Attributes</td><td>DCLA</td></tr>
<tr><td>8</td><td colspan="2">Invalid OPEN Attributes</td><td>DOPA</td></tr>
<tr><td>C</td><td colspan="2">A(Environment Block)</td><td>DENV</td></tr>
<tr><td>10</td><td>Offset of Graphics Extension</td><td>Offset of Filename Length</td><td></td></tr>
<tr><td>14</td><td>Filename Length</td><td>Filename (to 31 characters)</td><td></td></tr>
</table>

Declared and Invalid OPEN Attributes

Byte Number	Hex. Value	Attributes
1	01	STREAM
	02	RECORD
	04	DISPLAY
	10	reserved for (STRING)

Byte Number	Hex. Value	Attributes
2	01	SEQUENTIAL
	02	DIRECT
	04	TRANSIENT
	10	INPUT
	20	OUTPUT
	40	UPDATE
	80	BACKWARDS
3	01	BUFFERED
	02	UNBUFFERED
	04	KEYED
	08	EXCLUSIVE
	10	PRINT
4		Not used

Dynamic Storage Area (DSA)

Function

Holds housekeeping information, automatic variables, and temporaries for each block.

When Generated

During execution. Allocated by prolog code every time a new block is entered.

Where Held

In the LIFO storage stack. Certain library routines have their DSAs in library workspace (LWS). See Figure 41 on page 143.

How Addressed

From register 13.

	0	1	2	3 4	
0	Flag 0	Flag 1	Not Used		
4	A(Chain Back)				CCHB
8					
C	Save Area R14				
10	Save Area R15				
14	Save Area R0				
18	Save Area R1				
1C	Save Area R2				
20	Save Area R3				
24	Save Area R4				CRSA
28	Save Area R5				
2C	Save Area R6				
30	Save Area R7				
34	Save Area R8				
38	Save Area R9				
3C	Save Area R10				
40	Save Area R11				
44	Save Area R12				
48	A(LWS)				CLWS
4C	Segment #	A(NAB)			CNAB
50	Segment #	End of Prolog NAB			CEPN or CAPP
	or A(TIA) or A(TTA) in Dummy DSA or				
	To Save TFB1	Number of DSAs	Not Used		
54	Block-Enable Bits CENA		Current-Enable Bits CCNA		
58	A(Attaching DSA) in Dummy				CAAD

<table>
<tr><td>5C</td><td colspan="4">A(First Static ONCB)</td><td>CSON</td></tr>
<tr><td>60</td><td colspan="4">A(Most Recent Dynamic ONCB in Block)</td><td>CDON</td></tr>
<tr><td>64</td><td colspan="4">Not Used</td><td></td></tr>
<tr><td>68</td><td colspan="4">Not Used</td><td></td></tr>
<tr><td>6C</td><td colspan="4">Reserved for the Checkout Compiler</td><td></td></tr>
<tr><td>70</td><td colspan="4">A(ONCELLS)</td><td>CAOC</td></tr>
<tr><td>74</td><td>Reserved Checkout Compiler</td><td>Imple-mentation Defined</td><td>Flags 2</td><td>Control Task Flag</td><td></td></tr>
</table>

Flags

Flag 0 (CFF0)

CDSA	Bit 0 = 1	LWS DSA
CONC	Bit 1 = 1	ON-cells exist
COCH	Bit 2 = 1	Dynamic ONCBs allocated
CIMP	Bit 3	Reserved for the Checkout Compiler
CBEG	Bits 4 & 5	00 Procedure DSA
		01 Begin DSA
		10 Library DSA
		11 ON-unit DSA
CDUM	Bit 6 = 1	Dummy DSA
CSUB	Bit 7 = 1	Subtask dummy DSA

Flag 1 (CFF1)

CFCM	Bit 0 = 1	Byte CFFC is meaningful
CRNB	Bit 1 = 1	Restore NAB on GOTO
CRCE	Bit 2 = 1	Restore current-enable on GOTO
COVR	Bit 3 = 1	Callee can use this DSA
CGTO	Bit 4 = 1	EXIT DSA
CSNT	Bit 5 = 1	Statement number table exists
CSYE	Bit 6 = 1	SYSPRINT is enqueued by this block.
CFFB	Bit 7 = 1	Flags in Flags 2 are valid

Flags 2 (CFF2)

C2LD	Bit 0 = 1	Last PL/I DSA
C2ID	Bit 1 = 1	Ignore DSA for SNAP
C2IN	Bit 2 = 1	ILC DSA after interrupt
C2IC	Bit 3 = 1	Invocation Count in this DSA
C2SY	Bit 4 = 1	Symbolic dump for this DSA
C2FL	Bit 5 = 1	There are TSO line numbers
	Bit 6 = 1	CMPAT(V2)--Fullword subscripts
	Bit 7	Reserved

Control Task Flag

CCFC	Bit 0 = 1	Block has active subtasks
	Bits 1-7	Not used

This flag byte is the only one in the DSA used by the control task without synchronizing with the subtask. The subtask must never change it. This prevents interference between CPU's on a multiprocessing machine.

Entry Data Control Block

Function

Holds information that will enable an entry to be branched to and the correct static back-chain to be set up. Is used as an entry variable or when an entry is passed as a parameter.

When Generated

When the variable is allocated.

Where Held

Depends on the storage class of the data item.

How Addressed

Depends on the storage class of the data

```
     0         1         2         3         4
    ┌───────────────────────────────────────┐
  0 │        Address of entry point         │ Word 1
    ├───────────────────────────────────────┤
  4 │   Address of Statically Containing    │ Word 2
    │   DSA at Time of Assignment           │
    └───────────────────────────────────────┘
```

Word 1

Bit 0 = 0	Address of entry
Bit 0 = 1	Address of location containing 8-char. EBCDIC name of entry point

Word 2: Bit 0 is always set to zero.

Address of Statically Containing DSA: This address is set in register 5 when the assignment is made to the variable. It enables variables in other blocks to be accessed. When assignment is made the address of the current statically containing DSA is set. This will be the correct address for the entry. If it were not, the entry itself would not be known.

Environment Block (ENVB)

Function

Holds environment options for a file so that the file may be correctly opened during execution.

When Generated

During compilation

Where Held

In a static control section with the DCLCB for external files. In static internal storage for internal files.

How Addressed

From offset X'C' in the DCLCB

	0	1	2	3	4
0	NFLA	NFLB	NFLC	NFLD	
4	NFLE	NFLF	NFLG	NFLH	
8	Not Used				

C	A(Blocksize)
	or
	A(Pagesize 2260)
					NBLK or NPAG

10	A(Record Length)
	or
	A(Linesize 2260)
					NREC or NLIN

14	A(Number of Buffers)				NBUF

18	A(KEYLOC Value)
	or
	A(Attention Variable)
					NLOC or NATN

1C	A(KEYLENGTH)				NKYL

20	A(BUFFOFF Value)
	or
	A(INDEXAREA Size)
					NOFF or NNDX

24	A(NCP Value)
	or
	A(Size of ADDBUF)
					NNCP or NADD

28	A(Password String Locator)				NPAS
2C	A(BUFND Value)				NBND
30	A(BUFNI Value)				NBNI
34	A(BUFSP Value)				NBSP

Flags

NFLA

NCON	Bit 0 = 1	Consecutive
NIND	Bit 1 = 1	Indexed
NRG1	Bit 2 = 1	Regional (1)
NRG2	Bit 3 = 1	Regional (2)
NRG3	Bit 4 = 1	Regional (3)
NTPM	Bit 5 = 1	TP(M)
NTPR	Bit 6 = 1	TP(R)
NOTH	Bit 7 = 1	Other organization

NFLB

NFIX	Bit 0 = 1	Fixed
NVAR	Bits 0 & 1	10 Variable
NUND		11 Undefined
NDEC	Bit 2 = 1	Decimal
NTRO	Bit 2 = 1	TRKOFL>
NBLO	Bit 3 = 1	Blocked
NSPA	Bit 4 = 1	Spanned
NASA	Bit 5 = 1	CTLASA
N360	Bit 6 = 1	CTL360
NEGS	Bit 7 = 1	GRAPHIC

NFLC

NLVE	Bit 0 = 1	LEAVE
NRRD	Bit 1 = 1	REREAD
NGKY	Bit 2 = 1	GENKEY
NCBL	Bit 3 = 1	COBOL
NOWR	Bit 4 = 1	NOWRITE
NXAR	Bit 5 = 1	INDEXAREA
NTOT	Bit 6 = 1	TOTAL
NXAS	Bit 7 = 1	INDEXAREA with no argument

NFLD

NBUU	Bit 0 = 1	BUFFERS
NCPF	Bit 1 = 1	NCP
NFPS	Bit 2 = 1	PASSWORD
NKEL	Bit 3 = 1	KEYLENGTH
NKLC	Bit 4 = 1	KEYLOC
NVFY	Bit 5 = 1	VERIFY
NNOL	Bit 6 = 1	NOLABEL
NABF	Bit 7 = 1	ADDBUF

NFLE

N226	Bit 0 = 1	2260
NLOK	Bit 1 = 1	Lock (2260)
	Bits 2-3	Not used
NSTL	Bit 4 = 1	SCALARVARYING
NUSA	Bit 5 = 1	ANSCII
NBOF	Bit 6 = 1	BUFOFF
NBFL	Bit 7 = 1	BUFOFF(L)

NFLF

NXML	Bit 0 = 1	Index multiple
NX11	Bit 1 = 1	High index 2311
NX14	Bit 2 = 1	High index 2314
NOTM	Bit 3 = 1	No tape mark
NALT	Bit 4 = 1	Alternate tape
NOFT	Bit 5 = 1	OFL tracks
NXTN	Bit 6 = 1	Extent number
	Bit 7	Not used

NFLG

NFFM	Bit 0 = 1	F-format
NVFM	Bit 1 = 1	V-format
NUFM	Bit 2 = 1	U-format
NSP2	Bit 3 = 1	Spanned
NBL2	Bit 4 = 1	Blocked
	Bits 5-7	Not used

NFLH

NVSM	Bit 0 = 1	VSAM
NFBD	Bit 1 = 1	BUFND
NFBI	Bit 2 = 1	BUFNI
NFBS	Bit 3 = 1	BUFSP
NFSI	Bit 4 = 1	SIS
NFSK	Bit 5 = 1	SKIP
NFBW	Bit 6 = 1	BKWD
NFRS	Bit 7 = 1	REUSE

Event Variable Control Block

Function

To hold information about the operation with which the EVENT has been associated.

When Generated

Depends on the storage class of the event variable.

Where Held

Depends on the storage class of the event variable.

How Addressed

As other variables depending on storage class.

	0	1	2	3	4	
0	Flags 1	Flags 2	Status			
4	Anchor for ECB chain					EECH
8	A(DECB) or A(CCB) for I/O					EAEC
C	A(TCA appendage of task for I/O)					ETCA
10	A(DCLCB) or A(FCB) for I/O or A(Called Procedure) for Tasking					EUSI
14	Statement Number					ESND

Flags

Flags 1 (EFL0)

ECOM	Bit 0 = 1	Complete
EACT	Bit 1 = 1	Active
EIOF	Bit 2 = 1	I/O EVENT
EDSP	Bit 3 = 1	DISPLAY EVENT
EWIP	Bit 4 = 1	EV has caused entry to an ON-unit
ESNF	Bit 7 = 1	ESNO field contains the statement number

Flags 2 (EFL1)

ECHE	Bit 0 = 1	Chain of ECBs exists
EDUM	Bit 1 = 1	Dummy EVENT

File Control Block (FCB)

Function

Used to access all file information. Contains addresses of the ENVB, DTF, filename, etc.

When Generated

By the open routines during execution.

Where Held

In subpool 1.

How Addressed

From two byte PRV offset which is held at offset X'2' in DCLCB. The PRV address is held at offset X'4' in the TCA.

Common Section

The common section is followed by either the RECORD or STREAM sections.

	0	1	2	3	4	
-8	Eyecatcher					
0	Statement Mask					FFST
8	A(Invalid Statement Module)					FAIS
C	A(Library Transmitter)					FATM
10	A(DCLCB)					FADL
14	A(DCB) or A(ACB)					FADB or FACB
18	A(Open File Chain)					FAFO
1C	A(data management for in-line I/O)					FAIL
20	Error Bytes		Not Used			
24	FATA	FATB	FATC	Not used		
28	FFLA	FFLB	FFLC	FFLD		
2C	FFLE	FFLF	FFLG	FFLH		
30	Blocksize		Keylength			
34	Record length					FRCL

38	A(First Free IOCB)
	or
	A(Hidden Buffer for QISAM LOCATE)
						FAFR or FREC

3C	FTYP		FLEN			
40	Reserved for the Checkout Compiler					FGAS
44	FBIF	Not Used				
48	Not Used					

Statement Mask (FFST)

Bit number	*Statement + options*
0	READ SET
1	READ SET KEYTO
2	READ SET KEY
3	READ INTO
4	READ INTO KEYTO
5	READ INTO KEY
6	READ INTO KEY NOLOCK
7	READ IGNORE
8	READ INTO EVENT
9	READ INTO KEYTO EVENT
10	READ INTO KEY EVENT
11	READ INTO KEY NOLOCK EVENT
12	READ IGNORE EVENT
13	WRITE FROM
14	WRITE FROM KEYFROM
15	WRITE FROM EVENT
16	WRITE FROM KEYFROM EVENT
17	REWRITE
18	REWRITE FROM
19	REWRITE FROM KEY
20	REWRITE FROM EVENT
21	REWRITE FROM KEY EVENT
22	LOCATE SET
23	LOCATE SET KEYFROM
24	DELETE
25	DELETE DEY
26	DELETE EVENT
27	DELETE KEY EVENT
28	UNLOCK KEY
29	WRITE FROM KEYTO
30	WRITE FROM KEYTO EVENT
31-63	Reserved

Error Bytes

FER1

FTIP	X'02'	Input transmit (data set)
FTOP	X'03'	Output transmit (data set)
FTOM	X'1A'	OMR read error
FTIX	X'1C'	Input transmit (index set)
FTOX	X'1D'	Output transmit (index set)
FTIS	X'1E'	Input transmit (sequence set)
FTOS	X'1F'	Output transmit (sequence set)

FER2

FFEF	X'01'	End of file
FRVZ	X'04'	Zero length record variable
FRVS	X'05'	Short record variable
FRVG	X'06'	Long record variable
FKCN	X'07'	Key conversion in character string
FKDP	X'08'	Key duplication
FKSQ	X'09'	Key sequence
FKSP	X'0A'	Key specification (null key)
FKNF	X'0B'	Key not found
FKNS	X'0C'	No space for keyed record
FNIO	X'0D'	No IOCB available
FEAC	X'0E'	Active event
FEUP	X'0F'	No prior read before rewrite
FENC	X'10'	No completed read before rewrite
FETO	X'11'	Permanent output error
FRR2	X'12'	Zero length record read
FEOL	X'13'	Record referenced outside data set
FEXX	X'14'	Unidentified I/O error
FEIR	X'15'	Incomplete read for update
FKTP	X'16'	TP term address specification
FEXS	X'17'	Different FCB same record request
FKCB	X'18'	Key conversion (negative BINARY number)
FKSF	X'19'	Key specification (X'FF' etc)
FASQ	X'1B'	I/O sequence error
FESY	X'20'	Synad error encountered
FRVX	X'21'	Record length < KEYLEN + RKP
FERH	X'22'	Record already held
FEVN	X'23'	Record on non-mounted volume
FESP	X'24'	Data set cannot be extended
FEVS	X'25'	No virtual storage for VSAM
FKNR	X'26'	No keyrange for insertion
FENP	X'27'	No positioning for sequential read

FER2

FEUN	X'28'	Attempt to reposition failed
FEST	X'29'	Statement number for data set exceeded
FIEU	X'2A'	Index upgrade error
FEMP	X'2B'	Maximum number of index PTRs
FEIP	X'2C'	Invalid index PTRs
FESW	X'2D'	Invalid sequential write

FTYP: 6th and 7th characters of library transmitter name

FLEN: Length of FCB (including DCB)

FATA

FDBG	Bit 0 = 1	Open SYSPRINT for error message
FSYS	Bit 1 = 1	SYSPRINT
FCTR	Bit 2 = 1	Reserved for Checkout Compiler
FSTR	Bit 3 = 1	String operation
	Bit 4 = 1	Not used
FDSP	Bit 5 = 1	DISPLAY
FRIO	Bit 6 = 1	RECORD
FSIO	Bit 7 = 1	STREAM

FATB

FBAK	Bit 0 = 1	BACKWARDS
FUPD	Bit 1 = 1	UPDATE
FOUT	Bit 2 = 1	OUTPUT
FIPT	Bit 3 = 1	INPUT
	Bit 4 = 1	Not used
FTRA	Bit 5 = 1	TRANSIENT
FDIR	Bit 6 = 1	DIRECT
FSEQ	Bit 7 = 1	SEQUENTIAL

FATC

	Bit 0 = 1	Not used
FEGS	Bit 1 = 1	GRAPHIC option of the ENVIRONMENT attribute
FAXS	Bit 2 = 1	Axes
FPRT	Bit 3 = 1	PRINT
FXCL	Bit 4 = 1	EXCLUSIVE
FKYD	Bit 5 = 1	KEYED
FUNB	Bit 6 = 1	UNBUFFERED
FBUF	Bit 7 = 1	BUFFERED

FFLA

FFIX	Bit 0 = 1	F-format
FVAR	Bit 1 = 1	V-format
FUND	Bit 2 = 1	U-format
FBLO	Bit 3 = 1	Blocked
FSPA	Bit 4 = 1	Spanned
	Bits 5 & 6	Not used
FKLC	Bit 7 = 1	Key in record variable KEYLOC

FFLB

FCON	Bit 0 = 1	CONSECUTIVE
FIND	Bit 1 = 1	INDEXED
FRG1	Bit 2 = 1	REGIONAL(1)
FRG2	Bit 3 = 1	REGIONAL(2)
FRG3	Bit 4 = 1	REGIONAL(3)
FTMP	Bit 5 = 1	TP(M)
FTPR	Bit 6 = 1	TP(R)
FOTH	Bit 7 = 1	Other organization

FFLC

FQSM	X'00'	QSAM
FBSM	X'04'	BSAM
FBSL	X'08'	BSAM (Load)
FQTM	X'0C'	QTAM
FQIS	X'10'	QISAM
FBIS	X'14'	BISAM
FBDM	X'18'	BDAM
FVSM	X'1C'	VSAM

FFLD

FPPT	Bit 0 = 1	Paper tape
FPRI	Bit 1 = 1	Printer
FURD	Bit 2 = 1	Unit record device
FTRM	Bit 3 = 1	The foreground terminal
FEFL	Bit 4 = 1	ENDFILE module loaded
FPHB	Bit 5 = 1	Possible hidden buffer
FEML	Bit 6 = 1	Error module loaded
FGKY	Bit 7 = 1	Genkey

FFLE

FFER	Bit 0 = 1	I/O error
FERI	Bit 1 = 1	Permanent input error
FERO	Bit 2 = 1	Permanent output error
FEOF	Bit 3 = 1	End of file

FHID	Bit 4 = 1	Hidden buffer in use
FEOD	Bit 5 = 1	Move required
FFNV	Bit 6 = 1	Non-SCALARVARYING
FSTK	Bit 7 = 1	Not used

FFLF

FPRD	Bit 0 = 1	Previous READ
FPRS	Bit 1 = 1	Previous READ SET
FPLC	Bit 2 = 1	Previous LOCATE
FPRW	Bit 3 = 1	Previous REWRITE
FPOP	Bit 4 = 1	Previous OPEN or READ IGNORE
FCLS	Bit 5 = 1	Close in progress
FICL	Bit 6 = 1	Implicit close
FRSL	Bit 7 = 1	Previous OPEN (resume load) or READ IGNORE(0)

FFLG

FEPG	Bit 0 = 1	ENDPAGE
FEEX	Bit 1 = 1	End of extent
FCOP	Bit 2 = 1	COPY option active
	Bit 3	Not used
	Bits 4 & 5	Reserved for the Checkout Compiler
FVPF	Bit 6 = 1	Newly opened print file
FNOC	Bit 7 = 1	File not to be closed

FFLH

FILF	Bit 0 = 1	In-line I/O
FILL	Bit 1 = 1	In-line LOCATE
FHYP	Bit 2 = 1	Hyphen at the end of the line
FRGT	Bit 3 = 1	Retry get after concatenation
FCLU	Bit 4 = 1	Current line unfinished
FSPL	Bit 5 = 1	Initial call from IBMBSPL or blanks at the end of record
FBER	Bit 5 = 1	Blanks at the end of record
FNBW	Bit 6 = 1	New buffer wanted
FGPI	Bit 7 = 1	GET prompt issued — input

Built in Function Byte (FBIF)

FSKY	Bit 0 = 1	Samekey flag
	Bits 1-7	Not used

Record I/O Section

Offsets are from start of the FCB.

	0	1	2	3	4
4C	A(Last IOCB Used) or A(Dummy Buffer for LOCATE)				FALU or FCDA
50	A(first IOCB to be Checked) (BSAM)				FACK
54	Static Chain of IOCBs (BDAM/DISAM/DSAM/VSAM)				FIOC
58	A(IOCB for Last Completed Read)				FALR
5C	FEMT	FEFT	FRET	FAFB	
60	A(error module) When Loaded				FERM
64	FGAM or FFNC	FFLV or FFNF	KEYLOC-1 VSAM or Decrementing Line Count		
68	Record Count				FCCT
6C	A(Dummy Key Area)				FAKY
70	Size of IOCB (BDAM/BISAM) or Current Relative Block (BSAM)				FIOS or FREL
74	A(Exclusive Block FILE)				FXBA
78	Offset Table Used in Record Checking				FRTB
7C	Base OPTCD for RPL (VSAM)				FOPT
80	A(FCB) or A(FAFB)				FAWB

FEMT: 7th character of the error module name

FEFT: 7th character of the endfile module name

FRET: Data management return code (regional output)

FAFB: Work byte for associated files

FFNC: Function byte

FARF	Bit 0 = 1	READ file
FAPF	Bit 1 = 1	PUNCH file
FAWF	Bit 2 = 1	PRINT file
FOMR	Bit 3 = 1	OMR (no other lists on)
FRFI	Bit 4 = 1	R in FUNC option
FPFI	Bit 5 = 1	P in FUNC option
FPWI	Bit 6 = 1	W in FUNC option
FASC	Bit 7 = 1	Associated file

FFLV: VSAM flags

FKSD	Bit 0 = 1	KSDS
FESD	Bit 1 = 1	ESDS
FRDS	Bit 2 = 1	RRDS
FPTH	Bit 3 = 1	ALTERNATE INDEX PATH
FNUM	Bit 4 = 1	ALTERNATE INDEX PATH (non-unique)
FSKP	Bit 5 = 1	SKIP
	Bit 6 = 1	Not used
FPLO	Bit 7 = 1	Position lost

FCNF: Conflict byte

FPII	Bit 0 = 1	Prior READ invalid
FPPI	Bit 1 = 1	Prior PUNCH invalid
FPWI	Bit 2 = 1	Prior PRINT invalid
FPLI	Bit 3 = 1	Prior PRINT last line invalid
	Bit 4-7	Not used

Stream I/O Section

Offsets are from the start of the FCB.

	0 1	2 3 4	
4C	A(Next Available Byte in a Buffer)		FCBA
50	Bytes Remaining in Buffer	Value of Count Built-in Function	
54	Page Size	Line Size	
58	Current Line No.	Buffer Size	FMAX
5C	A(Copy Position in Buffer) or A(Next TPUT Position) for OUTPUT		FCPM or FNTP
60	A(DCLCB for COPY file)		FCPF
64	A(Copy Module Input or A(Tab Module Output)		FCPA or FTAB
68	Record Count		FRCT
6C	F(SIOCB)		FSCB

Fetch Control Block (FECB)

Function

The FECB is used to contain information about modules specified in FETCH statements.

How Addressed

FECBs are chained together. The chain starts in field TFEP, which is held in the TIA at offset X'3C'

Where Held

FECBs are set up by IBMBPFR in non-LIFO storage.

When Generated

When a module is fetched.

	0 1 2 3 4	
0	Chain Field	ZFCH
4	PRV Offset	ZFPO
8	Name of Module (8 bytes)	ZFNM
10	AMODE Switching Code	ZTRFCDE
20	A(Fetched module entry point)	ZTARGET
24	A(Call R14 Save Area)	ZSAVR14

Input/Output Control Block (IOCB)

Function

Used as a data management parameter list during certain record I/O statements and to hold information about statement type during the time between a record I/O statement and the associated WAIT statement.

When Generated

Either by the PL/I transmitter module (BISAM or BDAM) or by OPEN.

Where Held

In-non-LIFO storage for VSAM, in subpool 0 for BSAM (obtained by GETPOOL), BISAM or BDAM (obtained in subpool 1 for non-multitasking, in subpool 0 for tasking).

How Addressed

By fields in the FCB. IOCBs are chained together and the actual field used to address them depends on the type of statement being executed.

Common Section

	0	1	2 3 4		
0	Static Forward Chain			ICHN	
4	Chain of Free or Unchecked IOCBs or Region Number, Left Adjusted (BDAM)			INXT or IRGN	
8	IFLA	IFLB	Error Codes (IERR)		
C	Request Control Block			IRCB	
10	1st Word of Record Descriptor; A(RCD)			IORD	
14	2nd Word of Record Descriptor; Flags and Record Length			IORL	
18	1st Word of Key Descriptor			IOKD or IFNA	►IREF
1C	2nd Word of Key Descriptor			IOKL or IFBK	
20	A(EVENT Variable)			IEVT	

Flag Byte (IFLA)

IFXV	Bit 0 = 1	Record locked
IFMU	Bit 1 = 1	Record to move flag
IFSU	Bit 2 = 1	Varying string with non-scalar variable
IFUS	Bit 3 = 1	IOCB in use
IFER	Bit 4 = 1	General error flag
IFDR	Bit 5 = 1	Dummy records are being printed or displayed
IFDB	Bit 6 = 1	Dummy buffer acquired
IFCH	Bit 7 = 1	IOCB checked

Flag Byte (IFLB): Code byte containing offset within 'look-up' table used for record checking

Error Codes (IERR)

IEOF	X'01'	End of file
ITID	X'02'	Input transmit
ITOP	X'03'	Output transmit
IRVZ	X'04'	Zero length record variable
IRVS	X'05'	Short record variable
IRVG	X'06'	Long record variable
IKCN	X'07'	Key conversion
IKDP	X'08'	Key duplication
IKSQ	X'09'	Key sequence
IKSP	X'0A'	Key specification
IKNF	X'0B'	Key not found
IKNS	X'0C'	No space for keyed record
INIO	X'0D'	No IOCB available
IEAC	X'0E'	Active event
IEUP	X'0F'	No prior READ before REWRITE
IENC	X'10'	No completed READ before REWRITE
IETO	X'11'	Permanent output error
IRRZ	X'12'	Zero length record read
IEOL	X'13'	Record reference outside data set
IEXX	X'14'	Unidentified IO error

IOKL: Flags and key length

IREF: Relative block or record number (2 words) (BDAM)

IFNA: Next address feedback (BDAM spanned)

IFBK: BDAM feedback (BDAM spanned)

Non-VSAM Section

This section starts at offset X'24'.

	0 1 2 3 4	
24	A(ECB) for Regional Sequential Only or A(Exclusive Block) for Direct Only or A(Binary Region No.- Regional(1) Update	IADE or IXLV or IRLB
28	A(Implementation Appendage)	ITIA

Data Management Event Control Block

	0 1	2 3 4	
2C	BDAM Exception Codes in 2nd & 3rd Bytes		IECB
30	I/O Operation Type Set by Data Mgmt.	Record Length (ILEN)	
34	A(Data Control Block)		IDCB
38	A(Buffer) or A(Record Variable)		IREC
3C	A(Status Indicators) (BSAM & BDAM) or A(Logical Record)		ISTS or ILOG

40	A(Dummy Buffer) (BSAM)
	or
	A(Next Record Feedback)→IREF (BSAM)
	or
	A(KEY) (BDAM and BISAM)
			IADB
			or
			INLF
			or
			IKEY

44	A(Relative Block or Record) that is, A(IREF) (BDAM) or BISAM Exception Codes		IBLK or IEXI
48	A(Next Record Feedback)→IREF (BDAM) or Start of Any Appended Buffer (BSAM)		INDF or ISBF
4C	Start of Any Appended Buffer (BDAM-or-BISAM)		IDBF

VSAM Section

This section also starts at offset X'24'.

	0 1 2 3 4	
24	A(Dummy Buffer)	IDUB
28	A(First Key Area)	IKSV
2C	A(Second Key Area)	IKST
30	Pointer for LOCATE Requests	IPTR
34	A(ONKEY)	IONK

Data Management Event Control Block

	0 1 2 3 4	
38	A(Data Management Event Control Blocks)	IEVC
3C	A(Request Parameter List) SHOWCB Parameter List	IRPL
40	A(Header)	ISHD
44	A(Element)	ISEL
48	Type Codes	ISTC
4C	A(Block)	ISBL
50	A(User Area)	ISAR
54	Length of User Area	ISLN
58	Element Codes	ISEC
5C	User Area MODCB Parameter List	ISUA
60	A(Header)	IMHD
64	A(Element) Maximum of 3	IMEL
68	A(Element)	
6C	A(Element)	
70	MODDCB Type Codes	IMTC
74	A(Block)	IMBL
78	Not Used	IM2C
7C	Area	IARA
80	Not Used	IM2D
84	Area Length	IARL
88	Not Used	IM30
8C	Key Length	IKYL
90	Not Used	IM34
94	OPT Code	IOPT
98	Not Used	IM35
9C	Record Length	IRCL

Element control entries start at offset X'78' and continue to end of IOCB. Each entry occupies 2 words, with keyword type code set in 1st half-word as follows:

```
IMab=X'00ab'
```

For VSAM files, the IOCB has an associated appendage, comprising the RPL, a dummy buffer if the file has the BUFFERED attribute, and a key save area if the data set is a VSAM KSDS.

