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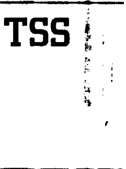

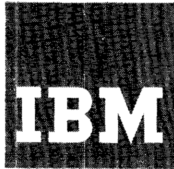

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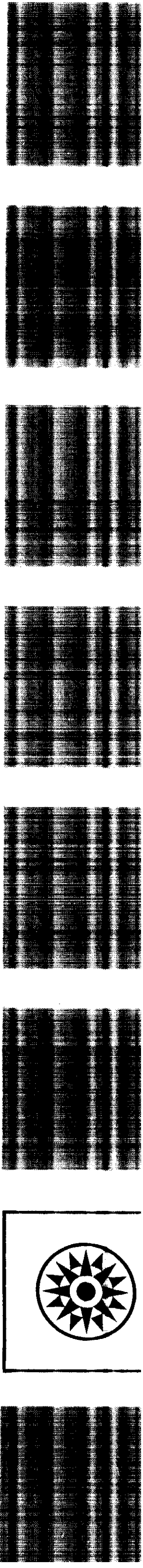
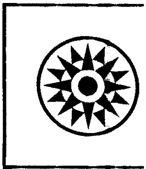


IBM System/360 Time Sharing System

IBM FORTRAN IV

This publication describes and illustrates the use of the IBM FORTRAN IV language for the IBM System/360 Time Sharing System referred to hereafter as Time Sharing System/360. The reader is presumed to have some knowledge of an existing FORTRAN language.

The IBM FORTRAN IV language is a symbolic programming language. It parallels the symbolism and format of mathematical notation. In addition, many programming features and facilities are available for expressing the method of solution of a mathematical problem as a meaningful FORTRAN program.



PREFACE

This publication describes the IBM System/360 Time Sharing System IBM FORTRAN IV language referred to in this manual as FORTRAN IV. A reader should have some knowledge of an existing FORTRAN language before using this publication. The publication FORTRAN General Information, Form F28-8074, is a useful source for such knowledge.

The material in the FORTRAN IV publication is arranged to provide a quick definition and syntactical reference to the various elements of the language by means of a box format. In addition, sufficient text describing each element, with appropriate examples of possible use, is given.

There are four appendixes which give additional information useful in writing a FORTRAN IV source program. They are:

A: Table of Source Program Characters
B: Other FORTRAN Statements Accepted by IBM FORTRAN IV
C: FORTRAN Supplied Subprograms
D: Sample Programs

First Edition
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A form is provided at the back of this publication for reader's comments. If the form has been removed, comments may be addressed to the IBM Corporation, Time Sharing System/360 Programming Publications, Department 504, 2651 Strang Blvd., Yorktown Heights, N. Y. 10598

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INTRODUCTION 5

The IBM System/360 Time Sharing System FORTRAN IV. 5

Features of the Time Sharing System FORTRAN IV. 5

ELEMENTS OF THE LANGUAGE 7

Statements 7
Coding FORTRAN Statements - Card Input. 7
Coding FORTRAN Statements - Keyboard Input 8
Initial Lines. 9
Continuation Lines 9

Constants. 10
Integer Constants 10
Real Constants. 11
Complex Constant. 12
Logical Constants 13
Literal Constants 13

Variables. 13
Variable Names. 14
Variable Types and Length Specifications 14
Type Declaration by the Predefined Specification. 15
Type Declaration by the IMPLICIT Specification Statement. 15
Type Declaration by Explicit Specification Statements 16

Arrays 16
Declaring the Size of an Array. . . . 18
Arrangement of Arrays in Storage. . . 19

Expressions. 19
Arithmetic Expressions. 19
Arithmetic Operators 20
Logical Expressions 23
Relational Operators 24
Logical Operators. 24

ARITHMETIC AND LOGICAL ASSIGNMENT STATEMENT 27

CONTROL STATEMENTS 29

The GO TO Statements 29
Unconditional GO TO Statement. . . 29
Computed GO TO Statement 30
The ASSIGN and Assigned GO TO Statements. 31

Additional Control Statements. 32
Arithmetic IF Statement. 32
Logical IF Statement 33
DO Statement 34
CONTINUE Statement 37
PAUSE Statement. 38
STOP Statement 38
END Statement. 39

INPUT/OUTPUT STATEMENTS. 40

Basic Input/Output Statements. 40
READ Statement. 41
The Form READ (a,x). 42
The Form READ (a,b) List 44
The Form READ (a) List 45
Indexing I/O Lists 46
Reading Format Statements. 47
WRITE Statement 47
The Form WRITE (a,x) 48
The Form WRITE (a,b) List. 49
The Form WRITE (a) List. 50
FORMAT Statement. 50
G Format Code. 52
Numeric Format Codes (I,F,E,D) . . . 56
I Format Code. 57
F Format Code. 58
D and E Format Codes 58
L Format Code. 59
A Format Code. 59
Literal Data in a Format Statement 61
H Format Code. 62
X Format Code. 63
T Format Code. 64
Scale Factor - P 64
Carriage Control 66

Additional Input/Output Statements . . . 67
END FILE Statement 67
REWIND Statement 67
BACKSPACE Statement. 67

SPECIFICATION STATEMENTS 68

The Type Statements. 68
IMPLICIT Statement 68
Explicit Specification Statements. 70
Adjustable Dimensions. 72

Additional Specification Statements. . . 73
DIMENSION Statement. 73
COMMON Statement 74
Blank and Labeled Common 76
EQUIVALENCE Statement. 77

SUBPROGRAMS. 80
Naming Subprograms. 80
Functions 80
Function Definition. 81
Function Reference 81
Statement Functions 81
FUNCTION Subprograms. 83
Type Specification of the FUNCTION Subprogram 84

RETURN and END Statements in a Function Subprogram 85
SUBROUTINE Subprograms. 86
CALL Statement 87
RETURN Statement in a SUBROUTINE Subprogram. 88
Multiple ENTRY into a Subprogram . 89
Additional Rules for Using ENTRY . 91
The EXTERNAL Statement 92
FORTRAN Supplied Subprograms. 93
BLOCK DATA Subprogram 93

APPENDIX A: SOURCE PROGRAM CHARACTERS . 95

APPENDIX B: OTHER FORTRAN FEATURES ACCEPTED BY FORTRAN IV. 96
READ Statement 96
PUNCH Statement. 96
PRINT Statement. 97
DATA Initialization Statement. . . 97
DOUBLE PRECISION Statement 98
Arguments of a FUNCTION or SUBROUTINE Program Enclosed by Slashes 98

APPENDIX C: FORTRAN SUPPLIED SUBPROGRAMS 99

Mathematical Function Subprograms. . . . 99

Machine Indicator Tests. 102

The EXIT, DUMP, and PDUMP Subprograms. .102
EXIT Subprogram. 102
DUMP Subprogram. 103
PDUMP Subprogram 103

APPENDIX D: SAMPLE PROGRAMS 104

Sample Program 1 104

Sample Program 2 105

INDEX. 112

ILLUSTRATIONS

FIGURES

Figure 1. FORTRAN Coding Form 8
Figure 2. Sample Program 1 104
Figure 3. Sample Program 2 107

TABLES

Table 1. Insurance Premium Codes. . . . 18
Table 2. Determining the Mode of an Expression Containing Variables of Different Types and Lengths 21
Table 3. Valid Combinations With Respect to the Arithmetic 22
Table 4. Mathematical Function Subprograms 99

THE IBM SYSTEM/360 TIME SHARING SYSTEM FORTRAN IV

The IBM Time Sharing System/360 FORTRAN IV is comprised of a language, a library of subprograms, and a compiler.

The FORTRAN language is especially useful in writing programs both in conversational and nonconversational mode for scientific and engineering applications that involve mathematical computations. In fact, the name of the language - FORTRAN - is derived from its primary use: FORmula TRANslating.

Source programs written in the FORTRAN language consist of a set of statements constructed from the elements of the language described in this publication.

The FORTRAN compiler analyzes the source program statements and transforms them into an object program that is suitable for execution on the IBM System/360. In addition, when the FORTRAN compiler detects errors in the source program, appropriate error messages are produced. At the user's option a complete listing of the source program is produced.

The FORTRAN compiler operates under control of Time Sharing System/360, which provides the FORTRAN compiler with input/output and other services. Object programs generated by the FORTRAN compiler also operate under System/360 Operating System control and depend on it for similar services.

The IBM Time Sharing System/360 FORTRAN IV language is compatible with and encompasses the American Standards Association (ASA) FORTRAN, including its mathematical subroutine provisions.

FEATURES OF THE TIME SHARING SYSTEM FORTRAN IV

The Time Sharing System/360 FORTRAN IV is a further development of previously implemented FORTRAN systems and contains many of the features of these systems. In addition, the following features facilitate the writing of source programs and reduce the possibility of coding errors:

1. Variable Attribute Control: The attributes of variables and arrays may now be explicitly specified in the source program. This facility is provided by a single explicit specification statement which allows a programmer to:

   a. Specify storage length.

   b. Explicitly type a variable as integer, real, complex, or logical.

   c. Specify the dimension of arrays.

   d. Specify data initialization values for variables.

2. Adjustable Array Dimensions: The dimensions of an array in a subprogram may be specified as variables; when the subprogram is called, the absolute array dimensions are substituted.

3. Additional Format Code: An additional format code - G - can be used to specify the format of numeric and logical data. Previously implemented format codes are also permitted.

4. Mixed Mode: Expressions may consist of constants and variables, of the same and/or different types and lengths.

5. Named I/O List: Formatting of input/output data is facilitated by reading and writing operations, without reference to a FORMAT statement or list.

6. Spacing Format Code: The T format code allows input/output data to be transferred, beginning at any specified position.

7. Literal Format Code: Apostrophes may be used to enclose literal data.

STATEMENTS

Source programs consist of a set of statements from which the compiler generates machine instructions, constants, and storage areas. A given FORTRAN statement effectively performs one of three functions:

1. Causes certain operations to be performed (e.g., add, multiply, branch).
2. Specifies the nature of the data being handled.
3. Specifies the characteristics of the source program.

FORTRAN statements are usually composed of certain FORTRAN key words used in conjunction with the basic elements of the language: constants, variables, and expressions. The five categories of FORTRAN statements are as follows:

1. Arithmetic and Logical Assignment Statements: Upon execution of an arithmetic or logical assignment statement, the result of calculations performed or conditions tested replaces the current value of a designated variable or subscripted variable.
2. Control Statements: These statements enable the user to govern the flow and terminate the execution of the object program.
3. Input/Output Statements: These statements, in addition to controlling input/output (I/O) devices, enable the user to transfer data between internal storage and an I/O medium.
4. Specification Statements: These statements are used to declare the properties of variables, arrays, and subprograms (such as type and amount of storage reserved) and to describe the format of data on input or output.
5. Subprogram Statements: These statements enable the user to name and define functions and subroutines.

The basic elements of the language are discussed in this section. The actual FORTRAN statements in which these elements are used are discussed in following sections.

CODING FORTRAN STATEMENTS - CARD INPUT

The statements of a FORTRAN source program can be written on a standard FORTRAN coding form, Form X28-7327 (Figure 1). FORTRAN statements are written one to a line from columns 7 through 72. If a statement is too long for one line, it may be continued on as many as 19 successive lines by placing any character, other than a blank or zero, in column six of each continuation line. For the first line of a statement, column six must be blank or zero.

Columns 1 through 5 of the first line of a statement may contain a statement number consisting of from 1 through 5 decimal digits. Leading zeros in a statement number are ignored. The statement numbers may be

assigned in any order; the value of statement numbers does not affect the order in which the statements are executed in a FORTRAN program.

Columns 73 through 80 are not significant to the FORTRAN compiler and may, therefore, be used for program identification, sequencing, or any other purpose.

Comments to explain the program may be written in columns 2 through 80 of a line, if the letter C is placed in column one. Comments may appear anywhere within the source program. They are not processed by the FORTRAN compiler, but are printed on the source program listing.

Blanks may be inserted where desired to improve readability.

IBM

FORTRAN Coding Form

PROGRAM

PROGRAMMER

DATE

PUNCHING INSTRUCTIONS

GRAPHIC

PUNCH

PAGE OF

CARD ELECTRO NUMBER*

STATEMENT NUMBER

CONT

FORTRAN STATEMENT

IDENTIFICATION SEQUENCE

*A standard card form, IBM electro 888157, is available for punching statements from this form

Figure 1. FORTRAN Coding Form

CODING FORTRAN STATEMENTS - KEYBOARD INPUT

It is desirable to free a conversational keyboard operator from strict positional requirements when typing in a FORTRAN source program. The following conventions for statement numbers, text starting posi-

tions, and continuation lines are accepted when input is from an on-line keyboard.

Initial Lines

If a line is the initial line of a statement, it may have a statement number. (The statement number, if any, must appear on the first line of the statement.) The numeric statement number must be the first nonblank material in the line. It can start in any column, and is terminated after five adjacent columns, or by the occurrence of a nonblank, nonnumeric character, whichever happens first.

If a statement has a statement number, the text of the statement begins with the first nonblank character following the statement number, unless this character is a horizontal tab. If a tab is used to separate the statement number from the text, the text begins with the first nonblank character following the tab.

If a statement does not have a statement number, the text of the statement begins with the first nonblank, nonnumeric character of the line, unless this character is a horizontal tab.

If a tab is used to begin the line, the text starts with the first nonblank character following the tab.

Continuation Lines

A line of input is a continuation line, rather than the initial line of a statement, if the last character (blanks included) of the last preceding noncomment line was a '-' (EBCDIC 60).

A continuation line in keyboard input may not have a statement number. The text of the line begins with the first character (blank or not) of the line, unless this character is a horizontal tab. If a tab is used to begin the line, the text starts with the first character (blank or not) following the tab.

Caution is needed in the use of '-' at the end of a line, and tab (in alphameric constants) or the letter C, at the beginning of a line, to avoid conflict between the FORTRAN text and the continuation, comment, and tab conventions of keyboard input.

CONSTANTS

A constant is a fixed, unvarying quantity. There are three classes of constants -- those that deal with numbers (numerical constants), those that deal with truth values (logical constants), and those that deal with literal data (literal constants).

Numerical constants may be integer, real, or complex numbers; logical constants may be .TRUE. or .FALSE.; literal constants may be a string of alphameric and/or special characters enclosed by quotes.

INTEGER CONSTANTS

Definition
Integer Constant - a whole number written without a decimal point. It occupies four locations of storage. Maximum Magnitude: 2147483647, i.e., $(2^{31}-1)$.

An integer constant may be positive, zero, or negative; if unsigned, it is assumed to be positive. Its magnitude must not be greater than the maximum and may not contain embedded commas.

Examples:

Valid Integer Constants:

0
91
173
-2147483647
-12

Invalid Integer Constants:

0.0	(contains a decimal point)
27.	(contains a decimal point)
3145903612	(exceeds the allowable range)
5,396	(embedded comma)

REAL CONSTANTS

Definition
<u>Real Constant</u>: - a number with a decimal point optionally followed by a decimal exponent, or an integer constant followed by a decimal exponent. This exponent may be written as the letter E or D followed by a signed or unsigned, one- or two-digit integer constant. A real constant may assume one of two forms: 1. From one through seven decimal digits, <u>optionally</u> followed by an E decimal exponent. This form occupies 4 storage locations. 2. Either one through seven decimal digits followed by a D decimal exponent or 8 to 16 decimal digits <u>optionally</u> followed by a D decimal exponent. This form occupies eight storage locations and is sometimes referred to as a double precision constant. Magnitude: (either form) 0 or 16^{-63} through 16^{63} (i.e., approximately 10^{75}).

A real constant may be positive, zero, or negative (if unsigned, it is assumed to be positive) and must be of the allowable magnitude. It may not contain embedded commas. The decimal exponent E or D permits the expression of a real constant as the product of a real constant times 10 raised to a desired power.

<u>Examples</u>:

<u>Valid</u> Real Constants (4 storage locations):

```
+0.
-999.9999
0.0
5764.1
7.0E+0                   (i.e., 7.0 x 10⁰ = 7.0)
19761.25E+1              (i.e., 19761.25 x 10¹ = 197612.5)
7E3         )
7.E3        |
7.0E3       }            (i.e., 7.0 x 10³ = 7000.0)
7.0E03      |
7.0E+03     )
7.0E-03                  (i.e., 7.0 x 10⁻³ = .007)
```

<u>Valid</u> Real Constants (8 storage locations):

```
21.98753829457168
1.0000000
7.9D3       )
7.9D03      |            (i.e., 7.9 x 10³ = 7900.0)
7.9D+03     }
7.9D+3      )
7.9D-03                  (i.e., 7.9 x 10⁻³ = .0079)
7.9D0                    (i.e., 7.9 x 10⁰ = 7.9)
0.0                      (i.e., 0.0 x 10⁰ = 0.0)
7D3                      (i.e., 7 x 10³ = 7000)
```

Invalid Real Constants:

0	(missing a decimal point)
3,471.1	(embedded comma)
1.E	(missing a one- or two-digit integer constant following the E. Note that it is not interpreted as 1.0 x 10^{0})
7.9D	(missing a one- or two-digit integer constant following the D)
1.2E+113	(E is followed by a 3 digit integer constant)
21.3D90	(value exceeds the magnitude permitted; that is, 21.3 x $10^{90}>16^{63}$)
23.5E+97	(value exceeds the magnitude permitted; that is, 23.5 x $10^{97}>16^{63}$)

COMPLEX CONSTANT

Definition
Complex Constant - an ordered pair of signed or unsigned real constants separated by a comma and enclosed in parentheses. A complex constant may assume one of two forms: 1. From one through seven decimal digits optionally followed by an E decimal exponent. In this form, each number in the pair occupies four storage locations. 2. Either one through seven decimal digits followed by a D decimal exponent or 8 through 16 decimal digits optionally followed by a D decimal exponent. In this form each number in the pair occupies eight storage locations. Magnitude: (either form) 0 or 16^{-63} through 16^{63} (i.e., approximately 10^{75}) for each real constant in the pair.

The real constants in a complex constant may be positive, zero, or negative (if unsigned, they are assumed to be positive), but they must be in the given range. The first real constant in a complex constant represents the real part of the complex number; the second represents the imaginary part of the complex number.

Examples:

Valid Complex Constants:

(3.2,- 1.86)	(has the value 3.2-1.86i)
(-5.0E+03,.16E+02)	(has the value -5000.+16.0i)
(4.0E+03,.16E+02)	(has the value 4000.+16.0i)
(2.1,0.0)	(has the value 2.1+0.0i)
(4.7D+2,1.9736148)	(has the value 470.+1.9736148i)

Where $i = \sqrt{-1}$

Invalid Complex Constants:

(292704,1.697)	(the real part does not contain a decimal point)
(1.2E113,279.3)	(the real part contains an invalid decimal exponent)

LOGICAL CONSTANTS

Definition
Logical Constant - There are two logical values: .TRUE. .FALSE.

A logical constant must be preceded and followed by a period. The logical constants .TRUE. and .FALSE. specify that the value of the logical variable they replace or the term of the expression they are associated with is true or false, respectively. (See the section "Logical Expressions.")

LITERAL CONSTANTS

Definition
Literal Constant - a string of alphameric and/or special characters enclosed in apostrophes.

The number of characters in the string, including blanks, may not be greater than 255. Since apostrophes delimit literal data, a single apostrophe within such data is represented by double apostrophes.

Examples:

```
'DATA'
'INPUT/OUTPUT AREA NO.  2'
'X-COORDINATE     Y-COORDINATE     Z-COORDINATE'
'3.14'
'DON'T'
```

VARIABLES

A FORTRAN variable is a symbolic representation of a quantity that may assume different values. The value of a variable may change either for different executions of a program or at different stages within the program.

For example, in the statement:

```
A = 5.0+B
```

both A and B are variables. The value of B is determined by some previous statement and may change from time to time. The value of A varies whenever this computation is performed with a new value for B.

VARIABLE NAMES

Definition
Variable Name - from 1 through 6 alphameric (i.e., numeric, 0 - 9, or alphabetic, A - Z and $) characters, the first of which must be alphabetic.

A variable name may not contain special characters (see Appendix A). Variable names are symbols used to distinguish one variable from another. A name may be used in a source program in one (and only one) way (e.g., the name of a variable and that of a subprogram may not be identical in the same source program).

The use of meaningful variable names can serve as an aid in documenting a program. That is, someone other than the programmer may look at the program and understand its function. For example, to compute the distance a car traveled in a certain amount of time at a given rate of speed, the following statement could have been written:

```
X = Y * Z
```

where * designates multiplication. However, it would be more meaningful to someone reading this statement if the programmer had written:

```
DIST = RATE * TIME
```

Examples:

Valid Variable Names:

```
JOHN
B292
VAN
RATE
L17NOY
SQ704
```

Invalid Variable Names:

```
B292704        (contains more than six characters)
4ARRAY         (first character is not alphabetic)
SI.X           (contains a special character)
```

VARIABLE TYPES AND LENGTH SPECIFICATIONS

The type of a variable corresponds to the type of data the variable represents. Thus, an integer variable represents integer data, a real variable represents real data, etc.

For every type of variable, there is a corresponding standard and optional length specification which determines the number of storage locations reserved for each variable. The following list shows each variable type with its associated standard and optional length:

Variable Type	Standard	Optional
Integer	4	2
Real	4	8
Complex	8	16
Logical	4	1

The three ways a programmer may declare the type of a variable are by use of the:

1. Predefined specification contained in the FORTRAN language.
2. IMPLICIT specification statement.
3. Explicit specification statements.

The optional length specification of a variable may be declared only by the IMPLICIT or Explicit specification statements. If, in these statements, no length specification is stated, the standard length is assumed (see the section "The Type Statements").

TYPE DECLARATION BY THE PREDEFINED SPECIFICATION

The predefined specification is a convention used to specify variables as integer or real, as follows:

1. If the first character of the variable name is I, J, K, L, M, or N, the variable is integer of standard length.

2. If the first character of the variable name is any other letter, the variable is real of standard length.

This convention is the traditional FORTRAN method of implicitly specifying the type of a variable as being either integer or real. In all examples that follow in this publication it is presumed that this specification holds, unless otherwise noted.

TYPE DECLARATION BY THE IMPLICIT SPECIFICATION STATEMENT

This statement allows a programmer to specify the type of variables in much the same way as was specified by the predefined convention. That is, in both, the type is determined by the first character of the variable name. However, the programmer, using the IMPLICIT statement, has the option of specifying which initial letters designate a particular variable type. Further, the IMPLICIT statement is applicable to all types of variables -- integer, real, complex, and logical.

The IMPLICIT statement overrides the variable type as determined by the predefined convention. For example, if the IMPLICIT statement specifies that variables beginning with the letters A through M are real variables, and variables beginning with the letters N through Y are integer variables, then the variable ITEM (which would be treated as an integer variable under the predefined convention) is now treated as a real variable. Note that variables beginning with the letters Z and $ are (by the predefined convention) treated as real variables. The IMPLICIT statement is presented in greater detail in the section "Type Statements."

TYPE DECLARATION BY EXPLICIT SPECIFICATION STATEMENTS

Explicit specification statements (INTEGER, REAL, COMPLEX, and LOGICAL) differ from the first two ways of specifying the type of a variable, in that an explicit specification statement declares the type of a particular variable by its name, rather than as a group of variables beginning with a particular character.

For example, assume:

1. That an IMPLICIT specification statement overrode the predefined convention for variables beginning with the letter I by declaring them to be real.

2. That a subsequent Explicit specification statement declared that the variable named ITEM is complex.

Then, the variable ITEM is complex and all other variables beginning with the character I are real. Note that variables beginning with the letters J through N are specified as integer by the predefined convention.

