UNIVAC

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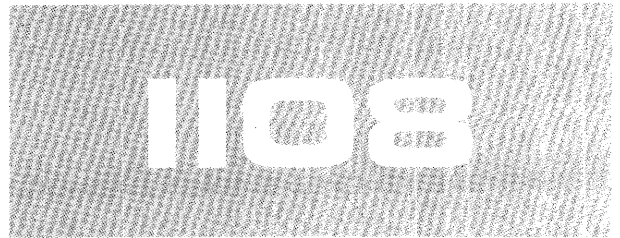
MULTI-PROCESSOR SYSTEM

ALGOL

PROGRAMMER'S REFERENCE

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UPDATING PACKAGE "A"

UNIVAC 1108 Multi-Processor System P.I.E. Bulletin 14, UP-4103.14, announces the release and availability of Updating Package "A" for the "UNIVAC 1108 Multi-Processor System ALGOL Programmers Reference Manual," UP-7544, 46 pages plus 1 Updating Summary Sheet. This material should be utilized in the following manner:

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* These pages, backups of revised pages, remain unchanged.
‡ Information in Appendix F has been greatly expanded and incorporated into Section 9.

1. INTRODUCTION

1.1. GENERAL

This manual describes the ALGOL language for the UNIVAC 1108 System. The basis for this language is the "Revised Report on the Algorithmic Language, ALGOL 60" (Communications of the ACM, Vol. 6, January 1963, 1–17). This implementation of ALGOL is very close to that of the report. Its one significant omission is the omission of dynamic own arrays. Some of its more significant additions include three new data types (**STRING, COMPLEX, REAL** 2), and default declarations. Provision is made for inclusion of procedures written in assembly language or FORTRAN V.

This manual is intended as an introduction to ALGOL 60 and as a reference manual in the use of UNIVAC 1108 ALGOL and is not intended as an exhaustive, self-contained description of ALGOL 60. The text consists principally of definitions and rules for writing ALGOL programs, examples of these rules, and some sample programs.

A set of appendices includes special sections on file-handling procedures, UNIVAC 1108 ALGOL syntax in chart form, and sample ALGOL programs; lists of basic symbols, library procedures, and diagnostic messages.

1.2. THE ALGOL COMPILER

The ALGOL compiler is a program which accepts statements expressed in ALGOL and produces programs for the UNIVAC 1108 System.

An ALGOL program is a sequence of statements written in ALGOL language. These are translated by the compiler into the language of the computer: machine language. The ALGOL statements are called the source code, and the translated statements are called the object code. The compiler itself is a program written in machine language and is called the UNIVAC 1108 ALGOL 60 Compiler. While translating the ALGOL statements, the compiler looks for errors in syntax (that is, for errors in the forms or construction of statements).

The compiler operates in two passes. The first pass scans the statements and does about 95 percent of the work required to produce the final object code. The second pass goes into operation immediately after all the statements have been scanned; it completes the remaining details of producing the object code. Upon successful compilation, the object code can be read into the main storage and executed. Activities that occur during compilation are sometimes referred to as compile-time activities; for instance, compile-time diagnostics. The execution phase is referred to as run-time.

1.3. ALGOL 60 AND UNIVAC 1108 ALGOL

There are several differences between ALGOL 60 as defined in the revised report and 1108 ALGOL 60. In that ALGOL is intended as a standard language and compatibility of programs between machines is becoming more and more important, those differences must be explicitly pointed out. They fall into two classes: extensions to ALGOL 60 and definition of things left undefined by the report; modifications or omission of ALGOL 60 entities.

1.3.1. Extensions to ALGOL 60

Extensions to ALGOL 60 include the following:

- **STRING** and **STRING ARRAY** variables enhance the value of ALGOL as a data processing language.

- New arithmetic types **COMPLEX** and **REAL 2** enhance the value of ALGOL to scientific users.

- **XOR,** an additional Boolean operator is provided.

- **EXTERNAL PROCEDURE** declarations are provided for convenience in programming large problems and for building libraries.

- I/O and other library procedures are provided and, related to them, are the **FORMAT** and **LIST** declarations.

- A compact form for **GO TO** and **FOR** statements is allowed.

- Variables are given values of zero or blank at the entrance to a block; thus initialization statements need not be made.

- The controlled variable of a **FOR** statement has a defined value when the statement is terminated by exhaustion of the **FOR** list.

- The **OTHERWISE** declaration or declaration by default is provided.

- The variables in a multiple assignment statement need not be the same type.

- Arguments of type **COMPLEX** and **REAL 2** are permitted for various standard functions.

1.3.2. Deviations from ALGOL 60

- Because of hardware requirements, identifiers are unique only to their first twelve characters and may contain no blanks; numbers may contain no blanks, and certain basic symbols are reserved identifiers (see Appendix A).

- **OWN** arrays are not dynamic.

- Numeric labels are not allowed.

- The comma is the only parameter delimiter allowed in a procedure call.

- A **LOCAL** declaration is required to resolve all forward references to identifiers.

- An integer raised to an integer power always produces a **REAL** value.

■ All the formal parameters of a procedure must be specified and must agree in type with the actual parameters.

These and other restrictions are covered in more detail in later sections of this manual.

1.4. LANGUAGE CONVENTIONS

ALGOL is described in terms of three languages in this manual: reference, publication, and hardware language.

The reference language is that which defines ALGOL in the ALGOL 60 Revised Report. It is computer independent and utilizes the basic ALGOL symbols to define the language syntax and semantics. Throughout the text, but sparingly, the syntax of 1108 ALGOL is described in terms of this reference language.

Example:

$< identifier> : := < letter > / < identifier > < letter > / < identifier > < digit >$

(Read : := as 'is' and / as 'or')

This says that an < identifier > is either a < letter > or an < identifier > followed by a < letter > or an < identifier > followed by a < digit >. Further discussion of identifiers is found in 2.2.

While having the advantage of compactness and precision, the formalism is not suitable as an introduction to ALGOL and so has been used only as a summary aid. Except for the formal definitions of the reference language, the hardware language (the language acceptable to the UNIVAC 1108) has been used throughout the text. All basic symbols which appear in the text, as well as all examples, are written in upper case letters. This is the form in which they appear in the hardware language.

For publication purposes, the boldface type delineates the basic UNIVAC 1108 ALGOL symbols. Transliteration rules for basic symbols are given in Appendix A.

Statements may be separated from each other by either the semicolon or the dollar sign. Because of keypunch limitations, the $ is commonly accepted and has been used in all examples throughout this manual.

The following symbols are considered equivalent:
 ·· is equivalent to : (colon)
 = is equivalent to := (replacement operator)

2. ELEMENTS OF THE LANGUAGE

2.1. THE CHARACTER SET

The ALGOL compiler employs a character set which is commonly available as a variant of the usual Hollerith code (FORTRAN H set) plus a few special UNIVAC 1108 characters. These are:

Letters	A-Z
Digits	0-9
Special characters	+ - = ( ) , $ / * . space
UNIVAC 1108 special characters	: & < > ' [ ] ;

In addition, some multiples of characters are given meaning as if they constituted a single character:

..	colon (interchangeable with :)
/ /	integer divide
**	exponentiation
&&	base 10 scale factor (double precision)
:=	replacement (instead of merely =)

A complete list of these characters and the transliteration rules from the ALGOL 60 report is given in Appendix A.

2.2. IDENTIFIERS

Identifiers are names that the programmer chooses to use to refer to the various things which make up a program — variables, labels, switches, formats, procedures, etc. Identifiers must begin with a letter and may be followed by any number of letters and/or digits. None of the special characters listed in 2.1 (including a space) may be used in an identifier. The compiler considers two identifiers identical if the first 12 characters are alike.

The following are all legitimate identifiers but the last two are not unique since their first 12 characters are identical.

X	A5
SUMX	A1B2C3
Y	NONLINEARRESIDUE
ALTITUDE	NONLINEARRESULT

Some basic symbols have the same form as identifiers and are called RESERVED IDENTIFIERS (see Appendix A). These can never be used except in their intended context as basic symbols. For example, the word **BEGIN** can never be used as the name of a quantity because it has an inherent meaning within the language and cannot be redefined. On the other hand, several common arithmetic functions are available for use without being declared, but these names can be redefined as identifiers (see Appendix B). All identifiers, including reserved identifiers, must

be separated from each other in the source language by DELIMITERS. All the special characters listed in 2.1 are delimiters. The space is a rather unique delimiter in that a sequence of spaces is treated as one space.

2.3. CONSTANTS

Six types of constants may be used in the UNIVAC 1108 ALGOL source program language. They are integer, real (single precision, floating point), double precision, complex, Boolean, and string constants.

2.3.1. Integer Constants

Integers are whole numbers represented internally by 35 bits plus the sign. Range of an integer N (in magnitude) is from zero to $2^{35} - 1$ inclusive ($2^{35} - 1 =$ 34359738367).

If positive, the integer may be prefixed with a plus sign. If negative, it must be prefixed with a minus sign.

EXAMPLES: 0   +23
               70   2222222222
              -204   +0

2.3.2. Real Constants

A real constant is a string of eight or fewer digits with a decimal point. The point may precede, follow or be imbedded within the digits. Internally it is represented as a floating point number with 9 bits for the sign of the number and exponent and 27 bits for the fraction. The plus sign is optional, but a negative sign must precede a negative constant. The magnitude ranges from approximately 10^{-38} to 10^{38} or it may be zero.

EXAMPLES: 3.1416   750.
          0.0   +1.7
           .645   -20.4

If desired, a scale factor may be appended to a real constant to indicate that it is to be multiplied by the indicated power of 10. This scale factor is represented by an ampersand followed perhaps by a plus or minus sign and then by an integer. The integer specifies the power of 10 to be used and is limited to two digits.
          2.65&6 means 2.65 x 10^6 or 2,650,000.
          -17.445&-5 means - 17.445 x 10^{-5} or - 0.00017445

In addition a real constant may be written as an integer followed by a scale factor or a scale factor by itself may be used to signify a real constant.
          2&-6 means 2.0&-6 or .000002
          &7 means 10^7 or 10,000,000.0

2.3.3. Double Precision Constants

Double precision constants are used for double precision calculations. The magnitude ranges from approximately 10^{-308} to 10^{308} or it may be zero. The maximum number of digits is 18.

Double precision constants are differentiated from real constants by use of &&
for power of ten, or by inclusion of between 9 and 18 digits in the fixed point
part. Double precision constants are ordinarily used only with variables of type
REAL 2.

The following are acceptable double precision constants:

```
3.141592653589793
1.0496523456666&-22
4.655&&-4
1.0&&2
4&&0
```

2.3.4. Complex Constants

The general form of a complex constant is:

```
<R1,R2>
```

where R1 and R2 are real or integer constants and where < and > are required.

Examples:

```
< 1.0, 1.0 >      represents 1 + i
< 7.0&-2, - 2 >   represents 0.07-2i
< 0.0, 1.0 >      represents i
```

2.3.5. Boolean Constants

Only two Boolean constants are allowed:

```
TRUE
FALSE
```

2.3.6. String Constants

A string constant is a string of characters not containing a quote but enclosed
by quotes. The maximum size of a string constant is 4095 characters.

Examples:

```
'STANDARD DEVIATION ='
'PRINCIPLE RATE PERIOD PAYMENT'
```

3. DECLARATIONS

3.1. GENERAL

An ALGOL program may be broken into logical segments called blocks which are complete and independent units. Their structure is discussed in Section 8. One important property of a block is that, at the beginning of the block, all of the local entities that are to be referenced inside the block must be declared. Declarations determine how the compiled program will treat certain of its elements; thus it is necessary to precede the use of an identifier with a declaration of type. An identifier may appear in only one declaration within a block; however a block may contain blocks within itself (as shown in 8.3). Any of these blocks may declare variables taking on names used in outer blocks, thus redefining them for the inner block.

3.2. TYPE DECLARATIONS

The type declaration defines the type of variable named by an identifier. This declaration specifies that all values which the identifier assumes must be of the designated type. The general form of type declaration is:

$$< type > \quad < type\ list >$$

where $< type\ list >$ is a list of identifiers separated by commas. Each declaration is terminated by a ; or $. The five possible type declarations are:

INTEGER — Integral values represented internally by 36 bits. The range of an integer (in magnitude) is zero thru $2^{35}-1$ inclusive.

REAL — Floating point numbers internally represented by 9 bits for sign of the number and the exponent and 27 bits for the fraction. The range of a real number (in magnitude) is 10^{-38} to 10^{38} and 0 with approximately 8 digits of precision. Any real quantity which is less than 10^{-38} is represented by zero.

REAL 2 — Floating point numbers internally represented by 12 bits for sign of the number and the exponent and 60 bits for fraction. The range of a REAL 2 number (in magnitude) is approximately 10^{-308} to 10^{308} and zero with approximately 18 digits of precision.

COMPLEX — Complex values of the form A + i*B where A and B are **REAL** numbers.

BOOLEAN — Truth values, **TRUE** or **FALSE**.

Examples of type declarations are:

```
INTEGER    I, J, K, COUNTER $
REAL       X, Y, TEMP, VELOCITY $
BOOLEAN    AJAX $
COMPLEX    Z1, Z2, U, V $
REAL 2     A, B, C $
```

3.3. ARRAY DECLARATIONS

When declaring simple variables as described above, a different name must be used for each different variable being defined. The **ARRAY** declaration provides a means of referring to a collection of numbers that fall into a matrix or array by the use of a single identifier.

This **ARRAY** declaration specifies to the compiler the structure which is to be imposed on this collection. An array is a group or set of elements arranged so that each may be identified by its position within the group. The compiler considers all elements of array to be of the same type.

Arrays in this compiler are restricted to those of rectangular construction in n-dimensional space.

For example, the declaration **REAL ARRAY** A(1:10) defines an array A with ten elements which may be referenced by:

```
A(1) A(2) A(3) A(4) A(5) A(6) A(7) A(8) A(9) A(10).
```

The general form of array declaration is

$<$ type $>$ **ARRAY** $<$ array list $>$ ($<$bound pair list$>$)

where type may be of any of the types given in 3.2. If type is omitted, it is assumed to be **REAL**. The array list specifies the names of the arrays. The bound-pair list consists of a bound pair for each array dimension. Each bound pair is of the form:

lower limit:upper limit

A complete array declaration for a single array is of the form:

ARRAY $A(l_1:u_1, l_2:u_2, l_3:u_3, --- l_n:u_n)$.

Where l's represent lower bounds and u's represent upper bounds. Either or both of the bounds may be negative, but $l_i \leq u_i$.

For example:

```
INTEGER ARRAY I(0:4, 1:3)
```

defines an array composed of five rows and three columns of integers as follows:

```
I(0,1)      I(0,2)      I(0,3)
I(1,1)      I(1,2)      I(1,3)
I(2,1)      I(2,2)      I(2,3)
I(3,1)      I(3,2)      I(3,3)
I(4,1)      I(4,2)      I(4,3)
```

In the previous declaration, the parts 0:4 and 1:3 are called bound pairs, and each set of them defines a subscript position. The first digit of the bound pair specifies the lowest possible value for that subscript position, and the second specifies the highest. An element of array I is referenced by the identifier I followed by a subscript list enclosed in parentheses (see 4.2.3.1). Since the lower bound of the first subscript position is 0, I(3,2) refers to the element in the fourth row and second column of array I. There is no limit to the number of subscript positions an array may have. However, declarations like

```
REAL ARRAY A(6:5) $
```

are not allowed, since the lower bound must not be greater than the upper bound. This declaration would result in an execution-time error.

Array identifiers of the same type, separated by commas, may be included in one declaration:

```
BOOLEAN ARRAY A(1..2), B(1:10,14:22), C(-2:7,0:100)
```

If two or more arrays are of the same type and same size, they may be listed sequentially with the dimension specification after the last array identifier in the group.

```
COMPLEX ARRAY COM, COMI,DECOM,COMCONJ(3:10) $
```

This declaration defines four one-dimensional arrays. Each consists of eight complex numbers and the subscripts of the elements range from three to ten.

One of the most important feature of ALGOL is that the expressions for the bound pairs need not be constants; they can be any expression referring to non-local variables and constants.

Example:

```
REAL ARRAY A(1:N,I//2:ENTIER(X),0:TIMEMAX),DP1,DP2(-INFINITY:
            DP1,DP2(-INFINITY:INFINITY) $
-INFINITY)- $
```

The size of these arrays depends on the values of N, I, X, TIMEMAX, and INFINITY. Therefore, the size varies from one execution to another. Because of this, the actual storage cells for the array are allocated during execution each time the block (in which the array declaration occurs) is entered; i. e., at the place the array is declared. This is called 'dynamic' storage allocation. All the variables in a program except own variables (see 3.5) are allocated in storage in this way. Section 8 explains the process of allocating variable storage for ALGOL. Note that the dynamic allocation concept cannot be used in the outermost block (i. e., the bound pair list may contain only constants in the array declarations in the outermost block).

3.4. STRING DECLARATIONS

The **STRING** declaration provides a means of referring to a collection of alphanumeric characters in Fieldata code by the use of a single identifier, and at the same time specifies to the compiler the structure which is to be imposed on this collection. The string declaration defines the name and length of the string:

STRING S(80) $

Strings may have substrings, either named or unnamed:

STRING S(L(40),R(40)) $

defines a string S as having a length of 80 characters with the first 40 characters being a string L and the second 40 a string R.

STRING S(6,S7(10),4,Q(8,Q9(1),2)) $
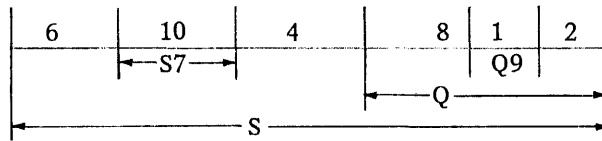
The above declaration defines the strings S, S7, and Q and Q9. It also gives their relative position since 6, 4, and 2 are unnamed substrings. The expression for the length of a string must be positive and less than 4096. Strings, like simple variables and arrays, may be declared with an identifier list:

STRING CARD (80), LINE(132), ITEM(CODE(DEPT(2), SECTION (8)),
        5,NAME(30), RATE(5), TIME(5), GROSS(10), NET(10))$

The string CARD holds 80 characters corresponding to a card image. Correspondingly, the string LINE holds one print line image. The string ITEM, on the other hand, has the somewhat complicated structure shown below:

DEPT(2)	SECTION(8)	(5)	NAME(30)	Rate (5)	Time (5)	Gross (10)	Net (10)
CODE(10)							
ITEM(75)							

ITEM has 75 characters partitioned into the strings CODE, NAME, RATE, TIME, GROSS, and NET. In addition, the string CODE of 10 characters is partitioned into the strings DEPT and SECTION. Thus

ITEM(8) ≡ CODE(8) ≡ SECTION(6).

3.4.1. String Arrays

A combination of the string and array declarations defines a quantity known as a string array. A string array is an array whose elements are strings. The form of declaration is:

STRING ARRAY S(<string part> : <array part>)

where < string part > specifies the length of each element of S (and also defines any substrings just like a string declaration) and < array part > is the list of bound pairs just as for a simple array (see 3.3).

Example:

```
STRING ARRAY S(L(40),R(40):1:10, 1:10) $
```

defines a two-dimensional array S with ten rows and ten columns. Each element of the array is a string of 80 characters. Furthermore each string consists of substrings L and R each 40 characters long. Referencing of substrings is discussed in 4.4.

3.5. OWN DECLARATIONS

Whenever a block is entered, the simple variables and arrays that are declared within that block are given the value zero, and strings are given the value (blank) in each of their character positions. The additional symbol **OWN** in front of any one of these types of declarations changes this initialization in the following way: the first time the block is entered they are given initial values as above. In subsequent entrances to the block they have the same value as they had on the last exit from the block.

Examples:

```
BEGIN INTEGER I $
      REAL FX, FY $
      OWN BOOLEAN ALPHA,BETA $
      OWN REAL ARRAY DEV (1:10, 1:10) $
```

In general all declarations allowed in 3.2, 3.3, and 3.4 of this chapter are also permitted as OWN declarations. The exception to this rule is that the length of a string or the length of any of the subscript positions of an array does not change after the first entrance to the block. Thus, if a block begins by:

```
BEGIN OWN ARRAY A(0:N)
```

and N has the value six (elements are numbered zero through six), the length of A remains seven throughout the program even if N has a different value at the next entrance to the block.

3.6. DEFAULT DECLARATIONS

The **OTHERWISE** declaration allows the programmer to specify that all simple variables (those without subscripts), unnamed in a type declaration are assumed to be of a given type.

```
BEGIN REAL X, FX, FPX $
      INTEGER OTHERWISE
```

means that any other simple variables besides X, FX, FPX that are encountered in this block are to be integers. The **OTHERWISE** declaration may not be used in connection with an array or string. A hazard of this declaration is that it carries the danger that 'new' variables may be created unintentionally and not noticed.

Example:

```
BEGIN INTEGER OTHERWISE $
      BOOMBOOM = 2$
      AEN      = 4$
BOOMBOOM = ((BOOMBOOM+AEN)*BOOMBOOM+AEN)*BOOMBOM
```

The variable BOOMBOM has crept into the calculation when BOOMBOOM was the proper one. Therefore the **OTHERWISE** declaration must be used with care. Another type declaration may follow the **OTHERWISE** declaration.

3.7. THE **COMMENT**

The **COMMENT** allows the programmer to include such things as clarifying remarks and identifying symbols in the printed compilation. A comment may serve any purpose the programmer desires once it is ignored by the compiler.

Two commonly used forms are:

> **BEGIN COMMENT** < any sequence not containing ; or $ >;
> ; **COMMENT** < any sequence not containing ; or $ >;

Example:

> **BEGIN COMMENT** SAMPLE PROGRAM USING UNIVAC 1108 ALGOL $

Any characters following an **END** and preceding another **END, ELSE,** or a semicolon are also treated as comments.

Examples:

```
END OF INNER LOOP END OF OUTER LOOP $
END THIS TERMINATES THE THEN PART ELSE
END OF HEAT TRANSFER PROGRAM $
```

3.8. **FORMAT, LIST, SWITCH, PROCEDURE, LOCAL**

The other declarations are of a more complicated nature and appear in other parts of the manual. **FORMAT** and **LIST** are concerned only with input/output and are discussed in Section 9. Procedures are discussed in Section 7 and switches in Section 5. The **LOCAL** declaration is added to the language to allow faster (one pass) translation into object code. It is discussed in Section 8.

4. EXPRESSIONS

4.1. GENERAL

An expression is a rule for computing a value. There are four kinds of expressions: arithmetic, Boolean, string, and designational. Expressions are composed of operands, operators and parentheses. Operands are constants, variables, function designators, or other expressions. Operators are symbols which designate arithmetic, relational, or logical operations, and parentheses are used to determine the sequence of operations to be performed. The value of an arithmetic expression is a number of the type **INTEGER, REAL, REAL 2** or **COMPLEX.** The value of a Boolean expression is either **TRUE** or **FALSE**, and the value of a string expression is a string of symbols. The value of a designational expression is a statement label. Expressions must be formed in accordance with mathematical convention and with the rules discussed in the following paragraphs.

4.2. ARITHMETIC EXPRESSIONS

Arithmetic quantities are combined into arithmetic expressions by means of the following arithmetic operators:

+ denotes addition
− denotes subtraction
* denotes multiplication
/ denotes division
** denotes exponentiation
// denotes integer division

The expression

A//B

can be written only when A and B are both of type **INTEGER.** The expression has the integer value of the unrounded quotient of A by B.

Thus 5//3 = 1

The expression

A**B

means A raised to the power B.

4.2.1. Ordering Rules for Operations

When arithmetic expressions are evaluated, the arithmetic operations are performed according to the following rules of priority or precedence.

Class 1	**	Exponentiation
Class 2	−	Unary minus[1]
Class 3	*	Multiplication
	/	Division
	//	Integer division
Class 4	+	Addition
	−	Subtraction

Expressions with operators in different classes are evaluated in order (1, 2, 3, and then 4) unless parentheses are used to change the order. Expressions containing operators in the same class are evaluated from left to right. Parentheses may be used to override the given order of evaluation. Expressions within innermost parentheses are evaluated first.

Examples:

Expression	Compiler Interpretation
A-B-C	(A-B)-C
A-B**C	A-(B**C)
A**B-C**D	(A**B)-(C**D)
A+B/C	A+(B/C)
A/B/C	(A/B)/C
A**B**C	(A**B)**C
-A**2	-(A**2)

4.2.2. Hierarchy of Operand Types

Mixed-mode arithmetic is permitted. The evaluated arithmetic expression assumes the type of the dominant operand type in the expression. The order of dominance is **COMPLEX, REAL 2, REAL,** and **INTEGER.** Exponentiation routines for **COMPLEX **REAL 2** and **REAL 2**COMPLEX** have not been implemented.

Example:

INTEGER	I $
REAL	R $
REAL 2	R2 $
COMPLEX	C $

then

I*R	IS REAL
R2+R	IS REAL 2
C-R2+I	IS COMPLEX

---

[1]*Note that the order of precedence for the unary minus and exponentiation has been reversed from 1107/1108 EXEC II ALGOL. Under the EXEC II system Y= -A**2 would always produce a positive result for Y.*

There are two exceptions to the above rule:

- A/B is **REAL** when A and B are **INTEGER**
- A**B is **REAL** when A and B are **INTEGER**

4.2.3. Operands of Arithmetic Expressions

The operands of arithmetic expressions are constants, variables, function designators (defined below), or other arithmetic expressions.

4.2.3.1. Subscripted Variables

A variable may be either a simple variable or a subscripted variable. A subscripted variable represents one of the following:

(1) A single element of an array denoted by the identifier which names the array followed by a subscript list enclosed in parentheses,

(2) A portion of a string variable, or

(3) A combination of both (1) and (2) in the case of **STRING** arrays. A subscript list consists of arithmetic expressions separated by commas.

The following are examples of subscripted variables:

```
A(I,J)
M(I+1,J+1)
V(F(P+1),Q+12)
Z(W(T),X(T),Y(T),Z(T))
X(13)
A(I*2,I//2)
```

The expressions which make up the subscript may be of any complexity. **REAL** values are allowed, in which case the real number is rounded to the nearest integer. Each subscript expression must have a value which is not less than the minimum and not greater than the maximum specified by the **ARRAY** declaration or for the string as specified by the **STRING** declaration (see Section 3). The number of subscript expressions must equal the number of dimensions of the array as given in the **ARRAY** declaration. Thus, if an array is declared as follows,

```
REAL ARRAY A(1:10,1:10)
```

then A(3,11) is undefined.

4.2.3.2. Function Designators

A function designator is either a call on a declared function procedure (see Section 7) or a call on a standard function. These standard functions are the ones commonly employed in mathematics, such as the square root, sine, and arctangent functions. A complete list of the available functions is given in Appendix B. For example, the function whose value is the square root of X is called SQRT; therefore if

```
REAL X 
```

then

SQRT (X)

is a function designator.

Operands themselves may be arithmetic expressions, and combining them by means of operators may give rise to more arithmetic expressions. Assuming the declarations:

```
REAL R $
INTEGER I $
INTEGER ARRAY A(0:10) $
```

Then the following are valid arithmetic expressions:

```
(R*I)/(A(1)+7)
(A(A(2))-I**3)*MOD(A(7),4)
```

MOD is an example of a standard function. In these examples, liberal use is made of parentheses to indicate order of evaluation.

4.3. BOOLEAN EXPRESSIONS

The only Boolean constants are **TRUE** and **FALSE** and these have their fixed, obvious meaning. A Boolean operand may be either a simple variable that has occured in a Boolean declaration, a subscripted variable that has appeared in a Boolean array declaration or a Boolean function designator such as NUMERIC, or a Boolean constant (see Appendix B). Boolean expressions are:

- Boolean operands

- Arithmetic or string expressions connected by the relational operators **LSS, LEQ, EQL, GEQ, GTR** or **NEQ**

- Boolean expressions connected by the logical operators **NOT, AND, OR, IMPL, EQIV,** or **XOR**

4.3.1. Relational Expressions

The relational operators have the semantic meanings

ALGOL EXPRESSION	MATHEMATICAL NOTATION	MEANING
A **LSS** B	$A < B$	Less than
A **LEQ** B	$A \leq B$	Less than or equal to
A **EQL** B	$A = B$	Equal to
A **GEQ** B	$A \geq B$	Greater than or equal to
A **GTR** B	$A > B$	Greater than
A **NEQ** B	$A \neq B$	Not equal to

For arithmetic or string expressions A and B, the Boolean expression:

    A < relational operator > B

is **TRUE** if the relation holds and **FALSE** if it does not. A and B may be mixed mode. If either A or B is **COMPLEX,** only the relations **EQL** and **NEQ** can be used. If A and B are both string expressions (see 4.4), the strings are compared character-by-character starting at the left. The shorter string is considered to be filled out with blanks to the length of the longer. The collation sequence of characters is that of Fieldata.

4.3.2. Boolean Operators

The six Boolean (logical) operators are:

NOT	negation
AND	conjunction
OR	inclusive disjunction (inclusive OR)
IMPL	implication
EQIV	equivalence
XOR	exclusive disjunction (exclusive OR)

The value of a Boolean expression of the form:

    A < Boolean operator > B

is obtained from the following table. **NOT** is a unary operator.