Label Data Control Block

Function

Holds the address of the data item and, if a label variable, the address of the associated DSA.

When Generated

Label constants	During compilation
Label variables	When the variable is allocated depending on storage class
Label temporaries	When required for GOTO to label constant

Where Held

Depends on the storage class of the data item.

How Addressed

As a variable.

Label Variable and Label Temporary

```
     0         1         2         3         4
     ┌─┬──────────────────────────────────────┐
   0 │ │   A(Label Constant) Assigned to the  │
     │ │          Label Variable              │
     ├─┼──────────────────────────────────────┤
   4 │ │ A(DSA) at the Time of Assignment of  │
     │ │           Owning Block               │
     └─┴──────────────────────────────────────┘
```

Word 1: bit 0 = 0 Address of label
              = 1 Text reference

Word 2: bit 0 always = 0

Label Constant

```
     0         1         2         3         4
     ┌────────────────────────────────────────┐
   0 │                A(Label)                │
     ├────────────────────────────────────────┤
   4 │ Value to be loaded into Reg. 2 on GOTO │
     │  It becomes the new base register.     │
     └────────────────────────────────────────┘
```

Library Workspace (LWS)

Function

Space reserved for two preformatted DSAs used by certain library modules.

When Generated

The first LWS is generated during program initialization. Subsequent LWSs are allocated before entry to any ON-unit. This is because the ON-unit may require the use of library modules using LWS but must not alter the environment of the interrupt.

Where Held

First allocation in the program management area. Subsequent allocations in the LIFO storage stack. ONCAs are generated with LWS.

How Addressed

From offset X'48' in each DSA.

	0 1	2 3 4	
0	DSA Flags	Offset to the ONCA	LLW0
4	The same back-chain and register save areas that are shown in the DSA (See the DSA Control Block)		
50	56 Byte Workspace		
88	DSA Flags	Offset to the ONCA	LLW1
8C	The same back-chain and register save areas that are shown in the DSA (See the DSA Control Block)		
D8	56 Byte Workspace		
110	Current ONCA (see the ONCA Control Block)		

DSA Flags: These flags are the same as Flag Byte 0 and Flag Byte 1 in the DSA. For further information on these flag bytes and their contents, see "Flags" on page 144.

ON Communications Area (ONCA)

Function

An area in which built-in function values or their addresses are placed, after the occurrence of a PL/I interrupt.

When Generated

The first ONCA is generated during program initialization. Subsequent ONCAs are generated with each allocation of LWS.

Where Held

Contiguous with LWS in the program management area and in the LIFO stack.

How Addressed

By an offset from the current generation of library workspace. The offset is held as a halfword at offset X'2' in LWS.

Dummy ONCA

The dummy ONCA holds default values for the condition built-in functions. These will be supplied if they are requested either when no interrupt has occurred, or when no no interrupt with the requested condition built-in function value has occurred. There is a chain back through all ONCAs to the dummy ONCA.

	0	1	2	3	4
0	Chain Back to Previous ONCA				LOCB
4	ONCODE		Flag LFG1	Not Used	
8	String Locator for ONFILE (8 bytes)				LOFL
10	String Locator for ONCHAR (8 bytes)				LOCH
18	String Locator for ONSOURCE (8 bytes)				LOSC
20	String Locator for ONKEY (8 bytes)				LOKY
28	String Locator for DATAFIELD (8 bytes)				LODF
30	String Locator for ONIDENT (8 bytes)				LOID
38	A(Record I/O EVENT Variable)				LEVT
3C	Pointer for ONATTN				LPAT
40	ONCOUNT				LCNT
44	Retry Environment				LREN
48	Retry Address for Conversion				LRAD
4C	X'40'	X'00000000'		Flag LFG3	
50	LCT1	Retry Codes		Not Used	

Flag (LFG1)

LFOF	Bit 0 = 1	ONFILE valid
LFOC	Bit 1 = 1	ONCHAR/ONSOURCE valid
LFID	Bit 2 = 1	ONIDENT valid
LFKY	Bit 3 = 1	ONKEY valid
LFDF	Bit 4 = 1	DATAFIELD valid
LFEV	Bit 5 = 1	Associate EVENT variable
LFAT	Bit 6 = 1	ONATTN valid
LFCT	Bit 7 = 1	1 ONCOUNT valid

Flag (LFG3)

LFSC	Bit 0 = 1	ONSOURCE or ONCHAR is used in an ON-unit
LFSS	Bit 1 = 1	ONSOURCE set in ONCA
	Bits 2-7	Not used

LCT1: Copy of TCA flag byte 1 (TFB1).

Retry Address (LRAD): The offset from the base of the library module involved to the address where a conversion is attempted again if ONSOURCE or ONCHAR is used.

ON Control Block (ONCB)

Function

Contains pointer to associated ON-unit, or indicates action to be taken when interrupt occurs.

How Addressed

From offset X'60' in the DSA.

When Generated

Static ONCBs are generated during compilation, one for each ON statement. Dynamic ONCBs are generated by the prolog code of the procedure or block in which the ON statement occurs, or are allocated in a VDA when the ON statement is executed.

Where Held

Static ONCBs are generated in the Static internal control section. Dynamic ONCBs are stored in the DSA of the block in which the associated ON-unit occurs.

Static and Dynamic ONCBs

Static ONCBs are generated for unqualified conditions. Dynamic ONCBs are generated for qualified conditions (ENDPAGE, ENDFILE, etc.)

Dynamic ONCB

```
     0         1         2         3         4
    ┌─────────────────────────────────────────┐
  0 │   A(previous dynamic ONCB in block)     │ LDBC
    │          or zero, if first              │
    ├─────────────────────────────────────────┤
  4 │               Qualifier                 │ LDQU
    ├─────────┬─────────┬─────────────────────┤
    │Condition│  Flag   │                     │
  8 │  Code   │ (LDFG)  │      Not Used       │
    ├─────────┴─────────┴─────────────────────┤
  C │                Target                   │ LDTR
    └─────────────────────────────────────────┘
```

Static ONCB

```
     0         1         2         3         4
    ┌─────────┬─────────┬─────────────────────┐
    │Condition│  Flag   │                     │
  0 │  Code   │ (LSFG)  │      Not Used       │
    ├─────────┴─────────┴─────────────────────┤
  4 │                Target                   │ LSTR
    └─────────────────────────────────────────┘
```

Qualifier: A(DCLCB) for I/O conditions A(SYMTAB) for CHECK A(CSECT) for CONDITION condition

Flag (LDFG and LSFG)

LSFO	Bit 0 = 1	SYSTEM specified
LSF1	Bit 1 = 1	Null ON-unit
LSF2	Bit 2 = 1	GOTO only ON-unit
LSF3	Bit 3 = 1	Condition established
LSF4	Bit 4 = 1	Not Used
LSF5	Bit 5 = 1	Enabled at block entry
LSF6	Bit 6 = 1	Condition enabled
LSF7	Bit 7 = 1	SNAP specified

Target: Address of ON-unit, or offset in DSA of word containing A(label variable).

PLIMAIN

Function

Holds address of entry point of main procedure.

When Generated

During compilation of procedures with the MAIN option.

Where Held

A separate control section in the load module.

How Addressed

Address resolved by linkage editor.

```
     0         1         2         3         4
   ┌─────────────────────────────────────────┐
 0 │ VCON(Primary Entry Point to Program)    │
   ├─────────────────────────────────────────┤
 4 │                  Zero                   │
   └─────────────────────────────────────────┘
```

Dummy PLIMAIN: A control section in IBMBPIRA and IBMTPIRA holding addresses of error message module. This control section is link-edited if no compiler generated PLIMAIN exists.

PLISTART Parameter List

Function

Used to pass housekeeping information extracted by compiler to PL/I initialization routines.

When Generated

PLISTART is a CSECT generated by the compiler for every external compilation. The parameter list is part of the PLISTART CSECT.

General Format of PLISTART

PLISTART contains the three standard entry points PLISTART, PLICALLA, and PLICALLB. When entry is made, addressability is established register 0 pointed at the parameter list and a branch made to entry point A,B, or C of the initialization routine from PLISTART, PLICALLA, and PLICALLB respectively.

The format of the parameter list for PLISTART is given below.

Addressed by register 0

	0 1 2	2 3 4	
0	A(PLIMAIN)		ZYMA
4	A(SYSPRINT DCLCB) | zero		ZYSP
8	A(PLIFLOW) | zero		ZYFL
C	A(PLITABS) | zero		ZYTB
10	Total length of PRV		ZYPR
14	Z'FFFF' (ZYV2)	len(PLISTART plist) (ZYBYTES)	
18	Zero in compile object code. A(remote shared library module list) at run time.		ZYAL
1C	A(PLICOUNT) | zero		ZYCT
20	A(PLIXOPT) | zero		ZYXO
24	A(IBMBPOPT) | zero (X'80000000' = end of release 2 marker)		ZYPO
28	A(PLIXHD) | zero		ZYHD
2C	A(IBMBEATA) if INTERRUPT compile-time option used| zero		ZYEA
30	X'80000000' (end of release 3 marker)		ZYLTR3
34	A(Version 2 signature)		ZYSIG

Record Descriptor (RD)

Function

To hold data about the record variable.

When Generated

During Compilation.

Where Held

Static control section.

How Addressed

From an offset from register 3 known to compiled code.

```
     0         1         2         3         4
    ┌───────────────────────────────────────┐
  0 │         A(Record Variable)            │ VRDA
    ├─────────┬─────────────────────────────┤
  4 │  Flag   │ Length of Data to Transmit  │ VRDL
    └─────────┴─────────────────────────────┘
```

Flag (VRDV): These bits indicate the type of INTO or FROM argument as follows:

VRFF	X'00'	For fixed length strings
VRFA	X'01'	For area variables
VRFV	X'02'	For varying length character strings
VRFB	X'03'	For varying length bit strings

Length (VRDL): This field is the length of data to be transmitted (length of variable or buffer for locate mode). The value is in bytes for all strings including bit strings.

For VARYING strings, the value includes the two length bytes, and is the current length for output operations and the maximum length for input operations.

String Locator/Descriptor

Function

Used to pass the address and the length of strings to other routines. Also for handling strings with adjustable lengths for example, DCL STRING CHAR (N)).

When Generated

Storage reserved during compilation. Fields completed during execution if string has adjustable length.

Where Held

Static internal control section.

How Addressed

From an offset from register 3 known to compiled code.

```
    0         1         2          3        4
    +-----------------------------------------+
  0 |         Byte Address of String          |
    +-------------------+-+---------+---------+
  4 | Allocated Length  |F|Not Used |   F2    |
    +-------------------+-+---------+---------+
```

F = '0' B Fixed string (First bit of second byte)

'1' B Varying string

F2: Used for bit strings to hold offset from byte address of first bit in string (3 bits)

Allocated Length

For varying strings this is the declared length. Length is held in bits for bit strings and in bytes for character strings. Length is held in a number of graphics for graphic strings.

String Descriptor

The string descriptor is the second word of the string locator/descriptor. It appears in structure descriptors and in the description field of controlled variables.

Structure Descriptor

Function

Contains information about the offset of each element within a structure, and the nature of each element. Used when passing a structure to another routine, or for accessing structure elements during execution, if the structure is declared with adjustable extents or with the REFER option.

When Generated

If the structure has no adjustable elements, during compilation. If the structure has adjustable elements, during execution from information held in the aggregate descriptor descriptor.

Where Held

Static internal control section.

How Addressed

From an offset from register 3 known to compiled code.

General Format

For each base element in the structure, a fullword field containing the offset of the start of the element from the start of the structure is given. If the base element is a string, area, or array, this fullword is followed by a descriptor, which is followed by the offset field for the next base element. If the base element is *not* a string, array, or area the descriptor field is omitted.

	0 1 2 3 4
0	Element Offset from the Start of the Structure
4	Element Descriptor (if Required)
8	Element Offset from the Start of the Structure
C	Element Descriptor (if Required)
	. . . For every base element in the structure, an entry is made consisting of an offset field and, if the element requires a descriptor, a descriptor.

Offset: The offset field is held in bytes. Any adjustments needed for bit-aligned addresses are held in the respective descriptors.

Symbol Table (SYMTAB)

Function

The symbol table holds the name of an identifier during execution and associates it with the address of that identifier. The identifier may be a variable or a program control constant. The symbol table is used only when you have data directed I/O or the CHECK condition, or specify the TEST(,SYM) compile-time option.

Only base elements have symbol tables. Major and minor structure identifiers do not have symbol tables. Base element symbol table names are usually fully qualified.

When Generated

During compilation, if data-directed I/O, the CHECK condition or the TEST(,SYM) compile-time option is used in the program.

Where Held

Static internal control section for internal names. Separate control section for external names.

How Addressed

By an address constant or by an offset from register 3 for internal data, or by an address generated by the linkage editor for external data.

Long Symbol Table Format

Long symbol tables always start on a word boundary. Blanks pad the end of the table to round the symbol table length to a multiple of 4.

Long symbol tables either have the name length field and name appended to the end of the symbol table or have a fullword address which points to the name length field and name.

	0 1	2	3 4	
0	Flags (VSF1) (VSF2)	Dimensionality (VSDM)	Level Number (VSLV)	
4	A(DED)			VSDD
8	Address Field A			VSFA
C	Address Field B			VSFB
10	Length of Name if bit 15 = '0' (VSLC)			
	Name (Fully Qualified) if bit 15 = '0' (VSNM)			

10	Address of 2-byte name length field and name if bit 15 = '1'	VSNA

Short Symbol Table Format

A short symbol table has only the 2-byte flags, 2-byte name length field and the name field. Short symbol tables always start on a word boundary. Blanks pad the end of the table to round the symbol table length to a multiple of 4.

	0 1	2 3 4	
0	Flags (VSF1) (VSF2)	Length of Name (VSSL)	
	Name (Fully Qualified)		VSSN

Flags: The flags in the program control constant symbol table have changed in OS PL/I Version 2. In OS PL/I Version 1, the flags in a program control constant symbol table are always set to '0800'X. The program control constant is a label or entry point and the symbol table format is short.

Below are the Version 2 flags for program control constants.

Bit	Hex Type and Explanation	
Bits 0, 1 and 2	X'000'B	Static variable or program control constant
	X'001'B	Based variable. Also see bits 12-13.
	X'010'B	Controlled (not parameter) variable
	X'011'B	Defined variable. Also see bits 12-13.
	X'100'B	Automatic variable
	X'101'B	Parameter (not controlled) variable
	X'110'B	Not set by compiler. Used by PLITEST at run-time to flag PLITEST declared variables which are not based.
	X'111'B	Controlled parameter variable
Bit 3	X'1'B	External
	X'0'B	Internal
Bit 4	X'1'B	Item may appear in some CHECK list or CHECK all. Always set to '1'B, if item is EXTERNAL. Always set to '1'B, if item is label or entry constant (maintains compatibility with version 1 short symbol table).
	X'0'B	Item appears in no CHECK list.
Bit 5	X'1'B	Address field A refers directly to data.
	X'0'B	Address field A refers to a locator.
Bit 6	X'1'B	A member of a structure.
	X'0'B	Not a member of a structure.
Bit 7	X'1'B	Long symbol table.
	X'0'B	Short symbol table.
Bit 8	X'1'B	Address field A addresses code.
	X'0'B	Address field A does not addresses code.
Bit 9	X'1'B	Dynamic check enabled.
	X'0'B	Dynamic check not enabled.

Bit 10	X'1'B	Dictionary reference precedes symbol table. Used by Checkout Compiler.
	X'0'B	Always zero for Optimizing Compiler.
Bit 11	X'1'B	Isub defined.
	X'0'B	Isub not defined.
Bit 12 and 13	X'11'B	Optimizing BASED implementation. The symbol table describes both the BASED variable and the based pointer qualification. The address field A, the storage flag bits 0-2, the data/locator flag bit 5 and the level number describe the BASED pointer qualification.
	X'10'B	Optimizing DEFINED implementation. The symbol table describes the DEFINED variable and the base variable on which it is defined.
	X'00'B	Not optimizing implementation. **Note:** Either storage bits 0-2 or these bits 12-13 indicate a BASED or DEFINED variable. If bits 0-2 are used, the symbol table describes only the BASED or DEFINED variable.
Bit 14	X'1'B	Formerly short symbol table, now long symbol table.
	X'0'B	Now short symbol table.
Bit 15	X'1'B	Symbol table points to identifier 2-byte name length field followed by identifier name.
	X'0'B	Symbol table has identifier name length and name appended to end of symbol table.

Note: The Optimizing Compiler never sets Bits 8-11.

Dimensionality: Dimensionality is the number of dimensions declared for an array item. Dimensionality is zero for other items.

Level Number: The level number is the level of the block in which the variable is declared. The level of a block is one greater than the level of the immediately containing block. The level of the external procedure block is 1. The level number is only set for AUTOMATIC, DEFINED, BASED, CONTROLLED parameter, non-CONTROLLED parameter and program control constant. For all others, the number is zero.

When the address field A refers to a DSA offset, the level number accesses the correct DSA. This DSA is either the current DSA or an enclosing block DSA. If you have a GET/PUT DATA or CHECK you may need to use the level number, since the GET/PUT DATA statement or CHECK condition may occur in a different block than that block in which the variables are declared.

For DEFINED and BASED variables, the level number may be the block of the defined base variable or the based pointer qualification rather than the DEFINED or BASED variable.

The level of the "hypothetical" outer outer block surrounding the external procedure is zero.

Address Fields: Addresses for different data types are held in different formats. As far as possible, addresses are held in address field A. However, sometimes more information is required than can be held in a fullword field. When this happens, address field B is used. See the logic description above for how address fields A and B are used by program control constants and variables.

For data types not listed below the address fields are set to zeros.

Address Field A

If STATIC
the address is the address of data or locator for items that have locators.

If AUTOMATIC
the address is the offset within the DSA of the data or offset of the locator for those items that have locators. The correct DSA is indicated by the block level number.

If CONTROLLED
Bytes 0-1 are zeros. Bytes 2-3 have the offset of the PRV. Flag bit 5 is initialized if the controlled variable has a locator or not.

If BASED
the address describes the declared pointer qualifier, not the based variable. The declared pointer qualifier may be automatic, static or non-parameter controlled. If the declared pointer qualifier information is not present, then:

- Field A is set to zeros
- Storage flag bits 0-2 are set to '001'B
- Data/locator flag bit 5 is set to '1'B
- Bits 12-13 are set to '00'B
- The level number refers to the BASED variable.

If PARAMETER
the address is the offset of the one-word field in the DSA containing the address of corresponding argument within the argument list.

The correct DSA is indicated by the block level number. Flag bit 5 indicates whether the argument has a locator or refers directly to the data.

If CONTROLLED parameter
the address is the offset of the one-word field in the DSA containing the PRV offset for the CONTROLLED variable. The correct DSA is indicated by the block level number. Flag bit 5 indicates whether the variable has a locator or refers directly to the data.

If DEFINED
the address is only supported when base variable is static, automatic or parameter.

For DEFINED variables with locators or descriptors (except when the base variable is STATIC EXTERNAL), the address is the offset within the DSA of the locator or locator/descriptor. Flags are marked AUTO with Bit 5 = '0'B.

For DEFINED variables without locators or descriptors, If the base variable is automatic or static, then this address field A describes the base variable, not the DEFINED variable.

If the base variable is a parameter, the address field A has the offset within the DSA to a one-word field with the address of the data. Flags are marked AUTO with Bit 5 = '0'B.

For DEFINED variables with locators or descriptors and defined upon a base STATIC EXTERNAL variable, this address field A describes the STATIC EXTERNAL base variable.

The correct DSA is indicated by the block level number. When locators or descriptors are built for the DEFINED variable, these items are built within the DSA of the same block in which the DEFINED variable is declared.

If CONDITION condition constant
the address of the 1-byte length field is followed by the condition name truncated to 7 characters. This is the same address which passes to the error handler if a SIGNAL CONDITION(...) statement executes within the program.

If file constant
the address is the DCLCB for the file.

If entry constant
the address is the address of the entry point, if resolved. For FETCHable entries, the address is the PRV offset for this fetchable entry point.

If label constant
the address is address of the associated label constant.

Address Field B

If STRUCTURE (not BASED structure)
the address is the offset from the start of the structure descriptor to the fullword field. This fullword field holds the offset of the base element from the start of the structure. Also see "Structure Descriptor."

If BASED STRING, BASED AREA or BASED ARRAY
the address is the address of the descriptor within internal static.

If BASED STRUCTURE
the address is the address of the fullword field within the structure descriptor situated in internal static. This holds the offset of the base element from the start of the structure.

Length: The length field contains the number of bytes in the following name field.

Name: The name field contains the fully or partially qualified name.

In PL/I Version 1 symbol tables, the fully qualified names must be < = 256. If the fully qualified name exceeds 256, message IEL0921 is issued and the name is truncated by eliminating names at the highest structure levels, until a partially qualified name is formed with length < = 256.

In OS PL/I Version 2 GET/PUT DATA or CHECK symbol tables, the symbol table name length must be < = 256 bytes. In OS PL/I Version 2 PLITEST symbol tables, the symbol table name may exceed 256 bytes and is always fully qualified.

Task Communication Area (TCA)

Function

The TCA is the central communication area for the program. It is used to address the error-handling and storage-management routines, and to point to the current segment of dynamic storage.

When Generated

During program initialization by IBMBPIR.

Where Held

In the program management area at the head of the initial segment area (ISA).

How Addressed

From Register 12

	0	1	2	3	4	
-8	"Eye Catcher"					
0	TFB0	TFB1	TFB2	TFB3		TFLG
4	A(PRV or Zero)					TPRV
8	Beginning of Segment Pointer (BOS)					TBOS
C	End of Segment Pointer (EOS)					TEOS
10	DSA next invocation count					TINC
14	A(current event variable)					TEVT
18	A(External Save Area)					TESA
1C	A(TRT Table for errors)					TTRT
20	Task Level					TTIC
24	A(Current Task Variable)					TTSK
28	A(TCA appendage)					TTIA
2C	A(Tasking Appendage)					TTTA
30	A(Save Area for Program Management)					TPSA
34	Open File Chain Anchor					TFOP
38	A(Loaded Module List)					TODL
3C	Unused					TBUG
40	A(Diagnostic File Block)					TDFB
44	PL/I Return Code (TORC)		User Return Code (TURC)			
48	A(Overflow Routine for Get VDA)					TOVV
4C	A(Flow Statement Number Table)					TSFT
50	A(Tab Table)					TTAB
54	A(Flow module)					TEFL
58	A(LPA Module - Region)					TPSR

	0	1	2	3	4
5C	A(LPA Module - LPA)				TPSL
60	A(LPA Module - LPA)				TPSM
64	PRV Initialization Word or Zero				TPRI
68	A(Module List)				TAML
6C	A(Get Dynamic Storage Routine)				TGET
70	A(Free Dynamic Storage Routine)				TFRE
74	A(Overflow Routine for Get DSA)				TOVF
78	A(ON Condition Handler)				TERR
7C	TXAF	Not Used	TRLR	TTLR	TENV
80	Normal GOTO Code Used When GOTO Out of a Block May Occur				TGTC
F0	A(EFCL) / Dummy if No FLOW or COUNT				TEFC
F4	A(Interpretive GOTO Routine)				TGTM
F8	A(Get Control Routine)				TGCL
FC	A(Free Control Routine)				TRCL
100	A(Enqueue SYSPRINT Routine)				TEQR
104	A(Dequeue SYSPRINT Routine)				TDQR
108	A(WAIT Routine)				TAWT
10C	A(COMPLETION Pseudo-variable Routine)				TACP
110	A(EVENT Assign Routine)				TAEA
114	A(Priority Routine)				TAPR
118	A(Enqueue/Dequeue Routines)				TEDR
11C	Reserved for Users				TUSR
120	A(Attention Checking Routine)				TATP
124	A(System Dependant Appendage) Appendage under CICS (Otherwise not Used)				TCIC

Flags (TFLG)

Indicate that an abnormal GOTO out of block may take place. Also indicate that certain special error conditions may arise.

Flag Byte 0 (TFB0)

TTIS	Bit 0 = 1	Subtask TCA
TTTT	Bit 1 = 1	Program may multitask
TTCK	Bit 2 = 1	Reserved for the Checkout Compiler
TTFT	Bit 3 = 1	Eldest task from attaching DSA
ITFD	Bit 4 = 1	Daughter tasks exist
TTKK	Bit 5 = 1	Operating under CICS
TTDB	Bit 6 = 1	Using a data base system
	Bit 7	Not used

Note: This flag byte is the only one in the TCA used by the central task without synchronizing with the subtask. The subtask must never change it. This prevents interference between CPUs on a multiprocessing machine.

Flag Byte 1(TFB1)

TGFD	Bit 0 = 1	At least one daughter task may exist
TGFE	Bit 1 = 1	At least one active EVENT I/O ON-unit
	Bit 2	Not used
TGFS	Bit 3 = 1	Exit routine active SORT
TGNQ	Bit 4 = 1	SYSPRINT enqueue by this task
TGTE	Bit 5 = 1	Task ending
	Bits 6 & 7	Not used

Flag Byte 2 (TFB2)

THQS	Bit 0 = 1	Raise SIZE for fixed-point divide, fixed-point overflow, exponent overflow, or decimal overflow exceptions
THQI	Bit 1 = 1	Ignore fixed-point divide, fixed-point overflow or exponent overflow exceptions
	Bit 2	Not used
THCC	Bit 3 = 1	Fast/Initialization in use
THFN	Bit 4 = 1	Initialized; set to '0'B when an ON FINISH statement is executed.
THQF	Bit 5 = 1	File associated with SIZE
THQR	Bit 6 = 1	Return to caller after normal return from ON-unit
THQC	Bit 7 = 1	I/O conversion

Flag Byte 3 (TFB3)

TMDF	Bit 0 = 1	Dynamic FLOW set on
TPNR	Bit 1 = 1	Prompt not required
	Bit 2	Not used
TNFP	Bit 3 = 1	No floating point instructions
TNOF	Bit 4 = 1	No FLOW for this GOTO
TISN	Bit 5 = 1	Implied SKIP next
TFCT	Bit 6 = 1	COUNT required
	Bit 7	Not used

Flag Byte 4 (TXAF)

TX31	Bit 0 = 1	Entry AMODE(31)
TXESPIE	Bit 1 = 1	ESPIE in use
TXESTAE	Bit 2 = 1	ESTAE in use
TXASYS	Bit 3 = 1	Extended architecture
	Bits 4-7	Not used.

TBOS: The pointer that points the the beginning of the current segment.

TEOS: The pointer that points to the end of the current segment.

TESA: The address of the save area for the calling routine, if IBMBPIR was not called from the control program.

TTRT: The translate-and-test table contains code used in error handling to identify relevant ON-cells.

TPSA: This points to a preformatted DSA reserved for storage management.

TFOP: Used when closing files at the end of a job.

TORC & TURC: A Standard area to keep these codes.

TOVV: Stack overflow routine for FDAs.

TSFT: This is used to address the flow statement table which holds statement numbers for use during execution.

TTAB: The address of a table of tabulator positions used in list-directed output.

TEFL.: The address of the module used to implement the compiler FLOW option.

Shared Library (TPSR, TPSL, & TPSM): Used when accessing PL/I library modules in the link-pack-area.

TPRI: Used to access word set in PRV when files are closed.

Storage Pointers (TGET, TFRE, & TOVF): Entry points to IBMBPGRA that get non-LIFO storage, free non-LIFO storage, and acquire a new segment for LIFO STORAGE

TERR: Address branched to after a software-detected interrupt occurs.

TENV: Identifies release of libraries being used. See also, "Flag Byte 4 (TXAF)" on page 194.

TRLR: The resident library release number.

TTLR: The transient library release number.

TGTC: Whenever a GOTO out of block occurs or could potentially occur because of the value of a label variable, compiled code branches to this code in the TCA.

The function of this code is described under "Handling Flow of Control" on page 32.

TGCL: Routine used in multitasking.

TEQR & TDQR: Library routines used in stream I/O (see Appendix C, "Stream-Oriented Input/Output" on page 241).

TAWT: Address of IBMBJWT, the module used to execute the WAIT statement.

TACP: Address of COMPLETION pseudo-variable module.

TAEA: Address of event assign module.

TAPR: Address of the priority routine.

TEDR: Used for enqueuing and dequeuing files other than SYSPRINT.

TCA Implementation Appendage (TIA)

Function

To hold control and communication information.

When Generated

During program initialization.

Where Held

Program management area. Addressed from offset X'28' in the TCA.

How Addressed

From X'28' in the TCA.

