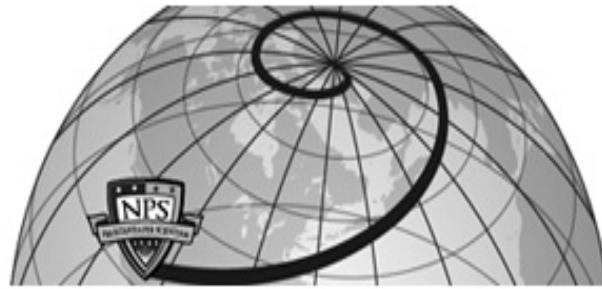




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Flynn, John P.; Moranville, Mark S.

Monterey, California. Naval Postgraduate School

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ALGOL-M  
AN IMPLEMENTATION OF A  
HIGH-LEVEL BLOCK STRUCTURED LANGUAGE  
FOR A MICROPROCESSOR-BASED COMPUTER SYSTEM

John P. Flynn



# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



# THESIS

ALGOL-M  
An Implementation of a  
High-level Block Structured Language  
for a Microprocessor-based Computer System

by

John P. Flynn  
and  
Mark S. Moranville

September 1977

Thesis Advisor:

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ALGOL-M

An Implementation of a  
High-level Block Structured Language  
for a Microprocessor-based Computer System

by

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Submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL  
SEPTEMBER, 1977



## ABSTRACT

The design and implementation of the ALGOL-M programming language for use on a microprocessor-based system is described. The implementation is comprised of two subsystems, a compiler which generates code for a hypothetical zero-address machine and a run-time monitor which executes this code. The system was implemented in PL/M to run on an 8080 microcomputer in a diskette-based environment with at least 20K bytes of user storage.



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## I. INTRODUCTION

### A. HISTORY OF ALGOL

The definition of the algorithmic language (ALGOL-60) was the result of the work of a committee of distinguished computer scientists and was originally published in 1960 [11]. The purpose of the developers of ALGOL-60 was the establishment of a universal computer language specifically designed to allow for the logical and efficient program representation of algorithms. Additional versions and extensions of ALGOL-60 such as ALGOL-68 [15] and ALGOL-W [16] have been developed and have found acceptance primarily in the academic communities and in Europe. The language ALGOL-E [10] is also based on ALGOL-60 and was developed as part of a complete system designed for teaching programming language concepts.

### B. MICROCOMPUTER SOFTWARE

The rapid development of microcomputer hardware since 1975 has generally resulted in a considerable lag in the corresponding development of compatible software, particularly that of high level languages. The Intel 8080 microprocessor is one of the few microprocessors which has endured long enough to permit software development to advance beyond the assembly language level. High level



languages which have been developed for 8080 based systems by students at the Naval Postgraduate School include a macro assembler (ML-80) [12], a BASIC compiler/interpreter (BASIC-E) [6], and a COBOL compiler/interpreter (MICRO-COBOL) [2]. The majority of high level languages currently available for microcomputer based systems are extensions of the original Dartmouth BASIC and, although they allow for a reasonable level of programming sophistication, they are encumbered by the inherent limitations of the BASIC language constructs.

#### C. OBJECTIVES OF ALGOL-M

The major objective of this project was to develop a dynamic, block-structured, recursive high level language which would provide adequate programming power and flexibility for applications programming using microcomputer based systems. ALGOL constructs were chosen because of their simplicity and power and because it was possible to write the grammar in LALR(1) form for use with available compiler-compiler generated parse tables [14]. ALGOL-M was developed to run on 8080 based microcomputer systems because of the availability of a high level system development language (PL/M) [8] which produces 8080 object code and which could be run on the Naval Postgraduate School's IBM 360. The availability of an 8080 based disk operating system (CP/M) [13] simulator on the IBM 360 was also a strong factor in the choice of 8080 microprocessor and CP/M



**operating system.**



## II. ALGOL-M LANGUAGE DESCRIPTION

### A. FEATURES OF THE ALGOL-M LANGUAGE

Although ALGOL-M was modeled after ALGOL-60, no attempt was made to make it a formal subset of ALGOL-60. This was done intentionally in order to provide a language which would be best suited to the needs of applications programmers using microcomputer systems. However, the basic structure of ALGOL-M is similar enough to ALGOL-60 to allow simple conversion of programs from one language to the other. This was considered particularly important in view of the fact that the standard publication language is ALGOL-60. Therefore, there exists a large source of applications programs and library procedures which can be simply converted to execute under ALGOL-M.

#### 1. Type Declarations

ALGOL-M supports three types of variables: integers, decimals, and strings. Integers may be any value between -16,384 and +16,384. Decimals may be declared with up to 18 digits of precision and strings may be declared as long as 255 characters. The default precision for decimals is ten digits and the default length for strings is ten characters. Decimal and string variable lengths may be integer variables which can be assigned actual values at run-time.

Another form of declaration in ALGOL-M is the array



declaration. Arrays may have up to 255 dimensions with each dimension ranging from -16,384 to +16,384. The maximum 8080 microprocessor address space of 64k bytes limits practical array sizes to something smaller than the maximum. Dimension bounds may be integer variables with the actual values assigned at run-time. Arrays may be of type integer, decimal or string.

## 2. Arithmetic Processing

Integer and binary coded decimal arithmetic are supported under ALGOL-M. Integers may be used in decimal expressions and will be converted to decimals at run-time. The integer and decimal comparisons of less-than (<), greater-than (>), equal-to (=), not-equal-to (<>), less-than-or-equal-to (<=), and greater-than-or-equal-to (>=) are provided. Additionally, the logical operators AND, OR and NOT are available.

## 3. Control Structures

ALGOL-M control structures consist of BEGIN, END, FOR, IF THEN, IF THEN ELSE, WHILE, CASE and GOTO constructs. Function and procedure calls are also used as control structures. ALGOL-M is a block structured language with a block normally bracketed by a BEGIN and an END. Blocks may be nested within other blocks to nine levels. Variables which are declared within a block can only be referenced within that block or a block nested within that block. Once program control proceeds outside of a block in which a variable has been declared, the variable may not be



referenced and, in fact, run-time storage space for that variable no longer exists.

Functions, when called, return an integer, decimal or string value depending on the type of the function. Procedures do not return a value when called. Both functions and procedures may have zero or more parameters which are call by value and both may be called recursively. Additionally, functions and procedures may be referenced before they are declared.

