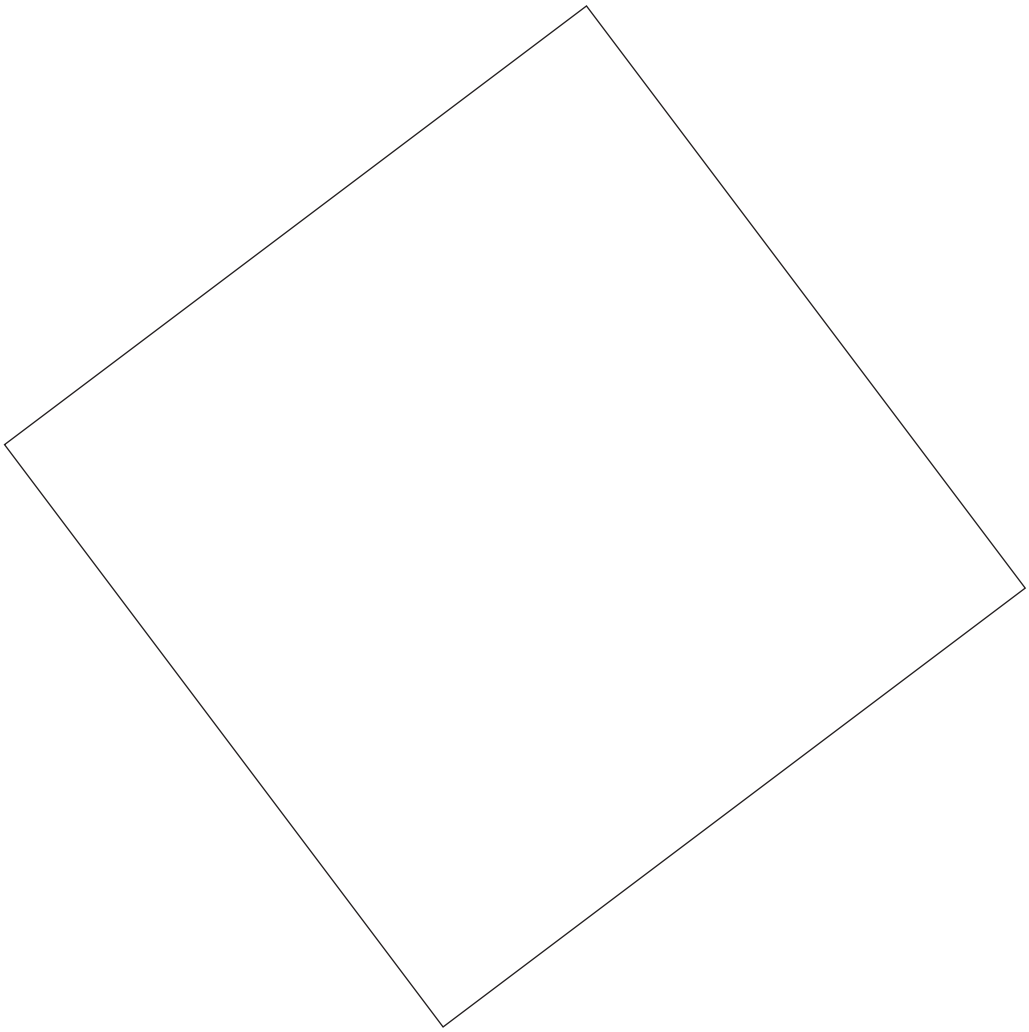
VisualAge for COBOL for OS/2

SC26-8419-02

Programming Guide

Version 1 Release 2



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VisualAge for COBOL for OS/2

SC26-8419-02

Programming Guide

Version 1 Release 2

Note!

Before using this information and the product it supports, be sure to read the general information under “Notices” on page xv.

| **Third Edition (September 1996)**

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Programming Interface Information

This *IBM VisualAge for COBOL for OS/2 Programming Guide* is intended to help the user create, compile, link, and run IBM VisualAge for COBOL for OS/2 application programs. This book documents General-Use Programming Interface and Associated Guidance Information provided by IBM VisualAge for COBOL for OS/2.

General-Use programming interfaces allow the customer to write programs that obtain the services of IBM VisualAge for COBOL for OS/2.

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About This Book

Welcome to IBM VisualAge for COBOL for OS/2, IBM's new COBOL development environment for OS/2, Windows 95, and Windows NT! IBM VisualAge for COBOL for OS/2 gives you a comprehensive development environment designed specifically for mission-critical, client/server applications.

IBM VisualAge for COBOL for OS/2 supports local and remote access to DB2, CICS, and VSAM, giving you access to data and transactions nearly anywhere in your enterprise. And all the IBM COBOL family of solutions support the high subset of ANSI 85 COBOL functions, so your applications can be ported across supported platforms, whether they are running on a mainframe, an RS/6000, or a personal computer with OS/2, Windows 95, or Windows NT.

IBM VisualAge for COBOL for OS/2 supports object-oriented extensions, allowing you to develop software objects using COBOL and share objects created by other languages, like C++.

IBM VisualAge for COBOL for OS/2 provides a complete development environment. The environment includes an editor, debugger, GUI designer, and performance analyzer, all integrated with WorkFrame. WorkFrame integrates your tools and files, so selecting a file also selects the application you need to control the execution of a program, examine and modify data, and perform many other useful functions.

How This Book Will Help You

This book will help you write, compile, link-edit, and run your IBM VisualAge for COBOL for OS/2 programs. It will also help you define OO classes and methods, invoke methods, and refer to objects in your programs.

This book assumes experience in developing application programs and some knowledge of COBOL. It focuses on using COBOL to meet your programming objectives and not on the definition of the COBOL language. For complete information on COBOL syntax, refer to *IBM COBOL Language Reference*.

There are some differences between host and PC COBOL. For details on language and system differences between IBM VisualAge for COBOL for OS/2 and IBM COBOL for MVS & VM, see Appendix A, “Summary of Differences with Host COBOL” on page 399.

This book also assumes familiarity with OS/2 or Windows and the IBM VisualAge for COBOL for OS/2 development environment. For information on OS/2 or Windows, see your operating system documentation. To learn about the IBM VisualAge for COBOL for OS/2 development environment, see the *Getting Started* guide.

Throughout this book, we use the term IBM VisualAge for COBOL for OS/2 to refer to both the OS/2 and Windows environments. To identify platform-specific information, we use one of these indicators:

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- Prefix the text with platform-specific text (for example, `Under OS/2...`)
- Add parenthetical qualifications (for example, `(Windows only)`)
- Bracket the text with icons. We use the following icons:

  OS/2 Informs you of information specific to OS/2.

  WIN Informs you of information specific to Windows.

Abbreviated Terms

Certain terms are used in a shortened form in this book. Abbreviations for the product names used most frequently in this book are listed alphabetically in Figure 1. Abbreviations for other terms, if not commonly understood, are shown in *italics* the first time they appear, and are listed in the glossary in the back of this book.

Figure 1. Common Abbreviations in this Book

Term Used	Long Form
CICS	CICS for OS/2
DB2	Database 2
OS/2	Operating System/2
SOM	System Object Model
STL	STL File System

In addition to these abbreviated terms, the term “COBOL 85 Standard” is used in this book to refer to the combination of the following standards:

- ISO 1989:1985, Programming languages - COBOL
- ISO 1989/Amendment 1, Programming Languages - COBOL - Amendment 1: Intrinsic function module
- X3.23-1985, American National Standard for Information Systems - Programming Language - COBOL
- X3.23a-1989, American National Standard for Information Systems - Programming Language - Intrinsic Function Module for COBOL

The two ISO standards are identical to the American National Standards.

Syntax Notation

Throughout this book, syntax for the compiler options is described using the structure defined below.

- Read the syntax diagrams from left to right, from top to bottom, following the path of the line. The following table shows the meaning of symbols at the beginning and end of syntax diagram lines.

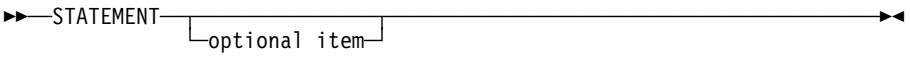
Syntax Notation

Symbol	Indicates
▸▸—	the syntax diagram starts here
—▸	the syntax diagram is continued on the next line
▸—	the syntax diagram is continued from the previous line
—▸◂	the syntax diagram ends here

Diagrams of syntactical units other than complete statements start with the ▸— symbol and end with the —▸ symbol.

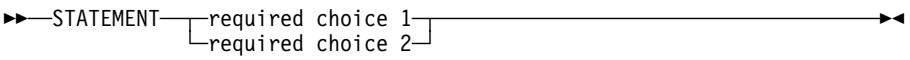
- Required items appear on the horizontal line (the main path).

- Optional items appear below the main path.

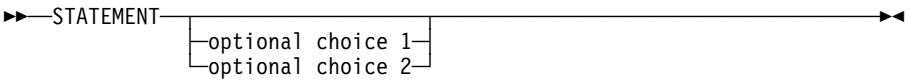


- When you can choose from two or more items, they appear vertically in a stack.

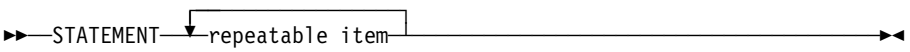
  If you **must** choose one of the items, one item of the stack appears on the main path.



  If choosing one of the items is optional, the entire stack appears below the main path.



- An arrow returning to the left above the main line indicates an item that can be repeated.



  A repeat arrow above a stack indicates that you can make more than one choice from the stacked items, or repeat a single choice.

- Keywords appear in uppercase letters (for example, PRINT). They must be spelled exactly as shown. Variables appear in all lowercase letters (for example, *item*). They represent user-supplied names or values.
- If punctuation marks, parentheses, arithmetic operators, or such symbols are shown, they must be entered as part of the syntax.
- Use at least one blank or comma to separate parameters.

How Examples Are Shown

This book shows numerous examples of sample COBOL statements, program fragments, and small programs to help illustrate the concepts being discussed. The examples of program code are written in lowercase, uppercase, or mixed case to demonstrate that you can write your programs in any of these three cases.

Where it helps to more clearly separate the examples from the explanatory text, they are indented, `presented in a different font style`, or are shown in boxes.

Names of files, COBOL keywords, commands, and options appearing in text are generally shown in SMALL UPPER CASE, unless they are mixed-case, in which case they are `presented in a different different font style`.

Summary of Changes

This section lists the key changes that have been made to the VisualAge for COBOL for OS/2 product since Release 1. Those documented in this publication have an associated page reference for you convenience. Technical changes are marked in the text by a change bar in the left margin.

Major Changes in Release 2

- Support for shared install (Standard Only)
  - Install only those files that must be local to your hard drive
  - Remainder of the files remain on the CD-ROM or on a LAN server
- Redeveloper tools (Professional Only)
  - Understand the resources, structure, and flow of your applications
  - Understand your program logic, control flow, and data flow
  - Upgrade existing applications by converting and structuring older COBOL programs to newer levels of COBOL
- Transaction Assistant: improved dialogue and steps
- Packaging Utility: enhanced diskette-generating interface and reduced space requirements
- Integrated SQL processing (Chapter 19, “Programming for a DB2 Environment” on page 339)
  - Eliminates the need for DB2 pre-processing
  - Removes restrictions such as the use OO extensions, nested programs, and batch compilation with SQL statements
- Optimization of compiler-generated code (“OPTIMIZE” on page 164)
- Transparent access of MVS PDS members for COPY files (OS/2 only) (Accessing MVS PDS files on page 182)
- Support for source file extensions other than .CBL (“Filenames and Extensions Supported” on page 137)
- Support for binary collating sequence for enhanced performance" (“COLLSEQ” on page 147)
- Support for _FAR16_Pascal and CDECL calling conventions (“CALLINT” on page 146)
- Support for Open Database Connectivity (ODBC) that provides you access to data from a variety of databases and file systems (Chapter 21, “Open Database Connectivity” on page 348)

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- Windows First Step provides an IBM COBOL application development environment on Windows 95 and Windows NT that includes a 32-bit compiler, run-time, editor, debug tool, and Performance Analyzer
- Support for the Standard Language File System (STL File System), which supports sequential, indexed, and relative files on the local system effeciently and consistently across workstation and PC systems (Chapter 7, “Processing Files” on page 88)

Part 1. Coding Your Programs

This part of the book explains how to do various programming tasks using the COBOL language. It discusses the most common topics, starting with basic ones, then building on those in succeeding chapters. Topics related to object-oriented COBOL are in Part 3, "Object-Oriented Programming Topics" on page 213. More complex programming topics are treated in Part 4, "Advanced Topics" on page 301.

For complete details on the COBOL language, see *IBM COBOL Language Reference*.

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Chapter 1. Introduction to COBOL Terms

This chapter is intended to help the non-COBOL programmer relate terms used in other programming languages to COBOL terms.

This chapter introduces COBOL fundamentals for:

- COBOL Terms for Variables, Structures, Literals, and Constants
- Assignment and Terminal Interaction
- Built-In (Intrinsic) Functions
- Tables and Pointers

COBOL Terms for Variables, Structures, Literals, and Constants

Most high-level programming languages share the concept of data being represented as variables, structures, literals, and constants. This section describes how these data representations are defined in COBOL. You place all data-item definitions in the DATA DIVISION of your program.

Variables

In COBOL you refer to a variable by a *data-name*. For example, if a customer name is a variable in your program, code:

```
Data Division.
    ⋮
01  Customer-Name               Pic X(20).
01  Original-Customer-Name      Pic X(20).
    ⋮
Procedure Division.
    ⋮
    Move Customer-Name to Original-Customer-Name
    ⋮
```

The data used in a COBOL program can be divided into three classes: alphabetic, alphanumeric, and numeric. For complete details on the classes and categories of data and the PICTURE clause rules for defining data, see *IBM COBOL Language Reference*.

Data Structure

Related data items are often parts of a larger, hierarchical data structure. A data item that is composed of subordinated data items is called a group item. An elementary data item is a data item that does not have any subordinate items. A record can be either an elementary data item or a group of data items.

Group Items Example

In the following example, `Customer-Record` is a group item composed of two group items (`Customer-Name` and `Part-Order`) both of which contain elementary data items. You can refer to the entire group item or to parts of the group item as shown in the MOVE statements in the Procedure Division.

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```
Data Division.
File Section.
FD  Customer-File
    Record Contains 45 Characters.
01  Customer-Record.
    05  Customer-Name.
        10 Last-Name            Pic x(17).
        10 Filler               Pic x.
        10 Initials             Pic xx.
    05  Part-Order.
        10 Part-Name            Pic x(15).
        10 Part-Color           Pic x(10).
Working-Storage Section.
01  Orig-Customer-Name.
    05  Surname                Pic x(17).
    05  Initials               Pic x(3).
01  Inventory-Part-Name        Pic x(15).
    ⋮
Procedure Division.
    ⋮
    Move Customer-Name to Orig-Customer-Name
    Move Part-Name to Inventory-Part-Name
    ⋮
```

Literals

When you know the value you want to use for a data item, you don't need to define or refer to a data-name; instead use a literal representation of the data value in the Procedure Division.

For example, you might want to prepare an error message for an output file:

```
Move "Invalid Data" To Customer-Name
```

Or, you might want to compare a data item to a certain number:

```
01  Part-number                Pic 9(5).
    ⋮
    If Part-number = 03519 then display "Part number was found"
```

In these examples, `"Invalid Data"` is a non-numeric literal, and `03519` is a numeric literal.

Constants

COBOL does not define a construct specifically for constants, but most programmers define a data item with an initial VALUE (as opposed to initializing a variable using the INITIALIZE statement):

```
Data Division.
⋮
01  Report-Header              pic x(50)  value "Company Sales Report".
⋮
01  Interest                   pic 9v9999 value 1.0265.
```

Figurative Constants

Certain commonly used constants and literals are provided as reserved words, called figurative constants. Because they represent fixed values, figurative constants do not require a data definition: ZERO, SPACE, HIGH-VALUE, LOW-VALUE, QUOTE, NULL, ALL.

For example: `Move Spaces To Report-Header`.

Assignment and Terminal Interactions

After you have defined a data item, you can assign a value to it at any time. Assignment takes many forms in COBOL, depending on the purpose behind the assignment:

Figure 2. How to Assign Values to a Data Item

What You Want to Do	How to Do It
Assign values to a data item or large data area	One of these ways: INITIALIZE statement MOVE statement STRING or UNSTRING statement VALUE clause (To set data items to the values you want them to have when the program is in its initial state.)
Replace characters or groups of characters in a data item	INSPECT statement
Receive input values from the terminal	ACCEPT statement
Receive input values from a file	READ (or READ INTO) statement
Assign the results of arithmetic	COMPUTE statement

Initializing a Variable (INITIALIZE Statement)

The following examples illustrate some uses of the INITIALIZE statement. (The symbol `b` indicates a space.)

Initializing a Variable to Blanks or Zeroes:

```
INITIALIZE identifier-1
```

IDENTIFIER-1 PICTURE	IDENTIFIER-1 Before	IDENTIFIER-1 After
9(5)	12345	00000
X(5)	AB123	bbbbb
99XX9	12AB3	bbbbb
XXBX/XX	ABbC/DE	bbbb/bb
**99.9CR	1234.5CR	**00.0bb
A(5)	ABCDE	bbbbb
+99.99E+99	+12.34E+02	+00.00E+00

Initializing a Right-Justified Field:

```
01  ANJUST                 PIC X(8)  JUSTIFIED RIGHT.
01  ALPHABETIC-1           PIC A(4)  VALUE "ABCD".
    ⋮
    INITIALIZE ANJUST
        REPLACING ALPHANUMERIC DATA BY ALPHABETIC-1
```

ALPHABETIC-1	ANJUST Before	ANJUST After
ABCD	bbbbbbbb	bbbbABCD

Initializing an Alphanumeric Variable:

```
01  ALPHANUMERIC-1         PIC X.
01  ALPHANUMERIC-3         PIC X(1) VALUE "A".
    ⋮
    INITIALIZE ALPHANUMERIC-1
        REPLACING ALPHANUMERIC DATA BY ALPHANUMERIC-3
```

ALPHANUMERIC-3	ALPHANUMERIC-1 Before	ALPHANUMERIC-1 After
A	y	A

Initializing a Numeric Variable:

```
01  NUMERIC-1              PIC 9(8).
01  NUM-INT-CMPT-3         PIC 9(7) COMP VALUE 1234567.
    ⋮
    INITIALIZE NUMERIC-1
        REPLACING NUMERIC DATA BY NUM-INT-CMPT-3
```

NUM-INT-CMPT-3	NUMERIC-1 Before	NUMERIC-1 After
1234567	98765432	01234567

Initializing an Edited Alphanumeric Variable:

```
01  ALPHANUM-EDIT-1        PIC XXBX/XXX.
01  ALPHANUM-EDIT-3        PIC X/BB VALUE "M/ƀƀ".
    ⋮
    INITIALIZE ALPHANUM-EDIT-1
        REPLACING ALPHANUMERIC-EDITED DATA BY ALPHANUM-EDIT-3
```

ALPHANUM-EDIT-3	ALPHANUM-EDIT-1 Before	ALPHANUM-EDIT-1 After
M/ƀƀ	ABƀC/DEF	M/ƀƀ/ƀƀƀ

Initializing a Structure (INITIALIZE Statement)

You can reset the values of all subordinate items in a group by applying the INITIALIZE statement to the group item. However, it is inefficient to initialize an entire group unless you really need all the items in the group initialized.

The following example shows how you can reset fields in a transaction record produced by a program to spaces and zeros. (Notice that the fields are not identical in each record produced.)

```
01  TRANSACTION-OUT.
    05  TRANSACTION-CODE              PIC X.
    05  PART-NUMBER                   PIC 9(6).
    05  TRANSACTION-QUANTITY          PIC 9(5).
    05  PRICE-FIELDS.
        10  UNIT-PRICE                PIC 9(5)V9(2).
        10  DISCOUNT                  PIC V9(2).
        10  SALES-PRICE               PIC 9(5)V9(2).
    ⋮
    INITIALIZE TRANSACTION-OUT
```

	TRANSACTION-OUT Before	TRANSACTION-OUT After
Record 1	R00138300024000000000000000	ƀ0000000000000000000000000
Record 2	R00139000048000000000000000	ƀ0000000000000000000000000
Record 3	S00141000012000000000000000	ƀ0000000000000000000000000
Record 4	C00138300000000425000000000	ƀ0000000000000000000000000
Record 5	C00201000000000000100000000	ƀ0000000000000000000000000

Note: The symbol ƀ represents a blank space.

Assigning Values to Variables or Structures (MOVE Statement)

Use the MOVE statement to assign values to variables or structures. For example, the following statement:

```
Move Customer-Name to Orig-Customer-Name
```

assigns the contents of the variable `Customer-Name` to the variable `Orig-Customer-Name`. If `Customer-Name` were longer than `Orig-Customer-Name`, truncation would occur on the

right. If it were shorter, the extra character positions on the right would be filled with spaces.

When you move a group item to another group item, be sure the subordinate data descriptions are compatible. The compiler performs all MOVE statements regardless of whether items fit, even if that means a destructive overlap could occur at run time. In such cases, you'll get a warning message when you compile your program.

Assigning Values to Numeric Variables

For variables containing numbers, moves can be more complicated because there are several ways numbers are represented. In general, the algebraic values of numbers are moved if possible (as opposed to the digit-by-digit move performed with character data):

```
01  Item-x            Pic 999v9.
    ⋮
    Move 3.06 to Item-x
```

This move would result in `Item-x` containing the value 3.0, represented by 0030.

Assigning Terminal Input to Variables (ACCEPT Statement)

Another way to assign a value to a variable is to read the value from the terminal. To enter data from the terminal, first associate the terminal with a mnemonic-name in the SPECIAL-NAMES Paragraph:

```
Environment Division.
Configuration Section.
Special-Names.
   Console is Names-Input.
```

Then the statement:

```
Accept Customer-Name From Names-Input
```

assigns the line of input entered at the terminal to the variable `Customer-Name`.

For more information on setting environment variables, see “Setting Environment Variables” on page 129.

Displaying Data Values on the Terminal (DISPLAY Statement)

In addition to assigning a variable a value read in from the terminal, you can also display the value of a variable on the terminal. For example, if the contents of the variable `Customer-Name` were JOHNSON, then the following statement:

```
Display “No entry for surname '” Customer-Name “' found in the file.”
```

would display this message on the terminal:

```
No entry for surname 'JOHNSON' found in the file.
```

Assigning Arithmetic Results

When assigning a number to a variable, it is sometimes better to use the COMPUTE statement instead of the MOVE statement. For example, the following two statements accomplish the same thing in most cases:

```
Move w to z
Compute z = w
```

However, when significant left-order digits would be lost in execution, the COMPUTE statement can detect the condition and allow you to handle it. The MOVE statement carries out the assignment with destructive truncation.

When you use the ON SIZE ERROR phrase of the COMPUTE statement, the compiler generates code to detect a size-overflow condition. If the condition occurs, the code in the ON SIZE ERROR phrase is performed, and the content of z remains unchanged. If the ON SIZE ERROR phrase is not specified, the assignment is carried out with truncation. There is no ON SIZE ERROR support for the MOVE statement.

Assigning Results of Computations (COMPUTE Statement)

The COMPUTE statement is also used to assign the result of an arithmetic expression (or intrinsic function) to a variable. For example:

```
Compute z = y + (x ** 3)
Compute x = Function Max(x y z)
```

For information on intrinsic functions, see the *IBM COBOL Language Reference*.

Built-in (Intrinsic) Functions

Some high-level programming languages have built-in functions that you can reference in your program as if they were variables having defined attributes and a predetermined value. In COBOL, these are called *intrinsic functions*; they provide various string- and number-manipulation capabilities.

Introduction to Intrinsic Functions

The groups of highlighted words in the following examples are referred to as *function-identifiers*. A function-identifier is the combination of the COBOL reserved word FUNCTION followed by a *function-name* (such as Max), followed by any arguments to be used in the evaluation of the function (such as x, y, z):

```
Unstring Function Upper-case(Name) Delimited By Space Into Fname Lname

Compute A = 1 + Function Log10(x)

Compute M = Function Max(x y z)
```

A function-identifier represents both the function's invocation and the data value returned by the function. Because it actually represents a data item, a function-identifier can be used in most places in the Procedure Division where a data item having the attributes of the returned value can be used.

Because the value of an intrinsic function is derived automatically at the time of reference, you do not need to define functions in the Data Division. Define only the non-literal data items that you use as arguments. Figurative constants are not allowed as arguments.

Using Function References in Other Contexts

Function-identifiers are loosely referred to in this book as function references. Whereas the COBOL word FUNCTION is a reserved word, the function-names are not reserved; you can use them in other contexts, such as for the name of a variable, and without references to a function.

For example, you could use SQRT to invoke an intrinsic function and/or to name a variable in your program:

```
Working-Storage Section.
01  x                 Pic 99  value 2.
01  y                 Pic 99  value 4.
01  z                 Pic 99  value 0.
01  Sqrt              Pic 99  value 0.
    ⋮
    Compute Sqrt = 16 ** .5
    Compute z = x + Function Sqrt(y)
    ⋮
```

Types of Intrinsic Functions

A function-identifier represents a value that is either a character string (alphanumeric data class) or a number (numeric data class) depending on the type of function. Two of the functions, MAX and MIN, can return either type of value depending on the type of arguments you supply.

Numeric intrinsic functions are further classified according to the type of numbers they return. See the *IBM COBOL Language Reference* for more details.

Nesting Functions

Functions can reference other functions as arguments as long as the results of the nested functions meet the requirements for the arguments of the outer function. For example:

```
Compute x = Function Max((Function Sqrt(5)) 2.5 3.5)
```

In this case, `Function Sqrt(5)` returns a numeric value. Thus, the three arguments to the MAX function are all numeric, which are allowable argument types for this function.

Some of the examples in the next three chapters show nesting of functions.

Substrings of Function-Identifiers

You can include a substring specification (reference modifier) in your function-identifier for alphanumeric functions.

Arguments to Intrinsic Functions

The ALL subscript, which enables you to easily reference all of the elements of an array as function arguments, and allowable types of function arguments are discussed in *IBM COBOL Language Reference*.

Arrays and Pointers

In COBOL, arrays are called tables. The language constructs available for representing and handling tables are discussed in Chapter 4, “Handling Tables” on page 44.

Pointers

Pointer data items can contain virtual storage addresses. You define them explicitly with the USAGE IS POINTER clause in the Data Division or implicitly as ADDRESS OF special registers.

Pointer data items can be:

- Passed between programs using the CALL ... BY REFERENCE statement
- Moved to other pointers using the SET statement
- Compared to other pointers for equality using a relation condition
- Initialized to contain an invalid address, using VALUE IS NULL

Use pointer data items to:

- Accomplish limited base addressing, particularly if you want to pass and receive addresses of a variably located record area.
- Handle a chained list.

Procedure Pointers

A procedure pointer is a pointer to an entry point. Define the entry address for a procedure entry point with the USAGE IS PROCEDURE-POINTER clause in the Data Division.

Chapter 2. Program Structure

A COBOL program consists of four divisions, each with a specific logical function. Only the IDENTIFICATION DIVISION is required.

- The IDENTIFICATION DIVISION, discussed on page 11.
- The ENVIRONMENT DIVISION, discussed on page 12.
- The DATA DIVISION, discussed on page 17.
- The PROCEDURE DIVISION, discussed on page 21.

To define a COBOL class or method, you need to define some divisions differently than you would for a program. For detail on the differences, see “Writing a Class Definition” on page 216 or “Writing a Method Definition” on page 220.

IDENTIFICATION DIVISION

Use the IDENTIFICATION DIVISION to name your program and to optionally give other identifying information. For example:

```
Identification Division.
Program-ID. Helloprog.
Author. A. Programmer.
Installation.  Computing Laboratories.
Date-Written.  12/15/95.
Date-Compiled. 12/17/95.
```

You can use the optional AUTHOR, INSTALLATION, DATE-WRITTEN, and DATE-COMPILED paragraphs for descriptive information about your program. The data you enter on the DATE-COMPILED paragraph is replaced with the latest compilation date.

PROGRAM-ID Paragraph

Use the PROGRAM-ID paragraph to name your program. The program name you assign is used in these ways:

- Other programs use the name to call your program.
- The name appears in the header on each page, except the first page, of the program listing generated when the program is compiled. (See “Changing Header of Source Listing” on page 12 for details.)

Marking Programs as RECURSIVE

Code the RECURSIVE attribute on the PROGRAM-ID clause so your program can be recursively re-entered while a previous invocation is still active.

RECURSIVE can be coded only on the outermost program of a compilation unit. Neither programs containing nested subprograms nor nested subprograms can be recursive.

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Marking Programs as COMMON

Use the COMMON attribute with the PROGRAM-ID clause so your program can be called by the containing program or by any program in the containing program. However, the COMMON program cannot be called by any program contained in itself. Only contained programs can have the COMMON attribute. For more information, see "Nested Programs" on page 310.

Marking Programs as INITIAL

Use the INITIAL attribute to specify that whenever a program is called, it is placed in its initial state, and any of its contained programs are also placed in their initial states.

Definition of Initial State: Essentially, a program is in its initial state when data items having VALUE clauses are set to the specified value, changed GO TO statements and PERFORM statements are set to their initial states, and non-EXTERNAL files are closed.

Avoiding Mismatches Between Names

To avoid mistakes when the name is case-sensitive, verify that the appropriate setting of the PGMNAME option is used.

Changing Header of Source Listing

The header on the first page of your source statement listing contains the identification of the compiler and the current release level, plus the date and time of compilation and the page number.

```
PP 5622-793 IBM VisualAge for COBOL for OS/2 1.2.0                  Date    04/28/96  Time 08:23:45   Page 1
```

You can customize the header on succeeding pages of the listing with the compiler-directing TITLE statement. See the *IBM COBOL Language Reference* for details of the TITLE statement.

ENVIRONMENT DIVISION

In the ENVIRONMENT DIVISION you can describe those aspects of your program that are dependent upon the characteristics of the computing environment in which you are working.

CONFIGURATION SECTION

You can use the CONFIGURATION SECTION to describe the computer for compiling your program (in the SOURCE-COMPUTER paragraph); describe the computer for running your program (in the OBJECT-COMPUTER paragraph); and specify such items as the currency sign, symbolic characters (in the SPECIAL-NAMES paragraph), and user-defined classes (in the REPOSITORY paragraph). Figure 3 on page 14 shows a sample of some of the entries you might include in the CONFIGURATION SECTION.

Specify the Collating Sequence

Using the PROGRAM COLLATING SEQUENCE clause and the ALPHABET clause of the SPECIAL-NAMES paragraph, you can establish the collating sequence used in the following operations:

- Non-numeric comparisons explicitly specified in relation conditions and condition-name conditions
- HIGH-VALUE and LOW-VALUE settings
- SEARCH ALL
- SORT and MERGE unless overridden by a COLLATING SEQUENCE phrase on the SORT or MERGE statement.

The sequence you use can be based on one of these alphabets:

- NATIVE

  NATIVE is the collating sequence specified by the locale setting. The locale setting refers to the national language locale name in effect at compile time. It is usually set at installation. See "Locale Sensitivity" on page 391 for more information about locale sensitivity.
- EBCDIC
- ASCII (use NATIVE if the native character set is ASCII, STANDARD-1[1] if it is not).
- ISO 7-bit code[2] , International Reference Version (use STANDARD-2).
- An alteration of the EBCDIC sequence that you define in the SPECIAL-NAMES paragraph.

You can also specify a collating sequence of your own definition.

Caution: If the code page is DBCS, the ALPHABET-NAME clause is not allowed.

Specifying Collating Sequence Example: Figure 3 on page 14 shows the ENVIRONMENT DIVISION coding used to specify a collating sequence where uppercase and lowercase letters are similarly handled for comparisons and for sorting or merging. When you change the ASCII sequence in the SPECIAL-NAMES paragraph, the overall collating sequence is affected, not just the collating sequence of the characters included in the SPECIAL-NAMES paragraph.

1 STANDARD-1 refers to *American National Standard X3.4, Code for Information Interchange*

2 ISO 7-bit code, as defined in *International 646, 7-Bit Coded Character Set for Information Processing Interchange, International Reference*.

```
Identification Division.

    ⋮

Environment Division.
  Configuration Section.
   Object-Computer.
      Program Collating Sequence Special-Sequence.
   Special-Names.
      Alphabet Special-Sequence Is
          "A" Also "a"
          "B" Also "b"
          "C" Also "c"
          "D" Also "d"
          "E" Also "e"
          "F" Also "f"
          "G" Also "g"
          "H" Also "h"
          "I" Also "i"
          "J" Also "j"
          "K" Also "k"
          "L" Also "l"
          "M" Also "m"
          "N" Also "n"
          "O" Also "o"
          "P" Also "p"
          "Q" Also "q"
          "R" Also "r"
          "S" Also "s"
          "T" Also "t"
          "U" Also "u"
          "V" Also "v"
          "W" Also "w"
          "X" Also "x"
          "Y" Also "y"
          "Z" Also "z".
```

Figure 3. Example of an Alternate Collating Sequence

Define Symbolic Characters

Use the SYMBOLIC CHARACTER clause to give symbolic names to any character of the specified alphabet. For example, to give a name to the plus character (X'2B' in the ASCII alphabet) code:

```
SYMBOLIC CHARACTERS PLUS IS 44
```

Use ordinal position to identify the character; position 1 corresponds to character X'00'.

Define a User-Defined Class

Use the CLASS clause to give a name to a set of characters listed in the clause. For example, name the set of digits by coding:

```
CLASS DIGIT IS "0" THROUGH "9"
```

The class name can only be referenced in a class condition. (This user-defined class is not the same concept as an object-oriented class.)

INPUT-OUTPUT SECTION:

Your IBM VisualAge for COBOL for OS/2 programs can process files with line sequential, sequential, indexed, or relative organization.

Use the FILE-CONTROL and I-O-CONTROL paragraphs to:

- Identify and describe the characteristics of your program files.
- Associate your files with the corresponding system file name, directly or indirectly.
- Optionally identify the file system (for example, VSAM or &stlf) associated with the file. You can also do this at program execution time.
- Provide information on how the file is accessed.

FILE-CONTROL Paragraph

The FILE-CONTROL paragraph associates each file in the COBOL program with a physical file known to your file system. Figure 4 shows an example of a FILE-CONTROL paragraph for a VSAM indexed file.

FILE-CONTROL Entries for a VSAM Indexed File:

```
SELECT COMMUTER-FILE          1
   ASSIGN TO COMMUTER         2
   ORGANIZATION IS INDEXED    3
   ACCESS IS RANDOM           4
   RECORD KEY IS COMMUTER-KEY 5
   FILE STATUS IS             5
     COMMUTER-FILE-STATUS
     COMMUTER-VSAM-STATUS.
```

Figure 4. Example of a FILE-CONTROL Paragraph

1 The SELECT clause chooses a file in the COBOL program to be associated with a corresponding system file.

2 The ASSIGN clause associates the program's name for the file with the name of the file as known to the system. COMMUTER may be the system file name or the name of the environment variable whose value (at run time) is used as the system file name with optional directory and path names.

3. Use the ORGANIZATION clause to describe the file's organization. If omitted, the default is ORGANIZATION IS SEQUENTIAL.
4. Use the ACCESS MODE clause to define the manner in which the records in the file will be made available for processing—sequential, random, or dynamic. If you omit this clause, ACCESS IS SEQUENTIAL is assumed.
5. You might have additional statements in the FILE-CONTROL paragraph depending on the type of file and file system you use. See the *IBM COBOL Language Reference* for more information about the FILE-CONTROL paragraph.

Chapter 7, “Processing Files” on page 88 provides a general overview on files and file processing.

Identifying Files to the Operating System

As stated in the previous example, the ASSIGN clause associates the program's name for a file with the name of the file as known to the operating system.

You can use either an environment variable or a system file name in the ASSIGN clause. If you specify an environment variable, its value is evaluated at run time and is used as the system file name with optional directory and path names.

If you plan to use a file system other than VSAM—for example, STL File System—you need to put a file system identifier before the file system name. For example, if the file `MYFILE` is a Btrieve file and you use `F1` as the file's name in your program, the ASSIGN clause would be

```
SELECT F1 ASSIGN TO BTR-MYFILE
```

Note that this assumes that `MYFILE` is a system file name and not an environment variable. If `MYFILE` is an environment variable, then its value will be used. For example, if it is set to `MYFILE=VSAM-YOURFILE`, the system file name in the ASSIGN clause becomes `YOURFILE` at run time, and the file is treated as a VSAM file, overriding the file system ID used in ASSIGN clause in the program.

Vary the Input/Output File at Run Time

The *file-name* you code in your SELECT sentence is used as a constant throughout your COBOL program, while the name of the file in your SET command can be associated with a different file at run time.

Changing a *file-name* in your COBOL program requires changing input/output statements and recompiling the program. In contrast, you can change the *assignment-name* in your SET command.

Example of Using Different Input Files: As an example, consider a COBOL program that might be used in exactly the same way for several different master files. It contains this SELECT sentence:

```
SELECT MASTER
    ASSIGN TO MASTERA
```

For example, if you are accessing both `checking` and `savings` files using the same `MASTER` file, you can set the MASTERA environment variable prior to the program execution as follows:

```
set MASTERA=d:\accounts\checking
```

to access the file named `checking` in the `d:\accounts` drive and directory and

```
set MASTERA=d:\accounts\savings
```

to do the same for the file named `savings`

The same program can be used to access both `checking` and `savings` files by way of the COBOL `MASTER` file without source program changes or recompilation.

Environment variable values in effect at the time of the program invocation are used for associating COBOL file names to the system file names (including any drive and path specifications).

DATA DIVISION

Define the characteristics of your data and group your data definitions into one of the sections in the DATA DIVISION:

- Define data used in input/output operations in the FILE SECTION (discussed in "FILE SECTION (Using Data in Input/Output Operations)").
- Define data developed for internal processing:
  - To be statically allocated and exist for the life of the run-unit: WORKING-STORAGE SECTION (discussed on page 19).
  - To be allocated each time a program is called and deallocated when the program ends: LOCAL-STORAGE SECTION (discussed on page 19).
- Describe data from another program in the LINKAGE SECTION (discussed on page 21).

Limits in the DATA DIVISION

The IBM VisualAge for COBOL for OS/2 compiler limits the maximum size of data division elements. For a complete list of these compiler limits, see *IBM COBOL Language Reference*.

FILE SECTION (Using Data in Input/Output Operations)

Define the data you use in input and output operations in the FILE SECTION:

- Name the input and output files your program will use.

  Use the FD entry to give names to your files that the input/output statements in the PROCEDURE DIVISION can refer to.

  Caution: Data items defined in the FILE SECTION are not available to PROCEDURE DIVISION statements until the file has been successfully opened.

- In the record description following the FD entry describe the records and their fields in the file. The *record-name* established is the object of WRITE and REWRITE statements.

Function and Use of FILE SECTION Entries

Entries in the FILE SECTION are summarized in Figure 5 on page 18.

Figure 5. FILE SECTION Entries

Clause	To Define
FD	The *file-name* to be referred to in PROCEDURE DIVISION input/output statements (OPEN, CLOSE, READ, START, and DELETE). Must match *file-name* in the SELECT clause. *file-name* is associated with the system file through the *assignment-name*.
RECORD CONTAINS *n*	Size of logical records (fixed length)
RECORD IS VARYING	Size of logical records (variable length)
RECORD CONTAINS *n* TO *m*	Size of logical records (variable length)
VALUE OF	An item in the label records associated with file. Comments only.
DATA RECORDS	Names of records associated with file. Comments only.
RECORDING MODE	Record type for sequential files.

Sharing Files Using the EXTERNAL and GLOBAL Clauses

Programs in the same run unit can refer to the same COBOL file names. You can also share physical files without using external or global file definitions in COBOL source programs.

For example, if you specify:

```
SELECT F1 ASSIGN TO MYFILE.
SELECT F2 ASSIGN TO MYFILE.
```

The application has two COBOL file names, but these COBOL files are associated with one system file.

EXTERNAL: Is used for separately compiled programs. A file that is defined as EXTERNAL can be referenced by any program in the run unit that describes the file. See “Sharing Files between Programs (EXTERNAL Files)” on page 333 for an example.

GLOBAL: Is used for programs in a nested, or contained, structure. If a program contains another program (directly or indirectly), both programs can access a common file by referencing a GLOBAL file name. For more information on contained programs and the GLOBAL clause, see "Nested Programs" on page 310.

WORKING-STORAGE SECTION and LOCAL-STORAGE SECTION

You can write a program that processes data without performing any input/output operations. All the data would be defined in the WORKING-STORAGE SECTION or LOCAL-STORAGE SECTION.

Most programs, however, have a combination of input and output file processing and internal data manipulation; the data files are defined in the FILE SECTION, and the data developed by the program is defined in the WORKING-STORAGE SECTION or LOCAL-STORAGE section.

What is the WORKING-STORAGE SECTION?

When a program is invoked, the WORKING STORAGE associated with the program is allocated. Any data items with VALUE clauses are initialized to the appropriate value at that time. For the duration of the run-unit, Working-Storage items persist in their last-used state. Exceptions are:

- A program with INITIAL specified on the PROGRAM-ID.

  In this case, WORKING-STORAGE data items are reinitialized each time the program is entered.

- A subprogram that is called and then cancelled.

  In this case, WORKING-STORAGE DATA items are reinitialized on the first reentry into the program following the CANCEL.

Working-Storage is deallocated at the termination of the run-unit.

What is the LOCAL-STORAGE SECTION?

Local-Storage is allocated each time the program is called and is deallocated when the program returns via an EXIT PROGRAM, GOBACK, or STOP RUN. Any data items with VALUE clauses are initialized to the appropriate value each time the program is called. The value in the data items is lost when the program returns.

Storage Sections Example

The following is an example of a recursive program that uses both Working-Storage and Local-Storage.

```
CBL apost,pgmn(lu)
*********************************
* Recursive Program - Factorials
*********************************
 Identification Division.
 Program-Id. factorial recursive.
 Environment Division.
 Data Division.
 Working-Storage Section.
 01  numb  pic 9(4)  value 5.
 01  fact  pic 9(8)  value 0.
 Local-Storage Section.
 01  num  pic 9(4).
 Procedure Division.
     move numb to num.

     if numb = 0
        move 1 to fact
     else
        subtract 1 from numb
        call 'factorial'
        multiply num by fact
     end-if.

     display num '! = ' fact.
     goback.
 End Program factorial.
```

Figure 6. Storage Sections Example

```
Recursive
 CALL's:  Main  1   2   3   4   5
-----------------------------------
L-S   num   5   4   3   2   1   0
-----------------------------------
W-S  numb   5   4   3   2   1   0
     fact   0   0   0   0   0   0
-----------------------------------

Recursive
GOBACK's:   5   4   3   2   1  Main
-----------------------------------
L-S   num   0   1   2   3   4   5
-----------------------------------
W-S  numb   0   0   0   0   0   0
     fact   1   1   2   6   24  120
-----------------------------------
```

LINKAGE SECTION (Using Data from Another Program)

How you share data depends on whether the programs are separately compiled or are nested.

Separately Compiled Programs

Many times an application's solution consists of many separately compiled programs that call and pass data to one another. The LINKAGE SECTION in the called program describes the data passed from another program. The calling program must use a CALL ... USING OR INVOKE ... USING statement to pass the data. For details on using data from other programs, see "Passing Data" on page 321.

Nested Programs

An application's solution might consist of nested programs—programs that are contained in other programs. Level-01 LINKAGE SECTION data items can include the GLOBAL attribute. This allows any nested program that includes the declarations to access these LINKAGE SECTION data items.

A nested program can also access data items in a sibling program (one at the same nesting level in the same containing program) that is declared with the COMMON attribute For more details, see "Nested Programs" on page 310.

With Recursion or Multithreading

If you compile your program as recursive or with the THREAD option, data defined in the LINKAGE SECTION may not be accessible between entries.

The ability to address a record in the LINKAGE SECTION is established by:

- Passing an argument to the program and specifying the record in an appropriate position in the USING phrase in the program *or*
- Using the Format 5 SET statement.

If you compile your program as recursive or with the THREAD option, the address to that record is valid for the particular instance of the program invocation. The address to the record in another execution instance of the same program must be re-established for that execution instance. Unpredictable results will occur if reference is made to a data item whose address has not been established.

PROCEDURE DIVISION

In the PROCEDURE DIVISION of a program you code the executable statements that process the data you have defined in the other divisions. The PROCEDURE DIVISION contains one or two headers and the logic of your program.

PROCEDURE DIVISION Headers

The PROCEDURE DIVISION begins with the division header and a *procedure-name* header. The division header for a program can simply be:

```
PROCEDURE DIVISION.
```

Or, you can code your division header to receive parameters with the USING phrase or to return a value with the RETURNING Phrase.

USING Phrase: To receive an argument that was passed by reference (the default) or by content, code the division header for a program like this:

```
PROCEDURE DIVISION USING dataname
```

Or this:

```
PROCEDURE DIVISION USING BY REFERENCE dataname
```

Take Note: *dataname* in these examples would need to be defined in the LINKAGE SECTION of the program.

To receive a parameter that was passed by value, code the division header for a program like this:

```
PROCEDURE DIVISION USING BY VALUE dataname
```

See “Passing Data” on page 321 for more information on BY VALUE.

RETURNING Phrase: To return a value as a result, code the division header like this:

```
Procedure Division RETURNING dataname2
```

You can also combine USING AND RETURNING in a PROCEDURE DIVISION header:

```
Procedure Division USING dataname RETURNING dataname2
```

Take Note: *dataname* and *dataname2* in these examples would need to be defined in the LINKAGE SECTION.

How Logic is Divided in the PROCEDURE DIVISION

The PROCEDURE DIVISION of a program is divided into sections, paragraphs, sentences, and statements:

Section Logical subdivision of your processing logic.

A section can contain several paragraphs.

A section can be the subject of the PERFORM statement.

Paragraph Subdivides a section, procedure, or program.

It contains a set of related statements that provide a function and is one of the basic building blocks of a structured program. A paragraph can be the subject of a statement.

Sentence Series of one or more COBOL statements ending with a period.

Many structured programs do not have separate sentences. Each paragraph can contain one sentence. Using scope terminators instead of periods to show the logical end of a statement is preferred. Scope terminators, both explicit and implicit, are discussed beginning on page 24.

Statement Performs a defined step of COBOL processing, such as adding two numbers.

A statement is a valid combination of words, beginning with a COBOL verb.

Statements Used in the PROCEDURE DIVISION

In the COBOL language, statements are imperative (indicating unconditional action), conditional, or compiler-directing.

Imperative and conditional statements can be ended implicitly or explicitly. If you end a conditional statement explicitly, it becomes a delimited scope statement (which is an imperative statement).

Imperative Statements

An imperative statement indicates that an unconditional action is to be taken. Examples are ADD, MOVE, INVOKE, and CLOSE. A full list of imperative statements can be found in *IBM COBOL Language Reference*.

Conditional Statements

A conditional statement is either a simple conditional statement (IF, EVALUATE, SEARCH) or a conditional statement made up of an imperative statement that includes a conditional phrase or option.

Examples of Conditional Phrases: For example, an arithmetic statement without ON SIZE ERROR is an imperative statement. But an arithmetic statement with the conditional option ON SIZE ERROR and without a scope terminator is a conditional statement.

The following are examples of conditional statements if they are coded without scope terminators:

- Data-manipulation statements with ON OVERFLOW.
- CALL statements with ON OVERFLOW.
- I/O statements with INVALID KEY, AT END, AT END-OF-PAGE.
- RETURN with AT END.

Using the NOT Phrase: For additional program control, the NOT phrase can also be used with conditional statements. For example, you can provide instructions to be performed when a particular exception does not occur, such as NOT ON SIZE ERROR. The NOT phrase cannot be used with the ON OVERFLOW phrase of the CALL statement, but it can be used with the ON EXCEPTION phrase.

Do Not Nest Conditional Statements: An unterminated conditional statement cannot be contained by (nested within) another statement. Except for nesting statements within IF statements, nested statements must be imperative statements and must follow the rules for imperative statements.

Compiler-Directing Statements

A compiler-directing statement is not part of the program logic. A compiler-directing statement causes the compiler to take specific action about the program structure, COPY processing, listing control, control flow, or CALL interface convention.

A description of compiler-directing statements can be found in *IBM COBOL Language Reference*. See "Compiler-Directing Statements" on page 179 for usage notes.

Explicit Scope Terminators

Explicit scope terminators end certain conditional and imperative forms of PROCEDURE DIVISION statements. Use an explicit scope terminator to make a conditional statement imperative (see "Delimited Scope Statements" on page 25). Or use an explicit scope terminator to clearly end an imperative statement. Explicit scope terminators are provided for certain COBOL verbs, such as scope terminator END-IF for the IF verb, and can be found in *IBM COBOL Language Reference*.

Example of Using Explicit Scope Terminators

```
MOVE 0 TO TOTAL
PERFORM UNTIL X = 10
  ADD 1 TO TOTAL
  IF X = 5
    DISPLAY "HALFWAY THROUGH"
    DISPLAY "TOTAL IS " TOTAL
  END-IF
  ADD 1 TO X
END-PERFORM
DISPLAY "FINAL TOTAL IS " TOTAL
```

Implicit Scope Terminators

An implicit scope terminator is a period (.) that ends the scope of all previous statements not yet ended.

Example of Using Implicitly Terminated Statements:

```
IF CAT
   DISPLAY "It is a cat."
ELSE
   IF DOG
      DISPLAY "It is a dog."
   ELSE
      DISPLAY "It is not a dog or cat.".
```

Each of the two periods in the above program fragment end the IF statements, making the code equivalent to the following example that has explicit scope terminators:

```
IF CAT
   DISPLAY "It is a cat."
ELSE
   IF DOG
      DISPLAY "It is a dog."
   ELSE
      DISPLAY "It is not a dog or cat."
   END-IF
END-IF
```

If you use implicit terminators, it can be unclear where statements end. As a result, you might end statements unintentionally, changing your program's logic. Explicit scope terminators make a program easier to understand and prevent unintentional ending of statements. For example, in the program fragment below, changing the location of the first period in the first implicit scope example changes the meaning of the code:

```
IF ITEM = "A"
  DISPLAY "VALUE OF ITEM IS " ITEM
  ADD 1 TO TOTAL.
  MOVE "C" TO ITEM
  DISPLAY " VALUE OF ITEM IS NOW " ITEM
IF ITEM = "B"
  ADD 2 TO TOTAL.
```

The two statements:

```
MOVE "C" TO ITEM
DISPLAY " VALUE OF ITEM IS NOW " ITEM
```

will be performed regardless of the value of ITEM, despite what the indentation indicates, because the first period terminates the IF statement. For improved program clarity and to avoid unintentional ending of statements, you should use explicit scope terminators instead of implicit scope terminators, especially within paragraphs. Use implicit scope terminators only at the end of a paragraph or the end of the program.

Delimited Scope Statements

A delimited scope statement is a conditional statement ended with an explicit scope terminator. A delimited scope statement can be used in these ways:

- To delimit the range of operation for a COBOL conditional statement and to explicitly show the levels of nesting.

  For example, use an END-IF statement instead of a period to end the scope of an IF statement within a nested IF.

- To code a conditional statement where the COBOL syntax calls for an imperative statement.

  For example, code a conditional statement as the object of an inline PERFORM:

```
PERFORM UNTIL TRANSACTION-EOF
  PERFORM 200-EDIT-UPDATE-TRANSACTION
  IF NO-ERRORS
    PERFORM 300-UPDATE-COMMUTER-RECORD
  ELSE
    PERFORM 400-PRINT-TRANSACTION-ERRORS
  END-IF
  READ UPDATE-TRANSACTION-FILE INTO WS-TRANSACTION-RECORD
    AT END
      SET TRANSACTION-EOF TO TRUE
  END-READ
END-PERFORM
```

An explicit scope terminator is required for the inline PERFORM statement, but it is not valid for the out-of-line PERFORM statement.

Rules for Delimited Scope Statements: Because a period implicitly ends the scope of all previous statements, do not use a period in a delimited scope statement.

In general, a delimited scope statement can be coded wherever an imperative statement is allowed by language rules.

Using Nested Delimited Scope Statements: When nested within another delimited scope statement with the same verb, each explicit scope terminator ends the statement begun by the most recently preceding (and as yet unpaired) occurrence of that verb.

Be careful when coding an explicit scope terminator for an imperative statement that is nested within a conditional statement. Ensure that the scope terminator is paired with the statement for which it was intended. In the following example, the scope terminator will be paired with the second READ statement, though the programmer intended it to be paired with the first.

```
READ FILE1
  AT END
     MOVE A TO B
     READ FILE2
END-READ
```

To ensure that the explicit scope terminator is paired with the intended statement, the preceding example can be recoded in this way:

```
READ FILE1
  AT END
     MOVE A TO B
     READ FILE2
     END-READ
END-READ
```

Declaratives

Declaratvies provide one or more special-purpose sections that are executed when an exceptional condition occurs.

PROCEDURE DIVISION

Each Declarative Section starts with a USE statement that identifies the function of the section; the series of procedures that follow specify what actions are to be taken when the conditon occurs. See the *IBM COBOL Language Reference* for a complete description of declaratives and Chapter 11, “Debugging Techniques” on page 189 and “Error Handling Techniques for Files” on page 102 for instances of their use.

Chapter 3. Numbers and Arithmetic

This chapter explains how COBOL views numeric data and how you can best represent numeric data and perform efficient arithmetic operations. The topics are:

- "General COBOL View of Numbers (PICTURE clause)."
- "Computational Data Representation (USAGE Clause)" on page 29.
- "Data Format Conversions" on page 33.
- "Sign Representation and Processing" on page 35.
- "Checking for Incompatible Data (Numeric Class Test)" on page 35.
- "Performing Arithmetic" on page 36.
- "Fixed-Point versus Floating-Point Arithmetic" on page 41.

General COBOL View of Numbers (PICTURE clause)

In general, you can view COBOL numeric data in a way similar to character-string data—as a series of decimal digit positions. However, numeric items can have special properties, such as an arithmetic sign.

Defining Numeric Items

Define numeric items using the character "9" in the data description to represent the decimal digits of the number instead of using an "x" like with alphanumeric items:

```
05  Count-x           Pic 9(4)   Value 25.
05  Customer-name     Pic x(20)  Value "Johnson".
```

You can code up to 18 digits in the PICTURE clause, as well as various other characters of special significance. The "s" in the following example means that the value is signed:

```
05  Price             Pic s99v99.
```

The field can hold a positive or negative value. The "v" indicates the position of an implied decimal point. Neither "s" nor "v" are counted in the size of the item, nor do they require extra storage positions, unless the item is coded as USAGE DISPLAY with the SIGN IS SEPARATE clause. An exception is internal floating point data (COMP-1 or COMP-2), for which there is no PICTURE clause.

Separate Sign Position (for Portability)

If you plan to port your program or data to a different machine, you might want to code the sign as a separate digit position in storage:

```
05  Price             Pic S99V99   Sign Is Leading, Separate.
```

This ensures that the convention your machine uses for storing a non-separate sign will not cause strange results when you use a machine that uses a different convention.

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Extra Positions for Displayable Symbols (Numeric Editing)

You can also define numeric items with certain editing symbols (such as decimal points, commas, and dollar signs) to make the data easier to read and understand when displayed or printed on reports. For example:

```
05  Price             Pic   9(5)v99.
05  Edited-price      Pic  $zz,zz9v99.
    ⋮
    Move Price To Edited-price
    Display Edited-price
```

If the contents of `Price` were 0150099 (representing the value 1,500.99), then `$ 1,500.99` would be displayed after the code is run.

How to Use Numeric-Edited Items as Numbers

Numeric-edited items are classified as alphanumeric data items, not as numbers. Therefore, they cannot be operands in arithmetic expressions or ADD, SUBTRACT, MULTIPLY, DIVIDE, and COMPUTE statements.

Numeric-edited items can be moved to numeric and numeric-edited items. In the following example, the numeric-edited item is *de-edited* and its numeric value is moved to the numeric data item.

```
Move Edited-price to Price
Display Price
```

If these two statements were to immediately follow the statements shown in the previous example, then `Price` would be displayed as 0150099, representing the value 1,500.99.

For complete information on the data descriptions for numeric data, refer to *IBM COBOL Language Reference*.

Computational Data Representation (USAGE Clause)

Control how the computer internally stores your numeric data items by coding the USAGE clause in your data description entries. The numeric data you use in your program will be one of the formats available with COBOL:

External decimal (USAGE DISPLAY)
External floating-point (USAGE DISPLAY)
Internal decimal (USAGE PACKED-DECIMAL)
Binary (USAGE BINARY)
Binary (COMP-5).
Internal floating-point (USAGE COMP-1, USAGE COMP-2)

COMP and COMP-4 are synonymous with BINARY, and COMP-3 is synonymous with PACKED-DECIMAL.

Regardless of what USAGE clause you use to control the computer's internal representation of the value, you use the same PICTURE clause conventions and decimal value in the VALUE clause except for floating point data.

External Decimal (USAGE DISPLAY) Items

When you code USAGE DISPLAY or omit the USAGE clause, each position (or byte) of storage contains one decimal digit. This corresponds to the format used for printing or displaying output, meaning the items are stored in displayable form.

What USAGE DISPLAY Items Are For

External decimal items are primarily intended for receiving and sending numbers between your program and files, terminals, and printers. However, it is also acceptable to use external decimal items as operands and receivers in your program's arithmetic processing, and it is often convenient to program this way.

Should You Use Them for Arithmetic

If your program performs a lot of intensive arithmetic and efficiency is a high priority, you might want to use one of COBOL's computational numeric data types for the data items used in the arithmetic.

The compiler has to automatically convert displayable numbers to the *internal* representation of their numeric value before they can be used in arithmetic operations. Therefore, it is often more efficient to define your data items as computational items to begin with, rather than as DISPLAY items. For example:

```
05  Count-x            Pic s9v9(5)  Usage Comp  Value 3.14159.
```

External Floating-Point (USAGE DISPLAY) Items

Displayable numbers coded in a floating-point format are called *external floating-point items*. Like external decimal items, you define external floating-point items explicitly with USAGE DISPLAY or implicitly by omitting the USAGE clause.

In the following example, `Compute-Result` is implicitly defined as an external floating-point item. Each byte of storage contains one character (except for V).

```
05  Compute-Result     Pic -9v9(9)E-99.
```

The VALUE clause is not allowed in the data description for external floating-point items. Also, the minus signs (–) do not mean that the mantissa and exponent will always be negative numbers, but that when displayed the sign will appear as a blank for positive and a minus sign for negative. If a plus sign (+) were used, positive would be displayed as a plus sign and negative as a minus sign.

Just as with external decimal numbers, external floating-point numbers have to be converted (automatically by the compiler) to an internal representation of the numeric value before they can be operated on.

Binary (BINARY, COMP, COMP-4, or COMP-5) Items

BINARY, COMP, and COMP-4 are synonyms on all platforms. COMP-5 is a new USAGE type based on the X/OPEN COBOL specification.

Binary format occupies 2, 4, or 8 bytes of storage and is handled for arithmetic purposes as a fixed-point number with the leftmost bit being the operational sign. For byte-reversed binary data, the sign bit is the leftmost bit of the rightmost byte.

How Much Storage BINARY Occupies

A PICTURE description with 4 or fewer decimal digits occupies 2 bytes; with 5 to 9 decimal digits, 4 bytes; with 10 to 18 decimal digits, 8 bytes.

Why Use Binary

Binary items are well suited for containing subscripts, switches, and arithmetic operands or results.

However, you might want to use packed decimal format instead of binary because:

- Binary format is not as well suited for decimal alignment as packed decimal format.
- Binary format is not converted to and from DISPLAY format as easily as packed decimal format.

Truncation of Binary Data (TRUNC Compiler Option)

Use the TRUNC(STD | OPT | BIN) compiler option (described in "TRUNC" on page 173) to indicate how binary data (BINARY, COMP, and COMP-4) is truncated.

COMP-5 Note: COMP-5 data is truncated according to TRUNC(BIN) regardless of which suboption of TRUNC you set.

Byte-Reversal of Binary Data (BINARY Compiler Option)

On the PC you sometimes need to be concerned with byte reversal. How binary data is stored depends on the platform you're running under or the products you're using.

For example, Intel platforms by default store binary data in *little-endian* format (most significant digit is on the highest address). S/370 and AIX by default store binary data in *big-endian* format (least significant digit is on the highest address).

The BINARY(NATIVE | S370) compiler option (described in "BINARY" on page 146) allows you to indicate whether binary data types BINARY, COMP, and COMP-4 are to be stored in big-endian or little-endian format.

COMP-5 is handled as the native binary data format regardless of the BINARY(NATIVE | S370) option setting.

COMP-5 is the recommended data type to use when interfacing with other languages (such as C or C++) or other products (such as CICS or DB2) that assume native binary data formats. However, a SORT or MERGE must not contain both big-endian and little-endian binary keys. That is, if the BINARY(S370) option is in effect and a SORT or

MERGE key is a COMP-5 data item, no other SORT or MERGE key may be a COMP, BINARY, or COMP-4 data item.

Packed Decimal (PACKED-DECIMAL or COMP-3) Items

Packed decimal format occupies 1 byte of storage for every two decimal digits you code in the PICTURE description, except that the right-most byte contains only 1 digit and the sign. Packed decimal format is handled as a fixed-point number for arithmetic purposes.

Why Use Packed Decimal

- Packed decimal format requires less storage per digit than DISPLAY format requires.
- Packed decimal format is better suited for decimal alignment than binary format.
- Packed decimal format is converted to and from DISPLAY format more easily than binary format.
- Packed decimal format is well suited for containing arithmetic operands or results.

Floating-Point (COMP-1 and COMP-2) Items

COMP-1 refers to short (single-precision) floating-point format, and COMP-2 refers to long (double-precision) floating-point format, which occupy 4 and 8 bytes of storage, respectively.

On the PC COMP-1 and COMP-2 data items are represented in IEEE format.

A PICTURE clause is not allowed in the data description of floating-point data items, but you can provide an initial value using a floating-point literal in the VALUE clause:

```
05  Compute-result    Usage Comp-1  Value 06.23E-24.
```

The characteristics of conversions between floating-point format and other number formats are discussed in the next section, “Data Format Conversions” on page 33.

Floating-point format is well suited for containing arithmetic operands and results and for maintaining the highest level of accuracy in arithmetic.

For complete information on the data descriptions for numeric data, see *IBM COBOL Language Reference*.

Figure 7. Internal Representation of Numeric Items

Numeric Type	PICTURE and USAGE and Optional SIGN Clause	Value	Internal Representation
External Decimal	PIC S9999 DISPLAY	+ 1234	31 32 33 34
		- 1234	71 32 33 34
		1234	31 32 33 34
	PIC 9999 DISPLAY	1234	31 32 33 34
	PIC S9999 DISPLAY SIGN LEADING	+ 1234	31 32 33 34
		- 1234	71 32 33 34
	PIC S9999 DISPLAY SIGN LEADING SEPARATE	+ 1234	2B 31 32 33 34
		- 1234	2D 31 32 33 34
	PIC S9999 DISPLAY SIGN TRAILING SEPARATE	+ 1234	31 32 33 34 2B
		+ 1234	31 32 33 F4 2D
Binary	PIC S9999 BINARY COMP COMP-4	+ 1234	04 D2[1]
		- 1234	FB 2E[1]
	COMP-5	+ 1234	D2 04
		- 1234	2E BF
	PIC 9999 BINARY COMP COMP-4	1234	04 D2[1]
	COMP-5	1234	D2 04
Internal Decimal	PIC S9999 PACKED-DECIMAL COMP-3	+ 1234	01 23 4C
		- 1234	01 23 4D
	PIC 9999 PACKED-DECIMAL COMP-3	1234	01 23 4F
Internal Floating Point	COMP-1	+ 1234	00 40 9A 44
		- 1234	00 40 9A C4
Internal Floating Point	COMP-2	+ 1234	00 00 00 00 00 48 93 40
		- 1234	00 00 00 00 00 48 93 C0
External Floating Point	PIC +9(2)9(2)E+99 DISPLAY	+ 1234	2B 31 32 2E 33 34 45 2B 30 32
		- 1234	2D 31 32 2E 33 34 45 2B 30 32

Note: [1] Values if specifying the BINARY(370) option.

Data Format Conversions

When the code in your program involves the interaction of items with different data formats, the compiler converts these items:

- Temporarily, for comparisons and arithmetic operations.

- Permanently, for assignment to the receiver in a MOVE, COMPUTE, and other arithmetic statement.

When possible, the compiler performs the move to preserve the numeric "value" as opposed to a direct digit-for-digit move. (For more information on truncation and predicting the loss of significant digits, refer to Appendix B, "Intermediate Results and Arithmetic Precision" on page 402.)

Conversion Takes Time

Conversion generally requires additional storage and processing time because data is moved to an internal work area and converted before the operation is performed. The results might also have to be moved back into a work area and converted again.

Conversions and Precision

Conversions between fixed-point data formats (external decimal, packed decimal, and binary) are completed without loss of precision, as long as the target field can contain all the digits of the source operand.

Conversions Where Loss of Precision Is Possible

A loss of precision is possible in conversions between fixed-point data formats and floating-point data formats (short floating-point, long floating-point, and external floating-point). These conversions happen during arithmetic evaluations that have a mixture of both fixed-point and floating-point operands. (Because fixed-point and external floating-point items both have decimal characteristics, reference to fixed-point items in the following examples includes external floating-point items as well, unless stated otherwise.)

When converting from fixed-point to internal floating-point format, fixed-point numbers in base 10 are converted to the numbering system used internally, base 16.

Although the compiler converts short form to long form for comparisons, zeros are used for padding the short number.

When a USAGE COMP-1 data item is moved to a fixed-point data item with more than 6 digits, the fixed-point data item will receive only 6 significant digits, and the remaining digits will be zero.

Conversions that Preserve Precision: If a fixed-point data item with 6 or fewer digits is moved to a USAGE COMP-1 data item and then returned to the fixed-point data item, the original value is recovered.

If a USAGE COMP-1 data item is moved to a fixed-point data item of 6 or more digits and then returned to the USAGE COMP-1 data item, the original value is recovered.

If a fixed-point data item with 15 or fewer digits is moved to a USAGE COMP-2 data item and then returned to the fixed-point data item, the original value is recovered.

If a USAGE COMP-2 data item is moved to a fixed-point (not external floating-point) data item of 18 digits and then returned to the USAGE COMP-2 data item, the original value is recovered.

Conversions that Result In Rounding: If a USAGE COMP-1 data item, a USAGE COMP-2 data item, an external floating-point data item, or a floating-point literal is moved to a fixed-point data item, rounding occurs in the low-order position of the target data item.

If a USAGE COMP-2 data item is moved to a USAGE COMP-1 data item, rounding occurs in the low-order position of the target data item.

If a fixed-point data item is moved to an external floating-point data item where the PICTURE of the fixed-point data item contains more digit positions than the PICTURE of the external floating-point data item, rounding occurs in the low-order position of the target data item.

Sign Representation and Processing

Sign representation affects the processing and interaction of your numeric data.

Given X'*sd*', where *s* is the sign representation and *d* represents the digit, the valid sign representations for external decimal (USAGE DISPLAY without the SIGN IS SEPARATE clause) are :

Positive: 0, 1, 2, 3, 8, 9, A, and B.

Negative: 4, 5, 6, 7, C, D, E, and F.

Signs generated internally are 3 for positive and unsigned, and 7 for negative.

Given X'*ds*', where *d* represents the digit and *s* is the sign representation, the valid sign representations for internal decimal (USAGE PACKED-DECIMAL) COBOL data are:

Positive: A, C, E, and F.

Negative: B and D.

Signs generated internally are C for positive, F for unsigned, and D for negative.

Checking for Incompatible Data (Numeric Class Test)

The compiler assumes that the values you supply for a data item are valid for the item's PICTURE and USAGE clauses and assigns the value you supply without checking for validity. When an item is given a value that is incompatible with its data description, references to that item in the PROCEDURE DIVISION will be undefined and your results will be unpredictable.

Frequently, values are passed into your program and assigned to items that have incompatible data descriptions for those values. For example, non-numeric data might be moved or passed into a field in your program that is defined as a numeric item. Or, perhaps a signed number is passed into a field in your program that is defined as an unsigned number. In either case, these fields contain invalid data. Ensure that the contents of a data item conforms to its PICTURE and USAGE clauses before using the data item in any further processing steps.

How to Do a Numeric Class Test

You can use the numeric class test to perform data validation. For example:

```
Linkage Section.
01  Count-x      Pic 999.
⋮
Procedure Division Using Count-x.
    If Count-x is numeric then display "Data is good"
⋮
```

The numeric class test checks the contents of a data item against a set of values that are valid for the particular PICTURE and USAGE of the data item.

Performing Arithmetic

COBOL provides various language features to perform arithmetic:

- ADD, SUBTRACT, MULTIPLY, DIVIDE, and COMPUTE statements (discussed in "COMPUTE and Other Arithmetic Statements").
- Arithmetic expressions (discussed in "Arithmetic Expressions" on page 37).
- Intrinsic functions (discussed in "Numeric Intrinsic Functions" on page 37).

For the complete details of syntax and usage for COBOL language constructs, refer to *IBM COBOL Language Reference*.

COMPUTE and Other Arithmetic Statements

The general practice is to use the COMPUTE statement for most arithmetic evaluations rather than ADD, SUBTRACT, MULTIPLY, and DIVIDE statements. This is because one COMPUTE statement can often be coded instead of several individual statements.

The COMPUTE statement assigns the result of an arithmetic expression to a data item:

```
Compute z = a + b / c ** d - e
```

or to many data items:

```
Compute x y z = a + b / c ** d - e
```

When to Use Other Arithmetic Statements

Some arithmetic might be more intuitive using the other arithmetic statements. For example:

```
Add 1 To Increment
```

instead of:

```
Compute Increment = Increment + 1
```

Or,

```
Subtract Overdraft From Balance
```

instead of:

```
Compute Balance = Balance - Overdraft
```

Or,

```
Add 1 To Increment-1, Increment-2, Increment-3
```

instead of:

```
Compute Increment-1 = Increment-1 + 1
Compute Increment-2 = Increment-2 + 1
Compute Increment-3 = Increment-3 + 1
```

You might also prefer to use the DIVIDE statement (with its REMAINDER phrase) for division in which you want to process a remainder. The REM intrinsic function also provides the ability to process a remainder. For an example of the REM function, see "Mathematics" on page 41.

Arithmetic Expressions

In the examples of COMPUTE shown above, everything to the right of the equal sign represents an arithmetic expression. Arithmetic expressions can consist of a single numeric literal, a single numeric data item or a single intrinsic function reference. They can also consist of several of these items connected by arithmetic operators. These operators are evaluated in a hierarchic order:

Figure 8. Operator Evaluation

Operator	Meaning	Order of Evaluation
Unary + or -	Algebraic Sign	First
**	Exponentiation	Second
/ or *	Division or multiplication	Third
Binary + or -	Addition or subtraction	Last

Operators at the same level are evaluated from left to right; however, you can use parentheses with these operators to change the order in which they are evaluated. Expressions in parentheses are evaluated before any of the individual operators are evaluated. Parentheses, necessary or not, make your program easier to read.

In addition to using arithmetic expressions in COMPUTE statements, you can also use them in other places where numeric data items are allowed. For example, you can use arithmetic expressions as comparands in relation conditions:

```
If (a + b) > (c - d + 5) Then...
```

Numeric Intrinsic Functions

Intrinsic functions can return an alphanumeric or numeric value.

Numeric intrinsic functions:

- Return a signed numeric value.
- Are considered to be temporary numeric data items.

- Can be used only in the places in the language syntax where expressions are allowed.
- Can save you time because you don't have to provide the arithmetic for the many common types of calculations that these functions cover.

  For more information on the practical application of intrinsic functions, including examples of their usage, refer to “Intrinsic Function Examples.”

Types of Numeric Functions

Numeric functions are classified into these categories:

Integer	Those that return an integer
Floating-Point	Those that return a long floating-point value
Mixed	Those that return an integer, a long floating-point value, or a fixed-point number with decimal places, depending on the arguments

The numeric functions available in COBOL under these categories are described in *IBM COBOL Language Reference*.

Nesting Functions and Arithmetic Expressions

Numeric functions can be nested; you can reference one function as the argument of another. A nested function is evaluated independently of the outer function, except when determining whether a mixed function should be evaluated with fixed-point or floating-point procedures.

Because numeric functions and arithmetic expressions hold similar status syntactically speaking, you can also nest an arithmetic expression as an argument to a numeric function:

```
Compute x = Function Sum(a b (c / d))
```

In this example, there are only three function arguments: a, b and the arithmetic expression (c / d).

ALL Subscripting and Special Registers

Two other useful features of intrinsic functions are the ALL subscript and special registers.

You can reference all the elements of an array as function arguments by using the ALL subscript. This feature is used with tables, and examples of its use are shown under “Processing Table Items (Intrinsic Functions)” on page 61.

The integer-type special registers are allowed as arguments wherever integer arguments are allowed.

Intrinsic Function Examples

You can use intrinsic functions to perform several different kinds of arithmetic, as outlined in Figure 9.

Figure 9. Types of Arithmetic that Numeric Intrinsic Functions Handle

Number Handling	Date/Time	Finance	Mathematics	Statistics
LENGTH MAX MIN NUMVAL NUMVAL-C ORD-MAX ORD-MIN	CURRENT-DATE DATE-OF-INTEGER DAY-OF-INTEGER INTEGER-OF-DATE INTEGER-OF-DAY WHEN-COMPILED	ANNUITY PRESENT-VALUE	ACOS ASIN ATAN COS FACTORIAL INTEGER INTEGER-PART LOG LOG10 MOD REM SIN SQRT SUM TAN	MEAN MEDIAN MIDRANGE RANDOM RANGE STANDARD-DEVIATION VARIANCE

The following examples and accompanying explanations show intrinsic functions in each of the categories listed in the preceding table.

General Number-Handling: Suppose you want to find the maximum value of two prices (represented as alphanumeric items with dollar signs), put this value into a numeric field in an output record, and determine the length of the output record. You could use NUMVAL-C (a function that returns the numeric value of an alphanumeric string) and the MAX function to do this:

```
01  X                     Pic 9(2).
01  Price1                Pic x(8)   Value "$8000".
01  Price2                Pic x(8)   Value "$2000.
01  Output-Record.
    05  Product-Name      Pic x(20).
    05  Product-Number    Pic 9(9).
    05  Product-Price     Pic 9(6).
    ⋮
Procedure Division.
    Compute Product-Price =
      Function Max (Function Numval-C(Price1) Function Numval-C(Price2))
    Compute X = Function Length(Output-Record)
```

Additionally, to ensure that the contents in Product-Name are in uppercase letters, you could use the following statement:

```
Move Function Upper-case(Product-Name) to Product-Name
```

Date/Time: The following example shows how to calculate a due date that is 90 days from today. The first eight characters returned by the CURRENT-DATE function represent the date in a 4-digit year, 2-digit month, and 2-digit day format (YYYYMMDD). In the example, this date is converted to its integer value. Then 90 is added to this value, and the integer is converted back to the YYYYMMDD format.

```
01  YYYYMMDD               Pic 9(8).
01  Integer-Form           Pic S9(9).
    ⋮
    Move Function Current-Date(1:8) to YYYYMMDD
    Compute Integer-Form = Function Integer-of-Date(YYYYMMDD)
    Add 90 to Integer-Form
    Compute YYYYMMDD = Function Date-of-Integer(Integer-Form)
    Display 'Due Date: ' YYYYMMDD
```

Finance: Business investment decisions frequently require computing the present value of expected future cash inflows to evaluate the profitability of a planned investment. The present value of money is its value today. The present value of an amount that you expect to receive at a given time in the future is that amount which if invested today at a given interest rate would accumulate to that future amount.

For example, assume a proposed investment of $1,000 produces a payment stream of $100, $200, and $300 over the next three years, one payment per year respectively. The following COBOL statements show how to calculate the present value of those cash inflows at a 10% interest rate:

```
01  Series-Amt1            Pic 9(9)V99       Value 100.
01  Series-Amt2            Pic 9(9)V99       Value 200.
01  Series-Amt3            Pic 9(9)V99       Value 300.
01  Discount-Rate          Pic S9(2)V9(6)    Value .10.
01  Todays-Value           Pic 9(9)V99.
    ⋮
    Compute Todays-Value =
      Function
        Present-Value(Discount-Rate Series-Amt1 Series-Amt2 Series-Amt3)
```

The ANNUITY function can be used in business problems that require you to determine the amount of an installment payment (annuity) necessary to repay the principal and interest of a loan. The series of payments is characterized by an equal amount each period, periods of equal length, and an equal interest rate each period. The following example shows how you could calculate the monthly payment required to repay a $15,000 loan at 12% annual interest in three years (36 monthly payments, interest per month = .12/12):

```
01  Loan                   Pic 9(9)V99.
01  Payment                Pic 9(9)V99.
01  Interest               Pic 9(9)V99.
01  Number-Periods         Pic 99.
    ⋮
    Compute Loan = 15000
    Compute Interest = .12
    Compute Number-Periods = 36
    Compute Payment =
      Loan * Function Annuity((Interest / 12) Number-Periods)
```

Mathematics: The following COBOL statement demonstrates how intrinsic functions can be nested, how arguments can be arithmetic expressions, and how previously complex mathematical calculations can be simply performed:

```
Compute Z = Function Log(Function Sqrt (2 * X + 1)) + Function Rem(X 2)
```

Here, the remainder of dividing X by 2 is found with an intrinsic function instead of using a DIVIDE statement with a REMAINDER clause.

Statistics: Intrinsic functions also make calculating statistical information on data easier. Assume you are analyzing various city taxes and want to calculate the mean, median, and range (the difference between the maximum and minimum taxes):

```
01  Tax-S                  Pic 99v999 value .045.
01  Tax-T                  Pic 99v999 value .02.
01  Tax-W                  Pic 99v999 value .035.
01  Tax-B                  Pic 99v999 value .03.
01  Ave-Tax                Pic 99v999.
01  Median-Tax             Pic 99v999.
01  Tax-Range              Pic 99v999.
    ⋮
    Compute Ave-Tax = Function Mean(Tax-S Tax-T Tax-W Tax-B)
    Compute Median-Tax = Function Median(Tax-S Tax-T Tax-W Tax-B)
    Compute Tax-Range = Function Range (Tax-S Tax-T Tax-W Tax-B)
```

Fixed-Point versus Floating-Point Arithmetic

Many statements in your program might involve arithmetic. For example, each of the following COBOL statements requires some kind of arithmetic evaluation:

- General arithmetic.

  ```
  compute report-matrix-col = (emp-count ** .5) + 1
  add report-matrix-min to report-matrix-max giving report-matrix-tot
  ```

- Expressions and functions.

  ```
  compute report-matrix-col = function sqrt(emp-count) + 1
  compute whole-hours = function integer-part((average-hours) + 1)
  ```

- Arithmetic comparisons.

  ```
  if report-matrix-col < function sqrt(emp-count) + 1
  if whole-hours not = function integer-part((average-hours) + 1)
  ```

For each arithmetic evaluation in your program—whether it is a statement, an intrinsic function, an expression, or some combination of these nested within each other—how you code the arithmetic determines whether it will be floating-point or fixed-point evaluation.

The following discussion explains when arithmetic and arithmetic comparisons are evaluated in fixed-point and floating-point. For details on the precision of arithmetic evaluations, see Appendix B, “Intermediate Results and Arithmetic Precision” on page 402.

Floating-Point Evaluations

In general, if your arithmetic evaluation has either of the characteristics listed below, it will be evaluated by the compiler in floating-point arithmetic:

- An operand or result field is floating-point.

  A data item is floating-point if you code it as a floating-point literal, or if you define it as USAGE COMP-1, USAGE COMP-2, or as external floating-point (USAGE DISPLAY with a floating-point PICTURE).

  An operand that is a nested arithmetic expression or a reference to numeric intrinsic function results in floating-point when:

  – An argument in an arithmetic expression results in floating-point.
  – The function is a floating-point function.
  – The function is a mixed-function with one or more floating-point arguments.

- An exponent contains decimal places.

  This is true if you use a literal that contains decimal places, give the item a PICTURE containing decimal places, or use an arithmetic expression or function whose result has decimal places.

  An arithmetic expression or numeric function yields a result with decimal places if any operand or argument—excluding divisors and exponents—has decimal places.

Fixed-Point Evaluations

In general, if your arithmetic operation contains neither of the characteristics listed above for floating-point, it will be evaluated by the compiler in fixed-point arithmetic. In other words, your arithmetic evaluations will be handled by the compiler as fixed-point only if all your operands are given in fixed-point, your result field is defined to be fixed-point, and none of your exponents represent values with decimal places. Nested arithmetic expression and function references must represent fixed-point values.

Arithmetic Comparisons (Relation Conditions)

If your arithmetic is a comparison (contains a relational operator), then the numeric expressions being compared—whether they are data items, arithmetic expressions, function references, or some combination of these—are really operands (comparands) in the context of the entire evaluation. This is also true of abbreviated comparisons; although one comparand might not explicitly appear, both are operands in the comparison. For example, in the following statement:

```
if (a + d) = (b + e) and c
```

there are two comparisons: `(a + d) = (b + e)` and `(a + d) = c`. Although `(a + d)` does not explicitly appear in the second comparison, it is nevertheless an operand in that comparison (and thus, evaluation of `(a + d)` is influenced by the attributes of `c`).

Implicit Note: Implicit comparisons (no relational operator used) are not handled as a unit—the two expressions being compared are treated separately as to whether they will be evaluated in floating-point or fixed-point. In the following example we actually have five arithmetic expressions that are evaluated independent of one another's attributes, and then are compared to each other.

Thus, the rules outlined so far for determining whether your evaluation will be done in fixed-point or floating-point arithmetic apply to your comparison statement as a unit.

```
evaluate (a + d)
  when (b + e) thru c
  when (f / g) thru (h * i)
   ⋮
end-evaluate
```

Your comparison operation (and the evaluation of any arithmetic expressions nested in your comparison) will be handled by the compiler as floating-point arithmetic if either of your comparands is a floating-point value or resolves to a floating-point value.

Your comparison operation (and the evaluation of any arithmetic expressions nested in your comparison) will be handled by the compiler as fixed-point arithmetic if both of your comparands are fixed-point values or resolve to fixed-point values.

Examples of Fixed-Point and Floating-Point Evaluations

For the examples shown on page 41, if you define the data items in the following manner:

```
01  employee-table.
    05  emp-count           pic  9(4).
    05  employee-record occurs 1 to 1000 times
                        depending on emp-count.
        10 hours             pic +9(5)e+99.
⋮
01  report-matrix-col       pic  9(3).
01  report-matrix-min       pic  9(3).
01  report-matrix-max       pic  9(3).
01  report-matrix-tot       pic  9(3).
01  average-hours           pic  9(3)v9.
01  whole-hours             pic  9(4).
```

- These evaluations would be done in floating-point arithmetic:

  ```
  compute report-matrix-col = (emp-count ** .5) + 1
  compute report-matrix-col = function sqrt(emp-count) + 1
  if report-matrix-tot < function sqrt(emp-count) + 1
  ```

- These evaluations would be done in fixed-point arithmetic:

  ```
  add report-matrix-min to report-matrix-max giving report-matrix-tot
  compute report-matrix-max =
    function max(report-matrix-max report-matrix-tot)
  if whole-hours not = function integer-part((average-hours) + 1)
  ```

Chapter 4. Handling Tables

A table is a collection of data items that have the same description. It is the COBOL equivalent to an array of elements. This chapter explains the concepts and coding techniques necessary for defining, referencing, initializing, searching, and processing table items, including both fixed-length and variable-length items.

Defining a Table (OCCURS Clause)

You could define table items as separate, consecutive entries in the DATA DIVISION, but this practice has disadvantages. First, the code does not clearly show the unity of the items. Second, you cannot take advantage of subscripting and indexing for easy reference to the table elements. (See "Referring to an Item in a Table" on page 46 for information on subscripting and indexing.)

Use the COBOL OCCURS clause in the DATA DIVISION entry to define a table, and you do not need separate entries for repeated data items. The OCCURS clause also supplies the information necessary for the use of subscripts or indexes. (For more information on the format of the OCCURS clause, refer to *IBM COBOL Language Reference*).

To code a table, give the table a group name and define a subordinate item (the table *element*) that is to be repeated *n* times:

```
01  table-name.
    05  element-name OCCURS n TIMES.
     .
     .  (subordinate items of the table element might follow)
     .
```

The following figures show how to code tables:

- One-Dimensional Table—Figure 10 on page 45
- Two-Dimensional Table—Figure 11 on page 45
- Three-Dimensional Table—Figure 12 on page 46.

For all the tables, the table element definition (which includes the OCCURS clause) is subordinate to the group item that contains the table; the OCCURS clause cannot appear in a level-01 description.

To create tables of more than one dimension, use nested OCCURS clauses. Tables of up to seven dimensions can be defined using this same method.

One Dimension

To create a one-dimensional table, use one OCCURS clause. For example:

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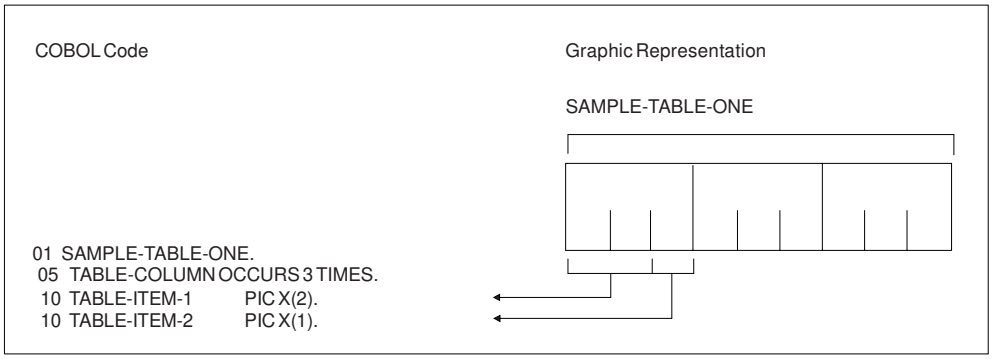

Figure 10. Coding a One-Dimensional Table

`SAMPLE-TABLE-ONE` is the group item that contains the table. `TABLE-COLUMN` names the table element of a one-dimensional table that occurs three times.

Two Dimensions

To create a two-dimensional table, define a one-dimensional table in each occurrence of another one-dimensional table. For example:

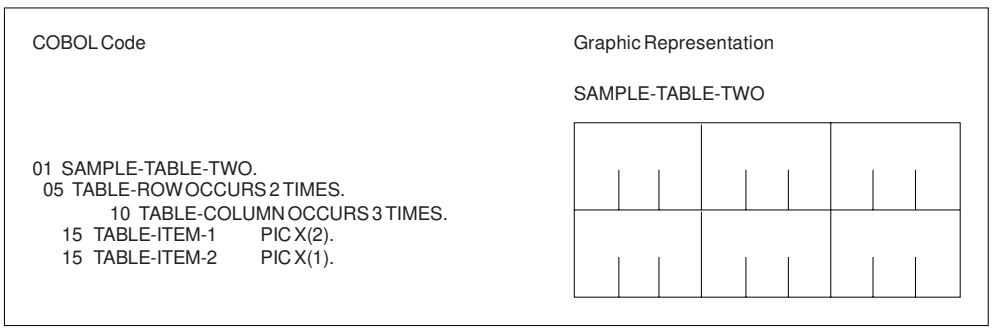

Figure 11. Coding a Two-Dimensional Table

`SAMPLE-TABLE-TWO` is the name of a two-dimensional table. `TABLE-ROW` is an element of a one-dimensional table that occurs two times. `TABLE-COLUMN` is an element of a two-dimensional table that occurs three times in each occurrence of `TABLE-ROW`.

Three Dimensions

To create a three-dimensional table, define a one-dimensional table in each occurrence of another one-dimensional table, which is itself contained in each occurrence of another one-dimensional table. For example:

COBOL Code

```
01  SAMPLE-TABLE-THREE.
 05  TABLE-DEPTH OCCURS 2 TIMES.
         10  TABLE-ROW OCCURS 2 TIMES.
              15  TABLE-COLUMN OCCURS 3 TIMES.
                   20  TABLE-ITEM-1       PIC X(2).
                   20  TABLE-ITEM-2       PIC X(1).
```

Graphic Representation

SAMPLE-TABLE-THREE

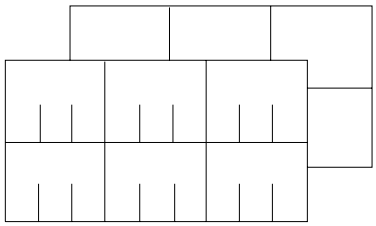

Figure 12. Coding a Three-Dimensional Table

In SAMPLE-TABLE-THREE, TABLE-DEPTH is an element of a one-dimensional table that occurs two times. TABLE-ROW is an element of a two-dimensional table that occurs two times within each occurrence of TABLE-DEPTH. TABLE-COLUMN is an element of a three-dimensional table that occurs three times within each occurrence of TABLE-ROW.

Referring to an Item in a Table

A table element has a collective name, but the individual occurrences within it do not have unique *data-names*. To refer to them, use the *data-name* of the table element, together with the occurrence number, called a *subscript*, of the desired item within the element.

The technique of supplying the occurrence number of individual table elements is called subscripting. See page 46. A related technique, called *subscripting using index-names (indexing)* is also available for table references.

An *index* is a symbol used to locate an item in a table. An index differs from a subscript in that an index is a value to be added to the address of a table to locate an item (the displacement from the beginning of the table). See page 47.

Subscripting

The lowest possible subscript value is 1, which points to the first occurrence of the table-element. In a one-dimensional table, the subscript corresponds to the row number. In a two-dimensional table, the two subscripts correspond to the column and row numbers. In a three-dimensional table, the three subscripts correspond to the depth, column, and row numbers.

You can use a literal subscript or a data-name for a variable subscript.

Literal Subscripts

The following are valid literal subscript references to SAMPLE-TABLE-THREE:

```
TABLE-COLUMN (2, 2, 1)
TABLE-COLUMN (2 2 1)       (The spaces are required for subscripting.)
```

In the table reference TABLE-COLUMN (2, 2, 1), the first value (2) refers to the second occurrence within TABLE-DEPTH, the second value (2) refers to the second occurrence within TABLE-ROW, and the third value (1) refers to the first occurrence within TABLE-COLUMN.

If a subscript is represented by a literal and the subscripted item is of fixed length, then the compiler resolves the location of the subscripted data item within the table at compile time.

Variable Subscripts

The following is a valid, variable subscript reference to SAMPLE-TABLE-TWO, (assuming that SUB1 and SUB2 are *data-names* containing positive integer values within the range of the table):

```
TABLE-COLUMN (SUB1 SUB2)
```

The *data-name* used as a variable subscript must be described as an elementary numeric integer data item.

If a *data-name* is being used as a subscript or qualifier, it cannot itself be subscripted.

If a subscript is represented by a *data-name*, the code generated for the application resolves the location at run time. The most efficient format for data used as a variable subscript is COMPUTATIONAL (COMP) with a PICTURE size of less than five digits.

Relative Subscripts

In relative subscripting, the subscript can be incremented or decremented by a specified integer amount. Relative subscripting is valid with either literal or variable subscripts. For example:

```
TABLE-COLUMN (SUB1 - 1, SUB2 + 3)
```

Subscripting Using Index-Names (Indexing)

You can refer to table elements by using a subscript, an index, or both. An index is a displacement from the start of the table, based on the length of the table element.

To reference a table by an index:

1. Define the *index-name* for a table in the INDEXED BY clause of the OCCURS clause in the table definition.
2. Choose direct or relative indexing (described below).
3. Initialize the *index-name* with a SET, PERFORM VARYING, or SEARCH ALL statement before using it in a table reference.
4. Use the index in SET, SEARCH, SEARCH ALL, PERFORM VARYING, or relational condition statements.

How the Index Value Is Determined

The compiler determines the index of an entry using the following formula:

I = *L* * (*S*-1)

where:

I is the index value.
L is the length of a table entry.
S is the subscript (occurrence number) of an entry.

To be valid during execution, an index value must correspond to a table element occurrence of not less than 1 nor greater than the highest permissible occurrence number. This restriction applies to both direct and relative indexing.

Direct Indexing

In direct indexing, the *index-name* is in the form of a displacement. The value contained in the index is then calculated as the occurrence number minus 1, multiplied by the length of the individual table entry.

For example:

```
05  TABLE-ITEM OCCURS 10 INDEXED BY INX-A PIC X(8).
```

For the fifth occurrence of `TABLE-ITEM`, the binary value contained in `INX-A` is (5 - 1) * 8 = 32.

Relative Indexing

In relative indexing, the *index-name* is followed by a space, followed by a + or a –, followed by another space, followed by an unsigned numeric literal. The literal is considered to be an occurrence number, and is converted to an index value before being added to or subtracted from the *index-name*.

Relative Indexing Example: If you code indexing for `SAMPLE-TABLE-THREE` as follows:

```
01  SAMPLE-TABLE-THREE
    05  TABLE-DEPTH OCCURS 3 TIMES INDEXED BY INX-A.
        10  TABLE-COLUMN OCCURS 4 TIMES INDEXED BY INX-B.
            15  TABLE-ROW OCCURS 8 TIMES INDEXED BY INX-C    PIC X(8).
```

a relative indexing reference to:

```
TABLE-ROW (INX-A + 1, INX-B + 2, INX-C - 1)
```

causes the following computation of the displacement:

```
  (contents of INX-A) + (256 * 1)
+ (contents of INX-B) + (64 * 2)
+ (contents of INX-C) - (8 * 1)
```

That is,

- Each occurrence of `TABLE-DEPTH` is 256 characters in length.

- Each occurrence of TABLE-COLUMN is 64 characters in length.
- Each occurrence of TABLE-ROW is 8 characters in length.

More Ways to Use Index References

- An index can be modified using a PERFORM, SEARCH, or SET statement.
- To compare two different occurrences of a table element, use a direct indexing reference together with a relative indexing reference, or use subscripting, which is easier to read in your code.
- An index can be shared among different tables. That is, you can use the index defined with one table to index another table if both table descriptions are identical. To be identical, the tables must have the same number of occurrences, as well as occurrences of the same length.
- Store index values in *index data items* you define with the USAGE IS INDEX clause. Use the SET statement to assign to an index the value that you stored in the index data item.

  For example, when you read records to load a variable-length table, you can store the index value of the last record in a data item defined as USAGE IS INDEX. Then, when you use the table index to look through or process the variable-length table, you can test for the end of the table by comparing the current index value with the index value of the last record you stored in the index data item.

  Because you're comparing a physical displacement, you can use index data items only in SEARCH and SET statements or for comparisons with indexes or other index data items. You cannot use index data items as subscripts or indexes.

Referring to a Substring of a Table Item

Both reference modification and subscripting can be coded for a table element in the same statement. For example, if you define a table like this:

```
01  ANY-TABLE.
    05  TABLE-ELEMENT            PIC X(10)
           OCCURS 3 TIMES
           VALUE "ABCDEFGHIJ".
```

the statement

```
MOVE "??" TO TABLE-ELEMENT ( 1 ) ( 3 : 2 )
```

will move the value "??" into table element number 1, beginning at character position 3, for a length of 2.

So, if ANY-TABLE looked like this before the change:

ABCDEFGHIJ
ABCDEFGHIJ
ABCDEFGHIJ

ANY-TABLE would look like this after the change:

AB??EFGHIJ
ABCDEFGHIJ
ABCDEFGHIJ

Putting Values into a Table

Use one of these methods to put values in a table:

- Load the table dynamically.
- Initialize the table (INITIALIZE statement).
- Assign values when you define the table (VALUE clause).

Loading the Table Dynamically

If the initial values of your table are different with each execution of your program, the table can be defined without initial values, and the changed values can be read into the table before your program refers to the table.

To load a table, use:

- The PERFORM . . . VARYING statement.
- Either subscripting or indexing.

When reading data to load your table, test to make sure that the data does not exceed the space allocated for the table. Use a named value giving the item count, rather than using a literal. Then, if you make the table bigger, you need to change only one value, instead of all references to a literal.

Initializing the Table (INITIALIZE Statement)

You can also load your table with a value during execution with the INITIALIZE statement. For example, to fill a table with 3s:

```
INITIALIZE TABLE-ONE REPLACING NUMERIC DATA BY 3.
```

The INITIALIZE statement cannot load a variable-length table (one that was defined using OCCURS DEPENDING ON).

Assigning Values When You Define the Table (VALUE Clause)

If your table contains stable values (for example a table that contains the days and months of the year), set the specific values your table holds when you define it.

Define static values in Working-Storage in one of the these ways:

- Initialize each table item individually.

- Initialize an entire table at the 01 level.
- Initialize all occurrences of a given table element to the same value.

Initializing Each Table Item Individually

- Describe the table storage area by arranging subordinate data description entries, setting the initial value of each subordinate entry in a VALUE clause.
- Code a REDEFINES entry to describe the table as a record that contains a repeating subordinate entry, defined with an OCCURS clause.

For an example of this method, see "Error Flag Table" and "Error Message Table" in Figure 13 on page 52.

This technique is practical only for small tables. To initialize larger tables, use MOVE, PERFORM, or INITIALIZE statements, as described above.

Initializing a Table at the 01 Level

Code a level-01 record and assign to it, through the VALUE clause, the contents of the whole table. Then, in a subordinate level data item, use an OCCURS clause to define the individual table items.

For example:

```
01  TABLE-ONE                        VALUE "1234".
    05  TABLE-TWO OCCURS 4 TIMES     PIC X.
```

Initializing a Variable-Size Table: A VALUE clause can also be present on a group item that contains an OCCURS clause with the DEPENDING ON option. Each subordinate structure that contains the DEPENDING ON option is initialized using the maximum number of occurrences. If the entire table is defined with the DEPENDING ON option, all the elements are initialized using the maximum defined value of the DEPENDING ON object.

In both cases, if the ODO OBJECT has a VALUE clause, it is logically initialized after the *ODO subject* has been initialized. For example:

```
01  TABLE-THREE                      VALUE "3ABCDE".
    05  X                            PIC 9.
    05  Y OCCURS 5 TIMES
          DEPENDING ON X             PIC X.
```

causes Y(1) to be initialized to A, Y(2) to B,... Y(5) to E, and finally the object of the ODO (X) is initialized to 3. Any subsequent reference to TABLE-THREE (such as DISPLAY) would refer to the first 3 elements, Y(1) through Y(3).

Initializing All Occurrences of a Table Element

You can use the VALUE clause on a table element to initialize the element to the indicated value.

As an example, this code:

```
01  T2.
    05  T-OBJ                              PIC 9    VALUE 3.
    05  T OCCURS 5 TIMES DEPENDING ON T-OBJ.
        10  X                              PIC XX   VALUE "AA".
        10  Y                              PIC 99   VALUE 19.
        10  Z                              PIC XX   VALUE "BB".
```

causes all the X elements (1 through 5) to be initialized to AA, all the Y elements (1 through 5) to be initialized to 19, and all the Z elements (1 through 5) to be initialized to BB. T-OBJ is then set to 3.

Example of Loading and Processing a Table

```
************************************************************
***           E R R O R   F L A G   T A B L E            ***
************************************************************
 01  Error-Flag-Table                    Value Spaces.
   88 No-Errors                          Value Spaces.
     05 Type-Error                       Pic X.
     05 Shift-Error                      Pic X.
     05 Home-Code-Error                  Pic X.
     05 Work-Code-Error                  Pic X.
     05 Name-Error                       Pic X.
     05 Initials-Error                   Pic X.
     05 Duplicate-Error                  Pic X.
     05 Not-Found-Error                  Pic X.
     05 Address-Error                    Pic X.
     05 City-Error                       Pic X.
     05 State-Error                      Pic X.
     05 Zipcode-Error                    Pic X.
     05 Home-Phone-Error                 Pic X.
     05 Work-Phone-Error                 Pic X.
     05 Home-Junction-Error              Pic X.
     05 Work-Junction-Error              Pic X.
     05 Driving-Status-Error             Pic X.
 01  Filler Redefines Error-Flag-Table.
     05 Error-Flag Occurs 17 Times
          Indexed By Flag-Index          Pic X.
```

Figure 13 (Part 1 of 2). Table with Static Values Defined for Every Table Element

```
************************************************************
***        E R R O R   M E S S A G E   T A B L E       ***
************************************************************
 01  Error-Message-Table.
     05  Filler                          Pic X(25) Value
          "Transaction Type Invalid".
     05  Filler                          Pic X(25) Value
          "Shift Code Invalid".
     05  Filler                          Pic X(25) Value
          "Home Location Code Inval.".
     05  Filler                          Pic X(25) Value
          "Work Location Code Inval.".
     05  Filler                          Pic X(25) Value
          "Last Name - Blanks".
     05  Filler                          Pic X(25) Value
          "Initials - Blanks".
     05  Filler                          Pic X(25) Value
          "Duplicate Record Found".
     05  Filler                          Pic X(25) Value
          "Commuter Record Not Found".
     05  Filler                          Pic X(25) Value
          "Address - Blanks".
     05  Filler                          Pic X(25) Value
          "City - Blanks".
     05  Filler                          Pic X(25) Value
          "State Is Not Alphabetic".
     05  Filler                          Pic X(25) Value
          "ZipCode Is Not Numeric".
     05  Filler                          Pic X(25) Value
          "Home Phone Number Error".
     05  Filler                          Pic X(25) Value
          "Work Phone Number Error".
     05  Filler                          Pic X(25) Value
          "Home Junction Is Blanks".
     05  Filler                          Pic X(25) Value
          "Work Junction Is Blanks".
     05  Filler                          Pic X(25) Value
          "Driving Status Invalid".
 01  Filler Redefines Error-Message-Table.
     05  Error-Message Occurs 17 Times
            Indexed By Message-Index      Pic X(25).
```

Figure 13 (Part 2 of 2). Table with Static Values Defined for Every Table Element

Processing a Table Using Subscripting and PERFORM...VARYING

The procedure shown in Figure 14 on page 54 processes the entire table shown in Figure 13 on page 52, using subscripting and the PERFORM...VARYING statement.