	0	1	2	3	4	
-8	"Eye Catcher"					
0	A(Byte Beyond ISA)					TISA
4	A(Old PICA)/Fake PICA					TAPC
8	A(Interrupt Handler)					TERA
C	Interrupt Mask		Flags1	Flags2		TINM
10	WIT chain anchor					TWTW
14	Anchor for Chain of Exclusive Blocks					TEXF
1C	A(Last Free Element)					TLFE
20	A(Dump Block)					TDUB
24	A(Dummy DSA)					TDDS
28	A(Get LWS Routine)					TLWR
2C	A(Extended Float Simulator)					TASM
30	Two Words for the Name of the Extended Float Simulator					TSNM
38	A(Storage Report Information)					TASR
3C	Chain of Fetched Entry Points					TFEP
40	A(STAE Exit Routine)					TAST
44	A(Housekeeping Interrupt Routine)					TERC
48	A(First Count Table)					TCTF
4C	A(Last Count Table Used)					TCTL
50	Saved A(TCA) for the Error Handler					TATC

<table>
<tr><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>54</td><td colspan="4">A(STAE Block)</td><td>TABD</td></tr>
<tr><td>58</td><td colspan="4">A(PLISTART Parameter List)</td><td>TRPS</td></tr>
<tr><td>5C</td><td>Flags3</td><td colspan="2">Not Used</td><td>Caller's Program Mask</td><td></td></tr>
<tr><td>60</td><td colspan="4">Real EOS (LIFO Stack)</td><td>TXRES</td></tr>
<tr><td>64</td><td colspan="4">ISA Increment Amount</td><td>TXIIC</td></tr>
<tr><td>68</td><td colspan="4">Heap Initial Allocation</td><td>TXHIN</td></tr>
<tr><td>6C</td><td colspan="4">Heap Increment Amount</td><td>TXHIC</td></tr>
<tr><td>70</td><td colspan="4">Heap Initial Address</td><td>TXHAD</td></tr>
<tr><td>74</td><td colspan="4">Heap Storage Chain</td><td>TXBOC</td></tr>
<tr><td>78</td><td colspan="4">Heap Free Chain</td><td>TXLFE</td></tr>
<tr><td>7C</td><td colspan="4">Error Counter</td><td>TERN</td></tr>
</table>

Flags1 (TFL1)

TFLA	Bit 0 = 1	Task terminated normally
TFLS	Bit 1 = 1	SYSPRINT open STREAM print
TFLJ	Bit 2 = 1	STAE exit in progress
TFLK	Bit 3 = 1	Dump I/O in progress
	Bits 4-7	Not used.

Flags2 (TFL2)

TFLD	Bit 0 = 1	Caller provided ISA
TFLR	Bit 1 = 1	Storage report required
TFLT	Bit 2 = 1	STAE required
TFLP	Bit 3 = 1	SPIE required
TFLX.	Bit 4 = 1	Syntax error in program management options
TFLM	Bit 5 = 1	Multiple STAE required
	Bits 6 & 7	Not used

Flags3 (TFL3)

TXHFR	Bit 0 = 1	Free heap segments
TXHBL	Bit 1 = 1	Heap below the 16M line
TXIFR	Bit 2 = 1	Free ISA segments

TXHIT	Bit 3 = 1	Heap initialized
TXHPA	Bit 4 = 1	Heap preallocated
	Bit 5 & 6	Not used
TXNHP	Bit 7	No heap processing

TISA: This holds the address beyond the end of the partition and is necessary because EOS gets altered when non-LIFO dynamic storage is allocated.

TAPC: Used to restore SPIE to that which existed when the PL/I program was called.

TERA: This is the address to which the branch is made after a program check interrupt (see above) has occurred.

Interrupt mask and flags (TINM): Wait information table (WIT) chain header (TWTW):

Start of the chain indication which events are being waited-on in the task.

TEXF: Used when handling exclusive files.

TLFE: Address of last free area of non-LIFO storage on the free area chain. It is used as a starting point when searching the chain.

TDUB: Used when a PLIDUMP is being executed.

TSAM: Used on machines that do not have the extended floating-point instructions to handle extended floating-point data.

TSNM: Used to hold the name of the extended float simulator, so that it can be invoked if required.

TCA Tasking Appendage (TTA)

Function

To hold control and communication information used in multitasking programs.

When Generated

During program initialization.

Where Held

Program Management area.

How Addressed

From X'2C' in the TCA.

	0 1 2 3 4	
0	POST Event Control Block	TPEC
4	Parameter list for Control Task (2 words)	TCTP
8	WAIT Event Control Block	TWEC
10	A(TCB)	TTCB
14	A(ECBLIST Element)	TAEE
18	A(TCA)	TTCA
1C	Not Used	
20	Chain of Sister Tasking Appendages	TSIS
24	Anchor for Subtask Sister Chain	TSUB
28	Anchor for I/O EVENT Chain	TIOE
2C	A(Attaching DSA)	TDSA
30	A(Task Invocation Point)	TALR

Post Codes to Control Task

X'0'	Completion pseudo-variable
X'4'	EVENT assignment
X'8'	PRIORITY pseudo-variable
X'C'	I/O EVENT completion
X'10'	WAIT termination
X'14'	Detach this block
X'18'	Dedicate control task
X'1C'	Liberate control task
X'20'	Attach a task

X'24'	End of task
X'28'	Terminate a subtask
X'2C'	Terminate a subtask

Task Variable (TV)

Function

To hold information about task

When Generated

Depends on storage class

Where Held

Depends on storage class

How Addressed

From offset X'24' in the TCA.

	0	1	2	3
0	KFL0	KFL1	Priority	
4	A(SYMTAB)			
8	A(TCA Tasking Appendages)			
C	A(Calling PROCEDURE)			

Flags

KFL0

KACT	Bit 0 = 1	Active
	Bits 1-7	Not used

KFL1

KDUM	Bit 0 = 1	Dummy
KSTE	Bit 1 = 1	Symbol table exists
	Bits 2-7	Not used

Appendix B. Record-Oriented Input/Output

Introduction

This appendix considers the implementation of the following statements:

- File declarations
- Open and close statements
- READ, WRITE, DELETE, LOCATE, UNLOCK, and REWRITE statements referred to generically as *transmission statements*.

Together, these statements make up record I/O.

The OS PL/I Optimizing Compiler uses the data management routines of MVS to implement record I/O. These routines offer facilities similar but not identical to those of the PL/I language. The data management routines require that:

1. A data control block (DCB) is set up to describe and identify the data set.
2. OPEN and CLOSE macro instructions are issued to open and close the data set.
3. GET, PUT, READ, or WRITE macro instructions are normally issued to store or obtain a new record.

The data management routines transmit the data one block at a time between the data management buffer and the external medium, but each separate macro instruction issued by the program results in only a single record being passed. When a transmission error occurs, or when the end-of-file is reached, the data management routines either set flags indicating the error or branch to error-handling or end-of-file routines that can be specified by the programmer.

The basic method used by the optimizing compiler to implement record I/O is to retain the source program information in a number of control blocks, and to pass these control blocks to PL/I library routines, which interpret the information and carry out the necessary action by calling data management routines in the appropriate manner. The method is summarized below, and shown diagrammatically in Figure 41 on page 204. Figure 55 on page 238 shows the overall scheme in greater detail.

Summary of Record I/O Implementation

File Declarations

For a file declaration, the compiler generates two control blocks: the declare control block (DCLCB) and the environment control block (ENVB). Together, these two control blocks contain a complete record of the file declaration.

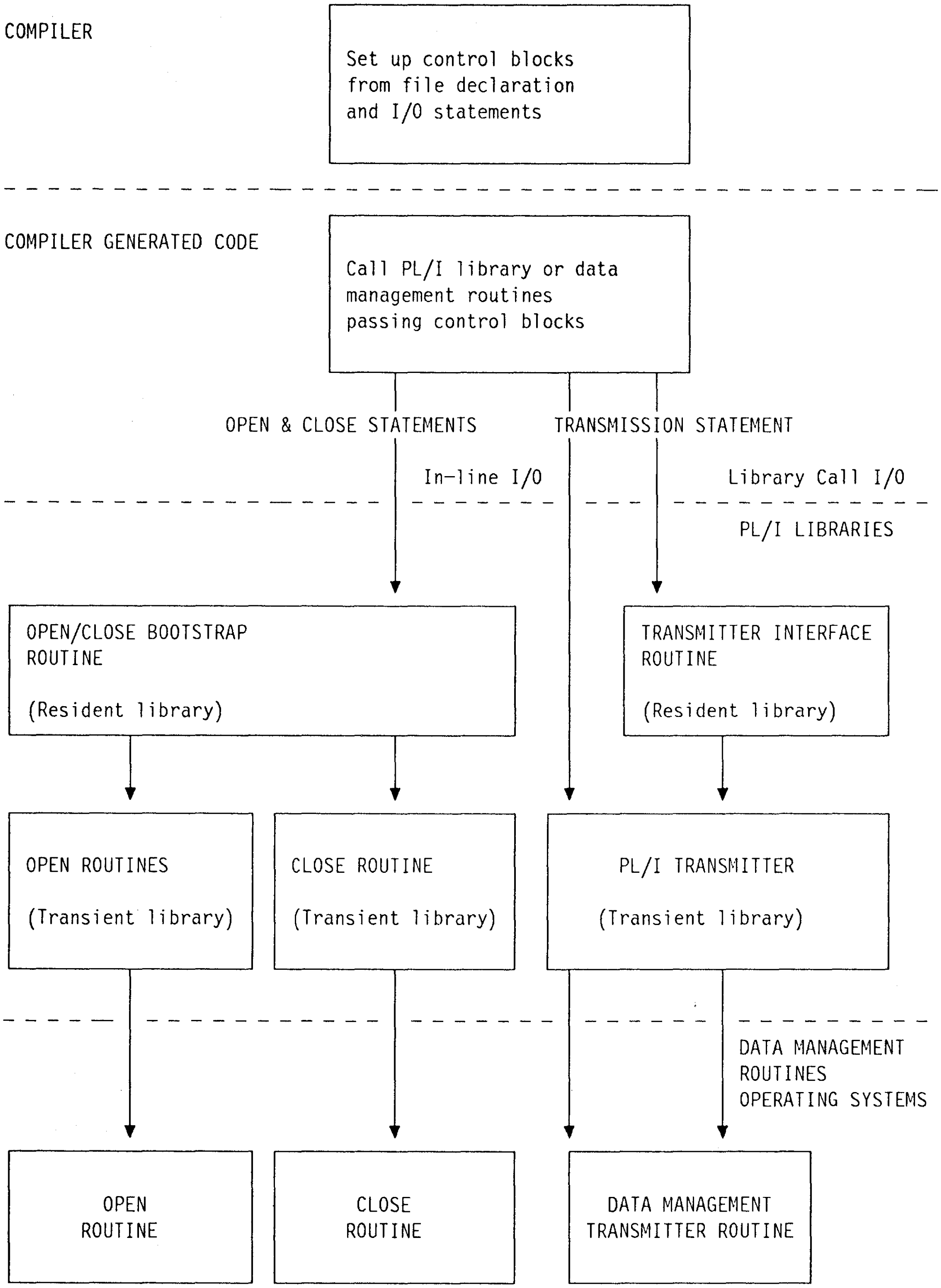


Figure 41. The Principles Used in Record I/O Implementation

OPEN Statements

OPEN statements are compiled as a call to a resident-library bootstrap routine, IBMBOCL, which has passed to it an open control block (OCB) containing the attributes and environment options that have been used in the OPEN statement.

The bootstrap routine loads and calls a number of transient routines that build a definitive control block, known as the *file control block (FCB)*, from information in the DCLCB, ENVB, and OCB. The file is associated with the data set, and the appropriate PL/I transmitter module is loaded.

The FCB is used during the execution of transmission statements to access all file information. It is addressed via the DCLCB and the pseudo-register vector.

Transmission Statements

For the majority of file and statement types, details of statement type, of record, key, and event variables are set up in control blocks during compilation; during execution, these control blocks are passed to a resident-library interface routine, IBMBRIO. IBMBRIO then calls a PL/I transient-library transmitter module, which issues the appropriate data management macro instruction, and checks for errors, before returning control to compiled code. This method is known as *library-call I/O*.

If the TOTAL option is used, the majority of transmission statements on buffered consecutive files are compiled as short calls to the data management routines. This method is known as *in-line I/O*. When using in-line I/O, subroutines of the PL/I transmitters are use to branch directly to the data management routines. When running in an MVS/XA environment, the subroutines set the correct addressing mode (AMODE) for data management. These transmitters are also used for error situations and end-of-file conditions.

The TOTAL option is a method used to inform the compiler that no additional information will be supplied about the file via the DD statement. (That is, that the TOTAL information about the file has been declared.) This allows the compiler to determine whether or not inline I/O statements can be used. The conditions when they are used are described in Figure 56 on page 239 and Figure 57 on page 240.

CLOSE Statements

CLOSE statements are implemented by a call to the open/close bootstrap routine IBMBOCL, which loads and calls the transient close routine IBMBOCA. This routine disassociates the file from the data set, and handles the necessary housekeeping.

Implicit Open

Implicit opening is handled by manipulation of addresses in the file control block (FCB). Any attempt to access the file when it is not open results in control being passed to the open routines in the PL/I libraries. The FCB is mapped in "File Control Block (FCB)" on page 152.

Implicit Close

Implicit closing is handled by the program termination routine checking for open files, and if it finds any, calling the PL/I library routine to close them.

As can be seen from the summary above, a large number of library subroutines and control blocks are used in the implementation of record I/O. These are summarized in two figures: Figure 42 on page 207 for library subroutines and Figure 44 on page 210 for control blocks. More detailed descriptions for each statement type are given below.

RESIDENT LIBRARY MODULES

IBMBOCL	Open/Close bootstrap routine
IBMBRIO	Record I/O interface routine

TRANSIENT LIBRARY MODULES

Open Modules

IBMBOPA	Open error handler
IBMBOPB	Open routine Phase I
IBMBOPC	Open routine Phase II
IBMBOPD	Open routine Phase III
IBMBOPE	Open routine Phase II (VSAM)
IBMBOPZ	Direct output file formatter

Close Module

IBMBOCA	Close module

Transmitter Modules

IBMBRAA	Regional sequential output
IBMBRAB	Regional sequential output
IBMBRAC	Regional sequential output
IBMBRAD	Regional sequential output
IBMBRAE	Regional sequential output
IBMBRAF	Regional sequential output
IBMBRAG	Regional sequential output
IBMBRAH	Regional sequential output
IBMBRAI	Regional sequential output
IBMBRBA	Regional sequential input/update
IBMBRBB	Regional sequential input/update
IBMBRBC	Regional sequential input/update
IBMBRBD	Regional sequential input/update
IBMBRBE	Regional sequential input/update
IBMBRBF	Regional sequential input/update
IBMBRBG	Regional sequential input/update
IBMBRCA	Unbuffered consecutive
IBMBRCB	Unbuffered consecutive
IBMBRCC	Unbuffered consecutive
IBMBRCD	Unbuffered consecutive OMR
IBMBRCE	Unbuffered consecutive associated file
IBMBRDA	Regional direct non-exclusive
IBMBRDB	Regional direct non-exclusive
IBMBRDC	Regional direct non-exclusive
IBMBRDD	Regional direct non-exclusive
IBMBRJA	Indexed sequential input/update
IBMBRJB	Indexed sequential input/update
IBMBRKA	Indexed direct non-exclusive
IBMBRKB	Indexed direct non-exclusive
IBMBRKC	Indexed direct non-exclusive

Figure 42 (Part 1 of 2). Library Subroutines Used in Record I/O

Transmitter Modules (Continued)

IBMBRLA	Indexed sequential output
IBMBRLB	Indexed sequential output
IBMBRQA	Buffered consecutive (non-spanned)
IBMBRQB	Buffered consecutive (non-spanned)
IBMBRQC	Buffered consecutive (non-spanned)
IBMBRQD	Buffered consecutive (non-spanned)
IBMBRQE	Buffered consecutive input (spanned)
IBMBRQF	Buffered consecutive output (spanned)
IBMBRQG	Buffered consecutive update (spanned)
IBMBRQH	Buffered consecutive OMR
IBMBRQI	Buffered consecutive associated file
IBMBRTP	Teleprocessing file input
IBMBRVA	VSAM ESDS transmitter
IBMBRVG	VSAM KSDS sequential output
IBMBRVM	VSAM KSDS other operations and path
IBMBRVI	RRDS
IBMBRXA	Exclusive regional direct update update/input
IBMBRXB	Exclusive regional direct update update/input
IBMBRXC	Exclusive regional direct update update/input
IBMBRXD	Exclusive regional direct update update/input
IBMBRYA	Exclusive indexed direct update update/input
IBMBRYB	Exclusive indexed direct update update/input
IBMBRYC	Exclusive indexed direct update update/input
IBMBRYD	Exclusive indexed direct update update/input
IBMBSOF	Stream output file
IBMBSOU	Stream output file
IBMBSOV	Stream output file
IBMBSTF	Stream output print file
IBMBSTI	Stream input file
IBMBSTU	Stream output print file
IBMBSTV	Stream output print file
IBMCSTI	Stream input file
IBMCSTP	Stream output file

Record I/O Error Modules

IBMBREA	Record I/O error module
IBMBREB	Record I/O error module
IBMBREC	Record I/O error module
IBMBREE	Record I/O error module
IBMBREF	Record endfile module

Figure 42 (Part 2 of 2). Library Subroutines Used in Record I/O

Access Method

The access method used for different PL/I file types is shown in Figure 43.

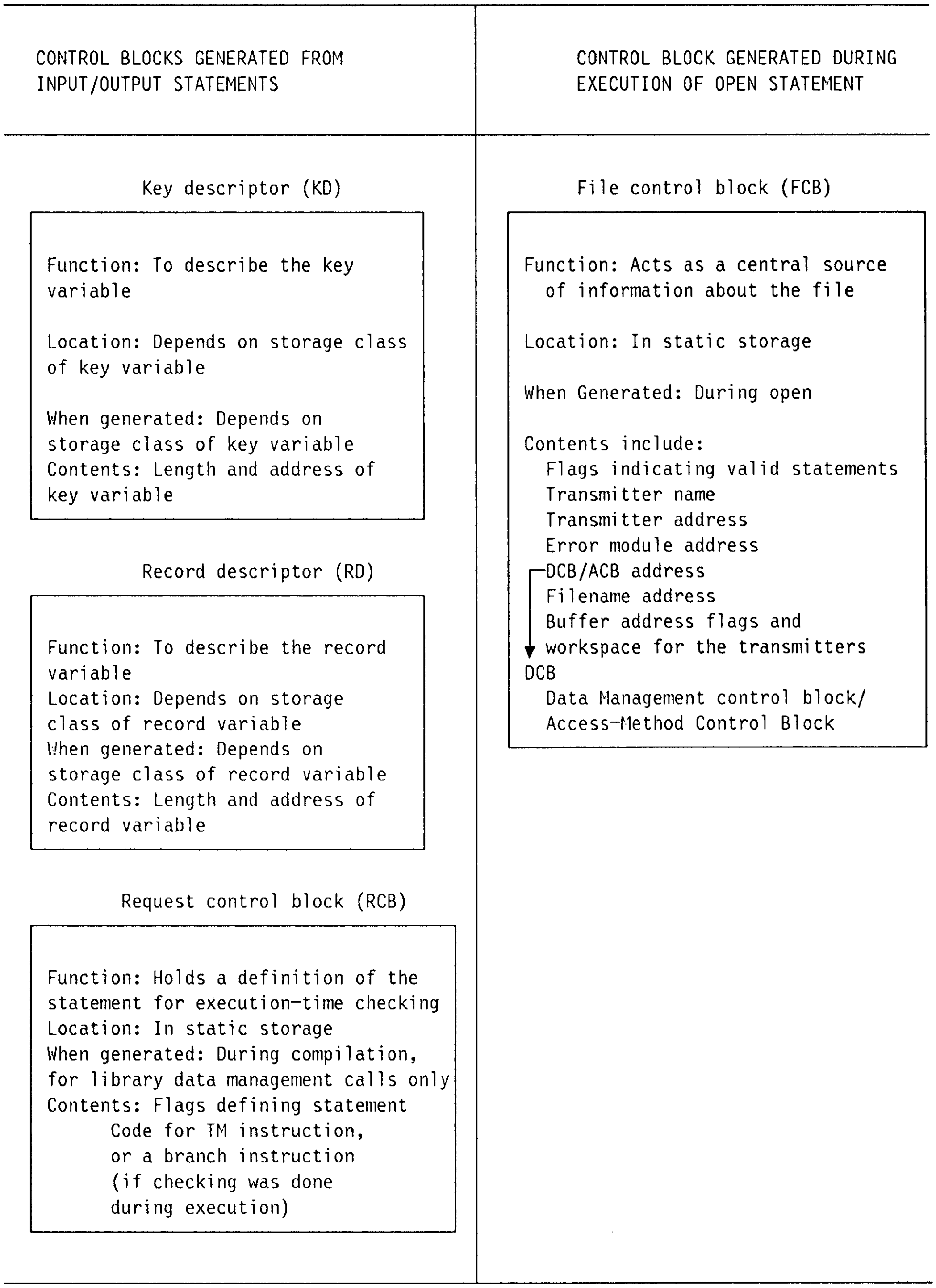
File Type	Access Method
Buffered consecutive	QSAM/VSAM
Unbuffered consecutive	BSAM/VSAM
Regional sequential (not spanned records)	BSAM
Regional sequential (spanned records only)	BDAM
Regional direct	BDAM
Indexed sequential	QISAM/VSAM
Indexed direct	BISAM/VSAM
TP buffered input/update	TCAM
VSAM	VSAM

Figure 43. Access Methods and File Types

Consecutive or indexed files can be used to access VSAM data sets; the PL/I open routines will determine the data type. For details see section on OPEN statement.

CONTROL BLOCKS GENERATED FROM FILE DECLARATION	CONTROL BLOCK GENERATED DURING EXECUTION OF OPEN STATEMENT
DCLCB Function: Holds all file attributes used in file declaration Location: Separate control section for external files, static internal for internal files When generated: During compilation Contents: Record of file attributes at declaration File name Address of ENVB Offset of FCB pointer in PRV	Open control block (OCB) Function: To contain file attributes given in OPEN statement Location: In static storage When generated: During compilation Contents: The attributes when specified on the OPEN statement
Environment control block (ENVB) Function: Holds information on environment options Location: In static storage When generated: During compilation Contents: Addresses of blocksize record length number of buffers KEYLOC value key length indexarea size addbuf	

Figure 44 (Part 1 of 2). The Fields Used in Implementing Record I/O



CONTROL BLOCKS GENERATED FROM INPUT/OUTPUT STATEMENTS

Key descriptor (KD)

Function: To describe the key variable

Location: Depends on storage class of key variable

When generated: Depends on storage class of key variable
Contents: Length and address of key variable

Record descriptor (RD)

Function: To describe the record variable
Location: Depends on storage class of record variable
When generated: Depends on storage class of record variable
Contents: Length and address of record variable

Request control block (RCB)

Function: Holds a definition of the statement for execution-time checking
Location: In static storage
When generated: During compilation, for library data management calls only
Contents: Flags defining statement
Code for TM instruction, or a branch instruction (if checking was done during execution)

CONTROL BLOCK GENERATED DURING EXECUTION OF OPEN STATEMENT

File control block (FCB)

Function: Acts as a central source of information about the file

Location: In static storage

When Generated: During open

Contents include:
Flags indicating valid statements
Transmitter name
Transmitter address
Error module address
DCB/ACB address
Filename address
Buffer address flags and workspace for the transmitters
DCB
Data Management control block/
Access-Method Control Block

Figure 44 (Part 2 of 2). The Fields Used in Implementing Record I/O

File Declaration Statements

For each file declaration, a declare control block (DCLCB) and, optionally, an environment control block (ENVB) are set up. Both are held in static internal storage for internal files, or in a separate control section for external files.

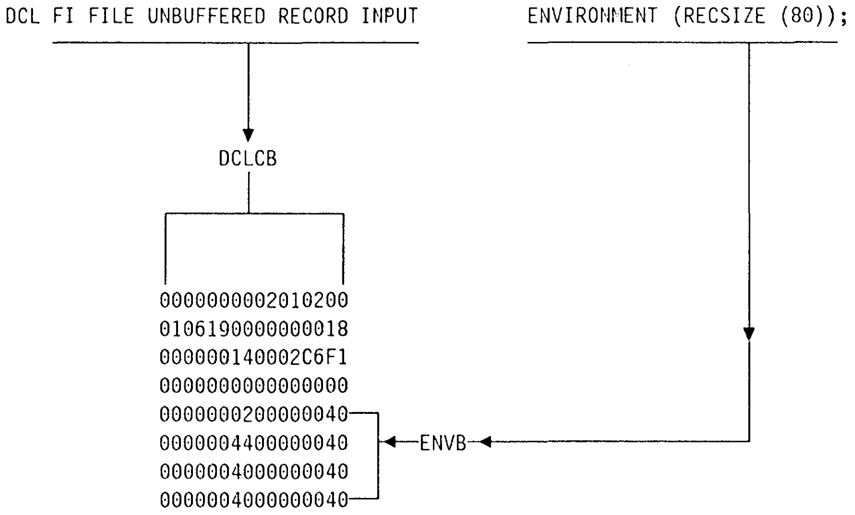
The *DCLCB* is a control block that contains the filename together with a record of the attributes obtainable from the file declaration, both those given explicitly and those deducible by default. This information is retained until the file is opened, when, unless the TOTAL option has been used in the file declaration, the information is merged with any attributes in the OPEN statement.

The *ENVB* contains the addresses of all environment options. The format of the ENVB is shown in "Environment Block (ENVB)" on page 147.

From information in the DCLCB and the ENVB, (and sometimes from the open control block (OCB) produced from the OPEN statement) a further control block, the *file control block (FCB)* is generated. During execution of an I/O statement, all information about the file is derived from the FCB.

Execution

No executable code is produced from the file declaration. Figure 45 shows the code resulting from a file declaration.



```
DCL FI FILE UNBUFFERED RECORD INPUT        ENVIRONMENT (RECSIZE (80));
```

```
0000000002010200
0106190000000018
000000140002C6F1
0000000000000000
0000000200000040
0000004400000040
0000004000000040
0000004000000040
```

Figure 45. Information in the File Declaration Is Held in the ENVB and the DCLCB Until the File Is Opened

OPEN Statement

Compiler Output

For an OPEN statement, the compiler generates a call to the open/close bootstrap routine, IBMBOCL, and an open control block (OCB). The OCB holds any attributes that are declared in the OPEN statement.

More than one file may be passed to the open routines. The last file has its last parameter flagged with its first bit set to '1'.

Execution

For an explicit open, a call is made to the open/close bootstrap routine, IBMBOCL. For each file to be opened, the following information is passed to IBMBOCL:

The address of the DCLCB
The address of the OCB (or zero, if no OCB exists)
The address of the TITLE (or zero, if none is specified)

IBMBOCL has four entry points:

IBMBOCLA explicit open
IBMBOCLB explicit open for library call I/O
IBMBOCLC explicit close
IBMBOCLD implicit close

When called by entry point A, IBMBOCL invokes the transient library open routines to open the file. If the environment option TOTAL has not been used in the file declaration, it will be necessary to determine the attributes of the file by merging the attributes in the file declaration with those used in the OPEN statement. Attributes in the file declaration are held in the ENVB and DCLCB. Attributes used in the OPEN statement are held in the OCB. If the TOTAL option has been used, attributes are taken from the declaration, and any contradictory attributes in the OPEN statement result in the raising of the ERROR condition.

The open modules build an FCB and DCB from the information in the control blocks, initialize the pseudo-register vector to point to the FCB, load the PL/I and data management transmitters, and return to compiled code. File transient open modules are used. Their functions are summarized below.

Actions Carried Out by Transient Open Routines

The transient open routines perform the following major functions when opening a file:

1. Build the file control block (FCB) and data control block (DCB), or, for VSAM the access method control block (ACB) for the file. The FCB is a PL/I control block used to access all file information. The DCB is a data management control block used to describe the data set. The ACB is the equivalent of the DCB for VSAM files.
2. Issue the data management OPEN macro instruction to associate the file with the data set.
3. Obtain and initialize buffers and any other blocks required for the file.

4. Determine which statement types are valid for the file, and store this information as a set of flags held in the FCB.

5. Select the appropriate PL/I transmitter, and load it for use during transmission statements.

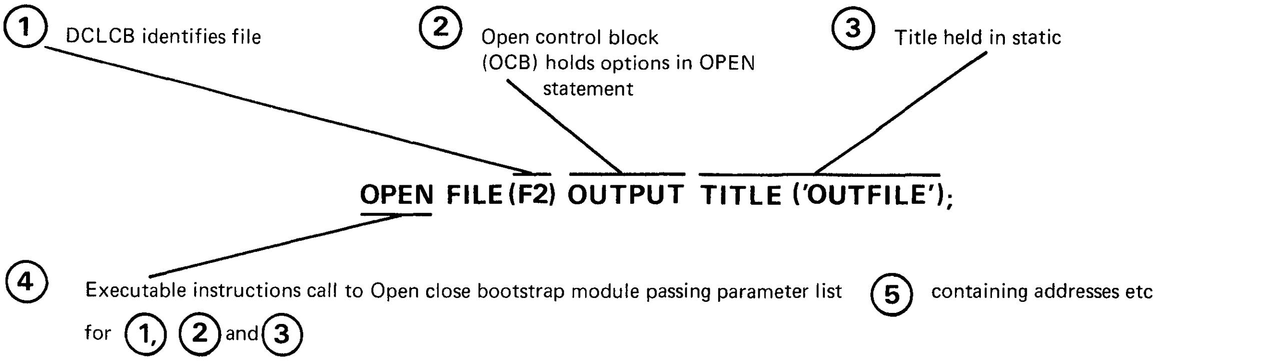
6. Check for errors, and raise the UNDEFINEDFILE condition if any are found.

7. Place the address of the FCB in the correct pseudo-register vector offset.

The execution of an OPEN statement is summarized in Figure 46 on page 215.

VSAM Data Sets

VSAM data sets, both KSDS and ESDS, are normally accessed by PL/I using VSAM macro instructions, however, in certain circumstances the data sets are accessed through the compatibility interface. If the file is declared with ENV (VSAM) the VSAM macro instructions will automatically be used. Even if it is not so declared, the PL/I open modules will normally detect that a VSAM data set is being accessed. To do this they issue an RDJFCB macro instruction. However, this action is not effective if the ALLOCATE command is being used under TSO to provide DD information, because, in this case, the RDJFCB macro instruction cannot determine that a VSAM data set is being accessed. In this situation the compatibility interface will be used. It is possible for the user to force the use of the compatibility interface by specifying either "RECFM" or "OPTCD=L" in the AMP parameter of the DD statement.