The Explicit specification statements are discussed in greater detail in the section "Type Statements."

ARRAYS

A FORTRAN array is a set of variables identified by a single variable name. A particular variable in the array may be referred to by its position in the array (e.g., first variable, third variable, seventh variable, etc.). Consider the array named NEXT, which consists of five variables, each currently representing the following values:

273, 41, 8976, 59, and 2

```
NEXT(1)       is the representation of 273
NEXT(2)       is the representation of 41
NEXT(3)       is the representation of 8976
NEXT(4)       is the representation of 59
NEXT(5)       is the representation of 2
```

Each variable in this array consists of the name of the array (i.e., NEXT) followed by a number enclosed in parentheses, called a subscript. The variables which comprise the array are called subscripted variables. Therefore, the subscripted variable NEXT(1) has the value 273; the subscripted variable NEXT(2) HAS THE value 41, etc.

The subscripted variable NEXT(I) refers to the "Ith" subscripted variable in the array, where I is an integer variable that can assume a value of 1, 2, 3, 4, or 5.

To refer to the first element of an array, the array name must be subscripted. The array name does not represent the first element. The number of subscripts must correspond to the declared dimensionality except in the EQUIVALENCE statement.

General Form
Subscripts - may be one of seven forms: v c' v+c' v-c' c*v c*v+c' c*v-c' Where: v represents an unsigned, nonsubscripted, integer variable. c and c' represent unsigned integer constants.

Whatever subscript form is used, its evaluated result must always be greater than zero. For example, when reference is made to the subscripted variable V(I-2), the value of I should be greater than 2.

Examples:

```
ARRAY (IHOLD)
NEXT(19)
MATRIX(I-5)
A(5*L)
W(4*M+3)
```

An array may consist of up to seven subscript parameters, separated by commas. Thus, the following are valid subscripted variables for their corresponding arrays:

Array Name	Subscripted Variable
A	A(5, 100, J, K+2)
TABLE	TABLE (1, 1, 1, 1, 1, 1, 1)
B	B(I, J, K, L, M, N)
MATRIX	MATRIX(I+2,6*JOB-3,KFRAN)

Consider the following array named LIST consisting of two subscript parameters, the first ranging from 1 through 5, the second from 1 through 3:

	Column1	Column2	Column3
Row1	82	4	7
Row2	12	13	14
Row3	91	1	31
Row4	24	16	10
Row5	2	8	2

Suppose it is desired to refer to the number in row 2, column 3; this would be:

```
LIST (2,3)
```

Thus, LIST (2,3) has the value 14 and LIST (4,1) has the value 24.

Ordinary mathematical notations might use LIST i,j to represent any element of the array LIST. In FORTRAN, this is written as LIST(I,J), where I equals 1,2,3,4, or 5, and J equals 1,2, or 3.

As a further example, consider the array named COST, consisting of four subscript parameters. This array might be used to store all the premiums for a life insurance applicant, given (1) age, (2) sex, (3) health, and (4) size of life insurance coverage desired. A code number could be developed for each statistic, where IAGE represents age, ISEX represents sex, IHLTH represents health, and ISIZE represents policy size desired (see Table 1).

Table 1. Insurance Premium Codes

AGE	
Age in years	Code
1-5	IAGE=1
6-10	IAGE=2
.	.
.	.
.	.
96-100	IAGE=20

SEX	
Sex	Code
Male	ISEX=1
Female	ISEX=2

HEALTH	
Health	Code
Poor	IHLTH=1
Fair	IHLTH=2
Good	IHLTH=3
Excellent	IHLTH=4

POLICY SIZE	
Dollars	Code
1,000	ISIZE=1
3,000	ISIZE=3
5,000	ISIZE=4
10,000	ISIZE=5
25,000	ISIZE=6
50,000	ISIZE=7
100,000	ISIZE=8

Suppose an applicant is 14 years old, male, in good health, and desires a policy of $25,000. From Table 1, these statistics can be represented by the codes:

```
IAGE=3          (11 - 15 years old)
ISEX=1          (male)
IHLTH=3         (good health)
ISIZE=6         ($25,000 policy)
```

Thus, COST (3, 1, 3, 6) represents the premium for a policy, given the statistics above. Note that "IAGE" can vary from 1 to 20, "ISEX" from 1 to 2, "IHLTH" from 1 to 4, and "ISIZE" from 1 to 8. The number of subscripted variables in the array COST is the number of combinations that can be formed for different ages, sex, health, and policy size available - a total of 20x2x4x8 or 1280. Therefore, there may be up to 1280 different premimums stored in the array named COST.

DECLARING THE SIZE OF AN ARRAY

The size of an array is determined by the number of subscript parameters of the array and the maximum value of each subscript. This information must be given for all arrays before using them in a FORTRAN program, so that an appropriate amount of storage may be reserved. Declaration of this information is made by a DIMENSION statement, a COMMON statement, or by one of the Explicit specification statements (INTEGER, REAL, COMPLEX, and LOGICAL); each is discussed in further detail in the section "Specification Statements."

ARRANGEMENT OF ARRAYS IN STORAGE

Arrays are stored in ascending storage locations, with the value of the first of their subscripts increasing most rapidly, and the value of the last increasing least rapidly.

Examples:

The array named A, consisting of one subscript parameter which varies from 1 to 5, appears in storage as follows:

```
A(1) A(2) A(3) A(4) A(5)
```

The array named B, consisting of two subscript parameters, whose first subscript varies over the range from 1 to 5, and second varies from 1 to 3, appears in ascending storage locations in the following order:

```
 B(1,1) B(2,1) B(3,1) B(4,1) B(5,1)┐
┌──────────────────────────────────┘
└►B(1,2) B(2,2) B(3,2) B(4,2) B(5,2)┐
┌──────────────────────────────────┘
└►B(1,3) B(2,3) B(3,3) B(4,3) B(5,3) .
```

Note that B(1,2) and B(1,3) follow in storage B(5,1) and B(5,2), respectively.

The following list is the order of an array named C, consisting of three subscript parameters, whose first subscript varies from 1 to 3, second varies from 1 to 2, and third varies from 1 to 3:

```
 C(1,1,1) C(2,1,1) C(3,1,1) C(1,2,1) C(2,2,1) C(3,2,1)┐
┌────────────────────────────────────────────────────┘
└►C(1,1,2) C(2,1,2) C(3,1,2) C(1,2,2) C(2,2,2) C(3,2,2)┐
┌────────────────────────────────────────────────────┘
└►C(1,1,3) C(2,1,3) C(3,1,3) C(1,2,3) C(2,2,3) C(3,2,3)
```

Note that C(1,1,2) and C(1,1,3) follow in storage C(3,2,1) and C(3,2,2), respectively.

EXPRESSIONS

Expressions in their simplest form consist of a single constant or variable. They may also designate a computation or show a relationship between two or more constants and/or variables. Expressions may appear in arithmetic and logical assignment statements and in certain control statements.

FORTRAN provides two kinds of expressions: arithmetic and logical. The value of an arithmetic expression is always a number whose type is integer, real, or complex. However, the evaluation of a logical expression always yields a truth value: .TRUE. or .FALSE..

ARITHMETIC EXPRESSIONS

The simplest arithmetic expression consists of a single constant, variable, or subscripted variable of the type integer, real, or complex. If the constant, variable, or subscripted variable is of the type

integer, the expression is in the integer mode. If it is of the type real, the expression is in the real mode, etc.

Examples:

Expression	Type of Quantity	Mode of Expression
3	Integer Constant	Integer
I	Integer Variable	Integer
3.0	Real Constant	Real
A	Real Variable	Real
3.14D3	Real Constant	Real with eight locations of storage reserved
B(2*I)	Real Variable (Specified as such in a Type statement)	Real with four locations of storage reserved
(2.0,5.7)	Complex Constant	Complex
C	Complex Variable (Specified as such in a Type statement)	Complex

In the expression B(2*I), the subscript (2*I), which must always represent an integer, does not affect the mode of the expression. That is, the mode of the expression is determined solely by the type of constant, variable, or subscripted variable appearing in that expression.

More complicated arithmetic expressions containing two or more constants and/or variables may be formed by using arithmetic operators that express the computation(s) to be performed.

Arithmetic Operators

The arithmetic operators are as follows:

Arithmetic Operator	Definition
**	Exponentiation
*	Multiplication
/	Division
+	Addition
-	Subtraction

RULES FOR CONSTRUCTING ARITHMETIC EXPRESSIONS: The following are the rules for constructing arithmetic expressions that contain arithmetic operators:

1. All desired computations must be specified explicitly. That is, if more than one constant, variable, subscripted variable, or subprogram name (see the section "SUBPROGRAMS") appears in an arithmetic expression, they must be separated from one another by an arithmetic operator. For example, the two variables A and B will not be multiplied if written:

   AxB or AB or A•B

   If multiplication is desired, then the expression must be written:

   A*B or B*A

2. No two arithmetic operators may appear in sequence in the same expression. For example, the following expressions are invalid:

   A*/B and A*-B

However, in the expression, A*-B, if the - is meant to be a minus sign rather than the arithmetic operator designating subtraction, then the expression could be written:

```
A*(-B)
```

In effect, -B will be evaluated first, and then A will be multiplied with it. (For further uses of parentheses, see Rule 6.)

3. The mode of an arithmetic expression is determined by the type and length specification of the variables in the expression. Table 2 indicates how the mode of variables of different types and lengths may be determined using the operators: +, -, *, /.

Table 2. Determining the Mode of an Expression Containing Variables of Different Types and Lengths

+ - * /	INTEGER (2)	INTEGER (4)	REAL (4)	REAL (8)	COMPLEX (8)	COMPLEX (16)
INTEGER (2)	Integer (2)	Integer (4)	Real (4)	Real (8)	Complex (8)	Complex (16)
INTEGER (4)	Integer (4)	Integer (4)	Real (4)	Real (8)	Complex (8)	Complex (16)
REAL (4)	Real (4)	Real (4)	Real (4)	Real (8)	Complex (8)	Complex (16)
REAL (8)	Real (8)	Real (8)	Real (8)	Real (8)	Complex (16)	Complex (16)
COMPLEX (8)	Complex (8)	Complex (8)	Complex (8)	Complex (16)	Complex (8)	Complex (16)
COMPLEX (16)	Complex (16)	Complex (16)	Complex (16)	Complex (16)	Complex (16)	Complex (16)

From Table 2 it can be seen that there is a hierarchy of type and length specification (see the section "The Type Statements") that determines the mode of an expression. For example, complex data that has a length specification of 16 when combined with any other types of constants and variables results in complex data of length 16.

Assume that the type of the following variables has been specified as follows:

Variable Names	Type	Length Specification
ROOT, E	Real variable	4,8
A, I, F	Integer variables	4,2,2
C,D	Complex variable	16,8

Then the following examples illustrate how constants and variables of differing types may be combined using the arithmetic operators: +, -, /, *:

Expression	Mode of Expression
ROOT*5	Real of length 4
A+3	Integer of length 4
C+2.9D10	Complex of length 16
E/F+19	Real of length 8

C-18.7E05	Complex of length 16
A/I-D	Complex of length 8

4. The arithmetic operator denoting exponentiation (i.e.,**) may only be used to combine the types of constants, variables, and subscripted variables shown in Table 3.

Table 3. Valid Combinations With Respect to the Arithmetic Operator **

Base		Exponent
Integer or Real (either length)	**	Integer or Real (either length)
Complex (either length)	**	Integer (either length)

Assume that the type of the following variables has been specified as follows, and that their length specification is standard:

Variable Names	Type
ROOT, E	Real variable
A, I, F	Integer variables
C	Complex variable

Then the following examples illustrate how constants and variables of differing types may be combined using the arithmetic operator, **.

Examples:

Expression	Type	Result
ROOT**(A+2)	(Real**Integer)	(Real)
C**A	(Complex**Integer)	(Complex)
ROOT**I	(Real**Integer)	(Real)
I**F	(Integer**Integer)	(Integer)
7.98E21**ROOT	(Real**Real)	(Real)
ROOT**2.1E5	(Real**Real)	(Real)
A**E	(Integer**Real)	(Real)

5. Order of Computation: Where parentheses are omitted, or where the entire arithmetic expression is enclosed within a single pair of parentheses, effectively the order in which the operations are performed is as follows:

Operation	Hierarchy
Evaluation of Functions (see the section "Subprograms")	1st (highest)
Exponentiation (**)	2nd
Multiplication and Division (* and /)	3rd
Addition and Subtraction (+ and -)	4th

In addition, if two operators of the same hierarchy (with the exception of exponentiation) are used consecutively, the two operations are performed from left to right. Thus, the arithmetic expression A/B*C is evaluated as if the result of the division of A by B was multiplied by C.

For example, the expression:

```
(A*B/C**I+D)
```

is effectively evaluated in the order:

```
a.  C**I      Call the result X   (exponentiation)
b.  A*B       Call the result Y   (multiplication)
c.  Y/X       Call the result Z   (division)
d.  Z+D       Final operation     (addition)
```

For exponentiation the evaluation is from right to left. Thus, the expression:

```
A**B**C
```

is evaluated as follows:

```
a.  B**C      Call the result Z
b.  A**Z      Final operation
```

6. Use of Parentheses: Parentheses may be used in arithmetic expressions, as in algebra, to specify the order in which the arithmetic operations are to be computed. Where parentheses are used, the expression within the parentheses is evaluated before the result is used.

   For example, the expression:

```
(B+((A+B)*C)+A**2)
```

   is effectively evaluated in the order:

```
a.  (A+B)     Call the result X
b.  (X*C)     Call the result Y
c.  A**2      Call the result Z
d.  B+Y+Z     Final operations
```

LOGICAL EXPRESSIONS

The simplest form of logical expression consists of a single logical constant, logical variable, or logical subscripted variable, the value of which is always a truth value (i.e., either .TRUE. or .FALSE.).

More complicated logical expressions may be formed by using logical and relational operators. These expressions may be in one of the three following forms:

1. Relational operators combined with arithmetic expressions whose mode is integer or real.
2. Logical operators combined with logical constants (.TRUE. and .FALSE.), logical variables, or subscripted variables.
3. Logical operators combined with either or both forms of the logical expressions described in items 1 and 2.

Item 1 is discussed in the following section, "Relational Operators"; items 2 and 3 are discussed in the section "Logical Operators."

Relational Operators

The six relational operators, each of which must be preceded and followed by a period, are as follows:

Relational Operator	Definition
.GT.	Greater than (>)
.GE.	Greater than or equal to (≥)
.LT.	Less than (<)
.LE.	Less than or equal to (≤)
.EQ.	Equal to (=)
.NE.	Not equal to (≠)

The relational operators express an arithmetic condition which can be either true or false. Only arithmetic expressions whose mode is integer or real may be combined by relational operators. For example, assume that the type of the following variables has been specified as follows:

Variable Names	Type
ROOT, E	Real variables
A, I, F	Integer variables
L	Logical variable
C	Complex variable

Then the following examples illustrate valid and invalid logical expressions using the relational operators.

Examples:

Valid Logical Expressions Using Relational Operators:

```
(ROOT*A).GT.E
A.LT.I
E**2.7.EQ.(5*ROOT+4)
57.9.LE.(4.7+F)
.5.GE..9*ROOT
E.EQ.27.3D+05
```

Invalid Logical Expressions Using Relational Operators:

C.LT.ROOT	(Complex quantities may never appear in logical expressions)
C.GE.(2.7,5.9E3)	(Complex quantities may never appear in logical expressions)
L.EQ.(A+F)	(Logical quantities may never be joined by relational operators)
E**2.EQ97.1E9	(Missing period immediately after the relational operator)
.GT.9	(Missing arithmetic expression before the relational operator)

Logical Operators

The three logical operators, each of which must be preceded and followed by a period, are as follows. (A and B represent logical constants or variables, or expressions containing relational operators.)

Logical Operator	Definition
.NOT.	.NOT.A - if A is .TRUE., then .NOT.A has the value .FALSE.; if A is .FALSE., then .NOT.A has the value .TRUE.
.AND.	A.AND.B - if A and B are both .TRUE., then A.AND.B has the value .TRUE.; if either A or B or both are .FALSE., then A.AND.B has the value .FALSE.
.OR.	A.OR.B - if either A or B or both are .TRUE., then A.OR.B has the value .TRUE.; if both A and B are .FALSE., then A.OR.B has the value .FALSE.

Two logical operators may appear in sequence only if the second one is the logical operator .NOT..

Only those expressions which, when evaluated, have the value .TRUE. or .FALSE. may be combined with the logical operators to form logical expressions. For example, assume that the type of the following variables has been specified as follows:

Variable Names	Type
ROOT, E	Real variables
A, I, F	Integer variables
L, W	Logical variables
C	Complex variable

Then the following examples illustrate valid and invalid logical expressions using both logical and relational operators.

Examples:

Valid Logical Expressions:

```
(ROOT*A.GT.A).AND.W
L.AND..NOT.(I.GT.F)
(E+5.9D2.GT.2*E).OR.L
.NOT.W.AND..NOT.L
L.AND..NOT.W.OR.I.GT.F
(A**F.GT.ROOT).AND..NOT.(I.EQ.E)
```

Invalid Logical Expressions:

A.AND.L	(A is not a logical expression)
.OR.W	(.OR. must be preceded by a logical expression)
NOT.(A.GT.F)	(missing period before the logical operator .NOT.)
(C.EQ.I).AND.L	(a complex variable may never appear in a logical expression)
L.AND..OR.W	(the logical operators .AND. and .OR. must always be separated by a logical expression)
.AND.L	(.AND. must be preceded by a logical expression)

Order of Computations in Logical Expressions: Where parentheses are omitted, or where the entire logical expression is enclosed within a single pair of parentheses, the order in which the operations are performed is as follows:

Operation	Hierarchy
Evaluation of Functions	1st (highest)
Exponentiation (**)	2nd
Multiplication and division (* and /)	3rd
Addition and subtraction (+ and -)	4th
.LT.,.LE.,.EQ.,.NE.,.GT.,.GE.	5th
.NOT.	6th
.AND.	7th
.OR.	8th

For example, the expression:

```
(A.GT.D**B.AND..NOT.L.OR.N)
```

is effectively evaluated in the following order:

1.	D**B	Call the result W	(exponentiation)
2.	A.GT.W	Call the result X	(relational operator)
3.	.NOT.L	Call the result Y	(highest logical operator)
4.	X.AND.Y	Call the result Z	(second highest logical operator)
5.	Z.OR.N	Final operation	

Use of Parentheses in Logical Expressions: Parentheses may be used in logical expressions to specify the order in which the operations are to be performed. Where parentheses are used, the expression contained within the most deeply nested parentheses (that is, the innermost pair of parentheses) is effectively evaluated first. For example, the logical expression:

```
((I.GT.(B+C)).AND.L)
```

is effectively evaluated in the following order:

1.	B+C	Call the result X
2.	I.GT.X	Call the result Y
3.	Y.AND.L	Final operation

The logical expression to which the logical operator .NOT. applies must be enclosed in parentheses if it contains two or more quantities. For example, assume that the values of the logical variables A and B are .FALSE. and .TRUE., respectively. Then the following two expressions are not equivalent:

```
.NOT.(A.OR.B)
.NOT.A.OR.B
```

In the first expression, A.OR.B, is evaluated first. The result is .TRUE.; but .NOT.(.TRUE.) implies .FALSE.. Therefore, the value of the first expression is .FALSE..

In the second expression, .NOT.A is evaluated first. The result is .TRUE.; but .TRUE..OR.B implies .TRUE.. Therefore, the value of the second expression is .TRUE..

General Form
a = b Where: a is any subscripted or nonsubscripted variable. b is any arithmetic or logical expression. Note: a must be a logical variable if, and only if, b is a logical expression.

The FORTRAN Arithmetic and Logical Assignment statement closely resembles a conventional algebraic equation; however, the equal sign of the FORTRAN Arithmetic statement specifies replacement rather than equivalence. That is, the expression to the right of the equal sign is evaluated, and the resulting value replaces the current value of the variable to the left of the equal sign.

Assume that the type of the following variables has been specified as:

Variable Names	Type	Length Specification
I, J, W	Integer variables	4,4,2
A, B, C, D	Real variables	4,4,8,8
E	Complex variable	8
G, H	Logical variables	4,4

Then the following examples illustrate valid arithmetic statements using constants, variables, and subscripted variables of different types:

Statements	Description
A = B	The value of A is replaced by the current value of B.
W = B	The value of B is truncated to an integer value, and the least significant part replaces the value of W.
A = I	The value of I is converted to a real value, and this result replaces the value of A.
I = I + 1	The value of I is replaced by the value of I + 1.
E = I**J+D	I is raised to the power J and the result is converted to a real value to which the value of D is added. This result replaces the real part of the complex variable E. The imaginary part of the complex variable is set to zero.
A = C*D	The most significant part of the product of C and D replaces the value of A.
G = .TRUE.	The value of G is replaced by the logical constant .TRUE..
H = .NOT.G	If G is .TRUE., the value of H is replaced by the logical constant .FALSE.. If G is .FALSE., the value of H is replaced by the logical constant .TRUE..

G = 3..GT.I	The value of I is converted to a real value; if the real constant 3. is greater than this result, the logical constant .TRUE. replaces the value of G. If 3. is not greater than I, the logical constant .FALSE. replaces the value of G.
E = (1.0,2.0)	The value of the complex variable E is replaced by the complex constant (1.0,2.0). Note that the statement E = (A,B) where A and B are real variables is invalid.

Normally, FORTRAN statements are executed sequentially; that is, after one statement has been executed, the statement immediately following it will be executed. This section discusses the statements that may be used to alter and control the normal sequence of execution of statements in the program.

THE GO TO STATEMENTS

These statements cause control to be transferred to the statement specified by a statement number. There are three GO TO statements: Unconditional GO TO, Computed GO TO, and Assigned GO TO. Every time the same Unconditional GO TO statement is executed, a transfer to the same specified statement is made. However, the Computed and Assigned GO TO statements cause control to be transferred to one of several statements, depending upon the current value of a particular variable.

Unconditional GO TO Statement

General Form
GO TO <u>xxxxx</u> Where: <u>xxxxx</u> is an executable statement number.

This GO TO statement causes control to be transferred to the statement specified by the statement number. Every subsequent execution of this GO TO statement results in a transfer to that same statement.

Example:

```
50 GO TO 25
10 A = B + C
      .
      .
      .
25 C = E**2
      .
      .
      .
```

Explanation:

In the above example, every time statement numbered 50 is executed, control is transferred to the statement numbered 25.

Computed GO TO Statement

General Form
GO TO (x_1, x_2, x_3, ...,x_n), i Where: x_1,x_2,...,x_n, are executable statement numbers. i is a nonsubscripted integer variable which is in the range: $1 \leq i \leq n$

This statement causes control to be transferred to the statement numbered x_1, x_2, x_3,..., or x_n, depending on whether the current value of i is 1, 2, 3,..., or n, respectively. If the value of i is outside the allowable range, the next statement is executed.

Example:

```
      GO TO (25, 10, 50, 7), ITEM
           .
           .
           .
   50 A = B+C
           .
           .
           .
   7  C = E**2+A
           .
           .
           .
   25 L = C.GT.D.AND.F.LE.G
           .
           .
           .
   10 B = 21.3E02
```

Explanation:

In this example, if the value of the integer variable ITEM is 1, statement 25 will be executed next. If ITEM is equal to 2, statement 10 will be executed next, and so on.

The ASSIGN and Assigned GO TO Statements

General Form
ASSIGN *i* TO *m* . . . GO TO *m*, ($x_1, x_2, x_3, \ldots, x_n$) Where: *i* is an executable statement number. $x_1, x_2, x_3, \ldots, x_n$ are executable statement numbers. *m* is a nonsubscripted integer variable of length 4 to which is assigned one of the following statement numbers: $x_1, x_2, x_3, \ldots x_n$.