#### 4. Input/Output

The ALGOL-M WRITE statement causes output to the console on a new line. The desired output is specified in a write list which is enclosed in parentheses. String constants may be used in a write list and are characterized by being enclosed in quotation marks. Any combination of integer, decimal and string variables or expressions may also be used in a write list. A WRITEON statement is also available which is essentially the same as the WRITE statement except that output continues on the same line as the output from a previous WRITE or WRITEON statement. When a total of 80 characters have been written to the console, a new line is started automatically. A TAB option may also be used in the write list which causes the following item in the write list to be spaced to the right by a specified amount.

Console input is accomplished by the READ statement followed by a read list of any combination of integer,



decimal and string variables enclosed in parentheses. If embedded blanks are desired in the input for a string variable, the console input must be enclosed in quotation marks. A READ statement will result in a halt in program execution at run-time until the input values are typed at the console and a carriage return is sent. If the values typed at the console match the read list in number and type, program execution continues. If an error as to number or type of variables from the console occurs, program execution is again halted until values are re-entered on the console.

## 5. Disk Access

ALGOL-M programs may read data from, or write data to, one or more disk files which may be located on one or more disk drives. When file input or output is desired, the appropriate READ or WRITE statement is modified by placing a filename identifier immediately after READ or WRITE. The actual name of the file may be assigned to the file name identifier when the program is written or it may be assigned at run-time. Various disk drives are referenced by the letters A through Z. A specific drive may be specified by prefixing the actual file name with the desired drive letter followed by a colon. Additionally, if random file access is desired, the file name identifier may be followed by an integer constant, variable or expression enclosed in parentheses. This integer value specifies the record within the file which is to be used for input/output.

Prior to the use of a file name identifier in a READ



or WRITE statement, the file name identifier must appear in a file declaration statement. The file name identifier can only be referenced within the same block (or a lower block) as the file declaration. Files are normally treated as unblocked sequential files. However, if blocked files are desired, the record length may optionally be specified in parentheses after the file name identifier in the file declaration statement.



### III. IMPLEMENTATION

#### A. COMPILER IMPLEMENTATION

##### 1. Compiler Organization

The compiler was designed to read source language statements from a diskette and to produce an intermediate language file with optional source listing at the console. A two pass approach was used to facilitate the implementation of GOTC statements, forward subroutines, and control statements. Pass one builds the symbol table and saves all branch locations for resolution during pass two. Pass one also computes the size of the program reference table (PRT) and writes this information out to the intermediate file. Pass two resolves all forward references and emits code to the intermediate file on disk.

##### 2. Scanner

The scanner analyses the source program and sends a sequence of tokens to the parser. In addition, the scanner provides a listing of the source file (if requested), ignores remarks, and sets the compiler toggles. Analysis of the first non-blank character in the inout file determines the general class of the next token. The rest of the token is then scanned as it is placed into the accumulator (ACCUM). The first byte of ACCUM contains the length of the token. In the case of constants that exceed the size of



ACCUm (32 bytes) a continuation flag is set. This permits the scanner and parser to continue as necessary to accept the entire constant.

When the scanner recognizes an identifier it searches the vocabulary table (VOCAB) to determine if the identifier is a reserved word. If found, the token number associated with the reserved word's position in the VOCAB table is returned. The reserved word COMMENT is a special case since it is not part of the grammar and is handled entirely by the scanner. The VOCAB table is one of the tables provided by the LALR(1) parse table generator[14].

Constants are passed unconverted from the scanner through the parser to the intermediate file. Although this procedure does not allow constant checking during compile time, it does save space in the compiler. The conversion routines must be in the run-time system for console input and their duplication in the compiler was not considered necessary.

### 3. Symbol Table

The symbol table stores attributes of program and compiler generated entities such as identifiers, procedures, and labels. The symbol table is constructed during pass one and the stored information is used by the compiler during pass two to verify that the program is semantically correct and to assist in code generation. Access to the symbol table is accomplished through various subroutines which operate on the symbol table through the use of based global



variables.

The symbol table is modeled after the BASIC-E symbol table [6]. It is an unordered linear list of entries which grows toward the top of memory. Individual entries are accessed via a chained hash addressing technique as illustrated in Figure 1. Each location in the hash table heads a linked list whose printnames all evaluate to the same hash address. If there is a zero in the hash table then there are no entries for that particular hash value. During references to the symbol table, the global variable PRINTNAME contains the address of a variable which contains the length of the variable name followed by the name itself. The variable SYMHASH contains the sum of the ASCII characters that make up the variable name, modulo 64. Entries which hash to the same value are chained so that the latest entry is the first one on the chain. They are, however, stored in the symbol table in the order in which they appear in the program.

Each entry in the symbol table contains the following information:

length of printname	1 byte
collision field	2 bytes
printname	variable length
type	1 byte
address	2 bytes
block level	1 byte
subtype	1 byte