(1) DCLCB identifies file

(2) Open control block (OCB) holds options in OPEN statement

(3) Title held in static

OPEN FILE(F2) OUTPUT TITLE ('OUTFILE');

(4) Executable instructions call to Open close bootstrap module passing parameter list (5) containing addresses etc for (1), (2) and (3)

(1) DCLCB set up during file declaration see figure 8.5

(2) Open control block in static. See Appendix A for Format :

```
        000048  0020000000D00800 CONSTANT
                00000000
```

(3) Title (held in static internal) is addressed via locator (also in static internal)

Title

```
        0000A0  D6E4E3C6C9D3C5
```

Locator

```
        000020  000000A000070000
```

(4) Machine Instructions

```
000088 41 10 3 064   LA    1,100(0,3)       Point R1 at P-lists
00008C 58 F0 3 00C   L     15,A..IBMBOCLA }
000090 05 EF         BALR  14, 15         } Branch to open/close bootstrap
```

(5) Parameter list

```
000064 00000044      A..CONSTANT          No. of files to be opened
000068 00000000      A..DCLCB
00006C 00000048      A..CONSTANT          A...OCB
000070 00000020      A..CONSTANT          A...LOCATOR for TITLE
000074 00000000      A..NULL ARGUMENT  }
000078 80000000      A..NULL ARGUMENT  } Used for print files only
```

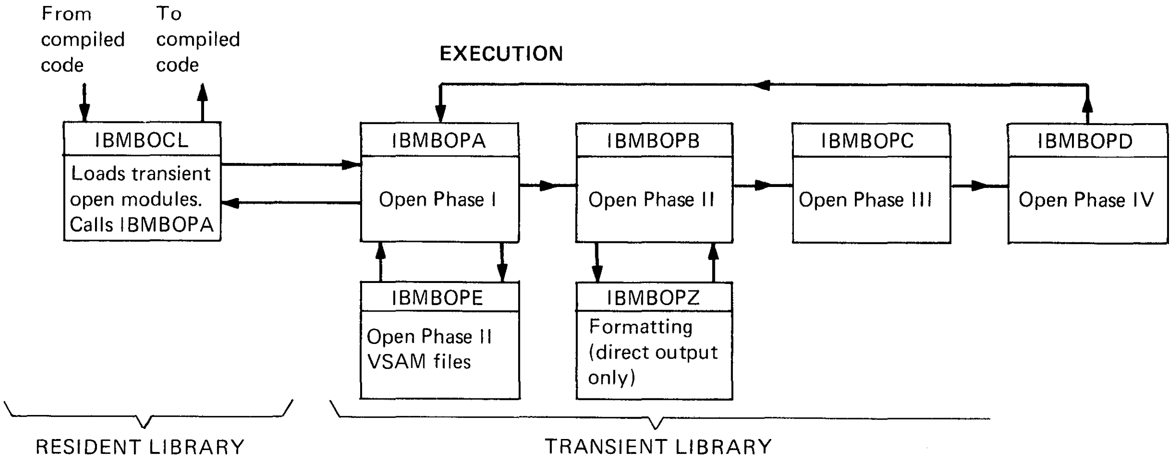


Figure 46. OPEN Statement

The flow through the PL/I open modules is as follows. IBMBOPA scans the list of files to be opened and sets a flag to indicate that IBMBOPE is required for any files declared with ENV (VSAM). If one or more files are found without ENV (VSAM), IBMBOPB is called to open them. Then on return from IBMBOPB, IBMBOPE is called to open any VSAM files. If IBMBOPB detects that any consecutive or indexed files are being used to access VSAM data sets, it will set the flag indicating that IBMBOPE is required and ignore that file. When all the non-VSAM files have been opened, IBMBOPD returns to IBMBOPA. IBMBOPA tests to see whether there are any VSAM files to be opened, and, if there are, calls IBMBOPE.

IBMBOPE opens the files starting with the first. Each file is completely opened before starting to process the next. The open process involves nine main steps, as follows:

1. Merge attributes from OPEN statement with file declaration and check for validity.
2. Get non-LIFO storage space for the FCB and ACB, and create the ACB using the GENCB macro instruction. The DDNAME is obtained from the filename or the TITLE option. The password is obtained from the PASSWORD environment option if specified.
3. Issue an OPEN macro instruction and test the return codes in the ACB.
4. Check the actual values of the RECSIZE, KEYLENGTH, and KEYLOC options against any values specified in the ENVIRONMENT option. Check that NCP/STRNO is not greater than one. If any errors or discrepancies are found, the ACB must be closed.
5. Set up the mask of invalid statements for use by IBMBRIO.
6. Get non-LIFO storage space for the IOCB and RPL, plus key space for a KSDS, and a dummy buffer for a buffered file. Create the RPL using a GENCB macro instruction.

   The OPTCD values are partially set as shown below. The transmitter merges the other options according to statement type. The OPTCD options set are:

KEY/ADR	KSDS/RRDS/ESDS
SEQ/DIR	SEQUENTIAL/DIRECT
KSDS or PATH	INPUT/UPDATE/DIRECT
UPD/NUP	UPDATE/INPUT or OUTPUT
GEN/FKS	GENKEY/not GENKEY

   KEQ, MVE, and SYN are always specified.

7. Load the appropriate library transmitter as follows:

```
ESDS  IBMBRVAA
KSDS SEQUENTIAL OUTPUT
      IBMBRVGA
KSDS SEQUENTIAL INPUT/UPDATE
DIRECT/PATH
      IBMBRVHA
KSDS DIRECT
      IBMBRVIA
```

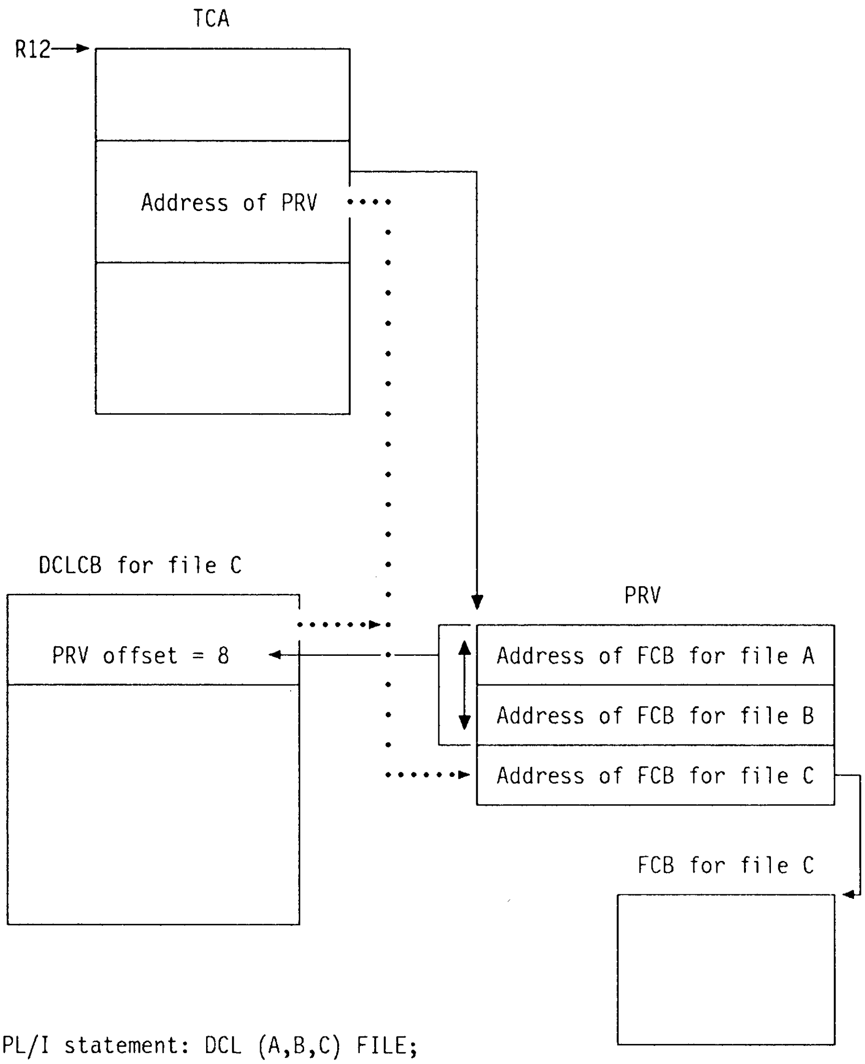
8. Insert "E" as the seventh character of the error module name, so that IBMBREEA will be loaded if an error occurs.

9. Add the FCB address to the chain of open files and set the address of the FCB in the pseudo-register.

The FCB and File Addressing

During execution of record I/O statements, all information about the file is obtained from the FCB. However, as the FCB is not created until execution, the FCB cannot be addressed directly by compiled code. Instead, compiled code obtains from the DCLCB the offset within the PRV at which the FCB address is held. This offset is placed in the DCLCB by the linkage editor. The mechanism is illustrated in Figure 47 on page 218.

The use of the pseudo-register vector allows separately compiled programs to refer to the same FCB for an external file, even though the address of the FCB cannot be known until execution. An explanation of the use of the pseudo-register vector is given in Chapter 3, "Compiler Output" on page 11, under the heading "The Pseudo-Register Vector."


TCA
R12
Address of PRV
DCLCB for file C
PRV offset = 8
PRV
Address of FCB for file A
Address of FCB for file B
Address of FCB for file C
FCB for file C

PL/I statement: DCL (A,B,C) FILE;

The address of the FCB for the file is obtained by adding the offset in the DCLCB to the PRV address which is held in the TCA

Figure 47. Addressing Files Via DCLCB and PRV

Transmission Statements (Library-Call I/O)

Compiler Output

For transmission statements the compiler generates a call to the PL/I transmitter interface module, IBMBRIO. IBMBRIO has the following parameter list passed to it:

Address of DCLCB

Address of request control block (RCB)

Address of record descriptor (RD); *or*,
address ignore factor; *or*,
address at which to set pointer

Address of key descriptor (KD); *or*,
zero if no key descriptor

Address of event variable (EV), *or*,
zero if no event variable

Abnormal locate return address (LOCATE statements only)

The DCLCB is generated from the file declaration, as described earlier in the appendix. The remainder of the control blocks in the parameter list are generated for the transmission statement.

The *request control block (RCB)* defines the statement type. It consists of two words. The first is a fullword of flags that define the statement type and option, indicating whether the statement is READ SET, READ INTO, WRITE FROM, etc. The second word is a test-under-mask (TM) instruction that is executed by IBMBRIO to check whether the statement is valid. The flags in the RCB are tested against flags in the FCB or dummy FCB. If the statement is invalid, a branch is made to an address held in either the FCB or the dummy FCB. If the file is not open, the dummy FCB will be accessed, and the branch will be made to the open/close bootstrap to open the file. If the file is open, a real FCB will be accessed, and the branch will be via a bootstrap to the error handler. The RCB is set up in static internal storage.

The *record descriptor (RD)* contains the address, length and type of the record variable. (The record variable is the variable to or from which the record will be transmitted.) A record descriptor is generated only if a record variable is used. The format is shown in "Record Descriptor (RD)" on page 180.

The *key descriptor (KD)* contains the address and length of the key variable. (The key variable is the variable to or from which the key will be transmitted.) It is generated only if a key variable is used.

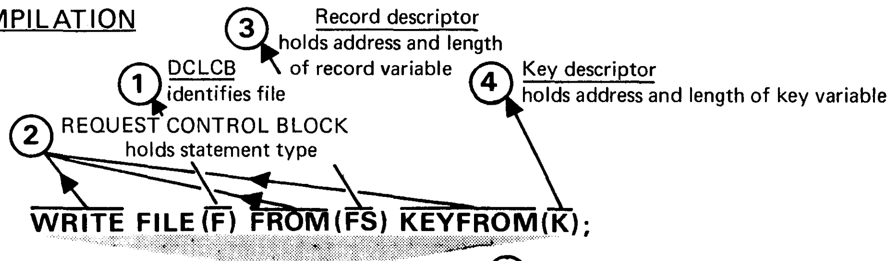
If the record variable or the key variable is STATIC INTERNAL, a complete RD or KD is set up and placed in static internal storage during compilation. In most other circumstances, a skeleton RD or KD will be set up, and will be completed by the inclusion of the address during execution. The completed descriptor may be moved into temporary storage. In certain conditions, no skeleton is produced; instead, the complete descriptor is built in temporary storage by compiled code.

The *event variable (EV)* (if used) contains information about the event that has been associated with the event I/O statement. The implementation of event I/O is covered briefly at the end of this appendix.

The *abnormal locate return block* is used only for LOCATE statements. It is the address of a block containing the address to which control will be passed if an error is detected in a LOCATE statement and a normal return is made after execution of the ON-unit. The abnormal-locate return address is usually the start of the next statement.

The code and control blocks generated for a transmission statement using a library call to the data management routines are shown in Figure 48 on page 221.

COMPILATION



EXECUTABLE INSTRUCTIONS ⑤ are a call to the PL/I library module IBMDRIO

completing and passing PARAMETER LIST ⑥ which holds addresses of 1, 2, 3 and 4.

① DCLCB, set up from file declaration holds address of FCB via pseudo register vector. (See file declaration).

② REQUEST CONTROL BLOCK holds record of statement type

```
  000028  0880200091022001  CONSTANT
```

③ RECORD DESCRIPTOR holds address and length of record, set up as far as possible during compilation, completed during execution. For statement above set up in temporary storage during prologue code

④ KEY DESCRIPTOR holds address and length of key, set up as far as possible during compilation, but, for this statement, completely built by compiled code in temporary storage (see 5).

⑤ Executable instruction

```
* STATEMENT NUMBER 4
000092  41 90  D 0B8     LA     9,184(0,13)       Pick up address record descriptor
000096  50 90  3 084     ST     9,132(0,3)        Place in parameter list
00009A  41 90  D 0B0     LA     9,176(0,13)       Pick up address key descriptor
00009E  50 90  3 088     ST     9,136(0,3)        Place in parameter list
0000A2  41 10  3 07C     LA     1,124(0,3)        Point R1 at parameter list
0000A6  58 F0  3 014     L      15,A..IBMBRIOA
0000AA  05 EF            BALR   14,15             Call IBMBRIO
```

Note: For this statement the record and key descriptors were set up in temporary storage during prologue code.

⑥ PARAMETER LIST passed to IBMBRIO

```
00007C  00000000   A..DCLCB            Filled in by linkage editor
000080  00000028   A..CONSTANT         Request control block
000084  00000000   A..RD               (Record descriptor)
000088  00000000   A..KD               (Key descriptor (built during execution))
00008C  00000000   A..NULL ARGUMENT
000090  80000000   A..NULL ARGUMENT
```

Figure 48 (Part 1 of 2). Handling a Transmission Statement

EXECUTION OF TRANSMISSION STATEMENT

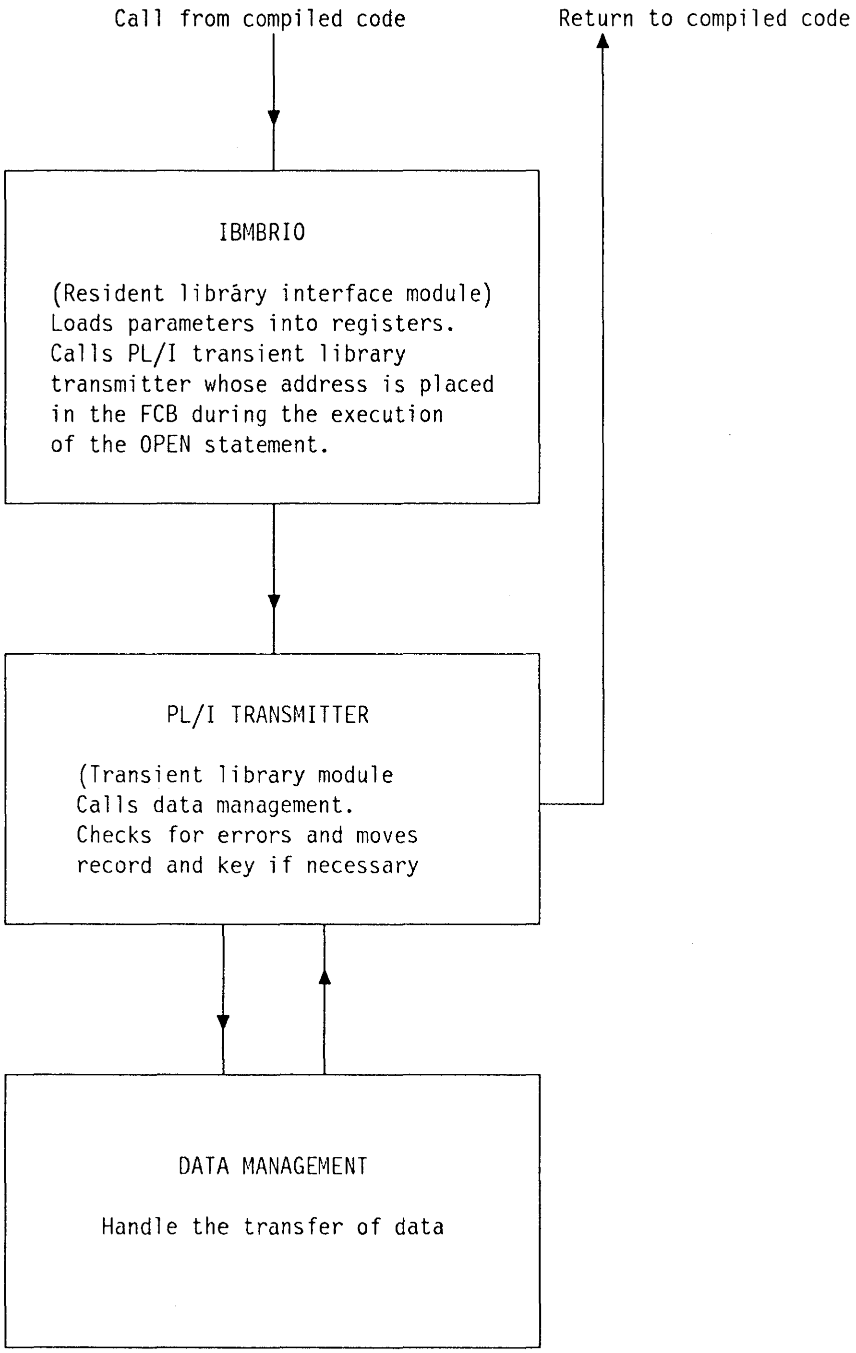

Call from compiled code
Return to compiled code
IBMBRIO
(Resident librâry interface module)
Loads parameters into registers.
Calls PL/I transient library
transmitter whose address is placed
in the FCB during the execution
of the OPEN statement.
PL/I TRANSMITTER
(Transient library module
Calls data management.
Checks for errors and moves
record and key if necessary
DATA MANAGEMENT
Handle the transfer of data

Figure 48 (Part 2 of 2). Handling a Transmission Statement

Execution

Compiled code calls the transmitter interface module, IBMBRIO, passing to it the parameter list shown above under "Compiler Output."

The interface module, IBMBRIO, first acquires a DSA, which is used by IBMBRIO and by the transmitter. It then initializes the registers for the transmitter, and executes the TM instruction in the request control block (RCB). This instruction tests a set of flags that are addressed by a pseudo-register offset contained in the DCLCB. The contents of the pseudo-register offset depends on whether the file is open. If the file is not open, it is opened, and return is made to this point to continue the statement. (See "Implicit Open for Library-Call I/O" on page 229, for further discussion of this topic.)

When the file is open, the TM instruction tests the validity flags in the FCB. This establishes the validity of the statement. If the statement is not valid, a branch is made to the address held in the word in the FCB following the statement validity flags. This address is an entry point in IBMBRIO that calls the error handling module, IBMBERR, with an error code indicating an invalid statement.

If the statement is valid, a branch is made to the transmitter whose address is held in the FCB.

Transmitter Action

After the file is open and the statement validated, control is passed to the transmitter, which checks the record and key variables for errors, and issues the appropriate data management macro instruction. After the data management macro instruction has been executed, control returns to the transmitter. The transmitter moves the data between the data management buffer and the record variable, or sets the pointer to the record, and checks to see whether any errors have occurred.

Transmitter modules do not acquire separate DSAs, but use the DSA acquired by IBMBRIO.

If the statement is valid, control is returned to compiled code. The situation when an error has been detected is described later in this appendix under the heading "Error Conditions in Transmission Statements."

In certain conditions, data management will require a parameter list known as the data event control block (DECB). The PL/I library routines include this block in a PL/I control block known as the input/output control block (IOCB). A number of IOCBs may be used. The number depends on the file type, and on the NCP subparameter in the DD statement or NCP option in the ENVIRONMENT attribute. Depending on the file type, IOCBs may be generated during the execution of the open statement, or by the transmitters when they are required.

The format of the IOCB is shown in "Input/Output Control Block (IOCB)" on page 164. The format of the DECB and a further description of its use is given in the publications *OS/VS2 MVS Data Management Macro Instructions*, or in *MVS/Extended Architecture Data Management Macro Instructions*. IOCBs are further described in the section "EVENT Option," below.

EVENT Option

When the EVENT option is used, transmission statements are always handled by library call. The compiler generates a call to IBMBRIO in the usual manner, except that the address of an event variable is passed in the parameter list.

The associated WAIT statement is compiled as a call to one of the library wait modules. The module called depends on whether or not the program is multitasking. The execution of an I/O statement with the EVENT option and its associated WAIT statement is shown in Figure 49 on page 225.

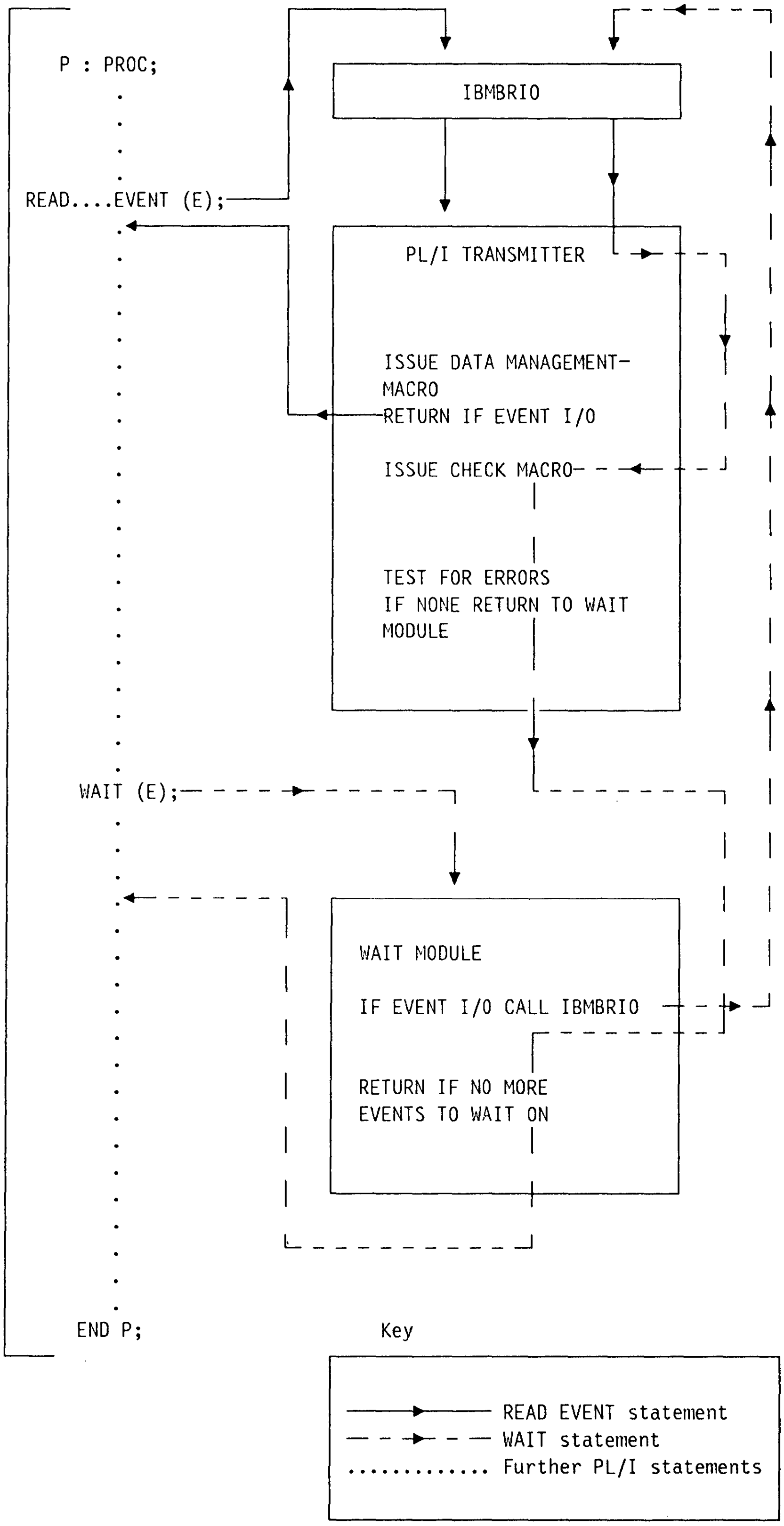


Figure 49. Handling the EVENT Option

Running

The principle used in event I/O is that the PL/I transmitter returns to compiled code as soon as the data management macro instruction has initiated the I/O.

When I/O with the EVENT option is being executed, the event variable associated with the event is set active and flagged to indicate that the event is an I/O event. When the WAIT statement is reached, the library wait module is entered. When the event is an I/O event, the PL/I library wait routine passes control to IBMBRIO. From information in the event variable, IBMBRIO locates the I/O operation associated with the event, and calls the transmitter. The transmitter then issues a CHECK macro instruction, and waits until the operation is complete. When control returns after the CHECK macro instruction, the transmitter assigns the transmitted data, and either returns to the wait module, or, if any errors are detected, enters one of the error routines. (For further details, see "Error Conditions in Transmission Statements" on page 229.)

IOCBs and Dummy Records

In event I/O, the existence of a dummy record may not be discovered until after a read has commenced on the record following the dummy. When this happens, the DECB and IOCB pointers are reset appropriately.

Raising Conditions in Event I/O

Because the CHECK macro instruction is not issued until the WAIT statement is executed, PL/I conditions raised in event I/O are handled during execution of the WAIT statement.

Exclusive I/O

In exclusive I/O, records are protected from simultaneous updates from different tasks by use of the ENQ and DEQ macro instructions.

When a READ statement for an exclusive file is being executed, an ENQ macro instruction is issued. Unless NOLOCK is specified, the DEQ macro instruction is not issued until a REWRITE, DELETE, or UNLOCK statement is executed. For unblocked records, the ENQ and DEQ instructions are issued on one record only. For blocked records, they are issued on the data set.

Eight PL/I transmitter modules are used to handle exclusive files. They are shown in Figure 42 on page 207. The ENQ and DEQ macro instructions are issued by calling the resident library routine IBMBPDQ, which is addressed from the TCA.

The protection of the data set depends on all files that access the data set having the EXCLUSIVE attribute. If the data set is accessed by a file that does not have the EXCLUSIVE attribute, the data set will not be protected.

For VSAM files the EXCLUSIVE attribute is ignored and the NOLOCK option and UNLOCK statement will have no effect (except that for UNLOCK, the key specification is checked.) Data set protection is provided by VSAM itself.

CLOSE Statements and Implicit Close

Compiler Output

For CLOSE statements, the compiler generates a call to the appropriate entry point of the open/close bootstrap module, passing it the addresses of the DCLCB and ENVB for the file.

No compiler action is taken for implicit close.

Execution

Files and data sets can be closed either by the PL/I CLOSE statement or by the termination of the program. In both cases, the close is carried out by library routines. The bootstrap module IBMBOCL is called either by compiled code, or, during program termination, by the termination routine, IBMBPIT or IBMTPJR for multitasking. It loads and calls the transient close routine, IBMBOCA.

The bootstrap routine IBMBOCL is passed a parameter list containing the addresses of the DCLCBs and ENVBs for the files that require closing. IBMBOCA then closes these files. This may involve completing I/O operations, and hence calling the transmitter. After handling any necessary transmission, IBMBOCA disassociates the file from the data set.

The ENVB is required if the LEAVE or REREAD option is in effect.

For implicit closing, the chain of open files starting in the TCA is scanned to determine which files must be closed. The addresses of the FCBs of these files are then passed to the close routine.

For an explicit close, it is necessary to set the address in the pseudo-register vector to point, once more, to the dummy FCB. This allows implicit opening to be handled should the file be opened again. (See "Implicit Open for Library-Call I/O" on page 229 for further details.)

When IBMBOCA has finished, it returns control (via IBMBOCL) either to compiled code (for an explicit close statement) or to the termination routine (for the end of the program). The code and control blocks generated for a CLOSE statement are summarized in Figure 50 on page 228.