A	B	NOT A	A OR B	A AND B	A XOR B	A IMPL B	A EQIV B
TRUE	TRUE	FALSE	TRUE	TRUE	FALSE	TRUE	TRUE
TRUE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE
FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	FALSE
FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE

Assume the following declarations:

```
BOOLEAN A,B $
REAL X,Y,Z $
STRING S(100) $
```

Then the following are legitimate Boolean expressions.

```
B AND A
10.0 LEQ X AND X LEQ 99.0
NOT B OR A
NOT (X LSS Y IMPL Z EQL Z**2)
NUMERIC(S) OR NOT ALPHABETIC(S)
```

In the above example NUMERIC and ALPHABETIC are standard functions (see Appendix B).

4.3.3. Precedence of Boolean Operations

Parentheses may be used to specify the order of operations in Boolean expressions. If parentheses are omitted (or within parentheses), Boolean expressions are scanned from left to right, and operations are performed according to the following precedence:

(1) Arithmetic operations according to 4.2.1.

(2) Relational operations

(3) **NOT**

(4) **AND**

(5) **OR XOR**

(6) **IMPL**

(7) **EQIV**

Example:

A+1 GTR B OR C AND G+2 NEQ H

will be computed as

((A+1) GTR B) OR (C AND ((G+2) NEQ H))

Parentheses should be used in compound expressions to avoid confusion or misinterpretation by human readers (not the compiler).

4.4. STRING EXPRESSIONS

Strings have no operators which produce a string result. Substrings of a declared string are defined by giving a starting position and a length. For example, if S is a string variable

STRING S(120)

then

S(i)

denotes the ith character in the string S where the characters are numbered from the left starting with one. Thus, S(6) is the sixth character in string S.

S(i,j)

denotes a string of j characters taken in ascending order from string S starting with the character in the ith position. S(1,10) is the substring of S consisting of the first ten characters of S. The substring S(1) is equivalent to S(1, 1). That is, if the length is omitted, it is taken to be 1.

In summary, consider string S.

```
STRING S(10,R(20),STACK(3,OP(5)),4)
```

In this string the following three string expressions all have the same value; that is, they all refer to the same five characters.

```
S(34,5)
STACK (4,5)
OP
```

Partial string-array variables are subscripted variables with two separate subscript lists separated by a colon (:). A subscripted string variable is written as

S(< string part >:< subscript list >)

If S is a two-dimensional string array, then

S(i:j, k)

denotes the ith character in the j, kth element of the string array S. If a group of characters is desired, then

S(i, l:j, k)

will denote the group of l characters taken in ascending order starting with the character in the ith position from the j, kth element in the string array. On the other hand, if the entire string from the j, kth element in the string array is desired, then the colon may be omitted. Thus,

S(j, k)

specifies the entire string.

Example:

```
STRING ARRAY S(L(40),R(40):1:10,1:10)
```

then

```
S(41,40:4,10)
```

specifies the last 40 characters of the string in the fourth row and tenth column of the two-dimensional array. Each of the elements consists of 80 characters.

A numeric string expression may be used as an arithmetic operand:

```
S(1,5)+1
S(1) EOL 1
```

When used in this context, the string expression is converted to an integer expression by a transfer function. If the string does not represent an integer, an error message is printed (see Appendices B and C). If the integer value of the string is greater than $(2^{35}-1)$, an error message results.

4.5. DESIGNATIONAL EXPRESSIONS

Designational expressions are expressions whose values are statement labels (see 5.5). The form of a designational expression is either a label, a switch variable, or a conditional expression in which the value of a Boolean expression determines which of two designational expressions to use. For further details see 6.2 and 6.3.

4.6. CONDITIONAL EXPRESSIONS

The value of an expression may depend on the value of a Boolean expression. For example,

```
IF X EQL Y THEN 1 ELSE 2
```

is an integer expression whose value is 1 or 2 depending on whether X equals Y. The general form of a conditional expression is:

IF <Boolean expression> THEN <simple expression>
ELSE <expression>

The expression following **THEN** and the expression following **ELSE** must be of the same kind (arithmetic, Boolean, or string). The expression following **ELSE** may be another conditional expression.

Example:

```
IF X GTR 0 THEN 0 ELSE (X EQL 0)
```

is illegal because in some cases it has an arithmetic value (0) and in other cases a Boolean value (X **EQL** 0). In the cases where the constituent expressions are arithmetic, then the type of the entire expression is always the more general of the two expressions:

```
IF X EQL 0 THEN <1.0,2.0> ELSE 2.0
```

has a value of either <1.0,2.0> or <2.0,0.0>; that is, a value of type **COMPLEX**. Note that **ELSE** must always be present in conditional expressions.

The <simple expression> may be any expression not starting with **IF**, or any expression put into parentheses. For example, the following is not a simple expression because it begins with **IF**, but it contains a simple expression in the parentheses.

```
IF A THEN X+(IF B THEN X ELSE Z) ELSE IF B THEN Z ELSE 0
```

5. STATEMENTS

5.1. GENERAL

The ALGOL statement is the fundamental unit of operation within the language. The operations to be performed are specified by statements which may be divided into two classes:

■ Assignment statements

■ Control statements

This section discusses assignment statements, combination of statements, statement labels, and rules for punctuating statements. Section 6 is devoted exclusively to control statements.

5.2. COMPOUND STATEMENTS

A number of statements may be grouped to form a compound statement which is to be considered as a single statement. The general form of a compound statement is:

BEGIN S1 $ S2 $ ..... $ SN END

where S_1 through S_n are single statements or other compound statements. The words **BEGIN** and **END** serve as opening and closing statement parentheses. Note the absence of $ between S_n and **END**.

5.3. ASSIGNMENT STATEMENTS

An assignment statement is of the form:

    v = e or
    v:= e

Where v is a variable (simple or subscripted), e is an expression, and the equal sign is known as the replacement operator. This replacement operator is not equivalent to the equal sign in mathematical notation. The assignment statement specifies that the expression e is to be evaluated and this value is to replace the current value of the variable v.

Examples:

                        Replace the current value of SUM with zero.

SUM = 0 $ Replace the current value of X with the value of
X = Y + Z $ (Y + Z).
A(I) = X1 $
N = N + 1 $ Replace the current value of the Ith element of
                        array A with the value of X1.

                        Increase the value of N by 1.

Note that the last example is not a valid algebraic equation, but it is a valid assignment statement. On the other hand, a valid algebraic equation such as:

Z**2 = X**2 + Y**2

has no meaning to the compiler as Z**2 is not an identifier. Neither an expression nor a constant may appear to the left of the replacement operator.

In the statement

N = IF X EQL Y THEN 1 ELSE 2

N is assigned the value 1 or 2 depending on whether X equals Y. In the assignment statement

    v = e

v must be compatible in type with e. The compiler includes transfer functions to transfer from the type of e to the type of v. The available transfer functions are summarized at the end of Appendix B. If v and e are of different types, then the compiler converts e to the type of v before the assignment is made.

If the conversion is from **REAL** to **INTEGER** then the result is rounded to the nearest integer as in the following example:

INTEGER I $
I = 1.57 $

The assignment statement assigns the value 2 to I. This is equivalent to writing I = ENTIER (1.57 + 0.5) where ENTIER is a standard function which returns the integral part of the argument.

If the expression e is **BOOLEAN,** then v must also be **BOOLEAN.** If e is a string expression then v must be type **STRING** or **INTEGER;** type **INTEGER** applies only if the expression is a numeric string (see Appendix B). If e is an arithmetic expression then the v must be arithmetic. v may be type **STRING** if e is **INTEGER.**

5.3.1. String Assignment Statements

If the variable V in V = S is a string variable, then this is known as a string assignment statement. In this case, the expression S must be either arithmetic or of type **STRING**. If S is an arithmetic expression then it is first converted to type **INTEGER** and then into its associated string.

In all cases, the replacement is made such that the leftmost character of the right-hand side replaces the leftmost character in the left-hand variable. If the string on the left-hand side is longer, extra spaces are supplied to the right as necessary to fill out the left-hand string. If the string on the right-hand side is longer, any excess of characters from the right-hand side is dropped (that is, the replacement is left justified in the left-hand string variable).

As an illustration, consider the following uses in which A is a string variable:

A before	Statement	A after
ABCDEF	A = 'XYZUVW'	XYZUVW
ABCDEF	A = 'LOOP-DE-LOOP'	LOOP-D
ABCDEF	A = 'HOW'	HOW
ABCDEF	A(2) = 'Q'	AQCDEF
ABCDEF	A(2,3) = 'XYZ'	AXYZEF
ABCDEF	A(2,3) = 69	A69 EF

It is preferable to write the last statement in the form A(2, 3) = '69Δ' so as to avoid the time consuming integer-to-string conversion. One word of caution, the string replacements are performed a character at a time starting with the leftmost character; hence, a replacement of the form

```
S(2, N-1) = S(1,N-1) $
```

will result in the character in the 1, 1 position, S(1, 1), being propagated down the string (i.e. the first N characters of the string S will all be the same as the character in S(1, 1)).

Characters in a string can be shifted right or left by this type of statement. To shift the characters in a string right, first move the string into another string of the same length and then perform a replacement operation. For example, let S and T be strings of the same length; then the following statements shift S right one position and leave the first character unchanged.

```
T = S
S(2, N-1) = T(1, N-1) $
```

Similarly S can be shifted left by

```
S(1,N-1) = S(2,N-1) $
```

5.4. MULTIPLE ASSIGNMENT STATEMENTS

The same value can be assigned to a number of variables by means of a multiple assignment statement. If the variables to which a value is being assigned are mixed in type, then type conversions are performed. Assume X, Y, and E are **REAL**, and I is **INTEGER**. Then the statement

```
X = I = Y = E $
```

evaluates E and assigns this value to Y; the value of Y is then rounded to an integer and assigned to I; the value of I is converted to **REAL** and assigned to X.

The general form of assignment statement is of the form

$$V_1=V_2=V_3......V_n=E$$

where the V's are variables (simple or subscripted) and E is an expression. If the V's include subscripted variables, then the order of evaluation is as follows:

(1) Any subscript expressions are evaluated in sequence from left to right.

(2) The expression E is evaluated.

(3) The value of the expression is assigned to all variables proceeding from right to left (as in the example X=I=Y=E) with the subscripts having values as determined in 1.

If the value of I is 1 before this statement is encountered,

```
A(I) = B(I+1) = I = I+1 $
```

then evaluation continues as follows (A and B real arrays)

(1) The subscript for A is determined as 1 and for B as 2.

(2) I is incremented by 1 thus it becomes 2.

(3) The integer is converted to REAL and assigned to A(1) and B(2).

Thus A(1)=B(2)=2.0

5.5. STATEMENT LABELS

In order to identify a statement a name may be attached to it. This name is called a statement label and permits one statement to refer to another. A label is an identifier — a string of letters and digits beginning with a letter. Numeric labels are not permitted in this implementation of ALGOL. The string may be of any length but, like any identifier they must be unique within the first 12 characters (see 2.2). The label precedes the statement and is separated from it by a ":" (or ..). Multiple labels are permitted.

Examples:

```
L1: Y = A*X + B*C $
START: SUMX = 0 $
START:SUMX = 0 $
L1: L2: L3: L4 X=Y $
```

A label is defined by its actual occurrence and is therefore local to the block in which it occurs. Of course, each label must be different from all other identifiers referenced within the block. See Section 8 for further discussion of labels and blocks.

5.6. PUNCTUATION

Each statement as well as each declaration must be terminated by a $ or a ;. In a compound statement, a $ preceding the **END** would be redundant and may be omitted.

The end of a line has no meaning as punctuation. There is no restriction as to the number of cards that may be used for forming a statement. Spaces must not appear within numbers, labels, or in basic symbols (except for **GO TO** and **REAL 2**). However, spaces must be used to separate adjacent symbols composed of letters or digits. Spaces may be used freely for indentation or to facilitate reading.

5.7. DUMMY STATEMENTS

A dummy statement performs no operation. It can be used to place a label.

Example:

```
L1: END
DO $
```

6. CONTROL STATEMENTS

6.1. GENERAL

The compiler translates successive statements in the order in which they appear in the program. The statements are also executed in this same order unless the programmer interrupts this normal sequence with a "transfer of control." Once the transfer has taken place, successive statement sequencing continues from the new point of reference.

Transfer of control in ALGOL is accomplished through use of three kinds of control statements — unconditional, conditional, and iterative.

6.2. UNCONDITIONAL CONTROL STATEMENTS.

The **GO TO** statement causes an unconditional transfer of control to another part of the program.

6.2.1. The **GO TO** Statement

The **GO TO** statement may be written in any one of three ways:

- **GO TO** <designational expression>
- **GOTO** <designational expression>
- **GO** <designational expression>

There are three forms of designational expressions, the label being the simplest.

Example:

```
L:Q = SIN(SQRT(Z))  $
.
.
.
GO TO L  $
```

GO TO L interrupts the normal sequence of instructions and restarts at the statement with the label L.

Alternatively the designational expression may take the form of a conditional expression.

Example:

```
GO TO IF X EQL Y THEN L1 ELSE L2 $
```

In this case if X equals Y, control is transferred to the statement labeled L1; otherwise, the transfer is to L2.

A third form of designational expression is a **SWITCH** variable explained below.

6.2.2. The **SWITCH**

The **SWITCH** declaration names a group of alternative points in a program to which control may be transferred. It includes a means for selecting a given designational expression from the **SWITCH** list by means of a subscript expression (evaluated at execution time) with the **SWITCH** identifier. In effect, the **SWITCH** declaration defines a **SWITCH** variable which is similar to a one-dimensional array except that the elements are designational expressions.

To start with, a switch must be described by a **SWITCH** declaration prior to its use as a switch variable. The range of subscripts is from 1 to n, where n is the number of elements in the switch list. If a subscript expression on a switch variable falls outside the defined range of the switch, then the switch operation is ignored.

The general form of the declaration is

SWITCH <switch identifier> = <switch list>

or

SWITCH SWITCH 1 = e_1, e_2, e_3, − − − e_n $

where SWITCH1 is the name of the switch and e_1 − − − e_n are designational expressions.

A switch element is referenced in a **GO TO** statement by means of the switch identifier with the appropriate subscript:

```
GO TO SWITCHN1(I)
```

where I is an arithmetic expression. This expression is evaluated when the **GO TO** is executed. Control is transferred to the statement designated by element I in the switch list of the **SWITCH** declaration (counting from left to right).

To illustrate, assume that it is necessary to transfer to statements labeled L1, L2, L3, and L4 depending on whether the value of J is 1, 2, 3 or 4. This could be accomplished with the following **GO TO** statement:

```
GO TO IF J EQL 1 THEN L1 ELSE
       IF J EQL 2 THEN L2 ELSE
       IF J EQL 3 THEN L3 ELSE
       IF J EQL 4 THEN L4   $
```

However, it is much easier to set up a switch to accomplish the same thing

```
SWITCH S = L1, L2, L3, L4 $
  •
  •
  •
  •
GO TO S(J) $
```

Example:

```
SWITCH S = L1, IF X GTR Y THEN L2 ELSE L3, L4, T(I+6), L5 $
```

If the switch variable S is referenced from a **GO TO** statement

```
GO TO S(J),
```

the following transfer of control is made depending upon the value of J:

(1) If J = 1 then control transfers to L1.
(2) If J = 2 then control transfers to either L2 or L3 depending upon X and Y.
(3) If J = 3 then control transfers to L4.
(4) If J = 4 then control transfers to the label which is the value of the (I+6)th designational expression of the switch T.
(5) If J = 5 then control transfers to L5.
(6) If J < 1

or

J > 5 then no transfer is executed.

6.3. CONDITIONAL CONTROL STATEMENTS

Conditional control statements cause certain statements to be executed or skipped depending on values of Boolean expressions. The **IF** statement provides for executing a statement if, and only if, some relation is true and for skipping over a statement if this relation is false.

The **IF** statement may take the form:

```
IF B1 THEN S1 $ S2 $
```

where B1 is a Boolean expression, S1 is a statement not beginning with **IF**, and S2 is any statement. If B1 is true, then S1 is executed after which control passes to S2. If B1 is false, then S1 is skipped and control continues at S2.

In diagram form:

B1 True

IF   B1   **THEN**   S1 $ S2 $

B1 False
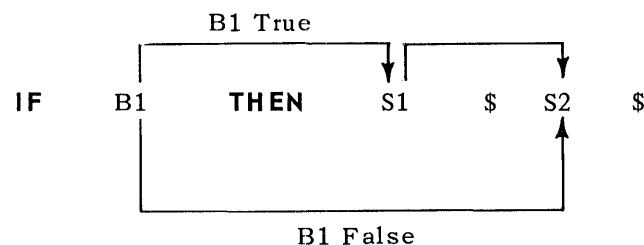
The general form of the **IF** statement is:

```
IF B1 THEN S1 ELSE S2 $ S3 $
```

If B1 is true, statement S1 is executed and statement S2 is skipped; if B1 is false, statement S1 is skipped and S2 is executed. In either case, control continues with statement S3 (except when either S1 or S2 contains a **GO TO** statement).

In diagram form

```
                  B1 True
         ┌───────────────┐ ┌──────────────────────────┐
         │               ▼ │                          ▼
   IF   B1   THEN    S1    ELSE    S2      $    S3    $
         │                          ▲       │          ▲
         └──────────────────────────┘       └──────────┘
                  B1 False
```
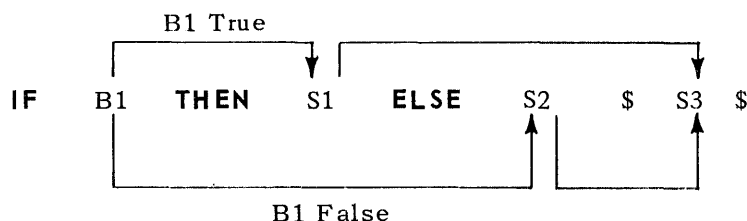
In conditional statements, the statement following **THEN** can not start with **IF**. It may be conditional only if it is enclosed by a **BEGIN – END** pair. There is no restriction on the type of statement following **ELSE**.

Example:

```
IF BOOL THEN BEGIN IF C GEQ -5 THEN GO TO CHECK
   END ELSE V = V+1 $
```

The following example illustrates "nested" conditional statements:

```
      B1 True
   ┌──────────┐ ┌────────────────────────────────────────────────────┐
   │          ▼ │                 B2 True                             ▼
   │            │         ┌───────────────┐ ┌──────────────────────┐  ▼
   │            │         │               ▼ │                      ▼▼
 IF  B1  THEN  S1  ELSE  IF  B2  THEN  S2  ELSE   S3   $   S4   $
   │                  ▲     │                      ▲      │      ▲
   └──────────────────┘     └──────────────────────┘      └──────┘
      B1 False                  B2 False
```
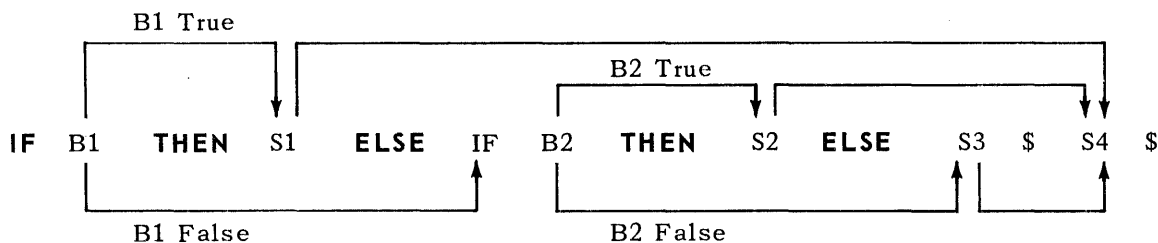
Example:

```
IF DISC LSS 0 THEN GO TO IMAGROOTS
   ELSE IF DISC EQL 0 THEN X1 = X2 = -B/(2*A)
   ELSE BEGIN
          SDISC = SQRT(DISC)    $
             X1  =  (-B+SDISC)/(2*A)    $
             X2  =  (-B - SDISC)/(2*A)
          END $
```

6.4. ITERATIVE CONTROL STATEMENTS – THE **FOR** STATEMENT

The **FOR** statement facilitates programming iterative operations. A part of the program is iterative if it is to be executed repeatedly a specified number of times, if it is to be executed for each one of a designated set of values assigned to a variable, or if it is to be executed repeatedly until some condition is fulfilled. The **FOR** statement handles any of these three conditions.

The general ALGOL **FOR** statement consists of a <**FOR** clause> followed by a statement S (simple or compound) where a<**FOR** caluse> is:

FOR <variable> = <**FOR** list> **DO**

The <**FOR** list> is a sequence of <**FOR** list elements> separated by commas. The value of each <**FOR** list element> is assigned to the controlled or iteration variable in turn from left to right and the statement S is executed once for each value.

All **FOR** list elements must be of a type compatible with the controlled variable which may be any type of simple or subscripted variable.

There are three possible kinds of **FOR** list elements:

- <arithmetic expression>
- <arithmetic expression> **STEP** <arithmetic expression> **UNTIL** <arithmetic expression>
- <arithmetic expression> **WHILE** <Boolean expression>

6.4.1. Simple List Element

FOR V = < arithmetic expression> **DO** S $

or

FOR V = e_1, e_2, e_3, e_4, − − − e_N **DO** S $

The controlled variable V is successively given the values of the arithmetic expressions, e_1, e_2, e_3, − − − e_N. The statement S is executed once for each value of V.

Example:

```
FOR  X  =  1.0,1.5,2.5,3.5,7.5  DO  S  $
```

6.4.2. **STEP − UNTIL** List Element

FOR V = < arithmetic expression > **STEP** < arithmetic expression >
UNTIL < arithmetic expression > **DO** S $

or

```
FOR  V  =  E1  STEP  E2  UNTIL  E3  DO  S  $
```

where E1 is the starting or initial value of V
       E2 is the increment by which V is increased algebraically
       E3 is the limiting or terminal value of V

The effect of the **FOR** statement is probably best described by the equivalent ALGOL statements:

```
V = E1 $
L1: IF (V-E3)*SIGN(E2) LEQ 0 THEN
BEGIN
S $
V = V + E2 $
GO TO L1
END
```

In all cases if the test fails initially, the statement S is not executed at all. SIGN (X) is a call on a standard function which will return the value 1,0, or −1 depending on whether the value of the argument X is positive, zero, or negative, respectively. This can be shown graphically as follows:
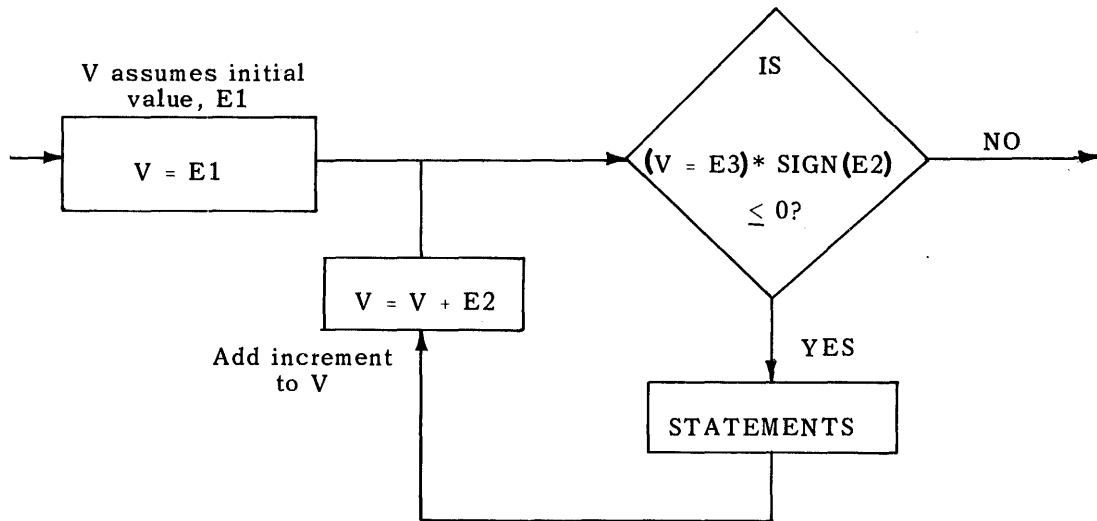
The statement S may redefine V as well as the variables appearing in E2 and E3. Changing E1 will have no effect on the execution of the **FOR** statement as the initial value is assigned to V before S is executed. Extreme care must be taken in assigning values to V within S as this may prevent V from reaching the terminal value.

The more compact form of the **FOR** statement

```
FOR V = (E1,E2,E3)DO S $
```

may be used instead of

```
FOR V = E1 STEP E2 UNTIL E3 DO S $
FOR I = 1 STEP 1 UNTIL N DO S $
FOR I = (1,1,N) DO S $
FOR X = (3.2,.1,9.9) DO S $
```

6.4.3. **WHILE** List

FOR V = < arithmetic expression > **WHILE** < Boolean expression > **DO** S $

or

FOR V = E **WHILE** B **DO** S $

First V is set equal to the arithmetic expression E. If B is true, statement S is executed. After the execution of S, V is replaced by E and again B is tested. If, on the other hand, B is false, then S is skipped and control resumes with the statement following the **FOR** statement.

This can be represented graphically as follows:
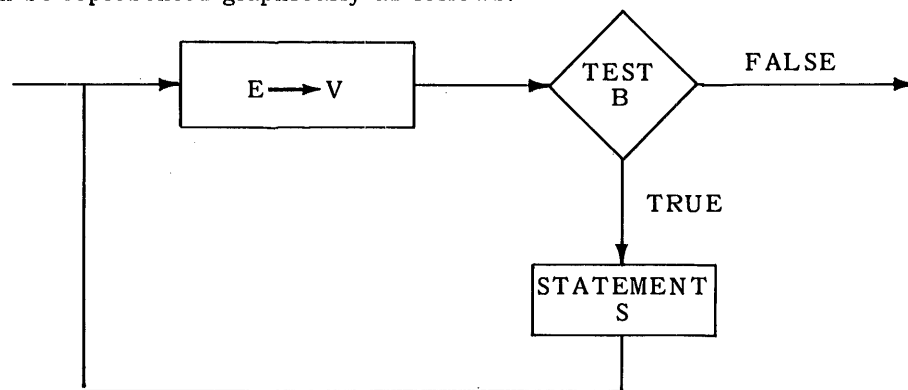
The statement S may redefine V or the variables in the expressions E and B.

Example (taken from Problem 2 Appendix D):

```
FOR B = 0.5 * (A/OLDB + OLDB)
        WHILE ABS(B-OLDB) GTR 10**(-6)*B
        DO OLDB = B $
```

In this example the **FOR** statement is executed until B, the square root of A, is accurate to six digits.

The three forms of the list elements may be combined:

```
FOR K = 1,3,5,10 STEP 2 UNTIL 20,50 WHILE B DO S $
```

The statement S will be executed for

K = 1,3,5,10,12,14,16,18,20 and

will then assume the value 50 as long as B is true.

6.4.4. Termination of **FOR** Statements

The following section should be carefully read because it deals with concepts that are not defined in rigorous ALGOL 60. The problem is that a program written in UNIVAC 1108 ALGOL 60 which utilized these concepts would possibly not work on a machine with a different version of ALGOL. The concern here is with the value of the iteration variable in a **FOR** statement when the **FOR** statement is terminated. The ALGOL 60 report leaves this value as undefined when the **FOR** statement is terminated by exhaustion of the **<FOR** list**>** , but in UNIVAC 1108 ALGOL it is well defined, and indeed, very useful. It is because of its usefulness that it is documented here with the warning that it may not work on another machine.

If the statement S has a **GO TO** statement leading out of the **FOR** statement, the value of the iteration variable is the same as it was before the **GO TO** statement was executed. (This is also true in ALGOL 60.) If the exit is made from the **FOR** statement because of the exhaustion of the **<FOR** list**>**, then the value of the variable is that value it held last as may be determined from the equivalent ALGOL statements. For example, to find the first nonblank character of a string, either one of two methods could be used.

```
STRING S(120)$
INTEGER I,R $
I=0 $
FOR I=I+1 WHILE (I LSS 121 AND S(I) EQL ' ')
DO $
IF I EQL 121 THEN GO TO STRINGALLBLANK
ELSE FOUNDIT: R=RANK(S(I)) $
```

That method depends on the exhaustion of the **<FOR** list**>** , either because the whole string has been scanned or because a nonblank character has been found. In one case, the final value of I is 121 and in the other it is the index to the nonblank character. Note that a dummy statement **DO** $ follows the **FOR** statement (see 5.7). RANK is a standard function returning the Fieldata equivalent of the first character of the string.

The second method is as follows:

```
FOR I=(1,1,120) DO IF S(I) NEQ ' ' THEN GO TO FOUNDIT $
GO TO STRINGALLBLANK $
FOUNDIT: R=RANK(S(I)) $
```

This method produces the correct value of I because an exit is made from the **FOR** statement by a **GO TO** statement.

A **GO TO** statement from outside a **FOR** statement referring to a label within the **FOR** statement may result in an undefined situation and should thus be avoided.

```
FOR  I=(1,1,N)  DO
     BEGIN
       •
       •
     L:
       •
       •
     END  $
 •
 •
GO  TO  L  $
```

The above statement, **GO TO** L, is not allowed.

However, it is easy to program the above logic by not using the **FOR** statement.