The Assigned GO TO statement causes control to be transferred to the statement numbered $x_1, x_2, x_3, \ldots,$ or x_n, depending on whether the current assignment of *m* is $x_1, x_2, x_3, \ldots,$ or x_n, respectively. For example, in the following statement:

```
GO TO N, (10, 25, 8)
```

If the current assignment of the integer variable N is statement number 8, the statement numbered 8 is executed next. If the current assignment of N is statement number 10, the statement numbered 10 is executed next. If N is assigned statement number 25, the statement numbered 25 is executed next.

The current assignment of the integer variable *m* is determined by the last ASSIGN statement executed. Only an ASSIGN statement may be used to initialize or change the value of the integer variable *m*. The value of the integer *m* is not the integer statement number; ASSIGN M TO I is not the same as I=M.

Example 1:

```
      .
      .
      .
   ASSIGN 50 TO NUMBER
10 GO TO NUMBER, (35, 50, 25, 12, 18)
      .
      .
      .
50 A = B + C
      .
      .
      .
```

Explanation:

In the above example, statement 50 is executed immediately after statement 10.

Example 2:

```
          .
          .
          .
       ASSIGN 10 TO ITEM
          .
          .
          .
    13 GO TO ITEM, (8, 12, 25, 50, 10)
          .
          .
          .
     8 A = B + C
          .
          .
          .
    10 B = C + D
       ASSIGN 25 TO ITEM
       GO TO 13
          .
          .
          .
    25 C = E**2
          .
          .
          .
```

Explanation:

In the above example, the first time statement 13 is executed, control is transferred to statement 10. On the second execution of statement 13, control is transferred to statement 25.

ADDITIONAL CONTROL STATEMENTS

Arithmetic IF Statement

General Form
IF ($\underline{a}$) $\underline{x}_1,\underline{x}_2,\underline{x}_3$ Where: $\underline{a}$ is an arithmetic expression which is not complex. $\underline{x}_1,\underline{x}_2,\underline{x}_3$ are statement numbers.

This statement causes control to be transferred to the statement numbered $\underline{x}_1,\underline{x}_2,\underline{x}_3$ when the value of the arithmetic expression ($\underline{a}$) is less than, equal to, or greater than zero, respectively. The first executable statement following the arithmetic IF statement should have a statement number; otherwise, it can never be referred to or executed.

Example:

```
          .
          .
          .
    IF (A(J,K)**3-B)10, 4, 30
          .
          .
          .
    4 D = B + C
          .
          .
          .
    30 C = D**2
          .
          .
          .
    10 E = (F*B)/D+1
          .
          .
          .
```

Explanation:

In the above example, if the value of the expression (A(J,K)**3-B) is negative, the statement numbered 10 is executed next. If the value of the expression is zero, the statement numbered 4 is executed next. If the value of the expression is positive, the statement numbered 30 is executed next.

Logical IF Statement

General Form
IF(a)s Where: a is any logical expression. s is any statement except a specification statement, DO statement, or another logical IF statement.

The logical IF statement is used to evaluate the logical expression (a) and to execute or skip statement s, depending on whether the value of the expression is .TRUE. or .FALSE., respectively.

Example 1:

```
          .
          .
          .
    5  IF(A.LE.0.0) GO TO 25
    10 C = D + E
    15 IF(A.EQ.B) ANSWER = 2.0*A/C
    20 F = G/H
          .
          .
          .
    25 W = X**Z
          .
          .
          .
```

Explanation:

In statement 5, if the value of the expression is .TRUE. (i.e., A is less than or equal to 0.0), the statement GO TO 25 is executed next, and control is passed to the statement numbered 25. If the value of the expression is .FALSE. (i.e., A is greater than 0.0), the statement GO TO 25 is ignored, and control is passed to the statement numbered 10.

In statement 15, if the value of the expression is .TRUE. (i.e., A is equal to B), the value of ANSWER is replaced by the value of the expression (2.0*A/C), and the statement numbered 20 is executed. If the value of the expression is .FALSE. (i.e., A is not equal to B), the value of ANSWER remains unchanged, and the statement numbered 20 is executed next.

Example 2:

Assume that P and Q are logical variables.

```
        .
        .
        .
  5 IF(P.OR..NOT.Q)A=B
 10 C = B**2
        .
        .
        .
```

Explanation:

In statement 5, if the value of the expression is .TRUE., the value of A is replaced by the value of B and statement 10 is executed next. If the value of the expression is .FALSE., the statement A = B is skipped and statement 10 is executed.

DO Statement

General Form
DO $\underline{x}$ (End of Range) $\underline{i}$ (DO Variable) = $\underline{m}_1$ (Initial Value), $\underline{m}_2$ (Test Value), $\underline{m}_3$ (Increment)
Where: $\underline{x}$ is an executable statement number, that is not defined before the DO statement.
$\underline{i}$ is a nonsubscripted integer variable.
$\underline{m}_1$, $\underline{m}_2$, $\underline{m}_3$, are either unsigned integer constants greater than zero or unsigned nonsubscripted integer variables whose value is greater than zero. The sum m_2+m_3+1 must not exceed the size of virtual storage. ($\underline{m}_3$, is optional; if it is omitted, its value is assumed to be 1. In this case, the preceding comma must also be omitted.)

The DO statement is a command to execute repeatedly the statements that follow, up to and including the statement numbered $\underline{x}$. The first time the statements in the range of the DO are executed, $\underline{i}$ is initialized to the value $\underline{m}_1$; each succeeding time $\underline{i}$ is increased by the value $\underline{m}_3$. When, at the end of the iteration, $\underline{i}$ is equal to the highest

value that does not exceed $\underline{m}_2$, control passes to the statement following the statement numbered $\underline{x}$. Thus, the number of times the statements in the range of the DO is executed is given by the expression:

$$\left[\frac{\underline{m}_2 - \underline{m}_1}{\underline{m}_3} \right] + 1$$

where the brackets represent the largest integral value not exceeding the value of the expression. If $\underline{m}_2$ is less than $\underline{m}_1$, the statements in the range of the DO are executed once. Upon completion of the DO, the DO variable is undefined.

There are several ways in which looping (repetitively executing the same statements) may be accomplished when using the FORTRAN language. For example, assume that a manufacturer carries 1000 different machine parts in stock. Periodically, he may find it necessary to compute the amount of each different part presently available. This amount may be calculated by subtracting the number of each item used, OUT(I), from the previous stock on hand, STOCK(I).

Example:

```
            .
            .
            .
 5     I=0
 10    I=I+1
 25    STOCK(I)=STOCK(I)- OUT(I)
 15    IF(I-1000) 10,30,30
 30    A=B+C
            .
            .
            .
```

Explanation:

The three statements (5, 10, and 15) required to control the loop could be replaced by a single DO statement, as shown in Example 1.

Example 1:

```
            .
            .
            .
       DO 25 I = 1,1000
 25    STOCK(I) = STOCK(I)-OUT(I)
 30    A=B+C
            .
            .
            .
```

Explanation:

In the above example, the DO variable I is set to the initial value of 1. Before the second execution of statement 25, I is increased by the increment 1 and statement 25 is again executed. After 1000 executions of the DO loop, I equals 1000. Since I is now equal to the highest value that does not exceed the test value 1000, control passes out of the DO loop, and statement 30 is executed next. Note that the DO variable I is now undefined; its value is not necessarily 1000 or 1001.

Example 2:

```
          .
          .
          .
      DO 25 I=1, 10, 2
  15  J=I+K
  25  ARRAY(J) = BRAY(J)
  30  A=B+C
          .
          .
          .
```

Explanation:

In the above example, statement 25 is the end of the range of the DO loop. The DO variable I is set to the initial value of 1. Before the second execution of the DO loop, I is increased by the increment 2, and statements 15 and 25 are executed a second time. After the fifth execution of the DO loop, I equals 9. Since I is now equal to the highest value that does not exceed the test value 10, control passes out of the DO loop, and statement 30 is executed next. Note that the DO variable I is now undefined; its value is not necessarily 9 or 11.

Programming Considerations in Using a DO Loop

1. The indexing parameters of a DO statment ($\underline{i}$, $\underline{m}_1$, $\underline{m}_2$, $\underline{m}_3$) may not be changed by a statement within the range of the DO loop.

2. There may be other DO statements within the range of a DO statement. All statements in the range of the inner DO must be in the range of the outer DO. A set of DO statements satisfying this rule is called a nest of DOs.

   Example 1:

```
      DO 50 I = 1, 4                            }
      A(I) = B(I)**2                            }  Range of
      DO 50 J=1, 5        }                     }  Outer DO
   50 C(J+1) = A(I)       }  Range of           }
                             Inner DO
```

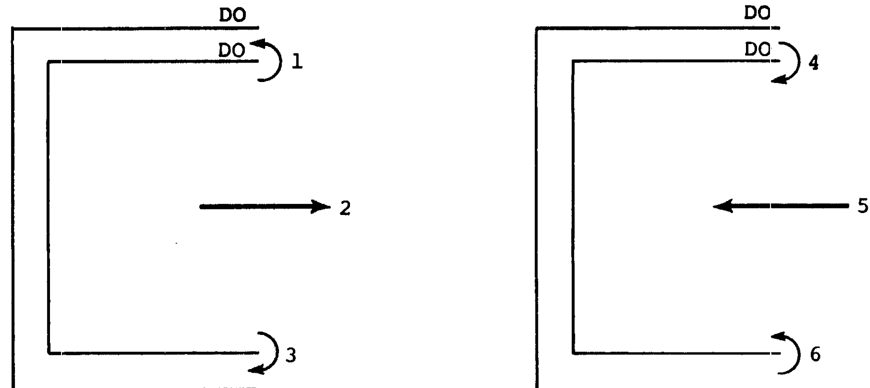
   Example 2:

```
      DO 10 INDEX = L, M                        }
      N = INDEX + K                             }
      DO 15 J = 1, 100, 2   }                   }  Range of
   15 TABLE(J) = SUM(J,N)-1 }  Range of         }  Outer DO
                               Inner DO         }
   10 B(N) = A(N)                               }
```

3. A transfer out of the range of any DO loop is permissible at any time.

4. If, and only if, a transfer is made from the range of an innermost DO loop, transfer back into the range of that innermost DO loop is allowed provided none of the indexing parameters ($\underline{i}$,$\underline{m}_1$,$\underline{m}_2$,$\underline{m}_3$) are changed outside the range of the DO. A transfer back into the range of any other DO in the nest of DOs is not permitted.

Example:



Explanation:

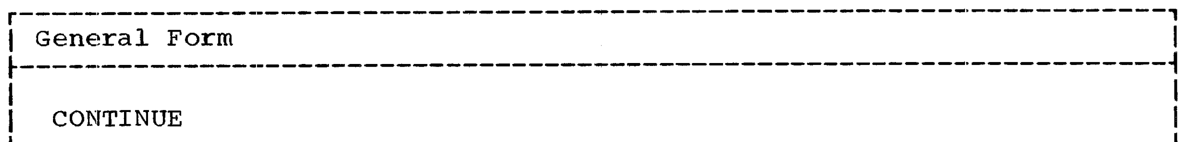
In the preceding example, the transfers specified by the numbers 1, 2, and 3 are permissible, whereas those specified by 4, 5, and 6 are not.

5. The indexing parameters ($\underline{i}$, $\underline{m}_1$, $\underline{m}_2$, $\underline{m}_3$) may be changed by statements outside the range of the DO statement only if no transfer is made back into the range of the DO statement using those parameters.

6. The last statement in the range of a DO loop (statement $\underline{x}$) may not be a GO TO, Arithmetic IF, PAUSE, STOP, RETURN or another DO statement. In addition, the last statement may not be a logical IF statement containing any of those statements.

7. The use of, and return from, a subprogram from within any DO loop in a nest of DOs is permitted.

CONTINUE Statement



General Form
CONTINUE

CONTINUE is a dummy statement which may be placed anywhere in the source program without affecting the sequence of execution. It may be used as the last statement in the range of a DO in order to avoid ending the DO loop with a GO TO, Arithmetic IF or another DO statement.

Example 1:

```
         .
         .
         .
   DO 30 I = 1, 20
 7 IF  (A(I)-B(I)) 5,30,30
 5 A(I) =A(I) +1.0
   B(I) = B(I) -2.0
   GO TO 7
30 CONTINUE
40 C = A(3) + B(7)
         .
         .
         .
```

Explanation:

In the preceding example, the CONTINUE statement is used as the last statement in the range of the DO to avoid ending the DO loop with the statement GO TO 7.

Example 2:

```
        .
        .
        .
      DO 30 I=1,20
      IF(A(I)-B(I))5,40,40
    5 A(I) = C(I)
      GO TO 30
   40 A(I) = 0.0
   30 CONTINUE
        .
        .
        .
```

In Example 2, the CONTINUE statement provides a branch point enabling the programmer to bypass the execution of statement 40.

PAUSE Statement

General Form
PAUSE PAUSE n PAUSE 'message' Where: n is an unsigned 1-through 5-digit integer constant. message is any literal constant.

The PAUSE statement causes the program to display 'PAUSE'. If n is specified, 'PAUSE n' is displayed; likewise, if 'message' is specified, 'PAUSE message' is displayed. The program waits until operator intervention causes it to resume execution, starting with the next statement after the PAUSE statement.

STOP Statement

General Form
STOP STOP n Where: n is an unsigned 1-through 5-digit integer constant.

This statement terminates the execution of the object program and displays n if specified.

END Statement

General Form
END

The END statement is a nonexecutable statement that defines the end of a source program or source subprogram for the compiler. Physically, it must be the last statement of each program or subprogram.

The END statement must be contained on a single line; however, interspersed blanks between the characters E, N, and D are permitted.

INPUT/OUTPUT STATEMENTS

The input/output statements enable a user to transfer data, belonging to a named collection of data, between I/O devices (such as disk units, card readers, and magnetic tape units) and internal storage. The named collection of data is called a data set and is not restricted to device correspondence. A data set is referred to by an unsigned integer constant or integer variable. Formerly, this reference was called a symbolic unit number. However, since it more appropriately refers to the data rather than any specific device, this number is referred to in this publication as the data set reference number.

For the FORTRAN user, a data set is considered to be a continuous string of data which may be subdivided into FORTRAN records. This subdivision of data sets into FORTRAN records is stated by the use of one or more of the following:

1. A FORMAT statement referred to by an I/O statement
2. An I/O list appearing in an I/O statement
3. A NAMELIST name appearing in an I/O statement

In addition to subdividing data sets into records, a FORMAT statement may be used to declare the form in which the data is to be transmitted.

There are five I/O statements: READ, WRITE, END FILE, REWIND, and BACKSPACE. The READ and WRITE statements are used to transfer data into or from internal storage. The END FILE statement defines the end of a data set; the REWIND and BACKSPACE statements control the positioning of data sets.

Even though the I/O statements described below are device independent, in that a given I/O statement may be applicable to a data set on any number of devices or device types, it is often meaningful to consider the original source, or ultimate destination of the data being transferred. Thus, for the sake of demonstration, subsequent examples will be in terms of card input and print-line output.

BASIC INPUT/OUTPUT STATEMENTS

The basic input/output statements are READ and WRITE. The statements FORMAT and NAMELIST, though not I/O statements, may be used in conjunction with certain forms of READ and WRITE statements. All four statements are presented in greater detail in the following sections.

READ STATEMENT

General Form
READ (a, b, END=c, ERR=d) list Where: a is an unsigned integer constant or an integer variable of length 4 that represents a data set reference number. b is either the statement number or array name of the FORMAT statement describing the data being read, or a NAMELIST name. c is the statement number to which transfer is made upon encountering the end of the data set. d is the statement number to which transfer is made upon encountering an error condition in data transfer. list is a series of variable or array names, separated by commas, which may be indexed and incremented. They specify the number of items to be read and the locations in storage into which the data is placed.

The READ statement may take many different forms. For example, the parameters END=c and ERR=d are optional and, therefore, may or may not appear in a READ statement. Furthermore, either the list or the parameter b may be omitted.

When one or more of the parameters END=c or ERR=d are used after the a and b portion of a READ statement, they may appear in any order within the parentheses. For example, the following are valid READ statements:

```
READ(5,50,ERR=10)A,B,C
READ(5,25, END=15) D,E,F,F,H
READ(N,30, ERR=100, END=8) X,Y,Z
```

If a transfer is made to a statement specified by the END parameter, no indication is given the program as to the number of items in the list (if any) read before encountering the end of the data set. If an END parameter is not specified in a READ statement, the end of the data set terminates execution of the object program.

If a transfer is made to a statement specified by the ERR parameter, no data is read into the list items associated with the record in error. No indication is given the program as to which input record or records are in error; only that one or more data items read into the list may be in error. If an ERR parameter is not specified in a READ statement, an error terminates execution of the object program.

The three basic forms of the READ statement are:

```
READ (a,x)
READ(a,b)list
READ(a)list
```

The parameters END=c and ERR=d may be used in the combination described above in each of these three forms.

The Form READ (a,x)

This form is used to read data from the data set associated with a into the locations in storage specified by the NAMELIST name x. The NAMELIST name x is a single variable name that refers to a specific list of variables or array names into which the data is placed. A specific list of variable or array names receives a NAMELIST name by use of a NAMELIST statement. The programmer need only use the NAMELIST name in the READ (a,x) statement to reference that list thereafter in the program.

The format and rules for constructing and using the NAMELIST statement are described in the following text.

General Form
NAMELIST/x/a,b,...,c/y/d,e,...,f/z/g,h,...,i
Where: x,y, and z,... are NAMELIST names.
a,b,c,d,... are variable or array names.

The following rules apply to defining and using a NAMELIST name:

1. A NAMELIST name consists of from 1 through 6 alphameric characters, the first of which is alphabetic.
2. A NAMELIST name is enclosed in slashes. The list of variable or array names belonging to a NAMELIST name ends with a new NAMELIST name enclosed in slashes or with the end of the NAMELIST statement.
3. A variable name or an array name may belong to one or more NAMELIST names.
4. A NAMELIST name may be defined only once by its appearance in a NAMELIST statement and must be so defined before its use. After it is defined in the NAMELIST statement, the NAMELIST name may appear only in input or output statements thereafter in the program.
5. A NAMELIST statement may appear anywhere in a FORTRAN program prior to its use in a READ/WRITE statement.
6. Variable or array names appearing anywhere in a NAMELIST statement or NAMELIST name may not appear in a FUNCTION, SUBROUTINE, or ENTRY statement.

Example:

Assume that A, I, and L are array names.

```
      .
      .
      .
NAMELIST /NAM1/A,B,I,J,L/NAM2/A,C,J,K
      .
      .
      .
READ (5,NAM1)
      .
      .
      .
```

Explanation:

The above READ statement causes the record that contains the input data for the variables and arrays that belong to the NAMELIST name referenced, NAM1, to be read from the data set associated with the data set reference number 5.

When a READ statement references a NAMELIST name, input data in the form described in the following text is read from the designated input data set.

Input Data

The first character in the record is always ignored. The second character of the first record of a group of data records to be read must be &, immediately followed by the NAMELIST name. This name is followed by any combination of data items 1 and 2 below, separated by commas. (A comma after the last item is optional.)

The form the data items may take is:

1. Variable name = constant

   The variable name may be a subscripted variable name or a single variable name. Subscripts must be integer constants.

2. Array name = set of constants (separated by commas)

   The set of constants may be in the form "k* constant," where k is an unsigned integer called the repeat constant. It represents the number of successive elements in the array to be initialized by the specified constant. The number of constants must be equal to the number of elements in the array.

Constants used in the data items may be integer, real, literal, complex, or logical data. If the constants are logical data, they may be in the form T or .TRUE. and F or .FALSE..

Any selected set of variable or array names belonging to the NAMELIST name appearing on the first record may be used as specified by items 1 and 2 in the preceding text. Names that are made equivalent to these names may not be used unless they also belong to the NAMELIST name.

The end of a group of data is signaled by the character string &END with no embedded blanks and all appearing in the same record.

Blanks must not be embedded in a constant or repeat constant, but may be used freely elsewhere in a data record. The last item on each record that contains data items must be a constant followed by a comma. (The comma is optional on the record that precedes the record containing &END.)

Example:

Assume that L is an array consisting of one subscript parameter ranging from 1 to 10.

```
                         Column 2
                         ↑
First Data Card:         &NAM1
Second Data Card:        I(2,3)=5, J=4,
Third Data Card:         A(3)=4.0, L=2,3,8*4,
      .                    .
      .                    .
      .                    .
Last Data Card:          &END
```

Explanation:

If this data is input to be used with the NAMELIST and READ statements previously illustrated, the following actions take place. The first data card is read and examined to verify that its name (and the data items that follow) is consistent with the NAMELIST name in the READ statement. If that NAMELIST name is not found it reads to the next namelist group. When the second data card is read, the integer constants 5 and 4 are placed in I(2,3) and J, respectively. When the third data card is read, the real constant 4.0 is placed in A(3). Also, since L is an array not followed by a subscript, the entire array is filled with the succeeding constants. Therefore, the integer constants 2 and 3 is placed in L(1) and L(2), respectively, and the integer constant 4 is placed in L(3), L(4),...,L(10).

The Form READ (a,b) List

This form is used to read data from the data set associated with a into the locations in storage specified by the variable names in the list. The list, used in conjunction with the specified FORMAT statement b (see the section "FORMAT statement"), determines the number of items (data) to be read, the locations, and the form the data will take in storage.

Example 1:

Assume that the variables A, B, and C have been declared as integer variables.

```
        .
        .
        .
   75 FORMAT (G10, G8, G9)
        .
        .
        .
      READ (J, 75) A, B, C
        .
        .
        .
```

Explanation:

The above READ statement causes input data from the data set associated with data set reference number J to be read into the locations A, B, and C according to the FORMAT statement referenced (statement 75). That is, the first 10 positions of the record are read into storage location A; the next 8 positions are read into storage location B; and the next 9 positions are read into storage location C.

The list can be omitted from the READ (a,b)list statement. In this case, a record is skipped or data is read from the data set associated

with a into the locations in storage occupied by the FORMAT statement numbered b.

Example 2:

```
          .
          .
          .
    98 FORMAT ('HEADING')
          .
          .
          .
       READ (5,98)
          .
          .
          .
```

Explanation:

The above statements would cause the characters H, E, A, D, I, N, and G in storage to be replaced by the next 7 characters in the data set associated with data set reference number 5.

Example 3:

```
          .
          .
          .
    98 FORMAT (G10,'HEADING')
          .
          .
          .
       READ (5,98)
          .
          .
          .
```

Explanation:

The above statements would cause the next record in the data set associated with data set reference number 5 to be skipped. No data is transferred into internal storage because there is no list item that corresponds with format code G10.

The Form READ (a) List

The form READ (a) list of the READ statement causes binary data (internal form) to be read from the data set associated with a into the locations of storage specified by the variable names in the list. Since the input data is always in internal form, a FORMAT statement is not required. This statement is used to retrieve the data written by a WRITE (a) list statement.

Example:

    READ (5) A, B, C

Explanation:

This statement causes the binary data from the data set associated with data set reference number 5 to be read into the storage locations specified by the variable names A, B, and C.

The list may be omitted from the READ (a) list statement. In this case, a record is skipped.

Example:

```
READ (5)
```

Explanation:

The above statements would cause the next record in the data set associated with data set reference number 5 to be skipped. No data is transferred into internal storage.