```
Perform
    Varying Sub From 1 By 1
    Until No-Errors
  If Error-Flag (Sub) = Error-On
    Move Space To Error-Flag (Sub)
    Move Error-Message (Sub) To Print-Message
    Perform 260-Print-Report
  End-If
End-Perform
```

Figure 14. Processing the Sample Table, Using Subscripting

Processing a Table Using Indexing

The procedure shown in Figure 15 processes the entire table, using indexing.

```
Set Flag-Index To 1
Perform Until No-Errors
  Search Error-Flag
    When Error-Flag (Flag-Index) = Error-On
      Move Space To Error-Flag (Flag-Index)
      Set Message-Index To Flag-Index
      Move Error-Message (Message-Index) To
          Print-Message
      Perform 260-Print-Report
  End-Search
End-Perform
```

Figure 15. Processing the Sample Table, Using Indexing

Creating Variable-Length Tables (DEPENDING ON Clause)

If you don't know before execution how many occurrences of a table element there are, you need to set up a variable-length table definition. To do this, use the OCCURS DEPENDING ON (ODO) clause. For example:

```
X OCCURS 1 TO 10 TIMES DEPENDING ON Y
```

`X` is the ODO subject, `Y` is the ODO object.

The cases to consider when using the ODO clause are:

- ODO object and subject are contained within the same group item, and that item is a **sending** field or that item is a **receiving** field.
- ODO object is outside of the group item that contains the subject.

ODO Object and Subject Contained in Group Item

Whether Maximum Length or Actual Length Is Used

If a group item is not complex ODO, contains both the subject and object of the ODO, and it is a receiving item, then the maximum length of the item is used. In this situation it is not necessary to set the value of the ODO object before a reference is made.

If the receiving item is followed by a data-item which is in the same record but is not subordinate to the receiver (is complex ODO), then the actual length is used and a compiler message is issued to inform you that the actual length, not the maximum, will be used. In this situation it is necessary to set the value of the ODO object before any reference to the item.

The following example contrasts how the length is determined for a group item whose subordinate items contain an OCCURS clause with the DEPENDING ON option and the object of that DEPENDING ON option, depending on whether it is the sending group item or the receiving group item.

```
WORKING-STORAGE SECTION.
01  MAIN-AREA.
    03  REC-1.
        05  FIELD-1                        PIC S9.
        05  FIELD-2 OCCURS 1 TO 5 TIMES
             DEPENDING ON FIELD-1           PIC X(05).

01  REC-2.
    05  REC-2-DATA                         PIC X(50).
```

Sending Group Item

If you want to move REC-1 to REC-2, the length of REC-1 is determined immediately prior to the MOVE, using the current value in FIELD-1. If the contents of FIELD-1 do not conform to its PICTURE, that is, if FIELD-1 does not contain an external decimal item, the result is unpredictable. (See Chapter 3, “Numbers and Arithmetic” on page 28 for more information on data and sign representation).

As you can see, you must be sure that you have the correct value placed in the ODO object before the MOVE is initiated.

Receiving Group Item

If you want to do a MOVE to REC-1, the length of REC-1, for the purpose of the MOVE, is determined using the maximum number of occurrences. In this example, that would be 5 occurrences of FIELD-2 plus FIELD-1 for a length of 26.

In this case, the ODO object (FIELD-1) need not be set before referencing REC-1 as a receiving item. However, the sending field's ODO object needs to be set to a valid numeric value between 1 and 5 for the ODO object of the receiving field to be validly set by the move.

Another Record Makes this Complex ODO

However, if REC-2 were followed by a data item which is in the same record but is not subordinate to REC-2, then the actual length of REC-2 is used and the ODO object must be set before the reference.

In the following example, REC-1 is followed by REC-2.

```
01  MAIN-AREA
    03  REC-1.
        05  FIELD-1                      PIC S9.
        05  FIELD-3                      PIC S9.
        05  FIELD-2 OCCURS 1 TO 5 TIMES
             DEPENDING ON FIELD-1         PIC X(05).
    03  REC-2.
        05  FIELD-4 OCCURS 1 TO 5 TIMES
             DEPENDING ON FIELD-3         PIC X(05).
```

If you do a MOVE to REC-1 in this case, the actual length of REC-1 is calculated immediately prior to the move using the current value of the ODO object (FIELD-1), and a compiler message is issued letting you know that the actual length, instead of the maximum length, was used. This case requires that you set the value of the ODO object (FIELD-1) prior to using the item as a receiving field.

ODO Object outside the Group

You must ensure that the object of the OCCURS DEPENDING ON clause contains a value that correctly specifies the current number of occurrences of the table elements. Figure 16 on page 57 shows how to define a variable-length table.

```
   DATA DIVISION.
   FILE SECTION.

   FD  LOCATION-FILE.
     01 LOCATION-RECORD.
       05  LOC-CODE                    PIC XX.
       05  LOC-DESCRIPTION             PIC X(20).
       05  FILLER                      PIC X(58).

   WORKING-STORAGE SECTION.
     01 FLAGS.
       05 LOCATION-EOF-FLAG            PIC X(5) VALUE SPACE.
          88 LOCATION-EOF              VALUE "FALSE".
     01 MISC-VALUES.
       05 LOCATION-TABLE-LENGTH        PIC 9(3) VALUE ZERO.
       05 LOCATION-TABLE-MAX           PIC 9(3) VALUE 100.
  ****************************************************************
  ***               L O C A T I O N   T A B L E                ***
  ***               FILE CONTAINS LOCATION CODES.              ***
  ****************************************************************
     01 LOCATION-TABLE.
       05 LOCATION-CODE OCCURS 1 TO 100 TIMES
              DEPENDING ON LOCATION-TABLE-LENGTH   PIC X(80).
```

Figure 16. Defining a Variable-Length Table

Figure 17 shows a do-until structure used to control loading of a variable-length table. When initialization is complete, LOCATION-TABLE-LENGTH will contain the subscript of the last item in the table. (This variable-length table is defined in Figure 16.)

```
Perform Test After
    Varying Location-Table-Length From 1 By 1
    Until Location-EOF
    Or Location-Table-Length = Location-Table-Max
  Move Location-Record To
      Location-Code (Location-Table-Length)
  Read Location-File
      At End Set Location-EOF To True
  End-Read
End-Perform
```

Figure 17. Loading a Variable-Length Table

Two factors that affect the successful manipulation of variable-length records are the correct calculation of records lengths and the conformance of the data in the OCCURS...DEPENDING ON object to its picture. If you are using variable-length group items in either a READ...INTO or WRITE...FROM statement, in conjunction with an OCCURS...DEPENDING ON statement, make sure that the receiver or intermediate field length is correct. The length of the variable portions of a group item is the product of

the object of the DEPENDING ON option and the length of the subject of the OCCURS clause.

If the content of the ODO object does not match its PICTURE clause, the program may abnormally terminate. See Chapter 3, “Numbers and Arithmetic” on page 28 for more information on data and sign representation.

Complex OCCURS DEPENDING ON

Complex OCCURS DEPENDING ON is supported as an extension to the COBOL 85 Standard.

The basic forms of complex ODO permitted by the compiler are:

- A data item described by an OCCURS clause with the DEPENDING ON option is followed by a non-subordinate element or group (variably-located item).
- A data item described by an OCCURS clause with the DEPENDING ON option is followed by a non-subordinate data item described by an OCCURS clause with the DEPENDING ON option (variably-located table).
- A data item described by an OCCURS clause with the DEPENDING ON option is nested within another data item described by an OCCURS clause with the DEPENDING ON option (table with variable-length elements).
- Index-name for a table with variable-length elements.

Complex ODO is tricky to use and can make maintaining your code more difficult. If you choose to use it in order to save disk space, follow the guidelines in Appendix C, “Complex OCCURS DEPENDING ON” on page 410.

Searching a Table (SEARCH Statement)

COBOL provides two search techniques for tables: serial and binary.

To perform *serial searches*:

- Use the PERFORM . . . VARYING statement with subscripting or indexing (discussed in “Creating Variable-Length Tables (DEPENDING ON Clause)” on page 54).
- Use SEARCH and indexing.

To perform *binary searches*, use indexing and the SEARCH ALL statement.

The following discussion assumes you are familiar with the format of the SEARCH and SEARCH ALL statements. If you are not, see *IBM COBOL Language Reference*.

Serial Search

Use the SEARCH statement to perform a serial search beginning at the current index setting. To modify the index setting, use the SET statement.

The conditions in the WHEN option are evaluated in the order in which they are written.

- If none of the conditions is satisfied, the index is increased to correspond to the next table element, and the WHEN conditions are evaluated again.
- If one of the WHEN conditions is satisfied, the search ends; the index remains pointing to the table element that satisfied the condition.
- If the entire table has been searched and no conditions were met, the AT END imperative statement is executed, if there is one. If you do not use the AT END option, control passes to the next statement in your program.

Searching More than One Level of a Table

Only one level of a table (a table element) can be referenced with each SEARCH statement. SEARCH statements can be nested to search multiple levels of a table. However, SEARCH statements can be nested only if you delimit each nested SEARCH statement with END-SEARCH. The WHEN condition must be followed by an imperative statement; the SEARCH statement is an imperative statement only when it is delimited by END-SEARCH.

Speeding Up Your Search

It is important to know if the found condition comes after some intermediate point in the table element. You can speed up the SEARCH by using the SET statement to set the index to begin the search after that point.

Arranging the table so that the data used most often is at the beginning also enables more efficient serial searching. If the table is large and is pre-sorted, a binary search is more efficient. See “Binary Search (SEARCH ALL Statement)” on page 60 more information on binary searches.

Serial Search Example

```
01  TABLE-ONE.
    05  TABLE-ENTRY1 OCCURS 10 TIMES
            INDEXED BY TE1-INDEX.
        10  TABLE-ENTRY2 OCCURS 10 TIMES
                INDEXED BY TE2-INDEX.
            15  TABLE-ENTRY3 OCCURS 5 TIMES
                    ASCENDING KEY IS KEY1
                    INDEXED BY TE3-INDEX.
                20  KEY1                   PIC X(5).
                20  KEY2                   PIC X(10).
    ⋮
PROCEDURE DIVISION.
    ⋮
    SET TE1-INDEX TO 1
    SET TE2-INDEX TO 4
    SET TE3-INDEX TO 1
    MOVE "A1234" TO KEY1 (TE1-INDEX, TE2-INDEX, TE3-INDEX + 2)
    MOVE "AAAAAAAA00" TO KEY2 (TE1-INDEX, TE2-INDEX, TE3-INDEX + 2)
    SEARCH TABLE-ENTRY3
      AT END
        MOVE 4 TO RETURN-CODE
      WHEN TABLE-ENTRY3(TE1-INDEX, TE2-INDEX, TE3-INDEX)
          = "A1234AAAAAAAA00"
        MOVE 0 TO RETURN-CODE
    END-SEARCH
```

Values after execution:

```
TE1-INDEX = 1
TE2-INDEX = 4
TE3-INDEX points to the TABLE-ENTRY3
          that equals "A1234AAAAAAAA00"
RETURN-CODE = 0
```

Binary Search (SEARCH ALL Statement)

When you use SEARCH ALL to perform a binary search, you do not need to set the index before you begin. The index used is always the one associated with the first *index-name* in the OCCURS clause, and it varies during execution to maximize the search efficiency.

To use the SEARCH ALL statement, your table must be ordered on the key or keys coded in the OCCURS clause. You can use any key in the WHEN condition, but all preceding *data-names* in the KEY option must also be tested. The test must be an equal-to condition, and the KEY *data-name* must be either the subject of the condition or the name of a conditional variable with which the tested *condition-name* is associated. The WHEN condition can also be a compound condition, formed from one of the simple conditions listed above, with AND as the only logical connective. The KEY and its object of comparison must be compatible, as stated in the relation test rules.

Binary Search Example

For example, a table defined like this:

```
01  TABLE-A.
    05  TABLE-ENTRY OCCURS 90 TIMES
                    ASCENDING KEY-1, KEY-2
                    DESCENDING KEY-3
                    INDEXED BY INDX-1.
       10  PART-1                    PIC 99.
       10  KEY-1                     PIC 9(5).
       10  PART-2                    PIC 9(6).
       10  KEY-2                     PIC 9(4).
       10  PART-3                    PIC 9(18).
       10  KEY-3                     PIC 9(5).
```

can be searched using the following instructions:

```
SEARCH ALL TABLE-ENTRY
  AT END
    PERFORM NOENTRY
  WHEN KEY-1 (INDX-1) = VALUE-1 AND
       KEY-2 (INDX-1) = VALUE-2 AND
       KEY-3 (INDX-1) = VALUE-3
    MOVE PART-1 (INDX-1) TO OUTPUT-AREA
END-SEARCH
```

These instructions will execute a search on the given table that contains 90 elements of 40 bytes and 3 keys. The primary and secondary keys (`KEY-1` and `KEY-2`) are in ascending order, but the least significant key (`KEY-3`) is in descending order. If an entry is found in which three keys are equal to the given values (`VALUE-1`, `VALUE-2`, and `VALUE-3`), `PART-1` of that entry will be moved to `OUTPUT-AREA`. If the matching keys are not found in any of the entries in `TABLEA`, the `NOENTRY` routine is performed.

Processing Table Items (Intrinsic Functions)

You can process alphanumeric or numeric table items using intrinsic functions as long as the table item's data description is compatible with the function's argument requirements. The *IBM COBOL Language Reference* describes the required data formats for the arguments of the various intrinsic functions.

Use a subscript or index to reference an individual data item as a function argument. Assuming `Table-One` is a 3x3 array of numeric items, you can find the square root of the middle element with a statement such as:

```
Compute X = Function Sqrt(Table-One(2,2))
```

Processing Multiple Table Items (ALL Subscript)

You might often need to process the data in tables iteratively. For intrinsic functions that accept multiple arguments, you can use the `ALL` subscript to reference all the items in the table or single dimension of the table. The iteration is handled automatically, making your code shorter and simpler.

Example 1

This example sums a cross section of Table-Two:

```
Compute Table-Sum = FUNCTION SUM (Table-Two(ALL, 3, ALL)))
```

Assuming that Table2 is a 2x3x2 array, the above statement would cause these elements to be summed:

```
Table-Two(1,3,1)
Table-Two(1,3,2)
Table-Two(2,3,1)
Table-Two(2,3,2)
```

Example 2

This example computes values for all employees.

```
01  Employee-Table.
    05  Emp-Count          Pic s9(4)  usage binary.
    05  Emp-Record         occurs 1 to 500 times
                           depending on Emp-Count.
        10  Emp-Name       Pic x(20).
        10  Emp-Idme       Pic 9(9).
        10  Emp-Salary     Pic 9(7)v99.
    ⋮
Procedure Division.
    Compute Max-Salary = Function Max(Emp-Salary(ALL))
    Compute I = Function Ord-Max(Emp-Salary(ALL))
    Compute Avg-Salary = Function Mean(Emp-Salary(ALL))
    Compute Salary-Range = Function Range(Emp-Salary(ALL))
    Compute Total-Payroll = Function Sum(Emp-Salary(ALL))
```

Example 3

Scalars and array arguments can be mixed for functions that accept multiple arguments:

```
Compute Table-Median = Function Median(Arg1 Table-One(ALL))
```

Efficient Coding for Tables

For efficient table-handling, follow these suggestions:

- If the table is searched sequentially, put the data values most likely to satisfy the search criteria at the beginning of a table.
- Use *index-names* instead of subscripts. This method is more efficient, but subscripting might be easier to understand and maintain. Relative index references are executed as fast as direct index references. For additional details, see "Subscripting" on page 46 and "Subscripting Using Index-Names (Indexing)" on page 47.
- Use binary (COMP) data items with 8 or fewer digits for subscripts and OCCURS DEPENDING ON objects. Use fewer than five digits, if possible.
- Avoid referencing errors by coding subscript and index checks into your program.

Chapter 5. Selection and Iteration

Use control structures to:

- Choose program actions based on the outcome of a decision.
- Control looping in your program.

Selection (IF and EVALUATE Statements)

Selection is providing for different program actions depending on the tested value of some data item or data items.

The IF and EVALUATE statements are COBOL selection constructs. The testing of a data item or data items is done in both of these statements by means of a conditional expression.

IF Statement

Use IF . . . ELSE to code a choice between two processing actions. (The word THEN is optional in a COBOL program.) For example:

```
IF condition-p
  statement-1
ELSE
  statement-2
END-IF
```

IF Statement with a Null Branch

There are two ways you can code an IF statement when one of the processing choices is no action. Because the ELSE clause is optional, you can code the following:

```
IF condition-q
  statement-1
END-IF
```

This coding is suitable for simple programming cases. However, if the logic in your program is complex (for example, you have nested IF constructs with action for only one of the processing choices), you might want to use the ELSE clause and code the null branch of the IF statement with the CONTINUE statement:

```
IF condition-q
  statement-1
ELSE
  CONTINUE
END-IF
```

Nested IF Statements

When an IF statement has another IF statement as one of its possible processing branches, these IF statements are said to be nested IFs. Theoretically, there is no limitation on the depth of nested IF statements. However, when the program has to test a

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variable for more than two values, EVALUATE is the better choice. (For more information, see “EVALUATE statement” on page 65).

Use nested IF statements sparingly; the logic can be difficult to follow, although proper indentation helps.

Logic of a Nested IF Statement: The following is pseudocode for a nested IF statement:

```
IF condition-p
  IF condition-q
    statement-1
  ELSE
    statement-2
  END-IF
  statement-3
ELSE
  statement-4
END-IF
```

Here an IF is nested, along with a sequential structure, in one branch of another IF. The structure for this logic is shown in Figure 18 on page 64.

When you code a structure like the one in Figure 18, the END-IF closing the inner nested IF becomes very important. Use END-IF instead of a period, because a period would end the outer IF structure as well.

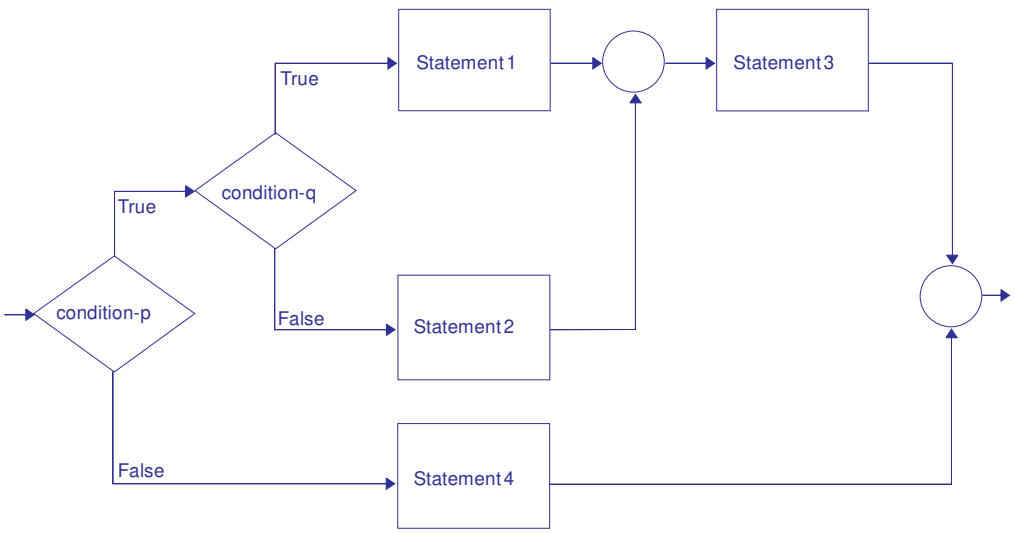

Figure 18. Control Logic Structure for Nested IF Statements

Good Coding Practice for Nested IFs: When you nest IF statements, readability and debugging will be easier if each IF statement has its own END-IF scope-terminator and if you use proper indentation. For example:

```
IF A = 1
  IF B = 2
    PERFORM C
  ELSE PERFORM D.
```

The ELSE PERFORM D phrase is interpreted as the ELSE phrase of the last previous IF which is, `IF B = 2`. If this is the intent, you can make the logic clearer with the following coding:

```
IF A = 1
  IF B = 2
    PERFORM C
  ELSE
    PERFORM D
  END-IF
END-IF
```

If the intent is to have `ELSE PERFORM D` depend on `IF A = 1`, the code would look like this:

```
IF A = 1
  IF B = 2
    PERFORM C
  END-IF
ELSE
  PERFORM D
END-IF
```

EVALUATE statement

The EVALUATE statement is an expanded form of the IF statement. An IF statement allows your program to act on one of two conditions: true or false. If you had three or more possible conditions instead of just two, and you were limited to using IF statements, you would need to nest or cascade the IF statements. Such nested IF statements are a common source of logic errors and debugging problems.

With the EVALUATE statement, you can test any number of conditions in a single statement and have separate actions for each. In structured programming terms, this is a case structure. It can also be thought of as a form of decision table.

Conditional Expressions

The IF and EVALUATE statements let you code different program actions that will be performed depending on the true or false value of a condition expression. COBOL lets you specify any of these simple conditions:

Figure 19. Conditions You Can Test For In COBOL

Condition Type	What It Tests	Where to Look for Information
Class	Whether your data is uppercase alphabetic, lowercase alphabetic, numeric, MBCS, Kanji, or consisting entirely of characters listed in the definition of a user-defined class-name. NUMPROC(PFD), which bypasses invalid sign processing, might affect the outcome of a test for numeric data.	"Checking for Incompatible Data (Numeric Class Test)" on page 35.
User-defined	A level-88 condition name, to discover whether a data item contains a particular value or range of values.	See "Condition-Names (Switches and Flags)" on page 66 for details on how to use level-88 items to define *condition-names* that you can test to control the processing of switches and flags.
Relation	Compares two items.	*IBM COBOL Language Reference*.
Sign	Whether a numeric operand is less than, greater than, or equal to zero.	*IBM COBOL Language Reference*.
Switch-status	Whether an UPSI switch is on or off.	*IBM COBOL Language Reference*.

You can create combined conditions by using logical connectives (AND, OR, or NOT), and you can combine conditions. Rules for using conditions are given in *IBM COBOL Language Reference*.

Condition-Names (Switches and Flags)

Some program decisions are based on whether the value of a data item is true or false, on or off, yes or no. To control these two-way decisions in your program, define level-88 items with meaningful names (a condition name) to act as switches.

Some program decisions are based not on an on or off condition of a data item, but instead, depend on the particular value (or range of values) of a data item. When condition-names are used to give more than just on or off values to a field, the field is generally referred to as a flag, not a switch. For details on flags, see the section "Flags" on page 67, below.

Flags and Switches Make Changing Code Easier: Flags and switches make your code easier to change. If you need to change the values for a condition, you have to change only the level-88 condition-name value.

For example, a program that uses a condition-name to test a field for a given numeric range—a salary range—need not be changed. If the program must be changed to

check for a different salary range, you would need to change only the condition-name value in the DATA DIVISION. You do not need to make changes in the PROCEDURE DIVISION.

Switches: For example, to test for an end-of-file condition for an input file named Transaction-File, you could use the following data definitions:

```
Working-Storage Section.
01  Switches.
    05  Transaction-EOF-Switch       Pic X  value space.
        88  Transaction-EOF                value "y".
```

The level-88 description says a condition named Transaction-EOF is turned on when Transaction-EOF-Switch has a value of "y". Referencing Transaction-EOF in your PROCEDURE DIVISION expresses the same condition as testing for `Transaction-EOF-Switch = "y"`. For example, the statement:

```
If Transaction-EOF Then Perform Print-Report-Summary-Lines
```

causes the report to be printed only if your program has read through to the end of the Transaction-File and if the Transaction-EOF-Switch has been set to "y".

Flags: To test for more than two values, assign more than one condition-name to a field by using multiple level-88 items.

Consider a program that updates a master file. The updates are read from a transaction file. The transaction file's records contain a field for the function to be performed: add, change, or delete. In the input file's record description, code a field for the function code using level-88 items:

```
01  Transaction-Input Record
    05  Transaction-Type             Pic X.
        88  Add-Transaction          Value "A".
        88  Change-Transaction       Value "C".
        88  Delete-Transaction       Value "D".
```

The code in the PROCEDURE DIVISION for testing these condition-names might look like this:

```
Evaluate True
  When Add-Transaction
    Perform Add-Master-Record-Paragraph
  When Change-Transaction
    Perform Update-Exisitng-Record-Paragraph
  When Delete-Transaction
    Perform Delete-Master-Record-Paragraph
End-Evaluate
```

Resetting Condition-Names (Switches and Flags)

Throughout your program, you might need to reset your switches or change your flags back to the original values they have in their data descriptions. To do so, you can use either a SET statement or define your own data item to use.

SET condition-name TO TRUE: When you use the SET *condition-name* TO TRUE statement, the switch or flag is set back to the original value it was assigned in its data description.

This method makes it easy for the reader to follow your code if you choose meaningful condition-names and if the value assigned has some association with a logical value of `True`.

The SET statement in the following example does the same thing as `Move "y" to Transaction-EOF-Flag`:

```
01 Switches
   05  Transaction-EOF-Switch        Pic X  Value space.
       88  Transaction-EOF                 Value "y".
         .
         .
         .
Procedure Division.
    000-Do-Main-Logic.
      Perform 100-Initialize-Paragraph
      Read Update-Transaction-File
          At End Set Transaction-EOF to True
      End-Read
```

The following example shows how you can assign a value for a field in an output record based on the transaction code of an input record.

```
01  Input-Record.
    05  Transaction-Type             Pic X(9).
         .
         .
         .
01  Data-Record-Out.
    05  Data-Record-Type             Pic X.
        88 Record-Is-Active          Value "A".
        88 Record-Is-Suspended       Value "S".
        88 Record-Is-Deleted         Value "D".
    05  Key-Field                    Pic X(5).
         .
         .
         .
```

```
Procedure Division.
         .
         .
         .
    Evaluate Transaction-Type of Input-Record
      When "ACTIVE"
        Set Record-Is-Active to TRUE
      When "SUSPENDED"
        Set Record-Is-Suspended to TRUE
      When "DELETED"
        Set Record-Is-Deleted to TRUE
    End-Evaluate
```

Level-88 Note: For a level-88 item with multiple values (such as `88 Record-is-Active Value "A" "O" "S"`), SET *condition-name* TO TRUE assigns the first value (here, `A`).

SWITCH-OFF: Establish a data item with this description:

```
01  SWITCH-OFF      Pic X  Value "n".
```

Then use SWITCH-OFF throughout your program to set on/off switches to off. With this method, whoever reads your code can easily see what you are doing to a switch. From this code:

```
01  Switches
    05  Transaction-EOF-Switch       Pic X  Value space.
        88  Transaction-EOF                 Value "y".
01  SWITCH-OFF                       Pic X  Value "n".
       .
       .
       .
Procedure Division.
       .
       .
       .
    Move SWITCH-OFF to Transaction-EOF-Switch
```

it is easy to see that you are setting the end-of-file switch to off. In other words, you have reset the switch to indicate that the end of the file has not been reached.

Iterative Loops (PERFORM Statement)

For looping (repeating the same code), use one of the forms of the PERFORM statement. You can use the PERFORM statement to loop a set number of times or to loop based on the outcome of a decision.

PERFORM statements can be inline or out-of-line.

Use the PERFORM statement to run a paragraph and then implicitly return control to the next executable statement. In effect, the PERFORM statement is a way of coding a closed subroutine that you can enter from many different parts of the program.

Coding a Loop to Be Performed a Definite Number of Times

Use the PERFORM . . . TIMES statement to execute a paragraph a certain number of times:

```
PERFORM 010-PROCESS-ONE-MONTH 12 TIMES
INSPECT . . .
```

When control reaches the PERFORM statement, the code for the paragraph 010-PROCESS-ONE-MONTH is executed 12 times before control is transferred to the INSPECT statement.

Conditional Looping

Use the PERFORM . . . UNTIL statement to execute a paragraph until a condition you choose is satisfied. You can use either of the following forms:

```
PERFORM . . . WITH TEST AFTER . . . UNTIL . . .
PERFORM . . . [WITH TEST BEFORE] . . . UNTIL . . .
```

In the following example, the implicit WITH TEST BEFORE phrase provides a do-while structure:

```
PERFORM  010-PROCESS-ONE-MONTH
  UNTIL MONTH EQUAL DECEMBER
INSPECT . . .
```

When control reaches the PERFORM statement, the condition (MONTH EQUAL DECEMBER) is tested. If the condition is satisfied, control is transferred to the INSPECT statement. If the condition is not satisfied, 010-PROCESS-ONE-MONTH is executed, and the condition is tested again. This cycle continues until the condition tests as true. (To make your program easier to read, you might want to code the WITH TEST BEFORE clause.)

Use the PERFORM . . . WITH TEST AFTER . . . UNTIL if you want to execute the paragraph at least once and then test before any subsequent execution. This is equivalent to the do-until structure.

Looping through a Table

Use the PERFORM statement to control a loop through a table. You can use either of the following forms:

```
PERFORM . . . WITH TEST AFTER . . . VARYING . . . UNTIL . . .
PERFORM . . . [WITH TEST BEFORE] . . . VARYING . . . UNTIL . . .
```

PERFORM. . .WITH TEST AFTER Example

You can use PERFORM . . . VARYING to initialize a table. In this form of the PERFORM statement, a variable is increased or decreased and tested until a condition is satisfied. The following code shows an example of looping through a table to check for invalid data:

```
*** BLANK FIELDS ARE NOT ALLOWED IN THE INPUT DATA  ***

 PERFORM TEST AFTER VARYING WS-DATA-IX
  FROM 1 BY 1
  UNTIL WS-DATA-IX = 12
  IF WS-DATA (WS-DATA-IX) EQUALS SPACES
    SET SERIOUS-ERROR TO TRUE
    DISPLAY ELEMENT-NUM-MSG5
  END-IF
 END-PERFORM

 INSPECT . . .
```

In the code above, when control reaches the PERFORM statement, WS-DATA-IX is set equal to 1 and the PERFORM statement is executed. Then the condition (WS-DATA-IX = 12) is tested. If the condition is true, control drops through to the INSPECT statement. If it is false, WS-DATA-IX is increased by 1, the PERFORM statement is executed, and the condition is tested again. This cycle of execution and testing continues until WS-DATA-IX is equal to 12.

In terms of the application, this loop controls input-checking for the 12 fields of item WS-DATA. Empty fields are not allowed, and this section of code loops through and issues error messages, as appropriate.

Executing a Group of Paragraphs or Sections

In structured programming, the paragraph you execute is usually a single paragraph. However, you can execute a group of paragraphs, a single section, or a group of sections using the PERFORM . . . THRU. statement.

WHEN YOU USE PERFORM . . . THRU use a paragraph-EXIT statement to clearly indicate the end point for the series of paragraphs.

Intrinsic functions can make the task of the iterative processing of tables simpler and easier for you to code. For information on using the ALL subscript with intrinsic functions to reference all the items in a table, see “Processing Table Items (Intrinsic Functions)” on page 61.

Chapter 6. String Handling

COBOL provides language constructs for performing these operations associated with string data items:

Figure 20. COBOL Data Constructs for Manipulating Strings

What You Want to Do	What to Use	Where to Look
Join data items	STRING Statement	On page 72
Split data items	UNSTRING Statement	On page 74
Manipulate null-terminated strings	Usual string handling statements.	On page 77
Reference substrings of data items	Reference modifiers	On page 78
Tally and replace data items	INSPECT statement	On page 81
Convert data items	Intrinsic Functions UPPER-CASE, LOWER-CASE, REVERSE, NUMVAL, and NUMVAL-C	On page 83
Evaluate data items	Intrinsic Functions CHAR, ORD, MAX, MIN, ORD-MAX, ORD-MIN, LENGTH, and WHEN-COMPILED	On page 84

Joining Data Items (STRING Statement)

Use the STRING statement to join all or parts of several data items into one data item. One STRING statement can save you several MOVE statements.

The STRING statement transfers data into the receiving item in the order you indicate. In the STRING statement you can also specify:

- Delimiters that cause a sending field to be ended and another to be started
- Special actions to be taken when an ON OVERFLOW condition occurs (when the single receiving field is filled before all of the sending characters have been processed).

STRING Statement Example

In the following example, an input record is read, and the STRING statement is used to select and format information as an output line consisting of a line number, customer name and address, invoice number, next billing date, and balance due, truncated to the dollar figure shown. (The symbol ␣ indicates a blank space.)

In the FILE SECTION, the following records are defined:

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```
01  RCD-01.
    05  CUST-INFO.
        10  CUST-NAME               PIC X(15).
        10  CUST-ADDR               PIC X(35).
    05  BILL-INFO.
        10  INV-NO                  PIC X(6).
        10  INV-AMT                 PIC $$,$$$.99.
        10  AMT-PAID                PIC $$,$$$.99.
        10  DATE-PAID               PIC X(8).
        10  BAL-DUE                 PIC $$,$$$.99.
        10  DATE-DUE                PIC X(8).
```

In the WORKING-STORAGE SECTION, the following fields are defined:

```
77  RPT-LINE                        PIC X(120).
77  LINE-POS                        PIC S9(3).
77  LINE-NO                         PIC 9(5) VALUE 1.
77  DEC-POINT                       PIC X VALUE ".".
```

The record, as read, contains the following information:

```
J.B.bSMITHbbbbb
444bSPRINGbST.,bCHICAGO,bILL.bbbbbb
A14275
$4,736.85
$2,400.00
09/22/76
$2,336.85
10/22/76
```

In the PROCEDURE DIVISION, the programmer initializes RPT-LINE to SPACES and sets LINE-POS, the data item to be used as the POINTER feld, to 4. (By coding the POINTER phrase of the STRING statement, you can use the explicit pointer field to control placement of data in the receiving field.) Then, the programmer issues this STRING statement:

```
STRING
   LINE-NO SPACE CUST-INFO INV-NO SPACE DATE-DUE SPACE
      DELIMITED BY SIZE
   BAL-DUE
      DELIMITED BY DEC-POINT
   INTO RPT-LINE
   WITH POINTER LINE-POS.
```

STRING Program Results

When the statement is performed, the following steps take place:

1. The field LINE-NO is moved into positions 4 through 8 of RPT-LINE .
2. A space is moved into position 9.
3. The group item CUST-INFO is moved into positions 10 through 59.
4. INV-NO is moved into positions 60 through 65.
5. A space is moved into position 66.
6. DATE-DUE is moved into positions 67 through 74.

7. A space is moved into position 75.
8. The portion of BAL-DUE that precedes the decimal point is moved into positions 76 through 81.
9. The value of LINE-POS is 82 after the STRING statement is performed.

After the STRING statement is performed, RPT-LINE appears as shown in the following:

```
Column

 4    10                                          60     67       76
 |    |                                           |      |        |
 ▼    ▼                                           ▼      ▼        ▼
00001 J.B. SMITH  444 SPRING ST., CHICAGO, ILL.  A14275 10/22/76 $2,336
```

Splitting Data Items (UNSTRING Statement)

Use the UNSTRING statement to split one sending field into several receiving fields. One UNSTRING statement can save you several MOVE statements.

You can indicate delimiters that, when encountered in the sending field, cause the current receiving field to be switched to the next one indicated. You might have the number of characters placed in each receiving field returned to you, and keep a count of the total number of characters transferred. You might also specify special actions for the program to take if all the receiving fields are filled before the end of the sending item is reached.

UNSTRING Statement Example

In the following example, selected information is taken from the input record; some is organized for printing and some for further processing.

In the FILE SECTION, the following records are defined:

```
*  Record to be acted on by the UNSTRING statement:
 01  INV-RCD.
     05  CONTROL-CHARS                PIC XX.
     05  ITEM-INDENT                  PIC X(20).
     05  FILLER                       PIC X.
     05  INV-CODE                     PIC X(10).
     05  FILLER                       PIC X.
     05  NO-UNITS                     PIC 9(6).
     05  FILLER                       PIC X.
     05  PRICE-PER-M                  PIC 99999.
     05  FILLER                       PIC X.
     05  RTL-AMT                      PIC 9(6).99.
*
*  UNSTRING receiving field for printed output:
 01  DISPLAY-REC.
     05  INV-NO                       PIC X(6).
     05  FILLER                       PIC X VALUE SPACE.
     05  ITEM-NAME                    PIC X(20).
     05  FILLER                       PIC X VALUE SPACE.
     05  DISPLAY-DOLS                 PIC 9(6).

*
*  UNSTRING receiving field for further processing:
 01  WORK-REC.
     05  M-UNITS                      PIC 9(6).
     05  FIELD-A                      PIC 9(6).
     05  WK-PRICE REDEFINES FIELD-A   PIC 9999V99.
     05  INV-CLASS                    PIC X(3).
*
*  UNSTRING statement control fields
 77  DBY-1                            PIC X.
 77  CTR-1                            PIC S9(3).
 77  CTR-2                            PIC S9(3).
 77  CTR-3                            PIC S9(3).
 77  CTR-4                            PIC S9(3).
 77  DLTR-1                           PIC X.
 77  DLTR-2                           PIC X.
 77  CHAR-CT                          PIC S9(3).
 77  FLDS-FILLED                      PIC S9(3).
```

In the PROCEDURE DIVISION, the programmer writes the following UNSTRING statement:

```
* Move subfields of INV-RCD to the subfields of DISPLAY-REC
*   and WORK-REC:
 UNSTRING INV-RCD
          DELIMITED BY ALL SPACES OR  "/" OR DBY-1
          INTO      ITEM-NAME   COUNT IN CTR-1
                    INV-NO DELIMITER IN DLTR-1 COUNT IN CTR-2
                    INV-CLASS
                    M-UNITS     COUNT IN CTR-3
                    FIELD A
                    DISPLAY-DOLS DELIMITER IN DLTR-2 COUNT IN CTR-4
          WITH POINTER CHAR-CT
          TALLYING IN FLDS-FILLED
          ON OVERFLOW GO TO UNSTRING-COMPLETE.
```

Before issuing the UNSTRING statement, the programmer places the value 3 in CHAR-CT (the POINTER field) to avoid working with the two control characters in INV-RCD. A period (.) is placed in DBY-1 for use as a delimiter, and the value 0 (zero) is placed in FLDS-FILLED (the TALLYING field). The data is then read into INV-RCD, as shown in the following:

```
Column

1        10        20        30        40        50        60
|        |         |         |         |         |         |
|        |         |         |         |         |         |
|        |         |         |         |         |         |
|        |         |         |         |         |         |
|        |         |         |         |         |         |
V        V         V         V         V         V         V
ZYFOUR—PENNY—NAILS     707890/BBA 475120 00122 000379.50
```

UNSTRING Program Results

When the UNSTRING statement is performed, the following steps take place:

1. Positions 3 through 18 (FOUR-PENNY-NAILS) of INV-RCD are placed in ITEM-NAME, left-justified in the area, and the unused character positions are padded with spaces. The value 16 is placed in CTR-1.
2. Because ALL SPACES is coded as a delimiter, the 5 contiguous SPACE characters are considered to be one occurrence of the delimiter.
3. Positions 24 through 29 (707890) are placed in INV-NO. The delimiter character, /, is placed in DLTR-1 , and the value 6 is placed in CTR-2.
4. Positions 31 through 33 are placed in INV-CLASS. See Note at end of list.
5. Positions 35 through 40 (475120) are examined and placed in M-UNITS. The value 6 is placed in CTR-3. See Note at end of list.
6. Positions 42 through 46 (00122) are placed in FIELD-A and right-justified in the area. The high-order digit position is filled with a 0 (zero). See Note at end of list.
7. Positions 48 through 53 (000379) are placed in DISPLAY-DOLS. The period (.) delimiter character in DBY-1 is placed in DLTR-2, and the value 6 is placed in CTR-4.

8. Because all receiving fields have been acted on and 2 characters of data in INV-RCD have not been examined, the ON OVERFLOW exit is taken, and execution of the UNSTRING statement is completed.

SPACE Note: In steps 4, 5, and 6, the delimiter is a SPACE, but because no field has been defined as a receiving area for delimiters, the SPACE is bypassed.

After the UNSTRING statement is performed, the fields contain:

- DISPLAY-REC contains:

  ```
  707890 FOUR-PENNY-NAILS           000379
  ```

- WORK-REC contains:

  ```
  475120000122BBA
  ```

- CHAR-CT (the POINTER field) contains the value 55.
- FLDS-FILLED (the TALLYING field) contains the value 6.

Manipulating Null-Terminated Strings

Null-terminated strings are supported using syntax shown in the *IBM COBOL Language Reference*. You can construct and manipulate null-terminated strings passed to or from a C program, for example, by using string handling mechanisms such as:

- Using null terminated literal constants (Z" ... ").
- Using INSPECT statement to count number of characters in a null-terminated string:

  ```
  INSPECT source-field TALLYING char-count
                       FOR CHARACTERS
                       BEFORE X"00"
  ```

- Using UNSTRING statement to move characters in a null-terminated string to a target-field and get the character count:

  ```
  WORKING-STORAGE SECTION.
   ...
  01  source-field          PIC X(1001).
  01  char-count     COMP-5 PIC 9(4).
  01  target-area.
      02 individual-char OCCURS 1 TO 1000 TIMES DEPENDING ON char-count
                           PIC X.
   ...
  PROCEDURE DIVISION.
   ...
      UNSTRING source-field DELIMITED BY X"00"
                           INTO target-area
                           COUNT IN char-count
        ON OVERFLOW
          DISPLAY "source not null terminated or target too short"
           ...
      END-UNSTRING
       ...
  ```

- Using a SEARCH statement to locate trailing null or space characters (Define the string being examined as a table of single characters.)
- Checking each character in a field in a loop (PERFORM) looking at each character of the field (Each character in the field can be examined using a reference modifier such as `source-field (I:1)`.)

The following example shows the use of several of these mechanism:

```
 01 L pic X(20) value z'ab'.
 01 M pic X(20) value z'cd'.
 01 N pic X(20).
 01 N-Length pic 99 value zero.
 01 Y pic X(13) value 'Hello, World!'.

* Display null-terminated string
     Inspect N tallying N-length
      for characters before initial x'00'
     Display 'N: ' N(1:N-length) ' Length: ' N-length

* Move null-terminated string to alphanumeric, strip null
     Unstring N delimited by X'00' into X

* Create null-terminated string
     String Y     delimited by size
            X'00' delimited by size
            into N.

* Concatenate two null-terminated strings
     String L     delimited by x'00'
            M     delimited by x'00'
            X'00' delimited by size
            into N.
```

Figure 21. Handling Null-Terminated Strings

Referencing Substrings of Data Items (Reference Modifiers)

Reference a substring of character-string data item items (including MBCS data items) with reference modifiers. Intrinsic functions that return character-string values are also considered alphanumeric data items, and can include a reference modifier.

The following example shows how to use a reference modifier to reference a substring of a data item:

```
Move Customer-Record(1:20) to Orig-Customer-Name
```

As this shows, in parentheses immediately following the data item you code the ordinal position (from the left) of the character you want the substring to start with and the length of the desired substring, separated by a colon.

The length is optional. If you omit the length, the substring created will automatically extend to the end of the item. Omitting the length, when possible, is recommended as a simpler, less error-prone coding technique.

These values can be variables or expressions.

Common Reference Modification Mistakes

If the leftmost character position or the length value is a fixed-point non-integer, truncation will occur to create an integer; if it is a floating-point non-integer, rounding will occur to create an integer.

Both numbers in the reference modifier must be at least 1, and their sum should not exceed the total length of the data item.

The following options detect out-of-range reference modifiers and flag violations with a run-time message:

- SSRANGE compiler option, discussed on page 171.
- CHECK run-time option, discussed on page “CHECK” on page 185.

For additional information on reference modification, see *IBM COBOL Language Reference*.

Benefits of Reference Modification

Assume that you want to retrieve the current time from the system and display its value in an expanded format. You can retrieve the current time value from the system with the ACCEPT statement, which returns the hours, minutes, seconds, and hundredths of seconds in this format:

```
HHMMSSss
```

However, you might prefer to view the current time in this format:

```
HH:MM:SS
```

Without reference notification you would have to define data items for both formats, the one from the system and the one you want, and write code to convert from one format to the other.

With reference modification, you do not need to provide names for the subfields that describe the TIME elements. The only data definition needed is:

```
01  REFMOD-TIME-ITEM            PIC X(8).
```

The code to retrieve and expand the time value would appear as follows:

```
ACCEPT REFMOD-TIME-ITEM FROM TIME.
DISPLAY "CURRENT TIME IS: "
* Retrieve the portion of the time value that corresponds to
*   the number of hours:
    REFMOD-TIME-ITEM (1:2)
    ":"
* Retrieve the portion of the time value that corresponds to
*   the number of minutes:
    REFMOD-TIME-ITEM (3:2)
    ":"
* Retrieve the portion of the time value that corresponds to
*   the number of seconds:
    REFMOD-TIME-ITEM (5:2).
```

Reference Modification of an Intrinsic Function

The simplest solution to our problem would be to reference a substring of the CURRENT-DATE function, which requires no DATA DIVISION entries and fewer lines of code.

```
Display "Current Date is:  "
   Function Current-Date(9:2)
   ":"
   Function Current-Date(11:2)
   ":"
   Function Current-Date(13:2).
```

Using Arithmetic Expressions as Reference Modifiers

You can also use an arithmetic expression as either of the integers in a reference modifier. For example:

Suppose that a field contains some characters, right-justified, and you want to move the characters to another field, but justified to the left instead of the right. Using reference modification and an INSPECT statement, you could do that.

The program would have the following data:

```
01  LEFTY                      PIC X(30).
01  RIGHTY                     PIC X(30) JUSTIFIED RIGHT.
01  I                          PIC 9(9)  USAGE BINARY.
```

The program would count the number of leading spaces and, using arithmetic expressions in a reference modification expression, move the right-justified characters into another field, left-justified:

```
MOVE SPACES TO LEFTY
MOVE ZERO TO I
INSPECT RIGHTY.
   TALLYING I FOR LEADING SPACE.
IF I IS LESS THAN LENGTH OF RIGHTY THEN
   MOVE RIGHTY ( I + 1 : LENGTH OF RIGHTY - I ) TO LEFTY
END-IF
```

The MOVE statement transfers characters from RIGHTY, beginning at the position computed in I + 1, for a length that is computed in LENGTH OF RIGHTY - I, into the field LEFTY.

Using Intrinsic Functions as Reference Modifiers

Because a numeric function-identifier can be used anywhere an arithmetic expression is allowed, it can be used as the leftmost character position and/or the length in the reference modifier.

For example:

```
05  WS-name           Pic x(20).
05  Left-posn         Pic 99.
05  I                 Pic 99.
    ⋮
Move Customer-Record(Function Min(Left-posn I):Function Length(WS-name)) to WS-name
```

When performed, this statement causes a substring of Customer-Record to be moved into the variable WS-name; the substring is determined at run time.

If you want to use a numeric, non-integer function in a position requiring an integer function, you can use the INTEGER or INTEGER-PART function to convert the result to an integer. For example:

```
Move Customer-Record(Function Integer(Function Sqrt(I)): ) to WS-name
```

For a list that shows which numeric functions return integer and non-integer results, see *IBM COBOL Language Reference*.

Referencing Substrings of Table Items

You can also reference substrings of table entries, including variable-length entries. This is discussed in Chapter 4, “Handling Tables” on page 44.

Tallying and Replacing Data Items (INSPECT Statement)

The INSPECT statement is useful for:

- Filling selective portions of a data item with a value.
- Replacing portions with a corresponding portion of another data item.
- Counting the number of times a specific character (zero, space, asterisk, for example) occurs in a data item.

INSPECT Statement Examples

The following examples show some uses of the INSPECT statement. In all instances, the programmer has initialized the COUNTR field to zero before the INSPECT statement is performed.

Example 1:

```
77  COUNTR                PIC   9   VALUE ZERO.
01  DATA-2                PIC X(11).
    ⋮
    INSPECT DATA-2
        TALLYING COUNTR FOR LEADING "0"
        REPLACING FIRST "A" BY "2" AFTER INITIAL "C"
```

DATA-2 Before	COUNTR After	DATA-2 After
00ACADEMY00	2	00AC2DEMY00
0000ALABAMA	4	0000ALABAMA
CHATHAM0000	0	CH2THAM0000

Example 2:

```
77  COUNTR                PIC   9   VALUE ZERO.
01  DATA-3                PIC X(8).
    ⋮
    INSPECT DATA-3
        REPLACING CHARACTERS BY ZEROS BEFORE INITIAL QUOTE
```

DATA-3 Before	COUNTR After	DATA-3 After
456"ABEL	0	000"ABEL
ANDES"12	0	00000"12
"TWAS BR	0	"TWAS BR

Example 3:

The following example shows the use of INSPECT CONVERTING with AFTER and BEFORE phrases. The table shows examples of the contents of DATA-4 before and after the conversion statement is performed.

```
01  DATA-4                PIC X(11).
    ⋮
    INSPECT DATA-4
        CONVERTING
           "abcdefghijklmnopqrstuvwxyz" TO
           "ABCDEFGHIJKLMNOPQRSTUVWXYZ"
        AFTER INITIAL "/"
        BEFORE INITIAL"?"
```

DATA-4 Before	DATA-4 After
a/five/?six	a/FIVE/?six
r/Rexx/RRRr	r/REXX/RRRR
zfour?inspe	zfour?inspe

Converting Data Items (Intrinsic Functions)

Intrinsic functions are available to convert character-string data items to the following:

- Upper or lower case
- Reverse order
- Numbers.

Besides using intrinsic functions to convert characters, you can also use the INSPECT statement. See the examples under "Tallying and Replacing Data Items (INSPECT Statement)" on page 81.

Converting to Uppercase or Lowercase (UPPER-CASE, LOWER-CASE)

This code:

```
01  Item-1             Pic x(30)  Value "Hello World!".
01  Item-2             Pic x(30).
    ⋮
    Display Item-1
    Display Function Upper-case(Item-1)
    Display Function Lower-case(Item-1)
    Move Function Upper-case(Item-1) to Item-2
    Display Item-2
```

would display the following messages on the terminal:

```
Hello World!
HELLO WORLD!
hello world!
HELLO WORLD!
```

The DISPLAY statements do not change the actual contents of `Item-1` and only affect how the letters are displayed. However, the MOVE statement causes uppercase letters to be moved to the actual contents of `Item-2`.

Converting to Reverse Order (REVERSE)

The following code:

```
Move Function Reverse(Orig-cust-name) To Orig-cust-name
```

would reverse the order of the characters in `Orig-cust-name`. For example, if the starting value was "JOHNSONbbb," the value after the statement is performed would be "bbbNOSNHOJ."

Converting to Numbers (NUMVAL, NUMVAL-C)

The NUMVAL and NUMVAL-C functions convert character strings to numbers. Use these functions to convert alphanumeric data items that contain free format character representation numbers to numeric form and process them numerically. For example:

```
01  R            Pic x(20)  Value "- 1234.5678".
01  S            Pic x(20)  Value "  $12,345.67CR".
01  Total        Usage is Comp-1.
    ⋮
    Compute Total = Function Numval(R) + Function Numval-C(S)
```

The difference between NUMVAL and NUMVAL-C is that NUMVAL-C is used when the argument includes a currency symbol and/or comma, as shown in the example. You can also place an algebraic sign in front or in the rear, and it will be processed. The arguments must not exceed 18 digits (not including the editing symbols). For exact syntax rules, see *IBM COBOL Language Reference*.

Numeric Result: Both NUMVAL and NUMVAL-C return long (double-precision) floating-point values. A reference to either of these functions, therefore, represents a reference to a numeric data item. For more information on characteristics of numeric data, see Chapter 3, “Numbers and Arithmetic” on page 28.

Why Use NUMVAL and NUMVAL-C

When you use NUMVAL or NUMVAL-C you don't need to statically declare numeric data in a fixed format and input data in a precise manner. For example, for this code:

```
01  X            Pic S999V99  leading sign is separate.
    ⋮
    Accept X from Console
```

The user of the application must enter the numbers exactly as defined by the PICTURE clause. For example:

```
+001.23
-300.00
```

However, using the NUMVAL function, you could code:

```
01  A            Pic x(10).
01  B            Pic S999V99.
    ⋮
    Accept A from Console
    Compute B = Function Numval(A)
```

and the input could be:

```
 1.23
 -300
```

Evaluating Data Items (Intrinsic Functions)

Several intrinsic functions can be used in evaluating data items:

- CHAR and ORD for evaluating integers and single alphanumeric characters with respect to the collating sequence used in your program.
- MAX, MIN, ORD-MAX, and ORD-MIN for finding the largest and smallest items in a series of data items.
- LENGTH for finding the length of data items.

- WHEN-COMPILED for finding the date and time the program was compiled.

Evaluating Single Characters for Collating Sequence (CHAR, ORD)

If you want to know the ordinal position of a certain character in the collating sequence, reference the ORD function using the character in question as the argument, and ORD will return an integer representing that ordinal position. One convenient way to do this is to use the substring of a data item as the argument to ORD:

```
IF Function Ord(Customer-record(1:1)) Is > 194 THEN ...
```

On the other hand, if you know what position in the collating sequence you want but don't know what character it corresponds to, then reference the CHAR function using the integer ordinal position as the argument, and CHAR will return the desired character:

```
INITIALIZE Customer-Name REPLACING ALPHABETIC BY Function Char(65)
```

Finding the Largest or Smallest Data Item (MAX, MIN, ORD-MAX, ORD-MIN)

If you have two or more alphanumeric data items and want to know which data item contains the largest value (evaluated according to the collating sequence), use the MAX or ORD-MAX function, supplying the data items in question as arguments. If you want to know which item contains the smallest value, you would use the MIN or ORD-MIN function.

MAX and MIN

The MAX and MIN functions simply return the contents of one of the variables you supply.

For example, with these data definitions:

```
05  Arg1         Pic x(10)  Value "THOMASSON ".
05  Arg2         Pic x(10)  Value "THOMAS    ".
05  Arg3         Pic x(10)  Value "VALLEJO   ".
```

the following statement:

```
Move Function Max(Arg1 Arg2 Arg3) To Customer-record(1:10)
```

would assign “VALLEJObbb” to the first ten character positions of `Customer-record`.

If MIN were used instead, then “THOMASbbbb” would be returned.

ORD-MAX and ORD-MIN

The functions ORD-MAX and ORD-MIN return an integer that represents the ordinal position of the argument with the largest or smallest value in the list of arguments you have supplied (counting from the left).

If the ORD-MAX function were used in the example above, you would receive a syntax error message at compile time, because you would be attempting to reference a numeric function in an invalid place (see *IBM COBOL Language Reference*). The following is a valid example of the ORD-MAX function:

```
Compute x = Function Ord-max(Arg1 Arg2 Arg3)
```

This would assign the integer 3 to x, if the same arguments were used as in the previous example. If ORD-MIN were used instead, the integer 2 would be returned.

Notes on MAX, MIN, ORD-MAX, ORD-MIN

This group of functions can also be used for numbers, in which case the algebraic values of the arguments are compared. For more information, see the appropriate section of Chapter 3, “Numbers and Arithmetic” on page 28.

The above examples would probably be more realistic if Arg1, Arg2 and Arg3 were instead successive elements of an array (table). For information on using table elements as function arguments, see the section on “Processing Table Items (Intrinsic Functions)” on page 61 in Chapter 4, “Handling Tables.”

Returning Variable-Length Results with Alphanumeric Functions

The results of alphanumeric functions might be of varying lengths and values depending on the function arguments.

In the following example, the amount of data moved to R3 and the results of the COMPUTE statement depend on the values and sizes of R1 and R2:

```
01  R1                  Pic x(10) value "e".
01  R2                  Pic x(05) value "f".
01  R3                  Pic x(20) value spaces.
01  L                   Pic 99.
    ⋮
    Move Function Max(R1 R2) to R3
    Compute L = Function Length(Function Max(R1 R2))
```

Here, R2 is evaluated to be larger than R1. Therefore, assuming that the symbol b represents a blank space, the string “fbbbb” would be moved to R3 (the unfilled character positions in R3 are padded with spaces), and L evaluates to the value 5. If R1 were the value “g” then R1 would be larger than R2, and the string “gbbbbbbbbb” would be moved to R3 (the unfilled character positions in R3 would be padded with spaces); the value 10 would be assigned to L.

You might be dealing with variable-length output from alphanumeric functions. Plan your program code accordingly. For example, you might need to think about using variable-length record files when it is possible that the records you will be writing might be of different lengths:

```
File Section.
FD  Output-File.
    01  Customer-Record   Pic X(80).

Working-Storage Section.
01  R1                  Pic x(50).
01  R2                  Pic x(70).
    ⋮
    Write Customer-Record from Function Max(R1 R2)
```

Finding the Length of Data Items (LENGTH)

The LENGTH function is useful in many programming contexts for determining the length of string items. The following COBOL statement shows moving a data item such as a customer name into the particular field in a record that is for customer names:

```
Move Customer-name To Customer-record(1:Function Length(Customer-name))
```

Numeric & Table: The LENGTH function can also be used on a numeric data item or a table entry. Numeric data and tables are discussed in Chapter 3, "Numbers and Arithmetic" on page 28 and in Chapter 4, "Handling Tables" on page 44.

LENGTH OF Special Register

In addition to the LENGTH function, another technique to find the length of a data item is to use the LENGTH OF special register. Coding either `Function Length(Customer-Name)` or `LENGTH OF Customer-Name` would return the same result— the length of `Customer-Name` in bytes.

Whereas the LENGTH function can only be used where arithmetic expressions are allowed, the LENGTH OF special register can be used in a greater variety of contexts. For example, the LENGTH OF special register can be used as an argument to an intrinsic function that allows integer arguments. (An intrinsic function cannot be used as an operand to the LENGTH OF special register.) The LENGTH OF special register can also be used as a parameter in a CALL statement.

Finding the Date of Compilation (WHEN-COMPILED)

If you want to know the date and time the program was compiled as provided by the system on which the program was compiled, you can use the WHEN-COMPILED function. The result returned has 21 character positions with the first 16 positions in the format:

```
YYYYMMDDhhmmsshh
```

to show the four-digit year, month, day, and time (in hours, minutes, seconds, and hundredths of seconds) of compilation.

WHEN-COMPILED Special Register

The WHEN-COMPILED special register is another technique you can use to find the date and time of compilation. It has the format:

```
MM/DD/YYhh.mm.ss
```

The WHEN-COMPILED special register supports only a two-digit year and carries the time out only to seconds. This special register can only be used as the sending field in a MOVE statement.

Chapter 7. Processing Files

Reading and writing data to and from files is an essential part of every program. Your program retrieves information, processes it as you request, and then produces the results.

A file system provides a way to access record-oriented files that are organized as sequential, relative, indexed, or byte stream (line sequential) files. An application can use file system functions to create and manipulate the records in any of these files.

Sequential, relative, and indexed files are supported through the Standard Language File System (STL File System). On OS/2, sequential and indexed files are also supported through Novell Btrieve and VSAM.

This chapter provides a brief introduction on file organization and access modes, describes the coding your COBOL programs need to identify and process files, and explains how files must be defined and identified to the operating system before your program can process them.

The topics in this chapter are:

"File Input/Output Overview" on page 89

"COBOL Coding for Files" on page 92

"Error Handling Techniques for Files" on page 102

"File Sorting and Merging" on page 111

"STL File System" on page 119

COBOL supports several different filesystems. Two ways you can select a filesystem are by setting the assignment-name environment variable or using the FILESYS runtime option. (See the *IBM COBOL Language Reference* for a complete discussion.) All the filesystems allow you to use COBOL statements to read or write COBOL files. However, files written using one filesystem cannot be read using a different file system

The STL File System provides the basic file facilities on a local filesystem. It supports all COBOL I/O except for line sequential.

OS/2 The VSAM filesystem has features which allow you to read and write files on remote systems such as MVS. It is provided with COBOL.

The Btrieve filesystem allows you to access files created by CICS. It is a separate item available from Btrieve Technologies.

Most programs will get the same results on all three file systems.

If you have more complex requirements, not covered within this book, or are going to be a frequent user of file systems, you should review the *Btrieve Programmer's Manual* and the publications for the SMARTdata UTILITIES for OS/2, which are provided as part of the on-line documentation.

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File Input/Output Overview

This section describes file organization and file access modes. You should decide on the file types you will use when you design your program. Your file management system handles the input/output requests and record retrieval from the input/output devices.

Figure 22 summarizes file organization, access modes, and record lengths for COBOL files.

Figure 22. File Organizations and Access Modes

File Organization	Sequential Access	Random Access	Dynamic Access
Sequential	Yes	No	No
Line sequential	Yes	No	No
Indexed	Yes	Yes	Yes
Relative	Yes	Yes	Yes

File I/O Limitations:

- For line sequential files, the maximum record size is 64K.
- For VSAM files:
  - Minimum record size: 1 byte
  - Maximum record size: 64,000 bytes
  - Maximum record key length: 255 bytes
  - Maximum relative key value: 2**32-2
  - Maximum number of bytes allocated for a file: 2**32
- For STL files:
  - Minimum record size: 1 byte
  - Maximum record size: 65536 bytes
  - Maximum record key length: 255 bytes
  - Maximum number or alternate keys: 253 bytes
  - Maximum relative key value: 2**32-1
  - Maximum number of bytes allocated for a file: 2**32-1

Additional or more restrictive limits might be applicable depending on the platform on which the target file is located. See the appropriate books for the file system of the target platform for these limits.

File Organization

You can organize your files as sequential, line sequential, indexed or relative.

Sequential File Organization

A sequential file contains records organized by the order in which they are entered. The order of the records is fixed.

Records in sequential files can only be read or written sequentially.

After you have placed a record into the file, you cannot shorten, lengthen, or delete it. However, you can update (REWRITE) a record if the length does not change. New records are added at the end of the file.

Line Sequential File Organization

Line sequential files are just like sequential files, except that the records can contain only characters as data. Line sequential files are supported by the native byte stream files of the operating system.

Line sequential files that are created with WRITE statements with the ADVANCING phrase can be directed to a printer (as well as a disk).

Indexed File Organization

An indexed file contains records ordered by a record key. Each record contains a field that contains the record key. The record key uniquely identifies the record and determines the sequence in which it is accessed with respect to other records. A record key for a record might be, for example, an employee number or an invoice number.

An indexed file can also use alternate indexes—record keys that let you access the file using a different logical arrangement of the records. For example, you could access the file through employee department rather than through employee number.

The record transmission (access) modes allowed for indexed files are sequential, random, or dynamic. When indexed files are read or written sequentially, the sequence is that of the key values. For a description of random and dynamic record transmission, see “File Access Modes” on page 91.

Relative File Organization

A relative record file contains records ordered by their relative key—the relative key being the relative record number representing the record's location relative to where the file begins. For example, the first record in the file has a relative record number of 1, the tenth record has a relative record number of 10, and so forth. The relative record number identifies the fixed- or variable-length record.

The record transmission modes allowed for relative files are sequential, random, or dynamic. When relative files are read or written sequentially, the sequence is that of the relative record number. For a description of random and dynamic record transmission, see “File Access Modes” on page 91.

Figure 23 (Page 1 of 2). Comparison of Different Files

Sequential	Line Sequential	Indexed	Relative
Records are in the order in which they are written.	Records are in the order in which they are written.	Records are in collating sequence by key field.	Records are in relative record number order.

Figure 23 (Page 2 of 2). Comparison of Different Files

Sequential	Line Sequential	Indexed	Relative
Access is sequential.	Access is sequential.	Access is by key through an index. Can have one or more alternate indexes.	Access is by relative record number, which is handled like a key.
A record cannot be deleted, but you can reuse its space for a record of the same length.	A record cannot be deleted (DELETE) or replaced (REWRITE).		

File Access Modes

You can access records in sequential and line sequential files sequentially only.

You can access records in indexed and relative files in three ways: sequentially, randomly, or dynamically.

Sequential Access

Code ACCESS IS SEQUENTIAL in the FILE-CONTROL entry.

For indexed files, records are accessed in the order of the key field selected (either primary or alternate).

For relative files, records are accessed in the order of the relative record numbers.

Random Access

Code ACCESS IS RANDOM in the FILE-CONTROL entry.

For indexed files, records are accessed according to the value you place in a key field.

For relative files, records are accessed according to the value you place in the relative key.

Dynamic Access

Code ACCESS IS DYNAMIC in the FILE-CONTROL entry.

Dynamic access is a mixed sequential-random access in the same program. Using dynamic access, you can use one COBOL file definition to perform both sequential and random processing, accessing some records in sequential order and others by their keys.

For example, suppose you had an indexed file of employee records, and the employee's hourly wage formed the record key. Also, suppose your program was interested in those employees earning between $7.00 and $9.00 per hour and those earning $15.00 per hour and above. To do this, retrieve the first record randomly (with a random-

retrieval READ) based on the key of 0700. Next, begin reading sequentially (using READ NEXT) until the salary field exceeds 0900. You would then switch back to a random read, this time based on a key of 1500. After this random read, switch back to reading sequentially until you reach the end of the file.

COBOL Coding for Files

Code your COBOL program according to the types of files you decide to use. The general format of input/output coding is shown in Figure 24. Explanations of user-supplied information (lowercase) follow the figure.

```
IDENTIFICATION DIVISION.
    ⋮
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
  FILE-CONTROL.
    SELECT filename ASSIGN TO assignment-name  1  2
    ORGANIZATION IS org ACCESS MODE IS access  3  4
    FILE STATUS IS status  5
    ⋮
DATA DIVISION.
  FILE SECTION.
   FD filename
   01 recordname  6
      nn . . . fieldlength & type  7  8
      nn . . . fieldlength & type
    ⋮
WORKING-STORAGE SECTION
 01 status  PICTURE 99.
    ⋮
PROCEDURE DIVISION.
    ⋮
    OPEN iomode filename   9
    ⋮
    READ filename
    ⋮
    WRITE recordname
    ⋮
    CLOSE filename
    ⋮
  STOP RUN.
```

Figure 24. Overview of COBOL Input/Output Coding

The user-supplied information in Figure 24 can be explained as follows:

1 filename
Any legal COBOL name. You must use the same filename on the SELECT and the FD statements, and on the OPEN, READ, START, DELETE, and CLOSE statements. This name is not necessarily the actual name of the file as known to the system. Each file requires its own SELECT, FD, and input/output statements. For WRITE and REWRITE, you specify a record defined for the file.

2 assignment-name
You can specify ASSIGN TO *assignment-name* to specify the target file system ID and the file of the name as known to the system directly, or you can set a value indirectly by using an environment variable.

If you want to have the system file name identified at OPEN time, you can specify ASSIGN USING *data-name*. The value of *data-name* at the time of the execution of the OPEN statement for the file is used and has the system file identification optionally preceded by the file system type identification. The following example illustrates how `inventory-file` is dynamically (by way of a MOVE statement) associated with a Btrieve file `d:\inventory\parts`.

```
SELECT inventory-file ASSIGN TO specific-inventory-file
⋮
     MOVE "d:\inventory\parts" TO a-file
     OPEN INPUT inventory-file
```

For more information, see the *IBM COBOL Language Reference Manual*.

3 org
Indicates the organization: LINE SEQUENTIAL, SEQUENTIAL, INDEXED, or RELATIVE. If this clause is omitted, the default is ORGANIZATION SEQUENTIAL.

4 access
Indicates the access mode, SEQUENTIAL, RANDOM, or DYNAMIC. If this clause is omitted, the default is ACCESS SEQUENTIAL.

5 status
The 2-character COBOL FILE STATUS key.

6 recordname
The name of the record used in the WRITE and REWRITE statements. You can specify more than one record for a file.

7 fieldlength
The logical length of the field.

8 type
Must match the file's record format. If you break the record description entry beyond the level-01 description, each element should map accurately against the record's fields.

9 iomode
Specifies the open mode.For example, if you are only reading from a file, code INPUT. If you are only writing to it, code OUTPUT or EXTEND. If you are doing both, code I-O.

Line Sequential: I-O is not a valid parameter of OPEN for line sequential files.

Accessing Files

Your programs are able to access STL, VSAM (OS/2 only), and Btrieve (OS/2 only) files. Use *assignment-name* to specify both the file you want to access and the file

system. For a detailed description of *assignment-name*, see the *IBM COBOL Language Reference*.

The general syntax involved in making an assignment to a file stored in an alternate file system is:

```
SELECT file ASSIGN TO FileSystemID-Filename
```

FileSystemID
One of the following three-character specifications:

- STL - For an STL file
- VSA - For a VSAM file (OS/2 only)
- BTR - For a Btrieve file (OS/2 only)

If the file system specification is not provided, then the run-time option FILESYS is used to select the file system. If a file system is not specified using FILESYS, the default is VSAM on OS/2 and STL on Windows.

Filename
The file you want to access. Alternatively, you can specify an environment variable (for details, see the *IBM COBOL Language Reference*).

OS/2 Usage Notes

1. The following file status indicators are not set for Btrieve:

   02

   21

   39

2. Btrieve does not support relative record file organization.

OS/2 Example— Accessing Novell Btrieve Files

- The following assignment would be valid:

  ```
  SELECT file1 ASSIGN USING 'BTR-MyFile'
  ```

- If the run-time option FILESYS(BTRIEVE) was in effect. the following assignment would be valid:

  ```
  SELECT file1 ASSIGN TO 'MyFile'
  ```

- Given that you defined the environment variable MYFILE (for example,

  ```
  SET MYFILE=BTR-MyFile
  ```

  ), the following assignment would be valid:

  ```
  SELECT file1 ASSIGN TO MYFILE
  ```

Distributed File Access (OS/2 Only)

Using the Distributed File feature of the SMARTdata UTILITIES, you can access either a local file or a remote file (for example, MVS VSAM, SAM, or PDS) without any source program change.

In the following example, the SELECT clause is used to associate a file on MVS with a file in your workstation program.

```
SELECT myfile ASSIGN TO TARGETFILE
```

You can associate `myfile` to an MVS file called MVSMAST by setting the TARGETFILE environment variable:

```
set TARGETFILE=m:MVSMAST
```

where the drive `m` is set to point to the specific MVS system and MVSMAST is the data set name on the MVS system.

See the *VSAM in a Distributed Environment* manual for more information.

Coding Input/Output Statements for Files

After identifying and describing the files in the ENVIRONMENT DIVISION and DATA DIVISION, process the records in the files in the PROCEDURE DIVISION of your program.

Figure 25 shows the possible combinations of input/output statements for sequential files. The 'X' indicates that the statement can be used with the open mode given at the top of the column.

Figure 25. Valid COBOL Statements for Sequential Files

Access Mode	COBOL Statement	OPEN INPUT	OPEN OUTPUT	OPEN I-O	OPEN EXTEND
Sequential	OPEN	X	X	X	X
	WRITE		X		X
	START				
	READ	X		X	
	REWRITE			X	
	DELETE				
	CLOSE	X	X	X	X

Figure 26 shows the possible combinations of input/output statements for line sequential files. The 'X' indicates that the statement can be used with the open mode given at the top of the column.

Figure 26 (Page 1 of 2). Valid COBOL Statements for Line Sequential Files

Access Mode	COBOL Statement	OPEN INPUT	OPEN OUTPUT	OPEN I-O	OPEN EXTEND
Sequential	OPEN	X	X		X
	WRITE		X		X
	START				
	READ	X			

Figure 26 (Page 2 of 2). Valid COBOL Statements for Line Sequential Files

Access Mode	COBOL Statement	OPEN INPUT	OPEN OUTPUT	OPEN I-O	OPEN EXTEND
	REWRITE				
	DELETE				
	CLOSE	X	X		X

Figure 27 shows the possible combinations with indexed and relative files. The 'X' indicates that the statement can be used with the open mode given at the top of the column.

Figure 27. Valid COBOL Statements with Indexed Files and Relative Files

Access Mode	COBOL Statement	OPEN INPUT	OPEN OUTPUT	OPEN I-O	OPEN EXTEND
Sequential	OPEN	X	X	X	X
	WRITE		X		X
	START	X		X	
	READ	X		X	
	REWRITE			X	
	DELETE			X	
	CLOSE	X	X	X	X
Random	OPEN	X	X	X	
	WRITE		X	X	
	START				
	READ	X		X	
	REWRITE			X	
	DELETE			X	
	CLOSE	X	X	X	
Dynamic	OPEN	X	X	X	
	WRITE		X	X	
	START	X		X	
	READ	X		X	
	REWRITE			X	
	DELETE			X	
	CLOSE	X	X	X	

File Position Indicator

The file position indicator marks the next record to be accessed for sequential COBOL requests. You do not set the file position indicator anywhere in your program; it is set by successful OPEN, START, READ, READ NEXT, and READ PREVIOUS statements. Subsequent READ, READ NEXT, or READ PREVIOUS requests use the established file position indicator location and update it.

The file position indicator is not used or affected by the output statements WRITE, REWRITE, or DELETE. The file position indicator has no meaning for random processing.

Opening a File

Before your program can use any WRITE, START, READ, REWRITE, or DELETE statements to process records in a file, it must first open the file with an OPEN statement. Whether the file is available and the OPTIONAL attribute of the file definition is specified affect OPEN processing.

For example, an OPEN EXTEND of a file that is neither optional nor available results in file status 35, and the OPEN statement fails. If the file is OPTIONAL, the OPEN EXTEND will create the file and return file status 05.

How you code the OPEN statement in your COBOL program for a file depends on whether the file is *empty* (a file that has never contained records) or loaded. For either type of file, check the file status key after each OPEN statement.

Figure 28 shows the COBOL statements used for loading a file.

Figure 28. Statements Used to Load Records into a File

	Sequential	**Line Sequential**	**Indexed**	**Relative**
Environment Division	SELECT ASSIGN FILE STATUS ACCESS MODE	SELECT ASSIGN ORGANIZATION IS LINE SEQUENTIAL FILE STATUS ACCESS MODE	SELECT ASSIGN ORGANIZATION IS INDEXED RECORD KEY ALTERNATE RECORD KEY FILE STATUS ACCESS MODE	SELECT ASSIGN ORGANIZATION IS RELATIVE RELATIVE KEY FILE STATUS ACCESS MODE
Data Division	FD entry	FD entry	FD entry	FD entry
Procedure Division	OPEN OUTPUT OPEN EXTEND WRITE CLOSE	OPEN OUTPUT OPEN EXTEND WRITE CLOSE	OPEN OUTPUT OPEN EXTEND WRITE CLOSE	OPEN OUTPUT OPEN EXTEND WRITE CLOSE

Opening a File with Records

To open a file that already contains records, use OPEN INPUT, OPEN I-O, or OPEN EXTEND.

Line Sequential: OPEN I-O is not valid for line sequential files.

If you open a sequential, line sequential, or relative file as EXTEND, the added records are placed after the last existing records in the file.

If you open an indexed file as EXTEND, each record you add must have a record key higher than the highest record in the file.

Reading Records from a File

Use the READ statement to retrieve (read) records from a file. To read a record, you must have opened the file INPUT or I-O. Check the file status key after each READ.

Line Sequential: OPEN I-O is not valid for line sequential

Records in sequential and line sequential files can be retrieved only in the sequence in which they were written.

Records in indexed and relative record files can be retrieved:

Sequentially
: According to the ascending order of the key you are using, the RECORD KEY or the ALTERNATE RECORD KEY, beginning at the current position of the file position indicator for indexed files, or according to ascending relative record locations for relative files.

Randomly
: In any order, depending on how you set the RECORD KEY or ALTERNATE RECORD KEY or the RELATIVE KEY before your READ request.

Dynamically
: Mixed sequential and random.

With dynamic access, you can switch between reading a specific record directly and reading records sequentially, by using READ NEXT and READ PREVIOUS for sequential retrieval and READ for random retrieval (by key).

When you want to read sequentially, beginning at a specific record, use START before the READ NEXT or the READ PREVIOUS statements to set the file position indicator to point to a particular record (see “File Position Indicator” on page 97). When you code START followed by READ NEXT, the next record is read and the file position indicator is reset to the next record. When you code START followed by READ PREVIOUS, the previous record is read and the file position indicator is reset to the previous record. The file position indicator can be moved randomly by using START, but all reading is done sequentially from that point.

You can continue to read records sequentially, or you can use the START statement to move the file position indicator. For example:

```
START file-name KEY IS EQUAL TO ALTERNATE-RECORD-KEY
```

When a direct READ is performed for an indexed file, based on an alternate index for which duplicates exist, only the first record in the data set (base cluster) with that alternate key value is retrieved. You need a series of READ NEXT statements to retrieve each of the data set records with the same alternate key. A FILE STATUS value of '02' is returned if there are more records with the same alternate key value to be read; a value of '00' is returned when the last record with that key value has been read.

Updating Records in a File

The COBOL language statements that can be used to update a file in the ENVIRONMENT DIVISION and DATA DIVISION are the same as those shown in Figure 28 on page 97.

Figure 29 shows the statements that you can use in the PROCEDURE DIVISION for sequential, line sequential, indexed, and relative files.

Figure 29 (Page 1 of 2). PROCEDURE DIVISION Statements Used to Update Files

Sequential	Line Sequential	Indexed	Relative
ACCESS IS SEQUENTIAL			
OPEN EXTEND WRITE CLOSE or OPEN I-O READ REWRITE CLOSE	OPEN EXTEND WRITE CLOSE	OPEN EXTEND WRITE CLOSE or OPEN I-O READ REWRITE DELETE CLOSE	OPEN EXTEND WRITE CLOSE or OPEN I-O READ REWRITE DELETE CLOSE
ACCESS IS RANDOM			
not applicable	not applicable	OPEN I-O READ WRITE REWRITE DELETE CLOSE	OPEN I-O READ WRITE REWRITE DELETE CLOSE
ACCESS IS DYNAMIC: Sequential Processing			
not applicable	not applicable	OPEN I-O READ NEXT READ PREVIOUS START CLOSE	OPEN I-O READ NEXT READ PREVIOUS START CLOSE

Figure 29 (Page 2 of 2). PROCEDURE DIVISION Statements Used to Update Files

Sequential	Line Sequential	Indexed	Relative
		ACCESS IS DYNAMIC: Random Processing	
not applicable	not applicable	OPEN I-O READ WRITE REWRITE DELETE CLOSE	OPEN I-O READ WRITE REWRITE DELETE CLOSE

Adding Records to a File

The COBOL WRITE statement adds a record to a file, without replacing any existing records. The record to be added must not be larger than the maximum record size set when the file was defined. Check the file status key after each WRITE statement.

Adding Records Sequentially

Use ACCESS IS SEQUENTIAL and code the WRITE statement to add records sequentially to the end of a file that has been opened with either OUTPUT or EXTEND.

Sequential and line sequential files are always written sequentially.

For indexed files, new records must be written in ascending key sequence. If the file is opened EXTEND, the record keys of the records to be added must be higher than the highest primary record key on the file when the file was opened.

For relative files, the records must be in sequence. If you include a RELATIVE KEY data-item in the SELECT clause, the relative record number of the record to be written is placed in that data item.

Adding Records Randomly or Dynamically

When you write records to an indexed data set and ACCESS IS RANDOM or ACCESS IS DYNAMIC, the records can be written in any order.

Replacing Records in a File

To replace records in a file, use REWRITE on a file that you have opened for I-O. If you try to use REWRITE on a file that is not opened I-O, the record is not rewritten and the status key is set to 49. Check the file status key after each REWRITE statement.

- For sequential files, the length of the record you rewrite must be the same as the length of the original record.
- For indexed files, you can change the length of the record you rewrite.
- For variable-length relative files, you can change the length of the record you rewrite.

To replace records randomly or dynamically, the record to be rewritten need not be read by the COBOL program. Instead, to position the record you want to update:

- For indexed files, move the record key to the RECORD KEY data item, and then issue the REWRITE.
- For relative files, move the relative record number to the RELATIVE KEY data item, and then issue the REWRITE.

Deleting Records from a File

Open the file I-O and use the DELETE statement to remove an existing record from an indexed or relative file. You cannot use DELETE on a sequential file or a line sequential file.

When ACCESS IS SEQUENTIAL, the record to be deleted must first be read by the COBOL program. The DELETE then removes the record that was just read. If the DELETE is not preceded by a successful READ, the deletion is not done and the status key value is set to 92.

When ACCESS IS RANDOM or ACCESS IS DYNAMIC, the record to be deleted need not be read by the COBOL program. To delete a record, the key of the record to be deleted is moved to the RECORD KEY data item and the DELETE is issued. Check the file status key after each DELETE statement.

File Sharing and Record Locking

Sometimes data needs to be accessible by many users of your COBOL program at the same time. If a file is to be accessed from multiple processes, you need to lock the file and/or individual records of the file.

The LOCK MODE clause is used to specify the locking technique used for a file. It is an optional clause of the file control entry. When LOCK MODE is specified, the file that is opened using the file connector[3] can be shared when it is opened. When LOCK MODE is omitted, opening the file causes it to become exclusive, unless the file is opened for input.

When LOCK MODE IS AUTOMATIC is specified for a file opened for I-O, a record lock is acquired when the READ statement is processed. It is released when a subsequent I/O statement for the file connector is processed.

Not STL: The LOCK MODE IS AUTOMATIC clause is not supported for STL File System.

Figure 30 shows the effect of using the LOCK MODE clause with other COBOL statements.

3 You can think of a file connector as the connection of the COBOL declared file to the associated physical file.

Figure 30. Using LOCK MODE with Other COBOL Statements

COBOL Statement	Effect of LOCK MODE clause
OPEN	The file that is opened can be shared; that is, the file may be opened using more than one file connector. If the OPEN statement fails due to locking constraints, the file status value is set to 98 (file locked).
WRITE	1. If two or more file connectors for a sequential file add records by sharing the file after opening it in extended mode, the records are in unspecified order. 2. If two or more file connectors for a relative file add records by sharing the file after opening it in extended mode, the relative key values returned are ascending by not necessarily consecutive. 3. If two or more file connectors for a indexed file add records by sharing the file after opening it in extended mode, the order of alternate keys allowing for duplicates is unspecified. 4. A successive WRITE statement releases an existing record lock.
START	The START statement neither acquires nor detects a record lock. However, a successful START statement releases an existing record lock.
READ	1. For files opened for INPUT, READ statements will not acquire a record lock. 2. The READ statement will only be successful if no other file connector holds a lock on the record being accessed. If the record is locked, the statement is unsuccessful and the file status value is set to 99 (record locked). The file position indicator setting is unaffected for a sequential READ and unspecified for a random READ. 3. When no next record exists when the READ statement is processed, the AT END condition is returned regardless of whether the file is shared; for example, if the file is opened in extend mode by another file connector. 4. If the file is opened for I-O, each record is locked as it is read and released by the next I-O statement accessing the file connector.
REWRITE	A successful REWRITE statement releases an existing record lock. REWRITE is not successful when another file connector holds a lock on the record to be deleted.
DELETE	A successful DELETE statement releases an existing record lock. DELETE is not successful when another file connector holds a lock on the record to be deleted.
CLOSE	A successful CLOSE statement releases any record locks or file locks.

Restriction for SORT/MERGE: The LOCK MODE IS AUTOMATIC clause must not be specified if the file is specified in a USING or GIVING phrase of a SORT or MERGE statement.

Error Handling Techniques for Files

When a program encounters an error in processing a file, whether logical errors in the program or input/output errors on the disk, control returns to your COBOL program, except in the following cases:

- There is no file status specified for the file
- There is no applicable EXCEPTION/ERROR declarative

- There is no INVALID KEY/AT END phrase specified for the error condition

In these cases, the run unit (or thread, if the program is running in a multi-thread environment) is terminated with an error message.

When an input/output statement operation fails, COBOL will not perform corrective action for you. You choose whether your program will continue running after a less-than-severe input/output error occurs.

COBOL offers five techniques for intercepting and handling certain input/output errors.

End-of-file phrase (AT END).
EXCEPTION/ERROR declarative.
FILE STATUS key.
File system Return Code.
INVALID KEY phrase.

If you choose to have your program continue (by incorporating error-handling code into your design), you must also code the appropriate error-recovery procedure; for example, a procedure to check the file status key value. Otherwise, your program might continue processing and impair the integrity of your data. Figure 31 on page 104 shows the flow of logic after a file system input/output error occurs.

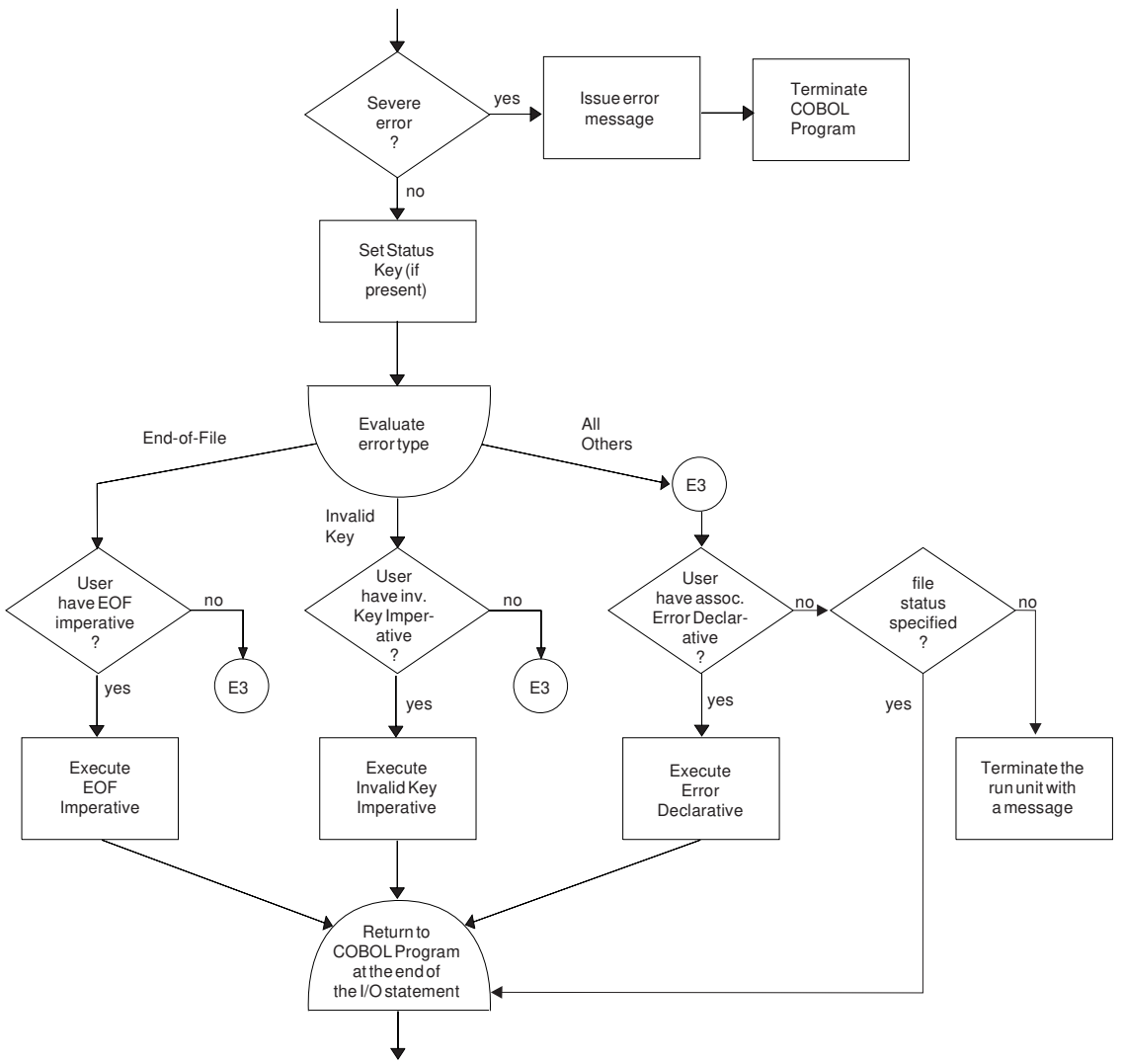


Figure 31. Flow of Logic after a File System I/O Error

End-of-File Phrase (AT END)

An end-of-file condition might or might not represent an error. In many designs, reading sequentially to the end of a file is done intentionally, and the AT END condition is expected.

For example, suppose you are processing a file containing transactions in order to update a master file:

```
PERFORM UNTIL TRANSACTION-EOF = "TRUE"
  READ UPDATE-TRANSACTION-FILE INTO WS-TRANSACTION-RECORD
    AT END
      DISPLAY "END OF TRANSACTION UPDATE FILE REACHED"
      MOVE "TRUE" TO TRANSACTION-EOF
  END READ
   ⋮
END-PERFORM
```

Sometimes, however, the condition will reflect an error. You code the AT END phrase of the READ statement to handle either case, according to your program design.

If you code an AT END phrase, on end-of-file the phrase is performed. If you do not code an AT END phrase, the associated ERROR declarative is performed.

Any NOT AT END phrase you code is performed only if the READ statement completes successfully. If the READ operation fails because of any condition other than end-of-file, neither the AT END nor the NOT AT END phrase is performed. Instead, control passes to the end of the READ statement after performing any associated declarative procedure.

If you have coded neither an AT END phrase nor an EXCEPTION declarative procedure, but have coded a status key clause for the file, control passes to the next sequential instruction after the input/output statement that detected the end-of-file (where presumably you have some coding to take appropriate action).

EXCEPTION/ERROR Declarative

You can code one or more ERROR declarative procedures in your COBOL program that will be given control if an input/output error occurs. You can have:

- A single, common procedure for the entire program.
- Group procedures for each file open mode (whether INPUT, OUTPUT, I-O, or EXTEND).
- Individual procedures for each particular file.

Place each such procedure in the declaratives section of your PROCEDURE DIVISION. (For the syntax detail, see *IBM COBOL Language Reference*.)

In your procedure, you can choose to try corrective action, retry the operation, continue, or end execution. You can use the ERROR declaratives procedure in combination with the file status key if you want a further analysis of the error.

Write an ERROR declarative procedure if you want the system to return control to your program after an error occurs. If you do not write an ERROR declarative procedure, your job could be canceled or abnormally terminated after an error occurs.

File Status Key

After each input/output statement is performed for a file, the FILE STATUS key is updated with a value that indicates the success or the failure of the operation. Using a FILE STATUS clause, you can test the FILE STATUS key after each input/output statement and set up error-handling procedures to use when a nonzero file status code is returned. Checking the file status key is highly recommended.

The system updates the FILE STATUS key after each input/output statement is performed on a file, placing values in the two digits of the file status key. In general, a zero in the first digit indicates a successful operation, and a zero in both digits means there is nothing abnormal to report. Establish a FILE STATUS key using the FILE STATUS clause in the FILE-CONTROL PARAGRAPH and data definitions in the DATA DIVISION.

```
FILE STATUS IS data-name-1
```

data-name-1
Specifies the 2-character COBOL FILE STATUS key that should be defined in the WORKING-STORAGE SECTION.

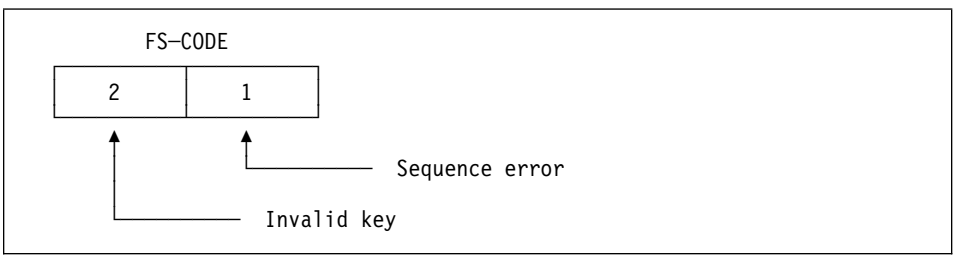
Btrieve (OS/2): A three-character key is stored for Btrieve files.

Caution: The *data-name* in the FILE STATUS clause cannot be variably located. (For more information on variably located data items, see Appendix C, “Complex OCCURS DEPENDING ON” on page 410.)

Your program can check the COBOL FILE STATUS key to discover whether an error has been made and, if so, what general type of error it is. For example, if a FILE STATUS clause is coded like this:

```
FILE STATUS IS FS-CODE
```

FS-CODE is used by COBOL to hold status information like this:



Follow these rules for each file:

- Define a different FILE STATUS key for each file.
- Check the FILE STATUS key after every input/output request.

  After an input or output statement is performed, check the contents of the status key. If it contains a value equal to or greater than 0, your program can issue an error message or can act based on the value of the code placed in the status key.

You do not have to reset the status key code, because it is set following each input/output attempt.