## SYMBOL TABLE STRUCTURE

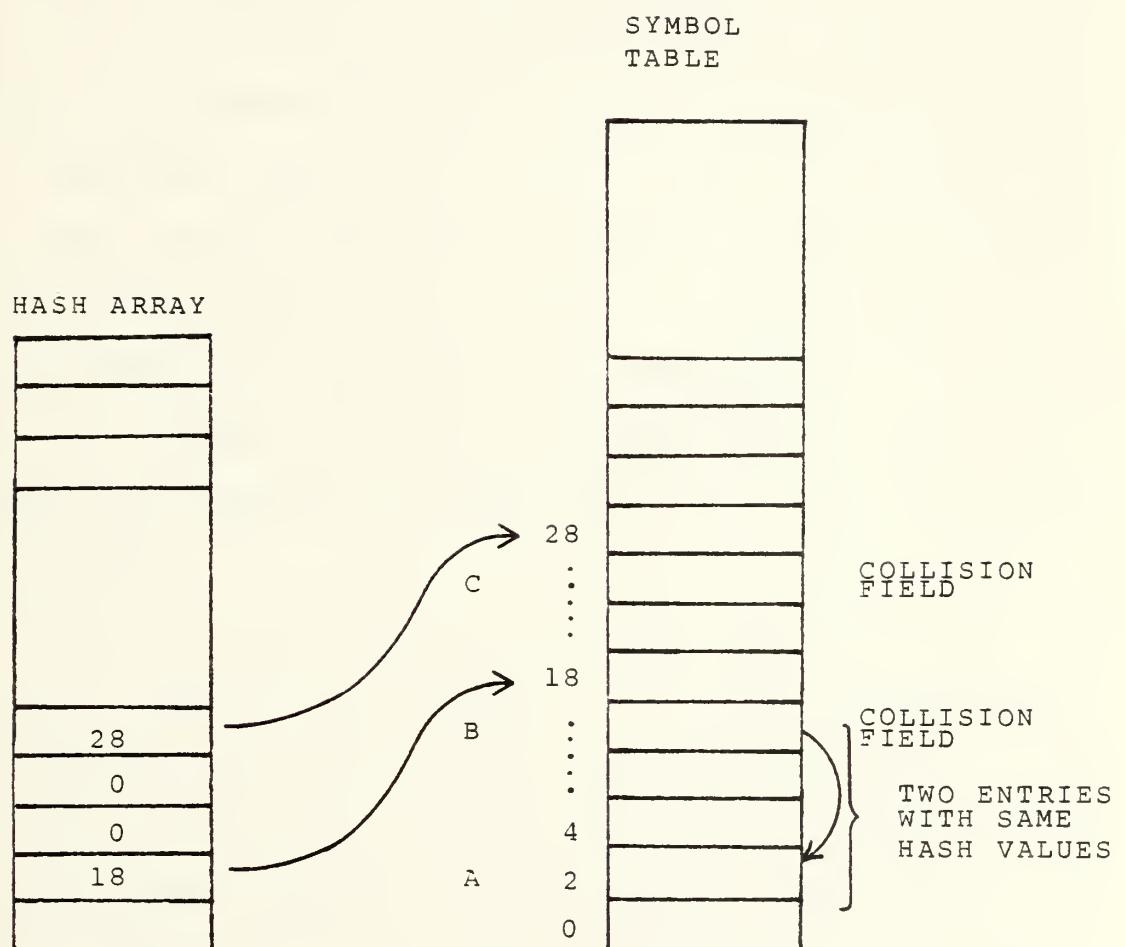


FIGURE 1



The address field indicates the identifier's position in the PRT unless the identifier is a label. For labels, it indicates the label's position in the code area. For subroutines, there are two extra symbol table entries: a parameter field which indicates the number of parameters associated with the subroutine (1 byte), and another address field which indicates the position of the subroutine in the code area.

Since ALGOL-M is completely block structured, there is a block number associated with each identifier in the symbol table. A "previous block level stack" was designed in order to retain the symbol table for debugging purposes during run-time. Each active block is used as an index into this stack which contains all blocks to which the active block is subordinate. When a block is deactivated (i.e., the corresponding block end is encountered), the block number is removed from the previous block stack and therefore any identifiers associated with that block become inaccessible.

Two different lookup routines were designed to facilitate symbol table lookup. The first is FULL\$LOOKUP which searches the current block and all outer blocks for an identifier. The second is NORMAL\$LOOKUP which simply checks the current block level. In most cases, FULL\$LOOKUP is used to determine if an identifier being used has been declared and NORMAL\$LOOKUP is used to determine if an identifier being declared has been previously declared in the same block level.



#### 4. Parser

The LALR parser is modeled after that of the BASIC-E parser [6], which is a table-driven pushdown automaton. It receives tokens from the scanner and analyzes them to determine if they are part of the ALGOL-M grammar. When the parser accepts a token, one of the following actions will be taken. It may save the token and continue to accept tokens in the lookahead state, or it may recognize the right part of one of the valid productions and apply the production state (cause a reduction to take place). Finally the parser may determine that the tokens received do not form a valid right part for a production in the grammar and cause a syntax error to be printed.

When an error is detected RECOVER is called and the parser backs up a state with an attempt to continue parsing from that state. If this fails, it continues to back up until the end of the currently pending reduction is reached. At that point the bad token is bypassed and an attempt to parse the following token is made until an acceptable token is found.

The major data structures in the parser are the LALR(1) parse tables and the parse stacks. The parse stacks consist of a state stack and six auxiliary stacks. These auxiliary stacks are parallel to the parse stack and are used to store information needed during code generation. The information stored in these stacks includes variable types, subtypes, and variable addresses.



## 5. Code Generation

The parser not only verifies the syntax of source statements, but also controls code generation by associating semantic actions with reductions. When a reduction takes place, the procedure SYNTHESIZE is called with the production number as a parameter. SYNTHESIZE copies the needed semantic information from the parse stacks into simple variables (to avoid extensive subscripting) and performs the appropriate semantic action. This is accomplished by the use of a large case statement with the production number as a key. The syntax of the language, along with the semantic actions taken, is listed in Appendix E.

## B. INTERPRETER IMPLEMENTATION

### 1. Building the ALGOL-M Pseudo Machine

The ALGOL-M pseudo machine, as shown in Figure 2, is a software emulation of a stack-oriented CPU with an instruction set which is particularly well suited for execution of ALGOL-M programs. The ALGOL-M interpreter is loaded at address 100 hex (as are all executable programs under the CP/M operating system) and proceeds to read the ALGOL-M intermediate code from disk, constructing the pseudo machine beginning at the first free memory location. The ALGOL-M intermediate code is read into a buffer in 128 byte segments. The first two bytes of the intermediate code represent an integer value equal to the number of bytes



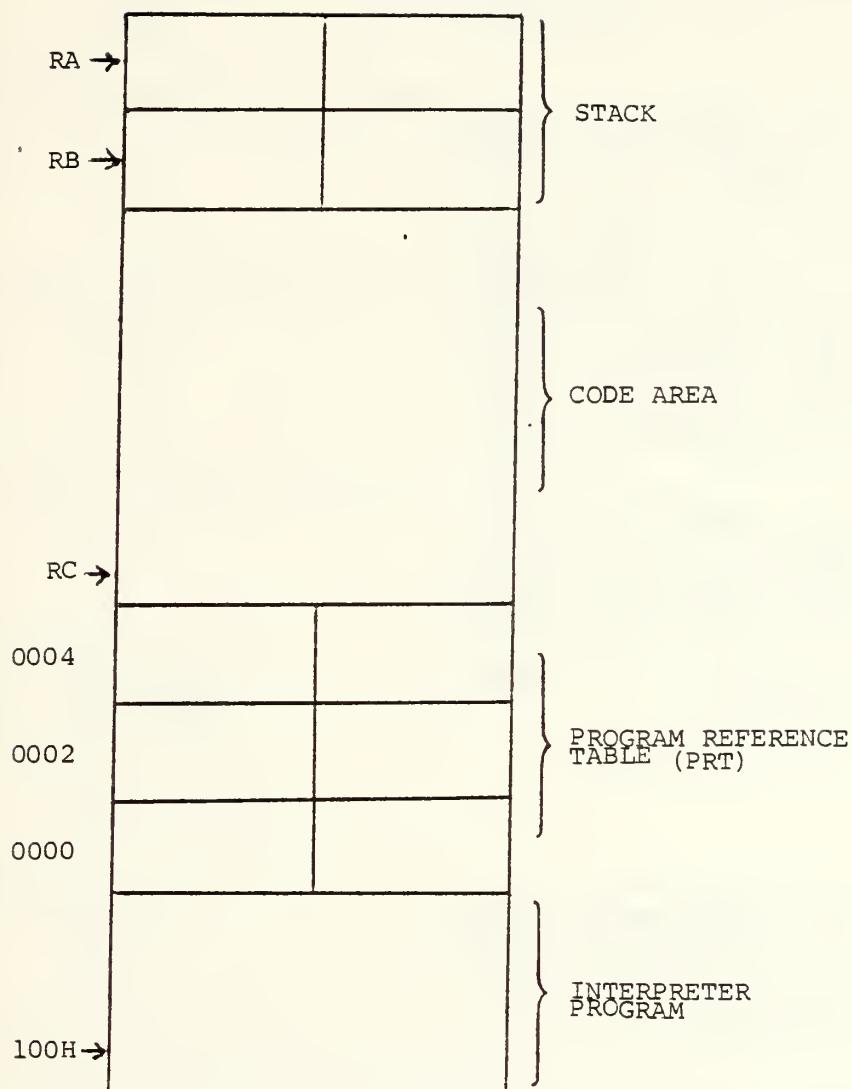
to be used for the program reference table (PRT). Each PRT location is two bytes in length and is used to contain information relative to ALGOL-M program identifiers, arrays, and subroutines.