Example:

```
       I = 0
LOOP:  I = I+1  $
        •
        •
     L: •
        •
        •
        •  IF  I  LSS  N  GO  TO  LOOP  $
        •
        •
        •
        •
     GO  TO  L  $
```

7. PROCEDURES

7.1. INTRODUCTION

A procedure in ALGOL is used to specify an independent section of a program (which usually represents an algorithm) that can be called or executed at different points throughout the same program or may be used in other programs. The operations to be performed are fixed, but a list of parameters makes it possible for a procedure to be used with varying values and/or variables.

A procedure must be declared in the declaration part of the block in which the procedure is referenced. More than one procedure may be defined at the beginning of a block. During program execution when a block is entered, the first statement executed is the first executable statement following the procedures (if any).

The procedure declaration consists of a procedure heading and a procedure body. The heading consists of a procedure identifier, a formal parameter list, if any, a value list, if any, and specifications, if any. The procedure body follows the specifications and consists of a statement, compound statement, or a block.

Example:

```
PROCEDURE NFACT (ARG1, ARG2) $
          INTEGER ARG1, ARG2 $
          BEGIN
               INTEGER I $
               ARG2 = 1 $
               FOR I = 1 STEP 1 UNTIL ARG1 DO
                    ARG2 = ARG2*I$
          END
```

In the above example NFACT is the identifier for a procedure that calculates the value of N factorial. ARG1 and ARG2 are the formal parameters (arguments) for the procedure. ARG1 is the number whose factorial is to be calculated, and ARG2 is the result after the procedure has been executed. ARG1 and ARG2 are **INTEGER** variables. The **BEGIN-END** pair sets off the body of the **PROCEDURE**. The **BEGIN-END** pair can be dropped if the procedure body is just one statement. Since I is declared as an **INTEGER,** it is local to NFACT.

A "call" of the above procedure would be of the form:

```
NFACT (N,FACT) $
•
•
•
NFACT (N1,FACT1) $
```

In the first call, the actual parameters N and FACT are substituted for the formal parameters ARG1 and ARG2. Later the parameters N1 and FACT1 are substituted for ARG1 and ARG2 in the same fashion. Thus procedure is a closed subroutine, and the call establishes a linkage to the subroutine.

An alternate form of the parameter list allows comments to be inserted between the formal parameters since the comma separating formal parameters is equivalent to:
) < string > : (

```
PROCEDURE NFACT (ARG1, ARG2)
```

could be written as:

```
PROCEDURE NFACT (ARG1) AND STORE RESULT IN: (ARG2) $
```

or

```
PROCEDURE NFACT (ARG1) ARG1 INPUT AND ARG2 OUTPUT: (ARG2) $
```

The following is a procedure for the multiplication of two matrices:

```
PROCEDURE MATMUL (A,B,C,N,M,P) $
REAL ARRAY A,B,C, $
INTEGER N,M,P $
BEGIN INTEGER I,J,K $
REAL TEMP $
FOR I=1 STEP 1 UNTIL N DO
FOR J=1 STEP 1 UNTIL P DO
BEGIN TEMP=0.0 $ FOR K=1 STEP 1 UNTIL M DO
TEMP=TEMP+B(I,K)*C(K,J) $
A(I,J)=TEMP END I,J LOOP
END MATMUL $
```

A procedure statement calls for the execution of a procedure body.

Given the declaration

```
REAL ARRAY A1(1:10,1:7), A2(1:10,1:15), A3(1:15,1:7) $
```

then the procedure statement

```
MATMUL (A1,A2,A3,10,15,7) $
```

has the effect of multiplying the two matrices A2 and A3 and storing the results in A1.

Expressions may also be used as actual parameters. Care must be taken to match the type and kind of each formal and actual parameter in any call.

7.2. VALUE ASSIGNMENT (CALL BY VALUE) AND NAME REPLACEMENT (CALL BY NAME)

The above procedure NFACT makes use only of the value of ARG1 whereas it changes the value of the actual parameter which replaces ARG2. Thus NFACT could be re-written as follows:

```
PROCEDURE NFACT (ARG1, ARG2)
    VALUE ARG1 $
    INTEGER ARG1, ARG2 $
    BEGIN
        INTEGER I $
        ARG2 = 1 $
        FOR I = 1 STEP 1 UNTIL ARG1 DO
            ARG2 = ARG2*I
    END$
```

The procedure statement

```
NFACT (NUMBER,FACTORIAL) $
```

has this effect: the value of the actual parameter, NUMBER, replaces ARG1 when the procedure statement is encountered and NFACT does not have access to the location assigned to NUMBER. ARG1 is known as a < Call by value > parameter. A value parameter must also have a type specification and cannot appear to the left of the replacement operator in the procedure.

Any parameter (such as ARG2) which is not listed in the **VALUE** part of the procedure declaration is said to be a < Call by name > parameter. The name FACTORIAL re-places the name ARG2. The value of FACTORIAL is changed as the procedure is executed.

In the following examples, numeric values or expressions are used as actual para-meters:

```
NFACT (15,FACT1) $
NFACT (J+K+M,FACT2) $
```

It should be noted that a value parameter which is an array or string identifier re-quires that the entire array or string supplied by the procedure call be copied locally within the procedure. As a result large amounts of working storage may be used un-expectedly when the procedure is called. All calculations in the procedure use that temporary copy. As an example, suppose it is necessary to find the determinant of a matrix without destroying the matrix. The usual computational methods for finding determinants destroy the matrix with which they are working. Thus the original matrix must be copied somewhere. Specifying the array as **VALUE** accomplishes this:

```
REAL PROCEDURE DET(A) SQUARE MATRIX WHOSE DIMENSION IS:(N)$
VALUE A,N $
REAL ARRAY A $
INTEGER N $
BEGIN
(STATEMENTS)
DET=... END DET $
```

This is an example of a function procedure explained in 7.4. If an expression is used as an actual parameter, and if the parameter is called by name, then the expression is reevaluated at each occurrence of the formal parameter in the procedure.

7.3. SPECIFICATIONS

The < type> of all formal parameters defined by a procedure declaration must be specified in the specification part of a procedure heading. The format of the specification part is as follows:

<specification> <identifier list>;

The specification may be in any one of the following forms:

<type>

ARRAY

<type> **ARRAY**

STRING

STRING ARRAY

PROCEDURE

<type> **PROCEDURE**

LABEL

SWITCH

FORMAT

LIST

and< type> is one ALGOL type: **INTEGER, REAL, REAL 2, BOOLEAN, or COMPLEX.**

The <identifier list> consists of the formal parameter identifiers contained in the procedure declaration separated by commas.

The reason that all formal parameters must be specified is that the compiler must know the type and kind or class of all parameters in order to compile proper machine code.

Examples:

```
INTEGER I, K ;
REAL X, Y ;
REAL ARRAY Z ;
BOOLEAN PROCEDURE F ;
STRING S ;
```

Specifications do not include information about lengths of strings, the dimensions and bounds of arrays, the formal parameter parts of procedures, or the contents of formats and lists. The actual declarations of these exist elsewhere in the program. The details of constructing a procedure can be illustrated by an example:

```
PROCEDURE TRANSPOSE (A) ORDER:(N) $
     VALUE N $
     ARRAY A $
     INTEGER N $
     BEGIN
          REAL W $
          INTEGER I, K $
          FOR I = 1 STEP 1 UNTIL N DO
          FOR K = 1+I STEP 1 UNTIL N DO
              BEGIN
                   W = A(I,K) $
                   A(I,K) = A(K,I) $
                   A(K,I) = W
              END
     END TRANSPOSE$
```

7.4. FUNCTION PROCEDURES

Procedures which are to be used as functions (e.g., SIN, EXP) must have a type associated with the procedure identifier (i.e. procedure name). This type declaration must be the first symbol of the procedure declaration. Also for the function procedure to have a value associated with it, the procedure identifier must occur at least once as the left part of an assignment statement in the procedure body. In addition, at least one of these assignment statements must be executed on a given procedure call for a value to be assigned to the procedure. If more than one such assignment statement is executed within the body, then the last one executed before exiting from the procedure determines the value associated with the procedure. Any other occurrences of the procedure identifier within the body of the procedure are considered as recursive calls on the procedure.

The procedure NFACT could be written so that the only parameter would be N and the value of NFACT would be N factorial.

```
INTEGER PROCEDURE NFACT (ARG) $
   INTEGER ARG $
   BEGIN
        INTEGER I, TEMP $
        TEMP = 1 $
        FOR I = 1 STEP 1 UNTIL ARG
            DO TEMP = TEMP*I$
        NFACT = TEMP
   END NFACT $
```

The call for the above procedure would be of the form

```
COMMENT SET FACT = N FACTORIAL$
FACT = NFACT(N) $
```

A function procedure is referenced by a function designator which defines a single numerical or logical value. NFACT(N) is a function designator which will have an integral value and can thus be used in any expression in which an integer variable could be used.

7.5. RECURSIVE PROCEDURES

In the example above, a new variable TEMP was used to store the intermediate result of the calculation of N factorial. Then the extra statement NFACT = TEMP was needed to give NFACT the proper value. The reason for this is that inside the procedure body, whenever the name of the procedure occurs on the left-hand side of an assignment statement, it is a <procedure assignment> statement, that is, the statement which assigns the value to the procedure. Wherever else the name occurs, it is a call on the procedure.

This kind of construction can be used to produce another version of NFACT which is even simpler to write. In fact, it requires only one statement in the procedure body:

```
INTEGER PROCEDURE NFACT(N) $
INTEGER N $
NFACT = IF N EQL 0 THEN 1 ELSE N*NFACT(N-1) $
```

which is equivalent to the recursive definition

factorial(n) = 1   n = 0

          = n*factorial (n-1)   n > 0

A procedure call with the actual parameter 4 (FACT = NFACT(4)) has the following effect. After the subroutine linkage is set up, the procedure body is virtually changed to:

```
NFACT=IF 4 EQL 0 THEN 1 ELSE 4*
NFACT (3)
```

NFACT(3) is another call of the functional procedure having the result that the call is replaced with the procedure body:

```
NFACT=IF 4 EQL 0 THEN 1 ELSE 4 *
    (IF 3 EQL 0 THEN 1 ELSE 3*NFACT(2))
```

This produces another call on NFACT resulting in another change of the statement. This goes on until finally:

```
NFACT=IF 4 EQL 0 THEN 1 ELSE 4*
(IF 3 EQL 0 THEN 1 ELSE 3*(IF 2
EQL 0 THEN 1 ELSE 2* (IF 1 EQL 0
THEN 1 ELSE 1*(IF 0 EQL 0 THEN 1
ELSE 1* (NFACT(0)))))) $
```

The process is terminated when 0 **EQL** 0 occurs in the relation of the conditional expression. The usual expression for the factorial is obtained after the unnecessary parts of the above statement have been removed:

4 factorial=4*3*2*1

All procedures written in ALGOL may be called from within themselves. But it should be mentioned that recursive procedures are not always put to good use. For example, using the recursive properties of procedures makes a much neater looking NFACT, but also a much less efficient one. However, recursive procedures may have practical uses. For example, multiple integration programs use a quadrature procedure to evaluate the inner function as well as to do the integration. (See ACM Algorithm 233 "Simpson's Rule for Multiple Integration," Communications of the ACM Vol. 7, No. 6, June 1964.)

7.6. EXTERNAL PROCEDURES

External procedures are procedures whose bodies do not appear in the main program. They are compiled separately and linked to the main program at its execution. The **EXTERNAL** declaration serves the purpose of informing the compiler of the existence of these procedures, their types (if any), and the proper manner to construct the necessary linkages. The general form of the external declaration is:

EXTERNAL <kind> <type> **PROCEDURE** < identifier list>

where <type> is the arithmetic type or is empty, < identifier list> is a list of identifiers of external procedures, and

< kind> ::= empty/FORTRAN/NON−RECURSIVE

The words 'FORTRAN' and 'NON−RECURSIVE' have special significance only in this context. Procedures of kind < empty> are ALGOL procedures and are treated exactly like an ordinary procedure declared within the program. However, they need not be written in ALGOL language. Procedures of kind 'FORTRAN' are FORTRAN subroutines or functions and procedures of kind 'NON−RECURSIVE' are necessarily written in machine language. In the following paragraphs we assume a knowledge of the UNIVAC 1108 Executive System, FORTRAN (see 7.6.2), and the UNIVAC 1108 Assembler (see 7.6.3).

7.6.1. ALGOL External Procedures

An ALGOL program which consists entirely of a procedure is nonexecutable because it contains only a procedure declaration (see 7.1.). When such a program is compiled, the name of the procedure is marked as an entry point when the program is entered into the program file. Like all names in the program file the first six characters of the procedure name must define it. Such a procedure may be referenced from another ALGOL program as an external procedure.

Example:

PROGRAM 1

```
BEGIN REAL PROCEDURE DET(A,N)$
REAL ARRAY A $
INTEGER N $
VALUE A,N $
BEGIN
COMMENT THIS PROCEDURE FINDS THE DETERMINANT OF A REAL N BY N
MATRIX A, LEAVING A UNCHANGED AND ASSIGNING THE VALUE TO DET $
 •
 •
DET =-. . . END DET
END $
```

PROGRAM 2

```
BEGIN REAL ARRAY MATRIX (1:10,1:10) $
       EXTERNAL REAL PROCEDURE DET $
       •
       •
WRITE(DET(MATRIX,10)) $
       •
       •
END $
```

A user could build a library of procedures that are useful to him and then refer to whichever he needed by merely declaring them as external procedures in his main program.

7.6.2. FORTRAN Subprograms

A FORTRAN subroutine or a FORTRAN function may be made available to an ALGOL program by the declaration:

EXTERNAL FORTRAN < type > **PROCEDURE** < identifier list >

Actual parameters in calls on such procedures may be either expressions or arrays. (Labels, string expressions, and string arrays are specifically excluded.) The FORTRAN subprogram is a subroutine or function depending on the absence or presence of < type > in the external declaration. A FORTRAN function is used like an ALGOL functional procedure i.e., as an expression. For example, if DET (above) were a FORTRAN subroutine:

PROGRAM 1

```
SUBROUTINE DET(A,N,D)
DIMENSION A(N,N)
C   DET FINDS THE DETERMINANT OF A REAL NXN
C   MATRIX A AND LEAVES THE RESULT IN D,
C   DESTROYING A.
       •
       •
    D=...

END
```

```
PROGRAM 2

BEGIN REAL ARRAY MATRIX(1:10,1:10) $
    REAL DETVALUE $
    EXTERNAL FORTRAN PROCEDURE DET $
    •
    •
    DET(MATRIX,10,DETVALUE) $
END $
```

7.6.3. Machine Language Procedures

A procedure written in 1108 Assembler language may be referenced in either of two ways. The more difficult manner occurs when the procedure is declared exactly as an ALGOL external procedure. In this case the Assembler procedure must behave like an ALGOL procedure (that is, it must be able to handle recursive calls). Here the nonrecursive case is considered. The form of the declaration for these is:

EXTERNAL NON–RECURSIVE < type > **PROCEDURE** < identifier list >

To understand how to write such procedures consider the coding produced by the ALGOL compiler as the result of a call in the following program:

```
EXTERNAL NON-RECURSIVE PROCEDURE PUNCH $
INTEGER Q, S $
•
PUNCH(Q,S) $
```

The statement PUNCH (Q,S) results in the four lines of coding:

```
LMJ             11,PUNCH
+               2
F               00,01,01,Q
F               00,01,01,S
```

The second line states the number of parameters being handed through and the following lines provide information about each parameter in turn. The actual form of F is defined elsewhere in the system by a FORM directive

```
F   FORM 6, 3, 3, 24
```

which specifies the number of bits in each field of F. (See "UNIVAC 1108 Assembler Programmers Reference Manual," UP-4040.)

The four fields of F are defined and encoded as follows:

KIND

00 = Expression
010 = Array
050 = Label

TYPE

01 = INTEGER
02 = REAL
03 = COMPLEX
04 = BOOLEAN
05 = STRING
06 = REAL 2

REFERENCE

00 = Constant
01 = Name
02 = Indirect
06 = Result

LOCATION

The location field specifies the location of the parameter. Indirect addressing may be specified and index register 11 is usually designated in this 24—bit field. With this in mind, the following rules should be followed in writing an Assembler procedure:

(1) The return point for a call with N parameters is (X11)+N+1.
(2) The value of the procedure (if any) must be left in register A2 (and A3 for **COMPLEX** and **REAL** 2), absolute 14.
(3) Registers 1—4 may not be used without saving and restoring.
(4) Register 10 must never be destroyed.
(5) The Ith parameter should be referenced by an indirect command, e.g.,

LA   A2,*I,X11

> If the parameter under reference is a double-word quantity (**COMPLEX** or **REAL** 2) its second half is in the next location, and the parameter should be referenced with a DL   A2,*I,X11

DL   A2,*I,X11

(6) When using an arithmetic or a Boolean expression, the word referenced in rule (5) is the value of the expression.
(7) When using either an arithmetic or a Boolean array, the word referenced in (5) is itself the address of the following information:

number of elements	, address of first element
precision	, N
lower bound (N)	, length (N)
.	.
lower bound (1)	, length (1)

where N is the number of dimensions of the array, lower bound (I) is the value of the lower bound of subscript position (I) and length (I) is its length.

(8) When using a string expression, the word referenced in (5) is a string descriptor of the form:

```
F    FORM    12,6,18
```

```
F    length, start, address
```

'length' is the length of the string which starts at character position 'start' of the word at 'address.' For this purpose 'start' is coded as 0—5 to select a sixth of a word, S1—S6.

(9) When using a string array, the word referenced in (5) consists of two addresses, the left one being the address of a string descriptor and the right one the address of the array information (as in 7). The address field of the string descriptor must be added to the first element address to find the first element of the string array. Both arrays and string arrays are stored by column.

(10) The name of the external procedure must be the entry point of the Assembler procedure.

8. BLOCK STRUCTURE

8.1. GENERAL

In ALGOL 60 a program is a block. In turn, this block may contain subblocks. This structure serves to facilitate the construction of a program, for these subblocks may be checked out independently before being fitted together in the final program.

8.2. BLOCKS

A block consists of two parts, a heading and a body. The heading comes first and is identified by the symbol **BEGIN** or **<label>** :**BEGIN**. This is followed by all the declarations needed within the block: simple variables, arrays, strings, lists, formats, procedures, etc. The body of the block contains the statements of the block. The end of the block comes with the matching **END** to the **BEGIN** of the block head.

Example:

```
BLOCK1: BEGIN REAL ARRAY X(1:10) $
              INTEGER I $
              FOR I=(1,1,10)DO X(I)=SIN(I) $
        END
```

The first two lines constitute the block head and the other statements constitute the body. The block head may appear in the body of another block. The inner block is then said to be 'nested' in the first (outer) block:

```
BEGIN INTEGER N $
      READ(N) $
          BEGIN REAL ARRAY A(1:N,1:N) $
              •
              •
          END INNER BLOCK
END OUTER BLOCK
```

As a special case, the first (outermost) block of the program need not be enclosed in a **BEGIN-END** pair, although formally this is required. Instead a program may start with a declaration. All other blocks do require a **BEGIN-END** pair. The double use of the **BEGIN-END** parentheses should be noted by the user. A group of statements enclosed by a **BEGIN-END** pair forms a compound statement if the statement following the **BEGIN** is not a declaration. If this statement is a declaration, a new block is defined rather than a compound statement.

8.3. LOCAL AND GLOBAL IDENTIFIERS

All identifiers declared within a block are called local identifiers (i.e., local to the given block). Any that do not occur in declarations in the given block, but that do appear in a block containing the given block, are called global or nonlocal identifiers (to the given block). Each block introduces, at the time it is entered, a new level of nomenclature in the sense that all identifiers declared for the block assume the meaning implied by the declaration. However, identifiers in blocks containing the given block which are not redeclared retain their old significance. When the block is left, all the identifiers declared within it lose all their significance. When a variable is declared in an outer and also in an inner block, the variable assumes the value last assigned in the outer block on exit from the inner block.

Example:

```
BLOCK1: BEGIN REAL X $
            INTEGER I $
            X=2 $
        BLOCK2: BEGIN REAL Y $
                    INTEGER I $
                    Y=X $
                    I=X $
        END BLOCK 2 $
            I=X $
END BLOCK 1
```

This example has two blocks, the first with variables X and I and the second with variables Y and I. The I of block 1 cannot be referenced from within block 2 because block 2 has its own I.

Note that an identifier such as Y in the example, existing in an inner block, can never be referenced from an outer block because the identifier has no meaning in the outer block. In particular, this means that all labels (which are defined not by declaration, but by occurrence) are local to the block in which they occur, and so cannot be referenced from outside. Thus, a **GO TO** statement cannot lead into the middle of a block. All blocks must be entered through their headings. Exit is made from a block either by "falling through" the bottom of the block through the last **END,** or by a **GO TO** statement which must lead to an outer block.

The **OTHERWISE** declaration has the effect of stopping any reference to global (simple variable) identifiers.

Example:

```
BEGIN REAL X $
        •
        •
        BEGIN INTEGER OTHERWISE $
        X=0 $
        •
        •
        END $
        •
        •
END $
```

In the inner block, the variable X is an integer variable (now defined in this block) rather than the **REAL** X of block 1. If, in the above example, a third block was nested in block 2 and reference was made to an undeclared variable called Z, then Z would be defined as an integer local to the block with the **OTHERWISE** declaration. Blocks need not be nested; they can be disjoint, in which case there is no communication of identifiers:

```
BEGIN REAL ...$
•
•
END $
BEGIN INTEGER...$
•
•
END $
```

The programs may be written by two different people, checked out separately, and then joined together in this manner with absolutely no problems about conflicting use of identifiers.

8.4.   THE LOCAL DECLARATION

Since the 1108 ALGOL 60 compiler examines the source language only once, it must never meet an identifier without knowing what the identifier represents. For example, suppose P and Q are procedures declared in the same block and in the body of P is a call to Q. The declarations could be arranged so that Q is first:

```
BEGIN PROCEDURE Q $
        BEGIN
        •
        •
        END Q $
    PROCEDURE P $
        BEGIN
        •
        •
        Q $
        •
        •
        END P $
```

But if Q also calls P (P and Q are mutually recursive) then clearly it is impossible to put them both first. The **LOCAL** declaration must be used to resolve such forward references (using an identifier before it is defined):

```
BEGIN LOCAL PROCEDURE P $
      PROCEDURE Q $
           BEGIN
           •
           P $
           •
           END Q $
      PROCEDURE P $
           BEGIN
           •
           •
           Q $
           •
           •
           END P $
```

The allowable uses of the LOCAL declaration are:

```
LOCAL LABEL ...
LOCAL PROCEDURE ...
LOCAL < type > PROCEDURE ...
LOCAL SWITCH ...
LOCAL FORMAT ...
LOCAL LIST ...
```

The only relaxation of this rule is that a label serving as the object of a **GO TO** statement or in a **SWITCH** declaration need not appear in a **LOCAL** declaration; instead it is assumed that it will eventually be defined in the block. Thus the **GO TO** statement or **SWITCH** declaration has the same effect as a **LOCAL** declaration. However, if the label is already defined in an outer block of the given block (either by occurrence, **LOCAL** or **SWITCH** declaration, or as the object of a **GO TO** statement) then that definition of the label is assumed for the inner block.

To further illustrate the concept of local and global identifiers consider the block displayed in Figure 8–1. The variables I, J, K, X, Y, Z and labels L1, L2, are local identifiers in block 1. Only I, K, X, Y, Z, L1, L2 will be global to block 2, while J is redefined and local in block 2 along with L, M, U, V. In block 3, I, Y, Z, L1, L2 from block 1 are global along with J, L, U, V from block 2. K, M, N, W, X, and L3 are local in block 3. Consider the statement, L3. The global variable Y will be replaced by the sum of the local variable X with the product of the global variables V, Z. The statement L4 in block 4 looks the same as L3 in block 3. However, the variable X in this case refers to the variable X in block 1 rather than the variable X in block 3; hence the effect of the statements will be different.

In block 5, the statement labeled L5 has an erroneous **GO TO** L4 after the word **THEN**. The label L4 is defined in block 4 and has no meaning within block 5 since the blocks are disjoint. However, the **GO TO** L1 is correct and will send control to the statement labeled L1 in block 1. This in effect will cause the program to re-enter block 2.

```
                               Block 1
INTEGER I,J,K;
REAL X,Y,Z;
L1: BEGIN
         INTEGER J,L,M;        Block 2
         REAL U, V;
         BEGIN
                       Block 3
                 INTEGER K,M,N;
                 REAL W,X;
                 L3: Y=X+V*Z;
         END;
         BEGIN
                       Block 4
                 BOOLEAN B1, B2;
                 INTEGER P, Q;
                 REAL Z1, Z2;
                 L4: Y=X+V*Z;
         END;
END;
L2: BEGIN
                       Block 5
         INTEGER V, Z;
         REAL I, M;
         BOOLEAN B1;
         L5: IF B1 THEN GOTO L4 ELSE
         GOTO L1;
END;
```
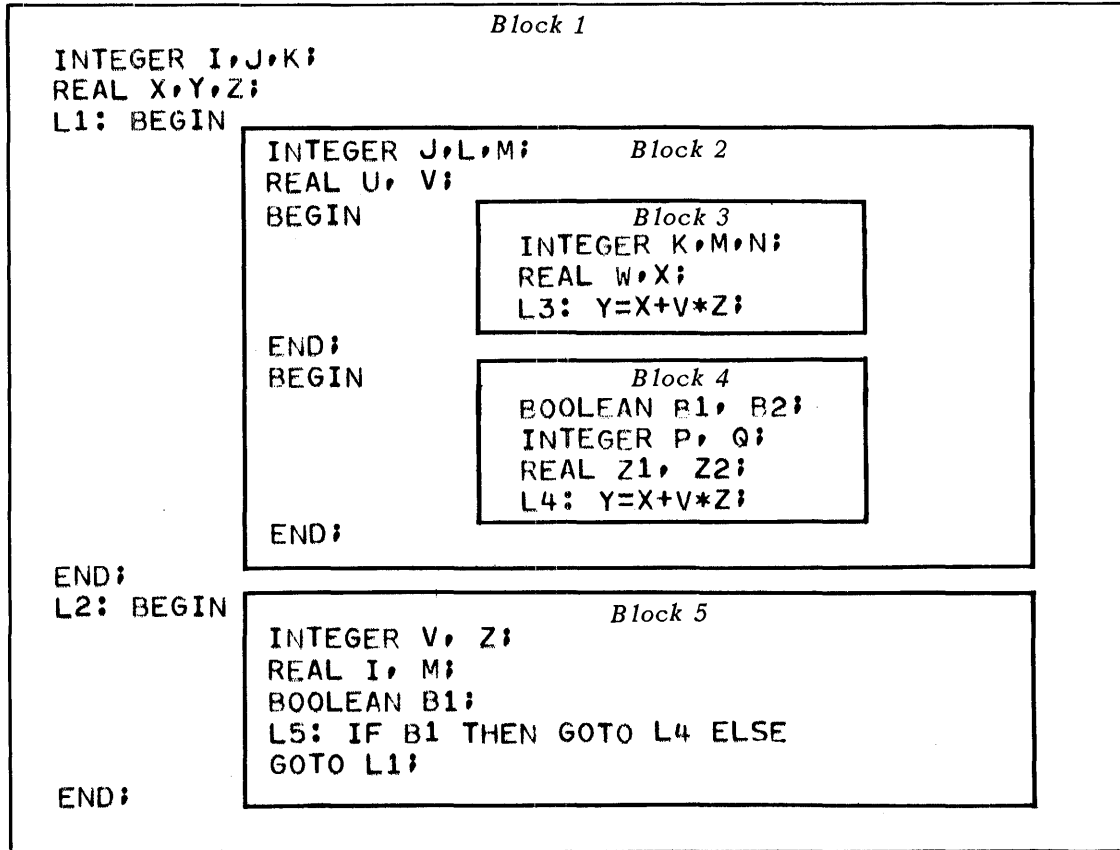
Figure 8-1. Local and Global Identifiers

9. INPUT/OUTPUT

9.1. GENERAL

Input and output operations are accomplished in UNIVAC 1108 ALGOL by means of library procedures. The two main ones, READ and WRITE, are more flexible than ordinary procedures written in ALGOL because the number of parameters in an actual call or even the order of the parameters is not rigidly specified. The general form of I/O call is:

<I/O procedure> (<device>, <format identifier> , <modifier list> , <parameter list> , <actual label list>)

where <I/O procedure> is **READ** or **WRITE**;

    < device > specifies the external medium;

    <format identifier> is the name of the format specifying output editing or card layout for input;

    <modifier list> specifies parameters whose action is to output markers in the information which later may be used for positioning;

    <parameter list> is a list of I/O variables and expressions;

    <actual label list > specifies where control will be transferred in case of contingencies.

The two other important I/O procedures, POSITION and REWIND, are concerned exclusively with magnetic tape and tape-simulated drum operations.

