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CONTROL DATA CORPORATION

FORTRAN EXTENDED VERSION 4 USER'S GUIDE

CDC® OPERATING SYSTEMS:
NOS 1
NOS/BE 1
SCOPE 2

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PREFACE

This user's guide provides helpful information for the user of CDC FORTRAN Extended. FORTRAN Extended is supported by the following operating systems:

NOS 1 for the CONTROL DATA® CYBER 170 Models 171, 172, 173, 174, 175; CYBER 70 Models 71, 72, 73, 74; and 6000 Series Computer Systems

NOS/BE 1 for the CDC® CYBER 170 Series; CYBER 70 Models 71, 72, 73, 74; and 6000 Series Computer Systems

SCOPE 2 for the CONTROL DATA CYBER 170 Model 176, CYBER 70 Model 76, and 7600 Computer Systems

This user's guide is written primarily for the FORTRAN programmer who is unfamiliar with CDC operating systems. It is a supplement to the FORTRAN Extended Version 4 Reference Manual, with minimal duplication of information. This guide concentrates on the interfaces between FORTRAN Extended and other software products, as well as on programming, debugging, and optimization techniques of particular interest to the FORTRAN Extended programmer.

Some topics of interest to the FORTRAN Extended programmer are discussed in other user's guides. These include the following:

- Interactive program creation and execution. For NOS/BE, this topic is covered in the INTERCOM Guide for FORTRAN Extended Users. For NOS users, parallel material is included in the NOS Time-Sharing User's Guide and the NOS Text Editor Reference Manual.
- Input/output implementation. This topic, with particular emphasis on the advanced input/output capabilities available through the CYBER Record Manager interface routines, is covered in the CYBER Record Manager Version 1 Guide for Users of FORTRAN Extended Version 4. SCOPE 2 users can find parallel information in the SCOPE 2 User's Guide.
- Debugging facility. The C$ DEBUG capability included with the FORTRAN Extended compiler is described in the FORTRAN Extended DEBUG User's Guide.

In addition, user's guides exist for SCOPE 2 and NOS/BE; these guides are recommended for programmers new to these systems.

Publication	Publication Number
NOS 1 Operating System Reference Manual, Volume 1	60435300
NOS/BE 1 Operating System Reference Manual	60493800
SCOPE 2 Reference Manual	60342600
NOS/BE 1 User's Guide	60494000
SCOPE 2 User's Guide	60372600
FORTRAN Extended Version 4 Reference Manual	60497800
CYBER Loader Version 1 Reference Manual	60429800
SCOPE 2 Loader Reference Manual	60454780
FORTRAN Extended DEBUG User's Guide	60498000
INTERCOM Interactive Guide for Users of FORTRAN Extended	60495000
CYBER Record Manager Version 1 Guide for Users of FORTRAN Extended Version 4	60495900
FORTRAN Common Library Mathematical Routines	60498200
UPDATE Reference Manual	60449900
CYBER Common Utilities Reference Manual	60495600

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PROGRAMMING TECHNIQUES 1

This section outlines some procedures designed to simplify and safeguard the production of FORTRAN Extended programs, as well as some techniques to improve their accuracy. Although the process of programming is essentially the same, regardless of the language in which the program is written, FORTRAN presents specific difficulties and specific opportunities.

TOP-DOWN PROGRAMMING

In recent years, the attempt to reduce the cost of computer systems has focused increasingly on the cost of software development and maintenance. The consensus is that these processes should be better controlled and more standardized than they have been in the past. The following criteria are those generally agreed upon for software, regardless of its function:

- It should be reliable. This requires extensive (and well planned) testing before the software is used for its intended purpose.
- It should be easy to read. This simplifies the process of maintenance, which is frequently done by different people than those who originally developed the software. This goal is achieved by avoiding convoluted algorithms and implementation-dependent tricks, and by providing ample and useful documentation. Very large programs usually require external documentation, in addition to the comments in the code itself.
- It should be modular. This is partly for the purpose of increased readability, and partly so that useful modules can be written once, to be used by many programs.

Several principal methods have been developed to achieve these goals. The method that has attracted the most interest, and that is advocated here, is top-down programming. This is more than just the advice to design first and code later, which has always been followed by good programmers. The key component of top-down programming is the formalization of the successive steps between the original requirements of an application and the final coded version of the program. The idea is to hold in check the tendency, when beginning to write a program, to write FORTRAN statements immediately. In top-down programming, FORTRAN is not used until the very last step – earlier steps are written in English or in a more informal pseudo-FORTRAN. (It is important to note that all steps must actually be written, or the purpose of top-down programming is defeated.)

Another important component of top-down programming is modularity. Modularity means limiting the size of program units, and ensuring that each performs a well-defined function. A good rule of thumb is that each program unit should be about one page long. This ensures that the purpose and logic of each module are readily comprehensible. When the purpose of each module is well-defined, it is frequently possible to use the same subprogram in more than one program (as explained under User Libraries, in section 6). The division of a program into modules should not be arbitrary, but should follow as much as possible the separation of functions between program units.

Nevertheless, the advantages of modularity must be weighed against their effect on optimization (see section 2). Subprogram calls are more expensive to execute than simple branches. Therefore, they should be kept to a minimum in frequently-executed loops. In any particular application, a balance must be struck between the decreased programmer time brought about by modularity, and the decreased execution time brought about by limiting subprogram calls.

The number of steps between problem definition and final coding depends on the size and complexity of the application, but at least four steps are always necessary. These steps can be summarized as follows:

1. The problem to be solved is defined as precisely as possible (in English).
2. An algorithm covering only major steps of the program is written, in English and, where appropriate, in mathematical notation. The major modules of the program are also defined.
3. For each module defined in step 2, the algorithm is broken down into lower level steps, written in a higher-level language than FORTRAN. This step is repeated until the program is in a form of pseudo-FORTRAN.
4. The program is coded in FORTRAN. If step 3 was done properly, this process can take place practically line-by-line.

To illustrate this procedure, we will follow the various steps for a simple example. The example is not ideal; because it is so small, it uses no subprograms, and therefore does not illustrate the development of separate modules. The example is program NEWTON, which is explained more fully, with input and output, in section 2.

The origin of the program is an application that needs to find the roots of a polynomial equation (presumably part of a larger application). After considering various methods, the programmer decides on Newton's method. The stages of program development are then written down as shown in figure 1-1.

Step 1 defines the problem as precisely as possible. In this case, the reader of the description is assumed to be familiar with Newton's method, so little description is necessary.

Step 2 presents the algorithm to be used. At this stage, the order in which major steps are to be executed is determined. In order to describe the algorithm, some of the data structures to be used might be defined. In a program longer than NEWTON, the algorithm would probably not be detailed enough to include any mathematical formulas.

In step 3, the algorithm is made more detailed and, for the first time, the program logic is defined. The language used in this step is very casual; it is a mixture of ALGOL, English, and FORTRAN. A more standardized language could be developed; the main point is to defer actual FORTRAN statements as long as possible. By the last iteration of step 3, each module should be written in a sort of pseudo-FORTRAN, with the statements appearing in their final order. Non-executable statements are generally omitted in step 3, as are most statement labels. Input/-output statements are only sketched in.

Step 1. Problem definition. Find the roots of a given equation using Newton's method.

Step 2. Algorithm specification

Given:

F(x)	The function
F'(x)	Its derivative
X_0	An initial approximation
e	The convergence criterion
max	Maximum number of iterations (in case of failure of convergence).

Algorithm:

Repeat the following until $|x_i - x_{i+1}| < e$ or until number of iterations= max:

$$x_{i+1} = x_i - \frac{f(x_i)}{f'(x_i)}$$

Step 3. Pseudo-FORTRAN

Given:

F	The name of the function whose roots are to be found; the text of the function to be provided in a manner to be determined in step 4.
DERIV	The name of a function that is the derivative of F; to be provided in the same manner as F.

Input values:

X0	Initial approximation to f(x) = 0
EPS	Convergence criterion
ITMAX	Maximum number of iterations

Algorithm:

```
Read X0, EPS, ITMAX
Do for I = 1 to ITMAX:
    X1 = X0 - F(X0)/DERIV(X0)
    If abs(X1 - X0) ≤ EPS go to Label1
    X0 = X1
End loop
Write "method has not converged in" I "iterations"
Stop
Label1  Write "method has converged in" I "iterations"
Write X0
Stop
```

Figure 1-1. Top-Down Programming Example (Sheet 1 of 2)

Step 4. Completed Program:

```
      PROGRAM NEWTON (INPUT, OUTPUT, TAPE5=OUTPUT)
C
C     PROGRAM *NEWTON* FINDS THE ROOTS OF THE EQUATION DEFINED IN THE
C     FUNCTION STATEMENT BY NEWTON*S METHOD. THE FOLLOWING VALUES ARE
C     INPUT
C
C          X0      INITIAL APPROXIMATION
C          EPS     CONVERGENCE CRITERION
C          ITMAX   MAXIMUM NUMBER OF ITERATIONS
C
C     EQUATION TO BE SOLVED
C
      F(X) = SIN(X) - (X+1.0)/(X-1.0)
C
C     DERIVATIVE OF EQUATION
C
      DERIV(X) = COS(X) + 2.0/(X-1.0)**2
C
      READ *, X0, EPS, ITMAX
      IF (DERIV(X0) .EQ. 0.0) GO TO 300
        DO 100 I=1,ITMAX
        ITS = I
        X1 = X0 - F(X0)/DERIV(X0)
        Y = F(X1)
        PRINT *, *X,Y *, X0, Y
        IF (ABS(X1 - X0) .LE. EPS) GO TO 200
        X0 = X1
  100   CONTINUE
      WRITE (5,20) ITMAX
      STOP
  200 WRITE (5,10) ITS, X0
      STOP
  300 WRITE (5,30) X0
      STOP
   10 FORMAT (* METHOD HAS CONVERGED IN *,I3,* ITERATIONS*,//* X = *,
     1E12.4)
   20 FORMAT (*   METHOD HAS NOT CONVERGED IN *,I3 ,* ITERATIONS*//
     1,* EXECUTION TERMINATED*)
   30 FORMAT (1X,E12.4, * IS INVALID VALUE FOR X0*)
      END
```

Figure 1-1. Top-Down Programming Example (Sheet 2 of 2)

Step 4 expands the version in step 3 into an actual FORTRAN program. This step requires a number of minor decisions, such as the types of variables, the sizes of arrays, the formats to be used for input/output, and the exact text of messages to be printed. The PROGRAM statement, non-executable statements, and statement labels are all added at this time, as well as extensive comments. In many cases, the text of the comments can be taken verbatim from earlier stages of program preparation.

CODING STYLE

Top-down programming deals with the overall process of preparing a program. In addition, it has been found to be helpful for an installation to prepare standards dealing with the physical appearance of programs. FORTRAN allows a relatively free format of the text of a program. This feature allows a uniform appearance among all the programs prepared at an installation. This is time-saving and convenient for the programmers, and can also serve to reenforce the principles of top-down programming. The following set of rules is one possibility for coding standards:

1. Begin each program unit with a comment block, immediately after the header line. The block should briefly state the purpose (and possibly the algorithm) of the program. In a subprogram, each of the formal parameters should be identified.

2. Additional comments should be interspersed throughout the program. Comments are especially desirable before each major step of the program. If a label occurs a long distance from the statements branching to it, a comment just before the label should explain how it is reached. Comments should also appear whenever the program does something devious, or non-obvious. Each comment should be preceded and followed by a line containing only a C in column 1. Code should be written in the form of paragraphs, with a comment preceding each paragraph.

3. Multiple statements per line (separated by the $ character) should not be used.

4. When continuation lines are necessary, the character in column 6 should be one that cannot be mistaken for part of the statement. The $ character can always be used for this purpose. For a very long statement, it may be useful to put numbers in column 6 to keep the cards in sequence (remember that 0 is not permitted). Continuation lines should be indented (they should start in column 8 or later).

5. The body of a DO loop should be indented by at least two spaces. If loops are nested, each inner loop should be indented from its outer loop. DO loops should always terminate with a CONTINUE statement.

6. Blanks should be used copiously to set off the components of a statement. Blanks should especially be used in the following contexts:

   Surrounding parentheses

   Surrounding the + or - operator

   Between the keyword of a statement and the rest of the statement

   Surrounding the = character in an assignment statement

   Between elements of a list in a specification statement

   Blanks should be omitted in the following contexts:

   On either side of the * / or ** operator (this sets off the components of an expression)

   Inside parentheses in an array subscript or subprogram reference

   After the control variable and index parameters in a DO statement (DO 100 I=1,50,2)

7. The labels in a program should be in numerical order. The FORMAT statements should be grouped together just before the END statement. The labels should be consistent in size (such as 3-digit labels for executable statements, and 1-digit labels for FORMAT statements).

Figure 1-2 shows a program unit before and after these standards are applied.

Before:

```
      PROGRAMNADA(INPUT,OUTPUT,TAPE5=INPUT)
      DIMENSIONB(10,10)
      COMMON/XYZ/C(10,10)
C     CONTROLLING ROUTINE FOR THE PROGRAM
      READ(5,2)I,J,K
2     FORMAT(2X3I4)
      IF(EOF(5))100,200
100   DO300M=1,I
300   B(J,M)=C(M,K)**2+I*K
      CALLWHATSIS(B,C,M)
      STOP
200   STOP
      END
```

After:

```
      PROGRAM NADA (INPUT, OUTPUT, TAPE5=INPUT)
C
C
C     PROGRAM NADA COMPUTES THE LOWEST VALUE OF N (GREATER THAN
C     2) FOR WHICH X**N + Y**N = Z**N. MOST OF THE WORK IS DONE
C     IN THE SUBPROGRAM WHATSIS; THE MAIN PROGRAM PERFORMS HOUSE-
C     KEEPING CHORES.
C
C
C     AUTHOR:   A. ALLIVER,  CDC 1977
C
C
      DIMENSION B(10,10)
      COMMON /XYZ/ C(10,10).
      READ (5,2) I, J, K
      IF (EOF(5).NE.0.0) STOP
        DO 100 M=1,I
        B(J,M) = C(M,K)**2 + I*K
  100   CONTINUE
      CALL WHATSIS (B, C, M)
      STOP
    2 FORMAT (2X, 3I4)
      END
```

Figure 1-2. Coding Style Example

The programs in this section are intended to illustrate the programming practices discussed in section 1 through application of some commonly used mathematical procedures and basic algorithms. The programs are typical of smaller special-purpose FORTRAN programs, rather than larger, more complex applications.

ACCTAB

Program ACCTAB (figure 2-1) computes acceleration as a function of mass and force. It reads two sets of data cards. The first set is read in line 9 and contains three numbers per card, representing time, force and mass. These values are used to generate a table of time versus acceleration. Acceleration is calculated in line 15 by the statement:

ACC (N) = F/AMASS

where ACC(N) is acceleration, F is force, and AMASS is mass. The variable AMASS is tested for a zero or negative value. The counter N is incremented each time a card is read. If N exceeds the maximum allowable table size, a message is printed and execution terminates. The variable NTIMES contains the total number of time values in the table. When the first set of cards has been read, the table is printed.

The program then reads the second set of cards, which contains selected time values, one per card. A table search is performed for the time values immediately above and below the input value. In lines 30 and 31, each time value is tested for validity. If a time is outside the table bounds, a message is printed and the next card is read. In lines 46 through 55, a second degree interpolation is performed for the acceleration value. This is accomplished by the formula:

$$ACCX = \frac{(T-T1)(T-T2)A0}{(T0-T1)(T0-T2)} - \frac{(T-T0)(T-T2)A1}{(T1-T0)(T1-T2)} + \frac{(T-T0)(T-T1)A2}{(T2-T0)(T2-T1)}$$

where T is the input time, A0, A1, and A2 are tabular acceleration values corresponding to the time points T0, T1, and T2, and $T0 < T \leq T1$. A diagram of interpolation is shown in figure 2-2.

Since, for a given input time, two tabular points beyond that time are required for interpolation, special processing is included in lines 31 through 33 for times falling between TIME(N-1) and TIME(N), where TIME(N) is the last point in the table. After the interpolation has been performed, time and acceleration are printed, the next card is read, and so on, until all input times have been processed. A sample input deck is shown in figure 2-3; the output is shown in figure 2-4.

Statements in the program test for table overflow (line 12), for an invalid value for AMASS (line 13), and for a zero divisor in the formula (line 49). The development of this program is explained in section 4.

NEWTON

Program NEWTON (figure 2-5) finds the roots of a polynomial equation by Newton's method. The iterative formula

$$x_{i+1} = x_i - f(x_i)/f'(x_i)$$

is applied to generate successive approximations to the equation $f(x) = 0$, where x_i is the current approximation, x_{i+1} is the new approximation, and $f'(x)$ represents the derivative of $f(x)$. The test for convergence is:

$$|x_i - x_{i-1}| < eps$$

where eps is a constant indicating the desired degree of accuracy.

In the example, the equation to be solved and its derivative are

$$f(x) = \sin(x) - (x+1)/(x-1)$$
$$f'(x) = \cos(x) + 2/(x-1)^2$$

The equation and its derivative are provided in the form of statement functions (lines 13 and 17); these can be easily replaced to apply the procedure to other functions. A data card is read containing the following information:

X0	Initial approximation to f(x) = 0 (real)
EPS	Convergence criterion (real)
ITMAX	Maximum number of iterations (integer); ensures that the program terminates even when the function fails to converge.

The DO-loop applies the iteration formula to calculate a new approximation X1 (line 23) and tests for convergence (line 26). If convergence has not occurred, the new approximation X1 becomes the current approximation X0 and the iteration is continued until either the process converges or the maximum number of iterations is reached. In either case, an appropriate message is printed and processing terminates. Sample input for the program is shown in figure 2-6, and the output generated from that input is shown in figure 2-7.

Line 20 tests for a zero value for the derivative; otherwise the division in line 23 produces an infinite value and the program aborts.

GAUSS

Program GAUSS (figure 2-8) solves a linear system of N equations in N unknowns by the Gauss-Seidel method. The system is of the form:

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n$$

```
      PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
C
      DIMENSION TIME(10), ACC(10)
C
C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
C
      N = 0
      IER = 0
  100 READ (4,*) T, AMASS, F
      IF (EOF(4) .NE. 0) GO TO 150
      N = N + 1
      IF (N .GT. 10 ) GO TO 600
      IF (AMASS .LE. 0.) GO TO 700
      TIME(N) = T
      ACC(N) = F/AMASS
      GO TO 100
C
C....PRINT ACCELERATION TABLE
C
  150 NTIMES = N
      PRINT 10
      PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
      IF (IER .NE. 0) GO TO 900
C
C....READ A CARD CONTAINING A TIME VALUE
C
  190 READ (4,*) T
      IF (EOF(4) .NE. 0) GO TO 900
      N = N + 1
      IF (T .LT. TIME(1) .OR. T .GT. TIME(NTIMES)) GO TO 800
      IF (T .LE. TIME(NTIMES-1)) GO TO 195
      IT = NTIMES - 1
      GO TO 220
C
C....SEARCH ACCELERATION TABLE
C
  195 LIM = NTIMES - 1
        DO 200 I = 2,LIM
        IT = I
        IF (T .LE. TIME(IT)) GO TO 220
  200   CONTINUE
      GO TO 950
C
C....DO SECOND DEGREE INTERPOLATION
C
  220 D1 = TIME(IT-1) - TIME(IT)
      D2 = TIME(IT-1) - TIME(IT+1)
      D3 = TIME(IT) - TIME(IT+1)
      IF (D1 .EQ. 0. .OR. D2 .EQ. 0. .OR. D3 .EQ. 0.) GO TO 850
      Q1 = T - TIME(IT-1)
      Q2 = T - TIME(IT)
      Q3 = T - TIME(IT+1)
      ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
     1 - Q1*Q3*ACC(IT)/(D1*D3)
     2 + Q1*Q2*ACC(IT+1)/(D2*D3)
      PRINT 25, T, ACCX
      GO TO 190
C
  600 PRINT *, '* TOO MUCH DATA. MAX NO. OF TIMES IS 10*'
      STOP
  700 PRINT *, '*INVALID VALUE FOR AMASS *', N
      IER = 1
      GO TO 100
  800 PRINT *, '* BAD TIME, VALUE IS*', T
      GO TO 190
  850 PRINT *, '* INTERPOLATION PROBLEMS, TABLE ERROR*'
      GO TO 190
  900 PRINT *, '* END ACCTAB*'
      STOP
C
   10 FORMAT ('1*',2('*        TIME     ACCEL*'))
   15 FORMAT (2(5XF7.2,2XF8.5))
   25 FORMAT ('* TIME = *',F7.2,'* ACCELERATION = *',F8.5)
      END
```

Figure 2-1. Program ACCTAB

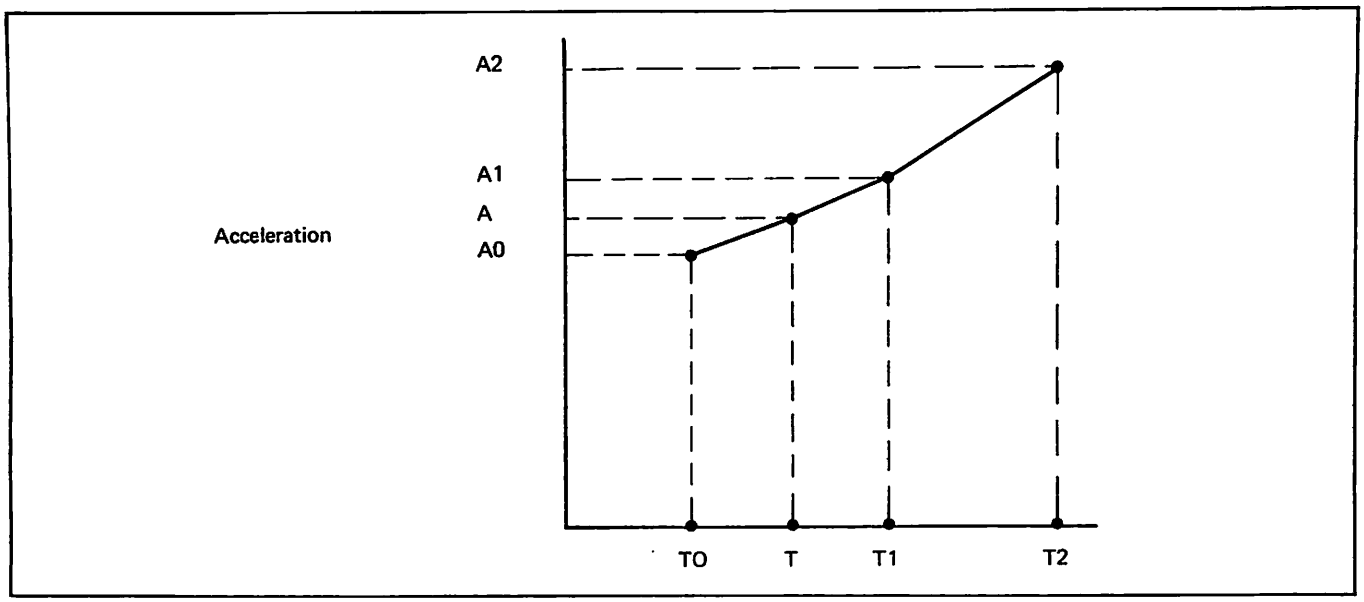


Figure 2-2. Second Degree Interpolation

```
(Time       Mass       Force)
0.          100.       1000.
1.          100.       1010.
2.          100.       1020.
3.          100.       1030.
4.          100.       1040.
5.          100.       1050.
7/8/9
0.
0.5                    (Selected Times)
3.6
4.9
6.0
6/7/8/9
```

Figure 2-3. Sample Input Deck

This can be rewritten as:

$$x_1 = -(a_{12}x_2 + a_{13}x_3 + \ldots + a_{1n}x_n)/a_{11}$$

$$x_2 = -(a_{21}x_1 + a_{23}x_3 + \ldots + a_{2n}x_n)/a_{22}$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$x_n = -(a_{n1}x_1 + a_{n2}x_2 + \ldots + a_{n,n-1}x_{n-1})/a_{nn}$$

Successive approximations are generated by applying the iteration

$$x_i^{(k+1)} = \sum_{j=1}^{i-1} b_{ij}x_j^{(k+1)} + \sum_{j=i}^{n} b_{ij}x_j^{(k)} + c_i$$

where:

$$b_{ij} = -a_{ij}/a_{ii} \text{ (for } i=1,n;\ j=1,n)$$

$$b_{ij} = 0 \text{ (for } i = j)$$

$$c_i = b_i/a_{ii} \text{ (for } i=1,n)$$

```
        TIME      ACCEL          TIME      ACCEL
        0.00   10.00000          1.00   10.10000
        2.00   10.20000          3.00   10.30000
        4.00   10.40000          5.00   10.50000
TIME =     0.00 ACCELERATION = 10.00000
TIME =      .50 ACCELERATION = 10.05000
TIME =     3.60 ACCELERATION = 10.36000
TIME =     4.90 ACCELERATION = 10.49000
 BAD TIME, VALUE IS6.
 END ACCTAB
```

Figure 2-4. ACCTAB Output

and the notation $x_i^{(k)}$ indicates the (k+i)st iteration of the solution vector for $x_1, x_2, \ldots, x_n$.

The algorithm begins with an initial guess at the value of the solution vector X(0) (X(0)= $(x_1(0), x_2(0), \ldots, x_n(0))$ and substitutes that vector into the right hand side of the relation to generate a vector X(1), which should be a better approximation to the solution. It then substitutes X(1) into the equation to yield X(2). Continuing in this manner, it generates successive approximations until it achieves the desired degree of accuracy. The criterion for convergence is

$$\max_{1 \le I \le n} \frac{|x_i^{(k+1)} - x_i^{(k)}|}{|x_i^{(k+1)}|} < E$$

for a prescribed E. In others words, when the difference between successive values of x_i is sufficiently small, the process is considered to have converged. If this criterion is not satisfied after a prescribed number of iterations, the process is assumed not to converge and the iteration is discontinued.

Input to the program is from data cards. Sample input is shown in figure 2-9. The first card specifies the number of equations and unknowns (N), the maximum number of iterations (MAXIT), and the convergence criterion (EPS). Succeeding cards specify the elements of the coefficient

```
      PROGRAM NEWTON (INPUT, OUTPUT, TAPE5=OUTPUT)
C
C     PROGRAM *NEWTON* FINDS THE ROOTS OF THE EQUATION DEFINED IN THE
C     FUNCTION STATEMENT BY NEWTON*S METHOD. THE FOLLOWING VALUES ARE
C     INPUT
C
C          X0:     INITIAL APPROXIMATION
C          EPS     CONVERGENCE CRITERION
C          ITMAX   MAXIMUM NUMBER OF ITERATIONS
C
C     EQUATION TO BE SOLVED
C
      F(X) = SIN(X) - (X+1.0)/(X-1.0)
C
C     DERIVATIVE OF EQUATION
C
      DERIV(X) = COS(X) + 2.0/(X-1.0)**2
C
      READ *, X0, EPS, ITMAX
      IF (DERIV(X0) .EQ. 0.0) GO TO 300
        DO 100 I=1,ITMAX
        ITS = I
        X1 = X0 - F(X0)/DERIV(X0)
        Y = F(X1)
        PRINT *, *X,Y *, X0, Y
        IF (ABS(X1 - X0) .LE. EPS) GO TO 200
        X0 = X1
  100   CONTINUE
      WRITE (5,20) ITMAX
      STOP
  200 WRITE (5,10) ITS, X0
      STOP
  300 WRITE (5,30) X0
      STOP
   10 FORMAT (* METHOD HAS CONVERGED IN *,I3,* ITERATIONS*,//* X = *,
     1E12.4)
   20 FORMAT (*   METHOD HAS NOT CONVERGED IN *,I3 ,* ITERATIONS*//
     1,* EXECUTION TERMINATED*)
   30 FORMAT (1X,E12.4, * IS INVALID VALUE FOR X0*)
      END
```

Figure 2-5. Program NEWTON

```
0.0 .0001 10
```

Figure 2-6. Input to NEWTON

matrix: each card contains the value of the element and two integers indicating the position of the element within the matrix. Zero elements need not be included.

The program begins by reading the input deck and scanning for errors (lines 42-48). If an error is encountered, the card number is printed along with an appropriate message and processing terminates after the entire deck is scanned.

Once the matrix has been read and stored in array A, the program applies the Gauss-Seidel scheme to generate the solution values. The solution values are stored in array X. An initial approximation for each value of X is required to initiate the process. For the sake of simplicity, the values of X are initially set to 0.

Three nested DO-loops control the iterative process (lines 56-72). Each pass through the outer loop constitutes

```
X,Y 0. .1728053032038
X,Y -.3333333333333 .0157649945177376
X,Y -.4168158924S1 .00001133754253679
X,Y -.4203564535842 3.197797582288E-11
METHOD HAS CONVERGED IN   4 ITERATIONS

X =   -.4204E+00
```

Figure 2-7. Output from NEWTON

one iteration. The variable MAXIT is used as the upper limit, allowing the process to terminate if convergence does not occur within the specified number of iterations. Each pass through the middle loop yields a new approximation XNEW for a particular element of the solution vector. The inner loop sums the rows of the matrix.

The variable CNV is initially set to 0. After an approximation to a particular x has been calculated, CNV is set to the difference between the new approximation and the previous approximation, if the difference is greater than the current contents of CNV. Thus, CNV always contains the maximum of the differences between the new and previous values of the solution vector.

```
      PROGRAM GAUSS (INPUT,OUTPUT,TAPE4=INPUT,TAPE5=OUTPUT)
C
C     PROGRAM *GAUSS* SOLVES A LINEAR SYSTEM OF N EQUATIONS IN N
C     UNKNOWNS BY THE GAUSS-SEIDEL METHOD.  INPUT IS FROM CARDS.
C     THE FIRST CARD CONTAINS THE
C     VALUES
C
C              N       NUMBER OF EQUATIONS AND UNKNOWNS
C              MAXIT   MAXIMUM NUMBER OF ITERATIONS
C              EPS     CONVERGENCE CRITERION
C
C     SUCCEEDING CARDS CONTAIN ELEMENTS OF THE COEFFICIENT
C     MATRIX. EACH CARD CONTAINS THE FOLLOWING VALUES
C
C              I       ROW POSITION OF ELEMENT (INTEGER)
C              J       COLUMN POSITION OF ELEMENT (INTEGER)
C              ELEMNT  VALUE OF COEFFICIENT (FLOATING POINT)
C
C     ZERO COEFFICIENTS NEED NOT BE INCLUDED. THE INPUT DECK IS
C     SCANNED FOR ERRORS.
C     AFTER A IS READ, THE NEXT N CARDS CONTAIN VALUES FOR B.
C
      DIMENSION A(50,51), X(50)
C
C     INITIALIZE WORKING ARRAYS
C
      NCARD = 1
      IERR = 0
        DO 150 I=1,50
        X(I) = 0.0
          DO 100 J=1,50
          A(I,J) = 0.0
  100     CONTINUE
  150   CONTINUE
C
C     READ FIRST CARD CONTAINING PARAMETER VALUES FOLLOWED
C     BY CARDS CONTAINING COEFFICIENTS
C
      READ (4,*) N, MAXIT, EPS
      IF (EOF(4) .NE. 0.0) GO TO 900
      IF (N .GT. 50) GO TO 910
  200 READ (4,*) I, J, ELEMNT
      IF (EOF(4)) 380, 350
  350 NCARD = NCARD + 1
      IF (I .LT. 1 .OR. I .GT. N) GO TO 360
      IF (J .LT. 1 .OR. J .GT. N+1) GO TO 360
      A(I,J) = ELEMNT
      GO TO 200
  360 IERR = 1
      PRINT *, *ERROR ON CARD *, NCARD
      GO TO 200
  380 IF (IERR .NE. 0) GO TO 650
C
C     BEGIN ITERATION
C
        DO 600 ITS=1,MAXIT
        CNV = 0.0
          DO 500 I=1,N
          SUM = 0.0
            DO 400 J=1,N
            IF (J .NE. I) SUM = SUM + A(I,J)*X(J)
  400       CONTINUE
          XNEW = (A(I,N+1) - SUM)/A(I,I)
          TEMP = ABS(X(I) - XNEW)/XNEW
          CNV = AMAX1 (CNV,TEMP)
          X(I) = XNEW
  500     CONTINUE
C
C     TEST FOR CONVERGENCE
```

Figure 2-8. Program GAUSS (Sheet 1 of 2)

```
      C
            IF (CNV .LE. EPS) GO TO 700
          500  CONTINUE
               PRINT *, ≠PROCESS HAS NOT CONVERGED IN ≠,MAXIT,≠ ITERATIONS≠
          650  PRINT *, ≠EXECUTION TERMINATED≠
               STOP
          700  PRINT *, ≠PROCESS HAS CONVERGED IN ≠,ITS,≠ ITERATIONS≠
               PRINT *, ≠SOLUTION VALUES ARE≠
               PRINT 30, (X(I),I=1,N)
           30  FORMAT (1X,8E12.4)
               STOP
          900  PRINT *, ≠INSUFFICIENT INPUT DATA, CANNOT CONTINUE≠
               STOP
          910  PRINT *, ≠N = ≠,N,≠ IS TOO LARGE; MUST BE .LE. 50≠
               STOP
               END
```

Figure 2-8. Program GAUSS (Sheet 2 of 2)

```
3 50 .0001
1 1 10.
1 2 1.
1 3 1.
1 4 24.
2 1 1.
2 2 10.
2 3 1.
2 4 24.
3 1 1.
3 2 1.
3 3 10.
3 4 24.
```

Figure 2-9. Input to GAUSS

At the completion of each iteration, CNV is compared with the convergence criterion EPS; if convergence has occurred, the solution values are printed and processing terminates. If convergence does not occur within the specified number of iterations, an appropriate message is printed and processing terminates. Figure 2-10 shows the output produced from execution with the input shown in figure 2-9.

```
PROCESS HAS CONVERGED IN 5 ITERATIONS
SOLUTION VALUES ARE
   .2000E+01    .2000E+01    .2000E+01
```

Figure 2-10. Output from GAUSS

OTOD

Program OTOD (figure 2-11) reads display coded octal numbers and converts them to decimal numbers. Input is from cards containing a single octal number, with up to 20 digits, appearing anywhere within the first 30 columns; the B suffix is optional. Octal digits are positive integers written in base 8 notation; therefore, they can only contain the digits 1 to 7.

The octal numbers are read according to 3R10 format specification. This produces a right-justified, zero-filled string 30 characters long contained in array OCT. The DECODE statement strips off each display coded octal digit and stores it in array IA in reverse order. The format specification produces an array of right-justified, zero-padded characters. For example, suppose a card is read containing 3742B in columns 10-14. Then the array OCT would contain the values shown in figure 2-12. After the number is decoded, the contents of array IA would be as shown in the same figure.

For each character, the DO-loop does the following:

Lines 24, 25	Tests for blank or B; the B must be at the end of the string.
Line 28	Tests for sign; + or - is the last character processed
Line 29	Tests for non-octal digit
Line 30	Tests for too many digits
Line 31	Converts display coded octal digit to internal format by subtracting 1R0 (33B)
Line 32	Sums place value of digit to form decimal number

When all digits of an octal number have been processed, the decimal number is signed and printed. In the above example, the procedure for converting to decimal is

$$3x8^3 + 7x8^2 + 4x8 + 2 = 2018_{10}$$

so that 2018 is printed.

A test for end of file is included after the READ statement; when all input cards have been read, a message is printed and processing terminates.

LINK

Program LINK (figure 2-13) assumes that a previously executed scientific program has calculated temperatures for regions of a grid at specified time intervals and that the results have been written to a file called INFIL. For each time point there is a record containing the time value, the region numbers, and the region temperatures. Regions and temperatures are packed into single words, with a region number in the lower half of a word and the temperature in the upper half. The record format and some sample records are shown in figure 2-14.

Program LINK reads the entire input file, reformats the data, and writes a new file called NEWFIL. In NEWFIL, there is one record for each region. Each record contains the region number, the time points, and the temperature at each time point, as shown in figure 2-15. Time values and associated temperatures are packed into a single word, with a temperature in the upper half of a word and the time in the lower half.

An array in ECS (Extended Core Storage) or LCM (Large Core Memory) is allocated for data read from the input file (line 8). The LEVEL statement defines the type of memory allocated for the array. Since data assigned to level 3 cannot be referenced in expressions, the MOVLEV subroutine is used to transfer the data to and from central memory.

The first record is buffered in and the length is obtained from the LENGTH subroutine (lines 20-23). The loop (lines 26-34) does the following: the time value, from the first word of the record, is stored in a separate array and the record is moved from the input buffer to ECS with the MOVLEV subroutine. The variable I, used as a pointer to the next available location in the ECS array, is incremented by the record length. If the value of I exceeds the array

```
      PROGRAM OTOD (INPUT,TAPE4=INPUT,OUTPUT)
C
C      PROGRAM *OTOD* READS OCTAL NUMBERS CONTAINING UP TO 20 DIGITS
C     AND CONVERTS THEM TO DECIMAL. INPUT IS ON CARDS; THE NUMBER MAY BE
C     ANYWHERE WITHIN THE FIRST 30 COLUMNS, AND THE B SUFFIX IS OPTIONAL
C
      INTEGER OCT(3), DEC
      DIMENSION IA(30)
C
      PRINT 50
C
C     READ AND DECODE DISPLAY CODED OCTAL NUMBER
C
  100 READ (4,10) OCT
      IF (EOF(4) .NE. 0) GO TO 800
      J = 0
      DEC = 0
      DECODE (30,15,OCT) (IA(30-I+1),I=1,30)
C
C     CONVERT DISPLAY TO INTERNAL, THEN TO DECIMAL
C
        DO 200 I=1,30
        IDIG = IA(I)
        IF(IDIG .EQ. 1R ) GO TO 200
        IF (IDIG .NE. 1R8) GO TO 150
        IF (J .EQ. 0) GO TO 200
        GO TO 850
  150   IF (IDIG .EQ. 1R+ .OR. IDIG .EQ. 1R-) GO TO 250
        IF (IDIG .LT. 1R0 .OR. IDIG .GT. 1R7) GO TO 700
        IF (J .GT. 19) GO TO 750
        IDIG = IDIG - 1R0
        DEC = DEC + IDIG*8**J
        J = J + 1
  200   CONTINUE
C
  250 IF (J .EQ. 0) GO TO 700
      IF (IDIG .EQ. 1R-) DEC = -DEC
      PRINT 20, (OCT(I),I=1,3), DEC
      GO TO 100
  700 PRINT 30, (OCT(I),I=1,3)
      GO TO 100
  750 PRINT 50
      GO TO 100
  800 PRINT 40
      STOP
  850 PRINT 70
      GO TO 100
   10 FORMAT (3R10)
   15 FORMAT (30R1)
   20 FORMAT (3(1XA10), 1XI20)
   30 FORMAT (3(1XA10), * IS NOT AN OCTAL NUMBER*)
   40 FORMAT (* END OTOD*)
   50 FORMAT (*1 OCTAL*, 20X, *DECIMAL*)
   60 FORMAT (* INPUT NUMBER HAS MORE THAN 20 DIGITS*)
   70 FORMAT (3(1XA10), * CONTAINS 8 OUT OF SEQUENCE*)
      END
```

Figure 2-11. Program OTOD

boundary, a warning message is printed; no more data is read but processing continues on the incomplete array. The next record is read and the record counter NTIMES is incremented; if NTIMES exceeds its limit, a warning message is printed and the incomplete array is processed. Records are read and stored in this manner until either the end-of-file is reached or the ECS array is full.