The remaining intermediate code is manipulated in accordance with the algorithm shown in Figure 3 in order to construct the pseudo machine code area.

## 2. Overview of the Interpreter

The ALGOL-M interpreter uses the pseudo machine code area as inout data. Each pseudo machine operator is equated to an integer value which is evaluated in order to provide the correct entry point into a large case statement in the interpreter. Each entry in the case statement contains the necessary code to cause proper run-time execution of the specific ALGOL-M pseudo instruction. The case statement is executed continually until the ALGOL-M program has been completed, at which time control is passed back to the operating system. A run-time stack is used to facilitate the execution of ALGOL-M pseudo instructions. The stack can be viewed as being two bytes wide and expanding or contracting above the ALGOL-M machine code area as necessary. The top item on the stack is addressed by the variable RA, while the next-to-top item is addressed by RB. The contents of the two bytes on top of the stack are referenced by the variable ARA while the two byte contents of the next-to-top stack position are referenced by the variable APB. The low order byte





ALGOL-M MACHINE  
MEMORY ORGANIZATION

FIGURE 2



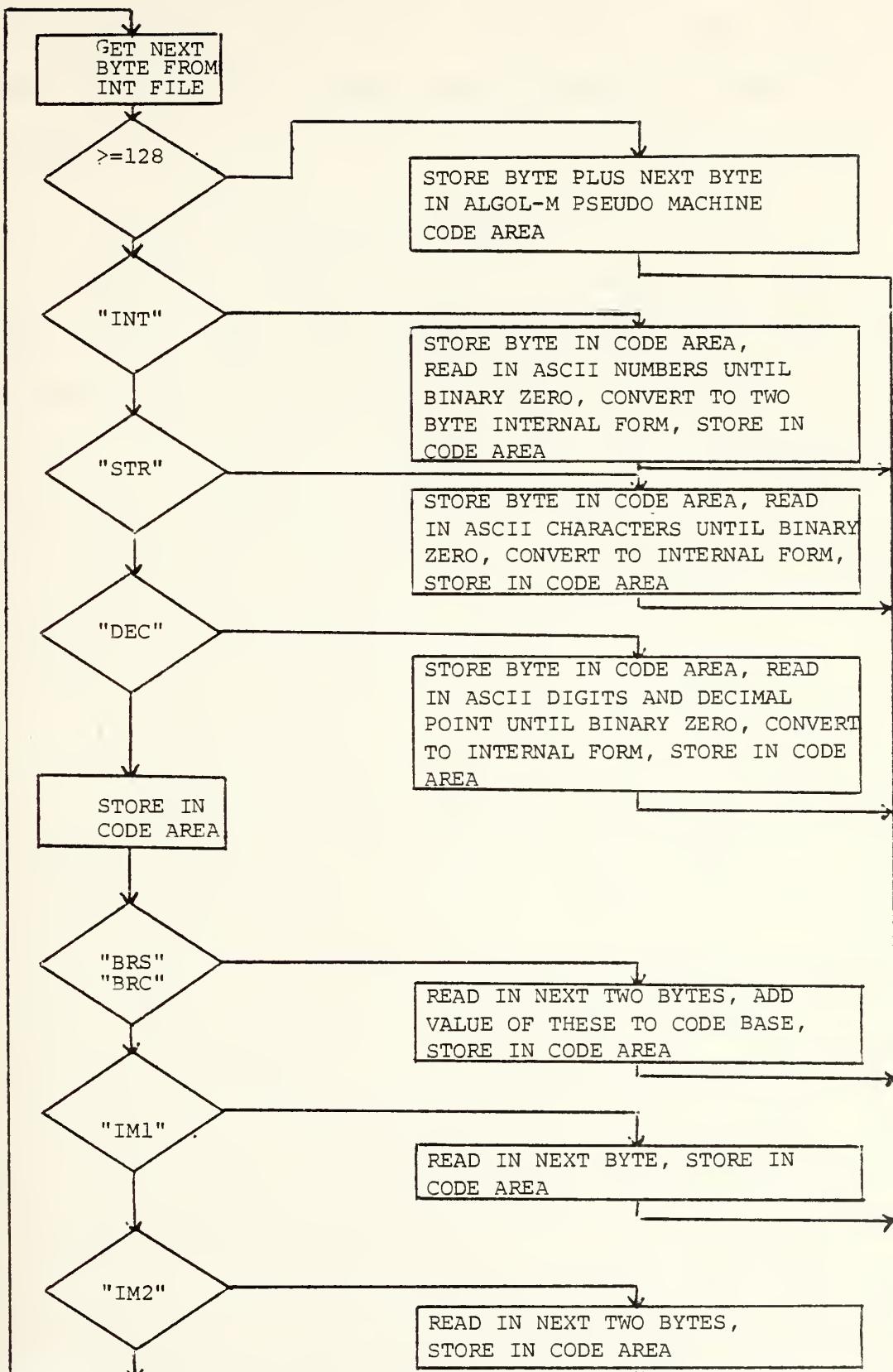


FIGURE 3



contents of the top and next-to-top stack locations are referenced by the variables BRA and BRB respectively. The various stack variables are depicted in Figure 4.