9.2. FREE-FORMAT OUTPUT ON PRINTER AND CARD PUNCH

Arrays and values of expressions can be printed by simply calling the WRITE procedure in the following way:

    WRITE(PRINTER, $v_1, v_2, \ldots, v_n$)

where each v_i is an expression or an array identifier. In a similar manner, if the output is to be punched, the call is:

    WRITE(PUNCH, $v_1, v_2, \ldots, v_n$)

PRINTER and PUNCH are device names which specify the output unit to be used. If no device is named, PRINTER is assumed:

    WRITE($v_1, v_2, \ldots, v_n$)

In the following description the word 'print' v is used in discussing the action of WRITE, but the word 'punch' may be substituted. Significant differences between the two devices are noted.

The action of WRITE is to evaluate the expressions in the order they are listed in the call and print their values in the following manner: except for string expressions, 10 values are printed on each line (6 per card if punching). Each value occupies a field of 12 character positions or columns. If the actual parameter is an array it is decomposed by columns. Each occurrence of WRITE begins printing on a new line.

Examples:

```
REAL ARRAY A(1:10) $

  .
  .
WRITE(PRINTER,A)$
```

acts the same as

```
WRITE(PRINTER,A(1),A(2),....,A(10))
```

For multidimensional arrays the decomposition is such that the leftmost subscript varies most frequently. Thus the sequence

```
BOOLEAN ARRAY A(1:2,1:2,1:2) $

  .
  .
WRITE(PRINTER,A) $
```

acts like

```
WRITE(PRINTER,A(1,1,1),A(2,1,1),A(1,2,1),A(2,2,1),
              A(1,1,2),A(2,1,2),A(1,2,2),A(2,2,2)) $
```

The expression or array element is printed in a form consistent with its type.

Type	Form
INTEGER	Integer form, right justified in the field. Includes a leading minus if the expression is negative. Leading zeros are not printed.
REAL and **REAL 2**	Both types are printed right justified in the form X.XXXX,±NN, where NN represents the power of ten, preceded by the appropriate sign. A negative number is preceded by a minus sign.
BOOLEAN	Either **TRUE** or **FALSE** is left justified in the field.
COMPLEX	The real and imaginary parts are each given a field as for **REAL**. Thus, only five expressions of type **COMPLEX** can be printed on the same line.

Strings are a slight exception in that they always start a new line. Whenever a string expression occurs as a parameter, the previous expressions, whether their number is a multiple of 10 or not, are printed. Then the string is printed on a new line. The next parameter will be printed on the following line. For example, if A and B are **REAL** and have the values 7.0 and 0.004 respectively, then the statement

```
WRITE('A=',A,'B=',B,'A OVER B',A/B)
```

would produce the following lines on·the printer:

```
A=
  7.0000,  00
B=
  4.0000,-03
A OVER B
  1.7500,  03
```

Example:

```
INTEGER ARRAY A(1:15) $
BOOLEAN ARRAY B(1:2,1:2) $
INTEGER I,J $
 .

 .
FOR I=(1,1,15)DO A(I)=I-3 $
FOR I=(1,1,2) DO FOR J=(1,1,2) DO B(I,J)=I GEQ J $
WRITE('VECTOR A',A,'MATRIX B',B) $
```

produces the following output:

```
VECTOR A

          -2            -1             0            1            2           3
           8             9            10           11           12          13
MATRIX B
TRUE          TRUE          FALSE          TRUE
```

```
      12             12             12            12           12          12
```

9.3. FREE-FORMAT INPUT FROM CARDS

For reading punched cards in free-format mode, the procedure READ is called with device CARDS:

$$READ(CARDS, v_1, v_2, \ldots, v_n)$$

where each v_i is a variable or array identifier. Again, if no device is written, CARDS is assumed:

$$READ(v_1, v_2, \ldots, v_n)$$

This procedure reads the next input card and scans the information on it. Each constant on the card is assigned to the next parameter in the order it appears in the call.

Arrays are handled in the same manner as for WRITE. Constants on the cards must be punched in the same form as they appear in the ALGOL source language (see 2.3) with the exception that a comma(,) may be used in place of the ampersand (&). Constants on a card are delimited by one or more blanks and by the end of the card. Therefore, there is no restriction as to where a constant may appear on the card. If there is not enough information on the first card to satisfy the READ procedure, a second card is read, and so on. Any information not taken from the last card is lost (i.e., the next call to READ reads a new card). An * punched on a card causes the remainder of the card to be ignored. Otherwise, all 80 columns of the card are scanned for information. An example of a call on READ:

```
REAL A,B $
INTEGER COUNTER $
 .
READ(CARDS,A,B,COUNTER) $
```

Data Card

```
-7.2    .099    362236
```

assigns the values −7.2 to A, .099 to B and 362236 to COUNTER. It is not necessary for the type of the constant on the card to match the type of the actual parameter. Transfer functions are used automatically if such functions are defined (see Appendix B).

9.4. LIST PARAMETERS – THE LIST DECLARATION

A LIST declaration associates a set of ordered expressions with a LIST identifier. The identifier used in the expressions must be defined prior to their inclusion in LIST declaration. Thus, the other declarations should precede the LIST declaration.

A LIST may include three kinds of elements:

■ Expressions

■ Array identifiers

■ **FOR** clauses

Example:
```
REAL ARRAY A(1:N,1:N) $
INTEGER I,J $
LIST L1(FOR I=(1,1,N) DO FOR J=(1,1,N) DO A(I,J)) $
 .
 .
 .
READ(L1)$
WRITE(L1) $
```

This example uses the same LIST for both input and output. Expressions in a list which are to be within the scope of the **FOR** statement are surrounded by parentheses and not by a **BEGIN-END** pair.

Another example utilizing LIST:

```
REAL X,XY $
INTEGER WIDDLE $
BOOLEAN ARRAY Q (1:10) $
STRING BEAN (36*5) $
INTEGER I $
LIST L(1.0,X,XY,FOR I=(1,1,5)DO(Q(I),BEAN(36*(I-1)+1,36)),
     SQRT(WIDDLE**3)) $
```

The **LIST** L defines the following sequence of expressions:

```
1.0 X XY Q(1)  BEAN(1,36) Q(2) BEAN(37,36) Q(3) BEAN(73,36)
Q(4) BEAN(109,36) Q(5) BEAN(145,36) SQRT(WIDDLE**3)
```

Besides being allowable as parameters to **READ** and **WRITE**, lists may also be used as parameters to **MAX** and **MIN**. All of the elements in the list are treated as call-by-name parameters and are not evaluated until they are referenced.

One precaution is required when using a **LIST**. Do not use a list containing an iteration variable within the scope of an outer iteration using the same variable as in the following:

```
INTEGER I $
ARRAY ARGGGHA (1:10) $
LIST LISP(FOR I=10 STEP -1 UNTIL 1 DO ARGGGHA(I)) $
.
FOR I=(1,2,47)DO
BEGIN
      .
      .
      WRITE (LISP) $
      .
END $
```

In this case the value of I would be changed in the course of the write statement causing an infinite loop.

9.5. FORMATTED OUTPUT – THE **FORMAT** DECLARATION

It is often desirable to print or punch information in a specific manner rather than to accept the positioning automatically provided by the WRITE procedure.

The **FORMAT** declaration, which is included with the other declarations at the beginning of the block, provides a means of specifying how a printed page (or punched card) is to be formatted. A format is a set of specifications that can be interpreted by the I/O procedures to control the editing of information. The format takes this form:

FORMAT < identifier> (<format specifications>)

The following lines specify two formats, FEIN and FTWAIN:

```
FORMAT FEIN(X10,D7.2,X5,R17.8,A1.1),
       FTWAIN(B6,S10,I5,X2,T14.9,A3,E)$
```

A single format identifier may be included as a parameter in a call on WRITE, but its position in the call does not matter. For example, the two following calls in WRITE are equivalent.

```
REAL A,B $
  •
  •
WRITE(PRINTER,FEIN,A,B)$
WRITE(A,B,FEIN)$
```

A format specification consists of a series of editing and/or nonediting codes separated by commas. An editing code corresponds to a value to be printed and specifies how the value is to be edited. A nonediting code controls printing, spacing or insertion of blanks or constants into the print line. The action of WRITE, when a format is being used, is to pair each output expression with its corresponding editing code in the format. Nonediting codes are executed as they are encountered.

9.5.1. Nonediting Codes

In nonediting codes listed below, s and t are unsigned integers and w indicates the number of character positions. Two conventions are that As is the same as As.0 and A is the same as A0.0. For phases that require a t, both s and t must be less than 64.

FORMAT CODE		ACTION(PRINTER)	ACTION(PUNCH)
As.t	Activate	Prints the line just edited. Skip s lines before printing and t lines after.	Punches the edited line into a card. s and t are ignored.
Es	Eject	Ejects the page to logical line s-1 if s-1 is below margin on current page. The next line to be printed, if it specifies A1.t, prints on line s. If s-1 is on the current page and is below the current line, Es skips to s-1 and the page is not ejected.	Ignored
Xw	Expunge	Skips the next w character positions (i.e., inserts w blanks in the line).	Same
'< any string not containing a '>'	Insert literal	Inserts the string enclosed in quotes into the line.	Same

Table 9-1. Output Nonediting Codes

9.5.2. Editing Codes

The editing codes are the same for both printing and punching. Each code acts on
one value to be printed. The w specifies the field width (that is, the total number
of character positions to be used in the editing, including signs, decimal points and
comma). If w is too small to do the proper numeric editing, two asterisks are printed
and the value is edited according to R12.5. Any editing done beyond the edge of the
output medium (132 or 128 columns on the printer, 80 columns on the card punch) is
lost. The d is interpreted differently for different codes. In format codes that use no
d (as Sw), w must be smaller than 4096. In codes that include d, w must be enough
larger than d to include at least the decimal point, a sign, and the exponent with its
sign if there is one.

FORMAT CODE		ACTION
Bw	Boolean	Prints **TRUE** or **FALSE** in the field, left justified. If the field is too short as much as possible is printed, e.g., B1 results in T or F.
Dw.d	Decimal	Prints a decimal number with d places after the decimal point, right justified in the field, and with a leading minus sign if negative.
Iw.d	Integer	Prints an integer number right justified in the field with a leading minus sign if negative. The integer is printed to the base d where d=0 and d=10 are equivalent. In the latter cases the .d can be omitted. Range of d: $2 \leq d \leq 10$.
Rw.d	Real	Prints d significant digits of a **REAL** or **REAL 2** variable in the form X.X. . . . . X, NN for **REAL** or X.X. . . . .X, NNN for **REAL 2**. A leading minus is printed if the number is negative. If the power of ten, NN or NNN, is negative it is preceded by a minus sign. Note that **w** must always exceed **d** by 6 or more (7 or more for **REAL 2**) to allow for ±., ±NN or ±., ±NNN.
Sw	String	Prints the first w characters of a string left justified in the field. If the string is shorter than w characters, the rest of the field is space filled.
Tw.d	Truncated	Prints a number with a decimal point right justified in the field. Only the first d significant digits are printed; a leading minus sign is printed if negative.

Table 9—2. Output Editing Codes

The type of the actual parameter is transferred to the type demanded by the editing
code in any case for which there are transfer functions defined. A complex number
is edited using two successive editing codes, the first for the real part and the
second for the imaginary part.

The following examples illustrate the use of various editing codes:

```
REAL A,B $
FORMAT F1(X2,D7.2,X5,R17.8,A1.1) $
.
.
.
A=72.474 $
B=-.12345678 $
WRITE(F1,A,B) $
```

The above coding would print A and B as follows:


```
F1 (X2, D7.2 X5, R17.8, A1.1) $
                                    1 blank line
ΔΔΔΔ72.47ΔΔΔΔΔΔΔΔΔ-1.2345678,-01
                                    1 blank line
```

If F1 above were
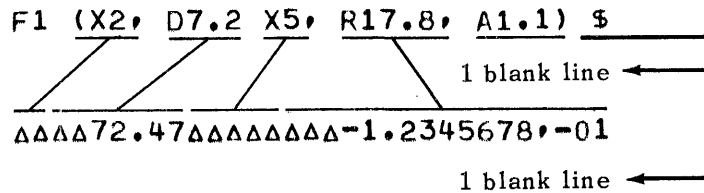

```
F1('A=', D7.2, X5, 'B=', R17.8, A2.1)
then the printout would be              2 blank lines
A=ΔΔ72.47ΔΔΔΔΔB=ΔΔΔ-1.2345678,-01
                                        1 blank line
```
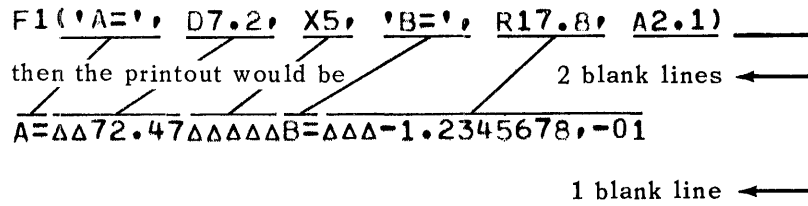
To compare the three real codes D, R and T, suppose

```
REAL A $
FORMAT OK(D10.4,R10.4,T10.4,A1) $
A=0.001107 $
WRITE(A,A,A,OK) $
```

The printed line would then be as indicated below:


```
OK (D10.4, R10.4, T10.4, A1) $
                              1 blank line
ΔΔΔΔΔ.0011Δ1.107,-03ΔΔΔ.001107
```
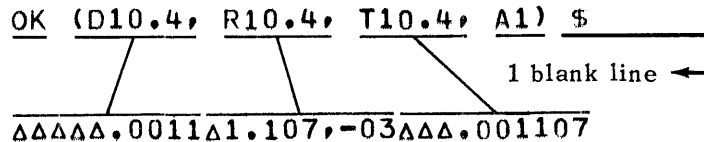
9.5.3. Repetition of Editing Codes

A single editing code (or a group of editing codes) can be used a number of times without actually repeating the code itself in the format statement. Three different methods can be used:

■ Simple repetition — used when the number of repetitions required is known.

■ Variable repetition — used when the number of repetitions depends on data.

■ Indefinite repetition — used when the number of repetitions is indeterminate.

9.5.3.1. Simple Repetition

An editing code may be repeated by prefixing it with an unsigned nonzero integer constant which specifies how many times that code is to be repeated.

Example:

```
FORMAT F1(R16.8,R16.8,R16.8,A1)
```

is equivalent to

```
FORMAT F1(3R16.8,A1)
```

It is also possible to repeat a group of editing codes by enclosing them in parentheses and preceding this parenthetical group with an unsigned nonzero integer constant indicating the number of repetitions of the group. There is no limit to the depth of nesting, editing codes or groups of codes.

Given the declaration

```
BOOLEAN ARRAY BOOL(1:7,-1:4) %
```

the following format would permit printing the array elements with only one row per line

```
FORMAT FORM (7(6B7,A1)) %
```

9.5.3.2. Variable Repetition

A second type of repetition is the variable repeat. Instead of an integer, an arithmetic expression or Boolean expression enclosed in colons specifies the number of repeats. The Boolean values **TRUE** and **FALSE** are equivalent to one and zero, respectively.

Example:

```
INTEGER ARRAY A(1:N,1:M) %
FORMAT F(:N:(:M:(R16.8),A1))
```

would print the array one row per line (so M should be less than 9). The expression (N or M) is evaluated every time the variable repeat is encountered during the format scan. If N or M have a value of zero or less, the group of format codes under control of that repeat expression is skipped. Note that in this type of repetition, the codes to be repeated must be enclosed in parentheses even if there is only one such code.

9.5.3.3. Indefinite Repetition

A final variant of editing code repetition is the indefinite or unlimited repeat. This is accomplished by enclosing a group of format codes in parentheses without preceding this parenthetical expression with an integer constant. The innermost parenthetical group that is not preceded by an integer constant is unlimited and will be used repeatedly until the output list is exhausted.

Given:

```
FORMAT ONANDON (E1,'VECTOR B',A1,(D7.2,A1)) $

REAL 2 ARRAY B(1:M) $
```

then

```
WRITE(B,ONANDON) $
```

will produce the following on a new page

```
VECTOR B

XXXX.XX
XXXX.XX
XXXX.XX
XXXX.XX
```

As an extension of this feature note that the parentheses surrounding an entire format are indefinite repeats. If there are more values to print upon reaching the end of the format string the whole format is repeated. Writing stops when the two following conditions are satisfied: there are no more values to be edited, and the right parenthesis of an indefinite repeat is encountered. Any editing code encountered when there is nothing more to be edited is treated as Xw. Nonediting codes are honored.

Example:

```
REAL A,B $
FORMAT Z(5D7.2,A2.3,'ABOVE IS DEBUG 1',A1) $
A = 17.00 $
B = -18.00 $
WRITE (A,A/2,B,B/2,Z) $
```

produces

```
ΔΔ17.00ΔΔΔ8.50Δ-18.00ΔΔ-9.00

ABOVE IS DEBUG 1
```

A common error to watch for is the omission of an activation code within an indefinite repeat (or within a format declaration in general):

```
FORMAT QTE(F,(8R16.8),A1.2)
```

would skip to the top of the next page but would not print anything. This error could be corrected as follows:

FORMAT QTE(E,(8R16.8,A1,2))

In this format, E is equivalent to E0 which has the effect of skipping to the bottom line of the current page. E0 followed by A1 will print on the top line of the next page.

Format codes to the right of an indefinite repeat or unlimited group can never be reached. The following output format:

FORMAT FORM9(X5,I5,D10.3,A1,(I5,4D10.3,A1),X10,I5,A1,2) $

used with a WRITE statement will cause the first two values to be printed according to I5 and D10.3. Since the inner parenthetical group is not preceded by an integer, printing will continue according to specifications within the parentheses until the output list is exhausted. The last three codes will never be reached.

The following example illustrates how versatile formats and lists can be. It prints an (N,M) array in a real format:

```
@ALG,SIT         TEST,TEST
CYCLE  000       COMPILED BY   1c03   0005   ON 04/19/68 AT 10:37:43
       S1        L1
       1         INTEGER M, N, I1, I2, I, J $
       2         REAL R $
       3         REAL ARRAY A(1:50,1:50) $
       4         FORMAT ALL(X11,:ENTIER(MIN(I1+9,N))-I1+1: ('COL',I3,X6),A1,:M:('ROW',I3,
       5                   :ENTIER(MIN(I1+9,N))-I1+1:(R12.5),A1),A2) $
       6         LIST HAIR (FOR I1=(1,10,N) DO (FOR I2=(I1,1,MIN(I1+9,N)) DO I2,
       7                    FOR J=(1,1,M) DO (J, FOR I2=(I1,1,MIN(I1+9,N)) DO A(I2,J))))$
       8            R  = 0.0$
       9            M  = 24$
       10           N  = 18$
       11           FOR I = (1,1,N) DO
       12           FOR J = (1,1,M) DO
       B1
       13              BEGIN
       14                 R = R + 1.0 $
       15                 A(I,J) = R
       E1
       16              END $
       17              WRITE (ALL,HAIR) $
START COMPLIATION TIME IS    10:37:42
END COMPLIATION PHASE 1      10:37:43
END COMPLIATION PHASE 2      10:37:43
       F1
COMPILATION COMPLETE
```

The WRITE statement using format ALL and list HAIR has the effect of printing the elements of a real array by rows with ten elements per line. The output has this form:

WXOT TEST

	COL 1	COL 2	COL 3	COL 4	COL 5	COL 6	COL 7	COL 8	COL 9	COL 10
ROW 1	1.0000,+00	2.5000,+01	4.9000,+01	7.3000,+01	9.7000,+01	1.2100,+02	1.4500,+02	1.6900,+02	1.9300,+02	2.1700,+02
ROW 2	2.0000,+00	2.6000,+01	5.0000,+01	7.4000,+01	9.8000,+01	1.2200,+02	1.4600,+02	1.7000,+02	1.9400,+02	2.1800,+02
ROW 3	3.0000,+00	2.7000,+01	5.1000,+01	7.5000,+01	9.9000,+01	1.2300,+02	1.4700,+02	1.7100,+02	1.9500,+02	2.1900,+02
ROW 4	4.0000,+00	2.8000,+01	5.2000,+01	7.6000,+01	1.0000,+02	1.2400,+02	1.4800,+02	1.7200,+02	1.9600,+02	2.2000,+02
ROW 5	5.0000,+00	2.9000,+01	5.3000,+01	7.7000,+01	1.0100,+02	1.2500,+02	1.4900,+02	1.7300,+02	1.9700,+02	2.2100,+02
ROW 6	6.0000,+00	3.0000,+01	5.4000,+01	7.8000,+01	1.0200,+02	1.2600,+02	1.5000,+02	1.7400,+02	1.9800,+02	2.2200,+02
ROW 7	7.0000,+00	3.1000,+01	5.5000,+01	7.9000,+01	1.0300,+02	1.2700,+02	1.5100,+02	1.7500,+02	1.9900,+02	2.2300,+02
ROW 8	8.0000,+00	3.2000,+01	5.6000,+01	8.0000,+01	1.0400,+02	1.2800,+02	1.5200,+02	1.7600,+02	2.0000,+02	2.2400,+02
ROW 9	9.0000,+00	3.3000,+01	5.7000,+01	8.1000,+01	1.0500,+02	1.2900,+02	1.5300,+02	1.7700,+02	2.0100,+02	2.2500,+02
ROW 10	1.0000,+01	3.4000,+01	5.8000,+01	8.2000,+01	1.0600,+02	1.3000,+02	1.5400,+02	1.7800,+02	2.0200,+02	2.2600,+02
ROW 11	1.1000,+01	3.5000,+01	5.9000,+01	8.3000,+01	1.0700,+02	1.3100,+02	1.5500,+02	1.7900,+02	2.0300,+02	2.2700,+02
ROW 12	1.2000,+01	3.6000,+01	6.0000,+01	8.4000,+01	1.0800,+02	1.3200,+02	1.5600,+02	1.8000,+02	2.0400,+02	2.2800,+02
ROW 13	1.3000,+01	3.7000,+01	6.1000,+01	8.5000,+01	1.0900,+02	1.3300,+02	1.5700,+02	1.8100,+02	2.0500,+02	2.2900,+02
ROW 14	1.4000,+01	3.8000,+01	6.2000,+01	8.6000,+01	1.1000,+02	1.3400,+02	1.5800,+02	1.8200,+02	2.0600,+02	2.3000,+02
ROW 15	1.5000,+01	3.9000,+01	6.3000,+01	8.7000,+01	1.1100,+02	1.3500,+02	1.5900,+02	1.8300,+02	2.0700,+02	2.3100,+02
ROW 16	1.6000,+01	4.0000,+01	6.4000,+01	8.8000,+01	1.1200,+02	1.3600,+02	1.6000,+02	1.8400,+02	2.0800,+02	2.3200,+02
ROW 17	1.7000,+01	4.1000,+01	6.5000,+01	8.9000,+01	1.1300,+02	1.3700,+02	1.6100,+02	1.8500,+02	2.0900,+02	2.3300,+02
ROW 18	1.8000,+01	4.2000,+01	6.6000,+01	9.0000,+01	1.1400,+02	1.3800,+02	1.6200,+02	1.8600,+02	2.1000,+02	2.3400,+02
ROW 19	1.9000,+01	4.3000,+01	6.7000,+01	9.1000,+01	1.1500,+02	1.3900,+02	1.6300,+02	1.8700,+02	2.1100,+02	2.3500,+02
ROW 20	2.0000,+01	4.4000,+01	6.8000,+01	9.2000,+01	1.1600,+02	1.4000,+02	1.6400,+02	1.8800,+02	2.1200,+02	2.3600,+02
ROW 21	2.1000,+01	4.5000,+01	6.9000,+01	9.3000,+01	1.1700,+02	1.4100,+02	1.6500,+02	1.8900,+02	2.1300,+02	2.3700,+02
ROW 22	2.2000,+01	4.6000,+01	7.0000,+01	9.4000,+01	1.1800,+02	1.4200,+02	1.6600,+02	1.9000,+02	2.1400,+02	2.3800,+02
ROW 23	2.3000,+01	4.7000,+01	7.1000,+01	9.5000,+01	1.1900,+02	1.4300,+02	1.6700,+02	1.9100,+02	2.1500,+02	2.3900,+02
ROW 24	2.4000,+01	4.8000,+01	7.2000,+01	9.6000,+01	1.2000,+02	1.4400,+02	1.6800,+02	1.9200,+02	2.1600,+02	2.4000,+02

	COL 11	COL 12	COL 13	COL 14	COL 15	COL 16	COL 17	COL 18
ROW 1	2.4100,+02	2.6500,+02	2.8900,+02	3.1300,+02	3.3700,+02	3.6100,+02	3.8500,+02	4.0900,+02
ROW 2	2.4200,+02	2.6600,+02	2.9000,+02	3.1400,+02	3.3800,+02	3.6200,+02	3.8600,+02	4.1000,+02
ROW 3	2.4300,+02	2.6700,+02	2.9100,+02	3.1500,+02	3.3900,+02	3.6300,+02	3.8700,+02	4.1100,+02
ROW 4	2.4400,+02	2.6800,+02	2.9200,+02	3.1600,+02	3.4000,+02	3.6400,+02	3.8800,+02	4.1200,+02
ROW 5	2.4500,+02	2.6900,+02	2.9300,+02	3.1700,+02	3.4100,+02	3.6500,+02	3.8900,+02	4.1300,+02
ROW 6	2.4600,+02	2.7000,+02	2.9400,+02	3.1800,+02	3.4200,+02	3.6600,+02	3.9000,+02	4.1400,+02
ROW 7	2.4700,+02	2.7100,+02	2.9500,+02	3.1900,+02	3.4300,+02	3.6700,+02	3.9100,+02	4.1500,+02
ROW 8	2.4800,+02	2.7200,+02	2.9600,+02	3.2000,+02	3.4400,+02	3.6800,+02	3.9200,+02	4.1600,+02
ROW 9	2.4900,+02	2.7300,+02	2.9700,+02	3.2100,+02	3.4500,+02	3.6900,+02	3.9300,+02	4.1700,+02
ROW 10	2.5000,+02	2.7400,+02	2.9800,+02	3.2200,+02	3.4600,+02	3.7000,+02	3.9400,+02	4.1800,+02
ROW 11	2.5100,+02	2.7500,+02	2.9900,+02	3.2300,+02	3.4700,+02	3.7100,+02	3.9500,+02	4.1900,+02
ROW 12	2.5200,+02	2.7600,+02	3.0000,+02	3.2400,+02	3.4800,+02	3.7200,+02	3.9600,+02	4.2000,+02
ROW 13	2.5300,+02	2.7700,+02	3.0100,+02	3.2500,+02	3.4900,+02	3.7300,+02	3.9700,+02	4.2100,+02
ROW 14	2.5400,+02	2.7800,+02	3.0200,+02	3.2600,+02	3.5000,+02	3.7400,+02	3.9800,+02	4.2200,+02
ROW 15	2.5500,+02	2.7900,+02	3.0300,+02	3.2700,+02	3.5100,+02	3.7500,+02	3.9900,+02	4.2300,+02
ROW 16	2.5600,+02	2.8000,+02	3.0400,+02	3.2800,+02	3.5200,+02	3.7600,+02	4.0000,+02	4.2400,+02
ROW 17	2.5700,+02	2.8100,+02	3.0500,+02	3.2900,+02	3.5300,+02	3.7700,+02	4.0100,+02	4.2500,+02
ROW 18	2.5800,+02	2.8200,+02	3.0600,+02	3.3000,+02	3.5400,+02	3.7800,+02	4.0200,+02	4.2600,+02
ROW 19	2.5900,+02	2.8300,+02	3.0700,+02	3.3100,+02	3.5500,+02	3.7900,+02	4.0300,+02	4.2700,+02
ROW 20	2.6000,+02	2.8400,+02	3.0800,+02	3.3200,+02	3.5600,+02	3.8000,+02	4.0400,+02	4.2800,+02
ROW 21	2.6100,+02	2.8500,+02	3.0900,+02	3.3300,+02	3.5700,+02	3.8100,+02	4.0500,+02	4.2900,+02
ROW 22	2.6200,+02	2.8600,+02	3.1000,+02	3.3400,+02	3.5800,+02	3.8200,+02	4.0600,+02	4.3000,+02
ROW 23	2.6300,+02	2.8700,+02	3.1100,+02	3.3500,+02	3.5900,+02	3.8300,+02	4.0700,+02	4.3100,+02
ROW 24	2.6400,+02	2.8800,+02	3.1200,+02	3.3600,+02	3.6000,+02	3.8400,+02	4.0800,+02	4.3200,+02

EXIT EXEC8 ALGOL LIBRARY

9.6. FORMATTED INPUT

As with writing, a format may be included as a parameter to the READ procedure. A format tells how the card is laid out. The major advantage in using formats is that constants need no longer be delimited by blanks, and strings need not be enclosed in string quotes — the format specifies the 'fields' in which information lies. The discussion that follows is based on an example designed to illustrate most of the fundamentals of reading formatted cards.

The format declaration is the same as described in 9.5. The difference between a format being used as a parameter to WRITE and one being used as a parameter to READ is that the editing and nonediting codes are interpreted slightly differently. However, they are enough alike that in many cases the same format may be used with both procedures.