Indexing I/O Lists

Variables within an I/O list may be indexed and incremented in the same manner as those within a DO statement. These variables and their indexes must be included in parentheses. For example, suppose it is desired to read data into the first five positions of the array A. This may be accomplished by using an indexed list as follows:

```
15 FORMAT (G10.3)
       .
       .
       .
   READ (2,15) (A(I),I=1,5)
```

This is equivalent to:

```
15 FORMAT (G10.3)
       .
       .
       .
   DO 12 I = 1,5
12 READ (2,15) A(I)
```

As with DO statements, a third indexing parameter may be used to specify the amount by which the index is to be incremented at each iteration. Thus,

```
READ (2,15) (A(I), I=1,10,2)
```

causes transmission of values for A(1), A(3), A(5), A(7), and A(9).

Furthermore, this notation may be nested. For example, the statement:

```
READ (2,15) ((C(I,J),D(I,J),J=1,3),I=1,4)
```

would transmit data in the following order:

```
C(1,1), D(1,1), C(1,2), D(1,2), C(1,3), D(1,3)
C(2,1), D(2,1), C(2,2), D(2,2), C(2,3), D(2,3)
C(3,1), D(3,1), C(3,2), D(3,2), C(3,3), D(3,3)
C(4,1), D(4,1), C(4,2), D(4,2), C(4,3), D(4,3)
```

Since J is the innermost index, it varies more rapidly than I.

As another example, consider the following:

```
READ (2,25) I,(C(J),J=1,I)
```

The variable I is read first and its value then serves as an index to specify the number of data items to be read into the array C.

If it is desired to read data into an entire array, it is not necessary to index that array in the I/O list. For example, assume that the array A consists of one subscript parameter varying in the range of 1 to 10. Then the following READ statement referring to FORMAT statement numbered 5:

```
READ (2,5) A
```

would cause data to be read into A(1), A(2),...,A(10).

The indexing of I/O lists applies to WRITE lists, as well as READ lists.

Reading Format Statements

FORTRAN provides the facility for variable FORMAT statements by allowing a FORMAT statement to be read into an array in storage and using the data in the array as the FORMAT specifications for subsequent I/O statements.

For example, the following statements result in A, B, and the array C being read, converted, and stored according to the FORMAT specifications read into the array FMT at object time:

```
     DIMENSION FMT (18)
  1  FORMAT (18A4)
     READ (5,1) FMT
     READ (5,FMT) A,B,(C(I),I=1,5)
```

1. The name of the variable FORMAT specification must appear in a DIMENSION statement, even if the array size is only 1.

2. The form of the format codes read into the FMT array at object time must take the same form as a source program FORMAT statement, except that the word FORMAT is omitted (see the section "The FORMAT Statement").

WRITE STATEMENT

General Form
WRITE (<u>a</u>, <u>b</u>) <u>list</u> Where: <u>a</u> is an unsigned integer constant or an integer variable of length 4 that represents a data set reference number. <u>b</u> is either the statement number or array name of the FORMAT statement describing the data being written, or a NAMELIST name. <u>list</u> is a series of variable or array names, separated by commas, which may be indexed and incremented. They specify the number of items to be written and the locations in storage from which the data is taken.

The WRITE statement may take many different forms. For example, the list or the parameter b may be omitted.

The three basic forms of the WRITE statement are:

```
WRITE(a,x)
WRITE(a,b)list
WRITE(a)list
```

The Form WRITE (a,x)

This form is used to write data from the locations in storage specified by the NAMELIST name x into the data set associated with a (see the section "The Form READ(a,x)").

Example:

```
WRITE(6,NAM1)
```

Explanation:

This statement causes all variable and array names (as well as their values) that belong to the NAMELIST name, NAM1, to be written on the data set associated with data set reference number 6.

When a WRITE statement references a NAMELIST name:

1. All variables and arrays and their values belonging to the NAMELIST name will be written out, each according to its type. The complete array is written out by columns.
2. The output data will be written such that:
   a. The fields for the data will be large enough to contain all the significant digits.
   b. The output can be read by an input statement referencing the NAMELIST name.

Example:

Assume that A is a 3 by 3 array.

```
       .
       .
       .
   NAMELIST/NAM1/A,B,I,D
   WRITE (8,NAM1)
       .
       .
       .
```

Assuming that the output is punched on cards, the format would be:

```
                          Column 2
                          ↑
First Output Card:        &NAM1
Second Output Card:       A=3.4,   4.5, 6.2,       25.1,
Third Output Card:          9.0, -15.2,-7.6,  0.576Eb12,
Fourth Output Card:       2.717,B=3.14,I=10,D=0.378E-15,
Fifth Output Card:        &END
```

The Form WRITE (a,b) List

This form is used to write data in the data set associated with a from the locations in storage specified by the variable names in the list. The list, used in conjunction with the specified FORMAT statement b, determines the number of items (data) to be written, the locations, and the form the data will take in the data set.

Example 1:

In the following example, assume that the variables A, B, and C have been declared as integer variables.

```
75  FORMAT (G10, G8, G9)
     .
     .
     .
WRITE (J, 75) A, B, C
```

Explanation:

The above WRITE statement causes output data to be written in the data set associated with the data set reference number J, from the locations A, B, C, according to the FORMAT statement referred to (statement 75). That is, the 10 rightmost digits in A are written in the data set associated with the data set reference number J; the next 8 positions in the data set will contain the 8 rightmost digits in B; and the next 9 positions in the data set will contain the 9 rightmost digits in C.

The list may be omitted from the WRITE (a,b) list statement. In this case, a blank record is inserted, or data is written in the data set associated with a from the locations in storage occupied by the FORMAT statement b.

Example 2:

```
98    FORMAT (' HEADING')
        .
        .
        .
      WRITE (5,98)
```

The above statements would cause a blank and the characters H, E, A, D, I, N, and G in storage to be written in the data set associated with data set reference number 5.

Example 3:

```
98    FORMAT (G10, 'HEADING')
        .
        .
        .
      WRITE (5,98)
```

Explanation:

The above statements would cause a blank record to be placed in the data set associated with data set reference number 5. No data is transferred into the data set.

The Form WRITE (a) List

The WRITE (a) list form of the WRITE statement causes binary data (internal form) from the locations of storage specified by the variable names in the list to be written in the data set associated with a. Since the output data is always in internal form, a FORMAT statement is not required. The READ (a) list statement is used to retrieve the data written by a WRITE (a) list statement.

Example:

```
WRITE (5)A, B, C
```

Explanation:

The statement causes the binary data from the locations specified by the variable names A, B, and C to be written in the data set associated with data set reference number 5.

FORMAT STATEMENT

General Form
xxxxx FORMAT (c_1,c_2,...,c_n/c_1',c_2',...,c_n'/...) Where: xxxxx is a statement number (1 through 5 digits). c_1,c_2,...,c_n and c_1',c_2',...,c_n' are format codes which may be delimited by one of the separators: comma, slash, or parenthesis. These codes specify the length, decimal point (if any), and position of the data in the data set. / may be used to separate FORTRAN records.

The FORMAT statement is used in conjunction with the READ and WRITE statements in order to specify the desired form of the data to be transmitted. The form of the data is varied by the use of different format codes. The twelve format codes are: G, T, X, P, literal, A, I, F, E, D, H, and L. Any number used in a FORMAT statement except a statement number or a literal must be less than 256.

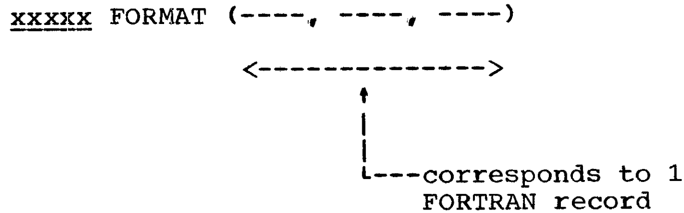
USE OF THE FORMAT STATEMENT: This section contains general information on the FORMAT statement. The points discussed below are illustrated by the examples that follow.

1. FORMAT statements are nonexecutable and may be placed anywhere in the source program.

2. A FORMAT statement may be used to define a FORTRAN record, as follows:

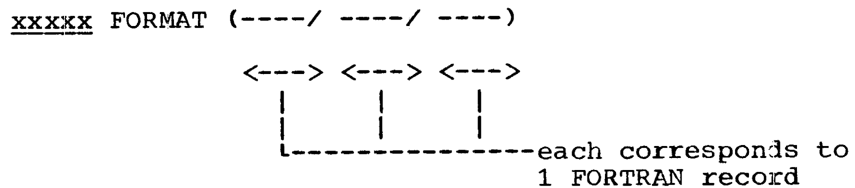
   a. If no slashes or additional parentheses appear within a FORMAT statement, a FORTRAN record is defined by the beginning of the FORMAT statement (left parenthesis) to the end of the FORMAT statement (right parenthesis). Thus, a new record is read when the format control is initiated (left parenthesis); a new record is written when the format control is terminated (right parenthesis).

Example:



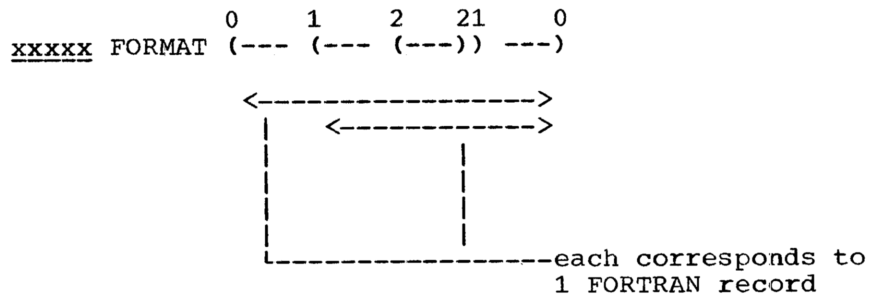
b. If slashes appear within a FORMAT statement, FORTRAN records are defined by the beginning of the FORMAT statement to the first slash in the FORMAT statement, from one slash to the next succeeding slash, or from the last slash to the end of the FORMAT statement. Thus, a new record is read when the format control is initiated, and thereafter a record is read upon encountering a slash; a new record is written upon encountering a slash or when format control is terminated.

Example:

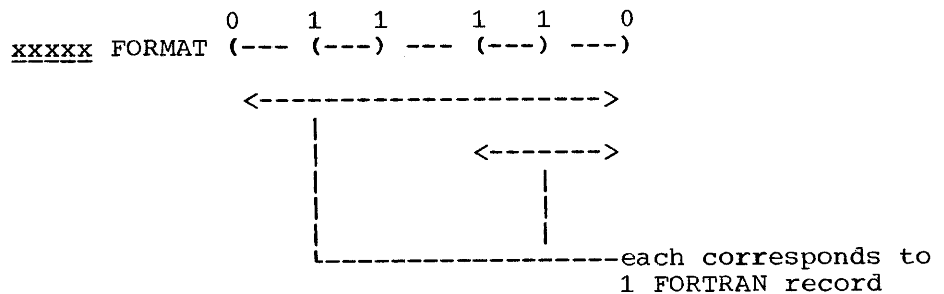


c. If more than one level of parentheses appears within a FORMAT statement, a record is defined by the beginning of the FORMAT statement to the end of the FORMAT statement; thereafter, from the first-level left parenthesis from the right of the FORMAT statement to the end of the FORMAT statement.

Example 1:



Example 2:



When defining a FORTRAN record by a FORMAT statement, it is important to consider the original source (input) or ultimate destination (output) of the record. For example, if a FORTRAN record is to be punched for output, the record should not be greater than 80 characters. For input, the FORMAT statement should not define a FORTRAN record longer than the record referred to in the data set.

3. Blank output records may be introduced or input records may be skipped by using consecutive slashes (/) in a FORMAT statement. If there are n consecutive slashes at the beginning or end of a FORMAT statement, n input records are skipped or n blank records are inserted between output records, respectively. If n consecutive slashes appear anywhere else in a FORMAT statement, the number of records skipped or blank records inserted is n-1.

4. Successive items in an I/O list are transmitted according to successive format codes in the FORMAT statement, until all items in the list are transmitted. If there are more items in the list than there are codes in the FORMAT statement, control transfers to the preceding left parenthesis of the FORMAT statement and the same format codes are used again with the next record. If there are fewer items in the list, the remaining format codes are not used.

5. A format code may be repeated as many times as desired by preceding the format code with an unsigned integer constant.

6. A limited parenthetical expression is permitted to enable repetition of data fields according to certain format codes within a longer FORMAT statement. Two levels of parentheses, in addition to the parentheses required by the FORMAT statement, are permitted. The second level of parentheses facilitates the transmission of complex quantities.

7. When transferring data on input or output, the type of format code used, type of data, and type of variables in the I/O list should correspond.

8. In the following examples, the output is shown as a printed line. A carriage control character 'x' (see "Carriage Control") is specified in the FORMAT statement but does not appear in the first print position of the print line. This carriage control character appears as the first character of the output record on any I/O medium except the printed line.

G Format Code

General Form
<u>a</u>G<u>w</u>.<u>s</u> Where: <u>a</u> is optional and is an unsigned integer constant used to denote the number of times the same format code is repetitively referenced. <u>w</u> is an unsigned integer constant less than or equal to 255 specifying the <u>total</u> field length. <u>s</u> is an unsigned integer constant specifying the <u>number of significant digits.</u>

The G format code is a generalized code, in that it may be used to determine the desired form of data, whether it be integer, real, complex, or logical.

The .s portion may be omitted when transferring integer or logical data. If present, it is ignored. When real data is transferred, the w portion of the G format code includes four positions for a decimal exponent field.

If the real data, say n, is in the range 0.1≤n≤10**s, where s is the s portion of the format code Gw.s, this exponent field is blank. Otherwise, the real data is transferred with an E or D decimal exponent, depending on the length specification (either 4 or 8 storage locations, respectively) of the real data.

For simplification, the following examples deal with the printed line; however, the concepts developed apply to all input/output media.

Example 1:

Assume that the variables A, B, C, and D are of type real, whose values are 292.7041, 82.43441, 136.7632, .8081945, respectively.

```
1    FORMAT  ('x',G12.4,G12.5,G12.4,G12.7)
2    FORMAT  ('x',G13.4,G13.5,G13.4)
3    FORMAT  ('x',G13.4)
        .
        .
        .
     WRITE (5, b) A, B, C, D
        .
        .
        .
```

Explanation:

a. If b had been specified as 1, the printed output would be: (b represents a blank)

```
Print Position 1                Print Position 48
↑                                               ↑
bbb292.7bbbbbb82.434bbbbbbb136.7bbbb.8081945bbbb
```

b. If b had been specified as 2, the printed output would be:

```
Print Position 1          Print Position 39
↑                                     ↑
bbbb292.7bbbbbbb82.434bbbbbbb136.7bbbb          Line 1
bbb0.8081bbbb                                   Line 2
```

From the example, it can be seen that by increasing the field width reserved (w), blanks are inserted.

c. If b had been specified as 3, the printed output would be:

```
Print Position 1
↑
bbbb292.7bbbb                                   Line 1
bbbb82.43bbbb                                   Line 2
bbbb136.7bbbb                                   Line 3
bbb0.8081bbbb                                   Line 4
```

From the example, it can be seen that the same format code was used for each variable in the list. Each repetition of the same format code caused a new line to be printed.

Example 2:

Assume that the variables I, J, K, and L are of type integer, whose values are 292, 443428, 4908081, and 40018, respectively.

```
    1   FORMAT  ('x',G10,2G7,G5)
    2   FORMAT  ('x',G6)
    3   FORMAT  ('x',4G10)
           .
           .
           .
        WRITE (5, b) I, J, K, L
           .
           .
           .
```

Explanation:

a. If b had been specified as 1, the printed output would be:

```
Print Position 1              Print Position 29
↑                             ↑
bbbbbbb292b443428490808140018                      Line 1
```

The same results would be achieved, if FORMAT statement 1 had been written:

```
            FORMAT ('x',G10, G7, G7, G5)
```

Note that the .s portion of the G format may be omitted when transmitting integer data.

b. If b had been specified as 2, the printed output would be:

```
Print Position 1
↑
bbb292                                             Line 1
443428                                             Line 2
908081                                             Line 3
b40018                                             Line 4
```

Note that the second format code G6 is an incorrect specification for the third variable K, i.e., 4908081. Thus, the leftmost digit is lost. In general, when the width specification w is insufficient, the leftmost characters are not printed.

c. If b had been specified as 3, the printed output would be:

```
Print Position 1               Print Position 40
↑                                        ↑
bbbbbbb292bbbb443428bbb4908081bbbbb40018           Line 1
```

From the above example, it can be seen that increasing the field width w improves readability.

Example 3:

Assume that the variable I is integer (length 2), A and B are real (length 4), D is real (length 8), C is complex (length 8), and L is logical (length 1) whose values are 292, 471.93, 81.91, 6.9310072, (2.1,3.7), and .TRUE., respectively.

```
 1  FORMAT  ('x',G3,2G9.2,G13.7,2G8.2,G3)
 2  FORMAT  ('x',G3/'x',2G10.2/'x',G9.1/'x',2G8.2,G3)
 3  FORMAT  (//'x',G3,2G9.2//'x',G13.7,2G8.2,G3///)
        .
        .
        .
    WRITE (5,b) I,A,B,D,C,L
        .
        .
        .
```

Explanation:

a. If b has been specified as 1, the printed output would be:

```
Print Position 1                             Print Position 53
↑                                                            ↑
292b0.47Eb03bb81.bbbbb6.931007bbbbb2.1bbbbb3.7bbbbbbT
```

When complex data is being transmitted, two format codes are required. The real and imaginary parts are each treated as separate real numbers, and the parentheses and comma are not printed as part of the output.

b. If b has been specified as 2, the printed output would be:

```
Print Position 1
↑
292                                      Line 1
bb0.47Eb03bbb81.bbbb                     Line 2
bbb6bbbb                                 Line 3
b2.1bbbbb3.7bbbbbbT                      Line 4
```

From the example, it can be seen that the use of the slash (/) to separate two format codes causes the data, not yet printed, to be printed on a new line. If the output data is to be punched on cards, the slash specifies that the following data will be punched on another card.

c. If b has been specified as 3, the printed output would be:

```
Print Position 1
↑
(blank line)                             Line 1
(blank line)                             Line 2
292b0.47Eb03bb81.bbbb                    Line 3
(blank line)                             Line 4
b6.931007bbbbb2.1bbbbb3.7bbbbbbT         Line 5
(blank line)                             Line 6
(blank line)                             Line 7
(blank line)                             Line 8
```

In the example, note that 2 consecutive slashes appearing at the beginning and 3 at the end of the series of format codes causes blank lines to be inserted as shown. However, the two consecutive slashes appearing elsewhere in the FORMAT statement cause the insertion of a blank line, as shown in line 4.

The principles illustrated in the previous output examples also apply when using the READ statement on input. In addition, there are further considerations when using the FORMAT statement on input or output.

1. When reading real input data with a G format code, a decimal point must be included.

2. The use of additional parentheses (up to two levels) within a FORMAT statement is permitted to enable the user to repeat the same format code when transmitting data. For example, the statement:

   ```
   10  FORMAT (2(G10.6,G7.1),G4)
   ```

   is equivalent to:

   ```
   10  FORMAT (G10.6, G7.1, G10.6, G7.1, G4)
   ```

3. If the data exists with a D decimal exponent, it is transferred with this D decimal exponent.

4. If a multiline listing is desired such that the first two lines are to be printed according to a special format and all remaining lines according to another format, the last format code in the statement should be enclosed in a second pair of parentheses. For example, in the statement:

   ```
   FORMAT ('x',G2,2G3.1/'x',G10.8/('x',3G5.1))
   ```

   If more data items are to be transmitted after the format codes have been completely used, the format repeats from the last left parenthesis. Thus, the printed output would take the form:

   ```
   G2,G3.1,G3.1
   G10.8
   G5.1,G5.1,G5.1
   G5.1,G5.1,G5.1
     .    .    .
     .    .    .
     .    .    .
   ```

   As another example, consider the statement:

   ```
   FORMAT ('x',G2/2('x',G3,G6.1),G9.7)
   ```

   If there are thirteen data items to be transmitted, the printed output on a WRITE statement would take the form:

   ```
   G2
   G3,G6.1,'x',G3,G6.1,G9.7
   G3,G6.1,'x',G3,G6.1,G9.7
   G3,G6.1
   ```

<u>Numeric Format Codes (I,F,E,D)</u>

Four types of format codes are available for the transfer of numeric data. These are specified in the following form:

General Form
aIw aFw.d aEw.d aDw.d Where: a is optional and is an unsigned integer constant used to denote the number of times the same format code is repetitively referenced. I, F, E, and D are format codes. w is an unsigned integer constant less than or equal to 255 specifying the total field length of the data. d is an unsigned integer constant specifying the number of decimal places to the right of the decimal point, i.e., the fractional portion.

For purposes of simplification, the following discussion of format codes deals with the printed line. The concepts developed apply to all input/output media.

I Format Code

The I format code is used in conjunction with the transferral of integer data. The code I10 may be used to print integer data; 10 print positions are reserved for the number. It is printed in this 10-position field right-justified (that is, the units position is at the extreme right).

If the number to be transmitted is greater than 10 positions, the excess leftmost digits are lost. If the number has less than 10 digits, the leftmost print positions are filled with blanks. If the quantity is negative, the position preceding the leftmost digit contains a minus sign. In this case, an additional position should be specified in the total field length for the minus sign. On input, if the field length specification w is greater than the number of digits being read into a field, the integer data is right-justified and high-order zeros are inserted.

The following examples show how each of the quantities on the left is printed according to the format code I3 (b represents a blank):

Internal Value	Printed Value	
721	721	
-721	721	(incorrect because of insufficient specification)
-12	-12	
568114	114	(incorrect because of insufficient specification)
0	bb0	
-5	b-5	
9	bb9	

F Format Code

The F format code is used in conjunction with the transferral of real data that does not contain a decimal exponent. For F format codes, w is the total field length reserved, and d is the number of places to the right of the decimal point (the fractional portion). This differs from the G format code, where the number of significant digits is specified. The total field length reserved must include sufficient positions for a sign (if any) and a decimal point. The sign, if negative, is printed.

If insufficient positions are reserved by d, the fractional portion is truncated from the right. If excessive positions are reserved by d, zeros are filled in on the right. The integer portion of the number is handled in the same fashion as numbers transmitted by the I format code.

The following examples show how each of the quantities on the left is printed according to the format code F5.2:

Internal Value	Printed Value	
12.17	12.17	
-41.16	41.16	(incorrect because of insufficient specification)
-.2	-0.20	
7.3542	b7.35	(last two digits of accuracy lost because of insufficient specification)
-1.	-1.00	
9.03	b9.03	
187.64	87.64	(incorrect because of insufficient specification)

D and E Format Codes

The D and E format codes are used in conjunction with the transferral of real data that contains a D or E decimal exponent, respectively. A D format code indicates a field length of 8; an E format code indicates a field length of 4. For D and E format codes, the fractional portion is again indicated by d. The w includes field d, spaces for a sign, the decimal point, and four spaces for the exponent. (For output, space should be reserved for at least one digit preceding the decimal point.)

The exponent is the power of 10 by which the number must be multiplied to obtain its true value. The exponent is written with a D or an E, followed by a space for the sign and two spaces for the exponent (maximum is 75).

The following examples show how each of the quantities on the left is printed according to the format codes (D10.3/E10.3):

Internal Value	Printed Value	
238.	b0.238Db03	
-.002	-0.200E-02	
.00000000004	b0.400D-10	
-21.0057	-0.210Eb02	(Last three digits of accuracy lost because of insufficient specification)

When reading input data, the start of the exponent field must be marked by an E, or, if that is omitted, by a + or - sign (not a blank). Thus, E2, E+2, +2, +02, E02, and E+02 all have the same effect and are permissible decimal exponents for input.