When the entire file, or as much of it as possible, has been read and stored in ECS, lines 38 through 48 construct the output records and write the output file NEWFIL. Each pass through the outer DO-loop constructs a single output record; each pass through the inner DO-loop stores a single word in the output record. On the first pass through the inner loop, the first input record is transferred to central memory via MOVLEV; its time value is packed with the temperature value of the first region and stored in the output buffer OUT to form the second word of the output record. On the second pass, the second input record is moved to central memory, and the time value is packed with the temperature value for the first region to form the third word of the first output record. When all times and temperatures for the region have been stored in the output buffer (inner loop completed), the region number is stored in the first word of the output buffer and the new record is written. Then, under control of the outer loop, the subsequent records are constructed and written in a like manner, until the entire array has been processed.

CORCO

Program CORCO (figure 2-16) assumes that a series of standardized tests has been given to two groups of students, and that the results have been stored in two corresponding files. For each test there is a record containing the test number, the number of students who took the test, and the number of students who correctly answered each question on the test. The record format, along with some sample records from both files, is shown in figure 2-17.

```
OCT:
        OCT(1)      5555555555555555536
        OCT(2)      4237302555555555555
        OCT(3)      5555555555555555555

IA:
        IA(1)       blanks
        IA(2)       blanks
          .
          .
          .
        IA(17)      00000000000000000002
        IA(18)      00000000000000000035
        IA(19)      00000000000000000037
        IA(20)      00000000000000000042
        IA(21)      00000000000000000036
        IA(22)      blanks
          .
          .
          .
```

Figure 2-12. Arrays OCT and IA in Program OTOD

The program reads the two files and, for each test, calculates the probability that a student will answer each question correctly, calculates a correlation coefficient, calculates a new probability for each question, and writes a new file. The output file record contains the test number, number of students, and the probability that a student will answer each question correctly. The output record format, along with some sample records, is shown in figure 2-18.

The program begins by reading a record from each file. Since data from the first file is needed immediately, the input operation on unit 5 must be complete before processing can continue; unit 5 is tested immediately after the BUFFER IN. However, data from the second file is not needed until later in the program; therefore, processing can continue while the input operation on unit 6 is in progress. Since execution of the UNIT function loops until input is complete, it should not be executed until just before the data is needed.

When the first BUFFER IN has completed, the loop (lines 22-24) calculates the probability that a student will answer a question correctly.

$$P = \frac{\text{No. of correct answers}}{\text{No. of students}}$$

After this calculation, data from the second file is needed. Unit 6 is tested; when the input operation has completed, the record from the second file is processed in the same manner as the record from the first file.

Lines 37 through 46 calculate the correlation coefficient for corresponding records of the two files. The formula is shown in figure 2-19. In the figure, X and Y are the probabilities for the first and second testings, respectively, and N is the number of students who took the test. The correlation coefficient has a value between -1 and 1. A negative coefficient indicates unreliable data. The test number and coefficient are printed. An example of the printed output is shown in figure 2-20.

When every question on a test was correctly answered by the same number of students, the divisor in the formula became zero, and the correlation coefficient infinite. Therefore, the LEGVAR function is used to check this possibility (line 47).

New probabilities are calculated by the relation:

$$NEWPR = (N_1X + N_2Y)/(N_1 + N_2)$$

where N_1 is the number of students in the first testing, N_2 is the number in the second testing, and X and Y are as before. The output record is written in line 55.

Records are read and processed in this manner until an end-of-file is encountered on either of the input files.

```
      PROGRAM LINK (OUTPUT,LNKFIL,TAPE4=LNKFIL,NEWFIL,TAPE5=NEWFIL)
C
C     PROGRAM *LINK* READS A BINARY FILE CONTAINING TIME
C     HISTORY DATA, REFORMATS THE DATA, AND WRITES THE REFORMATTED
C     DATA TO A NEW FILE
C
      COMMON /ECSCOM/ ECSBLK(5000)
      LEVEL 3, ECSBLK
      DIMENSION INBUF(50), OUTBUF(50), TIME(50)
      DATA MASKU/77777777770000000008/, MASKL/77777777778/
C
      I = 1
      J = 1
      NCARD = 1
      NTIMES = 1
      REWIND 4
C
C     READ FIRST RECORD TO DETERMINE RECORD LENGTH
C
      BUFFER IN (4,0) (INBUF(1), INBUF(50))
      IF (UNIT(4)) 100, 800, 800
  100 LENREC = LENGTH(4)
      IF (LENREC.GT.50) GO TO 900
C
C     READ REMAINDER OF FILE AND STORE IN ECS/LCM
C
  110 TIME(NTIMES) = SHIFT(INBUF(1),30) .AND. MASKL
      CALL MOVLEV (INBUF(1), ECSBLK(I), LENREC)
      I = I + LENREC
      BUFFER IN (4,0) (INBUF(1), INBUF(LENREC))
      NTIMES = NTIMES + 1
      IF (NTIMES .GT. 50) GO TO 900
      IF (UNIT(4)) 110, 200, 800
C
C     ALL DATA IS IN ECS. MOVE TO SCM, REFORMAT, AND WRITE NEW FILE
C
  200 NTIMES = NTIMES - 1
        DO 300 I=2,LENREC
        II = 1
          DO 250 J=1,NTIMES
          CALL MOVLEV (ECSBLK(II), INBUF(1), I)
          II = II + LENREC
          OUTBUF(J+1) = (INBUF(I) .AND. MASKU) .OR. TIME(J)
  250     CONTINUE
         OUTBUF(1) = INBUF(I) .AND. MASKL
        BUFFER OUT (5,0) (OUTBUF(1), OUTBUF(NTIMES+1))
        IF (UNIT(5)) 300, 800, 800
  300   CONTINUE
C
      PRINT *, *END LINK*
      STOP
  800 PRINT *, * DISK I/O ERROR*
      STOP
  900 PRINT *, *INPUT FILE EXCEEDS PROGRAM LIMITS.*
      PRINT *, *EXECUTION CONTINUING BUT SOME DATA MAY BE LOST*
      GO TO 200
      END
```

Figure 2-13. Program LINK

A. Record Format

word1	word2	word3		wordN
time	temp/region1	temp/region2	. . .	temp/regionN

B. Sample Actual Records

```
  1.0   1726620C0C0C000C0001   1726670000000000C002   3500000000000005   1726500000000
0000006
  2.0   1726434000000000C001   1726440000000000000    2645400000000005   1726460000000
0000006
  3.0   1723600000000000C001   1724560000000C00000    7257000000000005   1726414000000
0000006
  4.0   1725540000000000001   1725540000000000C      1725540000000000005   1725540000000
0000006
  5.0   1726620000000000001   1726610000000000C      1726560000000000005   1726550000000
0000006
  6.0   1726604300000000001   1726520000000000C      1724600000000000005   1725660000000
0000006
  7.0   1726610000000000001   1726400000000000C      1724520000000000005   1725630000000
0000006
  8.0   1726404300000000001   1723640000000000       1725550000000000005   1726400000003
0000006
  9.0   1720400000000000001   1724620000000000       1725740000000000005   1724500000000
0000006
 10.0   1726614000000000001   1726464000000C         1726540000000000005   6053037777000
0000006
```

Figure 2-14. Record Format for INFIL

A. Record Format

word1	word2	word3		wordM
region #	temp/time1	temp/time2	. . .	temp/timeM

B. Sample Actual Records

```
    1   1726620000172040000C   1726434000172140000C   c200001722500000   1726404000172
2600000
    2   1726670000172040000C   1726440000172140000C   2661000017225000C   1726520000172
2600000
    3   1726740000172040000C   1726444000172140000    7266000001722500000   1726404000172
2600000
    4   1727400000172040000C   1726450000172140C      1726570000172250000C   1724760000172
2600000
    5   1726550000172040000C   1726454000172140C      1726560000172250000C   1724600000172
2600000
    6   1726500000172040000C   1726460000172140       1726550000172250000C   1725660000172
2600000
```

Figure 2-15. Record Format for NEWFIL

```
      PROGRAM CORCO (OUTPUT,TESTA,TESTB,PROBS,
     1  TAPE5=TESTA,TAPE6=TESTB,TAPE7=PROBS)
C
      INTEGER TESTN1, TESTN2, TOTST
      DIMENSION IBUFA(150), IBUFB(150), OUTBUF(150), X(150), Y(150),
     1  IOUT(2)
      EQUIVALENCE (IOUT(1),OUTBUF(1))
C
C     READ INPUT FILES CONTAINING TEST RESULTS
C
      REWIND 5
      REWIND 6
      N=10
  100 BUFFER IN (5,0) (IBUFA(1),IBUFA(N+2))
      BUFFER IN (6,0) (IBUFB(1),IBUFB(N+2))
      IF (UNIT(5)) 110, 900, 800
C
C     CALCULATE PROBABILITIES FOR FIRST TESTING
C
  110 TESTN1 = IBUFA(1)
      NST1 = IBUFA(2)
        DO 120 I=1,N
        X(I) = FLOAT(IBUFA(I+2))/NST1
  120   CONTINUE
C
C     CALCULATE PROBABILITIES FOR SECOND TESTING
C
      IF (UNIT(6)) 130,900,800
  130 TESTN2 = IBUFB(1)
      NST2 = IBUFB(2)
        DO 140 I=1,N
        Y(I) = FLOAT(IBUFB(I+2))/NST2
  140   CONTINUE
C
C     CALCULATE CORRELATION COEFFICIENT
C
      SUMX = SUMY = SUMXY = SUMXSQ = SUMYSQ = 0.0
        DO 150 I=1,N
        SUMX = SUMX + X(I)
        SUMY = SUMY + Y(I)
        SUMXY = SUMXY + X(I)*Y(I)
        SUMXSQ = SUMXSQ + X(I)**2
        SUMYSQ = SUMYSQ + Y(I)**2
  150   CONTINUE
      R = (N*SUMXY - SUMX*SUMY)/
     1 (SQRT(N*SUMXSQ - SUMX**2)*SQRT(N*SUMYSQ - SUMY**2))
      IF (LEGVAR(R) .NE. 0) GO TO 1000
      PRINT 14, TESTN1, R
   14 FORMAT (* TEST NO. = *,I3,* CORRELATION COEFFICIENT = *,F5.2)
      TOTST = NST1 + NST2
C
C     CALCULATE NEW PROBABILITIES AND WRITE OUTPUT FILE
C
        DO 160 I=1,N
        OUTBUF(I+2) = (X(I)*NST1 + Y(I)*NST2)/TOTST
  160   CONTINUE
      IOUT(1) = TESTN1
      IOUT(2) = TOTST
      BUFFER OUT (7,0) (OUTBUF(1),OUTBUF(N+2))
      IF (UNIT(7)) 100, 800, 800
C
  800 PRINT *, *FATAL I/O ERROR*
      STOP
  900 PRINT *, *END CORCO*
      STOP
 1000 PRINT *, * INVALID COEFFICIENT*
      GO TO 100
      END
```

Figure 2-16. Program CORCO

A. Record Format

word1	word2	word3	word4	...
test no.	no. of students	#Q1	#Q2	...

B. Sample Actual Records

```
TEST A
 1 100  99  98  97  96  95  94  93  92  91  90
 2 100  65  76  95  95  68  31  97  35  98  47
 3 100  98  64  97  54  85  71  93  17  92  89
 4 100  65  68  28  98  94  95  85  68  68  78
 5 100  98  97  94  98  65  65  87  87  54  84
 6 100  74  75  76  78  79  81  93  56  65  93
 7 100  99  98  95  93  89  84  78  71  63  54
 8 100  71  72  73  74  75  76  77  78  79  80
 9 100  21  23  25  27  29  31  33  35  37  39
10 100  94  68  53  78  51  25  98  63  12  58

TEST B
 1 100  69  89  78  48  58  98  68  98  99  88
 2 100  83  81  79  77  75  73  71  69  67  65
 3 100  99   1  89  11  79  21  69  31  59  41
 4 100  99   1  89  11  90  22  72  34  65  47
 5 100  98  61  78  31  47  95  98  66  79  58
 6 100  94  94  85  78  48  98  65  24  47  98
 7 100  44  77  88  55  96  94  95  96  91  25
 8 100  75  75  75  75  75  75  75  75  75  75
 9 100  75  42  75  31  75  22  75  12  75  16
10 100  98  94  65  32  21  54  65  87  65  32
```

Figure 2-17. Input Records for CORCO

A. Record Format

word1	word2	word3	word4	...
test no.	no. of students	P(Q1)	P(Q2)	...

B. Sample Actual Records

```
 1 200  .84  .94  .88  .72  .77  .96  .81  .95  .95  .89
 2 200  .74  .79  .87  .86  .72  .52  .84  .52  .83  .56
 3 200  .99  .33  .93  .38  .82  .46  .81  .24  .76  .65
 4 200  .82  .35  .59  .55  .87  .59  .79  .51  .67  .63
 5 200  .98  .79  .86  .95  .56  .75  .93  .77  .67  .71
 6 200  .84  .85  .81  .78  .64  .90  .79  .40  .56  .96
 7 200  .72  .88  .92  .74  .93  .89  .87  .84  .77  .40
 9 200  .48  .33  .50  .29  .52  .27  .54  .24  .56  .28
10 200  .96  .81  .62  .55  .36  .40  .82  .75  .39  .45
```

Figure 2-18. Records on File PROBS

$$R = \frac{N\sum_{i=1} X_i Y_i - \sum_{i=1} X_i \sum_{i=1} Y_i}{\sqrt{N\sum_{i=1} X_i^2 - \left(\sum_{i=1} X_i\right)^2}\ \sqrt{N\sum_{i=1} Y_i^2 - \left(\sum_{i=1} Y_i\right)^2}}$$

Figure 2-19. Formula for Correlation Coefficient

```
TEST NO. =  1 CORRELATION COEFFICIENT = -.45
TEST NO. =  2 CORRELATION COEFFICIENT =  .24
TEST NO. =  3 CORRELATION COEFFICIENT =  .64
TEST NO. =  4 CORRELATION COEFFICIENT = -.42
TEST NO. =  5 CORRELATION COEFFICIENT =  .27
TEST NO. =  6 CORRELATION COEFFICIENT =  .59
TEST NO. =  7 CORRELATION COEFFICIENT =  .12
 INVALID COEFFICIENT
TEST NO. =  9 CORRELATION COEFFICIENT = -.35
TEST NO. = 10 CORRELATION COEFFICIENT =  .26
END CORCO
```

Figure 2-20. Printed Output from CORCO

OPTIMIZATION 3

The purpose of optimizing a program is to reduce the cost of executing it. This cost is literally a cost in money, whether the cost is charged to the individual user or shared among all the users. Because the cost of a job results from the use of several kinds of system resources, the cost can be reduced by reducing the use of one or more of these resources. These resources include central processor time, central memory field length, and the various resources used in input/output operations.

Frequently, however, a reduced expenditure of one resource requires an increased expenditure of another. For instance, the amount of memory required by a program can be reduced by using segmentation or overlays (section 7), but more central processor time is then required. Conversely, some optimization techniques, such as loop unrolling (described in this section), decrease central processor time at the expense of field length. Only the requirements of a particular application can determine whether specific optimizations are worthwhile.

A resource cost that is frequently overlooked when optimization is considered is programmer time. As discussed in section 1, program development, debugging, and maintenance frequently contribute more to the overall cost of a program than the computer resources required to execute it. Therefore, a programmer should be very cautious about optimizing a program in such a way as to make it less comprehensible or maintainable. Unless a program is to be executed repeatedly, or to use a lot of resources, not much time should be spent on user optimization.

This section describes both the optimizations that the compiler performs for the user as well as those the user can embody in the source code. Most of these optimizations decrease central processor time (not always at the expense of field length), but some decrease field length, input/output time, or real time (throughput).

It should be kept in mind that the best way to optimize code is to use efficient algorithms. The higher the level at which a program is optimized, the better the results.

Array subscript computation is discussed frequently in this section; therefore, the formulas for one-, two-, and three-dimensional arrays are shown in table 3-1 for convenient reference. These formulas do not apply to double precision or complex arrays.

Because it is reasonable to assume that any programmer interested in optimal program execution will compile the program under OPT=2 or UO (unsafe optimization), the optimizations performed by the compiler in those modes are discussed first.

COMPILER OPTIMIZATION

When OPT=2 is specified on the FTN control statement, the compiler optimizes the user code extensively in the process of generating object code. When the UO option is also specified, all the OPT=2 optimizations are performed, as well as some additional ones that could cause incorrect results. (The additional optimizations performed when UO is specified are identified below.)

OPT=2 mode is a global optimizer; that is, it analyzes the structure of an entire program unit during the optimization process. A brief description of the procedure followed by this optimizer will help to clarify the specific optimizations described here in more detail.

In optimizing mode, several passes are made over the source code. In the first pass, the syntax of statements is analyzed, a symbol table is constructed, and the statements are translated into an intermediate language similar to assembly language. Typically, several instructions in this intermediate language are required for each executable FORTRAN statement. At this stage, no register assignment has taken place; rather, an indefinite number of registers (R1,R2, . . . ,Rn) are used as needed. An example of a FORTRAN statement and its translation into intermediate language is shown in figure 3-1. The intermediate language used in this example is similar to that used by the compiler, but is different in format.

Local optimizations are performed before global optimization begins. (Local optimizations are also performed when OPT=0 or 1 is specified.) The local optimizations include constant evaluation and elimination of redundant subexpressions.

Global optimization begins by grouping sequences of intermediate language instructions into units called basic blocks. A basic block is a sequence of instructions with one entry and one point of exit. It has the property that if one instruction in a block is executed, all the instructions are executed. This grouping simplifies the process of analyzing the flow of control in the program. In figure 3-2, each section of code between comment lines constitutes a basic block.

TABLE 3-1. ARRAY SUBSCRIPT FORMULAS

Number of Dimensions	Declaration	Reference	Formula for Offset from First Element
1	A(I)	A(L) =	L-1
2	A(I,J)	A(L,M)=	L-1 + I*(M-1)
3	A(I,J,K)	A(L,M,N)=	L-1 + I*(M-1 + J*(N-1))

The next stage is to construct a directed graph in which the basic blocks are nodes, and the lines connecting the nodes indicate a conditional or unconditional transfer between blocks. The optimizer constructs a table indicating which variables are used and defined in each block.

The optimizer then identifies all the loops in the program unit (IF loops as well as DO loops). The loops are categorized according to how deeply they are nested. (An unnested loop is in the same category as the innermost loop of a nest.) Then, beginning with the innermost loops and proceeding outward, optimizations are performed for each loop. These optimizations include movement of invariant code outside the loop, strength reduction, elimination of dead variable definitions, and register assignment.

After all loops have been optimized, object code is generated. As a result of optimization, the order in which operations are performed can be different than the order in which those operations were specified in the source code. The result, however, is always identical.

```
FORTRAN Statement:

  Q = X + Y/Z

Intermediate Language Equivalent:

LOAD Y ⟶ R1

LOAD Z ⟶ R2

DIVIDE R1 / R2 ⟶ R3

LOAD X ⟶ R4

ADD R3 + R4 ⟶ R5

STORE R5 ⟶ Q
```

Figure 3-1. Intermediate Language Example

```
C
      X = Y
      DO 120 I=1,N
      A(I) = B(I)
120   CONTINUE
      GO TO (100,200,300) J
C
100   Z = Q
      GO TO 500
C
200   PRINT *, X
      GO TO 500
C
300   N = N + 1
      A(1) = 0
      RETURN
C
```

Figure 3-2. Basic Block Example

Users with a knowledge of COMPASS are encouraged to examine the object listing produced from an OPT=2 compilation to get an idea of the types of source code manipulation that take place. The listing can be compared with one produced by an OPT=0 compilation.

The compiler-produced optimizations discussed in this section are divided into machine-independent optimizations and machine-dependent optimizations. Machine-independent optimizations are those that would produce more efficient code on any machine. Primarily, they consist of the elimination of unnecessary operations. Optimizations in this category include common subexpression squeezing, elimination of dead variable definitions, invariant code motion, and compilation time evaluation of constants. Machine-dependent optimizations are those that take into account the specific features of the systems on which FORTRAN Extended programs run. They include replacing expensive operations with cheaper ones and taking advantage of the functional units present on some models.

MACHINE-INDEPENDENT OPTIMIZATIONS

As stated above, machine-independent optimizations are those that result in the elimination of operations. In some cases, the operations are completely removed from the source code; this saves space as well as time. In other cases, operations are moved out of loops so that they are executed less frequently; this does not necessarily save any space.

Invariant Code Motion

If a sequence of instructions appears in a loop, and the result of execution of the instructions does not depend on any variable whose value changes within the loop, the instructions are called invariant. If the instructions remain in the loop, they are redundantly executed as many times as the loop is executed; therefore, the optimizer removes such sequences from loops whenever possible.

For example, in the sequence:

```
      DO 100 I=1,N
      K(I) = J/L+I**2
100   CONTINUE
```

neither J nor L can change in value during execution of the loop and, therefore, J/L is invariant and can be safely removed from the loop. J/L is then calculated only once, rather than repeatedly. After optimization, the loop is equivalent to the following:

```
      R1 = J/L
      DO 100 I=1,N
      K(I) = R1+I**2
100   CONTINUE
```

(In this example of code after optimization, and those that follow, variables of the form Rn indicate machine registers rather than memory locations; thus, the examples should not strictly speaking be read as FORTRAN statements.)

Invariant code can extend for several statements, as shown in figure 3-3. This example also shows that IF loops that are essentially the same as DO loops are optimized in the same way.

Invariant code can also include code that is invisible in FORTRAN. For example, in the sequence:

```
      DIMENSION B(10,10,10)
      DO 10 I=1,N
      B(I,7,K) =I
10    CONTINUE
```

The relative location of the element of array B is calculated by the formula (see table 3-1):

I-1 + 10 x (6 + 10 x (K-1))

Without optimization, this entire calculation would be performed once for each execution of the loop. After optimization, however, the invariant part of the calculation is performed before entering the loop. This invariant part consists of the following subexpression which, in fact, is most of the calculation:

-1 + 10 x (6 + 10 x (K-1))

The optimizer only moves code out of a loop when it is certain that the code is actually invariant. There are circumstances in which execution of a sequence of instructions proves it to be invariant but the determination cannot be made at compilation time. These circumstances include the following:

- When a call is made to a subprogram within the loop, and the code that is being considered for invariancy uses the value of a variable that is either in common or is an actual parameter to the subprogram. For example, in figure 3-4, neither X**2 nor Y/Z can be moved out of the loop, because the subroutine MYSUB might change the value of X or Z. However, if the call to MYSUB were:

  CALL MYSUB (Q,R,Z+2)

  then Y/Z could be moved out of the loop, since the compiler assumes that the call to MYSUB does not change the value of Z.

Before optimization:

```
100   A  = P(I) + S/Q
      Y  = X/Z + D
      I  = I + 1
      IF(I.LT.12) GO TO 100
```

After optimization:

```
      R1 = S/Q
      Y  = X/Z + D
100   A  = P(I) + R1
      I  = I + 1
      IF(I.LT.12) GO TO 100
```

Figure 3-3. Invariant Code Motion Example

- When a conditional branch within the loop introduces the possibility that the code might never be executed. For example, in figure 3-5, the expression K+M can be moved out of the loop so that it is executed only once, but the store into J must be left in the loop.

- When the value of an expression ultimately depends on a variable that is capable of changing value in successive iterations of the loop. For example, in figure 3-6, the division L/N1 cannot be moved out of the loop because the value of L ultimately depends on that of I, which changes each time the loop is executed.

Taking the limitations of the optimizer into account, the user concerned with optimal performance can write loops so as to maximize the amount of optimization that can take place. Above all, loop structure should be kept simple and straightforward. Common should not be used for storage of strictly local variables. Finally, expressions should be written in such a way as to make invariant subexpressions easier to recognize. For example:

```
      DO 100 I=1,N
      A(I) = (1. + X) + B(I)
100   CONTINUE
```

```
      COMMON X
      DO 100 I = 1,N
      A(I) = X**2
      B(I) = Y/Z
      CALL MYSUB (Q,R,Z)
100   CONTINUE
```

Figure 3-4. Invariant Code (Example 1)

```
      LOGICAL L
      DO 100 I = 1,N
      IF (L) GO TO 110
      J = K+M
110   A(I) = B(I) + C(I)
100   CONTINUE
```

Figure 3-5. Invariant Code (Example 2)

```
      DO 100 I=1,N
      J = I+...
      K = J*...
      L = K+...
      M = L/N1 + N2*N3
100   CONTINUE
```

Figure 3-6. Invariant Code (Example 3)

is preferable to

```
      DO 100 I=1,N
        A(I) = 1. + B(I) + X
  100 CONTINUE
```

because 1. + X is recognized as an invariant expression only in the first case.

Common sense must be used to decide when rewriting loops interferes with the readability of code.

Whenever it is not clear whether the compiler can move invariant code, the user can move it. Moving code sometimes requires the creation of temporary variables to hold subexpressions; these variables should only be used locally, so that the optimizer does not generate unnecessary stores into them (as explained under Dead Definition Elimination). An exception to the effectiveness of this technique is that the program should not perform its own subscript calculation for a multidimensional array. For example, the sequence:

```
      DIMENSION B(10,10,10)
      DO 10 I=1,N
      B(I,7,K) = I
   10 CONTINUE
```

should not be rewritten as:

```
      DIMENSION B(10,10,10)
      ITEMP = -1 + 10*(6 + 10*(K-1))
      DO 10 I =1,N
      B(I+ITEMP) = I
   10 CONTINUE
```

even though the results are the same, because the rewritten version inhibits certain special-case optimizations the optimizer performs on array subscripts. (The expression in the rewritten version is not recognized as a subscript.)

Common Subexpression Elimination

A common subexpression is an expression that occurs more than once in the source code. In completely unoptimized code, the expression is evaluated each time it occurs. Instead, the optimizer tries to save the result of the expression in a register whenever possible and to use that result instead of reevaluating the expression.

For example, in the following sequence of code:

```
X = A*B*C
S(A*B) = (A*B)/C
```

all three occurrences of A*B are matched; A*B is evaluated only once, and the result is used three times. This procedure can take place only when all of the following conditions are true:

- The expressions can be recognized as the same expression. The compiler reorders each expression into a canonical order, and then compares expressions term-by-term. Only expressions that match exactly are used. For example, A+B, A+B+C, C+D, and so forth, are recognized as subexpressions of A+B+C+D, but A+C is not recognized. B+A can be matched with A+B, however, because they are rearranged into the same order. When a subexpression contains more than one operator of equal precedence, as in:

  ```
  A*B/C
  ```

  the expression is usually evaluated from left to right. Since the operators are associative, however, the compiler might reorder the operations. Parentheses can be used to ensure the desired grouping of sub-expressions:

  ```
  (A*B)/C
  ```

- The expressions must be in the same sequence of code, otherwise it is not feasible to allocate a register to save the result. The further apart two occurrences of the same expression are, the less likely it is that they will be matched. Furthermore, no code can occur between occurrences of the same expression that might cause it to change in value. For example, in the sequence:

  ```
  X = A(2)/B(2) - Q
  A(I) = 4.5
  Z = A(2)/B(2) + 13.4
  ```

  A(2)/B(2) cannot be matched as a common subexpression because of the possibility that I will be equal to 2 at execution time, changing the value of the expression. In this example, if the user is sure that I will not be equal to 2, the assignment to A(I) should be placed after the assignment to Z.

Keeping these restrictions in mind, the user can write expressions so as to maximize the chance that identical expressions are recognized by the optimizer. For example:

```
AA = X*A/Y
BB = X*B/Y
```

is not likely to result in subexpression elimination, but

```
AA = A*(X/Y)
BB = B*(X/Y)
```

will do so.

Dead Definition Elimination

As explained above, the optimizer divides a program unit into basic blocks as part of its analysis. In the process, it keeps track of the uses and definitions of each variable within the block. By investigating which combinations of blocks can be branched to from a given block, the optimizer determines whether the value of a variable is needed after the block is executed. If the value is needed, the variable is referred to as live on exit, otherwise it is referred to as dead on exit. If a variable is dead on exit from a block, the last store into the variable can be eliminated, since the value of the variable will not be needed again in the program.

For example, in the program unit shown in figure 3-7, the store into X in the line labeled 100 is eliminated, because there is path through the program in which X could be referenced subsequently.

Locally (that is, within a basic block), other stores of a variable can also be eliminated. For example, in the sequence:

```
X = Y + Z
A = X + B
X = X/R
```

all three of these statements must be executed whenever the first one is executed. Therefore, it is not necessary to store X after the first statement because it is almost immediately redefined. A dead definition is eliminated only if the optimizer can be certain that it is really dead. For instance, the logic of the program might be such that it is impossible to decide for certain where the last usage of the variable is. In this case, no stores can be deleted (except locally). Also, the ability of the optimizer to eliminate stores even locally is limited by the availability of registers. For example, in the sequence:

```
      X = Y +Z
      A(I+J,J+K,K+I) =(B(M,N) +
     1C(N,L)) ** (D(L,M)/E**X)/F
      X = Q/R/S/T
```

it is impossible to keep the value of X in a register throughout the execution of the second statement, so X must be stored and then subsequently loaded.

There is not much the user can do to help the optimizer eliminate dead definitions. Of course, many dead definitions result from incorrect or redundant code. For example, if the last statement to be executed in a program unit is a store into a local variable, the statement is superfluous and should be eliminated by the programmer. The best advice is to keep program logic simple and avoid unnecessary use of common blocks and equivalence classes.

Constant Evaluation

At all optimization levels, the compiler attempts to evaluate as many constant subexpressions as possible. The reason for this is that programs are usually executed many more times than they are compiled. For example:

```
X = 3.5 + 4.**2
```

The compiler evaluates the expression and replaces it with the constant 19.5. Some constant subexpressions serve no useful purpose and should be evaluated by the programmer, not the compiler. Others are justified, however, when they make programs more readable. This is particularly true when one of the components of the expression is a standard constant, such as pi or e. Because the expression is evaluated at compile time at minimal expense, it is better to leave such expressions unevaluated.

```
      SUBROUTINE A (M,V, I)
      DIMENSION V(M)
      READ *, X
      GO TO (100,200) I
  100 X = X/2.
      IF (M .GT. 20) GO TO 250
      STOP
  200 PRINT *, X
      RETURN
  250 V(M) = 25.6
      RETURN
      END
```

Figure 3-7. Variable Dead on Exit

The user can help the optimizer by grouping constant subexpressions within an expression. For example, it is better to write:

```
X = Y * (3.14159265358979 / 2.)
```

than:

```
X = 3.14159265358979 * Y / 2.
```

because the constant subexpression is recognized in the first case but not the second.

Test Replacement

Test replacement consists of replacing, in a loop, all or some occurrences of a variable with a function of a related variable. The control variable is especially likely to be eliminated. A variable can be eliminated if it satisfies the following conditions:

- It is not in common or a formal parameter
- Its value is not required outside the loop
- At least one of its appearances in the loop is in the form of a linear function (expecially as an array subscript); for example:

```
      DO 100 I = 1,N
      A(2,I) = 33.2
  100 CONTINUE
```

Test replacement of I can take place in this loop, but not in the following case:

```
      DO 110 I=1,N
      X = SQRT(FLOAT(I))
  100 CONTINUE
```

In test replacement, the increment and test portions of the loop code are rewritten so that a linear function of the control variable is incremented and tested, rather than the control variable itself; for example:

```
      DO 100 I=1,10
      A(I) = 2.5
  100 CONTINUE
```

In this loop, test replacement causes the address of the successive elements of the array A to be used for testing and incrementing, rather than the variable I. Because the distinction is easier to see in COMPASS code, the object code generated for this loop under OPT=0 and OPT=2 is shown in figure 3-8. It should be noted that the variable I, for all intents and purposes, does not exist in the second version.

When the control variable has more than one use within a loop, test replacement can still take place, but the control variable is not necessarily eliminated. However, at least one increment instruction per loop iteration is eliminated.

MACHINE-DEPENDENT OPTIMIZATION

As stated above, machine-dependent optimizations are those that take advantage of the peculiar features of the systems on which FORTRAN Extended programs can be run. They fall into three main categories:

- Those that replace slower operations by faster operations. In FORTRAN, the relative speeds of operations can be ranked as follows (slowest first):

**	Exponentiation
/	Division
*	Multiplication
+ -	Addition and subtraction

- Those that reorder instructions so as to use simultaneously as many functional units as possible. These optimizations are only carried out on systems with functional units; that is, the 6600, 6700, CYBER 70 Models 74 and 76, and CYBER 170 Models 175 and 176 Computer Systems.

- Those that schedule register usage so as to minimize stores and loads. These apply to all computer systems.

Strength Reduction

Strength reduction is one instance of the replacement of expensive operations by cheaper operations. Specifically, strength reduction replaces exponentiation by multiplication, and multiplication by addition.

Under OPT=0:

```
          SX7    1B
          SA7    I
)AA       BSS    0B

          SA5    CON.
          SA4    I
          BX7    X5
          SA7    X4+A-1B

          SA5    I
          SX7    X5+1B
          SX0    X7-13B
          SA7    A5
          MI     X0,)AA
```

Under OPT=2:

```
          SA1    CON.
          SB6    A+11B
          SB7    A

)AA       BSS    0B
          BX7    X1
          SA7    B7
          SB7    B7+1B
          GE     B6,B7,)AA
```

Figure 3-8. Test Replacement Generated Code

Some types of strength reduction are local optimizations. For example, any exponentiation by a small integer constant (less than about 12) is replaced by a series of multiplications. Exponentiation by larger integers results in a call to a Common Library routine, which also uses multiplication for exponentiation by any integer up to about 100.

Another example is multiplication by 2, which can be replaced by addition of the variable to itself; thus:

```
J = 2*I
```

becomes:

```
J = I+I
```

When OPT=2 is specified, strength reduction also takes place in other situations. For example, if a subscript expression is of the form:

```
n*I + m
```

where n and m are unsigned integer constants, and I is a variable that varies only linearly in the loop (such as the control variable), then the multiplication can be replaced by an addition. For example, in the loop:

```
    DO 120 I=1, 100
    B(4*I + 3) = 2.5
100 CONTINUE
```

the loop is rewritten as follows:

```
    R1 = 3
    DO 120 I=1, 100
    R1 = R1 + 4
    B(R1) = 2.5
120 CONTINUE
```

so that the multiplication is replaced by an addition.

Special Casing of Subscripts

In a multidimensional array, subscript computation requires one or more multiply instructions. The formula for this computation is shown in table 3-1. If any of the declared dimensions (except the last dimension, which is not used in a multiply) is a power of 2, the multiplication can be replaced with a shift instruction, which executes more quickly. This is possible because subscript dimensions are positive numbers less than $2^{17}-1$. (Shifts cannot replace multiplications of other integer variables because the results might overflow 48 bits, leading to invalid results.)

In the following example:

```
DIMENSION A(2,4,7)
    :
    :
A(I,J,K) = 452.3
```

the subscript calculation is:

```
I - 1 + 2 * (J-1 + 4*(K-1))
```

After optimization, both multiplications are performed by shifts instead of multiply instructions.

The replacement of multiplication by a shift also takes place when the array dimension is a sum or difference of two powers of 2. In this case, the number to be multiplied is shifted twice, and the two results are added or subtracted.

In the following example:

```
DIMENSION A(6,12,3)
    :
    :
A(I,J,K) = 452.3
```

the formula for the subscript is:

```
I-1 + 6*(J-1 + 12*(K-1))
```

or

```
I + 6*J + 72*K - 79
```

Both multiplications are performed using shift and add instructions.

Another type of special casing takes place when the first subscript expression of a subscript is a constant. In this case, the constant is added to the base address of array, saving one addition each time the subscript is calculated. For example, in the following case:

```
      DIMENSION A (10,10,10)
      DO 100 I=1,N
      A (4, J, I) = I
  100 CONTINUE
```

the address of the array element in the assignment statement is calculated as follows:

```
Address = Base address + (3 + 10 * (J - 1 + 10 * (I - 1)))
```

where the base address is the address of the first element in the array. Since the constant part of the calculation only needs to be performed once, 3 is added to the base address at compile time, effectively transforming the calculation to the following form:

```
Address = Biased base address +
    (10 * (J - 1 + 10 * (I - 1)))
```

The same principle can be applied to the case where the two leftmost subscript expressions, or all three, are constants.

Functional Unit Scheduling

The central processor in several of the computer systems on which FORTRAN Extended programs run has multiple functional units. The optimizer takes advantage of this feature whenever possible by scheduling instructions so as to use units simultaneously. This optimization is performed only when the program is compiled on a system with functional units; the compiler assumes that the program is to be executed on the same system on which it was compiled. However, performance is not degraded if the program is executed on a different system.

An important special case of functional unit scheduling is array element prefetching. Prefetching takes place when the elements of an array are used successively in a loop. With prefetching, loading of the next element to be used overlaps usage of the current element. For example:

```
      DO 100 I=1,N
      A(I) = B(I) + C(I)
  100 CONTINUE
```

Without prefetching, both B(I) and C(I) would have to be loaded before being added, so either the floating add unit or the increment unit (which is responsible for loads and stores) would be idle while the other unit was in use. With prefetching, B(I+1) and C(I+1) are fetched at the same time as B(I) and C(I) are added.

The potential danger with prefetching is that the last iteration of a loop might attempt to load a nonexistent array element. In the example, B(N+1) and C(N+1) are loaded (but not used) even if the arrays only have N elements. If the array is stored near the end of the user's field length, this attempt might result in an address out-of-range (an arithmetic mode 1 error). Thus, a program that executes correctly without prefetching might abort with prefetching. For this reason, prefetching is not performed for compilations under OPT=2 unless there is no danger of exceeding field length. However, when the UO (unsafe optimization) option is specified in addition to OPT=2, the compiler can prefetch for any array, without regard for the possibility of exceeding field length. Therefore, UO should not be used unless the user is sure that field length is not exceeded.

In the example above, field length is not exceeded because the increment between prefetched elements is only one word, and at least one word is guaranteed at the end of the field length.

Register Assignment

As one of the last stages of code generation, the optimizer decides which register to use for each variable and temporary quantity in every sequence of code. As part of the process, an attempt is made to minimize the number of loads and stores required. Whenever a program uses more quantities than there are registers, some of the quantities not immediately in use must be stored and subsequently loaded. To avoid this, the optimizer analyzes the register usage of a sequence of code and decides whether to put each quantity in an A, B, or X register.

For some quantities, no alternative is available. The value of most variable or array elements must be in an X register (which is 60 bits long), and the address of an operand to be loaded or stored must be in an A register. However, any quantity known to be less than or equal to 18 bits long can be kept in either a B register (which is 18 bits long) or an X register. These quantities include DO-loop control variables, limits, and increments, and any quantity used in array subscript calculation.

In the following example:

```
      DO 100 I=J,K,L
      A(I) = B(M,N,I)
  100 CONTINUE
```

I, J, K, L, M, and N can all be legally placed in B registers, because none of these quantities are allowed to exceed 18 bits.

Usually, register assignment consists of reallocating quantities from X registers to B registers, since X registers are usually scarcer than B registers, but occasionally the reverse is true. A special case of register assignment is retention of B registers across calls to basic external functions (library routines), which takes place only when the UO option is specified. Normally, all registers are saved whenever an external reference occurs, because it is impossible to determine at compile time what registers are used by the referenced function. However, when the UO option is specified, the compiler assumes that certain B registers are not used by basic external functions, and does not bother to save those registers when such functions are referenced. When the UO option is specified, the user

should ensure that functions with the same names as basic external functions are not loaded at execution time, unless the functions are referred to in EXTERNAL statements or type statements that override the default type.