In addition to the file status key, you can code a second identifier in the FILE STATUS clause to get more detailed information on input/output requests. For further details, see "File System Return Code."

You can use the status key alone, or in conjunction with the INVALID KEY option, or to supplement the EXCEPTION/ERROR declarative. Using the status key in this way gives you precise information about the results of each input/output operation.

What File Status Codes Mean

File status key values each correspond to an unique condition. For a complete list of the file status key values and their meanings, see the table titled "Status Key Values and Meanings" in the *IBM COBOL Language Reference*.

File Status Key Example

Figure 32 shows an example of the COBOL coding that performs a simple check on the status key opening a file.

```
IDENTIFICATION DIVISION.
PROGRAM-ID.  SIMCHK.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
  SELECT MASTERFILE ASSIGN TO MASTERA
  FILE STATUS IS MASTER-CHECK-KEY
   ⋮
DATA DIVISION.
   ⋮
WORKING-STORAGE SECTION.
01  MASTER-CHECK-KEY       PIC X(2).
   ⋮
PROCEDURE DIVISION.
   ⋮
 OPEN INPUT MASTERFILE
 IF MASTER-CHECK-KEY NOT = "00"
   DISPLAY "Non-zero file status returned from OPEN " MASTER-CHECK-KEY
   ⋮
```

Figure 32. Using the Status Key to Check an OPEN Statement

File System Return Code

The two-character FILE STATUS code is what you should use for your program logic, because it is independant of the file system you are using. But it may be too general to pinpoint the disposition of a request. You can get more detailed information about file system input/output requests by coding a second status area:

```
FILE STATUS IS data-name-1 data-name-2
```

data-name-1
Specifies the 2-character COBOL FILE STATUS key.

data-name-2
Specifies a data item that contains the file system return code when the COBOL FILE STATUS is not 0. *data-name-2* is at least 6 bytes long. *data-name-2* contains the exception information as indicated by the file system.

For the STL File System and Btrieve (OS/2 only), if *data-name-2* is 6 bytes in length, it will contain the return code. If it is greater than 6 bytes in length, it will also contain a message with further information. For example, given the definition

```
01  my-file-status-2.
    02 exception-return-value PIC 9(6).
    02 additional-info PIC X(100).
```

and an attempt to open a file with a different defintion than the one with which it was created, return code 39 would be returned in *exception-return-value* and a message telling you what keys you need to perform the open would be returned in *additional-info*.

See the *IBM COBOL Language Reference*. for the rules for coding *data-name-2*.

For information on interpreting the codes for your file system, see your file system documentation.

Checking File System Status Codes Example

Figure 33 shows an example of a COBOL program that reads an indexed file (starting on the fifth record), checks the file status key after each input/output request, and displays the file system codes when the file status key is not zero. Figure 33 also illustrates what the output from this program might look like, assuming that the file being processed contains six records.

```
IDENTIFICATION DIVISION.
PROGRAM-ID. EXAMPLE.
ENVIRONMENT DIVISION.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT FILESYSFILE ASSIGN TO FILESYSFILE
    ORGANIZATION IS INDEXED
    ACCESS DYNAMIC
    RECORD KEY IS FILESYSFILE-KEY
    FILE STATUS IS FS-CODE, FILESYS-CODE.
```

Figure 33 (Part 1 of 2). Getting File System Code Information on Input/Output Requests

```
DATA DIVISION.
FILE SECTION.
FD  FILESYSFILE
    RECORD  30.
01  FILESYSFILE-REC.
    10 FILESYSFILE-KEY            PIC X(6).
    10 FILLER                  PIC X(24).
WORKING-STORAGE SECTION.
01  RETURN-STATUS.
    05 FS-CODE                  PIC XX.
    05 FILESYS-CODE             PIC X(6).

PROCEDURE DIVISION.
    OPEN  INPUT FILEYSYSFILE.
    DISPLAY "OPEN INPUT FILESYSFILE FS-CODE: " FS-CODE.

    IF FS-CODE NOT = "00"
       PERFORM FILESYS-CODE-DISPLAY
       STOP RUN
    END-IF.

    MOVE "000005" TO FILESYSFILE-KEY.
    START FILESYSFILE KEY IS EQUAL TO FILESYSFILE-KEY.
    DISPLAY "START FILESYSFILE KEY="  FILESYSFILE-KEY
            " FS-CODE: "  FS-CODE.

    IF FS-CODE NOT = "00"
       PERFORM FILESYS-CODE-DISPLAY
    END-IF.

    IF FS-CODE = "00"
       PERFORM READ-NEXT UNTIL FS-CODE NOT = "00"
    END-IF.

    CLOSE FILESYSFILE.
    STOP RUN.

READ-NEXT.
    READ FILESYSFILE NEXT.
    DISPLAY "READ NEXT FILESYSFILE FS-CODE: " FS-CODE.
    IF FS-CODE NOT = "00"
       PERFORM FILESYS-CODE-DISPLAY
    END-IF.
    DISPLAY FILESYSFILE-REC.

FILESYS-CODE-DISPLAY.
    DISPLAY "FILESYS-CODE ==>", FILESYS-CODE.
```

Figure 33 (Part 2 of 2). Getting File System Code Information on Input/Output Requests

INVALID KEY Phrase

The INVALID KEY phrase will be given control if an input/output error occurs because of a faulty index or relative key. You can include INVALID KEY phrases on READ, START, WRITE, REWRITE, and DELETE requests for indexed and relative files.

INVALID KEY and ERROR Declaratives

INVALID KEY phrases differ from ERROR declaratives in these ways:

- INVALID KEY phrases operate for only limited types of errors, whereas the ERROR declarative encompasses all forms.
- INVALID KEY phrases are coded directly onto the input/output verb, whereas ERROR declaratives are coded separately.
- INVALID KEY phrases are specific for one single input/output operation, whereas ERROR declaratives are more general.

If you code INVALID KEY in a statement that causes an INVALID KEY condition, control is transferred to the INVALID KEY imperative statement. Here, any ERROR declaratives you have coded are not performed.

NOT INVALID KEY

Any NOT INVALID KEY phrase that you code is performed only if the statement completes successfully. If the operation fails because of any condition other than INVALID KEY, neither the INVALID KEY nor the NOT INVALID KEY phrase is performed. Instead control passes to the end of the statement after performing any associated ERROR declaratives.

Using FILE STATUS and INVALID KEY Example

Use the FILE STATUS clause with INVALID KEY to evaluate the status key and determine the specific INVALID KEY condition.

For example, assume you have a file containing master customer records and need to update some of these records with information in a transaction update file. You will read each transaction record, find the corresponding record in the master file, and make the necessary updates. The records in both files each contain a field for a customer number, and each record in the master file has a unique customer number.

The FILE-CONTROL entry for the master file of commuter records includes statements defining indexed organization, random access, MASTER-COMMUTER-NUMBER as the prime record key, and COMMUTER-FILE-STATUS as the file status key. The following example shows how you can use FILE STATUS with the INVALID KEY to more specifically determine the cause of an I/O statement failure.

```
.
.  (read the update transaction record)
.
MOVE "TRUE" TO TRANSACTION-MATCH
MOVE UPDATE-COMMUTER-NUMBER TO MASTER-COMMUTER-NUMBER
READ MASTER-COMMUTER-FILE INTO WS-CUSTOMER-RECORD
  INVALID KEY
    DISPLAY "MASTER CUSTOMER RECORD NOT FOUND"
    DISPLAY "FILE STATUS CODE IS: " COMMUTER-FILE-STATUS
    MOVE "FALSE" TO TRANSACTION-MATCH
END-READ
```

File Sorting and Merging

Arranging records in a particular sequence, a common requirement in data processing, can be done using sort or merge operations.

Sort operation

Accepts input that is not in sequence and produces output in a requested sequence.

Merge operation

Compares records from two or more sequenced files and combines them in order.

COBOL has special language features that assist in sort and merge operations. For information on the COBOL sort and merge language, see *IBM COBOL Language Reference*.

OS/2 For additional information on sorting and merging records on OS/2, see *SMARTsort for OS/2 and AIX* listed in "Bibliography" on page 437.

Basics of Sorting and Merging

To sort or merge files, do the following:

Figure 34 (Page 1 of 2). Preparing to Sort or Merge Files

Action	Code

Describe sort files and merge files.	SELECT statements in the FILE-CONTROL SECTION of the ENVIRONMENT DIVISION, and SD entries in the FILE SECTION of the DATA DIVISION.
	
	SELECT statements and SD entries are always needed for sort files and merge files, even if you are only sorting or merging data items from Working-Storage.
	
	The files described in an SD entry is the working file used for a sort or merge operation. You cannot perform any input/output operations on this file.
	
	Every SD entry must contain a record description. For example:
	
	`SD  SORT-WORK-1`
	`    RECORD CONTAINS 100 CHARACTERS.`
	`01  SORT-WORK-1-AREA.`
	`    05  SORT-KEY-1              PIC  X(10).`
	`    05  SORT-KEY-2              PIC  X(10).`
	`    05  FILLER                  PIC  X(80).`

Describe the input and output files, if any, for sorting or merging.	SELECT statements in the FILE-CONTROL SECTION of the ENVIRONMENT DIVISION, and FD entries in the FILE SECTION of the DATA DIVISION.

Figure 34 (Page 2 of 2). Preparing to Sort or Merge Files

Action	Code
Request the sort or merge operation.	SORT or MERGE statements in the PROCEDURE DIVISION. The SORT or MERGE statement specifies the key fields in the record upon which the sort or merge is to be sequenced. You can code a key or keys as ascending or descending, or when you code more than one key, as a mixture of the two. You can mix SORT and MERGE statements in the same program. A COBOL program can contain any number of sort or merge operations. In your COBOL program, you can perform the same sort or merge multiple times, or perform multiple sorts or merges. However, one operation must be completed before another can begin. For more information,see “The SORT Statement” on page 113 and “The MERGE Statement” on page 117.

Figure 35 on page 113 is an example of the ENVIRONMENT DIVISION and DATA DIVISION entries needed to describe sort files and an input file.

```
   ID Division.
     Program-ID. SmplSort.
   Environment Division.
     Input-Output Section.
     File-Control.
*
* Assign Name For A Sort File Is
* Treated As Documentation.
*
       Select Sort-Work-1 Assign To SortFile.
       Select Sort-Work-2 Assign To SortFile.
       Select Input-File  Assign To InFile.

   Data Division.
     File Section.
     SD  Sort-Work-1
         Record Contains 100 Characters.
     01  Sort-Work-1-Area.
         05  Sort-Key-1                Pic  X(10).
         05  Sort-Key-2                Pic  X(10).
         05  Filler                    Pic  X(80).

     SD  Sort-Work-2
         Record Contains 30 Characters.
     01  Sort-Work-2-Area.
         05  Sort-Key                  Pic  X(5).
         05  Filler                    Pic  X(25).

     FD  Input-File
     01  Input-Record                  Pic X(100).
      .
      .
      .
     Working-Storage Section.
     01  EOS-Sw                        Pic  X.
     01  Filler.
         05  Table-Entry Occurs 100 Times
               Indexed By X1            Pic X(30).
      .
      .
      .
```

Figure 35. ENVIRONMENT DIVISION and DATA DIVISION Entries for a Sort Program

The SORT Statement

You can use the SORT statement to do the following:

- Use input or output procedures to add, delete, change, edit, or otherwise change records.

  - To request that input procedures be performed on the sort records before they are sorted, use SORT . . . INPUT PROCEDURE.

    See “Coding the Input Procedure” on page 115 for more information on input procedures.

  - To request that output procedures be performed on the sort records after they are sorted, use SORT. . . . OUTPUT PROCEDURE.

    See “Coding the Output Procedure” on page 116 for more information on output procedures.

- Sort data items (including tables) in Working-Storage.
- Read records directly into a new file without any preliminary processing (SORT . . . USING).
- Transfer sorted records from the sort program directly to another file without any further processing (SORT . . . GIVING).

SORT Program Organization

A COBOL program containing a sort operation can be organized so that one or more input files are read and operated on by an input procedure. In the input procedure, a RELEASE statement (analogous to the WRITE statement) releases a record to be sorted. If you do not want to change or process the records in the files before the sorting operation begins, the SORT statement USING option releases the records in the files unchanged to the new file.

The sort operation then arranges the entire set of records in the sequence specified by the key(s).

After the sort, sorted records can be made available one at a time through a RETURN statement to an output procedure. If you want to put the sorted records in files without changing or processing these records, the SORT statement GIVING option names the output files and writes the sorted records to the output files.

Setting the Sort Criteria

To set sort criteria:

1. In the record description of the file to be sorted, define the key or keys on which it will be sorted.

   The key used in the SORT statement cannot be variably located. (For more information on variably located data items, see Appendix C, “Complex OCCURS DEPENDING ON” on page 410.)

2. In the SORT statement, code the key on which the file will be sorted.

   To sort on more than one key, list the keys in descending order of importance.

In the example below, `SORT-GRID-LOCATION` and `SORT-SHIFT` are defined in the DATA DIVISION before they are used in the SORT statement.

The example also shows the use of an input and an output procedure. Use an input procedure if you want to process the records before you sort them, and use an output procedure if you want to further process the records after you sort them.

```
DATA DIVISION.
     .
     .
     .
SD  SORT-FILE
    RECORD CONTAINS 115 CHARACTERS
    DATA RECORD SORT-RECORD.

01  SORT-RECORD.
    05  SORT-KEY.
        10  SORT-SHIFT               PIC X(1).
        10  SORT-GRID-LOCATION       PIC X(2).
        10  SORT-REPORT              PIC X(3).
    05  SORT-EXT-RECORD.
        10  SORT-EXT-EMPLOYEE-NUM    PIC X(6).
        10  SORT-EXT-NAME            PIC X(30).
        10  FILLER                   PIC X(73).

PROCEDURE DIVISION.
     .
     .
     .
    SORT SORT-FILE
        ON ASCENDING KEY SORT-GRID-LOCATION SORT-SHIFT
        INPUT PROCEDURE 600-SORT3-INPUT
        OUTPUT PROCEDURE 700-SORT3-OUTPUT.
     .
     .
     .
```

Alternate Collating Sequences

You can sort records on a user specified collating sequence for single byte character keys. The default collating sequence is the collating sequence specified by the locale setting in effect at compile time. To override the PROGRAM COLLATING SEQUENCE specified either explicitly or by the default, use the COLLATING SEQUENCE option of the SORT statement. You can use different collating sequences for multiple sorts in your program.

For DBCS keys, the collating sequence is that specified by the locale setting in effect at compile time.

Coding the Input Procedure

If you want to process the records in an input file before they are released to the sort program, use the INPUT PROCEDURE option of the SORT statement. You might use an input procedure to:

- Release data items to the new file from Working-Storage.

- Release records that have already been read in elsewhere in the program.
- Read records from an input file, select or process them, and release them to the new file.

Each input procedure must be contained in either paragraphs or sections. For example, to release records from Working-Storage (a table) to the new file:

```
    SORT SORT-WORK-2
      ON ASCENDING KEY SORT-KEY
      INPUT PROCEDURE 600-SORT3-INPUT-PROC
      .
      .
      .

600-SORT3-INPUT-PROC SECTION.
    PERFORM WITH TEST AFTER
       VARYING X1 FROM 1 BY 1 UNTIL X1 = 100
      RELEASE SORT-WORK-2-AREA  FROM  TABLE-ENTRY (X1)
       END-PERFORM.
```

Transferring Records to the Sort Program

To transfer records to the new file, all input procedures must contain at least one RELEASE or RELEASE FROM statement. To release A from X, for example, you can enter:

```
MOVE X TO A.
RELEASE A.
```

Figure 36 compares the RELEASE and RELEASE FROM statements.

Figure 36. Comparison of RELEASE and RELEASE FROM

RELEASE	RELEASE FROM

`MOVE EXT-RECORD`
`  TO SORT-EXT-RECORD`
`PERFORM RELEASE-SORT-RECORD`
`  .`
`  .`
`  .`
`RELEASE-SORT-RECORD.`
`  RELEASE SORT-RECORD`
	`PERFORM RELEASE-SORT-RECORD`
	`  .`
	`  .`
	`  .`
	`RELEASE-SORT-RECORD.`
	`  RELEASE SORT-RECORD FROM SORT-EXT-RECORD`

Coding the Output Procedure

If you want to select, edit, or otherwise change sorted records before writing them from the sort work file into another file, use the OUTPUT PROCEDURE option of the SORT statement.

Each output procedure must be contained in either a section or a paragraph and must include:

- At least one RETURN or RETURN INTO statement.

The RETURN statement makes each sorted record available to your output procedure (the RETURN statement for a sort file is similar to a READ statement for an input file).

You can use the AT END and END-RETURN phrases with the RETURN statement. The imperative statements on the AT END phrase will be performed after all the records have been returned from the sort file. The END-RETURN explicit scope terminator serves to delimit the scope of the RETURN statement.

If you use the RETURN INTO statement, instead of RETURN, your records will be returned to Working-Storage or to an output area.

- Any statements necessary to process the records that are made available, one at a time, by the RETURN statement.

Restrictions on Input and Output Procedures

The following restrictions apply to the procedural statements in input and output procedures:

- The input/output procedure must not contain any SORT or MERGE statements.
- The input/output procedure must not contain any STOP RUN, EXIT PROGRAM, or GOBACK statements.
- You can use ALTER, GO TO, and PERFORM statements in the input/output procedure to refer to procedure-names outside the input/output procedure. However, you must return to the input/output procedure after a GO TO or PERFORM statement.
- The remainder of the PROCEDURE DIVISION must not contain any transfers of control to points inside the input/output procedure (with the exception of the return of control from a Declarative Section).
- In a SORT or MERGE input or output procedure, calling a program is permitted, but the called program cannot issue a SORT or MERGE statement and the called program must return to the caller.

The MERGE Statement

You cannot specify an input procedure in the MERGE statement; use MERGE...USING.

The MERGE statement combines the files you name into one sequenced file. The files to be merged must be already be in the same sorted sequence.

The merge operation compares keys in the records of the input files, and passes the sequenced records one-by-one to the RETURN statement of an output procedure or to the file named in the GIVING phrase.

Determining Whether the Sort or Merge Was Successful

The SORT or MERGE statement returns one of the following completion codes after a sort is finished:

0 Successful completion of sort/merge

16 Unsuccessful completion of sort/merge

OS/2 The *SMARTsort for OS/2 and AIX* manual contains a detailed description of conditions under which a sort will be stopped.

The return code or completion code is stored in a SORT-RETURN special register. The contents of SORT-RETURN change after each SORT or MERGE statement is performed.

You should test for successful completion after each SORT or MERGE statement:

```
    SORT SORT-WORK-2
        ON ASCENDING KEY SORT-KEY
        INPUT PROCEDURE IS 600-SORT3-INPUT-PROC
        OUTPUT PROCEDURE IS 700-SORT3-OUTPUT-PROC.
    IF SORT-RETURN NOT=0
      DISPLAY "SORT ENDED ABNORMALLY. SORT-RETURN = "
      SORT-RETURN.
    .
    .
    .
600-SORT3-INPUT-PROC SECTION.
    .
    .
    .
700-SORT3-OUTPUT-PROC SECTION.
    .
    .
    .
```

Prematurely Stopping a Sort or Merge Operation

To stop a sort or merge operation, use the SORT-RETURN special register. Move the integer 16 into the register in:

- An input or output procedure.

  Sort or merge processing will be stopped immediately after the next RELEASE or RETURN statement is performed.

- A Declarative Section entered during processing of a USING or GIVING file.

  Sort or merge processing will be stopped on exit from the declarative section.

Control then returns to the statement following the SORT or MERGE statement.

If you do not reference SORT-RETURN anywhere in your program, COBOL will test the return code. If the code is 16, COBOL issues a run-time diagnostic message and terminates the run unit (or the thread, in a multi-thread environment). If you test SORT-RETURN for one or more (but not necessarily all) SORT or MERGE statements, COBOL will not check the return code.

SORT Special Registers

You can use the SORT-RETURN and SORT-CONTROL special registers to get or test values related to sort behavior.

The SORT-CONTROL special register is implicitly defined as

```
01 SORT-CONTROL GLOBAL PICTURE X(160) VALUE='file name'.
```

where `file name` is used as the system file identifier for the options file for the sort product. You can assign to SORT-CONTROL the *file name* of a file that contains your sort control statements. See the *SMARTsort for OS/2 and AIX* manual for information about the SMARTsort options file.

STL File System

The STL File System supports sequential, indexed, and relative files on the local system. It provides the basic file facilities that you need for accessing local files. It gives conformace to ANSI standards, good performance, and the ability to port easily between AIX, OS/2, and Windows systems.

Line sequential files are the only files not supported.

The file system is safe for use with threads; it is your responsibility to ensure that multiple threads do not access COBOL buffers at the same time. Multiple threads can perform operations on the same STL file, but you must use a `pthread_cond_wait` or its equivalent to force all but one of them to wait for the file access to complete on the active thread.

With the STL File System you can easily read and write files to be shared with PL/I programs.

Figure 37 (Page 1 of 3). The STL File System Return Codes

Code	Meaning	Notes
1	Invalid Operation	This return code should not occur; it indicates an error in the file system
2	I/O Error	A call to an operating system I/O routine returned an error code.
3	File Not Open	Attempt to do an operation (other than OPEN) on a file that is not open.
4	Key Value Not Found	Attempt to read a record using key which is not in the file.
5	Duplicate Key Value	Attempt to use a key a second time for a key which does not allow duplicates.
6	Invalid Key Number	
7	Different Key Number	This return code should not occur; it indicates an error in the file system.

Figure 37 (Page 2 of 3). The STL File System Return Codes

Code	Meaning	Notes
8	Invalid Flag for the Operation	This return code should not occur; it indicates an error in the file system.
9	End Of File	An end of file was detected. This is not an error.
10	I/O operation must be preceed by I/O GET op	The operation is looking for the current record and the current record has not been defined.
11	Error return from get space routine	The operating system indicates that not enough memory is available.
12	Duplicate key accepted	The operation specified a key and the key is a duplicate. See the description of File Status 2 in the COBOL Language Reference.
13	Sequential access and key sequence bad	Sequential access was specified but the records are not in sequential order
14	.Record length < max key.	The record length does not allow enough space for the all of the keys.
15	Access to file denied	The operation system reported that it cannot access the file. Either the file does not exist or the user does not have the proper permission of the operating system to access the file.
16	File Already Exists	You appempted to open a new file, but the operating system reports that the file already exists.
17	Record Locked	Record locking was specified and this record is locked.
18	File Locked	Attempt to open a file which is already open in exclusive mode.
19	File Table Full	The operating system reports that its file table is full.
20	Handle Table Full	The operating system reports that it cannot allocate any more file handles.
21	Title does not say STL.	Files opened for reading by the STL File System must contain a header record that contains “STL” at a certain offset in the file.
22	Bad indexcount arg for create	This return code should not occur; it indicates an error in the file system.
23	Index or rel record > 64k	Index and relative records are limted to a length of 64k.
24	Error found in file header or data in open of existing file	STL files begin with a header. The header or its associated data have inconsistent values.
25	Indexed open on seq file	Attempt to open an sequential file as an indexed or relative file.
Note: The following are errors detected in the adapter open routines.		
1000	Sequential open on indexed/rel file	Attempt to open an indexed or relative file as a sequential file.

Figure 37 (Page 3 of 3). The STL File System Return Codes

Code	Meaning	Notes
1001	Relative open of indexed file	Attempt to open a relative file as an indexed file.
1002	Index open of rel file	Attempt to open a indexed file as a sequential file.
1003	File does not exist	The operating system reports that the file does not exist.
1004	Number of keys differ	Attempt to open a file with a different number of keys.
1005	Record lengths differ	Attempt to open a file with a different record length.
1006	Record types differ	Attempt to open a file with a different record type.
1007	Key position or length differ	Attempt to open a file with a different key position or length.

SMARTdata Utilities (OS/2 Only)

This section gives you tips and hints for using the SMARTdata Utilities on OS/2.

Quick Start for Remote File Access

This section gives you the steps to quickly get started with accessing remote files.

1. Install and configure Communications Manager/2 (CM/2) on your OS/2 for APPC. Define an LU alias for the remote host. You will need a user ID and password on that host.
2. Copy the file CONFIG.DFM from the samples subdirectory to the directory defined by the EHNDIR environmental variable in your CONFIG.SYS file.
3. Edit CONFIG.DFM as follows:
   - Activate one of the target definitions by removing the appropriate semicolons.
   - Edit the remote_lu line and replace the sample value with the LU alias defined in CM/2 for the target you wish to access.
   - Edit the line containing local_lu and replace the existing value with the LU alias of your local machine as defined in CM/2.
4. From an OS/2 command line, issue the command STARTDFM.
5. Enter your user ID and password on the remote system when prompted.
6. Assign a drive to that host with the following command:

   ```
   DFMDRIVE ASSIGN x: //lualias
   ```

   Where x is a drive not currently accessed
   and `lualias` is the LU alias of the host system.
7. You can now access files on the remote host both through OS/2 commands and through VSAM applications through the drive letter assigned in the previous step.

Problems with Remote Files Access

We have found that the majority of problems that people encounter when installing Distributed File Manager (DFM) involve problems configuring the communications between the local machine and the host. Here are some common problems that people can make when setting up DFM with some solutions.

STARTDRM cannot find CONFIG.DFM. STARTDRM looks for the configuration file in the following places, in order:

1. Full path name, if provided on the command line
2. CONFIG.DFM in the current directory
3. CONFIG.DFM in the directory defined by the EHNDIR environmental variable

Problem in the configuration file.

- Ensure all semicolons are removed from the target definition.
- Ensure the remote_lu value for the target definition matches exactly the LU alias assigned to the target system in CM/2.
- Ensure your local_lu value matches the local LU alias in CM/2.
- Check for case mismatches between configuration file values and CM/2 values.

ID and password. Ensure you entered the correct user ID and password at the prompt.

Communication Manager setup problems. The most common cause of problems tends to be errors in the CM/2 setup that prevent DFM/2 from initializing an APPC conversation with the host. The APING utility available with the APPC Productivity Suite allows you to verify that you are able to make an LU 6.2 connection to the target system.

The DFM target is not available on the host system. For MVS, the target DFM is part of the DFSMS/MVS 1.2.0 product. It is a startable procedure. Ask your MVS administrator whether DFM/MVS is started. Also, have your administrator ensure that the SNA mode of QPCSUPP is defined on the MVS system.

Platform-Specific Behavior

It is important to remember that when accessing files on a remote system, you are constrained by the limitations of the remote file access method.

To better understand the limitations of the remote access methods, refer to the following documents:

SC26-4915 - Distributed FileManager/MVS Guide and Reference
SC41-9600 - AS/400 Distributed Data Management Guide

A list of known restrictions:

MVS Target

The MVS file access method associated with the remote file will limit the type of access you may use. For instance, if the remote file is a PDSE member, you can only access it sequentially. The same holds for SAM and VSAM ESDS files. You can only use keyed access if the remote file is a VSAM KSDS.

AS/400 Target

Specifying a SECURITY value other than the default PROGRAM will cause file space allocation problems.

File names appear to be limited to 10 characters including periods.

File names must be specified in upper case.

AS/400 allocate direct files with three extents with 1000 records per extent. All records are defined with unused records designated as inactive. This may cause problems if you access the file the return inactive flag (DDM_RTNINA).

AS/400 requires upper case for user ID and password.

Data Conversion

When accessing remote files, it is possible to have DFM convert the records between their native format on the target system and a local format used on the workstation. for instance, DFM can convert EBCDIC into ASCII or binary encoded decimal into byte reversed binary. Refer to the SdU documentation for the details of how to take advantage of this function. The following are some common problems that you may encounter:

Data conversion does not occur. Note that the data conversion function applies only when files are accessed through the VSAM interface. This means when files are viewed or edited from the command line, they will not be converted; however, if they are opened and accessed by an application that invokes the VSAM APIs either directly or through COBOL, the conversion should occur.

A case mismatch between the file name specified in the FILE_DESCRIPTOR_MAP statement of the DFM configuration file and the file name specified when accessing the file will also prevent conversion. While specifying the file name `user1.ddm.file1` may open the correct file on MVS, it will not match against USER1.DDM.FILE1 in the FILE_DESCRIPTOR_MAP.

Data conversion does not work when the DFMDRIVE GUI is used to assign a drive. When using the directory mapping function of the DFMDRIVE GUI, the value entered for the directory is prepended to the file name with a slash separating the directory name from the file name. The MVS target then removes the slash and replaces it with a dot before accessing the file. If the TARGET_FILENAME in the FILE_DESCRIPTOR_MAP definition contains a dot instead of a slash, the comparison will fail.

File Conversion

When accessing a remote file, SdU converts the file name from the local character set (as defined by the CODEPAGE environmental variable in CONFIG.SYS) into codepage 0500 used by DFM target systems. The current release of SdU is capable of converting between single-byte character sets only. If you are running the Kanji or Simplified Chinese version of SdU (Codepage of 0932, 1381 respectively), use only single-byte characters when specifying remote file names.

LAN-Installed SdU

If you are using a LAN-installed SdU and wish to use the remote file access portion of SdU when SdU is installed on a LAN disk then the following steps must be taken:

- Change directory to the subdirectory of the LAN disk where SdU is installed.
- Change directory into the DLL subdirectory.
- Copy the file DFMSFL0.DLL to a local disk.
- Locate the line of your CONFIG.SYS file that references the file DFMSFL0. Change the full path name to point to its location on your current disk.

Translation Tables

The environment variable FMTCDRA should be set to the name of the directory that contains the CDRA translation tables. To set this variable, issue the command
`FMTCDRA={Root_directory}\BIN\CONVTABL`

`For example, FMTCDRA=K:\IBMDDM\BIN\CONVTABL`

Client Enhancement for Stream Data Conversion

The DFMDRIVE end user interface is modified to allow the specification of a parameter list which will be attached to filenames passed to the DFM target server.

One specific use for passing a parameter list to the Distributed FileManager/MVS target server is to trigger Stream Data Conversion, that is, to access MVS/ESA EBCDIC data as ASCII data from the work station. Note, the following MVS/ESA APARs are required for target server Stream Data Conversion: Distributed FileManager/MVS OW14949 (PTF UW90205) and CDRA: OW14950 (PTF UW90206).

If the target server does not support Stream Data Conversion, the following message appears when using the DFMDRIVE ASSIGN or DFMDRIVE SETPARM line command:
`EHN0252E: Drive %1 target system does not support parameters`

Similarly, if the Graphical User Interface is used to send a parameter list to the target server, and it does not support a parameter list, a popup appears with the message:
`Target system does not support parameters..`

Listed below are sections of text in "VSAM in a Distributed Environment" SC26-7063-00 which have been revised to describe the method for passing a parameter list to the target system.

p504—Another function has been added so the section should read:

function
Is one of the following:

ASSIGN Assign a drive letter to a target system or to a set of files that reside on a target system.

RELEASE Release drive letters that you previously assigned with the ASSIGN function.

SETPARM Set parameter list which is to be passed to a previously assigned target system.

STATUS Display the assigned DFM for OS/2 drive letters.

p504— The Assigned Drive Letters section has been revised:

Assigning Drive Letters
If the target system is MVS, in addition to a directory (PDS or PDSE) name, a high-level data set name qualifier can be specified. In this case all access to the drive is to be assumed to be prefixed by the specified qualifier. If no qualifier is provided, all access will have an implicit prefix assigned to it. The implicit prefix is the current MVS user ID.

If the target system supports a parameter list attached to the file name, it is possible to specify that parameter list while assigning the drive. e.g. Distributed FileManager/MVS supports Stream Stream Data Conversion when the string ",TEXT" is attached to to filenames. The parameter list can be specified at the time the drive is assigned by appending it to the path name or the path name place holder single character "\" which implies all files accessed on target system. The path name place holder is required only if a parameter list is specified.

To assign a drive letter, use the following command:

```
DFMDRIVE ASSIGN {drive} {directory} {//sysname}
```

drive
The drive letter to be assigned. If no drive letter is specified, the next available drive letter is used.

directory{,parmlist}
The directory or path is specified to qualify a subset of files to which you want to assign a drive. Whether and how a directory or path can be specified depends on the target system.

If the directory or path is not specified, the drive letter is assigned to all target files or folders on the target system. The directory or path is limited to a maximum of 63 characters. A directory or path name consisting of a single backslash implies assignment to all target files or folders.

An optional parameter list can be appended to the directory or path by specifying a comma followed by the parameter list. The parameter list can have a maximum of 63 characters. When a parameter list is specified, the entire directory/parmlist string must be enclosed by quotation marks: "IBMUSER,PC_CCSID(437),TEXT" Alternatively, the quotation marks may be omitted if a backslash prefix is added to the directory (or path), e.g.

\IBMUSER,PC_CCSID(437),TEXT
or
\,PC_CCSID(437),TEXT
where the "\" means all target files.

The DFMDRIVE SETPARM command can be used to set or reset the parameter list after the DFMDRIVE ASSIGN command completes.

sysname
The system name of the target system. The name of the partner LU alias defined in an OS/2 Communications Manager profile. The // is required in front of the system name. If no sysname is specified, the default target system is used.

Figure 38. Examples of DFMDRIVE ASSIGN

Commands	Explanation
DFMDRIVE ASSIGN	Assigns the next available drive to all target files of of the default target system
DFMDRIVE ASSIGN /HELP	Displays help for DFMDRIVE ASSIGN
DFMDRIVE ASSIGN S:	Assigns drive S to all target files of the default target system
DFMDRIVE ASSIGN S: FLD1	Assigns drive S to directory FLD of the default target system
DFMDRIVE ASSIGN S: \,text	Assigns drive S to all target files of the default target system and attaches the parameter list ",text" to all file names passed to the target system
DFMDRIVE ASSIGN S: "IBMUSER,PC_CCSID(437)" //S1	Assigns drive S to all files with the high level qualifier IBMUSER on the target system name S1. (MVS only) It also attaches the parameter list ",PC_CCSID(437)" to all file names passed to S1.

p505—Releasing Drive Letters: No change from original documentation.

p505—A new Setting Drive Parameter lists section has been added:

Setting Drive Parameter lists
If the target system supports a parameter list attached to the file names, it is possible to specify that parameter list after the drive is assigned by using the DFMDRIVE SETPARM command.

The parameter list character string length limit is 63 characters when using DFMDRIVE SETPARM.

Note, the parameter list specified by DFMDRIVE SETPARM completely replaces any parameter list specified by the DFMDRIVE ASSIGN command or an earlier DFMDRIVE SETPARM command.

To set a drive parameter list, use the command

DFMDRIVE SETPARM drive parmlist

drive
The drive which has been previously assigned with DFMDRIVE ASSIGN. Specify * to set the same parameter list for all assigned drives for which the target system accepts parameter lists. (The original status will be unchanged for those drives which do not accept parameter lists.)

parmlist
The parameter list to be passed to the target system.

Figure 39. Examples of DFMDRIVE SETPARM:

Commands	Explanation
DFMDRIVE SETPARM S: TEXT	Sets the parameter list for drive S to "TEXT"
DFMDRIVE SETPARM S: PC_CCSID(437),TEXT,LF	Sets the parameter list for drive S to "PC_CCSID(437),TEXT,LF"
DFMDRIVE SETPARM * PC_CCSID(437),TEXT,LF	Sets the parameter list for all assigned drives which accept parameter lists to "PC_CCSID(437)

p505—Displaying the Status of All Drive Letters: No change from original documentation.

p511—Using the Graphical User Interface: Assigning a Drive Letter: "Directory" description:

Directory
The directory or path on the target server system that you want to assign to the selected drive letter. For example, in Figure 105, the directory QIWSADM is assigned to drive letter N: in the system SDFASB46.

An optional parameter list prefixed by a comma can be appended to the path (directory) name. When appending a parameter list to the path name either:

- Enclose the entire Path, Parmlist string with quotation marks or
- Prefix the path name with a backslash.

A single backslash used as the path name indicates all files on the target system.

Part 2. Compiling, Linking, and Running Your Programs

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Chapter 8. Compiling, Linking, and Running Programs

This chapter explains how to complete the following tasks:

- Set compiler and run-time environment variables
- Compile and link programs
- Specify compiler options
- Understand and respond to compiler errors and messages
- Run compiled programs

Setting Environment Variables

Environment variables are used to set values that can be read by programs. For example, the COBOL run time reads the environment variable COBPATH when a program dynamically loads another program.

OS/2 To specify environment variables, use the OS/2 SET command. There are two ways to set environment variables:

- Temporarily, by defining the environment variable using the SET command from the OS/2 command prompt (or as part of a command (`.cmd`) file).
- Persistently, by defining the environment variable using the SET command in the file CONFIG.SYS.

The environment variable definition using the SET command applies to programs run from that particular OS/2 window. For example, the following OS/2 command syntax sets the COBPATH environment variable (which defines the locations in which the COBOL run time locates dynamically-accessed programs) to include two directories:

```
C:> SET COBPATH=d:\cobdev\dll;d:\dev\dll;
```

However, if you open another OS/2 window, programs run from the new window will not be affected by the definition you have SET for COBPATH.

To set an environment variable persistently, add the appropriate SET command to the OS/2 file named CONFIG.SYS. If you SET environment variables in CONFIG.SYS, the values of these variables are defined automatically whenever you boot your computer and apply to all OS/2 windows and graphical applications.

For example, the installation process sets up OS/2 environment variables to access the compiler and libraries. These variables are listed in CONFIG.SYS.

The value that you assign to an environment variable can include other environment variables or the variable itself. For example, to add a directory to the value of COBPATH, which has already been set, issue the command

```
C:> SET COBPATH=%COBPATH%;d:\myown\dll;
```

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Setting Environment Variables

WIN In Windows 95, environment variables are set in the AUTOEXEC.BAT file. In Windows NT, environment variables are set in the System window (to get there, in Main double-click on Control Panel, then double-click on System.)

There are two ways to set environment variables:

- Temporarily, by defining the environment variable using the SET command from the command prompt (or as part of a command (`.cmd`) file) (Windows 95)
- Persistently, by defining the environment variable using the System window (Windows NT) or the SET command in the file AUTOEXEC.BAT (Windows 95)

To temporarily change an environment variable on Windows 95, use SET at the command prompt presented in a command window. This environment variable definition applies to programs run from that particular window. For example, the following command syntax sets the COBPATH environment variable (which defines the locations in which the COBOL run time locates dynamically-accessed programs) to include two directories:

```
C:> SET COBPATH=d:\cobdev\dll;d:\dev\dll;
```

However, if you open another Windows 95 window, programs run from the new window will not be affected by the definition you have SET for COBPATH.

To SET an environment variable persistently, add it in the System window (Windows NT) or add the appropriate SET command to the file named AUTOEXEC.BAT (Windows 95). If you set environment variables in this way, the values of these variables are defined automatically whenever you boot your computer and apply to all Windows windows and graphical applications.

On Windows NT changes made to user environment variables in the System window are stored, but you must restart your computer to make the values available to processes, including the command prompt.

For example, the installation process sets up environment variables to access the compiler and libraries. These variables are listed in AUTOEXEC.BAT (Windows 95) or the Registry (Windows NT).

The value that you assign to an environment variable can include other environment variables or the variable itself. For example, to add a directory to the value of COBPATH, which has already been set, issue the command

```
C:> SET COBPATH=%COBPATH%;d:\myown\dll;
```

SET Notation: Throughout this book, the setting of environment variables is illustrated with a SET command. On Windows NT the setting is done in an analogous manner,

with the variable name and the value, separated by an equal sign in the SET command, being entered on the two different fields in the System window.

Definitions of COBOL Environment Variables

If you do not specify environment variables, either a default value is applied or the variable is not defined. Environment variables are used by both the compiler and the runtime library.

Compiler Environment Variables

The COBOL compiler uses the following environment variables:

COBOPT

Is one way of specifying COBOL compiler options. You can specify multiple options. Separate each option by a space or comma. For example:

```
SET COBOPT=TRUNC(OPT) TERMINAL
```

Defaults: Individual compiler option defaults apply (see "Default Values for Compiler Options" on page 145).

SYSLIB

Specifies paths to be used for COBOL COPY statements with text-names that are unqualified by library names and for DB2 INCLUDE statements. For a description of how SYSLIB is used for COPY statements, see the description of *Library-name* and *text-name* on page COPY statement on page 181. See "SQL INCLUDE Statement" on page 341 for use with SQL INCLUDE.

Library-name

A user-defined word that specifies the path for the library text.

Defaults: If you do not specify a *library-name*, the compiler searches the library path(s) in the following order, the search ending when the file is found:

1. The current directory
2. The path(s) specified by the -Ixxx option, if set (see "Options Supported by COB2" on page 135)
3. The paths specified by the SYSLIB environment variable

See the COPY statement on page 181 for the search rules for copy files.

Text-name

A user-defined word that specifies the path for the copybook text.

Defaults: If you do not set *text-name* as an environment variable, the compiler uses the default search described with the COPY statement on page 181.

DB2DBDFT

Is one way of specifying the database for compiling your programs with embedded SQL statements. See "Compiling with the DB2 Co-Processor" on page 339 for more information on connecting to the target database.

Object-Oriented Programming Environment Variables

When you create object-oriented programs, there are different environment variables you need to set. System Object Model (SOM) requires you to set SOM-specific environment variables. For more information on environment variables needed when using SOM to create object-oriented COBOL programs, see Chapter 13, "Using System Object Model (SOM)" on page 261.

Run-Time Environment Variables

The COBOL run-time library uses the following environment variables.

assignment-name

The *name* can be any COBOL file that you want to specify in an ASSIGN clause. This use of *name* follows the rules for a COBOL word. For example:

```
SET OUTPUT=d:\january\results.car
```

You can then use the environment variable as a COBOL user-defined word in an ASSIGN clause. For example, based on the previous SET statement, your COBOL source program could include the following:

```
SELECT CARPOOL ASSIGN TO OUTPUT
```

Because OUTPUT was defined in the environment, this statement would result in data being written to the file `d:\january\results.car`.

Alternate File System: The general syntax involved in making an assignment to a file stored in an alternate file system is:

```
ASSIGN TO FileSystemID-Filename
```

FileSystemID

One of the following three-character specifications:

- BTR - For a Btrieve file (OS/2 only)
- STL - For an STL file
- VSA - For a VSAM file (OS/2 only)

If the file system specification is not provided, the run-time option FILESYS is used to select the file system. If FILESYS is not set, the default is VSAM for OS/2 and STL for Windows.

Filename

The file you want to access.

Alternatively, you can specify an environment variable (for details, see the *IBM COBOL Language Reference*).

Defaults: None. You must set all assignment-names. If you make an assignment to a user-defined word that was not set as an environment variable, the assignment is made to a file with the literal name of the user-defined word (OUTPUT in our earlier example). If the assginment is valid, this file is written to the current directory.

COBOL Run-Time Environment Variables

COBMSGS

Specifies the name of a file to which run-time error messages will be written. To capture run-time error messages into a file, use the SET command to set COBMSGS to a file name. If your program has a run-time error that terminates the application, the file that COBMSGS is set to will contain the error message indicating the reason for termination.

Defaults: None. If COBMSGS is not set, error messages are written to standard error, which defaults to the terminal.

COBPATH

Specifies directory path(s) to be used by the COBOL run time to locate dynamically accessed programs, such as .DLL (Dynamic Link Library) files. This variable must be set to run programs that require dynamic loading. For example:

```
SET COBPATH=D:\pgmpath\pgmdll
```

Defaults: None.

COBRTOPT

Specifies the COBOL run-time options. The run-time options are separated by a comma or a colon. Use parentheses or equal signs (=) as the delimiters for suboptions. Options are not case sensitive.

For example:

```
SET COBRTOPT=TRAP=ON:errcount
```

Is equivalent to:

```
SET COBRTOPT=trap(on):ERRCOUNT
```

Defaults: Individual run-time option defaults apply (see Chapter 10, “Run-Time Options” on page 185).

LANG

Specifies the national language locale name in effect for message catalogs and help files. LANG must always be set and is given an initial value during installation. The run-time library uses LANG to access the message catalog. For example, the following command sets the language locale name to U.S. English:

```
SET LANG=En_US
```

If LANG is not SET correctly, run-time messages appear in an abbreviated form.

Defaults: Set at installation.

LC_TIME

Specifies rules and symbols for formatting time and date information.

Defaults: Set at installation.

LIBPATH

Specifies the full path name for the COBOL run-time library.

Defaults: Set at installation.

NLSPATH

Specifies the full path name of message catalogs and help files. NLSPATH must always be set and is given an initial value during installation. The run-time library uses NLSPATH to access the message catalog. If NLSPATH is not set correctly, run-time messages appear in an abbreviated form.

For example:

```
SET NLSPATH=C:\COBOL\MESSAGES\%L\%N;%NLSPATH%
```

Cautions: When you set NLSPATH, be sure to add to the NLSPATH, not replace it. Other programs might use this environment variable. Also, note that %L and %N must be upper case.

Defaults: Vary. Set at installation.

SYSIN, SYSIPT, SYSOUT, SYSLST, CONSOLE, SYSPUNCH, SYSPCH

These COBOL environment names are used as the environment variable names corresponding to the mnemonic names used on ACCEPT and DISPLAY statements. Set them equal to files, not existing directory names. For example, the following command defines CONSOLE:

```
C:> SET CONSOLE=c:\mypath\terminal.txt
```

CONSOLE could then be used in conjunction with the following COBOL source code:

```
SPECIAL-NAMES.
   CONSOLE IS terminal
      ...
   DISPLAY 'Hello World' UPON terminal
```

If you set the environment variables SYSIN and SYSOUT to files which have write permission, GUI applications can use ACCEPT and DISPLAY statements to communicate with the user.

Defaults: SYSIN and SYSIPT are directed to the logical input device (keyboard). SYSOUT, SYSLIST, SYSLST, and CONSOLE are directed to the system logical output device (screen). SYSPUNCH and SYSPCH are not assigned a value by default and are not valid unless you explicitly define them.

TEMP

Specifies the location of temporary work files (if needed) for SORT and MERGE functions. For example:

```
SET TEMP=c:\shared\temp
```

Defaults: Vary. SET by the sort utility installation program.

Environment Variable Precedence: Some environment variables (such as COBPATH and NLSPATH) define directories in which to search for files. If multiple directory paths are listed, they are delimited by semi-colons. Paths defined by environment variables are evaluated in order, from the first path to the last in the SET statement. Therefore, if you have multiple files with the same name that are defined in the paths of an environment variable, be aware that the *first* located copy of the file is used.

Compiling and Linking Programs

The command COB2 invokes the COBOL compiler and linker. The syntax of COB2 is flexible, accepting compiler and linker options in any order on the command line. Likewise, if you want to compile multiple files, the filenames can be specified in any position in the command syntax. However, all options and filenames should be separated by spaces.

Because OS/2 and Windows are not case-sensitive, COB2 does not need to be capitalized. The general syntax for COB2 is:

```
cob2 [options] filenames
```

Figure 40. COB2 Command Syntax

For example, the following command:

```
C:> cob2 -g filea.cbl fileb.cbl -v
```

is equivalent to:

```
C:> cob2 filea.cbl -g -v fileb.cbl
```

Usage Notes

1. Any options specified apply to all files on the command line.
2. COB2 passes all files with extensions named in "Filenames and Extensions Supported" on page 137 to the linker; all other files are passed to the compiler.
3. The default location for compiler input and output is the current directory.

Options Supported by COB2

-B"xxx" Pass *xxx* string to the linker[4] as parameters. *xxx* is a list of linker options separated by blank spaces. The COB2 default parameters are also passed. There should be no spaces between -B and "xxx".

-c Compile programs but do not link them.

-comprc_ok=n Controls the COB2 behavior on the return code from the compiler. If the return code returned by the compiler is less than or equal to **n**, COB2 continues to the link step, or exit with zero return code for a compile only case. If the return code returned by the compiler is greater than **n**, COB2 exits with the same return code returned by the compiler.

The default is **-comprc_ok=8**.

4 For linker information, refer to the topic "Learn to use the VisualAge for COBOL linker" on the **Dev Tools** page of the Information Notebook.

WIN **-dll[:*xxx*]** Causes COB2 to produce linker files (.LIB and .EXP) to create a DLL named *xxx*. If *xxx* is omitted, the name of the first object (.OBJ) or COBOL source (usually .CBL or .PPR) file specified in the COB2 command is the name of the DLL (and .LIB and .EXP files).

-g Produce symbolic information used by the debugger.

-main:xxx Make object file *xxx*the COBOL main program of the executable (.EXE) file. *xxx*must be the filename of an object (.OBJ) file or source file specified to COB2. `COB2 -main:abc a1.cbl d:\cats\abc.obj b2.cbl` will result in abc being the main program. *xxx* cannot appear in a linker response file.

If -main is not specified, the first object or source file specified will, in the absence of a response file, be the COBOL main program.

If *xxx*is the name of multiple files of the same name specified to COB2, it must be qualified in the same way as the filename. If the syntax of -main:xxx is invalid or *xxx*is not the filename of an object or source file processed by COB2, COB2 will terminate.

WIN **-cmain:xxx** Make C or PL/I object file *xxx* the main program of the executable (.EXE) file. *xxx*must be the filename of an object (.OBJ) file specified to COB2 that contains a main program as defined by C or PL/I. `COB2 -cmain:abc a1.cbl d:\cats\abc.obj b2.cbl` will result in `abc` being the main program. *xxx*cannot appear in a linker response file.

If `-cmain` is not specified, the first object or source file specified will, in the absence of a response file, be the COBOL main program.

Warning: If a C or PL/I object file containing a main program is linked with COBOL object files, `-cmain` **must** be used to designate it as the main program; a COBOL program **cannot** be the main program. Unpredicatable execution behavior will occur if this is attempted; no diagnostics is issued.

If *xxx* is the name of multiple files of the same name specified to COB2, it must be qualified in the same way as the filename. If the syntax of `-cmain:xxx` is invalid or *xxx* is not the filename of an object file processed by COB2, COB2 will terminate.

-p Include the profile hooks that allow the Performance Analyzer to monitor the application execution and create a trace file.

-Ixxx Add a path *xxx* to the directories to be searched for COPY files if a *library-name* isn't specified (see “Compiler Environment Variables” on page 131). Only a single path is allowed per -I option. To add multiple paths, use multiple -I options. There should be no spaces between -I and *xxx*. (This is upper-case “eye,” not lower-case “el.”)

Specify LIB: If you use the COPY statement, you must also specify the LIB compiler option.

For a description of the manner in which the compiler evaluates paths for COPY files, see the description of the *Library-name* environment variable in "Run-Time Environment Variables" on page 132.

-qxxx Use the option *xxx* (where *xxx* is any compiler option) when calling the compiler. For multiple options, each option should be delimited by a blank or comma. There should be no spaces between `-q` and *xxx*. For example, you can use

```
-qoptiona,optionb
```

or

```
-q"optiona optionb"
```

Special Syntax

If you plan to use a batch or command file to automate your COB2 tasks, a special syntax is provided for the `-qxxx` option. Use the following syntax to prevent the command shell from passing invalid syntax to COB2:

- Use "=" (equals) and ":" (colon) rather than "( )" (parentheses) to specify compiler suboptions. For example, use

  ```
  -qBINARY=NATIVE:,ENTRYINT=OPTLINK:
  ```

  rather than

  ```
  -qBINARY(NATIVE),ENTRYINT(OPTLINK)
  ```

- Use "_" (underscore) rather than " ' " (apostrophe) where a compiler option requires a suboption to be delimited by apostrophes. For example, use

  ```
  -qEXIT=INEXIT=_String_,MYMODULE::
  ```

  rather than

  ```
  -qEXIT(INEXIT('String',MYMODULE))
  ```

- Do not use any blanks in the option string.

-v Display compile and link steps and execute them.

-# Display compile and link steps but do not execute them.

Filenames and Extensions Supported

Files with @ as the first character and files with the following extensions are assumed to be linker parameters and are passed to the linker. Those with recognized file extensions are processed as follows:

OS/2

.DEF The name of the module definition file, if required. For more information about module definition files, see “Creating a Module Definition File (OS/2 Only)” on page 367.

.DLL The name of the generated dynamic link library (DLL). The default DLL is the first source file listed in the COB2 command syntax with an extension of .DLL.

WIN

.EXP The name of the export file, if required. For more information about export files, see “Export Files (Windows Only)” on page 369.

.EXE The name of the generated executable file. If not specified, the name defaults to the name of the first COBOL source file listed in the COB2 command with the file extension .EXE.

.LIB The name of the import or standard library, which contains symbols referenced by your programs.

.MAP The name of the map file. If not specified, no map file is generated.

.OBJ The name of the object file(s) to be passed to the linker.

All other files are processed by the compiler. The file extension .CBL is most commonly used for COBOL source.

Examples using COB2

The following examples illustrate the use of COB2:

- To compile the file `alpha.cbl`, enter:

  ```
  cob2 -c alpha.cbl
  ```

  The compiler produces the files `alpha.obj` and `alpha.lst`.

- To compile `alpha.cbl` and `beta.cbl`, enter:

  ```
  cob2 -c alpha.cbl c:\mydir\beta.cbl
  ```

  The compiler produces the files `alpha.obj`, `beta.obj`, `alpha.lst`, and `beta.lst` in the current directory.

- To link two files together, compile them without the -c option. For example, to compile and link `alpha.cbl` and `beta.cbl` and generate `alpha.exe`, enter:

  ```
  cob2 alpha.cbl beta.cbl
  ```

  This command creates `alpha.obj` and `beta.obj`, then links `alpha.obj`, `beta.obj`, and the COBOL libraries. If the link step is successful, it produces an executable program named `alpha.exe`.

- In the following example:

  ```
  cob2 alpha.obj beta.cbl mylib.lib gamma.exe
  ```

  `beta.cbl` is compiled, and the string:

  ```
  alpha.obj beta.obj mylib.lib /out:gamma.exe
  ```

is passed to the linker. If linking is successful, the executable `gamma.exe` is produced.

- In the following example:

```
cob2 alpha.cbl alpha.def
```

`alpha.dll` will be produced (assuming a valid `alpha.def` file).

Alternative Ways to Specify Compiler Options

"Compiling and Linking Programs" on page 135 explains how to specify compiler options using the COB2 command. There are other ways to select the options used to compile your programs. Here are three additional methods:

1. The COBOPT environment variable (See "Definitions of COBOL Environment Variables" on page 131)
2. Command-line specification of compile environment variables and COB2 options, such as an OS/2 command (.CMD) file
3. Specification by way of *CONTROL (synonym, *CBL) or PROCESS (synonym, CBL) statements

These means of specification are listed in order of precedence. For example, an option specified using PROCESS overrides every other option specification *except for non-overridable options selected during product installation.*

Specifying Compiler Options with the PROCESS (CBL) Statement

You can code compiler options on the PROCESS statement in your COBOL source (.CBL) programs. The PROCESS statement is placed before the IDENTIFICATION DIVISION header and has the following format:

Format

```
PROCESS option 1 [,option 2] . . . [,option n]

        IDENTIFICATION DIVISION.
```

PROCESS Statement Rules

- Your programming organization can inhibit the use of PROCESS statements with the default options module of the COBOL compiler. When PROCESS statements are found in a COBOL program where not allowed by the organization, the COBOL compiler generates error diagnostics.
- One or more blanks must separate PROCESS and the first option. Separate options with a comma or a blank. Do not insert spaces between individual options and their suboptions.
- The PROCESS statement must be placed before any comment lines or compiler-directing statements.
- PROCESS can start in columns 1 through 66. A sequence field is allowed in columns 1 through 6. When used with a sequence field, PROCESS can start in

columns 8 through 66. If used, the sequence field must contain six characters, and the first character must be numeric.

You can use CBL as a synonym for PROCESS. CBL can start in columns 1 through 70. When used with a sequence field, CBL can start in columns 8 through 70.

- You can use more than one PROCESS statement. If multiple PROCESS statements are used, they must follow one another with no intervening statement of any other type.
- Options cannot be continued across multiple PROCESS statements.

Compiler-Detected Errors and Messages

As the compiler processes your source program, it checks for COBOL language errors you might have made. For each error discovered, the compiler issues a message. These messages are included in the compilation listing (subject to the FLAG option). The compiler listing file has the same name as the compiler source file, with the file extension .LST. For example, the compiler listing for `myfile.cbl` would be `myfile.lst`. The listing file is written to the directory from which COB2 was run.

Each message in the listing does the following:

- Explains the nature of your error
- Identifies the compiler phase that detected the error
- Identifies the severity level of the error

Wherever possible, the message provides specific instructions for correcting the error.

Compiler Error Messages

The messages for errors found during processing of compiler options, CBL and PROCESS statements, or BASIS, COPY and REPLACE statements are displayed near the top of your listing.

The messages for compilation errors found in your program (ordered by line number) are displayed near the end of the listing for each program.

A summary of all errors found during compilation is displayed near the bottom of your listing. Each message issued by the compiler is of the following form:

Format

LineID	Message code	Message text
[*nnnnnn*]	IGY*ppxxxx-l*	*text of message*

nnnnnn The number of the source statement of the last line the compiler was processing. Source statement numbers are listed on the source printout of your program. If you specified the NUMBER option at compile time, these are your original source program numbers. If you specified NONUMBER, the numbers are those generated by the compiler.

IGY The prefix that identifies this message as coming from the COBOL compiler.

pp Two characters that identify which phase of the compiler discovered the error. As an application programmer, you can ignore this information. If you are diagnosing a suspected compiler error, contact IBM for support.

xxxx A 4-digit number that identifies the error message.

l A character that indicates the severity level of the error: I, W, E, S, or U (see "Compiler Error Message Codes").

Caution: If you used the FLAG option to suppress messages, there might be additional errors in your program.

Compiler Error Message Codes

Errors the compiler can detect fall into five categories of severity:

I	Informational (Return Code=0)	An informational-level message is an aid to the user. No action is required from the user and the program executes correctly as it stands.
W	Warning (Return Code=4)	A warning-level message calls attention to a possible error. It is probable that the program executes correctly as written.
E	Error (Return Code=8)	An error-level message indicates a condition that is definitely an error. The compiler has attempted to correct the error but the results of program execution might not be what the user expects. The user should correct the error.
S	Severe (Return Code=12)	A severe-level message indicates a condition that is a serious error. The compiler was unable to correct the error. The program will not execute correctly, and execution should not be attempted. A .OBJ file might not be created.
U	Unrecoverable (Return Code=16)	An unrecoverable-level message indicates an error condition of such magnitude that the compilation was terminated.

In the following example, the part of the statement that caused the message to be issued is enclosed in quotes.

```
    .
    .
    .
LineID  Message code  Message text

     2  IGYDS0009-E   "PROGRAM" should not begin in area "A".  It was processed as if found in area "B".

     2  IGYDS1089-S   "PROGRAM" was invalid.  Scanning was resumed at the next area "A" item, level-number,
                      or the start of the next clause.

     2  IGYDS0017-E   "ID" should begin in area "A".  It was processed as if found in area "A".

     2  IGYDS1003-E   A "PROGRAM-ID" paragraph was not found.  Program name "CBLPGM01" was assumed.

     2  IGYSC1082-E   A period was required.  A period was assumed before "ID".

     2  IGYDS1102-E   Expected "DIVISION", but found "ALONGPRO".  "DIVISION" was assumed before "ALONGPRO".

     2  IGYDS1082-E   A period was required.  A period was assumed before "ALONGPRO".

     2  IGYDS1089-S   "ALONGPRO" was invalid.  Scanning was resumed at the next area "A" item, level-number,
                      or the start of the next clause.

     2  IGYDS1003-E   A "PROGRAM-ID" paragraph was not found.  Program name "CBLPGM02" was assumed.

     3  IGYPS0017-E   "PROCEDURE" should begin in area "A".  It was processed as if found in area "A".

    34  IGYSC0137-E   Program-name "ALONGPRO" did not match the name of any open program.  The "END PROGRAM" statement
                      was assumed to have ended program "CBLPGM02".

    34  IGYSC0136-E   Program "CBLPGM01" required an "END PROGRAM" statement at this point in the program.
                      An "END PROGRAM" statement was assumed.
Messages    Total    Informational    Warning    Error    Severe    Terminating

Printed:      12                                  10         2
   .
   .
   .
```

Correcting Errors in Your Source Program

Messages about source coding errors indicate where the error happened (LINEID) and the text of the message tells you what the problem is. With this information, you can correct the source program and re-compile.

Although you should try to correct errors, it is not necessary to fix all of them. A W-level or I-level message can be left in a program without much risk, and you might decide that the recoding and compilation needed to remove the error are not worth the effort. On the other hand, S-level and E-level errors indicate probable program failure and should be corrected.

U-level errors are in a class by themselves. Here, you have no choice but to correct the error, because the compiler is forced to end early and does not produce complete object code and listing. In contrast with the four lower levels of errors, a U-level error might not result from a mistake in the source program. It could come from a flaw in the compiler itself, or in the operating system.

After correcting the errors in your source program, re-compile the program. If this second compilation is successful, go on to the link-editing step. If the compiler still finds problems, repeat the above procedure until only informational messages are returned.

Generating a List of All Compiler Error Messages

You can generate a complete listing of compiler diagnostic messages, with their explanations, by compiling a program with a *program-name* of ERRMSG specified in the PROGRAM-ID paragraph. The rest of the program can be omitted. For example:

```
Identification Division.
Program-ID. ErrMsg.
```

The listing that is produced includes messages from all IBM COBOL platforms, including MVS/VM and AIX; some messages do not apply to OS/2 or Windows

Running COBOL programs

To run a COBOL program, first make sure that any needed environment variables are SET (see "Setting Environment Variables" on page 129). Then type the name of the executable module on the command line or execute a command file which invokes the module. For example, if

```
cob2 alpha.cbl beta.cbl
```

is successful, you can execute the program by typing:

```
alpha
```

If your program uses an environment variable name to assign a value to a system file name, set the environment variable before typing the command which executes the program.

If the run-time routines detect an error, they send a message to the error unit (STDERR).

If run-time messages are abbreviated or incomplete, one or both of the following environment variables might be incorrectly SET:

- LANG
- NLSPATH

Chapter 9. Compiler Options

You can direct and control compilation with the following:

- Compiler options
- Compiler-directing statements (compile directives)

Compiler options are listed and described in alphabetical order in “Compiler Option Descriptions” on page 145. Compiler-directing statements are listed at the end of this chapter, on page 179.

Compiler Options Summary

Compiler options affect the aspects of your program listed in Figure 41.

Figure 41 (Page 1 of 2). List of Compiler Options

Aspect of Your Program	Compiler Option	Abbreviations	Found on Page
Source language	APOST	None	166
	CURRENCY	CURR/NOCURR	148
	LIB	None	161
	NUMBER	NUM/NONUM	163
	QUOTE	Q	166
	SEQUENCE	SEQ/NOSEQ	169
	SQL	None	170
	WORD	WD/NOWD	177
Maps and listings	LINECOUNT	LC	161
	LIST	None	162
	MAP	None	163
	SOURCE	S/NOS	170
	SPACE	None	170
	TERMINAL	TERM/NOTERM	172
	VBREF	None	176
	XREF	X/NOX	177
Object module generation	COMPILE	C/NOC	148
	OPTIMIZE	OPT/NOOPT	164
	PGMNAME	PGMN(U|M)	165
	SEPOBJ	None	167
Object code control	BINARY	None	146
	TRUNC	None	173
	ZWB	None	178
Storage usage	DYNAM	DYN/NODYN	149

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Figure 41 (Page 2 of 2). List of Compiler Options

Aspect of Your Program	Compiler Option	Abbreviations	Found on Page
Debugging and diagnostics	FLAG	F/NOF	156
	FLAGSTD	None	157
	TEST	None	172
	SSRANGE	SSR/NOSSR	171
Other	ADATA	None	145
	CALLINT	None	146
	COLLSEQ	None	147
	ENTRYINT	None	150
	EVENTS	None	151
	EXIT	EX(INX,LIBX,PRTX,ADX)	151
	IDLGEN	IDL/NOIDL	159
	PROBE	None	166
	PROFILE	None	166
	SIZE	SZ	169
	THREAD	None	172
	TYPECHK	TC/NOTC	175

Default Values for Compiler Options

The default options that were set up when your compiler was installed are in effect for your program unless you override them with other options. To find out the default compiler options in effect, run a test compilation without specifying any options. The output listing lists the default options specified by your installation.

Non-overridable Options: In some installations, certain compiler options are set up so that you cannot override them. If you have problems, see your system administrator.

Performance Considerations

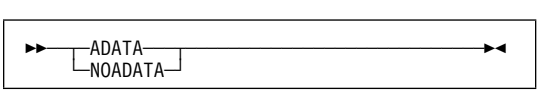
The OPTIMIZE, DYNAM, SSRANGE, TEST, and TRUNC compiler options can all affect runtime performance.

Compiler Option Descriptions

The compiler option descriptions that follow are given in alphabetical order. For a list of compiler options by effect, refer to Figure 41 on page 144.

Installation Defaults: The defaults listed with the options below are the defaults shipped with the product. They might have been changed by your installation.

ADATA



Default is: ADATA

Abbreviation is: None

Use ADATA when you want the compiler to create a SYSADATA file, which contains records of additional compilation information. This information is used by other tools, which will set ADATA ON for their use. The size of this files generally grows with the size of the associated program.

You cannot specify ADATA in a PROCESS (CBL) statement; it can be specified only:

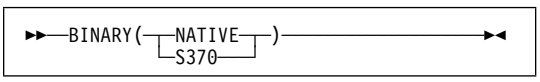
- On invocation of the compiler using an option list
- As a command option
- As an installation default

See "EXIT" on page 151 for information on using SYSADATA with your compiler-exit module.

APOST

See "QUOTE/APOST" on page 166.

BINARY



Default is: NATIVE

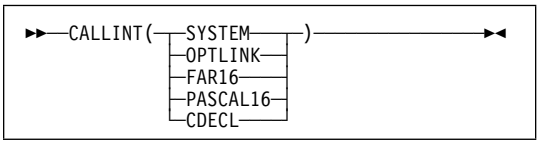
Abbreviation is: None

Specifying NATIVE means that BINARY, COMP, and COMP-4 data items are represented in the native format of the platform or product. For example, binary data on a PC would be stored in Little-Endian format (least significant digit on the highest address). Binary data on AIX would be stored in Big-Endian format (most significant digit on the highest address).

Specifying S370 means that binary data is represented in the Big-Endian format.

COMP-5 binary data, however, is always stored in the native format of the platform.

CALLINT



Default is: CALLINT(SYSTEM)

Abbreviations are: None

Use CALLINT to indicate the call interface convention applicable to CALLs.

This option may be overridden for specific call statements via the compiler directive >>CALLINT (see “Compiler-Directing Statements” on page 179)

See “ENTRYINT” on page 150 for the compiler option, ENTRYINT. ENTRYINT is used for the selection of the call interface convention for the program entry point or points.

SYSTEM
The SYSTEM suboption specifies that the call convention is that of the standard system linkage convention of the platform. WIN

On Windows, this is STDCALL, the linkage used by the system Windows APIs.

Alert: This convention cannot be used in all cases when the called program has multiple entry points. See “Multiple Entry Points on Windows” on page 331 for details.

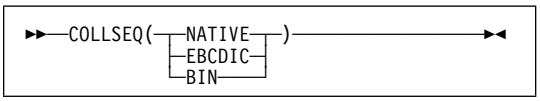
OPTLINK
The OPTLINK suboption specifies that the call convention is that of the _OPTLINK convention of VisualAge for C++ for OS/2 and VisualAge for C++ for Windows.

FAR16
The FAR16 suboption specifies that the call convention is that of the `_FAR16_Cdecl` convention.

PASCAL16
The PASCAL16 suboption specifies that the call convention is that of the `_FAR16_Pascal` convention.

WIN **CDECL**
The CDECL suboption specifies that the call interface convention is that of the CDECL calling convention as defined by Microsoft Visual C++ for Windows.

COLLSEQ



Default is: COLLSEQ(BIN)

Abbreviations are: None.

Specify COLLSEQ(EBCDIC) to use the EBCDIC collating sequence rather than the ASCII collating sequence.

Specify COLLSEQ(BIN) to use the hex values of the characters; the locale setting has no effect. This setting will give better execution-time performance.

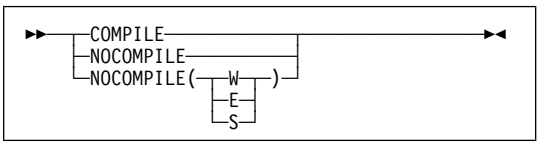
If you use the PROGRAM-COLLATING-SEQUENCE clause in your source with an alphabet-name of STANDARD-1, STANDARD-2, or EBCDIC, the COLLSEQ option will be

ignored. If you specify PROGRAM COLLATING SEQUENCE IS NATIVE, the value of NATIVE is taken from the COLLSEQ option.

Otherwise, when the alphabet-name specified on the PROGRAM-COLLATING-SEQUENCE clause is defined with literals, the collating sequence used is that given by the COLLSEQ option, modified by the user-defined sequence given by alphabet-name.

COLLSEQ has no effect on the collating sequence if the computer's code page is DBCS or EUC (Extended UNIX** Code).

COMPILE



Default is: NOCOMPILE(S)

Abbreviations are: C / NOC

Use the COMPILE option only if you want to force full compilation even in the presence of serious errors. All diagnostics and object code will be generated. Do not try to run the object code generated if the compilation resulted in serious errors—the results could be unpredictable or an abnormal termination could occur.

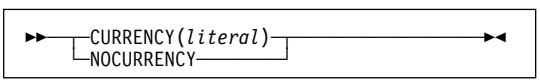
Use NOCOMPILE without any suboption to request a syntax check (only diagnostics produced, no object code).

Use NOCOMPILE with W, E, or S for conditional full compilation. For meanings of error codes, see “Compiler-Detected Errors and Messages” on page 140. Full compilation (diagnosis and object code) will stop when the compiler finds an error of the level you specify (or higher), and only syntax checking will continue.

If you request an unconditional NOCOMPILE, the following options have no effect because no object code will be produced:

LIST
SSRANGE
TEST

CURRENCY



Default is: NOCURRENCY

The default currency symbol is the dollar sign ($). You can use the CURRENCY option to provide an alternate default currency symbol to be used for the COBOL program.

NOCURRENCY specifies that no alternate default currency symbol will be used.

To change the default currency symbol, use the CURRENCY option where:

literal
Literal must be a valid COBOL non-numeric literal (including a hex literal) representing a one-byte, printable ASCII character that must not be any of the following:

- Digits zero (0) through nine (9)
- Uppercase alphabetic characters A B C D P R S V X Z
- Lowercase alphabetic characters a through z
- The space
- Special characters * + - / , . ; ( ) " =
- A figurative constant
- The uppercase alphabetic character G, if the COBOL program defines an MBCS item with the PICTURE symbol G; the PICTURE clause will be invalid for that MBCS item because the symbol G is considered to be a currency symbol in the PICTURE clause.
- The uppercase alphabetic character N, if the COBOL program defines an MBCS item with the PICTURE symbol N; the PICTURE clause will be invalid for that MBCS item because the symbol N is considered to be a currency symbol in the PICTURE clause.
- The uppercase alphabetic character E, if the COBOL program defines an external floating-point item; the PICTURE clause will be invalid for the external floating-point item because the symbol E is considered to be a currency symbol in the PICTURE clause.

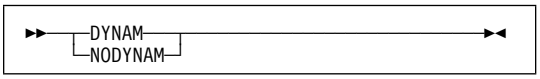
You can use the CURRENCY option as an alternative to the CURRENCY SIGN clause for selecting the currency symbol you will use in the PICTURE clause of a COBOL program.

When both the CURRENCY option and the CURRENCY SIGN clause are used in a program, the symbol coded in the CURRENCY SIGN clause will be considered the currency symbol in a PICTURE clause when that symbol is used.

When the NOCURRENCY option is in effect and you omit the CURRENCY SIGN clause, the dollar sign ($) is used as the PICTURE symbol for the currency sign.

Delimitor Note: The CURRENCY option literal can be delimited by either the quote or the apostrophe, regardless of the QUOTE/APOST compiler setting.

DYNAM



Default is: NODYNAM

Use DYNAM to cause non-nested programs invoked through the CALL *literal* statement to be loaded dynamically at run time. DYNAM causes dynamic loads (for CALL) and deletes (for CANCEL) of separately compiled programs at run time. CALL *identifier* statements always result in a run time load of the target program and are not impacted by this option.

The condition for the ON EXCEPTION phrase can occur for a CALL statement using the literal name only when the DYNAM option is in effect.

With NODYNAM, the target program name is resolved through the linker.

With the DYNAM option, this statement

```
CALL "myprogram" ...
```

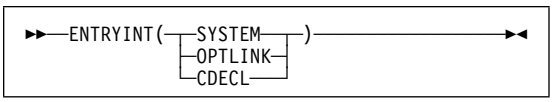
has the identical behavior as these statements%colon.

```
MOVE "myprogram" to id-1
CALL id-1 ...
```

See “Static, Dynamic, and Run-time Linking” on page 313 for information on subprogram calls.

DYNAM conforms to the COBOL 85 Standard.

ENTRYINT



Default is: ENTRYINT(SYSTEM)

Abbreviations are: None

Use ENTRYINT to indicate the call interface convention applicable to the program entry point(s) in the USING phrase of either the PROCEDURE DIVISION or ENTRY statement.

See “CALLINT” on page 146 for the compiler option, CALLINT. CALLINT is used for the selection of the call interface convention for CALLs.

SYSTEM

The SYSTEM suboption specifies that the call convention is that of the standard system linkage convention of the platform. WIN For Windows this is STDCALL.

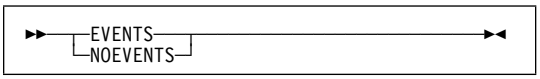
On Windows, this is STDCALL, the linkage used by the system Windows APIs.

Alert: This convention cannot be used in all cases when the called program has multiple entry points. See “Multiple Entry Points on Windows” on page 331 for details.

OPTLINK
The OPTLINK suboption specifies that the call convention is that of the _OPTLINK convention of VisualAge for C++ for OS/2 and VisualAge for C++ for Windows.

WIN **CDECL**
The CDECL suboption specifies that the call interface convention is that of the CDECL calling convention as defined by Microsoft Visual C++ for Windows.

EVENTS



Default is: NOEVENTS

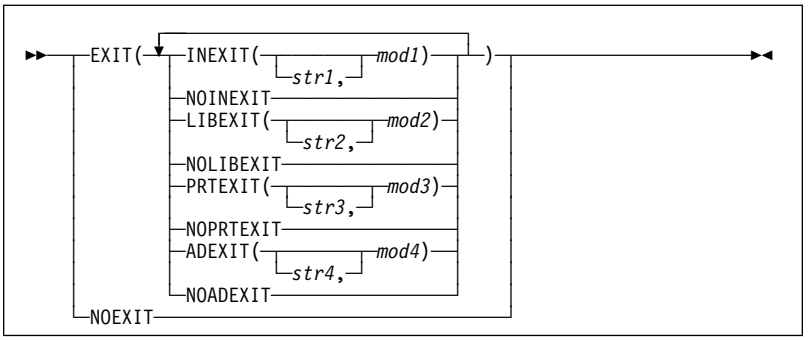
Abbreviation is: None

Use the EVENTS option only for compatibility with the COBOL/370 Release 1 EVENTS option. The compiler option substitutes the EVENTS option with the ADATA compiler option.

You cannot specify EVENTS in a PROCESS(CBL) statement; it can be specified only:

- On invocation of the compiler using an option list
- As a command option

EXIT



Default is: EXIT(ADEXIT(IWZRMGUX))

Abbreviations are: EX(INX | NOINX, LIBX | NOLIBX, PRTX | NOPRTX, ADX | NOADX)

If you specify the EXIT option without providing a least one suboption, NOEXIT will be in effect. The suboptions can be specified in any order, separated by either commas or spaces. If you specify both the positive and negative form of a suboption (INEXIT | NOINEXT, LIBEXIT | NOLIBEXIT, PRTEXIT | NOPRTEXIT, OR ADEXIT | NOADEXIT), the form specified last takes effect. If you specify the same suboption more than one time, the one specified last takes effect.

EXIT Compiler Option

Use the EXIT option to allow the compiler to accept user-supplied modules in place of SYSIN, SYSLIB (or copy library), and SYSPRINT. When creating your EXIT module, ensure that the module is linked as a DLL before you run it with the COBOL compiler. EXIT modules are invoked with the system linkage convention of the platform.

For SYSADATA, the ADEXIT suboption provides a module that will be called for each SYSADATA record immediately after the record has been written out to the file.

No PROCESS: The EXIT option cannot be specified in a PROCESS(CBL) statement; It can be specified only via the environment variable COBOPT, via the COB2 command option, or at installation time.

INEXIT(['str1',]mod1)
The compiler reads source code from a user-supplied load module (where *mod1* is the module name), instead of SYSIN.

LIBEXIT(['str2',]mod2)
The compiler obtains copy code from a user-supplied load module (where *mod2* is the module name), instead of *library-name* or SYSLIB. For use with either COPY or BASIS statements.

PRTEXIT(['str3',]mod3)
The compiler passes printer-destined output to the user-supplied load module (where *mod3* is the module name), instead of SYSPRINT.

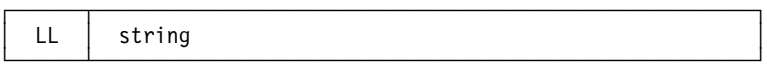
ADEXIT(['str4',]mod4)
The compiler passes the SYSADATA output to the user-supplied load module (where *mod4* is the module name).

The module names *mod1, mod2, mod3, mod4*, can refer to the same module.

The suboptions *'str1', 'str2', 'str3', 'str4'*, are character strings that are passed to the load module. These strings are optional; if you use them, they can be up to 64 characters in length and must be enclosed in apostrophes. Any character is allowed, but included apostrophes must be doubled, and lowercase characters are folded to uppercase.

Character String Formats

If either *'str1', 'str2', 'str3',* or *'str4'* is specified, the string is passed to the appropriate user-exit module with the following format:



where **LL** is a halfword (on a halfword boundary) containing the length of the string.
See Figure 42 on page 153 for the location of the character string in the parameter list.

User-Exit Work Area

When an exit is used, the compiler provides a user-exit work area that can be used to save the address of storage allocated by the exit module. This allows the module to be reentrant.

The user-exit work area is four fullwords, residing on a fullword boundary, that is initialized to binary zeroes before the first exit routine is invoked. The address of the work area is passed to the exit module in a parameter list. After initialization, the compiler makes no further reference to the work area. So, you will need to establish your own conventions for using the work area if more than one exit is active during the compilation. For example, the INEXIT module uses the first word in the work area, the LIBEXIT module uses the second word, and the PRTEXIT module uses the third word.

Linkage Conventions

Your EXIT modules should use standard linkage conventions between COBOL programs, between library routines, and between COBOL programs and library routines. You need to be aware of these conventions in order to trace the call chain correctly.

Parameter List for Exit Modules

The following table shows the format of the parameter list used by the compiler to communicate with the exit module.

Figure 42 (Page 1 of 2). Parameter List for LIBEXIT

Offset	Contains Address of	Description of Item
00	User-exit type	Halfword identifying which user exit is to perform the operation. 1=INEXIT; 2=LIBEXIT; 3=PRTEXIT; 4=ADEXIT
02	Operation code	Halfword indicating the type of operation. 0=OPEN; 1=CLOSE; 2=GET; 4=FIND
04	Return code	Fullword, placed by the exit module, indicating status of the requested operation. 0=Successful; 4=End-of-data; 12=Failed
08	Data length	Fullword, placed by the exit module, specifying the length of the record being returned by the GET operation.
12	Data or 'str2'	Fullword, placed by the exit module, containing the address of the record in a user-owned buffer, for the GET operation. 'str2' applies only to OPEN. The first halfword (on a halfword boundary) contains the length of the string; the string follows.
16	User-exit work area	Four-fullword work area provided by the compiler for use by user-exit module.
32	text-name	Fullword containing the address of a a null-terminated string containing the fully qualified text-name. Applies only to FIND.

Figure 42 (Page 2 of 2). Parameter List for LIBEXIT

Offset	Contains Address of	Description of Item
36	User exit parameter string	Fullword containing the address of a four-element array, each element of which is a structure that contain a two-byte length field followed by a 64 characters string that contain the exit parameter string.

Note: Only the second element of the parameter string array is used for LIBEXIT, to store the length of the LIBEXIT parameter string followed by the parameter string.

Using INEXIT

When INEXIT is specified, the compiler loads the exit module (*mod1*) during initialization, and invokes the module using the OPEN operation code (op code). This allows the module to prepare its source for processing and then pass the status of the OPEN request back to the compiler. Subsequently, each time the compiler requires a source statement, the exit module is invoked with the GET op code. The exit module then returns either the address and length of the next statement or the end-of-data indication (if no more source statements exist). When end-of-data is presented, the compiler invokes the exit module with the CLOSE op code so that the module can release any resources that are related to its input.

The compiler uses a parameter list to communicate with the exit module. The parameter list consists of 10 fullwords. The return code, data length, and data parameters are placed by the exit module for return to the compiler; and the other items are passed from the compiler to the exit module.

Figure 42 on page 153 shows the contents of the parameter list and a description of each item.

Using LIBEXIT

When LIBEXIT is specified, the compiler loads the exit module (*mod2*) during initialization. Calls are made to the module by the compiler to obtain copy text whenever COPY or BASIS statements are encountered.

Use LIB: If LIBEXIT is specified, the LIB compiler option must be in effect.

The first call invokes the module with an OPEN op code. This allows the module to prepare the specified library-name for processing. The OPEN op code is also issued the first time a new library-name is specified. The exit module returns the status of the OPEN request to the compiler by passing a return code.

Once the exit invoked with the OPEN op code returns, the exit module is then invoked with a FIND op code. The exit module establishes positioning at the requested text-name (or basis-name) in the specified library-name. This becomes the “active copy source”. When positioning is complete, the exit module passes an appropriate return code to the compiler.

The compiler then invokes the exit module with a GET op code, and the exit module passes the compiler the length and address of the record to be copied from the active copy source. The GET operation is repeated until the end-of-data indicator is passed to the compiler.

When end-of-data is presented, the compiler will issue a CLOSE request so that the exit module can release any resources related to its input.

Nested COPY Statements: Any record from the active copy source can contain a COPY statement. (However, nested COPY statements cannot contain the REPLACING phrase, and a COPY statement with the REPLACING phrase cannot contain nested copy statements.) When a valid nested COPY statement is encountered, the compiler issues a request based on the following:

- If the requested library-name from the nested COPY statement was not previously opened, the compiler invokes the exit module with an OPEN op code, followed by a FIND for the new text-name.
- If the requested library-name is already open, the compiler issues the FIND op code for the new requested text-name (an OPEN is not issued here).

The compiler does not allow recursive calls to text-name. That is, a COPY member can be named only once in a set of nested COPY statements until the end-of-data for that copy member is reached.

When the exit module receives the OPEN or FIND request, it should push its control information concerning the active copy source onto a stack and then complete the requested action (OPEN or FIND). The newly requested text-name (or basis-name) now becomes the active copy source.

Processing continues in the normal manner with a series of GET requests until the end-of-data indicator is passed to the compiler.

At end-of-data for the nested active copy source, the exit module should pop its control information from the stack. The next request from the compiler will be a FIND, so that the exit module can reestablish positioning at the previous active copy source.

The compiler now invokes the exit module with a GET request, and the exit module must pass the same record that was passed previously from this copy source. The compiler verifies that the same record was passed, and then the processing continues with GET requests until the end-of-data indicator is passed.

Figure 42 on page 153 shows the contents of the parameter list used for LIBEXIT and a description of each item.

Using PRTEXIT

When PRTEXIT is specified, the compiler loads the exit module (`mod3`) during initialization. The exit module is used in place of the SYSPRINT data set.

The compiler invokes the module using the OPEN operation code (op code). This allows the module to prepare its output destination for processing and then pass the

status of the OPEN request back to the compiler. Subsequently, each time the compiler has a line to be printed, the exit module is invoked with the PUT op code. The compiler supplies the address and length of the record that is to be printed, and the exit module returns the status of the PUT request to the compiler by a return code. The first byte of the record to be printed contains an ANSI printer control character.

Before the compilation is ended, the compiler invokes the exit module with the CLOSE op code so that the module can release any resources that are related to its output destination.

Figure 42 on page 153 shows the contents of the parameter list used for PRTEXIT and a description of each item.

Using ADEXIT

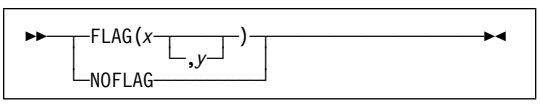
When ADEXIT is specified, the compiler loads the exit module (`mod4`) during initialization. The exit module is called for each record written to the SYSADATA data set.

The compiler invokes the module using the OPEN operation code (op code). This allows the module to prepare for processing and then pass the status of the OPEN request back to the compiler. Subsequently, each time the compiler has written a SYSADATA record, the exit module is invoked with the PUT op code. The compiler supplies the address and length of the SYSADATA record, and the exit module returns the status of the PUT request to the compiler by a return code.

Before the compilation is ended, the compiler invokes the exit module with the CLOSE op code so that the module can release any resources.

Figure 42 on page 153 shows the contents of the parameter list used for ADEXIT and a description of each item.

FLAG



Default is: FLAG(I)

Abbreviations are: F / NOF

x I, W, E, S, or U

y I, W, E, S, or U

(See “Compiler Error Message Codes” on page 141 for descriptions of error codes.)

Use FLAG(*x*) to produce diagnostic messages for errors of a severity level *x* or above at the end of the source listing.

FLAGSTD Compiler Option

Use FLAG(*x*,*y*) to produce diagnostic messages for errors of severity level *x* or above at the end of the source listing, with error messages of severity *y* and above to be embedded directly in the source listing. The severity coded for *y* must not be lower than the severity coded for *x*. To use FLAG(*x*,*y*), you must also specify the SOURCE compiler option.

Error messages in the source listing are set off by embedding the statement number in an arrow that points to the message code. The message code is then followed by the message text. For example:

```
  000413     MOVE CORR WS-DATE TO HEADER-DATE

==000413==>    IGYPS2121-S       " WS-DATE " was not defined as a data-name.  ...
```

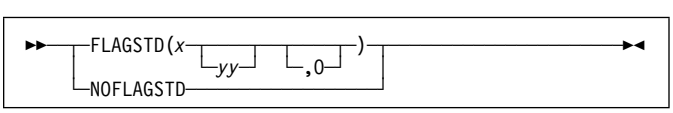
With FLAG(X,Y) selected, messages of severity *y* and above will be embedded in the listing following the line that caused the message. (Refer to the notes below for exceptions.)

Use NOFLAG to suppress error flagging. NOFLAG will not suppress error messages for compiler options.

Embedded Messages:

1. Specifying embedded level-U messages is accepted, but will not produce any messages in the source. Embedding a level-U message is not recommended.
2. The FLAG option does not affect diagnostic messages produced before the compiler options are processed.
3. Diagnostic messages produced during processing of compiler options, CBL and PROCESS statements, or BASIS, COPY, and REPLACE statements, are never embedded in the source listing. All such messages appear at the beginning of the compiler output.
4. Messages produced during processing of the *CONTROL (*CBL) statement are not embedded in the source listing.

FLAGSTD



Default is: NOFLAGSTD

x M, I, or H

Specifies the level or subset of COBOL 85 Standard to be regarded as conforming.

M Language elements that are **not** from the minimum subset are to be flagged as “nonconforming standard”.

I Language elements that are **not** from the minimum or the intermediate subset are to be flagged as “nonconforming standard”.

H The high subset is being used and elements will not be flagged by subset. And, elements in the IBM extension category will be flagged as “non-conforming Standard, IBM extension”.

yy D, N, or S

Specifies, by a single character or combination of any two, the optional modules to be included in the subset.

D Elements from Debug module level 1 are **not** flagged as “non-conforming standard”.

N Elements from Segmentation module level 1 are **not** flagged as “non-conforming standard”.

S Elements from Segmentation module level 2 are **not** flagged as “non-conforming standard”.

If S is specified, N is included (N is a subset of S).

O Obsolete language elements are flagged as “obsolete”.

Use FLAGSTD to get informational messages about the COBOL 85 Standard elements included in your program. You can specify any of the following items for flagging:

- A selected Federal Information Processing Standard (FIPS) COBOL subset
- Any of the optional modules
- Obsolete language elements
- Any combination of subset and optional modules
- Any combination of subset and obsolete elements
- IBM extensions (these are flagged any time FLAGSTD is specified and are identified as “non-conforming non-standard”)

  This includes the new language syntax for OO COBOL and for improved interoperability, and the PGMNAME(MIXED) compiler option.

The informational messages appear in the source program listing and contain the following information:

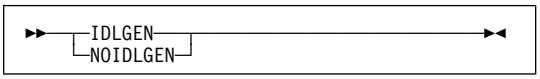
- Identify the element as “obsolete”, “non-conforming standard”, or “non-conforming non-standard” (a language element that is both obsolete and non-conforming is flagged as obsolete only).
- Identify the clause, statement, or header that contains the element.
- Identify the source program line and beginning location of the clause, statement, or header that contains the element.
- Identify the subset or optional module to which the element belongs.

FLAGSTD requires the standard set of reserved words.

In the following example, the line number and column where a flagged clause, statement, or header occurred are shown, as well as the message code and text. At the bottom is a summary of the total of the flagged items and their type.

```
   LINE.COL CODE       FIPS MESSAGE TEXT

            IGYDS8211  Comment lines before "IDENTIFICATION DIVISION":
                       nonconforming nonstandard, IBM extension to
                       ANS/ISO 1985.

      11.14 IGYDS8111  "GLOBAL clause":  nonconforming standard, ANS/ISO
                       1985 high subset.

      59.12 IGYPS8169  "USE FOR DEBUGGING statement":  obsolete element
                       in ANS/ISO 1985.


FIPS MESSAGES TOTAL             STANDARD      NONSTANDARD      OBSOLETE

                3                    1              1              1
```

IDLGEN



Default is: NOIDLGEN

Abbreviation: IDL

Use the IDLGEN option to indicate whether Interface Definition Language (IDL) should be generated for COBOL class definitions contained in the COBOL source file.

IDLGEN
Use IDLGEN to request that in addition to the normal compile of the COBOL source file, IDL definitions for classes defined in the file are generated.

NOIDLGEN
Use NOIDLGEN to request that no IDL definitions are generated.

The IDL file has the same name as the compiler source file, with the file extension IDL. For example, IDL file generated for `myfile.cbl` would be `myfile.idl`. The IDL file is written to the directory from which COB2 was run.

When a class definition includes references to other classes (such as on the INHERITS or METACLASS IS phrases, or typed object references as method parameters) that are defined in separate source files, the generated IDL will contain include statements for the IDL files of the referenced classes. The COBOL compiler will attempt to obtain the

file name (referred to as the *filestem* in the SOM documentation) for a referenced class from the SOM interface repository (IR). If the referenced class does not have an IR entry, then the external class-name of the referenced class is assumed as the filestem. An include is then generated of the form:

```
#include <"FILESTEM".idl>
```

This may be adequate for classes where external class-names are the same as the original source file name. However, in many cases this include statement will need to either be updated to reflect the correct filestem or preferably, the entire IDL file should be re-generated after the missing definition has been added to the IR.

When a COBOL source file contains more than one class definition (batch compile) and the IDLGEN option is used, the COBOL class definitions must be sequenced in an appropriate order within the source file. The generated IDL for such a batch compile will contain multiple class interfaces with the IDL interfaces in the same order as the COBOL classes were defined in the COBOL source file. The SOM IDL compiler requires that interfaces be defined before they are referenced, so if there are references between the classes in the COBOL batch compile, the referenced classes must precede the referencing classes in the COBOL source file.

The mapping of COBOL to IDL is designed to balance two (conflicting) objectives, namely enablement of object-oriented COBOL type checking and enabling COBOL classes to operate with other SOM-based programming languages. At a high level:

- COBOL classes map to IDL interfaces.
- COBOL methods map to IDL operation declarations.
- Where possible, the data types of COBOL method parameters are mapped to corresponding native IDL types. These cases include binary integer, floating point, pointer, object reference, and character types.

  All elementary USAGE DISPLAY types and fixed-length COBOL groups are mapped to IDL as array of character.

  Remaining COBOL types that to not naturally map to any native IDL data type are mapped to COBOL-specific "foreign" IDL types. These cases include packed-decimal, scaled binary, DBCS, and variable-length groups.
- Method formal-parameters that specify BY REFERENCE on the method PROCEDURE DIVISION header are given the IDL parameter attribute *inout* and parameters that specify BY VALUE are given the IDL parameter attribute *in*.

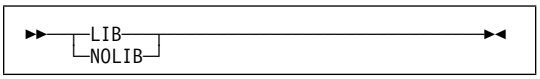
The IDL generated for the same COBOL class by the IBM COBOL compiler on MVS, OS/2, Windows, and AIX might differ; hence, the IDL should be regenerated for the target platform rather than ported between platforms. For example, the procedure-pointer data type in COBOL for MVS & VM is an 8-byte data item that does not map to any native IDL type, hence a COBOL specific mapping is used. On OS/2, Windows, and AIX, procedure-pointers are 4-byte data items that map to IDL pointers. Another example is that on MVS or AIX, a PIC S9(8) BINARY data item maps naturally to an IDL “long” type, while on OS/2 and Windows, the same data item may map either to an IDL

long or to a COBOL-specific data type that emulates S/370 binary format, depending on the compilation options used.

No PROCESS: The IDLGEN options cannot be specified on the PROCESS(CBL) statement.

See Chapter 12, "Writing Object-Oriented Programs" on page 214 and Chapter 14, "Using SOM IDL-Based Class Libraries" on page 267 for more information on IDL and SOM.

LIB



Default is: NOLIB

Abbreviation is: None

If your program uses COPY, BASIS, or REPLACE statements, you need to specify the LIB compiler option.

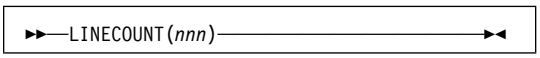
For more information, see the discussion of the *library-name* user-defined variable on page 131.

In addition, for COPY and BASIS statements, you need to define the library or libraries from which the compiler can take the copied code:

- If the library-name is specified with a user defined word (not a literal), you must set the corresponding environment variable to point to the desired directory/path for the copy file.
- If the library-name is omitted for a COPY statement, the path to be searched can be specified via the -Ixxx option on the cob2 command.
- If the library-name is specified with a literal, the literal value is treated as the actual path name.

LIB conforms to the COBOL 85 Standard.

LINECOUNT



Default is: LINECOUNT(60)

Abbreviation is: LC

nnn

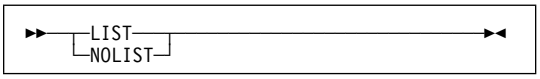
must be an integer between 10 and 255, or 0.

Use LINECOUNT(*nnn*) to specify the number of lines to be printed on each page of the compilation listing, or use LINECOUNT(0) to suppress pagination.

If you specify LINECOUNT(0), no page ejects are generated in the compilation listing.

The compiler uses three lines of *nnn* for titles. For example, if you specify LINECOUNT(60), 57 lines of source code are printed on each page of the output listing.

LIST



Default is: NOLIST

Abbreviation is: None

Use LIST to produce a listing of the assembler-language expansion of your source code.

You will also get these in your output listing:

- Global tables
- Literal pools
- Information about Working-Storage
- Size of the program's Working-Storage

If you want to limit the assembler listing output, use *CONTROL LIST or NOLIST statements in your PROCEDURE DIVISION. Your source statements following a *CONTROL NOLIST are not included in the listing until a *CONTROL LIST statement switches the output back to normal LIST format. For a description of the *CONTROL (*CBL) statement, see *IBM COBOL Language Reference*.

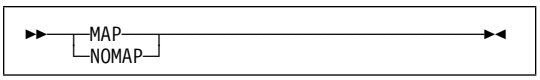
Batch Compiles: The number of and names of the resulting .asm files depend on the SEPOBJ option:

SEPOBJ The file for the first program in the source file has the name of the source file. The files for all subsequent programs in the source file have the names of the corresponding PROGRAM IDs.

NOSEPOBJ The one file for all programs in the source file has the name of the source file.

For information on using LIST output, see “Data Map Listing” on page 202.

MAP



Default is: NOMAP

Abbreviation is: None

Use MAP to produce a listing of the items you defined in the DATA DIVISION. Map output includes:

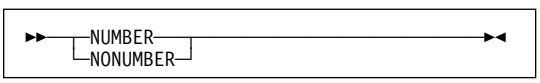
- DATA DIVISION map
- Global tables
- Literal pools
- Nested program structure map, and program attributes
- Size of the program's Working-Storage

If you want to limit the MAP output, use *CONTROL MAP or NOMAP statements in the PROCEDURE DIVISION. Source statements following a *CONTROL NOMAP are not included in the listing until a *CONTROL MAP statement switches the output back to normal MAP format. For a description of the *CONTROL (*CBL) statement, see the *IBM COBOL Language Reference*.

For information on using LIST output, see “Data Map Listing” on page 202.

By selecting the MAP option, you can also print an embedded MAP report in the source code listing. The condensed MAP information is printed to the right of data-name definitions in the FILE SECTION, WORKING-STORAGE SECTION, and LINKAGE SECTION of the DATA DIVISION.