Numbers for E, D, and F format codes need not have their decimal point punched. If it is not present, the decimal point is supplied by the d portion of the format code. If it is present in the card, its position overrides the position indicated by the d portion of the format code.

L Format Code

General Form
aLw Where: a is optional and is an unsigned integer constant used to denote the number of times the same format code is repetitively referenced. w is an unsigned integer constant less than or equal to 255, specifying the number of characters of data.

Logical variables may be read or written by means of the format code Lw.

On input, the first T or F encountered in the next w characters of the input record causes a value of .TRUE. or .FALSE., respectively, to be assigned to the corresponding logical variable. If the field w consists entirely of blanks, a value of .FALSE. is assumed.

On output, a T or an F is inserted in the output record corresponding to the value of the logical variable in the I/O list. The single character is preceded by w - 1 blanks.

A Format Code

General Form
aAw Where: a is optional and is an unsigned integer constant used to denote the number of times the same format code is repetitively referenced. w is an unsigned integer constant less than or equal to 255, specifying the number of characters of data.

The format code Aw is used to read or write data. If w is equal to the number of characters corresponding to the length specification of each item in the I/O list, w characters are read or written.

On input, if w is less than the length specification of each item in the I/O list, w characters are read and the remaining right-most characters in the item are replaced with blanks. If w is greater than the length specification, the number of characters equal to the difference between w and the length specification are skipped and the remaining characters are read.

On output, if w is less than the length specification of the item in the I/O list, the printed line will consist of the leftmost w characters of the item. If w is greater than the length specification, the printed line will consist of the characters right-justified in the field and will be preceded by blanks. Therefore it is important to always allocate enough area in storage to handle the characters being written (see the section "The Type Statements").

Example 1:

Assume that the array ALPHA consists of one subscript parameter ranging from 1 through 20. The following statements could be written to "copy" a record from one data set to another whose ultimate destination is a card punch.

```
           .
           .
           .
 10   FORMAT (20A4)
           .
           .
           .
      READ (5,10) (ALPHA(I),I=1,20)
           .
           .
           .
      WRITE (6,10) (ALPHA(I),I=1,20)
           .
           .
           .
```

Explanation:

In example, the READ statement would cause 20 groups of characters to be read from the data set associated with data set reference number 5. Each group of four characters would be placed into the 20 positions in storage starting with ALPHA(1) and ending with ALPHA(20). The WRITE statement would cause the 20 groups of four characters to be written on the data set associated with data set reference number 6.

Example 2:

As another example, consider all the variable names in the list of the following READ statement to have been explicitly specified as REAL, and the array CONST to have been specified as having one subscript parameter ranging from 1 through 10. Then assuming the following input data is associated with data set reference number 5:

ABCDE...XYZ$1234567890b

where ... represents the alphabetic characters F through W and b means a blank, the following statements could be written:

```
           .
           .
           .
 10   FORMAT  (27A1,10A1,A1)
 20   FORMAT  ('x',6(7A1,5X))
           .
           .
           .
      READ  (5,10)A,B,C,D,E,F,G,H,I,
     1            J,K,L,M,N,O,P,Q,R,
     2            S,T,U,V,W,X,Y,Z,$,
     3            (CONST (IND),IND=1, 10), BLANK
           .
           .
           .
```

```
         DO 50 INDEX = 1,5
            .
            .
            .
         WRITE (6,20)G,R,O,U,P,BLANK,CONST(INDEX),
        1            B,L,O,C,K,BLANK,CONST(INDEX),
        2            F,I,E,L,D,BLANK,CONST(INDEX),
        3            G,R,O,U,P,BLANK,CONST(INDEX+5),
        4            B,L,O,C,K,BLANK,CONST(INDEX+5),
        5            F,I,E,L,D,BLANK,CONST(INDEX+5)
            .
            .
            .
      50 CONTINUE
            .
            .
            .
```

Explanation:

The READ statement would cause the 37 alphameric characters and the blank in the data set associated with data set reference number 5 to be placed into the storage locations specified by the variable names in the READ list. Thus, the variables A through Z receive the values A through Z, respectively; the variable $ receives the value $; the numbers 1 through 9, and 0, are placed in the 10 fields in storage starting with CONST(1) and ending with CONST(10); and the variable BLANK receives a blank. The WRITE statement within the DO loop would cause the following heading to be printed. A subsequent WRITE statement within the DO loop could then be written to print the corresponding output data.

```
Print Position 1                                      Print Position 67
↑                                                                     ↑
|                                                                     |
GROUP 1      BLOCK 1     FIELD 1     GROUP 6     BLOCK 6     FIELD 6
    -            -           -           -           -           -
    -            -     (output data)     -           -           -
    -            -           -           -           -           -
GROUP 2      BLOCK 2     FIELD 2     GROUP 7     BLOCK 7     FIELD 7
    -            -           -           -           -           -
    -            -     (output data)     -           -           -
    -            -           -           -           -           -
    .            .           .           .           .           .
    .            .           .           .           .           .
    .            .           .           .           .           .
GROUP 5      BLOCK 5     FIELD 5     GROUP 0     BLOCK 0     FIELD 0
    -            -           -           -           -           -
    -            -     (output data)     -           -           -
    -            -           -           -           -           -
```

Literal Data in a Format Statement

Literal data consists of a string of alphameric and special characters written within the FORMAT statement and enclosed in apostrophes. The string of characters must be less than or equal to 255. For example:

```
25 FORMAT (' 1964 INVENTORY REPORT')
```

An apostrophe character within the string is represented by two successive apostrophes. For example, the characters DON'T are represented as:

```
DON''T
```

The effect of the literal format code depends on whether it is used with an input or output statement.

INPUT

A number of characters, equal to the number of characters between the apostrophes, are read from the designated data set. These characters replace, in storage, the characters within the apostrophes.

For example, the statements:

```
          .
          .
          .
  5    FORMAT (' HEADINGS')
          .
          .
          .
       READ (3,5)
          .
          .
          .
```

would cause the next nine characters to be read from the data set associated with data set reference number 3; these characters would replace the blank and the eight characters H,E,A,D,I,N,G, and S in storage.

OUTPUT

All characters (including blanks) within the apostrophes are written as part of the output data. Thus, the statements:

```
          .
          .
          .
  5    FORMAT (' THIS IS ALPHAMERIC DATA')
          .
          .
          .
       WRITE (2,5)
          .
          .
          .
```

would cause the following record to be written on the data set associated with the data set reference number 2:

```
THIS IS ALPHAMERIC DATA
```

H Format Code

General Form
*w*H Where: *w* is an unsigned integer constant less than or equal to 255, specifying the number of characters following H.

The H format code is used in conjunction with the transferral of literal data.

The format code wH is followed in the FORMAT statement by w (w≤255) characters. For example,

```
5    FORMAT (31H THIS IS ALPHAMERIC INFORMATION)
```

Blanks are significant and must be included as part of the count w. The effect of wH depends on whether it is used with input or output.

1. On input, w characters are extracted from the input record and replace the w characters of the literal data in the FORMAT statement.

2. On output, the w characters following the format code are written as part of the output record.

X Format Code

General Form
wX Where: w is an unsigned integer constant less than or equal to 255, specifying the number of blanks to be inserted on output or the number of characters to be skipped on input.

When the wX (w≤255) format code is used with a READ statement (i.e., on input), w characters are skipped before the data is read in. For example, if a card has six 10-column fields of integer quantities, and it is not desired to read the second quantity, then the statement:

```
5    FORMAT    (I10,10X,4I10)
```

may be used, along with the appropriate READ statement.

When the wX format code is used with a WRITE statement (i.e., on output), w characters are left blank. Thus, the facility for spacing within a printed line is available. For example, the statement:

```
10 FORMAT ('x',3(F6.2,5X))
```

may be used with an appropriate WRITE statement to print a line as follows:

```
123.45bbbbb817.32bbbbb524.67bbbbb
```

T Format Code

General Form
Tw Where: w is an unsigned integer constant less than or equal to 255, specifying the position in a FORTRAN record where the transfer of data is to begin.

Input and output may begin at any position by using the format code Tw (w≤255). Only when the output is printed does the correspondence between w and the actual print position differ. In this case, because of the carriage control character, the print position corresponds to w-1, as in the following example:

```
5  FORMAT (T40, '1964 INVENTORY REPORT' T80, 'DECEMBER' T1,  '  PART
   NO. 10095')
```

The above FORMAT statement would result in a printed line as follows:

```
Print                Print                       Print
Position 1           Position 39                 Position 79
↑                    ↑                           ↑
PART NO. 10095       1964 INVENTORY REPORT       DECEMBER
```

The statements:

```
5  FORMAT  (T40, ' HEADINGS')
        .
        .
        .
   READ (3,5)
```

would cause the first 39 characters of the input data to be skipped, and the next 9 characters would then replace the blank and the characters H,E,A,D,I,N,G and S in storage.

The T format code may be used in a FORMAT statement with any type of format code. For example, the following statement is valid:

```
5 FORMAT (T100, F10.3, T50, E9.3, T1, ' ANSWER IS')
```

Scale Factor - P

The representation of the data, internally or externally, may be modified by the use of a scale factor followed by the letter P preceding a format code.

The scale factor is defined for input and output as:

external quantity = internal quantity x 10 scale factor

For input, when scale factors are used in a FORMAT statement, they have effect only on real data which does not contain an E or D decimal exponent. For example, if input data is in the form xx.xxxx and, it is desired to use it internally in the form .xxxxxx, the format code used to effect this change is 2PF7.4.

INPUT

As another example, consider the input data:

27bbb-93.2094bb-175.8041bbbb55.3647

where b represents a blank.

The statements:

```
5  FORMAT (I2,3F11.4)
        .
        .
        .
   READ (6,5) K,A,B,C
```

would cause the variables in the list to assume the values:

```
K : 27            B : -175.8041
A : -93.2094      C : 55.3647
```

The statements:

```
5  FORMAT (I2,1P3F11.4)
        .
        .
        .
   READ (6,5) K,A,B,C
```

would cause the variables in the list to assume the values:

```
K : 27            B : -17.5804
A : -9.3209       C : 5.5364
```

The statements:

```
5  FORMAT (I2,-1P3F11.4)
        .
        .
        .
   READ (6,5) K,A,B,C
```

would cause the variable in the list to assume the values:

```
K : 27            B : -1758.041x
A : -932.094x     C : 553.647x
```

where the x represents an extraneous digit.

OUTPUT

Assume that the variables K,A,B, and C have the values:

```
K : 27            B : -175.8041
A : -93.2094      C : 55.3647
```

the statements:

```
5  FORMAT (I2,1P3F11.4)
        .
        .
        .
   WRITE (4,5) K,A,B,C
```

would cause the variables in the list to output the values:

```
K : 27            B : -1758.041x
A : -932.094x     C : 553.647x
```

where the x represents an extraneous digit.

The statements:

```
5  FORMAT (I2,-1P3F11.4)
       .
       .
       .
   WRITE (4,5) K,A,B,C
```

would cause the variables in the list to output the values:

```
K : 27            B : -17.5804
A : -9.3209       C : 5.5364
```

For output, when scale factors are used, they have effect only on real data. However, this real data may contain an E or D decimal exponent. A positive scale factor used with real data which contains an E or D decimal exponent increases the number and decreases the exponent. Thus, if the real data was in a form using an E decimal exponent, and the statement FORMAT (1X,I2,3E13.3) used with an appropriate WRITE statement resulted in the printed line:

```
27bbb-0.932Eb02bbb-0.175Eb03bbbb0.553Eb02
```

Then the statement FORMAT (1X,I2,1P3E13.3) used with the same WRITE statement would result in the printed output:

```
27bbb-9.320Eb01bbb-1.758Eb02bbbb5.536Eb01
```

The scale factor is assumed to be zero if no other value has been given. However, once a value has been given, it will hold for all format codes (i.e., those that correspond to real data) following the scale factor within the same FORMAT statement. This also applies to format codes enclosed within an additional pair of parentheses. Once the scale factor has been given, a subsequent scale factor of zero in the same FORMAT statement must be specified by 0P.

Carriage Control

When records written under format control are prepared for printing, the following convention for carriage control applies:

First Character	Carriage Advance Before Printing
Blank	One Line
0	Two lines
1	To first line of the next page
+	No advance

The first character of the output record may be used for carriage control and is not printed. It appears in all other media as data.

ADDITIONAL INPUT/OUTPUT STATEMENTS

The statements END FILE, REWIND, and BACKSPACE are used to control the data sets, as described in the following text.

END FILE Statement

General Form
END FILE a Where: a is an unsigned integer constant or integer variable of length 4 that represents a data set reference number.

The END FILE statement defines the end of the data set associated with a. A subsequent WRITE statement defines the beginning of a new data set.

REWIND Statement

General Form
REWIND a Where: a is an unsigned integer constant or integer variable of length 4 that represents a data set reference number.

The REWIND statement causes a subsequent READ or WRITE statement referring to a to read data from or write data into the first data set associated with a.

BACKSPACE Statement

General Form
BACKSPACE a Where: a is an unsigned integer constant or integer variable of length 4 that represents a data set reference number.

The BACKSPACE statement causes the data set associated with a to backspace one record. If the data set associated with a is already at its beginning, execution of this statement has no effect.

SPECIFICATION STATEMENTS

The specification statements provide the compiler with information about the nature of the data used in the source program. In addition, they supply the information required to allocate locations in storage for this data. Specification statements describing data may appear anywhere in the source program, but must precede any statements which refer to that data.

THE TYPE STATEMENTS

There are two kinds of type statements: the IMPLICIT specification statement and the Explicit specification statements (INTEGER, REAL, COMPLEX, and LOGICAL).

The IMPLICIT specification statement enables the user to:

1. Specify the type of a group of variables or arrays according to the initial character of their names.

2. Specify the amount of storage to be allocated for each variable according to the associated type.

The Explicit specification statements enable the user to:

1. Specify the type of a variable or array according to their particular name.

2. Specify the amount of storage to be allocated for each variable according to the associated type.

3. Specify the dimensions of an array.

4. Assign initial data values for variables and arrays.

IMPLICIT Statement

General Form
IMPLICIT <u>type</u>*<u>s</u>(a_1,a_2,...),...,<u>type</u>*<u>s</u>(a_1,a_2,...)
Where: <u>type</u> represents one of the following: INTEGER, REAL, COMPLEX, or LOGICAL. *<u>s</u> is optional and represents one of the permissible length specifications for its associated type. a_1, a_2,... represent single alphabetic characters each separated by commas, or a range of characters (in alphabetic sequence) denoted by the first and last characters of the range separated by a minus sign (e.g., (A-D)).

The IMPLICIT statement, if specified, should be the first statement in a main program, and the second statement in a FUNCTION, SUBROUTINE, or BLOCK DATA subprogram.

The IMPLICIT type statement enables the user to declare the type of the variables appearing in his program (i.e., integer, real, complex, or logical) by specifying that variables beginning with certain designated letters are of a certain type. Furthermore, the IMPLICIT statement allows the programmer to declare the number of locations to be allocated for each in the group of specified variables. The type a variable can assume, along with the permissible length specifications are as follows:

Type	Length Specification	
INTEGER	2 or 4	(standard length is 4)
REAL	4 or 8	(standard length is 4)
COMPLEX	8 or 16	(standard length is 8)
LOGICAL	1 or 4	(standard length is 4)

For each type there is a corresponding standard length specification. If this standard length specification (for its associated type) is desired, the *s may be omitted in the IMPLICIT statement. That is, the variables will assume the standard length specification. For each type there is also a corresponding optional length specification. If this optional length specification is desired, the *s must be included within the IMPLICIT statement.

Example 1:

```
IMPLICIT REAL (A-H, O-Z,$), INTEGER (I-N)
```

Explanation:

All variables beginning with the characters I through N are declared as INTEGER. Since no length specification was explicitly given (i.e., the *s was omitted), four storage locations (the standard length for INTEGER) are allocated for each variable.

All other variables (those beginning with the characters A through H, O through Z, and $) are declared as REAL with four storage locations allocated for each.

Note that the statement in Example 1 performs the exact same function of typing variables as the predefined convention (see "Type Declaration by the Predefined Specification").

Example 2:

```
IMPLICIT INTEGER*2(A-H), REAL*8(I-K), LOGICAL(L,M,N)
```

Explanation:

All variables beginning with the characters A through H are declared as integer, with two storage locations allocated for each. All variables beginning with the characters I through K are declared as real, with eight storage locations allocated for each. All variables beginning with the characters L, M, and N are declared as logical, with four locations allocated for each.

Since the remaining letters of the alphabet (O through Z and $) were left undefined by the IMPLICIT statement, the predefined convention will take effect. Thus, all variables beginning with the characters O through Z and $ are declared as real, each with a standard length of four locations.

Example 3:

```
IMPLICIT COMPLEX*16(C-F)
```

Explanation:

All variables beginning with the characters C through F are declared as complex, each with eight storage locations reserved for the real part of the complex data and eight storage locations reserved for the imaginary part. The types of the variables beginning with the characters A, B, G through Z, and $ are determined by the predefined convention.

Explicit Specification Statements

General Form
Type*s $a*s_1(k_1)/x_1/,b*s_2(k_2)/x_2/,\ldots,z*s_n(k_n)/x_n/$ Where: Type is INTEGER, REAL, LOGICAL, or COMPLEX. $*s,*s_1,*s_2,\ldots,*s_n$ are optional. Each s represents one of the permissible length specifications for its associated type. a,b,...,z represent variable, array, or function names (see the section, "SUBPROGRAMS") $(k_1),(k_2),\ldots,(k_n)$ are optional. Each k is composed of 1 through 7 unsigned integer constants, separated by commas, representing the maximum value of each subscript in the array. Each k may be an unsigned integer variable only when it appears in a Type statement in a subprogram. $/x_1/,/x_2/,\ldots,/x_n/$ are optional and represent initial data values.

The Explicit specification statements declare the type (INTEGER, REAL, COMPLEX, or LOGICAL) of a particular variable or array by its name, rather than by its initial character. This differs from the other ways of specifying the type of a variable or array (i.e., the predefined convention and the IMPLICIT statement). In addition, the information necessary to allocate storage for arrays (dimension information) may be included within the statement. However, if this information does not appear in an Explicit specification statement, it must appear in a DIMENSION or COMMON statement (see "DIMENSION Statement" or "COMMON Statement").

Initial data values may be assigned to variables or arrays by use of $/x_n/$, where x_n is a constant or list of constants separated by commas. This set of constants may be in the form "r* constant", where r is an unsigned integer, called the repeat constant. No element may have more than one initial value given in the same program. A function name may not have an initial value assigned to it. An initially defined variable or a variable of an array may not be in blank common. In a labeled common block, they may be initially defined only in a BLOCK DATA subprogram.

In the same manner in which the IMPLICIT statement overrides the predefined convention, the Explicit specification statements override the IMPLICIT and predefined convention. If the length specification is omitted (i.e.,*s), the standard length per type is assumed.

Example 1:

```
INTEGER*2 ITEM/76/, VALUE
```

Explanation:

This statement declares that the variables ITEM and VALUE are of type integer, each with two storage locations reserved. In addition, the variable ITEM is initialized to the value 76.

Example 2:

```
COMPLEX C,D/(2.1,4.7)/,E*16
```

Explanation:

This statement declares that the variables C, D, and E are of type complex. Since no length specification was explicitly given, the standard length is assumed. Thus, C and D each have eight storage locations reserved (four for the real part, four for the imaginary part) and D is initialized to the value (2.1,4.7). In addition, 16 storage locations are reserved for the variable E. Thus, if a length specification is explicitly written, it overrides the assumed standard length.

Example 3:

```
REAL*8 ARRAY, HOLD, VALUE*4, ITEM(5,5)
```

Explanation:

This statement declares that the variables ARRAY, HOLD, VALUE, and the array named ITEM are of type real. In addition, it declares the size of the array ITEM. The variables ARRAY and HOLD have eight storage locations reserved for each; the variable VALUE has four storage locations reserved; and the array named ITEM has 200 storage locations reserved (eight for each variable in the array). Note that when the length is associated with the type (e.g., REAL*8), the length applies to each variable in the statement unless explicitly overridden (as in the case of VALUE*4).

Example 4:

```
REAL A(5,5)/20*6.9E2,5*1.0/, B(100)/100*0.0/,TOAD*8(5)/5*0.0/
```

Explanation:

This statement declares the size of each array, A and B, and their type (real). The array A has 100 storage locations reserved (four for each variable in the array) and the array B has 400 storage locations reserved (four for each variable). In addition, the first 20 variables in the array A are initialized to the value 6.9E2 and the last five variables are initialized to the value 1.0. All 100 variables in the array B are initialized to the value 0.0. The array TOAD has 40 storage locations reserved (eight for each variable). In addition, each variable is initialized to the value 0.0.

Adjustable Dimensions

As shown in the previous examples, the maximum value of each subscript in an array was specified by a numeric value. These numeric values (maximum value of each subscript) are known as the absolute dimensions of an array and may never be changed. However, if an array is used in a subprogram (see the section "Subprograms") and is not in Common, the size of this array does not have to be explicitly declared in the subprogram by a numeric value. That is, the Explicit specification statement, appearing in a subprogram, may contain integer variables that specify the size of the array. When the subprogram is called, these integer variables then receive their values from the calling program. Thus, the dimensions (size) of a dummy array appearing in a subprogram are adjustable and may change each time the subprogram is called.

The absolute dimensions of an array must be declared in a calling program. The adjustable dimensions of an array, appearing in a subprogram, should be less than or equal to the absolute dimensions of that array, as declared in the calling program.

The following example illustrates the use of adjustable dimensions:

Example:

```
Calling Program              Subprogram
    .
    .
    .
REAL*8 A(5,5)                SUBROUTINE MAPMY(...,R,L,M,...)
    .                            .
    .                            .
    .                            .
CALL MAPMY(...,A,2,3,...)    REAL*8...,R(L,M),...
    .                            .
    .                            .
    .                            .
                             DO 100 I=1,L
                                 .
                                 .
                                 .
```

Explanation:

The statement REAL*8 A(5,5) appearing in the calling program declares the absolute dimensions of the array A. When the subroutine MAPMY is called, the dummy argument R assumes the array name A, and the dummy arguments L and M assume the values 2 and 3, respectively. The subscripted variables of the array A appearing in the calling program occupy unique storage locations in the following order:

A(1,1) A(2,1) A(3,1) A(4,1) A(5,1)

A(1,2) A(2,2) A(3,2) A(4,2) A(5,2)

A(1,3) A(2,3) A(3,3) A(4,3) A(5,3)

A(1,4) A(2,4) A(3,4) A(4,4) A(5,4)

A(1,5) A(2,5) A(3,5) A(4,5) A(5,5)

Thus, in the calling program the subscripted variable A(1,2) refers to the _sixth_ subscripted variable in the array A. However, in the subprogram MAPMY the subscripted variable A(1,2) refers to the _third_

subscripted variable in the array A, namely, A(3,1). This is so because the dimensions of the array A as declared in the subprogram are not the same as those in the calling program.

If the absolute dimensions in the calling program were the same as the adjusted dimensions in the subprogram, the subscripted variables A(1,1) through A(5,5) in the subprogram would always refer to the same storage locations as specified by the subscripted variables A(1,1) through A(5,5) in the calling program, respectively.

The numbers 2 and 3, which became the adjusted dimension of the dummy array R, could also have been variables in the argument list of the calling program. For example, assume that the following statement appeared in the calling program:

```
CALL MAPMY (...,A,I,J,...)
```

Then as long as the values of I and J were previously determined, the arguments may be variables. In addition, the variable dimension size may be passed through more than one level of subprograms. For example, within the subprogram MAPMY could have been a call statement to another subprogram in which dimension information about A could have been passed.