OPTIMIZATION EXAMPLE

A somewhat more complex example can serve to illustrate how various optimizations are combined. Figure 3-9 shows a simple program unit and the code that would be generated for it when compiled with each of the following two control statements:

```
FTN,OPT=0,ER=0,OL.

FTN,OPT=2,UO,OL.
```

Only the object code generated for the executable statements is shown; a full listing of the object code would also include code to allocate data blocks and common blocks, and

Source Code:

```
      1              SUBROUTINE O
                     INTEGER A, B, C
                     COMMON A(10,10), B(10,10), C(10,10)
                       DO 100 I=2,10
      5                A(I+1,I-1) = B(I+1,I+1) + C(I-1,I-1)
                 100   CONTINUE
                     RETURN
                     END
```

Under OPT=0:

```
                                                *                          LINE    4
000002 CODE.    7170000002                            SX7    2B
                          5170000012 DATA.            SA7    I
000003 CODE.                                  )AA     BSS    0B
                                                *                          LINE    5
000003 CODE.    5150000012           DATA.            SA5    I
                          7100000013                  SX0    13B
000004 CODE.    42705                               DX7    X0*X5
                     5247000144      //             SA4    X7+B
000005 CODE.    5237000262           //             SA3    X7+C-26B
                          36634                       IX6    X3+X4
000006 CODE.    5267777753           //             SA6    X7+A-24B
                                                *                          LINE    6
                          5150000012 DATA.            SA5    I
000007 CODE.    7275000001                          SX7    X5+1B
                          7207777764                  SX0    X7-13B
000010 CODE.    54750                               SA7    A5
                     0330000003      CODE.          MI     X0,)AA
                                                *                          LINE    7
000011 CODE.    0400000001           START.         EQ     EXIT.
```

Under OPT=2:

```
                                                *                          LINE    4
000002 CODE.    5120000172           //             SA2    B+26B
                          5110000310 //             SA1    C
000003 CODE.    6150000013                          SB5    13B
                          6160000002 //             SB6    A+2B
000004 CODE.    6170000132           //             SB7    A+132B
                                                *                          LINE    4
000005 CODE.                                  )AA     BSS    0B
000005 CODE.    36712                               IX7    X1+X2
                     54225                          SA2    A2+B5
                          54115                     SA1    A1+B5
                               56760                SA7    B6
000006 CODE.    66665                               SB6    B6+B5
                     0676000005      CODE.          GE     B7,B6,)AA
                                                *                          LINE    7
000007 CODE.    0400000001           START.         EQ     EXIT.
```

Figure 3-9. FORTRAN Subprogram and Generated Object Code

to establish communication between program units. The COMPASS instructions shown are not explained; they should be self-evident to anyone familiar with COMPASS. The code generated under OPT=2 shows the following features:

- Test replacement (the registers B6 and B7 hold linear functions of the control variable, which does not exist within the loop)
- Strength reduction (the multiplications that would normally be used in the subscript calculation have all been replaced by additions)
- Common subexpression elimination (not well shown in this example, because the expressions I+1 and I-1 have disappeared completely)
- Register assignment (use of B registers to hold array subscripts)
- Prefetching (of elements of B and C)

The object code under OPT=2 is two words shorter than the object code under OPT=0. More significantly, the loop itself is reduced from six words to two words.

SOURCE CODE OPTIMIZATION

A program compiled under OPT=2 almost always runs faster than a program compiled under OPT=0, OPT=1, or time-sharing (TS) mode. The amount of improvement depends primarily on the number of loops in the program, because that is where most of the optimization under OPT=2 takes place.

In addition to the optimizations performed by the compiler, the user can rewrite the source code in such a way as to improve its performance, especially for cases that the compiler is incapable of optimizing. Time should be devoted only to optimizing loops, especially innermost loops; optimizations in straight-line code are not likely to be fruitful.

Source code optimization should not be done at the expense of other desirable features; some optimizations decrease execution time while increasing field length. (This is rarely true for compiler optimizations.) Also, many optimizations decrease the comprehensibility or ease of maintenance of a program. The added cost in programmer time often exceeds the savings in execution time.

With these cautions in mind, the user can decide which of the source code optimizations described here is worthwhile in any given application.

HELPING THE COMPILER OPTIMIZE

Probably the most important source code optimizations are those intended to maximize the optimizations the compiler can perform. Many of these have already been discussed in the context of the compiler optimizations, so only a summary is necessary here.

A primary consideration is to avoid unnecessary use of common blocks and equivalence classes. With variables in common, every subroutine call or function reference requires the compiler to store the variable before the reference, because it cannot be determined at compile time whether the variable is used in the referenced subprogram. In particular, the practice sometimes encountered of allocating local scratch variables in unused portions of common blocks to save space is very detrimental, and can actually cause space to be wasted. For example, in the following sequence:

```
      COMMON I,A(1000),B(1000)
      DO 100 I = 1,1000
      A(I) = 4*B(I)
      CALL SUB1 (C,D)
100   CONTINUE
      CALL SUB2
      END
```

I is in common, therefore its value must be stored before each call to SUB1 or SUB2. These two stores, 30 bits each, occupy the same amount of space as the variable. If I were not in common, the stores could be eliminated, saving the same amount of space and considerably speeding execution.

Equivalence classes inhibit optimization in somewhat less obvious ways. The following example is typical:

```
DIMENSION X(100)
EQUIVALENCE (X(1),W)
      :
      :
W = Y
PRINT *,X(I)
STOP
END
```

Without the EQUIVALENCE statement, the assignment statement could be eliminated because the value of W is not used again in the program. However, because W is equivalenced to X(1), and the PRINT statement might reference X(1), the assignment statement cannot be eliminated.

These cautions are not meant to discourage legitimate uses of common blocks and equivalence classes. In particular, when variables are needed by more than one program unit, it is faster to pass them through common than as parameters, because the code for setting up and using the parameter list is eliminated.

Another major way to help the compiler optimize is to keep program logic straightforward and simple, and to keep program units short. Of course, this also improves program readability and modularity. But the advantage to the optimizer is that it is more likely to correctly identify loops and monitor the usage of variables in different portions of the program.

It has already been mentioned that the optimizer recognizes IF loops as well as DO loops. The user should keep in mind that the more closely the IF loop resembles a DO loop, the more different kinds of optimizations are performed. (The implication of this is that a DO loop should be used whenever possible.) For example, the IF loop in the following sequence of code:

```
      I = 1
100   A(I) = B(I) + C(I)
      I = I + 1
      IF (I.LE.12) GO TO 100
```

generates code essentially identical to that generated by the following DO loop:

```
      DO 100 I=1,12
      A(I) = B(I) + C(I)
100   CONTINUE
```

and all the same optimizations are performed. However, if the loop is changed to the following algebraically identical form:

```
      I = 1
100   A(I) = B(I) + C(I)
      I = I+ 1
      IF(I+5.LE.17) GO TO 100
```

some of the optimizations the compiler performed in the first case cannot be performed in the second (for example, test replacement).

LOOP RESTRUCTURING

When the user is rewriting a program to optimize the source code, special attention should be paid to the loops, because that is where most of the execution time is spent in a typical FORTRAN program. Frequently, the users can take advantage of their knowledge of the peculiarities of their own programs to rewrite loops in such a way as to reduce the total number of operations performed at execution time.

One of the best known methods of restructuring is called loop unrolling. The idea is to reduce the overhead resulting from incrementing and testing the loop control variable by reducing the number of times the loop is executed. For example, the following loop:

```
      DO 100 I=1,10000
      X(I) = Z(I)**2
100   CONTINUE
```

can be replaced by this loop:

```
      DO 100 I=1,9999,2
      X(I) = Z(I)**2
      X(I+1) = Z(I+1)**2
100   CONTINUE
```

In the second case, only half as many increment, test, and branch instructions are executed.

One disadvantage of loop unrolling is that it makes programs more difficult to understand. Carried to its logical conclusion, loops would be completely eliminated, and replaced with long sequences of assignment statements. Clearly the user who is this concerned with optimization would be better off coding in COMPASS in the first place.

A more technical limitation of unrolling arises in the case when it is not known at compile time just how often the loop will be executed. For example, if the DO statement is:

```
DO 100 I=1,J
```

unrolling does not produce the correct results unless J is an even number (assuming that each assignment statement is unrolled into two statements).

Another way to reduce the overhead associated with loops is to combine them. For example, in the sequence:

```
      DO 100 I=1,K
      A(I) = B(I) + C(I)
100   CONTINUE
      DO 110 J=1,K
      E(J) = F(J) + G(J)
100   CONTINUE
```

the two loops can be combined into one, thus reducing by half the overhead associated with the loop:

```
      DO 100 I=1,K
      A(I) = B(I) + C(I)
      E(I) = F(I) + G(I)
100   CONTINUE
```

Combining loops is usually worthwhile; however, its usefulness as an optimizing tool is limited by the requirement that both original loops must be executed the same number of times.

MISCELLANEOUS OPTIMIZATIONS

The following is a list of miscellaneous techniques for optimization which might be found helpful under particular circumstances. They are discussed very briefly.

1. Avoid mixing modes in an expression. Each conversion from one mode to another requires extra instructions. An exception is exponentiation; integers as exponents are usually quicker than real numbers, whatever the base. When a choice among modes is possible for an expression, the choice should be made according to the following hierarchy (from most efficient to least efficient):

   Integer

   Real

   Double Precision

   Double precision is especially inefficient, and should be avoided whenever possible. A single precision floating point number has 48 significant bits, which is more than enough for most purposes.

2. If a program is only going to be relocated once (see section 7), but executed many times, the DATA statement is preferable to assignment statements for initialization of variables, especially large arrays.

3. The forms of conditional branch, from slowest to fastest, are as follows:

   Computed GO TO

   IF statement

   Assigned GO TO

   Unfortunately, the assigned GO TO makes following the flow of control in a program more difficult, and also impedes the detection of logic errors during debugging; it must be used with caution. When more than four or five branches can be taken from a given point, the computed GO TO is more efficient than the IF statement.

4. More efficient code is generated if one branch of an arithmetic IF or two-branch logical IF immediately follows the IF statement. In this case, the path for this statement falls through instead of branching.

5. References to basic external functions should be consolidated whenever possible. For example:

   ```
   A = ALOG(C) + ALOG(D)
   ```

   is not as efficient as:

   ```
   A = ALOG(C*D)
   ```

6. If the executable statements in a function subprogram can be consolidated into a single assignment statement, a statement function is more efficient. Because the code for a statement function is expanded inline during compilation, the overhead associated with passing parameters, saving registers, and branching to and from the function is saved for each function reference.

7. Expressions should be factored whenever possible to reduce the number of operations required for evaluation. For example:

```
X = A*C + B*C + A*D + B*D
```

should be replaced by:

```
X = (A + B) * (C + D)
```

The first version requires four multiplications and three additions; the second requires only one multiplication and two additions.

PROGRAMMING FOR GREATER ACCURACY

The remainder of this section presents some miscellaneous ideas designed to improve the accuracy and efficiency of mathematical programs coded in FORTRAN Extended.

SUM SMALL TO LARGE

It is better to sum from small to large than from large to small. That is, when a group of numbers is to be added together, if the numbers vary widely in magnitude, a more accurate result is achieved if the smallest numbers are added first, and then the largest, rather than the other way around.

This can best be explained by an illustration. For the sake of simplicity, assume that the computer can only maintain four decimal digits of accuracy. When two numbers are added, only the four most significant digits of the result are kept, and the remainder is truncated. If the following series of numbers is to be added:

```
.00001234
.00005678
.00003121
.41610000
.21320000
```

the true result is .62940033. If the numbers are added in pairs from largest to smallest, and all but four significant digits of each result discarded, the result is .6293. If they are added from smallest to largest, the result is .6294, which is more accurate.

The explanation of this phenomenon is that, when adding from smallest to largest, because of carrying, the cumulative total of the small numbers often has one or more significant digits within the range of the larger numbers. Adding from largest to smallest, however, the total becomes very large immediately, and smaller numbers are ignored completely.

AVOID ILL-CONDITIONING

Because of the inherent properties of certain mathematical functions, precision is increasingly lost as the function approaches a certain value. In an effort to counteract this effect, programmers often use the double precision versions of the functions. However, this technique is drastically less efficient and often produces results that are less accurate. In many cases, better and faster results can be achieved by rewriting the referencing expressions and avoiding the double precision functions.

The problem arises for values of the argument for which the derivative of the function is very large. More precisely, when the following function:

$$g(x) = \frac{x\, f'(x)}{f(x)}$$

is very large, which is usually true when the derivative is very large.

For example, in the expression:

```
SQRT(1.-X**2)
```

when the value of X is very close to 1., the result of the expression tends not to be very accurate. Therefore, X is frequently declared double precision, and the expression rewritten as:

```
SNGL(DSQRT(1. - X**2))
```

However, noting that:

$$1 - X^2 = (1 - X)(1 + X)$$

The expression can be rewritten with greater accuracy as:

```
SQRT((1.+SNGL(X)) * SNGL(1.-X))
```

The amplification of relative error when the value of a function nears a certain value is a particular problem with trigonometric functions. With the tangent function, the function g(x) defined above has the value:

$$g(x) = \frac{x}{\sin(x)\cos(x)}$$

g increases without limit as x approaches any multiple of $\pi/2$ radians. When the value of x might be in this range, programmers frequently declare x double precision and compute the function as follows:

```
SNGL(DTAN(X))
```

However, greater accuracy and efficiency can be achieved by declaring x double precision and using the addition formula for tangents (since a double precision number is the sum of its upper and lower parts). The formula is as follows (where x_u is the upper word of the double precision number, and x_l is the lower word):

$$\tan(x_u + x_l) = \frac{\tan(x_u) + \tan(x_l)}{1 - \tan(x_u)\tan(x_l)}$$

Furthermore, for any number x less than 10^7, tan (x_l) is approximately the same as x_l. Therefore the formula can be rewritten as:

$$\tan(x_u + x_l) = \frac{\tan(x_u) + x_l}{1 - \tan(x_u)\, x_l}$$

or, in FORTRAN:

```
DOUBLE PRECISION X

XU = SNGL(X)

XL = X - XU

RESULT = (TAN(XU) + XL) / (1. - TAN(XU) * XL)
```

using no double precision arithmetic.

Similar substitutions can be made for sine and cosine, using the addition formulas and the information that $\sin(x_l)$ is approximately x_l, while $\cos(x_l)$ is approximately 1.0.

An even better example is the exponentiation function EXP. In this case, the larger the value of x, the larger the function g(x) defined above. The addition formula in this case is as follows:

$$\exp(x_u + x_l) = \exp(x_u) + x_l \exp(x_u)$$

or, in FORTRAN:

```
DOUBLE PRECISION X

RESULT = EXP(SNGL(X)) + (X - SNGL(X)) *
1(EXP(SNGL(X)))
```

DEBUGGING 4

Debugging can be difficult and time consuming, particularly where lengthly programs and intricate logic are involved. FORTRAN Extended and the operating systems that support it offer the programmer several features that can aid in the debugging process. By becoming familiar with these features, the amount of time involved in debugging programs can be substantially reduced.

The debugging process actually begins when the program is initially coded; a program that is well documented and has logic that is easy to follow is easier to debug than one that is not. (Refer to section 1 for a discussion of good programming practices.)

Debugging a FORTRAN program involves three steps, which can be summarized as follows:

Desk checking	The program is checked for obvious keypunch and logic errors. A simple test case can be followed through the program by hand to test the logic.
Compilation	The program is compiled using a fast compilation mode. Errors detected by the compiler are identified and corrected.
Execution	The program is executed using test cases designed to thoroughly test all aspects of the program. If possible, output should be compared with a known standard to ensure correctness.

In this section, these steps are illustrated by means of a sample program which is debugged using some of the features of FORTRAN Extended. Although the typical FORTRAN program is much longer than the sample program, portions of many longer programs often can be coded and debugged separately and the intermediate results checked. The program illustrated is program ACCTAB, which is discussed in section 2 in its final version. It is shown in figure 4-1, complete with bugs, as it might appear after initial coding.

DESK CHECKING

The programmer should examine a program for the more obvious errors before attempting to compile and execute it. Regardless of how carefully a program is desk checked, however, it might not run or even compile without errors on the first attempt. Because of this the programmer should not spend a lot of time desk checking; instead, the computer should be allowed to do as much of the debugging as possible. Even with a program as small as the sample program (figure 4-1), it is unlikely that desk checking would reveal all the bugs.

An examination of the sample program ACCTAB reveals some obvious blunders. The character . appearing in line 13 is a mispunch; the programmer intended to type a / . The compiler would have detected this particular error. On the other hand, if the character * had been punched instead of the character . , the statement would have been syntactically correct and the error not quite as obvious. In line 20, a left parenthesis should be a right parenthesis. The error in line 41 is obvious; the statement was punched starting in column 1 instead of in column 7. The compiler would have detected both of these errors.

In addition to checking for syntax errors, the programmer should examine the program for logic errors and ensure that no steps have been left out. Informative comments are helpful in verifying program logic. The comments included in ACCTAB indicate that all the necessary steps are present and in the correct logical sequence and that the flow of the program is essentially correct. Or is it? After interpolating and printing time and acceleration, the program is supposed to branch back and read the next statement; but the branch in line 48 goes back to the beginning of the program where the data for the table is read. The correct branch is to the statement labeled 190.

Although closer inspection of the program might reveal additional bugs, this illustration continues with an attempt to compile ACCTAB.

COMPILATION

The FORTRAN Extended compiler provides useful debugging information, particularly the diagnostic messages and the cross-reference map.

The following control statement is used for the first attempt at compilation of ACCTAB:

```
FTN,Q,R=3.
```

On the FTN control statement, the Q parameter specifies quick mode: the compiler performs a full syntactic scan of the source code but does not produce object code. The program cannot be executed in the absence of object code, but compilation errors would undoubtedly prevent execution anyway and Q mode compilation is substantially faster than normal compilation. For debugging purposes, compilation speed is more important than optimization of object code. When the program has been completely debugged and checked out, it will be recompiled to produce optimized object code. The R=3 parameter produces a long cross-reference map. By default, the compiler produces a list of informative and fatal diagnostics.

DIAGNOSTIC SCAN

The source listing and diagnostic messages issued during compilation of ACCTAB are shown in figure 4-2. Information provided in the diagnostic messages includes the line number where the error occurred, the severity of the error, and a brief description of the problem. In figure 4-2, two different codes appear in the severity column. Severity I indicates that the message is informative; the compiler can produce executable object code, although the results from executing the code might not be correct. As a matter of good programming practice, the programmer should try to eliminate the causes of informative diagnostics from the program. Severity code FE indicates that the error is fatal and the program cannot execute.

In figure 4-2, the first error in ACCTAB occurs in line 12, where times are being stored in the array TIME. In line 12 the array subscript is missing. The corrected line reads:

TIME(N) = T

Because the severity code is I, this error produced only a warning message. It would not have prevented the program from executing; however, it would have had catastrophic effects upon the results of the execution.

The next error is in line 18; it also has generated an informative message. The executable statement just before line 18 is an unconditional branch to statement label 100. Because the statement at line 18 has no label, there is no logical path to that statement. The correct branch is specified in line 9, but the label has been omitted from line 18. The corrected statement reads:

150 NTIMES = N

```
 1                PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
               C
                 DIMENSION TIME(10), ACC(10)
               C
 5             C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
               C
                 N = 0
                 100 READ (4,*) T, AMASS, F
                 IF (EOF(4) .NE. 0) GO TO 150
10               N = N + 1
                 IF (N .GT. 10 ) GO TO 600
                 TIME = T
                 ACC(N) = F.AMASS
                 GO TO 100
15             C
               C....PRINT ACCELERATION TABLE
               C
                 NTIMES = N
                 PRINT 10
20               PRINT 15, (TIME(I),ACC(I(,I=1,NTIMES)
               C
               C....READ A CARD CONTAINING A TIME VALUE
               C
                 190 READ (4 *) T
25               IF (EOF(4) .NE 0) GO TO 900
                 N = N + 1
               C
               C....SEARCH ACCELERATION TABLE
               C
30                 DO 200 I = 2,NTIMES
                   IT = I
                   IF (T .LE. TIME(IT)) GO TO 220
                 200   CONTINUE
                   GO TO 850
35             C
               C....DO SECOND DEGREE INTERPOLATION
               C
                 220 D1 = TIME(IT-1) - TIME(IT)
                   D2 = TIME(IT-1) - TIME(IT+1)
40                 D3 = TIME(IT) - TIME(IT+1)
               Q1 = T - TIME(IT-1)
                   Q2 = T - TIME(IT)
                   Q3 = T - TIME(IT+1)
                   ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
45                1 - Q1*Q3*ACC(IT)/(D1*D3)
                  2 + Q1*Q2*ACC(IT+1)/(D2*D3)
                   PRINT 25, T, ACCX
                   GO TO 190
               C
50               600 PRINT *, =TOO MUCH DATA. MAX NO. OF TIMES IS#
                   STOP
                 850 PRINT *, # INTERPOLATION PROBLEMS, TABLE ERROR#
                   GO TO 190
                 900 PRINT *, # END ACCTAB#
55                 STOP
               C
                  10 FORMAT (#1#,2(#        TIME      ACCEL#))
                  15 FORMAT (2(5XF7.2,2XF8.5))
                  25 FORMAT (# TIME = #,F7.2,# ACCELERATION = #,F8.5)
60                 END
```

Figure 4-1. Program ACCTAB Before Debugging

```
      1                 PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
                      C
                            DIMENSION TIME(10), ACC(10)
                      C
      5               C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
                      C
                            N = 0
                        100 READ (4,*) T, AMASS, F
                            IF (EOF(4) .NE. 0) GO TO 150
     10                     N = N + 1
                            IF (N .GT. 10 ) GO TO 600
                            TIME = T
                            ACC(N) = F/AMASS
                            GO TO 100
     15               C
                      C....PRINT ACCELERATION TABLE
                      C
                            NTIMES = N
                            PRINT 10
     20                     PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
                      C
                      C....READ A CARD CONTAINING A TIME VALUE
                      C
                        190 READ (4,*) T
     25                     IF (EOF(4) .NE. 0) GO TO 900
                            N = N + 1
                      C
                      C....SEARCH ACCELERATION TABLE
                      C
     30                       DO 200 I = 2,NTIMES
                              IT = I
                              IF (T .LE. TIME(IT)) GO TO 220
                        200   CONTINUE
                            GO TO 850
     35               C
                      C....DO SECOND DEGREE INTERPOLATION
                      C
                        220 D1 = TIME(IT-1) - TIME(IT)
                            D2 = TIME(IT-1) - TIME(IT+1)
     40                     D3 = TIME(IT) - TIME(IT+1)
                            Q1 = T - TIME(IT-1)
                            Q2 = T - TIME(IT)
                            Q3 = T - TIME(IT+1)
                            ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
     45                    1 - Q1*Q3*ACC(IT)/(D1*D3)
                           2 + Q1*Q2*ACC(IT+1)/(D2*D3)
                            PRINT 25, T, ACCX
                            GO TO 100
                      C
     50                 600 PRINT *, =TOO MUCH DATA. MAX NO. OF TIMES IS=
                            STOP
                        850 PRINT *, = INTERPOLATION PROBLEMS, TABLE ERROR=
                            GO TO 100
                        900 PRINT *, = END ACCTAB=
     55                     STOP
                      C
                         10 FORMAT (=1=,2(=        TIME     ACCEL=))
                         15 FORMAT (2(5XF7.2,2XF8.5))
                         25 FORMAT (= TIME = =,F7.2,= ACCELERATION = =,F8.5)
     60                  END

CARD NR. SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

      12    I      TIME       ARRAY NAME OPERAND NOT SUBSCRIPTED, FIRST ELEMENT WILL BE USED.
      18    I                 THERE IS NO PATH TO THIS STATEMENT.
      24    FE     *          SYNTAX ERROR IN INPUT/OUTPUT STATEMENT.
      25    FE     NEC        INVALID USE OF A CHARACTER STRING.
      25    FE     (          UNMATCHED PARENTHESIS.
      33    FE                UNRECOGNIZED STATEMENT.
      50    FE     TOOMUCHD   SYMBOLIC NAME HAS TOO MANY CHARACTERS.
      60    FE                UNDEFINED STATEMENT LABEL(S), SEE LIST BELOW.

        UNDEFINED LABELS
          150
```

Figure 4-2. Example after Desk Checking, with Diagnostics

The error in line 24 is a fatal error: a comma is missing from the READ statement. The corrected statement reads:

```
190 READ (4,*) T
```

The statement at line 25 has generated two fatal diagnostics. Neither states explicitly what the problem is. It often happens that error messages appear to have little relation to the errors that caused them. In such cases, it is sometimes necessary for the programmer to use some imagination in determining the cause of the diagnostic. In the example, it is easily seen that a period is missing from the .NE. operator. This is clear from reading the FORTRAN statement but not from reading the error message.

In line 38, the character = was mispunched as the - character. The compiler could not recognize the statement and generated a fatal error. The corrected line reads:

```
220 D1 = TIME(I-1) - TIME(I)
```

If the statement had been mispunched with two equal signs instead of two minus signs as follows:

```
220 D1 = TIME(I-1) = TIME(I)
```

it would have been interpreted as a multiple replacement statement, and no diagnostic would have been generated.

The message referring to line 50 appears to have little relation to the actual error. The opening ≠ of the character string was mispunched as an =. Once again, the message gives little clue as to what is wrong with the statement; however, it does indicate that something is wrong. If the programmer is unable to determine the specific error from the text of the message, the statement should be checked for syntax errors.

The last message refers to a list of undefined labels. A statement appearing in this list has been referenced in a GO TO or other branching statement, but does not appear as a statement label anywhere in the program. In locating the cause of this error, the programmer can make use of the cross-reference map.

CROSS-REFERENCE MAP

The cross-reference map (figure 4-3) is a list of all symbols used in the program, with the properties of each symbol and the references to each symbol listed by source line number. It can be used to detect errors that do not show up as compilation errors. A typical listing is that for the variable ACC; the map shows that it is located at address 12_8 relative to the starting address of the program; is of type real; is an array; is referenced once in line 3, twice in line 20, and three times in line 44; and appears to the left of an = in line 13.

For debugging purposes, it is useful to look at the column under the heading SN. A stray name flag appears under SN if the symbol appears only once in the program. Such symbols are likely to be keypunch errors, misspellings, and the like. In figure 4-3, the variables D1 and DI both have stray name flags. Also, they are both undefined; that is, they do not appear to the left of an = , in a common block, in an argument list, in an input statement, in an ASSIGN statement or in a DATA statement. Both variables are referenced in line 44. Apparently DI is a misspelling of D1. The attempt to define D1, in line 38, failed because that statement contained an error.

The EXTERNALS section of the reference map lists names of functions and subroutines called from the program. The programmer should check this section to make sure all function and subroutine references are correct. The external names appearing in ACCTAB are EOF (the FORTRAN function that tests for end-of-file) and TINE. TINE is referenced in line 32 and appears to be a misspelling of the array TIME. An error message has not been generated, because the compiler has no way of knowing what functions and subroutines will be loaded at execution time. This error is left uncorrected to illustrate its effect on further attempts to execute ACCTAB.

The last section of the cross-reference map lists each label used in the program, the line numbers in which the label is referenced, and the line where the label is defined. Statement label 150 is referenced in line 9 of ACCTAB, but does not appear as a statement label. This error, as previously noted, is corrected by inserting the label in line 18. This section of the map is also useful in locating duplicate labels: a statement label defined in more than one line generates a fatal error.

The corrected source listing is shown in figure 4-4.

EXECUTION TIME DEBUGGING

Errors detected during the execution of a program can cause abnormal termination or produce incorrect results. The standard dump (DMPX), load map, and the FORTRAN Extended debugging facility can help the programmer determine the causes of execution-time errors.

With all I and FE compilation errors presumably corrected, ACCTAB is ready for another compilation attempt. This time it is anticipated that the program will compile without errors and produce executable object code. Because the program is still in the testing phase, a compilation mode resulting in quick compilation but unoptimized object code is used; the input data is included in the deck.

The program is then compiled with the following control statement:

```
FTN,R=3,OPT=0.
```

When OPT=0 is specified in the control statement, the ER option is implied. When this option is specified and an execution-time error is detected, the approximate line number in the source program where the error occurred is printed in the dayfile. When OPT=1 or OPT=2 is specified, the default is ER=0. The T option is also implied when OPT=0 is specified; this option produces a full error traceback when an execution-time error is detected.

An important consideration in execution-time debugging is the use of test data. The programmer should design one or more test cases that completely test the program, including all options and all possible paths through the logic. It is frequently a good idea to include data that tests the limits of acceptable values. The programmer should determine what data causes execution errors or incorrect results, and then either correct the program or include program statements to check for invalid data.

Once satisfactory test data has been selected, the results must still be verified. Verification can be performed by comparing the results to a known standard, or, if none is available, by comparing to hand calculations.

```
      SYMBOLIC REFERENCE MAP (R=3)

ENTRY POINTS      DEF LINE      REFERENCES
     C  ACCTAB          1

VARIABLES     SN  TYPE            RELOCATION
    12  ACC       REAL        ARRAY                 REFS        3        25       3*44   DEFINED       13
    70  ACCX      REAL                              REFS       47   DEFINED       44
    56  AMASS     REAL                              REFS       13   DEFINED        8
    71  DI      * REAL        *UNDEF                REFS       44
    72  D1      * REAL        *UNDEF                REFS       44
    63  D2        REAL                              REFS     2*44   DEFINED       39
    64  D3        REAL                              REFS     2*44   DEFINED       40
    57  F         REAL                              REFS       13   DEFINED        8
    61  I         INTEGER                           REFS     2*20        31   DEFINED       20       36
    62  IT        INTEGER                           REFS       32      2*39      2*40       41       42       43       3*44
                                                  DEFINED       31
    54  N         INTEGER                           REFS       10        11       13       18       26
                                                  DEFINED        7        10       26
    66  NTIMES    INTEGER                           REFS       20        30   DEFINED       18
    65  Q1        REAL                              REFS     2*44   DEFINED       41
    66  Q2        REAL                              REFS     2*44   DEFINED       42
    67  Q3        REAL                              REFS     2*44   DEFINED       43
    55  T         REAL                              REFS       12        32       41       42       43       47
                                                  DEFINED        8
     C  TIME      REAL        ARRAY                 REFS        3        20      2*39      2*40       41       42       43
                                                  DEFINED       12

FILE NAMES        MODE
     C  INPUT
 20054  OUTPUT    MIXED                  WRITES       19        20        47       52       54
     C  TAPE4     FREE                    READS        8        24
EXTERNALS           TYPE    ARGS       REFERENCES
        EOF       REAL       1              9
        TINE      REAL       1             32

STATEMENT LABELS              DEF LINE    REFERENCES
    34  10      FMT               57          19
    41  15      FMT               58          20
    44  25      FMT               59          47
     C  100                        8          14
     C  150   *UNDEF                           9
     C  190                       24          48        53
400010  200                       33          30
     C  220                       38          32
     C  600                       50          11
     C  850                       52          34
     C  900          INACTIVE     54

STATISTICS
  PROGRAM LENGTH                    20B       C
        52000B CM USED
```

Figure 4-3. Cross-Reference Map

```
      PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
C
      DIMENSION TIME(10), ACC(10)
C
C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
C
      N = 0
  100 READ (4,*) T, AMASS, F
      IF (EOF(4) .NE. 0) GO TO 150
      N = N + 1
      IF (N .GT. 10 ) GO TO 600
      TIME(N) = T
      ACC(N) = F/AMASS
      GO TO 100
C
C....PRINT ACCELERATION TABLE
C
  150 NTIMES = N
      PRINT 10
      PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
C
C....READ A CARD CONTAINING A TIME VALUE
C
  190 READ (4,*) T
      IF (EOF(4) .NE. 0) GO TO 900
      N = N + 1
C
C....SEARCH ACCELERATION TABLE
C
        DO 200 I = 2,NTIMES
        IT = I
        IF (T .LE. TIME(IT)) GO TO 220
  200   CONTINUE
      GO TO 850
C
C....DO SECOND DEGREE INTERPOLATION
C
  220 D1 = TIME(IT-1) - TIME(IT)
      D2 = TIME(IT-1) - TIME(IT+1)
      D3 = TIME(IT) - TIME(IT+1)
      Q1 = T - TIME(IT-1)
      Q2 = T - TIME(IT)
      Q3 = T - TIME(IT+1)
      ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
     1 - Q1*Q3*ACC(IT)/(D1*D3)
     2 + Q1*Q2*ACC(IT+1)/(D2*D3)
      PRINT 25, T, ACCX
      GO TO 190
C
  600 PRINT *, # TOO MUCH DATA. MAX NO. OF TIMES IS 10#
      STOP
  850 PRINT *, # INTERPOLATION PROBLEMS, TABLE ERROR#
      GO TO 190
  900 PRINT *, # END ACCTAB#
      STOP
C
   10 FORMAT (#1#,2(#        TIME      ACCEL#))
   15 FORMAT (2(5XF7.2,2XF8.5))
   25 FORMAT (# TIME = #,F7.2,# ACCELERATION = #,F8.5)
      END
```

Figure 4-4. Example with Compilation Errors Corrected

The data shown in figure 4-5 is used to check out ACCTAB. The first data card results in a zero acceleration value; the second card introduces a zero into the acceleration calculation; the fifth card is a duplicate of the fourth. The second set of data consists of selected times for which the table search is performed. The first time corresponds to the lower limit of the table; the second time corresponds to a discrete point in the table; the third time causes the duplicate point to be used in an interpolation; the fourth time is below the lower limit of the table; the fifth and sixth times require interpolation to be performed; the seventh time corresponds to the last point in the table; and the last time exceeds the upper limit of the table.

DMPX AND LOAD MAP

The dayfile from the first test with data is shown in figure 4-6. This time, ACCTAB compiles without errors, is loaded and executed, but terminates with errors. A nonfatal loader error was detected. Because the error was nonfatal, the program went into execution and subsequently terminated with an arithmetic mode 1 error. Mode 1 errors are generated when the computer detects an address outside the field length reserved for the program. The computer tried to reference address 404334_8, which is outside the field length of ACCTAB. The load map (figure 4-7) shows that ACCTAB was loaded at address 111_8 with a last word address (LWA) of 20447. The error summary on the map states that ACCTAB references a function or subroutine called TINE, which could not be found by the loader. As previously noted, the EXTERNALS section of the cross-reference map indicates that TINE is referenced in line 32, where TINE is a misspelling of the array TIME. A dayfile message also specifies line 32 as the location of the arithmetic mode error. This message results from the ER option.

More information can be obtained from the object listing and the DMPX listing (figure 4-8). A DMPX listing is produced automatically when a program terminates abnormally. The DMPX consists of the contents of the hardware registers, the exchange package, the first 100_8 words of the program field length, and 200_8 words of memory centered on the instruction the central processor was executing when the error was detected.

The machine instructions associated with line 32 of the source listing are shown in figure 4-9. This listing was generated through the OL (object listing) control statement option. FORTRAN Extended generates an RJT (return jump) instruction to branch to an external entry point. In this case, the jump is to entry point TINE. This instruction occurs at relative address 4222. To locate this instruction in the dump, the relative address of the instruction must be added to the first word address (FWA) of the program:

```
 4222
  111
 4333
```

The instruction appearing at this address in the DMPX listing is:

```
0100404333
```

This is a return jump to address 404333, an illegal address generated by the loader when it was unable to locate the nonexistent entry point. Because the address is outside the program's field length, a mode 1 diagnostic was issued.

Program debugging continues with a correction of the misspelling, and rerunning of ACCTAB. The dayfile (figure 4-10) reveals that a mode 2 error was detected during execution. To determine the cause of this error, the FORTRAN debugging facility is used.

```
0. 100. 0.
1. 0. 1000.
2. 100. 1010.
3. 100. 1020.
3. 100. 1020.
4. 100. 1030.
5. 100. 1040.
0.
1.
-1.
2.5
3.5
4.5
5.
5.5
```

Figure 4-5. Test Data for ACCTAB

DEBUGGING FACILITY

FORTRAN Extended provides a debugging facility to monitor the execution of a program. (Refer to the FORTRAN Extended Reference Manual for a detailed description of the facility.) The debugging facility consists of statements that are included in the source input file and processed by the compiler. The statements can be interspersed with the FORTRAN source statements, or they can be included separately as an external deck. This allows debugging of portions of a program, or of individual subroutines, as well as the entire source file. In debug mode, programs execute regardless of compilation errors (up to a limit of 100 errors), but execution terminates when a fatal error is detected. Hence, the debug facility is useful in locating both compilation and execution-time errors. Debug output is written by default to a file named DEBUG. By equivalencing DEBUG to OUTPUT, the output can be interspersed with program output.

Because ACCTAB is being run and debugged for the first time, and no debugged program units are included in the source file, an external debug deck is used; the debug statements apply to the entire program. Debug statements are included to provide information about the arrays ACC and TIME. The job deck is shown in figure 4-11.

The D parameter on the FTN control statement implies debug mode. The debug deck performs the following:

Checks bounds for arrays TIME and ACC; prints a message if array bounds are exceeded

Prints a message each time the value of an element of T or ACC changes

The NOGO statement suppresses partial execution if compilation errors are detected.

The dayfile in figure 4-10 states that an infinite value is used near line 44 of the source listing. This is an arithmetic mode 2 error. Infinite operands are usually generated by dividing a nonzero number by zero, or by an addition, subtraction, multiplication whose result is greater than

10^{322}. Line 38 is the first line of the interpolation scheme. One of the variables used in the equation contains an infinite value (a value of $37770\ldots0_8$); however, it is not clear which variable contains the infinite value.

The debug file (figure 4-12) reveals that the second value stored into the array ACC was infinite, indicated by R. It is likely that this value, when used in the interpolation calculation, caused the program to terminate with a mode 2 error. Referring to line 13 of figure 4-4, where values are stored into array ACC, one might suspect that a division by zero occurred here. This is verified by recalling that the second data card contains a zero, which is subsequently stored into the variable AMASS. Notice that the program terminates only when the infinite value is used, not when it is generated. If the program were executed on a CYBER 70 Model 76 or 7000 series computer, the mode error would occur when the infinite value was generated. Figure 4-13 shows that coding has been inserted to test variable AMASS for a zero or negative value and to print a message if zero is detected.

For the next debugging step the data card containing the zero value is removed from the deck and ACCTAB is run again. The dayfile is shown in figure 4-14. An infinite value has again been used, near line 47. To determine the source of this infinite value, the following debug statement is used:

```
C$    STORES (D1,D2,D3,Q1,Q2,Q3)
```

This statement produces a printout of the intermediate values used in the interpolation scheme. These values can be useful in tracing the progress of the program. The resulting debug output, interspersed with program output, is shown in figure 4-15.

The debug file reveals that the last value stored in variable D3 was zero. D3 is calculated in line 43. If the two consecutive times used in the calculation are equal, the result is zero. Recall that a duplicate time point was included in the data for the acceleration table. A debug statement to print out values of the array TIME could be used to verify that the duplicate point caused the error. The coding to test for duplicate points is indicated in figure 4-16.

The output from the next run is shown in figure 4-17. Some of the acceleration values are correct, but accelerations corresponding to points outside the table limits are not printed. Also, the input time corresponding to the upper limit of the table does not appear.

An examination of the dayfile reveals that this run terminated with a mode 2 error. Although the program processed some input times correctly, it cannot process extreme values. This illustrates the importance of test data that includes such values. In figure 4-18, statements have been inserted in ACCTAB to process times that fall outside the table limits or coincide with the end points.

The output from the next run is shown in figure 4-19. The table has been generated correctly and hand calculations verify that the interpolations are correct. The two points falling outside the limits of the table, whose values are -1. and 5.5, have been detected. The program can now be considered debugged. Of course, there are numerous improvements that can be made to ACCTAB, and it is possible that future use will reveal more bugs.