NUMBER



Default is: NONUMBER

Abbreviations are: NUM / NONUM

Use NUMBER if you have line numbers in your source code and want those numbers to be used in error messages and MAP, LIST, and XREF listings.

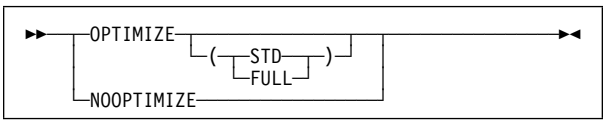
If you request NUMBER, columns 1 through 6 are checked to make sure that they contain only numbers, and the sequence is checked according to numeric collating sequence. (In contrast, SEQUENCE checks them according to ASCII collating sequence.) When a line number is found to be out of sequence, the compiler assigns to it a line number with a value one number higher than the line number of the preceding statement. Sequence-checking continues with the next statement, based on the newly assigned value of the previous line.

If you use COPY statements and NUMBER is in effect, be sure that your source program line numbers and the COPY member line numbers are coordinated.

Use NONUMBER if you do not have line numbers in your source code, or if you want the compiler to ignore the line numbers you do have in your source code. With NONUMBER in effect, the compiler generates line numbers for your source statements and uses those numbers as references in listings.

NONUMBER conforms to the COBOL 85 Standard.

OPTIMIZE



Default is: NOOPTIMIZE

Abbreviations are: OPT / NOOPT

Use OPTIMIZE to reduce the run time of your object program. Optimizations performed include the propagation of constants and the elimination of computations whose results are never used. Optimization might also reduce the amount of storage your object program uses. Because OPTIMIZE increases compile time, and can change the order of statements in your program, it should not be used when debugging.

If OPTIMIZE is specified without any suboptions, OPTIMIZE(STD) will be in effect.

The FULL suboption requests that in addition to the optimizations performed under OPT(STD), that the compiler discard unreferenced data items from the DATA DIVISION, and suppress generation of code to initialize these data items to their VALUE clauses. If the OPT(FULL) and MAP options are specified, then a BL number of XXXX in the data map information indicates that the data item was discarded.

Recomendation: Use OPTIMIZE(FULL) for database applications; it can have a huge performace ehnacement, because unused constants included by the associated COPY statements will be eliminated.

However:

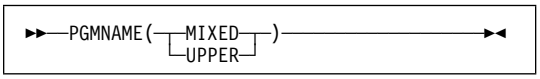
Do not use OPT(FULL) if your programs depend on making use of unused data items. Two common ways this has been done in the past are:

1. A technique sometimes used in OS/VS COBOL programs is to place an unreferenced table after a referenced table and use out-of-range subscripts on the first table to access the second table. To see if your programs have this problem, use the SSRANGE compiler option with the CHECK(ON) run-time option. To work around this problem, use the ability of COBOL to code large tables and use just one table.
2. The second technique utilizing unused data items is to place eyecatcher data items in the WORKING-STORAGE section to identify the beginning and end of the program

data, or to mark a copy of a program for a library tool that uses the data to identify a version of a program. To solve this problem, initialize these items with PROCEDURE DIVISION statements rather than VALUE clauses. With this method, the compiler will consider these items as used, and will not delete them.

The OPTIMIZE option is turned off in the case of a severe-level error or higher. The OPTIMIZE and TEST options are mutually exclusive; if you use both, OPTIMIZE will be ignored.

PGMNAME



Default is: PGMNAME(UPPER)

Abbreviations are: PGMN(LU|LM)

For compatibility with IBM COBOL for MVS & VM, LONGMIXED and LONGUPPER are also supported.

LONGUPPER can be abbreviated as UPPER, LU, or U. LONGMIXED can be abbreviated as MIXED, LM, or M.

COMPAT: If you specify PGMNAME(COMPAT), PGMNAME(UPPER) will be set, and you will receive a warning message.

The PGMNAME option controls the handling of names used in the following contexts:

- Program names defined in the PROGRAM-ID paragraph.
- Program entry point names on the ENTRY statement.
- Program name references in:
  - CALL statements
  - CANCEL statements
  - SET *procedure-pointer* TO ENTRY statements

PGMNAME(UPPER)

With PGMNAME(UPPER), program names are used at their full lengths, without truncation.

Program names that are specified in the PROGRAM-ID paragraph as COBOL user-defined words must follow the normal COBOL rules for forming a user-defined word.

When a program name is specified as a literal, in either a definition or a reference, then:

- The program name can be up to 160 characters in length.
- All the characters used in the name must be alphabetic, digits, or the hyphen.
- At least one character must be alphabetic.

- The hyphen cannot be used as the first or last character.

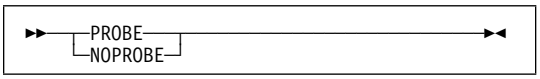
External program names are processed with alphabetic characters folded to upper case.

PGMNAME(MIXED)

Program names are processed as is, without truncation, translation, or folding to upper case.

With PGMNAME(MIXED), all program name definitions must be specified using the literal format of the program name in the PROGRAM-ID paragraph or ENTRY statement.

PROBE



Default is: PROBE

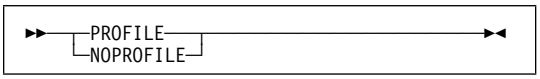
Abbreviation: None.

PROBE requests the generation of stack probes. This extra code causes a protection exception if there is not enough storage available on the stack.

Use PROBE if the program might be executed in a multithreading environment. For information about multithreading, see Chapter 23, “Preparing COBOL Programs for Multithreading” on page 375.

NOPROBE produces more efficient code and is appropriate for non-threading environments.

PROFILE

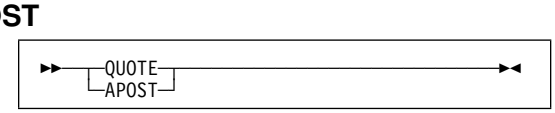


Default is: PROFILE

Abbreviation: None.

PROFILE instructs the compiler to generate the profile hooks that allow the EXTRA application to monitor application execution and generate a trace file. This option should be used with the `-p` option of the COB2 command (see “Compiling and Linking Programs” on page 135).

QUOTE/APOST



Default is: QUOTE

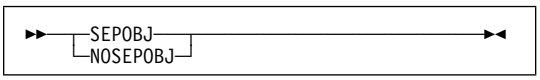
Abbreviations are: Q / APOST

Use QUOTE if you want the figurative constant [ALL] QUOTE or [ALL] QUOTES to represent one or more quotation mark (") characters. QUOTE conforms to the COBOL 85 Standard.

Use APOST if you want the figurative constant [ALL] QUOTE or [ALL] QUOTES to represent one or more apostrophe (') characters.

Delimiters: Either quotes or apostrophes can be used as literal delimiters, regardless of whether the APOST or QUOTE option is in effect. The delimiter character used as the opening delimiter for a literal must be used as the closing delimiter for that literal.

SEPOBJ



Default is: SEPOBJ

Abbreviation: None.

The option specifies whether or not each of the outermost COBOL programs in a batch compilation is to be generated as a separate object file rather than a single object file.

Batch Compilation

When multiple outer-most programs (non-nested programs) are compiled with a single invocation of the compiler (*batch* compiled), how many separate files are produced for the object program output of the batch compilation varies on the compiler option SEPOBJ.

Assume that the COBOL source file, `pgm.cbl`, contains three outer-most COBOL programs named `pgm1`, `pgm2` and `pgm3`. The following figures illustrate whether the object program output is generated as two (with NOSEPOBJ) or three (with SEPOBJ) files.

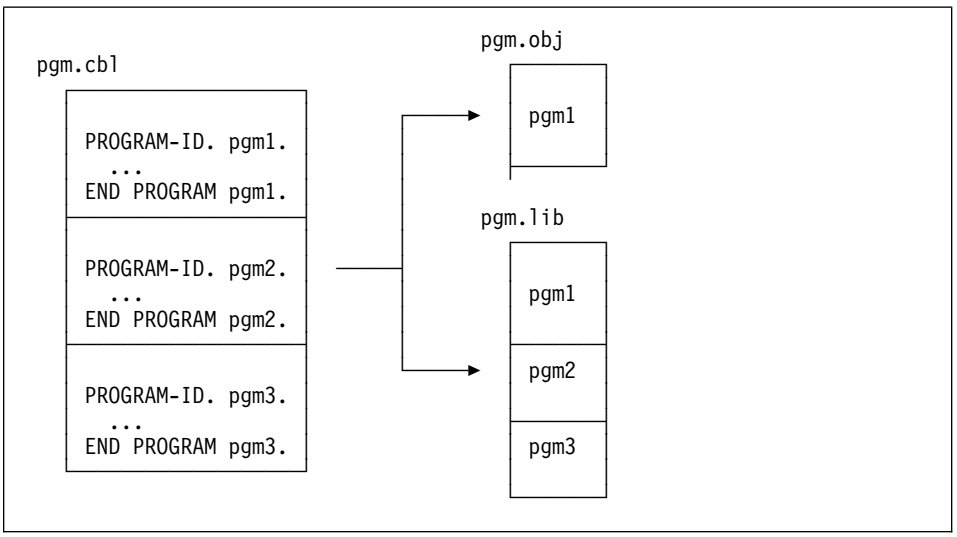


Figure 43. Batch compilation with NOSEPOBJ

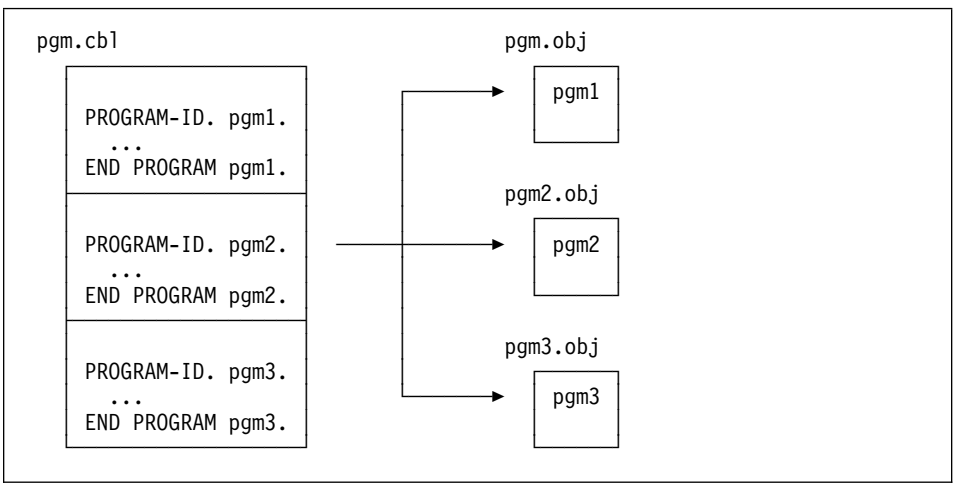


Figure 44. Batch compilation with SEPOBJ

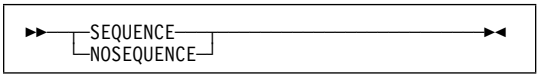
Considerations:

1. The SEPOBJ option is required to conform to the ANSI COBOL standard where pgm2 or pgm3 in the above example is called via CALL *identifier* from another program.
2. If the NOSEPOBJ option is in effect, the name(s) of object module file(s) are named with the name of the source file with .o, .OBJ and/or .LIB extensions. If the SEPOBJ option is in effect, the names of the object files (except for the first one) are based on the PROGRAM-ID name with the .o or .OBJ extension.

3. The programs called via CALL *identifier* must be referred to by the names of the object files (rather than the PROGRAM ID names) where PROGRAM ID and the object file name do not match.

You are responsible for giving the object file a valid file name for the platform and the file system. For example, if the FAT file system is used for OS/2 or Windows, the length of the PROGRAM ID name must be eight characters or fewer *except* when the object file name(s) are created from the source file name (as in the case with NOSEPOBJ option) as described above.

SEQUENCE



Default is: SEQUENCE

Abbreviations are: SEQ / NOSEQ

When you use SEQUENCE, the compiler examines columns 1 through 6 of your source statements to check that the statements are arranged in ascending order according to their ASCII collating sequence. The compiler issues a diagnostic message if any statements are not in ascending sequence (source statements with blanks in columns 1 through 6 do not participate in this sequence check and do not result in messages).

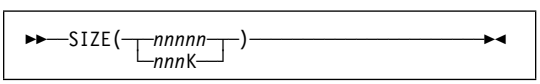
If you use COPY statements and SEQUENCE is in effect, be sure that your source program sequence fields and the copy member sequence fields are coordinated.

If you use NUMBER and SEQUENCE, the sequence is checked according to numeric, rather than ASCII, collating sequence.

Use NOSEQUENCE to suppress this checking and the diagnostic messages.

NOSEQUENCE conforms to the COBOL 85 Standard.

SIZE



Default is: 2097152 bytes (approximately 2 Meg).

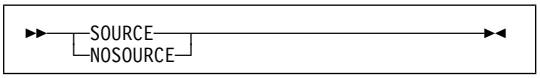
Abbreviation is: SZ

nnnnnn
A decimal number that must be at least 778240.

***nnn*K**
A decimal number in 1K increments. The minimum acceptable value is 782K.

Use SIZE to indicate the amount of main storage available for compilation (where 1K = 1024 bytes decimal).

SOURCE



Default is: SOURCE

Abbreviations are: S / NOS

Use SOURCE to get a listing of your source program. This listing will include any statements embedded by PROCESS or COPY statements.

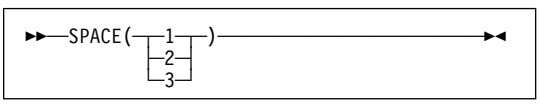
SOURCE must be specified if you want embedded messages in the source listing.

Use NOSOURCE to suppress the source code from the compiler output listing.

If you want to limit the SOURCE output, use *CONTROL SOURCE or NOSOURCE statements in your PROCEDURE DIVISION. Your source statements following a *CONTROL NOSOURCE are not included in the listing at all, unless a *CONTROL SOURCE statement switches the output back to normal SOURCE format. MAP format. For a description of the *CONTROL (*CBL) statement, see *IBM COBOL Language Reference*.

For information on using LIST output, see “Data Map Listing” on page 202.

SPACE



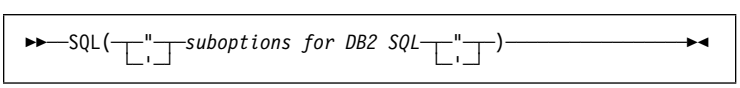
Default is: SPACE(1)

Abbreviation is: None

Use SPACE to select single, double, or triple spacing in your source code listing.

SPACE has meaning only when the SOURCE compiler option is in effect.

SQL



Default is: SQL("")

SSRANGE Compiler Option

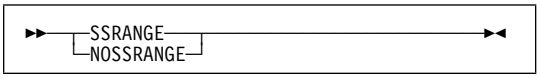
Abbreviation: None.

Use this option when you have SQL statements imbedded in your COBOL source. It allows you to specify options to be used in handling the SQL statements in your program and is required if the suboption string, which gives SQL options, is to be specified explicitly to DB2.

The syntax shown can be used on either the CBL or PROCESS statements. If the SQL option is given on the COB2 command, only ' is allowed for the string delimiter: `-q"SQL('options')"`.

See Chapter 19, “Programming for a DB2 Environment” on page 339 for more information.

SSRANGE



Default is: NOSSRANGE

Abbreviations are: SSR / NOSSR

Use SSRANGE to generate code that checks if subscripts (including ALL subscripts) or indexes try to reference an area outside the region of the table. Each subscript or index is not individually checked for validity; rather, the effective address is checked to ensure that it does not cause a reference outside the region of the table. Variable-length items will also be checked to ensure that the reference is within their maximum defined length.

Reference modification expressions will be checked to ensure that:

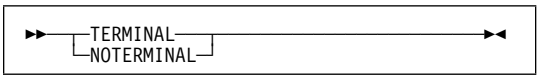
- The reference modification starting position is greater than or equal to 1.
- The reference modification starting position is not greater than the current length of the subject data item.
- The reference modification length value (if specified) is greater than or equal to 1.
- The reference modification starting position and length value (if specified) do not reference an area beyond the end of the subject data item.

If SSRANGE is in effect at compile time, the range-checking code is generated; range checking can be inhibited at run time by specifying CHECK(OFF) as a run-time option. This leaves range-checking code dormant in the object code. The range-checking code can then be optionally used to aid in resolving any unexpected errors without recompilation.

If an out-of-range condition is detected, an error message will be displayed and the program will be terminated.

Remember: You will only get range-checking if you compile your program with the SSRANGE option and run it with the CHECK(ON) run-time option.

TERMINAL



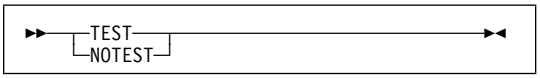
Default is: NOTERMINAL

Abbreviations are: TERM / NOTERM

Use TERMINAL to send progress and diagnostic messages to the SYSTERM data set.

Use NOTERMINAL if this additional output is not desired.

TEST



Default is: NOTEST

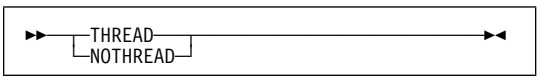
Abbreviation is: None

Use TEST to cause the compiler to produce object code that contains symbol and statement information that enables the debugger to perform symbolic source-level debugging.

Use NOTEST if you do not want to generate object code with debugging information.

Programs compiled with NOTEST execute with the debugger, but there is limited debugging support.

THREAD



Default is: NOTHREAD

Abbreviation is: None

THREAD indicates if the COBOL application is to be enabled for execution in a run unit with multiple threads. All programs within a run unit must be compiled with either the THREAD or NOTHREAD option.

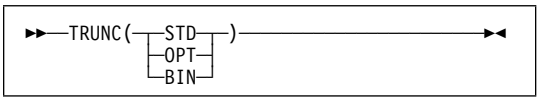
When the THREAD option is in effect, the following language elements are not supported. If encountered, they are diagnosed as errors:

- STOP RUN
- ALTER statement
- DEBUG-ITEM special register
- GO TO statement without procedure-name
- RERUN
- STOP literal statement
- Segmentation module
- USE FOR DEBUGGING statement
- WITH DEBUGGING MODE clause
- INITIAL phrase in PROGRAM-ID paragraph

Caution: RERUN is flagged as an error with THREAD, but is accepted as a comment with NOTHREAD.

See Chapter 23, “Preparing COBOL Programs for Multithreading” on page 375 for a discussion of COBOL support for multithreading.

TRUNC



Default is: TRUNC(STD)

Abbreviation is: None

TRUNC(STD) conforms to the COBOL 85 Standard, while TRUNC(OPT) and TRUNC(BIN) are IBM extensions.

TRUNC has no effect on COMP-5 data items; COMP-5 items are handled as if TRUNC(BIN) were in effect, regardless of the TRUNC option specified.

TRUNC(STD)

Use TRUNC(STD) to control the way arithmetic fields are truncated during MOVE and arithmetic operations. TRUNC(STD) applies only to USAGE BINARY receiving fields in MOVE statements and arithmetic expressions. When TRUNC(STD) is in effect, the final result of an arithmetic expression, or the sending field in the MOVE statement, is truncated to the number of digits in the PICTURE clause of the BINARY receiving field.

TRUNC(OPT)

TRUNC(OPT) is a performance option. When TRUNC(OPT) is specified, the compiler assumes that the data conforms to PICTURE and USAGE specifications of the USAGE BINARY receiving fields in MOVE statements and arithmetic expressions. The results are manipulated in the most optimal way, either truncating to the number of digits in the PICTURE clause, or to the size of the binary field in storage (halfword, fullword, or doubleword).

You should use the TRUNC(OPT) option only if you are sure that the data being moved into the binary areas will not have a value with larger precision than that

defined by the PICTURE clause for the binary item. Otherwise, unpredictable results might occur. This truncation is performed in the most efficient manner possible; therefore, the results will be dependent on the particular code sequence generated. It is not possible to predict the truncation without seeing the code sequence generated for a particular statement.

TRUNC(BIN)

The TRUNC(BIN) option applies to all COBOL language that processes USAGE BINARY data. When TRUNC(BIN) is in effect:

- BINARY receiving fields are truncated only at halfword, fullword, or doubleword boundaries.
- BINARY sending fields are handled as halfwords, fullwords, or doublewords when the receiver is numeric; TRUNC(BIN) has no effect when the receiver is not numeric.
- The full binary content of the field is significant.
- DISPLAY will convert the entire content of the binary field, with no truncation.

Recommendation: TRUNC(BIN) is the recommended option when interfacing with other products that might place values in COBOL binary data items that are larger than that defined by the data item's PICTURE clause (such as DB2 or PL/I). For CICS considerations, see “Selecting Compiler Options” on page 345.

TRUNC(BIN) should never be used as an install default, only for specific programs, due to the performance cost. A better approach is to use COMP-5 for binary data items passed to non-COBOL programs or other products and subsystems.

For more considerations in using TRUNC, see “Truncation of Binary Data (TRUNC Compiler Option)” on page 31.

TRUNC Example 1

```
01  BIN-VAR     PIC 99 USAGE BINARY.
⋮
    MOVE 123451 to BIN-VAR
```

Figure 45. Values of the Data Items after the MOVE

	Decimal	Hex	Display
Sender	123451	00|01|E2|3B	123451
Receiver TRUNC(STD)	51	00|33	51
Receiver TRUNC(OPT)	-7621	E2|3B	2J
Receiver TRUNC(BIN)	-7621	E2|3B	762J

A halfword of storage is allocated for BIN-VAR. The result of this MOVE statement if the program is compiled with the TRUNC(STD) option is 51; the field is truncated to conform to the PICTURE clause.

If the program is compiled with the TRUNC(BIN) option, the result of the MOVE statement is -7621. The reason for the unusual looking answer is that nonzero high-order digits were truncated. Here, the generated code sequence would merely move the lower halfword quantity X'E23B' to the receiver. Because the new truncated value overflowed into the sign bit of the binary halfword, the value becomes a negative number.

This MOVE statement should not be compiled with the TRUNC(OPT) option because 123451 has greater precision than the PICTURE clause for BIN-VAR. If TRUNC(OPT) was used, however, the results again would be -7621. This is because the best performance was gained by not doing a decimal truncation.

Assumption: The preceding example assumes that the BINARY(370) option is in effect.

TRUNC Example 2

```
01  BIN-VAR     PIC 9(6)  USAGE BINARY
⋮
    MOVE 1234567891 to BIN-VAR
```

Figure 46. Values of the Data Items after the MOVE

	Decimal	Hex	Display
Sender	1234567891	49|96|02|D3	1234567891
Receiver TRUNC(STD)	567891	00|08|AA|53	567891
Receiver TRUNC(OPT)	567891	00|08|AA|53	567891
Receiver TRUNC(BIN)	1234567891	49|96|02|D3	1234567891

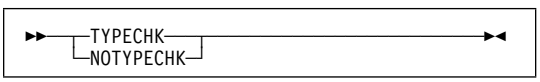
When TRUNC(STD) is specified, the sending data is truncated to six integer digits to conform to the PICTURE clause of the BINARY receiver.

When TRUNC(OPT) is specified, the compiler assumes the sending data is not larger than the PICTURE clause precision of the BINARY receiver. The most efficient code sequence in this case performed truncation as if TRUNC(STD) had been specified.

When TRUNC(BIN) is specified, no truncation occurs because all of the sending data will fit into the binary fullword allocated for BIN-VAR.

Assumption: The preceding example assumes that the BINARY(370) option is in effect.

TYPECHK



Default is: NOTYPECHK

Abbreviations are: TC/NOTC.

VBREF Compiler Option

Use TYPECHK to have the compiler enforce the rules for object-oriented type checking, and generate diagnostics for any violations.

Use NOTYPECHK to turn off the checking for typing violations.

The type conformance requirements are covered in the *IBM COBOL Language Reference* under the appropriate language elements. Type checking requirements include:

- The method being invoked on an INVOKE statement must be supported by the class of the referenced object.
- Method parameters on an INVOKE and the corresponding method PROCEDURE DIVISION USING must conform.
- The SET *object-reference-1* TO *object-reference-2* statement requires that the classes of the objects be of appropriate derivation relationships.
- A method override must have a conforming interface to the corresponding method in the parent class.

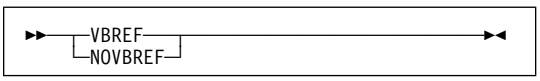
When TYPECHK is specified, there must be entries in the SOM Interface Repository (IR) for each class that is referenced in the COBOL source being compiled.

For COBOL classes, these IR entries can be created by using the COBOL IDLGEN option (see "IDLGEN" on page 159) when compiling the class definitions, to create an IDL file that describes the interface of the COBOL class. Compile the IDL using the SOM compiler with its "ir" emitter.

Note that if the COBOL program references classes that are provided by the SOM product itself (such as the SOMObject class), then the pre-generated IR for these classes that is provided as part of the SOMObjects for MVS product may be used to verify that the COBOL usage conforms to the class interfaces.

See Chapter 13, "Using System Object Model (SOM)" on page 261 in this guide, *SOMObjects Developers Toolkit User Guide Version 2.1*, and *SOMObjects Developers Toolkit Programmers Reference Manual Version 2.1* (available online) for further details on interface repositories, SOM, and type checking.

VBREF



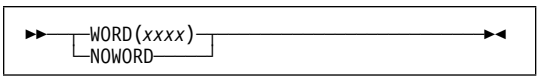
Default is: NOVBREF

Abbreviation is: None

Use VBREF to get a cross-reference among all verb types used in the source program and the line numbers in which they are used. VBREF also produces a summary of how many times each verb was used in the program.

Use NOVBREF for more efficient compilation.

WORD



Default is: NOWORD

Abbreviations are: WD / NOWD

xxxx
Are the ending characters of the name of the reserved word table (IGYC*xxxx*) to be used in your compilation. IGYC are the first 4 standard characters of the name, and *xxxx* can be 1 to 4 characters in length.

Use WORD(*xxxx*) to specify that an alternate reserved word table is to be used during compilation.

Alternate reserved word tables provide changes to the IBM-supplied default reserved word table. Your systems programmer might have created one or more alternate reserved word tables for your site. See your systems programmer for the names of alternate reserved word tables

IBM COBOL provides an alternate reserved word table (IGYCCICS) specifically for CICS applications. It is set up to flag COBOL words not supported under CICS with an error message. If you want to use this CICS reserved word table during your compilation, specify the compiler option WORD(CICS). For information on the CICS reserved word table, refer to “CICS has a Special Reserved Word Table” on page 344.

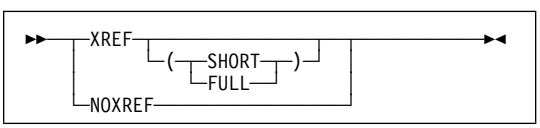
IBM COBOL provides an alternate reserved word table (IGYCNOOO) specifically for existing applications you might have that use OO reserved words (OBJECT, METHOD, and others) as user-defined words. IGYCNOOO does not reserve the new words used for OO, so your applications will still work if you refer to the new words:

CLASS-ID	METACLASS	RECURSIVE
END-INVOKE	METHOD	RETURNING
INHERITS	METHOD-ID	REPOSITORY
INVOKE	OBJECT	SELF
LOCAL-STORAGE	OVERRIDE	SUPER

If you want to use this NOOO reserved-word table during your compilation, specify the compiler option WORD(NOOO).

NOWORD conforms to the COBOL 85 Standard.

XREF



Default is: NOXREF

Abbreviations are: X / NOX

You can choose XREF, XREF(FULL), or XREF(SHORT).

Use XREF to get a sorted cross-reference listing. Names are listed in the order of the collating sequence indicated by the locale setting. This applies whether the names are in single-byte characters or contain multi-byte characters (such as DBCS).

Also included is a section listing all the program names that are referenced in your program, and the line number where they are defined. External program names are identified as such.

If you use XREF and SOURCE, cross-reference information will also be printed on the same line as the original source in the listing. Line number references or other information, will appear on the right hand side of the listing page. On the right of source lines that reference intrinsic functions, the letters 'IFN' will appear with the line numbers of the location where the function's arguments are defined. Information included in the embedded references lets you know if an identifier is undefined or defined more than once. (UND or DUP will be printed); if an item is implicitly defined (IMP), such as special registers or figurative constants; and if a program name is external (EXT).

If you use XREF and NOSOURCE, you'll get only the sorted cross-reference listing.

XREF(SHORT) will print only the explicitly referenced variables in the cross-reference listing. XREF(SHORT) applies to MBCS data names and procedure-names as well as ASCII names.

NOXREF suppresses this listing.

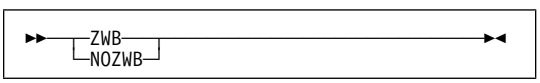
Notes:

text=Observe'.

1. Group names used in a MOVE CORRESPONDING statement are in the XREF listing. In addition, the elementary names in those groups are also listed.
2. In the data-name XREF listing, line numbers preceded by the letter “M:” indicate that the data item is explicitly modified by a statement on that line.
3. XREF listings take additional storage.

See Chapter 11, “Debugging Techniques” on page 189 for sample listings.

ZWB



Default is: ZWB

Abbreviation is: None

With ZWB, the compiler removes the sign from a signed external decimal (DISPLAY) field when comparing this field to an alphanumeric elementary field during execution.

If the external decimal item is a scaled item (contains the symbol 'P' in its PICTURE character-string), its use in comparisons is not affected by ZWB. Such items always have their sign removed before the comparison is made to the alphanumeric field.

ZWB affects how the program runs; the same COBOL source program can give different results, depending on the option setting.

ZWB conforms to the COBOL 85 Standard.

Use NOZWB if you want to test input numeric fields for SPACES.

Compiler-Directing Statements

Several statements help you to direct the compilation of your program. For the definition of these statements, see *IBM COBOL Language Reference*.

BASIS statement
This extended source program library statement provides a complete COBOL program as the source for a compilation.

***CONTROL (*CBL) statement**
This compiler-directing statement selectively suppresses or allows output to be produced. The names *CONTROL and *CBL are synonymous. This statement is described in the *IBM COBOL Language Reference*.

>>CALLINTERFACE statement
This compiler directing statement specifies the interface convention for calls, including whether argument descriptors are to be generated. The convention specified using >>CALLINT is in effect until another >>CALLINT specification is made. >>CALLINT can be used only in the PROCEDURE DIVISION.

The syntax and usage of the >>CALLINT statement is similar to the CALLINT compiler option. Exceptions are:

- CALLINT is a valid abbreviation in the statement syntax
- The statement syntax does not include parentheses
- The statement form can be used to apply to selective calls as described below.
- The statement syntax includes the keyword **DESCRIPTOR** and its variants.

See the *IBM COBOL Language Reference*. for the full syntax. See “CALLINT” on page 146 for details of the option form.

If you specify >>CALLINT with no suboptions, the call convention used is determined by the CALLINT compiler option. For example, if PROG1 is an IBM C program whose default call interface convention is _OPTLINK, or it is a COBOL

program compiled with the ENTRYINT(OPTLINK) option, use the >>CALLINT directive to change the interface for this call only:

```
>>CALLINT OPTLINK DESC
CALL "PROG1" USING PARM1 PARM2.
>>CALLINT
CALL "PROG2" USING PARM1.
```

If you specify >>CALLINT with an invalid argument, the entire directive will be ignored.

The >>CALLINT statement can be specified anywhere that a COBOL procedure statement can be specified. For example, the following is valid COBOL syntax:

```
      MOVE 3 TO
  >>CALLINTERFACE SYSTEM
      RETURN-CODE.
```

The effect of >>CALLINT is limited to the current program. A nested program or a program compiled in the same batch inherits the calling convention specified with the CALLINT compiler option, not the >>CALLINT compiler directive.

If you are writing a routine that is to be called with >>CALLINT SYSTEM, DESCRIPTOR, this is the argument-passing mechanism:

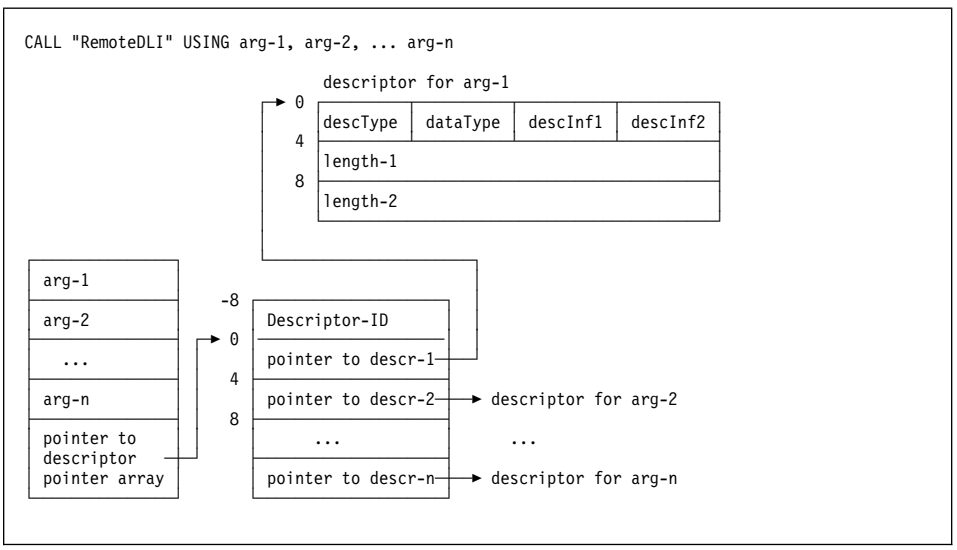


Figure 47. Argument Passing with SYSTEM(DESC)

pointer to desc Points to the descriptor for the specific argument; 0 if no descriptor exists for the argument.

descriptor-ID Set to COBDESC0 to identify this version of the descriptor, allowing for a possible change to the descriptor entry format in the future.

descType Set to X'02' (descElmt) for an elementary data item of USAGE DISPLAY with PICTURE X(n) or USAGE DISPLAY-1 with PICTURE G(n) or N(n). For all others (numeric fields, structures, tables), set to X'00'.

dataType Set as follows:

- descType = X'00': dataType = X'00'
- descType = X'02' and the USAGE is DISPLAY: dataType = X'02' (typeChar)
- descType = X'02' and the USAGE is DISPLAY-1: dataType = X'09' (typeGChar)

descInf1 Always set to X'00'

descInf2 Set as follows:

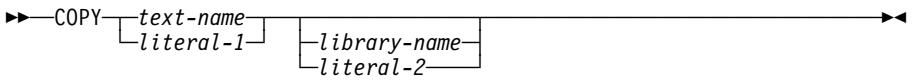
- if descType = X'00'; descInf2 = X'00'
- if descType = X'02'
  - If the CHAR(EBCDIC) option is in effect and the argument is not defined with the NATIVE option in the USAGE clause: descInf2 = X'40'
  - Else: descInf2 = X'00'

length-1 In the argument descriptor is the length of the argument for a fixed length argument or the current length for a variable length item.

length-2 The maximum length of the argument, if the argument is a variable length item.

For a fixed length argument `length-2` is equal to `length-1`.

COPY statement



This library statement places pre-written text into a COBOL program.

The uniqueness of text-name and library-name is determined after the formation and conversion rules for a system-dependent name have been applied. A user-defined word can be the same as a text-name or a library-name. If more than one COBOL library is available during compilation, text-name need not be qualified. If text-name is not qualified, a library-name of SYSLIB is assumed. The following affects library-name and text-name:

library-name

If you specify library-name as a literal (*literal-2*), it is treated as the actual path. If you specify library-name with a user-defined word, the name is used as an environment variable and the value of the environment variable is used for the path to locate the COPY text. To specify multiple path names, delimit them by using a a semicolon (;).

If you don't specify library-name, the path used is as described under text-name.

text-name

The processing of text-name as a user-defined word depends on whether the environment variable corresponding to the text-name is set. If the the environment variable **is** set, the value of the environment variable is used as the file name, and possibly the path name, for the copybook.

A text-name is treated as both the path and file name if:

- library-name (or literal-2) is not given **and**
- text-name is a literal (literal-1) or an environment variable, **and**
- The first character is '\' or the second character is ':'

For example,

```
COPY "\mycpylib\..." or COPY "d:\mycpylib\..."
```

If the environment variable corresponding to the text-name is **not** set, the copy text is searched for as the following names:

1. The text-name with the extension of `.cpy`
2. The text-name with the extension of `.cbl`
3. The text-name without an extension

For example, `COPY MyCopy` searches in the following order:

- `MyCopy.cpy` (in all the specified paths, as described above)
- `MyCopy.cbl` (in all the specified paths, as described above)
- `MyCopy` (in all the specified paths, as described above)

-I option

For other cases (when neither a library-name nor text-name indicates the path), the path searched is dependent on the -I option. For details, see “Options Supported by COB2” on page 135.

To have COPY A be equivalent to COPY A OF MYLIB specify -I%MYLIB%.

Based on the above rules, COPY "\X\Y" will be searched in the root directory, while COPY "X\Y" will be searched in the current directory.

COPY A OF SYSLIB is equivalent to COPY A. The -I option does not impact COPY statements with explicit library-name qualifications besides those with the library name of SYSLIB.

Environment Variable Notes If both library-name and text-name are environment variables the compiler will insert a path separator (\) between the two values. For example, COPY MYCOPY OF MYLIB with the settings of

```
SET MYCOPY=MYPDS(MYMEMBER)
SET MYLIB=MYFILE
```

results in MYFILE\MYPDS(MYMEMBER)

OS/2

Accessing MVS PDS files

Using a user-defined word as text-name enables you not only to access local files but to access PDS members on MVS without changing your mainframe source . For example:

```
COPY mycopybook
```

In this example, when the environment variable *mycopybook* is set to `H:mypds(mycopy)`, where:

H: is assigned to the specific host
`mypds` is the MVS PDS data set name
`mycopy` is the PDS member name

You can access MVS files from OS/2 using SdU (Smart Data Utilities), which allows MVS files to be accessed using an OS/2 pathname. However, note that it converts the path seperartor to "." to follow MVS naming conventions. You should keep this in mind when assigning values to your environment variables to ensure proper name formation. For example, these settings

```
SET MYCOPY=(MYMEMBER)
SET MYLIB=M:MYFILE\MYPDS
```

do not work because what is created is

```
M:MYFILE\MYPDS\(MYMEMBER)
```

which becomes

```
M:MYFILE.MYPDS.(MYMEMBER)
```

See the VSAM SMARTdata Utilities documentation for details on using DFMDRIVE to assign a drive letter to DFM.

For more information on the COPY statement, see the discussion of the COPY statement in the *IBM COBOL Language Reference*.

DELETE statement
This extended source library statement removes COBOL statements from the BASIS source program.

EJECT statement
This compiler-directing statement specifies that the next source statement is to be printed at the top of the next page.

ENTER statement
The compiler handles this statement as a comment.

INSERT statement
This library statement adds COBOL statements to the BASIS source program.

PROCESS (CBL) statement
This statement, which is placed before the IDENTIFICATION DIVISION header of an outermost program, indicates which compiler options are to be used during compilation of the program. (See page 139 for the format of this statement).

Compiler-Directing Statements

For details on specifying compiler options with the PROCESS (CBL) statement and with other methods, see the discussion under “Compiling and Linking Programs” on page 135.

REPLACE statement
This statement is used to replace source program text.

SKIP1/2/3 statement
These statements indicate lines to be skipped in the source listing.

TITLE statement
This statement specifies that a title (header) be printed at the top of each page of the source listing. (See “Changing Header of Source Listing” on page 12.)

USE statement
The USE statement provides *declaratives* to specify the following:

Error-handling procedures—EXCEPTION/ERROR
Debugging lines and sections—DEBUGGING

Chapter 10. Run-Time Options

The following run-time options are supported:

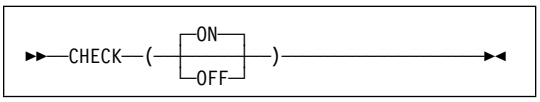
- CHECK
- DEBUG
- FILESYS
- ERRCOUNT
- TRAP
- UPSI

Syntax

Syntax of the run-time options follows. See “Definitions of COBOL Environment Variables” on page 131 to see where to specify them.

CHECK

CHECK flags checking errors in an application. In COBOL, index, subscript, and reference modification ranges are checking errors.



Default is: CHECK(ON).

Abbreviation is: CH

ON
Specifies that run-time checking is performed.

OFF
Specifies that run-time checking is not performed.

Usage Note

CHECK(ON) has no effect if NOSSRANGE was in effect at compile time.

Performance Consideration

If your COBOL program was compiled with SSRANGE, and you are not testing or debugging an application, performance improves when you specify CHECK(OFF).

DEBUG

DEBUG specifies whether the COBOL batch debugging features specified by the USE FOR DEBUGGING declarative are active.

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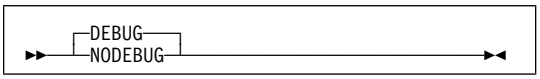


Default is: NODEBUG.

DEBUG
Activates the COBOL batch debugging features.

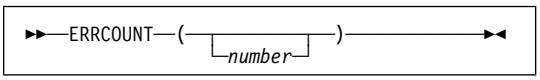
You must have the WITH DEBUGGING MODE clause in the ENVIRONMENT DIVISION of your application in order to compile the debugging sections.

NODEBUG
Suppresses the COBOL batch debugging features.

Performance Consideration
To improve performance, use this option only while debugging.

ERRCOUNT

ERRCOUNT specifies how many conditions of severity 1 (W-level) can occur before the run-unit terminates abnormally. Any severity 2 (E-level) or higher will result in termination of the run-unit independent of the ERRCOUNT option.

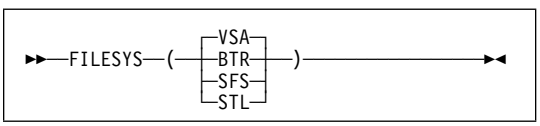


Default: ERRCOUNT(20).

number
The number of severity 1 conditions per individual thread that can occur while this run-unit is running. If the number of conditions exceeds *number*, the run-unit terminates abnormally.

FILESYS

FILSYS specifies the file system used for files for which no explicit file system selections are made, either through an ASSIGN or an evironment variable. The option applies to sequential, relative, and indexed files. For details about using FILESYS for access to CICS files, see “Accessing Novell Btrieve Data” on page 346.



Default is : FILESYS(VSA) for OS/2 and FILESYS(STL) for Windows.

STL
The file system is STL File System

VSA
The file system is VSAM (OS/2 only)

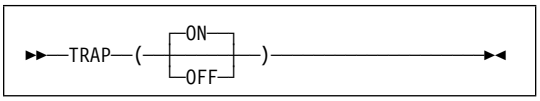
BTR
The file system is Novell Btrieve (OS/2 only)

Only the first three characters of the file system identifier are used and the identifier is case insensitive. For example, the following examples are all valid specifications for VSAM:

- FILESYS(VSA)
- FILESYS(vSAM)
- FILESYS(vsa)

TRAP

TRAP indicates whether COBOL intercepts exceptions.



Default is : TRAP(ON).

Note: If TRAP(OFF) is in effect and you do not supply your own trap handler to handle exceptional conditions, the conditions will result in a default action by the operating system. For example, if your program attempts to store into an illegal location, the default system action is to issue a message and terminate the process.

ON
Activates COBOL interception of exceptions.

OFF
Deactivates COBOL interception of exceptions.

Usage Notes

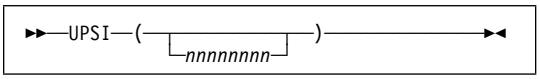
- Use TRAP(OFF) only when you need to analyze a program exception before COBOL handles it.
- When you specify TRAP(OFF) in a non-CICS environment, no exception handlers are established.
- Running with TRAP(OFF) (for exception diagnosis purposes) can cause many side effects, because COBOL requires TRAP(ON). When you run with TRAP(OFF), you can get side effects even if you do not encounter a software-raised condition, program check, or abend. If you do encounter a program check or an abend with TRAP(OFF) in effect, the following side effects can occur:
  - Resources obtained by COBOL are not freed.
  - Files opened by COBOL are not closed, so records might be lost.
  - No messages or dump output are generated.

The run-unit terminates abnormally if such conditions are raised.

- CICS consideration—When you specify TRAP(OFF) in a CICS environment, the standard CICS system action occurs.

UPSI

UPSI sets the eight UPSI switches on or off for applications that use COBOL routines.



Default is : UPSI(00000000).

nnnnnnnn
n represents one UPSI switch between 0 and 7, the leftmost *n* representing the first switch. Each *n* can either be 0 (off) or 1 (on).

Chapter 11. Debugging Techniques

COBOL provides several language elements and facilities to help you determine the cause of problems in program behavior. This chapter focuses on how to use source language for debugging and describes the compiler options that make debugging easier.

The VisualAge for COBOL Debugger is a graphical debugging tool you will find useful for debugging programs. For help with the Debugger, refer to its online help and information. This chapter only describes COBOL *source language* debugging techniques.

Using Source Language to Debug Programs

You can use several COBOL language features to pinpoint the cause of a failure in your program. If the program is part of a large application already in production, you will not want to re-compile and run the program again to debug. Instead, you can write a small test case to simulate the part of the program that failed and code some of these debugging features of the COBOL language in the test case to help detect the exact cause of the problem:

- DISPLAY statements
- USE EXCEPTION/ERROR declaratives
- Class test
- INITIALIZE or SET verbs
- Scope terminators
- File status keys
- USE FOR DEBUGGING declaratives

The rules for using each of these language features are explained in the *IBM COBOL Language Reference*.

Tracing Program Logic (DISPLAY Statements)

Adding DISPLAY statements can help you trace through the logic of the program. If, for example, you determine that the problem appears in an EVALUATE statement or in a set of nested IF statements, DISPLAY statements in each path will show you how the logic flow is working. If you determine that the problem is being caused by the way a numeric value is calculated, you can use DISPLAY statements to check the value of some of the interim results.

For example, to determine whether a particular routine started and finished you might insert code like this into your program:

```
DISPLAY "ENTER CHECK PROCEDURE"
    .
    .  (checking procedure routine)
    .
DISPLAY "FINISHED CHECK PROCEDURE"
```

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After you are sure that the routine works correctly, you can put asterisks in column 7 of the DISPLAY statement lines, which converts them to comment lines. Alternatively, you might put a 'D' in column 7 of your DISPLAY (or any other debugging) statements. If you include the WITH DEBUGGING MODE clause in the ENVIRONMENT DIVISION, the 'D' in column 7 will be ignored and the DISPLAY statements will be implemented. Without the DEBUGGING MODE clause, the 'D' in column 7 makes the statement a comment.

Before you put the program into production, delete all the debugging aids you used and re-compile the program. The program will run more efficiently and use less storage.

CICS Note: The DISPLAY statement cannot be used in programs running under CICS.

Handling Input/Output Errors (USE EXCEPTION/ERROR Declaratives)

If you have determined that the problem lies in one of the I/O procedures in your program, you can include the USE EXCEPTION/ERROR declarative to help debug the problem.

If the file fails to open for some reason, the appropriate EXCEPTION/ERROR declarative will be performed. The appropriate declarative might be a specific one for the file or one provided for the different open attributes—INPUT, OUTPUT, I/O, or EXTEND.

Each USE AFTER STANDARD ERROR statement must be coded in a separate section. This section(s) must be coded immediately after the DECLARATIVE SECTION keyword of the PROCEDURE DIVISION. The rules for coding these statements are provided in the *IBM COBOL Language Reference*.

Validating Data (Class Test)

If you suspect that your program is trying to perform arithmetic on non-numeric data or is somehow receiving the wrong type of data on an input record, you can use the class test to validate the type of data. The class test checks whether data is alphabetic, alphabetic-lower, alphabetic-upper, DBCS, or numeric.

Assessing Switch Problems (INITIALIZE or SET Statements)

Using INITIALIZE or SET statements to initialize a table or variable is useful when you suspect that the problem might be caused by residual data left in those fields. If the problem you are having happens intermittently and not always with the same data, the problem could be that a switch is not initialized but generally is set to the right value (0 or 1) by accident. By including a SET statement to ensure that the switch is initialized, you can either determine that the uninitialized switch is the problem or remove that as a possible cause.

Improving Program Readability (Explicit Scope Terminators)

Scope terminators can help you in debugging because they indicate clearly the end of a statement. The logic of your program will become more apparent, and therefore easier to trace, if you use scope terminators.

Finding Input/Output Errors (File Status Keys)

File status keys can help you determine if your program errors are due to the logic of your program or if they are I/O errors occurring on the storage media.

To use file status keys as a debugging aid, include a test after each I/O statement to check for a value other than zero in the status key. If the value is other than zero, you can expect that you will receive an error message. You can use a nonzero value as an indication that you should look at the way the I/O procedures in the program were coded. You can also include procedures to correct the error based on the value of the status key.

The status key values and their associated meanings are described in the *IBM COBOL Language Reference*.

Generating Information about Procedures (USE FOR DEBUGGING Declaratives)

USE FOR DEBUGGING declaratives are another way to generate information about your program or test case and how it is running. The declarative allows you to include statements in the program and indicate when they should be performed when you run your compiled program. For example, if you want to check how many times a procedure is run, you could include a debugging procedure in the USE FOR DEBUGGING declarative and use a counter to keep track of the number of times control passes to that procedure.

Rules for Debugging Statements and Debugging Lines

Each USE FOR DEBUGGING declarative must be coded in a separate section. This section or these sections must be coded in the Declaratives Section of the PROCEDURE DIVISION. The rules for coding them are provided in the *IBM COBOL Language Reference*.

You can have either debugging lines or debugging statements or both in your program. Debugging lines are statements in your program and are identified by a 'D' in column 7. Debugging statements are the statements coded in the DECLARATIVES SECTION of the PROCEDURE DIVISION.

- The debugging statements in a USE FOR DEBUGGING declarative must:
  - Be only in a Declarative Section.
  - Follow the header USE FOR DEBUGGING.
  - Be only in the outermost program; they are not valid in nested programs. Debugging sections are also never triggered by procedures contained in nested programs.
- Debugging lines must have a D in column 7 to identify them.

To use debugging lines and sections in your program, you must include both:

- WITH DEBUGGING MODE on the SOURCE-COMPUTER line in the ENVIRONMENT DIVISION..
- The DEBUG parameter on the EXEC statement of your JCL or on the CMS START command.

USE FOR DEBUGGING Example

The program segments in Figure 48 show what kind of statements are needed to use a DISPLAY statement and a USE FOR DEBUGGING declarative to test a program. The DISPLAY statement is used to generate information on the terminal or on the output file. The USE FOR DEBUGGING declarative is used with a counter to show how many times a routine was actually run.

The adding-to-a-counter technique can be used to check the following:

- How many times a PERFORM was executed. You will know whether a particular routine is being used and whether the control structure you are using is correct.
- How many times a loop routine actually executes. This will tell you whether the loop is executing and whether the number you have used for the loop is accurate.

```
Environment Division
   .
   .
Data Division.
   .
   .
   .
Working-Storage Section.
   .
   .   (other entries your program needs)
   .
01  Trace-Msg    PIC X(30) Value "  Trace for Procedure-Name : ".
01  Total        PIC 9(9)  Value 1.
   .
   .
Procedure Division.
Declaratives.
Debug-Declaratives Section.
    Use For Debugging On Some-Routine.
Debug-Declaratives-Paragraph.
    Display Trace-Msg, Debug-Name, Total.
End Declaratives.

Main-Program Section.
   .
   .  (source program statements)
   .
  Perform Some-Routine.
   .
   .  (source program statements)
   .
  Stop Run.
```

Figure 48 (Part 1 of 2). Example of Using the WITH DEBUGGING MODE Clause

```
Some-Routine.
    .
    .  (whatever statements you need in this paragraph)
    .
   Add 1 To Total.
Some-Routine-End
```

Figure 48 (Part 2 of 2). Example of Using the WITH DEBUGGING MODE Clause

In Figure 48, the DISPLAY statement coded in the Declaratives Section will issue this message:

```
Trace For Procedure-Name : Some-Routine 22
```

every time the procedure SOME-ROUTINE is run. The number at the end of the message, 22, is the value accumulated in the data-item, TOTAL; it shows the number of times SOME-ROUTINE has been run. The statements in the debugging declarative are performed before the named procedure is run.

Another Use for the DISPLAY Statement: You can also use the DISPLAY statement technique shown above to trace program execution and show the flow through your program. You do this by changing the USE FOR DEBUGGING declarative in the Declaratives Section to:

```
USE FOR DEBUGGING ON ALL PROCEDURES.
```

and dropping the word TOTAL from the DISPLAY statement. Now, a message will be displayed before every non-debugging procedure in the outermost program is run.

Using Compiler Options for Debugging

This section discusses the compiler options that generate information to help you find coding mistakes and other errors in your program.

The FLAG Option

The FLAG option lets you select the level of error to be diagnosed during compilation and indicate where the syntax-error messages appear in the listing. Use FLAG(I) or FLAG(I,I) to be notified of all errors in your program.

Code in the first parameter the lowest severity level of the syntax-error messages to be issued. You can code in the optional second parameter the lowest level of the syntax messages to be embedded in the source listing.

If you specify:

I (informational)
You get all the messages. I-level messages generate a return code of zero; RC=0.

W (warning)
You get all the warning messages and those of a higher severity. W-level errors generate a return code of four; RC=4.

E (error)
You get all error messages and those of a higher severity. E-level errors generate a return code of eight; RC=8.

S (severe)
You get all severe and U (unrecoverable) messages. S-level errors generate a return code of twelve; RC=12.

U (unrecoverable)
You get only unrecoverable messages. U-level errors generate a return code of sixteen; RC=16.

When you specify the second parameter, the syntax-error messages are embedded in the source listing at the point where the compiler had enough information available to detect the error. All embedded messages, except those issued by the library compiler phase, will directly follow the statement to which they refer. The number of the statement containing the error is also included with the message. Embedded messages are repeated with the rest of the diagnostic messages following the source listing.

Note:

- If NOSOURCE is one of your options, the syntax-error messages are included only in the list at the end of the listing.
- U-level errors are not embedded in the source listing, as an error of this severity terminates the compilation.

For an illustration of embedded messages and messages that appear in the source listing, see Figure 49 on page 195.

```
1DATA VALIDATION AND UPDATE PROGRAM                          FLAGOUT   Date 12/31/95  Time 14:57:02   Page    26
   LineID  PL SL  ----+-*A-1-B--+----2----+----3----+----4----+----5----+----6----+----7-|--+----8  Map and Cross Reference
   000977               /
   000978               ****************************************************************
   000979               ***          I N I T I A L I Z E   P A R A G R A P H           **
   000980               ***  Open files. Accept date, time and format header lines.    **
   000981         IA4690***   Load location-table.                                      **
   000982               ****************************************************************
   000983                  100-initialize-paragraph.
   000984                    move spaces to ws-transaction-record                                IMP 339
   000985                    move spaces to ws-commuter-record                                   IMP 315
   000986                    move zeroes to commuter-zipcode                                     IMP 326
   000987                    move zeroes to commuter-home-phone                                  IMP 327
   000988                    move zeroes to commuter-work-phone                                  IMP 328
   000989                    move zeroes to commuter-update-date                                 IMP 332
   000990                    open input update-transaction-file                                  203

 ==000990==> IGYPS2052-S An error was found in the definition of file "LOCATION-FILE".  The
                         reference to this file was discarded.

   000991                         location-file                                                  192
   000992                         i-o commuter-file                                              180
   000993                         output print-file                                              216
   000994                    if loccode-file-status not = "00" or                                248
   000995                       update-file-status not = "00" or                                 247
   000996                       updprint-file-status not = "00"                                  249
   000997      1                display "Open Error ..."
   000998      1                display "  Location File Status = " loccode-file-status         248
   000999      1                display "  Update   File Status = " update-file-status          247
   001000      1                display "  Print    File Status = " updprint-file-status        249
   001001      1              perform 900-abnormal-termination                                  1433
   001002                    end-if
   001003         IA4760     if commuter-file-status not = "00" and not = "97"                   240
   001004      1               display "100-OPEN"
   001005      1               move 100 to comp-code                                            230
   001006      1               perform 500-vsam-error                                           1387
   001007      1               display "Commuter File Status (OPEN) = "
   001008      1                        commuter-file-status                                    240
   001009      1               perform 900-abnormal-termination                                 1433
   001010         IA4790     end-if
   001011                    accept ws-date from date                                            UND

 ==001011==> IGYPS2121-S "WS-DATE" was not defined as a data-name.  The statement was discarded.

   001012         IA4810     move corr ws-date to header-date                                    UND 463

 ==001012==> IGYPS2121-S "WS-DATE" was not defined as a data-name.  The statement was discarded.

   001013                    accept ws-time from time                                            UND

 ==001013==> IGYPS2121-S "WS-TIME" was not defined as a data-name.  The statement was discarded.

   001014         IA4830     move corr ws-time to header-time                                    UND 457

 ==001014==> IGYPS2121-S "WS-TIME" was not defined as a data-name.  The statement was discarded.

   001015         IA4840     read location-file                                                  192
```

Note that the messages identifying syntax errors are imbedded in the source listing.

Figure 49 (Part 1 of 2). FLAG(I,I) Output

```
1DATA VALIDATION AND UPDATE PROGRAM                              FLAGOUT   Date 12/31/95  Time 14:57:02   Page    69
 LineID  Message code  Message text

    192  IGYDS1050-E   File "LOCATION-FILE" contained no data record descriptions.  The file definition was discarded.

    899  IGYPS2052-S   An error was found in the definition of file "LOCATION-FILE".  The reference to this file was discarded.

                       Same message on line:    990

   1011  IGYPS2121-S   "WS-DATE" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1012

   1013  IGYPS2121-S   "WS-TIME" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1014

   1015  IGYPS2053-S   An error was found in the definition of file "LOCATION-FILE".  This input/output statement was discarded.

                       Same message on line:   1027

   1026  IGYPS2121-S   "LOC-CODE" was not defined as a data-name.  The statement was discarded.

   1209  IGYPS2121-S   "COMMUTER-SHIFT" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1230

   1210  IGYPS2121-S   "COMMUTER-HOME-CODE" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1231

   1212  IGYPS2121-S   "COMMUTER-NAME" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1233

   1213  IGYPS2121-S   "COMMUTER-INITIALS" was not defined as a data-name.  The statement was discarded.

                       Same message on line:   1234

   1223  IGYPS2121-S   "WS-NUMERIC-DATE" was not defined as a data-name.  The statement was discarded.
 Messages    Total    Informational    Warning    Error    Severe    Terminating
 Printed:      19                                   1        18
 * Statistics for COBOL program FLAGOUT:
 *    Source records = 1755
 *    Data Division statements = 279
 *    Procedure Division statements = 479
 End of compilation 1,  program FLAGOUT,  highest severity: Severe.
 Return code 12
```

Note that some messages apply to more than one COBOL statement.

Figure 49 (Part 2 of 2). FLAG(I,I) Output

The NOCOMPILE Option

Use the NOCOMPILE option to produce a listing that will help you find your COBOL coding mistakes, such as missing definitions, improperly defined data names, and duplicate data names. You can use NOCOMPILE two ways: with or without parameters.

Using NOCOMPILE with Parameters

When you use NOCOMPILE(*x*), where *x* is one of the error levels, your program will be compiled, if all the errors are of a lower severity than the *x* level. If an error of *x* level or higher occurs, the compilation stops and your program will be syntax-checked only. You will receive a source listing if you have specified the SOURCE option.

Using NOCOMPILE without Parameters

When you use NOCOMPILE without parameters, the compiler only syntax-checks the source program. If you have also specified the SOURCE option, the compiler will produce a listing after the syntax-checking is completed. The compiler does not produce object code when NOCOMPILE without parameters is in effect.

The following compiler options are suppressed when you use NOCOMPILE without parameters: OPTIMIZE, SSRANGE, and TEST.

The SEQUENCE Option

The SEQUENCE option tells the compiler to check your source program and flag statements that are out of sequence. You can use this option to tell you if a section of your source program was moved or deleted accidentally.

When you use SEQUENCE, the compiler checks the source statement numbers you have supplied to see if they are in ascending order. Two asterisks are placed alongside any statement numbers out of sequence, and the total number of these statements is printed out as the first line of the diagnostics following the source listing.

The XREF Option

The XREF(FULL) option tells the compiler to generate a sorted cross-reference listing of data-names, procedure-names, and program-names. The cross-reference will include the line number where the data-name, procedure-name, or program-name was defined as well as the line numbers of all references.

You can use the cross-reference listing produced by the XREF option to find out where a data-name, procedure-name, or program-name was defined and referenced.

The XREF(SHORT) option allows you to control the cross-reference listing by printing only the explicitly referenced variables.

When you use both the XREF (with FULL or SHORT) and the SOURCE options, you will get a modified cross-reference printed to the right of the source listing. This embedded cross-reference gives the line number where the data-name or procedure-name was defined.

For more information on the XREF option and some example listings, see “A Data-Name, Procedure-Name, and Program-Name Cross-Reference Listing” on page 207.

The MAP Option

Use the MAP option to produce a listing of the items you defined in the DATA DIVISION, plus all items implicitly declared.

For more information on the MAP option, see “Data Map Listing” on page 202.

Embedded Map Summary

When you use the MAP option, an embedded MAP summary is generated to the right of the COBOL source data declaration. An embedded MAP summary contains condensed

data MAP information. For more information, see “Embedded MAP Summary” on page 203.

The SSRANGE Option

Use the SSRANGE compiler option to check:

- Subscripted or indexed data references.

  The subscripted or indexed data reference is checked to determine if the effective address of the desired element is within the maximum boundary of the specified table.

- Variable-length data references (a reference to a data item that contains an OCCURS DEPENDING ON clause).

  The variable-length data reference is checked to determine if the actual length is positive and within the maximum defined length for the group data item.

- Reference-modified data references.

  The reference-modified data reference is checked to determine if the offset and length are positive and the sum of the offset and length are within the maximum length for the data item.

When the SSRANGE option is specified, checking is not performed until run time and then, only if both of the following are true:

- The COBOL statement containing the indexed, subscripted, variable-length, or reference-modified data item is actually performed.
- The CHECK run-time option is ON at run time.

If any check finds that an address is generated that is outside of the address range of the group data item containing the referenced data, an error message will be generated and the program will stop running. The error message identifies the table or identifier that was being referenced and the line number in the program where the error happened. Additional information is provided depending on the type of reference that caused the error.

If all subscripts, indices, or reference modifiers are literals in a given data reference and they result in a reference outside of the data item, the error will be diagnosed at compile time, regardless of the setting of the SSRANGE compiler option.

SSRANGE can cause your program's performance to diminish somewhat because of the extra overhead needed to check each subscripted or indexed item.

The TEST Option

On the mainframe, you select the TEST option to prepare your program for use with the debugger. IBM VisualAge for COBOL for OS/2 includes a graphical debugger. However, rather than use the TEST option to prepare your executable COBOL program for use with the debugger, you can use the -g option of the COB2 command (see “Compiling and Linking Programs” on page 135).

Getting Useful Listing Components

This section introduces the different types of compiler listings produced by COBOL. The type of listing produced by the compiler depends on which compiler options you use.

After reading this section you should be familiar with each type of output; you will know how to request each type and what kind of information is provided in the output.

A Short Listing—the Bare Minimum

If you do not specify any compiler options and the default options are NOSOURCE, NOXREF, NOVBREF, NOMAP, NOOFFSET, and NOLIST, or if all the compiler diagnostic options have been turned off, you will get a short listing.

The short listing contains diagnostic messages about the compilation, a list of the options in effect for the program, and statistics about the content of the program. Figure 50 is an example of a short listing.

The listing is explained after Figure 50, and the numbers used in the explanation correspond to those in the figure. For illustrative purposes, some errors that cause diagnostic messages to be issued were deliberately introduced.

```
1PP 28H2178 IBM COBOL for OS/2    1       1.0        Date 12/27/95 Time 14:26:57   Page 1
 Invocation parameters:    2
0PROCESS(CBL) statements:
        CBL FLAG(I,I),MAP,TEST
        CBL NONUMBER,QUOTE,SEQ,XREF,VBREF,DUMP    3

0Options in effect:     4
     NOADATA
       QUOTE
       BINARY(NATIVE)
     NOCOMPILE(S)
     NOCURRENCY
       DUMP
     NOEXIT
       FLAG(I,I)
     NOFLAGSTD
     NOLIB
       LINECOUNT(60)
     NOLIST
       MAP
     NONUMBER
       NUMPROC(NOPFD)
       OBJECT
     NOOPTIMIZE
       PGMNAME(LONGUPPER)
     NOPROFILE
       SEQUENCE
       SOURCE
       SPACE(1)
     NOSSRANGE
       TERM
       TEST(ALL,SYM)
       TRUNC(STD)
       VBREF
     NOWORD
       XREF(FULL)
       ZWB
```

Figure 50 (Part 1 of 2). Example of a Short Listing

```
1DATA VALIDATION AND UPDATE PROGRAM     5               SLISTING  Date 12/27/95  Time 15:20:21   Page     2

LineID  Message code  Message text     6

        IGYDS0139-W   Diagnostic messages were issued during processing of compiler options.  These messages are
                      located at the beginning of the listing.

   193  IGYDS1050-E   File "LOCATION-FILE" contained no data record descriptions.  The file definition was discarded.

   889  IGYPS2052-S   An error was found in the definition of file "LOCATION-FILE".  The reference to this file
                      was discarded.

                      Same message on line:    983

   993  IGYPS2121-S   "WS-DATE" was not defined as a data-name.  The statement was discarded.

                      Same message on line:    994

   995  IGYPS2121-S   "WS-TIME" was not defined as a data-name.  The statement was discarded.

                      Same message on line:    996

   997  IGYPS2053-S   An error was found in the definition of file "LOCATION-FILE".  This input/output statement
                      was discarded.

                      Same message on line:   1009

  1008  IGYPS2121-S   "LOC-CODE" was not defined as a data-name.  The statement was discarded.

  1219  IGYPS2121-S   "COMMUTER-SHIFT" was not defined as a data-name.  The statement was discarded.

                      Same message on line:   1240

  1220  IGYPS2121-S   "COMMUTER-HOME-CODE" was not defined as a data-name.  The statement was discarded.

                      Same message on line:   1241

  1222  IGYPS2121-S   "COMMUTER-NAME" was not defined as a data-name.  The statement was discarded.

                      Same message on line:   1243

  1223  IGYPS2121-S   "COMMUTER-INITIALS" was not defined as a data-name.  The statement was discarded.

                      Same message on line:   1244

  1233  IGYPS2121-S   "WS-NUMERIC-DATE" was not defined as a data-name.  The statement was discarded.


-Messages    Total    Informational    Warning    Error   Severe   Terminating     7

0Printed:      21                         2         1       18

-* Statistics for COBOL program SLISTING:     8
*    Source records = 1765
*    Data Division statements = 277
*    Procedure Division statements = 513

0End of compilation 1,  program SLISTING,  highest severity 12.    9
0Return code 12
```

Figure 50 (Part 2 of 2). Example of a Short Listing

1 COBOL default page header, including compiler level information from the LVLINFO installation time compiler option

2 Message about options passed to the compiler at compiler invocation. This message does not appear if no options were passed.

3 Options coded in the PROCESS (or CBL) statement.

4 Status of options at the start of this compilation.

5 Customized page header resulting from the COBOL program TITLE statement.

6 Program diagnostics. The first message will refer you to the library phase diagnostics, if there were any. Diagnostics for the library phase are always presented at the beginning of the listing.

7 Count of diagnostic messages in this program, grouped by severity level.

8 Program statistics for the program SLISTING.

9 Program statistics for the compilation unit. When you perform a batch compilation (multiple outermost COBOL programs in a single compilation), the return code is the message severity level for the entire compilation.

A Listing of Your Source Code—for Historical Records

By using the SOURCE compiler option, you request a copy of your source code to be included with the compiler output. You will want this output for testing and debugging your program—and as an historical record when the program is completely debugged. Figure 51 on page 202 shows an example of SOURCE output.

Using Your Own Line Numbers

The NUMBER compiler option tells the compiler to use your line numbers in the compiled program. When you use the NUMBER option, the compiler does a sequence check of your source statement line numbers in columns 1 through 6 as the statements are read in. When a line number is found to be out of sequence, the compiler assigns to it a number with a value one higher than the line number of the preceding statement. The new value is flagged with two asterisks. A diagnostic message indicating an out of sequence error is also included in the compilation listing.

Figure 51 on page 202 shows an example of the output produced by the NUMBER compiler option. In the portion of the listing shown, the programmer numbered two of the statements out of sequence.

```
1DATA VALIDATION AND UPDATE PROGRAM  1                  SRCOUT    Date 12/21/95  Time 17:44:53   Page    22
  LineID  PL SL  ----+-*A-1-B--+----2----+----3----+----4----+----5----+----6----+----7-|--+----8  Cross-Reference  2
    3     4     5
                087000/*****************************************************************
                087100***                D O   M A I N   L O G I C                **
                087200***                                                         **
                087300*** Initialization. Read and process update transactions until **
                087400*** EOE. Close files and stop run.                         **
                087500*****************************************************************
                087600 procedure division.
                087700   000-do-main-logic.
                087800     display "PROGRAM SRCOUT - Beginning"
                087900     perform 050-create-vsam-master-file.
                088150     display "perform 050-create-vsam-master finished".
 088151**       088125     perform 100-initialize-paragraph
                088200     display "perform 100-initialize-paragraph finished"
                088300     read update-transaction-file into ws-transaction-record
                088400         at end
              1 088500       set transaction-eof to true
                088600     end-read
                088700     display "READ completed"
                088800     perform until transaction-eof
              1 088900       display "inside perform until loop"
              1 089000       perform 200-edit-update-transaction
              1 089100       display "After perform 200-edit   "
              1 089200       if no-errors
              2 089300         perform 300-update-commuter-record
              2 089400         display "After perform 300-update "
              1 089650       else
 089651**     2 089600         perform 400-print-transaction-errors
              2 089700         display "After perform 400-errors "
              1 089800       end-if
              1 089900       perform 410-re-initialize-fields
              1 090000       display "After perform 410-reinitialize"
              1 090100       read update-transaction-file into ws-transaction-record
              1 090200           at end
              2 090300         set transaction-eof to true
              1 090400       end-read
              1 090500       display "After '2nd READ'   "
                090600     end-perform
```

Figure 51. Example of SOURCE and NUMBER Output

1 COBOL default page header.

2 The scale line labels Area A, Area B, and source code column numbers

3 Source code line number assigned by compiler.

4 Program (PL) and statement (SL) nesting level.

5 Columns 1 through 6 of program (the sequence number area).

Data Map Listing

The MAP compiler option provides you with a mapping of all Data Division items, plus all implicitly declared variables, of your program. You can see an example of MAP output in Figure 52 on page 203. The numbers used in the explanation below correspond to the numbers used in Figure 52. The terms used in MAP output are described in Figure 54 on page 205.

```
1DATA VALIDATION AND UPDATE PROGRAM                  IGYTCARTA  Date 12/17/95  Time 10:37:29        Page 60

0Data Division Map


   1
0Data Definition Attribute codes (rightmost column) have the following meanings:
     D = Object of OCCURS DEPENDING    G = GLOBAL                          LSEQ= ORGANIZATION LINE SEQUENTIAL
     E = EXTERNAL                      O = Has OCCURS clause               SEQ= ORGANIZATION SEQUENTIAL
     VLO=Variably Located Origin       OG= Group has own length definition INDX= ORGANIZATION INDEXED
     VL= Variably Located              R = REDEFINES                       REL= ORGANIZATION RELATIVE


    2       3  4                                      5        6           7            8
0Source   Hierarchy and                                                                Data Def
 LineID   Data Name                                 Length(Displacement) Data Type      Attributes
      4  PROGRAM-ID IGYTCARA-----------------------------------------------------------------------------*
    180   FD COMMUTER-FILE . . . . . . . . . . . . . . . .                   File            INDX
    182   1  COMMUTER-RECORD . . . . . . . . . . . . . . .        80          Group
    183     2  COMMUTER-KEY. . . . . . . . . . . . . . . .        16(0000000) Display
    184     2  FILLER. . . . . . . . . . . . . . . . . . .        64(0000016) Display
    186   FD COMMUTER-FILE-MST . . . . . . . . . . . . . .                   File            INDX
    188   1  COMMUTER-RECORD-MST . . . . . . . . . . . . .        80          Group
    189     2  COMMUTER-KEY-MST. . . . . . . . . . . . . .        16(0000000) Display
    190     2  FILLER. . . . . . . . . . . . . . . . . . .        64(0000016) Display
    192   FD LOCATION-FILE . . . . . . . . . . . . . . . .                   File            SEQ
    203   FD UPDATE-TRANSACTION-FILE . . . . . . . . . . .                   File            SEQ
    208   1  UPDATE-TRANSACTION-RECORD . . . . . . . . . .        80          Display
    216   FD PRINT-FILE. . . . . . . . . . . . . . . . . .                   File            SEQ
    221   1  PRINT-RECORD. . . . . . . . . . . . . . . . .       121          Display
    228   1  WORKING-STORAGE-FOR-IGYCARA . . . . . . . . .         1          Display
```

Figure 52. Example of MAP Output

1 Explanations of the data definition attribute codes.

2 Source line number where the data item was defined

3 Level definition or number. The compiler generates this number in the following way:

- First level of any hierarchy is always 01. Increase 1 for each level— any item you coded as 02 through 49.
- Level numbers 66, 77, and 88, and the indicators FD and SD, are not changed.

4 Data-name that is used in the source module.

5 Length of data item. base locator value.

6 Hexadecimal displacement from the beginning of the containing structure.

7 The data type and usage. These terms are explained in Figure 54 on page 205.

8 Data definition attribute codes. The definitions are explained at the top of the DATA DIVISION Map.

Embedded MAP Summary

An embedded MAP summary is printed by specifying the MAP option when generating a listing. The summary appears in the right margin of the listing for lines in the DATA DIVISION that contain data declarations. Figure 53 on page 204 describes the fields included in the embedded map summary.

When both XREF data and an embedded MAP summary exist on the same line, the embedded MAP summary is printed first.

```
000002               Identification Division.
000003
000004               Program-id.    EMBMAP.

⋮
000176               Data division.
000177               File section.
000178
000179
000180               FD  COMMUTER-FILE
000181                   record 80 characters.                                    1   2
000182                 01 commuter-record.                                        80
000183                   05 commuter-key               PIC x(16).               16(0000000)
000184                   05 filler                     PIC x(64).               64(0000016)

⋮
000221        IA1620   01 print-record                 pic x(121).              121

⋮
000227               Working-storage section.
000228                 01 Working-storage-for-EMBMAP    pic x.                    1
000229
000230                 77 comp-code                    pic S9999 comp.           2
000231                 77 ws-type                      pic x(3)   value spaces.  3
000232
000233
000234                 01 i-f-status-area.                                        2
000235                   05 i-f-file-status            pic x(2).                 2(0000000)
000236                     88 i-o-successful           value zeroes.          IMP
000237
000238
000239                 01 status-area.                                           8
000240                   05 commuter-file-status       pic x(2).                 3     2(0000000)
000241                     88 i-o-okay                 value zeroes.          IMP
000242                   05 commuter-vsam-status.                                 6(0000002)
000243                     10 vsam-r15-return-code     pic 9(2) comp.            2(0000002)
000244                     10 vsam-function-code       pic 9(1) comp.            2(0000004)
000245                     10 vsam-feedback-code       pic 9(3) comp.            2(0000006)
000246
000247                 77 update-file-status           pic xx.                   2
000248                 77 loccode-file-status          pic xx.                   2
000249                 77 updprint-file-status         pic xx.                   2

⋮
000877               procedure division.
000878                 000-do-main-logic.
000879                   display "PROGRAM EMBMAP - Beginning".
000880                   perform 050-create-vsam-master-file.                 931

⋮
```

Figure 53. Example of an Embedded MAP Summary

1 Decimal length of data item

2 Hexadecimal displacement from the beginning of the base locator value

3 Special definition symbols These symbols are:

UND The user-name is undefined

DUP The user-name is defined more than once

IMP An implicitly defined name, such as special registers and figurative constants

IFN An intrinsic function reference

EXT An external reference

***** The program-name is unresolved because the NOCOMPILE option is in effect.

Figure 54. Terms Used in MAP Output

Usage	Description
ALPHA-EDIT	Alphabetic-Edited
ALPHABETIC	Alphabetic
AN-EDIT	Alphanumeric-Edited
BINARY	Binary (Computational)
COMP-1	Internal floating-point (single-precision)
COMP-2	Internal floating-point (double-precision)
DBCS	DBCS (Display-1)
DBCS-EDIT	DBCS Edited
DISP-NUM	External Decimal
DISPLAY	Alphanumeric
File processing method (VSAM)	File (FD)
GROUP	Group Fixed-Length
GRP-VARLEN	Group Variable-Length
INDEX	Index
INDX-NAME	Index-name
Level name	Condition (77)
Level name for condition name	Condition (88)
Level name for RENAMES	Condition (66)
NUM-EDIT	Numeric-Edited
OBJECT REFERENCE	Object reference
PACKED-DEC	Internal Decimal (Computational-3)
POINTER	Pointer
PROCEDURE-POINTER	Pointer to an externally invocable program (or function)
Sort file definition	Sort Definition (SD)

Nested Program Map

The MAP compiler option also supplies you with a nested program map if your program contains nested programs. The nested program map shows where the programs are defined and provides program attribute information.

```
1PP 28H2178 IBM COBOL for OS/2          1.0               Date 12/31/95  Time 14:50:21  Page  1
Nested Program Map

    1

Program Attribute codes (rightmost column) have the following meanings:
   C = COMMON
   I = INITIAL
   U = PROCEDURE DIVISION USING...

   2    3       4                                                    5

Source Nesting                                                       Program
LineID Level   Program Name from PROGRAM-ID paragraph                 Attributes
     2         NESTED. . . . . . . . . . . . . . . . . . . . . . . .
    12     1     X1. . . . . . . . . . . . . . . . . . . . . . . . .
    20     2       X11 . . . . . . . . . . . . . . . . . . . . . . .
    27     2       X12 . . . . . . . . . . . . . . . . . . . . . . .
    35     1     X2. . . . . . . . . . . . . . . . . . . . . . . . .
```

Figure 55. Example of Nested Program Map.

1 Explanations of the program attribute codes.

2 The source line number where the program was defined.

3 Depth of program nesting.

4 The program name.

5 The program attribute codes.

A PROCEDURE DIVISION Listing with Assembler Expansion (LIST Output)

The LIST compiler option provides you with a listing of the PROCEDURE DIVISION along with the assembler coding produced by the COBOL compiler. This type of output can be especially helpful when you are trying to find the failing verb in a program. You can also use this output to find the address in storage of a data item that was moved during the program.

Getting LIST Output

You request LIST output from the compiler by using the LIST compiler option when you compile your program.

The assembler listing will be written to a file with the same name as the source program with the extention ".asm," except for batch compiles with the SEPOBJ option; see "LIST" on page 162 for the file names generated in that case.

A Verb Cross-Reference Listing

The VBREF compiler-time option produces an alphabetic listing of all the verbs in your program and shows where each is referenced. The output includes each verb used, a count of the number of times it is used, and the line numbers where the verb is used. You can use VBREF output as a handy lookup when you need to find an instance of a particular verb.

```
1DATA VALIDATION AND UPDATE PROGRAM                          VBREFOUT  Date 12/27/95  Time 18:38:29   Page    49

    1       2                          3

 Count   Cross-reference of verbs       References

     2   ACCEPT . . . . . . . . . . .  1012 1014
     2   ADD. . . . . . . . . . . . .  1320 1336
     2   CALL . . . . . . . . . . . .  1436 1437
     5   CLOSE. . . . . . . . . . . .  908 958 983 1556 1565
    20   COMPUTE. . . . . . . . . . .  1536 1670 1674 1687 1690 1693 1694 1695 1708 1712 1716 1721 1726 1731 1739 1743
                                       1748 1753 1758 1763
     2   CONTINUE . . . . . . . . . .  1068 1077
     2   DELETE . . . . . . . . . . .  977 1223
    83   DISPLAY. . . . . . . . . . .  878 880 882 887 889 891 894 897 900 905 907 910 917 927 929 930 931 932 946 953
                                       955 960 966 973 979 985 1007 1039 1053 1057 1061 1063 1070 1072 1079 1083 1087
                                       1090 1092 1094 1096 1098 1100 1102 1104 1107 1110 1112 1113 1118 1127 1130 1138
                                       1141 1143 1147 1198 1201 1215 1225 1417 1418 1419 1420 1421 1422 1423 1431 1432
                                       1433 1434 1435 1515 1516 1522 1527 1528 1550 1551 1558 1559 1654
     2   EVALUATE . . . . . . . . . .  1191 1587
     1   EXIT . . . . . . . . . . . .  1464
    46   IF . . . . . . . . . . . . .  892 916 945 952 959 965 972 978 984 1006 1038 1054 1058 1080 1084 1089 1111 1126
                                       1137 1144 1155 1158 1161 1164 1167 1171 1175 1178 1181 1197 1214 1224 1270 1277
                                       1295 1302 1319 1351 1360 1369 1381 1391 1514 1526 1549 1557
   183   MOVE . . . . . . . . . . . .  918 950 970 996 997 998 999 1000 1001 1008 1013 1015 1027 1040 1055 1059 1066
                                       1081 1085 1091 1093 1095 1097 1099 1101 1114 1128 1139 1156 1159 1162 1165 1169
                                       1173 1176 1179 1182 1190 1193 1199 1205 1207 1210 1211 1216 1221 1226 1231 1238
                                       1239 1240 1241 1242 1243 1244 1245 1246 1247 1248 1249 1250 1251 1252 1259 1260
                                       1261 1262 1263 1264 1265 1269 1271 1274 1278 1280 1281 1283 1284 1285 1287 1288
                                       1289 1290 1294 1296 1299 1303 1305 1306 1308 1309 1321 1324 1329 1331 1333 1337
                                       1343 1344 1345 1346 1347 1348 1349 1350 1352 1353 1357 1358 1361 1363 1364 1366
                                       1368 1371 1372 1373 1374 1378 1379 1382 1384 1385 1387 1392 1394 1398 1404 1405
                                       1406 1407 1408 1409 1410 1411 1445 1448 1453 1456 1475 1476 1477 1478 1480 1481
                                       1482 1487 1494 1519 1532 1537 1538 1539 1547 1581 1591 1596 1601 1606 1611 1616
                                       1621 1626 1631 1636 1641 1646 1651 1656 1657 1709 1713 1718 1723 1728 1733 1740
                                       1745 1750 1755 1760 1765
     5   OPEN . . . . . . . . . . . .  944 964 1002 1473 1513
    61   PERFORM. . . . . . . . . . .  879 881 888 890 893 896 899 919 920 926 928 947 948 954 956 961 962 967 968 974
                                       975 980 981 986 987 1009 1010 1025 1041 1115 1116 1145 1194 1195 1200 1202 1206
                                       1208 1209 1212 1217 1218 1222 1227 1228 1232 1276 1286 1301 1310 1359 1370 1380
                                       1389 1395 1399 1534 1540 1541 1562 1563
     8   READ . . . . . . . . . . . .  883 901 971 1016 1028 1105 1520 1544
     1   REWRITE. . . . . . . . . . .  1213
     4   SEARCH . . . . . . . . . . .  1064 1073 1444 1452
    46   SET. . . . . . . . . . . . .  885 903 1018 1030 1043 1062 1071 1103 1108 1393 1443 1451 1523 1529 1546 1552
                                       1580 1589 1590 1594 1595 1599 1600 1604 1605 1609 1610 1614 1615 1619 1620 1624
                                       1625 1629 1630 1634 1635 1639 1640 1644 1645 1649 1650 1669 1673
     1   STOP . . . . . . . . . . . .  933
     4   STRING . . . . . . . . . . .  1266 1291 1354 1375
    33   WRITE. . . . . . . . . . . .  951 1196 1322 1323 1325 1326 1327 1328 1330 1332 1335 1484 1489 1492 1495 1497
                                       1501 1542 1684 1685 1697 1698 1699 1770 1772 1774 1775 1776 1777 1778 1779 1780
```

Figure 56. Example of VBREF Compiler Output

The numbers in the explanation below correspond to Figure 56.

1 Number of times the verb is used in the program.

2 Verb.

3 Line numbers where verb is used.

A Data-Name, Procedure-Name, and Program-Name Cross-Reference Listing

The XREF compiler option provides you with sorted cross-reference listings of data-names, procedure-names, and program-names. The listings also tell you the location of all references to a particular data-, procedure-, or program-name. This output will help you find, quickly, a reference to a particular data-, procedure-, or program-name in your program.

Group Names: Group names in a MOVE CORRESPONDING statement are listed in the XREF listing. The cross-reference listing includes the group names and all the elementary names involved in the move.

Using a Sorted Cross-Reference Listing

You can use XREF output to find where you have used a particular data- or procedure-name. If you need to find all of the statements that modify a particular data item, you can use the output to determine what line(s) referenced or modified a data item. With the XREF output, you can also determine the context in which a procedure is referenced in your program. For example, you can determine whether a verb was used in a PERFORM block or as part of a USE FOR DEBUGGING declarative. The context of the procedure reference is indicated by the characters preceding the line number.

```
1DATA VALIDATION AND UPDATE PROGRAM                          VBREFOUT  Date 12/27/94  Time 18:38:29   Page    50

An "M" preceding a data-name reference indicates that the data-name is modified by this reference.

    1        2                          3

 Defined   Cross-reference of data names   References

     264   ABEND-ITEM1
     265   ABEND-ITEM2
     347   ADD-CODE . . . . . . . . . . .  1126 1192
     381   ADDRESS-ERROR. . . . . . . . .  M1156
     280   AREA-CODE. . . . . . . . . . .  1266 1291 1354 1375
     382   CITY-ERROR . . . . . . . . . .  M1159

      4

Context usage is indicated by the letter preceding a procedure-name reference.
These letters and their meanings are:
    A = ALTER (procedure-name)
    D = GO TO (procedure-name) DEPENDING ON
    E = End of range of (PERFORM) through (procedure-name)
    G = GO TO (procedure-name)
    P = PERFORM (procedure-name)
    T = (ALTER) TO PROCEED TO (procedure-name)
    U = USE FOR DEBUGGING (procedure-name)

    5        6                          7

 Defined   Cross-reference of procedures   References

     877   000-DO-MAIN-LOGIC
     943   050-CREATE-VSAM-MASTER-FILE. .  P879
     995   100-INITIALIZE-PARAGRAPH . . .  P881
    1471   1100-PRINT-I-F-HEADINGS. . . .  P926
    1511   1200-PRINT-I-F-DATA. . . . . .  P928
    1573   1210-GET-MILES-TIME. . . . . .  P1540
    1666   1220-STORE-MILES-TIME. . . . .  P1541
    1682   1230-PRINT-SUB-I-F-DATA. . . .  P1562
    1706   1240-COMPUTE-SUMMARY . . . . .  P1563
    1052   200-EDIT-UPDATE-TRANSACTION. .  P890
    1154   210-EDIT-THE-REST. . . . . . .  P1145
    1189   300-UPDATE-COMMUTER-RECORD . .  P893
    1237   310-FORMAT-COMMUTER-RECORD . .  P1194 P1209
    1258   320-PRINT-COMMUTER-RECORD. . .  P1195 P1206 P1212 P1222
    1318   330-PRINT-REPORT . . . . . . .  P1208 P1232 P1286 P1310 P1370 P1395 P1399
    1342   400-PRINT-TRANSACTION-ERRORS .  P896
```

Figure 57. Example of XREF Output—Data-Name Cross-References

The numbers used in explanation below correspond to the numbers in Figure 57.

Cross-Reference of Data-Names

1 Line number where the name was defined.

2 Data-name.

3 Line numbers where the name was used. If an "M" precedes the line number, the data-item was explicitly modified at the location.

Cross-Reference of Procedure References

4 Explanations of the context usage codes for procedure references.

5 Line number where the procedure-name is defined.

6 Procedure-name.

7 Line numbers where the procedure is referenced and the context usage code for the procedure.

The XREF compiler option also provides you with a sorted cross-reference listing of program names in your main program.

```
1PP 28H2178 IBM COBOL for OS/2      1.0    12/31/95   NESTED   Date 0  12/31/95  Time 14:50:21  Page  1

   1        2                          3

 Defined   Cross-reference of programs     References


 EXTERNAL   EXTERNAL1. . . . . . . . . . . 25
       2    X. . . . . . . . . . . . . . . 41
      12    X1 . . . . . . . . . . . . . . 33 7
      20    X11. . . . . . . . . . . . . . 25 16
      27    X12. . . . . . . . . . . . . . 32 17
      35    X2 . . . . . . . . . . . . . . 40 8
```

Figure 58. Example of XREF Output - Program Cross-Reference

1 The line number where the program-name was defined. If the program is external, the word EXTERNAL will be displayed instead of a definition line number.

2 The program name.

3 Line numbers where the program is referenced.

Using an Embedded Cross-Reference

The XREF compiler option also provides you with a modified cross-reference embedded in the source listing. This embedded cross-reference provides the line number where the data-name or procedure-name was defined.

```
1DATA VALIDATION AND UPDATE PROGRAM                          EMBXREF   Date 12/27/95  Time 18:38:29   Page     2
  LineID  PL SL  ----+-*A-1-B--+----2----+----3----+----4----+----5----+----6----+----7-|--+----8  Map and Cross Reference

   ⋮
  000876               procedure division.
  000877                 000-do-main-logic.
  000878                   display "PROGRAM IGYCARPA - Beginning"
  000879                   perform 050-create-vsam-master-file.                          943
  000880                   display "perform 050-create-vsam-master finished".
  000881                   perform 100-initialize-paragraph                              995
  000882                   display "perform 100-initialize-paragraph finished"                  1
  000883                   read update-transaction-file into ws-transaction-record       204 338
  000884                       at end
  000885     1               set transaction-eof to true                               252
  000886                   end-read


   ⋮

  000995                 100-initialize-paragraph.                                     2
  000996                   move spaces to ws-transaction-record                          IMP
  000997                   move spaces to ws-commuter-record                             IMP 314
  000998                   move zeroes to commuter-zipcode                               IMP 325
  000999                   move zeroes to commuter-home-phone                            IMP 326
  001000                   move zeroes to commuter-work-phone                            IMP 327
  001001                   move zeroes to commuter-update-date                           IMP 331
  001002                   open input update-transaction-file                            204
  001003                       location-file                                             193
  001004                       i-o commuter-file                                         181
  001005                       output print-file                                         217


   ⋮

  001471               1100-print-i-f-headings.
  001472
  001473                   open output print-file.                                       217
  001474
  001475                   move function when-compiled to when-comp.                     IFN 696
  001476                   move when-comp (5:2) to compile-month.                    696 638
  001477                   move when-comp (7:2) to compile-day.                      696 640
  001478                   move when-comp (3:2) to compile-year.                     696 642
  001479                                                                               2
  001480                   move function current-date (5:2) to current-month.            IFN
  001481                   move function current-date (7:2) to current-day.              IFN 649
  001482                   move function current-date (3:2) to current-year.             IFN 651
  001483
  001484                   write print-record from i-f-header-line-1                     222 633
  001485                         after new-page.                                         139
  001486


   ⋮
```

Figure 59. Example of an Embedded Cross-Reference

1 The line number of the definition of the data-name or procedure-name in the program.

2 Special definition symbols. These symbols are:

UND The user-name is undefined

DUP The user-name is defined more than once.

IMP An implicitly defined name, such as special registers and figurative constants

IFN An intrinsic function reference

EXT An external reference

***** The program-name is unresolved because the NOCOMPILE option is in effect.

Debugging User Exit Modules

To debug a user exit routine, you must invoke the debugger on the main compiler module rather than COB2.EXE. This is because the main compiler module is a separate process started by COB2, and the debugger can debug only one process.

To do this, first invoke COB2 with the -# option to see how COB2 invokes the main compiler module and what options it passes. For example, given the following COB2 invocation for compiling PGMNAME.CBL with the IWZRMGUX user exit and linking it:

```
cob2 -q"EXIT(ADEXIT(IWZRMGUX))" pgmname.cbl
```

modify the COB2 invocation as follows:

```
cob2 -# -q"EXIT(ADEXIT(IWZRMGUX))" pgmname.cbl
```

This is what you'll see:

```
igyccob2 -q"EXIT(ADEXIT(IWZRMGUX))" pgmname.cbl
ilink  /free /nol /pm:vio pgmname.obj
```

You are interested in the IGYCCOB2 invocation because it is what actually calls your user exit.

You can debug the user exit as follows:

```
idbug igyccob2 -q"EXIT(ADEXIT(IWZRMGUX))" pgmname.cbl
```

The debugger will automatically stop at the beginning of your user exit, assuming you built the exit with debug information.

Debugging Assembler Routines

The debugger will automatically go to the Disassembly view if the module being debugged does not have debug information. If the module is an assembler routine, of course you can debug only in this view. You can set a breakpoint at a disassembled statement in the Disassembly view by double clicking in the prefix area. It should be noted that by default, during startup the debugger will run until it hits the first debuggable statement it finds. If instead you would like the debugger to stop at the very first instruction in the application (debuggable or not), you must use the "-i" option. For example:

```
IDBUG -i progname
```

Resolution to Common Problems

This section outlines common problems that you might encounter and how to resolve them.

OS/2

System Message SYS1808

Problem

During execution my program terminates with the following system message:

SYS1808: The process has stopped. The software diagnostic code (exception code) is 0005.

When the program is run under the debugger, the exception XCPT_ACCESS_VIOLATION occurs in the program initialization code (at the first step from the PROGRAM-ID statement).

Solution

Your program probably has a very large LOCAL-STORAGE SECTION or LINKAGE SECTION which is causing a stack overflow. Recompile the program with the STACK linker option. See “Compiling and Linking Programs” on page 135 for a full description.

Example

```
COB2 -B"/STACK:4000000"  MYPROG.CBL
```

Part 3. Object-Oriented Programming Topics

This part of the book covers object-oriented programming topics. Object-oriented programs are built from some new syntax plus the basic programming topics covered in Part 1, “Coding Your Programs” on page 1.

Chapter 12. Writing Object-Oriented Programs 214

Chapter 13. Using System Object Model (SOM) 261

Chapter 14. Using SOM IDL-Based Class Libraries 267

Chapter 15. Converting Procedure-Oriented Programs to Object-Oriented Programs 296

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Chapter 12. Writing Object-Oriented Programs

Object-oriented programs are based on classes and methods for objects. A class is a template defining the data structure and capabilities of an object. The data structure is commonly called instance data and the capabilities are commonly called methods. Usually, a program creates and works with multiple *object instances* of a class. Each instance has its own instance data and uses the methods defined for its class.

Consider a mail-order catalog business in which customers call service representatives to place orders. The service representatives are working with a user interface on the computer and creating an order. Therefore, in this situation there are two classes: user interface and order. Because there are many service representatives each processing a different customer's order, there are multiple instances of the two classes existing simultaneously.

Once classes are determined, the next step is to determine the methods the classes need to do their work. The order class must provide the following services:

- Add items to the order
- Delete items from the order
- Calculate the cost of the order
- Provide the order number to the service representative
- Write the final order for later processing

The following methods for the order class meet the above need:

AddItem
: Add an item to the order

DeleteItem
: Delete an item from the order

CalculateCost
: Calculate the cost of the order

GetOrderNumber
: Provide the order number

WriteOrder
: Write the final order

As you design your class and its methods, you discover the need for the class to keep some instance data. Typically, an order class needs the following instance data:

- Order number
- Order date
- Number of items in the order
- Table of items ordered

Diagrams are very helpful when designing classes and their methods. The following diagrams depict the order and user interface classes.

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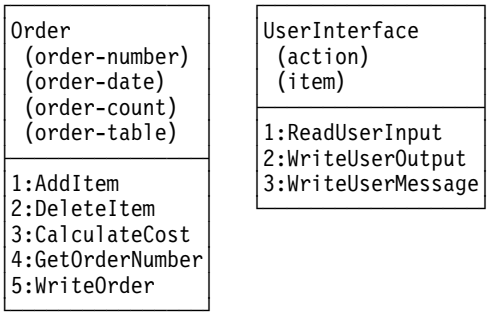
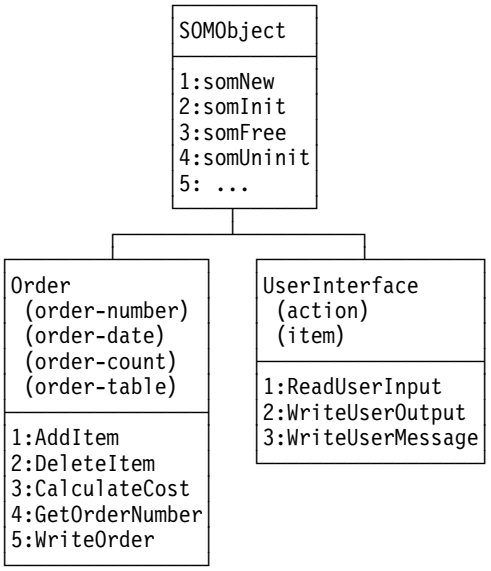


The words in parentheses are instance data and the words after the number and colon are methods.