If any dimension of an array is variable, that dimension and the array name must be dummy variables (i.e., they must appear in a FUNCTION, SUBROUTINE, or ENTRY statement).

ADDITIONAL SPECIFICATION STATEMENTS

DIMENSION Statement

General Form
DIMENSION $\underline{a}_1(\underline{k}_1),\underline{a}_2(\underline{k}_2), \underline{a}_3(\underline{k}_3),\ldots,\underline{a}_n(\underline{k}_n)$ Where: $\underline{a}_1, \underline{a}_2, \underline{a}_3,\ldots, \underline{a}_n$ are array names. $\underline{k}_1, \underline{k}_2, \underline{k}_3,\ldots,\underline{k}_n$ are each composed of 1 through 7 unsigned integer constants, separated by commas, representing the maximum value of each subscript in the array. $\underline{k}_1$ through $\underline{k}_n$ may be integer variables of length 4 only when they appear in a DIMENSION statement within a subprogram.

The information necessary to allocate storage for arrays used in the source program may be provided by the DIMENSION statement. The following examples illustrate how this information may be declared.

Examples:

```
DIMENSION A(10), ARRAY (5,5,5,5,5), LIST(10,100)
DIMENSION B(25,50),TABLE(25,25,25)
```

COMMON Statement

General Form
COMMON /r/a (k_1),b(k_2),.../r/c(k_3),d(k),... Where: a,b,...,c,d... are variable or array names. k_1,k_2,...k_3,k ... are optional and are each composed of one through seven unsigned integer constants, separated by commas, representing the maximum value of each subscript in the array. /r/... represent optional common block names consisting of one through six alphameric characters, the first of which is alphabetic. These names must always be embedded in slashes.

Although the COMMON statement may be used to provide dimension information, adjustable dimensions may never be used.

Variables or arrays that appear in a calling program or a subprogram may be made to share the same storage locations with variables or arrays in other subprograms by use of the COMMON statement. For example, if one program contains the statement:

```
COMMON TABLE
```

and a second program contains the statement:

```
COMMON LIST
```

the variable names TABLE and LIST refer to the same storage locations.

If the main program contains the statements:

```
REAL A,B,C
COMMON A,B,C
```

and a subprogram contains the statements:

```
REAL X,Y,Z
COMMON X,Y,Z
```

A shares the same storage location as X; B shares the same storage location as Y; and C shares the same storage location as Z.

Consider the following examples:

Example 1:

```
Calling Program              Subprogram
     .                       SUBROUTINE MAPMY (...)
     .                            .
     .                            .
COMMON A, B, C, R(100)            .
REAL A,B,C                   COMMON X, Y, Z, S(100)
INTEGER R                    REAL X,Y,Z
     .                       INTEGER S
     .                            .
     .                            .
CALL MAPMY (...)                  .
```

Explanation:

In the calling program, the statement COMMON A,B,C,R(100) would cause 412 storage locations (four locations per variable) to be reserved in the following order:

Beginning of common area	A 4 locations	B 4 locations	C 4 locations	Layout of storage
	R(1) 4 locations	. . .	R(100) 4 locations	

The statement COMMON X, Y, Z, S(100) would then cause the variables X, Y, Z, and S(1)...S(100) to share the same storage space as A, B, C, and R(1)...R(100), respectively.

From the above example, it can be seen that COMMON statements may be used to serve an important function: namely, as a medium to implicitly transmit data from the calling program to the subprogram. That is, values for X, Y, Z, and S(1)...S(100), because they occupy the same storage locations as A, B, C, and R(1)...R(100), do not have to be transmitted in the argument list of a CALL statement.

Example 2:

Assume COMMON is defined in a main program and three subprograms as follows:

```
Main program:  COMMON    A,B,C
Subprogram 1:  COMMON    D,E,F
Subprogram 2:  COMMON    Q,R,S,T,U
Subprogram 3:  COMMON    V,W,X,Y,Z
```

Further, assume the length specifications of the above variables are so defined that the common area is shared as follows:

<table>
<tr><td colspan="2">A
8 locations</td><td colspan="2">B
4 locations</td><td>C
2 locations</td></tr>
<tr><td colspan="2">D
8 locations</td><td colspan="2">E
4 locations</td><td>F
2 locations</td></tr>
<tr><td>Q
4 locations</td><td>R
4 locations</td><td>S
2 locations</td><td>T
2 locations</td><td>U
2 locations</td></tr>
<tr><td>V
4 locations</td><td>W
4 locations</td><td>X
2 locations</td><td>Y
2 locations</td><td>Z
2 locations</td></tr>
</table>

In this case, the variables A,B,C and D,E,F may be validly referred to in their respective programs, as may Q,R,S,T,U and V,W,X,Y,Z. In addition, all programs may validly refer to C,F,U, and Z. It is also possible to cross-reference D in Subprogram 1 and Q and R in Subprogram 2. Such correspondences are highly data dependent and in certain cases may be useful. For instance, if D is a complex variable, and Q and R are real variables, Q and R correspond to the real and imaginary parts of D, respectively. However, each such cross reference by the programmer must be considered on its own merits.

Blank and Labeled Common

In the preceding two examples, the common storage area (common block) established is called a blank common area. That is, no particular name was given to that area of storage. The variables that appeared in the COMMON statements were assigned locations relative to the beginning of this blank common area. However, variables and arrays may be placed in separate common areas. Each of these separate areas (or blocks) is given a name consisting of one through six alphameric characters (the first of which is alphabetic); those blocks which have the same name occupy the same storage space.

Those variables that are to be placed in labeled (or named) common are preceded by a common block name enclosed in slashes. For example, the variables A,B, and C will be placed in the labeled common area HOLD by the following statement:

```
COMMON/HOLD/A,B,C
```

In a COMMON statement, blank common may be distinguished from labeled common by preceding the variables in blank common by two consecutive slashes or, if the variables appear at the beginning of the common statement, by omitting any block name. For example, in the following statement:

```
COMMON A, B, C /ITEMS/ X, Y, Z / / D, E, F
```

the variables A, B, C, D, E, and F will be placed in blank common in that order; the variables X, Y, and Z will be placed in the common area labeled ITEMS.

Blank and labeled common entries appearing in COMMON statements are cumulative throughout the program. For example, consider the following two COMMON statements:

```
COMMON A, B, C /R/ D, E /S/ F
COMMON G, H /S/ I, J /R/P//W
```

These two statements have the same effect as the single statement:

```
COMMON A, B, C, G, H, W /R/ D, E, P /S/ F, I, J
```

Example 3:

Assume that A, B, C, K, X, and Y each occupy four locations of storage, H and G each occupy eight locations, and D and E each occupy two locations.

Calling Program

```
       .
       .
       .
COMMON H, A /R/ X, D // B
       .
       .
       .
CALL MAPMY(...)
       .
       .
       .
```

Subprogram

```
SUBROUTINE MAPMY(...)
       .
       .
       .
COMMON G, Y, C /R/ K, E
       .
       .
       .
```

Explanation:

In the calling program, the statement COMMON H,A/R/X,D//B causes 16 locations (four locations each for A and B, and eight for H) to be reserved in blank common in the following order:

Beginning of blank common	H 8 locations	A 4 locations	B 4 locations
	continuation of blank common		

and also causes six locations (four for X and two for D) to be reserved in the labeled common area R in the following order:

Beginning of labeled common R	X 4 locations	D 2 locations
	continuation of labeled common	

The statement COMMON G,Y,C/R/K,E appearing in the subprogram MAPMY would cause the variables G, Y, and C to share the same storage space (in blank common) as H, A, and B, respectively. It would also cause the variables K and E to share the same storage space (in labeled common area R) as X and D, respectively. The length of a COMMON area may be increased by using an EQUIVALENCE statement (see the section "EQUIVALENCE Statements").

EQUIVALENCE Statement

General Form
EQUIVALENCE (a, b, c, ...), (d, e, f,...) Where: a, b, c, d, e, f,... are variables that may be subscripted. The subscripts may have two forms: If the variable is singly subscripted it refers to the position of the variable in the array (i.e., first variable, 25th variable, etc.). If the variable is multi-subscripted it refers to the position in the array in the same fashion as the position is referred to in an arithmetic statement.

The EQUIVALENCE statement provides the option for controlling the allocation of data storage within a single program or subprogram. It is analogous to the option of using the COMMON statement to control the allocation of data storage among several programs. In particular, when the logic of the program permits it, the number of storage locations used can be reduced by causing locations to be shared by two or more variables of the same or differing types and lengths. The EQUIVALENCE statement cannot be used to obtain mathematical equality of two variables.

Example 1:

```
DIMENSION B(5), C(10, 10), D(5, 10, 15)
EQUIVALENCE (A, B(1), C(5,3)), (D(5,10,2), E)
```

Explanation:

This EQUIVALENCE statement indicates that the variables A,B(1), and C(5,3) are assigned the same storage locations. In addition, it specifies that D(5,10,2) and E are assigned the same storage locations. In this case, the subscripted variables refer to the position in an array in the same fashion as the position is referred to in an arithmetic statement. Note that variables or arrays that are not mentioned in an EQUIVALENCE statement are assigned unique storage locations. The EQUIVALENCE statement must not contradict itself or any previously established equivalences. For example, the further equivalence specification of B(2) with any other element of the array C, other than C(6,3), is invalid.

Example 2:

```
DIMENSION B(5), C(10, 10), D(5, 10, 15)
EQUIVALENCE (A, B(1), C(25)), (D(100), E)
```

Explanation:

This EQUIVALENCE statement indicates that the variable A, the first variable in the array B, namely B(1), and the 25th variable in the array C, namely C(5,3), are to be assigned the same storage locations. In addition, it also specifies that D(100), i.e., D(5,10,2), and E are to share the same storage locations. Note that the effect of the EQUIVALENCE statement in examples 1 and 2 is the same.

Variables that are brought into COMMON through EQUIVALENCE statements may increase the size of the block, as indicated by the following: statements:

```
COMMON A, B, C
DIMENSION D(3)
EQUIVALENCE (B,D(1))
```

This would cause a common area to be established containing the variables A, B, and C. The EQUIVALENCE statement would then cause the variable D(1) to share the same storage location as B, D(2) to share the same storage location as C, and D(3) would extend the size of the common area, in the following manner:

```
A        (lowest location of the common area)
B, D(1)
C, D(2)
   D(3)  (highest location of the common area)
```

Since arrays must be stored in consecutive forward locations, a variable may not be made equivalent to another variable of an array in such a way as to cause the array to extend before the beginning of the common area. For example, the following EQUIVALENCE statement is invalid:

```
COMMON A, B, C
DIMENSION D(3)
EQUIVALENCE (B, D(3))
```

because it would force D(1) to precede A, as follows:

```
     D(1)
  A, D(2)   (lowest location of the common area)
  B, D(3)
  C         (highest location of the common area)
```

Two variables in one COMMON block or in two different COMMON blocks may not be made equivalent.

SUBPROGRAMS

It is sometimes desirable to write a program which, at various points, requires the same computation to be performed with different data for each calculation. It would simplify the writing of that program if the statements required to perform the desired computation could be written only once and then could be referred to freely, with each subsequent reference having the same effect as though these instructions were written at the point in the program where the reference was made.

For example, to take the square root of a number, a program must be written with this object in mind. If a general program were written to take the square root of any number, it would be desirable to be able to incorporate that program (or subprogram) into other programs where square root calculations are required.

The FORTRAN language provides for the above situation through the use of subprograms. There are three classes of subprograms: Statement Functions, FUNCTION subprograms, and SUBROUTINE subprograms. In addition, there is a group of FORTRAN supplied subprograms (see Appendix C).

The first two classes of subprograms are called functions. Functions differ from SUBROUTINE subprograms, in that functions return at least one value to the calling program, whereas SUBROUTINE subprograms need not return any.

NAMING SUBPROGRAMS

A subprogram name consists of from one through six alphameric characters, the first of which must be alphabetic (special characters may not be used). The type of a subprogram can be indicated in the same manner as variables.

1. Type Declaration of a Statement Function: Such declaration may be accomplished in one of three ways: by the predefined convention, by the IMPLICIT statement, or by the Explicit specification statements. Thus, the same rules for declaring the type of variables apply to Statement Functions.

2. Type Declaration of FUNCTION Subprograms: Such declaration may be made in the same fashion as Statement Functions. In addition, the type (INTEGER, REAL, COMPLEX, and LOGICAL) may appear in the FUNCTION definition statement.

3. Type Declaration of a SUBROUTINE Subprogram: The type of a SUBROUTINE subprogram cannot be defined, because the results that are returned to the calling program are dependent only on the type of the variable names appearing in the argument list of the calling program and/or the implicit arguments in COMMON.

FUNCTIONS

A function is a statement of the relationship between a number of variables. To use a function in FORTRAN, it is necessary to:

1. Define the function (i.e., specify what calculations are to be performed).

2. Refer to the function by name, where required in the program.

Function Definition

There are three steps in the definition of a function in FORTRAN:

1. The function must be assigned a unique name by which it may be called (see the section "Naming Subprograms").

2. The arguments of the function must be stated.

3. The procedure for evaluating the function must be stated.

Items 2 and 3 are discussed in detail in the sections dealing with the specific subprogram (e.g., "Statement Functions," "FUNCTION Subprograms," etc.).

Function Reference

When the name of a function appears in any FORTRAN arithmetic expression, this, effectively, references the function. Thus, the appearance of a function with its arguments in parentheses causes the computations to be performed as indicated by the function definition. The resulting quantity replaces the function reference in the expression and assumes the type of the function. The type and length of the name used for the reference must agree with the type and length of the name used in the definition.

STATEMENT FUNCTIONS

Statement functions are defined by a single arithmetic or logical assignment statement within the program in which they appear. For example, the statement:

```
FUNC(A,B) = 3.*A+B**2.+X+Y+Z
```

defines the statement function FUNC, where FUNC is the function name and A and B are the function arguments.

The expression on the right defines those computations which are to be performed when the function is used in an arithmetic statement. This function might be used in a statement as follows:

```
C = FUNC(D,E)
```

which is equivalent to:

```
C = 3.*D+E**2.+X+Y+Z
```

Note the correspondence between A and B in the function definition statement and D and E in the arithmetic statement. The quantities A and B enclosed in parentheses following the function name are the arguments of the function. They are dummy variables for which the quantities D

and E, respectively are substituted when the function is used in an arithmetic statement.

General Form
name (a,b,...,n) = expression Where: name is any subprogram name (see the section "Naming Subprograms"). a,b,...,n are distinct (within the same statement) nonsubscripted variables. expression is any arithmetic or logical expression that does not contain subscripted variables. Any statement functions appearing in this expression must be defined previously.

A maximum of 15 variables appearing in the expression may be used as arguments of the function.

Note: All Statement Function definitions to be used in a program must precede the first executable statement of the program.

Examples:

Valid statement function definitions:

```
SUM(A,B,C,D) = A+B+C+D
FUNC(Z) = A+X*Y*Z
AVG(A,B,C,D) = (A+B+C+D)/4
ROOT(A,B,C) = SQRT(A**2+B**2+C**2)
VALID(A,B) = .NOT.A.OR.B
```

Note: The same dummy arguments may be used in more than one Statement Function definition and as variables outside Statement Function definitions.

Invalid statement function definitions:

```
SUBPRG(3,J,K)=3*I+J**3       (arguments must be variables)
SOMEF(A(I),B)=A(I)/B+3.      (arguments must be nonsub-
                              scripted)
SUBPROGRAM(A,B)=A**2+B**2    (function name exceeds limit
                              of six characters)
3FUNC(D)=3.14*E              (function name must begin with
                              an alphabetic character)
ASF(A)=A+B(I)                (subscripted variable in the
                              expression)
```

Valid statement function references:

```
NET = GROS - SUM(TAX, FICA, HOSP, MISC)
ANS = FUNC(RESULT)
GRADE = AVG(LAB, LECTUR, SUM(TEST1, TEST2, TEST3, TEST4), FACTOR)
```

Invalid statement function references:

```
WRONG = SUM(TAX,FICA)        (number of arguments
                             does not agree with
                             above definition)
MIX = FUNC(I)                (mode of argument
                             does not agree with
                             above definition)
```

FUNCTION SUBPROGRAMS

The FUNCTION subprogram is a FORTRAN subprogram consisting of any number of statements. It is an independently written program that is executed wherever its name appears in another program.

General Form
FUNCTION name ($a_1, a_2, a_3, \ldots, a_n$) . . . RETURN . . . END Where: name is subprogram name (see the section "Naming Subprograms"). $a_1, a_2, a_3, \ldots, a_n$ are nonsubscripted variable, array, or dummy names of SUBROUTINE or other FUNCTION subprograms. (There must be at least one argument in the argument list.)

Since the FUNCTION is a separate subprogram, the variables and statement numbers within it do not relate to any other program.

The FUNCTION subprogram may contain any FORTRAN statement except a SUBROUTINE statement, another FUNCTION statement, or BLOCK DATA statement.

The arguments of the FUNCTION subprogram (i.e., $a_1, a_2, a_3, \ldots, a_n$) may be considered to be dummy variable names. These are replaced at the time of execution by the actual arguments supplied in the function reference in the calling program. The actual arguments may be any of the following: any type of constant, any type of subscripted or nonsubscripted variable, an arithmetic or logical expression, or the name of another subprogram. The actual arguments must correspond in number, order, and type to the dummy arguments. The array size must also be the same, except when adjustable dimensions are used. All arguments in a subprogram refer to the storage area assigned to the arguments by the calling program.

The relationship between variable names used as arguments in the calling program and the dummy variables used as arguments in the FUNCTION subprogram is illustrated in the following example:

Example 1:

Calling Program

```
       .
       .
       .
A = SOMEF(B,C)
       .
       .
       .
```

FUNCTION Subprogram

```
FUNCTION SOMEF(X,Y)
SOMEF = X/Y
RETURN
END
```

Explanation:

In the above example, the value of the variable B of the calling program is used in the subprogram as the value of the dummy variable X; the value of C is used in place of the dummy variable Y. Thus if B = 10.0 and C = 5.0, then A = B/C, which is equal to 2.0.

The name of the function must be assigned a value at least once in the subprogram as the argument of a CALL statement, as a DO variable, as the variable name on the left side of an arithmetic statement, or in an input list (READ statement) within the subprogram.

Example 2:

Calling Program

```
       .
       .
       .
ANS = ROOT1*CALC(X,Y,I)
       .
       .
       .
```

FUNCTION Subprogram

```
FUNCTION CALC (A,B,J)
       .
       .
       .
I = J*2
       .
       .
       .
CALC = A**I/B
       .
       .
       .
RETURN
END
```

Explanation:

In this example, the values of X, Y, and I are used in the FUNCTION subprogram as the values of A, B, and J, respectively. The value of CALC is computed, and this value is returned to the calling program, where the value of ANS is computed. The variable I in the argument list of CALC in the calling program is not the same as the variable I appearing in the subprogram.

When a dummy argument is an array name, an appropriate DIMENSION or Explicit specification statement must appear in the FUNCTION subprogram. None of the dummy arguments may appear in an EQUIVALENCE statement or a COMMON statement.

Type Specification of the FUNCTION Subprogram

In addition to the three ways of declaring the type of a FUNCTION name (i.e., predefined convention, IMPLICIT statement, Explicit specification statement), there exists the option explicitly specifying the type of a FUNCTION name within the FUNCTION statement.

General Form
Type FUNCTION name*s ($a_1, a_2, a_3, \ldots, a_n$) Where: Type is INTEGER, REAL, COMPLEX, or LOGICAL. name is the name of the FUNCTION subprogram. *s is optional and represents one of the permissible length specifications for its associated type. $a_1, a_2, a_3, \ldots, a_n$ are nonsubscripted variable, array, or dummy names of SUBROUTINE or other FUNCTION subprograms. (There must be at least one argument in the argument list.)

Example 1:

```
REAL FUNCTION SOMEF (A,B)
    .
    .
    .
SOMEF = A**2 + B**2
    .
    .
    .
RETURN
END
```

Example 2:

```
INTEGER FUNCTION CALC*2 (X,Y,Z)
    .
    .
    .
CALC = X+Y+Z**2
    .
    .
    .
RETURN
END
```

Explanation:

The FUNCTION subprograms SOMEF and CALC in examples 1 and 2 are declared as type REAL (length 4) and INTEGER (length 2), respectively.

RETURN and END Statements in a Function Subprogram

Note that all of the preceding examples of FUNCTION subprograms contain both an END and at least one RETURN statement. The END statement specifies, for the compiler, the end of the subprogram; the RETURN statement signifies a logical conclusion of the computation and returns any computed value and control to the calling program.

There may, in fact, be more than one RETURN statement in a FORTRAN subprogram.

Example:

```
       FUNCTION DAV (D,E,F)
       IF (D-E) 10, 20, 30
    10 A = D+2.0*E
           .
           .
           .
    5  A = F+2.0*E
           .
           .
           .
    20 DAV = A+B**2
           .
           .
       RETURN
    30 DAV = B**2
           .
           .
           .
       RETURN
       END
```

SUBROUTINE SUBPROGRAMS

The SUBROUTINE subprogram is similar to the FUNCTION subprogram in many respects: the rules for naming FUNCTION and SUBROUTINE subprograms are the same, they both require an END statement, and they both contain the same sort of dummy arguments. Like the FUNCTION subprogram, the SUBROUTINE subprogram is a set of commonly used computations, but it need not return any results to the calling program, as does the FUNCTION subprogram.

The SUBROUTINE subprogram is called by the CALL statement, which consists of the word CALL followed by the name of the subprogram and its parenthesized arguments.

General Form
SUBROUTINE <u>name</u> (a_1,a_2,a_3,...,a_n) . . . RETURN END where: <u>name</u> is the subprogram name (see the section "Naming Subprograms"). a_1,a_2,a_3,...,a_n are arguments. (There need not be any.) Each argument used must be a nonsubscripted variable or array name, the dummy name of another SUBROUTINE or FUNCTION subprogram, or of the form * where the character "*" denotes a return point specified by a statement number in the calling program.

Since the SUBROUTINE is a separate subprogram, the variables and statement numbers within it do not relate to any other program.

The SUBROUTINE subprogram may contain any FORTRAN statement except a FUNCTION statement, another SUBROUTINE statement, or BLOCK DATA statement.

The SUBROUTINE subprogram may use one or more of its arguments to return values to the calling program. Any arguments so used must appear on the left side of an arithmetic statement or in an input list within the subprogram, as arguments of a CALL statement, or as DO variables. The SUBROUTINE name must not appear in any other statement in the SUBROUTINE subprogram.

The arguments (a_1, a_2, a_3,...,a_n) may be considered dummy variable names that are replaced at the time of execution by the actual arguments supplied in the CALL statement. The actual arguments must correspond in number, order, and type to the dummy arguments. The array size must also be the same except when adjustable dimensions are used. Dummy arguments may not appear in an EQUIVALENCE or DATA statement within the subprogram nor may they be given initial data values in an Explicit specification statement.

Example: The relationship between variable names used as arguments in the calling program and the dummy variable used as arguments in the SUBROUTINE subprogram is illustrated in the following example. The object of the subprogram is to "copy" one array directly into another.

Main Program	SUBROUTINE Subprogram
DIMENSION X(100),Y(100)	
.	SUBROUTINE COPY(A,B,N)
.	DIMENSION A (100),B(100)
.	DO 10 I = 1, N
CALL COPY (X,Y,K)	10 B(I) = A (I)
.	RETURN
.	END
.	

CALL Statement

The CALL statement is used only to call a subroutine subprogram.