The program should now be recompiled with the following control statement to produce optimized object code.

```
FTN,OPT=2.
```

```
16.16.15.FTST2UY  FROM    /C6
16.16.15.IP  00000576 WORDS - FILE INPUT  , DC 04
16.16.15.FTST2,T5,P4.
16.16.22.FTN,R=3,OPT=0,OL.
16.16.25.       .416 CP SECONDS COMPILATION TIME
16.16.25.LGO.
16.16.31.      NON-FATAL LOADER ERRORS - SEE MAP
16.16.32.MODE ERROR
16.16.32.JOB REPRIEVED
16.16.32. UNSATISFIED EXT IN ACCTAB  NEAR LINE 32
16.16.32.
16.16.32.       .027 CP SECONDS EXECUTION TIME
16.16.32. (PREVIOUS ERROR CONDITION RESET)
16.16.32.ERROR MODE =01.  ADDRESS =404334
16.16.33.OP  00005696 WORDS - FILE OUTPUT , DC 40
16.16.33.MS    7168  WORDS  (   25088 MAX USED)
16.16.33.CPA       1.196 SEC.         1.185 ADJ.
16.16.33.CPB        .171 SEC.          .171 ADJ.
16.16.33.IO        1.190 SEC.         1.190 ADJ.
16.16.33.CM       40.043 KWS.         2.443 ADJ.
16.16.33.SS                           4.991
16.16.33.PP        6.954 SEC.      DATE 10/24/77
16.16.33.EJ  END OF JOB, C6
```

Figure 4-6. Dayfile Showing Loader Errors and Mode 1 Errors

```
LOAD MAP - ACCTAB                                CYBER LOADER 1.3-460        12/24/77  16.16.31.      PAGE      1


FWA OF THE LOAD              111
LWA+1 OF THE LOAD          20447

TRANSFER ADDRESS -- ACCTAB             4247


********* ERROR SUMMARY

 NE4100///  UNSATISFIED EXTERNAL REF -- TINE


PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK        ADDRESS    LENGTH     FILE      DATE      PROCSSR VER LEVEL  HARDWARE    COMMENTS

ACCTAB           111      4453     LGO       12/24/77 FTN      4.6 460     666X I      PROGRAM   OPT=0 TRACE
/STP.END/       4564         1
/FCL.C./        4565        20
/Q8.IO./        4613       141
Q8NTRY=         4754         3 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   FCL INITIALIZATION ROUTINE.
COMIO=          4757        64 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   COMMON CODED I/O ROUTINES AND CONSTANTS.
EOF             5043        16 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   TEST FOR END OF FILE STATUS.
FLTIN=          5061       156 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   COMMON FLOATING INPUT CONVERTER.
FMTAP=          5237       356 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   CRACK APLIST AND FORMAT FOR KODER/KRAKER.
FORUTL=         5615        46 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   FCL MISC. UTILITIES.
FTNRPV=         5663       164 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   FORTRAN REPRIEVE.
INCOM=          6047       302 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   COMMON INPUT FORMATTING CODE
INPF=           6351       203 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LIST DIRECTED INPUT CONTROL
KODER=          6554       460 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   OUTPUT FORMAT INTERPRETER.
LDIN=           7234       260 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LIST DIRECTED INPUT FORMATTING
OUTCOM=         7514       154 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   COMMON OUTPUT CODE
FECMSK=         7670        41 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   INITIALIZE CONSTANTS.
FLTOUT=         7731       311 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   COMMON FLOATING OUTPUT CODE
FORSYS=        10242       611 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   FORTRAN OBJECT LIBRARY UTILITIES.
GETFIT=        11053        42 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LOCATE AN FIT GIVEN A FILE NAME.
LDOUT=         11115       241 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LIST DIRECTED OUTPUT FORMATTING
OUTC=          11356       156 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   FORMATTED WRITE FORTRAN RECORD.
OUTF=          11534       155 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LIST DIRECTED OUTPUT CONTROL
SYSAID=        11711         1 SL-FORTRAN   09/20/77 COMPASS 3.4 460                   LINK BETWEEN SYS=AID AND INITIALIZATION CODE.
/CON.RM/       11712         6
CIO.RM         11720        46 SL-SYSIO     09/20/77 COMPASS 3.4 460
/ACB.RM/       11766        10
MOVE.RM        11776        66 SL-SYSIO     09/20/77 COMPASS 3.4 460
MCT.RM         12056       233 SL-SYSIO     09/20/77 COMPASS 3.4 460
/JMPS.RM/      12311        11
/MEMC.RM/      12322         3
```

Figure 4-7. Load Map (Sheet 1 of 2)

```
LOAD MAP - ACCTAB                          CYBER LOADER 1.3-460      12/24/77  16.16.31.      PAGE      2


/OPES.FO/      12325        1
/OPEN.FO/      12326        7
OPEN.RM        12335      236 SL-SYSIO     09/20/77 COMPASS 3.4 460
/TERM.RM/      12573        1
/PUT.FO/       12574        7
PUT.SQ         12603     1477 SL-SYSIO     09/20/77 COMPASS 3.4 460
WAR.SQ         14302      303 SL-SYSIO     09/20/77 COMPASS 3.4 460
/CLSF.FO/      14605        7
CLSF.RM        14614       22 SL-SYSIO     09/20/77 COMPASS 3.4 460
/GET.BT/       14636        5
BTRT.SQ        14643      115 SL-SYSIO     09/20/77 COMPASS 3.4 460
WEOX.SQ        14760      150 SL-SYSIO     09/20/77 COMPASS 3.4 460
/SKFL.FO/      15130        7
SKFL.SQ        15137       51 SL-SYSIO     09/20/77 COMPASS 3.4 460
SYS.RM         15210       40 SL-SYSIO     08/31/77 COMPASS 3.4 460          PROCESS SYSTEM REQUEST.
ERR.RM         15250      406 SL-SYSIO     09/20/77 COMPASS 3.4 460
CHWR.SQ        15656        7 SL-SYSIO     09/20/77 COMPASS 3.4 460
OSUB.RM        15665       71 SL-SYSIO     09/20/77 COMPASS 3.4 460
OPEN.SQ        15756      305 SL-SYSIO     09/20/77 COMPASS 3.4 460
OPEX.SQ        16263       14 SL-SYSIO     09/20/77 COMPASS 3.4 460
/PUT.RT/       16277       11
RLEQ.RM        16310       43 SL-SYSIO     09/20/77 COMPASS 3.4 460
CLSF.SQ        16353      136 SL-SYSIO     09/20/77 COMPASS 3.4 460
/CLSV.FO/      16511        7
CLSV.SQ        16520      137 SL-SYSIO     09/20/77 COMPASS 3.4 460
/REW.FO/       16657        7
REW.SQ         16666       42 SL-SYSIO     09/20/77 COMPASS 3.4 460
/GET.FO/       16730        7
/RPAR.XX/      16737        1
/GET.RT/       16740       11
GET.SQ         16751     1070 SL-SYSIO     09/20/77 COMPASS 3.4 460
Z.SQ           20041      110 SL-SYSIO     09/20/77 COMPASS 3.4 460
FSU.SQ         20151      110 SL-SYSIO     09/20/77 COMPASS 3.4 460
RECOVR         20261      166 SL-SYSLIB    09/01/77 COMPASS 3.4 460          REPRIEVE INTERFACE


     .814 CP SECONDS              347000B CM STORAGE USED                 36 TABLE MOVES
```

Figure 4-7. Load Map (Sheet 2 of 2)

```
DMPX.

 P.  000000   A0  020500   B0  000000
 RA  236200   A1  004422   B1  000001    C(A1)=  0000  0000  0006  0000  4514    C(B1)=  0000  0000  0000  0000  0000
 FL  020500   A2  005044   B2  000000    C(A2)=  0000  0000  0000  0002  0500    C(B2)=  0001  4043  3400  0000  0000
 EM  000700   A3  011114   B3  000000    C(A3)=  2401  2005  0000  0000  0000    C(B3)=  0001  4043  340C  0000  0000
 RE  000050   A4  000004   B4  000000    C(A4)=  2401  2005  3700  0000  0111    C(B4)=  0001  4043  340C  0000  0000
 FE  000000   A5  004513   B5  006462    C(A5)=  0000  0000  000C  0000  0002    C(B5)=  7405  0767  6043  3521  5773
 MA  001400   A6  004651   B6  777765    C(A6)=  2000  0002  7777  6500  4620    C(B6)=
              A7  004514   B7  000000    C(A7)=  0000  0000  0000  0000  0002    C(B7)=  0001  4043  340C  000C  0000
 X0  CCCC  0000  0000  0000  0001
 X1  0000  0000  0000  0000  4514
 X2  0000  0000  0000  0002  0500
 X3  0000  0006  0000  0000  0001
 X4  2401  2005  3700  0000  0111
 X5  0000  0000  0000  0000  0002
 X6  0000  0000  0000  000C  0006
 X7  CCCC  0000  0000  0000  0002

   00000   00014 04334 00000 00000      00000 00000 00000 00000      11162 02524 00000 00111      17252 42025 24000 02165
   00004   24012 00537 00000 00111      00000 00000 00000 00000
   00054  -56110 03110 00054 54710      51100 00001 03110 00055      64550 02550 00000 46000      00000 00000 00000 00000
   00060   15051 52000 00000 00061      00000 20500 00000 00001      07040 00006 51600 00001      04000 00063 00000 00021
   00064   14071 70000 00000 00000      00000 00000 00000 20447      40000 00000 02000 00111      01000 00000 40000 00000
   00070   14071 75700 00000 00000      00000 00000 00000 00000
   00100  -54000 00000 01006 00001

   04234   40000 00000 00000 04234      40000 00000 00000 04235      40000 00000 00000 04236      40000 00000 00000 04237
   04240   40000 00000 00000 04240      00000 22600 00000 04617
   04244  -77777 77777 77776 36257      01030 32401 02550 04247      01027 77460 61020 04245      51100 04241 01000 05663
   04250   61020 00007 43700 46000      51700 04506 46000 46000      61020 00010 46000 46000      51160 04424 46000 46000
   04254   01000 06374 00100 04245      61020 00011 51100 04420      01000 0504E 00110 04245      03160 04275 46000 46000
   04260   61020 00012 51500 04506      71000 00001 36705 54750      01020 00013 51500 04506      71000 00012 43700 37605
   04264   36076 03300 04403 46000      61020 00014 51500 04507      51400 04506 10755 46000      52740 04523 46000 46000
   04270   61020 00015 51500 04511      51400 04510 51300 04506      44754 52730 04535 46000      01020 00016 04000 04253
   04274   61020 00022 46000 46000      51500 04506 10755 46000      51700 04512 46000 46000      01020 00023 51100 04432
   04300   01000 11373 00230 04245      61020 00024 51100 04435      01000 11373 00240 04245      71700 00001 51700 04513
   04304   51500 04513 71000 00003      72750 04523 20060 12607      72450 04535 51600 04440      12704 51700 04441 54160
   04310   01000 11462 46000 46000      51500 04513 51400 04512      72750 00001 37047 54750      03200 04304 46000 46000
   04314   61020 00024 51100 04443      01000 11462 46000 46000      01020 00030 46000 46000      51100 04444 46000 46000
   04320   01000 06374 00300 04245      61020 00031 51100 04420      01000 0504E 00310 04245      03160 04414 46000 46000
   04324   61020 00032 51500 04506      71000 00001 36705 54750      01020 00036 71700 00002      51700 04513 46000 46000
   04330   61020 00037 51500 04513      10755 51700 04514 46000      61020 00040 51100 04422      01004 04333 00400 04245
   04334   51500 04507 31065 24700      03270 04343 46000 46000      61020 00041 51500 04513      51400 04512 72750 00001
   04340   37047 54750 03200 04330      61020 00042 04000 04410      01020 00046 46000 46000      51500 04514 52450 04522
   04344   52350 04523 31043 24700      51700 04515 46000 46000      61020 00047 51500 04514      52450 04522 52350 04524
   04350   31043 24700 51700 04516      61020 00050 51500 04514      52450 04523 52350 04524      31043 24700 51700 04517
   04354   61020 00051 51500 04514      51400 04507 52350 04522      31043 24700 51700 04520      61020 00052 51500 04514
   04360   51400 04507 52350 04523      31043 24700 51700 04521      61020 00053 51500 04514      51400 04507 52350 04524
   04364   31043 24700 51700 04522      61020 00054 51500 04515      51400 04516 51300 04517      51200 04514 51100 04521
   04370   40045 40734 51400 04522      40635 52520 04534 44350      52520 04536 52220 04535      44057 51500 04520 40741
   04374   40151 40454 40537 40701      30375 44026 24603 40204      31762 24607 51600 04523      01020 00057 51100 04450
   04400   01000 11373 00570 04245      61020 00060 04000 04317      61020 00062 46000 46000      51100 04455 46000 46000
   04404   01000 11550 00620 04245      61020 00063 51100 04505      04000 10271 46000 46000      01020 00064 46000 46000
   04410   51100 04460 46000 46000      01000 11550 00640 04245      61020 00065 04000 04317      01020 00066 46000 46000
   04414   51100 04463 46000 46000      01000 11550 00660 04245      61020 00067 51100 04505      04000 10271 46000 46000
   04420   00000 00000 00000 04504      00000 00000 00000 00000      00000 00000 00000 04514      00000 00000 00000 00000
   04424   00000 00000 00000 00111      00000 00000 00000 04255      00030 00000 01000 04507      00030 00000 01000 04510
   04370   40045 40734 51400 04522      40635 52520 04534 44350      52520 04536 52220 04535      44057 51500 04520 40741
   04374   40151 40454 40537 40701      30375 44026 24603 40204      31762 24607 51600 04523      01020 00057 51100 04450
   04400   01000 11373 00570 04245      61020 00060 04000 04317      01020 00062 46000 46000      51100 04455 46000 46000
   04404   01000 11550 00620 04245      61020 00063 51100 04505      04000 10271 46000 46000      61020 00064 46000 46000
   04410   51100 04460 46000 46000      01000 11550 00640 04245      61020 00065 04000 04317      01020 00066 46000 46000
   04414   51100 04463 46000 46000      01000 11550 00660 04245      01020 00067 51100 04505      04000 10271 46000 46000
   04420   00000 00000 00000 04504      00000 00000 00000 00000      00000 00000 00000 04514      00000 00000 00000 00000
   04424   00000 00000 00000 00111      00000 00000 00000 04255      00030 00000 01000 04507      00030 00000 01000 04510
```

Figure 4-8. DMPX

```
                                        *                          LINE   32
004221 CODE.    6102000040              +          SB0    B2+40B
                        5110004311 CODE.           SA1    LAP3
004222 CODE.    0101000000          <EXT>  +       RJT    TIME,40B
                        0040004134
```

Figure 4-9. Object Listing (Partial)

```
10.32.26.FTST397  FROM     /C6
10.32.27.IP  00000512 WORDS - FILE INPUT  , DC 04
10.32.27.FTST3,T5,P4.
10.32.31.FTN,D,R=3.
10.32.35.       .455 CP SECONDS COMPILATION TIME
10.32.36.LGO.
10.32.41.MODE ERROR
10.32.41.JOB REPRIEVED
10.32.41.  INFINITE VALUE IN ACCTAB  NEAR LINE 44
10.32.41.
10.32.41.       .051 CP SECONDS EXECUTION TIME
10.32.41. (PREVIOUS ERROR CONDITION RESET)
10.32.41.ERROR MODE =02.  ADDRESS =004470
10.32.42.OP  00002880 WORDS - FILE OUTPUT , DC 40
10.32.42.MS     3584  WORDS  (   25088 MAX USED)
10.32.42.CPA       1.133 SEC.         1.133 ADJ.
10.32.42.CPB        .329 SEC.          .329 ADJ.
10.32.42.IO        1.278 SEC.         1.278 ADJ.
10.32.42.CM       50.998 KWS.         3.106 ADJ.
10.32.42.SS                           5.846
10.32.42.PP        7.844 SEC.      DATE 10/26/77
10.32.42.EJ  END OF JOB, C6
```

Figure 4-10. Dayfile Showing Mode-2 Error

```
Job statement
FTN,D,R=3.
LGO.
7/8/9
CS     DEBUG
CS     ARRAYS
CS     STORES (ACC,TIME)
CS     NOGO
    FORTRAN source statements
7/8/9
    Data
6/7/8/9
```

Figure 4-11. Sequence of Debug Statements

```
/DEBUG/  ACCTAB  AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS  0.
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS  0.
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   1.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS                  R
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   2.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS   10.10000000
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   3.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS   10.20000000
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   3.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS   10.20000000
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   4.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS   10.30000000
/DEBUG/          AT LINE   12- THE NEW VALUE OF THE VARIABLE TIME     IS   5.000000000
/DEBUG/          AT LINE   13- THE NEW VALUE OF THE VARIABLE ACC      IS   10.40000000
```

Figure 4-12. Debug Output Showing Array Contents

```
      PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT,DEBUG=OUTPUT)
C
      DIMENSION TIME(10), ACC(10)
C
C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
C
      IER = 0
      N = 0
  100 READ (4,*) T, AMASS, F
      IF (EOF(4) .NE. 0) GO TO 150
      N = N + 1
      IF (N .GT. 10 ) GO TO 600
      IF (AMASS .LE. 0.) GO TO 700
      TIME(N) = T
      ACC(N) = F/AMASS
      GO TO 100
C
C....PRINT ACCELERATION TABLE
C
  150 NTIMES = N
      PRINT 10
      PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
      IF (IER .NE. 0) GO TO 900
C
C....READ A CARD CONTAINING A TIME VALUE
C
  190 READ (4,*) T
      IF (EOF(4) .NE. 0) GO TO 900
      N = N + 1
C
C....SEARCH ACCELERATION TABLE
C
        DO 200 I = 2,NTIMES
        IT = I
        IF (T .LE. TIME(IT)) GO TO 220
  200   CONTINUE
      GO TO 850
C
C....DO SECOND DEGREE INTERPOLATION
C
  220 D1 = TIME(IT-1) - TIME(IT)
      D2 = TIME(IT-1) - TIME(IT+1)
      D3 = TIME(IT) - TIME(IT+1)
      Q1 = T - TIME(IT-1)
      Q2 = T - TIME(IT)
      Q3 = T - TIME(IT+1)
      ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
     1 - Q1*Q3*ACC(IT)/(D1*D3)
     2 + Q1*Q2*ACC(IT+1)/(D2*D3)
      PRINT 25, T, ACCX
      GO TO 190
C
  600 PRINT *, * TOO MUCH DATA. MAX NO. OF TIMES IS 10*
      STOP
  700 PRINT *, *INVALID VALUE FOR AMASS *, N
      IER = 1
      GO TO 100
  850 PRINT *, * INTERPOLATION PROBLEMS, TABLE ERROR*
      GO TO 190
  900 PRINT *, * END ACCTAB*
      STOP
C
   10 FORMAT (*1*,2(*        TIME     ACCEL*))
   15 FORMAT (2(5XF7.2,2XF8.5))
   25 FORMAT (* TIME = *,F7.2,* ACCELERATION = *,F8.5)
      END
```

Figure 4-13. Example with Zero Value Test

```
15.59.17.FTST4PV  FROM     /C6
15.59.18.IP  00000576 WORDS - FILE INPUT  , DC 04
15.59.18.FTST4,T5,P4.
16.02.42.FTN,D,R=3.
16.06.13.       .415 CP SECONDS COMPILATION TIME
16.06.13.LGO.
16.06.29.MODE ERROR
16.06.29.JOB REPRIEVED
16.06.29. INFINITE VALUE IN ACCTAB  NEAR LINE 47
16.06.29.
16.06.29.       .064 CP SECONDS EXECUTION TIME
16.06.30. (PREVIOUS ERROR CONDITION RESET)
16.06.30.ERROR MODE =02.  ADDRESS =004417
16.06.30.OP  00002944 WORDS - FILE OUTPUT , DC 40
16.06.30.MS     3584  WORDS  (   25088 MAX USED)
16.06.30.CPA       1.112 SEC.         1.112 ADJ.
16.06.30.CPB        .302 SEC.          .302 ADJ.
16.06.30.IO        1.265 SEC.         1.265 ADJ.
16.06.30.CM       49.567 KWS.         3.025 ADJ.
16.06.30.SS                           5.705
16.06.30.PP        9.352 SEC.      DATE 10/26/77
16.06.30.EJ  END OF JOB, C6
```

Figure 4-14. Dayfile Showing Mode 2 Error

```
/DEBUG/  ACCTAB  AT LINE   41- THE NEW VALUE OF THE VARIABLE D1      IS  -2.000000000
/DEBUG/          AT LINE   42- THE NEW VALUE OF THE VARIABLE D2      IS  -3.000000000
/DEBUG/          AT LINE   43- THE NEW VALUE OF THE VARIABLE D3      IS  -1.000000000
/DEBUG/          AT LINE   44- THE NEW VALUE OF THE VARIABLE Q1      IS  0.
/DEBUG/          AT LINE   45- THE NEW VALUE OF THE VARIABLE Q2      IS  -2.000000000
/DEBUG/          AT LINE   46- THE NEW VALUE OF THE VARIABLE Q3      IS  -3.000000000
TIME =    0.00 ACCELERATION =  0.00000
/DEBUG/  ACCTAB  AT LINE   41- THE NEW VALUE OF THE VARIABLE D1      IS  -2.000000000
/DEBUG/          AT LINE   42- THE NEW VALUE OF THE VARIABLE D2      IS  -3.000000000
/DEBUG/          AT LINE   43- THE NEW VALUE OF THE VARIABLE D3      IS  -1.000000000
/DEBUG/          AT LINE   44- THE NEW VALUE OF THE VARIABLE Q1      IS   1.000000000
/DEBUG/          AT LINE   45- THE NEW VALUE OF THE VARIABLE Q2      IS  -1.000000000
/DEBUG/          AT LINE   46- THE NEW VALUE OF THE VARIABLE Q3      IS  -2.000000000
TIME =    1.00 ACCELERATION =  5.70000
/DEBUG/  ACCTAB  AT LINE   41- THE NEW VALUE OF THE VARIABLE D1      IS  -2.000000000
/DEBUG/          AT LINE   42- THE NEW VALUE OF THE VARIABLE D2      IS  -3.000000000
/DEBUG/          AT LINE   43- THE NEW VALUE OF THE VARIABLE D3      IS  -1.000000000
/DEBUG/          AT LINE   44- THE NEW VALUE OF THE VARIABLE Q1      IS  -1.000000000
/DEBUG/          AT LINE   45- THE NEW VALUE OF THE VARIABLE Q2      IS  -3.000000000
/DEBUG/          AT LINE   46- THE NEW VALUE OF THE VARIABLE Q3      IS  -4.000000000
TIME =   -1.00 ACCELERATION = ********
/DEBUG/  ACCTAB  AT LINE   41- THE NEW VALUE OF THE VARIABLE D1      IS  -1.000000000
/DEBUG/          AT LINE   42- THE NEW VALUE OF THE VARIABLE D2      IS  -1.000000000
/DEBUG/          AT LINE   43- THE NEW VALUE OF THE VARIABLE D3      IS  0.
/DEBUG/          AT LINE   44- THE NEW VALUE OF THE VARIABLE Q1      IS   .5000000000
/DEBUG/          AT LINE   45- THE NEW VALUE OF THE VARIABLE Q2      IS  -.5000000000
/DEBUG/          AT LINE   46- THE NEW VALUE OF THE VARIABLE Q3      IS  -.5000000000
```

Figure 4-15. Debug Output and Printed Output

```
      PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
C
      DIMENSION TIME(10), ACC(10)
C
C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
C
      N = 0
      IER = 0
  100 READ (4,*) T, AMASS, F
      IF (EOF(4) .NE. 0) GO TO 150
      N = N + 1
      IF (N .GT. 10 ) GO TO 600
      IF (AMASS .LE. 0.) GO TO 700
      TIME(N) = T
      ACC(N) = F/AMASS
      GO TO 100
C
C....PRINT ACCELERATION TABLE
C
  150 NTIMES = N
      PRINT 10
      PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
      IF (IER .NE. 0) GO TO 900
C
C....READ A CARD CONTAINING A TIME VALUE
C
  180 READ (4,*) T
      IF (EOF(4) .NE. 0) GO TO 900
      N = N + 1
C
C....SEARCH ACCELERATION TABLE
C
        DO 200 I = 2,NTIMES
        IT = I
        IF (T .LE. TIME(IT)) GO TO 220
  200   CONTINUE
      GO TO 850
C
C....DO SECOND DEGREE INTERPOLATION
C
  220 D1 = TIME(IT-1) - TIME(IT)
      D2 = TIME(IT-1) - TIME(IT+1)
      D3 = TIME(IT) - TIME(IT+1)
      IF (D1 .EQ. 0. .OR. D2 .EQ. 0. .OR. D3 .EQ. 0.) GO TO 850
      Q1 = T - TIME(IT-1)
      Q2 = T - TIME(IT)
      Q3 = T - TIME(IT+1)
      ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
     1 - Q1*Q3*ACC(IT)/(D1*D3)
     2 + Q1*Q2*ACC(IT+1)/(D2*D3)
      PRINT 25, T, ACCX
      GO TO 180
C
  600 PRINT *, * TOO MUCH DATA. MAX NO. OF TIMES IS 10*
      STOP
  700 PRINT *, *INVALID VALUE FOR AMASS *, N
      IER = 1
      GO TO 100
  850 PRINT *, * INTERPOLATION PROBLEMS, TABLE ERROR*
      GO TO 180
  900 PRINT *, * END ACCTAB*
      STOP
C
   10 FORMAT (*1*,2(*        TIME     ACCEL*))
   15 FORMAT (2(5XF7.2,2XF8.5))
   25 FORMAT (* TIME = *,F7.2,* ACCELERATION = *,F8.5)
      END
```

Figure 4-16. Example with Duplicate Point Test

```
      TIME      ACCEL          TIME      ACCEL
      0.00    0.00000          2.00   10.10000
      3.00   10.20000          3.00   10.20000
      4.00   10.30000          5.00   10.40000
TIME =     0.00 ACCELERATION =   0.00000
TIME =     1.00 ACCELERATION =   5.70000
TIME =    -1.00 ACCELERATION = ********
 INTERPOLATION PROBLEMS, TABLE ERROR
TIME =     3.50 ACCELERATION =  10.25000
```

Figure 4-17. Output from Figure 4-16.

```
      TIME      ACCEL          TIME      ACCEL
      0.00    0.00000          2.00   10.10000
      3.00   10.20000          3.00   10.20000
      4.00   10.30000          5.00   10.40000
TIME =     0.00 ACCELERATION =   0.00000
TIME =     1.00 ACCELERATION =   5.70000
 BAD TIME, VALUE IS-1.
 INTERPOLATION PROBLEMS, TABLE ERROR
TIME =     3.50 ACCELERATION =  10.25000
TIME =     4.50 ACCELERATION =  10.35000
TIME =     5.00 ACCELERATION =  10.40000
 BAD TIME, VALUE IS5.5
 END ACCTAB
```

Figure 4-19. Output from Figure 4-18

```
      1                 PROGRAM ACCTAB (INPUT,OUTPUT,TAPE4=INPUT)
                C
                      DIMENSION TIME(10), ACC(10)
                C
      5         C....READ TIME, MASS, FORCE, AND COMPUTE ACCELERATION TABLE
                C
                      N = 0
                      IER = 0
                  100 READ (4,*) T, AMASS, F
     10               IF (EOF(4) .NE. 0) GO TO 150
                      N = N + 1
                      IF (N .GT. 10 ) GO TO 600
                      IF (AMASS .LE. 0.) GO TO 700
                      TIME(N) = T
     15               ACC(N) = F/AMASS
                      GO TO 100
                C
                C....PRINT ACCELERATION TABLE
                C
     20           150 NTIMES = N
                      PRINT 10
                      PRINT 15, (TIME(I),ACC(I),I=1,NTIMES)
                      IF (IER .NE. 0) GO TO 900
                C
     25         C....READ A CARD CONTAINING A TIME VALUE
                C
                  190 READ (4,*) T
                      IF (EOF(4) .NE. 0) GO TO 900
                      N = N + 1
     30         ----->    IF (T .LT. TIME(1) .OR. T .GT. TIME(NTIMES)) GO TO 800
                ----->    IF (T .LE. TIME(NTIMES-1)) GO TO 195
                ----->    IT = NTIMES - 1
                ----->    GO TO 220
                C
     35         C....SEARCH ACCELERATION TABLE
                C
                  195 LIM = NTIMES - 1
                        DO 200 I = 2,LIM
                        IT = I
     40                 IF (T .LE. TIME(IT)) GO TO 220
                  200   CONTINUE
                      GO TO 850
                C
                C....DO SECOND DEGREE INTERPOLATION
     45         C
                  220 D1 = TIME(IT-1) - TIME(IT)
                      D2 = TIME(IT-1) - TIME(IT+1)
                      D3 = TIME(IT) - TIME(IT+1)
                      IF (D1 .EQ. 0. .OR. D2 .EQ. 0. .OR. D3 .EQ. 0.) GO TO 850
```

Figure 4-18. Final ACCTAB Source Listing (Sheet 1 of 2)

```
                  Q1 = T - TIME(IT-1)
                  Q2 = T - TIME(IT)
                  Q3 = T - TIME(IT+1)
                  ACCX = Q2*Q3*ACC(IT-1)/(D1*D2)
                 1 - Q1*Q3*ACC(IT)/(D1*D3)
                 2 + Q1*Q2*ACC(IT+1)/(D2*D3)
                  PRINT 25, T, ACCX
                  GO TO 190
C
  500 PRINT *, ≠ TOO MUCH DATA. MAX NO. OF TIMES IS 10≠
      STOP
  700 PRINT *, ≠INVALID VALUE FOR AMASS ≠, N
      IER = 1
      GO TO 100
  800 PRINT *, ≠ BAD TIME, VALUE IS≠, T
      GO TO 190
  850 PRINT *, ≠ INTERPOLATION PROBLEMS, TABLE ERROR≠
      GO TO 190
  900 PRINT *, ≠ END ACCTAB≠
      STOP
C
   10 FORMAT (≠1≠,2(≠        TIME     ACCEL≠))
   15 FORMAT (2(5XF7.2,2XF8.5))
   25 FORMAT (≠ TIME = ≠,F7.2,≠ ACCELERATION = ≠,F8.5)
      END
```

Figure 4-18. Final ACCTAB Source Listing (Sheet 2 of 2)

This section describes some of the most commonly used procedures for batch execution of FORTRAN programs under NOS/BE, NOS, and SCOPE 2.

Batch execution usually involves reading a deck of punched cards, called the job deck, through the card reader at a remote batch terminal or at the central site of an installation. The equivalent of a job deck, in the form of card images, can also be submitted as a unit from a terminal under NOS (SUBMIT control statement), NOS/BE (INTERCOM BATCH command), and SCOPE 2 (HELLO7 SUBMIT command).

Job decks contain the following components in the order shown:

1. A group of control statements, beginning with the job statement.
2. A 7/8/9 card (characters 7, 8, and 9 multipunched in column 1).
3. Various combinations of the following groups of cards, separated by 7/8/9 cards:

   FORTRAN source programs

   Binary decks of previously compiled programs

   Data

   The order of programs or data cards depends on the order indicated by the control statements.
4. A 6/7/8/9 card (characters 6, 7, 8, and 9 multipunched in column 1).

SAMPLE JOB DECKS

The sample job decks shown in figures 5-1 through 5-3 are typical decks that might be used for FORTRAN program compilation and execution. Brief descriptions of some of the control statements most commonly used by FORTRAN users are found later in this section. Except as noted, control statements are common to all three operating systems.

A simple job for compilation and execution of a FORTRAN program is shown in figure 5-1. The object code and data output from the program are saved on permanent files.

The example shown in figure 5-2 executes the program compiled in figure 5-1 with data taken from a magnetic tape file. A new tape file is created.

The job shown in figure 5-3 executes the binary deck punched in figure 5-2 with two different sets of data.

JOB PROCESSING CONTROL STATEMENTS

Brief descriptions of some commonly used control statements for batch processing follow. Permanent file control statements and tape usage control statements are discussed later in this section. Loader control statements are discussed in section 7.

JOB STATEMENT

The job statement (figure 5-4) is the first control statement in every job deck. It assigns a name to the job, and it provides information used by the system in determining an initial scheduling priority for the job.

The parameters on this statement are:

jobname	One to seven letters or digits; the first character must be a letter. More than one job with the same name can be in the system at the same time; the system ensures unique job identification.
Tt	t is a number, containing one to five octal digits, that specifies the maximum number of central processor seconds the job can use. Exceeding this limit causes a fatal error condition. The default for NOS and NOS/BE is 100_8; the default for SCOPE 2 is 10_8.
ECfl	(NOS/BE) fl is the maximum number of words (in octal) of ECS (extended core storage) the job can use. Although the EC parameter is also applicable to SCOPE 2, where it indicates the maximum number of words of LCM (large core memory), its use is not recommended because it inhibits automatic LCM field length management.
MTn NTn	(NOS/BE, SCOPE 2) n is the maximum number of 7-track (MT) or 9-track (NT) tape units that the job will use concurrently. This is not the same as the number of tapes; if several tapes are read successively, only one tape unit is necessary. The UNLOAD control statement (described below) causes a tape to be removed from a device. Under NOS, the MT and NT parameters are specified on the RESOURC control statement.

As discussed in section 7, the CM parameter can also be specified on the job statement, but it is not recommended.

ACCOUNT CONTROL STATEMENT

The ACCOUNT control statement (figure 5-5) enables user validation by the system. If used, it should immediately follow the job statement. Either an ACCOUNT control statement or a USER control statement (which has the same parameters and format) is required for each job under NOS. The USER control statement is recommended because the ACCOUNT control statement is included only for compatibility with previous versions of the operating system.

The parameters for NOS are:

un	User number
pw	Password

Whether or not an ACCOUNT control statement is required under NOS/BE or SCOPE 2 depends on the installation. The parameters under NOS/BE are installation-defined. The parameters for SCOPE 2 are:

a Account number; seven letters or digits.

s Suffix to the account number; three letters or digits. Only the first seven characters are validated by the system.

p Project number; 10 letters or digits.

Various combinations of these parameters might be required by an installation.

RESOURC CONTROL STATEMENT (NOS)

The RESOURC control statement (figure 5-6) is required whenever a job uses more than one tape unit concurrently. The n following the MT (7-track) or NT (9-track) parameter indicates the maximum number of tape units that are used concurrently.

EXIT CONTROL STATEMENT

The EXIT control statement (figure 5-7) allows processing to continue after a fatal error has occurred. When no EXIT control statement is present, any fatal error causes job termination. When an EXIT control statement is present, processing might continue, depending on the type of error and the parameter on the statement.

```
MYJOB,T100.
ACCOUNT,12334,USER1.                          Required under NOS; might be required by
                                              particular installations under NOS/BE or SCOPE 2.
REQUEST,TAPE2,*PF.   }
REQUEST,LGO,*PF.     }  NOS/BE, SCOPE 2       Specify that TAPE2 and LGO are to be assigned
                                              to permanent file devices.
FTN,A,ER.                                     Compile program with debugging parameters
                                              specified. The A parameter prevents saving a bad
                                              binary as a permanent file by terminating the job
                                              in the event of a fatal compilation error; the ER
                                              parameter helps locate execution time fatal errors.
LGO.                                          Execute compiled program.
CATALOG,LGO,PROGRAM1,ID=MINE.   }
CATALOG,TAPE2,DATA1,ID=MINE.    }  NOS/BE, SCOPE 2
SAVE (LGO=PROGRAM1)   }
SAVE (TAPE2=DATA1)    }  NOS                  Save program binary and resulting data as
                                              permanent files.
7/8/9 card (characters 7, 8, and 9 multipunched in column 1)
    PROGRAM FIRST (INPUT,OUTPUT,TAPE2,TAPE1=INPUT)   INPUT is equivalenced so that the EOF function
                                                     can be used.
    READ (1,2) X,Y,Z
    IF (EOF(1) .NE. 0) . . .
    .
    .
    .
    IF (ERROR) PRINT *,  "X OUT OF RANGE:", X    File OUTPUT is used for display of monitoring
    .                                            messages.
    .
    .
    WRITE (2) TOTAL                              Binary data goes to TAPE2.
    .
    .
    .
    END
7/8/9 card
data for program
6/7/8/9 card (characters 6, 7, 8, and 9 multipunched in column 1)
```

Figure 5-1. Compilation and Execution

When an error occurs, the system searches through the control statements, skipping all control statements until an EXIT control statement with the appropriate parameter is found. If an appropriate statement is found, processing resumes with the control statement immediately after the EXIT control statement. If no appropriate control statement is found, the job terminates.

Three types of fatal errors can occur. How each type is handled depends on the operating system and the type of EXIT control statement specified. For a complete list of the errors in each category, refer to the operating system reference manual or diagnostic handbook.

1. Unrecoverable errors. This category includes job statement errors, accounting errors, and explicit operator action leading to job termination. Under all three operating systems, exit processing is ignored; the job is always terminated.

2. Special errors. This category includes FORTRAN fatal compilation errors when the A option has been selected on the FTN control statement. Under NOS, this category is the same as category 3. Under NOS/BE and SCOPE 2, control statements are skipped up to the next EXIT(S) statement.

3. All other errors. This category includes arithmetic mode errors, central processor time limit exceeded, and fatal loader errors. These errors cause a branch to the next EXIT control statement under NOS, and a branch to the next EXIT, EXIT(S), or EXIT(U) control statement under NOS/BE and SCOPE 2.

The fourth way an EXIT control statement can be reached is through normal job step advancement. That is, no error has occurred, but the EXIT control statement is the next control statement to be processed. Table 5-1 summarizes the processing that takes place when each of the four types of EXIT control statement is encountered after an error has occurred or through normal job step advancement.

JOB2,MT2.	NOS/BE, SCOPE 2	The MT parameter specifies that a maximum of two tape units are needed by the job (since tape writing and reading are to take place concurrently). Under NOS, the MT parameter is specified on the RESOURC statement instead of the job statement.
JOB2.	NOS	
ACCOUNT,12334,USER1.		
RESOURC,MT2.	NOS	
ATTACH,PROG,PROGRAM1,ID=MINE.	NOS/BE, SCOPE 2	Attaches the binary of the program compiled in figure 5-1.
GET,PROG=PROGRAM1.	NOS	
REQUEST,DATA2,MT,E,VSN=123456.	NOS/BE and SCOPE 2	Requests an SI (System Internal) format tape with existing ANSI standard format labels, the installation-defined density, and a VSN (volume serial number) of 123456. This tape is read by the program.
REQUEST,DATA2,MT,F=SI,VSN=123456.	NOS	
REQUEST,TAPE2,MT,N,RING,VSN=987654.	NOS/BE	Requests an SI format tape on which ANSI standard format labels are to be written. The tape has the installation-defined density and a VSN of 987654. A write-enabling ring is mounted with the tape (this must be specified as a comment under SCOPE 2). This tape is written by the program.
REQUEST,TAPE2,MT,N,VSN=987654. RING IN	SCOPE 2	
REQUEST,TAPE2,MT,PO=W,F=SI,VSN=987654.	NOS	
COPY,PROG,PUNCHB.		Specifies that the program is to be punched in binary format at job termination.
PROG,DATA2.		Rewinds, loads, and executes the program. The tape file DATA2 is substituted for INPUT (which occurs first in the PROGRAM statement) for all input/output references.
PURGE,DATA1,ID=MINE.	NOS/BE, SCOPE 2	Purges the data file saved as a permanent file in the previous job.
PURGE,DATA1.	NOS	
6/7/8/9		This is the only delimiter card used because the job contains only control statements.