The following example illustrates reading data from cards according to a specified format. The information pertains to student records with each card having the following format:

Column	Contents
1–5	Student number
6–7	Student initials
8–21	Student name
22	Status
23–24	Curriculum
38–44	Course name
47	Credit hours
60	Letter grade

The problem is to read the above data in a form that will make the manipulations easy and permit printing all the information. It is this type of problem which gives rise to the necessity of specifying the card format. The steps necessary to achieve this result are:

(1) Read a card

(2) Accept columns 1–5 as an integer   Student number

(3) Accept columns 6–7 as a string   Student initials

(4) Accept columns 8–21 as a string   Student name

(5) Accept column 22 as an integer   Status

(6) Accept columns 23–24 as an integer   Curriculum

(7) Skip the next 13 columns

(8) Accept columns 38–44 as a string   Course name

(9) Skip 2 columns

(10) Accept column 47 as an integer   Credit hours

(11) Skip 12 columns

(12) Accept column 60 as a string   Grade

The **FORMAT** declaration can be used to take care of all the above functions. For example, the format could be

FORMAT VAYDREI(A,I5,S2,S14,I1,I2,X13,S7,X2,I1,X12,S1)$

Note there is one entry in the format for each numbered line above. Each of the items in the above format is referred to as a 'format code'. Of course, the initial A is analogous to the terminal AS.t of the write and is required to activate the subsequent **READ** procedure.

A reasonable program segment for the above problem would be:

INTEGER STUDNO,STATI,CURCI,CREDS $
STRING INITIALS(2),NAME(14),COURSE(7),GRADE(1) $
FORMAT VAYDREI(A,I5,S2,S14,I1,I2,X13,S7,X2,I1,X12,S1) $
LIST FRIEDRICH(STUDNO,INITIALS,NAME,STATI,CURCI,
        COURSE,CREDS,GRADE) $
        READ(CARDS,FRIEDRICH,VAYDREI) $

Only two nonediting codes are permitted with an input format:

    A   activation code — required as the first code of the format to activate the subsequent READ procedure.

    Xw   — skip over w columns on the card

The editing codes (some of which are not in the example) have the following meanings, and w and d are restricted as before (see 9.5).

FORMAT CODE		ACTION
Bw	Boolean	Accepts Boolean information from the field — either **TRUE, FALSE,** or 1, 0.
Dw.d	Real	Accepts real information from the field. If the number is already real, (i.e., has a decimal point or exponent part) then that determines the decimal. Otherwise, a decimal point is inserted d places to the left of the right edge of the field.
Fw	Free	Accepts an unspecified number of values from the field. These numbers must be punched in free format mode; that is, values may be punched any where within w character positions.
Iw.d	Integer	Accepts information from the field as being integer to the base d. d=0 is equivalent to d=10.
Rw.d	Real	Same as Dw.d
Sw	String	Accepts the whole field as a string.
Tw.d	Real	Same as Dw.d

Table 9-3. Input Editing Codes

9.7. FILE HANDLING

The general form of I/O call is:

< I/O Procedure > (< device > , < format > , < modifier list > , < parameter list >, < actual label list>)

Where

< I/O Procedure > is   either   **READ** or **WRITE**
< device > is   CARD, PRINTER, PUNCH, FILE (filename, location),

APRINTER or APUNCH

< modifier list > see section 9.8.2.1
is a list of all of the I/O variables of lists
< actual label list> see section 9.8.3

When the device is FILE the above call takes either of two forms:

Sequential files

< IO Procedure> (File(filename), < modifier list > , < parameter list>,
< actual label list >)

Random Files

< IO Procedure> (FILE(filename, location), < modifier list > , < parameter list > ,
< actual label list >)

In these forms < filename > is the internal name of the file. According to system requirements, the name must be at most 12 characters long, left justified, and space-filled. If the string is less than 12 characters long, the compiler supplies trailing blanks.

< location > is an integer specifying the location relative to the beginning of the file at which the I/O operation is to begin.

The I/O operation is unformatted whenever the device is FILE. In case of doubt concerning allowable operations on files, and for information concerning the assignment and use of files, see the "UNIVAC 1108 Executive Programmers Reference Manual", UP-4144 (current version). The ALGOL linkages permit the user complete access to the file handling capabilities of the 1108 Executive.

To simulate magnetic tape on other devices, such as drum or FASTRAND, all files can be handled as sequential access storage devices that can be parameters to **REWIND** and **POSITION** statements (see 9.8).

If a non-existent file is referenced, the compiler assigns a temporary FASTRAND mass storage file to that name. Since the information in a sequential file is written out in blocks containing various extra words that specify information about the block, one should be careful about accessing the same file both randomly and sequentially.

9.7.1. Sequential Files

If the device name **FILE** is followed by only one parameter, then the file is treated as if it were a sequential file. Information in such files is stored in blocks of 252 words or less. The format of these blocks is:
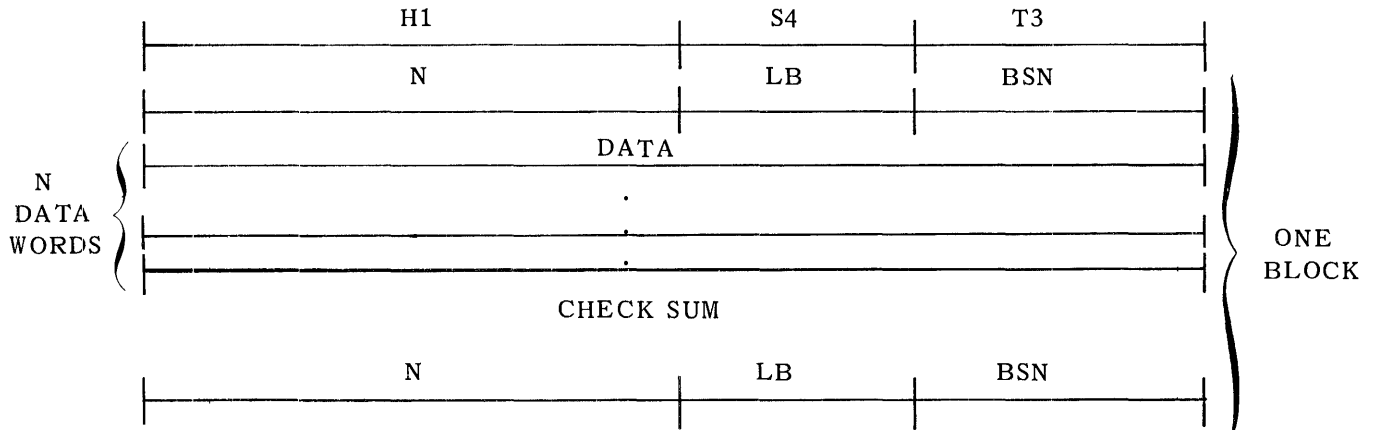
N   — number of words in block. Must be 249 words or less.
LB   — last block flag.
     = 0 for not last block.
     = 1 for last block.
BSN — block sequence number in logical record.

The **WRITE** statement writes one logical record. Information is packed in blocks with all but the last block containing 249 words of data. The last block (LB flag = 1) may contain less than 252 words. One logical record is the information written out by one write statement.

The **READ** procedure reads blocks of data from the device until all of the variables have been filled. All information in the last logical record read which is not used by that **READ** is lost, i.e., the next call on READ starts reading the following logical record.

See Section 9.8 for operations on sequential files.

9.7.2. Random Access Files

If the device name **FILE** is followed by two parameters, the first one is the name of the file, as before. The second is the location relative to the beginning of the file at which this READ or WRITE operation is to begin in the file.

Magnetic tape files cannot be referenced randomly. Integer, real and BOOLEAN variables take one word per variable. Real 2 and complex variables occupy two words. Strings are always left-justified in the first word in which they are written. Thus an N-character string occupies ENTIER$(N + 5)/6$ words. No descriptor is written out with any of the information, so it is not difficult to determine how many words any block of information will occupy.

9.7.3. Alternate Symbionts

The 1108 Executive allows the user to define print and punch files other than the standard two. Information is these files is written out when the output device is free. In particular, the file will be written out at the end of the run. To use this ability from ALGOL, specify device **APUNCH** or **APRINTER** with one parameter. This parameter is the internal name of the file to which the information is to be written pending output. If the file is a tape file, the output will not be written out automatically. This operation must be initiated by the appropriate Executive control statement.

9.8. OTHER DIRECTIVES

REWIND and **POSITION** operations are useful in manipulation of files. In addition supplementary marks can be made on a file in order to facilitate access to information.

9.8.1. REWIND

The form of the **REWIND** statement is:

REWIND ($<$file list$>_1$, **INTERLOCK,** $<$ file list $>_2$)

where either $<$ file list $>$ may be empty. If $<$ file list $>_1$ is empty then **INTERLOCK** should be left out.

This statement rewinds all of the files in $<$ file list $>_1$ with interlock or if they are temporary non-tape files, it releases them. All of the files in $<$ file list $>_2$ are rewound without interlock.

9.8.2. Modifiers and **POSITION**

9.8.2.1. Modifiers

A modifier list may be provided as a parameter to **WRITE**. This list may contain either EOF ($<$ expression $>$) or KEY ($<$ expression$>$) or both. Note that EOF and KEY mean the same thing as EOF (0) and KEY (0). If the modifier list contains KEY, then a KEY record is written *preceding* the usual record written out. If it contains EOF, then an EOF record is written *after* the usual record.

If $<$ expression $>$ is a string, the first six characters identify the record. The modifier EOI may also be used, in which case an end-of-information mark is written out after the usual record and EOF block.

9.8.2.2. POSITION

The procedure **POSITION** positions a file to a previously written KEY or EOF record, to the end of information, or advance it over a given number of ordinary records. The call is:

POSITION(FILE(filename), < position parameter> , < label list>)

where the position parameter is:

EOF   (<expression>)

—EOF (<expression>)

KEY   (<expression>)

—KEY (<expression>)

integer expression

EOI

—EOI

The direction of positioning is indicated by the sign of the position parameter, positive for forward and negative for backward. If the position parameter is EOI, the file is positioned to the next EOI mark. If the position parameter is an integer expression, the command advances over that many logical records ignoring KEY records.

Key records are also ignored when encountered by a READ statement. Abnormal exits from the **POSITION** procedure are listed in section 9.8.3.

The procedure **POSITION** always positions over the record it is looking for in the direction indicated.

9.8.3. Labels

In many of the I/O operations unexpected situations may be encountered. In order to inform the user of their existence and to enable him to recover, several label parameters may be supplied to the procedure. These are used as alternate exits in abnormal situations. If more labels are provided than are expected, the procedure will respond with an *Improper Parameter* message.

9.8.3.1. POSITION Procedure

At most two parameters are allowed. The following defines the exits that occur in various situations:

Parameter to **POSITION**	Condition	Exit to
EOF	End of Information	First Label
KEY	End of Information	First Label
integer expression	EOF Record	First Label
	End of Information	Second Label

If only one label is given, all exits to the second label go to the first. If no label is given, exit is made normally, that is to the next ALGOL statement.

9.8.3.2. **READ** Procedure

Control cards are identified by a master space (a 7–8 punch) in column 1. Except for the EOF control card, these cards are not read by an ALGOL program. However, the programmer can detect them by using labels as parameters to the **READ** procedure. In that case, if an attempt is made to read such a card, the **READ** procedure terminates reading and exits to the given label.

When an EOF card is encountered by the **READ** procedure, reading terminates. No new values are assigned to the remaining parameters in the input list. If a label is present as a parameter, the exit is made to that label. Otherwise, exit is made to the next ALGOL statement. The next time the **READ** procedure is called, it begins by reading the card after the EOF card. Thus, the purpose of EOF is to give the programmer a convenient method of separating sections of data of unknown length.

If a control card other than an EOF card is encountered, no more data cards can be read for that run.

At most three labels may be supplied as parameters to READ. If only one is specified all exits to the second label will be made to the first. If no third label is specified the program terminates upon encountering a situation that would require exiting to the third label.

The editing of the READ procedure is controlled in the following way, depending on the number of labels in the READ call:

DEVICE	CONDITION	EXIT TO LABEL NO.	NO LABEL
CARD	**EOF** Card	1	normal return
	any other control card	2	program terminated
	error in read	3	program terminated
FILE	**EOF** record	1	normal exit
	end of information	2	normal exit
	error in read	3	program terminated

Example:

```
BEGIN ARRAY A(1:20)$
LOCAL LABEL OK,FIN $
  •
  •
  •
WEED:READ(CARDS,A,OK,FIN)  $
  •
  •
  •
OK: WRITE ('EOF - CARD READER')  $ GO TO WEED $
FIN: WRITE('PROGRAM TERMINATED BY CONTROL CARD')  $
END $
```

9.8.3.3. WRITE Procedure

Only one label is allowed as a parameter to **WRITE**. Exit is made to this label if an attempt is made to write past the physical end of the FILE.

9.8.3.4. MARGIN Procedure

The procedure **MARGIN** provides the ALGOL user the means for controlling the form of the output of the PRINT symbiont (See "1108 Executive Programmer's Reference Manual" UP-4144). The form of the call on MARGIN is:

MARGIN(<control string>)

where <control string> is a string containing one or more control functions.

Spaces are ignored prior to the first, or between functions. Each function begins with a single letter, followed by a comma, followed by any special information required, and terminated by a period. The format of the information character string varies according to the function but must not contain a period.

The following control functions are allowed:

L — Space printer to logical line *nn*, where logical line is defined as the line number relative to the top margin setting (see M below). All line positioning and printing is performed within the defined margin settings. (The bottom logical line of a page is identical to the top logical line −1 of the next page.) Positioning to a logical line on printers with space-print operation is to logical line n − 1; therefore when n = 1, the logical line setting is the last line of the current page. This is also true when n = 0, or when n is greater than the length of the logical page. When n is less than or equal to the current line of the current page, the succeeding page is positioned to the logical line n − 1. The format of this function is:

     L,nn,

H — Initiate heading printing. This function provides the user with an automatic means of printing a heading on each succeeding page of his print file. The format of this function is:

     H, option, page #, text of heading

If the option field contains the letter X, a page and date will not be printed as part of the heading. Option n turns the heading off. A page count is maintained by the processing symbiont. When the *page #* field is blank, the page count current to the field is used to begin page numbering. When coded, *page #* is made the page number. In addition to the page number, the current date is included in the heading, and both will appear in the upper right corner of each page. This position of the heading is the second line above logical line 1. If the upper margin is one line or non-existent, no heading is printed. As many as 17 words of heading text may be supplied.

M — Set margins. This function supplies the information for re-adjusting page length and top and bottom margins. The standard print page definition is 66 lines per page with a top margin setting of six lines, and a bottom margin setting of three lines. Note that the top and bottom margins refer to the number of blank lines at the top and bottom of the page respectively. Thus the standard margin setting is 66,6,3 giving 57 printable lines. This page definition is assumed at the beginning of each print file. When the M function is used, a page alignment procedure is initiated with the page length parameter. This function is also used to return to the standard page length. The format of this function is:

M, length, top, botton

W — Set maximum line width. The standard of 22 words (132 characters) is assumed unless the W control is used. The format of the function is:

W, width

where *width* specifies the maximum line width in words.

S — Special form request. This function enables the user to instruct the operator to load a special form required to process the print or punch file. The format of this function is:

S, message text

where the *message text* can be up to ten words long. When this function is encountered by the processing symbiont, the message is displayed on the operator's console in the form:

run ID/filename c/u options
    message text

The user's message text is displayed on the line following the symbiont message. The options available to the operator for answering the message depend on the symbiont. The following options are included in the 0755 HSP, Card Punch and the 1004 Printer and Card Punch symbionts:

A — Begin processing the output file.

Q — Return file to symbiont queue. The print or punch file will be passed temporarily and placed behind the next file of this symbiont queue.

10. OPERATION

10.1. SOURCE CARD FORMAT

The source language statements to the compiler must come initially from punched cards. Only columns 1–72 are read for information in free format and anything following column 72 is considered to be a (space) delimiter. Columns 73–80 can be used for any purpose desired, e.g., short comments or serial identification. There is no restriction on placing statements on a card but the usual practice is to arrange them for easy reading and modification. The full 80 columns may be utilized for input data at execution time.

10.2. OPERATING INSTRUCTIONS

The ALGOL compiler operates like all the processors in the UNIVAC 1108 Executive System and, besides the standard options, includes some unique to itself. The available options are:

A   Accept the results of compilation even if errors were detected.

S   Single spaced listing of ALGOL source statements.

L   The compiled assembly language instructions are listed along with the source code.

N   (or lack of any other print option) Suppress all printing by the processor. If 'N', disregard any other print option.

T   Print the timing for phases 1 and 2 of compilation.

X   Abort the run immediately if any error is found.

Z   Delete the formation of run-time diagnostic information.

O,R   References to subscripted variables normally generate a call to a library procedure. This procedure, besides calculating the proper address, also checks that the requested operation is legal (i.e., that the subscript variables are in the range of the declaration). With the R option (remove checking) this checking is not done but the address calculation is, thus giving greater speed to the object program. The O option (open) is even faster in that the necessary coding to calculate the address is compiled in line, thus removing the call and return times from the reference. Of course, the O option requires more main storage. When the program is working, and if the subscript expressions are not data-dependent, then the R option should be used. If main storage permits, the O option should be used. Neither should be used when the program is being debugged.

APPENDIX A. BASIC SYMBOLS AND THEIR CARD CODES

This appendix lists the basic symbols of UNIVAC 1108 ALGOL 60, with the corresponding symbol for the reference language and the punched card code.

REFERENCE LANGUAGE	UNIVAC 1108 ALGOL 60	CARD CODE *
TRUE	TRUE	
FALSE	FALSE	
+	+	12
−	−	11
x	*	11−4−8
/	/	0−1
÷	//	0−1 0−1
↑	**	11−4−8 11−4−8
<	LSS	
≤	LEQ	
=	EQL	
≥	GEQ	
>	GTR	
≠	NEQ	
≡	EQIV	
⊃	IMPL	
∨	OR	
∧	AND	
¬	NOT	
go to	GO TO or GOTO	
if	IF	
then	THEN	
else	ELSE	
for	FOR	
do	DO	
, (comma)	, (comma)	0−3−8
.	.	12−3−8
10	&	2−8

Symbols for which a card code is not specified are reserved identifiers.

REFERENCE LANGUAGE	UNIVAC 1108 ALGOL 60	CARD CODE *
:	: or . .	5–8 or 12–3–8 12–3–8
;	$ or ;	11–3–8 or 11–6–8
: =	= or : =	3–8 or 5–8 3–8
STEP	STEP	
UNTIL	UNTIL	
WHILE	WHILE	
COMMENT	COMMENT	
(	(	0–4–8
)	)	12–4–8
⊏	(or ⊏	0–4–8 or 12–5–8
⊐	) or ⊐	12–4–8 or 11–5–8
' (apostrophe)	' (apostrophe)	4–8
BEGIN	BEGIN	
END	END	
OWN	OWN	
BOOLEAN	BOOLEAN	
INTEGER	INTEGER	
REAL	REAL	
ARRAY	ARRAY	
SWITCH	SWITCH	
PROCEDURE	PROCEDURE	
LABEL	LABEL	
VALUE	VALUE	
	< (for complex	12–6–8
	> constants)	6–8

Symbols for which a card code is not specified are reserved identifiers.

In addition, the following reserved identifiers have been introduced into the language:

LIST
FORMAT
EXTERNAL
OTHERWISE
LOCAL
GO
TO
XOR
STRING
COMPLEX
REAL 2

APPENDIX B. STANDARD PROCEDURES AND TRANSFER FUNCTIONS

The following procedures are available for use without being declared. The names are not reserved identifiers and may be redefined in any block. The * indicates "not applicable"

NAME	NO. OF PARAMETERS	TYPES OF PARAMETERS	RESULT	TYPE OF RESULT
ABS	1	INTEGER REAL REAL 2 COMPLEX	|x| |x| |x| |x|	INTEGER REAL REAL 2 REAL
ALPHABETIC	1	STRING	TRUE if the string consists of all spaces or alphabetics (A–Z); FALSE otherwise	BOOLEAN
ARCCOS	1	REAL REAL 2	Arccos(x) Arccos(x)	REAL REAL 2
ARCSIN	1	REAL REAL 2	Arcsin(x) Arcsin(x)	REAL REAL 2
ARCTAN	1	REAL REAL 2	Arctan(x) Arctan(x)	REAL REAL 2
CARDS	0	*	None	*
CLOCK	0	*	Present time of day in seconds since 00:00	INTEGER
COMPLEX	2	INTEGER, REAL	The complex number $x+i*y$	COMPLEX

NAME	NO. OF PARAMETERS	TYPES OF PARAMETERS	RESULT	TYPE OF RESULT
COS	1	REAL REAL 2 COMPLEX	Cos(x) Cos(x) Cos(x)	REAL REAL 2 COMPLEX
COSH	1	REAL REAL 2 COMPLEX	Cosh(x) Cosh(x) Cosh(x)	REAL REAL 2 COMPLEX
DOUBLE	1	INTEGER, REAL	Real 2 representation of x	REAL 2
DRUM	1	INTEGER	None	*
ENTIER	1	REAL, REAL 2	Integer part of x	INTEGER
EOF	0 or 1	Any expression	None	*
EOI	0	*	None	*
EXP	1	REAL REAL 2 COMPLEX	Exp(x) Exp(x) Exp(x)	REAL REAL 2 COMPLEX
IMAGINARY	1	COMPLEX	Imaginary part of x	REAL
INTEGER	1	REAL, REAL 2	Entier (x+0.5)	INTEGER
KEY	0 or 1	Any expression	None	*
LENGTH	1	STRING	Length of string	INTEGER
LN	1	REAL REAL 2 COMPLEX	Ln(x) Ln(x) Ln(x)	REAL REAL 2 COMPLEX
MARGIN	3 or 4	INTEGER first 3	(see section 9)	*
MAX	List of expressions	REAL, INTEGER	Algebraic largest element of list	REAL
MIN	List of expressions	REAL, INTEGER	Algebraic smallest element of list	REAL

NAME	NO. OF PARAMETERS	TYPES OF PARAMETERS	RESULT	TYPE OF RESULT
MOD	2	INTEGER	x(mod y)	INTEGER
NUMERIC	1	STRING	TRUE if the string is acceptable to the string-integer transfer function; FALSE otherwise	BOOLEAN
POSITION	Special list			*
PRINTER	0	*	None	*
PUNCH	0	*	None	*
RANK	1	STRING	The fieldata equivalent of the first character of the string	INTEGER
READ	Special list			*
REAL	1	INTEGER, REAL 2 COMPLEX	Real representation of x Real part of x	REAL REAL
REWIND	Special list			*
SIGN	1	INTEGER	1 x > 0 0 x = 0 -1 x < 0	INTEGER
SIN	1	REAL REAL 2 COMPLEX	Sin(x) Sin(x) Sin(x)	REAL REAL 2 COMPLEX

NAME	NO. OF PARAMETERS	TYPES OF PARAMETERS	RESULT	TYPE OF RESULT
SINH	1	REAL REAL 2 COMPLEX	Sinh(x) Sinh(x) Sinh(x)	REAL REAL 2 COMPLEX
SQRT	1	REAL REAL 2 COMPLEX	Sqrt(x) Sqrt(x) Sqrt(x)	REAL REAL 2 COMPLEX
TAN	1	REAL REAL 2 COMPLEX	Tan(x) Tan(x) Tan(x)	REAL REAL 2 COMPLEX
TANH	1	REAL REAL 2 COMPLEX	Tanh(x) Tanh(x) Tanh(x)	REAL REAL 2 COMPLEX
TAPE	1	INTEGER	None	*
WRITE	Special list	*	*	*

The following transfer functions transfer an expression of one type to another type. These functions are evoked automatically by the compiler whenever necessary. Functions for which the arguments are listed may be called explicitly.

FUNCTION	TYPE OF ARGUMENT	TRANSFERRED TO TYPE
REAL(X) DOUBLE(X) (intrinsic) COMPLEX(REAL(X),0)	INTEGER	REAL REAL 2 STRING COMPLEX
INTEGER(X) DOUBLE(X) COMPLEX(X,0) INTEGER(X)	REAL REAL 2	INTEGER REAL 2 COMPLEX INTEGER
REAL(X) COMPLEX(REAL(X),0) (intrinsic)	STRING	REAL COMPLEX INTEGER

APPENDIX C. ERROR MESSAGES

C1. COMPILATION ERRORS

The following is a list of error messages that can occur during compilation with an explanation of what may be the cause of an error. An * is printed under the approximate location of the offending syntax, but in some cases this may not be of help; for example, a missing left parenthesis is not found until the whole statement has been scanned. Spurious error messages may be printed for particularly malformed programs. These usually disappear after the first few errors have been eliminated.

ERROR	EXPLANATION
Illegal character pair	Self explanatory
Constant too large	Self explanatory
Improper block structure	A declaration has occured other than at the head of a block
Improper declaration	An element in the identifier list is not an identifier
Duplicate declaration/specification	A name in the identifier list has already been defined in this block
Improper declaration /specification	The identifier list is malformed
Improper specification	OWN, LOCAL, or EXTERNAL has been used in a procedure specification part
Improper specification	The name is not a formal parameter
Improper own declaration	OWN not followed by INTEGER, REAL, REAL2, COMPLEX, ARRAY
Improper external declaration	EXTERNAL not followed by <type>, FORTRAN, NONRECURSIVE or PROCEDURE
Duplicate value specification	The parameter has already been specified as value
Improper label specification	It does not occur in a specification part of a procedure
Improper value specification	It does not occur in a procedure specification part
Improper array declaration	Bound pairs malformed
Improper array declaration	Bound pairs either not separated by a comma or a : missing

ERROR	EXPLANATION
Improper list declaration	A malformed list
Improper switch declaration	Malformed switch list
Improper switch declaration	The '=' is missing
Improper procedure declaration	The next symbol after the procedure name is not a (or $
Improper procedure parameter	A formal parameter is not an identifier
Duplicate procedure parameter	There is another formal parameter of this name already
Improper parameter delimiter	The parameter delimiter is neither a comma nor) <letter string> : (
Improper procedure specification	This parameter has been named in a value specification
Improper label definition	A numeric or other malformed label
Duplicate label definition	Self explanatory
Improper format phrase	The w or d field is too large
Improper format phrase	A string field has more than 132 char.
Improper format phrase	An extra)
Improper repeat phrase	A zero repeat phrase
Improper repeat phrase	A noninteger expression as a variable repeat phrase
Undefined format symbol	Self explanatory
Improper string declaration	Expression for length is malformed
Improper string array declaration	Either length expression or subscript pairs are malformed
Improper procedure call	Incorrect number of arguments for library procedure
Improper procedure call	Arguments for library procedure are of incorrect type
Improper procedure assignment	Self explanatory
Improper IF statement	Malformed conditional statement
Improper IF statement	Self explanatory
Improper use of THEN	Self explanatory
Improper use of ELSE	Self explanatory

ERROR	EXPLANATION
Improper FOR statement	Malformed FOR list
Improper GO statement	GO not followed by a designational expression
Improper GO statement	A malformed designational expression
Extra right parenthesis	Self explanatory
Extra left parenthesis	Self explanatory
Missing operator	Implied multiplication has been used
Missing operator	Self explanatory
Missing operand	Self explanatory
Extra END	Self explanatory
Missing END	Self explanatory
Improper use of //operator	One or both operands are not integer
Improper assignment statement	The left-hand side is not a variable
Undefined transfer function	The transfer function called for by this statement is not defined
Improper use of a list identifier	List used in other than a procedure call
Improper use of label	A label appears out of context
Improper use of a reserved identifier	Reserved identifier appears out of context
Improper use of an array identifier	Array identifier appears out of context
Undefined relational operand	Self explanatory
Improper string expression	Malformed string expression
Misplaced semicolon	A semicolon ($) appears out of context
Misplaced comma	A comma appears out of context
Undefined variable	Reference is made to an undeclared variable
Misplaced colon	A colon appears out of context
Improper correction	Correction card out of order
Compiler capacity exceeded	Internal tables of compiler exceeded

C2. RUN-TIME ERRORS

An error during execution results in the printing of an error message, the name of the library procedure involved, if applicable, and the line number of the ALGOL program at which execution was currently taking place. The program is then terminated. The following is the list of the possible error messages.