The class structure of this object-oriented system is a tree structure. This structure shows how classes are related to each other and is known as the *inheritance hierarchy*. Order and user interface are basic classes, so they inherit from the System Object Model (SOM) base class, SOMObject.

Multiple Inheritance: All classes in COBOL inherit directly or indirectly from SOMObject. When multiple inheritance is used, the class structure might not be a tree—it may be an graph. However, the SOMObject class will always be at the root of the tree or graph.

The complete class structure for the mail-order catalog system is diagramed as follows:



More Methods: SOMObject has many methods other than the four listed here. See *SOMobjects Developers Toolkit User Guide Version 2.1* and *SOMobjects Developers*

Toolkit Programmers Reference Manual Version 2.1 for a complete description of all the SOM methods.

Writing a Class Definition

Like a COBOL program, a COBOL class definition consists of four divisions:

- IDENTIFICATION DIVISION

  The class name and class inheritance information are defined in this division.

- ENVIRONMENT DIVISION

  Associations between COBOL class names and SOM class names are defined in this division.

- DATA DIVISION

  Instance data is defined in this division.

- PROCEDURE DIVISION

  Methods are defined in this division.

Class IDENTIFICATION DIVISION: Required

In the IDENTIFICATION DIVISION of a class, you name a class and provide inheritance information for it. Optionally, you may give other identifying information. For example:

```
Identification Division.                Required
Class-Id.  Order INHERITS SOMObject.    Required
```

The AUTHOR, INSTALLATION, DATE-WRITTEN, and DATE-COMPILED paragraphs are optional and are treated as documentation.

CLASS-ID Paragraph

Use the CLASS-ID paragraph to:

- Name a class.

  In the example above, `Order` is the class name.

- Specify the System Object Model (SOM) base class or user-written class from which this class inherits its characteristics.

  In the example above, INHERITS `SOMObject` indicates `Order` inherits its basic characteristics from the base SOM class `SOMObject`.

- Name a metaclass.

  Discussed in "Writing a Metaclass Definition" on page 250.

`SOMObject` must be specified in the REPOSITORY paragraph in the ENVIRONMENT DIVISION (see "REPOSITORY Paragraph" on page 217). `Order` may optionally be specified in the REPOSITORY paragraph.

Class ENVIRONMENT DIVISION: Required

In the ENVIRONMENT DIVISION of a class, you describe the particular computer environment in which you are working and relate your class names to external SOM names. For example:

```
Environment Division.       Required
Configuration Section.      Required
Repository.                 Required
    Class SOMObject is 'SOMObject'
    Class Order is 'Order'.
```

The SOURCE-COMPUTER, OBJECT-COMPUTER, and SPECIAL-NAMES paragraphs are optional. If they are specified in a class CONFIGURATION SECTION, they apply to the entire class definition, including all methods introduced by the class.

A class CONFIGURATION SECTION can consist of the same entries as a program CONFIGURATION SECTION, except the INPUT-OUTPUT SECTION. (See "CONFIGURATION SECTION" on page 12.)

REPOSITORY Paragraph

The REPOSITORY paragraph declares to the compiler that the specified user-defined word is a class name and optionally relates the class name to an external class name in the SOM interface repository. You must specify any class name you explicitly reference in your class definition in the REPOSITORY paragraph. For example:

- SOM base classes.

  In the example above, `CLASS SOMObject IS 'SOMObject'` indicates what you are calling `SOMObject` in your COBOL program is also called `SOMObject` in the SOM interface repository. All SOM names are mixed-case, so `SOMObject` spelled in mixed-case is required to properly handle SOM case sensitivity.

- User-written classes from which your class is inheriting.

  Discussed in "Writing a Subclass Definition" on page 234.

- Metaclass to which your class belongs.

  Discussed in "Writing a Metaclass Definition" on page 250.

- Any class referenced in methods introduced by the class.

You may optionally include the name of the class you are defining. If you do not include the name of your class, it is treated as all upper-case regardless of how you typed it on the CLASS-ID. In the example above, `Order` is stored in the SOM interface repository in mixed-case.

Class DATA DIVISION: Optional

In the DATA DIVISION of a class, you describe the instance data the class needs. For example:

```
Data Division.
Working-Storage Section.
01  order-number  PIC 9(5).
01  order-date    PIC X(8).
01  order-count   PIC 99.
01  order-table.
    02  order-entry  OCCURS 10 TIMES.
        03  order-item  PIC X(5).
```

A class DATA DIVISION contains only a WORKING-STORAGE SECTION.

WORKING-STORAGE SECTION

A class WORKING-STORAGE SECTION describes instance data that is statically allocated when the instance is created and exists until the instance is freed. By default, the data is global to all the methods introduced by the class. Instance data in a COBOL class is *private*. Thus, it cannot be referenced directly by any other class or subclass. See "Special Methods" on page 223 for an example of how to share instance data in COBOL.

Syntax of the class WORKING-STORAGE SECTION is generally the same as in a program. (described in "WORKING-STORAGE SECTION and LOCAL-STORAGE SECTION" on page 19).

Exceptions:

1. You cannot use the VALUE clause to initialize the data.

   Class instance data is initialized by overriding the 'somInit' method. See "somInit" on page 223 for an example using 'somInit'.

   Level-88 Note: You can have 88 level numbers with the VALUE clause.

2. You cannot use the EXTERNAL attribute.
3. You can use the GLOBAL attribute, but it has no effect.

Class PROCEDURE DIVISION: Optional

The class PROCEDURE DIVISION contains only method definitions. See "Writing a Method Definition" on page 220 for details about defining methods. A class definition must be properly terminated with an END CLASS statement. For example:

```
End Class Order.
```

marks the end of the `Order` class.

Complete Class Example

The class definition for the order class:

Class Example

```
 IDENTIFICATION DIVISION.
*
*  Order is the name of the class
*  Order inherits from SOMObject (SOM base class)
*
 CLASS-ID.  Order INHERITS SOMObject.
 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
 REPOSITORY.
*
*  SOMObject is known as SOMObject in SOM repository
     CLASS SOMObject IS 'SOMObject'
*
*  Order is known as Order in SOM repository
     CLASS Order IS 'Order'.
 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
*  Instance data for Order class
*
 01  order-number  PIC 9(5).
 01  order-date    PIC X(8).
 01  order-count   PIC 99.
 01  order-table.
     02  order-entry  OCCURS 10 TIMES.
         03  order-item  PIC X(5).
 PROCEDURE DIVISION.
*
*  method definitions in here
*
 END CLASS Order.
```

The class definition for the user interface class:

```
 IDENTIFICATION DIVISION.
*
*  UserInterface is the name of the class
*  UserInterface inherits from SOMObject (SOM base class)
*
 CLASS-ID.  UserInterface INHERITS SOMObject.
 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
 REPOSITORY.
*
*  SOMObject is known as SOMObject in SOM repository
     CLASS SOMObject IS 'SOMObject'
*
*  UserInterface is known as UserInterface in SOM repository
     CLASS UserInterface IS 'UserInterface'.
 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
```

```
*  Instance data for UserInterface class
*
 01  uif-action  PIC X(10).
     88  uif-add     VALUE 'AddItem'.
     88  uif-delete  VALUE 'DeleteItem'.
     88  uif-quit    VALUE 'Quit'.
 01  uif-item    PIC X(5).
 PROCEDURE DIVISION.
*
*  method definitions in here
*
 END CLASS UserInterface.
```

Writing a Method Definition

A COBOL method can be defined only inside a class definition. Each method name within a class must be unique.

Like a COBOL program, a COBOL method definition consists of four divisions:

- IDENTIFICATION DIVISION

  The method name and whether it is overriding another method are defined in this division.

- ENVIRONMENT DIVISION

  Similar to a program ENVIRONMENT DIVISION.

- DATA DIVISION, discussed on page

  Similar to a program DATA DIVISION.

- PROCEDURE DIVISION

  Similar to a program PROCEDURE DIVISION.

Method IDENTIFICATION DIVISION: Required

Use the IDENTIFICATION DIVISION to name a method and indicate whether it is overriding another method from a superclass. Optionally, you can give other identifying information. For example:

```
Identification Division.     Required
Method-Id.  WriteOrder.      Required
```

The AUTHOR, INSTALLATION, DATE-WRITTEN, and DATE-COMPILED paragraphs are optional and are handled as documentation. You can use them for descriptive information about your method.

METHOD-ID Paragraph

Use the METHOD-ID paragraph to name the method. In the example above, `WriteOrder` is the method name. Other methods or programs use this name to invoke the method.

Method Override

Occasionally, a class defines a method whose name exists in a superclass. In this case, the superclass method must be overridden with the OVERRIDE clause on the METHOD-ID. System Object Model (SOM) provides two methods designed to be overridden. These SOM methods allow you to initialize instance data when an instance is created and save instance data when an instance is freed. The methods are called 'somInit' and 'somUninit' respectively. If you wish to override 'somInit', the IDENTIFICATION DIVISION is coded as follows:

```
Identification Division.           Required
Method-Id.  "somInit" Override.    Required
```

Method ENVIRONMENT DIVISION: Optional

The method ENVIRONMENT DIVISION has only one section, the INPUT-OUTPUT SECTION. The INPUT-OUTPUT SECTION relates your method files to the external file names known by the operating system. The syntax for a method INPUT-OUTPUT SECTION is the same as for a program INPUT-OUTPUT SECTION (see “INPUT-OUTPUT SECTION:” on page 15). For example:

```
Environment Division.
Input-Output Section.
File-Control.
    Select order-file Assign OrdrFile.
```

Method DATA DIVISION: Optional

A method DATA DIVISION consists of any of four sections:

- FILE SECTION

  A method FILE SECTION is the same as a program FILE SECTION except a method FILE SECTION can define only EXTERNAL files.

  (See “FILE SECTION (Using Data in Input/Output Operations)” on page 17 for more information.)

- LOCAL-STORAGE SECTION

  A separate copy of the data defined in the method LOCAL-STORAGE SECTION is allocated for each invocation of the method and is freed on the return from the method.

  If the VALUE clause is specified, the data item is initialized to the value on every invocation of the method.

  The method LOCAL-STORAGE SECTION is similar to a program LOCAL-STORAGE SECTION, except that the GLOBAL attribute has no effect.

  (See “WORKING-STORAGE SECTION and LOCAL-STORAGE SECTION” on page 19 for more information.)

- WORKING-STORAGE SECTION

  A single copy of the data defined in the method WORKING-STORAGE SECTION is allocated when the run-unit begins and persists in its last-used state until the run-

unit terminates. The same single copy of the WORKING-STORAGE data is used whenever the method is invoked, regardless of the invoking object.

If the VALUE clause is specified, the data item is initialized to the value on the first invocation of the method. The EXTERNAL clause may be specified for method WORKING-STORAGE data items (see "Sharing Data Using the EXTERNAL Clause" on page 332).

A method WORKING-STORAGE SECTION is similar to a program WORKING-STORAGE SECTION except the GLOBAL attribute has no effect.

(See "WORKING-STORAGE SECTION and LOCAL-STORAGE SECTION" on page 19 for more information.)

- LINKAGE SECTION

  A method LINKAGE SECTION is the same as a program LINKAGE SECTION except the GLOBAL attribute has no effect.

  (See "LINKAGE SECTION (Using Data from Another Program)" on page 21 for more information.)

See "Complete Class with Methods Example" on page 224 for a detailed example of a method DATA DIVISION.

If the same data item is defined in both the class DATA DIVISION and the method DATA DIVISION, a reference in the method to the data name refers to the data item in the method DATA DIVISION. The method DATA DIVISION takes precedence.

Method PROCEDURE DIVISION: Optional

In the PROCEDURE DIVISION of a method, you code the executable statements to complete the service the method is expected to provide. A method definition must be properly terminated with an END METHOD statement. For example:

```
End Method WriteOrder.
```

marks the end of the 'WriteOrder' method.

The EXIT METHOD statement returns control to the invoking program or method. GOBACK has the same effect as EXIT METHOD. If the RETURNING clause is specified when the method is invoked, the EXIT METHOD or GOBACK returns the value of the data item to the invoking program or method. STOP RUN MAY be specified in a method; however, it terminates the run-unit.

An implicit EXIT METHOD is generated as the last statement of every method PROCEDURE DIVISION.

All COBOL statements that can be coded in a program PROCEDURE DIVISION can be coded in a method PROCEDURE DIVISION except:

- EXIT PROGRAM
- ENTRY statements
- The following obsolete elements of ANSI COBOL-85:

- ALTER
- GOTO without a specified procedure name
- SEGMENTATION
- USE FOR DEBUGGING

Special Methods

Simulated Attribute Methods: Instance variables in COBOL are all *private* in the sense that they are fully encapsulated by the class, and are accessible directly only by the methods that are introduced by the class that defines them. Normally, a well-designed object-oriented application does not need to access instance variables from outside the class.

The concept of a *public* instance variable, as defined in other object-oriented languages, and the concept of a class *attribute*, as defined by SOM and CORBA, are not directly supported by COBOL. (A CORBA attribute is an instance variable that has 'get' and/or 'set' methods to access and modify the value of the instance variable from outside the class definition.) A COBOL programmer can provide this capability by coding 'getX' and/or 'setX' methods for any instance variables X for which direct access from outside the class is required. The recommended naming convention for these methods is either 'getX' and 'setX' or perhaps 'get_X' and 'set_X'. Direct specification of method names (such as _get_X) is not recommended because such names are not valid in IDL, and use of such method names with the COBOL IDLGEN compiler option specified would result in an IDL file that will not compile with the SOM compiler. For example, this method

```
Identification Division.
Method-Id. 'getOrderNumber'.
Data Division.
Linkage Section.
01  ord-num  PIC 9(5).
Procedure Division Using ord-num.
    Move order-number To ord-num.
    Exit Method.
End Method 'getOrderNumber'.
```

passes the order number to any program that invokes 'getOrderNumber'.

somInit: The 'somInit' method is automatically invoked when an object instance is created. The default 'somInit' in SOM does nothing; however, you can override it to do your own initialization of instance variables. For example:

```
Identification Division.
Method-Id. "somInit" Override.
Procedure Division.
    Move Function Current-Date(1:8) To order-date.
    Move 0 To order-count.
    Initialize order-table.
    Exit Method.
End Method "somInit".
```

somUninit: The 'somInit' method is automatically invoked when an object instance is freed. The default 'somUninit' in SOM does nothing; however, you can override it if you wish. For example:

```
 Identification Division.
 Method-Id. "somUninit" Override.
 Data Division.
 Local-Storage Section.
 01  sub  Pic 99.
 Procedure Division.
     Display order-date.
     Perform varying sub from 1 by 1 until sub > order-count
        Display order-table (sub)
     End-Perform.
     Exit Method.
 End Method "somUninit".
```

The PROCEDURE DIVISION is discussed further in “PROCEDURE DIVISION” on page 21.

Complete Class with Methods Example

The class and method definitions for the order class:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  Orders INHERITS SOMObject.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in class defintion
 REPOSITORY.
     CLASS SOMObject IS 'SOMObject'
     CLASS Orders IS 'Orders'.

 DATA DIVISION.
* Define instance data
 WORKING-STORAGE SECTION.
 01  order-number  PIC 9(5).
 01  order-date    PIC X(8).
 01  order-count   PIC 99.
 01  order-table.
     02  order-entry  OCCURS 10 TIMES.
         03  order-item  PIC X(5).
 PROCEDURE DIVISION.

* Method to initialize instance data
*  - this overrides the default 'somInit' method
 IDENTIFICATION DIVISION.
 METHOD-ID.  'somInit' OVERRIDE.

 PROCEDURE DIVISION.
     MOVE FUNCTION CURRENT-DATE(1:8) TO order-date.
```

```
     COMPUTE order-number = FUNCTION RANDOM ( 99999 ).
     MOVE 0 TO order-count.
     INITIALIZE order-table.
     EXIT METHOD.
 END METHOD 'somInit'.

* Method to add an item to an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  AddItem.

 DATA DIVISION.
* Use LOCAL-STORAGE for items that should be allocated
*  and initialized for each invocation of the method
 LOCAL-STORAGE SECTION.
 77  sub  PIC 99.
 01  found-flag  PIC 9  VALUE 1.
     88  found  VALUE 0.
 LINKAGE SECTION.
 01  in-item   PIC X(5).
 01  add-flag  PIC 9.

 PROCEDURE DIVISION USING in-item
                    RETURNING add-flag.
     MOVE 1 TO add-flag.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL (sub > 10) OR (found)
        IF order-item (sub) = SPACES
           MOVE in-item TO order-item (sub)
           ADD 1 TO order-count
           MOVE 0 TO add-flag
           SET found TO TRUE
        END-IF
     END-PERFORM.
     EXIT METHOD.
 END METHOD AddItem.

* Method to delete an item from an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  DeleteItem.

 DATA DIVISION.
* Use LOCAL-STORAGE for items that should be allocated
*  and initialized for each invocation of the method
 LOCAL-STORAGE SECTION.
 77  sub  PIC 99.
 01  found-flag  PIC 9  VALUE 1.
     88  found  VALUE 0.
 LINKAGE SECTION.
 01  out-item     PIC X(5).
 01  delete-flag  PIC 9.

 PROCEDURE DIVISION USING out-item
```

```
                    RETURNING delete-flag.
     MOVE 1 TO delete-flag.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL (sub > 10) OR (found)
        IF order-item (sub) = out-item
           MOVE SPACES TO order-item (sub)
           SUBTRACT 1 FROM order-count
           MOVE 0 TO delete-flag
           SET found TO TRUE
        END-IF
     END-PERFORM.
     EXIT METHOD.
 END METHOD DeleteItem.

* Method to compute the total cost of an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  ComputeCost.

 DATA DIVISION.
* Use LOCAL-STORAGE for items that should be allocated
*  and initialized for each invocation of the method
 LOCAL-STORAGE SECTION.
 77  sub   PIC 99.
 77  cost  PIC 9(5)V99.
 LINKAGE SECTION.
 01  total-cost  PIC 9(7)V99.

 PROCEDURE DIVISION USING total-cost.
     MOVE 0 TO total-cost.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL sub > order-count
*  Call a subroutine
*   NOTE:  The subroutine code is not
*          included in this example.
        CALL 'InventoryGetCost'
           USING order-item (sub) cost
        ADD cost TO total-cost
     END-PERFORM.
     EXIT METHOD.
 END METHOD ComputeCost.

* Method to return the order number
 IDENTIFICATION DIVISION.
 METHOD-ID.  'getOrderNumber'.

 DATA DIVISION.
 LINKAGE SECTION.
 01  ord-num  PIC 9(5).

 PROCEDURE DIVISION RETURNING ord-num.
     MOVE order-number TO ord-num.
     EXIT METHOD.
```

```
 END METHOD 'getOrderNumber'.

* Method to write completed order to file
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteOrder.

 ENVIRONMENT DIVISION.
 INPUT-OUTPUT SECTION.
 FILE-CONTROL.
     SELECT order-file ASSIGN OrdrFile.

 DATA DIVISION.
 FILE SECTION.
* Methods support only EXTERNAL files
 FD  order-file  EXTERNAL.
 01  order-record  PIC X(80).
* Use LOCAL-STORAGE for items that should be allocated
*  and initialized for each invocation of the method
 LOCAL-STORAGE SECTION.
 01  print-line.
     02  print-order-number  PIC 9(5).
     02  print-order-date    PIC X(8).
     02  print-order-count   PIC 99.
     02  print-order-table.
         03  print-order-entry  OCCURS 10 TIMES.
             04  print-order-item  PIC X(5).

 PROCEDURE DIVISION.
     OPEN OUTPUT order-file.
     MOVE order-number TO print-order-number.
     MOVE order-date   TO print-order-date.
     MOVE order-table  TO print-order-table.
     MOVE order-count  TO print-order-count.
     WRITE order-record FROM print-line.
     CLOSE order-file.
     EXIT METHOD.
 END METHOD WriteOrder.

 END CLASS Orders.
```

The class and method definitions for the user interface class:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  UserInterface INHERITS SOMObject.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in class definition
 REPOSITORY.
     CLASS SOMObject IS 'SOMObject'
     CLASS UserInterface IS 'UserInterface'.
```

Method Example

```
 DATA DIVISION.
* Define instance data
 WORKING-STORAGE SECTION.
 01  uif-action  PIC X(10).
     88  uif-add     VALUE 'AddItem'.
     88  uif-delete  VALUE 'DeleteItem'.
     88  uif-quit    VALUE 'Quit'.
 01  uif-item    PIC X(5).

 PROCEDURE DIVISION.

*  Method to get input from customer - action and item
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadUserInput.

 DATA DIVISION.
 LINKAGE SECTION.
 01  action  PIC X(10).
 01  item    PIC X(5).

 PROCEDURE DIVISION USING item action.
     DISPLAY 'Enter the action:  add, delete, quit'.
     ACCEPT action FROM SYSIN.
     MOVE FUNCTION UPPER-CASE (action) TO action.
     EVALUATE TRUE
         WHEN action = 'ADD'
             SET uif-add TO TRUE
             PERFORM Get-Item
         WHEN action = 'DELETE'
             SET uif-delete TO TRUE
             PERFORM Get-Item
         WHEN action = 'QUIT'
             SET uif-quit TO TRUE
     END-EVALUATE.
     MOVE uif-action TO action.
     EXIT METHOD.

 Get-Item.
     DISPLAY 'Enter the item'.
     ACCEPT item FROM SYSIN.
     MOVE item TO uif-item.

 END METHOD ReadUserInput.

* Method to inform customer how action was completed
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteUserMessage.

 DATA DIVISION.
 LINKAGE SECTION.
 01  flag  PIC 9.
```

```
 PROCEDURE DIVISION USING flag.
     IF flag = 0
        DISPLAY uif-action
                ' successfully completed on '
                uif-item
     ELSE
        DISPLAY uif-action
                ' unsuccessfully completed on '
                uif-item
     END-IF.
     EXIT METHOD.

 END METHOD WriteUserMessage.

*Method to display final order information
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteUserOutput.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 77  formated-cost  PIC $Z,ZZZ,ZZ9.99.
 LINKAGE SECTION.
 01  total-cost    PIC 9(7)V99.
 01  order-number  PIC 9(5).

 PROCEDURE DIVISION USING total-cost order-number.
     MOVE total-cost TO formated-cost.
     DISPLAY 'Your order costs ' formated-cost.
     DISPLAY 'Your order number is ' order-number.
     EXIT METHOD.

 END METHOD WriteUserOutput.

 END CLASS UserInterface.
```

Writing a Client Definition

Any program that requests services from methods in a class is a client program. The client program consists of the usual four divisions:

- IDENTIFICATION DIVISION
- ENVIRONMENT DIVISION
- DATA DIVISION
- PROCEDURE DIVISION

Method Services: A method may request services from another method. Therefore, a method can be a client and use the statements discussed in this section.

Client IDENTIFICATION DIVISION: Required

The client IDENTIFICATION DIVISION is coded as usual.

Client ENVIRONMENT DIVISION: Required

In the ENVIRONMENT DIVISION of a client, you describe the particular computer environment in which you are working and relate your class names to external System Object Model (SOM) names. For example:

```
Environment Division.      Required
Configuration Section.     Required
Repository.                Required
    Client UserInterface is 'UserInterface'
    Client Orders is 'Orders'.
```

REPOSITORY Paragraph

The REPOSITORY paragraph declares to the compiler that the specified user-defined word is a class name and optionally relates the class name to an external class name in the SOM interface repository. You must specify any class name you explicitly reference in your program in the REPOSITORY paragraph. In the example above, `Orders` and `UserInterface` are the only two classes this program references.

Client DATA DIVISION: Optional

In the DATA DIVISION of a client, you describe the data the client needs. Since the client is using classes, it needs one or more special data items called *object references*. Object references are handles to instances of classes the program creates. All requests to a method are handled through an object reference to the instance of the class that defined the method. For example:

```
Data Division.
Working-Storage Section.
01  orderObj Usage Object Reference Orders.
01  userObj  Usage Object Reference UserInterface.
01  univObj  Usage Object Reference.
```

The phrase USAGE OBJECT REFERENCE indicates a data item is used as a handle for an instance.

In the above example, three object references are defined. The first two, `orderObj` and `userObj` are *typed* object references because a class name appears after the OBJECT REFERENCE phrase. Thus, `orderObj` can only be used to reference instances of the `Orders` class, or one of its subclasses. Likewise, `userObj` can only be used to reference instances of the `UserInterface` class, or one of its subclasses. The other object reference, `univObj`, does not have a class name after its OBJECT REFERENCE phrase. It is a *universal* object reference and can reference instances of any class.

Remember: Class names used on the OBJECT REFERENCE phrase must be defined in the REPOSITORY paragraph of the CONFIGURATION SECTION.

Client PROCEDURE DIVISION: Optional

The client PROCEDURE DIVISION contains code to create and free instances of classes, manipulate object reference data items, and invoke methods.

Creating and Freeing Instances of Classes

Before anything can be done with methods in a class, an instance of the class must be created. SOM provides a method, 'somNew', to create an instance of a class. For example:

```
Invoke Orders 'somNew' Returning orderObj.
```

creates an instance of the `Orders` class and assigns its handle to the object reference `orderObj`.

When 'somNew' executes it automatically invokes 'somInit', another SOM method, that you can override to initialize your instance data.

Remember: The class name, in this case `Orders`, must be defined in the REPOSITORY paragraph of the CONFIGURATION SECTION. And the object reference, in this case `orderObj`, must be defined as USAGE OBJECT REFERENCE in the DATA DIVISION.

When you finish with an instance of a class, you should free it. Again, SOM provides a method, 'somFree', to free the instance. For example:

```
Invoke orderObj 'somFree'.
```

frees the instance of `orderObj`; `orderObj` now has an undefined value. When 'somFree' executes it automatically invokes 'somUninit', another SOM method that you can override to save or display your instance data.

Manipulating Object References

Object references can be compared in conditional statements. For example:

```
If orderObj = Null ...
If orderObj = Nulls ...
If orderObj = univObj ...
```

are all valid uses of object references in an IF statement. The first and second IF statements check whether `orderObj` is a null object reference (refers to no instance). The third IF statement checks whether `orderObj` and `univObj` refer to the same instance.

Note: In a method there is a forth form of object reference conditional:

```
If orderObj = Self ...
```

This checks whether the instance on which the method was invoked, `SELF`, refers to the same instance as `orderObj`.

It may be necessary to make an object reference null or make one object reference refer to the same instance as another object reference. The SET statement takes care of these situations:

```
Set orderObj To Null.
Set univObj To orderObj.
```

In the first SET statement, orderObj is set to NULL.

In the second SET statement, univObj is made to refer to the instance to which orderObj refers. In this syntax, if the receiver (univObj) is a universal object reference then the sender (orderObj) can be either a universal or typed object reference. However, if the receiver is a typed object reference the sender must also be a typed object reference and typed to the same class or a subclass.

Note: In a method there is a third form of SET object reference:

```
Set orderObj To Self.
```

This makes the receiver (orderObj) refer to the same instance on which the method was invoked, SELF.

Invoking Methods

To receive service from a method, the method must be invoked with the INVOKE statement. For example:

```
Invoke Orders 'somNew' Returning orderObj.
Invoke orderObj 'AddItem' Using item Returning flag.
```

In the first INVOKE, a class name is used to create a new instance whose handle is returned in the object reference orderObj. The class name, Orders, must be defined in the REPOSITORY paragraph of the CONFIGURATION SECTION. The object reference, orderObj, must be define as either an universal object reference or a typed to class Orders object reference.

In the second INVOKE, an object reference, orderObj, is used to invoke the method AddItem. The general syntax of this form of INVOKE is one of the following:

```
Invoke objref 'literal-name'.
Invoke objref identifier-name.
```

In both cases the invoked method must be defined in the class for which the object reference, objref, is an instance. If the identifier-name form of the method is used, the object reference, objref, must by an universal object reference.

Conformance between the invoked method and the object reference is checked at compile time if the following three items are all true:

1. objref is a typed object reference.
2. The literal form of the method name is used in the INVOKE statement.
3. The TYPECHK compile option is specified.

Otherwise, conformance requirements are checked at run time. Run-time checking, however, is not as thorough as compile-time checking.

INVOKE has the optional scope terminator END-INVOKE. The USING and RETURNING phrases on the INVOKE work the same as they do on the CALL statement. Also, INVOKE has the optional ON EXCEPTION and NOT ON EXCEPTION phrases like the CALL statement. See *IBM COBOL Language Reference*. for a discussion of USING, RETURNING, ON EXCEPTION, and NOT ON EXCEPTION.

The RETURN-CODE special register is not set by an INVOKE to a method.

Complete Client Example

A possible client program for the mail-order catalog using the Order and UserInterface classes:

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID.  'PhoneOrders'.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
*
*  Declare the classes used in the program
 REPOSITORY.
     CLASS Orders IS 'Orders'
     CLASS UserInterface IS 'UserInterface'.

 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
*  Declare the object references used in the program
 77  orderObj  USAGE OBJECT REFERENCE Orders.
 77  userObj  USAGE OBJECT REFERENCE UserInterface.
*
*  Declare other data items used in the program
 77  order-number  PIC 9(5).
 77  total-cost  PIC 9(7)V99.
 77  item  PIC X(5).
 77  action  PIC X(10).
 77  flag  PIC 9.

 PROCEDURE DIVISION.
*
*  Create an instance of the UserInterface class - userObj
     INVOKE UserInterface 'somNew' RETURNING userObj.
*
*  Create an instance of the Orders class - orderObj
     INVOKE Orders 'somNew' RETURNING orderObj.
*
*  Read customer input - action and item
     INVOKE userObj 'ReadUserInput' USING item action.

*
*  Begin customer driven loop based on action
     PERFORM UNTIL action = 'Quit'
*
*  Do appropriate action
          IF action (1:3) = 'Add'
             INVOKE orderObj 'AddItem' USING item
                                       RETURNING flag
          ELSE
```

```
            INVOKE orderObj 'DeleteItem' USING item
                                         RETURNING flag
          END-IF
*
*  Display result of action
          INVOKE userObj 'WriteUserMessage' USING flag
*
*  Read customer input - action and item
          INVOKE userObj 'ReadUserInput' USING item action
       END-PERFORM.
*  End customer driven loop based on action
*

*
*  Calculate the total cost of the order
       INVOKE orderObj 'ComputeCost' USING total-cost.
*
*  Determine the order number
       INVOKE orderObj 'getOrderNumber'
            RETURNING order-number.
*
*  Display information about the order
       INVOKE userObj 'WriteUserOutput'
           USING total-cost order-number.

*
*  Write the order to a file
       INVOKE orderObj 'WriteOrder'.

*
*  Free the object instances - orderObj and userObj
       INVOKE orderObj 'somFree'.
       INVOKE userObj 'somFree'.

       STOP RUN.
 END PROGRAM 'PhoneOrders'.
```

Writing a Subclass Definition

A subclass, sometimes called a child class, is a specialization of its superclass, sometimes called a parent class. The subclass is related to its superclass by an *is-a* type relationship. This means the phrase “Subclass S is a type of superclass P” makes sense within the application.

Subclassing has several advantages:

- Reuse of code.

  A subclass can reuse methods already existing in another class through inheritance.

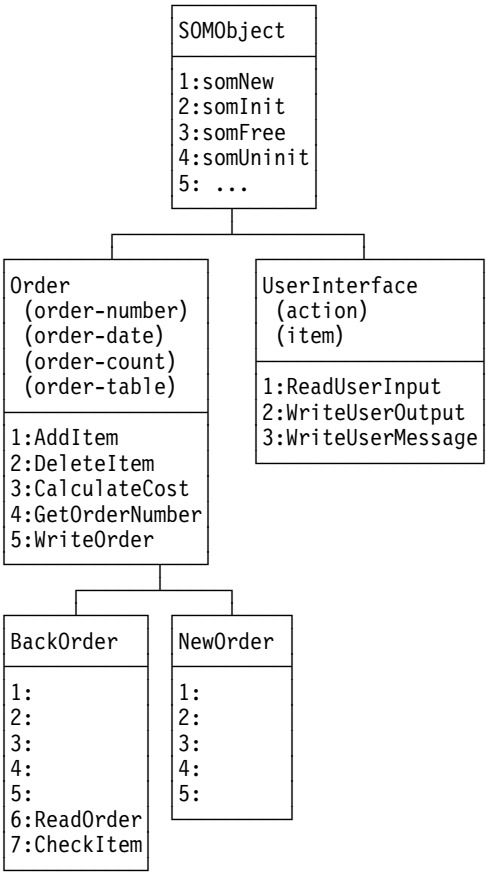
- More specific class.

A subclass can add new methods to handle specific instances the superclass does not handle.

- Change in action.

  A subclass can override a method inherited from its superclass. Overriding can be anything from a few minor changes in how the method works to a complete overhaul of what the method does.

In the mail-order catalogue application, `Order` is a general class. One of the first things you discover working with `Order` is there are two kinds of orders: new order and back order. While both new order and back order have all the characteristics of order, back order also has the characteristic of requiring the order be read from the file and checking the status of the items. It might make sense to make new order and back order subclasses of order, diagramed as follows:



A number and colon with nothing after then represent a method inherited from a superclass.

Subclass ENVIRONMENT DIVISION

In COBOL, a subclass inherits the methods from its superclass. A subclass may change, or override, one or more methods inherited from its superclass using the OVERRIDE clause on the METHOD-ID. Also, a subclass may add new methods it needs to perform its services.

In COBOL, instance data is private so the superclass must provide methods to allow the subclass to access instance data. A subclass can retrieve values from or store values in the instance data using the methods provided by the superclass. A subclass may also introduce new instance data of its own.

Multiple inheritance, inheriting from more than one superclass, is allowed in COBOL. Should there be a conflict in method names between two superclasses, the conflict is resolved according to the System Object Model (SOM) rules. See *SOMobjects Developers Toolkit User Guide Version 2.1* for an example.

Subclass IDENTIFICATION DIVISION: Required

In the IDENTIFICATION DIVISION of a subclass, you name the subclass and provide inheritance information for it. Optionally, you may give other identifying information. For example:

```
Identification Division.                Required
Class-Id.  BackOrder INHERITS Order.    Required
```

CLASS-ID Paragraph

The CLASS-ID paragraph names the subclass and indicates from what superclass or superclasses the subclass inherits. In the example above, `BackOrder` is the class name. It inherits all the methods from `Order`. Also, it can access `Order` instance data if `Order` provides methods to get and set its instance data.

The name(s) of the superclass(es) must be specified in the REPOSITORY paragraph in the ENVIRONMENT DIVISION (see "REPOSITORY Paragraph"). `BackOrder` may optionally be specified in the REPOSITORY paragraph.

Subclass ENVIRONMENT DIVISION: Required

In the ENVIRONMENT DIVISION of a subclass, you relate your subclass and class names to external System Object Model (SOM) names. For example:

```
Environment Division.       Required
Configuration Section.      Required
Repository.                 Required
    Class BackOrder is 'BackOrder'
    Class Order is 'Order'.
```

REPOSITORY Paragraph

The REPOSITORY paragraph relates your subclass and class names to the subclass and class names in the SOM interface repository. You must include:

- User-written classes from which your subclass is inheriting.
- Metaclass to which your subclass belongs.

Discussed in "Writing a Metaclass Definition" on page 250.

- Any class referenced in methods introduced by the subclass.

You may optionally include the name of the subclass you are defining. If you do not include the name of your subclass, it is treated as all upper-case regardless of how you typed it on the CLASS-ID. In the example above, `BackOrder` is stored in the SOM interface repository in mixed-case.

Subclass

DATA DIVISION: Optional

In the DATA DIVISION of a subclass, you describe any extra instance data the subclass needs. For example:

```
Data Division.
Working-Storage Section.
01  order-status  PIC X(3).
```

A subclass DATA DIVISION contains only a WORKING-STORAGE SECTION.

WORKING-STORAGE SECTION

A subclass WORKING-STORAGE SECTION describes instance data that is statically allocated when the instance is created and exists until the instance is freed. By default, the data is global to all the methods introduced by the subclass. Instance data in a COBOL subclass is *private*. Thus, it cannot be referenced directly by any other class or subclass.

Subclass PROCEDURE DIVISION: Optional

The subclass PROCEDURE DIVISION contains only method definitions. A subclass definition must be properly terminated with an END CLASS statement. For example:

```
End Class BackOrder.
```

marks the end of the `BackOrder` subclass.

Subclass Method IDENTIFICATION DIVISION: Optional

Use the IDENTIFICATION DIVISION to name a method and to optionally give other identifying information. The name of each method in a subclass must be unique. For example:

```
Identification Division.
Method-ID.  ReadOrder.
```

METHOD-ID Paragraph

Use the METHOD-ID PARAGRAPH to name the method. Other methods or programs use this name to invoke the method.

If the subclass defines a method whose name exists in a superclass the OVERRIDE clause must be specified on the METHOD-ID. For example :

```
Identification Division.
Method-Id.  AddItem Override.
```

When an object reference that is a handle to the `BackOrder` subclass invokes `AddItem`, this method is invoked rather than the method in the superclass `Order`.

Note: In a method, a subclass can invoke an overridden superclass method by using the INVOKE form:

```
Invoke Super 'AddItem'.
```

This invokes the method `AddItem` defined in the superclass rather than the method `AddItem` defined in the subclass.

In the case of multiple inheritance, a subclass may inherit several methods with the same name from different parents. To specify precisely which method from which parent is invoked use the following INVOKE form:

```
Invoke Class-A of Super 'AddItem'.
```

This invokes the method `AddItem` defined in the superclass Class-A rather than the method `AddItem` defined in any other superclass or in the subclass.

Subclass Method ENVIRONMENT DIVISION: Optional

The subclass method ENVIRONMENT DIVISION is coded in the same way a class method ENVIRONMENT DIVISION is coded. See “Method ENVIRONMENT DIVISION: Optional” on page 221 for a discussion of the class method ENVIRONMENT DIVISION.

Subclass Method DATA DIVISION: Optional

The subclass method DATA DIVISION is coded in the same way a class method DATA DIVISION is coded. See “Method DATA DIVISION: Optional” on page 221 for a discussion of the class method DATA DIVISION.

If the same data item is used in both the subclass DATA DIVISION and the method DATA DIVISION, a reference in the method to the data name refers to the data item in the method DATA DIVISION. The method DATA DIVISION takes precedence.

Subclass Method PROCEDURE DIVISION: Optional

In the PROCEDURE DIVISION of a subclass method, you code the executable statements to complete the service the method is expected to provide. A subclass method definition must be properly terminated with an END METHOD statement. See “Method PROCEDURE DIVISION: Optional” on page 222 for information about coding a method.

Complete Subclass with Methods Example

The new class and method definitions for the user interface class:

Subclass Example

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  UserInterface INHERITS SOMObject.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in class definition
 REPOSITORY.
     CLASS SOMObject IS 'SOMObject'
     CLASS UserInterface IS 'UserInterface'.

 DATA DIVISION.
* Define instance data
 WORKING-STORAGE SECTION.
 01  uif-action  PIC X(10).
     88  uif-add     VALUE 'AddItem'.
     88  uif-delete  VALUE 'DeleteItem'.
     88  uif-quit    VALUE 'Quit'.
 01  uif-item    PIC X(5).
 PROCEDURE DIVISION.

* Method to read customer input - request
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadUserRequest.

 DATA DIVISION.
 LINKAGE SECTION.
 01  request  PIC X(6).

 PROCEDURE DIVISION USING request.
     DISPLAY 'Enter the request:  new, status'.
     ACCEPT request FROM SYSIN.
     MOVE FUNCTION UPPER-CASE (request) TO request.
     EXIT METHOD.
 END METHOD ReadUserRequest.

* Method to read customer input for new request - action and item
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadUserInput1.

 DATA DIVISION.
 LINKAGE SECTION.
 01  action  PIC X(10).
 01  item    PIC X(5).

 PROCEDURE DIVISION USING item action.
     DISPLAY 'Enter the action:  add, delete, quit'.
     ACCEPT action FROM SYSIN.
     MOVE FUNCTION UPPER-CASE (action) TO action.
     EVALUATE TRUE
         WHEN action = 'ADD'
             SET uif-add TO TRUE
             PERFORM Get-Item
```

```
            WHEN action = 'DELETE'
                SET uif-delete TO TRUE
                PERFORM Get-Item
            WHEN action = 'QUIT'
                SET uif-quit TO TRUE
        END-EVALUATE.
        MOVE uif-action TO action.
        EXIT METHOD.

 Get-Item.
        DISPLAY 'Enter the item'.
        ACCEPT item FROM SYSIN.
        MOVE item TO uif-item.
 END METHOD ReadUserInput1.

* Method to read customer input for status request - order number
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadUserInput2.

 DATA DIVISION.
 LINKAGE SECTION.
 01  acct-numb  PIC 9(5).

 PROCEDURE DIVISION USING acct-numb.
        DISPLAY 'Enter the account number'.
        ACCEPT acct-numb FROM SYSIN.
        EXIT METHOD.
 END METHOD ReadUserInput2.

* Method to inform customer how action was completed
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteUserMessage.

 DATA DIVISION.
 LINKAGE SECTION.
 01  flag  PIC 9.

 PROCEDURE DIVISION USING flag.
        IF flag = 0
           DISPLAY uif-action
                   ' successfully completed on '
                   uif-item
        ELSE
           DISPLAY uif-action
                   ' unsuccessfully completed on '
                   uif-item
        END-IF.
        EXIT METHOD.
 END METHOD WriteUserMessage.

* Method to display order information
 IDENTIFICATION DIVISION.
```

```
 METHOD-ID.  WriteUserOutput.
 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 77  formated-cost  PIC $Z,ZZZ,ZZ9.99.
 LINKAGE SECTION.
 01  total-cost    PIC 9(7)V99.
 01  order-number  PIC 9(5).
 PROCEDURE DIVISION USING total-cost order-number.
     MOVE total-cost TO formated-cost.
     DISPLAY 'Your order costs ' formated-cost.
     DISPLAY 'Your order number is ' order-number.
     EXIT METHOD.
 END METHOD WriteUserOutput.

* Method to display out of stock items
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteUserStatus.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 77  sub  PIC 99.
 LINKAGE SECTION.
 01  out-table.
     02  out-entry  OCCURS 10 TIMES.
         03  out-item  PIC X(5).
 01  out-count  PIC 99.

 PROCEDURE DIVISION USING out-table out-count.
     IF out-count > 0
        PERFORM VARYING sub FROM 1 BY 1
                UNTIL sub > out-count
           DISPLAY 'Out of stock '
                   out-item (sub)
        END-PERFORM
     END-IF.
     EXIT METHOD.
 END METHOD WriteUserStatus.

 END CLASS UserInterface.
```

The new class and method definitions for the order class:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  Orders INHERITS SOMObject.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in program
 REPOSITORY.
     CLASS SOMObject IS 'SOMObject'
     CLASS Orders IS 'Orders'.
```

Subclass Example

```
 DATA DIVISION.
* Define instance data
 WORKING-STORAGE SECTION.
 01  order-number  PIC 9(5).
 01  order-date    PIC X(8).
 01  order-count   PIC 99.
 01  order-table.
     02  order-entry  OCCURS 10 TIMES.
         03  order-item  PIC X(5).
 PROCEDURE DIVISION.

* Method to intiialize instance data
*  - this overrides the default 'somInit' method
 IDENTIFICATION DIVISION.
 METHOD-ID.  'somInit' OVERRIDE.

 PROCEDURE DIVISION.
     MOVE FUNCTION CURRENT-DATE(1:8) TO order-date.
     COMPUTE order-number = FUNCTION RANDOM ( 99999 ).
     MOVE 0 TO order-count.
     INITIALIZE order-table.
     EXIT METHOD.
 END METHOD 'somInit'.

* Method to set instance data read by subclass
 IDENTIFICATION DIVISION.
 METHOD-ID.  'setInstanceData'.

 DATA DIVISION.
 LINKAGE SECTION.
 01  in-order.
     02  in-order-number  PIC 9(5).
     02  in-order-date    PIC X(8).
     02  in-order-count   PIC 99.
     02  in-order-table.
         03  in-order-entry  OCCURS 10 TIMES.
             04  in-order-item  PIC X(5).

 PROCEDURE DIVISION USING in-order.
     MOVE in-order-number TO order-number.
     MOVE in-order-date   TO order-date.
     MOVE in-order-count  TO order-count.
     MOVE in-order-table  TO order-table.
     EXIT METHOD.
 END METHOD 'setInstanceData'.

* Method to get instance data and give it to subclass
 IDENTIFICATION DIVISION.
 METHOD-ID.  'getInstanceData'.

 DATA DIVISION.
 LINKAGE SECTION.
```

```
 01  out-order.
     02  out-order-number  PIC 9(5).
     02  out-order-date    PIC X(8).
     02  out-order-count   PIC 99.
     02  out-order-table.
         03  out-order-entry  OCCURS 10 TIMES.
             04  out-order-item  PIC X(5).

 PROCEDURE DIVISION USING out-order.
     MOVE order-number TO out-order-number.
     MOVE order-date   TO out-order-date.
     MOVE order-count  TO out-order-count.
     MOVE order-table  TO out-order-table.
     EXIT METHOD.
 END METHOD 'getInstanceData'.

*Method to add an item to an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  AddItem.
 DATA DIVISION.

 LOCAL-STORAGE SECTION.
 77  sub  PIC 99.
 01  found-flag  PIC 9  VALUE 1.
     88  found  VALUE 0.
 LINKAGE SECTION.
 01  in-item   PIC X(5).
 01  add-flag  PIC 9.

 PROCEDURE DIVISION USING in-item
                    RETURNING add-flag.
     MOVE 1 TO add-flag.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL (sub > 10) OR (found)
        IF order-item (sub) = SPACES
           MOVE in-item TO order-item (sub)
           ADD 1 TO order-count
           MOVE 0 TO add-flag
           SET found TO TRUE
        END-IF
     END-PERFORM.
     EXIT METHOD.
 END METHOD AddItem.

*Method to delete an item from an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  DeleteItem.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 77  sub  PIC 99.
 01  found-flag  PIC 9  VALUE 1.
```

```
    88  found  VALUE 0.
 LINKAGE SECTION.
 01  out-item     PIC X(5).
 01  delete-flag  PIC 9.

 PROCEDURE DIVISION USING out-item
                   RETURNING delete-flag.
     MOVE 1 TO delete-flag.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL (sub > 10) OR (found)
        IF order-item (sub) = out-item
           MOVE SPACES TO order-item (sub)
           SUBTRACT 1 FROM order-count
           MOVE 0 TO delete-flag
           SET found TO TRUE
        END-IF
     END-PERFORM.
     EXIT METHOD.
 END METHOD DeleteItem.

* Method to compute the total cost of an order
 IDENTIFICATION DIVISION.
 METHOD-ID.  ComputeCost.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 77  sub   PIC 99.
 77  cost  PIC 9(5)V99.
 LINKAGE SECTION.
 01  total-cost  PIC 9(7)V99.

 PROCEDURE DIVISION USING total-cost.
     MOVE 0 TO total-cost.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL sub > order-count
*  Call a subroutine
*   NOTE:  The subroutine code is not
*          included in this example.
        CALL 'InventoryGetCost'
           USING order-item (sub) cost
        ADD cost TO total-cost
     END-PERFORM.
     EXIT METHOD.
 END METHOD ComputeCost.

* Method to return the order number
 IDENTIFICATION DIVISION.
 METHOD-ID.  'getOrderNumber'.

 DATA DIVISION.
 LINKAGE SECTION.
 01  ord-num  PIC 9(5).
```

```
 PROCEDURE DIVISION RETURNING ord-num.
     MOVE order-number TO ord-num.
     EXIT METHOD.
 END METHOD 'getOrderNumber'.

* Method to write completed order to a file
 IDENTIFICATION DIVISION.
 METHOD-ID.  WriteOrder.

 ENVIRONMENT DIVISION.
 INPUT-OUTPUT SECTION.
 FILE-CONTROL.
     SELECT order-file ASSIGN OrdrFile.

 DATA DIVISION.
 FILE SECTION.
 FD  order-file  EXTERNAL.
 01  order-record  PIC X(80).
 LOCAL-STORAGE SECTION.
 01  print-line.
     02  print-order-number  PIC 9(5).
     02  print-order-date    PIC X(8).
     02  print-order-count   PIC 99.
     02  print-order-table.
         03  print-order-entry  OCCURS 10 TIMES.
             04  print-order-item  PIC X(5).

 PROCEDURE DIVISION.
     OPEN OUTPUT order-file.
     MOVE order-number TO print-order-number.
     MOVE order-date   TO print-order-date.
     MOVE order-count  TO print-order-count.
     MOVE order-table  TO print-order-table.
     WRITE order-record FROM print-line.
     CLOSE order-file.
     EXIT METHOD.
 END METHOD WriteOrder.

 END CLASS Orders.
```

The subclass and method definitions for the new order subclass:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  NewOrders INHERITS Orders.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in subclass defintion
 REPOSITORY.
     CLASS NewOrders IS 'NewOrders'
     CLASS Orders IS 'Orders'.
```

```
 DATA DIVISION.

 PROCEDURE DIVISION.

* All methods are inherited from superclass

 END CLASS NewOrders.
```

The subclass and method definitions for the back order subclass:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  BackOrders INHERITS Orders.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in subclass definition
 REPOSITORY.
     CLASS BackOrders IS 'BackOrders'
     CLASS Orders IS 'Orders'.
 DATA DIVISION.

 PROCEDURE DIVISION.

* Method to read back order from file
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadOrder.

 ENVIRONMENT DIVISION.
 INPUT-OUTPUT SECTION.
 FILE-CONTROL.
     SELECT backorder-file ASSIGN BackFile.

 DATA DIVISION.
 FILE SECTION.
 FD  backorder-file  EXTERNAL.
 01  backorder-record  PIC X(80).
 LOCAL-STORAGE SECTION.
 01  backorder.
     02  backorder-number  PIC 9(5).
     02  backorder-date    PIC X(8).
     02  backorder-count   PIC 99.
     02  backorder-table.
         03  backorder-entry  OCCURS 10 TIMES.
             04  backorder-item  PIC X(5).
 77  eof-flag  PIC 9  VALUE 1.
     88  eof  VALUE 0.
 LINKAGE SECTION.
 01  order-number  PIC 9(5).

 PROCEDURE DIVISION USING order-number.
     OPEN INPUT backorder-file.
```

```
     PERFORM UNTIL eof
        READ backorder-file INTO backorder
           AT END
              SET eof TO TRUE
           NOT AT END
              IF order-number = backorder-number
                 INVOKE SELF 'setInstanceData' USING backorder
              END-IF
        END-READ
     END-PERFORM.
     CLOSE backorder-file.
     EXIT METHOD.
 END METHOD ReadOrder.

* Method to check whether item is still not in stock
 IDENTIFICATION DIVISION.
 METHOD-ID.  CheckItem.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 01  backorder.
     02  backorder-number  PIC 9(5).
     02  backorder-date    PIC X(8).
     02  backorder-count   PIC 99.
     02  backorder-table.
         03  backorder-entry  OCCURS 10 TIMES.
             04  backorder-item  PIC X(5).
 77  sub  PIC 99.
 77  status-flag  PIC 9.
     88  in-stock   VALUE 0.
     88  out-stock  VALUE 1.
 LINKAGE SECTION.
 01  out-table.
     02  out-entry  OCCURS 10 TIMES.
         03  out-item  PIC X(5).
 01  out-count  PIC 99.

 PROCEDURE DIVISION USING out-table out-count.
     INVOKE SELF 'getInstanceData' USING backorder.
     MOVE 0 TO out-count.
     PERFORM VARYING sub FROM 1 BY 1
              UNTIL sub > backorder-count
*  Call a subroutine
*   NOTE:  The subroutine code is not
*          included in this example.
        CALL 'InventoryGetItem'
            USING backorder-item (sub) status-flag
        IF out-stock
           ADD 1 TO out-count
           MOVE backorder-item (sub) TO out-item (out-count)
        END-IF
     END-PERFORM.
```

```
    EXIT METHOD.
 END METHOD CheckItem.

 END CLASS BackOrders.
```

A possible new client program:

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID.  'PhoneOrders'.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
*
*  Declare the classes used in the program
 REPOSITORY.
     CLASS NewOrders IS 'NewOrders'
     CLASS BackOrders IS 'BackOrders'
     CLASS UserInterface IS 'UserInterface'.

 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
*  Declare the object references used in the program
*  Note:  univObj is a universal object reference
 77  univObj  USAGE OBJECT REFERENCE.
 77  userObj  USAGE OBJECT REFERENCE UserInterface.
*
*  Declare other data items used in the program
 77  order-number  PIC 9(5).
 77  total-cost  PIC 9(7)V99.
 77  out-count  PIC 9(2).
 77  request  PIC X(6).
 77  action  PIC X(10).
 77  flag  PIC 9.
 77  item  PIC X(5).
 01  item-table.
     02  item-entry  OCCURS 10 TIMES.
         03  item-element  PIC X(5).

 PROCEDURE DIVISION.
*
*  Create an instance of the UserInterface class - userObj
     INVOKE UserInterface 'somNew' RETURNING userObj.
*
*  Read customer input - request
     INVOKE userObj 'ReadUserRequest' USING request.
*
*  What is the customer's request?
     IF request = 'STATUS'
        PERFORM CheckBackOrder
     ELSE
        PERFORM CreateNewOrder
```

```
     END-IF.
*
*  Free the instance of the UserInterface class - userObj
     INVOKE userObj 'somFree'.

     STOP RUN.

 CreateNewOrder.
*
*  Create an instance of the NewOrders class - univObj
     INVOKE NewOrders 'somNew' RETURNING univObj.
*
*  Read customer input - action and item
     INVOKE userObj 'ReadUserInput1' USING item action.

*
*  Begin customer driven loop based on action
     PERFORM UNTIL action = 'Quit'
*
*  Do appropriate action
          IF action (1:3) = 'Add'
             INVOKE univObj 'AddItem' USING item
                                      RETURNING flag
          ELSE
             INVOKE univObj 'DeleteItem' USING item
                                         RETURNING flag
          END-IF
*
*  Display result of action
          INVOKE userObj 'WriteUserMessage' USING OMITTED flag
*
*  Read customer input - action and item
          INVOKE userObj 'ReadUserInput1' USING item action
     END-PERFORM.
*  End customer driven loop based on action
*

*
*  Calculate the total cost of the order
     INVOKE univObj 'ComputeCost' USING total-cost.
*
*  Determine the order number
     INVOKE univObj 'getOrderNumber'
           RETURNING order-number.
*
*  Display information about the order
     INVOKE userObj 'WriteUserOutput'
         USING total-cost order-number.

*
*  Write the order to a file
     INVOKE univObj 'WriteOrder'.
```

```
*
*  Free the NewOrders instance - univObj
     INVOKE univObj 'somFree'.

 CheckBackOrder.
*
*  Create an instance of the BackOrders class - univObj
     INVOKE BackOrders 'somNew' RETURNING univObj.
*
*  Read customer input - order number
     INVOKE userObj 'ReadUserInput2' USING order-number.
*
*  Read the back-ordered information from a file
     INVOKE univObj 'ReadOrder' USING order-number.
*
*  Check whether the back-ordered items are now in stock
     INVOKE univObj 'CheckItem' USING item-table out-count.
*
*  Display the status of the back-ordered items
     INVOKE userObj 'WriteUserStatus' USING item-table out-count.
*
*  Free the BackOrders instance - univObj
     INVOKE univObj 'somFree'.

 END PROGRAM 'PhoneOrders'.
```

Writing a Metaclass Definition

A metaclass is a special type of class whose instances are called class-objects. Class-objects are the run-time objects that represent SOM classes. Object-oriented COBOL applications either use the default metaclasses provided automatically by the SOM environment, or explicit metaclass definitions may be provided for specialized purposes.

Metaclasses have their own methods and can have their own instance data. The most common use of a metaclass is to control how an instance of a class is created. The method in the metaclass that creates the instance of a class is a *constructor* method. Metaclasses are also useful when multiple instances of a class are created and data must be gathered from all the instances. See the *SOMobjects Developers Toolkit User Guide Version 2.1* and *SOMobjects Developers Toolkit Programmers Reference Manual Version 2.1* (available online) for further details on metaclasses and their uses.

In the mail-order catalogue application, `BackOrder` required the reading of a file to establish its instance data. Reading the file cannot be done by `somInit` because an order number is needed as a parameter. This is a good place to use a metaclass with a constructor method to create the instance of `BackOrder` and read the file.

Metaclass IDENTIFICATION DIVISION: Required

In the IDENTIFICATION DIVISION of a metaclass, you name the metaclass and provide inheritance information for it. Optionally, you may give other identifying information. For example:

```
Identification Division.                        Required
Class-Id.  MetaBackOrder INHERITS SOMClass.     Required
```

CLASS-ID Paragraph

The CLASS-ID paragraph names the metaclass and indicates from what base System Object Model (SOM) class the metaclass inherits. In the example above, `MetaBackOrder` is the class name. It inherits from the base SOM class `SOMClass`. All metaclasses inherit directly or indirectly from `SOMClass`.

`SOMClass` must be specified in the REPOSITORY paragraph in the ENVIRONMENT DIVISION (see "REPOSITORY Paragraph"). `MetaBackOrder` may optionally be specified in the REPOSITORY paragraph.

Metaclass ENVIRONMENT DIVISION: Required

In the ENVIRONMENT DIVISION of a metaclass, you relate your metaclass names to external SOM names. For example:

```
Environment Division.       Required
Configuration Section.      Required
Repository.                 Required
    Class MetaBackOrder is 'MetaBackOrder'
    Class SOMClass is 'SOMClass'.
```

REPOSITORY Paragraph

The REPOSITORY paragraph relates your metaclass and class names to the metaclass and class names in the SOM interface repository. You must include:

- SOM base classes.

  In the example above, `CLASS SOMClass IS 'SOMClass'` indicates what you are calling SOMClass in your COBOL program is also called SOMClass in the SOM repository.

- User-written classes from which your metaclass is inheriting.

  Discussed in "Writing a Subclass Definition" on page 234.

- Any class referenced in methods introduced by the metaclass.

You may optionally include the name of the metaclass you are defining. If you do not include the name of your metaclass, it is treated as all upper-case regardless of how you typed it on the CLASS-ID. In the example above, `MetaBackOrder` is stored in the SOM interface repository in mixed-case.

Metaclass DATA DIVISION: Optional

In THE DATA DIVISION of a metaclass, you describe any instance data the metaclass needs. For example:

```
Data Division.
Working-Storage Section.
01  total-orders  PIC X(3).
```

A metaclass DATA DIVISION contains only a WORKING-STORAGE SECTION.

WORKING-STORAGE SECTION

A metaclass WORKING-STORAGE SECTION describes instance data that is statically allocated when the first instance of an object in the metaclass is created and exists until the COBOL run-unit terminates. By default, the data is global to all the methods introduced by the metaclass. Instance data in a COBOL metaclass is *private*. Thus, it cannot be referenced directly by any other class or metaclass.

Metaclass PROCEDURE DIVISION: Optional

The metaclass PROCEDURE DIVISION contains only method definitions. A metaclass definition must be properly terminated with an END CLASS statement. For example:

```
End Class MetaBackOrder.
```

marks the end of the `MetaBackOrder` metaclass.

Metaclass Method IDENTIFICATION DIVISION: Optional

The metaclass method IDENTIFICATION DIVISION is coded in the same way a class method IDENTIFICATION DIVISION is coded. See “Method IDENTIFICATION DIVISION: Required” on page 220 for a discussion of the class method IDENTIFICATION DIVISION.

Metaclass Method ENVIRONMENT DIVISION: Optional

The metaclass method ENVIRONMENT DIVISION is coded in the same way a class method ENVIRONMENT DIVISION is coded. See “Method ENVIRONMENT DIVISION: Optional” on page 221 for a discussion of the class method ENVIRONMENT DIVISION.

Metaclass Method DATA DIVISION: Optional

The metaclass method DATA DIVISION is coded in the same way a class method DATA DIVISION is coded. See “Method DATA DIVISION: Optional” on page 221 for a discussion of the class method DATA DIVISION.

If the same data item is used in both the metaclass DATA DIVISION and the method DATA DIVISION, a reference in the method to the data name refers to the data item in the method DATA DIVISION. The method DATA DIVISION takes precedence.

Metaclass Method PROCEDURE DIVISION: Optional

In the PROCEDURE DIVISION of a metaclass method, you code the executable statements to complete the service the method is expected to provide. For the most part, a metaclass method PROCEDURE DIVISION is coded in the same way a class method

PROCEDURE DIVISION is coded. See “Method PROCEDURE DIVISION: Optional” on page 222 for a discussion of the class method PROCEDURE DIVISION.

Constructor Method

A metaclass constructor method is usually invoked with a class name so the use of the following INVOKE form is needed in the constructor method to create an instance of the class:

```
Invoke Self 'somNew' Returning anObj.
```

This creates an instance of the class on which the method was invoked, SELF, and returns the handle to that instance in the object reference `anObj`.

Method Only: SELF can be used only in a method.

Changes to Class or Subclass Definitions

When a class or subclass uses an explicit metaclass, the name of the metaclass must be specified with the METACLASS IS clause in the CLASS-ID paragraph. For example:

```
Identification Division.
Class-Id.  BackOrder Inherits Order
                     Metaclass is MetaBackOrder.
```

Also, the name of the metaclass must be specified in the REPOSITORY paragraph of the CONFIGURATION SECTION. For example:

```
Environment Division.
Configuration Section.
Repository.
     Class MetaBackOrder Is 'MetaBackOrder'
     Class BackOrder Is 'BackOrder'
     Class Order Is 'Order'.
```

Changes to the Client Program

To use the metaclass constructor method, the client program invokes the constructor method instead of 'somNew'. For example:

```
Invoke BackOrder 'CreateObject' Using order-number Returning anObj.
```

The method `CreateObject` is defined in the metaclass for `BackOrder`. This method invokes `somNew` to create an instance, reads the data from the file using the order number, and returns the handle to the instance in the object reference `anObj`. See “Complete Metaclass with Methods Example” on page 254 for a detailed example of using a metaclass constructor method.

Any method in a metaclass can be invoked with the class name. For example:

```
Invoke BackOrder 'CountOrders'.
```

Or, a metaclass object reference can be defined as a handle to the metaclass. For example:

```
Working-Storage Section.
01  metaObj Usage Object Reference Metaclass BackOrder.
```

The object reference `metaObj` is a handle to the metaclass for `BackOrder`, not a handle to `BackOrder` itself.

The metaclass object reference is used as follows:

```
 Procedure Division.

     ⋮
 Invoke backObj 'somGetClass' Returning metaObj.
 Invoke metaObj 'CountOrders'.
```

The first INVOKE statement invokes a SOM method `somGetClass` which takes an object reference, `backObj`, to an instance and returns an object reference, `metaObj`, for the metaclass to which `backObj` belongs.

The second INVOKE statement uses the object reference to the metaclass, `metaObj` to invoke the method `CountOrders` which is defined in the metaclass. See "Complete Metaclass with Methods Example" for a detailed example of using a metaclass method.

Complete Metaclass with Methods Example

The metaclass and method definitions for the back order subclass:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  MetaBackOrders INHERITS SOMClass.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in metaclass definition
 REPOSITORY.
     CLASS MetaBackOrders IS 'MetaBackOrders'
     CLASS BackOrders IS 'BackOrders'
     CLASS SOMClass IS 'SOMClass'.

 DATA DIVISION.
* Define instance data
 WORKING-STORAGE SECTION.
 01  status-count  PIC 99.
 PROCEDURE DIVISION.

* Method to initialize instance data
 IDENTIFICATION DIVISION.
 METHOD-ID.  'somInit' OVERRIDE.

 PROCEDURE DIVISION.
     MOVE 0 TO status-count.
     EXIT METHOD.
 END METHOD 'somInit'.

* Method to create and initialize instances of BackOrders
 IDENTIFICATION DIVISION.
 METHOD-ID.  CreateBackOrders.
```

```
 DATA DIVISION.
 LINKAGE SECTION.
 01  order-number  PIC 9(5).
 01  anObj  USAGE OBJECT REFERENCE.

 PROCEDURE DIVISION USING order-number RETURNING anObj.
     INVOKE SELF 'somNew' RETURNING anObj.
     INVOKE anObj 'ReadOrder' USING order-number.
     ADD 1 TO status-count.
     EXIT METHOD.
 END METHOD CreateBackOrders.

* Method to return the number of back orders processed
 IDENTIFICATION DIVISION.
 METHOD-ID.  CountBackOrders.

 DATA DIVISION.
 LINKAGE SECTION.
 01  out-count  PIC 9(2).

 PROCEDURE DIVISION RETURNING out-count.
     MOVE status-count TO out-count.
     EXIT METHOD.
 END METHOD CountBackOrders.

 END CLASS MetaBackOrders.
```

The new subclass and method definitions for the back order subclass:

```
 IDENTIFICATION DIVISION.
 CLASS-ID.  BackOrders INHERITS Orders
                       METACLASS MetaBackOrders.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
* Declare classes used in subclass definition
 REPOSITORY.
     CLASS MetaBackOrders IS 'MetaBackOrders'
     CLASS BackOrders IS 'BackOrders'
     CLASS Orders IS 'Orders'.

 DATA DIVISION.

 PROCEDURE DIVISION.

* Method to read back order from file
 IDENTIFICATION DIVISION.
 METHOD-ID.  ReadOrder.

 ENVIRONMENT DIVISION.
 INPUT-OUTPUT SECTION.
```

```
 FILE-CONTROL.
     SELECT backorder-file ASSIGN BackFile.

 DATA DIVISION.
 FILE SECTION.
 FD  backorder-file  EXTERNAL.
 01  backorder-record  PIC X(80).
 LOCAL-STORAGE SECTION.
 01  backorder.
     02  backorder-number  PIC 9(5).
     02  backorder-date    PIC X(8).
     02  backorder-count   PIC 99.
     02  backorder-table.
         03  backorder-entry  OCCURS 10 TIMES.
             04  backorder-item  PIC X(5).
 77  eof-flag  PIC 9  VALUE 1.
     88  eof  VALUE 0.
 LINKAGE SECTION.
 01  order-number  PIC 9(5).

 PROCEDURE DIVISION USING order-number.
     OPEN INPUT backorder-file.
     PERFORM UNTIL eof
        READ backorder-file INTO backorder
           AT END
              SET eof TO TRUE
           NOT AT END
              IF order-number = backorder-number
                 INVOKE SELF 'setInstanceData' USING backorder
              END-IF
        END-READ
     END-PERFORM.
     CLOSE backorder-file.
     EXIT METHOD.
 END METHOD ReadOrder.

*Method to check whether item is still not in stock
 IDENTIFICATION DIVISION.
 METHOD-ID.  CheckItem.

 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 01  backorder.
     02  backorder-number  PIC 9(5).
     02  backorder-date    PIC X(8).
     02  backorder-count   PIC 99.
     02  backorder-table.
         03  backorder-entry  OCCURS 10 TIMES.
             04  backorder-item  PIC X(5).
 77  sub  PIC 99  VALUE 0.
 77  status-flag  PIC 9.
     88  in-stock   VALUE 0.
```

```
    88  out-stock  VALUE 1.
 LINKAGE SECTION.
 01  out-table.
     02  out-entry  OCCURS 10 TIMES.
         03  out-item  PIC X(5).
 01  out-count  PIC 99.

 PROCEDURE DIVISION USING out-table out-count.
     INVOKE SELF 'getInstanceData' USING backorder.
     MOVE 0 TO out-count.
     PERFORM VARYING sub FROM 1 BY 1
             UNTIL sub > backorder-count
*  Call a subroutine
*   NOTE:  The subroutine code is not
*          included in this example.
        CALL 'InventoryGetItem'
            USING backorder-item (sub) status-flag
        IF out-stock
           ADD 1 TO out-count
           MOVE backorder-item (sub) TO out-item (out-count)
        END-IF
     END-PERFORM.
     EXIT METHOD.
 END METHOD CheckItem.

 END CLASS BackOrders.
```

A possible new client program:

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID.  'PhoneOrders'.

 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
*
*  Declare the classes used in the program
 REPOSITORY.
     CLASS NewOrders IS 'NewOrders'
     CLASS BackOrders IS 'BackOrders'
     CLASS UserInterface IS 'UserInterface'.

 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
*  Declare the object references used in the program
 77  univObj  USAGE OBJECT REFERENCE.
*  Note:  metaObj is an object reference to a metaclass
 77  metaObj  USAGE OBJECT REFERENCE METACLASS BackOrders.
 77  userObj  USAGE OBJECT REFERENCE UserInterface.
*
*  Declare other data items used in the program
 77  order-number  PIC 9(5).
 77  total-cost  PIC 9(7)V99.
```

```
 77  out-count  PIC 9(2).
 77  request  PIC X(6).
 77  action  PIC X(10).
 77  flag  PIC 9.
 77  item  PIC X(5).
 01  item-table.
     02  item-entry  OCCURS 10 TIMES.
         03  item-element  PIC X(5).

 PROCEDURE DIVISION.
*
*  Create an instance of the UserInterface class - userObj
     INVOKE UserInterface 'somNew' RETURNING userObj.
*
*  Read customer input - request
     INVOKE userObj 'ReadUserRequest' USING request.
*
*  What is the customer's request?
     IF request = 'STATUS'
        PERFORM CheckBackOrder
     ELSE
        PERFORM CreateNewOrder
     END-IF.
*
*  Free the instance of the UserInterface class - userObj
     INVOKE userObj 'somFree'.

     STOP RUN.

 CreateNewOrder.
*
*  Create an instance of the NewOrders class - univObj
     INVOKE NewOrders 'somNew' RETURNING univObj.
*
*  Read customer input - action and item
     INVOKE userObj 'ReadUserInput1' USING item action.

*
*  Begin customer driven loop based on action
     PERFORM UNTIL action = 'Quit'
*
*  Do appropriate action
          IF action (1:3) = 'Add'
             INVOKE univObj 'AddItem' USING item
                                      RETURNING flag
          ELSE
             INVOKE univObj 'DeleteItem' USING item
                                         RETURNING flag
          END-IF
*
*  Display result of action
```

```
         INVOKE userObj 'WriteUserMessage' USING OMITTED flag
*
*  Read customer input - action and item
         INVOKE userObj 'ReadUserInput1' USING item action
     END-PERFORM.
*  End customer driven loop based on action
*

*
*  Calculate the total cost of the order
     INVOKE univObj 'ComputeCost' USING total-cost.
*
*  Determine the order number
     INVOKE univObj 'getOrderNumber'
           RETURNING order-number.
*
*  Display information about the order
     INVOKE userObj 'WriteUserOutput'
         USING total-cost order-number.

*
*  Write the order to a file
     INVOKE univObj 'WriteOrder'.

*
*  Free the NewOrders instance - univObj
     INVOKE univObj 'somFree'.

 CheckBackOrder.
*
*  Read customer input - order number
     INVOKE userObj 'ReadUserInput2' USING order-number.

*
*  Begin customer driven loop based order number
     PERFORM UNTIL order-number < 0
*
*  Create an instance of the BackOrders class (univObj) and
*   read the back order from a file using a metaclass method
        INVOKE BackOrders 'CreateBackOrders'
              USING order-number RETURNING univObj
*
*  Check whether the back-ordered items are now in stock
        INVOKE univObj 'CheckItem'
              USING item-table out-count
*
*  Display the status of the back-ordered items
        INVOKE userObj 'WriteUserStatus'
              USING item-table out-count
*
*  Read customer input - order number
        INVOKE userObj 'ReadUserInput2'
```

```
              USING order-number
     END-PERFORM.
*  End customer driven loop based on order number
*

*
*  Get an object reference to the metaclass
*  Note:  'somGetClass' is a SOM method
     INVOKE univObj 'somGetClass' RETURNING metaObj.
*
*  How many back orders were processed?
*  Note: Metaclass object reference to invoke metaclass method
     INVOKE metaObj 'CountBackOrders' RETURNING out-count.
*
*  Display number of back orders processed
     INVOKE userObj 'WriteUserMessage' USING out-count OMITTED.

*
*  Free the metaclass instance - metaObj
*  Note:  This also frees all BackOrders instances
     INVOKE metaObj 'somFree'.

 END PROGRAM 'PhoneOrders'.
```

Others the Same: Other programs stay the same as the subclass example on page 238.

Chapter 13. Using System Object Model (SOM)

System Object Model (SOM) is an object-oriented programming technology that allows class implementers to describe the *interface* for a class in a standard language called the Interface Definition Language (IDL). Unlike the object model found in formal object-oriented programming languages, SOM is language-neutral. It preserves the key object-oriented programming characteristics of encapsulation, inheritance, and polymorphism without requiring the implementer of a SOM class and user of a SOM class to use the same programming language.

Required Level: SOM 2.1 is the required level.

SOM Interface Repository

The SOM Interface Repository (IR) is a database in which the SOM Compiler optionally creates and maintains class definitions. The SOM IR is used by the COBOL compiler when compiling object-oriented COBOL programs. When compiling a class definition or client program with the IDLGEN or the TYPECHK option, the interface information for referenced classes must be present in the IR. (All referenced classes are declared in the REPOSITORY paragraph of the CONFIGURATION SECTION.)

Accessing the IR

The interface repository files to be used are specified outside the COBOL program using a SOM environment variable. The environment variable that specifies the IR is SOMIR. This environment variable is set as follows:

```
set SOMIR=c:\mydir\mycls.ir
```

If you do not set the SOMIR environment variable, the IR emitter creates a file named "som.ir" in the current directory.

SOM provides "som.ir" to include all of its types, classes, and methods. You can add your class interfaces to this SOM IR; however, this is not recommended because "som.ir" soon becomes very large. A better approach is to create an ordered list of separate IR files. SOM processes the IR list from left to right. Therefore, the leftmost IR should be SOM's "som.ir" and the rightmost IR should be the development IR since SOM permits updates only in the rightmost IR file. For example:

```
set SOMIR=c:\som\som.ir;c:\dept\dept.ir;c:\work\work.ir
```

In this case, `som.ir` is SOM's IR that is not updated, `dept.ir` is a stable department IR that is not updated, and `work.ir` is the working IR that is updated.

You may set SOMIR at the time you use it; however, it is easier to put the statement in the above example into your CONFIG.SYS (OS/2) or AUTOEXEC.BAT (Windows 95) file or set it in the System window (Windows NT). For more information see the Interface Repository chapter of the *SOMobjects Developers Toolkit User Guide Version 2.1* (available online).

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Populating the IR

The IR can be populated with interface information from COBOL classes via the following procedure:

1. Compile the class definition with the IDLGEN compiler option.
2. Compile the IDL source files with the SOM compiler, using the IR emitter.

Some COBOL class definitions with complex interdependencies may have to be compiled in two steps. For example, there may be circular compilation order dependencies, such as when two class definitions each contain references to the other. Such complex configurations may be compiled with the following procedure:

1. Compile all of the COBOL class definition source files with the IDLGEN, NOTYPECHK, and NOCOMPILE compiler options. This generates IDL files for the class interfaces, but does not perform type checking or generate an object file.
2. Compile the IDL files with the SOM compiler, using the IR emitter. This populates the IR with the class interface information.
3. Compile the COBOL class definitions again, with the NOIDLGEN and TYPECHK compiler options. This final compile performs full type checking and generates object files.

Compiling IDL Files

Compile IDL files and populate the IR using the SOM Compiler with the **-usir** option. For example:

```
sc -usir myclass.idl
```

The SOM Compiler, sc, is started with the file `myclass.idl` and **-usir** option, which means update the IR. The rightmost IR file in the SOMIR list is the one updated.

SOM Environment Variables

The following environment variables specify information that is needed by the SOM compiler, interface repository framework, and run time. For full details, see *SOMobjects Developers Toolkit User Guide Version 2.1* (available online).

SMINCLUDE

Specifies where to look for **#include** files included by the .idl file being compiled.

```
set SMINCLUDE=.;c:\toolkt20\include;c:\som\include
```

SMTMP

Specifies where to put intermediate output files. This directory should not be the same as the ones where input and output files are located.

```
set SMTMP=c:\tmp\garbage
```

SMEMIT

Specifies which emitters the SOM compiler runs.

For a COBOL class the most frequent emitter is the .h emitter which produces a header file for use by a C client of the COBOL class.

```
set SMEMIT="h"
```

For example, the following series of statements

```
set SMEMIT="h"
sc -usir myclass.idl
```

directs the SOM Compiler to produce 'myclass.h', and populate the IR from the 'myclass.idl' input specification.

SOMIR

Specifies the location of the interface repositories.

```
set SOMIR=c:\mydir\mycls.ir
```

As with the SOMIR environment variable, you can type these environment variables when you need them. However, it is easier to put the above "set" statements in your CONFIG.SYS file (OS/2) or AUTOEXEC.BAT (Windows 95) file or set them in the System window (Windows NT). For more information see the SOM Compiler chapter of the *SOMobjects Developers Toolkit User Guide Version 2.1* (available online).

System Object Model (SOM) Services

IBM COBOL implements a subset of the ANSI Object-Oriented COBOL syntax based on the SOM object-oriented engine. Not all essential object-oriented capabilities are implemented in native COBOL syntax. Instead, SOM application programming interfaces, methods and functions are used. For example, native COBOL syntax is available for class definitions, object-reference datatype, and method invocation. However object creation, destruction, initialization, and termination are handled by invoking SOM methods provided by the `SOMObject` and `SOMClass` classes. Many other SOM facilities are available to COBOL programmers either for direct use or for overriding and customizing. These are described in *SOMobjects Developers Toolkit User Guide Version 2.1* (available online).

SOM Methods and Functions

The following SOM methods and function are especially important to COBOL programmers:

somNew

A method in SOMClass to create a new object instance of a class. During creation, `somInit` is invoked for customized initialization of the object.

somFree

A method in SOMObject to free an object instance releasing the storage used. Prior to freeing storage, “somUninit” is invoked for customized uninitialization.

somFree must not be invoked to destroy an active object, i.e. an object upon which a method has been invoked that has not yet returned control to the invoker.

somInit

A method in SOMObject that has no default function, but may be overridden explicitly in a COBOL class definition to perform customized initializations when an object is created.

somUninit

A method in SOMObject that has no default function, but may be overridden explicitly in a COBOL class definition to perform customized uninitialization (typically the inverse of the function performed by a customized somInit).

somGetClass

A method in SOMObject that returns an object reference for the class-object associated with the metaclass of an object.

somIsObj

A function that determines whether an object-reference refers to a valid object.

"somIsObj" returns a Boolean. While COBOL has no BOOLEAN data type, COBOL programmers can declare the return value as PIC X and test the value using a symbolic character or hex literal.

```
...
Data Division.
Working-Storage Section.
01  somBoolean  Pic X.
    88  invalid-obj  Value X'00'.
    88  valid-obj    Value X'01'.
Procedure Division.
    ...
    Call 'somIsObj' Using By Value anObj Returning somBoolean.
    If invalid-obj
     Display 'Object reference does not refer to a valid object'
    End-if.
    ...
```

Function Note: When compiling a program that calls a SOM function, such as somIsObj:

- The PGMNAME(MIXED) compiler option must be specified, because the API names are case-sensitive. Otherwise, the compiler will translate somIsObj to SOMISOBJ, and you will get an unresolved external reference.
- The SOM API functions use the SYSTEM linkage convention. Hence the CALLINT(SYSTEM) compiler option or the >>CALLINT SYSTEM directive must be in effect for the CALL statement.

Your invocations of SOM methods does not require any special considerations; the correct linkage conventions are used automatically for method invocations.

SOM Initialization

During initialization of programs using object-oriented features, the COBOL run-time system automatically initializes the SOM environment and creates class-objects for classes referenced in the application. Application programmers do not have to perform these initializations manually.

Class Initialization

The SOM architecture specifies that every SOM class exports an initialization function `<classname>NewClass`. Normally COBOL programmers do not use this function directly, but the function is available on all COBOL classes. The COBOL run-time system automatically initializes all classes referenced within a COBOL program by calling their class initialization functions prior to the execution of the first user-written COBOL statement in the PROCEDURE DIVISION.

The class initialization function has a case-sensitive name, thus any COBOL program that explicitly calls a class-initialization function must be compiled with PGMNAME(LONGMIXED).

If an external class-name is specified in the REPOSITORY paragraph for a class, then the external class-name is used to form the initialization function name. If an external class-name is not specified in the REPOSITORY paragraph for a class, then the class-name declared is processed to form a CORBA-compliant external class name and this name is used to form the class initialization function. In a CORBA-compliant external class-name

- the name is folded to upper case
- hyphens in the name are translated to zero (0)
- if the first character in the name is a digit
  - 1 through 9 are translated to A through I
  - 0 is translated to J

For example:

```
Identification Division.
Class-Id.  Employee inherits SOMObject.
Environment Division.
Configuration Section.
Repository.
    Class SOMObject is class "SOMObject".
 ...
End-Class Employee.

The class initialization function names in the above cases are:
   EMPLOYEENewClass
   SOMObjectNewClass
```

and

```
Identification Division.
Class-Id.  Employee inherits SOMObject.
Environment Division.
Configuration Section.
Repository.
    Class Employee is class "Employee"
    Class SOMObject is class "SOMObject".
 ...
End-Class Employee.

The class initialization function names in the above cases are:
   EmployeeNewClass
   SOMObjectNewClass
```

Class Interface Evolution

One of the benefits of SOM is that classes can undergo changes over time and retain backward binary compatibility, i.e. not require recompilation of programs and classes that reference the changed class. Changes that can be made to classes without recompilation requirements include:

1. Adding new methods.
2. Changing the size of an object by adding or deleting instance data.
3. Inserting new parent classes above a class in the inheritance hierarchy.
4. Relocating methods upward in the class hierarchy.

The SOM engine provides several alternative mechanisms for method resolution (see *SOMobjects Developers Toolkit User Guide Version 2.1* (available online) for details). IBM COBOL uses SOM name-lookup resolution to invoke methods. Thus when COBOL methods are invoked from COBOL code, the somewhat more stringent recompilation requirements of the SOM offset-resolution mechanism are not applicable. For example, COBOL methods that are invoked with COBOL INVOKE statements are not subject to the restriction in item four above. A COBOL method may be relocated anywhere in a class hierarchy without requiring recompilation of the COBOL programs that invoke the method.

Methods defined in COBOL classes may be invoked from other languages, such as C code built with the SOM C emitter, that use offset-resolution. In this case, the standard SOM requirements apply. Note that COBOL does not provide language comparable to the SOM “release-order” mechanism, which is used to ensure methods can be added to a class definition without requiring recompilation of code that invokes the methods using offset-resolution. When adding methods to an existing COBOL class, it is recommended that the new methods be added at the *end* of the PROCEDURE DIVISION of the class definition, *after* all of the existing methods. This will ensure that any existing code invoking the original methods does not require recompilation.

Chapter 14. Using SOM IDL-Based Class Libraries

This chapter is intended for COBOL programmers who want to use SOM IDL[5]-based class libraries, either as clients of the class, or by specializing the class using subclassing.

The chapter assumes that you understand the System Object Model (SOM), at least conceptually, and know where to find more detailed documentation about SOM when you need it. It also assumes that you have access to the documentation for the particular class library that you are intending to use.

To get started, you need one of the object-enabled IBM COBOL products, together with the executables for the class library, plus its documentation, as above.

SOM Objects — a Refresher

A SOM class library consists of executable code and interface information that defines the operations that the library supports, including the parameters for invoking the operations — known as the operation "signatures."

When the library is being used at run time, the components that are present in memory are illustrated in Figure 60 on page 268.

SOM IDL

The interface information for a SOM class library may be in various forms:

- IDL files;
- an Interface Repository (IR) — a machine-readable form of IDL, used during compilation;
- a book or on-line documentation describing the interfaces in IDL, together with operational descriptions of the methods.

IDL expresses the contract between the provider of object services, in this case the class library, and the user of these services: the COBOL program, method or subclass. The interface description is formally independent of the language in which either the user of the service or the service itself is implemented. This property is known as "language-neutrality." The separation of the interface from the implementation also allows flexibility in the deployment of the objects on the nodes of a network.

5 There are various forms of Interface Definition Language (IDL), such as those for the Distributed Computing Environment (DCE) or the Object Management Group's Common Object Request Broker Architecture (OMG CORBA), but in this chapter, we shall be concerned only with IBM's System Object Model Interface Definition Language (SOM IDL). SOM IDL is consistent with CORBA version 1.1, but is not identical to the current version of CORBA, 2.0. Also, SOM IDL allows some additional data types, such as pointers, that are not included in CORBA.

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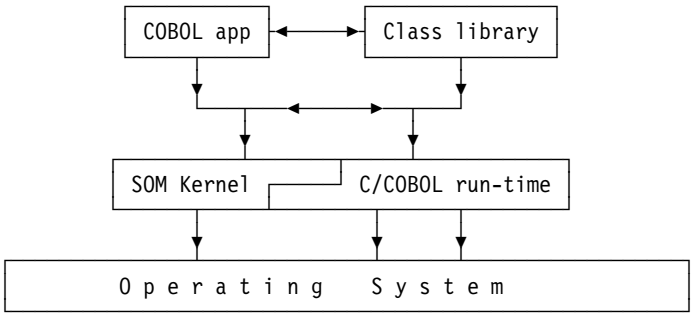

Figure 60. Run-time components of a SOM class library. The example also shows the COBOL components that are using the library.

IDL data types have their origins in the C and C++ data model. Becuase many of them do not have an exact counterpart in the COBOL language, there needs to be a translation or "mapping" between IDL and COBOL. The mapping recommended here makes the explicit assumption that the data structures may be passed **directly**[6] between the COBOL and C/C++ mappings to SOM IDL.

Mapping IDL to COBOL

To use an IDL-based class library from COBOL, you must be able to map the elements of IDL in which it is expressed into the COBOL language. Typically, you find the description of the class library in a user's guide and reference, containing not only the guidelines for using the class library, but also the calling sequences for the individual methods expressed in SOM IDL. This, and the following sections, tell you how to map these IDL definitions into COBOL:

- "IDL Identifiers" on page 269 describes how to map IDL identifiers to COBOL names.
- "IDL Attributes" on page 269 explains how to express IDL `attributes` in COBOL.
- "Common IDL Types" on page 270 covers the "normal" IDL elements that virtually all interfaces use.
- "Complex Types" on page 275 is provided for completeness; most interfaces do not use these complex IDL constructs.
- "Argument and Return Value Passing Conventions" on page 278 is a discussion of argument passing mechanisms.

6 The standard CORBA model presumes a "stub" routine between the invoking and invoked object to do argument translation, marshalling, and so on. Passing the structures directly yields very significant gains in efficiency, but it also means that some of the mappings may not seem as "natural" to the COBOL programmer as they would be if the transfer were mediated by a stub routine. It also means that you must ensure that you have the correct alignment and padding of any structures that are passed across an interface. In general the recommended way to achieve this for IDL-based interfaces is to specify the SYNCHRONIZED clause for COBOL mappings to any IDL `structs` or `arrays` that directly contain `structs`

IDL Identifiers

The only IDL names that must be *identical* in COBOL are the class (IDL interface) and method (IDL operation) names. These may be specified exactly by using literals:

- For a class, in the REPOSITORY paragraph using the CLASS IS clause.
- For a method, by using the literal form of the method name in the METHOD-ID paragraph. When you invoke a method, you use either the literal form of the name or a data name initialized with the exact method name.

The other identifiers, such as parameter, constant, and exception names, are internal to your program or class, and don't have to be identical to the IDL. However, it is a good idea to keep the spelling of these close to that of the IDL originals to enhance the readability and maintainability of your programs.

IDL Attributes

An IDL `attribute` behaves like instance data that you can see outside the class definition (but note that there need not be any *actual* instance variable corresponding with it). Attributes are modeled as a pair of operations, one to set and one to get the attribute value. Attribute operations return errors by means of standard exceptions.

The mapping for attributes is best explained through an example. Consider the following IDL specification:

```
interface foo {
  struct position_t {
    float x, y;
  };

  attribute float radius;
  readonly attribute position_t position;
};
```

This is exactly equivalent to the following illegal[7] IDL specification:

```
interface foo {
  struct position_t {
    float x, y;
  };

  float _get_radius();
  void _set_radius(in float r);
  position_t _get_position();
};
```

The COBOL code to use these operations is straightforward:

7 Illegal, because IDL identifiers are not permitted to start with an underscore (_) character.

```
1 radius comp-1.
1 position-t.
 2 x comp-1.
 2 y comp-1.
  ...
  Invoke a-foo '_get radius' using value evp returning radius
  Invoke a-foo '_set_radius' using value radius evp
  Invoke a-foo '_get_position' using value evp
      returning position-t
```

Common IDL Types

These are the IDL types that you normally encounter in SOM IDL interfaces. The complex types are discussed in the next section.

Reference Summary

Figure 61. IDL Type to COBOL Mapping

IDL Type	COBOL Equivalent
boolean	display picture x [+ level-88s...]
char	display picture x
double	computational-2
enum	binary picture 9(9) [+ level-88s...]
float	computational-1
interface	object reference
long	computational-5 or binary picture s9(9)[1]
octet	display picture x
pointer	pointer
short	computational-5 or binary picture s9(4)[1]
string	display pic x(n+1), z'value' or variable-length alphanumeric table[2]
unsigned long	computational-5 or binary picture 9(9)[1]
unsigned short	computational-5 or binary picture 9(9)[1]

Note:

1. USAGE COMPUTATIONAL-5 data items are available only on the OS/2 and AIX versions of IBM COBOL. But if you map this IDL type to USAGE BINARY rather than COMP-5, you must either know that the expected range of values is accommodated by the PICTURE clause, or use the TRUNC(BIN) compiler option and, on the workstation or PC, ensure that the BINARY(NATIVE) compiler option is in effect.

   Also be aware that there are significant performance effects associated with the use of COMP-5 data items or the TRUNC(BIN) compiler option (which affects every USAGE BINARY data item in your program). So if you know that the picture accommodates the expected range of values, USAGE BINARY may be the better choice.
2. See “string” on page 273 for details.

boolean

The SOM IDL `boolean` type is mapped to a one-byte alphanumeric data item, together with suitable level-88 condition names. The condition names are recommended for convenience, but are not essential. For example, the following IDL:

```
boolean that;
```

could be written in COBOL as:

```
       1 that display pic x.
        88 that-false value x'00'.
        88 that-true value x'01' thru x'ff'.
```

char

The SOM IDL `char` type maps to a one-byte alphanumeric data item. The IDL declaration:

```
char that;
```

could be written in COBOL as:

```
       1 that display pic x.
```

double

The SOM IDL `double` type represents 64-bit floating-point data, and is mapped to USAGE COMPUTATIONAL-2 in IBM COBOL. The IDL definition:

```
double that;
```

could be written in COBOL as:

```
       1 that comp-2.
```

enum

The closest COBOL equivalent to a SOM IDL `enum`[8] is an unsigned binary full-word, together with condition name entries for each of the enumeration members. For example, the following IDL:

```
enum that{red, white, blue, green};
```

could be written in COBOL as:

```
       1 that binary pic 9(9).
        88 that-red value 1.
        88 that-white value 2.
        88 that-blue value 3.
        88 that-green value 4.
```

---

8 Note that a SOM IDL `enum` is different from a C or C++ `enum`:

1. it is always exactly four bytes long, whereas a C/C++ `enum` is one, two or four bytes long, depending on the maximum enum value and on compiler options;
2. the members are numbered sequentially starting from one, whereas a C/C++ `enum` starts at zero by default, or may optionally have specific values assigned to the enumeration members.

In the unlikely event that any enumeration member exceeds 999,999,999, decimal picture considerations may apply — see the note in Figure 61 on page 270.

float

The SOM IDL `float` type represents 32-bit floating-point data and is mapped to COMPUTATIONAL-1 in IBM COBOL. For IDL:

```
float that;
```

you could write in COBOL:

```
        1 that comp-1.
```

interface

The use of an IDL `interface` as an argument to, or result of, an operation denotes an object reference to an instance of the class to which the interface has been mapped. In simple terms, if a method has an `interface` type as one of its parameters, specify an OBJECT REFERENCE to an instance of a class that supports that interface. Suppose you have the following skeletal IDL interface:

```
interface that {
  ...
  }
```

You would specify the corresponding class in the REPOSITORY paragraph as usual:

```
        Repository.
          class that 'that'.
```

Then you declare an instance of the `that` class:

```
        1 a-that object reference that.
```

and pass it according to the rules in “Argument and Return Value Passing Conventions” on page 278.

long

The SOM IDL `long` type describes 32-bit signed binary quantities, and is approximated by USAGE BINARY data items with a PICTURE clause of S9(9) in COBOL. On the workstation or PC, the type is exactly mapped by a USAGE COMPUTATIONAL-5 data item with a PICTURE clause of S9(5) through S9(9). Whichever mapping you use, be aware of the discussion in the note in Figure 61 on page 270.

For the IDL declaration:

```
long that;
```

you could write in COBOL:

```
        1 that binary pic s9(9).
```

or, on the workstation or PC:

```
        1 that comp-5 pic s9(9).
```

octet

The SOM IDL `octet` type represents an 8-bit quantity that is guaranteed to be unchanged during transmission between different objects. It is most closely matched in COBOL by a one-byte alphanumeric data item. Thus for IDL:

```
octet that;
```

you could write in COBOL:

```
        1 that display pic x.
```

pointer

A SOM IDL `pointer` corresponds with a COBOL POINTER data item. The IDL declaration:

```
pointer that;
```

would be written in COBOL as:

```
        1 that pointer.
```

short

The SOM IDL `short` type defines 16-bit signed binary data, and is most closely matched by COBOL data items with USAGE BINARY and a PICTURE clause of S9(4). On the workstation or PC, the type is exactly mapped by a USAGE COMPUTATIONAL-5 data item with a PICTURE clause of S9(1) through S9(4). Whichever mapping you use, be aware of the discussion in the note in Figure 61 on page 270.

The SOM IDL definition:

```
short that;
```

could be written in COBOL as:

```
        1 that binary pic s9(4).
```

or, on the workstation or PC:

```
        1 that comp-5 pic s9(4).
```

string

The SOM IDL type `string` is one of the most important types, since it is widely used in operations and interfaces. It is also one of the most difficult to match in COBOL, because SOM IDL strings are modeled on those of C and C++. These have a null terminator to determine the length of the string, and are passed via a typed pointer. IBM COBOL does not support such null-terminated strings as a native data type. However, the null-terminated literal — `Z'string-value'` — alleviates some of the problems and, when it can be passed BY CONTENT, is an exact match to a SOM IDL `in string`[9]. A null-terminated literal may also be used to set the initial VALUE of a data item to be used as a `string` argument.

---

9 See the note in Figure 63 on page 278 about some restrictions on the use of BY CONTENT.

In general though, IDL strings are mapped to pointers to the appropriate character string data or buffer. Except for `in` strings, what is actually passed in a method invocation is just the pointer. But, for this to work operationally, the pointer must be set to the address of the *underlying* character string data or buffer in PICTURE X format. There are several styles of data definition, depending on whether the parameter is an `in`, `inout`, or `out` argument, or a return value. These are discussed in more detail under "String Type" on page 280. For now, note that the declarations described below may be used to represent both the COBOL and SOM IDL view of a variable-length string simultaneously.

The main cases to distinguish are bounded and unbounded strings. Bounded strings have a fixed upper limit on their size. The IDL declaration:

```
string<100> that;
```

represents a SOM IDL string of no more than 100 characters in length, and may be approximated by the following COBOL data declarations:

```
1 that-l binary pic 9(9).
1 that.
 2 that-v pic x occurs 1 to 101 depending that-l.
```

The "`-l`" suffix denotes the length of the string, the "`-v`" its value. Note the extra position to allow for the null terminator, and note that the data item `that`, in addition to being a valid SOM IDL string, is also variable-length in COBOL, because of the OCCURS DEPENDING clause.

For unbounded strings, the maximum length must be inferred from ancillary information about the interface and the semantics of its operations. Thus, for the IDL declaration:

```
string that;
```

which represents an unbounded SOM IDL string, you may, for example, know that the strings that are passed across the interface do not in practice exceed 4095 characters. Then the following COBOL declarations would be appropriate:

```
1 that-l binary pic 9(9).
1 that.
 2 that-v pic x occurs 1 to 4096 depending that-l.
```

See "Helper Routines Source Code" on page 295 for the C source code for a pair of "helper" routines to synchronize the two representations, for example, either the bounded or unbounded `that`, above:

- `'IDLStringToCOBOL' using that that-l`

  This routine sets the COBOL OCCURS subject `that-l` from the position of the mandatory null terminator.

  If you prefer, you can achieve the same result in COBOL:

```
Move 100 to that-l
Move zero to tally
Inspect that tallying tally for characters before x'00'
Move tally to that-l
```

- `'IDLStringFromCOBOL' using that that-l`

  This routine inserts the null terminator at the string position indicated by the COBOL OCCURS object.

  If you prefer, you can do this quite easily yourself in COBOL:

```
Move x'00' to that-v(that-l)
```

unsigned long and unsigned short

The unsigned forms of binary data are mapped as for SOM IDL types `long` and `short`, above, except that the picture clause does not specify the character "S." Thus for the following IDL declarations:

```
unsigned long this;
unsigned short that;
```

you could write in COBOL:

```
1 this binary pic 9(9).
1 that binary pic 9(4).
```

or, on the workstation or PC:

```
1 this comp-5 pic 9(9).
1 that comp-5 pic 9(4).
```

void

When used as a return type for an operation, the IDL type `void` means that the operation doesn't return anything. You map this in COBOL merely by omitting the RETURNING phrase in the corresponding INVOKE statements or PROCEDURE DIVISION headers.