Figure 5-2. Execution with Data on Magnetic Tape

```
JOBBB.
ACCOUNT,12334,USER1.
COPYBR,INPUT,BIN.                                  Copies the binary program to the file BIN to
                                                   enable repeated execution.
REQUEST,TAPE2,*PF.   }
REQUEST,TAPE3,*PF.   } NOS/BE, SCOPE 2
BIN.                                               Executes the program using the first group of
                                                   data cards.
CATALOG,TAPE2,OUT1,ID=MINE.        NOS/BE, SCOPE 2 Saves program output as a permanent file.
BIN, , ,TAPE3.                                     Executes the program with a second set of data
                                                   cards. The name TAPE2 is changed to TAPE3
                                                   so that output will be written to a different file.
CATALOG,TAPE3,OUT2,ID=MINE.        NOS/BE, SCOPE 2
SAVE,TAPE3=OUT2.          NOS
7/8/9
binary program
7/8/9                    }
7/8/9                    } NOS/BE, SCOPE 2
6/7/9 (characters 6, 7, and 9 multipunched in column 1)   NOS
data set 1
7/8/9
data set 2
6/7/8/9
```

Figure 5-3. Execution of Binary Program with Two Sets of Data Cards

jobname,Tt,ECfl,MTn,NTn.	NOS/BE
jobname,Tt.	NOS
jobname,Tt,MTn,NTn.	SCOPE 2

Figure 5-4. Job Statement Format

ACCOUNT,parameter list.	NOS/BE
ACCOUNT,un,pw.	NOS
ACCOUNT,as,p.	SCOPE 2

Figure 5-5. ACCOUNT Control Statement Format

RESOURC,MT=n,NT=n.	NOS

Figure 5-6. RESOURC Control Statement Format

EXIT.	NOS/BE, NOS, SCOPE 2
EXIT, {C S U}.	NOS/BE, SCOPE 2

Figure 5-7. EXIT Control Statement Format

REWIND CONTROL STATEMENT

The REWIND control statement (figure 5-8) positions a file at beginning-of-information. For a tape file, beginning-of-information is defined as a point immediately after all header labels. For a mass storage file, beginning-of-information is the beginning of the first record in the file.

RETURN CONTROL STATEMENT

The RETURN control statement (figure 5-9) releases a file from the job with which it is associated. The effect of RETURN depends on the type of file:

Local (scratch) file	The contents of the file are destroyed.
Permanent file	The file remains in existence, but is no longer attached.

Tape file	Trailer labels are written and the file is rewound and unloaded. The number of tape units the job is permitted, as requested on the job statement (NOS/BE, SCOPE 2) or RESOURC statement (NOS) is decreased by one. Under NOS this takes place only when the maximum number is actually in use.
Print or punch file	The file is printed or punched.

UNLOAD CONTROL STATEMENT

The UNLOAD control statement (figure 5-10) is identical in its effect to the RETURN control statement, with one exception: for tape files, the number of tape units required by the job is not decreased. Thus, the UNLOAD control statement is used whenever more than one tape is to be used successively in a job. If all the tapes are used concurrently, it is irrelevant whether UNLOAD or RETURN is used, since each tape requires its own tape unit.

COPY AND SKIP OPERATIONS

It is frequently necessary to copy part or all of one file to another or to skip forward or backward in a file. The copy and skip operations accomplish this.

Some control statements copy or skip sections and partitions. Both terms refer to groupings of data within a file, terminated by special delimiters. A section is a less inclusive grouping than a partition, and a partition is less inclusive than a file. The FORTRAN user is primarily interested in end-of-partition boundaries, because these are the applicable boundaries in the following contexts:

- A 7/8/9 card in the file INPUT is interpreted by Record Manager as an end-of-partition.
- The FORTRAN ENDFILE statement writes an end-of-partition.
- When an output file (a file being written) is closed as the result of program termination, or when REWIND or BACKSPACE is executed, an end-of-partition is written following the last record.
- The EOF function detects end-of-partition.

The only case in which the FORTRAN user needs to be concerned with sections is that of files with unformatted records under NOS/BE and NOS. The unformatted WRITE statement writes Record Manager W type records. For this record type, an end-of-partition boundary is detected as an end-of-section boundary by the operating system and, therefore, by the copy and skip operations. This requires processing that differs in some ways from that for other files, as discussed below.

Under SCOPE 2, a boundary written as end-of-partition is always recognized as end-of-partition, regardless of the record type.

COPY Control Statement

The COPY control statement (figure 5-11) copies all the information on lfn_1 to lfn_2 up to the end-of-information of

REWIND,lfn_1, . . . ,lfn_n.

lfn Logical file name of file to be rewound.

Figure 5-8. REWIND Control Statement Format

RETURN,lfn_1, . . . ,lfn_n.

lfn Logical file name of file to be returned.

Figure 5-9. RETURN Control Statement Format

UNLOAD,lfn_1, . . . ,lfn_n.

lfn Logical file name of file to be unloaded.

Figure 5-10. UNLOAD Control Statement Format

COPY,lfn_1,lfn_2.

Figure 5-11. COPY Control Statement Format

TABLE 5-1. EXIT PROCESSING

Condition Resulting in Search for EXIT	Action Taken When EXIT Encountered				
	EXIT (NOS)	EXIT (SCOPE 2, NOS/BE)	EXIT (C) (SCOPE 2, NOS/BE)	EXIT (S) (SCOPE 2, NOS/BE)	EXIT(U) (SCOPE 2, NOS/BE)
Normal job step advancement	Terminate job	Terminate job	Continue with next control statement	Terminate job	Continue with next control statement
Unrecoverable error	Terminate job	Terminate job	Terminate job	Terminate job	Terminate job
Special error	Continue with next control statement	Continue skipping	Continue skipping	Continue with next control statement	Continue skipping
Other error	Continue with next control statement	Continue with next control statement	Terminate job	Continue with next control statement	Continue with next control statement

lfn_1 (or double end-of-partition, if present). The copy starts from the current position of both files; therefore, either file might have information preceding the duplicated information. After all information has been copied to lfn_2, an end-of-partition is written to lfn_2 under SCOPE 2 and NOS, and a double end-of-partition is written under NOS/BE.

Under NOS/BE and NOS, a double end-of-partition on lfn_1 does not terminate COPY processing on files with W type (FORTRAN unformatted) records. COPYBR can be used to copy portions of these files.

COPYBF and COPYCF Control Statements

The COPYBF and COPYCF control statements (figure 5-12) copy the specified number of partitions from lfn_1 to lfn_2. Copying takes place from the current position of both files until the specified number of end-of-partition boundaries has been read from lfn_1. COPYBF is intended for binary files, and COPYCF is intended for coded files. Under SCOPE 2, there is no difference between the two. Under NOS/BE, there is no difference for mass storage files, but binary tapes should be copied by COPYBF, and coded tapes should be copied by COPYCF. Under NOS, COPYCF is intended for print files, or any files generated by FORTRAN formatted output statements; COPYBF should be used for all other files.

Because COPYBF and COPYCF count end-of-partition boundaries without regard for intervening data, the amount of information is not always what would be expected. For example, in the files shown in figure 5-13, the following control statement:

```
COPYBF,FILEA,FILEB,3.
```

would copy the information from A to B when FILEA is positioned at point A in all three cases; the file is positioned immediately after the third end-of-partition.

If an end-of-information is encountered on lfn_1, a single end-of-partition is written to lfn_2 at the end of the copy.

Under NOS and NOS/BE, COPYBF and COPYCF should not be used on files with W type (FORTRAN unformatted) records; COPYBR should be used instead.

COPYBR Control Statement

The COPYBR control statement (figure 5-14) copies the specified number of sections from lfn_1 to lfn_2. The FORTRAN user uses this control statement primarily to copy files whose records were written by FORTRAN unformatted WRITE statements. The end-of-partition boundaries on these files are recognized as end-of-section boundaries under NOS/BE and NOS. Under SCOPE 2, COPYBF should be used.

NOS/BE and SCOPE 2 Skip Operations

The SKIPF and SKIPB control statements (figure 5-15) skip sections. SKIPF bypasses sections in a forward direction; SKIPB bypasses sections in a reverse direction. End-of-section boundaries are skipped until the specified number, n, has been read. The file denoted by lfn is then positioned immediately after the nth boundary (for SKIPF) or immediately after the preceding boundary (for SKIPB). An end-of-partition boundary is counted as an end-of-section. If a level number is present, only sections of that level or higher are counted. In particular, if the level number is 17, only end-of-partition boundaries are counted (a level 17 section is equivalent to a partition). Under NOS/BE, level 17 must be used to skip partitions for all files except those with W type (FORTRAN unformatted) records. For files with W type records, level 0 should be used. Under SCOPE 2, level 17 is used for partitions on all files.

Figure 5-16 shows how files are positioned by SKIPF and SKIPB. In each case, the position of the file is moved from A to B after execution of the control statement shown.

COPYBF,lfn_1,lfn_2,n.

COPYCF,lfn_1,lfn_2,n.

lfn_1	Logical file name of the file to copy from
lfn_2	Logical file name of the file to copy to
n	Number of partitions to be copied

Figure 5-12. COPYBF and COPYCF Control Statement Formats

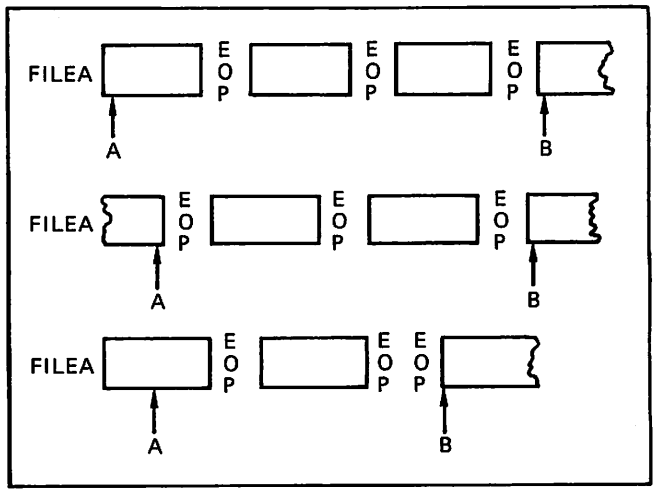


Figure 5-13. COPYBF Example

COPYBR,lfn_1,lfn_2,n.

Figure 5-14. COPYBR Control Statement Format

SKIPF,lfn,n,lev.

SKIPB,lfn,n,lev.

lfn	File to be repositioned
n	Number of sections to be skipped
lev	Level of sections to be skipped

Figure 5-15. SKIPF and SKIPB Control Statement Formats (NOS/BE, SCOPE 2)

NOS Skip Operations

The SKIPF, SKIPBF, SKIPR, and BKSP control statements (figure 5-17) skip partitions and sections.

SKIPF bypasses partitions in a forward direction; SKIPBF bypasses partitions in a reverse direction. End-of-partition boundaries are skipped until the specified number, n, have been read. The file denoted by lfn is then positioned immediately after the nth boundary (for SKIPF) or immediately after the preceding boundary (for SKIPBF). SKIPF and SKIPBF skip partitions on all files except those with W type (FORTRAN unformatted) records. For these files, SKIPR and BKSP should be used.

SKIPR bypasses sections in a forward direction; BKSP bypasses sections in a reverse direction. End-of-section boundaries are skipped until the specified number, n, have been read. The file denoted by lfn is then positioned immediately after the nth boundary (for SKIPR) or immediately after the preceding boundary (for BKSP). An end-of-partition boundary is counted as an end-of-section.

PERMANENT FILE USAGE

If a mass storage file containing user data or programs is to remain in existence between jobs, it must be made a permanent file. Because permanent file concepts and control statements differ substantially between NOS on the one hand and NOS/BE and SCOPE 2 on the other, they are described separately.

NOS/BE AND SCOPE 2 PERMANENT FILES

Creating a permanent file under NOS/BE or SCOPE 2 involves the following steps:

1. The file must be assigned to a permanent file device before it is written. The required control statement is REQUEST.
2. Before the end of the first job using the file, the file must be identified to the system as a permanent file. The required control statement is CATALOG.

Using an existing permanent file requires these steps:

1. Subsequent jobs must obtain access to the file from the system before use. The required control statement is ATTACH.
2. If changes to a file are to be made permanent, the system must be notified. The required control statement is EXTEND or ALTER.
3. When the file is no longer needed as a permanent file, it should be removed from the system catalog. The required control statement is PURGE.

The following control statements and parameters are those most frequently used under NOS/BE and SCOPE 2.

SKIPF,lfn,np,m.

SKIPFB,lfn,np,m.

SKIPR,lfn,ns,lvl,m.

BKSP,lfn,ns,m.

lfn	Logical file name of the file to be repositioned
np	Number of partitions to be skipped
ns	Number of sections to be skipped
lvl	Level number of sections; 17 indicates partitions, all other values indicate sections, the default is 0
m	File mode: C for coded, B for binary (default)

Figure 5-17. SKIPF, SKIPBF, SKIPR, and BKSP Control Statement Formats (NOS)

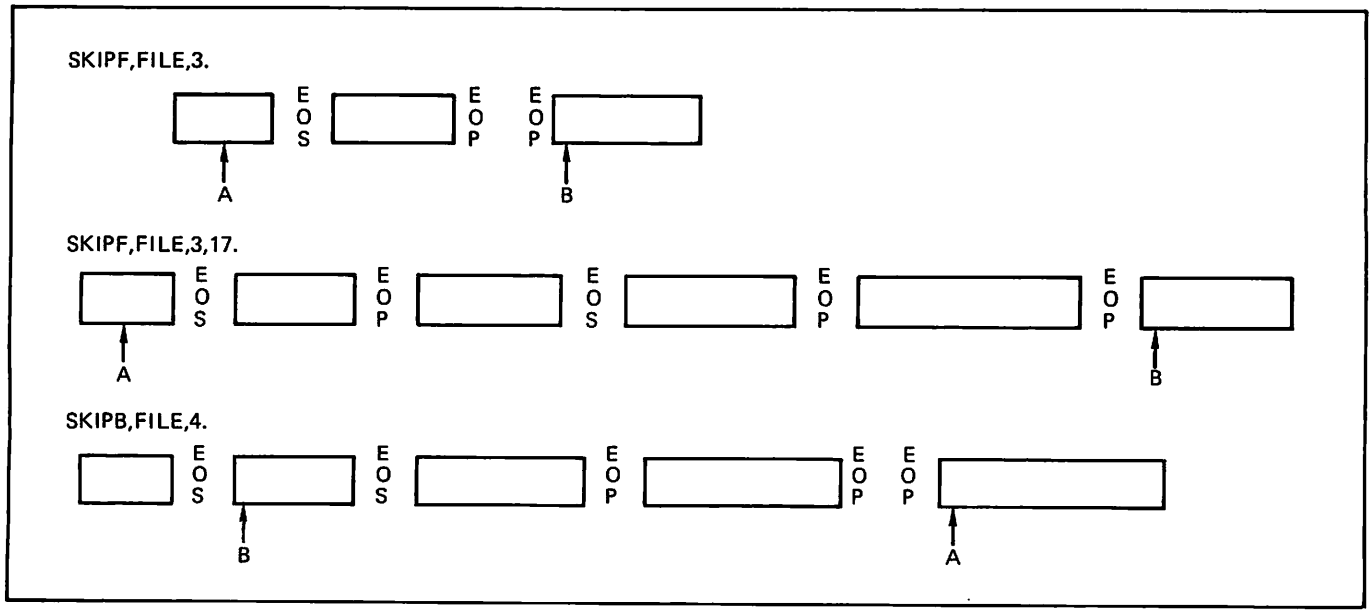


Figure 5-16. SKIPB and SKIPF Examples (NOS/BE, SCOPE 2)

REQUEST Control Statement

The REQUEST control statement for permanent files (figure 5-18) ensures that the file can be made permanent. This control statement must appear before any other reference to the file in the job in which it is created. It specifies that the file is to be assigned automatically to a permanent file device when it is first referenced. The REQUEST control statement is not applicable to an existing permanent file.

CATALOG Control Statement

The CATALOG control statement (figure 5-19) declares a file to be permanent. The file must exist on a permanent file device. A file should be cataloged as soon as possible after creation, so as to be more secure in event of system failure.

ATTACH Control Statement

The ATTACH control statement (figure 5-20) makes a previously cataloged permanent file available as a local file to the current job. The logical file name can be different from job to job. A file should not be attached until just before it is needed, since each attached permanent file represents increased overhead for the operating system. Similarly, the file should be returned by the RETURN control statement as soon as it is no longer needed within a job.

ALTER and EXTEND Control Statements

All files processed by FORTRAN Extended are sequential files except those processed by the mass storage input/output routines (READMS, WRITMS) and some of those processed by the CRM interface routines. (See the FORTRAN Extended Reference Manual for descriptions of both these kinds of files.) On a sequential file, information can be added only at the end; existing records cannot be modified. If the file is permanent, it cannot be changed unless either the EXTEND or ALTER control statement (figure 5-21) is used.

EXTEND is used when information has been added at end-of-information. It causes the current end-of-information to become the permanent end-of-information, thus making the added information part of the permanent file.

ALTER can be used to change the length of the file. It specifies that the current file position is to become the permanent end-of-information. Thus, the file can either be shortened or (when information has been added) lengthened.

Although the functions of ALTER and EXTEND overlap, each has its specialized uses. When all the information that has been added to a file is to become part of the file, but the current file position is not at end-of-information, EXTEND must be used. If any of the information currently in the file is not to be part of the permanent file, ALTER must be used.

PURGE Control Statement

The PURGE control statement removes permanent file status, so that the file referenced disappears at the end of a job. A permanent file can be purged whether or not it is attached. If the file is attached, the format shown in figure 5-22 is used. If it is not attached, the format shown in figure 5-23 is used and the file is attached after being purged.

```
REQUEST,lfn,*PF.
```

Figure 5-18. REQUEST Control Statement Format for Permanent Files (NOS/BE, SCOPE 2)

```
CATALOG,lfn,pfn,ID=idname,RP=days.

lfn      Logical file name

pfn      Permanent file name; if omitted, the lfn is used
         as the pfn

idname   Owner or creator of the file

days     Number of calendar days the file is to be
         retained in the system; the default is installa-
         tion-defined
```

Figure 5-19. CATALOG Control Statement Format (NOS/BE, SCOPE 2)

```
ATTACH,lfn,pfn,ID=idname.

lfn      Logical file name; if omitted, pfn is used as lfn

pfn      Permanent file name under which the file was
         cataloged

idname   Name of the owner or creator of the file used
         when the file was cataloged
```

Figure 5-20. ATTACH Control Statement Format (NOS/BE, SCOPE 2)

```
EXTEND,lfn.

ALTER,lfn.

    lfn   Logical file name of file to be extended
          or altered.
```

Figure 5-21. EXTEND and ALTER Control Statement Formats (NOS/BE, SCOPE 2)

```
PURGE,lfn.

lfn   Logical file name
```

Figure 5-22. PURGE Control Statement Format for Attached Files (NOS/BE, SCOPE 2)

```
PURGE,lfn,pfn,ID=idname.

lfn      Logical file name

pfn      Permanent file name

idname   Name of the owner or creator used when the
         file was cataloged
```

Figure 5-23. PURGE Control Statement Format for Unattached Files (NOS/BE, SCOPE 2)

Because the file remains attached to the job, it can be altered and then recataloged. If the file is not going to be used anymore, a RETURN control statement should follow PURGE to remove the file from the system.

NOS PERMANENT FILES

Two kinds of permanent files are used under NOS: direct access files and indirect access files. With indirect access files, the user attaches a local copy of the file; only the local copy is read or written. If the local copy is altered, it does not replace the permanent copy unless the system is so instructed. With direct access files, all reads and writes are performed directly on the only copy of the file. For most applications, direct access files are not as convenient as indirect access files, as they are less secure (because they are written directly) and they might use more system resources (because mass storage space is preallocated). Direct access files are more efficient for very large files, however.

Creating a permanent file in batch mode involves the following steps:

1. The USER or ACCOUNT control statement identifies the owner of the file to the system.
2. The file is created like any other file.
3. After the file is created, it is saved as a permanent file. The required control statement is SAVE (for indirect access) or DEFINE (for direct access).

Using an existing permanent file requires these steps:

1. A job using an indirect access file must obtain a copy of the file for use as a local file. The required control statement is GET. For a direct access file, the only copy is made available to the job through the ATTACH control statement.
2. For indirect access files, if changes are made to the local copy, and these changes are to become part of the permanent copy, the local copy replaces the permanent copy. The required control statement is REPLACE.
3. When the file is no longer needed as a permanent file, it should be removed from the system. The required control statement is PURGE for both types of files.

The following control statements and parameters are those most frequently used for permanent files.

SAVE Control Statement

The SAVE control statement (figure 5-24) declares a local file to be permanent. A permanent copy is made of the current contents of the local file, and the local file is rewound. Subsequent changes can be made to the local file, but the changes are not permanent unless the REPLACE control statement is used.

GET Control Statement

The GET control statement (figure 5-25) obtains a local copy of a permanent file and assigns to it the logical file name lfn. If a file named lfn is already assigned to the user, it is returned even if errors occur in processing the GET control statement. The local copy is always rewound.

REPLACE Control Statement

The REPLACE control statement (figure 5-26) destroys the permanent copy of the file specified by pfn and replaces it with the local file specified by lfn. If pfn does not exist, a permanent copy of the local file is saved with the name pfn (in this case, REPLACE is identical to SAVE). It is not necessary for lfn to be a local copy of pfn; it could be a new file, or a local copy of some other permanent file.

DEFINE Control Statement

The DEFINE control statement (figure 5-27) specifies that a file is to be a direct access permanent file. It can occur either before the first reference to the file (that is, the file does not exist yet) or after the last reference. The latter method is usually preferable, since it keeps system resources free as long as possible. However, the first method is more secure in the event of system failure. DEFINE is not applicable to existing direct access files; ATTACH must be used instead.

SAVE,lfn=pfn.

lfn	Logical file name of the local file to be made permanent
pfn	Permanent file name; if the equals sign and the pfn are omitted, the lfn is used as the pfn

Figure 5-24. SAVE Control Statement Format (NOS)

GET,lfn=pfn.

lfn	Logical file name to be assigned to the local copy of a permanent file; if lfn and the equals sign are omitted, the pfn is used as the lfn
pfn	Permanent file name

Figure 5-25. GET Control Statement Format (NOS)

REPLACE,lfn=pfn.

lfn	Logical file name of the local file to replace a permanent file
pfn	Permanent file name of the file to be replaced

Figure 5-26. REPLACE Control Statement Format (NOS)

DEFINE,lfn=pfn.

lfn	Logical file name of file to be made a direct access file.
pfn	Permanent file name to be assigned. If the equals sign and pfn are omitted, the lfn is used as the pfn.

Figure 5-27. DEFINE Control Statement Format (NOS)

ATTACH Control Statement

The ATTACH control statement (figure 5-28) makes an existing direct access permanent file available to a job. Subsequent output operations write directly to the only copy of the file.

ATTACH,lfn=pfn.

lfn Logical file name to be assigned to direct access permanent file.

pfn Permanent file name. If lfn and the equals sign are omitted, the pfn is used as the lfn.

Figure 5-28. ATTACH Control Statement Format (NOS)

PURGE Control Statement

The PURGE control statement (figure 5-29) removes a permanent file from the system. It is applicable to both direct and indirect access files. For indirect access files, no local copy is made when PURGE is executed; if a local copy exists, it is not destroyed by PURGE.

PURGE,pfn.

pfn Permanent file name of the file to be purged

Figure 5-29. PURGE Control Statement Format (NOS)

MAGNETIC TAPE PROCESSING

The user finds it necessary to know about magnetic tape processing in two different situations:

- When it is necessary to read an already existing tape. The tape could have been written at the installation in question, or sent there from somewhere else. In either case, it is necessary to know the exact attribute parameters with which the tape was created. If the tape was written on a computer system not manufactured by CDC, or was written by a different CDC system such as one of the 3000 series, special processing is required. This manual does not describe how to process such tapes; the user is referred to the appropriate operating system reference manual.

- After deciding that a tape is the most economical way to store data between jobs for a given application. Tapes are cheaper than the equivalent amount of disk space; however, disks are quicker in terms of real time. When planning an application using tapes, the user determines the type of tape processing before running the first job that writes to the tape. Because all processing is specified by the original user, tape attribute parameters can be chosen strictly on the basis of efficiency or expediency. The discussion that follows assumes that this is the case.

When designing a tape application, a number of decisions must be made about the characteristics of the tape. Among the attributes that must be chosen are the following:

- Tape drive used to read and write the tape (7-track or 9-track). Data is stored in 6-bit units on 7-track tapes, and in 8-bit units on 9-track tapes (the remaining bit is used for parity). On a 9-track tape, four 6-bit characters in memory are converted to three 8-bit characters on tape. For 9-track tapes, conversion mode is according to either ASCII or EBCDIC codes.

- Tape density. Tapes can be written at 200, 556, or 800 bits per inch on a 7-track tape, or 800 or 1600 bits per inch on a 9-track tape. 9-track tapes can be written at 6250 bits per inch under NOS/BE only.

- Tape format. For a new application, one of the formats designed for use with CDC systems should be chosen, because these formats are the most efficient on CDC systems. Under NOS, I (the system default) and SI formats are available. Under NOS/BE and SCOPE 2, SI format (the system default) is available. To read existing tapes, it might be necessary to specify one of the S or L tape formats.

- Label type. A tape can be either labeled or unlabeled. Labeled tapes are strongly recommended. They provide greater security against accidental overwriting, and they are simpler to process because they can be assigned without operator intervention. Labels are either ANSI standard or user-defined. ANSI labels are the system default and are preferred for new applications.

Tapes are processed by the following steps:

1. A volume serial number (VSN) for the tape must be determined. At many installations, tapes are blank-labeled before being made available to programmers. In this case, a serial number is recorded on the tape that agrees with the serial number on the visual sticker on the tape. If the tape has not been blank-labeled, the user selects an arbitrary volume serial number.

2. In the job that creates the tape, a LABEL control statement (NOS and NOS/BE) or REQUEST control statement (SCOPE 2) must appear before the control statement that writes the tape (such as COPY or LGO). This control statement specifies the attributes that are to be permanently associated with the tape. At the end of the job, or when a specific request is made, the tape is logically unloaded and physically dismounted. The procedure used to specify how long the tape is to be retained depends on the installation; however, if the expiration date field of the label is set, the tape cannot be overwritten before that date without explicit operator command. Before the tape can be written, a write-enabling ring must be mounted; this is explicitly requested through the LABEL or REQUEST control statement.

3. Any future job using the tape specifies the VSN on a LABEL control statement (NOS and NOS/BE) or REQUEST control statement (SCOPE 2).

The formats of the LABEL control statement under NOS and NOS/BE, and the REQUEST control statement (for tapes) under SCOPE 2, are shown in figures 5-30 through 5-32.

LABEL,lfn,D=den,CV=conv,PO=p,F=format,VSN=vsn,LB=lab,labwr.

lfn Logical file name of the tape file.

den Tape density; the default is an installation parameter. Implies whether tape is 7-track or 9-track.

LO	200 bpi (7-track)
HI	556 bpi (7-track)
HY	800 bpi (7-track)
HD	800 bpi (9-track)
PE	1600 bpi (9-track)

conv Conversion mode for 9-track tapes; the default is an installation parameter.

AS	ASCII conversion
EB	EBCDIC conversion

p Processing option. See the NOS Reference Manual for options other than the following:

R Enforce ring out. If the tape is mounted with the write ring in, job processing is suspended until the operator remounts the tape correctly. Recommended for tapes to be read.

W Enforce ring in. If the tape is mounted without the write ring in, job processing is suspended until the operator remounts the tape correctly.

format Tape format:

I	NOS Internal (default)
SI	NOS/BE internal
S	Stranger
L	Long stranger

vsn Volume serial number. See the discussion in text.

lab Indicates whether the tape is labeled.

KL	NOS labeled (ANSI standard labels; default)
NS	Nonstandard labels
KU	Unlabeled

labwr Indicates whether labels are to be written or read (checked).

R	Existing labels are to be checked (default)
W	Labels are to be written

Figure 5-30. LABEL Control Statement Format (NOS)

LABEL,lfn,wr,ring,D=d,F=f,N=n,VSN=vsn.

lfn Logical file name of the tape file.

wr Indicates whether the label is to be written or read (checked). No default.

W	Label to be written
R	Label to be checked

ring Indicates the presence or absence of a write-enabling ring; the default is an installation option.

RING	Write-enabling ring required
NORING	Write-enabling ring prohibited

d Tape density. Also indicates whether the tape is 7-track or 9-track.

LO	200 bpi (7-track)
HI	556 bpi (7-track)
HY	800 bpi (7-track)
HD	800 bpi (9-track)
PE	1600 bpi (9-track)
GE	6250 bpi (9-track)

f Tape format; the default is SI (system internal) format.

S	Stranger tape
L	Long stranger tape

n Conversion mode for 9-track tapes; the default is an installation option.

US	ASCII code
EB	EBCDIC code

vsn Volume serial number. See the discussion in text.

Figure 5-31. LABEL Control Statement Format (NOS/BE)

REQUEST,lfn,den,con,VSN=vsn,lab. RING IN

lfn Logical file name of the tape file.

den Tape density; the default is an installation option. Also determines whether the tape is 7-track or 9-track.

LO	200 bpi (7-track)
HI	556 bpi (7-track)
HY	800 bpi (7-track)
HD	800 bpi (9-track)
PE	1600 bpi (9-track)

con Conversion mode for 9-track tapes; the default is an installation option.

US	ASCII code
EB	EBCDIC code

vsn Volume serial number. See the discussion in text.

lab Indicates whether labels are to be written or read (checked).

N	New label to be written
E	Existing label to be checked (default)

Figure 5-32. REQUEST Control Statement Format for Tapes (SCOPE 2)

LIBRARY FILES 6

This section describes some efficient techniques when a group of routines are frequently used together or called from many other routines. The section describes how a user library can be created using EDITLIB (NOS/BE), LIBEDT (SCOPE 2) or LIBGEN (NOS). Maintenance and use of a user library is also described. In addition, this section describes how a source language program can be created or maintained using the UPDATE utility. The COPYL and LIBEDIT utilities that edit records on a file are also described. Table 6-1 indicates the utilities that operate under SCOPE 2, NOS/BE, and NOS. EDITLIB is discussed further in the NOS/BE Reference Manual, LIBGEN, LIBEDIT, and GTR are discussed in the NOS Reference Manual, LIBEDT is discussed in the SCOPE 2 Reference Manual, and COPYL is discussed in the CYBER Common Utilities Reference Manual.

In this section, the word library implies one of several different types of file, depending on the context. In a general sense, the word library refers to a collection of records. When the word library is qualified by the word user or program, however, it implies a particular type of file:

> A user library is a file in a format that can be used by the loader to satisfy external references or name call references. It must be created by a library-creating utility, EDITLIB, LIBEDT, or LIBGEN for the NOS/BE, SCOPE 2, and NOS operating systems, respectively. All records on a user library must be binary modules.
>
> A program library is a file in a format created or maintained by the UPDATE utility. Information in a program library consists of compressed images of punch cards in Hollerith format.

This section uses the program GETACC to illustrate user library and program library construction and maintenance. Subroutines GENTAB and INTERP are part of a physical card deck that also contains the main program GETACC. If GETACC is to be executed only once with one set of data, its existence as a card deck is reasonably efficient. Considering execution of GETACC with many sets of data over a period of time, however, leads to the need for keeping GETACC and its subroutines in some form other than punch cards containing source language programs.

Several alternatives can be chosen to provide for use of program GETACC over an extended period. These include the following when the program and its subroutines are kept together:

1. Keeping the main program and its two subroutines as a source language card deck
2. Storing an image of the deck as a permanent file
3. Storing the compiled program and subroutines as a permanent file

Alternative 1 requires the continued existence of a physical card deck. In this particular example, the GETACC deck is small, but it is susceptible to the problems of all card decks: mistreatment that results in card bending or warping, bulky size, and possible card shuffling.

Alternative 2 eliminates the inconvenience of a physical deck. Resubmission of the program for processing is accomplished by a deck containing only control statements and data. And, if the data is also on a permanent file, the program can be executed from a terminal that does not include a card reader.

Both alternatives 1 and 2 are expensive in terms of machine time, since a source language program must be compiled each time it is executed. If the program is compiled before it is stored, repetitive use of the program requires only loading and execution time. As long as a program and its subroutines will not be changed, use of a binary object module (alternative 3) is efficient.

Alternative 3 is less useful if changes are to be introduced. When a main program and the subprograms it calls are stored as one file, a change in any routine requires a recompilation of the entire source deck; that recompilation requires the existence of those routines in source format. In the absence of anticipated changes, alternative 3 stores the program in less space than required by a source program.

TABLE 6-1. UTILITY SUPPORT

Utility	Function	Applicable Operating System		
		NOS	NOS/BE	SCOPE 2
UPDATE	Coded card file maintenance	X	X	X
COPYL	Copy of a file with replacement of selected records	X	X	X
LIBGEN	User library creation	X	—	—
LIBEDIT	Modification of sequential file of binary modules	X	—	—
GTR	Extraction of records from file	X	—	—
EDITLIB	User library creation and modification	—	X	—
LIBEDT	User library creation and modification	—	—	X

When changes to a program are anticipated, other alternatives should be considered:

4. Separating the main program from its subprograms, and separating the subprograms from each other in their source language and compiled forms

5. Storing all the source language routines in one program library and storing all the compiled routines in one user library file

Alternative 4 saves compilation time, because only the changed routine needs to be recompiled as a result of a change in that routine. This alternative adds to the programmer burden, however. When many separate routines are involved, the programmer must keep track of separate files or card decks, or keep track of many partitions in one file for both the source language and binary forms of routines. The control statements needed to execute GETACC would have to call for loading of three files by name, such as:

```
LOAD, GETACCB.
LOAD, GENTABB.
LOAD, INTERPB.
EXECUTE.
```

(See section 7.)

Alternative 5, storing source language programs in UPDATE format and compiled programs in user library format, eliminates several problems of the other alternatives. The card deck can be eliminated once the initial UPDATE program library is created; for instance, a change to one routine calls only for recompilation of the changed routine. All routines on the user library can be referenced by a single control statement identifying the file on which the library resides. Assuming GETACC and its subroutines exist on a user library (MYLIB), GETACC can be executed by:

```
LIBRARY,MYLIB.
LIBLOAD, MYLIB, GETACC.
EXECUTE,GETACC.
```

With subroutines on a declared library, the programmer references only the name of the main program to be executed. The loader examines that program to determine what subroutines are required, then searches the library for those routines without further programmer references.

This last alternative is described in detail in this section. While the small routines GETACC, GENTAB, and INTERP might be more easily handled in card deck format, the principles they illustrate are essential for efficient handling of source programs and frequently used routines.

USER LIBRARIES

A user library is a file of binary modules in a special format constructed by a library-creating utility. In general, a library file contains, in addition to the modules, a directory and tables that can be used by the loader to quickly locate any module. Some of the information in the tables includes lists of entry points, lists of external references within a module, and field length information. The specific format of the library depends on the operating system it is associated with and, in general, is not of concern to the user.

A user library is similar to a system library that is associated with the operating system. It differs from a system library in that it is created and maintained by an individual programmer and also must be explicitly referenced and attached by any job that uses the library.

Because the procedures and control statements needed to create and maintain a user library differ substantially between NOS on the one hand and NOS/BE and SCOPE 2 on the other, they are described separately here.

For FORTRAN programs, a user library can only contain one main program, unless the main programs are compiled using the SYSEDIT parameter on the FTN control statement (see the FORTRAN Extended Reference Manual). This parameter is necessary because otherwise, multiple references to the same file name in different main programs cause duplicate entry points.

NOS/BE AND SCOPE 2 USER LIBRARIES

The utility called to create a library differs between NOS/BE and SCOPE 2, but the general procedure is the same, as shown in figure 6-1. Under the NOS/BE operating system, the utility EDITLIB is called; under the SCOPE 2 operating system, LIBEDT is called. Creating a user library involves the following steps:

1. The routines to be made a part of the library must exist in compiled form. They can be on one or more files stored on tape, cards, or mass storage. They can be routines in any language and need not all be FORTRAN routines. The control statement that creates the proper binary format for each routine is a compiler or assembler call.

2. Detailed instructions, known as directives, must be available to EDITLIB or LIBEDT at the time the utility is called. The file containing the directives is identified by the I parameter in the EDITLIB or LIBEDT control statement.

3. The EDITLIB or LIBEDT utility is called to create a user library.

4. The file on which the user library is created should be a permanent file. The control statements that make a file permanent are the REQUEST control statement before the library is created, and the CATALOG control statement after the file exists (described in section 5). If the library is changed in a later run, the EXTEND control statement (section 5) is then necessary, to make the changes permanent.

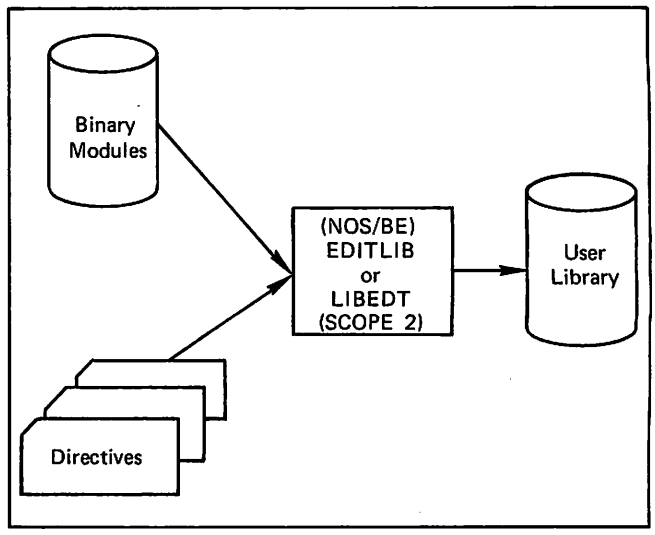


Figure 6-1. NOS/BE and SCOPE 2 User Library Creation

Directives in General

Directives are the supplementary control information for EDITLIB or LIBEDT. They indicate the library to be manipulated, the program on a sequential input file (or old user library) to be made part of the library, and whether a new library is to be created or an existing library is to be modified. Directives must exist on a sequential file in the form of punch cards or punch card images.

The format of a directive is similar to control statement format. Directives can begin in any card column; they can contain embedded blanks. Any parameters on the directive must appear within a set of parentheses, however.

In both EDITLIB and LIBEDT directives, the proglist parameter can reference a single program or a set of programs; it can take any of the following formats:

name	Reference a single program by name.
name/name/. . ./name	Reference several programs by name in any order.
$name_1$ + $name_2$	Reference an inclusive interval of programs to be included in the directive processing by the names of the first and last programs in the interval.
$name_1$ - $name_2$	Reference an exclusive interval of programs to be omitted from the directive processing by the names of the first and last programs in the interval.
$name_1$ + *	Reference an inclusive interval of programs to be included in the directive processing by the name of the first program in the interval through end-of-partition or end-of-information.
$name_1$ - *	Reference an exclusive interval of programs to be excluded from the directive processing by the name of the first program in the interval through end-of-partition or end-of-information.
* + $name_1$ or * - $name_1$	Reference an interval of programs to be included (+) or excluded (-) from the directive processing with the interval beginning at the current file position and extending through the named program.
*	Reference an interval of programs that consists of all programs starting at the present file position and continuing through end-of-partition or end-of-information.

Any interval must be specified such that the beginning of the interval occurs before the end of the interval when LIBEDT or EDITLIB searches the file in a forward direction. The search is end-around; that is, the search begins at the current position of the specified file, continues until end-of-information, then resumes at beginning-of-information if necessary. A search stops when the entire file has been examined once and the specified programs have not been found, or when the end of the specified interval occurs. The programs that indicate the interval range are included in that interval. Once the beginning of the interval is found, searching continues only until end-of-information; an interval cannot wrap around the end of a file.

Directives for EDITLIB and LIBEDT are shown separately below, because they differ in some respects.

NOS/BE and SCOPE 2 Sample User Library Creation

The sample job deck shown in figure 6-2 illustrates the general structure of a job that creates a user library. This example uses a program with main program GETACC and subroutines GENTAB and INTERP.

The EDITLIB and LIBEDT control statements shown in figure 6-2 indicate that the directives are part of the job deck (I=INPUT). Directives in the example have these functions:

The LIBRARY directive identifies the library to be manipulated (MYLIB).

The NEW parameter on the LIBRARY directive indicates a new library is to be created as opposed to a modification of an existing library.