ERROR	EXPLANATION
Incorrect number of arguments	Incorrect number of arguments to an ALGOL or library procedure
Memory capacity exceeded	Space for dynamic storage of variables has been exceeded
Bad input/checksum error	Tape or drum hardware error, or possibly an attempt to read a non-ALGOL formatted tape
Undefined type conversion	Self explanatory
Insufficient data for program	Non-EOF control card read with no exit label in READ call
Improper parameter	A formal and actual parameter do not agree in either type or kind
Improper array declaration	A lower bound expression is greater than the corresponding upper bound expression
Improper string declaration	The string length is negative or greater than 4095
Unrecoverable tape/drum error	Hardware fault
Attempt to pass end of record	Record is shorter than the input list
Constant out of range	Self explanatory
Characteristic overflow	A real number of magnitude greater than 10^{38} generated
Attempted division by zero	Self explanatory
Improper number of dimensions	Reference to a subscripted variable has a different number of subscript positions than was declared for the array
Subscript out of range	Subscript expression is out of the range of the declaration
Result undefined	Arithmetic library function not defined for argument
Argument out of range	Argument out of range for a meaningful result for an arithmetic library procedure
Illegal character	Data card has an illegal character
Illegal format phrase	Self explanatory

APPENDIX D. EXAMPLES OF PROGRAMS

This appendix contains some simple examples illustrating the use of UNIVAC 1108 ALGOL 60. Each has been run on the 1108 and some sample input and results are shown.

```
BEGIN
COMMENT                        EXAMPLE 1
          CALCULATION OF VALUE OF ARITHMETIC EXPRESSION
          WITH READ IN VARIABLES $
REAL      A,B,C  $
INTEGER   TOILL $
     READ (CARDS,A,B,C) $
     TOILL = A+B**C/A $
     WRITE (PRINTER,A,B,C,TOILL) $

DATA

5 6.2 1.222

RESULTS:

5.0000,+00   6.2000,+00   1.2220,+00      7
```

```
BEGIN
COMMENT                        EXAMPLE 2
          CALCULATION OF SQUAREROOT, B, OF A REAL NUMBER,
          A, WITH 6 DIGITS ACCURACY BY NEWTON-RAPHSON ITERATION $
REAL      A,B,OLDB $
     READ (CARDS,A) $
     OLDB = 1.0 $
     FOR B = 0.5*(A/OLDB+OLDB) WHILE ABS(B-OLDB) GTR 10**(-6)*B DO
          OLDB = B $
     WRITE (PRINTER,A,B) $
END PROGRAM $

DATA

5.77777

RESULTS:

5.7778,+00 2.4037,+00
```

```
BEGIN
COMMENT                     EXAMPLE 3
        VALUE OF A POLYNOMIAL Y=B(0)+B(1)*X........ +B(N)*X**N    $
REAL     X,Y $
INTEGER  K,N $
   READ (CARDS,N) $
COMMENT DEGREE OF POLYNOMIAL READ FROM CARDS. INNER BLOCK PERFORMS
        READING OF COEFFICIENTS AND CALCULATIONS AND PRINTING OF
        RESULTS $
   BEGIN
   REAL ARRAY B(0:N) $
      READ (CARDS,B) $
      READ (CARDS,X) $
      Y = B(N) $
      FOR K=N-1 STEP -1 UNTIL 0 DO Y = Y*X+B(K) $
      WRITE (PRINTER,'VALUE OF A POLYNOMIAL OF DEGREE','N=',N,
         'COEFFICIENTS',B,'X=',X,'Y=',Y) $
   END CALCULATION $
END PROGRAM $

DATA

4
1.223 3.5 7.52 -4.02 -33.5
5.55
```

RESULTS:

```
VALUE OF A POLYNOMIAL OF DEGREE
N=
            4

COEFFICIENTS

   1.2230,+00   3.5000,+00   7.5200,+00  -4.0200,+00  -3.3500,+01
X=
   5.5500,+00
Y=
  -3.2220,+04
```

```
BEGIN
COMMENT                      EXAMPLE 4
          PROGRAM WITH A REAL PROCEDURE, BIG, WHICH FINDS THE LARGEST
          OF THE N LOWER-INDEXED ELEMENTS (STARTING WITH INDEX=1) OF A
          ONE-DIMENSIONAL ARRAY, A, WITH POSITIVE ELEMENTS $
     REAL PROCEDURE BIG(N,A) $
     VALUE N $
     INTEGER N $
     REAL ARRAY A $
     BEGIN
        INTEGER B $
        REAL  C,D $
        B = 1 $
        D = A(1) $
L:      C = D - A(B+1) $
        IF C LSS 0 THEN D = A(B+1) $
        B = B+1 $
        IF B LSS N THEN GO TO L $
        BIG = D $
     END BIG $
REAL ARRAY F(1:50) $
REAL H,K $
 READ (CARDS,F) $
COMMENT  CALL OF BIG TO FIND THE LARGEST OF THE 20 LOWER
ELEMENTS OF F $ H = BIG(20,F) $
 WRITE (PRINTER,H) $
COMMENT  LARGEST ELEMENT IN F $
 K = BIG(50,F) $
COMMENT  USE OF BIG IN MORE COMPLEX EXPRESSION $
 H = H + BIG(10,F)/K*BIG(15,F) $
 WRITE (PRINTER,H,K) $
END PROGRAM $

DATA

1.22 3.55 1 22.2 0.5 7.2 8.12 21.4 4.1 22.5 0.422
55.2 0.12345 5.88 3.55 7.53 4 5 2 3 1 77 5 22.1
5.1 2.3 3.2 4.2 9.85 8.99 5.66 66 44 11 2 44.7
55.12 44.1 2.89 7.521 8.56 5.42 4.88 6.789 5.423
7.1234 9.753 8.741 5 6

RESULTS:

5.5200,+01
7.1330,+01 7.7000,+01
```

Example 5. Newton's Method of Successive Approximations
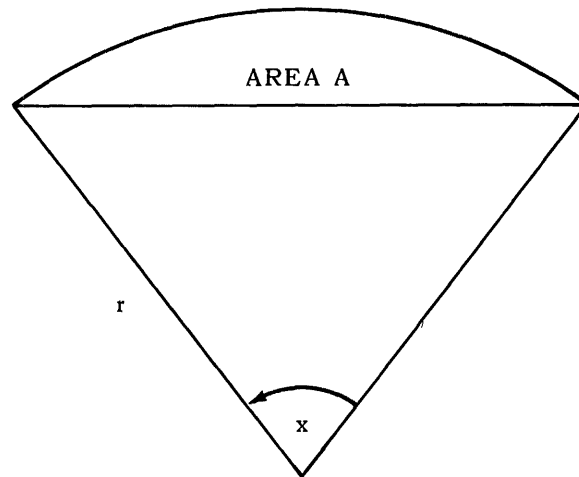
Given: An area A defined by a circular arc of radius r and its chord.

Required: Find the value of angle x subtended by the arc.

Solution: The relationship between A and x is:

$$A = \frac{r^2}{2} (x - \sin x)$$

Like many practical problems, this one has no analytic solution. However, methods have been developed to find approximate solutions to such problems. The method to be used here is called Newton's Method. If the solution x to

$$f(x) = 0$$

is to be found, then a sequence of values approximating the solution x is given by

$$x_{n+1} = x_n - f(x_n)/f'(x_n).$$

For this problem

$$f(x_n) = (1/2)r^2(x_n - \sin x_n) - A$$

and

$$f'(x_n) = (1/2)r^2(1 - \cos x_n).$$

Therefore, using elementary algebra, the approximation scheme is

$$x_{n+1} = x_n - \frac{x_n - \sin x_n - 2A/r^2}{1 - \cos x_n}$$

This equation is solved repeatedly, each time with the previous value of x_{n+1} substituted for x_n to compute a new value for x_{n+1}. The second term of the equation is the difference between successive approximations.

When this difference becomes less than some specified value, the sequence of approximations is said to have converged to a solution. The iteration procedure is then terminated and the problem is considered solved.

Practical considerations place a limitation on the number of iterations permitted. If the sequence of approximations does not converge within a prescribed number of iterations, the procedure is terminated and the approximate solution is rejected.

The conditions used in this example are:

Area = 1.5

Radius = 5.0

The first approximation is $x_1 = 1.0$. The iteration procedure is then performed for a maximum of nine iterations. If the successive approximations differ by less than 0.00001, then the sequence of approximations is considered convergent. The iteration procedure is then terminated and the sequence of approximations and differences is printed out in the form of a table. Otherwise, the program is terminated with no output.

The following identifiers in the program represent the corresponding physical quantities:

AREA   Area enclosed by chord and arc (A)

RADIUS   Radius of circle (r)

ANGLE   Approximation to the angle x

CHANGE   Difference between successive approximations

SMALL   Criterion for convergence

G   For convenience, the quantity $2A/r^2$

The program is as follows:

```
BEGIN
    COMMENT                          EXAMPLE 5
                SAMPLE PROGRAM USING UNIVAC 1108 ALGOL $
    REAL AREA, RADIUS, SMALL, G $
    INTEGER I, K $
    REAL ARRAY ANGLE(1:10), CHANGE(1:9) $
    FORMAT F10(X9,'ITERATION',X5,'ANGLE',X9,'CHANGE',A1.1),
           F11(X13,I1,D15.6,D14.5,A1),
           F12(X9,'THE ITERATION PROCEDURE HAS CONVERGED',A1) $
    COMMENT SET UP VALUES TO BE USED IN PROBLEM $
      AREA = 1.5 $
      RADIUS = 5.0 $
      SMALL = 1.0&-5 $
      G = (2.0*AREA)/(RADIUS**2) $
    COMMENT  BEGIN ITERATION LOOP -- MAXIMUM OF 9 ITERATIONS $
      ANGLE(1) = 1.0 $
      FOR I = 1 STEP 1 UNTIL 9 DO
        BEGIN
        COMMENT COMPUTE CHANGE IN APPROXIMATE SOLUTION $
          CHANGE(I) = (ANGLE(I)-SIN(ANGLE(I))-G)/(1.0-COS(ANGLE(I))) $
        COMMENT TEST FOR CONVERGENCE OF APPROXIMATE SOLUTION $
          IF ABS(CHANGE(I)) LSS SMALL THEN GO TO L110 $
        COMMENT APPROXIMATION HAS NOT CONVERGED - COMPUTE NEXT
                APPROXIMATION $
          ANGLE(I+1) = ANGLE(I) - CHANGE(I)
        END $
    COMMENT  END OF LOOP - ITERATION PROCEDURE HAS NOT CONVERGED $
      GO TO FIN $
    COMMENT  THE ITERATION PROCEDURE HAS CONVERGED $
L110: WRITE (PRINTER,F10) $
      WRITE (PRINTER,F11, FOR K=1 STEP 1 UNTIL I DO
            (K,ANGLE(K),CHANGE(K))) $
      WRITE (F12) $
    FIN:
END OF PROGRAM $
```

Note that a completely blank card gives a blank line in print.

The sample gave the following result:

ITERATION	ANGLE	CHANGE
1	1.000000	.08381
2	.916186	.00742
3	.908770	.00006
4	.908714	.00000

THE ITERATION PROCEDURE HAS CONVERGED

This is in excellent agreement with the theory.

APPENDIX E. JENSEN'S DEVICE AND INDIRECT RECURSIVITY

The purpose of this section is to acquaint the reader with two interesting programming techniques, namely Jensen's Device and Indirect Recursivity. A thorough treatment of the recursive concept may be found in "The Use of Recursive Procedures in ALGOL 60", H. Rutishauser *The Anual Review in Automatic Programming*, Pergamon Press, London, 1963.

Jensen's Device comprises the use of two parameters in a procedure call, in which one is a function of the other. Neither may be a value parameter.

The following example is a method of evaluating an approximation to the definite integral of a function by means of Simpson's Rule over one interval. The algorithm may be written:

```
REAL PROCEDURE SIMPS (X,ARITH, A, B) $
VALUE A,B $ REAL X, ARITH, A,B $
BEGIN REAL FA, FM, FB $
    X=A $ FA=ARITH $ X=B $ FB=ARITH $
    X=(B-A)/2 $ FM=ARITH $
    SIMPS=(B-A)*(FA+4*FM+FB)/6
END SIMPSON INTEGRATION $
```

In a call of SIMPS, ARITH may be any arithmetic expression. Jensen's Device refers to the case when ARITH is a function of X. For example, the call:

```
I=SIMPS(Z,EXP(Z*Z), 0.0, 1.0)
```

would cause ARITH to be replaced by EXP(Z*Z) in the running program. This call evaluates an approximation to the integral

$$\int_0^1 e^{z^2}\, dz$$

In evaluating an approximation to the double integral

$$\int_0^1 \int_0^1 e^{xy}\, dy\, dx$$

indirect recursivity may be used by making the parameter corresponding to ARITH a call to SIMPS itself, thus

```
I=SIMPS(X,SIMPS(Y,EXP(X*Y), 0.0, 1.0), 0.0, 1.0)
```

More material may be found in: E.W. Dijkstra, *A Primer of ALGOL 60 Programming, Bound Variables*, Academic Press, London, 1962, pp. 57-59.

APPENDIX G. SYNTAX CHARTS

G1. GENERAL

This appendix summarizes the syntax of the UNIVAC 1108 ALGOL 60 compiler in chart form. Charts for the input/output procedures are also included as well as a brief description of possible format specifications.

The use of the charts is very simple and almost self explanatory. The concept being defined is specified in a rectangle at the top of each chart.
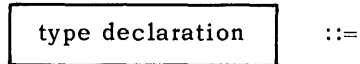
The definition consists of a series of symbols connected by lines indicating the flow of symbols which define the concept. Two kinds of symbols are used: those with round corners (or circles) and those with square corners. The round-cornered boxes contain symbols that stand for themselves. Square-cornered boxes contain names of concepts which are defined elsewhere in the chart and may be found by a quick reference to the Table of Contents for the appendix.

In some places a special "or" symbol has been used to conserve space. It should be understood as follows:
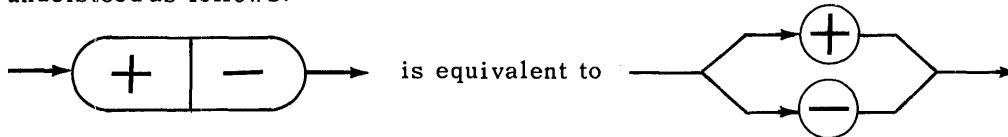
In some sections a pair of letters may mark two spots in a definition. Underneath that section that letter pair followed by a name appears. This means that name will be used in lieu of the string of symbols between the letter pair in other charts.

The charts use only one of the two possible representations for some symbols in ALGOL. The following equivalences should be noted:

Symbol used in this chart	Alternate representation
(	[
)	]
:	..
=	:=
GO TO	GO or GOTO
$	;

In addition, comments may be inserted in the program by means of the following equivalences:

      $ COMMENT \<any sequence not containing a $>$ equivalent to $

      BEGIN COMMENT \<any sequence not containing a $>$ "   " BEGIN

      END \<any sequence not containing END or ELSE or $ >$ "   " END

The charts make no mention of the use of spaces within ALGOL. A space has no meaning in the language (outside of strings) except that it must not appear within numbers, identifiers, or basic symbols, and must be used to separate adjacent symbols composed of letters or digits. Spaces may be used freely to facilitate reading.

G2. | Program | ::=
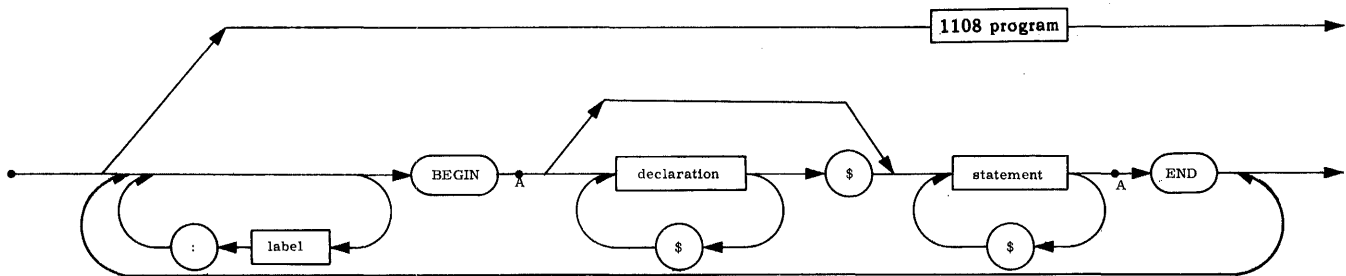
AA: | 1108 program |

Explanation: A program is a complete set of declarations and statements which define an algorithm for solving a problem. The logic of this algorithm (its correctness) is the business of the programmer. The compiler only checks that the syntax (form) is correct.

A UNIVAC 1108 program is simply an ordinary program without the outermost BEGIN-END pair.

Notice that the $ is used to separate declarations and statements and is not inherently a part of a declaration or statement. Nevertheless, it will be shown in most examples for clarity.

G3. Declaration ::=

type declaration

array declaration

string declaration

string array declaration

switch declaration

external procedure declaration

procedure declaration

local declaration

list declaration

format declaration
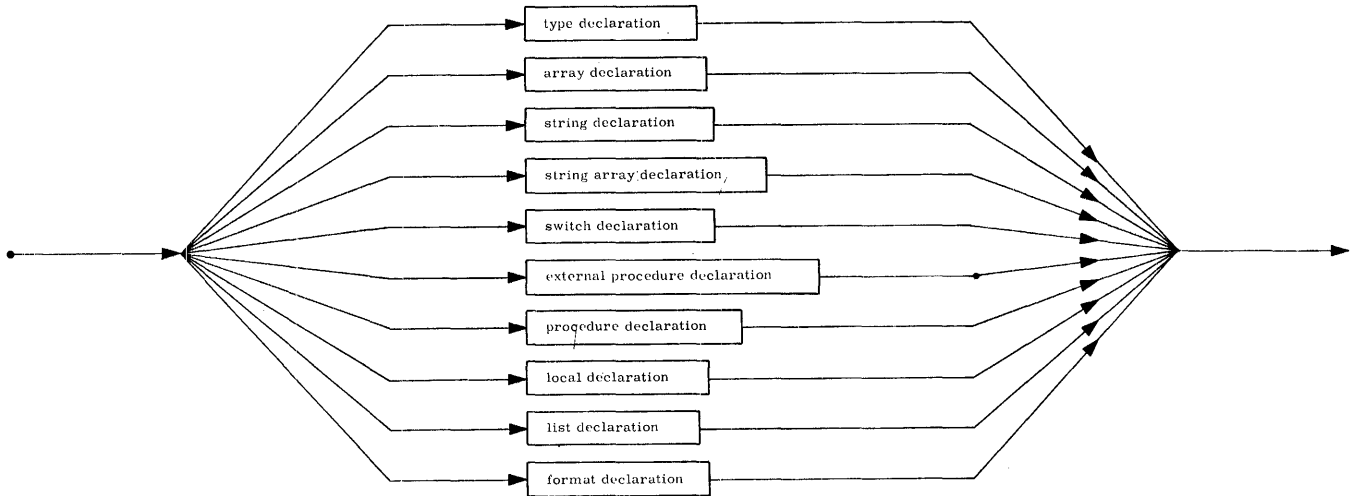
Explanation: There are 10 types of declarations each of which is defined in detail on the following pages.

G3.1. | Type Declaration | ::=
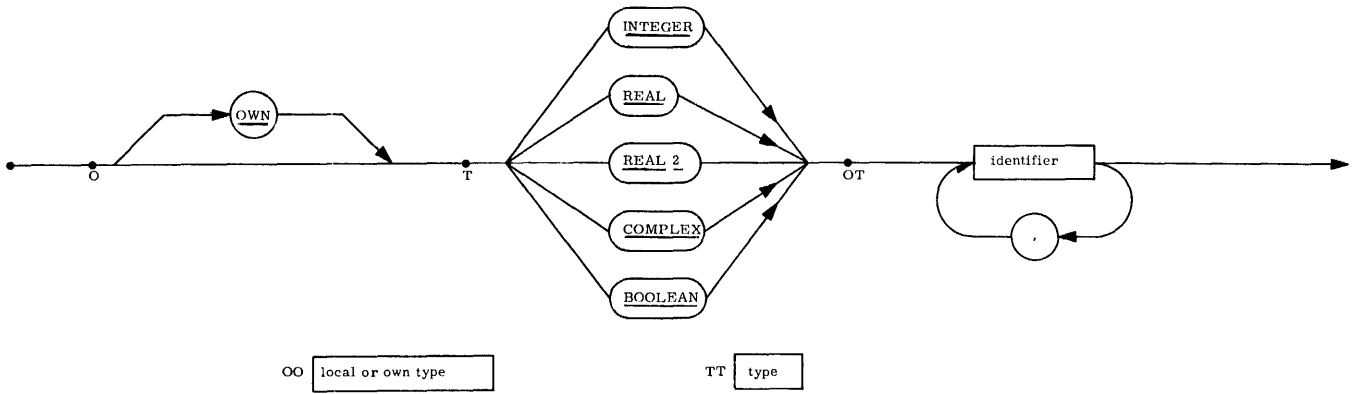
Explanation: A type declaration declares the mode of arithmetic that the following identifiers will assume in the block. Types **REAL** 2 and **COMPLEX** associate two 1108 words with the identifier, the others one. Upon entrance to a block, identifiers are given the value zero, unless they are also declared **OWN**, in which case they have the same value they had on the last exit from the block.

Examples:

```
INTEGER I4,PAK,LOOPCNT $
OWN BOOLEAN ANYLEFT,LASTOUT $
COMPLEX C,CINVS $
REAL 2 DP $
OWN REAL QIN,QOUT,MAXITEM $
```

G3.2. | Array Declaration | ::=
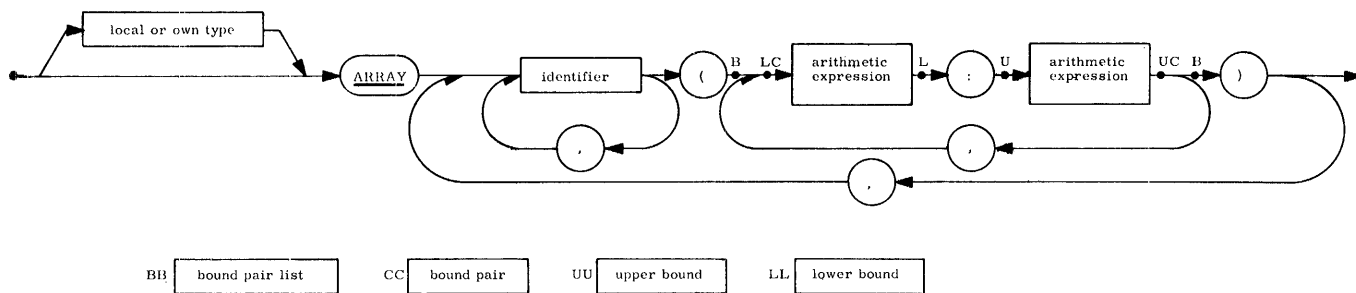
Explanation: An array declaration associates an identifier with a one-dimensional or larger matrix of values. The arithmetic expressions define the lower and upper limits of each dimension. The type plays the same role as for simple variables. If omitted, type **REAL** is assumed.

Examples:

```
COMPLEX ARRAY CCON4 (0:N),CP1(1:N+1) $
BOOLEAN ARRAY BAND,BOR,BXOR(-4:4) $
REAL ARRAY B(I-1:I+1),XINITIAL,YINITIAL(-N:N,-N:N,1:2) $
OWN INTEGER ARRAY I(1:5),J,K,L(ENTIER(X):P112) $
ARRAY XYZ4(1:N*2) $
```

G3.3. | String Declaration | ::=

SS: | substring declaration

LL: | length part
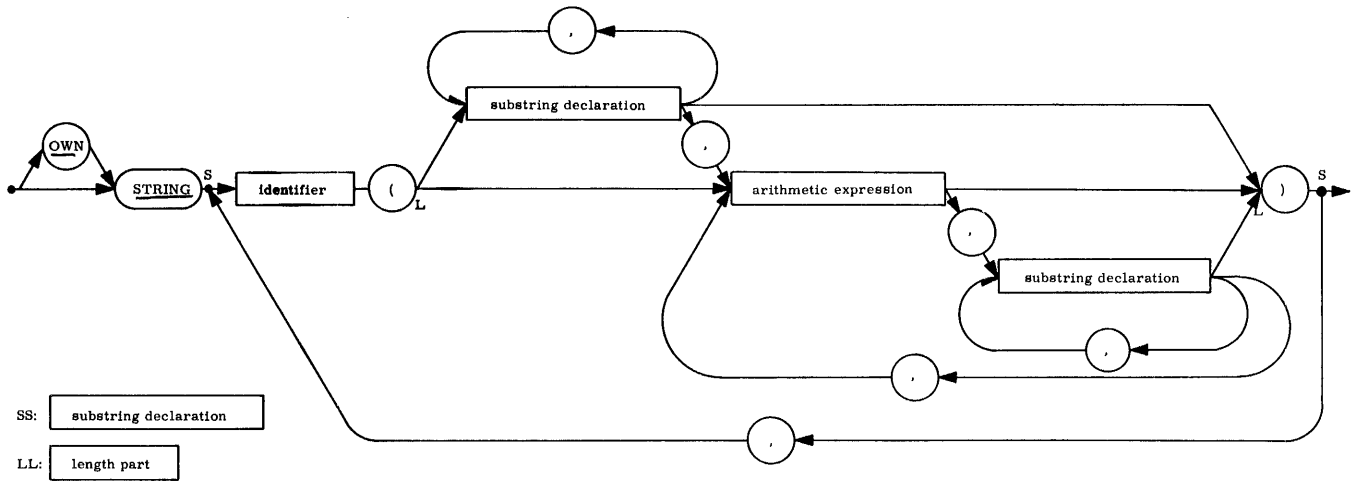
Explanation: A string declaration associates an identifier with a variable whose value is a string of characters. The number of characters in the string must be less than 4096. A group of characters of a string may be named as a substring.

Examples:

```
STRING ST1(36),NAME(INITIALS(2),LAST(16)) $
STRING PI(N+2),QUOTE(1) $
OWN STRING NEXTOUT(80) $
STRING ALPHA(BETA(2,GAMMA(4),2),DELTA(EPSILON(6)),20) $
```

G3.4. | **String Array Declaration** | ::=
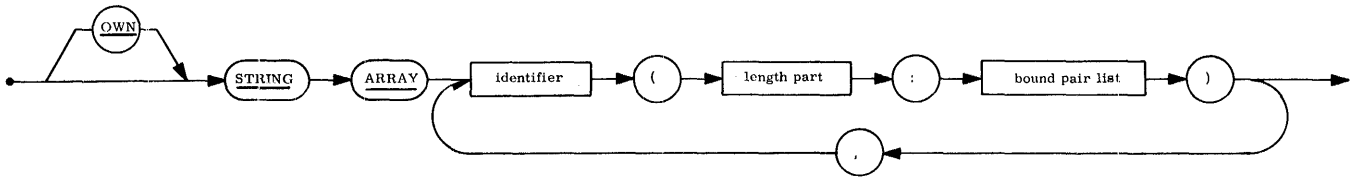
Explanation: A string array is a matrix whose elements are strings. Appended to the length part of the declaration are the bound pairs for each dimension, just as for an ordinary array.

Examples:

```
STRING ARRAY SA(80:0:100),CARD(LABEL(8),OP(6),2,OPERAND(64):1:N) $
OWN STRING ARRAY LASTFILE (CLENGTH:1:507) $
```

G3.5. | Switch Declaration | ::=
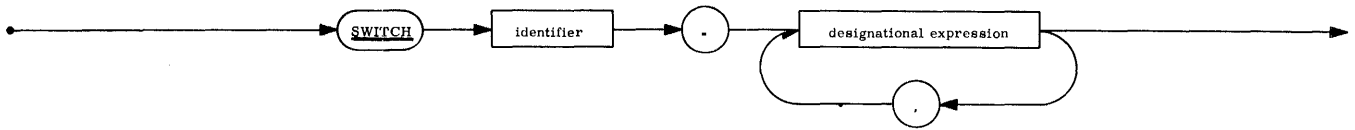
Explanation: A switch declaration associates an identifier with an ordered list of designational expressions. A switch is used to transfer to a label depending on the value of some variable.

Examples:

```
SWITCH JUMP = L1,START,FEIL4,CALC $
SWITCH BRANCH = IF BETA EQL 0 THEN L1 ELSE JUMP(J),START $
```

G3.6. | External Procedure Declaration | ::=
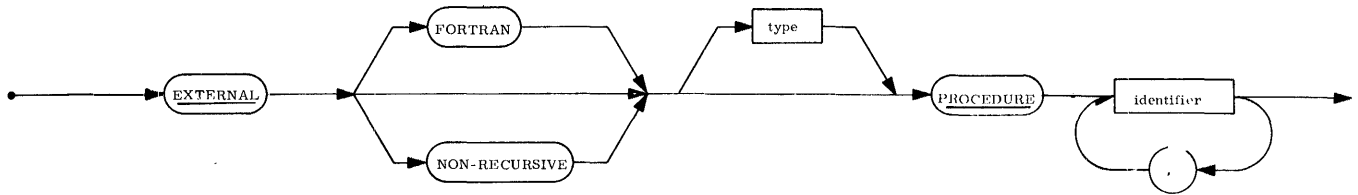
Explanation: This declaration specifies a list of identifiers which are to be the names of procedures not found in the program. These procedures may be written in assembly language (NON-RECURSIVE), FORTRAN or ALGOL. The type of the external procedures is specified if they are functional procedures.

Examples:

```
EXTERNAL FORTRAN REAL PROCEDURE CBRT $
EXTERNAL FORTRAN PROCEDURE NTRAN,INVS $
EXTERNAL PROCEDURE ROOTFINDER,KEYIN,KEYOUT $
EXTERNAL NON-RECURSIVE PROCEDURE TYPEIN,TYPEOUT $
```

G3.7. Procedure Declaration ::=

HH	procedure heading
TT	procedure body
SS	specification part
VV	value part
FF	formal parameter part

Explanation: A procedure declaration associates an algorithm with a procedure identifier. The principal constituent of a procedure declaration is a statement which is executed when the procedure is "called" (see 7.4). The procedure heading specifies that certain identifiers appearing within the procedure body are formal parameters. A parameter may also be specified as "VALUE" in which case the procedure statement, when called has access only to the value of the corresponding actual parameter, and not to the actual parameter itself.