(1) DCLCB identifies file to be closed

CLOSE FILE(F2)

(2) Executable instructions consist of a call to the open/close bootstrap module passing parameter list (3)

(1) DCLCB set up for file declaration see figure 8.5

(2) Executable instructions

```
* STATEMENT NUMBER 5
0000AC  41  10  3  094      LA    1,148(0,3)       Place address DCLCB in p-list
0000B0  58  F0  3  010      L     15,A. .IBMBOCLC  } Call open/close toolstrap
0000B4  05  EF              BALR  14,15            }
```

(3) Parameter list

```
000094  00000044   A. .CONSTANT        Address of constant showing number of files to be closed
000098  00000000   A. .DCLCB           Address DCLCB
00009C  80000000   A. .NULL ARGUMENT   Used for disposition options, flagged in first bit to indicate last argument
```

CLOSE FILE(F1);

COMPILATION

```
L      7,F0              Pass address of constant with number of files to be closed
ST     7,2528(0,3)       Pass address of DCLCB of file
LA     1,2524(0,3)       Point R1 at parameter list
L      15,A. .IBMBOCLC   Branch to open/close bootstrap
BALR   14,15
```

EXECUTION

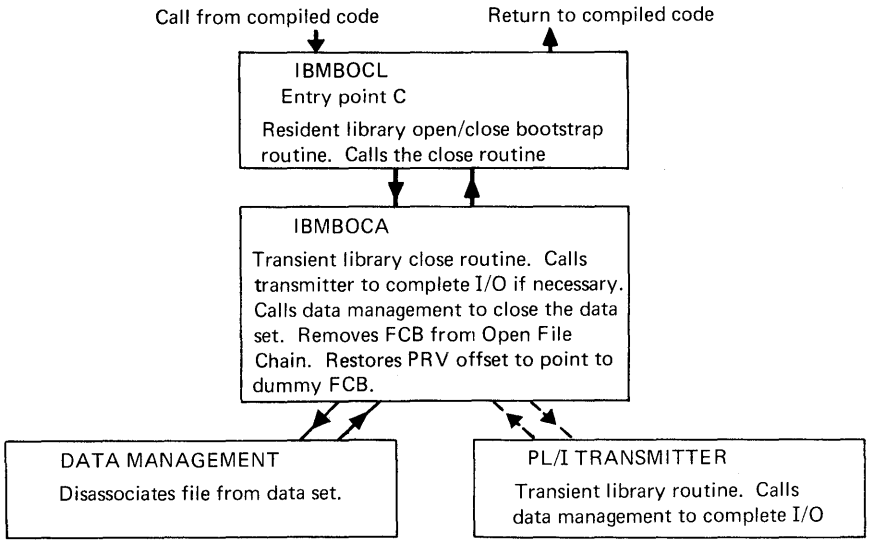

Call from compiled code
Return to compiled code
IBMBOCL
Entry point C
Resident library open/close bootstrap routine. Calls the close routine
IBMBOCA
Transient library close routine. Calls transmitter to complete I/O if necessary. Calls data management to close the data set. Removes FCB from Open File Chain. Restores PRV offset to point to dummy FCB.
DATA MANAGEMENT
Disassociates file from data set.
PL/I TRANSMITTER
Transient library routine. Calls data management to complete I/O

Figure 50. The Execution of an Explicit CLOSE Statement

Implicit Open for Library-Call I/O

Compiler Output

There is *no* compiler output for an implicit open, because it is not always possible to predict which transmission statements will cause implicit opening of a file.

Execution

Implicit opening is handled by manipulation of addresses (see Figure 51 on page 230).

When IBMBRIO is called for a transmission statement, it executes a test-under-mask (TM) instruction against a set of flags held at an offset from the address held in the pseudo-register vector. The address held in the pseudo-register vector depends on whether the file is open. If the file is open, the pseudo-register offset contains the address of the FCB for the file. If the file is not open, the pseudo-register offset contains the address of a dummy FCB in the program management area.

The address is set during program initialization to point to the dummy FCB, and is reset to the dummy FCB whenever a file is closed.

The first word in the dummy FCB is a set of statement validity flags. These are all set to zero. Consequently any TM instruction executed by IBMBRIO will give a negative result. The second word of the dummy FCB is the address of an entry point in the open/close bootstrap module. If the TM instruction yields a negative result, IBMBRIO branches to the address held immediately after the statement validity flags. Consequently when an attempt is made to execute a transmission statement on a file that is not open, control passes automatically to the open routines.

The open routines open the file, and set up an FCB and DCB for the file. The address of the FCB is placed in the pseudo-register offset, and execution of the statement is attempted again by branching once more to IBMBRIO.

Error Conditions in Transmission Statements

To provide PL/I error handling facilities with the minimum possible overhead to error-free programs, transient-library modules are used. These are not loaded unless an error occurs. Two modules are available for every file type except VSAM:

1. The ENDFILE routine, IBMBREF, which can deal only with the ENDFILE condition.
2. A general error module capable of handling all conditions that may arise, including ENDFILE, but loaded only if the TRANSMIT, RECORD, KEY, or ERROR condition occurs. (See Figure 52 on page 231.)

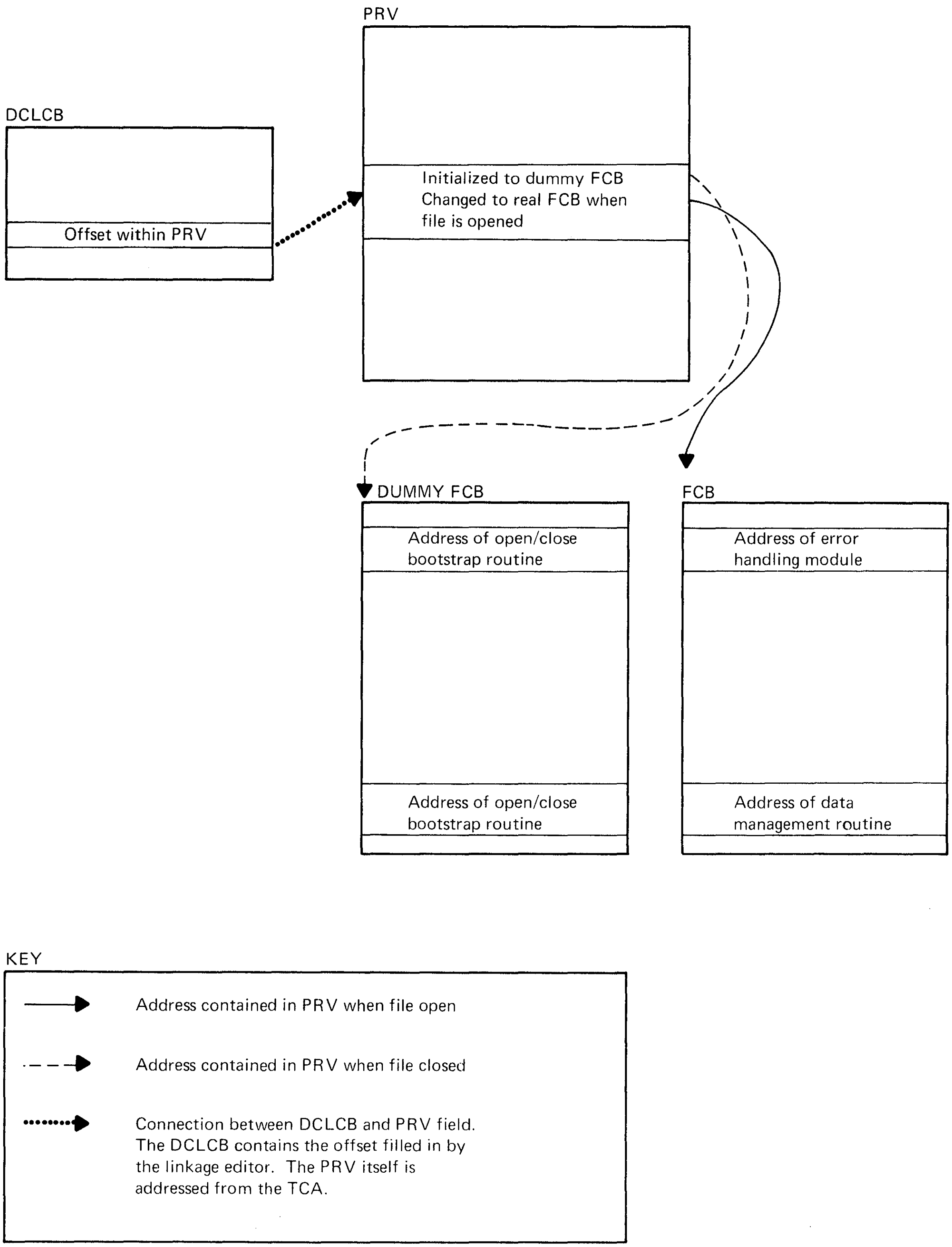


Figure 51. The Addressing Mechanism Used during Implicit Open

Record I/O Error Module	File Types
IBMBREA	Consecutive buffered
IBMBREB	Indexed
IBMBREC	Regional, consecutive unbuffered, and transient
IBMBREE	VSAM
ENDFILE Module IBMBREF	All SEQUENTIAL/INPUT/ UPDATE file types (excluding VSAM)

Figure 52. Record I/O Error Modules

This method is used because the short ENDFILE module gives faster execution to those programs that use the ENDFILE condition to handle program flow. The transient error modules for all file types are identified by the six letters IBMBRE followed by a further single character (see Figure 52).

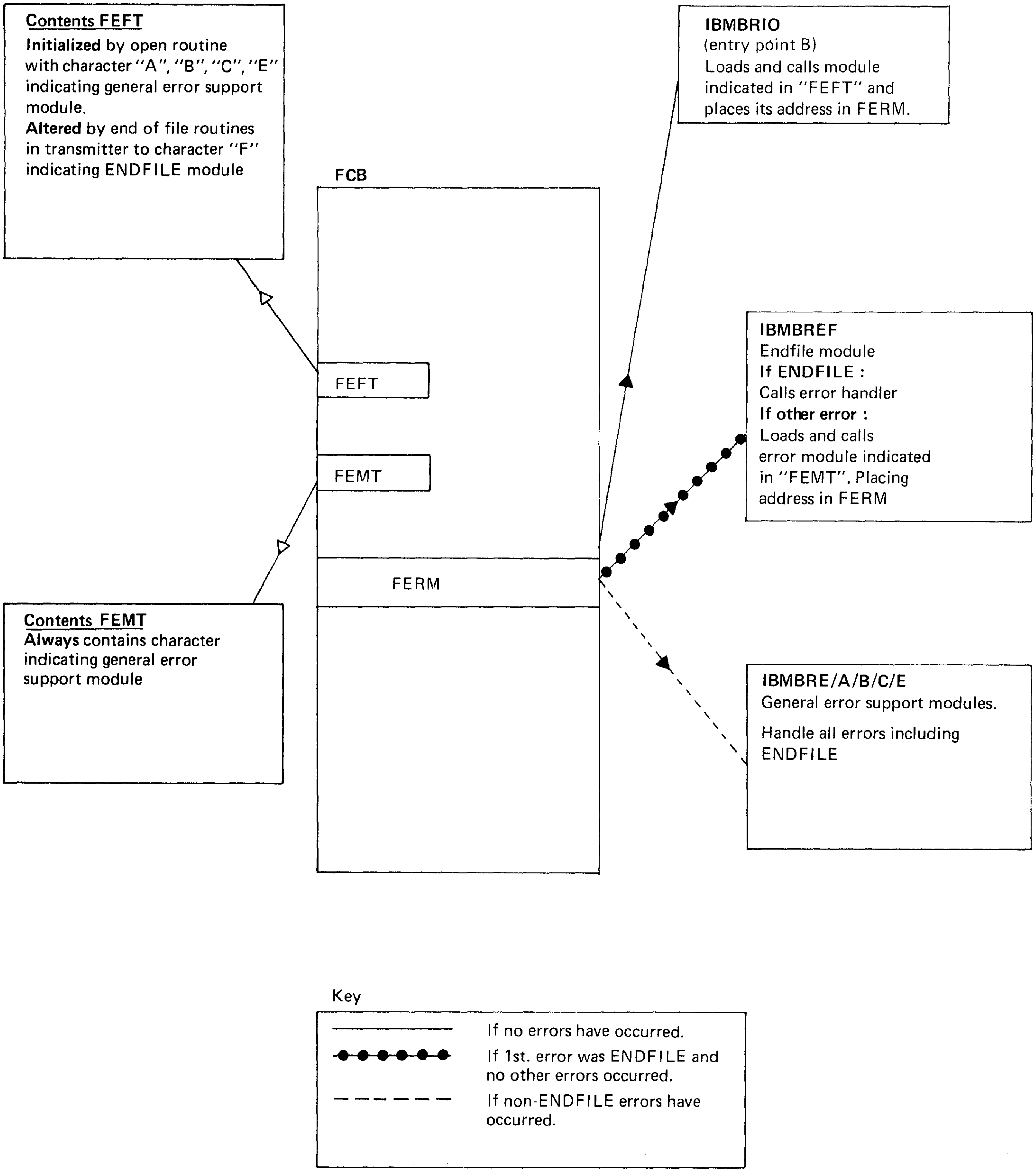
If a transmission error occurs, the transmission error routine within the transmitter will be entered, whether an in-line or library-call statement is being executed. The transmission error routine has been nominated in the SYNAD exit address placed in the DCB by the OPEN routines. Similarly, if end-of-file occurs, the end-of-file routine within the transmitter will be executed. Record and key errors are detected either by the transmitter or by compiled code.

When any of the errors or PL/I conditions mentioned above occurs during the execution of a record I/O statement, control is passed to the address held in the word "FERM" in the FCB. The address may be any one of the following:

- The address of IBMBREF, the ENDFILE module.
- The address of the general error module for the file type.
- The address of a bootstrap routine, IBMBRIOB. This routine constructs the name of an error module by taking the skeleton IBMBRE*A and replacing the "*" by the letter in the single character field "FEFT" in the FCB. IBMBRIO then loads this error module, places the address of the module in FERM, and branches to the module.

So, by changing the contents of the field FEFT, the transmitter can select a particular error module. The contents of FEFT is one of the following:

- A character indicating the name of the general error module for the file type. This character is placed in FEFT during the execution of the OPEN statement.
- The character "F," indicating the name of the ENDFILE module. The contents of FEFT is changed to "F" by the end-of-file routine in the transmitter, which is entered when data management detects end-of-file.



Contents FEFT
Initialized by open routine with character "A", "B", "C", "E" indicating general error support module.
Altered by end of file routines in transmitter to character "F" indicating ENDFILE module

Contents FEMT
Always contains character indicating general error support module

IBMBRIO
(entry point B)
Loads and calls module indicated in "FEFT" and places its address in FERM.

IBMBREF
Endfile module
If ENDFILE :
Calls error handler
If other error :
Loads and calls error module indicated in "FEMT". Placing address in FERM

IBMBRE/A/B/C/E
General error support modules.

Handle all errors including ENDFILE

———————	If no errors have occurred.
●—●—●—●—●—●	If 1st. error was ENDFILE and no other errors occurred.
— — — — — —	If non-ENDFILE errors have occurred.

Figure 53. The Fields Used in Record I/O Error Handling

Thus the module loaded by the bootstrap routine IBMBRIOB, and the address placed in FERM, depend on whether end-of-file or another error is the first to occur on the file.

The result of this arrangement is that the general error module can be called in an end-of-file situation. Similarly, the ENDFILE module can be called when another type of error occurs, if ENDFILE was the first condition to occur. To overcome this problem, the general error module contains code to handle ENDFILE, and the ENDFILE module contains code to test for other conditions, and load and call the general error module if appropriate.

The ENDFILE module constructs the name of the general error module in a similar manner to that used by IBMBRIOB, described above. However, the sixth letter of the name is taken from a field in the FCB called "FEMT". FEMT always holds the character that identifies the general error module for the file. When the name has been constructed, the general module is loaded, its address is placed in FERM, and a branch is made to the module by way of the bootstrap routine in IBMBRIO.

General Error Routines (Transient)

The general error routines set up a parameter list and the relevant built-in function values in the ONCA. They then call the resident error handler IBMBERR to handle the condition. If a normal return is made from an ON-unit, the general error module will raise any further conditions that have occurred by calling IBMBERR with the appropriate error code. After all conditions have been raised, a return is made to compiled code, or, in event I/O, to the wait module.

ENDFILE Routine

The ENDFILE routine checks to ensure that the situation which has resulted in the call is really end-of-file, and, if so, passes control to the error handler.

TRANSMIT Condition

For certain file types, when a permanent transmission error occurs, action must be taken to prevent subsequent issuing of data management macro instructions. To achieve this, addresses are manipulated so that, instead of IBMBRIO calling the transmitter by its primary entry point, it calls an error routine within the transmitter, which in turn calls the error handler to raise the TRANSMIT condition.

In-Line I/O Statements

Most transmission statements on buffered consecutive files are implemented by short in-line calls to the data management routines (see Figure 56 on page 239 and Figure 57 on page 240 for details). Such statements are referred to as "in-line I/O statements." Only READ, WRITE, and LOCATE statements are handled in this way. OPEN and CLOSE statements are always executed by library calls.

Control Blocks

For in-line I/O statements, the only control blocks that are set up are the FCB and DCB. The request control block, record descriptor, and key descriptor are not required as they are merely parameters for full library subroutines.

Executable Instructions

For in-line I/O, a call is made to a special entry in a transmitter. In an MVS/XA environment, this transmitter provides the correct addressing mode and directly calls the data management routine via the address held in the FCB for output files, and in the DCB for input files. In addition to calling the data management routine, compiled code moves the data as necessary to or from the record variable, or sets appropriate pointers. Compiled code may also check for the RECORD condition.

For U-format and V-format records on output files, compiled code does not call data management direct. Instead a call is made to another short call within the PL/I transmitters. These routines are addressed through the field in the FCB that normally addresses the data management routines. This field is initialized by the open routines when U-format or V-format records are used on the file. The compiler can thus produce the same code for all record types.

For certain types of blocked file, unblocking is handled by compiled code. Fields in the DCB hold the address of the current record, the address of the end of the block, and the record length. Before a call is made to data management, a check is made to see whether the end of the block has been reached. This is done by adding the record length to the current record address. If the resultant address is the end of the block, a call is made to data management for a new block; otherwise, the new address can be taken as the start of the required record.

Error Conditions

If an error occurs during transmission, or if end-of-file is reached, the data management routines will branch to the ENDFILE or SYNAD routines that are held in the PL/I transmitter. (The PL/I transmitter is *always* loaded by the open routines.) The ENDFILE and SYNAD routines set an error flag in the FCB, and return to compiled code, normally via the data management routine. If the error flag is on, or if the RECORD condition has occurred, compiled code branches to IBMBRIOD. This results in a call being made to the transient error module.

Typical code produced for an in-line I/O statement is shown in Figure 54 on page 236.

Implicit Open for In-Line Calls

Implicit opening for in-line calls is handled in a similar way to that used for library calls.

The field that, in a normal FCB, points to the data management transmitter, in the dummy FCB points to the open/close bootstrap routine, IBMBOCL (see Figure 51 on page 230). This results in a branch being made to the OPEN routines when an attempt is made to access a file that is not open. When the open routines have been executed, the address in the pseudo-register vector is altered to point to the FCB that has been created for the file.

If the file is successfully opened, a test is made to see whether the entry to IBMBOCL was for an in-line call and, if it was, control is passed to the data management address held in the DCB. This causes the data management module to be entered and a return made to compiled code.

```
         SOURCE STATEMENTS

1        TOTAL: PROC OPTIONS(MAIN);
2  1            DCL LINE FILE RECORD INPUT
                    ENV(FB,RECSIZE(80),BLKSIZE(400),TOTAL);
3  1            DCL CARD CHAR(80);
4  1            READ FILE(LINE) INTO(CARD);
5  1            END TOTAL;
```

```
* STATEMENT NUMBER  4
00005E  18 72                   LR  7,2             Save program base
000060  58 F0 3 024             L   15,36(0,3)      Load R15 address of DCLCB
000064  18 BF                   LR  11,15           Load R11 DCLCB
000066  58 10 C 004             L   1,4(0,12)       Load R1 PRV
00006A  5A 10 B 000             A   1,0(0,11)       Add PRV offset in DCLCB to
                                                      address in R1
00006E  58 20 1 000             L   2,0(0,1)        Point R2 at FCB
000072  58 10 2 014             L   1,20(0,2)       Point R1 at DCB
000076  18 81                   LR  8,1             Load address of DCB
000078  BF 17 8 04D             ICM 1,7,77(8)       Get last record address
00007C  4A 10 8 052             AH  1,82(0,8)       Add logical record length
                                                      to access required record
000080  59 10 8 048             C   1,72(0,8)       Compare with end of buffer
000084  47 40 7 03A             BL  CL.2            Branch around Library call
000088  18 18                   LR  1,8             Restore DCB address if a new
                                                      buffer is required
00008A  41 80 3 028             LA  8,40(0,3)       Pass abnormal return address
                                                      (CL.3) in R8 for error
                                                        handling
00008E  58 F0 2 01C             L     15,28(0,2)    Get short transmitter
000092  05 EF                   BALR  14,15         Branch and link to data
                                                      management routine
000094  47 F0 7 03E             B     CL.4          Don't need next instruction
000098                    CL.2  EQU   *             Label branched to, if no data
                                                      management call
000098  BE 17 8 04D             STCM  1,7,77(8)     Save record address
00009C                    CL.4  EQU   *
00009C  D2 4F D 0B8 1 000       MVC   CARD(80),0(1) Move record into record
                                                        variable
0000A2                    CL.3  EQU   *
0000A2  91 C0 2 02C             TM    44(2),X'C0'   Test for errors
0000A6  47 80 7 052             BZ    CL.5          Branch if no errors
0000AA  58 F0 3 01C             L     15,A..IBMBRIOD If errors, call error
                                                      bootstrap routine
0000AE  05 EF                   BALR  14,15
0000B0                    CL.5  EQU   *
0000B0  18 27                   LR    2,7           Restore Program Base
```

Figure 54. In-Line I/O Transmission Statement

A further problem arises over deblocking. For certain blocked files, before data management is called, a test is made to see whether the end of the block has been reached. For such files, values are placed in the dummy FCB that ensure that if the test for end-of-block is made before the file has been opened, the test will reveal an apparent end-of-block. A branch will therefore be made to the transmitter field in the dummy FCB, and control will pass to the open/close bootstrap routine.

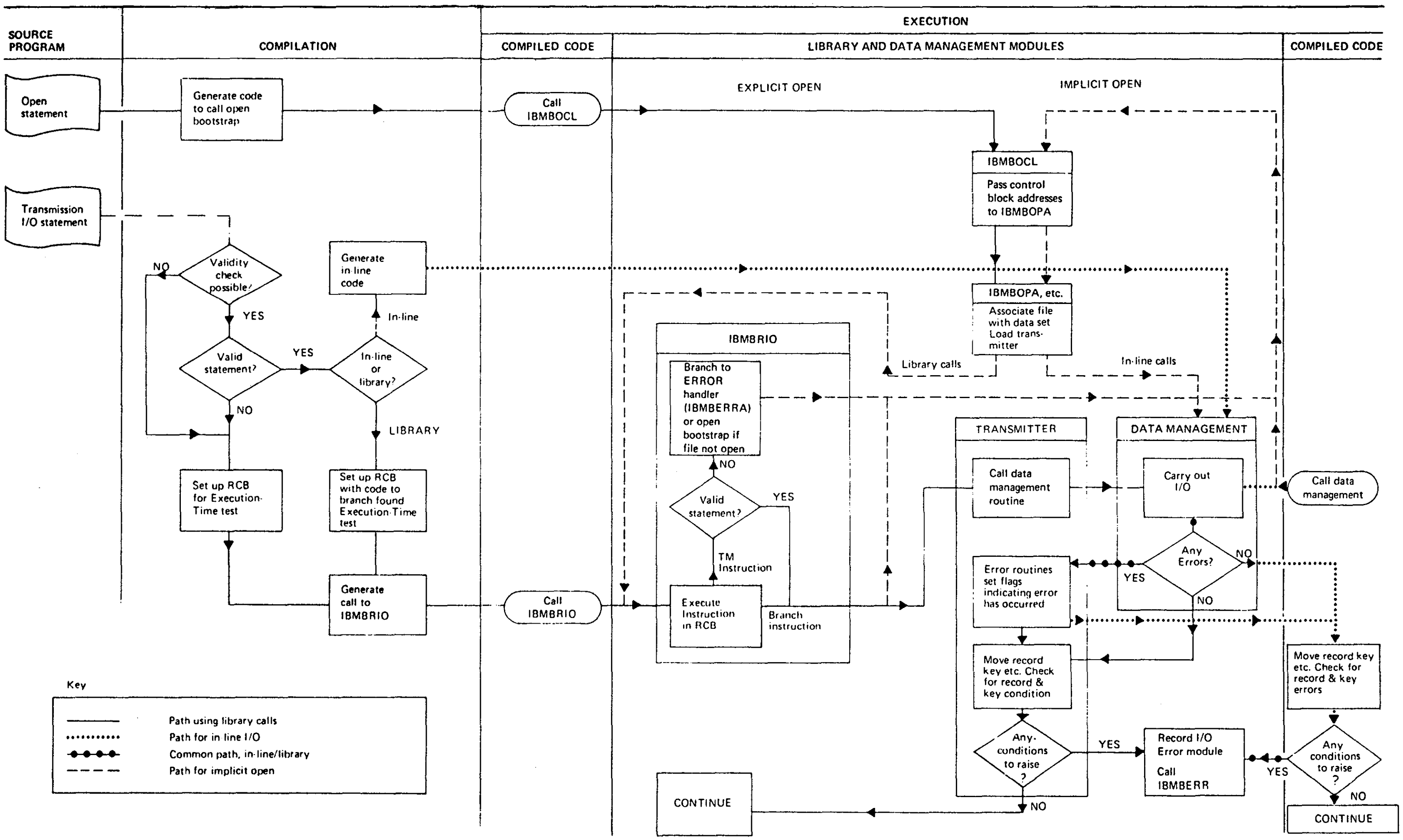

SOURCE PROGRAM
COMPILATION
EXECUTION
COMPILED CODE
LIBRARY AND DATA MANAGEMENT MODULES
COMPILED CODE
Open statement
Generate code to call open bootstrap
Call IBMBOCL
EXPLICIT OPEN
IMPLICIT OPEN
IBMBOCL
Pass control block addresses to IBMBOPA
Transmission I/O statement
Validity check possible?
NO
YES
Generate in-line code
In-line
Valid statement?
YES
In-line or library?
NO
LIBRARY
IBMBOPA, etc.
Associate file with data set Load transmitter
Library calls
In-line calls
IBMBRIO
Branch to ERROR handler (IBMBERRA) or open bootstrap if file not open
NO
Valid statement?
YES
TM Instruction
Execute Instruction in RCB
Branch instruction
Set up RCB for Execution-Time test
Set up RCB with code to branch found Execution-Time test
Generate call to IBMBRIO
Call IBMBRIO
TRANSMITTER
DATA MANAGEMENT
Call data management routine
Carry out I/O
Call data management
Any Errors?
YES
NO
NO
Error routines set flags indicating error has occurred
Move record key etc. Check for record & key condition
Move record key etc. Check for record & key errors
Any conditions to raise ?
YES
NO
Record I/O Error module
Call IBMBERR
YES
Any conditions to raise ?
NO
CONTINUE
CONTINUE
Key
Path using library calls
Path for in line I/O
Common path, in-line/library
Path for implicit open

Figure 55. Overview of Record I/O

Statement for Record Types F and FB	**Record Variable Requirements**	**ENVIRONMENT Option Requirements**
READ SET	None	None
READ INTO	Length known at compile time (max. length if a varying string or area[1])	RECSIZE known at compile time SCALARVARYING option if varying string
WRITE FROM (fixed string)	Length known at compile time	RECSIZE known at compile time
WRITE FROM (varying string)		RECSIZE known at compile time SCALARVARYING option used
WRITE FROM Area[1]		RECSIZE known at compile time
LOCATE A	Length known at compile time (max. length if varying string or area[1])	RECSIZE known at compile time SCALARVARYING if varying string

Figure 56. Conditions Under Which I/O Statements Are Handled In-Line for Record Types F and FB

[1] Including structures whose last element is an unsubscripted area.

Notes to Figure 56 :

- File type is consecutive buffered with the TOTAL option used.
- All statements must be found to be valid during compilation. File parameters or file variables are *never* handled by in-line code.
- BLKSIZE may be specified instead of RECSIZE for F, V, and U formats (but not FB, VB).

Statement for Record Types U, V and VB	**Record Variable Requirements**	**ENVIRONMENT Option Requirements**
READ SET	None	Not BACKWARDS
READ INTO	Length known at compile time (max. length if a varying string or area[1])	RECSIZE known at compile time SCALARVARYING option if varying string
WRITE FROM (fixed string)	Length known at compile time	RECSIZE known at compile time
WRITE FROM (varying string)		RECSIZE known at compile time SCALARVARYING option used
WRITE FROM Area[1]		RECSIZE known at compile time
LOCATE	Length known at compile time (max. length if varying string or area[1])	RECSIZE known at compile time SCALARVARYING if varying string

Figure 57. Conditions Under Which I/O Statements Are Handled In-Line for Record Types U, V, and VB

[1] Including structures whose last element is an unsubscripted area.

Notes to Figure 57 :

- File type is consecutive buffered with the TOTAL option used.
- All statements must be found to be valid during compilation. File parameters or file variables are *never* handled by in-line code.
- BLKSIZE may be specified instead of RECSIZE for F, V, and U formats (but not FB, VB).

Appendix C. Stream-Oriented Input/Output

Note on Terminology

In this appendix, the terms *source* and *target* are used when referring to transfer of data. The *source* is the point from which the data is taken; the *target* is the point to which it is moved, possibly in a converted format.