All directives between the LIBRARY directive and the FINISH directive refer to the library named.

The ADD directive specifies that all programs on file LGO are to be incorporated in the library (because * appears as the proglist parameter). File LGO was created by the FTN control statement, which has a default B=LGO parameter for binary output.

The ENDRUN directive terminates directive execution.

```
job statement
ACCOUNT control statement (if required)
FTN.
REQUEST,MYLIB,*PF.
EDITLIB,USER,I=INPUT.     NOS/BE
LIBEDT,I=INPUT,M=1.     SCOPE 2
CATALOG,MYLIB,ID=MINE.
7/8/9

        Routines GETACC, GENTAB, INTERP

7/8/9
LIBRARY(MYLIB,NEW)
REWIND(LGO)
ADD(*,LGO)
FINISH.
ENDRUN.
6/7/8/9
```

Figure 6-2. Sample User Library Creation (NOS/BE, SCOPE 2)

The library name specified in the LIBRARY directive is the same as the file name specified on the permanent file control statements. In subsequent loader control statements (described in section 7), the library is always identified by the name of the file on which it resides.

Output from EDITLIB and LIBEDT includes the user library and a listing that shows operations performed and the contents of the library. By default, the listing is written to file OUTPUT. Figure 6-3 shows output from the deck in figure 6-2 when EDITLIB is called. Information listed includes:

1. A list of the directives as read from the directive file and as interpreted by EDITLIB. (An error in directive format might cause a different interpretation.)

2. Status information resulting from execution; in particular, detailed information about each program added to the library, such as:

   a. Contents of the prefix table (a loader table).

   b. Octal number of words in the routine excluding the prefix table. Execution field length is zero for relocatable programs, because the loader determines length at load time.

   c. Access level and field length, which refer to status bits explained in the NOS/BE Reference Manual.

   d. A list of all entry points in the program. Entry points include the program unit names specified on the PROGRAM and SUBROUTINE statements. File names referenced in the PROGRAM statement are entry points for the main program and external references in any subprogram (such as GENTAB) performing input/output on these files.

   e. A list of external references within the program. In program GENTAB, for example, external references shown refer to FORTRAN library routines required to execute the READ and WRITE statements, as well as to the EOF function called by the program, and the file names referenced in the program (unless the program was compiled with the SYSEDIT parameter).

NOS/BE and SCOPE 2 Sample User Library Modification

An existing user library can be changed under NOS/BE or SCOPE 2 using the EDITLIB or LIBEDT utility that originally created the library (figure 6-4). A program on the library can be deleted or replaced by another version of the program, and new programs can be added.

Figure 6-5 shows a sample job deck that deletes program GENTAB, adds program NEWTAB, and replaces program GETACC with a new version. In this example, the new version of GETACC is within the deck and is compiled and written by default to file LGO. The new routine NEWTAB was compiled in a previous job and stored as a permanent file with the name NEWONE.

The existing user library was stored in figure 6-2 as a file with the permanent file name MYLIB. In the present job, it is attached with the logical file name MOD. Consequently, the LIBRARY directive must identify the library as MOD, not MYLIB.

The ADD and REPLACE directives identify the names of the programs and the files on which they reside. The REWIND directive is not required (since files are searched end-around), but it makes searching more efficient when the program in question is known to be before the current file position.

After library operations are complete, the LISTLIB directive lists the names of the programs on the library. LISTLIB output is shown in figure 6-6.

NOS/BE EDITLIB Control Statement and Directives

The EDITLIB control statement (figure 6-7) creates and maintains a user library that the CYBER loader can use in satisfying externals and name call references under NOS/BE.

In addition to the directives shown in table 6-2, other directives exist for EDITLIB. They allow field length and access status bits to be set in the directory of the library. The ADD and REPLACE directives have additional parameters for these same items. See the NOS/BE Reference Manual for information about these other directives. The directives shown in table 6-2 are sufficient for creating and modifying a user library using sequential files with type REL relocatable programs.

The user library produced by EDITLIB execution is in random format; consequently, the library cannot be copied by any of the copy utilities without losing its integrity. If it is necessary to copy the library to a tape for backup purposes, the RANTOSEQ directive must be used. To restore the library to mass storage in a format that can be used by the loader, the SEQTORAN directive must be used.

SCOPE 2 LIBEDT Control Statement and Directives

The LIBEDT control statement (figure 6-8) creates and maintains a user library that the SCOPE 2 loader can use in satisfying externals and name call references under SCOPE 2.

Directives for LIBEDT are shown in table 6-3. Other directives exist to allow a library to be copied to a sequential file, rearrange a library, or otherwise update the library and control other types of records in the file. See the SCOPE 2 Reference Manual for information about these other directives. Those directives shown in table 6-3 are sufficient for creating and modifying a library using a sequential file of type REL programs.

The column of table 6-3 entitled Required Position refers to the location a directive must occupy in respect to a run. A run is defined as a group of operations with a particular library. (More than one library can be manipulated through a single call to LIBEDT even though only one is shown in the examples in this section.) A run begins with a LIBRARY directive and ends with a FINISH directive. Thus, table 6-3 indicates that the ADD directive must appear between LIBRARY and FINISH, but that the LISTLIB directive cannot appear between LIBRARY and FINISH directives, and that it does not matter whether ERROR appears between them or not.

Under SCOPE 2, a library has a format recognizable by SCOPE 2 Record Manager as FO=LB. A library file contains a number of partitions, the first being a directory used by the loader.

```
EDITLIB        VERSION 2.3                        DATE  07/26/77      TIME  11.36.35.

      ******  LIBRARY(MYLIB,NEW)
                                 1  LIBRARY(MYLIB,NEW)
      ******  REWIND(LGO)
                                 2  REWIND(LGO)
      ******  ADD(*,LGO)
                                 3  ADD(*,LGO)
      ******  FINISH.
                                 4  FINISH.
      ******  ENDRUN.
                                 5  ENDRUN.
```

①

```
   EDITLIB        VERSION 2.3                        DATE  07/26/77      TIME  11.36.35.

 PROCESSING DIRECTIVE NUMBER     1

 PROCESSING DIRECTIVE NUMBER     2

 PROCESSING DIRECTIVE NUMBER     3

  FOLLOWING PROGRAM ADDED ②
    PREFIX TABLE INFORMATION
    PROGRAM NAME
        GETACC
ⓐ   SYSTEM NAME     NOS/BE 1.207/26/77  11.29.31     PROCESSOR NAME   FTN    4.6   452
    DEPENDENCIES    HARDWARE   I                 INSTRUCTION  66  6X   X
    THIS IS A RELOCATABLE PROGRAM.
ⓑ   BINARY LENGTH = 210      AND EXECUTION FIELD LENGTH =  0         (OCTAL).
ⓒ   ACCESS LEVEL IS  0
    FIELD LENGTH MAY NOT BE INCREASED.
ⓓ   ENTRY POINTS
        GETACC              INPUTE              OUTPUTE              TAPE4E
    EXTERNAL REFERENCES
        EOF                 GENTAB              INPFI.               INTERP              OUTCI.
        OUTFI.              01NTRY.             STOP.

  FOLLOWING PROGRAM ADDED
    PREFIX TABLE INFORMATION
    PROGRAM NAME
        GENTAB
    SYSTEM NAME     NOS/BE 1.207/26/77  11.29.31     PROCESSOR NAME   FTN    4.6   452
    DEPENDENCIES    HARDWARE   I                 INSTRUCTION  66  6X   X
    THIS IS A RELOCATABLE PROGRAM.
    BINARY LENGTH = 266      AND EXECUTION FIELD LENGTH =  0         (OCTAL).
    ACCESS LEVEL IS  0
    FIELD LENGTH MAY NOT BE INCREASED.
    ENTRY POINTS
        GENTAB
ⓔ   EXTERNAL REFERENCES
        EOF                 INPFI.              OUTCI.               OUTFI.              OUTPUTE
        TAPE4E

  FOLLOWING PROGRAM ADDED
    PREFIX TABLE INFORMATION
    PROGRAM NAME
        INTERP
    SYSTEM NAME     NOS/BE 1.207/26/77  11.29.31     PROCESSOR NAME   FTN    4.6   452
    DEPENDENCIES    HARDWARE   I                 INSTRUCTION  66  6X   X
    THIS IS A RELOCATABLE PROGRAM.
    BINARY LENGTH = 136      AND EXECUTION FIELD LENGTH =  0         (OCTAL).
    ACCESS LEVEL IS  0
    FIELD LENGTH MAY NOT BE INCREASED.
    ENTRY POINTS
        INTERP
    EXTERNAL REFERENCES
        OUTFI.              OUTPUTE

 PROCESSING DIRECTIVE NUMBER     4

 PROCESSING DIRECTIVE NUMBER     5
```

Figure 6-3. Output from Sample User Library Creation

NOS USER LIBRARIES

The utility called to create a user library under NOS is LIBGEN. Creating a user library involves the following steps:

1. The routines to be made part of the library must exist in compiled form. They can be routines in any language and need not all be FORTRAN routines. All routines must be relocatable, however. The control statement that creates the proper binary format for each routine is a compiler or assembler call.
2. All routines must be on the same sequential format file. The COPYBR control statement can be used to copy separately compiled routines to one file, if necessary.

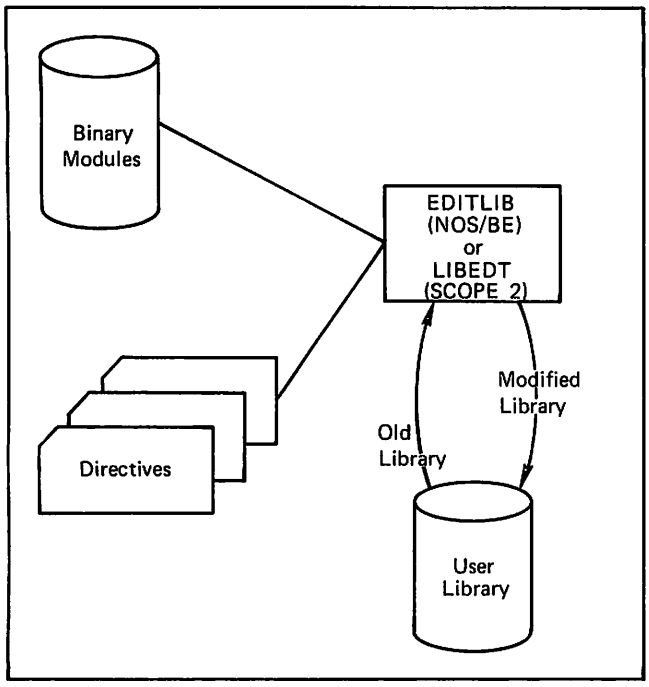


Figure 6-4. NOS/BE and SCOPE 2 User Library Modification

```
job statement
ACCOUNT control statement
FTN.
ATTACH,MOD,MYLIB,ID=MINE.
ATTACH,NEWONE,ID=MINE.
EDITLIB or LIBEDT control statement
EXTEND,MOD.
7/8/9

          new version of routine GETACC

7/8/9
LIBRARY(MOD,OLD)
DELETE(GENTAB)
REWIND(LGO)
REPLACE(GETACC,LGO)
ADD(NEWTAB,NEWONE)
FINISH.
LISTLIB(*,MOD)
ENDRUN.
6/7/8/9
```

Figure 6-5. Sample User Library Modification (NOS/BE, SCOPE 2)

3. The LIBGEN utility is called to create a user library.
4. The file on which the user library was created should be made a permanent file. Direct access is preferable for library files. The control statement that makes a file permanent is DEFINE (described in section 5). Libraries can be kept on tape and copied to disk before use, but they must be on disk while in use.

The general use of LIBGEN is shown in figure 6-9.

Sample User Library Creation

The sample job deck shown in figure 6-10 illustrates the general structure of a job that creates a user library. This example uses a program with main program GETACC and subroutines GENTAB and INTERP. The CATALOG control statement lists the contents of the file. In this example, the U parameter indicates that the file is a user library, and the R parameter specifies that the file is to be rewound before and after execution of CATALOG.

The LIBGEN control statement in figure 6-10 indicates that the routines to be made part of the library are found on file LGO, the default binary file from a call to FTN. The new library is to be created on permanent file LIBFILE. The name of the library is to be MYLIBN; this name appears in a listing of the file contents, as shown in figure 6-11.

Sample User Library Re-creation

An existing user library cannot be modified under NOS. If any changes are to be made to an existing library, a new library must be created from a sequential source file containing all the binary modules to be on the library:

If the sequential source file originally used to create the library exists, it can be edited through the COPYL utility or the LIBEDIT utility (figure 6-12).

If the sequential source file does not exist, the GTR utility can be used to extract records from the existing library and the resulting file can be used as input to COPYL or LIBEDIT (figure 6-13).

In either case, the new library is then created through LIBGEN.

The choice of COPYL or LIBEDIT usually is governed by the type of changes to be made. If the only change is a replacement of records by records of the same name and type, either utility can be used. In this instance, control statement parameters identify the source file and the file containing replacement records, and all matching records are replaced.

If new programs are to be added, COPYL offers an advantage in a simplified deck structure. A control statement parameter can be used to indicate that records on the replacement file are to be added to the output file. To add programs using LIBEDIT, however, a directive record is required. Furthermore, knowledge about the structure of the file is required, because the location of the new records must be specified. LIBEDIT directives allow records to be added from more than one file, which can be an advantage.

If existing programs are to be deleted, the location of the program in the library affects which utility is easier to use. Records can be deleted from the end of a file through COPYL by specifying the name of the last record to be copied from the source file. Deletions elsewhere in the file require SKIPR or COPYBR control statements referencing

```
LISTING OF LIBRARY MOD      FOLLOWS

 FOLLOWING PROGRAM LISTED
   PREFIX TABLE INFORMATION
   PROGRAM NAME
        INTERP
   SYSTEM NAME     NOS/BE 1.207/26/77  11.29.31      PROCESSOR NAME    FTN     4.6    452
   DEPENDENCIES    HARDWARE    I                INSTRUCTION  66  6X    X
   THIS IS A RELOCATABLE PROGRAM.
   BINARY LENGTH = 136       AND EXECUTION FIELD LENGTH =  0          (OCTAL).
   ACCESS LEVEL IS  0
   FIELD LENGTH MAY NOT BE INCREASED.
   ENTRY POINTS
        INTERP
   EXTERNAL REFERENCES
        OUTFT.                OUTPUT=

 FOLLOWING PROGRAM LISTED
   PREFIX TABLE INFORMATION
   PROGRAM NAME
        GETACC
```

Figure 6-6. Typical LISTLIB Output

TABLE 6-2. EDITLIB DIRECTIVES

Directive Format	Required Position	Function
*/ comment	Anywhere	Specify a comment to be listed in the print file.
LIBRARY (lfn, {NEW / OLD})	Beginning of run	Specify the library to be manipulated and whether it is to be created or modified.
FINISH.	End of run	Indicate end-of-processing of the library specified by the preceding LIBRARY directive.
ADD (proglist, lfn_1) ADD (proglist, lfn_2, LIB)	In run	Add specified programs from the sequential file lfn_1 or from library file lfn_2.
REPLACE (proglist, lfn_1, LIB) REPLACE (proglist, lfn_2, LIB)	In run	Replace the specified programs on the existing library with programs of the same name and type now residing on sequential file lfn_1 or library file lfn_2.
DELETE (proglist)	In run	Remove the specified programs from the existing library.
LISTLIB (proglist, lfn)	Outside run	List information about the specified programs from library file lfn.
CONTENT (lfn)	Anywhere	List the contents of file lfn whether it is a sequential file or library file.
REWIND (lfn_1/ . . . /lfn_n)	Anywhere	Rewind specified sequential files.
SKIPF ({n / prog}, lfn_1) SKIPF ({n / prog}, lfn_2, F)	Anywhere	Skip forward n sections on sequential file lfn_1 or n partitions on lfn_2 or skip forward until a program of name prog is found.
SKIPB ({n / prog}, lfn_1) SKIPB ({n / prog}, lfn_2, F)	Anywhere	Skip backward n sections on sequential file lfn_1 or n partitions on lfn_2, or skip backward until a program of name prog is found.
ENDRUN.	Outside run	Stop directive execution, but continue syntax checking of any following directives.
RANTOSEQ (lfn_1, lfn_2)	Outside run	Copy the random library on file lfn_1 to a sequential file lfn_2.
SEQTORAN (lfn_1, lfn_2)	Outside run	Copy sequential file lfn_1 containing a dumped library to mass storage file lfn_2 in a format the loader can use.

the COPYL source file. Deleting records during LIBEDIT operations can be accomplished through directives by specifying the name of the record to be deleted.

LIBGEN Control Statement

The LIBGEN control statement (figure 6-14) generates a user library that the CYBER loader can use in satisfying external references.

The file referenced by the F parameter is the source file which contains the program units that are to be incorporated into the library. In many instances, this file would be one created by the COPYL utility, although binary output from compilation can be used; all of the records in the library must be relocatable binary programs. If any other record types are on the source file, they are ignored by LIBGEN.

LIBGEN rewinds the source file before and after creating the user library. At the start of library creation, LIBGEN scans the source file, stopping at the first partition boundary or at end-of-information. Using the information on the source file, LIBGEN builds a directory of all entry points, program names, and external references on the file. LIBGEN then copies the directory to the file specified by the P parameter, copies all records from the source file to the library file, and follows the records with an index that gives the relative address of each record in the library.

The directory on the user library is listed as record type ULIB. Its name is that specified by the N parameter. The file index on the user library is listed as record type OPLD, with a name corresponding to the library name.

LIBEDIT Control Statement and Directives

The LIBEDIT control statement (figure 6-15) creates and maintains a file of binary records.

A file created by LIBEDIT cannot be used during loading to selectively satisfy entry points from among its records. The entire file can be loaded and executed, however, if the file contains a main program. The file can also be used as input to LIBGEN.

Many different types of records, including overlays and text records, can be processed by LIBEDIT. Only relocatable programs (type REL) are described here, because only relocatable programs can be written to a user library under NOS.

Directives for LIBEDIT are shown in table 6-4. Other directives exist to change the contents of the prefix tables and otherwise control file contents. See the NOS Reference Manual for information about other directives.

The format of the LIBEDIT directives requires the character * to appear in column 1, with no embedded blanks. If a card or card image in the directive file does not begin with *, it is presumed to be a continuation of the previous card.

Directives are not needed if the only change to the source file is to replace records.

GTR Control Statement

The GTR control statement (figure 6-16) extracts specified records from the named file. GTR operates with either a library file or a sequential file.

EDITLIB,USER,I=lfn_1,L=lfn_2.

USER	Indicates a user library (default).
lfn_1	Logical file name of the file containing directives. The default file name is INPUT.
lfn_2	Logical file name of the file to which EDITLIB is to write listable output. The default file name is OUTPUT.

Figure 6-7. EDITLIB Control Statement Format

LIBEDT,I=lfn_1,L=lfn_2,M=m.

lfn_1	Logical file name of the file containing directives. The default file name is INPUT.
lfn_2	Logical file name of the file to which printable output is to be written. The default file name is OUTPUT.
m	Indicator of listing completeness: 0 for short listing (default); 1 for long listing.

Figure 6-8. LIBEDT Control Statement Format

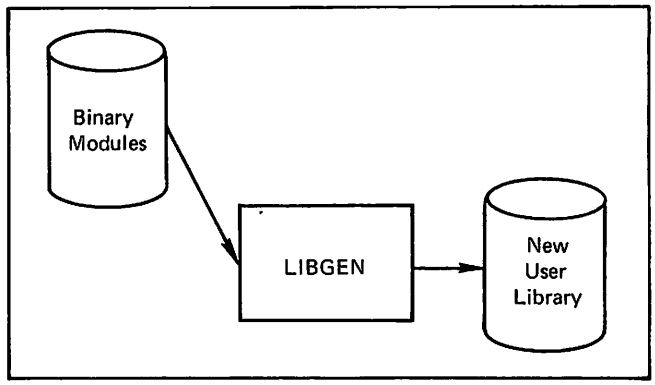


Figure 6-9. NOS User Library Creation

```
job statement
USER control statement
FTN,OPT=2.
LIBGEN,F=LGO,P=LIBFILE,N=MYLIBN.
DEFINE,LIBFILE.
CATALOG,LIBFILE,U,R.
7/8/9
        Routines GETACC, GENTAB, and INTERP
6/7/8/9
```

Figure 6-10. Sample User Library Creation (NOS)

```
      CATALOG OF LIBFILE          FILE     1              77/11/23. 15.13.03.      PAGE      1
REC   NAME      TYPE      LENGTH  CKSUM     DATE      COMMENTS

  1   MYLIBN    ULIB          20   0603   77/11/23.
  2   GETACC    REL          204   4626   77/11/23. 15.12.59  NOS 1.2  FTN 4.6460  666X  I  PROGRAM
        GETACC
        INPUT=
        TAPE4=
        OUTPUT=
  3   GENTAB    REL          230   6324   77/11/23. 15.12.59  NOS 1.2  FTN 4.6460  666X  I  SUBROUTINE
        GENTAB
  4   INTERP    REL          164   6721   77/11/23. 15.12.59  NOS 1.2  FTN 4.6460  666X  I  SUBROUTINE
        INTERP
  5   MYLIBN    OPLD          11   7305   77/11/23.

  6   * EOF *       SUM =    651
```

Figure 6-11. Listing of NOS User Library

TABLE 6-3. LIBEDT DIRECTIVES

Directive Format	Required Position	Function
*/ comment	Anywhere	Specify a comment to be listed on the print file.
LIBRARY (lfn, {NEW / OLD})	Beginning of run	Specify the library to be manipulated and whether it is to be created or modified.
FINISH.	End of run	Indicate end-of-processing of the library specified by the preceding LIBRARY directive.
ERROR ({STOP / ABORT / SKIP})	Anywhere	Indicate whether LIBEDT is to abort its execution immediately (STOP), continue the run until the directory is listed and then abort (ABORT), or list the directory at end-of-run (SKIP) after a warning level message is written to the listing file.
ADD (proglist, lfn_1) ADD (proglist, lfn_2, LIB)	In run	Add the specified programs from the sequential file with logical file name lfn_1 or from the library on lfn_2.
REPLACE (proglist, lfn_1) REPLACE (proglist, lfn_2, LIB)	In run	Replace the specified programs on the existing library with programs of the same name and type residing on file lfn_1 or library lfn_2.
DELETE (proglist)	In run	Remove the specified programs from the existing library.
LISTLIB (proglist, lfn) LISTLIB (proglist, lfn, N=1)	Outside run	List information about the specified programs from library file lfn, showing information about the directory and each program. N=1 specifies a more detailed list.
CONTENT (lfn)	Anywhere	List the contents of sequential file lfn.
REWIND (lfn_1, . . . lfn_n)	Anywhere	Rewind the specified sequential files.
SKIPF ({prog / n}, lfn) SKIPF ({prog / n}, lfn, P)	Anywhere	On sequential file lfn, skip forward n sections; or skip forward until a program of name prog is found. P indicates partitions are to be skipped.
SKIPB ({prog / n}, lfn) SKIPB ({prog / n}, lfn, P)	Anywhere	On sequential file lfn, skip backward n sections; or skip backward until program of name prog is found. P indicates partitions are to be skipped.

GTR differs from other utilities that require directives in that the GTR directives must appear on the control statement. No blank characters can appear between the terminator of the control statement and the directive.

A logical deletion can be achieved using GTR because records to be copied to the output file are specified by name or interval of records in the source file. Records are deleted when their names are omitted.

The output file produced by GTR is in sequential format. To re-create it in user library format, it must be used as a source file for LIBGEN, even when the source of records is an existing library file. The output file is rewound after GTR processing.

COPYL Control Statement

The COPYL control statement (figure 6-17) maintains a file of binary records.

The types of binary records COPYL can process include relocatable records (type REL), level 0,0 overlays with named entry points (type ABS), and overlays of other than level 0,0 without named entry points (type OVL). COPYL determines record types by examining the tables produced by the compiler for loader use.

A binary file is one in which each record is presumed to begin with a prefix table. A prefix table is constructed by the compiler for each program unit compiled, in a format required by the loader. The information in the prefix table documents the status and characteristics of the program and includes the system on which the program was compiled, the program name, and the type of system for which the program is optimized. The contents of the prefix table and the tables following it are used by COPYL to determine the record name and type.

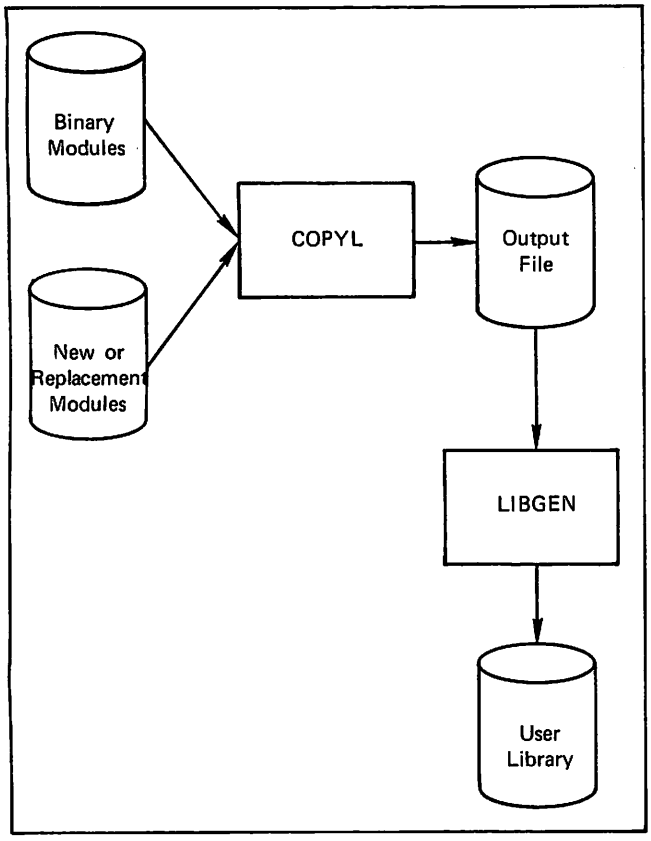


Figure 6-12. COPYL Use in Re-creating a User Library (NOS)

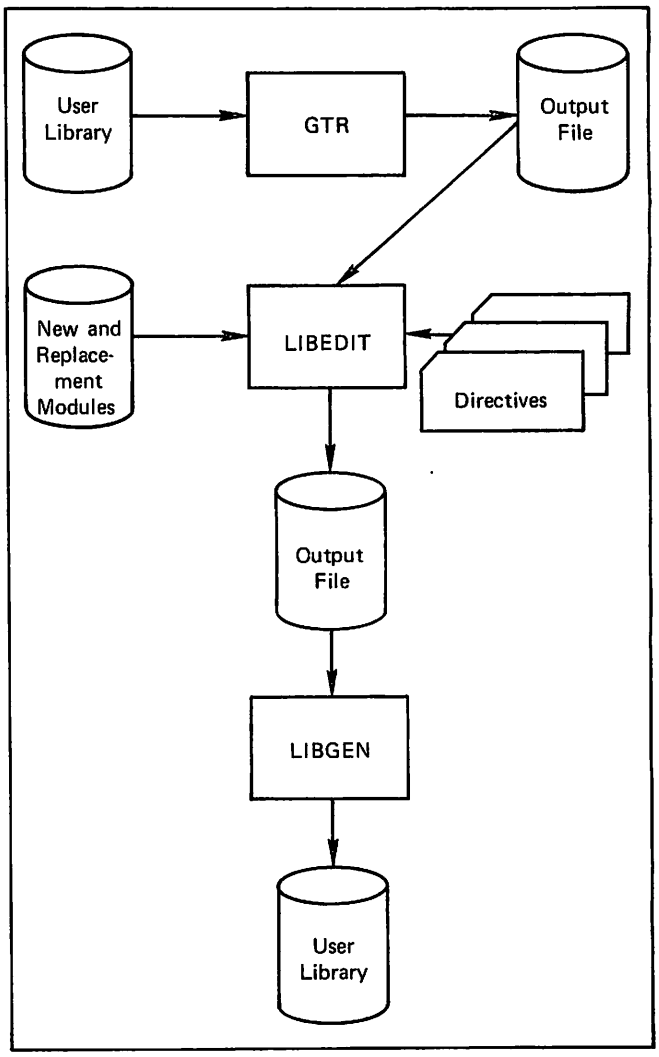


Figure 6-13. GTR and LIBEDIT Use in Re-creating a User Library (NOS)

LIBGEN,F=lfn_1,P=lfn_2,N=libname.

lfn_1	Logical file name of the file containing relocatable program units to be made into a user library. The default file name is LGO.
lfn_2	Logical file name of the file to contain the user library. The default file name is ULIB.
libname	Name of the user library being created. The default library name is the logical file name specified by the P parameter.

Figure 6-14. LIBGEN Control Statement Format

The format of the file produced by COPYL is sequential, with each binary record being a section. This file is identical in format to one created by compilations that write to the same file, or by copy operations that copy several records to a single file. No directory or index exists for the file.

Once a file of binary records exists, COPYL can maintain it by adding new records and replacing an existing record with another record of the same name. Deletion of records is also possible when the records to be deleted are at the end of the existing file, but when records are to be deleted elsewhere in the existing file, one of the copy or skip utilities must be used to produce a new output file.

When COPYL executes, it begins by rewinding the existing old file if so indicated by the R parameter. It rewinds the file of replacement records, then compares the contents of the old file with the replacement file. Each record from the old file is copied to the new output file as it is encountered, unless a record with the same name exists on the replacement file. If so, the record on the replacement file is copied

LIBEDIT,I=lfn_1,P=lfn_2,N=lfn_3,B=lfn_4.

lfn_1	Logical file name of directives. The default file name is INPUT. If no directives exist, I=0 must be specified.
lfn_2	Logical file name of the existing file to be edited. The default file name is OLD.
lfn_3	Logical file name of the file to be produced by LIBEDIT. The default file name is NEW.
lfn_4	Logical file name of the file containing new or replacement records. The default file name is LGO. If a replacement file does not exist, B=0 should be specified.

Figure 6-15. LIBEDIT Control Statement Format

TABLE 6-4. LIBEDIT DIRECTIVES

Directive Format	Function
*TYPE,REL	Indicate that all subsequent directives refer to type REL, relocatable records.
*FILE,lfn *FILE,*	Specify the file containing replacement directives by name or by * to indicate the file specified on the LIBEDIT control statement.
*BEFORE,rec,rep_1-rep_2	Specify that the replacement record rep_1 or group of records rep_1 through rep_2 are to be placed before rec, the name of a record on the source file.
*AFTER,rec,rep_1-rep_2	Specify that the replacement record rep_1 or group of records rep_1 through rep_2 are to be placed after rec, the name of a record on the source file.
*DELETE,rec_1-rec_2	Specify the name of the record or the group of records to be deleted.
*REPLACE,rec_1-rec_2	Specify the name of the record or group of records to be replaced by records of the same name on the replacement file.

GTR,lfn_1,lfn_2. directives

lfn_1	Logical file name of the file to be searched. The default file name is OLD.
lfn_2	Logical file name of the file to which selected records are to be written. The default file name is LGO.
directives	Directives identifying the records to be copied. More than one directive can appear, separated by commas. Directive format can be:
REL/name,–$name_2$	Name of the record or interval of records to be copied. Only type REL is shown.
REL/*	All records of type REL are to be copied to the file lfn_2.

Figure 6-16. GTR Control Statement Format

COPYL,lfn_1,lfn_2,lfn_3,lastrec,opts.

lfn_1	Logical file name of the existing file to be maintained. The default file name is OLD.
lfn_2	Logical file name of the file containing new binary records to be added or new versions of binary records that are to replace existing records of the same name. The default file name is LGO.
lfn_3	Logical file name of the updated version of lfn_1. The default file name is NEW.
lastrec	Name of the last record on lfn_1 that is to be processed. If this parameter is omitted, all records on lfn_1 are processed.
opts	Characters R or A or both, which specify processing options:
R	Rewind lfn_1 and lfn_3 before processing
A	Add all records from lfn_2 that do not match the type and name of a record on lfn_1.

Figure 6-17. COPYL Control Statement Format

instead. It does not matter what order records exist on the replacement file in relation to the records on the old file, because COPYL manipulates the replacement file as necessary to process all of its records. If a partition boundary is encountered on the old file, copying stops. Copying might stop sooner if the COPYL statement has a nonblank fourth (lastrec) parameter. If the fourth parameter specifies the name of a record on the old file, COPYL stops processing after that record is copied to the new file.

If, after all records on the replacement file have been substituted for records of the same name, unprocessed records remain on the replacement file, COPYL checks the A parameter to determine their disposition. If the A parameter has been specified, uncopied records on the replacement file are copied to the output file; but if the A parameter has been omitted, uncopied records are ignored. By this technique, new records always become the last records of the new file. The new file is rewound or left at its current position, depending on the R parameter of the COPYL control statement.

UPDATE SOURCE FILE MAINTENANCE

UPDATE is a utility that allows card images to be stored on mass storage without sacrificing the ability to change those cards. In fact, UPDATE is specifically designed for maintaining or updating card image files; it cannot be used for binary files.

Two types of operations can be performed by UPDATE. The first is called a creation run; the second is called a correction run. They are diagrammed in figures 6-18 and 6-19.

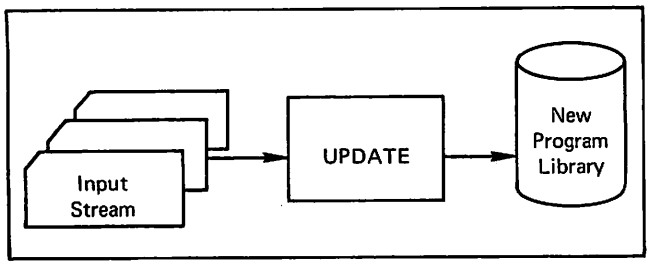


Figure 6-18. UPDATE Program Library Creation Run

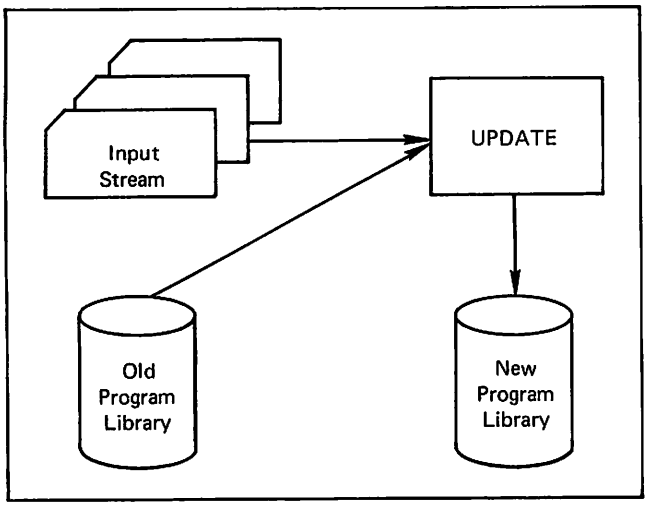


Figure 6-19. UPDATE Program Library Correction Run

The format in which the source lines are maintained is called a program library. The creation run creates the program library from a file of card images. A program library cannot be directly altered; however, during a correction run, a modified version of the program library can be written to another file. In this case, the original version is known as an old program library, and the modified version is known as the new program library. Both of these files are in UPDATE format, which is not suitable as input to a compiler or assembler. Therefore, a third file, known as the compile file, can be produced during either a creation or correction run. The compile file consists of specified portions of the program library, restored to their original format.

To ensure unique identification of the cards in an UPDATE file, three units are used: deck, correction set, and card. A deck is a group of cards identified by a DECK directive. Since no group smaller than a deck can be written to the compile file, the FORTRAN programmer should ensure that only program units to be used together should be in the same deck. Each card in a deck is identified uniquely as follows:

name.seqnum

where name is the name given to the deck, and seqnum is the order of the card within the deck.

A correction set is a group of text cards and directives introduced during a correction run by an IDENT directive. If a card is added to a deck as part of a correction set, it is identified by the correction set name rather than by the deck name. The form of identification is as follows:

ident.seqnum

where ident is the name of the correction set, and seqnum is the order of the card within the set.

UPDATE requires an input stream during its execution. The input stream consists of two types of cards:

Text cards of the source programs

Directives to provide detailed instructions for UPDATE.

These cards are interspersed in the input stream. Several input streams can be used in a single run, but this section assumes only one is used. A run is all operations on a program library that result from a single call to UPDATE.

UPDATE DIRECTIVES

The directives for UPDATE specify detailed processing. A directive must begin with a master control character in column 1, with the name of the directive following immediately. Any number of blanks, or a comma, can separate the directive name from the directive parameters. No other blanks are allowed within the directive. No terminating punctuation should appear.

The directives shown in table 6-5 are limited to those that create a program library and perform insertions and deletions by individual cards, decks, or correction sets. More than two dozen other directives exist. See the UPDATE Reference Manual for a full description of all UPDATE processing.

UPDATE CONTROL STATEMENT

The UPDATE control statement shown in figure 6-20 is limited to the parameters required to create a program library and use it as described in this section. More than two dozen parameters exist, nevertheless, to control output listing contents, change the file from random to sequential format, merge file contents, and change the characteristics of input or output files.

CREATION RUN

A creation run is the original conversion of a card file to a mass storage file of card images called a program library. During the creation run, UPDATE examines each card, compresses blank columns to minimize space occupied by the card image, and assigns a unique identifier to the card. Each card receives an identifier that identifies the deck it belongs to and its sequence number within that deck. The card identifier is a permanent one: no other card throughout the history of the file will receive the same identifier. The format of the card identifier is:

deck.seqnum

where deck is a one through nine character deck name, and seqnum is a decimal number 1 through 131071 assigned by UPDATE.

Decks

A deck, in UPDATE terminology, is a grouping of cards made in response to programmer instructions specified by a DECK directive. A DECK directive specifies a name to be associated with all the cards that follow it in the input stream until a deck-ending directive (DECK, COMDECK) or the end of the input stream occurs. UPDATE decks can be arbitrary designations, but for programmer convenience each routine that can be separately compiled is usually given a separate deck name. A group of routines often forms a single deck when recompilation of one routine forces recompilation of the others. Routines GETACC, INTERP, and GENTAB, for example, could be created as a program library with any number of decks, but three decks allow each routine to be considered independent of the others.

A deck is the only unit that can be extracted from the program library and written to a file (called the compile file) in a form corresponding to the original card or card image.

Decks written to the program library can be regular decks or common decks. These differ in that common decks can be called from within a regular deck. By using a common deck, a programmer can ensure that a set of statements required in several routines never deviates among routines. One physical copy of the statements exists as a common deck, but that common deck can be inserted into any number of decks when these decks are extracted from the program

TABLE 6-5. UPDATE DIRECTIVES

Directive Format	Use
*CALL deck	Write a common deck to the compile file.
*COMDECK deck	Define a common deck.
*COMPILE $deck_1, \ldots, deck_n$	Write the specified decks to the compile file and new program library.
*COMPILE $deck_1.deck_2$	Write the inclusive range of decks to these files.
*DECK deck	Define a deck to be included in the program library.
*DELETE $ident_1$.seqnum,$ident_2$.seqnum	Deactivate the inclusive range of cards.
*DELETE ident.seqnum	Deactivate the specified card.
*IDENT idname	Define a correction set.
*INSERT ident.seqnum	Write subsequent text cards after the card identified.
*PURDECK $deck_1, \ldots, deck_n$	Permanently remove the specified decks from the program library.
*PURDECK $deck_1.deck_2$	Permanently remove the inclusive range of decks
*PURGE $idname_1, \ldots, idname_n$	Permanently remove the specified correction sets from the program library.
*PURGE $idname_1.idname_2$	Permanently remove the inclusive range of correction sets.
*YANK $idname_1, \ldots, idname_n$	Temporarily remove the specified correction sets from the program library.
*YANK $idname_1.idname_2$	Temporarily remove the inclusive range of correction sets.
*YANKDECK $deck_1, \ldots, deck_n$	Temporarily deactivate the decks specified.
*/ comment	Copy text to the listable output file.

library. A typical use of a common deck involves a set of DATA statements, COMMON statements, and a DIMENSION statement applicable to several routines, or a set of useful arithmetic statement functions. Assume the following statements:

```
COMMON /BLOCKA/ ARYAA (50), ARYBB (26)
DATA ARYAA/ 1,2. . .50/, ARYBB/1HA, 1HB, . . . ,1HZ/
```

These statements could be made into a common deck callable from subroutines SUB1 and SUB2 in decks SUB1 and SUB2 by using the cards shown in figure 6-21.