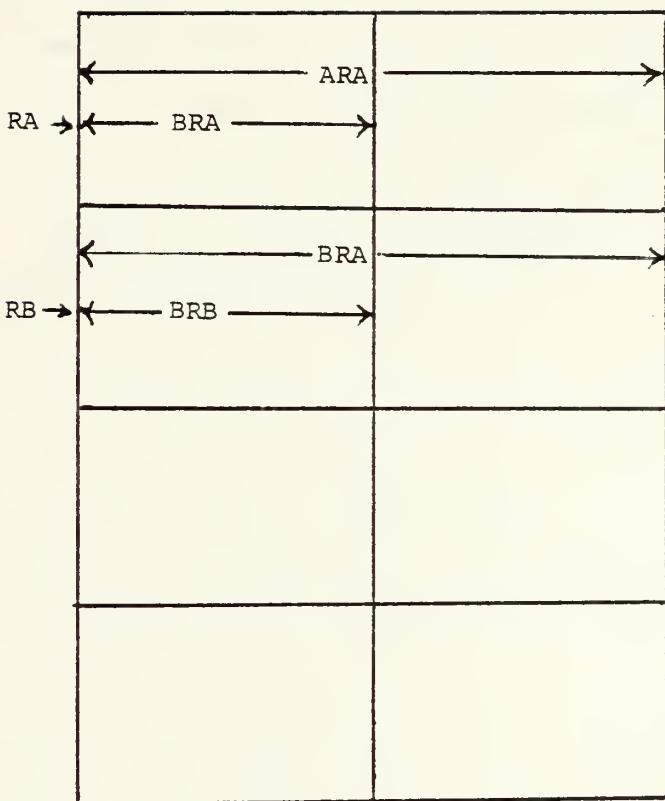
### 3. Allocation of Storage Space

Run-time storage space is required for the values associated with ALGOL-M program identifiers which have been declared as integer, decimal, or string values, and for information needed to process arrays and subroutines. A sequential number is assigned to each new identifier as it is recognized by the compiler. This number is used to reference the PRT at run-time in order to store or retrieve the value associated with each identifier.

#### a. Integers

Integer values range from -16,384 to +16,384 and are stored directly in the two bytes allocated in the PRT for integer identifiers. A maximum length of two bytes for integer values was chosen because the resulting range of possible integer values was considered adequate for the primary use of integers as program control counters, such as array subscripts and loop boundaries. Additionally, two-byte values were the most convenient size to work with in the implementation language PL/M 181. The high order bit of the integer representation is the sign bit, with zero indicating a positive value and one indicating a negative value. The second bit of the integer representation is always zero in order to permit





ALGOL-M STACK  
VARIABLES

FIGURE 4



differentiation between integers and other types on the stack. The ALGOL-M internal form for addresses is also a two byte value.

#### b. Decimals

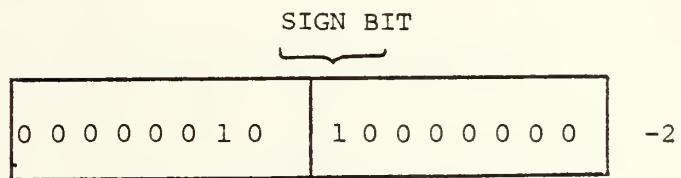
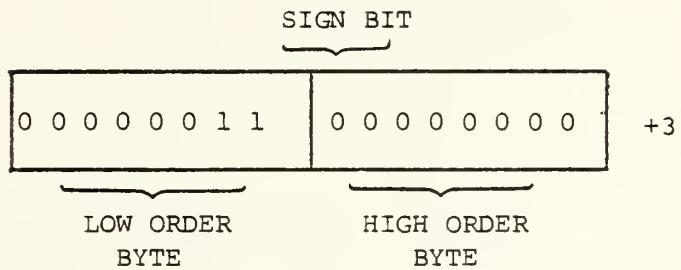
Decimal values up to 18 digits in length are permitted in the ALGOL-M language. Each decimal identifier is associated with a unique PRT entry. The value stored in the two byte PRT entry represents the run-time address of the location on the ALGOL-M stack where the actual decimal value is stored. The format for decimal storage is shown in Figure 6.

The next-to-last byte of the allocated space for decimal identifiers contains the number of bytes used for storage of that value. This value is a function of the size declared for the decimal by the programmer and may be delayed until run-time. A maximum of 18 digits of precision may be declared with the default precision being ten digits. The first byte of the decimal storage area contains a value representing the number of bytes used to hold the actual packed digits. This value may be less than the number of bytes which could be stored in the allocated area. In order to save storage space, the decimal values are packed two digits per byte of storage space.

ALGOL-M is a block structured language based upon a stack model for execution. Thus, it allows efficient allocation of storage for decimal identifiers. A block is normally bracketed by the ALGOL-M keywords



```
BEGIN
INTEGER A,B;
A := 3;
B := -2;
END
```



INTEGER STORAGE

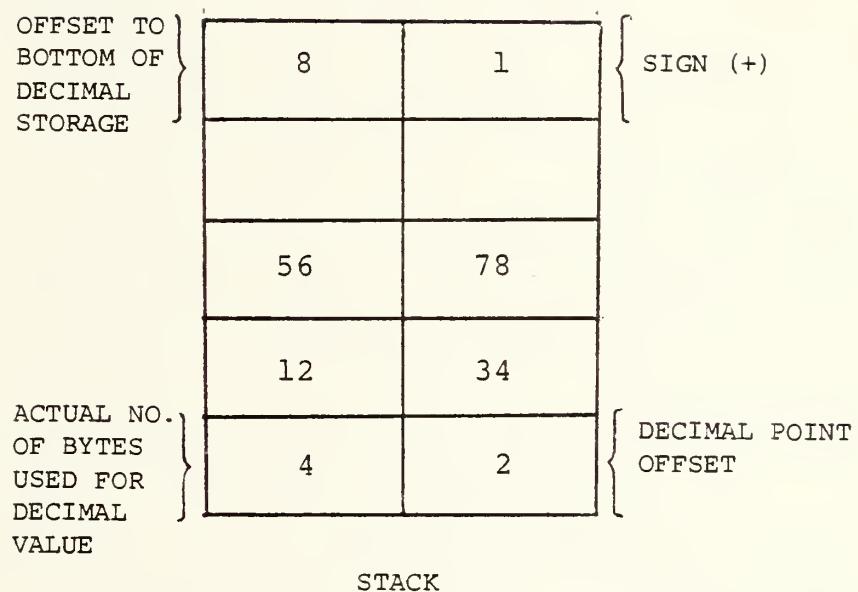
FIGURE 5



```

BEGIN
DECIMAL(12) X;
X := 123456.78;
END

```



DECIMAL STORAGE

FIGURE 6



BEGIN and END. Blocks may be embedded within a higher level block as shown in Figure 7. Identifiers which are declared in a given block are considered local to that block and global to any lower lever block and therefore may be referenced from those blocks. However, once execution of an ALGOL-M program proceeds beyond a given block, the identifiers declared within that block may no longer be referenced and, in fact, the storage allocated for those identifiers is removed from the ALGOL-M machine stack.