Introduction

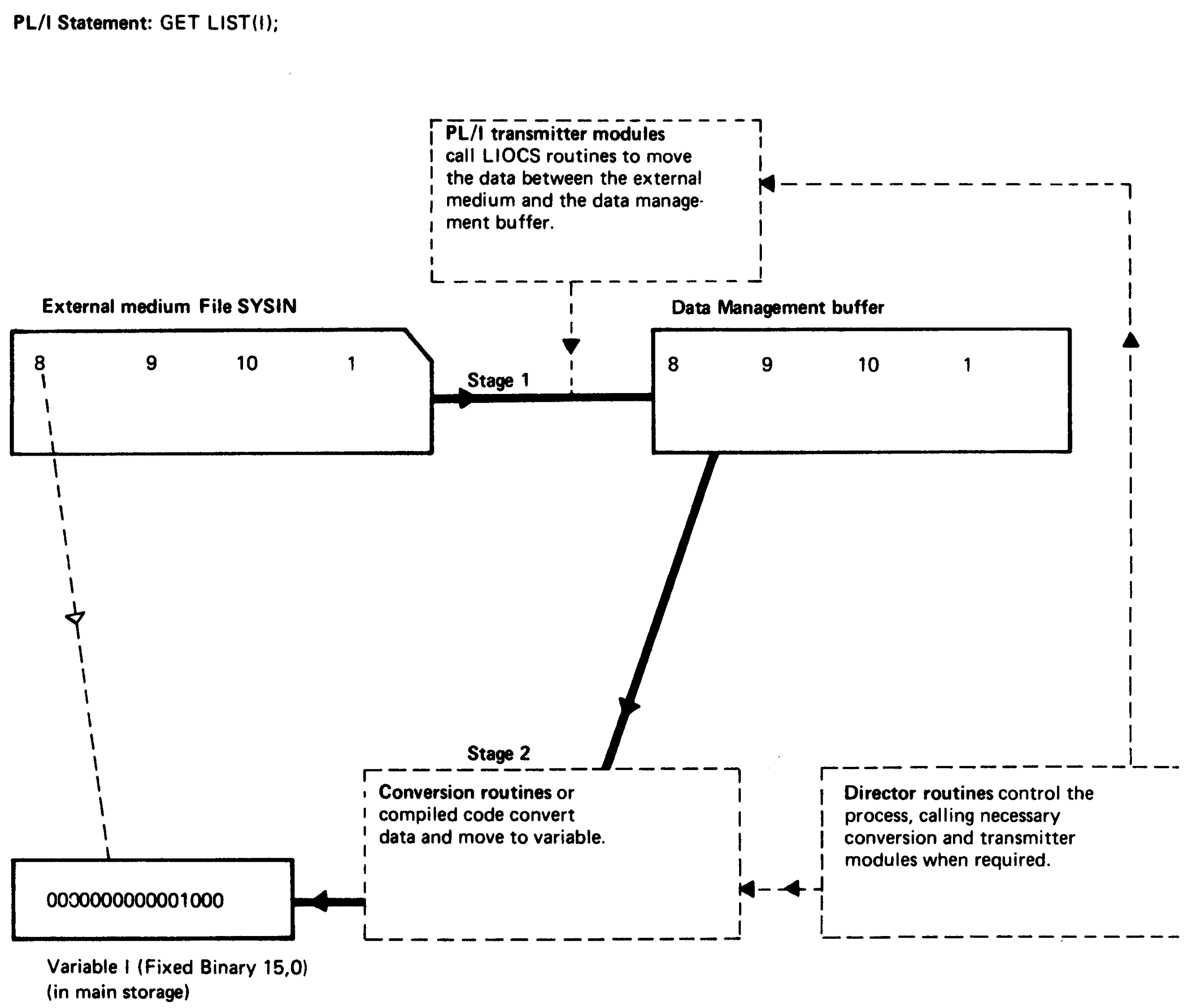
PL/I stream-oriented input/output allows the programmer to move data between a PL/I variable and an external medium without any concern about internal and external data types or any attention to record boundaries (with the exception of GRAPHIC files). Both conversion and record boundary problems are handled automatically.

Note: For stream file use in graphic files, see DBCS continuation rules.

Although it appears to the programmer that the data is moved directly between the external medium and the PL/I variable, the move is, in fact, a two stage process, as shown in Figure 58 on page 242. In the first stage, the data is moved to a data management buffer. In the second stage, it is moved from the buffer to the target. When the data is moved to or from an external medium, a complete record is always moved. When the data is moved to or from a PL/I variable, only as much data as is contained in the variable is moved. The amount of data moved in the one stage need bear no relation to the amount moved in the other. Thus synchronization of the two stages is the principal job in implementing stream I/O.

Transmission between the buffer and the external medium is handled by the routines of OS data management. These routines are called by the PL/I transient library transmitters in the same way as that used in library-called record I/O. The movement between the buffer and the PL/I variables is generally handled by the PL/I conversion routines. The transmitters and the conversion routines are called by *director routines*. These routines determine which modules are required, and when they are needed.

Data items transmitted by stream I/O are not affected by record boundaries (see Figure 59 on page 243). There may be any number of data items in a record, and an item may span any number of records. Because the data management routines make only one record available to the program at any one time, a method is needed to build up complete items if they span the record boundary. Similarly, because GET and PUT statements may read or write less than a complete record, a method is needed of keeping track of the position reached in the record, so that the next GET or PUT can start from the correct position.


PL/I Statement: GET LIST(I);
PL/I transmitter modules call LIOCS routines to move the data between the external medium and the data management buffer.
External medium File SYSIN
8 9 10 1
Stage 1
Data Management buffer
8 9 10 1
Stage 2
Conversion routines or compiled code convert data and move to variable.
Director routines control the process, calling necessary conversion and transmitter modules when required.
0000000000001000
Variable I (Fixed Binary 15,0) (in main storage)

Stream input/output is a two stage process. The data is moved between the external medium and the data management buffer, and between the buffer and the variable. Any necessary conversions are made between the buffer and the variable. The operation is controlled by director modules. The director modules call the appropriate routines to do the transmission and conversion. Transmission is carried out in a similar way to that used for RECORD I/O.

Note that a further input statement will require the value 9 which is already in the data management buffer. *Consequently the transmitter need not be called and a pointer must be kept to the position reached in the buffer.*

Figure 58. The Principles Used in Stream I/O

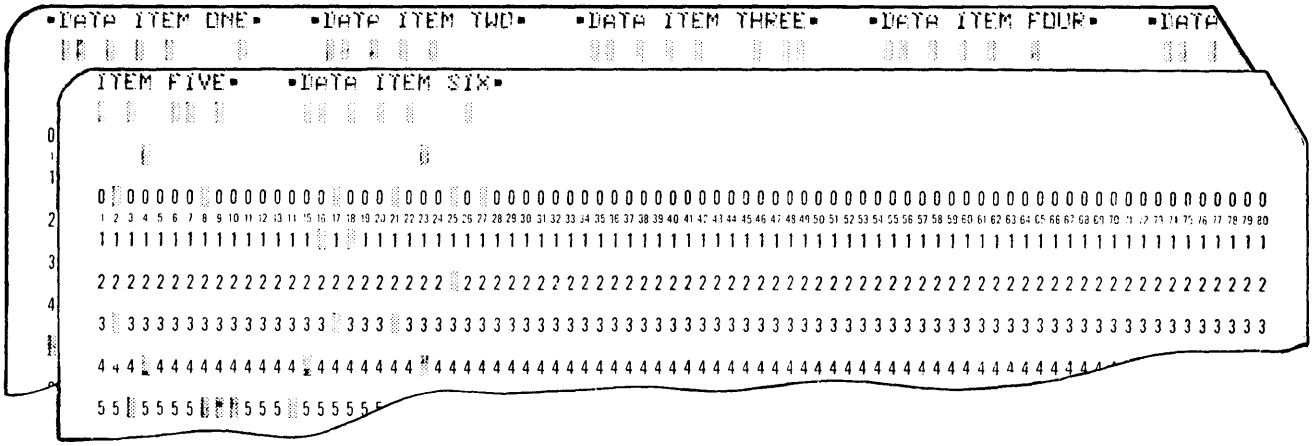


Figure 59. Record Boundaries Do Not Affect Stream I/O

Operations in a Stream I/O Statement

A stream I/O operation can involve any or all of the following operations:

1. Opening the file, and raising the ERROR condition if the statement is invalid.
2. Keeping track of the position in the buffer.
3. Calling the transmitter for a new record.
4. Building in intermediate workspace an item too large to be held in the current record.
5. Determining which conversion is required, and calling the routine to carry out the conversion.
6. Enqueuing and dequeuing on SYSPRINT.

Control of operations (2) through (5) is handled by *director routines*. For list-directed and data-directed I/O, PL/I library director routines are used. For edit-directed I/O, the job is shared between library routines, compiler-generated subroutines, and compiled code.

Before the director module or director code receives control, an initialization/termination module is called. This module handles item 1 in the list above: checking statement validity, and opening the file if it is not already open. The initialization/termination routine is also called when every PUT statement is completed, to dequeue on SYSPRINT and, for conversational files, to complete the output. The routine is also called on the completion of GET statements with the COPY option, to transmit the data to the copy file.

Because there are three modes of stream I/O, the exact situation cannot be defined in a generalized discussion or diagram. However, the basic principles are shown in Figure 60 on page 245. The sequence is:

1. A call to the initialization module, to check statement validity, and to open the file if necessary.
2. A return to compiled code, to set up parameters for the director module.
3. A call to the director module to handle any conversion, transmission, and housekeeping problems that may be involved.
4. For PUT statements, a terminating call to the initialization/ termination routine to dequeue on SYSPRINT.

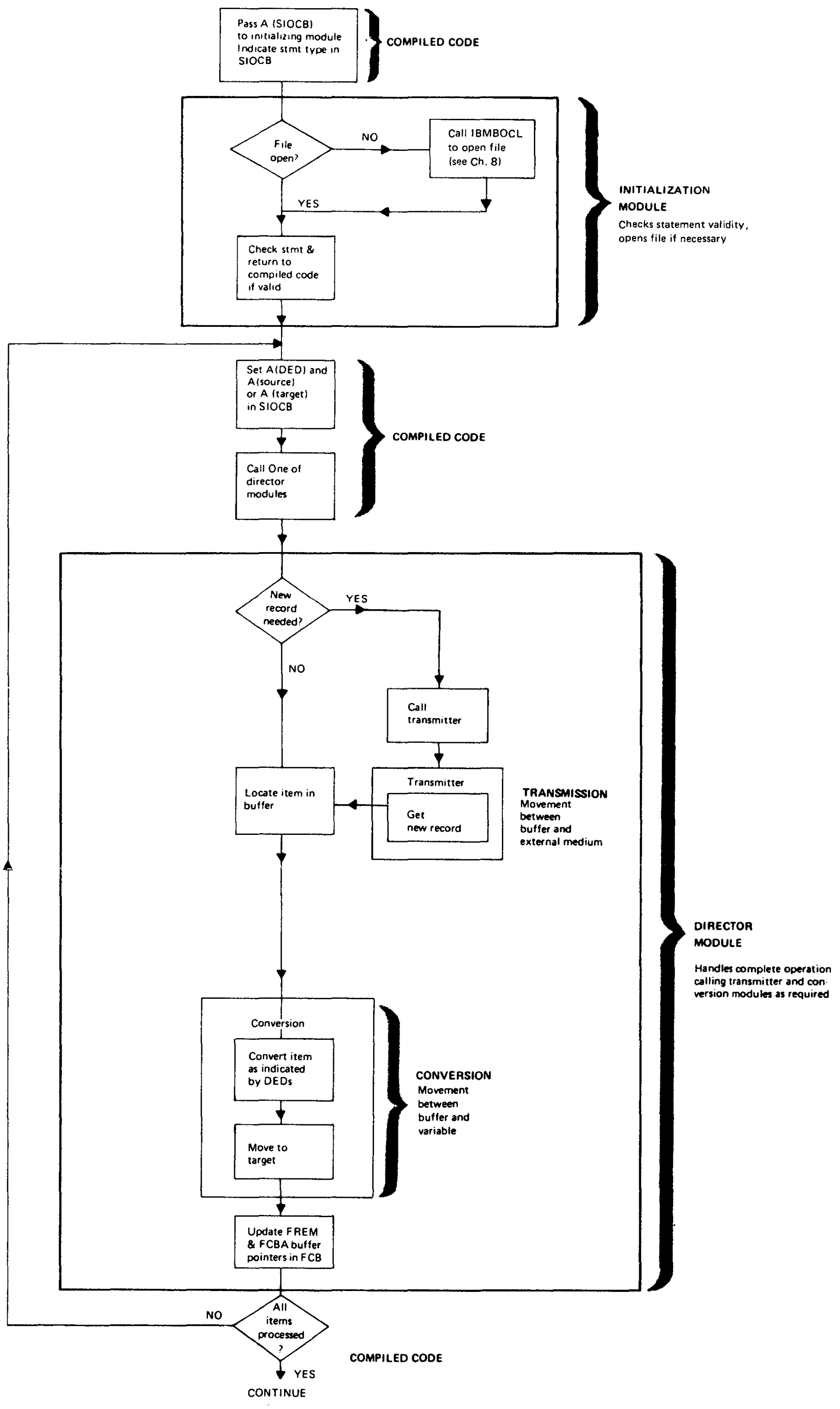

Pass A (SIOCB) to initializing module Indicate stmt type in SIOCB
COMPILED CODE
File open?
NO
Call IBMBOCL to open file (see Ch. 8)
YES
Check stmt & return to compiled code if valid
INITIALIZATION MODULE
Checks statement validity, opens file if necessary
Set A(DED) and A(source) or A (target) in SIOCB
Call One of director modules
COMPILED CODE
New record needed?
YES
NO
Call transmitter
Locate item in buffer
Transmitter
Get new record
TRANSMISSION
Movement between buffer and external medium
DIRECTOR MODULE
Handles complete operation calling transmitter and conversion modules as required
Conversion
Convert item as indicated by DEDs
Move to target
CONVERSION
Movement between buffer and variable
Update FREM & FCBA buffer pointers in FCB
NO
All items processed ?
YES
CONTINUE
COMPILED CODE

Figure 60. Simplified Flow Diagram of a Stream I/O Statement

Stream I/O Control Block (SIOCB)

To simplify communication between the large number of routines that may be used in a stream I/O operation, a control block is set up for the duration of the execution of the stream I/O statement. This control block is known as the *stream I/O control block (SIOCB)*. The SIOCB contains the addresses of the source and target (or their locators), and of the DEDs of the source and the target. The SIOCB is passed directly to the conversion routines. The contents of the SIOCB is as follows:

- Address of source or source locator
- Address of source DED
- Address of target or target locator
- Address of target DED
- Flag bytes
- Address of FCB for file
- Abnormal return address (next statement)
- Save word used by compiler
- Count of items transmitted (Halfword)
- Address of ONCA
- Area present only for GET or PUT STRING, to hold a dummy file control block (27 fullwords).

File Handling

In stream I/O, file organization is always sequential and the access method used is the queued sequential access method (QSAM).

Transmission

Transmitters are called by the director modules or, in certain cases, by the initialization module, or by the close module to complete transmission when the program is terminated.

As with record I/O, transmitters call data management modules. The PL/I transmitters contain the EODAD and SYNAD routines, which are entered when end-of-file or other errors are detected in the routines. Nine different transmitter modules are used in stream I/O; these include two for conversational files. The stream I/O transmitters are listed in "Transmitter Modules" on page 274.

Opening the File

The same basic method is used for opening the file as is used for record I/O. During compilation, a declare control block (DCLCB) and an environment control block (ENVB) are set up. An open control block (OCB) is also set up if any environment options are declared in the OPEN statement. At open time, the information addressed from the DCLCB, ENVB, and the OCB (if any) is merged with any information in the DD statement, and an FCB is set up. The PL/I transmitter is loaded, and its address placed in the FCB. A DCB, addressed from the FCB, is set up. The DCB contains the address of the data management transmitter. Finally, the address of the FCB is placed in the pseudo-register vector.

Implicit Open

Implicit opening is handled by the initialization routines, which check to see whether the file is open and, if not, call the open/close bootstrap routine IBMBOCL.

The FCB for stream I/O is similar to that used for record I/O. However, it contains certain additional fields which are needed only for stream I/O. The most important of these fields are the buffer control fields.

Keeping Track of Buffer Position

Two fields in the FCB are used to keep track of the position which has been reached in the data management buffer, and to indicate when a new record will be required. These fields are the buffer control fields:

FCBA Points at the position reached in current record.

FREM Number of unused bytes remaining in the record.

FCBA points to the position reached in the record and enables the director routines to identify from where the next input item must be read, or where the next output item must be written. FREM contains the number of bytes left in a record. It enables the director modules to determine when a new record will be required, and whether an item is too large to be held in the remainder of the record and will consequently require intermediate workspace. Figure 61 on page 248 illustrates the use of FCBA and FREM.

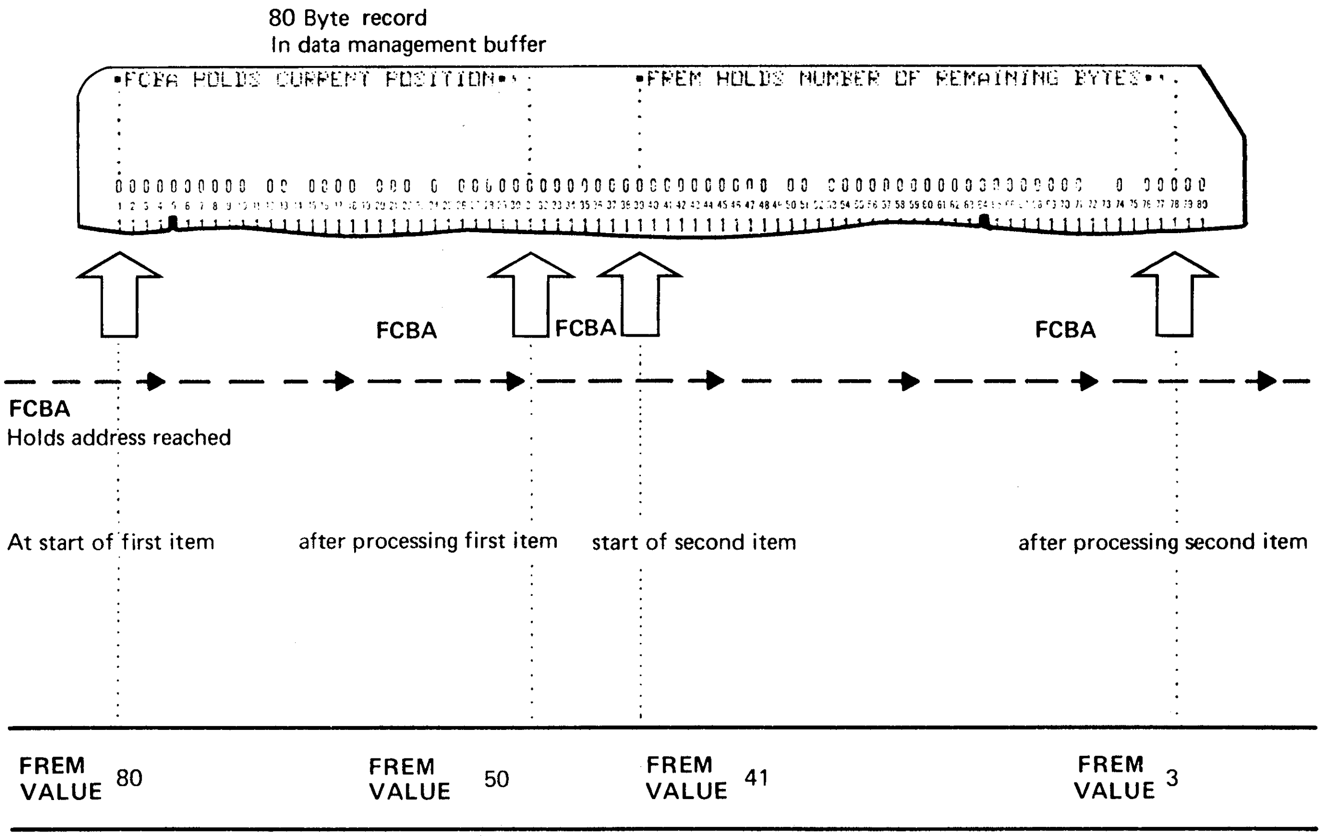
Enqueuing and Dequeuing on SYSPRINT

Because SYSPRINT is used as the standard file for error messages, it is necessary for output to SYSPRINT to be enqueued. This prevents error messages from one task in a PL/I program interrupting other output to SYSPRINT from another task.

When SYSPRINT is used it is enqueued by the initialization routine. When any PUT statement is completed, regardless of the output file, a call is made to the initialization/termination routine. This routine then checks to see if SYSPRINT has been enqueued and, if it has, dequeues it by calling the DEQ routine.

PL/I STATEMENT:

```
GET FILE (SYSIN) LIST (A, B);
```


80 Byte record
In data management buffer
•FCBA HOLDS CURRENT POSITION•
•FREM HOLDS NUMBER OF REMAINING BYTES•
FCBA
FCBA
FCBA
FCBA
Holds address reached
At start of first item
after processing first item
start of second item
after processing second item
FREM VALUE 80
FREM VALUE 50
FREM VALUE 41
FREM VALUE 3

FREM holds number of remaining bytes

Figure 61. The Use of FREM and FCBA in Recording Buffer Position

Handling the Conversions

Conversions in stream I/O are normally handled by the library conversion package. The conversion package consists of conversion routines and conversion director routines. Conversion director routines examine the DEDs of the source and the target passed in the argument list, and determine which entry point of which conversion module is required. Each possible conversion has a unique entry point in one of the conversion routines. For stream I/O, the argument list passed is contained in the first four words of the SIOCB.

A number of conversion director modules are used exclusively by edit-directed stream I/O. These are called *external conversion directors*, and are listed in "External Conversation Director Modules" on page 275. Each module corresponds to a particular format of input or output. When the type of input or output has been determined by the director modules, the appropriate conversion director routine can be called to handle the conversion.

In edit-directed I/O, the conversion required is normally predictable during compilation, because it is implied in the format list. Consequently, the conversion modules can be called from compiled code rather than from the stream I/O director routines. A third possibility is that compiled code will handle the conversion in-line.

When a library conversion module is required by compiled code, the conversion director module may be called, or the conversion module itself may be called directly. When the conversion module is called, compiled code must carry out the jobs normally handled by conversion director modules, that is, setting up a number of fields that are used in handling the CONVERSION condition and other PL/I exceptional conditions.

Handling GET and PUT Statements

There are considerable differences in detail between the handling of GET and PUT statements for the three different modes of stream I/O. A generalized impression is given in Figure 60 on page 245 and summarized above.

This appendix first covers the implementation of list-directed GET and PUT statements in some detail, and then highlights the differences for data-directed and edit-directed I/O.

List-Directed GET and PUT Statements

PUT LIST Statement

Implementation of a list-directed output statement is shown in Figure 62 on page 251. The process consists of five steps:

1. Compiled code calls the initialization routine, passing the address of the DCLCB and of the SIOCB. Flags indicating the statement type have been set in the SIOCB by compiled code.
2. The initialization routine, IBMBSIO, calls the open routine if the file is not open, and checks the validity of the statement. If the statement is invalid, a

branch is made to the error handler, passing an error code indicating "invalid statement." This results in a message being generated, and the ERROR condition being raised. If the statement is valid, control is returned to compiled code.

IBMBSIO also handles any format options, by calling the formatting module IBMBSPL. Control then returns to compiled code.

3. Compiled code places the address of the source (or its locator, if the item is a string) and the address of the source DED in the SIOCB. Compiled code then calls the director module.

4. The director module completes the SIOCB with the address of the target locator and the address of the DED of the target. The target locator gives the length required for the item. As the target is a character string, a locator will always be used for it. The address of the target is a position in the buffer. For PRINT files, the position is indicated in the tab table, which will either have been set up by the programmer by use of PLITABS, or may be the default tab table in the library module IBMBSTAA. For non-print files, each item is followed by a single blank. PLITABS is addressed from the TCA.

   When the starting position for the item has been found, the director module determines whether there is enough space in the output buffer for the converted item. There may not be, for one of two reasons:

   a. The end of the buffer has been reached.

   b. The converted item will be too large to hold in the buffer.

   If the end of the buffer has been reached, the transmitter is called to acquire a new record. If the converted item will be too long to fit in the buffer, intermediate workspace will be needed.

   If it is simply a case of acquiring a new record, the director calls the transmitter to acquire it. The director then calls the appropriate conversion routine, passing it the SIOCB as a parameter list. The conversion routine will then move the data from the PL/I variable to the new record in the data management buffer.

   If, however, the converted item will span the boundary between the current and subsequent records, intermediate workspace is acquired in the form of a VDA. The converted item is then placed in the VDA. As much of the data as will fit is moved from the VDA into the data management buffer, and a new record is acquired by a call to the output transmitter. The new record is then filled from the VDA. This process is continued until the complete item has been moved into buffers. The buffer pointers FREM and FCBA are updated.

   If there are further data items to be handled, a return is made to step (2), and the address of a new source field and its DED are placed in the SIOCB. This process is continued until all items in the data list have been processed.

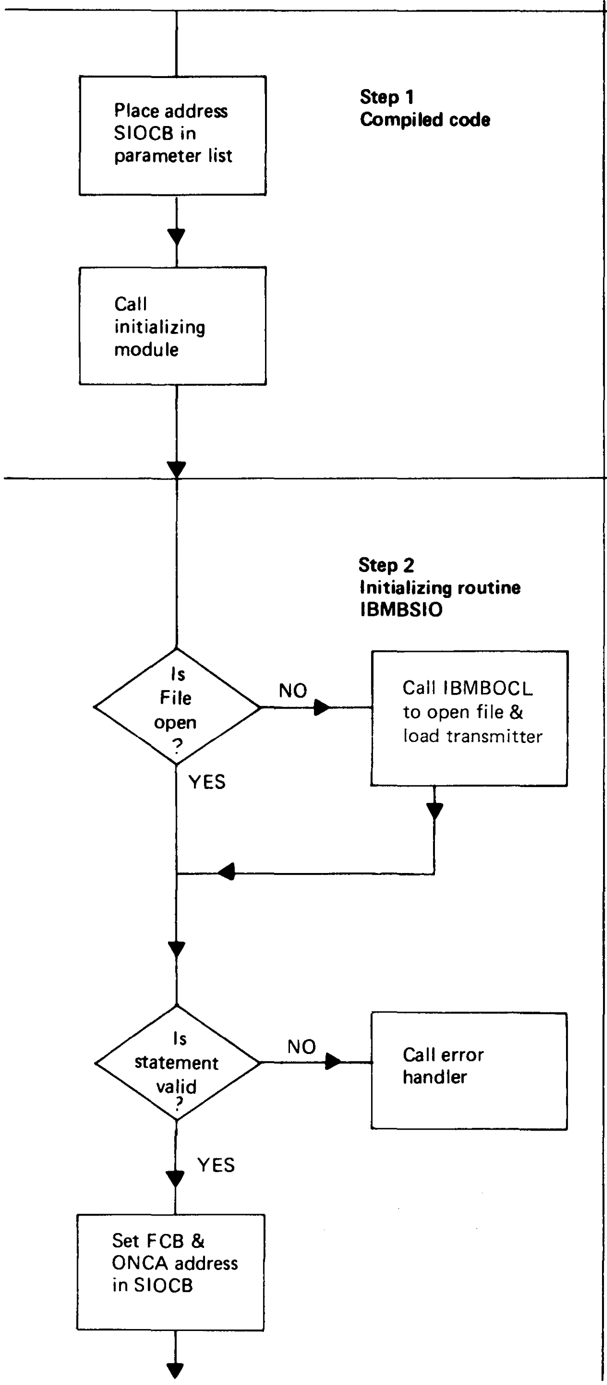
5. The statement is completed by a call to the initialization/ termination routine. This checks to see whether SYSPRINT has been used and, if so, dequeues on SYSPRINT. For conversational files, it also calls the transmitter to transmit any information that is still held in the buffer.

The object code produced for a PUT LIST statement is shown in Figure 63 on page 253.

PUT LIST (A)

FLOW DIAGRAM

COMPILED CODE & NOTES

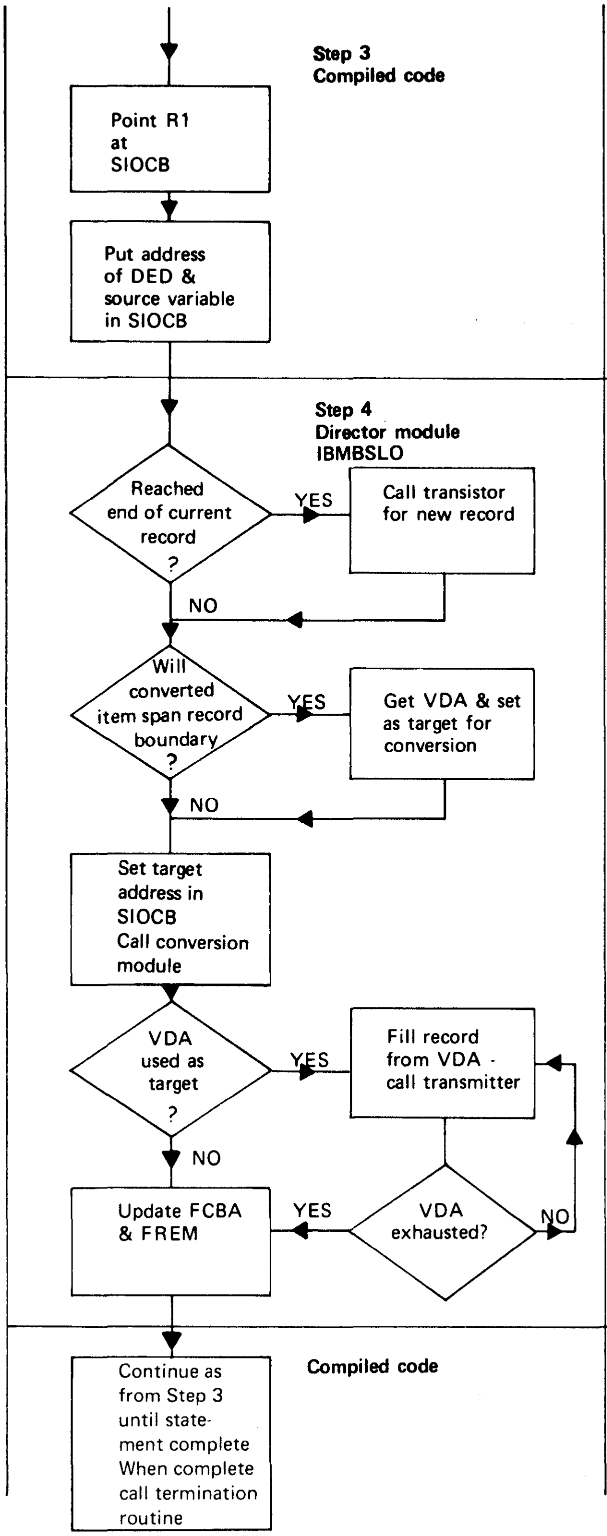

Place address SIOCB in parameter list
Step 1
Compiled code
Call initializing module
Step 2
Initializing routine IBMBSIO
Is File open ?
NO
YES
Call IBMBOCL to open file & load transmitter
Is statement valid ?
NO
YES
Call error handler
Set FCB & ONCA address in SIOCB

```
LA    7,200(0,13)       Load address SIOCB
ST    7,76(0,3)         Place in parameter list
OI    76(3),X'80'       Mark end of parameter list
LA    1,200(0,13)       Saves SIOCB in a temporary
ST    1,192(0,13)         pointer
MVI   217(13),X'40'     Set LIST OUTPUT flag
LA    1,72(0,3)         Point R1 at parameter list
L     15,A..IBMBSIOA    Call stream output
BALR  14,15               initializer
```

The initialization routine is passed the address of the FCB and the address of the SIOCB.