Examples:

```
PROCEDURE ZEROSET (A,N) $
VALUE N $ INTEGER N $ ARRAY A $
BEGIN COMMENT THIS PROCEDURE ZEROES AN ARRAY ASSUMED
    DECLARED ARRAY A(1:N) $
INTEGER I $
FOR I = 1 STEP 1 UNTIL N DO A(I) = 0 END ZEROSET $
INTEGER PROCEDURE FACTORIAL (NUMBER) $
VALUE NUMBER $ INTEGER NUMBER $
FACTORIAL = IF NUMBER LSS 2 THEN 1 ELSE NUMBER * FACTORIAL
    (NUMBER-1) $
BOOLEAN PROCEDURE BOOL $
BOOL = NOT (FINISHED AND OFF OR FIRST AND LAST) $
```

G3.8. | Local Declaration | ::=

Explanation: The local declaration is a preliminary declaration of identifiers before they are actually declared (or, in the case of a label, used). This is necessary to allow forward references, use of an identifier before it has been defined.

Examples:

```
LOCAL LABEL L1,ENDFILE $
LOCAL SWITCH SALPHA $
LOCAL BOOLEAN PROCEDURE SLASH,ENDTAPE $
```

G3.9. | List Declaration | ::=
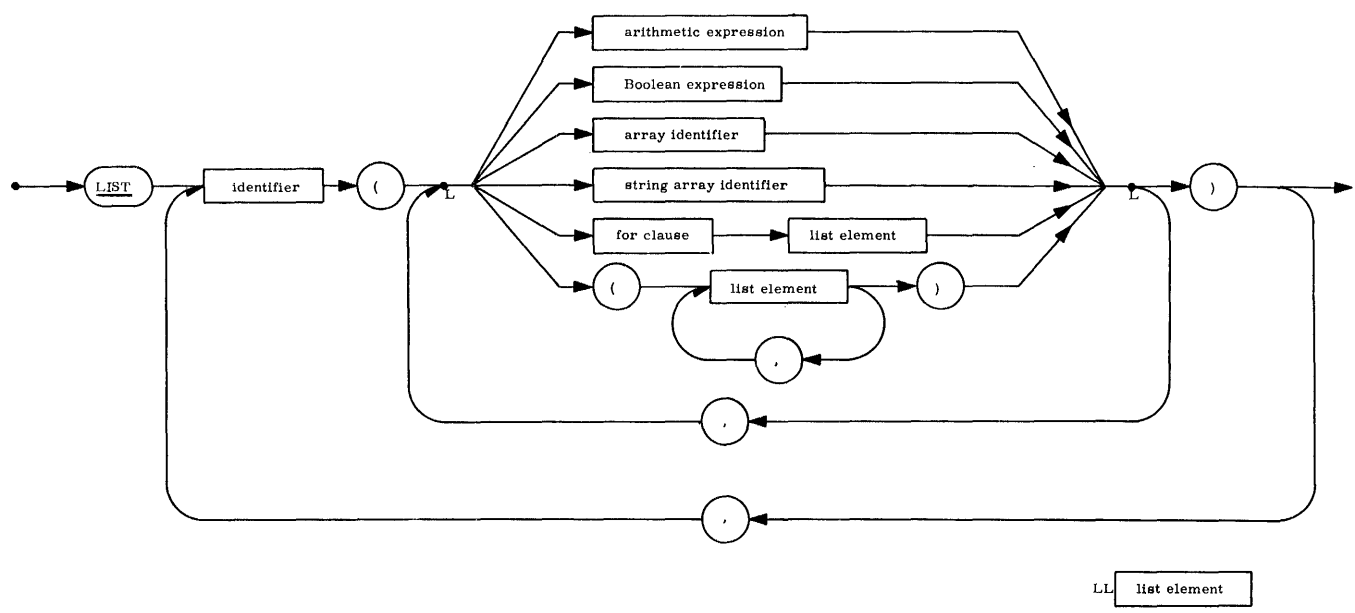
Explanation: A list defines an ordered sequence of expressions and array identifiers. A list may only be used as a parameter to a procedure, and, ultimately, only be a procedure written in some language other than ALGOL.

Examples:

```
LIST OUT (A+1,N+1,FOR I = (1,1,NMAX)DO(Q(I),QRES(I))) $
LIST L1(A,B,C), .2(IF MOD(Q,2)EQL 0 THEN B ELSE Q) $
```

G3.10. | Format Declaration | ::=
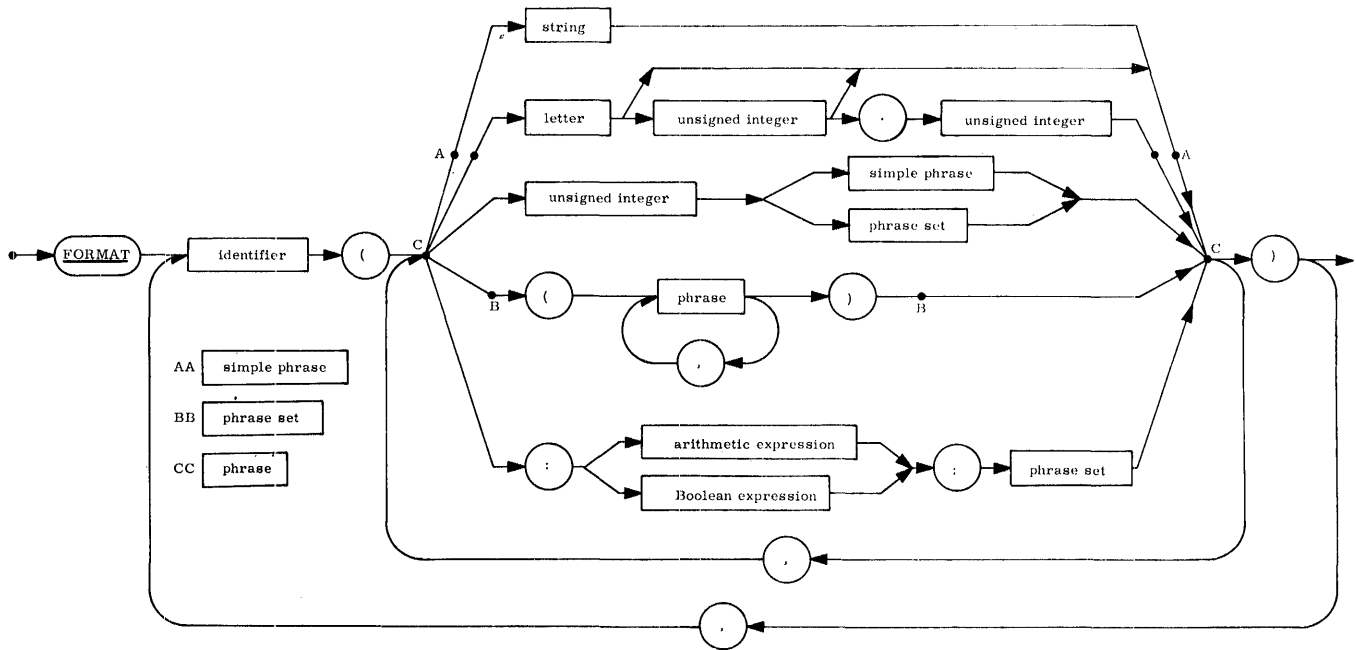
Explanation: A format is a special string of symbols which are passed on to an input/output routine for editing and control. Integers in front of a format code specify the number of times that code is to be repeated.

Examples:

```
FORMAT NEWPAGE(E,'X-COORDINATE',X28,'Y-COORDINATE',A1) $
FORMAT REP(5(4 R16.8,A1),A0.2,S12,'=',D10.1,S12,'=',r10.1,A1) $
FORMAT VECTOR (10T10.4,A1),PATTERN('SWITCHES ARE',8B6,A1) $
FORMAT MATRIX (:N:(:M:(D4.2,A1))) $
```

G4. | Statement | ::=
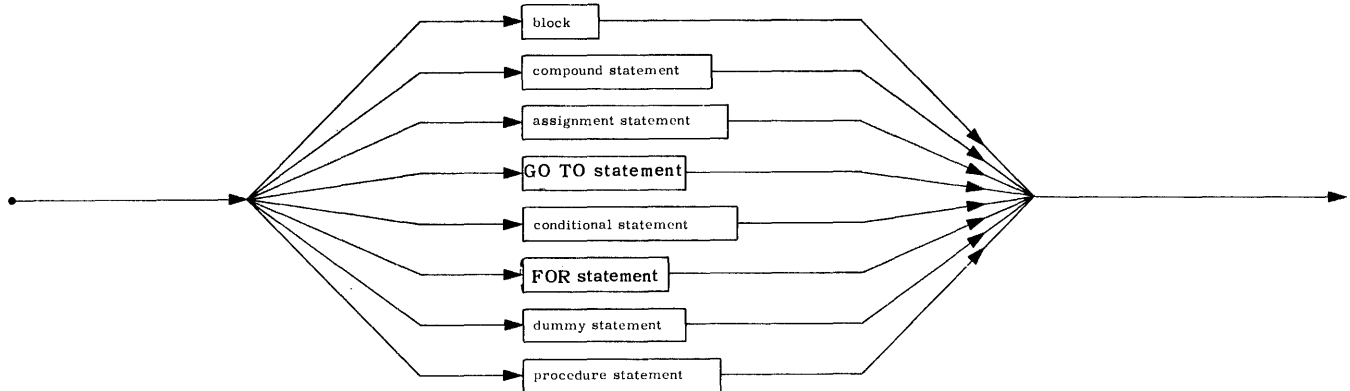
Explanation: Statements define the sequence of operations to be performed by the program. The eight types of statements are each defined in the following pages.

G4.1. | Block | ::=
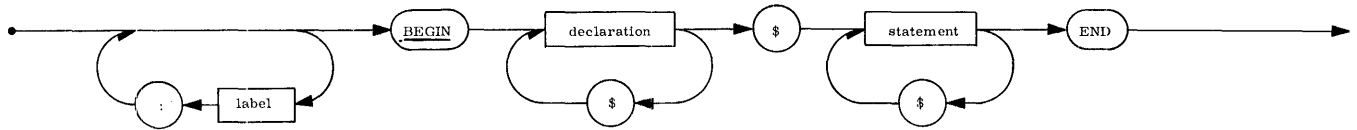
Explanation: A block automatically introduces a new level of nomenclature by a set of declarations. This means that any identifier declared in the block has the meaning assigned by the declaration, and any entity represented by such an identifier outside the block is completely unaccessible inside the block. The identifiers declared within a block are said to be local (to that block) while all other identifiers are nonlocal or global to that block.

Example:

```
L:BEGIN INTEGER ARRAY A(1:10) $
        A(1) = 1 $
        FOR J = (2,1,10) DO A(J) = A(J-1)+ J $
        FOR J = (1,1,10) DO WRITE (J,A(J)) $
END $
```

G4.2. | Compound Statement | ::=
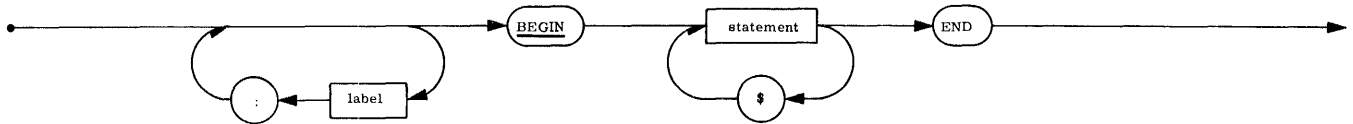
Explanation: A compound statement serves to group a set of statements by enclosing them with a BEGIN-END pair. This group is then treated as a single statement.

Example:

```
BEGIN T= 0 $ FOR I = 1 STEP 1 UNTIL M DO
      T= B(J,I) * C(I,K) +T $
      IF T GTR 820 OR OVFLOW THEN GO TO SPILL $
END$
```

G4.3. | Assignment Statement | ::=
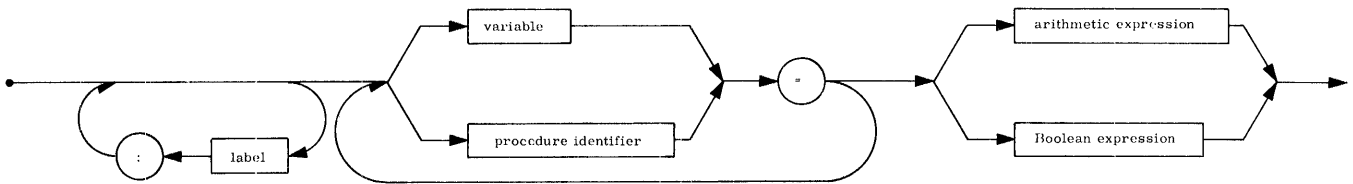
Explanation: An assignment statement assigns the value of the expression on the right-hand side to the variable and procedure identifiers on the left-hand side. A procedure identifier is only permitted on the left-hand side if the statement appears in the body of that functional procedure. If any of the left-part variables are subscripted variables, they are evaluated before the expression is evaluated. Transfers of type are automatically evoked when necessary.

Examples:

```
A(I) = B(I) = &35 $
AANDB = A AND B OR EPS1 GEQ EPS2 $
P = SQRT(B**2 - 4*A*C) $
T = S - MYO*EPSO*(2*PI*F)**2$
S(V,K-2) = COS(ANGLE) + 0.5 *(IF S1 THEN K**3 ELSE K**5) $
NAME(1, 6:P + 1) = 'IFTHEN' $
```

G4.4. | GO TO Statement | ::=
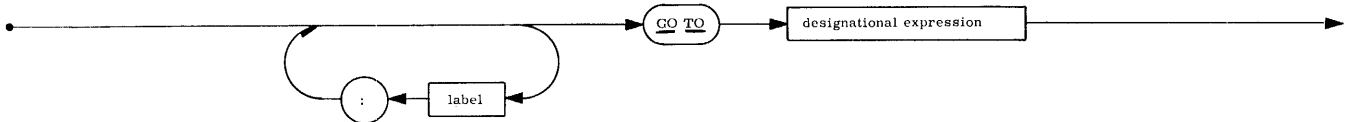
Explanation: A **GO TO** statement transfers control to the statement with the label determined by the designational expression.

Examples:

```
GO TO PART4 $
GO TO OPS (I-2) $
GO TO IF ALPHA GTR 0 THEN Q17 ELSE JUMP(-ALPHA) $
GO TO TRACK (IF MOD(P,2) EQL 1 THEN I ELSE A(I)) $
```

G4.5. | Conditional Statement | ::=
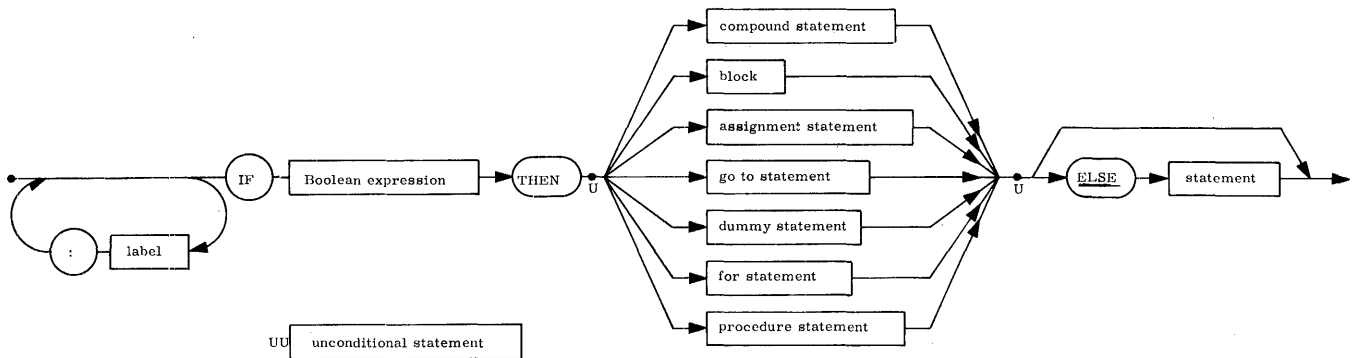
Explanation: The **IF** statement causes the execution of one of a pair of statements depending on the value of a Boolean expression. If this expression is TRUE then the statement after the THEN is executed and the statement after the ELSE is skipped. If FALSE, then the statement after the ELSE is executed, if the ELSE clause is present.

Examples:

```
IF C1 GTR 10 THEN A(0,0) = KMAX(I) ELSE GO TO LOOP $
IF BOOL(J) IMPL BOOL(J+1) THEN STEP(J) = 'VALID' ELSF STEP(J) =
    'INVALID' $
IF I GEQ 0 THEN BEGIN FOR K = -I STEP 1 UNTIL I DO B(K) = -COS(A-I) $
                SUM = ADDUP(B) END ELSE
                BEGIN IF I EQL -1 THEN GO TO ERROR ELSE
                    GO TO NEXT END $
```

G4.6. | FOR Statement | ::=
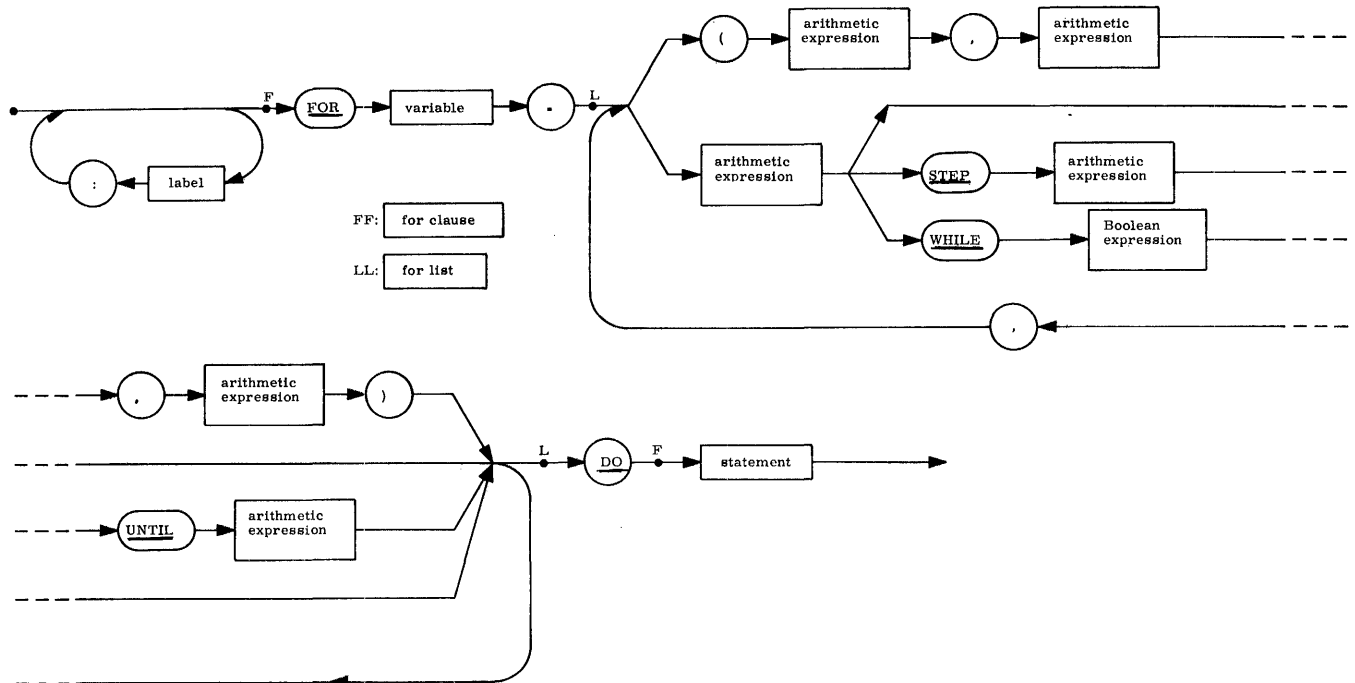
Explanation: The **FOR** statement controls the execution of the statement following the **DO** a number of times while the variable to the left of the = is assigned the values determined by the **FOR** list. The (,,) construction is equivalent to the **STEP-UNTIL** construction.

Examples:

```
FOR I = 1 STEP 1 UNTIL N DO FOR J = 1 STEP 1 UNTIL M DO
A(I,J) = 0 $
FOR S - S + 1 WHILE P(S) NEQ 'A' AND S LEQ 80 DO BEGIN
                  N=N*10 + P(S) $ IF OVFLOW THEN GO TO
                  SIZERR END $
FOR S = (1,2*S-S, 2**10),-1,-2,-4 DO IF LOGAND(S,VAR)
                  THEN GO TO YES $
```

G4.7. | Dummy Statement | ::=
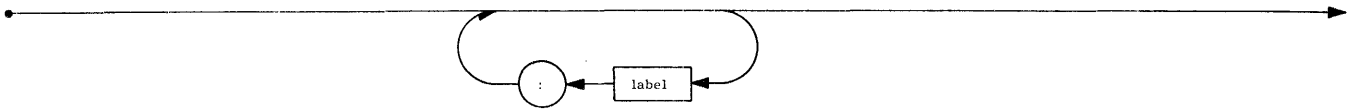
Explanation: A dummy statement does nothing. It may serve to place a label.

Examples:

```
FOR I = (1,1,N) DO FOR J = (1,1,N) DO BEGIN
    IF I EQL J THEN GO TO ENDLOOP $
    •
    •
    •
    ... $ ENDLOOP: END $
S = 0 $
FOR S = S + 1 WHILE P(S) NEQ 'A' DO $
```

G4.8. | Procedure Statement | ::=
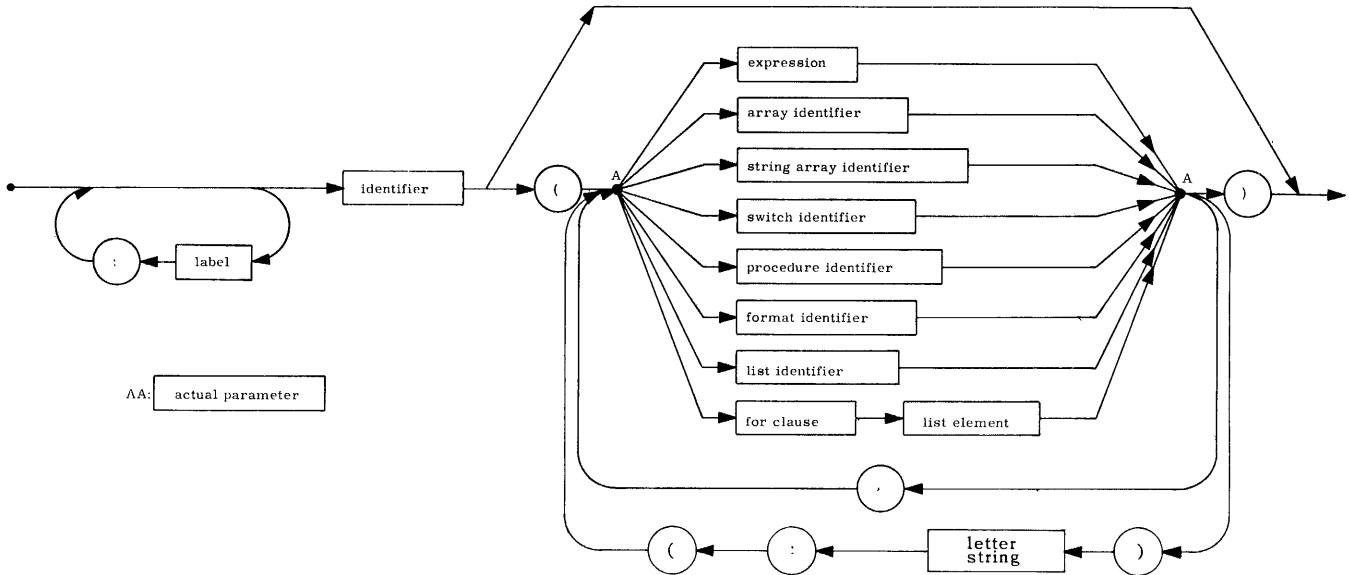
Explanation: A procedure statement is a call on a declared procedure. The actual parameters of the call replace the formal or dummy parameters throughout the body of the declared procedure. If the corresponding formal parameter has been "VALUE" specified then only the value of the actual parameter is used by the procedure.

Examples:

```
MARGIN (62,56,4) $
P(A,B,C,I,J,K) $
ROOTFINDER (N,O,ERGDET,KOEF,-4&&0,&&-5,5.0&&-1,1000) $
```

G5. | Expression | ::=

```
                              ┌──────────────────────┐
                         ┌───▶│ arithmetic expression │───┐
                         │    └──────────────────────┘    │
    ●──────────────────◀─┼───▶│  Boolean expression  │───▶│───────────────────▶
                         │    └──────────────────────┘    │
                         └───▶│designational expression│──┘
                              └──────────────────────┘
```
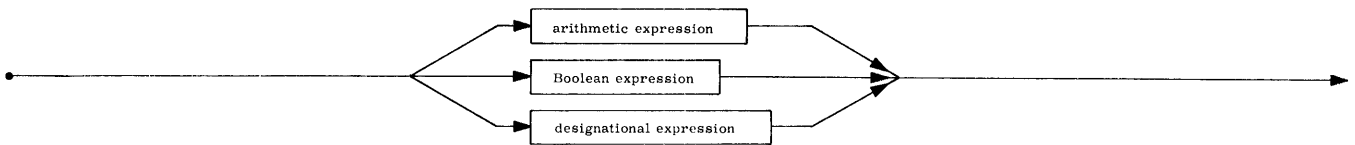
Explanation: There are three types of expressions, classified according to their values. An arithmetic expression has a numerical or a string value, a Boolean expression is either TRUE or FALSE, and a designational expression has a label as a value.

G5.1. | Variable | ::=
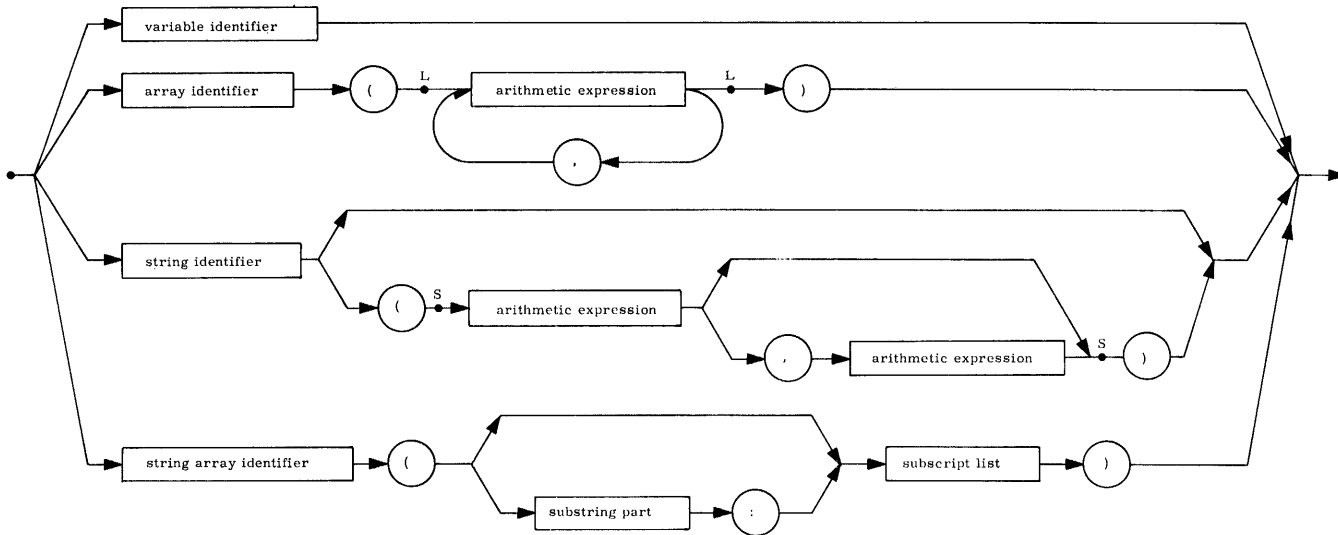
LL: subscript list

SS: substring part

Explanation: A variable is a designation given to a single value. A variable identifier is a variable named in a type declaration.