General Form
CALL name (a_1,a_2,a_3,...,a_n) Where: name is the name of a subroutine subprogram. a_1,a_2,a_3,...,a_n are the actual arguments that are being supplied to the subroutine subprogram. Each may be of the form &n where n is a statement number (see "RETURN Statements in a SUBROUTINE Subprogram").

Examples:

```
CALL OUT
CALL MATMPY (X,5,40,Y,7,2)
CALL QDRTIC (X,Y,Z,ROOT1,ROOT2)
CALL SUB1 (X+Y*5,'ABDF',SINE)
```

The CALL statement transfers control to the subroutine subprogram and replaces the dummy variables with the value of the actual arguments that appear in the CALL statement. The arguments in a CALL statement may be any of the following: any type of constant, any type of subscripted or nonsubscripted variable, an arithmetic expression, the name of a subprogram, or a statement number (see "RETURN Statements in a SUBROUTINE Subprogram").

The arguments in a CALL statement must agree in number, order, and type with the corresponding arguments in the subroutine subprogram. The array sizes must also be the same in the subroutine and the calling programs, except when adjustable dimensions are used (see "Adjustable Dimensions"). If an actual argument corresponds to a dummy argument that is defined or redefined in the referenced subprogram, the actual argument must be a variable name, subscripted variable name, or array name. All arguments in a subprogram refer to the storage area assigned to the arguments by the calling program.

RETURN Statement in a SUBROUTINE Subprogram

General Form
RETURN RETURN *i* Where: *i* is an integer constant or variable of length 4 whose value, say n, denotes the nth statement number in the argument list of a SUBROUTINE statement.

The normal sequence of execution following the RETURN statement of a SUBROUTINE subprogram is to the next statement following the CALL in the calling program. It is also possible to return to any numbered statement in the calling program by using a return of the type where *i* is an integer constant or variable. Returns of the type RETURN may be made in either a SUBROUTINE or FUNCTION subprogram (see, "RETURN and END Statements in a FUNCTION Subprogram"). Returns of the type RETURN *i* may only be made in a SUBROUTINE subprogram. In a main program, a RETURN statement performs the same function as a STOP statement.

Example:

```
    Calling Program                        Subprogram

         .                                 SUBROUTINE SUB (X,Y,Z,*,*)
         .                                      .
         .                                      .
   10 CALL SUB (A,B,C,&30,&40)                  .
   20 Y = A + B                       100  IF (R) 200,300,400
         .                            200  RETURN
         .                            300  RETURN 1
         .                            400  RETURN 2
   30 Y = A + C                            END
         .
         .
         .
   40 Y = B + C
         .
         .
         .
      END
```

Explanation:

In the preceding example, execution of statement 10 in the calling program causes entry into subprogram SUB. When statement 100 is executed, the return to the calling program will be to statement 20, 30, or 40, if R is less than, equal to, or greater than zero, respectively.

A CALL statement that uses a RETURN i form may be best understood by comparing it to a CALL and computed GO TO statement in sequence. For example, the CALL statement:

```
CALL SUB (P,&20,Q,&35,R,&22)
```

is equivalent to:

```
CALL SUB (P,Q,R,I)
GO TO (20,35,22),I
```

where the index I is assigned a value of 1, 2, or 3 in the called subprogram.

Multiple ENTRY into a Subprogram

The standard (normal) entry into a SUBROUTINE subprogram from the calling program is made by a CALL statement that references the subprogram name. The standard entry into a FUNCTION subprogram is made by a function reference in an arithmetic expression. Entry is made at the first executable statement following the SUBROUTINE or FUNCTION statement.

It is also possible to enter a subprogram (either SUBROUTINE or FUNCTION) by a CALL statement or a function reference that references an ENTRY statement in the subprogram. Entry is made at the first executable statement following the ENTRY statement.

General Form
ENTRY name ($a_1, a_2, a_3, \ldots, a_n$) Where: name is the name of an entry point (see "Naming Subprograms"). $a_1, a_2, a_3, \ldots, a_n$ are the dummy arguments corresponding to an actual argument in a CALL statement or in a function reference.

ENTRY statements do not affect control sequencing during normal execution of a subprogram. The order, type, and number of arguments need not agree between the SUBROUTINE or FUNCTION statement and the ENTRY statements, nor do the ENTRY statements have to agree among themselves in these respects. Each CALL or function reference, however, must agree in order, type, and number with the SUBROUTINE, FUNCTION, or ENTRY statement that it references. Entry may not be made into the range of a DO; further, a subprogram may not reference itself directly or through any of its entry points. This statement is regarded as nonexecutable within its subprogram. If it appears in a function subprogram the name given in the FUNCTION statement is still used to return the value of the function to the point of reference, rather than the name of the ENTRY statement.

Example 1:

Calling Program

```
  .
  .
  .
1 CALL SUB1 (A,B,C,D,E,F)
  .
  .
  .
2 CALL SUB2 (G,H,P)
  .
  .
  .
3 CALL SUB3
  .
  .
  .
```

Subprogram

```
SUBROUTINE SUB1 (U,V,W,X,Y,Z)
  .
  .
  .
U = V
  .
  .
  .
ENTRY SUB2 (T,U,V)

  .
  .
  .
ENTRY SUB3
  .
  .
  .
END
```

Explanation:

In the preceding example, the execution of statement 1 causes entry into SUB1, starting with the first executable statement of the subroutine. Execution of statements 2 and 3 also causes entry into the called program, starting with the first executable statement following the ENTRY SUB2(T,U,V) and ENTRY SUB3 statements, respectively.

Entry into a subprogram initializes all references in the whole subprogram to items in the argument list. Return from a subprogram is made by way of the entry point referenced. ENTRY statements may only appear in FUNCTION or SUBROUTINE subprograms. The dummy arguments in a subprogram may appear in any statement if they first appear as dummy

arguments in a FUNCTION, SUBROUTINE, or ENTRY statement. The following is a valid example:

```
SUBROUTINE SUB (X,Y,Z,I)
     .
     .
     .
ENTRY SUB1 (A,B)
     .
     .
     .
     .
C = A+B
     .
     .
     .
```

Example 2:

Calling Program

```
         .
         .
         .
    CALL SUB1 (A,B,C,D,E,F)
         .
         .
         .
    CALL SUB2(G,&10,&20)
         .
         .
         .
    CALL SUB3(&10,&20)
5   Y =A+B
         .
         .
         .
10  Y = C+D
20  Y = E+F
         .
         .
         .
```

Subprogram

```
     SUBROUTINE SUB1 (U,V,W,X,Y,Z)
     RETURN
     ENTRY SUB2 (T,*,*)
     U = V* W+T
     ENTRY SUB3 (*,*)
     X = Y**Z
50   IF (U-X) 100, 200, 300
100  RETURN 1
200  RETURN 2
300  RETURN
     END
```

Explanation:

In the example above, a call to SUB1 merely performs initialization. Subsequent calls to SUB2 and SUB3 result in execution of different sections of the subroutine SUB1. Then, depending upon the result of the arithmetic IF at statement 50, return is made to the calling program at statement 10, 20, or 5.

Additional Rules for Using ENTRY

1. A CALL may only change the value of explicit arguments (or implicit arguments in COMMON). It cannot affect the value of those which are initialized by some previous CALL.

2. If a name is identified as a dummy argument only by its appearance in a given ENTRY statement, no use of that dummy argument may appear in statements preceding (physically) the ENTRY statement.

3. The appearance of an ENTRY statement does not alter the rules regarding the placement of Statement Functions in subprograms.

The EXTERNAL Statement

```
General Form

EXTERNAL a,b,c,...

Where: a,b,c,...  are names of subprograms that are used as
       arguments in other subprograms.
```

The name of any subprogram that is used as an argument in another subprogram must appear in an EXTERNAL statement. For example, assume that SUB and MULT are subprogram names in the following statements:

Example 1:

```
    Calling Program                  Subprogram

         .                              SUBROUTINE SUB(X,Y,Z)
         .                              IF (X) 4,6,6
         .                         4    D = Y (X,Z**2)
    EXTERNAL MULT
         .                                   .
         .                                   .
         .                                   .
    CALL SUB (A, MULT,C)           6    RETURN
         .                              END
         .
         .
```

Explanation:

In this example, the subprogram name MULT is used as an argument in the subprogram SUB. The subprogram name MULT is passed to the dummy variable Y, as are the variables A and C passed to the dummy variables X and Z, respectively. The subprogram MULT will be called and executed only if the value of A is negative.

Example 2:

```
         .
         .
         .
    CALL SUB (A,B,MULT (C,D),37)
         .
         .
         .
```

Explanation:

In this example, an EXTERNAL statement is not required because the subprogram named MULT is not an argument; it is executed first and the result becomes the argument.

FORTRAN SUPPLIED SUBPROGRAMS

FORTRAN provides the programmer with a library of commonly used function and subroutine subprograms. There are three classes of subprograms provided:

1. Mathematical function subprograms--defined as FUNCTION subprograms.

2. Subroutines which test the status of pseudo machine indicators (sense lights)--defined as SUBROUTINE subprograms.

3. The three subprograms EXIT, DUMP, and PDUMP--also defined as SUBROUTINE subprograms.

The EXIT subroutine terminates program execution; DUMP dumps storage and terminates program execution; PDUMP dumps storage and continues program execution.

Variables used as arguments of mathematical functions must be declared (i.e., by the Explicit specification statements, the IMPLICIT statement, or the predefined convention), in accordance with the function in which they appear.

The entire library, along with appropriate definitions of each subprogram, is given in Appendix C.

BLOCK DATA SUBPROGRAM

In order to enter data into a COMMON block, a separate subprogram must be written. This separate subprogram contains only the DATA, COMMON, DIMENSION, EQUIVALENCE, and Type statements associated with the data being defined. Data may be entered into labeled (named), but not unlabeled, COMMON by the BLOCK DATA subprogram.

General Form
BLOCK DATA . . . END

1. The BLOCK DATA subprogram may not contain any executable statements.

2. The first statement of this subprogram must be the BLOCK DATA statement.

3. All elements of a COMMON block must be listed in the COMMON statement, even though they do not all appear in the DATA statement; for example, the variable A in the COMMON statement in the following example does not appear in the DATA statement:

```
BLOCK DATA
COMMON/ELN/C,A,B/RMG/Z,Y
REAL B(4)/1.0,1.2,2*1.3/,Z*8(3)/3*7.64980825D0/
COMPLEX C/(2.4,3.769)/
END
```

4. Data may be entered into more than one COMMON block in a single BLOCK DATA subprogram.

5. No element may have more than one initial value assigned in the same program.

Alphabetic Characters	EBCDIC or BCDIC Card Punches
A	12-1
B	12-2
C	12-3
D	12-4
E	12-5
F	12-6
G	12-7
H	12-8
I	12-9
J	11-1
K	11-2
L	11-3
M	11-4
N	11-5
O	11-6
P	11-7
Q	11-8
R	11-9
S	0-2
T	0-3
U	0-4
V	0-5
W	0-6
X	0-7
Y	0-8
Z	0-9
$	11-3-8

Numeric Characters	EBCDIC or BCDIC Card Punches
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

Special Characters	EBCDIC Card Punches	BCDIC Card Punches
+	12-6-8	12
-	11	11
/	0-1	0-1
=	6-8	3-8
.	12-3-8	12-3-8
)	11-5-8	12-4-8
*	11-4-8	11-4-8
, (comma)	0-3-8	0-3-8
(	12-5-8	0-4-8
' (apostrophe)	5-8	4-8
blank	(no punch)	(no punch)

Source programs are coded in either BCDIC or EBCDIC character codes. Mixing of the two, however, is not allowed.

The 48 characters listed above comprise the set of characters acceptable by FORTRAN. In previously implemented FORTRAN languages, there existed dual characters in the sense that two graphics (characters) were associated with a single card code. The most commonly used set of dual characters was the following:

+	&
=	#
(	
)	%
' (apos.)	@

However, in IBM System/360 each of these duals now has separate card codes. Thus, when specifying, for instance, a + character, care should be taken that a 12-6-8 punch is used instead of a 12 punch which now represents an &. The card codes for the remaining duals is as follows: #(8-3), (this graphic is now represented as a <)(12-4-8), %(0-4-8), and @(8-4).

APPENDIX B: OTHER FORTRAN FEATURES ACCEPTED BY FORTRAN IV

This section discusses those features of previously implemented FORTRAN IV languages that are incorporated into the IBM Time Sharing System/360 FORTRAN IV language. The inclusion of these additional language facilities allows existing FORTRAN programs to be re-compiled for use on the IBM System/360 with little or no re-programming.

READ Statement

General Form
READ b,list Where: b, is the statement number or array name of the FORMAT statement describing the data. list is a series of variable or array names, separated by commas, which may be indexed and incremented. They specify the number of items to be read and the locations in storage into which the data is placed.

This statement causes data to be read from the data set associated with the system input.

PUNCH Statement

General Form
PUNCH b, list Where: b is the statement number or array name of the FORMAT statement describing the data. list is a series of variable or array names, separated by commas, which may be indexed and incremented. They specify the number of items to be written and the locations in storage from which the data is taken.

The PUNCH statement causes data to be written in the data set associated with the system output.

PRINT Statement

General Form
PRINT b, list
Where: b is the statement number or array name of the FORMAT statement describing the data.
list is a series of variable or array names, separated by commas, which may be indexed and incremented. They specify the number of items to be written and the locations in storage from which the data is taken.

The PRINT statement causes data to be written in the data set associated with the system output.

DATA Initialization Statement

General Form
DATA $v_1,\ldots,v_n/i_1*d_1,\ldots,i_n*d_n/,v_{n+1},\ldots,v\ /i_{n+1}*d_{n+1},\ldots,i\ *d\ /,\ldots$
Where: $v_1,\ldots,v$ are variables, subscripted variables (in which case the subscripts must be integer constants), or array names.
$d_1,\ldots,d$ are values representing integer, real, complex, logical, or literal data constants.
$i_1,\ldots,i$ represent unsigned integer constants indicating the number of consecutive variables that are to be assigned the value of $d_1,\ldots,d$.

A data initialization statement is used to define initial values of variables and arrays. There must be a one-for-one correspondence between these variables (i.e., $v_1,\ldots,v$) and the data constants (i.e., $d_1,\ldots,d$).

Example 1:

```
DIMENSION D(5,10)
DATA A, B, C/5.0,6.1,7.3/,D/25*1.0/
```

Explanation:

The DATA statement indicates that the variables A, B, and C are to be initialized to the values 5.0, 6,1, and 7.3, respectively. In addition, the statement specifies that the first 25 variables in the array D are to be initialized to the value 1.0.

Example 2:

```
DIMENSION A(5), B(3,3), L(4)
DATA A/5*1.0/, B/9*2.0/, L/4*.TRUE./, C/'FOUR'/
```

Explanation:

The DATA statement specifies that all the variables in the arrays A and B are to be initialized to the values 1.0 and 2.0, respectively. All the logical variables in the array L are initialized to the value .TRUE.. The letters T and F may be used as an abbreviation for .TRUE. and .FALSE., respectively. In addition, the variable C is initialized with the literal data constant FOUR.

An initially defined variable, or variable of an array, may not be in blank common; however, in a labeled common block, they may be initially defined only in a block data subprogram. (See the section "SUBPROGRAMS.")

DOUBLE PRECISION Statement

General Form
DOUBLE PRECISION a,b,c,...   Where: a,b,c,... are variable names that may be dimensioned in the statement, or function names.

The DOUBLE PRECISION statement explicitly specifies that the variables a,b,c,... are of type double precision. This statement overrides any specification of a variable made by either the predefined convention or the IMPLICIT statement. This specification is identical to that of type REAL*8.

In addition, FUNCTION subprograms may be typed double precision, as follows:

DOUBLE PRECISION FUNCTION name (a_1,a_2,a_3,...,a_n)

Arguments of a FUNCTION or SUBROUTINE Program Enclosed by Slashes

Arguments in a FUNCTION or SUBROUTINE subprogram may be enclosed in slashes within the commas. This form is equivalent to the normal format without the slashes.

MATHEMATICAL FUNCTION SUBPROGRAMS

Table 4. Mathematical Function Subprograms

Function	Name	Definition	In-Line (I) Out-of-Line (O)	No. of Arg.	Type of Arguments	Function
Exponential	EXP	e^{arg}	O	1	Real *4	Real *4
	DEXP	e^{arg}	O	1	Real *8	Real *8
	CEXP	e^{arg}	O	1	Complex *8	Complex *8
	CDEXP	e^{arg}	O	1	Complex *16	Complex *16
Natural Logarithm	ALOG	ln (Arg)	O	1	Real *4	Real *4
	DLOG	ln (Arg)	O	1	Real *8	Real *8
	CLOG	ln (Arg)	O	1	Complex *8	Complex *8
	CDLOG	ln (Arg)	O	1	Complex *16	Complex *16
Common Logarithm	ALOG10	log_{1} (Arg)	O	1	Real *4	Real *4
	DLOG10	log_{1} (Arg)	O	1	Real *8	Real *8
Arcsine	ARCSIN	arcsin (Arg)	O	1	Real *4	Real *4
	DARSIN				Real *8	Real *8
Arccosine	ARCOS	arcos (Arg)	O	1	Real *4	Real *4
	DARCOS				Real *8	Real *8
Arctangent	ATAN	arctan (Arg)	O	1	Real *4	Real *4
	ATAN2	arctan (Arg_1,Arg_2)	O	2	Real *4	Real *4
	DATAN	arctan (Arg)	O	1	Real *8	Real *8
	DATAN2	arctan (Arg_1/Arg_2)	O	2	Real *8	Real *8
Trigonometric Sine (Argument in radians)	SIN	sin(Arg)	O	1	Real *4	Real *4
	DSIN	sin(Arg)	O	1	Real *8	Real *8
	CSIN	sin(Arg)	O	1	Complex *8	Complex *8
	CDSIN	sin(Arg)	O	1	Complex *16	Complex *16
Trigonometric Cosine (Argument in radians)	COS	cos(Arg)	O	1	Real *4	Real *4
	DCOS	cos(Arg)	O	1	Real *8	Real *8
	CCOS	cos(Arg)	O	1	Complex *8	Complex *8
	CDCOS	cos(Arg)	O	1	Complex *16	Complex *16
Trigonometric Tangent	TAN	tan (Arg)	O	1	Real *4	Real *4
	DTAN				Real *8	Real *8
Trigonometric Cotangent	COTAN	cotan (Arg)	O	1	Real *4	Real *4
	DCOTAN				Real *8	Real *8
Square Root	SQRT	(Arg)	O	1	Real *4	Real *4
	DSQRT	(Arg)	O	1	Real *8	Real *8
	CSQRT	(Arg)	O	1	Complex *8	Complex *8
	CDSQRT	(Arg)	O	1	Complex *16	Complex *16
Hyperbolic Sine	SINH	sinh (Arg)	O	1	Real *4	Real *4
	DSINH				Real *8	Real *8

(Continued)

Table 4. Mathematical Function Subprograms (Continued)

Function	Name	Definition	In-Line (I) Out-of-Line (O)	No. of Arg.	Type of Arguments	Function
Hyperbolic Cosine	COSH DCOSH	cosh (Arg)	O	1	Real *4 Real *8	Real *4 Real *8
Hyperbolic Tangent	TANH DTANH	tanh(Arg) tanh (Arg)	O O	1 1	Real *4 Real *8	Real *4 Real *8
Remaindering	MOD AMOD DMOD	Arg$_1$(mod Arg$_2$)	I I I	2 2 2	Integer *4 Real *4 Real *8	Integer *4 Real *4 Real *8
Absolute value	IABS ABS DABS	$\lvert Arg \rvert$	I I I	1 1 1	Integer *4 Real *4 Real *8	Integer *4 Real *4 Real *8
Modulus	CABS CDABS	$\lvert a^2+b^2 \rvert$ for a+bi	O O	1 1	Complex *8 Complex *16	Real *4 Real *8
Truncation	INT AINT IDINT	Sign of Arg times largest integer $<\lvert Arg \rvert$	I I I	1 1 1	Real *4 Real *4 Real *8	Integer *4 Real *4 Integer *4
Largest value	AMAX0 AMAX1 MAX0 MAX1 DMAX1	Max (Arg$_1$,Arg$_2$,...)	I I I I I	≥2 ≥2 ≥2 ≥2 ≥2	Integer *4 Real *4 Integer *4 Real *4 Real *8	Real *4 Real *4 Integer *4 Integer *4 Real *8
Smallest value	AMIN0 AMIN1 MIN0 MIN1 DMIN1	Min (Arg$_1$,Arg$_2$,...)	I I I I I	≥2 ≥2 ≥2 ≥2 ≥2	Integer *4 Real *4 Integer *4 Real *4 Real *8	Real *4 Real *4 Integer *4 Integer *4 Real *8
Float	FLOAT DFLOAT	Convert from integer to real	I I	1 1	Integer *4 Integer *4	Real *4 Real *8
Fix	IFIX HFIX	Convert from real to integer	I I	1 1	Real *4 Real *4	Integer *4 Integer *2
Transfer of sign	SIGN ISIGN DSIGN	Sign of Arg$_2$ times $\lvert Arg_1 \rvert$	I I I	2 2 2	Real *4 Integer *4 Real *8	Real *4 Integer *4 Real *8
Positive difference	DIM IDIM	Arg$_1$-Min(Arg$_1$,Arg$_2$)	I	2	Real *4 Integer *4	Real *4 Integer *4
Obtaining most significant part of a Real *8 argument	SNGL		I	1	Real *8	Real *4
Obtain real part of complex argument	REAL		I	1	Complex *8	Real *4

(Continued)

Table 4. Mathematical Function Subprograms (Continued)

Function	Name	Definition	In-Line (I) Out-of-Line (O)	No. of Arg.	Type of Arguments	Function
Obtain imaginary part of complex argument	AIMAG		I	1	Complex *8	Real *4
Express a Real *4 argument in Real *8 form	DBLE		I	1	Real *4	Real *8
Express two real arguments in complex form	CMPLX DCMPLX	$C=Arg_1,+iArg_2$	I I	2 2	Real *4 Real *8	Complex *8 Complex *16
Obtain conjugate of a complex argument	CONJG DCONJG	C=X-iY For Arg=X+iY	I I	1 1	Complex *8 Complex *16	Complex *8 Complex *16

MACHINE INDICATOR TESTS

In the following list of pseudo machine indicator test subroutines, assume that i is an integer expression and that j is an integer variable. These subroutines are referred to by CALL statements.

SLITE (i): If i = 0, all sense lights will be turned off. If i = 1, 2, 3, or 4, the corresponding sense light will be turned on.

SLITET (i,j): Sense light i (equal to 1, 2, 3, or 4) will be tested and turned off. The variable j will be set to 1 if i was on, or j will be set to 2 if i was off.

Example:

Assume that it is desired to continue with the program if sense light i is on and to write results if sense light i is off. This can be done by using the Logical IF statement or a computed GO TO statement:

```
          .
          .
          .
      CALL SLITET (3,KEN)
      GO TO (6, 17) ,KEN
17    WRITE (3, 26) (ANS (K) , K=1, 10)
6     CONTINUE
          .
          .
```

Explanation:

When the statement CALL SLITET(3,KEN) is executed, the variable KEN is assigned the value 1 or 2 depending on whether sense light 3 is on or off, respectively (and the sense light is turned off). If KEN is 1, statement 6 is executed next; if KEN is 2, statement 17 is executed.

OVERFL (j): j is set to 1 if a floating-point overflow condition exists, i.e., if the result of an arithmetic operation is greater than 16^{63}; j is set to 2 if no overflow condition exists; j is set to 3 if floating-point underflow condition exists, i.e., if the result of an arithmetic operation is less than 16^{-63}. The machine is left in a no overflow condition.

DVCHK (j): If the divide check indicator is on, j is set to 1 and the divide check indicator is turned off; if the divide check indicator is off, j is set to 2.