It opens the file if necessary and acquires the first record for print files. If the statement is invalid it calls the error handler. If the statement is valid it places the addresses of the ONCA and the FCB in the SIOCB and returns to compiled code.

Figure 62 (Part 1 of 2). Flow of Control through a PUT LIST Statement


Step 3
Compiled code
Point R1 at SIOCB
Put address of DED & source variable in SIOCB
Step 4
Director module
IBMBSLO
Reached end of current record ?
YES
Call transistor for new record
NO
Will converted item span record boundary ?
YES
Get VDA & set as target for conversion
NO
Set target address in SIOCB
Call conversion module
VDA used as target ?
YES
Fill record from VDA - call transmitter
NO
Update FCBA & FREM
YES
VDA exhausted?
NO
Compiled code
Continue as from Step 3 until statement complete
When complete call termination routine

```
LA    14,A            Get the address of A
LA    15,DED..A       Get the address of DED..A
L     1,192(0,13)     Reloads R1
STM   14,15,0(1)      Put addresses of A and DED..A
                        in SIOCB
L     1,192(0,13)     Restore SIOCB
L     15,A..IBMBSIOT  Call termination
BALR  14,15             routine
```

The director module calls the transmitter and conversion modules when required and handles any housekeeping problems.

Before calling the conversion module it completes the SIOCB with the address of the target locator and the address of the target DED.
The target for the conversion is either the data management buffer or a VDA acquired for intermediate workspace.

If the statement is complete compiled code continues with the next statement. If the statement is not complete compiled code places new data in the SIOCB and once more calls the director module.
When statement complete make terminating call to dequeue on SYSPRINT

Figure 62 (Part 2 of 2). Flow of Control through a PUT LIST Statement

```
PL/I Source Statements:
     DCL A,B STATIC;
     PUT LIST (A,B);
```

```
* STATEMENT NUMBER  3
00005E  41 70 D 0C8     LA    7,200(0,13)      Pick up address of SIOCB
000062  50 70 3 04C     ST    7,76(0,3)        Store in parameter list
000066  96 80 3 04C     OI    76(3),X'80'      Mark end of parameter list
00006A  41 10 D 0C8     LA    1,200(0,13)      SIOCB pointer
00006E  50 10 D 0C0     ST    1,192(0,13)        to temporary pointer
000072  92 40 D 0D9     MVI   217(13),X'40'    Set LIST OUTPUT flag in SIOCB
000076  41 10 3 048     LA    1,72(0,3)        Point R1 at SIOCB
00007A  58 F0 3 02C     L     15,A..IBMBSIOA   Branch to initializing module
00007E  05 EF           BALR  14,15
000080  41 E0 D 0B8     LA    14,A             Pick up address of A
000084  41 F0 3 038     LA    15,DED..A        Pick up address of DED..A
000088  58 10 D 0C0     L     1,192(0,13)      Restore SIOCB address
00008C  90 EF 1 000     STM   14,15,0(1)       Store addresses in SIOCB
000090  58 F0 3 034     L     15,A..IBMBSLOA   Call list-directed director
000094  05 EF           BALR  14,15              routine
000096  41 E0 3 050     LA    14,B             Pick up address of B
00009A  58 10 D 0C0     L     1,192(0,13)      Point R1 at SIOCB
00009E  50 E0 1 000     ST    14,0(0,1)        Place address B in SIOCB
0000A2  58 F0 3 034     L     15,A..IBMBSLOA   Call list-directed director
0000A6  05 EF           BALR  14,15              routine
0000A8  58 10 D 0C0     L     1,192(0,13)      Point R1 at SIOCB
0000AC  58 F0 3 030     L     15,A..IBMBSIOT   Make terminating call to
0000B0  05 EF           BALR  14,15              dequeue on SYSPRINT

                   Note:  The DEDs for A and B have been
                          commoned.  Consequently the same
                          address is kept in the SIOCB for
                          both calls to the director modules.
```

Figure 63. Code Generated for Typical List-Directed I/O Statement

GET LIST Statement

GET LIST statements follow the same sequence, but the transmission is in the opposite direction. The main differences are:

- If record spanning is involved, the item is assembled in intermediate workspace before it is converted.
- A locator is built for the source string from the input, and the addresses of the locator and of a character DED for the source are placed in the SIOCB by the director module. The address of the target or its locator and the address of the target DED are placed in the SIOCB by compiled code.
- Unless the COPY option is being used, no final call is made to the initialization/termination routine.

Data-Directed GET and PUT Statements

Data-directed GET and PUT statements follow a similar sequence to list-directed statements, in that there is first a call to the initialization module, followed by a call to a director routine. However, the data-directed director module is passed all the variables involved in the statement rather than one variable at a time, and handles the complete statement without returning to compiled code.

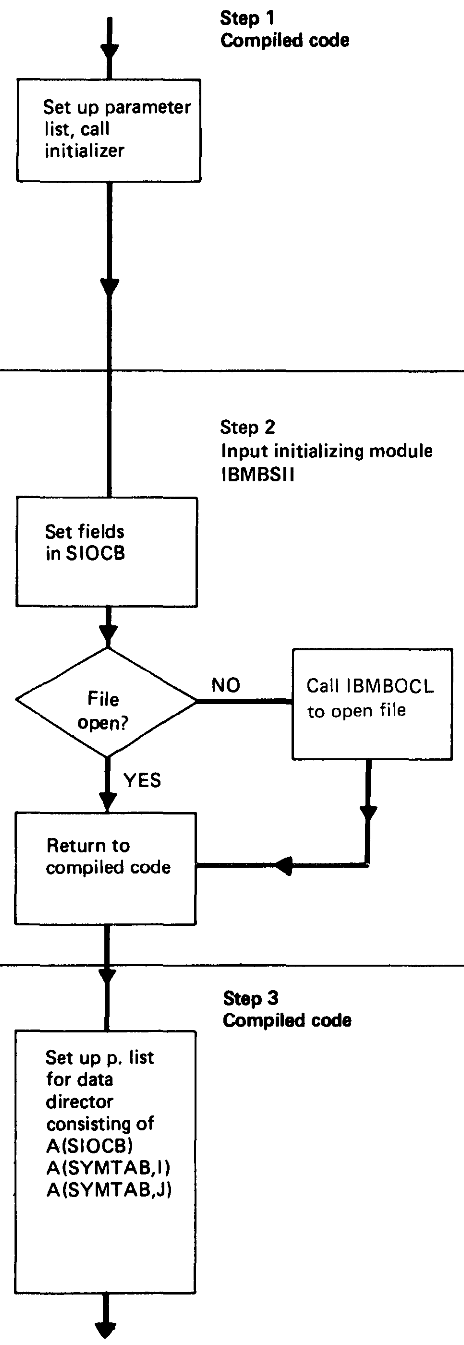
The data-directed director module handles the reading or writing of the names, the equals signs, and the punctuation, and then calls the list-directed director module to handle the value for each variable.

When the data-directed module has identified the location of the variable to or from which the data is to be moved, it calls the list-directed director module which then handles the movement of the value of the variable. When the value of the variable has been transmitted, control returns to the data-directed module, which handles the next name, determines the address of the variable associated with the name, and calls the list-directed director module to handle the transmission of the value. This process continues until the statement is complete. For output, the director module completes the statement with a final semicolon. Figure 64 on page 255 shows the complete process.

The list-directed director module is called separately for each item. It is passed the SIOCB with the addresses of the source or target (or its locator) and the address of its DED correctly set up by the data-directed director module. The item is then handled as if it were a list-directed item.

GET DATA (A,B);

FLOW DIAGRAM


Step 1
Compiled code
Set up parameter list, call initializer
Step 2
Input initializing module IBMBSII
Set fields in SIOCB
File open?
NO
Call IBMBOCL to open file
YES
Return to compiled code
Step 3
Compiled code
Set up p. list for data director consisting of A(SIOCB) A(SYMTAB,I) A(SYMTAB,J)

COMPILED CODE & NOTES

Step 1

```
LA    7,216(0,13)       Pick up address of SIOCB
ST    7,84(0,3)         Place in parameter list
OI    84(3),X'80'       Flag last argument in parameter list
LR    1,7               Get address of parameter list
MVI   233(13),X'84'     Set flag DATA INPUT in SIOCB
MVI   234(13),X'01'     Reset flag value
LA    14,104(0,3)       Set abnormal return
ST    14,240(0,13)      Store address in SIOCB
LA    1,80(0,3)         Point R1 at parameter list
ST    15,A..IBMBSIIA    Branch to stream
BALR  14,15               initializing module
```

Step 2

The input initializing module is passed the address of the SIOCB and the FCB for the file.

It checks the validity of the statement, opens the file and places the address of the FCB in the SIOCB and returns to compiled code

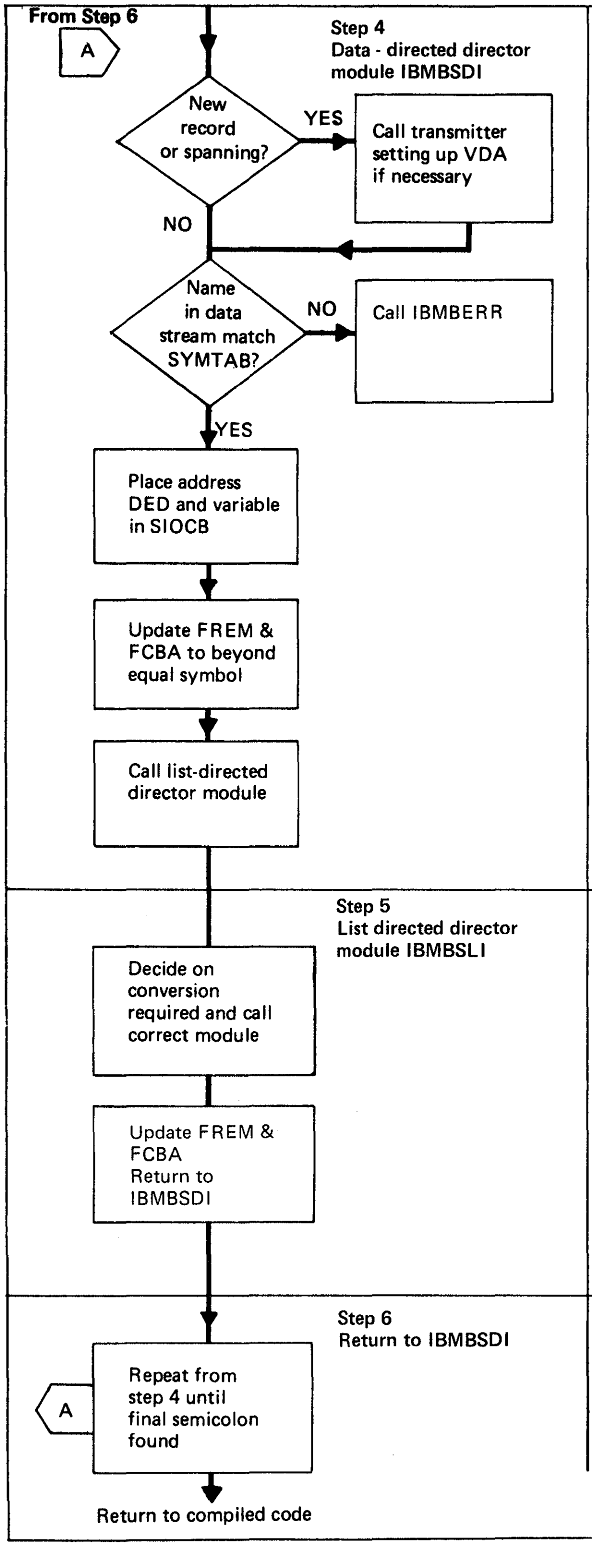
Step 3

```
        LA    15,216(0,13)      Pick up address of SIOCB
        ST    15,88(0,3)        Place address in parameter
                                list

                                The parameter list contains
                                addresses of symbol tables
                                and variables already set up
                                in static.

        LA    1,88(0,3)         Point R1 at parameter list
        L     15,A..IBMBSDIA    Call data-directed director
        BALR  14,15               module
CL.2 EQU  *                     Abnormal locate return
                                address
```

Figure 64 (Part 1 of 2). Handling a GET DATA Statement



The data directed director module is passed the address of the SIOCB and either a list of symbol table addresses or an address in the symbol table vector.

The module reads in the name, checks that the name read is in the symbol tables passed and if not raises the NAME condition.

When the variable is identified the module places the address of the target and its DED in the SIOCB and calls the list-directed director module passing it the SIOCB.

The list directed module completes the operation as for list directed I/O

On return to the data directed module a search is made for the next name and the action continued as from step 4 until a semicolon is reached in the input stream

Figure 64 (Part 2 of 2). Handling a GET DATA Statement

Identifying the Name

If a data list is included in the statement, for example:

```
PUT DATA (A,B,C);
```

the source or target variables are identified from a list of symbol tables. If a data list is not included in the statement, for example:

```
PUT DATA;
```

the source or target variables are identified from the symbol table vector.

A symbol table associates a name with the address of a variable. The symbol table vector is a list of the symbol tables known in the external procedure. The items in a symbol table vector are arranged in program block order. When a symbol table vector is used, the address passed is the start of entries for items known in the current block. Symbol table format is shown in Appendix A, "Control Blocks" on page 119.

The object code produced for a PUT DATA statement is shown in Figure 65 on page 258.

Edit-Directed GET and PUT Statements

Edit-directed I/O differs from the other modes of stream I/O in that the conversions required and the positions in the record where an item is to be placed or will be found are indicated in the format list of the I/O statement.

The format list contains two related types of information:

1. The type and length of the item (for example, F(3), A(25), etc.), known as *data format information*.
2. Spacing information (for example, X(3), COL(70), etc.), known as *control format information*.

Both types of information are compiled as *format DEDs* (or *FEDs*) and are passed by compiled code to the routines that require the information.

Because the information is available during compilation, it is possible for the compiler to determine the conversions that will be required. It is consequently possible for compiled code to call the required conversion or conversion director routine, or to generate in-line conversion code without the assistance of a library director module.

```
PL/I source statements:
     DCL A,B,C;
     PUT DATA (A,B,C);
```

```
         RELEVANT SECTION OF THE STATIC INTERNAL STORAGE MAP

000048  00000000                A..DCLCB     ─┐  Parameter list
00004C  80000000                A..TEMP      ─┘  for IBMBSIOA

000050  00000000                A..TEMP      ─┐
000054  00000060                A..SYMTAB     │  Parameter list
000058  00000074                A..SYMTAB     │  for IBMBSDOA
00005C  80000088                A..SYMTAB    ─┘
000060  8500000100000038        SYMBOL TABLE..A
        000000B800000000
        0001C100
000074  8500000100000038        SYMBOL TABLE..B
        000000BC00000000
        0001C200
000088  8500000100000038        SYMBOL TABLE..C
        000000C000000000
        0001C300
00009C

         RELEVANT SECTION OF THE OBJECT PROGRAM LISTING

* STATEMENT NUMBER  3
00005E  41 70 D 0E8     LA    7,232(0,13)      Pick up address of SIO CB
000062  50 70 3 04C     ST    7,76(0,3)        Store in parameter list
000066  96 80 3 04C     OI    76(3),X'80'      Mark end of parameter list
00006A  18 17           LR    1,7              Place SIOCB in R1
00006C  50 10 D 0E0     ST    1,224(0,13)      Save SIOCB
000070  92 80 D 0F9     MVI   249(13),X'80'    Set data output
000074  92 01 D 0FA     MVI   250(13),X'01'      flags
000078  41 10 3 048     LA    1,72(0,3)        Point R1 at parameter list
00007C  58 F0 3 02C     L     15,A..IBMBSIOA   Call initializing
000080  05 EF           BALR  14,15              routine
000082  41 F0 D 0E8     LA    15,232(0,13)     Pick up address of SIO CB
000086  50 F0 3 050     ST    15,80(0,3)       Place in parameter list
00008A  96 80 D 0FB     OI    251(13),X'80'    Mark end of parameter list
00008E  41 10 3 050     LA    1,80(0,3)        Point R1 at parameter list
000092  58 F0 3 028     L     15,A..IBMBSDOA   Call director routine
000096  05 EF           BALR  14,15
000098  58 10 D 0E0     L     1,224(0,13)      Get SIOCB
00009C  58 F0 3 030     L     15,A..IBMBSIOT  Make terminating call to
0000A0  05 EF           BALR  14,15              dequeue on SYSPRINT
```

Figure 65. Typical Data-Directed Code

Compiler-Generated Subroutines

To further optimize edit-directed I/O, a number of compiler-generated subroutines have been provided. They carry out the following functions:

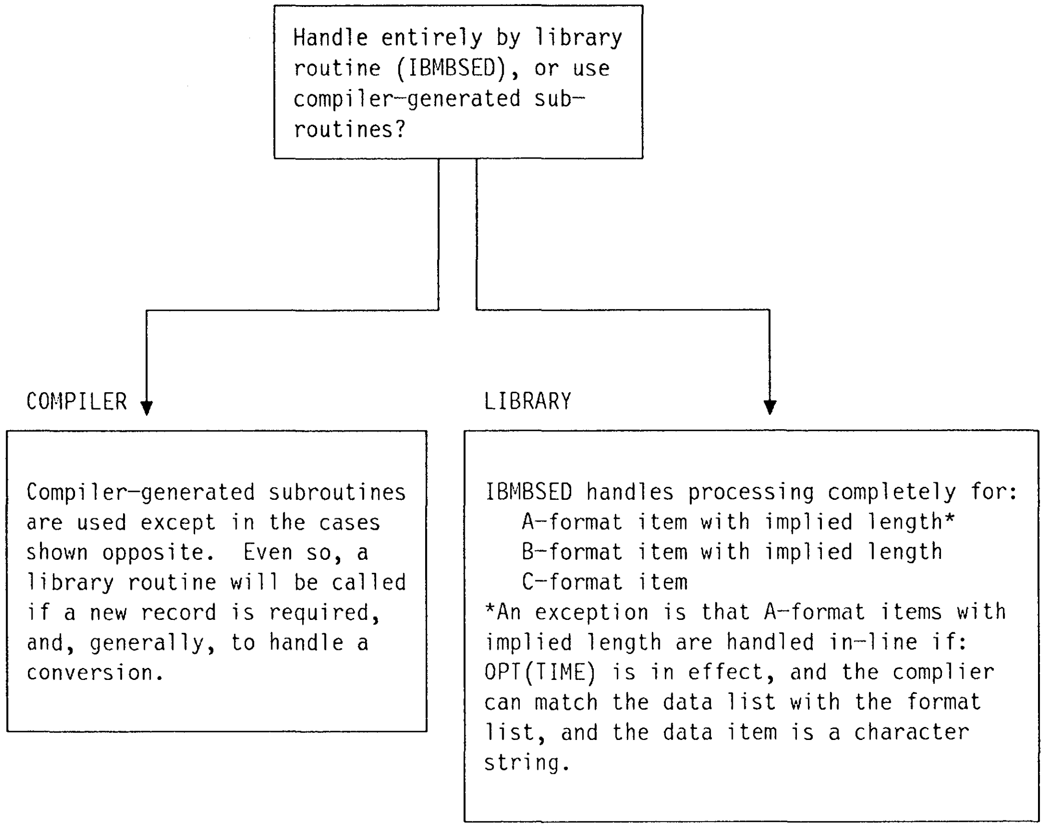
- Keeping track of the buffer position, freeing and acquiring intermediate workspace where necessary, and calling the library when a new record is required.
- Handling X format control items, except where a new record is required.

These compiler-generated subroutines have the advantage over library modules that they are not external, and consequently do not have to follow the external calling conventions.

The compiler-generated subroutines are supported by two types of library director module:

- Two short modules, IBMBSEO and IBMBSEI, that interface with the transmitter and are called by the compiler-generated subroutines when a new record is required.
- A routine, IBMBSEDA, that handles the complete processing of an item (as the director does for list-directed I/O). This routine is called when the item cannot be handled by the compiler-generated subroutines.

The decision on whether to use compiler-generated subroutines or the overall library director module is made at compile time. Figure 66 on page 260 shows the conditions under which each method is used.



Handle entirely by library routine (IBMBSED), or use compiler-generated subroutines?

Compiler-generated subroutines are used except in the cases shown opposite. Even so, a library routine will be called if a new record is required, and, generally, to handle a conversion.

IBMBSED handles processing completely for:
A-format item with implied length*
B-format item with implied length
C-format item
*An exception is that A-format items with implied length are handled in-line if: OPT(TIME) is in effect, and the complier can match the data list with the format list, and the data item is a character string.

Figure 66. The Use of the Library in Edit-Directed I/O

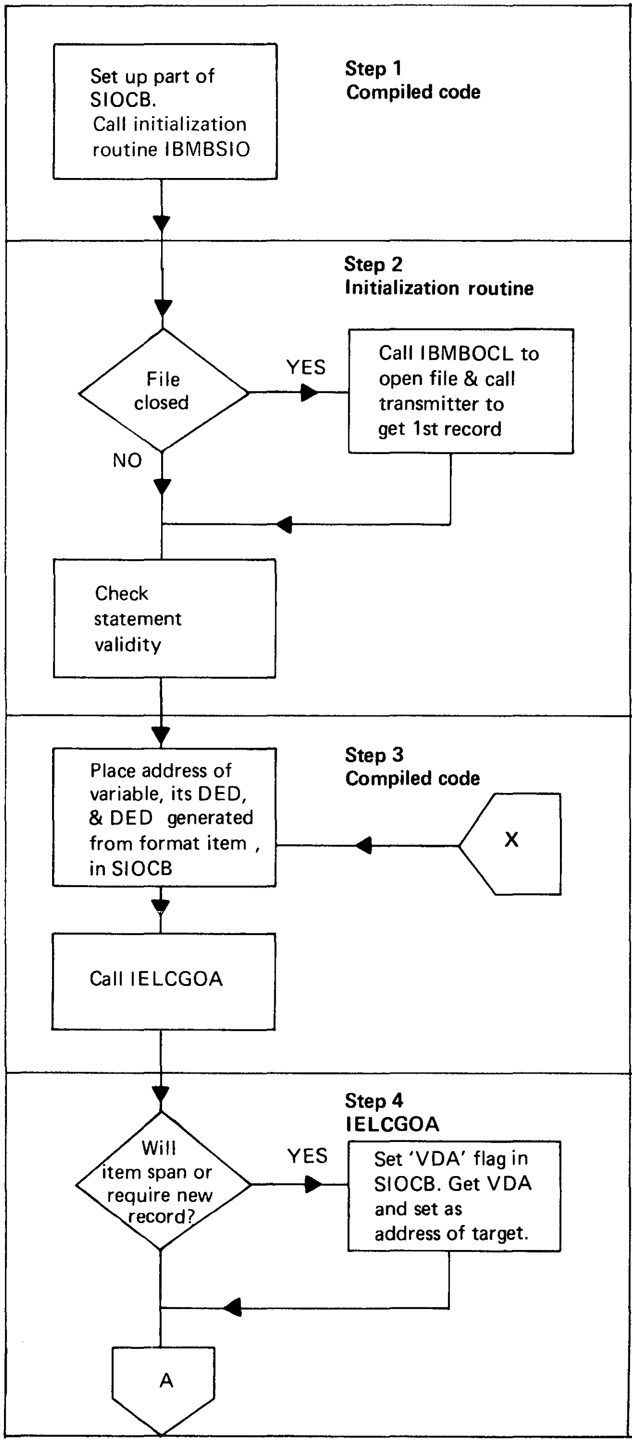
A typical edit-directed statement takes the form:

1. A call to the initialization module to open the file (if necessary), and check statement validity.
2. A call to a compiler-generated subroutine to check whether a new record is required, and, if so, to call the module IBMBSEI or IBMBSEO to acquire a new record by making a call to the transmitter. The SIOCB is completed with source or target DEDs and the addresses of the source and the target or their locators.
3. A call to a conversion module or conversion director, or a compiled-code conversion.
4. A further call to a compiler-generated subroutine, to update the buffer control fields, and free any intermediate workspace if spanning was involved.
5. A terminating call to the initialization/termination routine.

This sequence is illustrated in the annotated flowchart in Figure 67 on page 261. Figure 68 on page 263 shows the code generated for a GET EDIT statement.

PUT EDIT (B)(A);

FLOW DIAGRAM


Set up part of SIOCB. Call initialization routine IBMBSIO
Step 1
Compiled code
Step 2
Initialization routine
File closed
YES
NO
Call IBMBOCL to open file & call transmitter to get 1st record
Check statement validity
Step 3
Compiled code
Place address of variable, its DED, & DED generated from format item , in SIOCB
X
Call IELCGOA
Step 4
IELCGOA
Will item span or require new record?
YES
Set 'VDA' flag in SIOCB. Get VDA and set as address of target.
A

NOTES

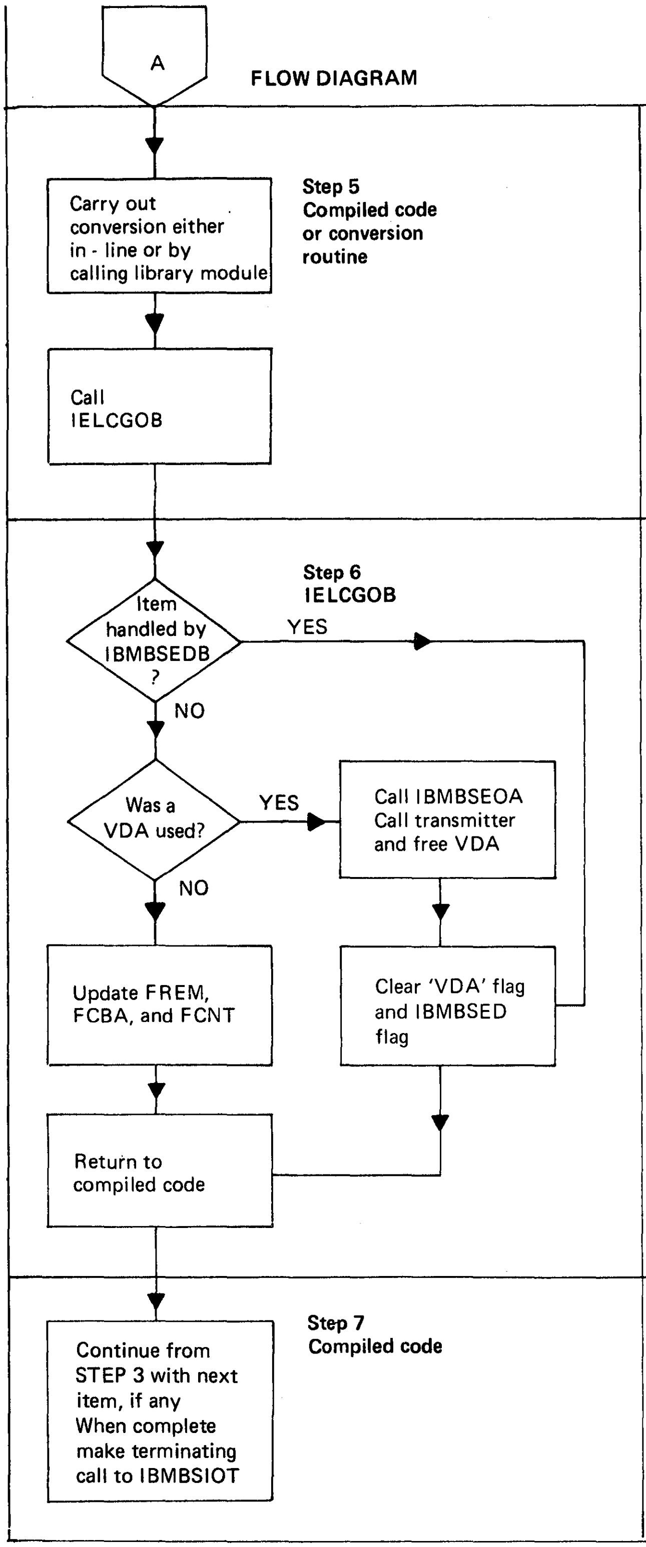
```
LA      7,216(0,13)        Pick up address of SIOCB
ST      7,84(0,3)          Place in parameter list
OI      84(3),X'80'        Mark end of parameter list
LR      1,7                Point R1 at SIOCB
ST      1,208(0,13)        Save in temp
MVI     233(13),X'20'      Set EDIT OUTPUT flag
LA      1,80(0,3)          Point R1 at parameter list
L       15,A..IBMBSIOA     Branch to initialization
BALR    14,15                routine
```

Test if file is open, and open if necessary, calling transmitter to locate record.
Place address of ONCA and FCB in the SIOCB.
Check statement validity.

```
LA   14,B           Get address of data
LA   15,DED..B      Get address of DED..B
L    1,208(0,13)    Get SIOCD address
STM  14,15,0(1)     Place addresses of B and DED..B in SIOCB
LA   14,68(0,3)     Get address of FED
L    7,A..IELCGOG   Branch to compiler-generated
BALR 6,7              subroutine
```

Acquire VDA for item if necessary.
Either if there is no room in current record, or,
if the converted item will span the record boundary.