Complex Types

These are types that, although defined in SOM IDL, are rarely found as a type definition or as an argument to or result of an operation.

Reference Summary

Figure 62. IDL Type to COBOL Mapping

IDL Type	COBOL Equivalent
`any`	`group + COBOL type`
`array`	`table`
`sequence`	`group + variable-length table`
`struct`	`group`
`union`	`group + redefines`

any

The IDL `any` type is a self-describing representation of any of the IDL types, including another IDL `any`. The descriptor is mapped to COBOL as a group item, which includes

a pointer to the actual data item of the particular type. Suppose you want to map the following IDL declaration:

```
any that;
```

In COBOL, this would be represented by the following COBOL group item:

```
        1 that.
         2 that-type object reference TypeCode.
         2 that-value pointer.
```

The `that-type` field is a reference to an instance of the "TypeCode" class, which has methods that provide information about the IDL type. A simple numeric type code is insufficient to describe an IDL type, because some types have additional information. For example, the type information for an IDL bounded string includes the size of the upper bound.

The `that-value` field points to the start of the data for the item that the `any` represents.

array

IDL `array`s map to COBOL tables — groups whose subordinate items contain the OCCURS clause. The underlying IDL type can be any of the IDL types, including `array` itself, and is mapped according to the rules in this or the preceding section.

A simple instance of the IDL `array` type:

```
long that[4][5];
```

is represented in COBOL as:

```
        1 that.
         2 occurs 4.
          3 that-v binary pic s9(9) occurs 5.
```

The "`-v`" suffix denotes the individual element values. The un-suffixed name is used to pass the entire array as an argument to a method; the suffixed name is used to refer to individual elements of the array.

You must specify the SYNCHRONIZED clause on the group item if the `array` contains a `struct` or `union` at any level of the `array`. This is to ensure that the subordinate items are aligned on their natural boundaries, in conformance with the default alignment of SOM IDL structures.

sequence

An IDL `sequence` is a one-dimensional array with a descriptor that specifies a maximum and current size for the sequence. If the maximum size is explicitly declared, the sequence is said to be "bounded." Otherwise, the sequence is "unbounded," and the maximum size is determined at run time (in an application-specific way) and is set prior to passing the sequence to an operation. There are no restrictions on the element type of a sequence. In particular, it is possible to have a sequence of another sequence type.

Let's look at a simple example, a bounded sequence of IDL type `long`:

```
sequence<long,10> that;
```

The descriptor for the maximum and current size and address of this sequence is represented in COBOL as a group item:

```
        1 that.
         2 that-maximum binary pic 9(9).
         2 that-length binary pic 9(9).
         2 that-buffer pointer.
```

Then the element data are mapped as a variable-length table of the appropriate type, in this case, an array of IDL `long`s:

```
        1 that-t.
         2 that-v binary pic s9(9) occurs 1 to 10
             depending that-length.
```

struct

An IDL `struct` type corresponds with a COBOL group item containing the individually mapped components of the `struct` as subordinate data items. Thus the following IDL `struct`:

```
struct that {
  long x;
  double y;
  };
```

could be represented in COBOL as:

```
        1 that sync.
         2 x binary pic s9(9).
         2 y comp-2.
```

The SYNCHRONIZED clause is required so that the alignment of the subordinate items approximates the default alignment of SOM IDL structures. In most practical cases, the alignment would be correct either way, but specifying SYNCHRONIZED is a sensible precaution.

union

A SOM IDL `union` has a discriminator that indicates which format variant to use. In COBOL, this is mapped to a group item containing the discriminator, plus the union itself represented by using the REDEFINES clause. Then, in the PROCEDURE DIVISION, use an EVALUATE statement to determine which format is currently in effect.

An example should make this all clearer. Suppose you have the following IDL:

```
union that switch (long) {
  case 2: char x;
  case 5: long y;
  default: float z;
  };
```

The data declaration part of the COBOL mapping could be written as follows:

```
1 that sync.
 2 that-d binary pic s9(9).
 2 that-u display pic x(4).
 2 that-x redefines that-u display pic x.
 2 that-y redefines that-u binary pic s9(9).
 2 that-z redefines that-u comp-1.
```

The SYNCHRONIZED clause makes sure that COBOL mimics the default SOM IDL alignment rules. Thus, in the unlikely event that any IDL structures have "holes," COBOL would insert slack bytes in the record as appropriate.

Notice the extra member of the union, `that-u`, whose size is the maximum of the sizes of the explicit union members. This is needed because of the COBOL restriction that a data item being redefined must be at least as large as the item redefining it. Alternatively, you could just declare the union members in order of decreasing size, although that may lose the correspondence between the COBOL declaration and the original IDL.

Whichever style you adopt, you can use an EVALUATE construct such as the following to determine which of the union members is currently in effect:

```
Evaluate that-d
  When 2
    Display 'case 2: IDL-char:  ' that-z
  When 5
    Display 'case 5: IDL-long:  ' that-x
  When other
    Display 'default case: IDL-float:  ' that-y
End-evaluate
```

Argument and Return Value Passing Conventions

This section describes how to write COBOL argument-passing constructs, such as BY REFERENCE or BY VALUE, to comply with the IDL access intent specifiers.

Argument/Result Passing Summary

Figure 63 (Page 1 of 2). Argument/Result Passing Conventions

IDL Type	in	inout/out	return value
any	content[1]	reference[1]	type[3]
array	content[1]	reference[1]	pointer[4]
boolean	value	reference[1]	type[3]
char	value	reference[1]	type[3]
double	value	reference[1]	type[3]
enum	value	reference[1]	type[3]
float	value	reference[1]	type[3]
long	value	reference[1]	type[3]
object ref	value	reference[1]	type[3]
octet	value	reference[1]	type[3]

Figure 63 (Page 2 of 2). Argument/Result Passing Conventions

IDL Type	in	inout/out	return value
pointer	value	reference[1]	type[3]
short	value	reference[1]	type[3]
sequence	content[1]	reference[1]	type[3]
string	content[1]	pointer[2]	pointer[4]
struct	content[1]	reference[1]	type[3]
union	content[1]	reference[1]	type[3]
unsigned long	value	reference[1]	type[3]
unsigned short	value	reference[1]	type[3]

Note:

1. For IBM COBOL for MVS & VM you can use BY CONTENT or BY REFERENCE only if the argument is not the last. This is due to the S/390 linkage conventions of the high-order bit of the last argument address being set ON to indicate the end of the argument list. This confuses C and C++ programs that attempt to manipulate the address as a pointer. An alternative to BY REFERENCE (for this situation and in general) is to pass BY VALUE a pointer that has previously been set to the address of the data item.
2. For inout and out strings, you must pass a pointer to the string data or buffer BY REFERENCE.
3. The term "type" means the COBOL equivalent of the IDL type, specified directly in the RETURNING phrase of the INVOKE statement.
4. The term "pointer" means a COBOL POINTER that has been set to the address of the equivalent data item or output buffer.

IDL Access Intent Specifiers

The IDL intent specifiers, in, inout, and out, do not correspond exactly with COBOL BY VALUE, BY CONTENT, and BY REFERENCE phrases. The IDL access intent determines only the semantics of the parameter, without necessarily implying a particular argument passing mechanism. In COBOL, both BY VALUE and BY CONTENT have input-only semantics but use different mechanisms, while BY REFERENCE parameters may have either input-output or output-only semantics, depending how they are used. Some kinds of output parameters, IDL strings for example, cannot be expressed directly in COBOL, but must be mapped to pointers.

Literal Arguments

For return values, and for inout and out arguments, you must pass a data item. For input arguments however, you may be able to specify a literal, passed BY VALUE:

- Integer-valued fixed-point numeric literals and the figurative constant ZERO are formally equivalent to full-word binary data items, and thus match signed or unsigned long IDL types.
- Floating-point literals are formally equivalent to double-word floating-point (COMPUTATIONAL-2) data items, and thus match the IDL double type.
- Single-byte alphanumeric literals, symbolic characters, and figurative constants (other than ZERO) match boolean, char, and octet.

or BY CONTENT:

- Null-terminated literals of the form `Z'value'` match the IDL `string` type.

Complex Types

For the complex types (not including `string`, which is discussed separately below), you pass the level-1 group item. In the examples above, this is always the COBOL data name `that`. Where the conventions expect a pointer, this is set:

- For an argument, prior to executing the INVOKE statement
- For a return value, on return from the method

The rules for passing these types are quite involved and are described in some detail in the *SOM User's Guide*. Generally, you provide the storage for all `in` and `inout` arguments, all modes of `struct` and `union` parameters, and, curiously enough, for `out array` arguments. The called method allocates some or all of the storage for all other `out` arguments and return values. You are not allowed to modify this returned storage, though you can, of course, use it otherwise, to copy it, for example. You must free it using `OMMFree` when you are finished with it. See "Helper Routines Source Code" on page 295.

If you have to supply `inout` arguments of any of the complex types, you would do well to allocate the storage dynamically, using `OMMAllocate`, and declare the COBOL equivalent type in the LINKAGE SECTION[10]. See "Memory Management" on page 291 for more information about `OMMAllocate` and `OMMFree`.

String Type

The examples in this section all presume the SOM IDL declaration:

```
string<100> that;
```

You pass `in string` types in several ways. Where the content is known, you could specify it as a null-terminated literal, either directly or as the value of a data item:

```
       1 that pic x(101) value z'initial value'.
         ...
         Invoke anObject 'method'
             using value evp content z'this or that'
         ...
         Invoke anObject 'method' using value evp content that
```

For variable-content strings, you may find it convenient to use a plain (PICTURE X) alphanumeric data declaration for the string buffer. You can use reference modification if you want to see the valid part of the string:

[10] This is because later versions of CORBA allow the called routine to *re-allocate* `inout` arguments when the output value is inconsistent with the type or size of the input data item. For this to work, a standard memory management protocol must be used by both the caller and the called routine.

```
1 that-l binary pic 9(9).
1 that pic x(101).
  ...
  Display 'Content of "that" = "' that(1:that-l) '"'
```

However, if you want the string to behave naturally as a variable-length string in both COBOL and the SOM IDL-based library, use the dual representations:

```
1 that-l binary pic 9(9).
1 that.
 2 that-v pic x occurs 1 to 101 depending that-l.
```

You can synchronize either the reference modified or the OCCURS DEPENDING form of the COBOL string representation with the IDL representation by using the `IDLStringToCOBOL` and `IDLStringFromCOBOL` helper routines given in "Helper Routines Source Code" on page 295."

For `inout` and `out` strings, you must pass the string buffer with an extra level of indirection. The way that you express the extra level of indirection in COBOL is to pass a pointer, which for `inout` strings has previously been set to the address of the string data. As usual, you have a choice of passing this pointer BY REFERENCE, or declaring a second pointer that you have set to the address of the first, then passing this second pointer BY VALUE:

```
1 ptr1 pointer.
1 ptr2 pointer.
1 that-l binary pic 9(9).
  ...
Linkage section.
  1 that.
   2 that-v pic x occurs 1 to 101 depending that-l.
    ...
    Set ptr1 to address of that
    Invoke anObject 'method' using value evp reference ptr1 ...
    ...
    Set ptr2 to address of ptr1
    Invoke anObject 'method' using value evp ptr2
```

It's clear why the extra level of indirection is needed for `out` strings, given that they are allocated by the method and may be arbitrarily long. But the output size of an `inout` string is limited by the input size: the upper bound for a bounded string, and the actual input size for an unbounded string[11].

For a return value, specify a pointer, which the method sets to the address of the output string before it returns.

For all the output modes of string, including `inout`, declare the string buffer itself in the LINKAGE SECTION, to allow the method to allocate, or re-allocate, the storage for the

[11] Because of this restriction, `inout` strings are not very useful, but you still need to pass the pointer rather than the string itself, because later versions of the CORBA argument conventions **do** allow reallocation of the string if the output is larger than the input.

string. Storage for an `inout` string should be acquired by calling `OMMAllocate`, so that (in future) methods can re-size the string if necessary.

Be aware of your responsibilities for any storage allocated and returned by a SOM IDL-based library method. You can look at the storage, by declaring appropriate LINKAGE SECTION data items as usual, but do not attempt to modify it[12]. If you want to do that, make a copy of it and modify the copy. Also, note that you are responsible for freeing the storage for the original returned string when you have finished with it, by calling the `OMMFree` routine.

You can find the source code for `OMMAllocate` and `OMMFree` under "Helper Routines Source Code" on page 295.

Given the IDL definition:

```
interface this {
  string that (
    in string in_string,
    inout string inout_string,
    out string out_string
  );
};
```

and assuming an arbitrary limit of 99 characters on the string sizes, the following COBOL fragments illustrate these various techniques. This code is written in a very simple style, does not check for errors, and might not be complete.

[12] This is because the storage may be protected, and you cannot assume that you have appropriate write privileges.

```
Data division.
 Local-/Working-storage section.
  1 inout-string-p pointer.
  1 out-string-p pointer.
  1 return-string-p pointer.
    ...
  1 work-string-l binary pic 9(9).
  1 inout-string-l binary pic 9(9).
  1 out-string-l binary pic 9(9).
  1 return-string-l binary pic 9(9).
    ...
  1 work-string pic x(100).
  1 in-string pic(100) value z'Nothing strange for in strings'.
  1 evp pointer.
    ...
 Linkage section.
  1 inout-string.
   2 inout-string-v pic x occurs 1 to 100 depending inout-string-l.
  1 out-string.
   2 out-string-v pic x occurs 1 to 100 depending out-string-l.
  1 return-string.
   2 return-string-v pic x occurs 1 to 100 depending return-string-l.
  1 ev.
   2 major pic x.
  88 no-exception value x'00'.
  ...
```

```
 Procedure division.
     ...
* Acquire storage for, and initialize, inout-string:
     Move 100 to inout-string-l
     Call 'OMMAllocate' using content length of inout-string
         returning inout-string-p
     Set address of inout-string to inout-string-p
     Move z'Initial value for inout-string' to inout-string
     Call 'IDLStringToCOBOL' using inout-string inout-string-l
* Invoke method 'that' on an instance of the 'this' class:
     Invoke a-this 'that' using value evp
         reference in-string inout-string-p out-string-p
         returning return-string-p
* De-reference the returned pointers and copy one string:
     Set address of inout-string to inout-string-p
     Call 'IDLStringToCOBOL' using inout-string inout-string-l
     Set address of out-string to out-string-p
     Call 'IDLStringToCOBOL' using out-string out-string-l
     Set address of return-string to return-string-p
     Call 'IDLStringToCOBOL' using return-string return-string-l
     Move out-string to work-string
* Operate on copy, and free allocated storage when done:
     Move function reverse(work-string) to work-string
     If work-string = out-string then
       Display '"' out-string '" is palindromic.'
     End-if
     ...
     Call 'OMMFree' using inout-string-p
     Call 'OMMFree' using out-string-p
     Call 'OMMFree' using return-string-p
     ...
```

Other SOM Topics

You will find it helpful to be familiar with the topics discussed in this section.

Errors and Exceptions

SOM uses two error or exception mechanisms: `SOMError` and CORBA-style exceptions.

`SOMError` is used for internal errors in the kernel classes, and is not really relevant to the average user. Methods of the kernel classes are used to create an object — `somNew` and `somNewNoInit` — or destroy it — `somFree`. The main implication of `SOMError` for these methods is that you don't have to provide an environment argument when you invoke them, and of course you don't have to check for exceptions after they return.

However you do need to know how to use the SOM exception mechanism, which is used for most other methods. Exceptions aren't necessarily errors, but errors *do* use the SOM exception mechanism.

SOM exceptions are not the same as C++ exceptions, but instead set the value of an exception structure, which you can think of as a special kind of “return code,” accessed via the environment variable (ev).

There are two ways of passing the environment variable, depending on the callstyle of the method you want to invoke — and check. For each of them, provide a global (per thread) environment variable, as shown in Figure 64 on page 286. For callstyle `oidl` methods, there's no explicit environment variable parameter. Such methods just use the global environment variable implicitly. Callstyle `idl` methods, on the other hand, use the same global environment variable, but passed explicitly, as the first argument to the method. Again, see Figure 64 on page 286 for an example of how this is accomplished in COBOL.

The environment variable is opaque, except for the exception type field (`major`) at the beginning of the structure. This is a C/C++ `enum` — a single byte, origin zero, with three values: `NO_EXCEPTION`, `USER_EXCEPTION` and `SYSTEM_EXCEPTION` — and is coded in COBOL as DISPLAY PIC X, with suitable level-88 condition names as illustrated in Figure 64 on page 286.

Every callstyle `idl` operation (that is, a method whose first parameter is an environment structure) can return one of the standard system exceptions[13], even if it does not declare any explicit exceptions with a `raises` expression in the `operation` declaration. This means that you must check the exception type field of the environment variable after **every** invocation of a method of a class defined with callstyle `idl`.

When one of these callstyle `idl` methods that you've invoked detects a condition that is to be expressed as an exception, it uses the `somSetException` function to supply the exception name and an exception structure.

Then, if you decide to handle the exception, perhaps by printing a message and continuing, you must reset the environment variable and free the associated exception structure by using the `somExceptionFree` function. Of course, there are other ways of handling exceptions. You may want to change the state of one of the input arguments to the method, then re-try it, or you might prefer to terminate your program rather than attempting to continue.

But in every case, at a minimum check the successful completion of each method. It's not good programming practice to assume that a method completed successfully without checking it. You will not get a reliable implementation of your application unless you do so.

COBOL Example

The program fragments in Figure 64 on page 286 show in some detail how you can accomplish the foregoing in IBM COBOL. The data names are not mandatory; only suggestions.

[13] See the *SOM User's Guide* for a list of the CORBA standard exceptions.

In the WORKING-STORAGE or LOCAL-STORAGE SECTION:

```
      ******************************************************************
      * Declare the environment variable pointer:                      *
      ******************************************************************
         1 evp pointer.
```

In the LINKAGE SECTION:

```
      ******************************************************************
      * Declare the environment variable itself:                       *
      ******************************************************************
         1 ev.
          2 major pic x.
           88 no-exception value x'00'.
           88 any-exception value x'01' thru x'ff'.
           88 user-exception value x'01'.
           88 system-exception value x'02'.
          2 pic display x(15).
```

In the PROCEDURE DIVISION:

```
      ******************************************************************
      * Acquire a global environment variable                          *
      ******************************************************************
           Call 'somGetGlobalEnvironment' returning evp
           Set address of ev to evp
           ...
      ******************************************************************
      * Check environment after invoking a method                      *
      ******************************************************************
           Invoke anObject 'op1' using value evp other-args ...
           If any-exception then
      *      respond to exception appropriately, perhaps by using:
             Call 'Print-ev' using evp content z'op1 on anObject'
           End-if
           ...
```

Figure 64 (Part 1 of 3). Checking SOM exceptions in COBOL

Here's a sample subroutine for printing out exceptions:

```
      ****************************************************************
      * Subroutine for printing exceptions                           *
      ****************************************************************
       Identification division.
         Program-id.
           'Print-ev'.
       Data division.
        Working-storage section.
         1 counter binary pic 9(9) value 0.
        Local-storage section.
         1 d pic x(130).
         1 eip pointer.
         1 i binary pic 9(9).
         1 j binary pic 9(9).
         1 jr redefines j.
          2 pic xxx.
          2 jrd pic x.
         1 p binary pic 9(9).
         1 s pic 9(9).
        Linkage section.
         1 evp pointer.
         1 kind pic x(40).
         1 ev global.
          2 major pic x.
           88 any-exception value x'01' thru x'ff'.
           88 user-exception value x'01'.
           88 system-exception value x'02'.
          2 pic x(15).
         1 ei pic x(100).

       Procedure division using evp kind.
           Add 1 to counter
           Set address of ev to evp
           Call 'SLZ' using counter s i
           Move 1 to p
           String 'Check #' s(i : ) ':  method invocation "'
               delimited size into d pointer p
           Move 0 to i
           Inspect kind tallying i for characters before initial x'00'
           String kind(1 : i) '" returned '
               delimited size into d pointer p
           Evaluate true
             When user-exception
               String 'a user' delimited size into d pointer p
             When system-exception
               String 'a system' delimited size into d pointer p
             When other
               String 'an unknown' delimited size into d pointer p
           End-evaluate
```

Figure 64 (Part 2 of 3). Checking SOM exceptions in COBOL

```
           Move 0 to j
           Move major to jrd
           Call 'SLZ' using j s i
           String ' exception (major = ' s(i : ) ')'
               delimited size into d pointer p
           Display d(1 : p - 1)
           Call 'somExceptionId' using value evp returning eip
           Set address of ei to eip
           Move 0 to i
           Inspect ei tallying i for characters before initial x'00'
           Display '  Exception ID:  <' ei(1 : i) '>'
           Call 'somExceptionFree' using value evp
           Goback
           .
       End program 'Print-ev'.

      ****************************************************************
      * Subroutine to strip leading zeroes                           *
      ****************************************************************
       Identification division.
         Program-id.
           'SLZ'.
       Data division.
        Linkage section.
         1 uint binary pic 9(9).
         1 str pic x(9).
         1 pos binary pic 9(9).
       Procedure division using uint str pos.
           Move uint to str
           Move 0 to pos
           Inspect str(1 : length str - 1)
               tallying pos for leading '0'
           Add 1 to pos
           Goback
           .
       End program 'SLZ'.
```

Figure 64 (Part 3 of 3). Checking SOM exceptions in COBOL

Initializers

IBM COBOL directly supports the existing `somInit` and `somUninit` protocols. For classes that use `somInit` — and this includes all pure COBOL classes — you can use the `somNew` method to create and initialize an object instance in one step. This is an appropriate technique when all instances have the same initial value, or do not have an explicit initial value at all. If, on the other hand, you want to parameterize object initialization, so that each object instance has a unique initial value, you may prefer the convenience of a metaclass; see the discussion of metaclasses later in this section.

You can execute the non-default initializer methods (as a client) of a class by using the documented technique of first invoking `somNewNoInit`, then invoking the appropriate initializer method explicitly. This is the recommended way of creating an instance of one of the SOM-enabled collections, for example.

You do need to know how to specify the so-called `somInitCtrl` structure that is used to control the progress of the initializer as it traverses the class hierarchy. For a client of a class initializer method (as opposed to a sub-class that provides its own initializer

methods), this structure is initially null, represented in COBOL as an OMITTED argument. Suppose that the IDL for the initialization method is:

```
void ISHeap_withNumber(inout somInitCtrl ctrl, in long number);
```

then COBOL code for invoking this initializer might be:

```
       1 a-heap object reference isheap.
         ...
         Invoke isheap 'somNewNoInit' returning a-heap
         Invoke a-heap 'ISHeap_withNumber'
             using value evp reference omitted value 10000
```

For COBOL subclasses of classes that use explicit initializers, the recommended technique is to use metaclass methods to instantiate and initialize the COBOL object. After creating the instance, the metaclass method invokes the initializer for each parent (and with multiple inheritance, there may be several), then initializes any instance data introduced by the subclass itself. There is nothing to prevent you from doing this directly in the client code; but where it is possible to encapsulate the logic in a metaclass method, it is both more reliable and more convenient to do so, especially when the subclass inherits from multiple parents.

Using a metaclass method is also a good way of creating and initializing your own pure COBOL objects in a single step, particularly where each object may have a unique initial value.

If You Need to Look at the IDL File

Generally, the documentation for a class library has all the information you need to use (as a client) or specialize (subclass) the classes. In particular, you would expect to find the interfaces — types and operations (methods) — expressed in IDL, together with the semantics of the operations and descriptions of the protocols for using the library. The operation definitions would include the required data types and argument passing conventions. The class library protocols are the rules for using the library: which objects must be instantiated, and in what order; what methods must be invoked to initialize the classes; what the relation between the classes is; and so on.

Sometimes, however, you may need more detailed information about a class library, for example when you are specializing the library by subclasssing. To get this additional information, you may need to look at the IDL or header files. It is then helpful to know their structure: what is relevant and what you can ignore. Consider the sample IDL file `spred` from the collection class library, shown in Figure 65 on page 290.

```
/*****************************************************************
*                                                                *
*  Licensed Materials - Property of IBM                          *
*                                                                *
*  5688-198 (C) Copyright IBM Corp. 1995                         *
*  All rights reserved                                           *
*                                                                *
*  US Government Users Restricted Rights - Use, duplication or   *
*  disclosure restricted by GSA ADP Schedule Contract with IBM   *
*  Corp.                                                         *
*                                                                *
*****************************************************************/

#ifndef _ISPRED_IDL  1
#define _ISPRED_IDL

#include <somobj.idl>  2

interface ISPredicate : SOMObject {  3

     boolean evaluateFor (in SOMObject element);  4

#ifdef __SOMIDL__  5
     implementation {
              releaseorder: evaluateFor;

              somDefaultInit: override,init;
              somDestruct:    override;

              callstyle      = idl;
              majorversion   = 1;
              minorversion   = 0;
              filestem       = spred;
              dllname        = "sccl.dll";
              functionprefix = sISPredicate_;

#ifdef __PRIVATE__  6
              passthru C_xh_before = "#include <ssglobal.xih>";
#endif
   };
#endif
};
#endif
```

Figure 65. Sample collection class IDL file

Typically, the IDL file consists of some IDL definitions, guarded so that they are processed only once per IDL compilation, plus some implementation-specific information, also guarded so that it is conditionally included. Refer to the numbered keys in Figure 65:

1 One of three conditional sections in the file; its purpose is to ensure that the IDL definitions in the file are processed no more than once during the IDL compilation. The matching `#endif` statement is at the end of the file.

2 The `#include` statement incorporates another IDL file that you may have to refer to.

3 The compound statement specifies the IDL element that this file defines, the `ISPredicate` interface.

4 This definition is for the (single) new operation `evaluateFor` that `ISPredicate` introduces.

5 The start of some SOM-specific implementation information, which needn't concern you; its matching `#endif` is the second to last.

6 A directive that is needed only by the implementation itself. Again it is not relevant to you, as a client of the class.

Memory Management

It is important to avoid memory leaks. This is particularly true with objects, because there are typically so many individual object instances created and destroyed. The idea is to ensure that, when an object is destroyed or assigned, all of its associated storage is also freed. "Helper Routines Source Code" on page 295 contains the source code for a pair of C routines that you can use to allocate and free dynamic storage for data that is pointed to by an object, for an `inout` argument to a method, and so on:

- `'OMMAllocate' using storage-size returning a-pointer`, to allocate storage, where `storage-size` is the 4-byte unsigned binary number of bytes to allocate;
- `'OMMFree' using a-pointer`, to free the previously allocated storage element that `a-pointer` addresses.

You **must** use `OMMFree` to free output storage allocated and returned to you by SOM class libraries. See "Complex Types" on page 280 and "String Type" on page 280 for details of how and when to do this.

You can also use these routines to manage dynamic storage (as opposed to instance data) for your own classes. Let's look at an example of a variable-length string class, where the string data is not an explicit part of the instance, but is instead a separate storage area that the instance **refers to**.

Here's the COBOL definition for the class:

```
      ****************************************************************
      * COBOL variable-length string class definition.               *
      ****************************************************************
       Identification division.
         Class-id.
           varstring inherits somobject.
       Environment division.
        Configuration section.
         Repository.
           Class varstring 'VarString'
           Class somobject 'SOMObject'
           .

      ****************************************************************
      * Variable-length string class instance data.                  *
      ****************************************************************
       Data division.
        Working-storage section.
         1 vstlen binary pic 9(9).
         1 vstptr pointer.

      ****************************************************************
      * Variable-length string class method:  default initialization;  *
      * set the instance to a predictable state.                     *
      ****************************************************************
       Identification division.
         Method-id.
           'somInit' override.
       Procedure division.
1          Set vstptr to null
           Move 0 to vstlen
           Goback
           .
       End method 'somInit'.
```

Figure 66 (Part 1 of 3). COBOL variable-length string class example

```
      ****************************************************************
      * Variable-length string class method:  assignment from a literal*
      ****************************************************************
       Identification division.
         Method-id.
            'SetVarstring'.
       Data division.
        Local-storage section.
         1 strsze pic 9(9) binary.
        Linkage section.
         1 valptr pointer.
         1 setval pic x(100).
         1 vstval pic x(100).
       Procedure division using by value valptr.
2          If vstptr not = null then
             Call 'OMMFree' using vstptr
           End-if
           Move 0 to vstlen
           Set address of setval to valptr
           Inspect setval tallying vstlen
               for characters before initial x'00'
           Add 1 to vstlen giving strsze
           Call 'OMMAllocate' using strsze returning vstptr
           Set address of vstval to vstptr
           Move setval(1:strsze) to vstval(1:strsze)
           Goback
           .
       End method 'SetVarstring'.

      ****************************************************************
      * Variable-length string class method:  return string (pointer). *
      ****************************************************************
       Identification division.
         Method-id.
            'GetVarstring'.
       Data division.
        Linkage section.
         1 valptr pointer.
       Procedure division returning valptr.
           Set valptr to vstptr
           Goback
           .
       End method 'GetVarstring'.
```

Figure 66 (Part 2 of 3). COBOL variable-length string class example

```
      ****************************************************************
      * Variable-length string class method: assign from another string*
      ****************************************************************
       Identification division.
         Method-id.
           'AssignVarstring'.
       Data division.
        Local-storage section.
         1 strsze binary pic 9(9).
         1 valptr pointer.
        Linkage section.
         1 str object reference varstring.
       Procedure division using value str.
3          If self not = str then
             Invoke str 'GetVarstring' returning valptr
             Invoke self 'SetVarstring' using value valptr
           End-if
           Goback
           .
       End method 'AssignVarstring'.

      ****************************************************************
      * Variable-length string class method:  free associated storage. *
      ****************************************************************
       Identification division.
         Method-id.
           'somUninit' override.
       Procedure division.
4          If vstptr not = null then
             Call 'OMMFree' using vstptr
             Set vstptr to null
             Move 0 to vstlen
           End-if
           Goback
           .
       End method 'somUninit'.

       End class varstring.
```

Figure 66 (Part 3 of 3). COBOL variable-length string class example

There are several points to notice about the use of storage in this example:

1 All VarString instances are created in a predictable initial state, with the length set to zero, and the string pointer set to null.

2 Before assigning a new value to an instance, the storage allocated for any current value is freed. If this weren't done, the storage would be “orphaned,” causing a memory leak.

3 When assigning one string to another, you have to check whether the sender is identical to the receiver before doing the assignment and thereby prematurely freeing the sender's storage.

4 Although `somFree` de-allocates the storage for the instance data, it does NOT free any storage that the instance refers to; thus it is critical to do that when the instance is uninitialized.

Helper Routines Source Code

The C source in Figure 67 may be used to implement the helper functions for string representation and memory management discussed in this chapter. You can either statically link the functions into your application, or generate a dynamic load library (DLL) for the functions and bind your application to the DLL.

```
/*********************************************************************/
/* Helper functions for using SOM IDL-based class libraries.         */
/*********************************************************************/

/* MVS pragma to generate long, mixed-case names                     */
#pragma longname

/* Macro to clear the high-order bit of the argument address (MVS/VM) */
#define Clean(p,q) p=(void*)((int)q&0x7fffffff)
#include <som.h>

/* Object Memory Management:  allocate memory.                       */
somToken OMMAlloc(size_t *sze){
  size_t *s;
  Clean(s,sze);
  return SOMMalloc(*s);
}

/* Object Memory Management:  free allocated memory.                 */
void OMMFree(somToken *ptr){
  somToken *p;
  Clean(p,ptr);
  SOMFree(*p);
  return;
}

/* Set COBOL representation (ODO object) from IDL string length      */
void IDLStringToCOBOL(char *str, long *len) {
  char *s;
  long *l;
  Clean(s,str);
  Clean(l,len);
  (*l)=strlen(s);
  return;
}

/* Set IDL string length (null byte) from COBOL (ODO) representation  */
void IDLStringFromCOBOL(char *str, long *len) {
  char *s;
  long *l;
  Clean(s,str);
  Clean(l,len);
  s[*l]=0;
  return;
}
```

Figure 67. C source for IDL-based library helper functions

Chapter 15. Converting Procedure-Oriented Programs to Object-Oriented Programs

Conventional COBOL programs belong to one of three types:

- Batch.
- Online.
- Subprogram.

Batch programs are often constructed to access files and/or databases and produce reports. In the access files and/or databases case, the file or database is the object of the action; however, the program is structured around the action—delete, insert, or update. In the produce reports case, the report can be viewed as an object; however, the program structure reflects the structure of the report.

Online transaction processing programs are built around the transactions which they process and these are reflected in the user interface maps or panels which make up the transaction. Online transactions may access several files or databases from one panel. In this case, there is a one to many relationship between the source of the action and the targets of the action, all of which can be viewed as objects.

Subprograms normally are called to provide a function too large or complex to include in the main program. They are also used to implement general purpose functions required by many other programs; in which case, they embody reusable code. In many cases, the subprogram alters the values of some parameters based on the values of other parameters. In other cases, the subprogram accesses files/databases or prints reports. In this case, the parameter list can be viewed as a message to trigger some action on a file or database object.

Wrapping a Procedure-Oriented Program

Wrapping is a technique to integrate existing procedure-oriented code with new object-oriented code. Two of the definitions for *wrap* are:

1. To enclose as if with a protective covering.
2. To conceal as if by enveloping.

Wrappers are objects that provide an interface between object-oriented code and procedure-oriented code. They enclose the procedure-oriented code in a package, concealing its true nature and making it seem like object-oriented code.

Wrappers are useful in two situations:

- Glass-top coordination.
- Boundary interface coordination.

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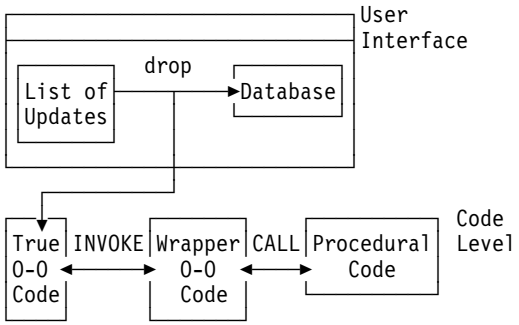
Glass-top Coordination

This type of wrapper integrates the old and new code at the user interface or "glass-top" level. As user interfaces move toward a object-oriented approach, you find direct manipulation used more. This implies actions such as "dragging" and "dropping" objects into or onto other objects. When this occurs, the objects involved must work together to take the appropriate action. If one of the objects is really procedure-oriented code, the wrapper is an interface to the true objects.

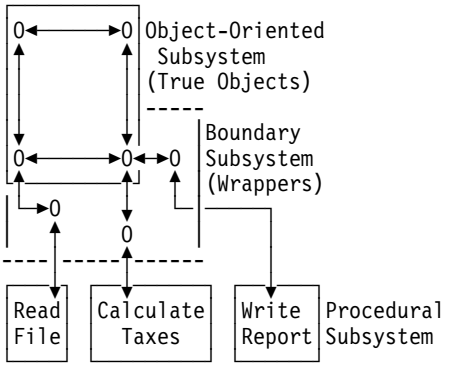
For example, you have a stable set of procedural code for updating a database. However, you would like to include the database as part of a graphical user interface. The goal is to drop a list object representing an update to the database on the database object and have the update performed. You need to write a wrapper class to accept messages from the list object; i. e. the list object invokes methods in the wrapper. The methods in the wrapper class interpret the information from the list object and use the CALL statement to call the appropriate subprogram in the old procedural code.



Boundary Interface Coordination

Boundary interface wrappers create objects for procedural code outside the boundaries of the new object-oriented subsystem. These wrappers allow the object-oriented part of the system to deal with the procedure-oriented part of the system as if it were object-oriented. Thus, you can phase in new object-oriented code and continue to use your existing procedure-oriented code.

You can write a wrapper for each subprogram in the procedural code. Or if several subprograms are working with the same object, processing the same file or producing the same report, you can write a single wrapper for all the related subprograms. The appropriate method in the wrapper is invoked from a true object and the method in turn calls the appropriate subprogram.



Required Change to Procedural Code

If you decide to use wrappers, there is one change you must make to your procedural code. Since methods are always recursive, it is possible to INVOKE method A which CALLs program B. While program B is executing, method A could be invoked again causing a second call to program B. This second call is considered a recursive call. Therefore, any procedural code invoked from a method should have the RECURSIVE clause on the PROGRAM-ID statement.

For example:

```
Identification Division.
Program-Id.  ProgB recursive.
Environment Division.

⋮
```

Coexistence

The object-oriented and procedure-oriented parts of your system can exist quite well together. Certainly, you want to reuse your existing code as long as it continues to meet your needs. However, you can add new function to your system using object-oriented implementations. Only if your existing code no longer meets your needs or its maintenance cost is too high should you consider converting the entire procedure-oriented system to an object-oriented system.

Converting a Procedure-Oriented Program

Taking as input a typical COBOL batch or online program, the goal is to produce a formal specification of the program in object-oriented form. The conversion involves four steps:

- Identify objects.
- Analyze data flow and usage.
- Reallocate code to objects.
- Write the object-oriented code.

Step Three

Identify Objects

First, partition the DATA DIVISION into potential objects by identifying every record as an object and every field in the record as its instance data. You can start by taking record structures that define files and making them objects called `FfffffFile`, where `Fffff` is a name of your choosing. Record structures that define database views become objects called `VvvvvView`. Map or panel record structures become objects called `UuuuuInterface`. Other record structures in the WORKING-STORAGE SECTION not related to files, databases, maps, or panels become objects called `WwwwWork`. Finally, record structures in the LINKAGE SECTION become objects called `PppppParameter`.

Now you have a lot of potential objects, some of which are redundant. Study the potential objects and decide if two or more are slight variations of the same object. Maybe you have two detail lines as potential objects that differ in only one or two of their fields. If possible use REDEFINES or some other technique to combine the two detail lines into one and, thus, combine the two potential objects into one object.

The result of this step is an object list with the name of each object and its instance data.

Analyze Data Flow and Usage

Analyze the file and database accesses to collect the access operations, such as SELECT, UPDATE, INSERT, DELETE, READ, and WRITE, for each object. The purpose is to find the relationship between objects via access sequence. For example, if one record read from the input file results in one detail line written to a report then a relationship exists between the file and the report objects. The relationships are tied to the source object and the target object.

Trace the data flow between objects to identify those objects which use instance data from another object.

If the two objects share a superclass - subclass (parent - child) relationship, then the subclass inherits methods from the superclass and shares instance data via 'get' and 'set' methods. (The `get` and `set` methods are written in the superclass definition.)

If the two objects are separate and distinct, then they are collaborators. Collaborators do not inherit anything from each other. Instance data that needs to be shared between two collaborators is typically passed as parameters on an INVOKE statement.

The result of this step is an object relationship table listing all the inheritance and collaboration relationships between objects.

Reallocate Code to Objects

For each object you identified, collect all references to it from the PROCEDURE DIVISION. Look for procedural code that changes the state of the object's instance data. If an instruction affects several data items in different objects, it must be changed or duplicated and the proper form associated with the correct object.

For example:

```
Move 0 To input-z output-z.
```

must be changed to

```
Move 0 To input-z.
Move 0 To output-z.
```

The first MOVE is associated with the appropriate input object and the second with the appropriated output object.

Now couple the procedural instructions from the PROCEDURE DIVISION with the objects to form methods. Take the code you pulled from the program and organize it into task-oriented methods.

Refer to the object relationship table from step two and determine if any new methods must be written to facilitate passing data between two objects. See “Writing a Method Definition” on page 220 for information about writing methods.

The result of this step is completed method definitions.

Write the Object-Oriented Code

Write a class definition using the object list from step one and the methods from step three. See “Writing a Class Definition” on page 216 for information about writing classes.

Also, write the client program to create instances of the classes and invoke methods. See “Writing a Client Definition” on page 229 for information about writing client programs.

Your client program may be a modification of your original procedure-oriented program with invokes and manipulation of object references added where needed in the procedural code. This is the case when all the procedure-oriented code was not placed into methods. However, if all the procedure-oriented code was placed into methods, then your client program is a new program you write from scratch.

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Chapter 16. Porting Applications between Platforms

Your personal computer (PC) has a different hardware and operating system architecture than IBM mainframes or AIX workstations. Because of fundamental platform differences, some problems can arise as you move COBOL programs between the PC, workstation, and mainframe environments.

The following information describes some of the differences between development platforms and provides instructions to help you minimize portability problems.

Getting Mainframe Applications to Compile on the PC

As you move programs to the PC from the mainframe, one of your first goals is to get the applications you have already been using to compile in the new environment without errors.

Choosing the Right Compiler Options

Some mainframe COBOL compiler options are not applicable on the PC, and are treated as comments. For a full list of differences between host COBOL and IBM VisualAge for COBOL for OS/2 (including compiler options), see Appendix A, "Summary of Differences with Host COBOL" on page 399.

Two compiler options might yield unpredictable results and are flagged by the compiler with W-level messages:

CMPR2
This compiler option impacts the interpretation of language elements. The PC compiler does not support VS COBOL II Release 2 language elements that are in conflict with the ANSI 85 COBOL Standard. A program depending on the CMPR2 option is not portable.

NOADV
Programs that require the use of NOADV are sensitive to device control characters and almost certainly are not portable. If your program relies on NOADV, revise it such that language specification does not assume a printer control character as the first character of the `01` record for the file.

Differences from Mainframe COBOL Language Features

The following section describes some language features that are valid under mainframe COBOL but can create errors or unpredictable results in your PC compilation. Where possible, a solution to the potential problem is provided.

ACCEPT and DISPLAY statements
On the PC, the targets of DISPLAY or ACCEPT statements are determined by checking COBOL environment variables (see "Run-Time Environment Variables" on page 132). If your mainframe program assumes the use of host DDNAMEs as the targets of ACCEPT or DISPLAY statements, ensure that these targets are defined by equivalent environment variables with values set to appropriate PC filenames.

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ASSIGN clause
There is a different syntax and mapping to the system filename based on ASSIGNMENT name (see the *IBM COBOL Language Reference*).

CALL statement
A filename as a CALL argument is not supported.

CLOSE statement
The phrases FOR REMOVAL, WITH NO REWIND, and UNIT/REEL are treated as comments. Avoid their use in portable programs.

LABEL RECORD clause
LABEL RECORD IS *data-name*, USE...AFTER...LABEL PROCEDURE, and GO TO MORE-LABELS are treated as errors. Programs depending on user label processing supported through MVS QSAM are not portable.

POINTER and PROCEDURE-POINTER data items
Under mainframe COBOL, a POINTER data item is defined as 4 bytes, and a PROCEDURE-POINTER data item is defined as 8 bytes. On the PC, the size of these data items are consistent with the native pointer definition of the platform (for example, 4 bytes for a 32-bit machine).

RERUN clause
Treated as a comment.

SHIFT-IN, SHIFT-OUT special registers
Not applicable on the PC; results in an E-level message.

SORT-CONTROL special register
Because it identifies a system filename, this register is sensitive to the filename conventions of the platform. Be aware of the differences in naming conventions between the PC and the mainframe.

WRITE statement
If you specify WRITE...ADVANCING with the environment names C01-C12 or S01-S05, the ADVANCING phrase is ignored.

Using the COPY Statement to Help Port Programs

In many cases, potential portability problems can be avoided by using the COPY statement to isolate platform-specific code. For example, you can include platform-specific code in a compilation for a given platform and exclude it from compilation for a different platform. You can also use the COPY REPLACING phrase to globally change non-portable source code elements, such as filenames.

For information about the COPY statement, see the *IBM COBOL Language Reference*.

Getting Mainframe Applications to Run on the PC

Once you have downloaded your source program from the mainframe and compiled it on the PC without errors, the next step is to run the program. In many cases, you can get the same results from the PC run as from the mainframe COBOL run without

serious source-language modifications. In order to assess whether or not you should make source-language modifications to you program, you need to know about elements and behavior of the COBOL language that vary due to the underlying hardware or software architectures.

Data Representations Causing Run-Time Differences

COBOL stores USAGE PACKED-DECIMAL data in the same manner on both the mainframe and on the PC, but all other computational data is, by default, represented differently. Most programs act the same on the PC as they do on the mainframe regardless of the data representation. To ensure that this is true for your programs, you should try to understand the differences described in the following sections.

ASCII vs EBCDIC

The PC uses the ASCII-based character set while the mainframe uses the EBCDIC character set. This means that most characters have a different hexadecimal value. For example, the hexadecimal value for a blank is X'20' in the ASCII character set and X'40' in the EBCDIC character set.

This means that code dependent on the EBCDIC hexadecimal values of character data probably fails when run using ASCII. For example, code that tests whether or not a character is a blank by comparing it with X'40' fails when run using the ASCII collating sequence.

In the ASCII character set, characters '0' through '9' have the hexadecimal values X'30' through X'39'. The ASCII lowercase letter 'a' has the hexadecimal value X'61', and the uppercase letter 'A' has the hexadecimal value X'41'. In the EBCDIC character set, characters '0' through '9' have the hexadecimal values X'F0' through X'F9'. In EBCDIC, the lowercase letter 'a' has the hexadecimal value X'81', and the uppercase letter 'A' has the hexadecimal value X'C1'. These differences have some important consequences:

- While 'a' < 'A' is true for EBCDIC, it is false for ASCII.
- While 'A' < '1' is true for EBCDIC, it is false for ASCII.
- While x >= '0' almost always means that x is a digit in EBCDIC, this is not true for ASCII.

Because of the differences described, the results of sorting character strings are different under EBCDIC and ASCII. For many programs, this has no effect, but you should be aware of potential logic errors if your program depends on the exact sequence in which some character strings are sorted. If your program is dependent on the EBCDIC collating sequence and you are porting it to the PC, you can obtain the EBCDIC collating sequence using PROGRAM COLLATING SEQUENCE IS EBCDIC or the COLLSEQ(EBCDIC) compiler option.

NATIVE vs NONNATIVE

The PC holds integers in a form that is byte-reversed when compared to the form in which they are held on the mainframe.

The mainframe representation is known as “Big Endian,” as in “big-end-in.” In other words, the most significant digit of the number is stored first. The PC represen-

tation is known, conversely, as “Little Endian,” as in “little-end-in.” On the PC, the least significant digit of the number is stored first.

For most programs this difference should create no problems. However, if your program depends on the hexadecimal value that an integer has, you should be aware of potential logic errors.

For programs that use mainframe binary data and rely on the internal representation of integer values, you should compile the entire program with the BINARY(S370) compiler option. For such programs, you should avoid the USAGE COMP-5 type, which is treated as the native binary data format regardless of whether or not the BINARY(370) option is specified.

IEEE vs HEXADEC

The PC represents floating-point data using the IEEE format while the mainframe uses the hexadecimal format.

Figure 68 summarizes the differences between normalized floating-point IEEE and hexadecimal for USAGE COMP-1 data:

Figure 68. Normalized IEEE vs. normalized hexadecimal for COMP-1 data

Specification	IEEE	Hexadecimal
Range	±1.17E-38 to 3.37E+38	±5.4E-79 to ±7.2E+75
Exponent representation	8 bits	7 bits
Mantissa representation	23 bits	24 bits
Accuracy	6 digits	6 digits

Figure 69 summarizes the differences between normalized floating-point IEEE and hexadecimal for USAGE COMP-2 data:

Figure 69. Normalized IEEE vs. normalized hexadecimal for COMP-2 data

Specification	IEEE	Hexadecimal
Range	±2.23E-308 to ±1.67E+308	±5.4E-79 to ±7.2E+75
Exponent representation	11 bits	7 bits
Mantissa representation	52 bits	56 bits
Digits of accuracy	15 digits	16 digits

For most programs these differences should create no problems. However, use caution in porting if your program depends on hexadecimal representation of data.

EBCDIC DBCS vs ASCII multi-byte strings

Mainframe double-byte character strings (DBCS) are enclosed in shift codes, while PC multi-byte character strings (including DBCS) are not enclosed in shift codes. The hexadecimal values used to represent the same characters are also different.

For most programs this should make not make porting difficult. However, if your program depends on the hexadecimal value of a graphic string or on a character string containing mixed character and graphic data, use caution in your coding practices.

Note: On the PC, DBCS data can contain single-byte characters as well as double-byte characters.

Environment Differences Affecting Portability

There are some differences, other than data representation, between the PC and mainframe platforms that can also affect the portability of your programs. This section describes some of these differences.

File names

File naming conventions on the PC are very different from those on the mainframe. The following file name, for example, is valid on the PC but not on the mainframe:

```
d:\programs\data\myfile.dat
```

This can have an effect on portability if you use file names in your COBOL source programs.

Control codes

Some characters that have no particular meaning on the mainframe are interpreted as control characters on the PC. This can lead to incorrect processing of ASCII test files. Files should not contain any of the following characters:

X'0A' (“LF - line feed”)
X'0D' (“CR - carriage return”)
X'1A' (“EOF - end of file”)

Device-dependent control codes

Use of device-dependent (platform-specific) control codes in your programs or files can cause problems when trying to port them to other platforms that do not necessarily support the control codes.

As with all other very platform-specific code, it is best to isolate such code as much as possible so that it can be replaced easily when you move the application to another platform.

Language Elements Causing Run-Time Differences

In general, you can expect your portable COBOL programs to behave the same way on the PC that they do on the mainframe. However, be aware of the differences in FILE STATUS values use for I/O processing.

If your program is written to respond to status key data items, you should be concerned with two issues, depending on whether the program is written to respond to the first status key or the second status key:

1. If your program is written to respond to the first file status data item *(data-name-1)*, be aware that values returned in the 9X range are platform-dependent. If your program depends on the interpretation of a particular 9X value (for example, 97),

do not expect the value to have the same meaning on the PC that it does on the mainframe. Instead, revise your program so that it responds to **any** 9X value as a generic I/O failure.

2. If your program is written to respond to the second file status data item *(data-name-8)*, be aware that the values returned are both platform and file system dependent. For example, VSAM returns values with a different record structure on the mainframe than it does on the PC. Also, different file systems (for example, Btrieve rather than IBM's VSAM) return different values. If your program relies on the interpretation of the second file status data item, it is probably not portable.

For more information about the FILE STATUS clause, see the *IBM COBOL Language Reference*.

Writing PC Code to Run on the Mainframe

You can use IBM VisualAge for COBOL for OS/2 to write new applications, taking advantage of the productivity gains and increased flexibility of using your PC. The purpose of this section is to make you aware of how to avoid using IBM VisualAge for COBOL for OS/2 features not supported by mainframe COBOL.

Language Features Supported Only by the PC Compiler

IBM VisualAge for COBOL for OS/2 supports several language features not supported by the mainframe COBOL compiler. As you write code on your PC that is intended to run on the mainframe, avoid using these new features:

- ORGANIZATION LINE SEQUENTIAL
- Format 5 SET statement extension that allows setting of pointers or ADDRESS OF special register to an address of level 01, 02-49, or 77 in the LINKAGE SECTION or the WORKING-STORAGE SECTION
- LOCK MODE IS AUTOMATIC
- READ statement using PREVIOUS phrase
- START statement using < or <= in the KEY PHRASE
- USAGE COMP-5 data items

Compiler Options Supported Only on the PC

A number of new compile-time options are available with IBM VisualAge for COBOL for OS/2. Do not use any of the following options in your source code if you intend to port this code to the mainframe COBOL compiler:

- BINARY
- CALLINT (also a compiler directive)
- ENTRYINT
- PROBE
- PROFILE
- THREAD

Names Supported Only on the PC

Be aware of the difference in naming conventions supported on the PC and mainframe file systems. Try to avoid hard-coding the names of files in your source programs. Instead, use mnemonic names (in turn, mapped to mainframe DDNAMEs or PC environment variables) which can be defined on each platform, allowing you to compile your program without source code changes to accommodate the file name changes.

Specifically, consider how you refer to files in the following language elements:

- ACCEPT and DISPLAY target names
- ASSIGN clause
- COPY statement (*text-name* and *library-name*)

Writing Applications That Are Portable between the PC and AIX

The PC and AIX COBOL environments are similar, and their language support is practically identical. However, there are two key differences between these platforms that you should keep in mind when developing applications that are portable between the PC and the AIX workstation:

1. As you can expect when porting programs between the PC the mainframe, hard-coded filenames in your source programs can lead to problems. See “Names Supported Only on the PC” for a description of how and where to avoid using literal file names in your source programs.
2. As discussed in the discussion of NATIVE vs NONNATIVE on 304, the PC represents integers in “Little Endian” format. Like the mainframe, AIX workstations maintain integers in “Big Endian” format. Therefore, if your PC COBOL program depends on the internal representation of an integer, the program is probably not portable to AIX; avoid writing programs that rely on such internal representation. If your program *requires* manipulating the internal representation of PC-format integers, use the BINARY(S370) compiler option and avoid the USAGE COMP-5 type.

Chapter 17. Subprograms

Often, an application will consist of several, separately compiled programs linked together.

When a run unit consists of several, separately compiled programs that call each other, the programs must be able to communicate with each other. They need to transfer control and usually need to have access to common data. The following sections describe the methods that allow separately compiled programs to communicate with one another.

COBOL programs that are nested within each other can also communicate. All the required subprograms for an application can be contained in one program and thereby require only a single compilation. This method is explained in "Nested Programs" on page 310.

Transferring Control to Another Program

In the PROCEDURE DIVISION, a program can call another program (generally called a subprogram in COBOL terms), and this called program can itself call other programs. The program that calls another program is referred to as the *calling* program, and the program it calls is referred to as the *called* program. When the called program processing is completed, the program can either transfer control back to the calling program or end the run unit.

The called COBOL program starts running at the top of the PROCEDURE DIVISION.

Not Recomended: You can specify another entry point where the program will begin running by using the ENTRY label in the called program. However, this is not recommended in a structured program.

Recursive Calls

If a called program directly or indirectly executes its caller (such as program `X` calling program `Y`; program `Y` calling program `Z`; and program `Z` then calling program `X`), this is called a *recursive* call. Recursive calls are allowed if you code the RECURSIVE attribute on the PROGRAM-ID paragraph of the recursively invoked program and/or if you specify the THREAD compiler option. If you try to recursively call a COBOL program that does not have the RECURSIVE attribute coded on its PROGRAM-ID paragraph, the run unit will end abnormally.

For considerations in using the LINKAGE SECTION with recursive calls, see "With Recursion or Multithreading" on page 21.

Main Programs and Subprograms

No specific source code statements or options identify a COBOL program to be a main program or a subprogram. If a COBOL program is the first program in the run unit, that

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COBOL program is the *main program*. Otherwise, it and all other COBOL programs in the run unit are subprograms.

Whether a COBOL program is a main program or a subprogram can be significant for either of two reasons:

- If execution ends in the main program, the main program must use a STOP RUN or GOBACK statement. STOP RUN terminates the run unit, and closes all files opened by the main program and its called subprograms. Control is returned to the caller of the main program, which is often the operating system. GOBACK has the same effect in the main program. An EXIT PROGRAM performed in a main program has no effect.

  A subprogram can end with an EXIT PROGRAM, a GOBACK, or a STOP RUN statement. If the subprogram ends with an EXIT PROGRAM or a GOBACK statement, control returns to its immediate caller without ending the run unit. An implicit EXIT PROGRAM statement is generated if there is no next executable statement in a called program. If the subprogram ends with a STOP RUN statement, the effect is the same as it is in a main program: all COBOL programs in the run unit are terminated, and control returns to the caller of the main program.
- A subprogram is usually left in its *last-used state* when it terminates with EXIT PROGRAM or GOBACK. The next time it is called in the run unit, its internal values will be as they were left, except that return values for PERFORM statements will be reset to their first values. In contrast, a main program is initialized each time it is called. There are three exceptions:
  1. A subprogram that is called and then cancelled will be in the initial state the next time it is called.
  2. A program with the INITIAL attribute will be in the initial state each time it is called.
  3. Data defined in the LOCAL-STORAGE section is in initial state each time it is called.

Making Calls between COBOL Programs

You can transfer control to nested and/or non-nested COBOL programs.

Calls to nested programs allow you to create applications using structured programming techniques. They can also be used in place of PERFORM procedures to prevent unintentional modification of data items. Calls to nested programs can be made using either the CALL *literal* or CALL *identifier* statement. For more information on nested programs, see “Nested Programs.”

Nested Programs

A COBOL program can contain or “nest” other COBOL programs. The nested programs can themselves nest yet other programs. A nested program can be directly or indirectly nested in a program.

Figure 70 describes a nested program structure with directly and indirectly nested programs.

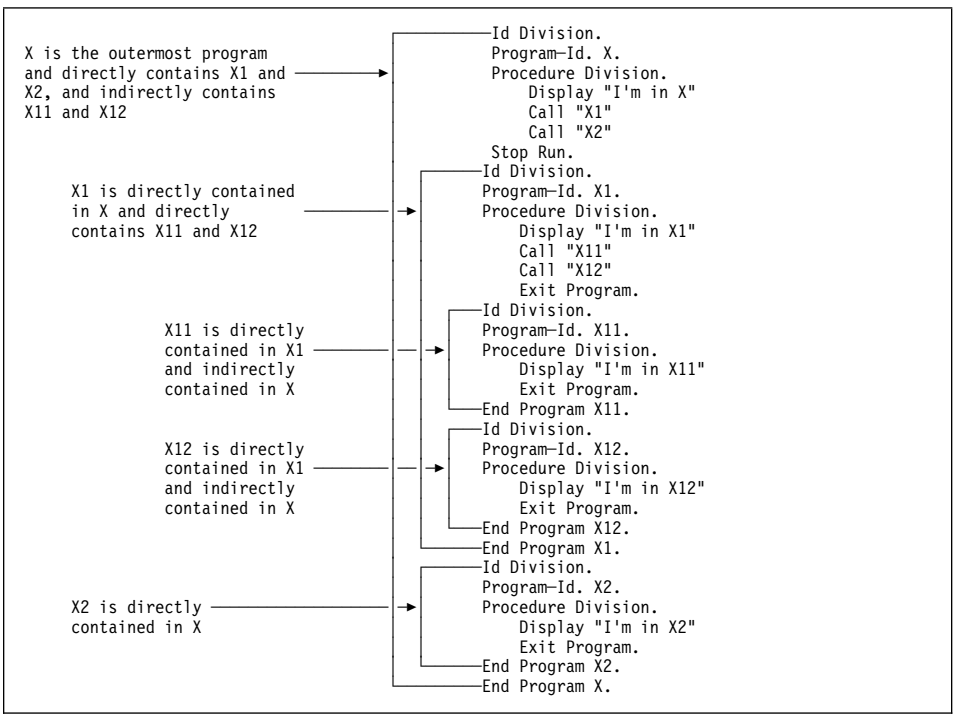

Figure 70. Nested Program Structure with Directly and Indirectly Contained Programs

Conventions for Using Nested Program Structure

Follow these conventions when using nested program structures:

- The IDENTIFICATION DIVISION is required in each program. All other divisions are optional.
- Nested program names must be unique.
- Nested program names can be any valid COBOL word or a non-numeric literal.
- Nested programs cannot have a CONFIGURATION SECTION. The outermost program must set any CONFIGURATION SECTION options that might be required.
- Each nested program is included in the nesting program immediately before its End Program header (see Figure 70).
- Nested and nesting programs must be terminated by an End Program header.

Calling Nested Programs

A nested program can only be called by its directly nesting program, unless the nested program is identified as COMMON in its PROGRAM-ID clause. In that case, the *common program* can also be called by any program that is nested (directly or indi-

rectly) in the same program as the common program. Only nested programs can be identified as COMMON. Recursive calls are not allowed.

Figure 71 shows the outline of a nested structure with some nested programs identified as COMMON.

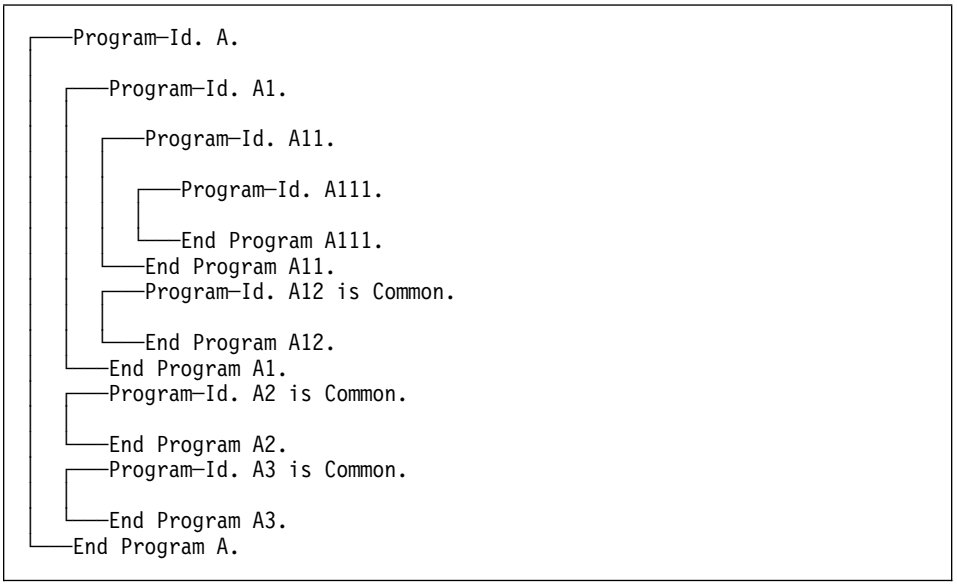

Figure 71. A Nested Structure with COMMON Programs

The following table describes the calling hierarchy for the structure that is shown in Figure 71. Programs A12, A2, and A3 are identified as COMMON, and t he calls associated with them differ.

Figure 72. Calling Hierarchy for Nested Structures with COMMON programs

This Program	Can call these programs	And can be called by these programs
A	A1, A2, A3	None
A1	A11, A12, A2, A3	A
A11	A111, A12, A2, A3	A1
A111	A12, A2, A3	A11
A12	A2, A3	A1, A11, A111
A2	A3	A, A1, A11, A111, A12, A3
A3	A2	A, A1, A11, A111, A12, A2

Note that:

- A2 cannot call A1 because A1 is not common and is not contained in A2.
- A1 can call A2 because A2 is common.

Scope of Names in a Nested Program

Names in nested programs are divided into two classes: local and global. The class determines whether a name is known beyond the scope of the program that declares it. A specific search sequence locates the declaration of a name after it is referenced in a program.

Local Names: Names are local unless declared to be otherwise (except the program name). Local names are not visible or accessible to any program outside of the one in which they were declared; this includes both contained and containing programs.

Global Names: A name that is global (indicated using the GLOBAL clause) is visible and accessible to the program in which it is declared, and to all the programs that are directly and indirectly contained in that program. This allows the contained programs to share common data and files from the containing program, simply by referencing the name of the item.

Any item that is subordinate to a global item (including condition names and indexes) is automatically global.

The same name can be declared with the GLOBAL clause more than one time, providing that each declaration occurs in a different program. Be aware that masking, or hiding, a name in a nested program is possible by having the same name occur in different programs of the same containing structure. This could possibly cause some problems when a search for a name declaration is taking place.

Searching for Name Declarations: When a name is referenced in a program, a search is made to locate the declaration for that name. The search begins in the program that contains the reference and continues outward to containing programs until a match is found. The search follows this process:

1. Declarations in the program are searched first.
2. If no match is found, only global declarations are searched in successive outer containing programs.
3. The search ends when the first matching name is found; otherwise, an error exists if no match is found.

Note that the search is for a global name, not for a particular type of object associated with the name, such as a data item or file connector. The search stops when any match is found, regardless of the type of object. If the object declared is of a different type than what was expected, an error condition exists.

Static, Dynamic, and Run-time Linking

COBOL calls can be made to a subprogram that is either linked into the same executable module as the caller (static linking) or a subprogram that is provided in a dynamic link library or DLL (dynamic linking). IBM VisualAge for COBOL for OS/2 also provides for run-time resolution of the target subprogram from a DLL. If it is linked statically, it is part of the caller's executable module and is loaded with the caller. If it is linked

dynamically or resolved at run time, it is provided in a library and is loaded either when the caller is loaded or when it is called.

Static linking and dynamic linking are done for COBOL CALL *literal* subprograms only. See "Static Linking Overview" on page 365 for a discussion on static linking. See "Dynamic Linking Overview" on page 365 for a discussion of dynamic linking.

Run-time resolution is always done for COBOL CALL *identifier* and is done for CALL *literal* when the DYNAM option is in effect.

CALL Identifier

The COBOL CALL *identifier*, where *identifier* is a data item that contains the name of a non-nested subprogram when the program is run, always results in the target subprogram being loaded when it is called. Also, the name of the dynamic link library must match the name of the target entry point. See "Terminology Notes" on page 366 for a discussion of COBOL terminology.

CALL literal

The COBOL CALL *literal*, where *literal* is the explicit name of a non-nested subprogram being called, can be resolved statically, dynamically or at run time. If the NODYNAM compile-time option is in effect, either static or dynamic linking can be done. If DYNAM is in effect, the CALL *literal* is resolved the same as CALL *identifier*: the target subprogram is loaded when it is called, and the name of the dynamic link library must match the name of the target entry point.

These call definitions apply only in the case of a COBOL program calling a non-nested program. When a COBOL program calls a nested program, the CALL is resolved by the compiler without any system intervention.

For a detailed description of the CALL statement, see the *IBM COBOL Language Reference*. For more information on calling subprograms in DLLs see Chapter 22, "Building Dynamic Link Libraries" on page 365.

Making Calls between COBOL and C/C++ Programs

You can call functions written in C or C++ from your COBOL programs and vice versa. This chapter describes how to perform such interlanguage calls from your COBOL and C or C++ programs.

Matching Data and Linkages

Some COBOL data types have C/C++ equivalents, but others do not. When you pass data between COBOL and C/C++ functions, be sure to restrict data exchange to appropriate data types. For a detailed description of how COBOL programs can share data with other programs, see Chapter 18, "Data Sharing" on page 321.

The following table shows the correspondence between the data types available in COBOL and C/C++.

C/C++ Data Types	COBOL Data Types
wchar_t	DISPLAY-1 (PICTURE N, G) wchar_t is the processing code whereas DISPLAY-1 is the file code.
char	PIC X
signed char	No appropriate COBOL equivalent.
unsigned char	No appropriate COBOL equivalent.
short signed int	PIC S9-S9(4) COMP-5. Can be COMP, COMP-4, or BINARY if you use the TRUNC(BIN) compiler option.
short unsigned int	PIC 9-9(4) COMP-5. Can be COMP, COMP-4, or BINARY if you use the TRUNC(BIN) compiler option.
long int	PIC 9(5)-9(9) COMP-5. Can be COMP, COMP-4, or BINARY if you use the TRUNC(BIN) compiler option.
long long int	PIC 9(10)-9(18) COMP-5. Can be COMP, COMP-4, or BINARY if you use the TRUNC(BIN) compiler option.
float	COMP-1
double	COMP-2
enumeration	Equivalent to level 88, but not identical.
char(n)	PICTURE X(n)
array pointer (*) to type	No appropriate COBOL equivalent.
pointer(*) to function	PROCEDURE-POINTER

Figure 73. Correspondence between COBOL and C/C++ Data Types

Example - Calling C/C++ Functions from a COBOL Program

The following COBOL program illustrates several concepts:

- C/C++ programs are called using the COBOL CALL statement. The CALL statement does not indicate if the called program is written in COBOL or C/C++.
- COBOL supports calling programs with mixed-case names.
- Arguments can be passed to C/C++ programs in different ways (for example, CALL BY REFERENCE, CALL BY VALUE, etc.).
- You must declare a function return value on the CALL statement that calls a C/C++ function.
- You must map COBOL data types to appropriate C/C++ data types.

These concepts are illustrated in the following COBOL source program, COBCALLC.CBL:

```
      * These compiler options allow for
      * case-sensitive names for called programs
      * and set the call interface/linking
      * convention to that of the IBM C/C++ default.
      *
       CBL PGMNAME(MIXED) CALLINT(OPTLINK)
      *
      *
       IDENTIFICATION DIVISION.
       PROGRAM-ID. "COBCALLC".
      *
       DATA DIVISION.
       WORKING-STORAGE SECTION.
      *
       01 N4               PIC 9(4)  COMP-5.
       01 NS4              PIC S9(4) COMP-5.
       01 N9               PIC 9(9)  COMP-5.
       01 NS9              PIC S9(9) COMP-5.
       01 NS18             PIC S9(18) COMP-5.
       01 D1               USAGE COMP-2.
       01 D2               USAGE COMP-2.
       01 R1.
           02 NR1               PIC 9(8) COMP-5.
           02 NR2               PIC 9(8) COMP-5.
           02 NR3               PIC 9(8) COMP-5.
```

Figure 74 (Part 1 of 2). COBCALLC.CBL - A COBOL Program That Calls a C Program

```
       PROCEDURE DIVISION.
           MOVE 123 TO N4
           MOVE -567 TO NS4
           MOVE -13579456 TO N9
           MOVE 98765432 TO NS9
           MOVE 12345678902468 TO NS18
           DISPLAY "Call MyFun with n4=" N4 " ns4=" NS4 " N9=" n9
           DISPLAY "            ns9="  NS9 " ns18="  NS18
      *
      * The following CALL illustrates several ways to pass
      * arguments.
      *
           CALL "MyFun" USING N4 BY VALUE NS4 BY REFERENCE N9 NS9 NS18
           MOVE 1024 TO N4
      *
      * The following CALL returns the C function return value.
      *
           CALL "MyFunR" USING BY VALUE N4 RETURNING NS9
           DISPLAY "n4=" N4 " and ns9= n4 times n4= " NS9
           MOVE -357925680.25 TO D1
           CALL "MyFunD" USING BY VALUE D1 RETURNING D2
           DISPLAY "d1=" D1 " and d2= 2.0 times d2= " D2
           MOVE 11111 TO NR1
           MOVE 22222 TO NR2
           MOVE 33333 TO NR3
           CALL "MyFunV" USING R1
           STOP RUN.
```

Figure 74 (Part 2 of 2). COBCALLC.CBL - A COBOL Program That Calls a C Program

The COBOL default is that arguments are passed BY REFERENCE. If an argument is passed BY REFERENCE, C gets a pointer to the argument. If you pass an argument BY VALUE in the CALL statement, COBOL passes the actual argument. BY VALUE can be used only for the following data types:

- Alphanumeric DISPLAY items
- BINARY
- COMP
- COMP-1
- COMP-2
- COMP-4
- COMP-5
- OBJECT REFERENCE
- POINTER
- PROCEDURE-POINTER

For a detailed description of the CALL statement, see the *IBM COBOL Language Reference*.

Linkage Conventions for CALLing C Programs from COBOL

There are important linkage considerations for COBOL programs that CALL C/C++ functions. Because C/C++ and COBOL use different default linkage conventions, you may need to use the >>CALLINT compiler directive or CALLINT compiler option for your COBOL programs that call C/C++ functions.

For example, if your COBOL program calls a program which used the default C Set++ linkage convention, compile your program with the CALLINT(OPTLINK) option or use the >>CALLINT OPTLINK compiler directive. Neither is the default.

Selective Change: The compiler directive format is useful where you want to change the linkage convention for a particular call rather than the whole program.

For details about CALLINT, see “CALLINT” on page 146.

Calling C/C++ with a Variable Parameter List

C/C++ allows calls to a given program to be made with a varying number of parameters. You need to know which of the following methods the called C/C++ program uses to determine how many parameters have been passed to it.

The called C/C++ program may use the `_parmdwords` function to get the number of parameters passed from the AL register. (See the *C Library Reference* for details.) Using SYSTEM linkage (i.e. the CALLINT(SYSTEM) option) will cause COBOL to set the AL register to the number of parameters pas sed.

Alternately, the called C/C++ program may use the `va_start`, `va_arg` and `va_end` macros to manage the variable aspect of the parameter list. If so, you need to know how the called program determines the end of the parameter list. For example, some programs look for a null pointer to signify the end of the parameter list. COBOL does not terminate the parameter list with a null; you can supply it yourself by passing `BY VALUE 0.` as the last argument.

Example - C Programs That are Called by and Call COBOL Programs

The following C program illustrates that a CALLed C function receives arguments in the order in which they were passed in the COBOL CALL statement. It also shows how a C program can call a COBOL program (in this case, a program named `TPROG1`, see Figure 76 on page 319).

The file `MyFun.c` contains the following C source code:

```
typedef struct { unsigned long hi; unsigned long lo; } longlong;

void
MyFun(short * ps1, short s2, long *k1, long *k2, longlong *m)
{
    double two_pow_32; /* two to the power 32 */
    double x;

    two_pow_32 = 2.0 * 0x80000000;
    x = two_pow_32*m->hi + m->lo;
    printf("MyFun got s1=%d s2=%d k1=%d k2=%d x=%25.20Lg\n",
         *ps1,s2, *k1, *k2, x);
}


long
MyFunR(short s1)
{
    return(s1 * s1);
}


double
MyFunD(double d1)
{
    double z;

    /* example of C calling COBOL */
    z = 1122.3344;
        (void) TPROG1(&z);
    /* example of C returning a value to COBOL */
    return(2.0 * d1);
}

void
MyFunV(long *pn)
{
    printf("MyFunV got %d %d %d\n", *pn, *(pn+1), *(pn+2));
}
```

Figure 75. MyFun.C - A C Program That Calls and is Called by COBOL Programs

`MyFun.c` consists of the following functions:

MyFun illustrates passing a variety of arguments.

MyFunR illustrates how to pass and return a long variable.

MyFunD illustrates C calling a COBOL program and it also illustrates how to pass and return a double variable.

MyFunV illustrates passing a pointer to a record and accessing the items of the record in a C program.

Example - COBOL Program Called by a C Program

In Figure 74 on page 316, you find a COBOL program that calls C functions. In Figure 75 on page 318, you find a C program that is called by a COBOL program and calls a COBOL program. The following example illustrates how to write COBOL programs that are called by C programs.

The file TPROG1.CBL is called by the C function MYFUND in the C program MyFun.c (see Figure 75 on page 318). The called COBOL program contains the following source code:

```
*
* Sets the calling convention to that of IBM C/C++
*
 CBL ENTRYINT(OPTLINK)
*
 IDENTIFICATION DIVISION.
 PROGRAM-ID. TPROG1.
*
 DATA DIVISION.
 LINKAGE SECTION.
*
 01 X                USAGE COMP-2.
*
 PROCEDURE DIVISION USING X.
     DISPLAY "TPROG1 got x= " X
     GOBACK.
```

Figure 76. TPROG1.CBL - A COBOL Program Called by a C Program

Linkage Conventions for Called COBOL Programs

There are important linkage considerations for COBOL programs called by C functions. Because C and COBOL use different default linkage conventions, you may need to specify the ENTRYINT compiler option for your COBOL programs called by C/C++ programs.

For example, if your COBOL program is called by a C Set++ program, you should compile your program with the ENTRYINT(OPTLINK) option. This option (not the default) sets the linking convention to that of C Set++.

For details about ENTRYINT, see “ENTRYINT” on page 150.

Pre-Initializing the COBOL Environment

If your main program is written in C and makes multiple calls to a COBOL program, you should pre-initialize the COBOL environment in your C program. For example, if your C

program repeatedly calls a COBOL program to carry out I/O tasks, you will probably want the COBOL program to remain in its last-used state.

For additional information, see Chapter 25, “Pre-initializing the COBOL Run-Time Environment” on page 393.

Results of Running COBCALLC

Compile and link the COBOL programs `COBCALLC.CBL` and `TPROG.CBL` and the C program `MyFun.c` and run `COBCALLC` using the following commands:

1. `icc -c MyFun.c`
2. `cob2 cobcallc MyFun.out tprog1.cbl -o cobcallc`

   Run the program by entering `COBCALLC`.

The results are as follows:

```
call MyFun with n4=00123 ns4=-00567 n9=0013579456
           ns9=0098765432 ns18=0000012345678902468
MyFun got s1=123 s2=-567 k1=13579456 k2=98765432 x=12345678902468
n4=01024 and ns9= n4 times n4= 0001048576
TPROG1 got x=  .11223344000000000E+04
d1=-.35792568025000000E+09 and d2= 2.0 times d2= -.71585136050000000E+09
MyFunV got 11111 22222 33333
```

Figure 77. Result Compiling and Running the Examples in This Chapter

Chapter 18. Data Sharing

When a run unit consists of several, separately-compiled programs that call each other, the programs must be able to communicate with each other. They also usually need to have access to common data.

This chapter will describe how to write programs that can share data with other programs. For the purposes of this discussion, a "subprogram" is any program called by another program.

Passing Data

Data can be passed between programs in three ways:

BY REFERENCE The subprogram refers to and processes the data items in storage of the calling program rather than working on a copy of the data.

BY CONTENT The calling program passes only the contents of the *literal*, or *identifier*. With a CALL . . . BY CONTENT, the called program cannot change the value of the *literal* or *identifier* in the calling program, even if it modifies the variable in which it received the *literal* or *identifier*.

BY VALUE The calling program or method is passing the value of the *literal*, or *identifier*, not a reference to the sending data item.

Whether you pass data items BY REFERENCE, BY CONTENT, or BY VALUE depends on what you want your program to do with the data:

- If you want the definition of the argument of the CALL statement in the calling program and the definition of the parameter in the called program to share the same memory, use:

  CALL . . . BY REFERENCE *identifier*.

  Any changes made by the subprogram to the parameter affects the argument in the calling program.

- If you want to pass the address of a record area to a called program, use:

  CALL . . . BY CONTENT ADDRESS OF *record-name*.

  The subprogram receives the ADDRESS special register for the record-name you specify.

  You must define the record-name as a level-01 or level-77 item in the LINKAGE SECTION of the called and calling programs. A separate ADDRESS special register is provided for each record in the LINKAGE SECTION.

- If you do not want the definition of the argument of the CALL statement in the calling program and the definition of the parameter in the called subprogram to share the same memory, use:

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CALL . . . BY CONTENT *identifier*.

- If you want to pass a literal value to a called program, use:

  CALL . . . BY CONTENT *literal*.

  The called program cannot change the value of the literal.

- If you want to pass the length of a data item, use:

  CALL . . . BY CONTENT LENGTH OF *identifier*.

  The calling program passes the length of the *identifier* from its LENGTH special register.

- If you want to pass both a data item and its length to a subprogram, use a combination of BY REFERENCE and BY CONTENT, for example:

```
CALL 'ERRPROC' USING BY REFERENCE A
     BY CONTENT LENGTH OF A
```

- If you want to pass data to C programs
  that expect the value of the arugment, use:

  CALL . . . BY VALUE

  that expect a reference (pointer) to the argument, use:

```
   CALL . . . BY REFERENCE
 or
   CALL . . . BY CONTENT
```

  Use BY REFERENCE if you want the C program to be able to modify the value of the argument. Use BY CONTENT if you do **not** want the C program to modify the value of the argument.

  Parameters must be of certain data types to be passed BY VALUE. See the *IBM COBOL Language Reference*.

- If you want to return a value, use:

  CALL . . . RETURNING

Describing Arguments in the Calling Program

In the calling program, the arguments are described in the DATA DIVISION in the same manner as other data items in the DATA DIVISION. Data items in a calling program can be described in the LINKAGE SECTION of all the programs it calls directly or indirectly.

Here, storage for these items is allocated in the highest outermost program. That is, program A calls program B, which calls program C. Data items in program A can be described in the LINKAGE sections of programs B and C, and the one set of data can be made available to all three programs.

If you reference data in a file, the file must be open when the data is referenced.

Code the USING clause of the CALL statement to pass the arguments.

Describing Parameters in the Called Program

You must know what is being passed from the calling program and describe it in the LINKAGE SECTION of the called program.

Code the USING clause after the PROCEDURE-DIVISION header to receive the parameters.

LINKAGE SECTION

The number of *data-names* in the *identifier* list of a called program must not be greater than the number of *data-names* in the *identifier* list of the calling program. There is a one-to-one positional correspondence; that is, the first *identifier* of the calling program is passed to the first *identifier* of the called program, and so forth. The compiler does not try to match arguments and parameters.

See Figure 78 for an example.

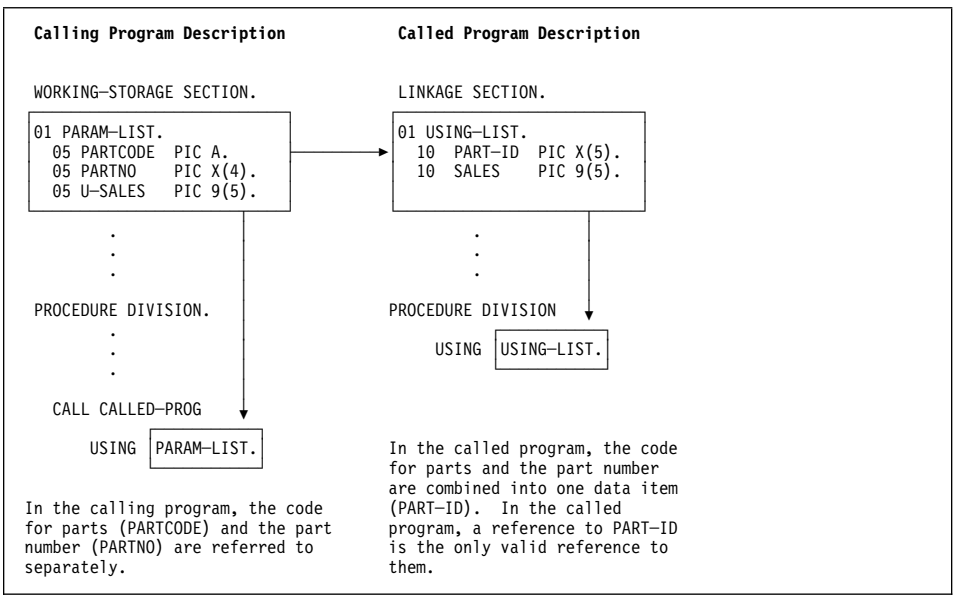

Figure 78. Common Data Items in Subprogram Linkage

PROCEDURE DIVISION

If an argument was passed BY VALUE, the PROCEDURE DIVISION header of the subprogram must indicate that:

```
PROCEDURE DIVISION USING BY VALUE.
```

If an argument was passed BY REFERENCE or BY CONTENT, the PROCEDURE DIVISION header does not need to indicate how the argument was passed.The header can either be:

```
PROCEDURE DIVISION USING
```

or:

```
PROCEDURE DIVISION USING BY REFERENCE
```

Grouping Data to Be Passed

Think about grouping all the data items you want to pass between programs and putting them under one level-01 item. If you do this, you can pass a single level-01 record between programs. For an example of this method, see Figure 78 on page 323.

To make the possibility of mismatched records even smaller, put the level-01 record in a COPY library, and copy it in both programs. (That is, copy it in the WORKING-STORAGE SECTION of the calling program and in the LINKAGE SECTION of the called program.)

Null-Terminated Strings

Null-terminated strings are supported using syntax shown in the *IBM COBOL Language Reference*. You can manipulate null-terminated strings passed from a C program, for example, by using string handling mechanisms such as those found below:

```
 01 L pic X(20) value z'ab'.
 01 M pic X(20) value z'cd'.
 01 N pic X(20).
 01 N-Length pic 99 value zero.
 01 Y pic X(13) value 'Hello, World!'.

* Display null-terminated string
     Inspect N tallying N-length
      for characters before initial x'00'
     Display 'N: ' N(1:N-length) ' Length: ' N-length

* Move null-terminated string to alphanumeric, strip null
     Unstring N delimited by X'00' into X

* Create null-terminated string
     String Y     delimited by size
            X'00' delimited by size
            into N.

* Concatenate two null-terminated strings
     String L     delimited by x'00'
            M     delimited by x'00'
            X'00' delimited by size
            into N.
```

Using Pointers to Process a Chained List

You can manipulate pointer data items, which are a special type of data item to hold addresses, when you want to pass and receive addresses of record areas. Pointer data items are data items that are either defined with the USAGE IS POINTER clause, or

are ADDRESS special registers. A typical application for using pointer data items is in processing a chained list (a series of records where each one points to the next).

For this example, picture a chained list of data that is composed of individual salary records. Figure 79 shows one way to visualize how these records are linked in storage:

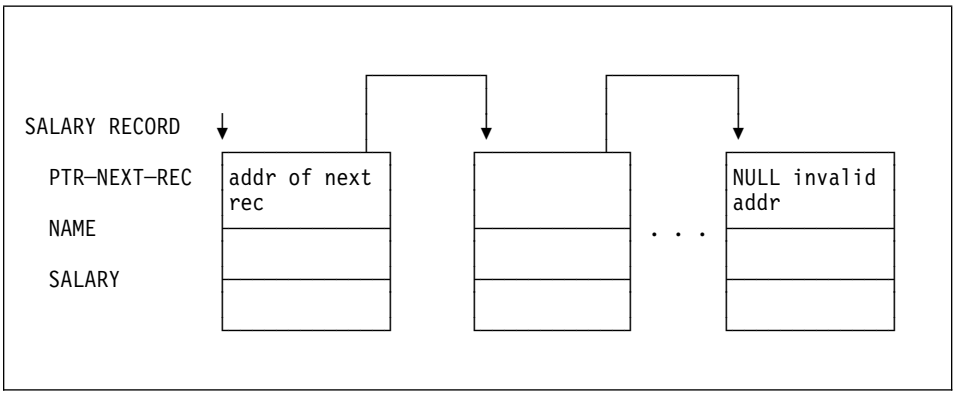

Figure 79. Representation of a Chained List Ending with NULL

The first item in each record points to the next record, except for the last record. The first item in the last record contains a null value instead of an address. to indicate that it is the last record,

The high-level logic of an application that processes these records might look something like this:

```
OBTAIN ADDRESS OF FIRST RECORD IN CHAINED LIST FROM ROUTINE
CHECK FOR END OF THE CHAINED LIST
DO UNTIL END OF THE CHAINED LIST
   PROCESS RECORD
   GO ON TO THE NEXT RECORD
END
```

Figure 80 on page 326 contains an outline of the processing program, LISTS, used in this example of processing a chained list.

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID. LISTS.
 ENVIRONMENT DIVISION.
 DATA DIVISION.
******
 WORKING-STORAGE SECTION.
 77  PTR-FIRST         POINTER  VALUE IS NULL.
 77  DEPT-TOTAL        PIC 9(4) VALUE IS 0.
******
 LINKAGE SECTION.
 01  SALARY-REC.
   02  PTR-NEXT-REC    POINTER.
   02  NAME            PIC X(20).
   02  DEPT            PIC 9(4).
   02  SALARY          PIC 9(6).
 01  DEPT-X            PIC 9(4).
******
 PROCEDURE DIVISION USING DEPT-X.
******
* FOR EVERYONE IN THE DEPARTMENT RECEIVED AS DEPT-X,
* GO THROUGH ALL THE RECORDS IN THE CHAINED LIST BASED ON THE
* ADDRESS OBTAINED FROM THE PROGRAM CHAIN-ANCH
* AND CUMULATE THE SALARIES.
* IN EACH RECORD, PTR-NEXT-REC IS A POINTER TO THE NEXT RECORD
* IN THE LIST; IN THE LAST RECORD, PTR-NEXT-REC IS NULL.
* DISPLAY THE TOTAL.
******
     CALL "CHAIN-ANCH" USING PTR-FIRST
     SET ADDRESS OF SALARY-REC TO PTR-FIRST
******
     PERFORM WITH TEST BEFORE UNTIL ADDRESS OF SALARY-REC = NULL
      IF DEPT = DEPT-X
        THEN ADD SALARY TO DEPT-TOTAL
        ELSE CONTINUE
      END-IF
      SET ADDRESS OF SALARY-REC TO PTR-NEXT-REC
     END-PERFORM
******
     DISPLAY DEPT-TOTAL
     GOBACK.
```

Figure 80. Program for Processing a Chained List

Passing Addresses between Programs

To obtain the address of the first SALARY-REC record area, the LISTS program calls the program CHAIN-ANCH:

```
CALL "CHAIN-ANCH" USING PTR-FIRST
```

PTR-FIRST is defined in WORKING-STORAGE in the calling program (LISTS) as a pointer data item:

```
WORKING-STORAGE SECTION.
01  PTR-FIRST         POINTER  VALUE IS NULL.
```

On return from the call to CHAIN-ANCH, PTR-FIRST contains the address of the first record in the chained list.

PTR-FIRST is initially defined as having a null value as a logic check. If something goes amiss with the call, and PTR-FIRST never receives the value of the address of the first record in the chain, a null value remains in PTR-FIRST and, according to the logic of the program, the records will not be processed.

NULL is a figurative constant used to assign the value of an invalid address (nonnumeric 0) to pointer items. It can be used in the VALUE IS NULL clause, in the SET statement, and as one of the operands of a relation condition with a pointer data item.

The LINKAGE SECTION of the calling program contains the description of the records in the chained list. It also contains the description of the department code that is passed, using the USING clause of the CALL statement.

```
LINKAGE SECTION.
01  SALARY-REC.
    02  PTR-NEXT-REC    POINTER.
    02  NAME            PIC X(20).
    02  DEPT            PIC 9(4).
    02  SALARY          PIC 9(6).
01  DEPT-X            PIC 9(4).
```

To base the record description SALARY-REC on the address contained in PTR-FIRST, use a SET statement:

```
CALL "CHAIN-ANCH" USING PTR-FIRST
SET ADDRESS OF SALARY-REC TO PTR-FIRST
```

Checking for the End of the Chained List

The chained list in this example is set up so the last record contains an invalid address. To do this, the pointer data item in the last record would be assigned the value NULL.

A pointer data item can be assigned the value NULL in two ways:

- A pointer data item can be defined with a VALUE IS NULL clause in its data definition.
- NULL can be the sending field in a SET statement.

In the case of a chained list in which the pointer data item in the last record contains a null value, the code to check for the end of the list would be:

```
IF PTR-NEXT-REC = NULL
   ⋮

(logic for end of chain)
```

If you haven't reached the end of the list, process the record and move on to the next record.

In the program LISTS, this check for the end of the chained list is accomplished with a DO WHILE structure:

```
PERFORM WITH TEST BEFORE UNTIL ADDRESS OF SALARY-REC = NULL
  IF DEPT = DEPT-X
    THEN ADD SALARY TO DEPT-TOTAL
    ELSE CONTINUE
  END-IF
  SET ADDRESS OF SALARY-REC TO PTR-NEXT-REC
END-PERFORM
```

Continuing Processing the Next Record

To move on to the next record, set the address of the record in the LINKAGE-SECTION to be equal to the address of the next record. This is accomplished through the pointer data item sent as the first field in SALARY-REC:

```
SET ADDRESS OF SALARY-REC TO PTR-NEXT-REC
```

Then repeat the record-processing routine, which will process the next record in the chained list.

A Variation: Incrementing Addresses Received from Another Program

The data passed from a calling program might contain header information that you want to ignore (for example, in data received from a CICS application that is not migrated to the command level).

Because pointer data items are not numeric, you cannot directly perform arithmetic on them. However, you can use the SET verb to increment the passed address in order to bypass header information.

You could set up the LINKAGE SECTION like this:

```
LINKAGE SECTION.
01  RECORD-A.
  02  HEADER          PIC X(12).
  02  REAL-SALARY-REC PIC X(30).
⋮
01  SALARY-REC.
  02  PTR-NEXT-REC    POINTER.
  02  NAME            PIC X(20).
  02  DEPT            PIC 9(4).
  02  SALARY          PIC 9(6).
```

Within the Procedure Division, "base" the address of SALARY-REC on the address of REAL-SALARY-REC:

```
SET ADDRESS OF SALARY-REC TO ADDRESS OF REAL-SALARY-REC
```

SALARY-REC is now based on the address of RECORD-A + 12.

Using Procedure Pointers

Procedure pointers are data items defined with the USAGE IS PROCEDURE-POINTER clause. You can set procedure-pointer data items to contain entry addresses of (or pointers to) these entry points:

- Another COBOL program that is not nested.
- An alternate entry point in another COBOL program (as defined in an ENTRY statement).
- A program written in another language. For example, to receive the entry address of a C function, call the function with the CALL RETURNING format of the CALL statement. It will return a pointer that you can convert to a procedure-pointer using a form of the SET statement.

Rules for Using Procedure Pointers

A procedure-pointer data item can be set only using the SET statement. For example:

```
CALL 'MyCFunc' RETURNING ptr.
SET proc-ptr TO ptr.
CALL proc-ptr USING dataname.
```

Therefore, if you set your procedure-pointer item to an entry address in a load module called using CALL-*identifier* and your program subsequently CANCELs that called module, then your procedure-pointer item becomes undefined, and reference to it thereafter is not reliable.

For a complete definition of the USAGE IS PROCEDURE-POINTER clause and the SET statement, refer to the *IBM COBOL Language Reference*.

Windows Restriction

WIN

In general, SYSTEM (STDCALL) linkage cannot be used for programs that are called via a procedure pointer if they have any arguments. This is due to the associated convention for forming names (also known as "name decoration").

With STDCALL linkage, the name is formed by suffixing to the entry name the number of bytes in the parameter list. For example, a program named `abc` that passes an argument by reference and a 4-byte integer by value would have 8 bytes in the parameter list; the resulting name would be `_abc@8`. This creates a restriction on setting a procedure pointer to the address of an entry point: because there is no syntactical way to specify the arguments that are to be passed to the entry point on the SET statement,

the generated name will have '0' as the number of bytes in the parameter list. This will cause the link to fail due to unresolved external references when the entry point has arguments.

You can use the CALLINT compiler directive to ensure that calls to programs with arguments, made using a procedure pointer, use the OPTLINK convention.

For example:

```
      CBL
      IDENTIFICATION DIVISION.
      PROGRAM-ID. XC.
      DATA DIVISION.
      WORKING-STORAGE SECTION.
      01   PP1 PROCEDURE-POINTER.
      01   HW  PIC X(12).
      PROCEDURE DIVISION USING XA.
   * Use OPTLINK linkage:
         >>CALLINT OPTLINK
         SET PP1 TO ENTRY "X".
   * Restore default linkage:
         >>CALLINT
         MOVE "Hello World." to HW
         DISPLAY "Calling X."
   * Use OPTLINK linkage:
         >>CALLINT OPTLINK
         CALL PP1 USING HW.
   * Restore default linkage:
         >>CALLINT
         GOBACK.
      END PROGRAM X.