### c. Strings

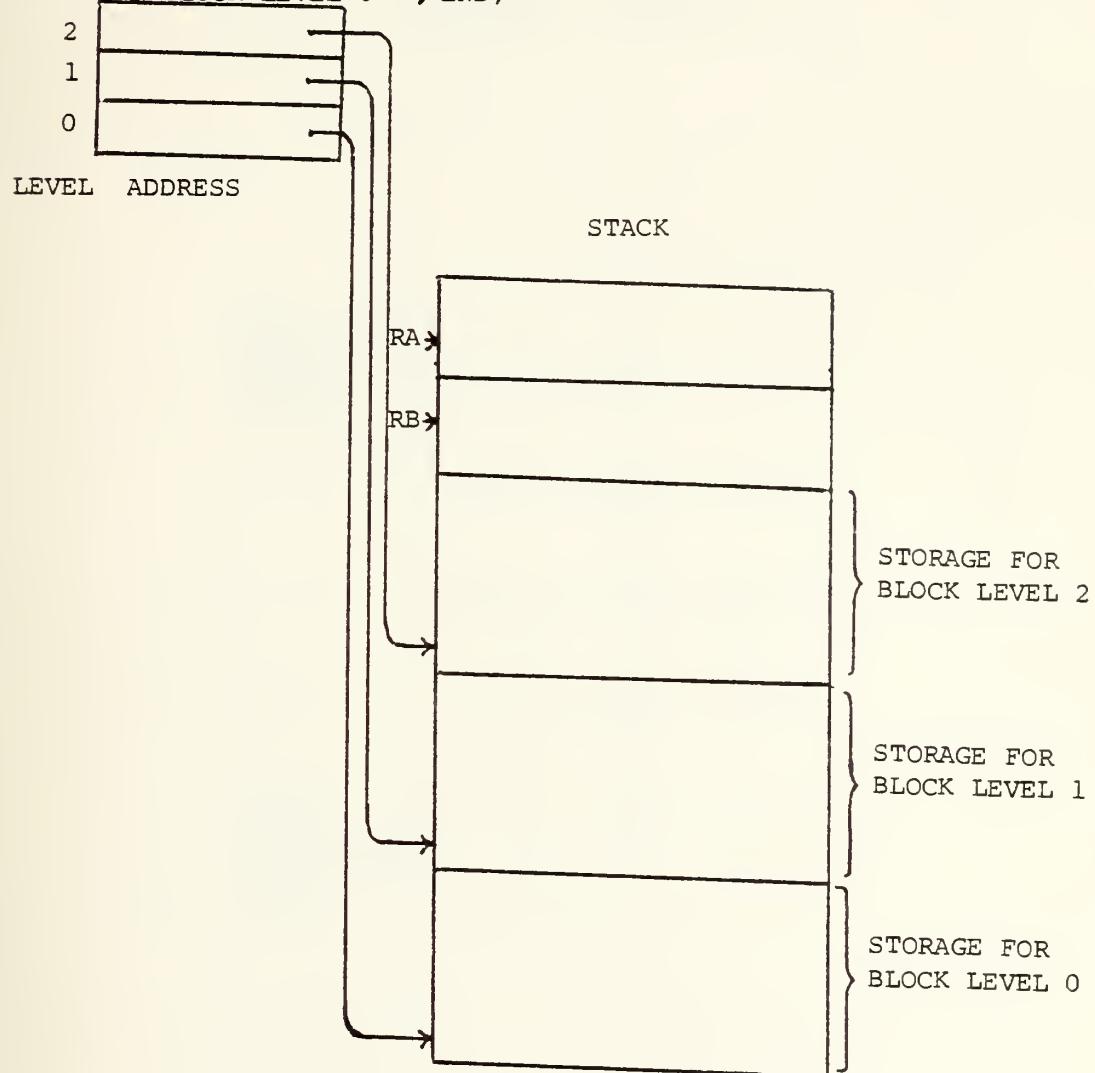
Strings of ASCII characters up to 255 bytes in length are permitted in ALGOL-M. In the same manner as used for decimal storage, the string identifier is associated with a unique PRT entry. The corresponding PRT entry contains the address of the actual string storage space on the ALGOL-M stack. The format for string storage is shown in Figure 8. The next-to-last byte of the allocated storage space for a string identifier contains the value of the number of bytes actually allocated by the programmer up to a maximum of 255 bytes. The first byte of the allocated string storage area contains the value of the actual number of ASCII characters stored in the allocated area. The concept of storage allocation as related to block levels is the same as described for decimal identifiers.



```

BLOCK LEVEL 0 → BEGIN
    DECIMAL A,B,C;
BLOCK LEVEL 1 → BEGIN
    STRING X,Y,Z;
BLOCK LEVEL 2 → BEGIN
    DECIMAL C,D,E;
END BLOCK LEVEL 2 → END;
END BLOCK LEVEL 1 → END;
END BLOCK LEVEL 0 → END;

```

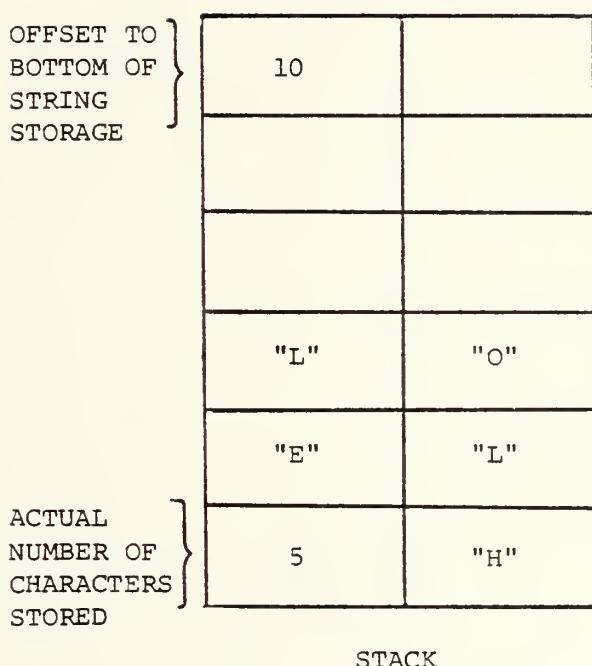


BLOCK LEVELS AND STACK STORAGE

FIGURE 7



```
BEGIN
STRING(9) TESTWORD;
TESTWORD := "HELLO";
END
```



STRING STORAGE

FIGURE 8



d. Arrays

ALGOL-M arrays may be of type integer, decimal, or string. Arrays may consist of up to 255 dimensions with each dimension containing up to 16,384 elements. The upper and lower bounds of each dimension may consist of any positive integers, variables, or arithmetic expressions. Each array name is associated with a unique PRT entry. The PRT entry contains the address pointer to the actual array storage area on the ALGOL-M machine stack. The first part of the array storage area on the stack consists of the displacement vector and other information which is necessary to calculate the address of any specific array element at run-time. The format for array storage is shown in Figure 9. The allocated storage area for each array element is exactly like that used for integers, decimals, or strings which are declared as single identifiers. The algorithm used for calculating the displacement vector is expressed as:

$$D_I = \begin{cases} \text{IF } I=N \text{ THEN } 1, \text{ OTHERWISE} \\ (U_{I+1} - L_{I+1} + 1) \cdot D_{I+1} \end{cases}$$

where N is the number of dimensions, I is the respective dimension, and U is the upper bound and L is the lower bound of a dimension.

The offset vector, V, is calculated by:

$$V = - \sum_{i=1}^N L_i D_i$$

The offset vector represents the correction necessary for non-zero-origin subscripts. This approach to locating elements in dynamically declared arrays is essentially the same as that used in ALGOL-F [10].



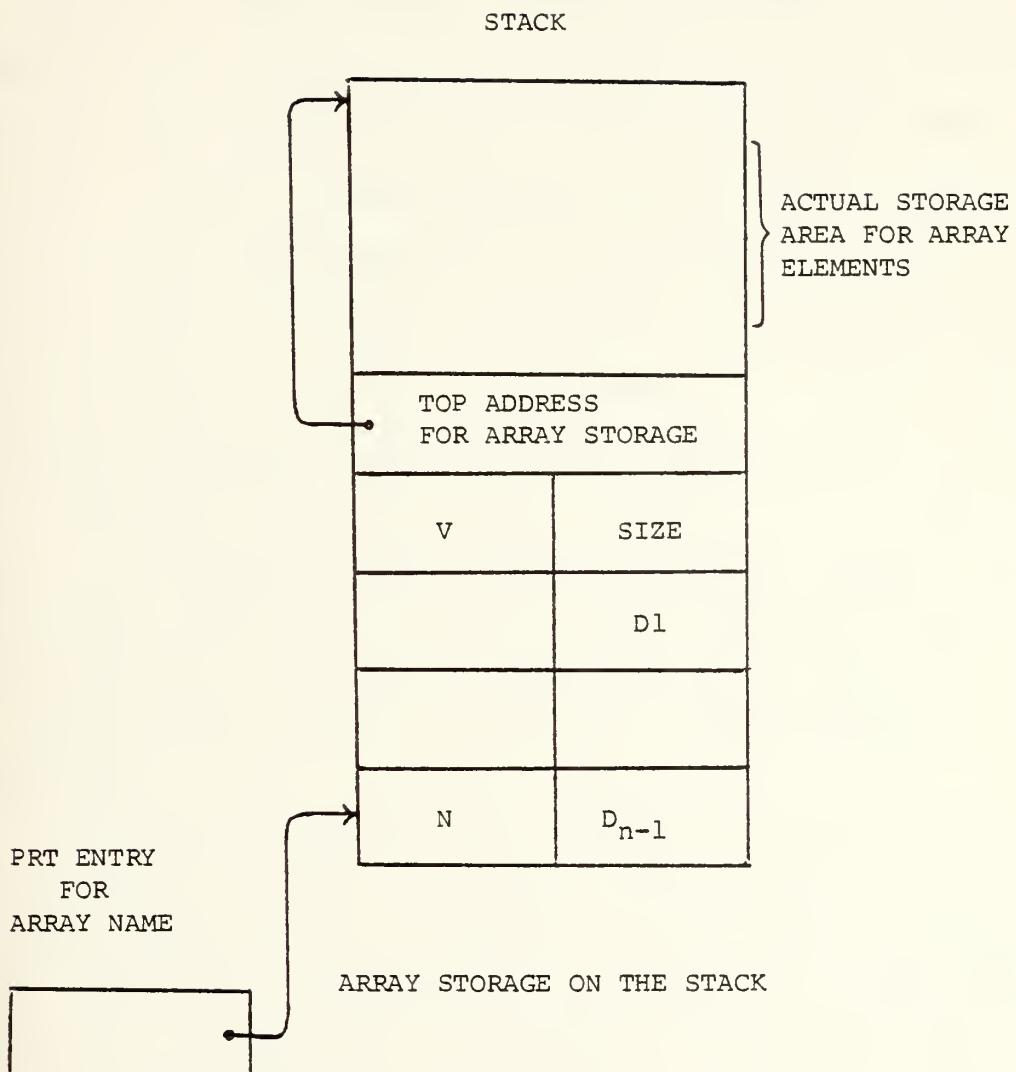


FIGURE 9



#### 4. Storage and Retrieval of Variables

Once allocation of storage for variables has been completed at run-time, storage and retrieval of actual values is relatively simple. A check is first made to insure that the number of bytes to be stored is less than or equal to the storage space allocated for a given variable. In the case of strings, if the destination storage space is not large enough to hold the entire string, as many characters as possible are stored and a run-time warning message is issued advising that string overflow has occurred. For decimal storage, if the total number of packed digits to be stored is larger than the available storage space, non-significant digits are deleted until the decimal value can be stored. If a significant digit must be deleted in order to store a decimal value, an error message is generated and the stored decimal value is arbitrarily set to 1.0 to allow continuation of program execution.

Array elements are stored exactly as the corresponding single element variables. However, the data located at the beginning of each array storage area (refer to Figure 9) is used to calculate the actual location of a specific array element. This is accomplished by initializing the offset variable to the value of the rightmost subscripted value. This value is then added to the product of the next rightmost subscripted value and the n-1 displacement vector value. This procedure is continued until the left-most subscripted value has been used in



the calculation. Next the offset vector, v , plus one, is subtracted from the offset variable and the result is multiplied by the size of the area allocated to each array element. The result of this calculation is the total offset, in bytes, from the beginning of the storage area for the array to the specific array element in question. A check is made to insure the calculated total offset is not greater than the offset which would result in access to the last array element. An error message is generated by the interpreter if a subscripted variable is referenced with subscripts that are not within the declared array dimensions.

## 5. Arithmetic Operations

Arithmetic operations for integer variables are straightforward because the implementation language, PL/M [8], provides all of the necessary two byte arithmetic operations. Therefore, the two integer values which are to be added, subtracted, multiplied, or divided are placed one above the other on the stack and the appropriate routine performs the necessary arithmetic operation, replacing the original two integer values with the result of that operation. The resulting value is then available to store into the space allocated for an integer variable or to be used as one of the integer values for continued arithmetic operations.