Figure 67 (Part 1 of 2). Edit-Directed Statement with Matching Data and Format Lists


A
FLOW DIAGRAM
Carry out conversion either in - line or by calling library module
Step 5
Compiled code or conversion routine
Call IELCGOB
Step 6
IELCGOB
Item handled by IBMBSEDB ?
YES
NO
Was a VDA used?
YES
NO
Call IBMBSEOA
Call transmitter and free VDA
Update FREM, FCBA, and FCNT
Clear 'VDA' flag and IBMBSED flag
Return to compiled code
Continue from STEP 3 with next item, if any
When complete make terminating call to IBMBSIOT
Step 7
Compiled code

NOTES

```
L      15,A..IBMBSAOA      Call output conversion
BALR   14,15                  director (A-format)

L      7,A..IELCGOH        Call compiler-generated
BALR   6,7                    director routine

L      1,208(0,13)         Get SIOCB address
```

Update buffer control fields
Handle housekeeping

Continue as necessary
When complete call termination
routine to dequeue on SYSPRINT

```
L      15,A..IBMBSIOT
BALR   14,15
```

Figure 67 (Part 2 of 2). Edit-Directed Statement with Matching Data and Format Lists

```
PL/I source statements:
    DCL A,B;
    GET EDIT (A,B) (F(3), X(8));
```

```
* STATEMENT NUMBER  3
00005E  41 70 D 0D8     LA    7,216(0,13)       Pick up address of SIOCB
000062  50 70 3 05C     ST    7,92(0,3)         Store in parameter list
000066  96 80 3 05C     OI    92(3),X'80'       Mark end of parameter list
00006A  18 17           LR    1,7               Place SIOCB in R1
00006C  50 10 D 0D0     ST    1,208(0,13)       Save SIOCB
000070  92 24 D 0E9     MVI   233(13),X'24'     Set EDIT INPUT flags in SIOCB
000074  41 E0 3 060     LA    14,96(0,3)        Pick up return address (CL.2)
000078  50 E0 D 0F0     ST    14,240(0,13)      Store in SIOCB
00007C  41 10 3 058     LA    1,88(0,3)         Point R1 at parameter list
000080  58 F0 3 038     L     15,A..IBMBSIIA    Call stream I/O
000084  05 EF           BALR  14,15               initialization routine
000086  41 E0 D 0B8     LA    14,A              Pick up address of data
00008A  41 F0 3 040     LA    15,DED..A         Pick up address of DED..A
00008E  58 10 D 0D0     L     1,208(0,13)       Get SIOCB address
000092  90 EF 1 008     STM   14,15,8(1)        Puts addresses of A and DED..A
                                                  in SIOCB
000096  41 E0 3 044     LA    14,68(0,3)        Point R14 at FED
00009A  58 70 3 014     L     7,A..IELCGIX      Call compiler-generated
00009E  05 67           BALR  6,7                 subroutine
0000A0  58 F0 3 034     L     15,A..IBMBSFIA    Call conversion director routine
0000A4  05 EF           BALR  14,15
0000A6  58 70 3 018     L     7,A..IELCGIB      Call compiler-generated
0000AA  05 67           BALR  6,7                 subroutine
0000AC  41 E0 3 04A     LA    14,74(0,3)        Pick up FED of X format item
0000B0  58 10 D 0D0     L     1,208(0,13)       Pick up address of SIOCB
0000B4  58 70 3 014     L     7,A..IELCGIX      Call compiler-generated
0000B8  05 67           BALR  6,7                 subroutine
0000BA  41 E0 D 0BC     LA    14,B              Pick up address of B
0000BE  50 E0 1 008     ST    14,8(0,1)         Store in SIOCB
0000C2  41 E0 3 044     LA    14,68(0,3)        Point R14 at FED
0000C6  58 70 3 014     L     7,A..IELCGIX      Call compiler-generated
0000CA  05 67           BALR  6,7                 subroutine
0000CC  58 F0 3 034     L     15,A..IBMBSFIA    Call conversion director routine
0000D0  05 EF           BALR  14,15
0000D2  58 70 3 018     L     7,A..IELCGIB      Call compiler-generated
0000D6  05 67           BALR  6,7                 subroutine
0000D8          CL.2    EQU   *                 Abnormal return address
```

Figure 68. Code Generated for an Edit-Directed Statement with Matching Data and Format Lists

Handling Control Format Items

Control format items are implemented by calling a formatting module, and passing it the SIOCB containing the address of an FED for a control format item. There are four formatting modules:

IBMBSPL	Library routine for SKIP, PAGE, and LINE formats and options.
IBMBSXC	Library routine for X and COLUMN formats.
IELCGOC	Compiler-generated subroutine for X output items that do not span a record boundary.
IELCGIX	Compiler-generated subroutine for X input items that do not span a record boundary. (This module also has other functions; see the section "Compiler-generated Director Routines" near the end of this appendix.)

Matching and Nonmatching Data and Format Lists

In the majority of edit-directed statements, the data and format lists can be matched during compilation, since the programmer requires specific conversions for specific variables. However, it is possible to write statements which, because of iteration factors, cannot be matched at compile time.

For example, in the statement

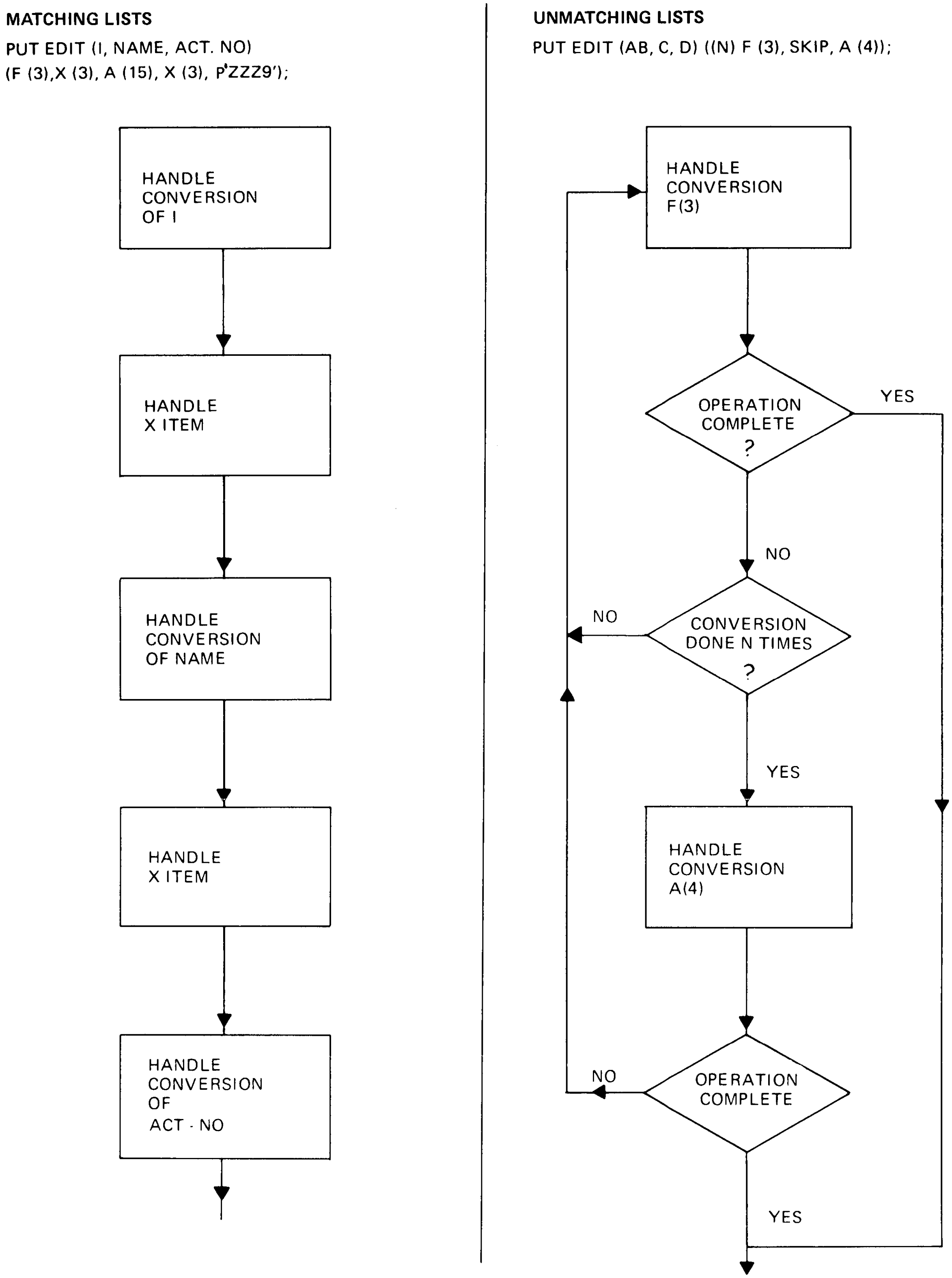
```
    PUT EDIT (A,B,C) (N(F(3)), X(10));
```

It is not possible to know at which point the ten-character space indicated by "X(10)" will be required, without knowing the value of N. If the statement had been

```
    PUT EDIT (A,B,C) (F(3), X(10));
```

the code would be compiled in the order: handle the conversion of a variable, handle an X item, handle the conversion of a variable, etc., until the data list was exhausted. However, as it is not known at which point the X items will be required in the unmatched statement, it is impossible to compile sequential code to handle the statement. Consequently, the code for each item is compiled separately, and branches are made between the code for data items and the code for format items as the value of the repetition factor indicates. In the example above, the branches would be made when the F item had been executed N times, and when the X item had been executed once.

The code sequence used for matching and non-matching data and format lists are shown in Figure 69 on page 265.



MATCHING LISTS

PUT EDIT (I, NAME, ACT. NO)
(F (3),X (3), A (15), X (3), P'ZZZ9');

UNMATCHING LISTS

PUT EDIT (AB, C, D) ((N) F (3), SKIP, A (4));

Figure 69. Code Sequences Used for Matching and Nonmatching Data and Format Lists

Formatting for Print Files

Formatting information such as page size, line size, page length and tab positions for print files are accessed by list and data-directed director modules from a field TTAB held at offset X'50' in the TCA. The field holds the address of the tab table to be used. That is, either the PLITABS control section, if provided by the user, or the IBMBSTAB control section, if the default is to be used.

The control section PLITABS can be provided by the user either as a control section which is link-edited with the object module or as a PL/I structure declared in his program as PLITABS. This structure is then compiled as a suitable control section by the optimizing compiler.

The programmer may also use the default which is provided as a transient library module loaded by the open routines. The format of PLITABS and its default values are given in the programmer's guide for this compiler.

When the open routines are called, they inspect the TCA to determine whether PLITABS has been provided by the user. If it has not, they load the transient library routine IBMBSTAB, which holds the default tab setting. When the routine is loaded, the address of entry point IBMBSTAB is placed in the TTAB field in the TCA. If PLITABS has been provided by the user, its address will have been placed in TTAB by the linkage editor.

Handling Format Options

Format options (for example, GET SKIP(4), PUT PAGE, GET SKIP LIST) are handled by a call to the appropriate entry point of the initialization routine.

The initializing module calls the formatting module IBMBSPL to carry out the formatting.

Input and Output of Complete Arrays

When transmitting complete arrays, it is not economical for a return to be made to compiled code after each item has been handled. Accordingly, the list- and data-directed director modules have a facility that enables them to handle complete arrays. The modules access the array multipliers, and handle the indexing from information held in the array descriptors. For edit-directed I/O, each element is handled separately, the necessary indexing being carried out by compiled code.

PL/I Conditions in Stream I/O

The following errors and PL/I conditions are particularly relevant to the implementation of stream I/O: TRANSMIT, CONVERSION, NAME(data-directed input only), ENDFILE, and unexpected end of file. Unexpected end of file occurs when the end of file is reached in the middle of an input item.

TRANSMIT Condition

The rules for raising the TRANSMIT condition in stream I/O are that the condition shall be raised after the assignment or output of the potentially incorrect data item. Thus TRANSMIT can be raised on input for a data item even though the transmitter has not been called during the processing of the statement involved.

When the TRANSMIT condition is detected by the data management routines, control is passed to the error routine in the transmitter, which sets a flag in the FCB indicating a transmission error. For input, the director module inspects this flag, and, if it is set, sets a flag in the SIOCB. TRANSMIT is raised for every item that is taken from a record in the block with which the transmission error was associated. It is raised after each potentially incorrect value has been assigned. For output, TRANSMIT is raised by the transmitter as soon as it occurs.

A special entry point, IBMBSEIT, is used by the compiler-generated subroutines to raise the TRANSMIT condition. When called by this entry point, IBMBSEIT calls the error handler with the appropriate error code for the TRANSMIT condition.

CONVERSION Condition

The CONVERSION condition is detected by the conversion modules in the PL/I library. (Conversions that could cause the CONVERSION condition are not handled in-line except where "NOCONVERSION" is specified.) CONVERSION is raised by calling a special library module, IBMBSCVA. This module analyzes the type of conversion error, and calls the error handler with an appropriate error code. For input, the module also saves the field that caused the conversion; it is necessary to do so, because the field could be lost if an ON-unit was entered and a further GET statement was executed on the same file which resulted in a new record being acquired.

NAME Condition

The NAME condition can occur only in data-directed input. It is raised by the data-directed director module when it cannot find a symbol table to match the name read in, or when the name is unobtainable (it might, for example, be out of subscript range.) DATAFIELD is set up, and the file positioned for the next read, before calling the error handler, with the appropriate error code.

ENDFILE Condition and Unexpected End of File

End of file is detected by the transmitter routines, which then enter the SYNAD routine in the transmitter. This routine sets a flag in the FCB. On return to the director modules, the flag is tested and, depending on the situation in which the transmitter was called, ENDFILE or unexpected end of file is raised by calling the error handler.

For unexpected end of file, the ERROR condition is always raised as soon as the end of file is detected. ENDFILE, in the case of list- and data-directed I/O, is not raised until a further attempt is made to read the input file.

Built-In Functions in Stream I/O

The built-in functions that are relevant to stream I/O are COUNT, DATAFIELD, ONCHAR, and ONSOURCE.

The COUNT built-in function is handled by the director routines. A count of transmitted items for the statement is kept in the SIOCB, and then copied into the FCB after every transmission to or from a PL/I variable.

The DATAFIELD built-in function is handled by the data-directed director routine, which places the address of the string locator/descriptor for the offending field in the ONCA. The field is first moved to a workspace area, as the buffer may get lost if further stream I/O operations take place in an ON-unit.

The COPY Option

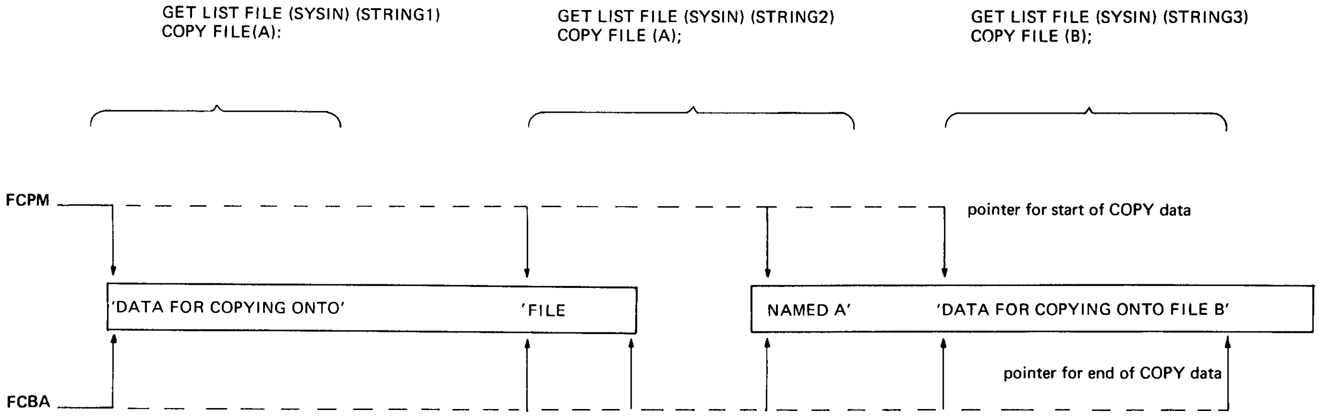
The COPY option allows input data to be copied onto a specified output file. At the start of a GET statement with the COPY option, a flag is set in the FCB, and the current buffer position is saved in the field FCPM in the FCB.

A resident library routine, IBMBSCP, is used to handle the data, and to transmit it to the copy file by calling the appropriate transmitter. IBMBSCP is called at the end of the GET statement, and during the statement if a new buffer is acquired. As shown in Figure 70 on page 269, the data transmitted to the copy file is that which is held between the pointers FCPM and FCBA. FCBA points to the next byte to be read; FCPM points to the start of the data to be copied. FCPM is updated to point to the start of the new buffer when a transmitter call is made during the execution of the statement. The copy flag is turned off during the terminating call to IBMBSII.

If an interrupt occurs during the execution of a GET statement with the COPY option, it is possible that the terminating call to IBMBSII will be bypassed because of a GOTO from an ON-unit, or because the job is terminated. For this reason, a test is made on the copy flag at the start of every GET statement, and when the file is closed. If the copy flag is on, IBMBSCP is called to handle the data. When the data has been transmitted, the flag is turned off.

Handling the Copy File

During the initializing call, IBMBSII determines whether the copy file is open and, if it is not, calls IBMOCL to open the file. The address of the DCLCB for the copy file is then stored in the FCB of the input file. The data is transmitted to the file by calling the transmitter for the file type.


GET LIST FILE (SYSIN) (STRING1)
COPY FILE(A):
GET LIST FILE (SYSIN) (STRING2)
COPY FILE (A);
GET LIST FILE (SYSIN) (STRING3)
COPY FILE (B);
FCPM
pointer for start of COPY data
'DATA FOR COPYING ONTO'
'FILE
NAMED A'
'DATA FOR COPYING ONTO FILE B'
pointer for end of COPY data
FCBA

Data is transmitted to the copy file at the end of each statement and at those times when it can no longer be held between the pointers FCBA and FCPM. In the example above this will be at the end of each GET statement and at the end of the first record.

Figure 70. The Current Buffer Pointer FCBA and FCPM, the Copy Pointer, Keep Track of the Data to be Copied

The STRING Option

The STRING option allows data to be transmitted between a string and one or more PL/I variables by means of a stream I/O statement.

The STRING option is implemented by treating the string specified in the statement as if it were the buffer, and the other PL/I variables as if they were the sources or targets. The difference in housekeeping between string and file operations is resolved by the use of a string housekeeping routine, IBMBSIS. IBMBSIS is called in the place of the stream I/O initialization/termination routine. IBMBSIS sets up a dummy FCB that is initialized so that the correct action is taken should the director modules attempt to read or write beyond the end of the string. After the dummy FCB has been initialized, the director modules are called to convert and move the data as in normal stream I/O.

To implement the string option, compiled code passes the string housekeeping module an extended SIOCB in which the dummy FCB is created. The buffer control fields FCBA and FREM in the dummy FCB are set up as if the string were a record. The field that, in a normal FCB, would hold the address of the transmitter, holds addresses of other sections of code.

For a PUT STRING statement, the transmitter address field is initialized to point to the error handler. Register 1 will have been pointed to the head of the FCB by the caller. The error code for exceeding string size is, therefore, placed at the head of the FCB, and the correct error condition is automatically raised when the branch to the error handler is made.

For a GET STRING statement, the address in the transmitter field is the address of code that sets the end-of-file flag and returns to the caller. This code is held within the dummy FCB.

As far as the caller is concerned, attempting to read beyond the end of the string is equivalent to finding an end-of-file mark in a stream I/O statement. Where the ENDFILE condition or unexpected end of file would be raised for a stream file, a 'GET STRING SIZE EXCEEDED' message is generated, and the ERROR condition is raised.

Completing String-Handling Operations

One or more further calls may be made to the string housekeeping routine IBMBSIS at entry point T, to update the string characteristics after a data item has been transmitted.

PUT Statements with Fixed-length Strings: IBMBSIS is called after the first item has been assigned to the string, to pad the remainder of the string with blanks.

PUT Statements with Varying Strings: IBMBSIS is called to update the length of the string after each item is transmitted.

GET Statements with Varying String: IBMBSIS is always called.

The need to make a further call to IBMBSIS is flagged in the SIOCB when IBMBSISA is called to initialized a statement. The library director routines and the compiler-generated subroutines test this flag, and call IBMBSIS if necessary.

The Conversational System and Conversation Files

When using a conversational system, the PL/I programmer can attach his terminal as the input or output device used by one or more stream files.

Three transient library routines are used to implement this facility. Two are transmitters that are used to interface with the conversational system using the appropriate macro instructions, or simulations of them for CMS, to effect the input and output. They also poll for attention interrupts. The third module is a formatting module that overcomes the special formatting difficulties that arise when working at a terminal.

When the file is opened, the OPEN routine tests every stream I/O file to see whether it is to be associated with a terminal. If the file is to be associated with a terminal, the appropriate conversational transmitter loaded:

```
IBMBSIC for input
IBMBSOC for output
```

A flag is set in the FCB of the file to indicate that the file is a conversational file

The two transmitter modules handle the input, output, and prompting. Formatting differences between conversational and normal I/O are handled by a transient library routine, IBMBSPC. This routine is called by the formatting routine, IBMBSPL, when a conversational file is being handled.

If a conversational module is used, its address is placed in the TCA loaded-module list.

Conversational Transmitter Modules

Output Transmitter IBMBSOC

The output module IBMBSOC is similar to other output transmitters except that it interfaces with TSO, and uses the TPUT macro instruction. For CMS it uses a simulation of TPUT. The macro instruction is used with the WAIT option to ensure proper queueing of output to the terminal.

Input Transmitter IBMBSIC

The input transmitter carries out a similar function to other PL/I input transmitters. However, it also has to handle certain prompting functions, and implements certain facilities required only for conversational output.

Input: Input is achieved by issuing a TGET macro instruction to the TSO control program. For CMS it uses a TGET simulation.

Prompting: Prompting is carried out before every input statement, unless the last character transmitted to the foreground terminal was a colon. At the start of a statement, the prompting sequence is: skip to a new line, print a colon, and skip to the start of the next line. If the GET statement is not completed by the data transmitted from the terminal, a further call to the transmitter will be made by the director module handling the stream I/O. A further prompt is then issued to the programmer. Second and subsequent prompts take the form of a plus character followed by a colon.

Prompts are issued by placing the required prompt-code in a suitable field, and using a TPUT macro instruction with a HOLD option. This ensures that any terminal output from previously executed PUT statements will appear at the terminal before the user is prompted to enter his input.

The prompt is issued to the foreground terminal irrespective of whether a PL/I output file is associated with the terminal.

Formatting

To simplify terminal usage various methods of data input are allowed that do not conform strictly to PL/I language specifications. For example list-directed input need not have a delimiting comma or blank and the trailing blanks need not be entered if a character item in edit-directed I/O does not fill the specified field width.

Formatting Module IBMBSPC

To simplify the use of a terminal, default formatting conventions are assumed. These apply to PAGE, SKIP, and LINE instructions and can be summarized as follows:

- SKIP instructions of 3 lines or less are followed.
- PAGE and LINE and SKIP instructions of more than 3 lines are interpreted as SKIP(3) instructions.

This default formatting can be overridden by the use of a PLITABS structure that specifies a value of 1 or greater for the page length. (PLITABS is described above under the heading "Formatting for Print Files.")

IBMBSPC checks the page-length value in the PLITABS control section. This control section will be either the default taken from the PL/I transient library module IBMBSTAB, or, if the values have been specified by the programmer, will be the values in the structure declared with the name PLITABS, or, possibly, a link-edited control section called PLITABS. In the library module IBMBSTAB, the page-length value is zero.

If the page-length value in the PLITABS control section is zero, the formatting conventions described above are used. These are referred to as *squashed mode*. If the value is greater than zero, normal formatting is undertaken.

The method of formatting used is for IBMBSPC to insert the required number of 'new line' characters in the output buffer, and to call the transmitter to transmit the buffer contents. (In the special case of SKIP (0), backspace characters are used.

The normal PL/I rules for ENDPAGE apply to formatted terminal output. ENDPAGE is not raised for squashed mode output.

Summary of Subroutines Used

This section gives a summary of the subroutines used in the implementation of stream-oriented input/output. Detailed descriptions of the library modules are given in the relevant program logic manuals.

Ten different types of subroutine are used in stream I/O. They are:

1. Initializing Modules
2. Director modules
3. Transmitter modules
4. Formatting modules
5. Conversion modules
6. External conversion director modules
7. Conversational modules
8. The conversion fix-up module (IBMBSCV)
9. The copy module (IBMBSCP)
10. The string housekeeping module (IBMBSIS)

The types of modules are dealt with below.

Initializing Modules

Initializing modules initialize the stream I/O statement. There are two of these modules:

IBMBSII	Input initializer
IBMBSIO	Output initializer

A further module is used for string handling, which is listed under "Miscellaneous Modules" on page 275.

IBMBSII is discussed in "The COPY Option" on page 268, while IBMBSIO is described under "PUT LIST Statement" on page 249.

Director Modules

Library Director Routines

IBMBSLI List-directed input

Entry point A: element item
Entry point B: complete array

IBMBSLO List-directed output

Entry point A: element item
Entry point B: complete array

IBMBSDI Data-directed input

Entry point A: with data list
Entry point B: all known variables

IBMBSDO Data-directed output

Entry point A: element variables and whole arrays
Entry point B: single array elements
Entry point C: all known variables and SIGNAL CHECK output
Entry point D: CHECK output for a single item
Entry point T: output a final semicolon only.

Modules Used with Compiler-Generated Subroutines

IBMBSEI Edit-directed input

Entry point A: housekeeping for input item spanning a record boundary.

Entry point T: raise TRANSMIT for spanning input item

IBMBSEO Edit-directed output housekeeping for output item spanning a record boundary.

Module for Complete Library Control of Edit-Directed I/O of a Single Item

IBMBSED

Entry point A: edit-directed input
Entry point B: edit-directed output

Compiler-Generated Director Routines

For input:

IELCGIX Provides the address of the source of an edit-directed data or X-format item.

IELCGIB Completes the transmission of an edit-directed data item, by freeing the VDA if one was used, updating the COUNT built-in function value, and calling IBMBSEIT if TRANSMIT has been raised.

For output:

IELCGOG Provides the address of the target of an edit-directed data item.

IELCGOH Completes the transmission of an edit-directed data item, updating the buffer items in the DCLCB, counting the data item, and freeing a VDA if one was used.

Transmitter Modules

The actual movement of the data between the external medium and the buffer area is carried out by a series of seven transmitter modules, which interface with the routines of OS data management. These modules essentially complete the setting up of the DCB, and issue the data management GET and PUT macro instructions, thus reading or writing one record.

One module is used for input, six for output. The output modules are divided into two groups: one group for PL/I print files, the other for all other output files. Both output module groups contain three modules: one for F-format records, one for V-format records, and one for U-format records. All modules interface with the queued sequential access method.

The following transmitters are used:

IBMBSTI	Input transmitter
IBMBSOF	Output transmitter for F-format records
IBMBSOV	Output transmitter for V-format records
IBMBSOU	Output transmitter for U-format records
IBMBSTF	Print transmitter for F-format records
IBMBSTV	Print transmitter for V-format records
IBMBSTU	Print transmitter for U-format records

Formatting Modules

Formatting modules control the position of the data on the external medium. There are three formatting modules: two library subroutines, and one compiler-generated subroutine.

Library Subroutines

IBMSBPL PAGE, LINE, and SKIP format items and options

Entry point A: PAGE option or format item
Entry point B: LINE option or format item
Entry point C: SKIP option or format item

IBMBSXC X and COLUMN format items

Entry point A: X format input
Entry point B: X format output
Entry point C: COLUMN format input
Entry point D: COLUMN format output

Compiler-Generated Subroutine

IELCGOCA X items, in edit-directed output, that do not span a record boundary.

External Conversation Director Modules

The following external conversion director routines are used exclusively in edit-directed I/O:

IBMBSAI	input A, B, and P character formats
IBMBSAO	output A, B, and P character formats
IBMBSCI	input C format
IBMBSCO	output C format
IBMBSFI	input F and E formats
IBMBSFO	output F and E formats
IBMBSPI	input P format arithmetic
IBMBSPO	output P format arithmetic

Conversational Modules

Transmitters:

IBMBSIC	input transmitter
IBMBSOC	output transmitter

Formatting module:

IBMBSPC	formatting module

Miscellaneous Modules

The other subroutines used in stream I/O are:

IBMBSCV	the conversion fix-up module
IBMBSCP	the copy module
IBMBSIS	the string housekeeping module

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