THE EXIT, DUMP, AND PDUMP SUBPROGRAMS

EXIT Subprogram

A CALL to the EXIT subprogram terminates the execution of the object program.

DUMP Subprogram

A CALL to the DUMP subprogram by the statement:

CALL DUMP $(A_1, B_1, F_1, \ldots, A_n, B_n, F_n)$

causes the indicated limits of storage to be dumped and execution to be terminated.

1. A and B are variable data names that indicate the limits of storage to be dumped; either A or B may represent upper or lower limits.

2. F_n is an integer indicating the dump format desired:

F_n =	Format
0	Hexadecimal
1	Logical *1
2	Logical *4
3	Integer *2
4	Integer *4
5	Real *4
6	Real *8
7	Complex *8
8	Complex*16
9	Literal

3. If the argument F_n is omitted, it is assumed to be equal to 0, and the dump will be hexadecimal.

4. The arguments A and B should be in the same program (main program or subprogram) or same common block.

PDUMP Subprogram

A CALL to the PDUMP subprogram by the statement:

CALL PDUMP $(A_1, B_1, F_1, \ldots, A_n, B_n, F_n)$

causes the indicated limits of storage to be dumped and execution to be continued. The PDUMP arguments are the same as the DUMP arguments.

APPENDIX D: SAMPLE PROGRAMS

SAMPLE PROGRAM 1

Sample program 1 (Figure 2) is designed to find all of the prime numbers between 1 and 1000. A prime number is an integer that cannot be evenly divided by any integer except itself and 1. Thus 1, 2, 3, 5, 7, 11,... are prime numbers. The number 9, for example, is not a prime number, since it can evenly be divided by 3.

IBM FORTRAN Coding Form

PROGRAM: SAMPLE PROGRAM 1 — DATE: 6/66 — PAGE 1 OF 1

```
C     PRIME NUMBER PROBLEM
  100 WRITE (6,8)
    8 FORMAT (52H FOLLOWING IS A LIST OF PRIME NUMBERS FROM 1 TO 1000/
     119X,1H1/19X,1H2/19X,1H3)
  101 I=5
    3 A=I
  102 A=SQRT(A)
  103 J=A
  104 DO 1  K=3,J,2
  105 L=I/K
  106 IF(L*K-I)1,2,4
    1 CONTINUE
  107 WRITE (6,5)I
    5 FORMAT (I20)
    2 I=I+2
  108 IF(1000-I)7,4,3
    4 WRITE (6,9)
    9 FORMAT (14H PROGRAM ERROR)
    7 WRITE (6,6)
    6 FORMAT (31H THIS IS THE END OF THE PROGRAM)
  109 STOP
      END
```

Figure 2. Sample Program 1

SAMPLE PROGRAM 2

The n points (x_i, y_i) are to be used to fit an m degree polynomial by the least-squares method.

$$y = a_0 + a_1 x + a_2 x^2 + \ldots + a_m x^m$$

In order to obtain the coefficients $a_0, a_1, \ldots, a_m$, it is necessary to solve the normal equations:

$$
\begin{array}{ll}
(1) & W_0 a_0 + W_1 a_1 + \ldots + W_m a_m = Z_0 \\
(2) & W_1 a_0 + W_2 a_1 + \ldots + W_{m+1} a_m = Z_1 \\
\cdot & \\
\cdot & \\
\cdot & \\
(m+1) & W_m a + W_{m+1} a_1 + \ldots + W_{2m} a_m = Z_m
\end{array}
$$

where:

$$W_0 = n \qquad Z = \sum_{i=1}^{n} y_i$$

$$W_1 = \sum_{i=1}^{n} x_i \qquad Z_1 = \sum_{i=1}^{n} y_i x_i$$

$$W_2 = \sum_{i=1}^{n} x_i^2 \qquad Z_2 = \sum_{i=1}^{n} y_i x_i^2$$

$$\vdots \qquad \vdots$$

$$Z_m = \sum_{i=1}^{n} y_i x_i^m$$

$$\vdots$$

$$W_{2m} = \sum_{i=1}^{n} x_i^{2m}$$

After the W's and Z's have been computed, the normal equations are solved by the method of elimination which is illustrated by the following solution of the normal equations for a second degree polynomial ($m = 2$).

$$
\begin{array}{ll}
(1) & W_0 a_0 + W_1 a_1 + W_2 a_2 = Z_0 \\
(2) & W_1 a_0 + W_2 a_1 + W_3 a_2 = Z_1 \\
(3) & W_2 a_0 + W_3 a_1 + W_4 a_2 = Z_2
\end{array}
$$

The forward solution is as follows:

1. Divide equation (1) by W_0
2. Multiply the equation resulting from step 1 by W_1 and subtract from equation (2).
3. Multiply the equation resulting from step 1 by W_2 and subtract from equation (3).

The resulting equations are:

(4) $a_0 + b_{12}a_1 + b_{13}a_2 = b_{14}$

(5) $b_{22}a_1 + b_{23}a_2 = b_{24}$

(6) $b_{32}a_1 + b_{33}a_2 = b_{34}$

where:

$b_{12} = W_1/W_0$, $b_{13} = W_2/W_0$, $b_{14} = Z_0/W_0$

$b_{22} = W_2-b_{12}W_1$, $b_{23} = W_3-b_{13}W_1$, $b_{24} = Z_1-b_{14}W_1$

$b_{32} = W_3-b_{12}W_2$, $b_{33} = W_4-b_{13}W_2$, $b_{34} = Z_2-b_{14}W_2$

Steps 1 and 2 are repeated using equations (5) and (6), with b_{22} and b_{32} instead of W_0 and W_1. The resulting equations are:

(7) $a_1 + c_{23}a_2 = c_{24}$

(8) $c_{33}a_2 = c_{34}$

where:

$c_{23} = b_{23}/b_{22}$, $c_{24} = b_{24}/b_{22}$

$c_{33} = b_{33}-c_{23}b_{32}$, $c_{34} = b_{34}-c_{24}b_{32}$

The backward solution is as follows:

(9) $a_2 = c_{34}/c_{33}$ from equation (8)

(10) $a_1 = c_{24}-c_{23}a_2$ from equation (7)

(11) $a = b_{14}-b_{12}a_1-b_{13}a_2$ from equation (4)

Figure 3 is a possible FORTRAN program for carrying out the calculations for the case: $n = 100$, $m \leq 10$. W_0, W_1, W_2, ..., W_{2m} are stored in W(1), W(2), W(3), ..., W(2M+1), respectively. Z_0, Z_1, Z_2, ..., Z_m are stored in Z (1), Z (2), Z (3), ..., Z(M+1), respectively.

IBM FORTRAN Coding Form

PROGRAM SAMPLE PROGRAM 2 — DATE 6/66 — PAGE 1 OF 3

```
      REAL X(1ØØ),Y(1ØØ),W(21),Z(11),A(11),B(11,12)
    1 FORMAT (I2,I3/(4F14.7))
    2 FORMAT (5E15.6)
      READ (5,1) M,N,(X(I),Y(I),I=1,N)
      LW = 2*M+1
      LB = M+2
      LZ = M+1
      DO 5   J=2,LW
    5 W(J) = Ø.Ø
      W(1) = N
      DO 6   J=1,LZ
    6 Z(J) = Ø.Ø
      DO 16  I=1,N
      P = 1.Ø
      Z(1) = Z(1)+Y(I)
      DO 13  J=2,LZ
      P = X(I)*P
      W(J) = W(J)+P
   13 Z(J) = Z(J)+Y(I)*P
      DO 16  J=LB,LW
      P = X(I)*P
```

Figure 3. Sample Program 2

IBM FORTRAN Coding Form

PROGRAM SAMPLE PROGRAM 2 — DATE 6/66 — PAGE 2 OF 3

```
   16 W(J) = W(J)+P
   17 DO 2Ø  I=1,LZ
      DO 2Ø  K=1,LZ
      J = K+I
   2Ø B(K,I) = W(J-1)
      DO 22  K=1,LZ
   22 B(K,LB) = Z(K)
   23 DO 31  L=1,LZ
      DIVB = B(L,L)
      DO 26  J=L,LB
   26 B(L,J) = B(L,J)/DIVB
      I1 = L+1
      IF (I1-LB) 28,33,33
   28 DO 31  I=I1,LZ
      FMULTB = B(I,L)
      DO 31  J=L,LB
   31 B(I,J) = B(I,J)-B(L,J)*FMULTB
   33 A(LZ) = B(LZ,LB)
      I = LZ
   35 SIGMA = Ø.Ø
      DO 37  J=I,LZ
```

Figure 3. Sample Program 2 (Continued)

IBM FORTRAN Coding Form

PROGRAM SAMPLE PROGRAM 2 — DATE 6/66 — PAGE 3 OF 3

```
   37 SIGMA = SIGMA+B(I-1,J)*A(J)
      I = I-1
      A(I) = B(I,LB)-SIGMA
   40 IF (I-1) 41,41,35
   41 WRITE (6,2) (A(I),I=1,LZ)
      STOP
      END
```

*A standard card form, IBM electro 888157, is available for punching statements from this form

Figure 3. Sample Program 2

The elements of the W array, except W(1), are set equal to zero. W(1) is set equal to N. For each value of I, X_i and Y_i are selected. The powers of X_i are computed and accumulated in the correct W counters. The powers of X_i are multiplied by Y_i, and the products are accumulated in the correct Z counters. In order to save machine time when the object program is being run, the previously computed power of X_i is used when computing the next power of X_i. Note the use of variables as index parameters. By the time control has passed to statement 17, the counters have been set as follows:

$$W(1) = N \qquad Z(1) = \sum_{I=1}^{N} Y_I$$

$$W(2) = \sum_{I=1}^{N} X_I \qquad Z(2) = \sum_{I=1}^{N} Y_I X_I$$

$$W(3) = \sum_{I=1}^{N} X_I^2 \qquad Z(3) = \sum_{I=1}^{N} Y_I X_I^2$$

$$\vdots \qquad \vdots$$

$$Z(M+1) = \sum_{I=1}^{N} Y_I X_I^M$$

$$\vdots$$

$$W(2M+1) = \sum_{I=1}^{N} X_I^{2M}$$

By the time control has passed to statement 23, the values of W, W_1, ..., W_2m+_1 have been placed in the storage locations corresponding to columns 1 through M + 1, rows 1 through M + 1, of the B array, and the values of Z_0, Z_1, ..., Zm have been stored in the locations corresponding to the column of the B array. For example, for the illustrative problem (M = 2), columns 1 through 4, rows 1 through 3, of the B array would be set to the following computed values:

W_0	W_1	W_2	Z_0
W_1	W_2	W_3	Z_1
W_2	W_3	W_4	Z_2

This matrix represents equations (1), (2), and (3), the normal equations for M = 2.

The forward solution, which results in equations (4), (7), and (8) in the illustrative problem, is carried out by statements 23 through 31. By the time control has passed to statement 33, the coefficients of the AI terms in the M + 1 equations which would be obtained in hand calculations have replaced the contents of the locations corresponding to columns 1 through M + 1, rows 1 through M + 1, of the B array, and the constants on the right-hand side of the equations have replaced the contents of the locations corresponding to column M + 2, rows 1 through M + 1, of the B array. For the illustrative problem, columns 1 through 4, rows 1 through 3, of the B array would be set to the following computed values:

1	b_{12}	b_{13}	b_1
0	1	c_{23}	c_{24}
0	0	c_{33}	c_{34}

This matrix represents equations (4), (7), and (8).

The backward solution, which results in equations (9), (10), and (11) in the illustrative problem, is carried out by statements 33 through 40. By the time control has passed to statement 41, which prints the values of the A9 terms, the values of the (M + 1) $*A_I$ terms have been stored in

the M + 1 locations for the A array. For the illustrative problem, the A array would contain the following computed values for a_2, a_1, and a_0, respectively:

Location	Contents
A(3)	c_{34}/c_{33}
A(2)	$c_{24}-c_{23}a_2$
A(1)	$b_{14}-b_{12}a_1-b_{13}a_2$

The resulting values of the AI terms are then printed according to the FORMAT specification in statement 2.

A format code 59-62
ABS
(see mathematical function subprograms)
Addition
(see arithmetic operators)
Additional input/output statements 67
BACKSPACE 67
END FILE 67
REWIND 67
Adjustable dimensions 70-72
AIMAG
(see mathematical function subprograms)
AINT
(see mathematical function subprograms)
ALOG
(see mathematical function subprograms)
ALOG10
(see mathematical function subprograms)
Alphabetic characters (table) 95
Alphameric characters 14,95
AMAX0
(see mathematical function subprograms)
AMAX1
(see mathematical function subprograms)
American Standards Association (ASA) FORTRAN 5
AMIN0
(see mathematical function subprograms)
AMIN1
(see mathematical function subprograms)
AMOD
(see mathematical function subprograms)
AND
(see logical operators)
Arithmetic and logical assignment 7,27-28
Arithmetic expressions 19-23
arithmetic operators 20-23
mode of 21
order of computation in 22-23
use in logical expressions 23
use of parentheses in 23
Arithmetic IF 32-33
Arithmetic operators 20-23
Arrangement of arrays in storage 19
Arrays 16-19
arrangement in storage 19
declaring the size of 18
suscripted variables 16
subscripts 17-18
ASSIGN statement 31-32
Assigned GO TO statement 31-32
ATAN
(see mathematical function subprograms)

BACKSPACE statement 67
Basic input/output statements 40-50
READ 41-47
WRITE 47-50
Basic Operating System 5
Basic Programming Support 5
Blank common 76-77
Blank fields
(see X format code)
Blank lines
(see carriage control)
Blanks 8
BLOCK DATA subprogram 93

C (see comments lines)
CABS
(see mathematical function subprograms)
CALL statement 87-88
Carriage control 66
CCOS
(see mathematical function subprograms)
CDCOS
(see mathematical function subprograms)
CDEXP
(see mathematical function subprograms)
CDLOG
(see mathematical function subprograms)
CDSIN
(see mathematical function subprograms)
CDSQRT
(see mathematical function subprograms)
CEXP
(see mathematical function subprograms)
Character card punch codes 95
CLOG
(see mathematical function subprograms)
CMPLX
(see mathematical function subprograms)
Coding form 8
Comments lines 9-10
COMMON statement 74-77
blank COMMON 76-77
declaring the size of an array 18
labeled COMMON 76-77
Compiler 5
Complex constants 12-13
COMPLEX statement 70-71
(see also FUNCTION subprograms)
Computed GO TO statement 30
CONJG
(see mathematical function subprograms)
Constants 7,11-14
complex 12-13
double-precision 11-12
integer 10
literal 13
logical 13
real 11-12
Continuation lines 7
CONTINUE statement 37-38
Control statements 7,29-39
arithmetic IF 32-33
assigned GO TO 31-32
computed GO TO 30
CONTINUE 37-38
DO 34-36
END 39
logical IF 33-34
PAUSE 38
STOP 38

unconditional GO TO 29
Conversion codes
(see format codes)
COS
(see mathematical function subprograms)
CSIN
(see mathematical function subprograms)
CSQRT
(see mathematical function subprograms)

D decimal exponent 11-12,58-59
D format code 58-59
DABS
(see mathematical function subprograms)
DATA initialization statement 97-98
Data set 40
Data set reference number 40
DATAN
(see mathematical function subprograms)
DATAN2
(see mathematical function subprograms)
DBLE
(see mathematical function subprograms)
DCMPLX
(see mathematical function subprograms)
DCONJG
(see mathematical function subprograms)
DCOS
(see mathematical function subprograms)
Decimal exponents 11-12,58-59
Declaring the size of an array 18
Device (I/O) 40
DEXP
(see mathematical function subprograms)
DFLOAT
(see mathematical function subprograms)
Digit
(see numeric characters)
DIM
(see mathematical function subprograms)
DIMENSION statement 72-73
adjustable dimensions 72-73
declaring the size of an array 18
Division
(see arithmetic operators)
DLOG
(see mathematical function subprograms)
DLOG10
(see mathematical function subprograms)
DMAX1
(see mathematical function subprograms)
DMIN1
(see mathematical function subprograms)
DMOD
(see mathematical function subprograms)
DO statement 34-37
DO variable 34-36
Double-precision constants 11
DOUBLE PRECISION statement 98
DSIGN
(see mathematical function subprograms)
DSIN
(see mathematical function subprograms)
DSQRT
(see mathematical function subprograms)
DTANH
(see mathematical function subprograms)
DUMP subprogram 93,102-103

DVCHK
(see machine indicator tests)

E decimal exponent 11-12,58-59
E format code 58-59
END FILE statement 67
END parameter in a READ statement 41
END statement 39
in FUNCTION subprograms 85-86
ENTRY statement 89-91
EQ (see relational operators)
EQUIVALENCE statement 77-79
ERR parameter in a READ statement 41
EXIT subprogram 93,102
EXP
(see mathematical function subprograms)
Explicit specification statement 7,70-73
Exponentiation 23
(see also arithmetic operators)
Exponents
(see decimal exponents)
Expressions 19-26
arithmetic 19-23
logical 23-26
EXTERNAL statement 92

F format code 58
FALSE 13
(see also logical expressions)
Features of operating system FORTRAN IV 5-6
Fields 7-8
blanks (see also X format code) 8
comments 7-8
continuation 7
identification 7
statement number 7
FLOAT
(see mathematical function subprograms)
Format codes 50-66
A code 59-61
carriage control 66
D and E codes 58-59
F code 58
G code 52-57
H code 62-63
I code 57-58
L code 59
numeric codes 56
scale factor-P 64-65
T code 64
X code 63
FORMAT statement 40,50-66
format codes 50-66
FORTRAN record 40,50-52
literal data 61-62
reading FORMAT statements 47
FORTRAN
American Standards Association 5
basic operating system 5
basic programming support 5
coding form 7-8
compiler 5
library 92,99-103
object program 5
record 40,50-52
source program 5
statements 7

supplied subprograms 92,99-103
Functions 80-81
definition of 81
FUNCTION subprograms 83-86
reference to 81
statement function subprograms 81-83

G format code 52-56
GE (see relational operators)
GO TO statements 29-32
assigned 30-32
computed 30
unconditional 29
GT (see relational operators)

H format code 62-63
HFIX
(see mathematical function subprograms)
Hierarchy of operations
in a logical expression 25-26
in an arithmetic expression 22

I format code 57
I/O list
within a NAMELIST 43-44,48
within a READ 41
within a WRITE 47-48
IABS
(see mathematical function subprograms)
IDIM
(see mathematical function subprograms)
IDINT
(see mathematical function subprograms)
IFIX
(see mathematical function subprograms)
Imaginary number
(see complex constants)
IMPLICIT specification statement 15,68-70
In-line
(see mathematical function subprograms)
Increment 34
Indexing I/O lists 46-47
Indexing parameters in a DO 34-35
Initial value 34
Input/output statements 7,40-66
BACKSPACE 67
END FILE 67
READ 41-47
REWIND 67
WRITE 47-50
INT
(see mathematical function subprograms)
Integer constants 10
INTEGER statements 70-73
(see also FUNCTION subprograms)
ISIGN
(see mathematical function subprograms)

L format code 59
Labeled COMMON 76-77
LE (see relational operators)
Length specification
(see optional length specification, standard length specification)
Library (see FORTRAN)
Lines
(see blank lines, continuation lines)
List (see I/O list)

Literal constants 13
Literal data in a FORMAT statement 61-62
Logical constants 13
Logical expressions 23-26
logical operators 24-25
order of computation in 25-26
relational operators 24
use of parentheses in 26
Logical IF statement 33-34
Logical operators 24-25
LOGICAL statement 70-73
(see also FUNCTION subprograms)
Looping (see DO statement)
LT (see relational operators)

Machine indicator tests 102
Mathematical function subprograms 93,99-101
MAX0
(see mathematical function subprograms)
MAX1
(see mathematical function subprograms)
MIN0
(see mathematical function subprograms)
MIN1
(see mathematical function subprograms)
Mixed-mode 5-6
(see also expressions)
MOD
(see mathematical function subprograms)
Mode of an arithmetic expression 19-22
Muliline listing 56
Multiple ENTRY into a subprogram 89-91
Multiplication
(see arithmetic operators)

Named common
(see labeled COMMON)
NAMELIST statement 42-44,48
NE (see relational operators)
Nest of DOs 36-37
NOT (see logical operators)
Numeric characters 95
Numeric FORMAT codes 56-57

Object program 5
Operators
(see arithmetic, logical, relational)
Optional length specification for variables 14-15
(see also type statements)
OR (see logical operators)
Order of computation in arithmetic expressions 22-23
Order of computation in logical expressions 25-26
Out-of-line
(see mathematical function subprograms)
OVERFL
(see machine indicator tests)

P format code 64
Parentheses
use of 23,26
Parentheses in arithmetic expressions 23
Parentheses in logical expressions 26
PAUSE statement 38
PDUMP subprogram 93,103

Pre-defined specification (convention) 15
PRINT statement 97
Programming considerations in using a DO loop 36-37
PUNCH statement 96

Range of a DO statement 34-35
READ statement 41-47
 READ (a) list 45-46
 READ (a,b) list 44-45
 READ (a,x) 42-44
 READ b, list 96
Reading FORMAT statements 46-47
REAL
 (see mathematical function subprograms)
Real constants 11-12
REAL statement 70-73
 (see also FUNCTION subprograms)
Relational operators 24
Repeat constant 43
RETURN statement
 in a FUNCTION subprogram 84
 in a main program 89
 in a SUBROUTINE subprogram 88-89
REWIND statement 67

Sample program
 program 1 104
 program 2 105-111
Scale factor-P 64-66
Sense light subroutines 93
SIGN
 (see mathematical function subprograms)
SIN
 (see mathematical function subprograms)
Slashes in a FORMAT statement 50-51,54-55
SLITE
 (see machine indicator tests)
SLITET
 (see machine indicator tests)
SNGL
 (see mathematical function subprograms)
Source program 5
Source program characters 95
Special characters (table) 95
Specification statements 7,68-79
 COMMON 74-77
 DIMENSION 72-73
 EQUIVALENCE 77-79
 explicit 70-73
 EXTERNAL 92
 FORMAT 40,50-66
 IMPLICIT 15,68-70
 NAMELIST 42-44,48
Standard length specification for variables 14-15
 (see also type statements)
Statement numbers 7-8
Statements 7-9
 arithmetic and logical assignment 7,27-28
 comments lines 8
 continuation of 7
 control 7,29-39
 input/output 7,40-66
 number 7
 specification 7-8,68-79
 subprogram 7,80-93
STOP statement 38
SQRT
 (see mathematical function subprograms)
Subprogram names as arguments
 (see EXTERNAL statement)
Subprograms 7,80-93
 FORTRAN supplied 92-93,99-103
 FUNCTION 81-83
 statement functions 81-83
 SUBROUTINE 86-89
Subscripted variable 16-18
Subscripts 16-18
Subtraction
 (see arithmetic operators)
Symbolic unit number
 (see data set reference number)

T format code 64
TANH
 (see mathematical function subprograms)
Test value 35-36
TRUE 13
 (see also logical expressions)
Type and length specification 15
Type declaration 15-16
 explicit 16
 IMPLICIT 15
 pre-defined 15
Type specification of FUNCTION subprograms 84-86
Type statements 68-73
 explicit 70-73
 IMPLICIT 68-70

Unconditional GO TO statement 29

Variable FORMAT statements
 (see reading FORMAT statements)
Variables 7,13-14
 subscripted 16-18
 type declaration 15-16
 types and length specifications 14-15
 variable names 14

WRITE statement 47-50
 WRITE (a) list 50
 WRITE (a,b) list 49
 WRITE (a,x) 48

X format code 63

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