   * Use OPTLINK linkage:
      CBL ENTRYINT(OPTLINK)
      IDENTIFICATION DIVISION.
      PROGRAM-ID. X.
      DATA DIVISION.
      LINKAGE SECTION.
      01   XA    PIC 9(9).
      PROCEDURE DIVISION USING XA.
         DISPLAY XA.
         GOBACK.
      END PROGRAM X.
```

Figure 81. Using CALLINIT to Resolve References

Without the CALLINT compiler directives and the CALLINT compiler option, an unresolved reference to _X@0 would be found when the link was done.

Non-COBOL: If the program being called is C or PL/I and uses the STDCALL interface, use the **pragma** statement in the called program to form the name without STDCALL name decoration.

Multiple Entry Points on Windows

WIN

The call interface convention SYSTEM (STDCALL) cannot always be used for calling programs with multiple entry points (PROCEDURE DIVISION USING ... AND ENTRY XXX USING ...). If the number of parameters in each entry point is not the same or if the caller does not pass the number of arguments expected by the called entry point, using the STDCALL convention causes unpredictable results due to corruption of the stack.

The STDCALL convention requires the called program to clean up the stack, where the calling program placed the arguments. Because it has no way of determining how many arguments were actually pass to it, it uses the expected number of arguments. When this does not accurately reflect the number passed, it is impossible to do the clean up correctly.

Because a common exit point can be used for programs with multiple entry points, the different entry points having a different number arguments also makes it impossible to determine correctly how to clean up the stack.

Data Type: Because STDCALL linkage uses four bytes on the stack for each argument, differences in data type are immaterial.

Passing Return Code Information

You can use the RETURN-CODE special register to pass and receive return codes between programs. Methods do not return information in the RETURN-CODE special register, but they can check the register after a CALL to a program.

You can also use the RETURNING phrase on the PROCEDURE DIVISION header in your method to return information to an invoking program or method. If you use PROCEDURE DIVISION. . .RETURNING with CALL. . .RETURNING, the RETURN-CODE register will not be set.

RETURN-CODE Special Register

When a COBOL program returns to its caller, the contents of the RETURN-CODE special register are set according to the value of the RETURN-CODE of the program returning to the caller.

Setting of the RETURN-CODE by the called program is limited to calls between COBOL programs. For example, if your COBOL program calls a C program, you can't expect the calling program's RETURN-CODE to be set.

For equivalent functionality between COBOL and C programs, have your COBOL program call the C program with the RETURNING option. If the C program (function) correctly declares a function value, the RETURNING value of the calling COBOL program will be set.

INVOKE Note: The RETURN-CODE special register is not set by use of the INVOKE statement.

PROCEDURE DIVISION RETURNING . . .

You can use the RETURNING phrase on the PROCEDURE DIVISION header of you program to return information to the calling program:

```
PROCEDURE DIVISION RETURNING dataname2
```

Upon successful return from the called program to its caller, the value in *data-name-2* is stored into the identifier specified in the CALL-RETURNING phrase:

```
CALL . . . RETURNING dataname2
```

CALL . . . RETURNING

The RETURNING phrase on the CALL statement can be specified for calls to functions written in C/C++ or subroutines written in COBOL.

It has the following format:

```
CALL . . . RETURNING dataname2
```

The return value of the called program is stored into *dataname2*.

dataname2 must be defined in the DATA DIVISION of the calling COBOL program. The data type of the return value declared in the target function must be identical to the datatype of *dataname2*.

Sharing Data Using the EXTERNAL Clause

Separately compiled programs and/or methods (including programs in a batch sequence) can share data items by using EXTERNAL clause.

EXTERNAL is coded on the 01-level data description in the WORKING-STORAGE SECTION of a program or method, and the following rules apply:

- Items subordinate to an EXTERNAL group item are themselves EXTERNAL.
- The name used for the data item cannot be used on another EXTERNAL item in the same program.
- The VALUE clause cannot be coded for any group item, or subordinate item, that is EXTERNAL.

Any COBOL program or method in the run unit, having the same data description for the item as the program containing the item, can access and process the data item. For example, if program A had the following data description:

```
01 EXT-ITEM1     EXTERNAL     PIC 99.
```

program B could access that data item by having the identical data description in its WORKING-STORAGE SECTION.

Remember, any program that has access to an EXTERNAL data item can change its value. Do not use this clause for data items you need to protect.

Sharing Files between Programs (EXTERNAL Files)

Using the EXTERNAL clause for files allows separately compiled programs or methods in the run unit to have access to common files.

The rules for using EXTERNAL files are described in the *IBM COBOL Language Reference*. In addition, it is recommended that:

- The data-name in the FILE STATUS clause of all the programs that will check the file status code must match.
- For all programs that want to check the same file status field, the EXTERNAL clause should be coded on the level-01 data definition for the file status field in each program.

Advantages of EXTERNAL Files

The example on page 335, shows some of the advantages of using EXTERNAL files:

- The main program can reference the record area of the file, although the main program does not contain any I/O statements.
- Each subprogram can control a single I/O function, such as OPEN or READ.
- Each program has access to the file.

Example Using EXTERNAL Files

The following table gives the names and describes the function of the main program and subprograms used in the example shown in Figure 83 on page 335.

Figure 82 (Page 1 of 2). Program Names for Input-Output Using EXTERNAL Files

Name	Function
ef1	This is the main program. It calls all the subprograms, and then verifies the contents of a record area.
ef1openo	This program opens the external file for output and checks the File Status Code.
ef1write	This program writes a record to the external file and checks the File Status Code.

Figure 82 (Page 2 of 2). Program Names for Input-Output Using EXTERNAL Files

Name	Function
ef1openi	This program opens the external file for input and checks the File Status Code.
ef1read	This program reads a record from the external file and checks the File Status Code.
ef1close	This program closes the external file and checks the File Status Code.

Additionally, COPY statements ensure that each subprogram contains an identical description of the file.

Each program in the example declares a data item with the EXTERNAL clause in its WORKING-STORAGE SECTION. This item is used for checking file status codes, and is also placed using the COPY statement.

Each program uses three copy library members:

- The first is named efselect and is placed in the File-Control paragraph.

```
Select ef1
   Assign To ef1
   File Status Is efs1
   Organization Is Sequential.
```

- The second is named effile and is placed in the FILE SECTION.

```
Fd ef1 Is External
          Record Contains 80 Characters
          Recording Mode F.
01  ef-record-1.
    02 ef-item-1     Pic X(80).
```

- The third is named efwrkstg and is placed in the WORKING-STORAGE SECTION.

```
01  efs1             Pic 99 External.
```

```
       Identification Division.
       Program-Id.
           ef1.
      *
      * This is the main program that controls the external file
      * processing.
      *
       Environment Division.
       Input-Output Section.
       File-Control.
           Copy efselect.
       Data Division.
       File Section.
           Copy effile.
       Working-Storage Section.
           Copy efwrkstg.
       Procedure Division.
           Call "ef1openo"
           Call "ef1write"
           Call "ef1close"
           Call "ef1openi"
           Call "ef1read"
           If ef-record-1 = "First record" Then
             Display "First record correct"
           Else
             Display "First record incorrect"
             Display "Expected: " "First record"
             Display "Found   : " ef-record-1
           End-If
           Call "ef1close"
           Goback.
       End Program ef1.
       Identification Division.
       Program-Id.
           ef1openo.
      *
      * This program opens the external file for output.
      *
       Environment Division.
       Input-Output Section.
       File-Control.
           Copy efselect.
       Data Division.
       File Section.
           Copy effile.
       Working-Storage Section.
           Copy efwrkstg.
       Procedure Division.
           Open Output ef1
           If efs1 Not = 0
             Display "file status " efs1 " on open output"
             Stop Run
           End-If
           Goback.
       End Program ef1openo.
```

Figure 83 (Part 1 of 3). Input-Output Using EXTERNAL Files

```
       Identification Division.
       Program-Id.
           ef1write.
      *
      * This program writes a record to the external file.
      *
       Environment Division.
       Input-Output Section.
       File-Control.
           Copy efselect.
       Data Division.
       File Section.
           Copy effile.
       Working-Storage Section.
           Copy efwrkstg.
       Procedure Division.
           Move "First record" to ef-record-1
           Write ef-record-1
           If efs1 Not = 0
             Display "file status " efs1 " on write"
             Stop Run
           End-If
           Goback.
       End Program ef1write.
       Identification Division.
       Program-Id.
           ef1openi.
      *
      * This program opens the external file for input.
      *
       Environment Division.
       Input-Output Section.
       File-Control.
           Copy efselect.
       Data Division.
       File Section.
           Copy effile.
       Working-Storage Section.
           Copy efwrkstg.
       Procedure Division.
           Open Input ef1
           If efs1 Not = 0
             Display "file status " efs1 " on open input"
             Stop Run
           End-If
           Goback.
       End Program ef1openi.
```

Figure 83 (Part 2 of 3). Input-Output Using EXTERNAL Files

```
 Identification Division.
 Program-Id.
     ef1read.
*
* This program reads a record from the external file.
*
 Environment Division.
 Input-Output Section.
 File-Control.
     Copy efselect.
 Data Division.
 File Section.
     Copy effile.
 Working-Storage Section.
     Copy efwrkstg.
 Procedure Division.
     Read ef1
     If efs1 Not = 0
       Display "file status " efs1 " on read"
       Stop Run
     End-If
     Goback.
 End Program ef1read.
 Identification Division.
 Program-Id.
     ef1close.
*
* This program closes the external file.
*
 Environment Division.
 Input-Output Section.
 File-Control.
     Copy efselect.
 Data Division.
 File Section.
     Copy effile.
 Working-Storage Section.
     Copy efwrkstg.
 Procedure Division.
     Close ef1
     If efs1 Not = 0
       Display "file status " efs1 " on close"
       Stop Run
     End-If
     Goback.
 End Program ef1close.
```

Figure 83 (Part 3 of 3). Input-Output Using EXTERNAL Files

Command Line Arguments

OS/2 and Windows call all main programs with a string that gives the command line arguments. Figure 84 on page 338 shows how to read the command line arguments:

```
*
 IDENTIFICATION DIVISION.
 PROGRAM-ID. "testarg".
*
 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
*
 DATA DIVISION.
 WORKING-STORAGE SECTION.
*
 linkage section.
 01  os-parm.
     05 parm-len         pic s999 comp.
     05 parm-string.
         10 parm-char             pic x occurs 0 to 100 times
                         depending on parm-len.
*
 PROCEDURE DIVISION using os-parm.
     display "parm-len=" parm-len
     display "parm-string='" parm-string "'"
     evaluate parm-string
       when "01" display "case  one"
       when "02" display "case two"
       when "95" display  "case ninety five"
       when other display "case unknown"
     end-evaluate
     GOBACK.
```

Figure 84. testarg — An Example of Command Line Arguments

The result of compiling and running the program,

```
cob2 testarg.cbl
testarg 95
```

is

```
parm-len=002
parm-string='95'
case ninety five
```

Chapter 19. Programming for a DB2 Environment

In general, the coding for your COBOL program will be the same whether or not you want it to access a DB2 database. However, to retrieve, update, insert, and delete DB2 data and use other DB2 services, you must use SQL statements.

To communicate with DB2, you need to do the following:

- Delimit SQL statements with EXEC SQL and END-EXEC STATEMENTS
- Declare a communications area (SQLCA) in the WORKING-STORAGE SECTION
- Declare all host variables used in SQL statements in the WORKING-STORAGE OR LINKAGE sections
- Code any SQL statements you need
- Start DB2 if it is not already started
- Compile with the SQL option
- Check the return code from DB2 in the SQLCA to handle exceptional conditions that are indicated

These basics of coding SQL in a COBOL program are described in detail in the *IBM DB2 Application Programming Guide* and the *SQL Reference* (see “Related Publications for OS/2” on page 438).

Compiling with the DB2 Co-Processor

Your source program containing imbedded SQL statements is handled by the compiler without your having to use a separate pre-processor. When the compiler encounters SQL statements and at significant points in the source program, it interfaces with the DB2 co-processor, which processes the SQL statements by taking appropriate actions and indicating to the compiler what native COBOL statements to generate at that point.

Because the compiler is working in conjunction with the DB2 co-processor, DB2 must be started before you compile your program. To be connected to the target database for the compile, you can connect before you start the compile or have the compiler make the connection for you by specifying the database either using the DATABASE suboption in the SQL option or by naming it in the DB2DBDFT environment variable.

Options for the DB2 Co-Processor

The option string that you provide on the SQL compiler option is made available to the DB2 co-processor. The content of the string is viewed solely by the DB2 co-processor and not by the compiler. The following COB2 command will pass the database name "SAMPLE" and the DB2 option "BLOCKING ALL" to the co-processor:

```
cob2 -q"sql('database sample blocking all')" mysql.cbl...
```

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The SQL options that you include in the suboption string are cumulative. See the DB2 Command Reference for information on these options.

How Options Are Accumulated

The options specified from multiple sources are concatenated in the order of the specifications.

For example, the command

```
cob2 mypgm.cbl -q"SQL('string')"
```

and the mypgm.cbl source file with

```
 cbl ... SQL("string2") ...
 cbl ... SQL("string3") ...
```

will result in the SQL option string passed to the DB2 co-processor to be

"*string1 string2 string3*"

Note that the concatenated strings are delimited with single spaces. When multiple instances of the same SQL suboptions are found, the last specification of that suboption in the concatenated string will be in effect.

This concatenation of multiple SQL option specifications allows you to separate SQL suboptions which may not fit into a single CBL statement into multiple CBL statements.

The compiler limits the length of the concatenated DB2 option string to 4K bytes.

Package and Bind File Names

Two of the suboptions that you can specify with the SQL option are `package name` and `bind file name`. If you do not specify these options, default names are constructed for them based on the source file name for a non-batch compilation and on the first program for a batch compilation. For subsequent, non-nested, programs of a batch compilation, the names are based on the PROGRAM ID of each program.

Package Name

The base name (the source file name or the PROGRAM ID) is modified as follows:

- Names longer than eight characters are truncated to eight characters
- Letters are folded to upper case
- Any character other than A-Z, 0-9, or _ (under score) is changed to 0
- If the first character is not alphabetic, it is changed to A

Thus, if the base name is *9123aB-cd*, the package name would be *A123AB0C*.

Bind File Name

The extension .BND is added to the base name.

Unless explicitly specified, the file name is relative to the current directory.

Ignored Options

The following options, which were meaningful to and used by the pre-processor, are ignored by the co-processor:

- MESSAGES
- NOLINEMACRO
- OPTLEVEL
- OUTPUT
- SQLCA
- TARGET
- WCHARTYPE

SQL INCLUDE Statement

An SQL INCLUDE statement is treated identically to a native COBOL COPY statement, including the path search and the file extensions used.

For Example,

```
EXEC SQL INCLUDE name
```

is treated identically to

```
COPY name.
```

The *name* on an SQL INCLUDE statement follows the same rules as those for the copy text-name and is processed identically to a COPY statement with that text-name without a REPLACING clause. See “Compiler Environment Variables” on page 131 and the discussion on the COPY statement in the “Compiler-Directing Statements” on page 179 section for details.

COBOL does not use the DB2 environment variable DB2INCLUDE for SQL INCLUDE processing. However, if you are using the standard DB2 copy files, there are no other settings that you have to make. If the search rules call for using SYSLIB as the library name, the compiler will find the copy files by using the DB2 environment variable DB2PATH, which is set during DB2 install, to extend the setting of SYSLIB to include the DB2 include directory. The SYSLIB string that is used is essentially `%SYSLIB%;%DB2PATH%\INCLUDE\COBOL_A`.

COBOL Language Usage with SQL

Some restrictions on the use of COBOL language that applied when the pre-processor was used are lifted with the use of the co-processor.

Specifically the following are permitted:

- `EXEC SQL BEGIN DECLARE SECTION` and `EXEC SQL END DECLARE SECTION` statements are no longer required to identify host variables used on SQL statements

- Batch compilation is supported: the source file may contain multiple non-nested COBOL programs
- The source program may contain nested programs
- The source program may contain OO COBOL language extensions

It is recommended that binary data items that are specified in an SQL statement be:

- Declared as USAGE COMP-5 *or*
- Used with the TRUNC(BIN) option and the BINARY(NATIVE) option if USAGE BINARY, COMP or COMP-4 item is specified

If you specify a BINARY, COMP, or COMP-4 item with option TRUNC(OPT) or TRUNC(STD) in effect, it will be accepted by the compiler but may invalidate the data due to the application of the decimal truncation rule. It is your responsibility to insure that truncation does not affect the validity of the data.

Level of SQL Support

SQL statements are supported at the level of DB2 for OS/2 Single-User, Version 2 on OS/2 and DB2 for Windows 95 and Windows NT Version 2.1.1 on Windows, including:

- Large Objects (BLOB, CLOB, ...)
- Compound SQL

Limit: The size of large objects is currently limited to 16M bytes for a group or elementary data item.

Testing the Return Code

In general, when DB2 finishes processing an SQL statement, DB2 sends back a return code in the SQLCODE OF SQLCA and SQLSTATE OF SQLCA fields. Your program should test the SQLCODE and/or SQLSTATE fields and take any necessary action depending on whether the operation succeeded or failed.

Chapter 20. Programming for a CICS Environment (OS/2 Only)

OS/2

When you develop programs to run under the Customer Information Control System (CICS), be aware of the steps you must take as well as certain COBOL language restrictions. A discussion of these coding considerations follows. For additional information about developing COBOL programs to run under CICS, consult the CICS *Application Programming Guide* (see "Related Publications for OS/2" on page 438).

An Overview of COBOL in a CICS Environment

CICS applications can be written in COBOL and run on the PC using CICS for OS/2. There are 8 general steps involved in preparing COBOL applications that work under CICS:

1. Initialize the CICS environment using the CICSENV command file. You can edit CICSENV.CMD to configure your CICS and COBOL environment variables (see *CICS Customization* for details on CICSENV.) For example, make sure that your programs, files, and copybooks are accessible by the operating system.
2. Create your COBOL application. For CICS-specific COBOL programming considerations, see "Preparing COBOL Applications to Run under CICS" on page 344. Specifically, use an editor to do the following:
   - Code your program using COBOL statements and CICS commands
   - Create COBOL copybooks
   - Create CICS screen maps used by your program

   For a detailed description of COBOL programming under CICS, see the CICS *Application Programming Guide.*
3. Process the CICS screen maps using the CICSMAP command. Consult the CICS *Application Programming Guide* for details on CICSMAP.
4. Use the CICS command CICSTCL:

   Translate CICS commands will be translated into valid COBOL statements.

   Compile The COBOL compiler will be invoked and the program will be compiled.

   Link The compiled COBOL program will be linked using standard linkage routines.
5. Start CICS using CICSRUN.
6. Define your application's resources, such as transactions, application programs, and files for CICS through the CICS-supplied transaction CEDA.
7. Activate CICS resources (such as PCT and FCT entries) by shutting down CICS using CQIT. Then restart CICS using CICSRUN.

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8. Logon to CICS and run the application by entering the 4-character transaction-id associated with the application.

If you want to execute code using CICS ECI (External Call Interface), you need to have CICS Client for OS/2 installed. Otherwise, you will encounter an error due to a missing DLL. You also need to start CICS Client before executing.

Preparing COBOL Applications to Run under CICS

In general, the COBOL language is supported in a CICS environment. However, there are certain restrictions and considerations you should be aware of when preparing COBOL applications to run on CICS.

CICS has a Special Reserved Word Table

COBOL provides an alternate reserved word table (IGYCCICS) specifically for CICS application programs. If you use the compiler option WORD(CICS), COBOL words not recommended under CICS are flagged by the compiler with an error message.

In addition to the COBOL words restricted by the IBM-supplied default reserved word table, the IBM-supplied CICS reserved word table restricts the following COBOL words:

ACCEPT	FILE-CONTROL	RERUN
CLOSE	INPUT-OUTPUT	REWRITE
DELETE	I-O-CONTROL	SD
DISPLAY	MERGE	SORT
FD	OPEN	START
FILE	READ	WRITE

Additional Language Restrictions

The following guidelines should be followed when coding COBOL programs that run under CICS:

- Do not use EXEC, CICS, DLI, or END-EXEC for variable names.
- Do not use the FILE-CONTROL entry in the ENVIRONMENT DIVISION.
- Do not use the FILE SECTION of the DATA DIVISION.
- Do not use user-specified parameters to the main program.
- Do not use USE declaratives (except USE FOR DEBUGGING).
- The following COBOL language statements are not recommended for use in a CICS environment:
  - ACCEPT (Format 1 or 2)
  - CLOSE
  - DELETE
  - DISPLAY
  - MERGE
  - OPEN
  - READ

  - REWRITE
  - SORT
  - START
  - STOP *literal*
  - WRITE

  Attention: Mainframe CICS does not support any of the COBOL language elements on the preceding list. If you use any of these COBOL language elements, be aware that:

    - The application is not completely portable to the mainframe CICS environment.
    - In the case of a CICS failure, a backout (restoring the resources associated with the failed task) will not be possible.

- When coding nested (contained) programs, pass DFHEIBLK and DFHCOMMAREA as parameters to any nested programs that contain EXEC commands and/or references to the EIB. The same parameters must also be passed to any program that forms part of the control hierarchy between such a program and its top level program.

Selecting Compiler Options

TRUNC(BIN) is the recommended option under CICS. However, if you are certain that the non-truncated values of BINARY, COMP, or COMP-4 data items conform to PICTURE specifications, using TRUNC(OPT) may improve program performance.

COMP-5 can be used instead of BINARY, COMP, or COMP-4 as EXEC CICS command arguments. COMP-5 is treated with the behavior of BINARY, COMP, or COMP-4 as if BINARY(NATIVE) and TRUNC(BIN) were in effect, regardless of explicitly setting those options.

WORD(CICS) is recommended if you want those COBOL language elements not supported under CICS to be flagged at compile time.

The PGMNAME(MIXED) option must be used for applications that use CICS Client for OS/2.

The following options should be **avoided** when compiling programs to run in a CICS environment:

- BINARY(S370) if you use BINARY, COMP, or COMP-4 data
- NOLIB
- TRUNC(STD) or TRUNC(OPT)

All other COBOL compiler options are supported. For detailed information on individual compiler options, see Chapter 9, “Compiler Options” on page 144.

Selecting Run-Time Options

Use the FILESYS run-time option to specify the file system used for files when no specific file selection has been made on the ASSIGNment name. For a detailed description of FILESYS, see Chapter 10, “Run-Time Options” on page 185.

Planning for ASCII-EBCDIC Differences

If your CICS program is running on an ASCII platform (such as OS/2 or AIX, and you access EBCDIC data, be aware that the neither CICS nor the COBOL run time will automatically convert the data to the ASCII collating sequence.

Some data access methods (such as VSAM) can carry out such conversions automatically, but you should not assume that the data will be converted. If your program is designed to access mainframe data, you might want to add logic to your program to test whether or not the data is EBCDIC and, if necessary, carry out an explicit collating sequence conversion.

Dynamic Calls under CICS

Dynamic calls work in the CICS environment, however you have to be careful to set the COBPATH environment correctly. Consider the following example.

The program contains

```
WORKING-STORAGE SECTION.
  01  WS-COMMAREA     PIC 9 VALUE ZERO.
  77   SUBPNAME       PIC X(8) VALUE SPACES
 ...
PROCEDURE DIVISION.
  MOVE 'alpha' TO SUBPNAME.
  CALL SUBPNAME USING DFHEIBLK, DFHCOMMAREA, WS-COMMAREA.
 ...
```

Notice that since `alpha` is a COBOL program containing CICS statements, CICS control blocks DFHEIBLK and DFHCOMMAREA must be passed to `alpha`. The source for `alpha` is in the file `alpha.ccp`. The CICS command CICSTCL is used to translate, compile and link `alpha.ccp`. CICSTCL creates an `alpha.dll` and stores it in the run-time directory. The run-time directory is typically `x:\cics300\runtime`, where `x` is the drive where CICS is installed. You must set the environment variable COBPATH to include `x:\cics300\runtime`. CICS documentation describes how to set environment variables for CICS.

Accessing Novell Btrieve Data

Your non-CICS programs are able to access Btrieve files (the default file system used by CICS for OS/2). For more information, see “Accessing Files” on page 93.

Calls between COBOL and C++ under CICS

Be aware of three rules governing calls between COBOL and C/C++ programs under CICS:

1. COBOL programs which contain CICS commands can call C/C++ programs as long as the called C/C++ programs do not contain any CICS commands.
2. C/C++ Programs which contain CICS commands can call COBOL programs as long as the called COBOL programs do not contain any CICS commands.
3. COBOL programs can EXEC CICS LINK or EXEC CICS XCTL to a C/C++ program regardless of whether or not the C/C++ program contains CICS commands.

Therefore, if your COBOL program invokes a C/C++ program that contains CICS commands (or vice versa), use EXEC CICS LINK or EXEC CICS XCTL rather than the COBOL CALL statement.

Debugging CICS Programs

Before you debug your CICS programs, you need to translate them into COBOL. Then you debug CICS programs the same way you would debug any other COBOL program. For an overview of COBOL language-based debugging techniques, see Chapter 11, “Debugging Techniques” on page 189.

Alternatively, you can debug CICS programs using the graphical debugger shipped with the product. See *CICS for OS/2 Application Programming* for instructions about how to invoke the graphical debugger under CICS. Be sure to instruct the compiler to produce symbolic information used by the graphical debugger (see “Compiling and Linking Programs” on page 135). ◁□

Chapter 21. Open Database Connectivity

This chapter contains information to help you use the Open Database Connectivity (ODBC) interface in you COBOL applications. With ODBC, not only can you access data from a variety of databases and file systems that support the ODBC interface, but you can do so dynamically.

Your COBOL applications that use embedded SQL for database access must be processed by a pre- or co-processor for a particular database and have to be recompiled if the target database changes. Because ODBC is a call interface, there is no compile-time designation of the target database as there is with embedded SQL. Not only can you avoid having multiple versions of your application for multiple databases, but your application can dynamically determine which database to target.

Introducing ODBC

ODBC is a specification for an application program interface (API) that enables applications to access multiple database management systems using Structured Query Language (SQL).

ODBC permits maximum interoperability: a single application can access many different database management systems. This enables you to develop, compile, and ship an application without targeting a specific type of data source. Users can then add the database drivers, which link the application to the database management systems of their choice.

Background

The X/Open Company and the SQL Access Group jointly developed a specification for a callable SQL interface, referred to as the *X/Open Call Level Interface*. The goal of this interface is to increase portability of applications by enabling them to become independent of any one database vendor's programming interface.

ODBC was originally developed by Microsoft for Microsoft operating systems based on a preliminary draft of X/Open CLI. Since this time, other vendors have provided ODBC drivers that run on other platforms, such as OS/2 and UNIX systems. The VisualAge for COBOL for OS/2 package includes the DataDirect** ODBC drivers from INTERSOLV**, Inc.

ODBC Driver Manager

When you use the ODBC interface, your application makes calls through a Driver Manager. The Driver Manager dynamically loads the necessary driver for the database server to which the application connects. The driver, in turn, accepts the call, sends the SQL to the specified data source (database), and returns any result.

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Choosing Embedded SQL or ODBC

Embedded SQL and ODBC have advantages particular to them. Some of the advantages of embedded SQL are:

- Static SQL usually provides better performance than dynamic SQL. It does not have to be prepared at run time, thus reducing both processing and network traffic.
- With static SQL, database administrators have to grant users access to a package only rather than access to each table or view that will be used.

Some of the advantages of ODBC are:

- It provides a consistent interface regardless of what kind of database server is used.
- You can have more than one concurrent connection.
- Applications do not have to be bound to each database on which they will execute. Although VisualAge for COBOL for OS/2 does this bind for you automatically, it binds automatically to only one database. If you want to choose which database to connect to dynamically at run time, you must take extra steps to bind to a different database.

Using the ODBC Drivers

VisualAge for COBOL for OS/2 provides an ODBC Driver Manager and a set of ODBC database drivers under an agreement with INTERSOLV, Inc.

To enable ODBC for data access in VisualAge for COBOL for OS/2, you must:

1. Install the ODBC Driver Manager and drivers by selecting the “ODBC Drivers” component during VisualAge for COBOL for OS/2 installation.
2. Install the RDBMS client (eg., Oracle 7 SQL*NET, DB2 CAE, etc.).

Important: During the installation process, a license file for the ODBC driver is installed on your system.

File `ivib.lic`, is installed in x:\IBMCOBOL\ODBC.

You must keep this file installed in the install directory, because it will be used when you run your application to verify that you are licensed to use the ODBC driver. In “Setting Licensing Information for ODBC Driver Manager/Driver” on page 359 you learn how to use a function call to trigger the verification.

On-line Help

On-line help is available for the ODBC drivers, both as a reference book and as context-sensitive help. The specific file names and so on may differ; you should note the names given in this section for the file names for VisualAge for COBOL for OS/2.

Environment-Specific Information

The ODBC drivers are 32-bit drivers. The required network software supplied by your database system vendors must be 32-bit compliant.

OS/2

OS/2

ODBC.INI: OBDC.INI is an operating system binary file located in in the directory specified by the USER_INI environment variable. Since this file is binary, you cannot edit it with a text editor.

Configuring Data Sources: A **data source** consists of a DBMS and any remote operating system and network necessary to access it. After the drivers have been installed, the data source must be configured using the ODBC Administrator program. Start the ODBC Administrator by double-clicking on the ODBC Administrator icon in the Works folder.

Driver Names: The file names for the drivers that come with VisualAge for COBOL for OS/2 start with IB and have a file extension of .DLL. (They are dynamic link libraries.) The number in the name corresponds to the version level of the driver. When you install the ODBC drivers, your CONFIG.SYS file is modified to add the correct path to the environment variable LIBPATH.

Windows

WIN

ODBC.INI: ODBC.INI is a subkey of the HKEY_CURRENT_USER\\SOFTWARE\\ODBC key in the Windows NT and Windows 95 registry. The ODBC.INI subkey is maintained by the ODBC Administrator, which is located in the main COBOL program group. Since Windows can support multiple users, the ODBC.INI subkey is stored under unique user keys in the registry.

Configuring Data Sources A **data source** consists of a DBMS and any remote operating system and network necessary to access it. After the drivers have been installed, the data source must be configured using the ODBC Administrator program, which is located in the main COBOL program group. Because Windows 95 and Windows NT can host multiple users, each user must configure their own data sources. For detailed configuration information for the specific driver you wish to configure, refer to the appropriate section of the on-line help.

Driver Names: The file names for the drivers that come with VisualAge for COBOL for OS/2 start with IB and have a file extension of .DLL. (They are dynamic link libraries.) The number in the name corresponds to the version level of the driver. When you install the ODBC drivers, your Registry is modified to add the correct path to your environment.

Connecting to a Data Source

Your ODBC application will need to connect to the data source either using a logon dialog box or a connection string, depending on the data source.

Using a Logon Dialog Box

Some ODBC applications display a logon dialog box when you are connecting to a data source. In these cases, the data source name has already been specified.

In the logon dialog box, do the following:

1. Type the name of the remote database or select the name of the remote database from the Database Name drop-down list.

   You must have cataloged any database you want to access from the client.

2. If required, type your user name (authorization ID).

3. If required, type your password.

   If you leave your user name and password blank, the ODBC application assumes you have already logged on using SQLLOGN2 (under DOS) or using User Profile Management (under OS/2). If you have not, the application returns an error. You must either type your user name and password in the dialog box or log on using SQLLOGN2 and STARTDRQ (under DOS) or using User Profile Management (under OS/2).

4. Click OK to complete the logon and to update the values in ODBC.INI.

Using a Connection String

If your application requires a connection string to connect to a data source, you must specify the data source name that tells the driver which ODBC.INI section to use for the default connection information. Optionally, you may specify `attribute=value` pairs in the connection string to override the default values stored in ODBC.INI. These values are not written to ODBC.INI.

You can specify either long or short names in the connection string. The connection string has the form:

```
DSN=data_source_name[;attribute=value[;attribute=value]...]
```

An example of a connection string for INFORMIX 5 is

```
DSN=INFORMIX TABLES;DB=PAYROLL
```

Supported ODBC Functions

All database drivers are ODBC Level 1-compliant: they support all ODBC Core and Level 1 functions. A limited set of Level 2 functions is also supported. The drivers support the functions listed in the following table. Any additions to these supported functions or differences in the support of specific functions are listed in the *ODBC Conformance Level* topic of the on-line help for each individual driver.

Core Functions	SQLFreeEnv	SQLGetTypeInfo
	SQLFreeStmt	SQLParamData
SQLAllocConnect	SQLGetCursorName	SQLPutData
SQLAllocEnv	SQLNumResultCols	SQLSetConnectOption
SQLAllocStmt	SQLPrepare	SQLSetStmtOption
SQLBindCol	SQLRowCount	SQLSpecialColumns
SQLBindParameter	SQLSetCursorName	SQLStatistics
SQLCancel	SQLTransact	SQLTables
SQLColAttributes		
SQLConnect	**Level 1 Functions**	**Level 2 Functions**
SQLDescribeCol		
SQLDisconnect	SQLColumns	SQLDataSources
SQLDrivers	SQLDriverConnect	SQLExtendedFetch[1]
SQLError	SQLGetConnectOption	SQLMoreResults
SQLExecDirect	SQLGetData	SQLNativeSql
SQLExecute	SQLGetFunctions	SQLNumParams
SQLFetch	SQLGetInfo	SQLParamOptions
SQLFreeConnect	SQLGetStmtOption	SQLSetScrollOptions

Note: [1]Forward scrolling only

Error Messages

Error messages may come from

- An ODBC driver
- The database system
- The Driver Manager

An error reported on an ODBC driver has the following format:

```
[vendor] [ODBC_component] message
```

ODBC_component is the component in which the error occurred. For example, an error message from INTERSOLV's SQL Server driver would look like this:

```
[INTERSOLV] [ODBC SQL Server driver] Login incorrect.
```

If you get this type of error, check the last ODBC call your application made for possible problems or contact your ODBC application vendor.

An error that occurs in the data source includes the data source name, in the following format:

```
[vendor] [ODBC_component] [data_source] message
```

With this type of message, ODBC_component is the component that received the error from the data source indicated. For example, you may get the following message from an Oracle data source:

```
[INTERSOLV] [ODBC Oracle driver] [Oracle] ORA-0919: specified length too long for CHAR column
```

If you get this type of error, you did something incorrectly with the database system. Check your database system documentation for more information or consult your database administrator. In this example, you would check your Oracle documentation.

The Driver Manager is a DLL that establishes connections with drivers, submits requests to drivers, and returns results to applications. An error that occurs in the Driver Manager has the following format:

```
[vendor] [ODBC DLL] message
```

vendor can be Microsoft or INTERSOLV. For example, an error from the Microsoft Driver Manager might look like this:

```
[Microsoft] [ODBC DLL] Driver does not support this function
```

ODBC APIs from COBOL

Included with VisualAge for COBOL for OS/2 are copybooks that make it easier for you to access data bases with ODBC drivers using ODBC calls from your COBOL programs. This section describes the supplied copybooks, how ODBC API argument types map to COBOL data descriptions, and additional COBOL functions and considerations applicable to ODBC APIs.

For details on the ODBC APIs, see the on-line help.

The copybook for ODBC-enablement is based on ODBC Version 2.5. It is expected that the copybook will be updated and shipped with refreshes of VisualAge for COBOL for OS/2 to reflect any updates to the ODBC level.

For specific information related to an ODBC driver, such as the ODBC level or extensions supported by that driver, please refer to the specifications available with that driver.

The following illustrate how to access ODBC from COBOL programs:

"CALL Interface Convention" on page 354

"Using the Supplied Copybook" on page 354

"Mapping of ODBC C Types" on page 354

"Passing a Pointer as an Argument" on page 355

"Accessing Function Return Values" on page 357

"Testing Bits with a Bit Mask" on page 358

"Setting Licensing Information for ODBC Driver Manager/Driver" on page 359

LIB Files:

OS/2 When you link your ODBC applications, you must include the import library ODBC.LIB, which is supplied with VisualAge for COBOL for OS/2.

WIN When you link your ODBC applications, you must include the import library ODBC32.LIB, which is included in the ODBC SDK (from Microsoft).

CALL Interface Convention

Programs making ODBC calls must be compiled with the CALLINT(SYSTEM) option or use the >>CALLINT SYSTEM directive for ODBC calls.

Using the Supplied Copybook

The supplied copybook, ODBCCOB.CPY, defines the symbols for constant values described for ODBC APIs, mapping constants used in calls to ODBC APIs to symbols specified in ODBC guides so that argument (input and output) and function return values can be specified and tested.

some COBOL-specific adaptations have been made:

- Underscores, "_", are replaced with hyphens, "-" in the copybook. For example, SQL_SUCCESS is specified as SQL-SUCCESS.
- Names longer than 30 characters are truncated to 30 characters. This applies only to SQL_GB_GROUP_BY_CONTAINS_SELECT, which is specified as SQL-GB-GROUP-BY-CONTAINS-SELEC.

A COPY statement to include this copybook should be specified in the DATA DIVISION as follows:

- For a program, the COPY statement should be specified in the WORKING-STORAGE SECTION, in the outer-most program if programs are nested.
- For a method, the COPY statement should be specified in the WORKING-STORAGE SECTION of the method (not the WORKING-STORAGE SECTION of the CLASS definition). This must be done for each method that makes ODBC calls.

Mapping of ODBC C Types

The data types specified in ODBC APIs are defined in terms of ODBC C types in the API definitions. The following table shows corresponding COBOL declarations for the indicated ODBC C types of the arguments.

Figure 85 (Page 1 of 2). Mapping of ODBC C Type to COBOL Data Declaration

ODBC C type	Equivalent COBOL data declaration	Description
SWORD	COMP-5 PIC S9(4)	Signed short integer (2 byte binary)
UWORD	COMP-5 PIC 9(4)	Unsigned short integer (2 byte binary)
SDWORD	COMP-5 PIC S9(9)	Signed long integer (4 byte binary)
UDWORD	COMP-5 PIC 9(9)	Unsigned long integer (4 byte binary)
UCHAR FAR *	POINTER[1]	Pointer to unsigned character.
HDBC	POINTER	Connection handle
HENV	POINTER	Environment handle
HSTMT	POINTER	Statement handle

Figure 85 (Page 2 of 2). Mapping of ODBC C Type to COBOL Data Declaration

ODBC C type	Equivalent COBOL data declaration	Description
HWND	POINTER	Window handle

Note:

1. It is a pointer to a null-terminated string. The target (of the pointer) item can be defined with PIC X(*n*), where *n* is large enough to represent the null terminated field. See "Manipulating Null-Terminated Strings" on page 77 for additional considerations on handling null terminated strings in COBOL.

Passing a Pointer as an Argument

If an argument is specified as a pointer to one of the above data types, then you need to do one of the following:

- Pass the target item of the pointer BY REFERENCE, **or**
- Define a pointer data item that will point to the target item and pass that BY VALUE, **or**
- Pass the ADDRESS OF the target item BY VALUE.

To illustrate, assume the function is defined as

```
RETCODE SQLSomeFunction(PSomeArgument)
```

where `PSomeArgument` is defined as an argument pointing to `SomeArgument`.

The argument may be passed to `SQLSomeFunction` in one of the following ways:

1. Pass `SomeArgument` BY REFERENCE:

   ```
   CALL "SQLSomeFunction" USING BY REFERENCE SomeArgument
   ```

   `USING BY CONTENT SomeArgument`, may be used instead if `SomeArgument` is an input argument.

2. Define a pointer data item `PSomeArgument` to point to `SomeArgument`:

   ```
   SET PSomeArgument TO ADDRESSS OF SomeArgument
   CALL "SQLSomeFunction" USING BY VALUE PSomeArgument
   ```

3. Pass ADDRESS OF `SomeArgument` BY VALUE:

   ```
   CALL "SQLSomeFunction" USING BY VALUE ADDRESS OF SomeArgument
   ```

Note that the last approach can be used only if the target argument, `SomeArgument`, is a level 01 item in the LINKAGE SECTION. If `SomeArgument` is a level 01 item in the LINKAGE SECTION, the addressibility to `SomeArgument` can be set in one of the following ways:

1. Explicitly via

   ```
   SET ADDRESS OF SomeArgument TO a-pointer-data-item
   ```

   or

   ```
   SET ADDRESS OF SomeArgument to ADDRESS OF an-identifier
   ```

or

2. Implicitly by having `SomeArgument` passed in as an argument to the program from which the ODBC function call is being made.

The following shows a fragment of a sample program invoking the `SQLAllocEnv` function:

```
      ...
     WORKING-STORAGE SECTION.
           COPY "odbccob.cpy".
        ...
     01  SQL-RC     COMP-5    PIC S9(4).
     01  Henv       POINTER.
        ...
     PROCEDURE DIVISION.
        ...
           CALL "SQLAllocEnv" USING BY REFERENCE Henv
                              RETURNING SQL-RC
           IF SQL-RC NOT = SQL-SUCCESS
              THEN
                DISPLAY "SQLAlloc failed."
                 ...
              ELSE
                 ...
```

The above is further illustrated using `SQLConnect` function. Any one of the following examples can be used for calling the `SQLDriver` function:

Example 1:

```
    ...
  CALL "SQLConnect" USING BY VALUE     hdbc
                                BY REFERENCE szDSN
                                BY VALUE     SQL-NTS
                                BY REFERENCE szUID
                                BY VALUE     SQL-NTS
                                BY REFERENCE szAuthStr
                                BY VALUE     SQL-NTS
                           RETURNING SQL-RC
          ...
```

Example 2:

```
   ...
 SET PszDSN TO ADDRESS OF szDSN
 SET PszUID TO ADDRESS OF szUID
 SET PszAuthStr TO ADDRESS OF szAuthStr
 CALL "SQLConnect" USING BY VALUE     hdbc
                                          PszDSN
                                          SQL-NTS
                                          PszUID
                                          SQL-NTS
                                          PszAuthStr
                                          SQL-NTS
                           RETURNING SQL-RC
        ...
```

Example 3:

```
   ...
 CALL "SQLConnect" USING BY VALUE     hdbc
                                          ADDRESS OF szDSN
                                          SQL-NTS
                                          ADDRESS OF szUID
                                          SQL-NTS
                                          ADDRESS of szAuthStr
                                          SQL-NTS
                           RETURNING SQL-RC
        ...
```

In **Example 3**, `szDSN`, `szUID`, and `szAuthStr` must be defined as level 01 items in the LINKAGE SECTION.

Note that the BY REFERENCE or BY VALUE phrase applies to all arguments until overridden by another BY REFERENCE, BY VALUE, or BY CONTENT phrase.

Accessing Function Return Values

The function return values for an ODBC call should be specified using the RETURNING phrase on the CALL statement:

```
          CALL "SQLAllocEnv" USING BY VALUE Phenv RETURNING SQL-RC
          IF SQL-RC NOT = SQL-SUCCESS
             THEN
                DISPLAY "SQLAllocEnv failed."
                  ...
             ELSE
                 ...
           END-IF
                 ...
```

Testing Bits with a Bit Mask

Some of the ODBC APIs require you to set bit masks and to query bits. A callable library routine, `iwzODBCTestBits`, is supplied for your use for querying bits.[14].

This routine may be called as follows:

```
CALL "iwzODBCTestBits" USING identifier-1, identifier-2
                    RETURNING identifier-3
```

identifier-1
This is the field being tested. It must be a 2- or 4-byte binary number field, that is, USAGE COMP-5 PIC 9(4) or PIC 9(9).

identifier-2
This is the bit mask field to select the bits to be tested. It must be defined with the same USAGE and PICTURE as *identifier-1*.

identifier-3
This is the return value for the test and has the following return values:

0 None of the bits indicated by *identifier-2* is ON in *identifier-1*.

1 All the bits selected by *identifier-2* are ON in *identifier-1*.

-1 One or more bits are ON and one or more bits are OFF among the bits selected by *identifier-2* for *identifier-1*.

-100 Invalid input argument found (such as an 8-byte binary number field is used as *identifier-1*)

It must be defined with USAGE COMP-5 with PIC S9(4).

Multiple bits can be set in a field using COBOL arithmetic expressions with the bit masks defined in the ODBCCOB copybook. For example, the bits for SQL-CVT-CHAR, SQL-CVT-NUMERIC, and SQL-CVT-DECIMAL can be set to `InfoValue` field by:

```
COMPUTE InfoValue = SQL-CVT-CHAR + SQL-CVT-NUMERIC + SQL-CVT-DECIMAL
```

And `InfoValue` can be passed to the `iwzTestBits` function as the second argument.

Note that the operands of the arithmetic expression above represent disjoint bits from each other as defined for each of such bit mask symbols in ODBCCOB copybook. You should be careful not to repeat the same bit in an arithmetic expression for this purpose (since the operations are arithmetic additions not logical ORs). For example,

```
COMPUTE InfoValue = SQL-CVT-CHAR + SQL-CVT-NUMERIC + SQL-CVT-DECIMAL
                  + SQL-CVT-CHAR
```

will result is `InfoValue` not having the SQL-CVT-CHAR bit on.

[14] The IWZODBC.LIB import library must be linked with any application that calls `iwzODBCTestBits`

The call interface convention in effect at the time of the call must be CALLINT SYSTEM DESCRIPTOR.

Setting Licensing Information for ODBC Driver Manager/Driver

If you are using the ODBC Driver Manager/drivers shipped with VisualAge for COBOL for OS/2, you need to call `iwzODBCLicInfo` immediately following a call to the `SQLConnect`, `SQLDriverConnect`, or `SQLBrowseConnect` function.[15] You need to pass the argument **hdbc** to `iwzODBCLicInfo`:

```
CALL "iwzODBCLicInfo" USING BY VALUE Hdbc
.
```

See “Sample Program Using Supplied Copybooks” for the call.

Sample Program Using Supplied Copybooks

Two other copybooks are supplied for your optional use, if you want to use prepared COBOL statements for commonly used functions for ODBC initialization, error handling, and clean-up (SQLAllocEnv, SQLAllocConnect, iwzODBCLicInfo, SQLAllocStmt, SQLFreeStmt, SQLDisconnect, SQLFreeConnect and SQLFreeEnv). These copybooks may be used with or without modifications.

In addition to the ODBCCOB.CPY copybook, the two other copybooks are ODBCDATA.CPY and ODBCPROC.CPY. Also a skeleton sample program, ODBCSAMP.CBL, illustrating the use of these copybooks is included.

ODBCPROC.CPY includes COBOL procedure statements that can be performed for initialization, termination, and error processing.

ODBCDATA.CPY contains data declarations used by ODBCPROC.CPY in the WORKING-STORAGE SECTION (or LOCAL-STORAGE SECTION).

Example Notes:

1. The PGMNAME(MIXED) compiler option should be used; the ODBC entry points are case sensitive.
2. The sample code (ODBCSAMP.CBL, ODBCPROC.CPY, and ODBCDATA.CPY) is located in the SAMPLES\ODBC subdirectory under the main COBOL install directory.
3. ODBCCOB.CPY is in the INCLUDE subdirectory under the main COBOL install directory.
4. Including these two subdirectories in your SYSLIB environment variable will ensure that the copybooks are available to the compiler.

The following illustrates the use of the copybooks:

[15] The IWZODBC.LIB import library must be linked with any application that calls `iwzODBCLicInfo`.

Sample Program

```
      ****************************************************************
      * ODBCSAMP.CBL                                                 *
      *--------------------------------------------------------------*
      * Sample program using ODBCCOB, ODBCDATA, and ODBCPROC         *
      * copybooks                                                   *
      ****************************************************************
       IDENTIFICATION DIVISION.
       PROGRAM-ID. "ODBC-Sample".
       DATA DIVISION.

       WORKING-STORAGE SECTION.
      *  copy ODBC API constant definitions
           COPY "odbccob.cpy" SUPPRESS.

      *  copy additional definitions used by ODBCPROC procedure
           COPY "odbcdata.cpy".

      *  arguments used for SQLConnect
       01  szDSN                     PIC X(10) VALUE Z"MyDataBase".
       01  szUID                     PIC X(10) VALUE Z"USERID".
       01  szAuthStr                 PIC X(10) VALUE Z"PASSWORD".

       PROCEDURE DIVISION.
       Do-ODBC SECTION.
        Start-ODBC.
           DISPLAY "Sample ODBC program starts"

      *  allocate henv & hdbc
           PERFORM ODBC-Initialization
      *  connect to data source
           CALL "SQLConnect" USING BY VALUE     Hdbc
                                   BY REFERENCE szDSN
                                   BY VALUE     SQL-NTS
                                   BY REFERENCE szUID
                                   BY VALUE     SQL-NTS
                                   BY REFERENCE szAuthStr
                                   BY VALUE     SQL-NTS
                             RETURNING SQL-RC
           IF SQL-RC NOT = SQL-SUCCESS
             MOVE "SQLConnect" TO SQL-stmt
             PERFORM SQLError-Function
           END-IF
```

Figure 86 (Part 1 of 2). Example of Using the ODBC Copybooks

```
*  set licensing informationm
     PERFORM SQL-SetLicInfo-Function

*  allocate hstmt
     PERFORM SQLAllocStmt-Function.

****************************************
*  add application specific logic here  *
****************************************

*  clean-up environment
     PERFORM ODBC-Clean-Up.

*  End the sample program execution
     GOBACK.

*  copy predefined COBOL ODBC calls which are performed
     COPY  "odbcproc.cpy".
*********************************************
* End of ODBCSAMP.CBL:  ODBC-Sample program *
*********************************************
```

Figure 86 (Part 2 of 2). Example of Using the ODBC Copybooks

The following shows the copybook ODBCDATA.CPY:

```
*****************************************************************
* ODBCDATA.CPY                                                  *
*---------------------------------------------------------------*
* Data definitions to be used with sample ODBC function calls   *
*  and included in WORKING-STORAGE or LOCAL-STORAGE SECTION     *
*****************************************************************
* ODBC Handles
 01  Henv                     POINTER            VALUE NULL.
 01  Hdbc                     POINTER            VALUE NULL.
 01  Hstmt                    POINTER            VALUE NULL.

* Arguments used for SQLError calls
 01  szSQLState.
     02 szSQLState-Chars              PIC X(5).
     02 szSQLState-Null               PIC X.
 01  fNativeError             COMP-5  PIC S9(9).
 01  szErrorMsg                       PIC X(511) VALUE SPACES.
 01  cbErrorMsgMax            COMP-5  PIC S9(4)  VALUE 511.
 01  cbErrorMsg               COMP-5  PIC S9(4).

* Misc declarations used in sample function calls
 01  SQL-RC                   COMP-5  PIC S9(4)  VALUE 0.
 01  Saved-SQL-RC             COMP-5  PIC S9(4)  VALUE 0.
 01  char-count               COMP-5  PIC  9(9)  VALUE 0.
 01  SQL-stmt                         PIC X(30).

**********************
* End of ODBCDATA.CPY *
**********************
```

Figure 87. Supplied Copybook ODBCDATA

The following shows the copybook ODBCPROC.CPY:

```
      ****************************************************************
      * ODBCPROC.CPY                                                 *
      *--------------------------------------------------------------*
      *  Sample ODBC initialization, clean-up and error handling     *
      *    procedures                                                *
      ****************************************************************
      *** Initialization functions SECTION *****************************
       ODBC-Initialization SECTION.
      *
         SQLAllocEnv-Function.
            CALL "SQLAllocEnv" USING BY REFERENCE Henv
                               RETURNING SQL-RC
            IF SQL-RC NOT = SQL-SUCCESS
              MOVE "SQLAllocEnv" TO SQL-stmt
              PERFORM SQLError-Function
            END-IF.
      *
         SQLAllocConnect-Function.
            CALL "SQLAllocConnect" USING BY VALUE     Henv
                                         BY REFERENCE Hdbc
                                   RETURNING SQL-RC
            IF SQL-RC NOT = SQL-SUCCESS
                MOVE "SQLAllocConnect" to SQL-stmt
                PERFORM SQLError-Function
            END-IF.

      *** SQL-SetLicInfo SECTION ***********************************
       SQL-SetLicInfo-Function SECTION.
         SQL-SetLicInfo.
            CALL "iwzODBCLicInfo" USING BY VALUE Hdbc.

      *** SQLAllocStmt function SECTION *****************************
       SQLAllocStmt-Function SECTION.
         SQLAllocStmt.
            CALL "SQLAllocStmt" USING BY VALUE     Hdbc
                                      BY REFERENCE Hstmt
                                RETURNING SQL-RC
            IF SQL-RC NOT = SQL-SUCCESS
                MOVE "SQLAllocStmt" TO SQL-stmt
                PERFORM SQLError-Function
            END-IF.

      *** Cleanup Functions SECTION ***********************************
       ODBC-Clean-Up SECTION.
      *
         SQLFreeStmt-Function.
            CALL "SQLFreeStmt" USING BY VALUE Hstmt
                                     SQL-DROP
                                          RETURNING SQL-RC
            IF SQL-RC NOT = SQL-SUCCESS
                MOVE "SQLFreeStmt" TO SQL-stmt
                PERFORM SQLError-Function
            END-IF.
```

Figure 88 (Part 1 of 3). Supplied Copybook ODBCPROC

```
      *
        SQLDisconnect-Function.
           CALL "SQLDisconnect" USING BY VALUE Hdbc RETURNING SQL-RC
           IF SQL-RC NOT = SQL-SUCCESS
               MOVE "SQLDisconnect" TO SQL-stmt
               PERFORM SQLError-Function
           END-IF.
      *
        SQLFreeConnect-Function.
           CALL "SQLFreeConnect" USING BY VALUE Hdbc RETURNING SQL-RC
           IF SQL-RC NOT = SQL-SUCCESS
               MOVE "SQLFreeConnect" TO SQL-stmt
               PERFORM SQLError-Function
           END-IF.
      *
        SQLFreeEnv-Function.
           CALL "SQLFreeEnv" USING BY VALUE Henv RETURNING SQL-RC
           IF SQL-RC NOT = SQL-SUCCESS
               MOVE "SQLFreeEnv" TO SQL-stmt
               PERFORM SQLError-Function
           END-IF.
```

Figure 88 (Part 2 of 3). Supplied Copybook ODBCPROC

```
*** SQLError function SECTION ***********************************
 SQLError-Function SECTION.
  SQLError.
     MOVE SQL-RC TO SAVED-SQL-RC
     DISPLAY "Return Value = " SQL-RC
     PERFORM WITH TEST AFTER UNTIL SQL-RC =  SQL-SUCCESS
                                         OR SQL-NO-DATA-FOUND
                                         OR SQL-INVALID-HANDLE

       IF SQL-RC = SQL-SUCCESS-WITH-INFO
         THEN
            DISPLAY SQL-stmt " successful with information"
         ELSE
            DISPLAY SQL-stmt " failed"
       END-IF

       CALL "SQLError" USING BY VALUE     Henv
                                          Hdbc
                                          Hstmt
                             BY REFERENCE szSqlState
                                          fNativeError
                                          szErrorMsg
                             BY VALUE     cbErrorMsgMax
                             BY REFERENCE cbErrorMsg
                        RETURNING SQL-RC
       IF SQL-RC = SQL-SUCCESS OR SQL-SUCCESS-WITH-INFO
         THEN
           DISPLAY "SQL-State = " szSQLState-Chars
           INSPECT szErrorMsg TALLYING char-count
                               FOR CHARACTERS BEFORE X"00"
           DISPLAY "Message = " szErrorMsg (1:char-count)
           MOVE 0 TO char-count
         ELSE
           DISPLAY "Return value = " SQL-RC
       END-IF
           MOVE "SQLError" TO SQL-stmt
     END-PERFORM

     IF Saved-SQL-RC NOT = SQL-SUCCESS-WITH-INFO
       DISPLAY "Application being terminated"
*       you might do <CALL "SQLTransact" USING BY VALUE ...
*       SQL-Rollback> or some other processing here.
       STOP RUN
     END-IF.
***********************
* End of ODBCPROC.CPY *
***********************
```

Figure 88 (Part 3 of 3). Supplied Copybook ODBCPROC

Chapter 22. Building Dynamic Link Libraries

By using linking you can have a program call another program which is not contained in the calling program's source code. Before or during execution, the calling program's object module is linked with the called program's object module.

Before you begin creating COBOL dynamic link libraries, you should understand the differences between static and dynamic linking.

Static Linking Overview

Static linking involves a calling program being linked to a called program module, resulting in a single executable module. The result of statically linking programs is an .EXE file or DLL subprogram that contains the executable code for multiple programs. This may include both the calling program and the called program. When the program is loaded, the operating system attempts to place a single file containing the executable code and data into memory.

The primary advantage of static linking is that you can create self-contained, independent programs. In other words, the executable program consists of one part (the .EXE file) that you need to keep track of. The disadvantages of static linking are as follows:

- Linked external programs are built into the executable files, making these files larger.
- The behavior of executable files cannot be changed without re-linking.
- External called programs cannot be shared, requiring duplicate copies of programs to be loaded in memory if more than one calling program needs to access them.

To overcome these disadvantages, use dynamic linking.

Dynamic Linking Overview

Dynamic linking allows several programs to use a single copy of an executable module. The executable module is completely separate from the programs that use it. Several subprograms can be built into a dynamic link library (DLL), and calling programs can use these subprograms as if they were part of the calling program's own executable code. You can change the dynamically-linked subprograms without recompiling or relinking the calling program.

DLLs are typically used to provide common functions that can be used by a number of programs. For example, DLLs can be used to implement subprogram packages, subsystems, and interfaces to other programs. DLLs are also used to create OO class libraries (see Chapter 12, “Writing Object-Oriented Programs” on page 214).

For more information on building DLLs with IBM VisualAge for COBOL for OS/2, see *Building VisualAge for Cobol Parts for Fun and Profit.*

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You can dynamically link with the supplied run-time DLLs, as well as with your own COBOL DLLs.

OS/2 For an in-depth discussion of static versus dynamic linking, refer to the *OS/2 Application Design Guide*.

Terminology Notes

If you are new to the PC, you might find the terminology used to discuss DLLs confusing.

Keep in mind that a dynamic link library (DLL) is, above all, a *library* of functions. Even if there is only one function provided by the DLL (as in the example provided in this chapter), the purpose of a DLL is to serve as a repository of frequently-used functions.

In COBOL terms, a DLL is a collection of outermost programs. While these outermost programs may contain nested programs, only the outermost programs (known as entry points) are callable by programs external to the DLL. Just as you can compile and link several COBOL programs together as a single executable (.EXE) you link one or more compiled outermost COBOL programs together to create a DLL.

Because outermost programs in the DLL are part of a library of programs, each program is referred to as a *subprogram* in the DLL. Even if a DLL provides only one program, that program is considered a subprogram of the DLL.

How the Linker Resolves References to DLLs

When you compile a program, the compiler generates an object module for the code in the program. If you use any subprograms ("functions" as described in C, "subroutines" in other languages) that are in an external object module, the compiler adds an external program reference to your program object module.

The linker resolves these external references. If it finds a reference to external subprograms in an import library (see "Creating an Import Library" on page 371) or in a DLL's module-definition file (see "Creating a Module Definition File (OS/2 Only)" on page 367), the code for the external subprogram is in a DLL. To resolve external reference to DLLs, the linker adds information to the executable file that tells the loader where to find the DLL code when the executable file is loaded.

The DLLs that you reference can be created to load when the executable that calls them is loaded (pre-load) or to load when they are first referenced (load on call). However, not all references to DLLs by COBOL CALLs are resolved by the linker: `CALL identifier` and `CALL literal` with the DYNAM option are resolved by COBOL when the CALL is executed.

Creating a DLL

A DLL is built using compiled source code and a module-definition (.DEF) file (OS/2) or export (.EXP) file (Windows). Every DLL must have an accompanying .DEF file. The .DEF file contains information that includes:

- The name of the DLL (limited to eight characters)
- When to load the DLL (pre-load or load on call)
- How to manage memory for the DLL
- When to initialize the DLL
- The names of subprograms included in the DLL

In every case, the first step is to construct your DLL. You write the source code for DLL subprograms the way you write any other COBOL source programs.

Example of a

DLL Source File

The following COBOL source code is a simple example of a DLL source subprogram. When compiled, a DLL can contain numerous outermost programs, each of which is considered a subprogram within the DLL.

In the case of the following example, the DLL contains only a single subprogram. When the subprogram named MYDLL contained in the DLL named MYDLL.DLL, is called by another program and executed, it will DISPLAY the text MYDLL ENTERED on the computer screen.

```
IDENTIFICATION DIVISION.
PROGRAM-ID. MYDLL.
PROCEDURE DIVISION.
    DISPLAY "MYDLL ENTERED".
    EXIT PROGRAM.
```

Figure 89. MYDLL.CBL— Example of a simple COBOL DLL source program

The source code for the subprograms contained in the DLL is compiled and linked using COB2 (for more details on how to compile and link DLLs, see Chapter 8, “Compiling, Linking, and Running Programs” on page 129). However, on OS/2, before you are ready to build your DLL, you need to create its module definition file. This is discussed in the following section.

Creating a Module Definition File (OS/2 Only)

You must use a module definition file when you create any DLL. A module definition (.DEF) file is a text file that describes the names, attributes, exports, imports, and other characteristics of a program or dynamic link library.

When you create a DLL, its .DEF file must contain a list of all the subprograms in the DLL that can be called by a program (or by another DLL). You specify these external subprograms by using an EXPORTS statement in the file.

Example of a Module Definition File

The .DEF file for the compiled MYDLL.CBL source program (see Figure 89 on page 367) is shown in the following figure. It illustrates the statements most frequently used in module definition files that build DLLs.

```
;*********************************************
;* MYDLL.DEF                                 *
;* Description: Provides the module definition *
;* for MYDLL.DLL, a simple COBOL DLL         *
;*********************************************
LIBRARY MYDLL INITINSTANCE TERMINSTANCE
PROTMODE
DATA MULTIPLE READWRITE LOADONCALL NONSHARED
CODE LOADONCALL EXECUTEREAD
EXPORTS
   MYDLL
```

Figure 90. MYDLL.DEF— DLL module definition file for MYDLL.DLL

The module statements specified in this .DEF file are as follows:

LIBRARY MYDLL
Identifies the executable file as a dynamic link library and specifies that MYDLL is the name of the DLL.

INITINSTANCE
Indicates that the DLL library initialization routine is called each time a new process gains access to the library. Using this keyword without a termination flag implies TERMINSTANCE for DLLs with 32-bit entry points.

TERMINSTANCE
Indicates that the DLL library termination routine is called each time a process surrenders access to the library. Using this keyword without an initialization flag implies INITINSTANCE.

Concurrent Use: You must use the INITINSTANCE and TERMINSTANCE attributes if the DLL is used concurrently by multiple processes.

PROTMODE
Specifies that the DLL can be run in protected (OS/2) mode only.

DATA MULTIPLE READWRITE LOADONCALL NONSHARED
Defines the default attributes for data segments within the DLL.

- MULTIPLE indicates that there is a unique copy of the data segment for each process. You must use the MULTIPLE attribute if the DLL is used concurrently by multiple processes.

- READWRITE means that you can read from or write to the data segment. The alternative is READONLY; you can only read from the data segment. READWRITE is the default.
- LOADONCALL means that the data segment is loaded into memory when it is first accessed. The alternative is PRELOAD; the data segment is loaded as soon as a process accesses the DLL. LOADONCALL is the default.
- NONSHARED indicates that the data segment cannot be shared and must be loaded separately for each process. You must use the NONSHARED attribute if the DLL is used concurrently by multiple processes.

CODE LOADONCALL
Defines the default attributes for code segments within the DLL. LOADONCALL means that the code segment is loaded when it is first accessed. The alternative to LOADONCALL is PRELOAD; the code segment is loaded as soon as a process accesses the DLL. LOADONCALL is the default.

EXECUTEREAD
Indicates that the code segments can be both executed and read. EXECUTEREAD is the default and must be used.

EXPORTS
Defines the names of the subprograms and variables to be exported to other run-time modules. Following the EXPORTS keyword are the export definitions, which are the names of the subprograms that you want to export. Each name must be entered on a separate line.

Restrictions on Run-time Linking: If you plan to make a call to a DLL using COBOL `CALL identifier` (see the following section), or COBOL `CALL literal` with the DYNAM option, you are restricted as follows:

- You can export only one name.
- The exported name must be the same as the DLL's filename.
- If the DLL is a COBOL DLL, you must link with the same COBOL library as was the DLL: IWZRLIB.LIB or IWZRLIBM.LIB.[16]

For a complete description of module definition files, refer to the *OS/2 Application Design Guide*.

Export Files (Windows Only)

WIN

You must use an export file when you create any DLL. An export (.EXP) file is a binary file that tells the linker what parts are exported by the DLL. It is built by the COB2 command when you compile and link the DLL.

16 The default library is determined by the THREAD compiler option: IWZRLIB.LIB is the default when the NOTHREAD option is specified; IWZRLIBM.LIB is the default when the THREAD option is specified.

Coding for CALL identifier

Your COBOL program can make a CALL to a user-defined identifier rather than to a literal DLL subprogram name when the name of the target subprogram is not known until execution time. For more information about the CALL statement, see the *IBM COBOL Language Reference*.

For example, the following COBOL source program will call MYDLL in MYDLL.DLL (see Figure 89 on page 367):

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID. DYNCALL.
*
*    THIS PROGRAM USES CALL identifier to call a subprogram
*          NAMED MYDLL in a DLL. IT REQUIRES A DLL
*          NAMED MYDLL.DLL.
*
*
 DATA DIVISION.
 WORKING STORAGE SECTION.
 77  CALLNAM PIC IS X(8).
 PROCEDURE DIVISION.
     DISPLAY "START SAMPLE PROGRAM DYNCALL".
     MOVE "MYDLL" TO CALLNAM.
     CALL CALLNAM.
     DISPLAY "DYNCALL SUCCESSFUL".
     STOP RUN.
```

Figure 91. DYNAM.CBL— Run-Time DLL reference resolution

In the preceding example, the statement:

```
MOVE "MYDLL" TO CALLNAM.
```

Is a reference to the single subprogram MYDLL of the DLL MYDLL.DLL. This DLL must be in a directory defined by the COBPATH environment variable (see “Run-Time Environment Variables” on page 132). For more information about restrictions on calls that are resolved at run time to DLLs, see “Restrictions on Run-time Linking” on page 369.

Coding for CALL literal

Rather than use calls that are resolved at run time, you can use COBOL CALL `literal`. By default, these calls are resolved by the linker.

Note: text='DYNAM Setting'. Whether these calls are resolved by the linker depends on the setting of the DYNAM compile-time option. If the setting is DYNAM, the call is treated the same as CALL `identifier` and is resolved at run time. If the setting is NODYNAM, CALL `literal` is resolved by the linker. With call resolution by the linker, calls to subprograms in a DLL using CALL `literal`, the DLL's object code will not be included in the executable module for your main program.

To make such a call to an entry point in a DLL, use an import library. The import library tells the linker where to find the DLL subprograms used by your program.[17]

Unlike calls that result in run-time resolution, with link-time resolution you can have multiple entry points (outermost programs) in the DLL called.

Creating an Import Library

OS/2

For call resolution to a DLL by the linker you need to explicitly create an import library. To create an import library, use IMPLIB.EXE, the import library manager included with IBM VisualAge for COBOL for OS/2.

To create the import library for your DLL, first create its .DEF file (see "Creating a Module Definition File (OS/2 Only)" on page 367). Then use IMPLIB to create the import library. For the sample MYDLL previously discussed, we could create a library named MYDLL.LIB with the following syntax:

```
implib mydll.lib mydll.def
```

For IMPLIB SYNTAX, enter the command at an OS/2 command prompt with no arguments.

Once you have created the import library, convert the library to the new library format:

```
ILIB /CONV /NOE /NOBR mydll.lib
```

This improves linking performance.

An import library does not contain any object modules. Instead, the import library contains information that tells the linker which DLLs are used by your program and which individual subprograms are used within each DLL. When you link an executable module, the linker uses this import library to resolve external references to DLLs.

You use import libraries every time you compile and link a program that uses the system APIs. For example, all the OS/2 functions are implemented in DLLs, and OS2386.LIB is an import library that tells the linker where to find each OS/2 function.

If you invoke the linker directly, give the name of the import library where you normally specify library names.

WIN On Windows the import library is created by the COB2 command when you compile and link your DLL.

[17] Alternatively, you can use an IMPORTS statement in a .DEF file for your program.

OS/2 (Using .DEF files for stand-alone programs is not discussed here; see the *OS/2 Application Design Guide*).

Sample Program Using Call Resolution by the Linker

Figure 91 on page 370 shows a COBOL main program that makes a call to an entry point in a DLL that is resolved at **run time.** If you have created an import library using IMPLIB, you can call the same DLL, but have the entry resolved by the linker. The following program is identical to DYNCALL.CBL, except that the CALL is made directly to a symbol exported in a .DEF file rather than to a user-defined word:

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID. STATCALL.
*
*    THIS PROGRAM CALLS A SUBPROGRAM CALLED MYDLL WHICH
*          RESOLVES AT LINK-TIME.  THE DLL IN WHICH "MYDLL"
*          IS FOUND IS NOT REQUIRED TO BE NAMED MYDLL.DLL
*
 PROCEDURE DIVISION.
     DISPLAY "START SAMPLE PROGRAM STATCALL".
     CALL "MYDLL"
     DISPLAY "STATCALL SUCCESSFUL".
     STOP RUN.
```

Figure 92. STATCALL.CBL— Link-Time DLL reference resolution

In this example, the CALL reference to MYDLL is not a direct reference to MYDLL.DLL (although, in this case, the DLL happens to have the same name). The CALL is to the symbolic name MYDLL, which was exported in the MYDLL.DEF file (see Figure 90 on page 368). MYDLL, in turn, is the name of the only COBOL subprogram in MYDLL.DLL. When STATCALL is built using COB2, the CALL to MYDLL in MYDLL.DLL will be resolved by the linker.

Compiling and Linking Your DLL

COB2

Use COB2 to compile your source files and create a DLL (see Chapter 8, “Compiling, Linking, and Running Programs” on page 129).

When you use COB2 to compile and link your DLL, specify the names of all the DLL source files followed by the name of the module definition file (OS/2 only) on the command line. The name of the first source file is used as the name of the DLL unless you specify a filename with filetype .DLL, as in TEST.DLL on OS/2 or use the `-dll` option, as in `-dll:TEST` on Windows.

For example, use COB2 to compile and link the DLL and main executable programs described in this chapter. The DLL and programs that call it must be compiled in separate steps.

- The following COB2 command will build the DLL named MYDLL.DLL (see Figure 89 on page 367):

  OS/2

```
cob2 mydll.cbl mydll.def
```

```
WIN
cob2 mydll.cbl -dll:mydll
```

- The following COB2 command will build the program DYNCALL.EXE, which calls the DLL subprogram MYDLL with run-time resolution (see Figure 91 on page 370):

  ```
  cob2 dyncall.cbl
  ```

- The following COB2 command will build the program STATCALL.EXE, which calls the DLL subprogram MYDLL with link-time resolution (see Figure 92 on page 372):

  ```
  cob2 statcall.cbl mydll.lib
  ```

Creating Object-Oriented DLLs

COBOL supports the use of class programs as DLLs (for information about creating class programs, see Chapter 12, “Writing Object-Oriented Programs” on page 214).

The procedure for creating class program DLLs is the same as that for creating procedural program DLLs, with one exception. Class program DLLs require a different set of entries in the EXPORTS section of the module definition file for the DLL

To build the definition file for a class:

1. Compile the COBOL class with the IDLGEN compiler option
2. Compile the IDL with the SOM compiler's `def` emitter

For example

```
cob2 -qidlgen ClassA.cbl
sc   -sdef ClassA.idl
```

See the *SOMObjects Toolkit Users' Guide*, available online, for details. (For more information about module definition files, see “Creating a Module Definition File (OS/2 Only)” on page 367.)

Your class program is identified as a SOM subclass in the REPOSITORY paragraph of the ENVIRONMENT DIVISION. In the .DEF file for the DLL, export the name of the class program exactly as it is identified in the REPOSITORY paragraph, with 3 required strings appended to the end of the class name. These strings are:

1. *class-name*NewCLass
2. *class-name*ClassData
3. *class-name*CClassData

Mixed Case: The export specification is case-sensitive: specify the class name and required strings in correct mixed case.

For example, suppose you have two class programs, CLASSA.CBL and CLASSB.CBL, specified as CLASSA and CLASSB in their respective REPOSITORY paragraphs. If you want to compile and link-edit these two class programs as a single DLL, the EXPORTS section of the DLL's module definition file needs to specify the following:

```
EXPORTS
     ClassANewClass
     ClassAClassData
     ClassACClassData
     ClassBNewClass
     ClassBClassData
     ClassBCClassData
```

Note that a variation on each class name is exported verbatim, with three different strings appended onto the class name. In the case of `ClassA`, the resulting export statement includes:

*ClassA*NewCLass
*ClassA*ClassData
*ClassA*CClassData

This book does not address the details of creating SOM DLLs. If you would like a detailed explanation of why these three entries are required in the EXPORTS paragraph, see the *SOMObjects Developer Toolkit Users Guide* (available online).

Chapter 23. Preparing COBOL Programs for Multithreading

In the PC environment, programs may run within the threads of processes. COBOL supports multithreaded execution by means of the THREAD compiler option (see "THREAD" on page 172). In order to understand this chapter's discussion of COBOL support for multithreading, you need to be familiar with the following terms:

Process
The operating system and multithreading applications can handle execution flow within a process. Multiple processes can run concurrently, and programs run within a process can share resources. Processes can be manipulated (for example, they can be given a high or low priority in terms of the amount of time the system devotes to running the process).

Thread
Within a process, an application can initiate one or more threads. Within the thread, control is transferred between executing programs.

Run-unit
In a multithreaded environment, a COBOL run-unit is defined as the portion of the process including threads with actively executing COBOL programs. The COBOL run-unit continues until no COBOL program is active in the execution stack for any of the threads (for example, a called COBOL program contains a GOBACK statement and returns control to a C program). Within the run-unit, COBOL programs can call non-COBOL programs, and vice versa.

Program Invocation Instance
Within a thread, control is transferred between separate COBOL and non-COBOL programs. For example, a COBOL program can CALL another COBOL program or a C program. Each separately invoked (as in, CALLed) program is a program invocation instance. Program invocation instances of a particular program might exist in multiple threads within a given process.

The following illustration shows the relationships between processes, threads, run-units, and program invocation instances.

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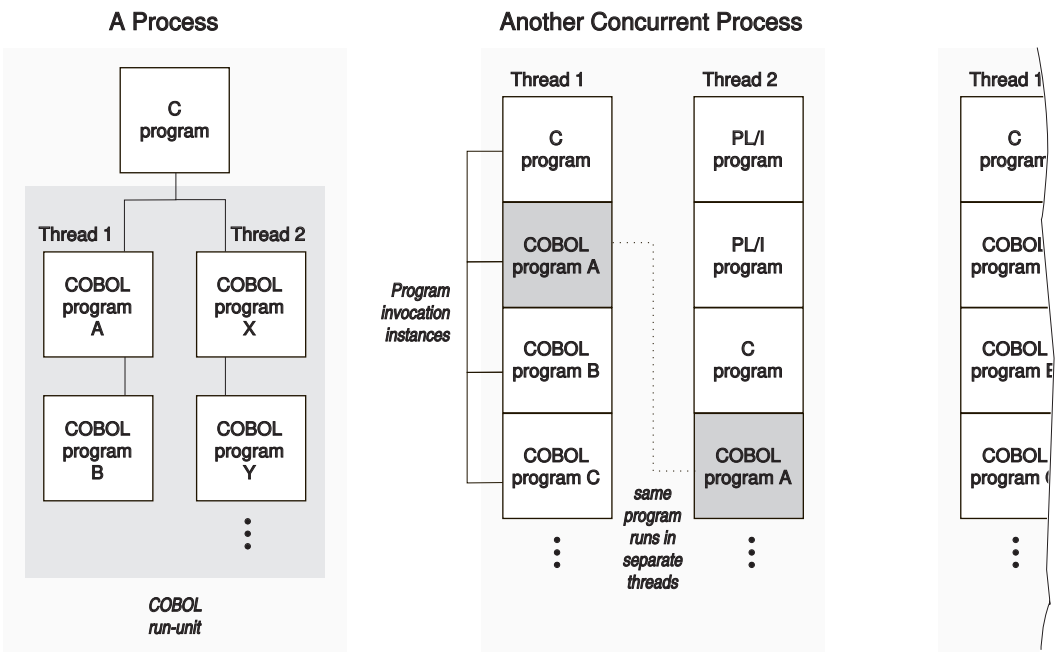

Figure 93. Schematic Illustration of Multithreading Concepts

COBOL does not directly support initiating or managing program threads. However, COBOL programs can run as threads in multithreaded environments. In other words, COBOL programs can be invoked by other applications such that they are running in multiple threads within a process or as multiple program invocation instances within a thread. This enables COBOL programs to run in multithreading environments like Presentation Manager and MQSeries Three Tier applications.

This remainder of this chapter contains information that will help you prepare your COBOL programs for multithreaded environments.

Caution: Do not confuse multiprocessing or multithreading with “multitasking,” which is generally used to describe the external behavior of applications. That is, the operating system appears to be running more than one application simultaneously. Multitasking has no relevance in this discussion.

How Language Elements Are Interpreted in a Multithreaded Environment

Because your COBOL programs can be run as separate threads within a process, be aware that language elements might be interpreted in two ways:

Run-unit scope
: The language element persists for the duration of the COBOL run-unit execution and is available to other programs within the thread.

Program invocation instance scope
The language element persists only within a particular program invocation instance.

These two types of scope are important in two contexts:

Reference
Describes where an item can be referenced from. For example, if a data item has run-unit reference scope, any program invocation instance in the run-unit can reference the data item.

State
Describes how long an item persists in storage. For example, if a data item has program invocation instance state scope, it will remain in storage only while the program invocation instance is running.

The following table summarizes the reference and state scope of various COBOL language elements.

Figure 94. Reference and State Scope for Language Elements in a Multithreading Environment

Language Element	Reference Scope	State Scope
ADDRESS-OF special register	Same as associated record	Program invocation instance
Files	Run-unit	Run-unit
Index data	Program	Program invocation instance
LENGTH of special register	Same as associated identifier	Same as associated identifier
LINAGE-COUNTER special register	Run-unit	Run-unit
LINKAGE-SECTION data	Run-unit	Based on scope of underlying data.
LOCAL-STORAGE data	Within the thread	Program invocation instance
RETURN-CODE	Run-unit	Program invocation instance
SORT-CONTROL, SORT-CORE-SIZE, SORT-RETURN, TALLY special registers	Run-unit	Program invocation instance
WHEN-COMPILED special register	Run-unit	Run-unit
WORKING-STORAGE data	Run-unit	Run-unit

Working with Run-Unit Scoped Elements

If you have resources with run-unit scope (such as GLOBAL data declared in the WORKING-STORAGE section), it is your responsibility to synchronize access to that data from multiple threads using logic in the application. You can do one or both of the following:

- Structure the application such that run-unit scoped resources are not accessed simultaneously from multiple threads.
- If you are going to access resources simultaneously from separate threads, synchronize access using facilities provided by C or by platform functions.

If you have resources with run-unit scope, and you want those resources to be isolated within an individual program invocation instance (for example, programs with individual copies of data), define the data in the local storage section so that it will have program invocation instance scope.

Working with Program Invocation Instance Scoped Elements

With these language elements, storage is allocated for each individual program invocation instance. Therefore, even if a program is invoked multiple times among multiple threads, each time it is invoked it will be allocated separate storage. For example, if program X is invoked in two or more threads, each program invocation instance of X gets its own set of resources, such as storage.

Because the storage associated with these language elements is program invocation instance scoped, data is protected from access across threads and you do not have to concern yourself with access synchronization. However, this data cannot be shared between invocations of programs unless it is explicitly passed.

Choosing THREAD for Multithreading Support

Select the THREAD compiler option for multithreading support. Choose THREAD only if you think your program will be invoked more than once in a single process by an application (such as a MQSeries Three Tier application.) Compiling with THREAD prepares the COBOL run-time environment for threading support. However, compiling with THREAD may reduce program performance. You must compile all of the programs in the run unit with THREAD; you cannot mix programs compiled with THREAD and those compiled with NOTHREAD in one run unit.

The default option is NOTHREAD. For more information about the THREAD compiler option, see “THREAD” on page 172.

Language Restrictions under THREAD

When THREAD is in effect, the following language elements are not supported and are flagged by the compiler with error-level messages:

- ALTER statement
- DEBUG-ITEM special register
- GO TO statement without a procedure name
- INITIAL PROGRAM
- RERUN
- Segmentation module
- STOP literal statement
- STOP RUN

Recursion with Threading

If a program is compiled with the THREAD compiler option, the program may be invoked recursively in a threading or non-threading environment. This applies whether or not the RECURSIVE phrase is specified in the PROGRAM-ID paragraph.

For considerations in using the LINKAGE SECTION with recursive calls, see "With Recursion or Multithreading" on page 21.

Control Transfer within a Multithreaded Environment

Be aware of the following control transfer issues when writing COBOL programs for a multithreaded environment:

CALL and CANCEL

As is the case in single-threaded environments, a program invoked is in its initial state the first time it is called within a run unit and the first time it is called after a CANCEL to the CALLED program.

EXIT PROGRAM

EXIT PROGRAM from the first program of a thread terminates that thread. EXIT PROGRAM returns to the caller of the program without terminating the thread in all other cases. EXIT PROGRAM from a main program is treated as a comment.

GOBACK

Same as EXIT PROGRAM, except that GOBACK from a main program terminates the thread.

If it can be determined that there are no other COBOL programs active in the run unit, the COBOL run unit termination process (including closing all open COBOL files) is performed on the GOBACK from the first program of this thread. This determination can be made if all COBOL programs invoked within the run unit have returned to their invokers via GOBACK or EXIT PROGRAM.

Examples on when this determination cannot be made are:

- A thread with one or more active COBOL programs was terminated (for example, because of an exception or via pthread_exit).
- A longjmp was executed which resulted in collapsing active COBOL programs in the invocation stack.

In general, it is recommended that the programs initiating and managing multiple threads use the COBOL pre-initialization interface.

Pre-initialization

If your program initiates multiple COBOL threads (for example, your C program calls COBOL programs to carry out I/O), do not assume the COBOL programs will "clean up" their environment. Particularly, do not assume that files will be automatically closed. You should pre-initialize the COBOL environment so that your application can control the COBOL "clean-up" (see Chapter 25, "Pre-initializing the COBOL Run-Time Environment" on page 393).

STOP RUN: There is no COBOL function that effectively does a STOP RUN in a threaded environment. If you need this behavior, consider invoking the C `exit()`

function from your COBOL program and using `_iwzCOBOLTerm` after the run-unit termination exit.

Limitations on COBOL in a Multithreaded Environment

Some COBOL applications depend on subsystems or other applications. In a multithreaded environment, these dependencies result in some limitations on COBOL programs:

DB2
The DB2 application may be run in multiple threads. However, any necessary synchronization for DB2 data access is the responsibility of the application.

SORT/MERGE
SORT and MERGE should only be active in one thread at a time. However, this is not enforced by the COBOL run-time environment— it must be controlled by the application.

VSAM file I/O
I/O for VSAM files should be active from only one thread at a time. However, this is not enforced by the COBOL run-time environment— it must be controlled by the application.

In general, synchronizing access to resources visible to an application within a run unit is the responsibility of the application. The exceptions to this are DISPLAY and ACCEPT, which can be executed from multiple threads without any synchronization by applications.

Example of Using COBOL in a Multithreaded Environment

This example consists of a C main program that creates two COBOL threads, waits for the COBOL threads to finish, then exits.

Sample Code for the Multithreading Example

The example has three code samples:

thrcob.c A C main program that creates the COBOL threads, waits for them to finish, then exits.

subd.cbl A COBOL program that is run by the thread created by `thrcob.c`.

sube.cbl A second COBOL program that is run by the thread created by `thrcob.c`.

The sample code for `thrcob.c` is shown in Figure 95 on page 381.

```
#define INCL_DOSPROCESS
#define INCL_DOSSEMAPHORES
#define LINKAGE _System
#define STACKSIZE 4096
#include <os2.h>
#include   <stdio.h>
#include   <setjmp.h>
#pragma handler(SUBD)
#pragma handler(SUBE)

long done;
jmp_buf Jmpbuf;

extern void _iwzCOBOLInit(int fcode, PFN StopFun, int *err_code, void *StopArg);
extern void _iwzCOBOLTerm(int fcode, int *err_code);
extern void LINKAGE SUBD(void);
extern void LINKAGE SUBE(void);

int LINKAGE
StopFun(long *stoparg)
{
   printf("inside StopFun. Got stoparg = %d\n", *stoparg);
   *stoparg = 123;
   longjmp(Jmpbuf,1);
}


long StopArg = 0;

void LINKAGE
testrc(int rc, const char *s)
{
   if (rc != 0){
           printf("%s: Fatal error rc=%d\n",s,rc);
           exit(-1);
         }
}
```

Figure 95 (Part 1 of 2). Source code for thrcob.c

```
void LINKAGE
pgmy()
{
   TID  t1, t2;
   int rc;
   int parm1, parm2;

   parm1 = 20;
   parm2 = 10;
   _iwzCOBOLInit(1, StopFun, &rc, &StopArg);
   printf( "_iwzCOBOLinit got %d\n",rc);
   rc = DosCreateThread(&t1, (PFNTHREAD)SUBD,(ULONG)&parm1, 0, STACKSIZE);
   testrc(rc,"create 1");
   rc = DosCreateThread(&t2, (PFNTHREAD)SUBE,(ULONG)&parm2, 0, STACKSIZE);
   testrc(rc,"create 2");
   printf("threads are %x and %x\n",t1, t2);

   DosWaitThread(&t1, DCWW_WAIT);
   DosWaitThread(&t2, DCWW_WAIT);

   printf("test gets done = %d \n",done );
   _iwzCOBOLTerm(1, &rc);
   printf( "_iwzCOBOLTerm got expect rc=0, got rc=%d\n",rc);
}


LINKAGE
main()
{
   if (setjmp(Jmpbuf) ==0) {
           pgmy();
       }
}
```

Figure 95 (Part 2 of 2). Source code for thrcob.c

The sample code for `subd.cbl` is shown in Figure 96.

```
       IDENTIFICATION DIVISION.
       PROGRAM-ID. "subd".
      *
       ENVIRONMENT DIVISION.
       CONFIGURATION SECTION.
      *
       DATA DIVISION.
       LOCAL-STORAGE SECTION.
       01 N2               PIC 9(8) comp-5 value 0.
      *
       LINKAGE SECTION.
       01 N1               PIC 9(8) comp-5.
      *
       PROCEDURE DIVISION using by reference n1.
           perform n1 times
                DISPLAY "subd gets " n1 " " n2
                compute n2 = n2 + 1
           end-perform
           DISPLAY "subd goback with " n1 " " n2
           GOBACK.
```

Figure 96. Source code for subd.cbl

The sample code for sube.cbl is shown in Figure 97 on page 383.

```
 IDENTIFICATION DIVISION.
 PROGRAM-ID. "sube".
*
 ENVIRONMENT DIVISION.
 CONFIGURATION SECTION.
*
 DATA DIVISION.
 LOCAL-STORAGE SECTION.
 01 N2               PIC 9(8) comp-5 value 0.
*
 LINKAGE SECTION.
 01 N1               PIC 9(8) comp-5.
*
 PROCEDURE DIVISION using by reference n1.
     perform n1 times
          DISPLAY "sube gets " n1 " " n2
          compute n2 = n2 + 1
     end-perform
     DISPLAY "sube goback with " n1 " " n2
     GOBACK.
```

Figure 97. Source code for sube.cbl

Compiling, Linking, and Running the Multithreading Example

To create and run the multithreading example, follow these steps:

1. To compile thrcob.c, enter `icc /Gm+ /C+ thrcob.c` at a command prompt
2. To compile subd.cbl, enter `cob2 -qthread -c subd.cbl`
3. To compile sube.cbl, enter `cob2 -qthread -c sube.cbl`
4. To generate the executable thrcob.exe, enter `cob2 thrcob.obj subd.obj sube.obj`
5. To run the program thrcob, enter `thrcob`

Chapter 24. National Language Support Considerations

This chapter provides an overview of things you need to know about National Language Support (NLS) when using IBM VisualAge for COBOL for OS/2.

The NLS support of this product includes the support for multiple code pages. The characters represented in a supported code page can be used in COBOL names, data definitions, literals, and in common entries.

The following list summarizes the double-byte character set (DBCS) code page support:

User-defined names

DBCS names are supported.

Data type

DBCS data type (with PICTURE N or G) is supported.

Literal

DBCS literals are supported.

Comments

DBCS comments are supported.

Collating sequence

Collating sequences for single-byte character set (ASCII and DBCS data are locale sensitive: that is, based on the collating sequence indicated by the locale, except for ASCII compares with a non-NATIVE collating sequence in effect).

This collating sequence rule applies to the single-byte characters whether the single-byte characters are from a ASCII or DBCS code page.

Since the ANSI COBOL language elements dictate the knowledge of the collating sequence at compile time, it is expected that the locale setting in effect at the compile time and at the application execution time are consistent.

Code Pages Supported for OS/2

The following code pages are supported for OS/2:

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Type of Code Page	Code Page	Countries or Languages Supported
	437	UK, US, Western European[1] countries
	850	UK, US, Western European[2] countries, Spanish Latin American countries
	852	Central and Eastern European[3] countries
	855	Central and Eastern European[4] countries
	857	Turkey
	862	Hebrew
	864	Arabic
	866	Russian
	868	Urdu
	869	Greece
	874	Thailand
	921	Latvia, Lithania
	922	Estonia
ASCII	1098	Parsi
	932, 942	Japan
	949	Korea
	938, 948, 950	China (Taiwan)
DBCS[5]	1381	China (mainland)

Notes:

1. Denmark, France, Germany, Italy, Norway, Portugal, Spain, Sweden, and Switzerland.
2. Austria, Albania, Belgium, Brazil, Canada, Catalonia, Denmark, Finland, France, Germany, Iceland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.
3. Bosnia Hercegovinia, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia
4. Bosnia Hercegovinia, Bulgaria, Macedonia, Serbia
5. Characters in the DBCS code pages are 1 to 2 bytes long.

Code Pages Supported for Windows

The following code pages are supported for Windows:

Type of Code Page	Code Page	Countries Supported
ASCII	1250	Eastern European[1] countries
	1251	Bulgaria, Serbia
	1252	Western European[2] countries, US, UK
	1254	Turkish
	1255[3]	Hebrew
	1256[3]	Arabic
DBCS[4]	943	Japan
	949	Korea
	950	China (Taiwan)
	936	China (mainland)

Notes:

1. Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia
2. Austria, Albania, Belgium, Brazil, Canada, Denmark, Finland, France, Germany, Iceland, Italy, LA Spanish, the Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.
3. Windows 95 only
4. Characters in the DBCS code pages are 1 to 2 bytes long.

DBCS User-Defined Word Support

You can form user-defined words using double-byte characters.

Usage Notes

A user-defined word containing double-byte characters must not contain more than 15 characters.

A DBCS user-defined word can contain both multi-byte and single-byte characters. When a character exists in both single-byte and multi-byte forms, its single-byte and multi-byte representations will not be regarded as equivalent. For example, “A” represented in double-bytes will not be considered to match “A” represented in a single byte.

Alphabet-names, class-names, condition-names, data-names, file-names, mnemonic-names, record-names, and symbolic characters must contain at least one single-byte alphabetic character or one multi-byte character.

A user-defined word containing multi-byte characters may not be continued.

Restrictions on Specific User-Defined Words

The IBM COBOL compiler supports the *level-number* user-defined word only when represented in SBCS digits.

Support for the *library-name*, *program-name*, and *text-name* user-defined words with DBCS depends on the DBCS name support of the platform. IBM COBOL will allow double-byte characters in these names.

DBCS Literal Support

There are two literal types to represent double-byte character constants: N'dbcs characters' and G'dbcs characters'.

Additionally, you can specify any character in one of the supported code pages using the alphanumeric literal syntax. However, such a literal is treated as alphanumeric in COBOL language semantics (that is, semantics appropriated for single-byte characters).

The literal delimiters can be apostrophes or quotes depending on the APOST or QUOTE compiler option setting.

A non-numeric literal containing double-byte characters cannot be continued. The maximum length of a N or G literal is 28 double-byte characters. The maximum length of a N or G literal is limited only by the available space in Area B on a single source line.

Figurative constant [ALL]SPACE and [ALL]SPACES represent space characters in SBCS or DBCS.

The ALL literal represents all or part of the string generated by successive concatenations of the single-byte characters or double-byte characters comprising the literal. The literal must be a non-numeric literal or a DBCS literal. The literal must not be a figurative constant.

DBCS Data Type Support

The DBCS class and category are defined as shown in the following table.

Level of Item	Class	Category
Elementary	Alphabetic	Alphabetic
	Numeric	Numeric
	Alphanumeric	Numeric edited
		Alphanumeric edited
		Alphanumeric
	DBCS	DBCS

Level of Item	Class	Category
Nonelementary (Group)	Alphanumeric	Alphabetic
		Numeric
		Numeric edited
		Alphanumeric edited
		Alphanumeric
		DBCS

If a data item is declared with PICTURE N or G, the selected locale must indicate a DBCS code page. In all other cases, the PICTURE characters N and G and USAGE DISPLAY-1 are flagged as errors.

Declaring DBCS Data

DBCS data is declared as follows:

PICTURE clause

A double-byte character position is represented by picture symbols N, G, or B.

A DBCS data item has the PICTURE character string with PICTURE symbols G, G and B, or N. Each PICTURE symbol represents a DBCS character position. The number of bytes occupied by each double-byte character is assumed to be two. That is, single-byte characters of a DBCS code page should not be included in a DBCS data item.

Operations on DBCS strings not conforming to this rule might produce unpredictable results, such as the truncation of a string at a byte position in the middle of a double-byte character.

This rule will not be enforced at run time. For a code page with characters represented in double bytes, the following padding and truncation rules apply where COBOL language semantics specify truncation or padding with spaces:

- Padding

  For operations involving DBCS data items, the padding is done using the double-byte space characters until the data area is filled. This is based on the number of byte positions allocated for the data area.

  Where the padding may not be in the multiple of the code page width (for example, a group item moved to a DBCS data item), the padding is done with single-byte space characters.

- Truncation

  The truncation is done based on the size of the target data area on the byte boundary of the end of that data area. It is the application program's responsibility to ensure that such a truncation does not result in truncation of bytes representing a partial double-type character.

USAGE clause
A DBCS data item is specified with USAGE DISPLAY-1. When you use PICTURE symbol G, you must specify USAGE DISPLAY-1. When you use PICTURE symbol N, USAGE DISPLAY-1 is implied and the USAGE clause may be omitted.

VALUE clause
The associated VALUE clause (if specified) must specify a DBCS literal or the figurative constants SPACE OR SPACES.

Reference modification
For the purpose of handling *reference modifications*, each character in a DBCS data item is considered to occupy the number of bytes corresponding to the code page width (that is, 2).

DBCS Class Test

Kanji and DBCS class test are defined to be consistent with their IBM System/370 definitions. Both class tests are internally performed by converting the double-byte characters to the double-byte characters defined for IBM System/370. The converted double-byte characters are tested for DBCS and Japanese graphic characters.

Kanji class test results in testing for valid Japanese graphic characters. This includes Katakana, Hiragana, Roman, and Kanji character sets.

The Kanji class test is done by checking the converted characters for X'41' - X'7E' for the first byte and X'41' - X'FE' for the second byte plus the space character, X'4040'.

DBCS class test results in testing for valid graphic characters for the code page.

The DBCS class test is done by checking the converted characters for X'41' - X'FE' for both the first and second byte of each character plus the space character, X'4040'.

Collating Sequence

Considerations for DBCS and ASCII collating sequence are as described below. Any comparison involving a group item will be handled based on the comparison of the byte for byte positions in hex.

The following clauses in the SPECIAL-NAMES paragraph may be specified only if the code page in effect is an ASCII code page:

- ALPHABET clause
- SYMBOLIC CHARACTER clause
- CLASS clause

These clauses, if specified with a DBCS code page in effect, will be diagnosed and treated as comments.

DBCS Collating Sequence

Data items and literals of class DBCS can be used in a relation condition with any relational operator. Each operand must be either of class DBCS, alphabetic, or alphanumeric (elementary or group). Note that this allows, for example, a comparison of a DBCS item with an alphanumeric item. No conversion or editing is done. No distinction is made between items of category DBCS and items of category DBCS edited.

DBCS comparisons are performed based on the rules for non-numeric comparisons. The comparison is based on the *locale* setting for the collating sequence if the operands are elementary DBCS or alphanumeric data items.

The PROGRAM COLLATING SEQUENCE clause has no effect on comparisons involving data items of class DBCS or DBCS literals.

ASCII Collating Sequence

The ANSI COBOL rules on the PROGRAM COLLATING SEQUENCE clause and the COLLATING SEQUENCE clause on SORT and MERGE apply.

If the collating sequence in effect is NATIVE (which is default if neither the COLLATING SEQUENCE clause nor the PROGRAM COLLATING SEQUENCE clause is specified), the collating sequence is based on the *locale* setting. This applies to SORT or MERGE statements as well as to the program collating sequence.

Note that the collating sequence impacts the processing of the alphabetic clause (for example, *literal-1* THRU *literal-2*), SYMBOLIC CHARACTERS specifications, and VALUE range specifications for Level 88 items as well as relation conditions and SORT and MERGE statements.

Since the rules of the COBOL user-defined alphabet name and symbolic characters assume a character-by-character collating sequence (not a collating sequence which may depend on a sequence of multiple characters), the locale-sensitive collating is that aspect that can be expressed by assigning a weight on each character in the code set.

Intrinsic Functions with Collating Sequence Sensitivity

The following intrinsic functions are dependent on the ordinal positions of characters. These intrinsic functions are not supported for the DBCS data type (for example, supported for single-byte characters, alphabetic or numeric). For an ASCII code page, these intrinsic functions are supported based on the collating sequence in effect. For a DBCS code page, the ordinal positions of single-byte characters are assumed to correspond to the hex representations of the single-byte characters. For example, the ordinal positions for 'A' is 66 (X'41' + 1) and the ordinal position for '*' is 43 (X'2A' + 1).

- CHAR

  Returns the character of the ordinal position given.

- MAX

  Returns the contents of the argument that contains the maximum value. Note that the arguments may be alphabetic or alphanumeric.

- ORD

Returns the ordinal position of the given character.

- ORD-MAX

  Returns the highest ordinal position of the characters given. ORD-MAX with numeric arguments are supported independent of the code page in effect.

- ORD-MIN

  Returns the lowest ordinal position of the characters given. ORD-MIN with numeric arguments are supported independent of the code page in effect.

Any comparisons involving a group item will be handled based on the comparison of the byte-for-byte positions in hex.

Comments

Character strings that form comments may contain any characters, including DBCS characters. A single DBCS character may not be split (and continued) across multiple source lines.

Messages Enabled for NLS

The following messages are NLS enabled and appropriate message text and formats are used based on the locale setting:

- Compiler messages
- Run-time messages
- Compiler listing headers

  This includes locale-sensitive date and time formats.

- debugger user interface

Cross-Reference Output Sequence

The cross-reference output is ordered in the collating sequence indicated by the locale setting.

Locale Sensitivity

This product is sensitive to the locale setting for the following features:

- code page selection

  This applies to the source program, including non-numeric literal values.

- messages

  This applies to the message text, the date and time format, and order for XREF for the compiler listing output and to run-time message text. The compile-time locale is used for compiler output, the run-time setting for run-time output.

- collating sequence

Locale sensitivity for the collating sequence applies only when the collating sequence is NATIVE; the locale has no impact on the collating sequence if COLLSEQ(BIN) or COLLSEQ(EBCDIC) is in effect.

The collating sequence for single-byte alphanumeric characters for the program collating sequence is based on the compile-time locale.

The collating sequence for SORT or MERGE statements is always based on the run-time locale.

The run-time locale-based collating sequence is always applicable to DBCS data, independent of the COBOL source-level collating sequence specification (which applies to single-byte alphanumeric data), except for comparisons of literals. Comparisons of DBCS literals are based on the compile-time locale. Thus, DBCS literals should not be used in the source program within a statement with an implied relational condition between two DBCS literals (such as VALUE G *literal1* THRU G *literal2*) unless the intended run-time locale is the same as the compile-time locale.

The compile-time and run-time locale settings are assumed to be the same for other uses of the collating sequence.

The following are **not** affected by the locale setting, as the ANSI COBOL Standard defines specific COBOL language elements for controlling these items:

- Decimal point and numeric separator
- Currency sign

Chapter 25. Pre-initializing the COBOL Run-Time Environment

Pre-initialization allows an application to initialize the COBOL run-time environment once, perform multiple executions using the environment, and then explicitly terminate the environment. Pre-initialization is used to invoke COBOL programs multiple times from a non-COBOL (for example, C or C++) environment.

The pre-initialization has two primary benefits:

- Keeps the COBOL environment ready for program calls

  Since the COBOL run unit is not terminated on return from first COBOL program in the run unit, the COBOL programs invoked from a non-COBOL environment can be invoked in its last-used state.

- Performance

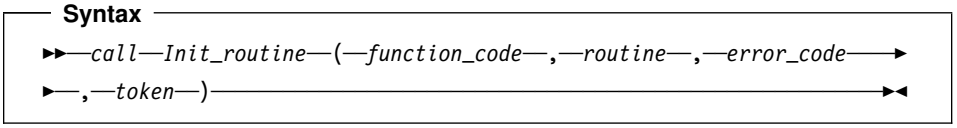
  Creating and taking down the COBOL run-time environment repeatedly uses a great deal of overhead and can slow down your application's performance.

Use pre-initialization services for multilanguage applications where non-COBOL programs need to use a non-COBOL program in its last-used state. For example, a file may be opened on a first call to a COBOL program, and the invoking program expects subsequent calls to that program to find the file left open.

Use the interfaces described below to initialize and terminate a persistent COBOL run-time environment. If you plan to run your program in an MVS or VM environment, use the pre-initialization interfaces described in *Language Environment Programming Guide*.

Initialize Persistent COBOL Environment

Syntax



call
Invocation of *Init_routine*, using language elements appropriate to the language from which the call is being made.

Init_routine
The name of the initialization routine: `_iwzCOBOLInit` or `IWZCOBOLINIT` for OS/2 and Windows (using OPTLINK linkage convention); `_IwzCOBOLInit` for Windows (using STDCALL linkage convention).

function_code (input) — A 4-byte binary number, passed by value
`function_code` can be

1 The first COBOL program invoked following this function invocation is treated as a subprogram.

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routine (input)
Address of the routine to be invoked if the run unit terminates. The token argument passed to this function will be passed on to the run unit termination exit routine. This routine, when invoked on the run unit termination, must not return to the invoker of the routine but rather do a longjmp or exit(). This routine will be invoked with the SYSTEM linkage convention.

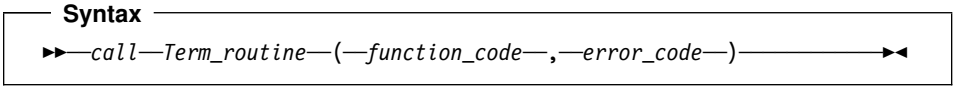
error_code (output) — A 4-byte binary number
`error_code` can be

0	pre-initialization was successful.
1	pre-initialization failed.

token (input)
4 byte token to be passed on to the exit routine specified in the earlier argument when that routine is invoked on the run unit termination.

Terminate Pre-initialized COBOL Environment

Syntax



call
Invocation of *Term_routine*, using language elements appropriate to the language from which the call is being made.

Term_routine
The name of the initialization routine: `_iwzCOBOLTerm` or `IWZCOBOLTERM` for OS/2 or Windows (using OPTLINK linkage convention); `_IwzCOBOLTerm` for Windows (using STDCALL linkage convention)

function_code (input), a 4-byte binary number, passed by value
function_code can be:

1	Clean up the pre-initialized COBOL run-time environment as if a COBOL STOP RUN statement had been performed; for example, all COBOL files are closed. However, the control returns to the caller of this service, not to the invoker of the COBOL main program; the routine named in the call to the pre-initialization routine is not invoked. (See Figure 99 on page 397. StopFun does not get called.)

error_code (output), a 4-byte binary number
error_code can be:

0	termination was successful.
1	termination failed.

The first COBOL program called following the invocation of the pre-inialization routine is treated as a subprogram. Thus, a GOBACK from this (initial) program *does not* trigger

run-unit termination semantics (such as the closing of files). Note that the run unit termination (such as with STOP RUN) *does* free the pre-initialized COBOL environment prior to the invocation of the run unit exit routine.

If Not Active: If your program invokes the termination routine and the COBOL environment is not already active, the termination routine invocation has no effect on the execution and the control is returned to the invoker with an error code of 0.

Example of Pre-initializing the COBOL Environment

Figure 98 illustrates how the pre-initialized COBOL environment works. The example shows a C program initializing the COBOL environment, calling COBOL programs, then terminating the COBOL environment.

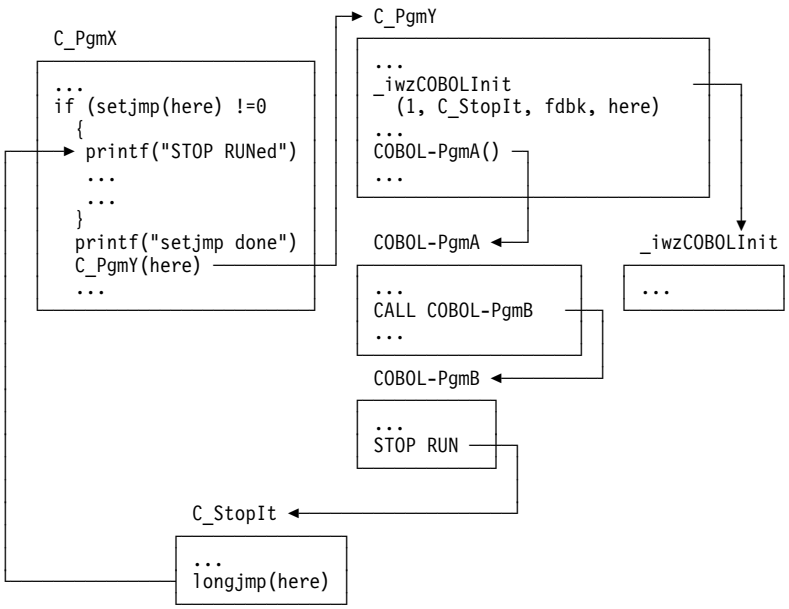


Figure 98. Illustration of Pre-Initialized COBOL Environment

The following example shows the use of COBOL pre-initialization. A C main program calls the COBOL program XIO several times. The first call to XIO opens the file, the second call writes one record, and so on. The final call closes the file. The C program then uses C-stream I/O to open and read the file. It assumes the use of VisualAge for C++.

This sample program is included with IBM VisualAge for COBOL for OS/2. To test and run the program, enter the following commands in a command window:

```
cob2 -c xio.cbl
icc testinit.c xio.obj
testinit
```

The result is:

```
_iwzCOBOLinit got 0
xio entered with x=0000000000
xio entered with x=0000000001
xio entered with x=0000000002
xio entered with x=0000000003
xio entered with x=0000000004
xio entered with x=0000000099
StopArg=0
_iwzCOBOLTerm expects rc=0 and got rc=0
FILE1 contains ----
11111
22222
33333
---- end of FILE1
```

Note that in this example, the run unit was not terminated by a COBOL STOP RUN; it was terminated when the main program called `_iwzCOBOLTerm`.

The following C program is in the file testinit.c

Example of Pre-initializing

```
#ifdef _AIX
typedef int (*PFN)();
#define LINKAGE
#else
#include <os2.h>
#define LINKAGE _System
#endif

#include   <stdio.h>
#include   <setjmp.h>

extern void _iwzCOBOLInit(int fcode, PFN StopFun, int *err_code, void *StopArg);
extern void _iwzCOBOLTerm(int fcode, int *err_code);
extern void LINKAGE XIO(long *k);

jmp_buf Jmpbuf;
long StopArg = 0;

int LINKAGE
StopFun(long *stoparg)
{
        printf("inside StopFun\n");
        *stoparg = 123;
        longjmp(Jmpbuf,1);
}



main()
{
        int rc;
        long k;
        FILE *s;
        int c;

        if (setjmp(Jmpbuf) ==0) {
                _iwzCOBOLInit(1, StopFun, &rc, &StopArg);
                printf( "_iwzCOBOLinit got %d\n",rc);
                for (k=0; k <= 4; k++) XIO(&k);
                k = 99; XIO(&k);
        }
        else printf("return after STOP RUN\n");
        printf("StopArg=%d\n", StopArg);
        _iwzCOBOLTerm(1, &rc);
        printf("_iwzCOBOLTerm expects rc=0 and got rc=%d\n",rc);
        printf("FILE1 contains ---- \n");
        s = fopen("FILE1", "r");
        if (s) {
                while (  (c = fgetc(s) ) != EOF ) putchar(c);
        }
        printf("---- end of FILE1\n");
}
```

Figure 99. Source code for testinit.c. A C program that shows the use of pre-initialization.

The following COBOL program is in the file xio.cbl

Example of Pre-initializing

```
       IDENTIFICATION DIVISION.
       PROGRAM-ID.     xio.