UPDATE,I=lfn_1,P=lfn_2,N=lfn_3,C=lfn_4,mode.

lfn_1	Logical file name of the file containing the input stream. The default file name is INPUT.
lfn_2	Logical file name of the file containing an existing program library to be used or corrected. The default file name is OLDPL.
lfn_3	Logical file name of the file to which a new program library is to be written. The default file name is NEWPL. N=0 suppresses new program library generation.
lfn_4	Logical file name of the file to which decks are to be written in the original format. The default file name is COMPILE. C=0 suppresses compile file generation.
mode	UPDATE mode, which affects the decks written to the compile file and to the new program library:
	Q — Only decks specified by COMPILE directives are written
	F — All decks in the old program library are written whether they are modified or not
	omitted — All decks are written to new program library; corrected decks and decks specified by COMPILE directives are written to compile file

Figure 6-20. UPDATE Control Statement Format

```
*COMDECK ARYDEF
    COMMON/BLOCKA/...
    DATA ARYAA/...
*DECK SUB1
    SUBROUTINE SUB1
*CALL ARYDEF
    READ...
     :
    END
*DECK SUB2
    SUBROUTINE SUB2
*CALL ARYDEF
     :
    END
```

Figure 6-21. Input Stream Cards

In response to the cards shown in figure 6-21, one physical copy of the COMMON statement and the DATA statement exist in the program library. The copy of deck SUB1 in the program library includes a directive *CALL ARYDEF. As a result of the CALL directive, any copy of the deck SUB1 written to the compile file includes the COMMON and DATA statements between the statement SUBROUTINE SUB1 and the READ statement shown above; that is, subroutine SUB1 would expand to:

```
SUBROUTINE SUB1
COMMON /BLOCKA/. . .
DATA ARYAA/. . .
READ. . .
```

Sample Creation Run

The sample job deck shown in figure 6-22 illustrates the general structure of a job that creates a program library from a file of source language programs. This example uses the program of figure 4-7, with main program GETACC and subroutines GENTAB and INTERP.

The UPDATE control statement shown in figure 6-22 indicates that the directives supplying detailed instructions for UPDATE are part of the job deck, with the default I=INPUT. Directives in the figure have these functions:

The DECK directive specifies a deck name for the cards that follow. UPDATE assigns a sequence number within the deck for each card.

The cards of source language programs become text in the program library.

Output from UPDATE includes the program library with three decks and a listing that shows the results of execution. The program library is saved as a permanent file with the name PL2.

The call to the FORTRAN compiler is made in figure 6-22 in order to provide a listing of the card identifiers assigned by UPDATE. These identifiers must be known to the programmer before cards can be added to or deleted from a program library through a correction run. The listing can be made in the same job that creates the library or in any subsequent job. Part of the listing from the compiler call is shown in figure 6-23. The text cards added to the program library are also listed as part of the UPDATE output.

```
job statement
ACCOUNT control statement
REQUEST,NEWPL,*PF.     NOS/BE, SCOPE 2
UPDATE,I=INPUT,N=NEWPL,C=COMPILE.
CATALOG,NEWPL,PL2,ID=MINE.     NOS/BE, SCOPE 2
SAVE,NEWPL=PL2.     NOS
FTN,I=COMPILE,R=0,TS, PW=72.
7/8/9
*DECK DGETACC
    GETACC source program
*DECK DGENTAB
    GENTAB source program
*DECK DINTERP
    INTERP source program
6/7/8/9
```

Figure 6-22. Sample Program Library Creation

CORRECTION RUN

A correction run is a run that uses an existing program library rather than one that creates a program library. During a correction run, new cards can be added and existing cards can be deleted. Changes can be made on the basis of individual cards, a range of cards, or all the cards of a particular correction set identifier. These changes become part of a new program library. Any run that simply extracts a deck from the existing program library and copies it to the compile file, such as shown in figure 6-24, is also a correction run.

Any correction run that makes a change to a program library must begin with an IDENT directive that gives a name to all the following changes. For the rest of the life of the program library, any card that is added to the library is identified by a card identifier that has the format:

ident.seqnum

where ident is the correction set identifier, and seqnum is a number assigned by UPDATE.

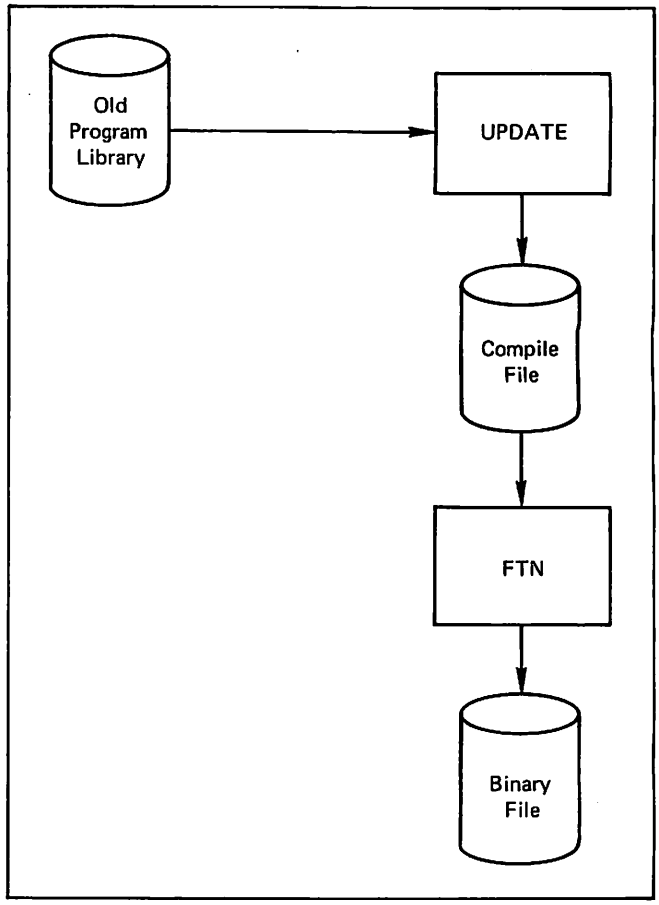


Figure 6-24. Using a Routine on a Program Library

Sample Correction Runs

The sample job decks in figures 6-25 and 6-26 illustrate correction runs. The examples differ in that the first deck uses an existing program library, but does not update the entire program library as the second example does. Both examples presume the existence of the program library created in figure 6-22 and cataloged as a permanent file with the name PL2.

The example in figure 6-25 illustrates a procedure useful when changes are to be made to an existing routine. The input stream contains directives that add a new card to the deck DGETACC. In this particular example, the card added is merely a comment for illustration purposes, but could have easily been many cards that substantially change the

```
      PROGRAM GETACC (INPUT, TAPE4=INPUT, OUTPUT)
      DIMENSION TIME(100), ATAB(100)
C
      N = 3
      NMAX = 100
C
C....GENTAB GENERATES THE ACCELERATION TABLE
C
      CALL GENTAB (NMAX, TIME, ATAB, NTIMES, IER)
      IF (IER .NE. 0) GO TO 900
C
C....READ A CARD CONTAINING A TIME VALUE
C
  100 READ (4,*) T
      IF (EOF(4) .NE. 0) GO TO 900
C
C....INTERP INTERPOLATES FOR ACCELERATION
C
      CALL INTERP (NTIMES, TIME, ATAB, T, ACC, IER)
      IF (IER .NE. 0) GO TO 100
```

Card Identifier

Correction Set Identifier	Sequence Number
DGETACC	2
DGETACC	3
DGETACC	4
DGETACC	5
DGETACC	6
DGETACC	7
DGETACC	8
DGETACC	9
DGETACC	10
DGETACC	11
DGETACC	12
DGETACC	13
DGETACC	14
DGETACC	15
DGETACC	16
DGETACC	17
DGETACC	18
DGETACC	19
DGETACC	20
DGETACC	21

Figure 6-23. Listing of Card Identifiers

program GETACC. In order to be sure that the new cards did not introduce an error into a successfully running routine, the entire routine is then extracted from the program library and compiled. Once the program has executed successfully, UPDATE should be run once more, this time writing a new program library and making it a permanent file.

A new program library can be written and preserved as a permanent file each time UPDATE executes. If errors are subsequently found, another correction run is needed to change the newly inserted cards or to delete erroneous cards. Each subsequent correction run must specify a unique correction set identifier, and as a result, one fix might ultimately appear in the program library with several different correction sets as card identifiers. Consequently, the technique of trial runs is often useful.

The UPDATE control statement of figure 6-25 contains only a Q parameter, which instructs UPDATE to write only decks identified on COMPILE directives to the compile file, in the original format. When this parameter is used, no new program library is generated when the N parameter is omitted.

Directives in figure 6-25 have the following functions:

1. The IDENT directive provides a correction set identifier name. All subsequent cards in the input stream, until a PURGE directive or an IDENT directive appears, are part of the set and are sequenced by UPDATE within that set.

```
job statement
ACCOUNT control statement
ATTACH,OLDPL,PL2,ID=MINE.     NOS/BE, SCOPE 2
GET,OLDPL=PL2.     NOS
UPDATE,Q.
FTN,B=0,I=COMPILE,TS.
7/8/9
*IDENT TRYIT
*INSERT DGETACC.18
C.C.C. THIS IS NEW, INSERTED BY TRYIT .C.C.C
*DELETE DGETACC.7,DGETACC.9
*COMPILE DGETACC
6/7/8/9
```

Figure 6-25. Sample Use of Program Library

```
job statement
ACCOUNT control statement
ATTACH,OLDPL,PL2,ID=MINE.     NOS/BE, SCOPE 2
GET,OLDPL=PL2.     NOS
REQUEST,PL3,*PF.   NOS/BE, SCOPE 2
UPDATE,F,N=PL3,C=0.
CATALOG,PL3,ID=MINE.     NOS/BE, SCOPE 2
SAVE,PL3.     NOS
PURGE,OLDPL.
7/8/9
*IDENT TRYIT
*INSERT DGETACC.18
C.C.C  THIS IS NEW . . .
*DELETE DGETACC.7,DGETACC.9
6/7/8/9
```

Figure 6-26. Sample Correction Run Creating a New Program Library

2. The INSERT directive identifies the location at which following text cards are to be inserted; namely, after the card identified as DGETACC.18.

3. The card that begins with C is not recognized by UPDATE as one of its directives. Any card that is not recognized as an UPDATE directive is treated as a text card to be inserted.

4. The DELETE directive causes three comment cards to be removed from the deck. When two card identifiers are separated by a comma as shown in the figure, a range of cards is indicated. Both cards specified, and all those between, are deleted.

5. The COMPILE directive ensures that deck DGETACC is written to the compile file and the new program library.

The FORTRAN compiler call tests whether the corrected routine compiles correctly. Because execution is not planned, B=0 is specified to suppress executable binary code. The TS parameter calls for quick compilation with little optimization. The source for compilation is the file COMPILE, the default file name when a C parameter is not specified on the UPDATE call. The compile file contains only deck DGETACC (the main program GETACC), because Q mode is specified on the UPDATE control statement. No decks appear on the compile file in the absence of COMPILE directives under Q mode.

The source listing produced by the FORTRAN compiler is shown, in part, in figure 6-27. Notice that the deleted cards do not appear on the compile file, although they still exist on the program library and can be reactivated by a YANK directive that references the correction set identifier. The new card added appears with a card identifier corresponding to the correction set identifier and sequence number in that set.

In the second correction run example (figure 6-26), the changes made to the existing program library are incorporated into a new program library.

The UPDATE control statement, in the absence of a P parameter, assumes the existing program library is on the file OLDPL. The new program library is to be written to the file PL3. Because the changes to the program library were checked out in the previous example, there is no need for the compile file and it is suppressed by the C=0 parameter. The new program library, PL3, is made a permanent file before the old program library is purged. If the CATALOG or SAVE control statement fails for any reason, the old program library is preserved.

The UPDATE mode is specified as F. As a result, all decks on the old program library are written to the new program library. If the Q mode was specified, only the deck DGETACC would have been written to the new library.

The PURGE control statement eliminates the previous version of the program library.

UPDATE Listing

Figure 6-28 shows the output listing from figure 6-25. Information printed includes the following:

1. Identification of the run as a creation run (CREATION RUN) or correction run (OLDPL).

2. A copy of the input stream.

3. The full text of cards modified, with the card identifiers (3a) and an indication whether the card was inserted (I), deleted (D), or added as a result of a YANK directive (A).

4. A list of correction set identifiers. Notice that all deck names are also considered to be correction set names. The order of identifiers is significant when the YANK or PURGE directives specify a range of identifiers, because the range specified must be in the same chronological order in which the identifiers were inserted into the program library.

5. A list of decks already on the old program library, plus any decks added in the current run. All program libraries contain a deck YANK$$$ that is used internally by UPDATE to track YANK operations.

6. A list of decks written to the new program library. The UPDATE mode and COMPILE directives control the decks written to the new program library.

7. A list of decks written to the compile file. The UPDATE mode and COMPILE directives control the decks written to the new program library. The decks on the compile file can be compiled by *FORTRAN* Extended.

```
      PROGRAM GETACC (INPUT, TAPE4=INPUT, OUTPUT)                    OGETACC    2
      DIMENSION TIME(100), ATAB(100)                                 OGETACC    3
C                                                                    OGETACC    4
      N = 0                                                          OGETACC    5
      NMAX = 100                                          CARDS DELETED OGETACC  6
      CALL GENTAB (NMAX, TIME, ATAB, NTIMES, IER)                    OGETACC   10
      IF (IER .NE. 0) GO TO 900                                      OGETACC   11
C                                                                    OGETACC   12
C....READ A CARD CONTAINING A TIME VALUE                             OGETACC   13
C                                                                    OGETACC   14
  100 READ (4,*) T                                                   OGETACC   15
      IF (EOF(4) .NE. 0) GO TO 900                                   OGETACC   16
C                                                                    OGETACC   17
C....INTERP INTERPOLATES FOR ACCELERATION                            OGETACC   18
C.C.C. THIS IS NEW, INSERTED BY TRYIT .C.C.C          CARD ADDED ---> TRYIT      1
C                                                                    OGETACC   19
      CALL INTERP (NTIMES, TIME, ATAB, T, ACC, IER)                  OGETACC   20
      IF (IER .NE. 0) GO TO 100                                      OGETACC   21
      WRITE 15, T, ACC                                               OGETACC   22
```

Figure 6-27. Listing from Corrected Deck

```
UNLABELED OLDPL              IDENT    TRYIT (1)                     UPDATE 1.2-452.      07/21/77  09.29.37.

*****     *IDENT TRYIT                                         )
*****     *INSERT DGETACC.18                                   )
          C.C.C. THIS IS NEW, INSERTED BY TRYIT .C.C.C         } (2)
*****     *DELETE DGETACC.7,DGETACC.9                          )
*****     *COMPILE DGETACC                                     )


          MODIFICATIONS / CONTROL CARDS  (3)
                                                                                          (3a)
DGETACC  C                                                                       DGETACC     7        D
DGETACC  C....GENTAB GENERATES THE ACCELERATION TABLE                            DGETACC     8        D
DGETACC  C                                                                       DGETACC     9        D
DGETACC  C.C.C. THIS IS NEW, INSERTED BY TRYIT .C.C.C                            TRYIT       1     I


               CORRECTION IDENTS ARE LISTED IN CHRONOLOGICAL ORDER OF INSERTION

          DGETACC   DGENTAB   DINTERP   TRYIT  (4)


           DECK LIST AS READ FROM OLDPL PLUS ADDED NEW DECKS

          YANK$$$   DGETACC   DGENTAB   DINTERP  (5)


DECKS ARE LISTED IN THE ORDER OF THEIR OCCURRENCE ON A NEW PROGRAM LIBRARY IF ONE IS CREATED BY THIS UPDATE

          YANK$$$   DGETACC  (6)


          DECKS WRITTEN TO COMPILE FILE

          DGETACC  (7)


 THIS UPDATE REQUIRED  33700B WORDS OF CORE.
```

Figure 6-28. Typical UPDATE Output Listing

LOADING FORTRAN PROGRAMS 7

After a FORTRAN program has been compiled, it must be put in the proper format and placed in memory before execution can take place. These functions are performed by an operating system utility called the loader. For NOS and NOS/BE, the loader is called the CYBER Loader; for SCOPE 2, the loader is called the SCOPE 2 Loader. These two loaders have many common features, and some incompatibilities, which are pointed out where necessary.

In the simplest type of loading, the binary object code for an executable program, consisting of a main program and its associated subprograms, is written to a file. The program is then loaded and executed by a control statement containing the name of the file (LGO is the default file name from a call to the FORTRAN Extended compiler). Use of more advanced features of the loader can provide the following advantages for the user:

- Reduction of field length requirements by dividing large programs into smaller portions that need not all be in memory at the same time. This can be accomplished with overlays or segments.
- Increased code modularity by grouping frequently used routines into libraries that can be referenced by more than one program. Creation of user libraries is described in section 6.
- Faster execution time for repeatedly executed programs by eliminating the necessity for relocation each time the program is executed.
- More information for program debugging by requesting a detailed load map.

Which loader features to use is a decision that can only be made based on the requirements of a given application. In particular, segments and overlays, while reducing field length requirements, can increase execution time because of the time required to move programs into and out of memory. Three types of loading are of particular interest to the FORTRAN user:

- Basic loading. This is accomplished through control statements, and consists of loading all the necessary object code into memory at the same time. This is the commonest type of loading, because most programs are small compared to the amount of central memory available.
- Segment loading. This is accomplished by the SEGLOAD control statement in conjunction with segmentation directives. Programs are divided into units called segments; the segments are linked into any number of tree structures. At execution time, when a segment not already in memory is required, it is loaded automatically.
- Overlay loading. This is accomplished by OVERLAY directives in the source program. Programs are divided into smaller units called overlays. At execution time, the overlays are loaded as specified by the user through the OVERLAY subroutine. Because overlays are fully described in the FORTRAN Extended Reference Manual, they are not described further here.

Overlays and segments have comparative advantages and disadvantages. Segments provide more flexibility in the type of structure that can be constructed; overlay structure is restricted to a single tree. Furthermore, segments are loaded automatically, while overlays must be loaded explicitly. On the other hand, segmentation poses certain problems related to interprogram communication, especially for the FORTRAN user. (These problems are described below.) Also, overlays are generally faster to load than segments, and segments cannot be put into libraries.

Several processes take place for any kind of loading; one of these processes is relocation. When a program unit is compiled, the object code is produced in relocatable format. The addresses of variables and instructions are only temporary, and are defined relative to the beginning of the program unit, or of a common block. Before the program can be executed, the addresses must be made absolute; that is, defined relative to the beginning of the user's field length. Relocation is the function of the loader, and takes place in different ways depending on the type of load. One of the advantages of overlays and segmentation is that relocation is performed only once, reducing the time required for subsequent loads of the same program.

Another process that takes place during loading is the satisfaction of external references. An external reference is a reference by one program unit to an entry point in another program unit. In a FORTRAN program, external references include names of referenced subprograms, whether user-defined subprograms or library subprograms. In addition, input/output statements generate references to FORTRAN Common Library and Record Manager routines, as well as to the file information tables for all files used. Although the user is not concerned with these external references when specifying the simplest types of loads, some situations that can arise in more advanced types of loading require the user to be aware of the existence of these external references.

When a file is loaded, external references are satisfied by matching them with entry points on the file whenever possible. If unsatisfied externals remain after this process, they are satisfied by searching library files until a matching entry point is found. The library files associated with a job are called the library set. When the same entry point occurs on more than one file, or more than once on the same file, the loader must use the search order that has been established to determine which entry point to use to satisfy the external reference. The order in which libraries are searched is defined below, under Library Search Order.

BASIC LOADING

A basic load is a load that does not involve dividing the object code into smaller units. All the object code for an execution is present in memory at the same time. A basic load is accomplished entirely through control statements, without the need for special loader directives or subroutine calls.

The control statements that define the processing for one complete load operation are referred to as a load sequence. The control statements in a load sequence are recognized by the system as loader control statements, and cannot be interrupted by any other control statements (except for

MAP and REDUCE). A load sequence ends with a completion statement (EXECUTE, NOGO, or a name call statement). The simplest example of a load sequence is a single name call statement (such as LGO).

When the first loader control statement is encountered, the loading process begins. This process involves the following sequence of events:

All control statements in the load sequence are read.

The control statements are processed in order.

Libraries are searched to satisfy externals.

Execution field length is determined.

The load map is written.

Program execution is initiated (unless the sequence is terminated by NOGO).

For execution of a FORTRAN program to begin, one and only one main program must be loaded. Additionally, labeled and blank common blocks and any number of subprograms can be loaded. The main program need not be loaded first. Normally, the only subprograms loaded are those referred to by the main program or by other loaded subprograms; however, other subprograms can be explicitly loaded by the SLOAD control statement.

Because the actual arrangement of code in memory is determined by the operating system capability called the Common Memory Manager (CMM), the order in which subprograms and common blocks occur in memory cannot be determined in advance. Even when the user knows the order in which code is loaded, it is not good practice to make a program dependent on this ordering. In particular, the practice of over-indexing blank common on the assumption that blank common is loaded last is not necessarily valid when CMM manages memory, and it might lead to incorrect results when the optimizing facility is used.

NAME CALL STATEMENT

The name call statement (figure 7-1) always terminates a load sequence and causes execution to begin. The other actions taken depend on whether the name is the name of a file or of an entry point.

If the name is a file name, the file is rewound and its contents loaded into memory. If the file contains end-of-partition boundaries, only the first partition is loaded.

If the name is not a file name, the loader assumes that it is an entry point name. (This feature is not supported under NOS.) The loader searches the library set until a matching entry point is found, and loads the program containing the entry point. In either case, the loader then satisfies all external references and begins execution.

$name(p_1,p_2,\ldots,p_n)$

name	Logical file name of the file to be loaded and executed, or name of the main program to be loaded and executed.
p	Alternate file names for execution time file name substitution.

Figure 7-1. Name Call Statement Format

The FORTRAN programmer must ensure that one and only one main program is loaded before execution begins.

The file name call is the commonest call and is usually used for the simple case in which the object code is written by default to the file LGO. The entry point name call is useful when a frequently executed program is kept on a library. In this case, the entry point used in the call is the name of the main program.

Parameters can be included on the name call statement. The parameters applicable to FORTRAN Extended are the print limit specification (described in the FORTRAN Extended Reference Manual) and the alternate file name specification.

File name parameters on the name call statement are used to override the file names specified on the PROGRAM statement when the program was compiled; thus, an already compiled program can perform input/output on any file. The file name parameters are positional; the first parameter corresponds to the first file name in the PROGRAM statement, and so on. If a file name is to be substituted, but another file name to the left is to be unchanged, the parameter for the earlier file name is omitted (with the omission indicated by two adjacent commas). File equivalencing specifications in the PROGRAM statement are not counted in marking position, nor is the PL parameter in the name call statement (as defined in the FORTRAN Extended Reference Manual).

Examples of alternate file name specification are shown in figure 7-2.

EXECUTE CONTROL STATEMENT

The EXECUTE control statement (figure 7-3) completes the loading process and begins execution. EXECUTE can only be used when the main program has already been loaded in the same load sequence. Before beginning execution, EXECUTE satisfies any external references not already satisfied, writes the load map, and sets the execution field length. EXECUTE is used to complete a load sequence and begin execution whenever loading is more complicated than that performed by a simple name call statement. In particular, EXECUTE is used whenever individual program units have been loaded from a file by means of SLOAD.

SLOAD CONTROL STATEMENT

The SLOAD control statement (figure 7-4) explicitly loads only the named program units from the named file. It does not load programs to satisfy external references; this can be accomplished by an EXECUTE control statement in the same load sequence. (EXECUTE only satisfies references to programs in the library set.)

Although SLOAD can be used to load program units from a single file, a more likely use is to load program units from several files. SLOAD is the simplest way to load routines from more than one non-library file, because a name call statement can only load routines from one file. When SLOAD is used, the user must be sure to explicitly load all needed routines that are not on library files, since there is no other way to satisfy external references.

The following load sequence explicitly loads a main program (MAIN) and four subprograms (SUB1 through SUB4) from two different files, and initiates execution:

```
SLOAD(FILE1,MAIN,SUB1,SUB2)
SLOAD(FILE2,SUB3,SUB4)
EXECUTE.
```

LOAD CONTROL STATEMENT

The LOAD control statement (figure 7-5) loads the entire contents of a file. Loading stops when an end-of-partition or end-of-information is encountered. External references are not satisfied.

Example 1

PROGRAM statement:

```
PROGRAM FOIST (INPUT, OUTPUT, TAPE3)
```

Name call statement:

```
LGO(FIRST, SECOND)
```

File names actually used:

FIRST
SECOND
TAPE3

Example 2

PROGRAM statement:

```
PROGRAM NEXT (TAPE1,TAPE2,INPUT,OUTPUT)
```

Name call statement:

```
BIN(, , ,FILEX)
```

File names actually used:

TAPE1
TAPE2
INPUT
FILEX

Example 3

PROGRAM statement:

```
PROGRAM LAST (INPUT,OUTPUT,TAPE1=
*INPUT,TAPE2=OUTPUT)
```

Name call statement:

```
PROG(,AAA,BBB)
```

File names actually used:

INPUT (also used for references to TAPE1)

AAA (also used for references to TAPE2)

Parameter BBB is ignored because it does not correspond to any file specification.

Figure 7-2. Alternate File Name Examples

LOAD is more convenient than SLOAD when the entire contents of more than one file are to be loaded. As usual, one and only one main program must be loaded.

NOGO CONTROL STATEMENT

The NOGO control statement (figure 7-6) is similar to the EXECUTE statement, except that execution is not initiated. The loader satisfies external references, generates absolute addresses and writes the load map, and then writes the absolute binary code to the named file. This file can subsequently be loaded and executed.

EXECUTE(,p_1,. . . ,p_n)

p — Optional file name specification, identical in format and effect to the same specification in the name call statement.

A comma must occur between the left parenthesis and the first file name unless the entry point parameter (discussed in the loader reference manual) is used.

Figure 7-3. EXECUTE Control Statement Format

SLOAD(lfn,$name_1$,. . . ,$name_n$)

lfn — Logical file name of the file from which to load. The file is or is not rewound, depending on the absence or presence of the no rewind indicator:

- lfn — The file is rewound before loading
- lfn/NR — The file is not rewound before loading

name — Name of the program unit to be loaded.

Figure 7-4. SLOAD Control Statement Format

LOAD(lfn$_1$,. . . ,lfn$_n$)

lfn — Logical file name of the file to be loaded. The file is or is not rewound, depending on the absence or presence of the no rewind indicator:

- lfn — The file is rewound before loading
- lfn/NR — The file is not rewound before loading

Figure 7-5. LOAD Control Statement Format

NOGO(lfn)

lfn — Name of the file on which absolute binary is to be written.

Figure 7-6. NOGO Control Statement Format

The primary use of NOGO is for a program that is to be executed several times. By saving the absolute binary on a permanent file, the time required to load the program in subsequent jobs is reduced.

The following control statements compile a program and write the relocatable binary code to LGO; LGO is then loaded and written as an absolute program to the file BINS, which is subsequently executed and also saved as a permanent file for future execution.

```
REQUEST,BINS,*PF. (NOS/BE,SCOPE 2)
FTN.
LOAD(LGO)
NOGO(BINS)
BINS.
CATALOG,BINS, . . . (NOS/BE, SCOPE 2)
    or
SAVE(BINS) (NOS)
```

LIBRARY CONTROL STATEMENT

The LIBRARY control statement (figure 7-7) establishes a global library set to be used for satisfying external references. It cannot be used within a load sequence. The library set established remains in effect (regardless of any loading procedures that take place) until another LIBRARY control statement is encountered. The second LIBRARY control statement either establishes a new global library set or (if it is specified with no parameters) deletes the global library set altogether; LIBRARY control statements are not cumulative under NOS/BE and NOS. Under SCOPE 2, LIBRARY control statements can be cumulative; see the SCOPE 2 Loader Reference Manual.

Libraries can be created through the EDITLIB utility under NOS/BE, the LIBEDT utility under SCOPE 2, or the LIBGEN utility under NOS. These utilities are discussed in section 6.

LDSET CONTROL STATEMENT

The LDSET control statement (figure 7-8) performs several different types of operations. Presetting unused memory, selectively loading or omitting routines, setting the default rewind indicator, and controlling the load map are all possible through LDSET. The loader reference manuals describe these capabilities; only two parameters are described here.

The LIB option of the LDSET statement establishes a local library set, which remains in effect only during the load sequence of which the LDSET statement is a part. Establishing a local library set has no effect on the global library set. LDSET can be specified with the LIB option more than once in a load sequence; if LIB is specified with no file names, the local library set is cleared.

LIBRARY(lfn_1, . . . ,lfn_n)

lfn — Logical file name of a library-format file to become part of the global library set. Maximum number is 2 user and 2 system libraries, 1 user and 13 system libraries, or 0 user and 24 system libraries. If LIBRARY is specified with no parameters, the global library set is cleared.

Figure 7-7. LIBRARY Control Statement Format

The ERR option is used to change the default conditions under which a job is aborted if loader errors occur. The most likely parameter to be used is ALL; this provides that nonfatal errors, as well as catastrophic and fatal errors, abort the job. In the absence of this option, a program might begin execution and then abort because of a condition diagnosed by the loader as nonfatal. This is particularly undesirable for a program that takes a long time to execute, or that changes the contents of files in a manner difficult to reconstruct. In situations like this, the ALL option catches the error condition before the job starts executing. The option can also be used to simplify debugging by aborting the job at the earliest possible point.

Although most nonfatal loader errors are not likely to affect program execution, some can have adverse effects. For example, the existence of an unsatisfied external is a nonfatal error. Whether this would cause the program to abort depends on whether the external is actually referenced during execution.

LIBRARY SEARCH ORDER

In the process of satisfying externals or locating an entry point for the name call statement, ambiguity can arise when the same entry point or program name occurs twice within the libraries available to the job step. For this reason, a rigorous search order has been established so that it is always possible to determine how each external is satisfied.

The search order for external references is as follows:

Global library set

Local library set

SYSLIB (the default system library); NOS, NOS/BE only

The search order for the name call statement is as follows:

Local files

Global library set

Local library set

NUCLEUS (system library; NOS/BE, SCOPE 2 only)

LDSET,LIB=lfn_1/. . ./lfn_n,ERR=p.

lfn — Logical file name of the file to become part of the local library set.

p — Specifies the type of loader error for which a job is to be aborted. The default is an installation option. Must be one of the following:

- ALL — Job is aborted for catastrophic, fatal, and nonfatal errors
- FATAL — Job is aborted for catastrophic and fatal errors
- NONE — Job is aborted only for catastrophic errors

Figure 7-8. LDSET Control Statement Format

Within each library set, libraries are searched in the order that they were defined.

If the loading of programs from libraries produces new external references that must be satisfied from the library set, these references are satisfied the next time the appropriate entry point is encountered. If the end of all the library sets is encountered, and unsatisfied references remain, the search is begun again from the beginning. This circular search continues until either all references have been satisfied, or until the entire library set has been searched once with no new satisfaction of references.

FIELD LENGTH CONTROL

The amount of memory needed to execute a job step is normally calculated and requested by the loader. However, the user can control this procedure by using the CM parameter on the job statement, as well as the REDUCE and RFL control statements.

The format of the REDUCE control statement is shown in figure 7-9; the format of the RFL control statement is shown in figure 7-10. The effect of the CM parameter depends on the operating system:

- Under NOS/BE, the CM parameter establishes a maximum field length available to the job, and assigns that field length to the job initially. This parameter should not in general be used, since it inhibits dynamic adjustment of field length.
- Under SCOPE 2, the CM parameter can only be overridden by a request from within a program; this can occur during a FORTRAN compilation. Otherwise, its action is the same as under NOS/BE.
- Under NOS, the CM parameter can be overridden by the MFL control statement (see the Loader Reference Manual). Otherwise, it establishes a maximum value for field length.

To inhibit reduce mode:

REDUCE(-)	NOS
REDUCE(OFF)	NOS/BE INTERCOM

(CM parameter or RFL under NOS/BE batch, SCOPE 2)

To restore reduce mode:

REDUCE.	NOS/BE batch, NOS, and SCOPE 2
REDUCE(ON)	NOS/BE INTERCOM

Figure 7-9. REDUCE Control Statement Format

RFL(n)

n	Number of words of central memory field length, in octal.

Figure 7-10. RFL Control Statement Format

Under NOS/BE and SCOPE 2, all jobs begin in reduce mode in the absence of the CM parameter. Under NOS, all jobs begin in reduce mode regardless of the CM parameter. In reduce mode, the loader sets the field length for every job step before execution begins; therefore, only the amount of memory actually needed is allocated. If a REDUCE(OFF) control statement (NOS/BE INTERCOM), a REDUCE(-) control statement (NOS), or an RFL control statement (NOS/BE batch and SCOPE 2) is encountered, reduce mode is turned off. In the case of an RFL control statement, the field length specified becomes the execution field length until another RFL control statement is encountered or reduce mode is reestablished by a REDUCE control statement (NOS/BE batch, NOS, and SCOPE 2) or a REDUCE(ON) control statement (NOS/BE INTERCOM). Under NOS, REDUCE(-) must be preceded or followed by an RFL control statement because otherwise the field length is reduced to zero.

FORTRAN users are not usually required to manage their own field length because the compiler tries to assure that adequate field length is always available; however, under some circumstances, compilation speed can be improved by providing an RFL control statement prior to compilation. This is particularly true when compiling with the TS option or the OPT=2 option. Although both these compilation modes control their own field length by requesting more central memory when necessary, providing an initial value greater than the default can reduce compilation time.

An RFL control statement does not improve execution time of a compiled program, because execution field length is calculated by the loader. Reduce mode should be reestablished before execution begins.

BASIC LOAD EXAMPLES

The control statements shown in figure 7-11 illustrate the use of global and local library sets. The example applies to NOS and NOS/BE; under SCOPE 2, there is no default system library.

When the file LGO1 is loaded, the library set is empty except for the default system library, SYSLIB; therefore, SYSLIB is the only library searched to satisfy externals for LGO1.

```
LGO1.
LIBRARY(ALGOL)
LDSET(LIB=USER/AX)
LGO2.
LGO3.
LIBRARY.
LGO4.
```

Figure 7-11. Basic Load

The LIBRARY(ALGOL) control statement specifies that the global library set is to consist of ALGOL. The LDSET(LIB=USER/AX) loader control statement specifies that the current load sequence is to use local libraries named USER and AX; thus, when the file LGO2 is loaded, the libraries ALGOL, USER, AX, and SYSLIB are searched (in that order) to satisfy externals.

When LGO3 is loaded, only ALGOL and SYSLIB are searched to satisfy externals, because USER and AX were local to the load sequence completed by LGO2. The next LIBRARY statement clears the global library set, so that the only library searched to satisfy externals for LGO4 is SYSLIB.

As another example, consider compilation of a program with an OPT=2 parameter on the compiler call. Assume the following message was listed in the output listing:

```
63000B CM USED
```

After the user made some minor modifications, the program was recompiled and executed with the following control statements:

```
RFL,63000.
FTN,OPT=2.
REDUCE.
LGO.
```

The RFL control statement eliminates the necessity for the compiler to request additional field length. The REDUCE control statement restores reduce mode so that no more field length than necessary is used for execution of the program.

SEGMENT LOADING

Segmentation allows the user to decrease the execution time field length requirements of a program by dividing it into smaller portions called segments, which are loaded and unloaded as needed, rather than all being in memory at the same time, as for a basic load. Segments (each of which contains one or more program units) are grouped into structures called trees, and the trees are grouped into one or more levels. One particular segment, called the root segment, stays in memory at all times.

Segments are built whenever a SEGLOAD control statement is encountered. The building takes place according to the segment directives provided by the user. The segmented program is saved on a file and can be executed in the same load sequence, or at a later time.

Execution of a segmented program always begins with the root segment. A segmented FORTRAN program contains one and only one main program, which must be in the root segment. Whenever a subprogram is referenced, the segment containing the subprogram is automatically loaded. This segment might overwrite a previously loaded segment.

Compared to overlays, which is the other method of dividing large programs into smaller units, segmentation provides several advantages. The structures that can be created are more varied; whereas overlays allow only one tree with at most three levels of branching, segments can be grouped into any number of independent levels, each containing any number of trees. Furthermore, segments can be built from previously compiled programs; with overlays, the structure must be specified at the time the program is compiled. Finally, loading of segments is automatic and takes place whenever a program unit in a segment is referenced; overlays must be loaded explicitly.

Segments have some disadvantages, however, especially for the FORTRAN user. For one thing, segmented programs cannot be put into libraries. Also, the treatment of labeled common blocks requires the FORTRAN user to explicitly specify the blocks used by the FORTRAN Common Library (as explained below). However, neither of these disadvantages should be considered as a conclusive objection to the use of segmentation.

One additional disadvantage applies both to segments and overlays: the increase in execution time resulting from moving programs into and out of memory during execution. Whether this outweighs the savings in field length provided by these two methods can only be decided based on a specific application.

SEGMENTED PROGRAM STRUCTURE

A segmented program consists of one or more levels, each of which contains one or more trees.

A tree consists of a root segment and zero or more branch segments, each of which in turn can have zero or more branches of its own. An example of a tree is shown in figure 7-12; A is the root segment and B and C are its branches. C in turn has one branch, D.

Trees can be grouped into levels. The lowest level can only contain one tree; the root segment of this tree is the root segment of the whole program. An example of a segmented program containing three levels is shown in figure 7-13. The first level contains one tree, the second level contains two trees (one of these trees contains only one segment), and the third level contains one tree. Segment A is the root segment of the whole structure.

If segment y is in the same tree as segment x and can be reached from x by branching upward, x is called the ancestor of y. For example, in figure 7-13, segments A and C are ancestors of segment D. Neither B nor C is an ancestor of the other.

The structure of a segmented program determines which segments can be in memory at the same time. Such segments are called compatible, and fall into two categories:

- Segments in different levels, which are always compatible
- Segments in the same level, which are compatible only if they are in the same tree, and only if one of the segments is an ancestor of the other segment. In figure 7-13, C is compatible with D but not with B; E and F are not compatible.

Any two segments have a nearest common ancestor, determined as follows:

- If the segments are in different trees, the root segment of the whole structure is their nearest common ancestor.

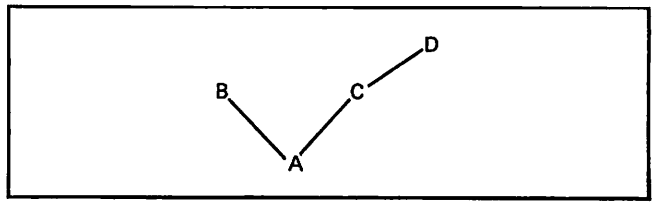


Figure 7-12. Sample Tree Structure

- If one of the segments is the ancestor of the other segment in the same tree, it is the nearest common ancestor of the two segments.
- If the segments are in the same tree, but neither is the ancestor of the other, then the nearest common ancestor is the highest segment from which both segments can be reached by branching. Another way to put this is that the nearest common ancestor is the root of the smallest subtree containing both segments.