Examples:
DELTA
BOOLV(7)
CARD
CARD(4)
CARD(I, 6)
A(P(4), N*SIN(ANG), 3)
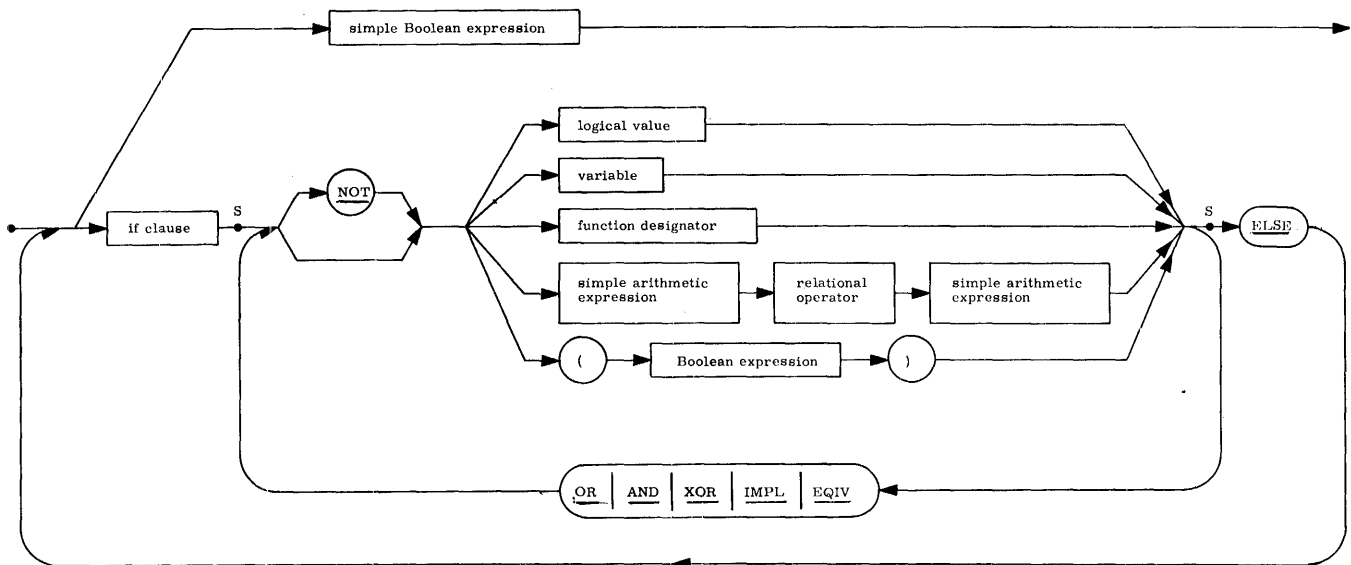CUROUT(J, K)
CUROUT(1:J, K)
CUROUT(1, 6: J, K)

Explanation: A variable is a designation given to a single value. A variable identifier is a variable named in a type declaration.

Examples:

```
DELTA
BOOLV(7)
CARD
CARD(4)
CARD(I, 6)
A(P(4),N*SIN(ANG),3)
CUROUT( J,K)
CUROUT(1:J,K)
CUROUT(1,6: J,K)
```

G5.2. | Function Designator | ::=
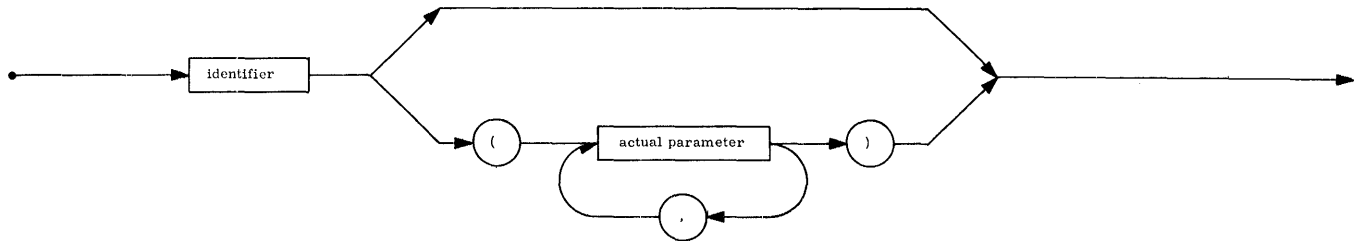
Explanation: A function designator defines a single numeric or logical value by applying the rules of the procedure declaration to the actual parameters. Only a procedure which has a type associated with it can be a function designator. Besides those functional procedures declared in the program, several standard ones are available for use without being declared.

Examples:

```
CLOCK
ARCTAN(1.0)
BACKSLASH(A1,A2)
```

G5.3. | Arithmetic Expression | ::=

Explanation: An arithmetic expression is a rule for computing a numerical value.

Examples:

```
A(4) + 2 * SQRT(D**3) - DELTA
IF A LSS &-5 THEN 0 ELSE A&+5
Q(MOD(N,2) + 1) * (IF FIRST THEN 10 ELSE RATIO)//3
```

G5.4. | Boolean Expression | ::=

Explanation: A Boolean expression is a rule for computing a logical value.

Examples:

```
FIRST AND NOT SPECIAL
A LSS DELTA OR ITERATIONS GTR MAXN
IF BETA THEN TRUE ELSE IF STEP(I) IMPL STEP(I+1) THEN QVALUE
IF BETA THEN TRUE ELSE IF STEP(I) IMPL STEP(I+1) THEN QVALUE(P,I)
        ELSE QVALUE(P,I-1)
```

G5.5. | Designational Expression | ::=
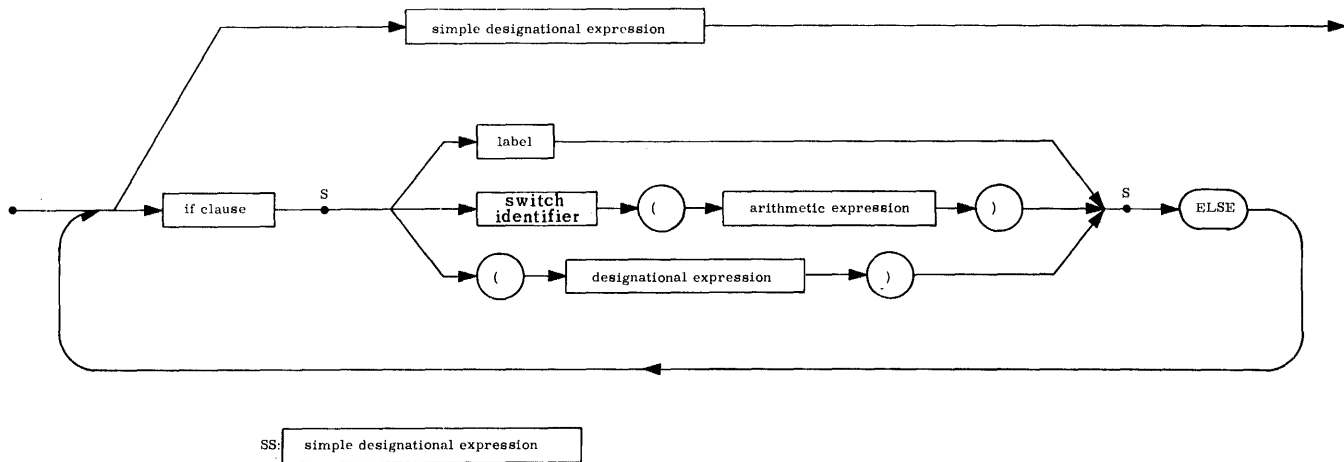
Explanation: A designational expression is a rule for computing the label of a statement. A switch identifier followed by an arithmetic expression in parenthesis refers to the label in the corresponding position in the switch declaration.

Examples:

```
L10
IF BETA THEN CALC ELSE NEXT (K//2)
```

G6. BASIC ELEMENTS

G6.1. | Identifier | ::= ·

| Letter | ::=

| Letter String | ::=

| Digit | ::=
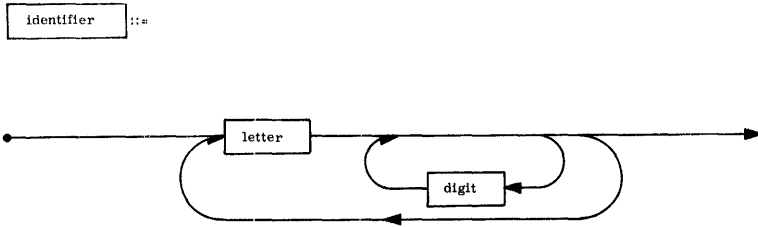
| identifier | ::=

| variable identifier | ::= | array identifier | ::=

| string identifier | ::= | string array identifier | ::=

| switch identifier | ::= | procedure identifier | ::=

| list identifier | ::= | format identifier | ::=

| label | ::= · | identifier |

| letter | ::=

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

| letter string | ::=

letter

| digit | ::=

0 1 2 3 4 5 6 7 8 9
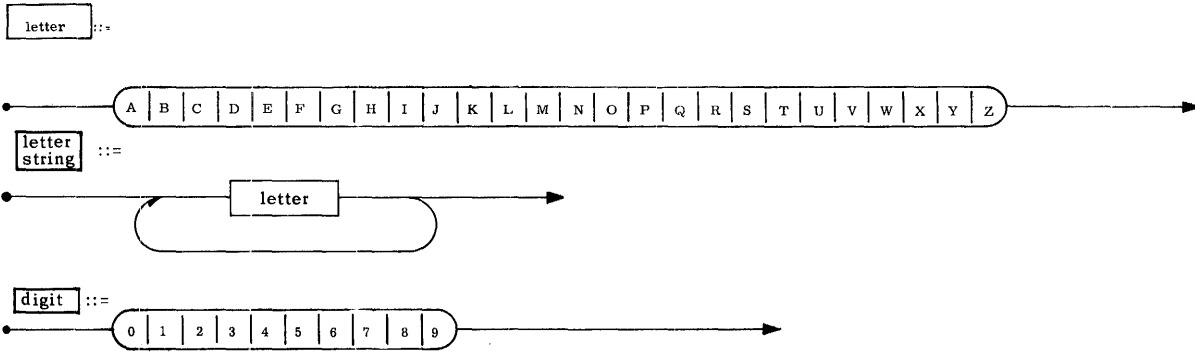
Explanation: An identifier is a name chosen to represent a variable, array, etc. Only the first 12 characters of an identifier uniquely define it.

Examples:

```
P47
DELTA
SQRTROOOF2
E1C4PDQ
```

G6.2. | Number | ::=

UU:	unsigned integer
II:	integer
PP:	unsigned number
QQ:	decimal number
TT:	complex number
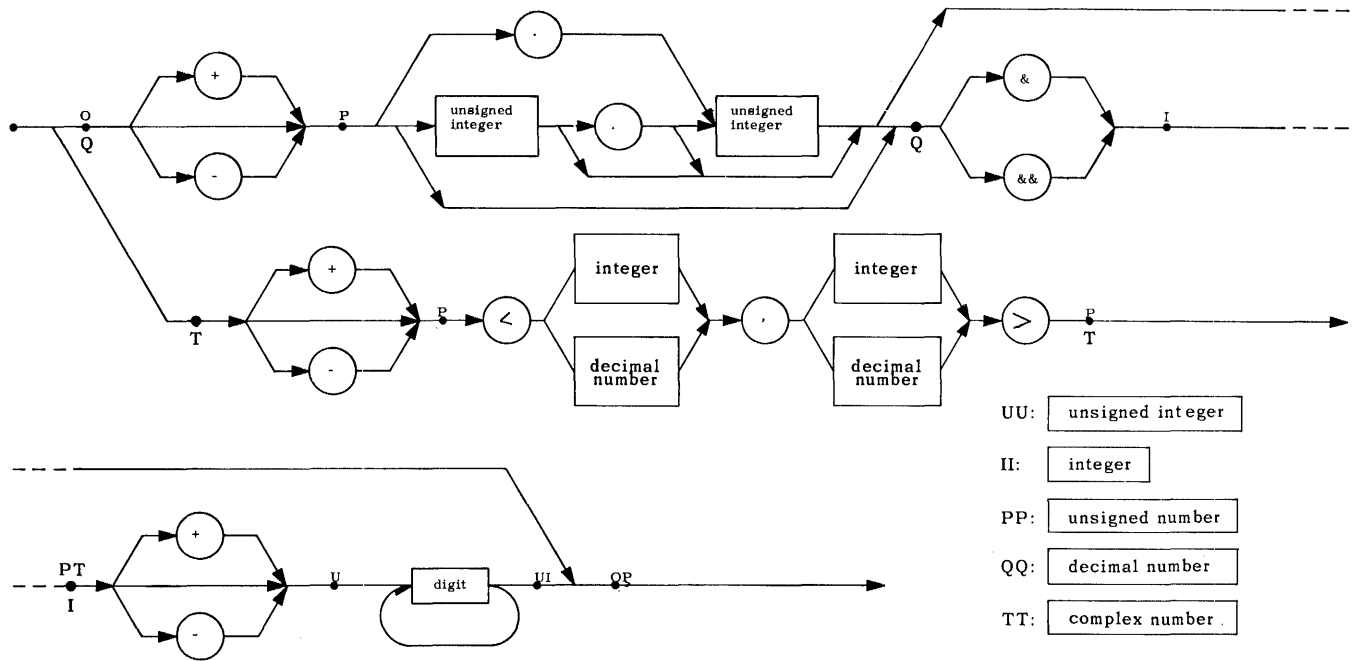
Explanation: A number is written in its usual decimal notation with the conventions of & for power of ten and corner brackets for complex numbers. Numbers are of four types: **REAL, INTEGER, REAL 2** and **COMPLEX. REAL 2** is differentiated from **REAL** by use of && for power of ten, or there may be between 9 and 18 digits in the fixed point part. **COMPLEX** numbers are distinguished by the corner brackets, where the first number is the real part and the second the imaginary.

Examples:

```
1
-1009
-.4031
3.1459
-18.0&4
-<1,0>
20&-5
+1800.&&0
&-6
+< -.06, &-2>
```

G6.3. | String | ::=

| Logical Value | ::=
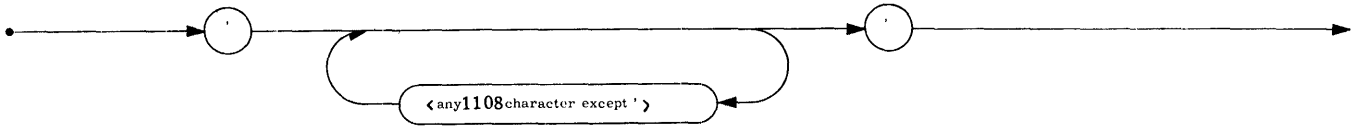
Explanation: A string constant is any string of characters which are used as parameters to procedures or with string variables.
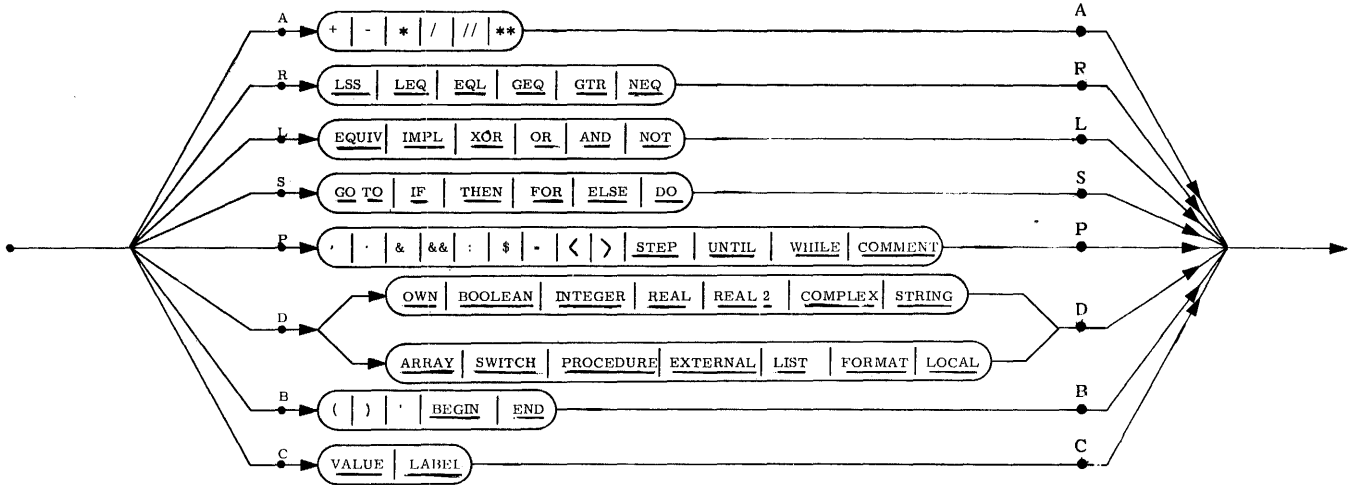
Examples:

```
'DOGGENBURG STR. 22'
'NEQ'
'BJARNE WIST'
'227 KALPHA'
'REAL ARRAY'
```
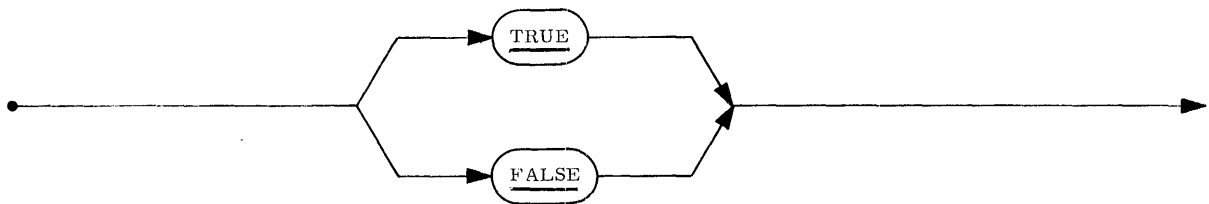

Explanation: A logical value is a Boolean constant.

G6.4. | Delimiter | ::=

AA:	arithmetic operator
RR:	relational operator
LL:	Boolean operator
SS:	sequential operator

PP:	separator
DD:	declarator
BB:	bracket
CC:	specificator

G7. INPUT/OUTPUT PROCEDURES

G7.1. | Input Procedure Statement | ::=
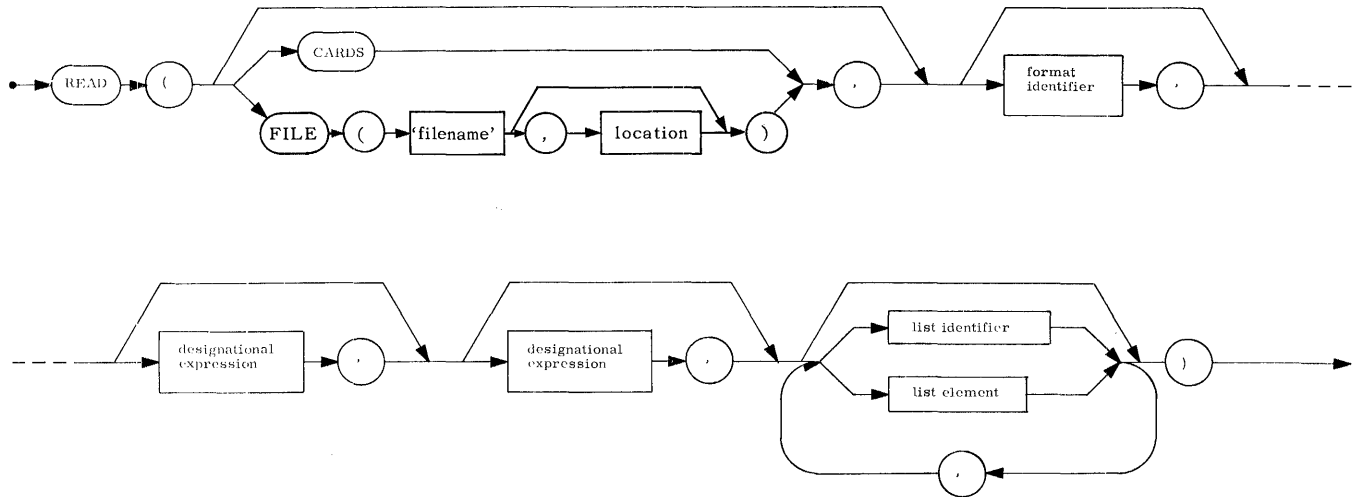
Explanation: A call on procedure READ reads data from the specified input device into the variables indicated by the list elements. The designational expressions are used as exit points in case end-of-file or end-of-information conditions are met on that device. Note that READ( ) is a legitimate statement but the effect is the same as "No operation".
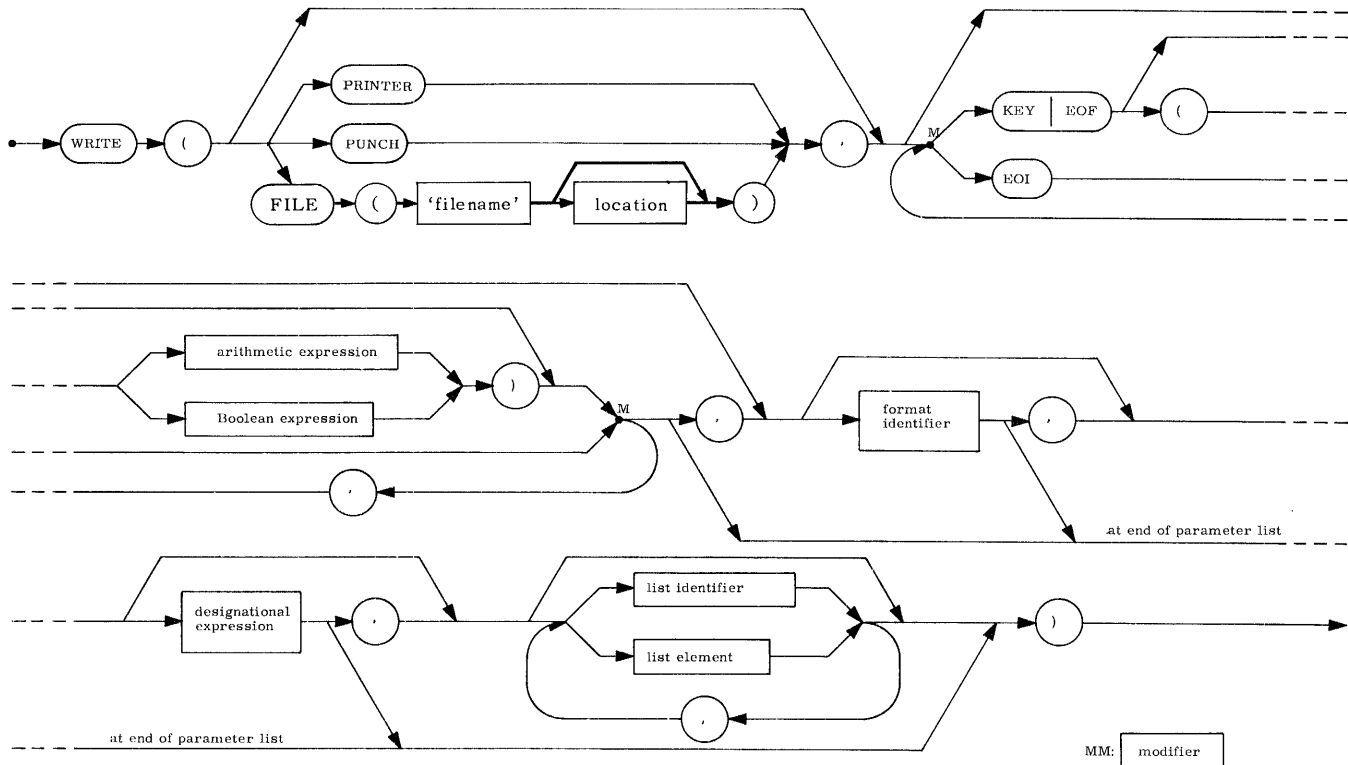
Examples:

```
READ(CARDS,LEOF,LEOI,A,B,C,S,EPSILON) $
READ(FILE(INDEX), FOR I=(1,1,KMAX) DO FOR J=(1,1,LMAX)
    DO ERG(I,J)) $
READ(DATE) $
```

G7.2. | Output Procedure Statement | ::=

Explanation: A call on procedure WRITE outputs the values defined by the list to the device specified. Modifiers (KEY, EOF, EOI) produce special marks on tape. A format controls editing on paper and punched cards. The designational expression is used as a return point if the output device functions abnormally. Note that WRITE( ) is the same as "No operation".

Examples:

```
WRITE (PRINTER, F10, FOR I=(1,1,N) DO A(I,J)) $
WRITE ('CHECKPOINT CHARLIE',A) $
WRITE (FILE('TAPE1'),KEY(I),ABORTLAB,DUMPLIST) $
WRITE (FILE('OUTPUT'),EOF('LAST'),EOI) $
```

G7.3. | Position Procedure Statement | ::=
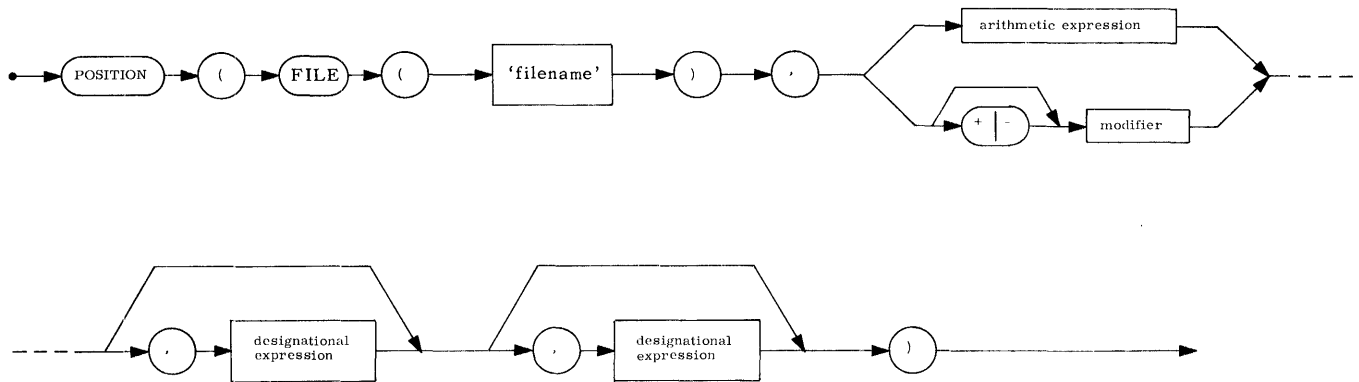
Explanation: The procedure POSITION positions a file forward or backward a number of records or searches for a KEY, EOF, or EOI marker. The designational expressions are used as exits in case the search fails.
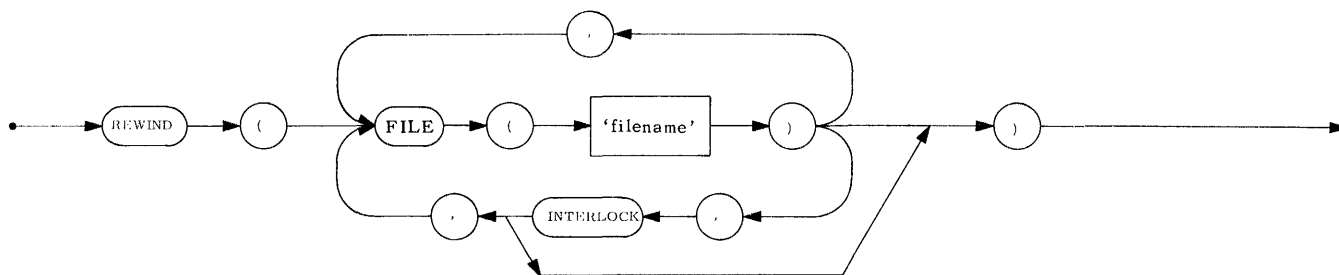
Examples:

```
POSITION (FILE('TAPE'),-2) $

POSITION (FILE('INPUT'), KEY('PRICES'),ABORT) $

POSITION (FILE('OUTPUT'), EOI) $
```

G7.4. | Rewind Procedure Statement | ::=

Explanation: A call on procedure REWIND rewinds the specified files. The modifier INTERLOCK will cause all previously named files to be rewound with interlock (read/write protect).

Examples:

```
REWIND (FILE('INPUT'), FILE('OUTPUT')) $
REWIND (FILE('TAPE1'), INTERLOCK, FILE('TAPE2')) $
```

G7.5. Summary of Format Codes

A format code of the form Qw.d where Q is a letter and w and d are unsigned integers is interpreted according to the following table. The integer w, except where noted, always specifies the width of the field under consideration. Also, $Qw = Qw.0$ and $Q \equiv Q0.0$. The word "print" has been used in the description of output action, but "punch" may be freely substituted.

Letter	Input	Output
A Activate	Read one card	Print the edited line, skipping w lines before and d lines after printing. (w and d ignored for punch).
B Boolean	Accept a logical value from the field either TRUE, FALSE, or 1,0.	Print a Boolean expression as either TRUE or FALSE.
D Decimal	Accept a real value. If the actual number is of INTEGER type then insert a decimal point d places to the left of the right end of the field.	Print a number with decimal point inserted and d digits after the decimal point.
E Eject		Eject the page to logical line $w - 1$.
F Free	Accept an unspecified number of values from the field punched in free-format mode.	
I Integer	Accept an integer from the field.	Print an integer to the base d ($d=0 \equiv d=10$).
R Real	Same as letter D.	Print d digits of a real number with decimal point and attached exponent part.
S String	Accept a string from the field.	Print a string.
T Significance	Same as letter D.	Print the first d significant digits of a number with the decimal point inserted.
X Skip	Skip the field.	Skip the field.

G7.6. Grouping of Format Codes

Format codes may be repeated in execution by four methods:

(a) Placing an unsigned integer in front of a format code:

7D9.2

This has the same effect as if the phrase D9.2 was written 7 times.

(b) Enclosing a group of format codes in parentheses and placing an unsigned integer before the parenthetical expression:

7(6R18.8,A1)

This has the effect of expanding the phrase inside the parenthesis 7 times.

(c) Similar to (b) above but using an integer or Boolean expression enclosed in colons before the parenthetical expression. The value of the expression determines the number of times the enclosed code or group of codes is to be repeated:

:NMAX//3+1:(6R18.8,A1)

(d) Enclosing a group of format codes in parentheses but not preceding this parenthetical expression with an integer constant. This means the enclosed codes are to be used until there is no more output (or input) to process. The parentheses surrounding the entire format string are interpreted in this manner.

FORMAT FOUT(4(S10,X5),A2)

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