      ****************************************************************

       ENVIRONMENT    DIVISION.
       CONFIGURATION   SECTION.
       INPUT-OUTPUT    SECTION.
       FILE-CONTROL.
           SELECT file1 ASSIGN TO FILE1
             ORGANIZATION IS LINE SEQUENTIAL
             FILE STATUS IS file1-status.

       DATA           DIVISION.
       FILE SECTION.
       FD FILE1.
       01 file1-id pic x(5).

       WORKING-STORAGE SECTION.
       01 file1-status  pic xx    value is zero.

       LINKAGE SECTION.
      *
       01 x               PIC S9(8) COMP-5.

       PROCEDURE DIVISION using x.

           display "xio entered with x=" x
           if x = 0 then
              OPEN output FILE1
           end-if
           if x = 1  then
              MOVE ALL "1" to file1-id
              WRITE file1-id
           end-if
           if x = 2 then
              MOVE ALL "2" to file1-id
              WRITE file1-id
           end-if
           if x = 3 then
              MOVE ALL "3" to file1-id
              WRITE file1-id
           end-if
           if x = 99 then
              CLOSE file1
           end-if
           GOBACK.
```

Figure 100. Source code for xio.cbl. A COBOL program that shows the use of pre-initialization.

Appendix A. Summary of Differences with Host COBOL

This appendix gives an overview of the product function differences between IBM COBOL for MVS & VM and IBM COBOL Set for AIX and IBM VisualAge for COBOL for OS/2.

Figure 101 lists the differences between IBM COBOL for MVS & VM and workstation IBM COBOL. For information on COBOL language differences between IBM COBOL for MVS & VM and workstation IBM COBOL, see the *IBM COBOL Language Reference*.

Figure 101 (Page 1 of 3). Product Differences Between Mainframe and Workstation IBM COBOL

Product Function	Workstation Implementation
Compiler options	The following compiler options are treated as comments: ADV, AWO, BUFSIZE, DATA, DECK, DBCS, FASTSRT, FLAGMIG, LANGUAGE, NAME, OUTDD, RENT, and suboptions of TEST. These options are flagged with I-level messages.
	The following compiler options are treated as comments; however, if specified, the application might yield unpredictable results: NOADV and CMPR2. These options are flagged with W-level messages.
Data Representation	Binary data types are handled based on the specification of the BINARY compiler option.
	Sign representation for external decimal data are ASCII-based. Specifying NUMPROC(NOPFD) allows the full range of valid sign values for the numeric class test.
	EBCDIC vs ASCII—you can specify the EBCDIC collating sequence using the following language elements: ALPHABET clause, PROGRAM COLLATING SEQUENCE clause, and the COLLATING SEQUENCE phrase of the SORT and MERGE verbs.
	DBCS—Under AIX, OS/2, and Windows, you do not use shift-in or shift-out delimiters for DBCS literals.
	Within an alphanumeric literal, using control characters X'00' through X'1F' can yield unpredictable results.

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Figure 101 (Page 2 of 3). Product Differences Between Mainframe and Workstation IBM COBOL

Product Function	Workstation Implementation
environment-variables	IBM COBOL Set for AIX and IBM VisualAge for COBOL for OS/2 recognize the following as environment variables: • ASSIGNment name • COBMSGS • COBOPT • COBPATH • COBRTOPT • DB2DBDFT • LANG • LC_COLLATE • LC_MESSAGES • LC_TIME • LIBPATH • library-name specified as a user-defined word • text-name specified as a user-defined word • LOCPATH • NLSPATH • SYSIN, SYSIPT, SYSOUT, SYSLST, SYSLIST, CONSOLE, SYSPUNCH, and SYSPCH • TMP
File specification	All files are treated as single volume files. All other file specifications are treated as comments. This affects the following: REEL, UNIT, MULTIPLE FILE TAPE clause, and CLOSE...UNIT/REEL.
Inter-Language Communication (ILC)	ILC is available with C, C++, and PL/I programs.

Figure 101 (Page 3 of 3). Product Differences Between Mainframe and Workstation IBM COBOL

Product Function	Workstation Implementation
I-O	I-O support for sequential, relative, and indexed files is provided using STL File System, VSAM (OS/2 and AIX), and Btrieve (OS/2) only, but not for relative files). Sizes and values are different for the data-name returned from the file system. IBM COBOL Set for AIX and IBM VisualAge for COBOL for OS/2 do not provide direct support for tape drives or diskette drives. Line Sequential I-O is supported using the native byte stream file support of the platform. The following language elements are treated as comments for Line Sequential files, as well as for Sequential, Relative, and Indexed files: • ADVANCING phrase of WRITE statement • APPLY WRITE ONLY clause • AT END-OF-PAGE phrase of WRITE statement • BLOCK CONTAINS clause • CODE-SET clause • DATA RECORDS clause • FILE STATUS value 39 (fixed file attribute conflict) • LABEL RECORDS clause • LINAGE clause • OPEN I-O option • PADDING CHARACTER clause • RECORD CONTAINS 0 clause • RECORD CONTAINS clause (format 3) • RECORD DELIMITER clause • RECORDING MODE clause • RERUN clause • RESERVE clause • REVERSED phrase of OPEN statement • VALUE OF clause of file description entry
Run-time options	The following run-time options are not recognized by IBM VisualAge for COBOL for OS/2 and will be treated as invalid options: AIXBLD, ALL31, CBLPSHPOP, CBLQDA, COUNTRY, HEAP, MSGFILE, NATLANG, SIMVRD, and STACK.
Source code line	A COBOL source line can be less than 72 characters. A line ends on column 72 or where a carriage control character is found.

Appendix B. Intermediate Results and Arithmetic Precision

The compiler handles arithmetic statements as a succession of operations, performed according to operator precedence, and sets up an intermediate field to contain the results of these operations.

Intermediate results are possible in the following cases:

- In an ADD or SUBTRACT statement containing more than one operand immediately following the verb.
- In a COMPUTE statement specifying a series of arithmetic operations or multiple result fields.
- In arithmetic expressions contained in conditional statements and reference modification specifications.
- In the GIVING option with multiple result fields for the ADD, SUBTRACT, MULTIPLY, or DIVIDE statements.
- In a statement with an intrinsic function used as an operand.

For a discussion on when the compiler uses fixed-point or floating-point arithmetic, refer to “Fixed-Point versus Floating-Point Arithmetic” on page 41.

Calculating Precision of Intermediate Results

The compiler uses algorithms to determine the number of *integer* and decimal places reserved for intermediate results.

In the following discussion of how the compiler determines the number of integer and decimal places reserved for intermediate results, these abbreviations are used:

i The number of integer places carried for an intermediate result.

d The number of decimal places carried for an intermediate result.

ROUNDED
If the ROUNDED option is used, one more integer or decimal might be added for accuracy, if necessary. Only the final results are rounded; the intermediate results are not rounded.

dmax In a particular statement, the largest of:

- The number of decimal places needed for the final result field(s).
- The maximum number of decimal places defined for any operand, except divisors or exponents.
- The *outer-dmax* for any function operand.

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inner-dmax
The *inner-dmax* for a function is the largest of:

- The number of decimal places defined for any of its elementary arguments.
- The *dmax* for any of its arithmetic expression arguments.
- The *outer-dmax* for any of its embedded functions.

outer-dmax
The number that determines how a function result contributes to operations outside of its own evaluation (for example, if the function is an operand in an arithmetic expression or an argument to another function).

op1 The first operand in a generated arithmetic statement. For division, *op1* is the divisor.

op2 The second operand in a generated arithmetic statement. For division, *op2* is the dividend.

i1,i2 The number of integer places in *op1* and *op2*, respectively.

d1,d2 The number of decimal places defined for *op1* and *op2*, respectively.

ir The intermediate result field obtained when a generated arithmetic statement or operation is performed. *ir1*, *ir2*,. . ., represent successive intermediate results. These intermediate results are generated either in registers or in storage locations. Successive intermediate results might have the same location.

The compiler handles each statement as a succession of operations. For example, the following statement:

```
COMPUTE Y = A + B * C - D / E + F ** G
```

is calculated as:

```
** F              BY G          yielding ir1
MULTIPLY B        BY C          yielding ir2
DIVIDE E          INTO D        yielding ir3
ADD A             TO ir2        yielding ir4
SUBTRACT ir3      FROM ir4      yielding ir5
ADD ir5           TO ir1        yielding Y
```

Fixed-Point Data and Intermediate Results

The number of integer and decimal places in an *intermediate result* can be determined by using the following guidelines:

Figure 102. Determining the Precision of an Intermediate Result

Operation	Integer Places	Decimal Places
+ or -	(*i1* or *i2*) + 1, whichever is greater	*d1* or *d2*, whichever is greater
*	*i1* + *i2*	*d1* + *d2*
/	*i2* + *d1*	(*d2* - *d1*) or *dmax*, whichever is greater

You must define the operands of any arithmetic statements with enough decimal places to give the desired accuracy in the final result.

Figure 103 indicates the action of the compiler when handling intermediate results for fixed-point numbers.

Figure 103. Determining When the Compiler Might Truncate Intermediate Results

Value of i + d	Value of d	Value of i + dmax	Action Taken
<30 =30	Any value	Any value	*i* integer and *d* decimal places are carried for *ir*.
>30	<*dmax* =*dmax*	Any value	30-*d* integer and *d* decimal places are carried for *ir*.
	>*dmax*	<30 =30	*i* integer and 30-*i* decimal places are carried for *ir*.
		>30	30-*dmax* integer and *dmax* decimal places are carried for *ir*.

Exponentiations Evaluated in Fixed-Point Arithmetic

Exponentiation is represented by the expression *op1* ** *op2*. Based on the characteristics of *op2*, the compiler handles exponentiation of fixed-point numbers in one of three ways:

- When *op2* is expressed with decimals, floating-point rules (see "Floating-Point Data and Intermediate Results" on page 408) are used to calculate the exponentiation.
- When *op2* is an integral literal or constant, the value *d* is computed as:

  ```
  d = d1 * |op2|
  ```

  When *op1* is a data-name or variable, the value *i* is computed as:

  ```
  i = i1 * |op2|
  ```

  When *op1* is a literal or constant, the actual value of *op1* ** |*op2*| is computed and *i* is set equal to the number of integers in that value.

  Having calculated *i* and *d*, the compiler takes the action indicated in the following figure to handle intermediate results:

Figure 104. Determining When the Compiler Might Truncate Intermediate Results for Exponentiation

Value of i + d	Other Conditions	Action Taken
<30	Any	*i* integer and *d* decimal places are carried for *ir*.
=30	*op1* has an odd number of digits	*i* integer and *d* decimal places are carried for *ir*.
	op1 has an even number of digits	The exponentiation is handled the same as it is when *op2* is an integral data-name or a variable, except in the case of a 30-digit integer raised to the power of literal 1, where the computation is done following the rules for *op1* with an odd number of digits.
>30	Any	The exponentiation is handled the same as it is when *op2* is an integral data-name or a variable.

If *op2* is negative, the value of 1 is divided by the result produced by the preliminary computation described above. The values of *i* and *d* that are used are calculated using the rules for division found in Figure 102 on page 403.

- When *op2* is an integral data-name or a variable, *dmax* decimals and `30-dmax` integers are used. Here, *op1* is multiplied by itself (`|op2| - 1`) times. For example, the following statement:

  `COMPUTE Y = A ** B`, where B has a value of 4

  is calculated as:

  MULTIPLY A BY A yielding *ir1*
  MULTIPLY *ir1* BY A yielding *ir2*
  MULTIPLY *ir2* BY A yielding *ir3*
  MOVE *ir3* TO *ir4* which has *dmax* decimals

  The values of *i* and *d* that are used for the above multiplications are calculated using the rules for multiplication found in Figure 102 on page 403.

  If B is positive, Y = *ir4*.

  If B is negative, however,

  DIVIDE *ir4* INTO 1 yielding *ir5*, which has *dmax* decimals
  Y = *ir5*

  If *op2* is equal to zero, the answer is 1. Division-by-0 and exponentiation SIZE ERROR conditions apply. For specific information on the SIZE ERROR option, see the *IBM COBOL Language Reference*.

Fixed-point exponents with more than 9 significant digits are always truncated to 9 digits. If the exponent is a literal or constant, an E-level compiler diagnostic message is issued; otherwise, an informational message is issued at run time.

Truncated Intermediate Results

Whenever the number of digits in a decimal is greater than 30, the field is truncated to 30 digits. You will get a warning message when you compile the program. If truncation happens at run time, a message is issued and the program continues running.

If you think an intermediate result field might exceed 30 digits, you can use floating-point operands (COMP-1 and COMP-2) to avoid truncation.

Binary Data and Intermediate Results

If an operation involving binary operands requires intermediate results greater than 18 digits, the compiler converts the operands to internal decimal before performing the operation. If the result field is binary, the result will be converted from internal decimal to binary.

Binary items are used most efficiently when the intermediate result is not greater than 9 digits.

Intrinsic Functions Evaluated in Fixed-Point Arithmetic

Integer functions and mixed functions can both return an integer result. The *inner-dmax* and *outer-dmax* values are determined by the characteristics of the function.

Integer Functions: These functions always return an integer, and the *outer-dmax* will always be zero. For those functions whose arguments must be integer, the *inner-dmax* will also always be zero.

The following table summarizes the precision of the function results:

Figure 105 (Page 1 of 2). Precision of Integer Intrinsic Functions

Function	Inner-Dmax	Outer-Dmax	Function Result
DATE-OF-INTEGER	0	0	8-digit integer
DAY-OF-INTEGER	0	0	7-digit integer
FACTORIAL	0	0	fixed-point, 30-digit integer
INTEGER-OF-DATE	0	0	7-digit integer
INTEGER-OF-DAY	0	0	7- digit integer
LENGTH	n/a	0	9- digit integer
MOD	0	0	integer with as many digits as min(i1 i2)
ORD	n/a	0	3-digit integer
ORD-MAX		0	9-digit integer
ORD-MIN		0	9-digit integer

Figure 105 (Page 2 of 2). Precision of Integer Intrinsic Functions

Function	Inner-Dmax	Outer-Dmax	Function Result
INTEGER		0	With a fixed-point argument, result will be fixed-point integer with one more integer digit than the argument. With a floating-point argument, result will be fixed-point, 30-digit integer.
INTEGER-PART		0	With a fixed-point argument, result will be fixed-point integer with the same number of integer digits as the argument. With a floating-point argument, result will be fixed-point, 30-digit integer.

Mixed Functions: When the compiler handles a mixed function as fixed-point arithmetic, the result will be either integer or fixed-point with decimals (when any argument is floating-point, the function becomes a floating-point function and will follow floating-point rules). For MAX, MIN, RANGE, REM, and SUM, the *outer-dmax* is always equal to the *inner-dmax*. To determine the precision of the result returned for these functions, apply the rules for fixed-point arithmetic to each step in the algorithm used to calculate the function result.

MAX

1. Assign the first argument to your function result.
2. For each remaining argument:
   a. Compare the algebraic value of your function result with the argument.
   b. Assign the greater of the two to your function result.

MIN

1. Assign the first argument to your function result.
2. For each remaining argument:
   a. Compare the algebraic value of your function result with the argument.
   b. Assign the lesser of the two to your function result.

RANGE

1. Use the steps for MAX to select your maximum argument.
2. Use the steps for MIN to select your minimum argument.
3. Subtract the minimum argument from the maximum.
4. Assign the difference to your function result.

REM

1. Divide argument-1 by argument-2.
2. Remove all non-integer digits from the result of step 1.
3. Multiply the result of step 2 by argument-2.
4. Subtract the result of step 3 from argument-1.

5. Assign the difference to your function result.

SUM

1. Assign the value 0 to your function result.
2. For each argument:
   a. Add the argument to your function result.
   b. Assign the sum to your function result.

Floating-Point Data and Intermediate Results

Floating-point instructions are used to compute an arithmetic expression if any of the following conditions are true:

- A receiver or operand in the expression is COMP-1, COMP-2, external floating-point data, or a floating-point literal.
- An exponent contains decimal places.
- An exponent is an expression that contains an exponentiation or divide operator and *dmax* is greater than zero.
- An intrinsic numeric function is a floating-point function.

If any operation in an arithmetic expression is computed in floating-point, the entire expression is computed as if all operands were converted to floating-point and the operations are evaluated using floating-point instructions.

If an expression is computed in floating-point, double-precision floating-point is used if any receiver or operand in the expression is not COMP-1, or if a multiplication or exponentiation operation appears in the expression. Whenever double-precision floating-point is used for one operation in an arithmetic expression, all operations in the expression are computed as if double-precision floating-point instructions were used.

Alert: If a floating-point operation has an intermediate result field in which exponent overflow occurs, the job will be abnormally terminated.

Exponentiations Evaluated in Floating-Point Arithmetic

Floating-point exponentiations are always evaluated using double-precision floating-point arithmetic.

The value of a negative number raised to a fractional power is undefined. For example, (-2) ** 3 is equal to -8, but (-2) ** (3.000001) is not defined. When an exponentiation is evaluated in floating-point and there is a possibility that the value of the exponentiation will be undefined (as in the example above), then the value of the exponent is evaluated at run time to determine if it is actually an integer.

Intrinsic Functions Evaluated in Floating-Point Arithmetic

The floating-point numeric functions will always return a double precision floating-point value. For a list of the floating-point, fixed-point and mixed functions, see “Numeric Intrinsic Functions” on page 37.

Mixed functions with floating-point arguments will be evaluated using floating-point arithmetic.

Arithmetic Expressions in Non-arithmetic Statements

Arithmetic expressions can appear in contexts other than arithmetic statements. For example, an arithmetic expression can be used with the IF statement. In such statements, the rules for intermediate results, floating point, and double-precision floating-point apply, with the following changes:

- Abbreviated IF statements are handled as though the statements were not abbreviated.
- An explicit relation condition exists when a required relational operator is used to define the comparison between two operands (here referred to as comparands). In an explicit relation condition where one or both of the comparands is an arithmetic expression, the rules for intermediate results are determined taking into consideration the attributes of both comparands. That is to say, *dmax* is defined to be the maximum number of decimal places defined for any operand of either comparand, except divisors and exponents. The rules for floating-point and double-precision floating-point apply if any of the following conditions are true:
  - Any operand in either comparand is COMP-1, COMP-2, external floating- point data, or a floating-point literal.
  - An exponent contains decimal places.
  - An exponent is an expression that contains an exponentiation or divide operator and *dmax* is greater than zero.

  For example, in the statement:

  ```
  IF operand-1 = expression-1 THEN . . .
  ```

  where `operand-1` is a data-name defined to be COMP-2, and `expression-1` contains only fixed-point operands, the rules for floating-point arithmetic apply to `expression-1` because it is being compared to a floating-point operand.
- When the comparison between an arithmetic expression and either a data item or another arithmetic expression is defined without using a relational operator, then no explicit relation condition is said to exist. Here, the arithmetic expression is evaluated without regard to the attributes of the operand with which the comparison is being made. For example, in the statement:

  ```
  EVALUATE expression-1
    WHEN expression-2 THRU expression-3
    WHEN expression-4
       ⋮
  END-EVALUATE
  ```

  each arithmetic expression is evaluated in fixed-point or floating-point arithmetic based on its own characteristics.

Appendix C. Complex OCCURS DEPENDING ON

Complex OCCURS DEPENDING ON is supported as an extension to the COBOL 85 Standard.

The basic forms of complex ODO permitted by the compiler are:

- A data item described by an OCCURS clause with the DEPENDING ON option is followed by a non-subordinate element or group (a variably-located item).
- A data item described by an OCCURS clause with the DEPENDING ON option is followed by a non-subordinate data item described by an OCCURS clause with the DEPENDING ON option (variably-located table).
- A data item described by an OCCURS clause with the DEPENDING ON option is nested within another data item described by an OCCURS clause with the DEPENDING ON option (table with variable-length elements).
- Index-name for a table with variable-length elements.

Be Sure to Set Values of

ODO Objects

Every ODO object in an 01-level must be set before any reference is made to a complex ODO item in the 01-level. (Note: An ODO object cannot be variably located.) For instance, in the following example, before EMPLOYEE-NUMBER can be referred to, COUNTER-1 and COUNTER-2 must be set, even though EMPLOYEE-NUMBER does not directly depend on either of the ODO objects for its value.

The length of the variable portions of each record is the product of the ODO object and the length of the subject of the OCCURS clause. The length is calculated at the time of a reference to one of the following:

- A data item following, and not subordinate to, a variable-length table in the same level-01 record (variably-located item).

  1 in the following example.
- A group item following, and not subordinate to, a variable-length table in the same level-01 record (variably-located group).

  2 in the following example.
- An index name for a table that has variable-length elements.

  3 in the following example.
- An element of a table that has variable-length elements.

  4 in the following example.

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Complex ODO Example

Any item that meets one of these four criteria is considered to be a "complex ODO item." The following example illustrates each of the possible occurrences of a complex ODO item.

```
01 FIELD-A.

   02 COUNTER-1                          PIC S99.
   02 COUNTER-2                          PIC S99.
   02 TABLE-1.
      03 RECORD-1 OCCURS 1 TO 5 TIMES
                  DEPENDING ON COUNTER-1    PIC X(3).
   02 EMPLOYEE-NUMBER                    PIC X(5).  1
   02 TABLE-2 OCCURS 5 TIMES                        2
              INDEXED BY INDX.                      3
      03 TABLE-ITEM                      PIC 99.    4
      03 RECORD-2 OCCURS 1 TO 3 TIMES
               DEPENDING ON COUNTER-2.
         04 DATA-NUM                     PIC S99.
```

How Length Will be Calculated

Whenever a reference is made to one of these four data items, the actual length, if used, is computed as follows:

- The contents of COUNTER-1 are multiplied by 3 to calculate the length of TABLE-1.
- The contents of COUNTER-2 are multiplied by 2 and added to the length of TABLE-ITEM to calculate the length of TABLE-2.
- The length of FIELD-A is calculated by adding the length of COUNTER-1, COUNTER-2, TABLE-1, EMPLOYEE-NUMBER, and TABLE-2 times 5.

Changes in ODO Object Value

If a data item described by an OCCURS clause with the DEPENDING ON option is followed in the same level-01 record by non-subordinate data items, a change in the value of the ODO object, and a subsequent reference to a complex ODO item during the course of program execution, will have the following effects:

- The size of any group containing the related OCCURS clause will reflect the new value of the ODO object.
- Whenever a MOVE to a group containing an ODO object is executed, the MOVE is made based on the current contents of the object of the DEPENDING ON option.

  Caution: The value of the ODO object may change because a MOVE is made to it or to the group in which it is contained. The value of the ODO object may also change because the group in which it is contained is a record area that has been changed by execution of a READ statement.
- The location of any non-subordinate items following the item described with the OCCURS clause will be affected by the new value of the ODO object. If you wish to preserve the contents of these items, the following procedure can be used: Prior

to the change in the ODO object, move all non-subordinate items following the variable item to a work area; after the change in the ODO object, move all the items back.

Changing ODO Object with Complex-ODO Index Names

You must be careful when using complex-ODO index names. If you set an index name (like 'INDX' in the previous example) for a table with variable-length entries ('TABLE-2'), and then change the value of the ODO object ('COUNTER-2'), be aware that the offset in your index is no longer valid for the table, since the table has changed. If, at this point, you were to code statements that used your index name, thinking the index name had a valid value for the table, the statements would yield unexpected results. This would apply to coding:

- A reference (using your index name) to an element of the table
- A format-1 SET statement of the type SET INTEGER-DATA-ITEM TO INDEX-NAME
- A format-2 SET statement of the type SET INDEX-NAME UP/DOWN BY INTEGER.

To avoid making this type of error, you can do the following:

1. Save the value of your index name (in the form of its integer occurrence number) in an integer data-item before changing the ODO object.
2. Immediately after changing the ODO object, restore the value of your index name from the integer data-item.

For example:

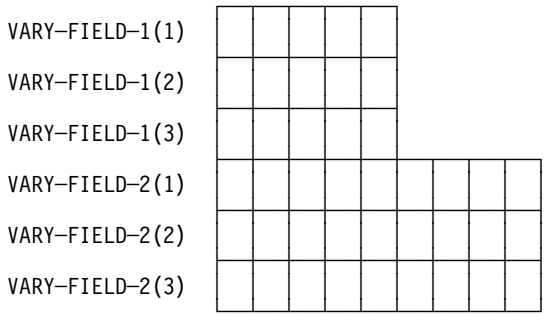
```
77   INTEGER-DATA-ITEM-1      PIC 99.

     SET INDX TO 5
*          INDX is valid at this point.
     SET INTEGER-DATA-ITEM-1 TO INDX
     MOVE NEW-VALUE TO COUNTER-2.
*          INDX is not valid at this point.
     SET INDX TO INTEGER-DATA-ITEM-1.
*          INDX Is now valid and can be
*          used with expected results.
```

Changing ODO Object with Variable Occurrence Table

The following example applies to changing an ODO object by adding an element to a variable occurrence table with variably-located items following it. The example updates a record containing an OCCURS clause with the DEPENDING ON option and at least one other subsequent entry. In this case, the subsequent entry is another OCCURS clause with the DEPENDING ON option.

```
WORKING-STORAGE SECTION.
01  VARIABLE-REC.
    05  FIELD-1                              PIC X(10).
    05  CONTROL-1                            PIC S99.
    05  CONTROL-2                            PIC S99.
    05  VARY-FIELD-1 OCCURS 1 TO 10 TIMES
         DEPENDING ON CONTROL-1               PIC X(5).
    05  GROUP-ITEM-1.
        10  VARY-FIELD-2
             OCCURS 1 TO 10 TIMES
             DEPENDING ON CONTROL-2           PIC X(9).
01  STORE-VARY-FIELD-2.
    05  GROUP-ITEM-2.
        10  VARY-FLD-2
             OCCURS 1 TO 10 TIMES
             DEPENDING ON CONTROL-2           PIC X(9).
```

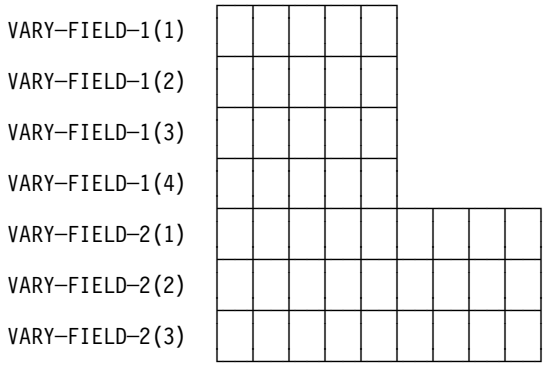
Assume that both CONTROL-1 and CONTROL-2 contain the value 3. In this situation, storage for VARY-FIELD-1 and VARY-FIELD-2 would look like this:



In order to add a fourth field to VARY-FIELD-1, the following steps are required to prevent VARY-FIELD-1 from overlaying the first 5 bytes of VARY-FIELD-2:

```
MOVE GROUP-ITEM-1 TO GROUP-ITEM-2
ADD 1 TO CONTROL-1
MOVE "additional field" TO
  VARY-FIELD-1 (CONTROL-1)
MOVE GROUP-ITEM-2 TO GROUP-ITEM-1
```

The updated storage for VARY-FIELD-1 and VARY-FIELD-2 would now look like this:



The intent of this last example is to emphasize that if you want to preserve the values contained in data items that follow a variable-length item within the same record, you must move them to another field prior to changing the length of the variable-length item, and then move them back after the length indicator has been changed.

Glossary

The terms in this glossary are defined in accordance with their meaning in COBOL. These terms may or may not have the same meaning in other languages.

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American National Standard definitions are preceded by an asterisk (*).

A

* **abbreviated combined relation condition**. The combined condition that results from the explicit omission of a common subject or a common subject and common relational operator in a consecutive sequence of relation conditions.

abend. Abnormal termination of program.

* **access mode**. The manner in which records are to be operated upon within a file.

* **actual decimal point**. The physical representation, using the decimal point characters period (.) or comma (,), of the decimal point position in a data item.

* **alphabet-name**. A user-defined word, in the SPECIAL-NAMES paragraph of the ENVIRONMENT DIVISION, that assigns a name to a specific character set and/or collating sequence.

* **alphabetic character**. A letter or a space character.

* **alphanumeric character**. Any character in the computer's character set.

alphanumeric-edited character. A character within an alphanumeric character-string that contains at least one B, 0 (zero), or / (slash).

* **alphanumeric function**. A function whose value is composed of a string of one or more characters from the computer's character set.

* **alternate record key**. A key, other than the prime record key, whose contents identify a record within an indexed file.

ANSI (American National Standards Institute). An organization consisting of producers, consumers, and general interest groups, that establishes the procedures by which accredited organizations create and maintain voluntary industry standards in the United States.

* **argument**. An identifier, a literal, an arithmetic expression, or a function-identifier that specifies a value to be used in the evaluation of a function.

* **arithmetic expression**. An identifier of a numeric elementary item, a numeric literal, such identifiers and literals separated by arithmetic operators, two arithmetic expressions separated by an arithmetic operator, or an arithmetic expression enclosed in parentheses.

* **arithmetic operation**. The process caused by the execution of an arithmetic statement, or the evaluation of an arithmetic expression, that results in a mathematically correct solution to the arguments presented.

* **arithmetic operator**. A single character, or a fixed two-character combination that belongs to the following set:

Character	Meaning
+	addition
–	subtraction
*	multiplication
/	division
**	exponentiation

* **arithmetic statement**. A statement that causes an arithmetic operation to be executed. The arithmetic statements are the ADD, COMPUTE, DIVIDE, MULTIPLY, and SUBTRACT statements.

array. In Language Environment, an aggregate consisting of data objects, each of which may be uniquely

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referenced by subscripting. Roughly analogous to a COBOL table.

*** ascending key**. A key upon the values of which data is ordered, starting with the lowest value of the key up to the highest value of the key, in accordance with the rules for comparing data items.

ASCII. American National Standard Code for Information Interchange. The standard code, using a coded character set consisting of 7-bit coded characters (8 bits including parity check), used for information interchange between data processing systems, data communication systems, and associated equipment. The ASCII set consists of control characters and graphic characters.

Extension: IBM has defined an extension to ASCII code (characters 128-255).

assignment-name. A name that identifies the organization of a COBOL file and the name by which it is known to the system.

*** assumed decimal point**. A decimal point position that does not involve the existence of an actual character in a data item. The assumed decimal point has logical meaning with no physical representation.

*** AT END condition**. A condition caused:

1. During the execution of a READ statement for a sequentially accessed file, when no next logical record exists in the file, or when the number of significant digits in the relative record number is larger than the size of the relative key data item, or when an optional input file is not present.
2. During the execution of a RETURN statement, when no next logical record exists for the associated sort or merge file.
3. During the execution of a SEARCH statement, when the search operation terminates without satisfying the condition specified in any of the associated WHEN phrases.

B

big-endian. Default format used by the mainframe and the AIX workstation to store binary data. In this format, the least significant digit is on the highest address. Compare with “little-endian.”

binary item. A numeric data item represented in binary notation (on the base 2 numbering system). Binary items have a decimal equivalent consisting of the decimal digits 0 through 9, plus an operational sign. The leftmost bit of the item is the operational sign.

binary search. A dichotomizing search in which, at each step of the search, the set of data elements is divided by two; some appropriate action is taken in the case of an odd number.

*** block**. A physical unit of data that is normally composed of one or more logical records. For mass storage files, a block may contain a portion of a logical record. The size of a block has no direct relationship to the size of the file within which the block is contained or to the size of the logical record(s) that are either contained within the block or that overlap the block. The term is synonymous with physical record.

breakpoint. A place in a computer program, usually specified by an instruction, where its execution may be interrupted by external intervention or by a monitor program.

Btrieve. A key-indexed record management system that allows applications to manage records by key value, sequential access method, or random access method. IBM COBOL supports COBOL sequential and indexed file I-O language through Btrieve.

buffer. A portion of storage used to hold input or output data temporarily.

built-in function. See “intrinsic function”.

byte. A string consisting of a certain number of bits, usually eight, treated as a unit, and representing a character.

C

callable services. In Language Environment, a set of services that can be invoked by a COBOL program using the conventional Language Environment-defined call interface, and usable by all programs sharing the Language Environment conventions.

called program. A program that is the object of a CALL statement.

*** calling program**. A program that executes a CALL to another program.

case structure. A program processing logic in which a series of conditions is tested in order to make a choice between a number of resulting actions.

*** character**. The basic indivisible unit of the language.

character position. The amount of physical storage required to store a single standard data format character described as USAGE IS DISPLAY.

character set. All the valid characters for a programming language or a computer system.

*** character-string**. A sequence of contiguous characters that form a COBOL word, a literal, a PICTURE character-string, or a comment-entry. Must be delimited by separators.

checkpoint. A point at which information about the status of a job and the system can be recorded so that the job step can be later restarted.

*** class**. The entity that defines common behavior and implementation for zero, one, or more objects. The objects that share the same implementation are considered to be objects of the same class.

*** class condition**. The proposition, for which a truth value can be determined, that the content of an item is wholly alphabetic, is wholly numeric, or consists exclusively of those characters listed in the definition of a class-name.

*** Class Definition**. The COBOL source unit that defines a class.

*** class identification entry**. An entry in the CLASS-ID paragraph of the IDENTIFICATION DIVISION which contains clauses that specify the class-name and assign selected attributes to the class definition.

*** class-name**. A user-defined word defined in the SPECIAL-NAMES paragraph of the ENVIRONMENT DIVISION that assigns a name to the proposition for which a truth value can be defined, that the content of a data item consists exclusively of those characters listed in the definition of the class-name.

class object. The run-time object representing a SOM class.

*** clause**. An ordered set of consecutive COBOL character-strings whose purpose is to specify an attribute of an entry.

CMS (Conversational Monitor System). A virtual machine operating system that provides general interactive, time-sharing, problem solving, and program development capabilities, and that operates only under the control of the VM/SP control program.

*** COBOL character set**. The complete COBOL character set consists of the characters listed below:

Character	Meaning
0,1...,9	digit
A,B,...,Z	uppercase letter
a,b,...,z	lowercase letter
b	space
+	plus sign
–	minus sign (hyphen)
*	asterisk
/	slant (virgule, slash)
=	equal sign
$	currency sign
,	comma (decimal point)
;	semicolon
.	period (decimal point, full stop)
"	quotation mark
(	left parenthesis
)	right parenthesis
>	greater than symbol
<	less than symbol
:	colon

*** COBOL word**. See “word.”

code page. An assignment of graphic characters and control function meanings to all code points; for example, assignment of characters and meanings to 256 code points for 8-bit code, assignment of characters and meanings to 128 code points for 7-bit code.

*** collating sequence**. The sequence in which the characters that are acceptable to a computer are ordered for purposes of sorting, merging, comparing, and for processing indexed files sequentially.

*** column**. A character position within a print line. The columns are numbered from 1, by 1, starting at the leftmost character position of the print line and extending to the rightmost position of the print line.

*** combined condition**. A condition that is the result of connecting two or more conditions with the AND or the OR logical operator.

*** comment-entry**. An entry in the IDENTIFICATION DIVISION that may be any combination of characters from the computer’s character set.

*** comment line**. A source program line represented by an asterisk (*) in the indicator area of the line and any characters from the computer’s character set in area A and area B of that line. The comment line serves only for documentation in a program. A special form of

comment line represented by a slant (/) in the indicator area of the line and any characters from the computer's character set in area A and area B of that line causes page ejection prior to printing the comment.

*** common program**. A program which, despite being directly contained within another program, may be called from any program directly or indirectly contained in that other program.

*** compile**. (1) To translate a program expressed in a high-level language into a program expressed in an intermediate language, assembly language, or a computer language. (2) To prepare a machine language program from a computer program written in another programming language by making use of the overall logic structure of the program, or generating more than one computer instruction for each symbolic statement, or both, as well as performing the function of an assembler.

*** compile time**. The time at which a COBOL source program is translated, by a COBOL compiler, to a COBOL object program.

compiler. A program that translates a program written in a higher level language into a machine language object program.

compiler directing statement. A statement, beginning with a compiler directing verb, that causes the compiler to take a specific action during compilation.

compiler directing statement. A statement that specifies actions to be taken by the compiler during processing of a COBOL source program. Compiler directives are contained in the COBOL source program. Thus, you can specify different suboptions of the directive within the source program by using multiple compiler directive statements in the program.

*** complex condition**. A condition in which one or more logical operators act upon one or more conditions. (See also "negated simple condition," "combined condition," and "negated combined condition.")

*** computer-name**. A system-name that identifies the computer upon which the program is to be compiled or run.

condition. An exception that has been enabled, or recognized, by Language Environment and thus is eligible to activate user and language condition handlers. Any alteration to the normal programmed flow of an application. Conditions can be detected by the hardware/operating system and results in an interrupt. They can also be detected by language-specific generated code or language library code.

*** condition**. A status of a program at run time for which a truth value can be determined. Where the term 'condition' (condition-1, condition-2,...) appears in these language specifications in or in reference to 'condition' (condition-1, condition-2,...) of a general format, it is a conditional expression consisting of either a simple condition optionally parenthesized, or a combined condition consisting of the syntactically correct combination of simple conditions, logical operators, and parentheses, for which a truth value can be determined.

*** conditional expression**. A simple condition or a complex condition specified in an EVALUATE, IF, PERFORM, or SEARCH statement. (See also "simple condition" and "complex condition.")

*** conditional phrase**. A conditional phrase specifies the action to be taken upon determination of the truth value of a condition resulting from the execution of a conditional statement.

*** conditional statement**. A statement specifying that the truth value of a condition is to be determined and that the subsequent action of the object program is dependent on this truth value.

*** conditional variable**. A data item one or more values of which has a condition-name assigned to it.

*** condition-name**. A user-defined word that assigns a name to a subset of values that a conditional variable may assume; or a user-defined word assigned to a status of an implementor defined switch or device. When 'condition-name' is used in the general formats, it represents a unique data item reference consisting of a syntactically correct combination of a 'condition-name', together with qualifiers and subscripts, as required for uniqueness of reference.

*** condition-name condition**. The proposition, for which a truth value can be determined, that the value of a conditional variable is a member of the set of values attributed to a condition-name associated with the conditional variable.

*** CONFIGURATION SECTION**. A section of the ENVIRONMENT DIVISION that describes overall specifications of source and object programs and class definitions.

CONSOLE. A COBOL environment-name associated with the operator console.

*** contiguous items**. Items that are described by consecutive entries in the Data Division, and that bear a definite hierarchic relationship to each other.

copybook. A file or library member containing a sequence of code that is included in the source program at compile time using the COPY statement. The file can be created by the user, supplied by COBOL, or supplied by another product.

CORBA. The Common Object Request Broker Architecture established by the Object Management Group. IBM's *Interface Definition Language* used to describe the *interface* for SOM classes is fully compliant with CORBA standards.

*** counter**. A data item used for storing numbers or number representations in a manner that permits these numbers to be increased or decreased by the value of another number, or to be changed or reset to zero or to an arbitrary positive or negative value.

cross-reference listing. The portion of the compiler listing that contains information on where files, fields, and indicators are defined, referenced, and modified in a program.

currency sign. The character '$' of the COBOL character set or that character defined by the CURRENCY compiler option. If the NOCURRENCY compiler option is in effect, the currency sign is defined as the character '$'.

currency symbol. The character defined by the CURRENCY compiler option or by the CURRENCY SIGN clause in the SPECIAL-NAMES paragraph. If the NOCURRENCY compiler option is in effect for a COBOL source program and the CURRENCY SIGN clause is also **not** present in the source program, the currency symbol is identical to the currency sign.

*** current record**. In file processing, the record that is available in the record area associated with a file.

*** current volume pointer**. A conceptual entity that points to the current volume of a sequential file.

D

*** data clause**. A clause, appearing in a data description entry in the DATA DIVISION of a COBOL program, that provides information describing a particular attribute of a data item.

*** data description entry** . An entry in the DATA DIVISION of a COBOL program that is composed of a level-number followed by a data-name, if required, and then followed by a set of data clauses, as required.

DATA DIVISION. One of the four main components of a COBOL program, class definition, or method definition. The DATA DIVISION describes the data to be processed by the object program, class, or method: files to be used and the records contained within them; internal working-storage records that will be needed; data to be made available in more than one program in the COBOL run unit. (Note, the Class DATA DIVISION contains only the WORKING-STORAGE SECTION.)

*** data item**. A unit of data (excluding literals) defined by a COBOL program or by the rules for function evaluation.

*** data-name**. A user-defined word that names a data item described in a data description entry. When used in the general formats, 'data-name' represents a word that must not be reference-modified, subscripted or qualified unless specifically permitted by the rules for the format.

DBCS (Double-Byte Character Set). See "Double-Byte Character Set (DBCS)."

*** debugging line**. A debugging line is any line with a 'D' in the indicator area of the line.

*** debugging section**. A section that contains a USE FOR DEBUGGING statement.

*** declarative sentence**. A compiler directing sentence consisting of a single USE statement terminated by the separator period.

*** declaratives**. A set of one or more special purpose sections, written at the beginning of the Procedure Division, the first of which is preceded by the key word DECLARATIVES and the last of which is followed by the key words END DECLARATIVES. A declarative is composed of a section header, followed by a USE compiler directing sentence, followed by a set of zero, one, or more associated paragraphs.

*** de-edit**. The logical removal of all editing characters from a numeric edited data item in order to determine that item's unedited numeric value.

*** delimited scope statement**. Any statement that includes its explicit scope terminator.

*** delimiter**. A character or a sequence of contiguous characters that identify the end of a string of characters and separate that string of characters from the following string of characters. A delimiter is not part of the string of characters that it delimits.

*** descending key**. A key upon the values of which data is ordered starting with the highest value of key down to the lowest value of key, in accordance with the rules for comparing data items.

digit. Any of the numerals from 0 through 9. In COBOL, the term is not used in reference to any other symbol.

*** digit position**. The amount of physical storage required to store a single digit. This amount may vary depending on the usage specified in the data description entry that defines the data item.

*** direct access**. The facility to obtain data from storage devices or to enter data into a storage device in such a way that the process depends only on the location of that data and not on a reference to data previously accessed.

*** division**. A collection of zero, one or more sections or paragraphs, called the division body, that are formed and combined in accordance with a specific set of rules. Each division consists of the division header and the related division body. There are four (4) divisions in a COBOL program: Identification, Environment, Data, and Procedure.

*** division header**. A combination of words followed by a separator period that indicates the beginning of a division. The division headers are:

```
IDENTIFICATION DIVISION.
ENVIRONMENT DIVISION.
DATA DIVISION.
PROCEDURE DIVISION.
```

DLL. See “dynamic link library.”

do construction. In structured programming, a DO statement is used to group a number of statements in a procedure. In COBOL, an in-line PERFORM statement functions in the same way.

do-until. In structured programming, a do-until loop will be executed at least once, and until a given condition is true. In COBOL, a TEST AFTER phrase used with the PERFORM statement functions in the same way.

do-while. In structured programming, a do-while loop will be executed if, and while, a given condition is true. In COBOL, a TEST BEFORE phrase used with the PERFORM statement functions in the same way.

Double-Byte Character Set (DBCS). A set of characters in which each character is represented by two bytes. Languages such as Japanese, Chinese, and Korean, which contain more symbols than can be represented by 256 code points, require Double-Byte Character Sets. Because each character requires two bytes, entering, displaying, and printing DBCS characters requires hardware and supporting software that are DBCS-capable.

*** dynamic access**. An access mode in which specific logical records can be obtained from or placed into a mass storage file in a nonsequential manner and obtained from a file in a sequential manner during the scope of the same OPEN statement.

dynamic link library. A file containing executable code and data bound to a program at load time or run time, rather than during linking. The code and data in a dynamic link library can be shared by several applications simultaneously.

Dynamic Storage Area (DSA). Dynamically acquired storage composed of a register save area and an area available for dynamic storage allocation (such as program variables). DSAs are generally allocated within STACK segments managed by Language Environment.

E

*** EBCDIC (Extended Binary-Coded Decimal Interchange Code)**. A coded character set consisting of 8-bit coded characters.

EBCDIC character. Any one of the symbols included in the 8-bit EBCDIC (Extended Binary-Coded-Decimal Interchange Code) set.

edited data item. A data item that has been modified by suppressing zeroes and/or inserting editing characters.

*** editing character**. A single character or a fixed two-character combination belonging to the following set:

Character	Meaning
b	space
0	zero
+	plus
–	minus
CR	credit
DB	debit
Z	zero suppress
*	check protect
$	currency sign
,	comma (decimal point)
.	period (decimal point)
/	slant (virgule, slash)

element (text element). One logical unit of a string of text, such as the description of a single data item or verb, preceded by a unique code identifying the element type.

*** elementary item**. A data item that is described as not being further logically subdivided.

enclave. When running under the Language Environment product, an enclave is analogous to a run unit. An enclave can create other enclaves on MVS and CMS by a LINK, on CMS by CMSCALL, and the use of the system () function of C.

***end class header**. A combination of words, followed by a separator period, that indicates the end of a COBOL class definition. The end class header is:

```
END CLASS class-name.
```

***end method header**. A combination of words, followed by a separator period, that indicates the end of a COBOL method definition. The end method header is:

```
END METHOD method-name.
```

*** end of Procedure Division**. The physical position of a COBOL source program after which no further procedures appear.

*** end program header**. A combination of words, followed by a separator period, that indicates the end of a COBOL source program. The end program header is:

```
END PROGRAM program-name.
```

*** entry**. Any descriptive set of consecutive clauses terminated by a separator period and written in the IDENTIFICATION DIVISION, ENVIRONMENT DIVISION, or DATA DIVISION of a COBOL program.

*** environment clause**. A clause that appears as part of an ENVIRONMENT DIVISION entry.

ENVIRONMENT DIVISION. One of the four main component parts of a COBOL program, class definition, or method definition. The ENVIRONMENT DIVISION describes the computers upon which the source program is compiled and those on which the object program is executed, and provides a linkage between the logical concept of files and their records, and the physical aspects of the devices on which files are stored.

environment-name. A name, specified by IBM, that identifies system logical units, printer and card punch control characters, report codes, and/or program switches. When an environment-name is associated with a mnemonic-name in the ENVIRONMENT DIVISION, the mnemonic-name may then be substituted in any format in which such substitution is valid.

environment variable. Any of a number of variables that describe the way an operating system is going to run and the devices it is going to recognize.

execution time. See “run time.”

execution-time environment. See “run-time environment.”

*** explicit scope terminator**. A reserved word that terminates the scope of a particular Procedure Division statement.

exponent. A number, indicating the power to which another number (the base) is to be raised. Positive exponents denote multiplication, negative exponents denote division, fractional exponents denote a root of a quantity. In COBOL, an exponential expression is indicated with the symbol ‘**’ followed by the exponent.

*** expression**. An arithmetic or conditional expression.

*** extend mode**. The state of a file after execution of an OPEN statement, with the EXTEND phrase specified for that file, and before the execution of a CLOSE statement, without the REEL or UNIT phrase for that file.

extensions. Certain COBOL syntax and semantics supported by IBM compilers in addition to those described in ANSI Standard.

*** external data**. The data described in a program as external data items and external file connectors.

*** external data item**. A data item which is described as part of an external record in one or more programs of a

run unit and which itself may be referenced from any program in which it is described.

*** external data record**. A logical record which is described in one or more programs of a run unit and whose constituent data items may be referenced from any program in which they are described.

external decimal item. A format for representing numbers in which the digit is contained in bits 4 through 7 and the sign is contained in bits 0 through 3 of the rightmost byte. Bits 0 through 3 of all other bytes contain 1's (hex F). For example, the decimal value of +123 is represented as 1111 0001 1111 0010 1111 0011. (Also know as "zoned decimal item.")

*** external file connector**. A file connector which is accessible to one or more object programs in the run unit.

external floating-point item. A format for representing numbers in which a real number is represented by a pair of distinct numerals. In a floating-point representation, the real number is the product of the fixed-point part (the first numeral), and a value obtained by raising the implicit floating-point base to a power denoted by the exponent (the second numeral).

For example, a floating-point representation of the number 0.0001234 is: 0.1234 -3, where 0.1234 is the mantissa and -3 is the exponent.

*** external switch**. A hardware or software device, defined and named by the implementor, which is used to indicate that one of two alternate states exists.

F

*** figurative constant**. A compiler-generated value referenced through the use of certain reserved words.

*** file**. A collection of logical records.

*** file attribute conflict condition**. An unsuccessful attempt has been made to execute an input-output operation on a file and the file attributes, as specified for that file in the program, do not match the fixed attributes for that file.

*** file clause**. A clause that appears as part of any of the following DATA DIVISION entries: file description entry (FD entry) and sort-merge file description entry (SD entry).

*** file connector**. A storage area which contains information about a file and is used as the linkage between a file-name and a physical file and between a file-name and its associated record area.

File-Control. The name of an ENVIRONMENT DIVISION paragraph in which the data files for a given source program are declared.

*** file control entry**. A SELECT clause and all its subordinate clauses which declare the relevant physical attributes of a file.

*** file description entry**. An entry in the File Section of the DATA DIVISION that is composed of the level indicator FD, followed by a file-name, and then followed by a set of file clauses as required.

*** file-name**. A user-defined word that names a file connector described in a file description entry or a sort-merge file description entry within the File Section of the DATA DIVISION.

*** file organization**. The permanent logical file structure established at the time that a file is created.

***file position indicator**. A conceptual entity that contains the value of the current key within the key of reference for an indexed file, or the record number of the current record for a sequential file, or the relative record number of the current record for a relative file, or indicates that no next logical record exists, or that an optional input file is not present, or that the at end condition already exists, or that no valid next record has been established.

*** File Section**. The section of the DATA DIVISION that contains file description entries and sort-merge file description entries together with their associated record descriptions.

file system. The collection of files and file management structures on a physical or logical mass storage device, such as a diskette or minidisk.

*** fixed file attributes**. Information about a file which is established when a file is created and cannot subsequently be changed during the existence of the file. These attributes include the organization of the file (sequential, relative, or indexed), the prime record key, the alternate record keys, the code set, the minimum and maximum record size, the record type (fixed or variable), the collating sequence of the keys for indexed files, the blocking factor, the padding character, and the record delimiter.

*** fixed length record**. A record associated with a file whose file description or sort-merge description entry requires that all records contain the same number of character positions.

fixed-point number. A numeric data item defined with a PICTURE clause that specifies the location of an optional sign, the number of digits it contains, and the location of an optional decimal point. The format may be either binary, packed decimal, or external decimal.

floating-point number. A numeric data item containing a fraction and an exponent. Its value is obtained by multiplying the fraction by the base of the numeric data item raised to the power specified by the exponent.

*** format**. A specific arrangement of a set of data.

*** function**. A temporary data item whose value is determined at the time the function is referenced during the execution of a statement.

*** function-identifier**. A syntactically correct combination of character-strings and separators that references a function. The data item represented by a function is uniquely identified by a function-name with its arguments, if any. A function-identifier may include a reference-modifier. A function-identifier that references an alphanumeric function may be specified anywhere in the general formats that an identifier may be specified, subject to certain restrictions. A function-identifier that references an integer or numeric function may be referenced anywhere in the general formats that an arithmetic expression may be specified.

function-name. A word that names the mechanism whose invocation, along with required arguments, determines the value of a function.

G

*** global name**. A name which is declared in only one program but which may be referenced from that program and from any program contained within that program. Condition-names, data-names, file-names, record-names, report-names, and some special registers may be global names.

*** group item**. A data item that is composed of subordinate data items.

H

header label. (1) A file label or data set label that precedes the data records on a unit of recording media. (2) Synonym for beginning-of-file label.

*** high order end**. The leftmost character of a string of characters.

I

IBM COBOL extension. Certain COBOL syntax and semantics supported by IBM compilers in addition to those described in ANSI Standard.

IDENTIFICATION DIVISION. One of the four main component parts of a COBOL program, class definition, or method definition. The IDENTIFICATION DIVISION identifies the program name, class name, or method name. The IDENTIFICATION DIVISION may include the following documentation: author name, installation, or date.

*** identifier**. A syntactically correct combination of character-strings and separators that names a data item. When referencing a data item that is not a function, an identifier consists of a data-name, together with its qualifiers, subscripts, and reference-modifier, as required for uniqueness of reference. When referencing a data item which is a function, a function-identifier is used.

IGZCBSN. The COBOL for MVS & VM bootstrap routine. It must be link-edited with any module that contains a COBOL for MVS & VM program.

*** imperative statement**. A statement that either begins with an imperative verb and specifies an unconditional action to be taken or is a conditional statement that is delimited by its explicit scope terminator (delimited scope statement). An imperative statement may consist of a sequence of imperative statements.

*** implicit scope terminator**. A separator period which terminates the scope of any preceding unterminated statement, or a phrase of a statement which by its occurrence indicates the end of the scope of any statement contained within the preceding phrase.

*** index**. A computer storage area or register, the content of which represents the identification of a particular element in a table.

*** index data item**. A data item in which the values associated with an index-name can be stored in a form specified by the implementor.

indexed data-name. An identifier that is composed of a data-name, followed by one or more index-names enclosed in parentheses.

*** indexed file**. A file with indexed organization.

*** indexed organization**. The permanent logical file structure in which each record is identified by the value of one or more keys within that record.

indexing. Synonymous with subscripting using index-names.

*** index-name**. A user-defined word that names an index associated with a specific table.

*** inheritance (for classes)**. A mechanism for using the implementation of one or more *classes* as the basis for another class. A *sub-class* inherits from one or more *super-classes*. By definition the inheriting class conforms to the inherited classes.

*** initial program**. A program that is placed into an initial state every time the program is called in a run unit.

*** initial state**. The state of a program when it is first called in a run unit.

inline. In a program, instructions that are executed sequentially, without branching to routines, subroutines, or other programs.

*** input file**. A file that is opened in the INPUT mode.

*** input mode**. The state of a file after execution of an OPEN statement, with the INPUT phrase specified, for that file and before the execution of a CLOSE statement, without the REEL or UNIT phrase for that file.

*** input-output file**. A file that is opened in the I-O mode.

*** INPUT-OUTPUT SECTION**. The section of the ENVIRONMENT DIVISION that names the files and the external media required by an object program or method and that provides information required for transmission and handling of data during execution of the object program or method definition.

*** Input-Output statement**. A statement that causes files to be processed by performing operations upon individual records or upon the file as a unit. The input-output statements are: ACCEPT (with the identifier phrase), CLOSE, DELETE, DISPLAY, OPEN, READ, REWRITE, SET (with the TO ON or TO OFF phrase), START, and WRITE.

*** input procedure**. A set of statements, to which control is given during the execution of a SORT statement, for the purpose of controlling the release of specified records to be sorted.

instance data. Data defining the state of an object. The instance data introduced by a class is defined in the WORKING-STORAGE SECTION of the DATA DIVISION of the class definition. The state of an object also includes the state of the instance variables introduced by base classes that are inherited by the current class. A separate copy of the instance data is created for each object instance.

*** integer**. (1) A numeric literal that does not include any digit positions to the right of the decimal point.

(2) A numeric data item defined in the DATA DIVISION that does not include any digit positions to the right of the decimal point.

(3) A numeric function whose definition provides that all digits to the right of the decimal point are zero in the returned value for any possible evaluation of the function.

integer function. A function whose category is numeric and whose definition does not include any digit positions to the right of the decimal point.

interface. The information that a *client* must know to use a *class*—the names of its *attributes* and the signatures of its *methods*. With direct-to-SOM compilers such as COBOL, the interface to a class may be defined by native language syntax for class definitions. Classes implemented in other languages might have their interfaces defined directly in SOM Interface Definition Language (IDL). The COBOL compiler has a compiler option, IDLGEN, to automatically generate IDL for a COBOL class.

Interface Definition Language (IDL). The formal language (independent of any programming language) by which the *interface* for a class of *objects* is defined in a IDL file, which the SOM compiler then interprets to create an implementation template file and binding files. SOM's Interface Definition Language is fully compliant with standards established by the Object Management Group's Common Object Request Broker Architecture (*CORBA*).

interlanguage communication (ILC). The ability of routines written in different programming languages to communicate. ILC support allows the application writer to readily build applications from component routines written in a variety of languages.

intermediate result. An intermediate field containing the results of a succession of arithmetic operations.

*** internal data**. The data described in a program excluding all external data items and external file connectors. Items described in the LINKAGE SECTION of a program are treated as internal data.

*** internal data item**. A data item which is described in one program in a run unit. An internal data item may have a global name.

internal decimal item. A format in which each byte in a field except the rightmost byte represents two numeric digits. The rightmost byte contains one digit and the sign. For example, the decimal value +123 is represented as 0001 0010 0011 1111. (Also known as packed decimal.)

*** internal file connector**. A file connector which is accessible to only one object program in the run unit.

*** intra-record data structure**. The entire collection of groups and elementary data items from a logical record which is defined by a contiguous subset of the data description entries which describe that record. These data description entries include all entries whose level-number is greater than the level-number of the first data description entry describing the intra-record data structure.

intrinsic function. A pre-defined function, such as a commonly used arithmetic function, called by a built-in function reference.

*** invalid key condition**. A condition, at object time, caused when a specific value of the key associated with an indexed or relative file is determined to be invalid.

*** I-O-CONTROL**. The name of an ENVIRONMENT DIVISION paragraph in which object program requirements for rerun points, sharing of same areas by several data files, and multiple file storage on a single input-output device are specified.

*** I-O-CONTROL entry**. An entry in the I-O-CONTROL paragraph of the ENVIRONMENT DIVISION which contains clauses that provide information required for the transmission and handling of data on named files during the execution of a program.

*** I-O-Mode**. The state of a file after execution of an OPEN statement, with the I-O phrase specified, for that file and before the execution of a CLOSE statement without the REEL or UNIT phase for that file.

*** I-O status**. A conceptual entity which contains the two-character value indicating the resulting status of an input-output operation. This value is made available to the program through the use of the FILE STATUS clause in the file control entry for the file.

iteration structure. A program processing logic in which a series of statements is repeated while a condition is true or until a condition is true.

K

K. When referring to storage capacity, two to the tenth power; 1024 in decimal notation.

*** key**. A data item that identifies the location of a record, or a set of data items which serve to identify the ordering of data.

*** key of reference**. The key, either prime or alternate, currently being used to access records within an indexed file.

*** key word**. A reserved word or function-name whose presence is required when the format in which the word appears is used in a source program.

kilobyte (KB). One kilobyte equals 1024 bytes.

L

*** language-name**. A system-name that specifies a particular programming language.

Language Environment-conforming. A characteristic of compiler products (COBOL/370, COBOL for MVS & VM, AD/Cycle C/370, C/C++ for MVS and VM, PL/I for MVS and VM) that produce object code conforming to the Language Environment format.

last-used state. A program is in last-used state if its internal values remain the same as when the program was exited (are not reset to their initial values).

*** letter**. A character belonging to one of the following two sets:

1. Uppercase letters: A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z
2. Lowercase letters: a, b, c, d, e, f, g, h, i, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z

*** level indicator**. Two alphabetic characters that identify a specific type of file or a position in a hierarchy. The level indicators in the DATA DIVISION are: CD, FD, and SD.

*** level-number**. A user-defined word, expressed as a two digit number, which indicates the hierarchical position of a data item or the special properties of a data description entry. Level-numbers in the range from 1 through 49 indicate the position of a data item in the hierarchical structure of a logical record. Level-numbers in the range 1 through 9 may be written either as a single digit or as a zero followed by a significant digit. Level-numbers 66, 77 and 88 identify special properties of a data description entry.

*** library-name**. A user-defined word that names a COBOL library that is to be used by the compiler for a given source program compilation.

*** library text**. A sequence of text words, comment lines, the separator space, or the separator pseudo-text delimiter in a COBOL library.

LILIAN DATE. The number of days since the beginning of the Gregorian calendar. Day one is Friday, October 15, 1582.

*** LINAGE-COUNTER**. A special register whose value points to the current position within the page body.

LINKAGE SECTION. The section in the DATA DIVISION of the called program that describes data items available from the calling program. These data items may be referred to by both the calling and called program.

literal. A character-string whose value is specified either by the ordered set of characters comprising the string, or by the use of a figurative constant.

little-endian. Default format used by the PC to store binary data. In this format, the most significant digit is on the highest address. Compare with “big-endian.”

locale. A set of attributes for a program execution environment indicating culturally sensitive considerations, such as: character code page, collating sequence, date/time format, monetary value representation, numeric value representation, or language.

*** LOCAL-STORAGE SECTION**. The section of the DATA DIVISION that defines storage that is allocated and freed on a per-invocation basis, depending on the value assigned in their VALUE clauses.

*** logical operator**. One of the reserved words AND, OR, or NOT. In the formation of a condition, either AND, or OR, or both can be used as logical connectives. NOT can be used for logical negation.

*** logical record**. The most inclusive data item. The level-number for a record is 01. A record may be either an elementary item or a group of items. The term is synonymous with record.

*** low order end**. The rightmost character of a string of characters.

M

main program. In a hierarchy of programs and subroutines, the first program to receive control when the programs are run.

*** mass storage**. A storage medium in which data may be organized and maintained in both a sequential and nonsequential manner.

*** mass storage device**. A device having a large storage capacity; for example, magnetic disk, magnetic drum.

*** mass storage file**. A collection of records that is assigned to a mass storage medium.

*** megabyte (M)**. One megabyte equals 1,048,576 bytes.

*** merge file**. A collection of records to be merged by a MERGE statement. The merge file is created and can be used only by the merge function.

metaclass. A SOM class whose instances are SOM class-objects. The methods defined in metaclasses are executed without requiring any object instances of the class to exist, and are frequently used to create instances of the class.

method. Procedural code that defines one of the operations supported by an object, and that is executed by an INVOKE statement on that object.

*** Method Definition**. The COBOL source unit that defines a method.

*** method identification entry**. An entry in the METHOD-ID paragraph of the IDENTIFICATION DIVISION which contains clauses that specify the method-name and assign selected attributes to the method definition.

*** method-name**. A user-defined word that identifies a method.

*** mnemonic-name**. A user-defined word that is associated in the ENVIRONMENT DIVISION with a specified implementor-name.

multitasking. Mode of operation that provides for the concurrent, or interleaved, execution of two or more tasks. When running under the Language Environment product, multitasking is synonymous with *multithreading*.

MVS/XA* (Multiple Virtual Storage/Extended Architecture). An IBM operating system that manages multiple virtual address spaces in IBM processors operating in extended architecture mode. MVS/XA supports the 31-bit addressing mechanism of extended architecture mode, and therefore, allows an address space as large as 2^{31} bytes (2048 megabytes or 2 gigabytes).

N

name. A word composed of not more than 30 characters that defines a COBOL operand.

*** native character set**. The implementor-defined character set associated with the computer specified in the OBJECT-COMPUTER paragraph.

*** native collating sequence**. The implementor-defined collating sequence associated with the computer specified in the OBJECT-COMPUTER paragraph.

*** negated combined condition**. The 'NOT' logical operator immediately followed by a parenthesized combined condition.

*** negated simple condition**. The 'NOT' logical operator immediately followed by a simple condition.

nested program. A program that is directly contained within another program.

*** next executable sentence**. The next sentence to which control will be transferred after execution of the current statement is complete.

*** next executable statement**. The next statement to which control will be transferred after execution of the current statement is complete.

*** next record**. The record that logically follows the current record of a file.

*** noncontiguous items**. Elementary data items in the WORKING-STORAGE and LINKAGE SECTIONs that bear no hierarchic relationship to other data items.

*** nonnumeric item**. A data item whose description permits its content to be composed of any combination of characters taken from the computer's character set. Certain categories of nonnumeric items may be formed from more restricted character sets.

*** nonnumeric literal**. A literal bounded by quotation marks. The string of characters may include any character in the computer's character set.

null. Figurative constant used to assign the value of an invalid address to pointer data items. NULLS can be used wherever NULL can be used.

*** numeric character**. A character that belongs to the following set of digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

numeric-edited item. A numeric item that is in such a form that it may be used in printed output. It may consist of external decimal digits from 0 through 9, the decimal point, commas, the dollar sign, editing sign control symbols, plus other editing symbols.

*** numeric function**. A function whose class and category are numeric but which for some possible evaluation does not satisfy the requirements of integer functions.

*** numeric item**. A data item whose description restricts its content to a value represented by characters chosen from the digits from '0' through '9'; if signed, the item may also contain a '+', '–', or other representation of an operational sign.

*** numeric literal**. A literal composed of one or more numeric characters that may contain either a decimal point, or an algebraic sign, or both. The decimal point must not be the rightmost character. The algebraic sign, if present, must be the leftmost character.

O

object. An entity that has state (its data values) and operations (its methods). An object is a way to encapsulate state and behavior.

object code. Output from a compiler or assembler that is itself executable machine code or is suitable for processing to produce executable machine code.

*** OBJECT-COMPUTER**. The name of an ENVIRONMENT DIVISION paragraph in which the computer environment, within which the object program is executed, is described.

*** object computer entry**. An entry in the OBJECT-COMPUTER paragraph of the ENVIRONMENT DIVISION which contains clauses that describe the computer environment in which the object program is to be executed.

object deck. A portion of an object program suitable as input to a linkage editor. Synonymous with *object module* and *text deck*.

object module. Synonym for *object deck* or *text deck*.

*** object of entry**. A set of operands and reserved words, within a DATA DIVISION entry of a COBOL program, that immediately follows the subject of the entry.

*** object program**. A set or group of executable machine language instructions and other material designed to interact with data to provide problem solutions. In this context, an object program is generally the machine language result of the operation of a COBOL compiler on a source program. Where there is no danger of ambiguity, the word 'program' alone may be used in place of the phrase 'object program.'

*** object time**. The time at which an object program is executed. The term is synonymous with execution time.

*** obsolete element**. A COBOL language element in Standard COBOL that is to be deleted from the next revision of Standard COBOL.

ODBC. Open Database Connectivity that provides you access to data from a variety of databases and file systems.

ODO object. In the example below,

```
WORKING-STORAGE SECTION
01  TABLE-1.
    05  X                   PICS9.
    05  Y OCCURS 3 TIMES
          DEPENDING ON X    PIC X.
```

`X` is the object of the OCCURS DEPENDING ON clause (ODO object). The value of the ODO object determines how many of the ODO subject appear in the table.

ODO subject. In the example above, `Y` is the subject of the OCCURS DEPENDING ON clause (ODO subject). The number of `Y` ODO subjects that appear in the table depends on the value of `X`.

*** open mode**. The state of a file after execution of an OPEN statement for that file and before the execution of a CLOSE statement without the REEL or UNIT phrase for that file. The particular open mode is specified in the OPEN statement as either INPUT, OUTPUT, I-O or EXTEND.

*** operand**. Whereas the general definition of operand is "that component which is operated upon," for the purposes of this document, any lowercase word (or words) that appears in a statement or entry format may be considered to be an operand and, as such, is an implied reference to the data indicated by the operand.

*** operational sign**. An algebraic sign, associated with a numeric data item or a numeric literal, to indicate whether its value is positive or negative.

*** optional file**. A file which is declared as being not necessarily present each time the object program is executed. The object program causes an interrogation for the presence or absence of the file.

*** optional word**. A reserved word that is included in a specific format only to improve the readability of the language and whose presence is optional to the user when the format in which the word appears is used in a source program.

OS/2 (Operating System/2*). A multi-tasking operating system for the IBM Personal Computer family that allows you to run both DOS mode and OS/2 mode programs.

*** output file**. A file that is opened in either the OUTPUT mode or EXTEND mode.

*** output mode**. The state of a file after execution of an OPEN statement, with the OUTPUT or EXTEND phrase specified, for that file and before the execution of a CLOSE statement without the REEL or UNIT phrase for that file.

*** output procedure**. A set of statements to which control is given during execution of a SORT statement after the sort function is completed, or during execution of a MERGE statement after the merge function reaches a point at which it can select the next record in merged order when requested.

overflow condition. A condition that occurs when a portion of the result of an operation exceeds the capacity of the intended unit of storage.

P

packed decimal item. See "internal decimal item."

*** padding character**. An alphanumeric character used to fill the unused character positions in a physical record.

page. A vertical division of output data representing a physical separation of such data, the separation being based on internal logical requirements and/or external characteristics of the output medium.

*** page body**. That part of the logical page in which lines can be written and/or spaced.

*** paragraph**. In the Procedure Division, a paragraph-name followed by a separator period and by zero, one, or more sentences. In the IDENTIFICATION and ENVIRONMENT DIVISIONs, a paragraph header followed by zero, one, or more entries.

*** paragraph header**. A reserved word, followed by the separator period, that indicates the beginning of a paragraph in the IDENTIFICATION and ENVIRONMENT DIVISIONs. The permissible paragraph headers in the IDENTIFICATION DIVISION are:

```
PROGRAM-ID. (Program IDENTIFICATION DIVISION)
CLASS-ID. (Class IDENTIFICATION DIVISION)
METHOD-ID. (Method IDENTIFICATION DIVISION)
AUTHOR.
INSTALLATION.
DATE-WRITTEN.
DATE-COMPILED.
SECURITY.
```

The permissible paragraph headers in the ENVIRONMENT DIVISION are:

```
SOURCE-COMPUTER.
OBJECT-COMPUTER.
SPECIAL-NAMES.
REPOSITORY. (Program or Class CONFIGURATION SECTION)
FILE-CONTROL.
I-O-CONTROL.
```

*** paragraph-name**. A user-defined word that identifies and begins a paragraph in the Procedure Division.

parameter. Parameters are used to pass data values between calling and called programs.

password. A unique string of characters that a program, computer operator, or user must supply to meet security requirements before gaining access to data.

*** phrase**. A phrase is an ordered set of one or more consecutive COBOL character-strings that form a portion of a COBOL procedural statement or of a COBOL clause.

*** physical record**. See "block."

pointer data item. A data item in which address values can be stored. Data items are explicitly defined as pointers with the USAGE IS POINTER clause. ADDRESS OF special registers are implicitly defined as pointer data items. Pointer data items can be compared for equality or moved to other pointer data items.

portability. The ability to transfer an application program from one application platform to another with relatively few changes to the source program.

preloaded. In COBOL this refers to COBOL programs that remain resident in storage under IMS instead of being loaded each time they are called.

*** prime record key**. A key whose contents uniquely identify a record within an indexed file.

*** priority-number**. A user-defined word which classifies sections in the Procedure Division for purposes of segmentation. Segment-numbers may contain only the characters '0','1', ... , '9'. A segment-number may be expressed either as a one- or two-digit number.

*** procedure**. A paragraph or group of logically successive paragraphs, or a section or group of logically successive sections, within the Procedure Division.

*** procedure branching statement**. A statement that causes the explicit transfer of control to a statement other than the next executable statement in the sequence in which the statements are written in the source program. The procedure branching statements are: ALTER, CALL, EXIT, EXIT PROGRAM, GO TO, MERGE, (with the OUTPUT PROCEDURE phrase), PERFORM and SORT (with the INPUT PROCEDURE or OUTPUT PROCEDURE phrase).

Procedure Division. One of the four main component parts of a COBOL program, class definition, or method definition. The Procedure Division contains instructions for solving a problem. The Program and Method Procedure Divisions may contain imperative statements, conditional statements, compiler directing statements, paragraphs, procedures, and sections. The Class Procedure Division contains only method definitions.

procedure integration. One of the functions of the COBOL optimizer is to simplify calls to performed procedures or contained programs.

PERFORM procedure integration is the process whereby a PERFORM statement is replaced by its performed procedures. Contained program procedure integration is the process where a CALL to a contained program is replaced by the program code.

*** procedure-name**. A user-defined word that is used to name a paragraph or section in the Procedure Division. It consists of a paragraph-name (which may be qualified) or a section-name.

procedure-pointer data item. A data item in which a pointer to an entry point can be stored. A data item defined with the USAGE IS PROCEDURE-POINTER clause contains the address of a procedure entry point.

*** program identification entry**. An entry in the PROGRAM-ID paragraph of the IDENTIFICATION DIVISION which contains clauses that specify the program-name and assign selected program attributes to the program.

*** program-name**. In the IDENTIFICATION DIVISION and the end program header, a user-defined word that identifies a COBOL source program.

*** pseudo-text**. A sequence of text words, comment lines, or the separator space in a source program or COBOL library bounded by, but not including, pseudo-text delimiters.

*** pseudo-text delimiter**. Two contiguous equal sign characters (==) used to delimit pseudo-text.

*** punctuation character**. A character that belongs to the following set:

Character	Meaning
,	comma
;	semicolon
:	colon
.	period (full stop)
"	quotation mark
(	left parenthesis
)	right parenthesis
b	space
=	equal sign

Q

QSAM (Queued Sequential Access Method). An extended version of the basic sequential access method (BSAM). When this method is used, a queue is formed of input data blocks that are awaiting processing or of output data blocks that have been processed and are awaiting transfer to auxiliary storage or to an output device.

*** qualified data-name**. An identifier that is composed of a data-name followed by one or more sets of either of the connectives OF and IN followed by a data-name qualifier.

*** qualifier**.

1. A data-name or a name associated with a level indicator which is used in a reference either together with another data-name which is the name of an item that is subordinate to the qualifier or together with a condition-name.
2. A section-name that is used in a reference together with a paragraph-name specified in that section.
3. A library-name that is used in a reference together with a text-name associated with that library.

R

*** random access**. An access mode in which the program-specified value of a key data item identifies the logical record that is obtained from, deleted from, or placed into a relative or indexed file.

*** record**. See “logical record.”

*** record area**. A storage area allocated for the purpose of processing the record described in a record description entry in the File Section of the DATA DIVISION. In the File Section, the current number of character positions in the record area is determined by the explicit or implicit RECORD clause.

*** record description**. See “record description entry.”

*** record description entry**. The total set of data description entries associated with a particular record. The term is synonymous with record description.

recording mode. The format of the logical records in a file. Recording mode can be F (fixed-length), V (variable-length), S (spanned), or U (undefined).

record key. A key whose contents identify a record within an indexed file.

*** record-name**. A user-defined word that names a record described in a record description entry in the DATA DIVISION of a COBOL program.

*** record number**. The ordinal number of a record in the file whose organization is sequential.

recursion. A program calling itself or being directly or indirectly called by a one of its called programs.

recursively capable. A program is recursively capable (can be called recursively) if the RECURSIVE attribute is on the PROGRAM-ID statement.

reel. A discrete portion of a storage medium, the dimensions of which are determined by each implementor that contains part of a file, all of a file, or any number of files. The term is synonymous with unit and volume.

reentrant. The attribute of a program or routine that allows more than one user to share a single copy of a load module.

*** reference format**. A format that provides a standard method for describing COBOL source programs.

reference modification. A method of defining a new alphanumeric data item by specifying the leftmost character and length relative to the leftmost character of another alphanumeric data item.

*** reference-modifier**. A syntactically correct combination of character-strings and separators that defines a unique data item. It includes a delimiting left parenthesis separator, the leftmost character position, a colon separator, optionally a length, and a delimiting right parenthesis separator.

*** relation**. See “relational operator” or “relation condition.”

*** relational operator**. A reserved word, a relation character, a group of consecutive reserved words, or a group of consecutive reserved words and relation characters used in the construction of a relation condition. The permissible operators and their meanings are:

Operator	**Meaning**
IS GREATER THAN	Greater than
IS >	Greater than
IS NOT GREATER THAN	Not greater than
IS NOT >	Not greater than
IS LESS THAN	Less than
IS <	Less than
IS NOT LESS THAN	Not less than
IS NOT <	Not less than
IS EQUAL TO	Equal to
IS =	Equal to
IS NOT EQUAL TO	Not equal to
IS NOT =	Not equal to
IS GREATER THAN OR EQUAL TO	Greater than or equal to
IS >=	Greater than or equal to
IS LESS THAN OR EQUAL TO	Less than or equal to
IS <=	Less than or equal to

*** relation character**. A character that belongs to the following set:

Character	**Meaning**
>	greater than
<	less than
=	equal to

*** relation condition**. The proposition, for which a truth value can be determined, that the value of an arithmetic expression, data item, nonnumeric literal, or index-name has a specific relationship to the value of another arithmetic expression, data item, nonnumeric literal, or index name. (See also “relational operator.”)

*** relative file**. A file with relative organization.

*** relative key**. A key whose contents identify a logical record in a relative file.

*** relative organization**. The permanent logical file structure in which each record is uniquely identified by an integer value greater than zero, which specifies the record’s logical ordinal position in the file.

*** relative record number**. The ordinal number of a record in a file whose organization is relative. This number is treated as a numeric literal which is an integer.

* **reserved word**. A COBOL word specified in the list of words that may be used in a COBOL source program, but that must not appear in the program as user-defined words or system-names.

* **resource**. A facility or service, controlled by the operating system, that can be used by an executing program.

* **resultant identifier**. A user-defined data item that is to contain the result of an arithmetic operation.

reusable environment. A reusable environment is when you establish an assembler program as the main program by using either ILBOSTP0 programs, IGZERRE programs, or the RTEREUS run-time option.

routine. A set of statements in a COBOL program that causes the computer to perform an operation or series of related operations. In Language Environment, refers to either a procedure, function, or subroutine.

* **routine-name**. A user-defined word that identifies a procedure written in a language other than COBOL.

* **run time**. The time at which an object program is executed. The term is synonymous with object time.

run-time environment. The environment in which a COBOL program executes.

* **run unit**. A stand-alone object program, or several object programs, that interact via COBOL CALL statements, which function at run time as an entity.

S

SBCS (Single Byte Character Set). See "Single Byte Character Set (SBCS)".

scope terminator. A COBOL reserved word that marks the end of certain Procedure Division statements. It may be either explicit (END-ADD, for example) or implicit (separator period).

* **section**. A set of zero, one or more paragraphs or entities, called a section body, the first of which is preceded by a section header. Each section consists of the section header and the related section body.

* **section header**. A combination of words followed by a separator period that indicates the beginning of a section in the Environment, Data, and Procedure Divisions. In the ENVIRONMENT and DATA DIVISIONs, a section header is composed of reserved words followed by a separator period. The permissible section headers in the ENVIRONMENT DIVISION are:

```
CONFIGURATION SECTION.
INPUT-OUTPUT SECTION.
```

The permissible section headers in the DATA DIVISION are:

```
FILE SECTION.
WORKING-STORAGE SECTION.
LOCAL-STORAGE SECTION.
LINKAGE SECTION.
```

In the Procedure Division, a section header is composed of a section-name, followed by the reserved word SECTION, followed by a separator period.

* **section-name**. A user-defined word that names a section in the Procedure Division.

selection structure. A program processing logic in which one or another series of statements is executed, depending on whether a condition is true or false.

* **sentence**. A sequence of one or more statements, the last of which is terminated by a separator period.

* **separately compiled program**. A program which, together with its contained programs, is compiled separately from all other programs.

* **separator**. A character or two contiguous characters used to delimit character-strings.

* **separator comma**. A comma (,) followed by a space used to delimit character-strings.

* **separator period**. A period (.) followed by a space used to delimit character-strings.

* **separator semicolon**. A semicolon (;) followed by a space used to delimit character-strings.

sequence structure. A program processing logic in which a series of statements is executed in sequential order.

* **sequential access**. An access mode in which logical records are obtained from or placed into a file in a consecutive predecessor-to-successor logical record sequence determined by the order of records in the file.

* **sequential file**. A file with sequential organization.

* **sequential organization**. The permanent logical file structure in which a record is identified by a

predecessor-successor relationship established when the record is placed into the file.

serial search. A search in which the members of a set are consecutively examined, beginning with the first member and ending with the last.

*** 77-level-description-entry**. A data description entry that describes a noncontiguous data item with the level-number 77.

*** sign condition**. The proposition, for which a truth value can be determined, that the algebraic value of a data item or an arithmetic expression is either less than, greater than, or equal to zero.

*** simple condition**. Any single condition chosen from the set:

Relation condition
Class condition
Condition-name condition
Switch-status condition
Sign condition

Single Byte Character Set (SBCS). A set of characters in which each character is represented by a single byte. See also "EBCDIC (Extended Binary-Coded Decimal Interchange Code)."

slack bytes. Bytes inserted between data items or records to ensure correct alignment of some numeric items. Slack bytes contain no meaningful data. In some cases, they are inserted by the compiler; in others, it is the responsibility of the programmer to insert them. The SYNCHRONIZED clause instructs the compiler to insert slack bytes when they are needed for proper alignment. Slack bytes between records are inserted by the programmer.

SOM. *System Object Model*

*** sort file**. A collection of records to be sorted by a SORT statement. The sort file is created and can be used by the sort function only.

*** sort-merge file description entry**. An entry in the File Section of the DATA DIVISION that is composed of the level indicator SD, followed by a file-name, and then followed by a set of file clauses as required.

*** SOURCE-COMPUTER**. The name of an ENVIRONMENT DIVISION paragraph in which the computer environment, within which the source program is compiled, is described.

*** source computer entry**. An entry in the SOURCE-COMPUTER paragraph of the ENVIRONMENT DIVISION which contains clauses that describe the computer environment in which the source program is to be compiled.

*** source item**. An identifier designated by a SOURCE clause that provides the value of a printable item.

source program. Although it is recognized that a source program may be represented by other forms and symbols, in this document it always refers to a syntactically correct set of COBOL statements. A COBOL source program commences with the IDENTIFICATION DIVISION or a COPY statement. A COBOL source program is terminated by the end program header, if specified, or by the absence of additional source program lines.

*** special character**. A character that belongs to the following set:

Character	Meaning
+	plus sign
–	minus sign (hyphen)
*	asterisk
/	slant (virgule, slash)
=	equal sign
$	currency sign
,	comma (decimal point)
;	semicolon
.	period (decimal point, full stop)
"	quotation mark
(	left parenthesis
)	right parenthesis
>	greater than symbol
<	less than symbol
:	colon

*** special-character word**. A reserved word that is an arithmetic operator or a relation character.

SPECIAL-NAMES. The name of an ENVIRONMENT DIVISION paragraph in which environment-names are related to user-specified mnemonic-names.

*** special names entry**. An entry in the SPECIAL-NAMES paragraph of the ENVIRONMENT DIVISION which provides means for specifying the currency sign; choosing the decimal point; specifying symbolic characters; relating implementor-names to user-specified mnemonic-names; relating alphabet-names to character sets or collating sequences; and relating class-names to sets of characters.

*** special registers**. Certain compiler generated storage areas whose primary use is to store information produced in conjunction with the use of a specific COBOL feature.

*** standard data format**. The concept used in describing the characteristics of data in a COBOL DATA DIVISION under which the characteristics or properties of the data are expressed in a form oriented to the appearance of the data on a printed page of infinite length and breadth, rather than a form oriented to the manner in which the data is stored internally in the computer, or on a particular external medium.

*** statement**. A syntactically valid combination of words, literals, and separators, beginning with a verb, written in a COBOL source program.

STL File System. STandard Language File System: native workstation and PC file system for COBOL and PL/I. Supports sequential, relative, and indexed files, including the full ANSI 85 COBOL standard I/O language and all of the extensions described in *IBM COBOL Language Reference*, unless exceptions are explicitly noted.

structured programming. A technique for organizing and coding a computer program in which the program comprises a hierarchy of segments, each segment having a single entry point and a single exit point. Control is passed downward through the structure without unconditional branches to higher levels of the hierarchy.

*** sub-class**. A class that inherits from another class. When two classes in an inheritance relationship are considered together, the sub-class is the inheritor or inheriting class; the *super-class* is the inheritee or inherited class.

*** subject of entry**. An operand or reserved word that appears immediately following the level indicator or the level-number in a DATA DIVISION entry.

*** subprogram**. See "called program."

*** subscript**. An occurrence number represented by either an integer, a data-name optionally followed by an integer with the operator + or -, or an index-name optionally followed by an integer with the operator + or -, that identifies a particular element in a table. A subscript may be the word ALL when the subscripted identifier is used as a function argument for a function allowing a variable number of arguments.

*** subscripted data-name**. An identifier that is composed of a data-name followed by one or more subscripts enclosed in parentheses.

*** super-class**. A class that is inherited by another class. See also *sub-class*.

switch-status condition. The proposition, for which a truth value can be determined, that an UPSI switch, capable of being set to an 'on' or 'off' status, has been set to a specific status.

*** symbolic-character**. A user-defined word that specifies a user-defined figurative constant.

syntax. (1) The relationship among characters or groups of characters, independent of their meanings or the manner of their interpretation and use. (2) The structure of expressions in a language. (3) The rules governing the structure of a language. (4) The relationship among symbols. (5) The rules for the construction of a statement.

*** system-name**. A COBOL word that is used to communicate with the operating environment.

System Object Model (SOM). IBM's object-oriented programming technology for building, packaging, and manipulating class libraries. SOM conforms to the Object Management Group's (OMG) Common Object Request Broker Architecture (CORBA) standards.

T

*** table**. A set of logically consecutive items of data that are defined in the DATA DIVISION by means of the OCCURS clause.

*** table element**. A data item that belongs to the set of repeated items comprising a table.

text deck. Synonym for *object deck* or *object module*.

*** text-name**. A user-defined word that identifies library text.

*** text word**. A character or a sequence of contiguous characters between margin A and margin R in a COBOL library, source program, or in pseudo-text which is:

- A separator, except for: space; a pseudo-text delimiter; and the opening and closing delimiters for non-numeric literals. The right parenthesis and left parenthesis characters, regardless of context within

the library, source program, or pseudo-text, are always considered text words.

- A literal including, in the case of nonnumeric literals, the opening quotation mark and the closing quotation mark that bound the literal.
- Any other sequence of contiguous COBOL characters except comment lines and the word 'COPY' bounded by separators that are neither a separator nor a literal.

top-down design. The design of a computer program using a hierarchic structure in which related functions are performed at each level of the structure.

top-down development. See "structured programming."

trailer-label. (1) A file or data set label that follows the data records on a unit of recording medium. (2) Synonym for end-of-file label.

*** truth value**. The representation of the result of the evaluation of a condition in terms of one of two values: true or false.

U

*** unary operator**. A plus (+) or a minus (-) sign, that precedes a variable or a left parenthesis in an arithmetic expression and that has the effect of multiplying the expression by +1 or -1, respectively.

unit. A module of direct access, the dimensions of which are determined by IBM.

universal object reference. A data-name that can refer to an object of any class.

*** unsuccessful execution**. The attempted execution of a statement that does not result in the execution of all the operations specified by that statement. The unsuccessful execution of a statement does not affect any data referenced by that statement, but may affect status indicators.

UPSI switch. A program switch that performs the functions of a hardware switch. Eight are provided: UPSI-0 through UPSI-7.

*** user-defined word**. A COBOL word that must be supplied by the user to satisfy the format of a clause or statement.

V

*** variable**. A data item whose value may be changed by execution of the object program. A variable used in an arithmetic expression must be a numeric elementary item.

*** variable length record**. A record associated with a file whose file description or sort-merge description entry permits records to contain a varying number of character positions.

*** variable occurrence data item**. A variable occurrence data item is a table element which is repeated a variable number of times. Such an item must contain an OCCURS DEPENDING ON clause in its data description entry, or be subordinate to such an item.

*** variably located group.**. A group item following, and not subordinate to, a variable-length table in the same level-01 record.

*** variably located item.**. A data item following, and not subordinate to, a variable-length table in the same level-01 record.

*** verb**. A word that expresses an action to be taken by a COBOL compiler or object program.

VM/SP (Virtual Machine/System Product). An IBM-licensed program that manages the resources of a single computer so that multiple computing systems appear to exist. Each virtual machine is the functional equivalent of a "real" machine.

volume. A module of external storage. For tape devices it is a reel; for direct-access devices it is a unit.

volume switch procedures. System specific procedures executed automatically when the end of a unit or reel has been reached before end-of-file has been reached.

VSAM/2. A file system that supports COBOL sequential, relative, and indexed organizations. This file system is available as part of IBM VisualAge for COBOL for OS/2.

W

*** word**. A character-string of not more than 30 characters which forms a user-defined word, a system-name, a reserved word, or a function-name.

*** WORKING-STORAGE SECTION**. The section of the DATA DIVISION that describes working storage data items, composed either of noncontiguous items or working storage records or of both.

Z

zoned decimal item. See “external decimal item.”

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