This process is repeated for more than two segments. For example, in figure 7-13, segment A is the nearest common ancestor of segments H and G, segment C is the nearest common ancestor of segments C and D (note that a segment can be its own ancestor), and segment H is the nearest common ancestor of segments I and J.

BUILDING A SEGMENTED PROGRAM

When a SEGLOAD control statement is encountered, the loader creates a segmented program. All the control statements in the same load sequence as the SEGLOAD control statement are used in the segmentation process. However, these statements take on a different meaning than in a basic load.

Instead of causing loading, LOAD, SLOAD, and the name call statement specify files (or programs on files, in the case of SLOAD) from which relocatable program units and common blocks are to be read during the creation of segments. EXECUTE and the name call statement signal the end of the load sequence and the execution of the segmented program, but execution always begins at the main entry point in the root segment. This entry point can come from any file, not just the file specified in the name call statement. NOGO terminates the load sequence and causes the segmented program to be written to the file specified in the SEGLOAD control statement; the program is not executed. No file name can be specified in the NOGO control statement in a segmented load.

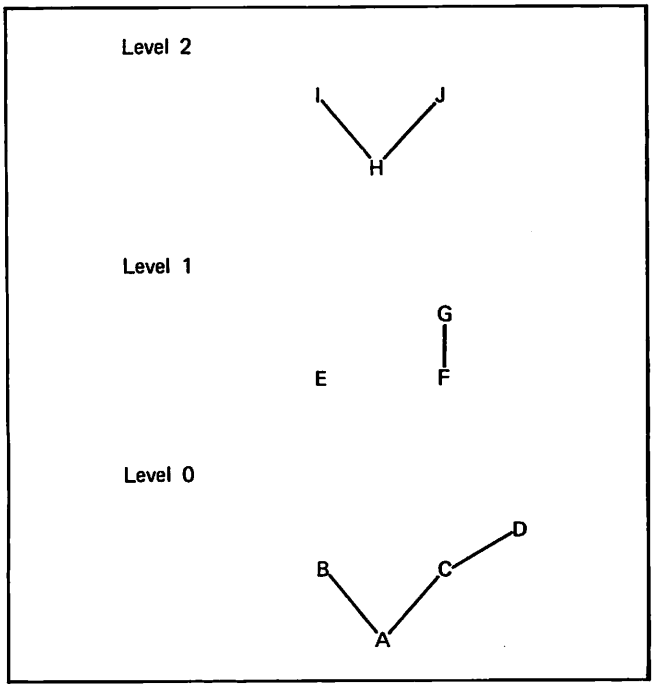


Figure 7-13. Segmented Program with Three Levels

For example, a load sequence consists of the following control statements:

```
LOAD(ABC)
SLOAD(DEF,GHI,JKL,MNO)
SEGLOAD, B=PQR.
LDSET(LIB=MYLIB)
LGO.
```

All program units from the files ABC and LGO are included in the segmented program, and the program units GHI, JKL, and MNO from the file DEF are also included. External references are satisifed from these files, from the global library set, and from the local library MYLIB. After the segmented program is built, the binaries are written to the file PQR, the root segment is loaded, and execution begins at the main entry point in the root segment.

To build a segmented program, the loader collects all the information in the control statements in the load sequence and in the segment directives, and then builds the program based on that information. When building segments, the loader reads program units from the load files and divides them into fixed programs and movable programs. Fixed programs are those explicitly assigned to segments by the user through TREE and INCLUDE directives. Movable programs are those encountered by the loader while either loading other programs or satisfying external references. External references are satisfied from load files and from the global and local library sets. The loader then assigns each movable program to the nearest common ancestor of all the segments that reference the program.

When a program unit is present on a load file (unless the file was specified by SLOAD), but is not referenced by any segment, the loader includes it in the root segment. Because such a program is not referenced in any standard way by the FORTRAN program units (or else it would be loaded to satisfy an external reference), its inclusion in the segmented program is of no value, and is wasteful of field length; therefore, the user should ensure that the load files contain only program units that are actually used in the segmented program.

The treatment of common blocks differs from that of program units. Blank common is always loaded after the highest address in the highest level of segmentation. The location of a labeled common block depends on whether or not the block is specified in a GLOBAL directive. If the block is declared global, a single copy of the block is kept in the specified segment. If the block is not declared global, a separate copy is made for each segment that references the block. In this case, data placed in the block by a program unit in one segment cannot be accessed by a program unit in a different segment. Therefore, any block used for communication between program units in different segments should be declared global by the user. A global block can only be preset from the segment containing it.

After all program units and common blocks have been assigned to segments, the loader converts addresses into absolute addresses. The space allocated for a non-global common block is the same for each copy, and is the greatest length declared for it by any program unit. The space allocated for a level is the length of the longest tree in that level. Blank common is allocated after all segments.

As the segmented program is built, it is written to a file (either the file specified on the SEGLOAD control statement, or the file ABS if none was specified). If the completion statement of the load sequence is EXECUTE or a name call statement, the program is then executed, beginning at the main entry point in the root segment. If the completion statement is NOGO, execution does not take

place. In either case, the file is normally saved by the user and executed again at a later time (since segmentation is unlikely to be used for a program executed only once).

SEGMENT DIRECTIVES

The segment directives are found on the file indicated by the I parameter on the SEGLOAD control statement (figure 7-14). SEGLOAD directives have three fields: label, verb, and specification. The label field begins in column 1 and ends with one or more blanks. The verb field begins after the label field, and ends with one or more blanks. The specification field begins after the verb field. The contents of each of these fields depend on the directive.

The directives can be in any order except for LEVEL, TREE, and END. END must be the last directive. If the segmentation structure is to contain more than one level, LEVEL directives are used to separate the levels. Between each pair of LEVEL directives, TREE directives define the trees that constitute the level. Within a particular level, TREE directives can be in any order.

The format of the TREE directive is shown in figure 7-15. The label field contains the tree name, which is not needed if it is not referenced elsewhere in the directives. The specification field contains an expression that defines the root of the tree and its branching structure. This expression consists of tree segment names, separated by the characters - , (and). The character - indicates that the segment or tree name to the left of the minus sign is the parent of the expression to the right of the minus sign. This expression is either another segment or tree name or a subexpression enclosed in parentheses. The character , indicates that the segments, tree names, or subexpressions separated by the comma are on the same level, branching from a common parent. Examples of tree expressions are shown in figure 7-16.

When writing a tree expression, it is always necessary to ensure that the tree specified is a valid tree. For example, the following pair of TREE directives does not generate a valid tree:

```
A   TREE  B-(C,D)
    TREE  A-(E,F)
```

SEGLOAD(I=lfn_1,B=lfn_2)

lfn_1	Logical file name of file containing segment directives. The default is INPUT.
lfn_2	Logical file name of the file to which a segmented program is to be written. The default is ABS.

Figure 7-14. SEGLOAD Control Statement Format

Label	Verb	Specification
tname	TREE	exp

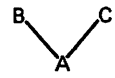
tname	Optional tree name.
exp	Tree expression. The format is described in the text.

Figure 7-15. TREE Directive Format

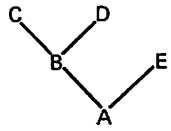
The INCLUDE directive (figure 7-17) forces inclusion of object programs into a specific segment, thus overriding the rules that place an object program into the nearest common ancestor of all referencing segments. Using INCLUDE, duplicate copies of a program unit can be placed in more than one segment.

The INCLUDE directive can sometimes be used to decrease the maximum field length required by a segmented program. For example, in figure 7-13, suppose that both segments B and E reference the subroutine SUB1. This subroutine would normally be included in the root segment A. Because A is always present in memory, this subroutine is always loaded, even when neither B nor E is loaded. If the length of segments C and D is greater than the length of B, the total space allocated for level 0 is greater than the space actually

1. The expression A-(B,C) can be diagrammed as follows:



2. The expression A-((B-(C,D)),E) can be diagrammed as follows:



3. When one of the names in an expression is a tree name, the entire tree is substituted in the generated structure. For example, if the following two TREE directives appear:

```
F     TREE    B-(C,D)
      TREE    A-(F,E)
```

the resulting tree would appear as follows:

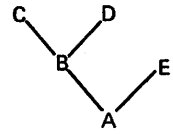


Figure 7-16. TREE Directive Examples

Label	Verb	Specification
segname	INCLUDE	$program_1, \ldots,$ $program_n$

segname	Name of the segment in which program units are to be included. If omitted, all program units named in the directive are included in the root segment.
program	Name of the program unit to be included in the segment.

Figure 7-17. INCLUDE Directive Format

needed at any time. By forcing copies of SUB1 into B and E, the length of level 0 can be reduced. The directives to do this are shown in figure 7-18.

The fixed programs contained in a segment are defined by the TREE and INCLUDE directives. When a segment name appears in a TREE directive, the loader searches for a program unit with that name and includes it in the segment with the same name. However, the INCLUDE directive overrides the TREE directive. If a segment name appears in an INCLUDE directive, the programs specified in the INCLUDE directive are forced into the segment; so is the program with the same name as the segment.

The primary value of INCLUDE for the FORTRAN user is to help avoid CALL-RETURN conflicts, such as those described below. Care must be taken in using INCLUDE that extra copies of common blocks are not created, unless each such block is referenced only by program units in the segment it is forced into; otherwise, each segment will use the copy of the block contained in that segment, and information stored in one segment will not be available to other segments.

The LEVEL directive (figure 7-19) delimits levels within the directive sequence. As each LEVEL directive is encountered, a new level is begun. Thus, the trees included in any given level are those defined by TREE directives occurring between the LEVEL directives.

The GLOBAL directive (figure 7-20) ensures that only one copy of a labeled common block is created. If a segment name is present in the label field, the block is kept in that segment; otherwise, the block is kept in the root segment of the whole structure. When a block is kept in a segment other than the root, it is overwritten whenever an incompatible segment is loaded unless the -SAVE parameter is used. -SAVE specifies that the contents of the block are to be written to a file whenever the segment is overwritten, and restored when the segment is reloaded. -SAVE is unnecessary for a block kept in the root segment. ECS common blocks can be specified by the GLOBAL directive, but because these blocks are never overwritten, -SAVE is also unnecessary for them.

Label	Verb	Specification
B	INCLUDE	SUB1
E	INCLUDE	SUB1

Figure 7-18. INCLUDE Directive Example

Label	Verb	Specification
	LEVEL	

Figure 7-19. LEVEL Directive Format

Label	Verb	Specification
segname	GLOBAL	$bname_1, \ldots,$ $bname_n$-SAVE

segname	Name of the segment in which labeled common blocks are to be included. If omitted, all blocks named are included in the root segment.
bname	Name of the labeled common block to be included in the segment.
-SAVE	Optional parameter indicating that the contents of common blocks are to be saved whenever the block is not loaded.

Figure 7-20. GLOBAL Directive Format

Global common blocks can be freely referenced or defined by the owning segment, or by any segment that is known to be in memory at the same time as the owning segment. In particular, this includes all descendants of the owning segment, because if a descendant is loaded, the ancestor is automatically loaded. Other compatible segments can reference the block whenever the user is sure that the owning segment is already loaded, but such references do not force loading of the owning segment, and no check is made by the loader. If the owning segment is not loaded, the results of a reference to the block are not valid.

The common blocks used by Record Manager and the FORTRAN Common Library are treated the same by the segment loader as user-declared common blocks; that is, local copies are made for each segment declaring them unless they are declared global. When multiple copies exist, it is almost certain that input/output will not function properly. To avoid this problem, the FORTRAN Common Library common blocks (as a minimum) should be declared global by the user. The names of these blocks are:

Q8.IO.
FCL.C.
STP.END

(The periods are a part of the names.)

Declaration of these blocks as global is usually sufficient to ensure correct operation of input/output. Under unusual circumstances, however, it might be also necessary to declare some Record Manager common blocks as global.

The END directive (figure 7-21) is required as the last segment directive. Examples of sequences of segment directives are shown in figures 7-22 and 7-23. The segmented program shown in figure 7-13 can be defined with the segment directives shown in figure 7-22. In the segment directives shown in figure 7-23, the user has placed all the FORTRAN Common Library labeled common blocks in the root segment to ensure correct communication between segments. In addition, the function RANF has been included in each segment in which it is called; this was done so that the sequence of values produced by successive calls is the same, regardless of the order in which the segments are loaded.

Label	Verb	Specification
	END	

Figure 7-21. END Directive Format

LOADING AND EXECUTING A SEGMENTED PROGRAM

A segmented program is brought into execution in one of two ways. If an EXECUTE or name call statement terminates the load sequence that creates the segmented program, the program is loaded and executed after it is created. The name call statement must not specify the file containing the segmented program. At any other time, the program is loaded and executed by a name call statement specifying the name of the file containing the program. In either case, any file name parameters on the name call or EXECUTE control statement are passed to the program just as for a basic load.

When execution begins, the resident segment control program, which occupies approximately 1000_8 words, is loaded first, and then the root segment is loaded. Execution begins with the main program, which must be unique and must be in the root segment. When a segmented program is built, all intersegment external references are replaced with calls to the resident segment routines. During execution of a call to an entry point, the segment resident routines regain control and load the required segment unless it is already loaded. Any ancestors of the segment (in the same tree) are also loaded. Control is then returned to the specified entry point.

Because of the way in which external references are trapped, several restrictions are imposed on segmented programs that do not apply to basic loads. One of these is that subprogram names cannot be passed as actual parameters.

A more complicated restriction results from the fact that the CALL statement is implemented through the return jump (RJ) instruction, as described in the COMPASS Reference Manual. As part of its operation, the return jump instruction stores, in the entry point of the routine being called, a branch back to the calling routine. When the RETURN control statement in the called routine is executed, a branch takes place to the entry point of the routine, which in turn causes a branch back to the calling routine. In a segmented program, the branch that is stored in the entry point is not trapped by the loader (since it does not exist at load time) and, therefore, cannot result in segment loading. This can lead to invalid results in cases like the one illustrated in figure 7-24.

In this example, root segment A branches to two incompatible segments, B and C. B1, one of the subprograms in segment B, calls A1, a subprogram in segment A. When the call is executed, the return jump stores into the entry point of A1 a branch back to B1. However, A1 calls C1, a routine in segment C, before returning; therefore, C is loaded, overwriting B. When the RETURN control statement in A1 is executed, the branch that is stored in the entry point attempts to return to B1. Because the segment resident routines are unaware of the existence of this branch, segment B is not loaded, and a branch to some meaningless address in segment C is executed instead.

To summarize, if a routine in one segment calls a routine in another segment, the calling segment must be loaded at the time control is returned from the called segment. This problem does not arise when the calling segment is either the root segment or an ancestor of the called segment, because the calling segment is then always loaded at the same time as the called segment.

There is no automatic way to avoid conflicts of this type. Frequently, they can be avoided by careful planning when the program is designed. In addition, the C$ CALLS and C$ FUNCS statements of the FORTRAN debugging facility can be used to trace program flow while the program is being debugged.

Label	Verb	Specification
BRANCH	TREE	C-D
	TREE	A-(B,BRANCH)
	LEVEL	
	TREE	E
	TREE	F-G
	LEVEL	
	TREE	H-(I,J)
	END	

Figure 7-22. Segment Directives Example 1

Label	Verb	Specification
	GLOBAL	Q8.IO.,FCL.C.,STP.END
FRUIT	TREE	APPLE-(PLUM,LEMON)
	TREE	ALDER-(FRUIT,CONIFER)
CONIFER	TREE	FIR-(PINE,SPRUCE)
	LEVEL	
	TREE	MAPLE-OAK-(BIRCH,ASPEN)
PINE	INCLUDE	RANF
FIR	INCLUDE	RANF
OAK	INCLUDE	RANF
	END	

This tree can be diagrammed as follows:

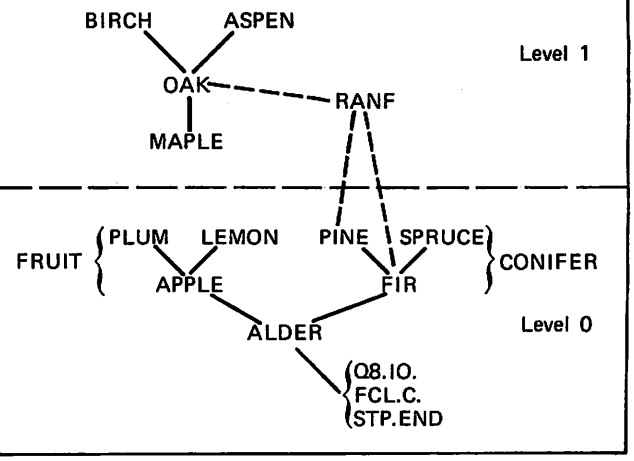


Figure 7-23. Segment Directives Example 2

Segment directives:

Label	Verb	Specification
	TREE	. A-(B,C)

Tree structure:

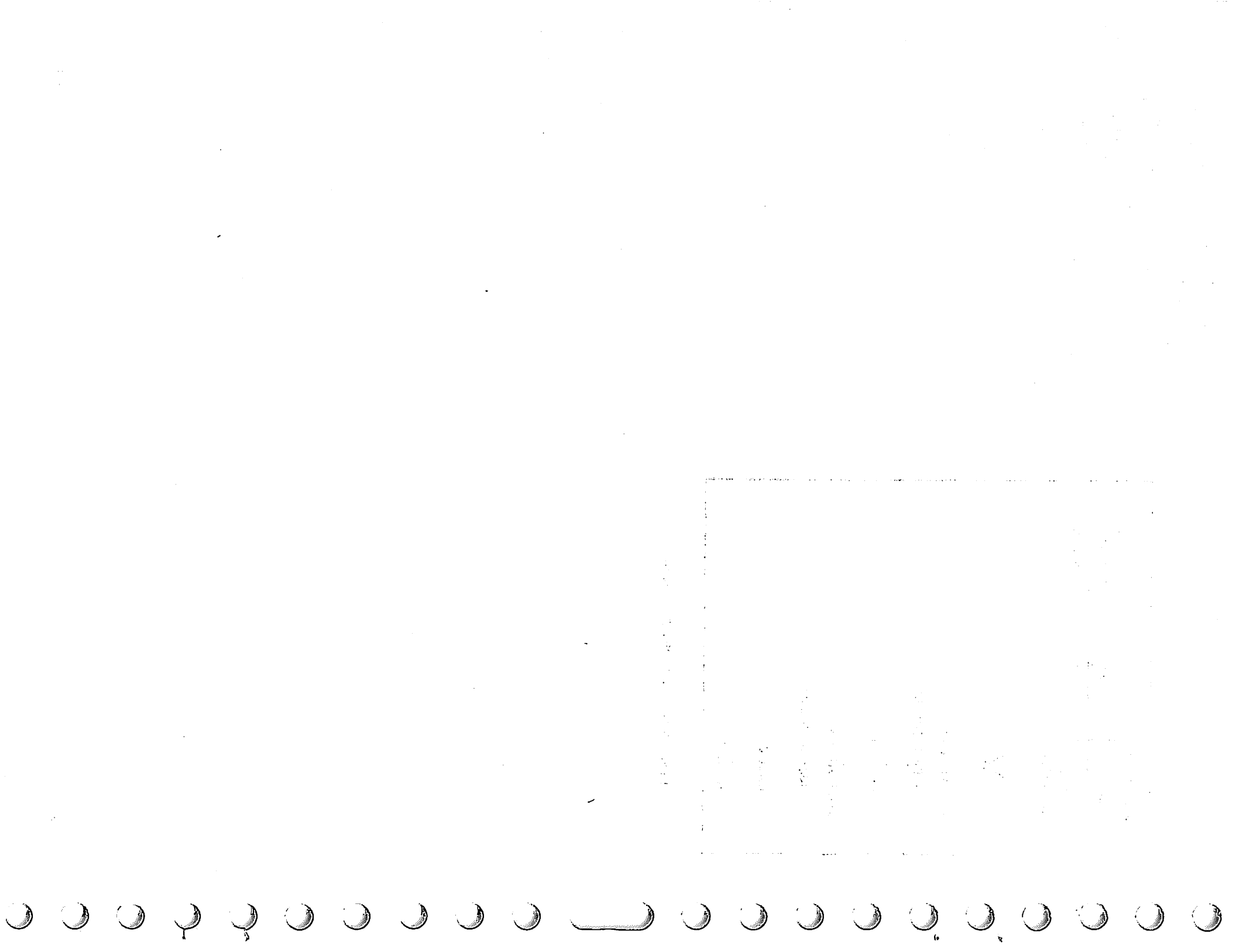
Code in B1 (in B):

```
SUBROUTINE B1
    .
    .
CALL A1
    .
    .
```

Code in A1 (in A):

```
SUBROUTINE A1
    .
    .
CALL C1
    .
    .
RETURN
```

Figure 7-24. CALL-RETURN Conflict



STANDARD CHARACTER SET A

Control Data operating systems offer the following variations of a basic character set:

CDC 64-character set

CDC 63-character set

ASCII 64-character set

ASCII 63-character set

The set in use at a particular installation was specified when the operating system was installed.

Depending on another installation option, the system assumes an input deck has been punched either in 026 or in 029 mode (regardless of the character set in use). Under NOS/BE, the alternate mode can be specified by a 26 or 29 punched in columns 79 and 80 of the job statement or any 7/8/9 card. The specified mode remains in effect through the end of the job unless it is reset by specification of the alternate mode on a subsequent 7/8/9 card.

Under NOS, the alternate mode can be specified by a 26 or 29 punched in columns 79 and 80 of any 6/7/9 card, as described above for a 7/8/9 card. In addition, 026 mode can be specified by a card with 5/7/9 multipunched in column 1, and 029 mode can be specified by a card with 5/7/9 multipunched in column 1 and a 9 punched in column 2.

Graphic character representation appearing at a terminal or printer depends on the installation character set and the terminal type. Characters shown in the CDC Graphic column of the standard character set table are applicable to BCD terminals; ASCII graphics characters are applicable to ASCII-CRT and ASCII-TTY terminals.

STANDARD CHARACTER SETS

CDC Graphic	ASCII Graphic Subset	Display Code	Hollerith Punch (026)	External BCD Code	ASCII Punch (029)	ASCII Code	CDC Graphic	ASCII Graphic Subset	Display Code	Hollerith Punch (026)	External BCD Code	ASCII Punch (029)	ASCII Code
:†	:	00††	8-2	00	8-2	072	6	6	41	6	06	6	066
A	A	01	12-1	61	12-1	101	7	7	42	7	07	7	067
B	B	02	12-2	62	12-2	102	8	8	43	8	10	8	070
C	C	03	12-3	63	12-3	103	9	9	44	9	11	9	071
D	D	04	12-4	64	12-4	104	+	+	45	12	60	12-8-6	053
E	E	05	12-5	65	12-5	105	-	-	46	11	40	11	055
F	F	06	12-6	66	12-6	106	*	*	47	11-8-4	54	11-8-4	052
G	G	07	12-7	67	12-7	107	/	/	50	0-1	21	0-1	057
H	H	10	12-8	70	12-8	110	(	(	51	0-8-4	34	12-8-5	050
I	I	11	12-9	71	12-9	111	)	)	52	12-8-4	74	11-8-5	051
J	J	12	11-1	41	11-1	112	$	$	53	11-8-3	53	11-8-3	044
K	K	13	11-2	42	11-2	113	=	=	54	8-3	13	8-6	075
L	L	14	11-3	43	11-3	114	blank	blank	55	no punch	20	no punch	040
M	M	15	11-4	44	11-4	115	, (comma)	, (comma)	56	0-8-3	33	0-8-3	054
N	N	16	11-5	45	11-5	116	. (period)	. (period)	57	12-8-3	73	12-8-3	056
O	O	17	11-6	46	11-6	117	≡	#	60	0-8-6	36	8-3	043
P	P	20	11-7	47	11-7	120	[	[	61	8-7	17	12-8-2	133
Q	Q	21	11-8	50	11-8	121	]	]	62	0-8-2	32	11-8-2	135
R	R	22	11-9	51	11-9	122	%	%	63††	8-6	16	0-8-4	045
S	S	23	0-2	22	0-2	123	≠	" (quote)	64	8-4	14	8-7	042
T	T	24	0-3	23	0-3	124	→	_ (underline)	65	0-8-5	35	0-8-5	137
U	U	25	0-4	24	0-4	125	∨	!	66	11-0 or 11-8-2†††	52	12-8-7 or 11-0†††	041
V	V	26	0-5	25	0-5	126							
W	W	27	0-6	26	0-6	127	∧	&	67	0-8-7	37	12	046
X	X	30	0-7	27	0-7	130	↑	' (apostrophe)	70	11-8-5	55	8-5	047
Y	Y	31	0-8	30	0-8	131	↓	?	71	11-8-6	56	0-8-7	077
Z	Z	32	0-9	31	0-9	132	<	<	72	12-0 or 12-8-2†††	72	12-8-4 or 12-0†††	074
0	0	33	0	12	0	060							
1	1	34	1	01	1	061	>	>	73	11-8-7	57	0-8-6	076
2	2	35	2	02	2	062	≤	@	74	8-5	15	8-4	100
3	3	36	3	03	3	063	≥	\	75	12-8-5	75	0-8-2	134
4	4	37	4	04	4	064	¬	^ (circumflex)	76	12-8-6	76	11-8-7	136
5	5	40	5	05	5	065	; (semicolon)	; (semicolon)	77	12-8-7	77	11-8-6	073

†Twelve or more zero bits at the end of a 60-bit word are interpreted as end-of-line mark rather than two colons. End-of-line mark is converted to external BCD 1632.

††In installations using a 63-graphic set, display code 00 has no associated graphic or card code; display code 63 is the colon (8-2 punch). The % graphic and related card codes do not exist and translations from ASCII/EBCDIC % yield a blank (55_8).

†††The alternate Hollerith (026) and ASCII (029) punches are accepted for input only.

OCTAL-DECIMAL INTEGER CONVERSION TABLE

Octal	10000	20000	30000	40000	50000	60000	70000
Decimal	4096	8192	12288	16384	20480	24576	28672

Octal	0000 to 0377
Decimal	0000 to 0255

	0	1	2	3	4	5	6	7
0000	0000	0001	0002	0003	0004	0005	0006	0007
0010	0008	0009	0010	0011	0012	0013	0014	0015
0020	0016	0017	0018	0019	0020	0021	0022	0023
0030	0024	0025	0026	0027	0028	0029	0030	0031
0040	0032	0033	0034	0035	0036	0037	0038	0039
0050	0040	0041	0042	0043	0044	0045	0046	0047
0060	0048	0049	0050	0051	0052	0053	0054	0055
0070	0056	0057	0058	0059	0060	0061	0062	0063
0100	0064	0065	0066	0067	0068	0069	0070	0071
0110	0072	0073	0074	0075	0076	0077	0078	0079
0120	0080	0081	0082	0083	0084	0085	0086	0087
0130	0088	0089	0090	0091	0092	0093	0094	0095
0140	0096	0097	0098	0099	0100	0101	0102	0103
0150	0104	0105	0106	0107	0108	0109	0110	0111
0160	0112	0113	0114	0115	0116	0117	0118	0119
0170	0120	0121	0122	0123	0124	0125	0126	0127
0200	0128	0129	0130	0131	0132	0133	0134	0135
0210	0136	0137	0138	0139	0140	0141	0142	0143
0220	0144	0145	0146	0147	0148	0149	0150	0151
0230	0152	0153	0154	0155	0156	0157	0158	0159
0240	0160	0161	0162	0163	0164	0165	0166	0167
0250	0168	0169	0170	0171	0172	0173	0174	0175
0260	0176	0177	0178	0179	0180	0181	0182	0183
0270	0184	0185	0186	0187	0188	0189	0190	0191
0300	0192	0193	0194	0195	0196	0197	0198	0199
0310	0200	0201	0202	0203	0204	0205	0206	0207
0320	0208	0209	0210	0211	0212	0213	0214	0215
0330	0216	0217	0218	0219	0220	0221	0222	0223
0340	0224	0225	0226	0227	0228	0229	0230	0231
0350	0232	0233	0234	0235	0236	0237	0238	0239
0360	0240	0241	0242	0243	0244	0245	0246	0247
0370	0248	0249	0250	0251	0252	0253	0254	0255

Octal	1000 to 1377
Decimal	0512 to 0767

	0	1	2	3	4	5	6	7
1000	0512	0513	0514	0515	0516	0517	0518	0519
1010	0520	0521	0522	0523	0524	0525	0526	0527
1020	0528	0529	0530	0531	0532	0533	0534	0535
1030	0536	0537	0538	0539	0540	0541	0542	0543
1040	0544	0545	0546	0547	0548	0549	0550	0551
1050	0552	0553	0554	0555	0556	0557	0558	0559
1060	0560	0561	0562	0563	0564	0565	0566	0567
1070	0568	0569	0570	0571	0572	0573	0574	0575
1100	0576	0577	0578	0579	0580	0581	0582	0583
1110	0584	0585	0586	0587	0588	0589	0590	0591
1120	0592	0593	0594	0595	0596	0597	0598	0599
1130	0600	0601	0602	0603	0604	0605	0606	0607
1140	0608	0609	0610	0611	0612	0613	0614	0615
1150	0616	0617	0618	0619	0620	0621	0622	0623
1160	0624	0625	0626	0627	0628	0629	0630	0631
1170	0632	0633	0634	0635	0636	0637	0638	0639
1200	0640	0641	0642	0643	0644	0645	0646	0647
1210	0648	0649	0650	0651	0652	0653	0654	0655
1220	0656	0657	0658	0659	0660	0661	0662	0663
1230	0664	0665	0666	0667	0668	0669	0670	0671
1240	0672	0673	0674	0675	0676	0677	0678	0679
1250	0680	0681	0682	0683	0684	0685	0686	0687
1260	0688	0689	0690	0691	0692	0693	0694	0695
1270	0696	0697	0698	0699	0700	0701	0702	0703
1300	0704	0705	0706	0707	0708	0709	0710	0711
1310	0712	0713	0714	0715	0716	0717	0718	0719
1320	0720	0721	0722	0723	0724	0725	0726	0727
1330	0728	0729	0730	0731	0732	0733	0734	0735
1340	0736	0737	0738	0739	0740	0741	0742	0743
1350	0744	0745	0746	0747	0748	0749	0750	0751
1360	0752	0753	0754	0755	0756	0757	0758	0759
1370	0760	0761	0762	0763	0764	0765	0766	0767

Octal	0400 to 0777
Decimal	0256 to 0511

	0	1	2	3	4	5	6	7
0400	0256	0257	0258	0259	0260	0261	0262	0263
0410	0264	0265	0266	0267	0268	0269	0270	0271
0420	0272	0273	0274	0275	0276	0277	0278	0279
0430	0280	0281	0282	0283	0284	0285	0286	0287
0440	0288	0289	0290	0291	0292	0293	0294	0295
0450	0296	0297	0298	0299	0300	0301	0302	0303
0460	0304	0305	0306	0307	0308	0309	0310	0311
0470	0312	0313	0314	0315	0316	0317	0318	0319
0500	0320	0321	0322	0323	0324	0325	0326	0327
0510	0328	0329	0330	0331	0332	0333	0334	0335
0520	0336	0337	0338	0339	0340	0341	0342	0343
0530	0344	0345	0346	0347	0348	0349	0350	0351
0540	0352	0353	0354	0355	0356	0357	0358	0359
0550	0360	0361	0362	0363	0364	0365	0366	0367
0560	0368	0369	0370	0371	0372	0373	0374	0375
0570	0376	0377	0378	0379	0380	0381	0382	0383
0600	0384	0385	0386	0387	0388	0389	0390	0391
0610	0392	0393	0394	0395	0396	0397	0398	0399
0620	0400	0401	0402	0403	0404	0405	0406	0407
0630	0408	0409	0410	0411	0412	0413	0414	0415
0640	0416	0417	0418	0419	0420	0421	0422	0423
0650	0424	0425	0426	0427	0428	0429	0430	0431
0660	0432	0433	0434	0435	0436	0437	0438	0439
0670	0440	0441	0442	0443	0444	0445	0446	0447
0700	0448	0449	0450	0451	0452	0453	0454	0455
0710	0456	0457	0458	0459	0460	0461	0462	0463
0720	0464	0465	0466	0467	0468	0469	0470	0471
0730	0472	0473	0474	0475	0476	0477	0478	0479
0740	0480	0481	0482	0483	0484	0485	0486	0487
0750	0488	0489	0490	0491	0492	0493	0494	0495
0760	0496	0497	0498	0499	0500	0501	0502	0503
0770	0504	0505	0506	0507	0508	0509	0510	0511

Octal	1400 to 1777
Decimal	0768 to 1023

	0	1	2	3	4	5	6	7
1400	0768	0769	0770	0771	0772	0773	0774	0775
1410	0776	0777	0778	0779	0780	0781	0782	0783
1420	0784	0785	0786	0787	0788	0789	0790	0791
1430	0792	0793	0794	0795	0796	0797	0798	0799
1440	0800	0801	0802	0803	0804	0805	0806	0807
1450	0808	0809	0810	0811	0812	0813	0814	0815
1460	0816	0817	0818	0819	0820	0821	0822	0823
1470	0824	0825	0826	0827	0828	0829	0830	0831
1500	0832	0833	0834	0835	0836	0837	0838	0839
1510	0840	0841	0842	0843	0844	0845	0846	0847
1520	0848	0849	0850	0851	0852	0853	0854	0855
1530	0856	0857	0858	0859	0860	0861	0862	0863
1540	0864	0865	0866	0867	0868	0869	0870	0871
1550	0872	0873	0874	0875	0876	0877	0878	0879
1560	0880	0881	0882	0883	0884	0885	0886	0887
1570	0888	0889	0890	0891	0892	0893	0894	0895
1600	0896	0897	0898	0899	0900	0901	0902	0903
1610	0904	0905	0906	0907	0908	0909	0910	0911
1620	0912	0913	0914	0915	0916	0917	0918	0919
1630	0920	0921	0922	0923	0924	0925	0926	0927
1640	0928	0929	0930	0931	0932	0933	0934	0935
1650	0936	0937	0938	0939	0940	0941	0942	0943
1660	0944	0945	0946	0947	0948	0949	0950	0951
1670	0952	0953	0954	0955	0956	0957	0958	0959
1700	0960	0961	0962	0963	0964	0965	0966	0967
1710	0968	0969	0970	0971	0972	0973	0974	0975
1720	0976	0977	0978	0979	0980	0981	0982	0983
1730	0984	0985	0986	0987	0988	0989	0990	0991
1740	0992	0993	0994	0995	0996	0997	0998	0999
1750	1000	1001	1002	1003	1004	1005	1006	1007
1760	1008	1009	1010	1011	1012	1013	1014	1015
1770	1016	1017	1018	1019	1020	1021	1022	1023

GLOSSARY B

BASIC LOAD – Loading and executing a program by means of control statements, with all the absolute code in central memory at the same time.

BEGINNING-OF-INFORMATION – The first record in a file. Occurs after header labels on a tape.

BINARY MODULE – A compiled program suitable for use by the loader.

COMPILATION TIME – The time during which a source language program is changed into a binary module by the FORTRAN Extended compiler. Contrast with EXECUTION TIME and LOAD TIME.

CYBER LOADER – The loader associated with the NOS and NOS/BE operating systems.

DAYFILE – A job history log maintained by the system during execution of the job and printed upon termination of the job.

DEBUGGING – The identification and correction of errors in an applications program.

DEBUGGING FACILITY – A special set of statements, inserted by the user into a source program and processed by the compiler, which provides useful debugging information.

DESK CHECKING – Visual inspection of applications program for errors.

DMPX – A system-produced printout of the exchange package, hardware register contents, and 200 words of memory centered on the p-counter, produced when a user's program terminates abnormally due to an execution time error.

DIRECT ACCESS – Under NOS, a type of permanent file for which all changes are made directly to the only copy of the file.

EDITLIB – A utility routine that creates and maintains a user library of binary modules. EDITLIB operates under the NOS/BE operating system.

END-OF-INFORMATION – The end of the last record of a file. On a tape, trailer labels are past the end-of-information.

EXECUTION TIME – The time during which a loaded binary program is executed. Contrast with COMPILATION TIME and LOAD TIME.

EXTERNAL REFERENCE – A reference in one program unit to an entry point in another program unit.

FIELD LENGTH – The number of memory words assigned to a program.

FILE – A collection of information that begins at beginning-of-information and ends at end-of-information. A file is referenced by its logical file name.

FUNCTIONAL UNIT – One of the components of the central processor of a 6600, 6700, CYBER 70 Models 74 and 76, and CYBER 170 Models 175 and 176 Computer Systems. A specialized unit that can process operands in parallel with other units.

INDIRECT ACCESS – Under NOS, a type of permanent file for which a local copy, separate from the permanent copy, is supplied on each access. Changes are made to the local copy.

INTERMEDIATE LANGUAGE – A temporary form of the generated code for a FORTRAN compilation, similar to assembly language but without specific addresses or register names.

ITEMIZE – A utility routine that produces a listing of the contents of a file or library. ITEMIZE operates under the NOS, NOS/BE, and SCOPE 2 operating systems.

LIBGEN – A utility routine that creates a user library of binary modules. LIBGEN operates under the NOS operating system.

LOAD MAP – A listing that shows how memory was allocated by the loader during a load operation.

LOAD TIME – The time during which a binary module is loaded into memory and linked with other routines needed before execution can begin.

LOADER – The system capability that loads a compiled program into memory and prepares it for execution. See CYBER LOADER and SCOPE 2 LOADER.

MODE ERROR – An execution time error which causes the executing program to abort. Possible mode errors are:

MODE 0 - Zero value in p-counter

MODE 1 - Address out of range

MODE 2 - Infinite operand

MODE 4 - Indefinite operand.

OBJECT CODE – Binary code produced by the compiler and input to the loader.

OBJECT LISTING – A compiler-generated listing of the object code produced for a program, represented as COMPASS code.

OPTIMIZATION – The process of rearranging or rewriting code to produce the same results in a more efficient way.

OPTIMIZING MODE – One of the compilation modes of the FORTRAN Extended compiler as indicated by the control statement options OPT=0, 1, 2, or by omission of the TS option.

OVERLAY – One or more relocatable programs that were relocated and linked together into a single absolute program.

PARTITION – A division of a file that ends with a tape mark on a magnetic tape file or with a zero-length level 17 marker on a mass storage file.

On a listing from ITEMIZE, a partition boundary is listed as *EOF.

PERMANENT FILE – A mass storage file, saved by the system between jobs.

PROGRAM LIBRARY – A file in a format produced by the UPDATE utility.

REDUCE MODE – A job execution mode in which the loader automatically sets the field length for executing a program.

REFERENCE MAP – List of all symbols appearing in a program, with the properties of each symbol and references to each symbol listed by source line number; produced by the FORTRAN Extended compiler.

SCOPE 2 LOADER – The loader associated with the SCOPE 2 operating system.

SECTION – A logical division of a file; a section contains one or more records and a partition contains one or more sections.

SEGMENT – An absolute subdivision of a segment program that is automatically called into memory as needed (except for the root segment).

SOURCE LISTING – A listing of a source program, produced by the compiler.

TOP-DOWN PROGRAMMING – A technique of program development in which the program is developed in successively more detailed stages.

UPDATE – A utility routine that allows source language programs to be maintained in compressed format on a mass storage file. UPDATE operates under the NOS, NOS/BE, and SCOPE 2 operating systems.

USER LIBRARY – A file of binary modules that can be used by the loader to load routines and satisfy externals. The utilities that create user libraries are: EDITLIB (NOS/BE), LIBEDT (SCOPE 2), and LIBGEN (NOS).

W TYPE RECORD – A Record Manager record type in which each record is prefixed by a control word.

6/7/8/9 card – A card with the characters 6, 7, 8, and 9 multipunched in column 1; acts as end-of-information in a card deck.

7/8/9 CARD – A card with the characters 7, 8, and 9 multipunched in column 1; acts as end-of-partition for a card deck.

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