Decimal arithmetic is accomplished by manipulating packed decimal strings, each of which is loaded in a ten



byte register (two digits per byte). The result of the decimal arithmetic operation is stored in a third register. Decimal values are also stored in the packed decimal form, shown in Figure 6. Decimal strings are only unpacked when and if they are written to disk or console at run-time. Decimal addition is accomplished by adding the two registers, subtraction is done using nines complement arithmetic, multiplication is done through a shift and add algorithm, and division by a shift and subtract method. After the decimal arithmetic operation is completed, the result is placed on the top of the stack in preparation for a decimal store operation or use as a new value in a continuing algebraic expression.

#### b. String Operations

The ALGOL-M compiler is designed to handle strings up to 255 characters in length. The concatenation operator allows two or more strings to be combined to produce a new string consisting of all the characters contained in the original strings. The process of concatenation takes place on the stack with strings being combined repeatedly as necessary for multiple concatenations. The resulting string is then available for storage in the space allocated to a string identifier. If the result of concatenation produces a string which is longer than the allocated storage space, the string is truncated as necessary and an error message is issued by the interpreter.



## 7. Subroutines

There are two types of subroutines in ALGOL-M: functions and procedures. The only difference between the two is that a function returns a value to the top of the stack while a procedure does not. Subroutines are fully recursive and can be called prior to their declaration.

### a. Invocation

A subroutine can be invoked with zero or more actual parameters. The actual parameters consist of integer, decimal, or string expressions which are evaluated and passed to the subroutine via the execution stack. In addition to parameter values, the only other information needed to call a procedure is the procedure address in the code area. The actual format of the stack at the point of a subroutine call is indicated in Figure 10.

### b. Storage Allocation

Storage for variables and parameters declared within a subroutine is allocated on the stack at run-time. The actual parameters and the subroutine call information is also stored on the execution stack. To allow subroutine call by value and to save memory, it was necessary to move the actual parameter values and subroutine call information off the stack prior to allocating storage for the formal parameters and local variables. This was accomplished by moving them to the top of available memory. Storage can then be allocated for the formal parameters on top of the



STACK CONFIGURATION FOR  
PRO OPERATOR

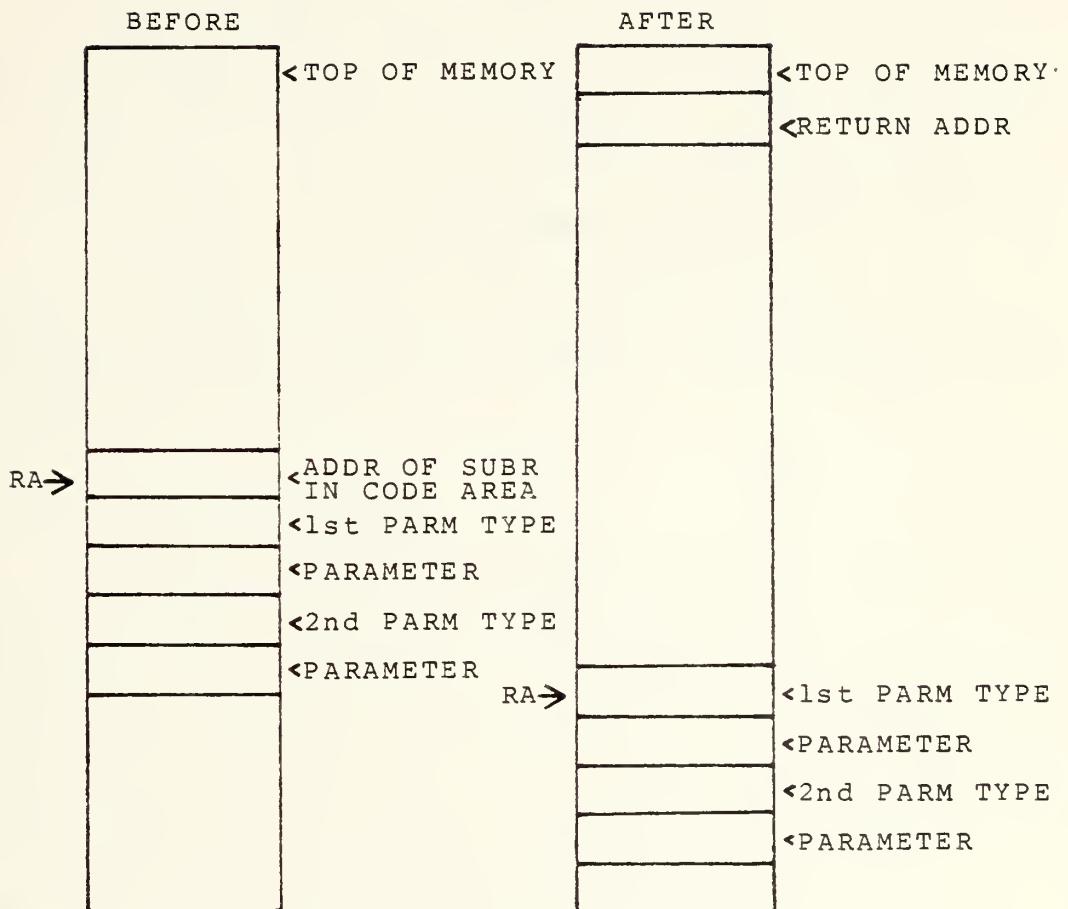


FIGURE 10



stack in the normal manner. This move was accomplished through the SAV operator as illustrated in Figure 11. The SAV operator also checks to determine if the call is a recursive call and if so, saves the procedure control block (PCB) on top of the stack. The PCB is similar in structure to that of ALGOL-E[10]. Although this procedure slows down the execution speed of the interpreter, it was considered more important to save memory space. Storing subroutine values on the stack as indicated above simplifies the deallocation of memory at the end of the subroutine. This is accomplished by simply removing elements from the stack down to the appropriate level.

#### c. Parameter Mapping

Parameter mapping is done through the use of the SV2 operator as illustrated in Figure 12. The operator copies the actual parameter information at the top of memory into the area allocated on top of the stack. The PCB which keeps track of subroutine variables is then set with pointers to the current parameter values.

#### d. Function Return Value

Included with the allocated area for parameters and local variables, there is an additional allocated area for the return value of functions. The function name is treated as a simple variable within the function and the return value is assigned to it. This value is copied to the top of the stack when the function returns.



STACK CONFIGURATION FOR  
SAV OPERATOR

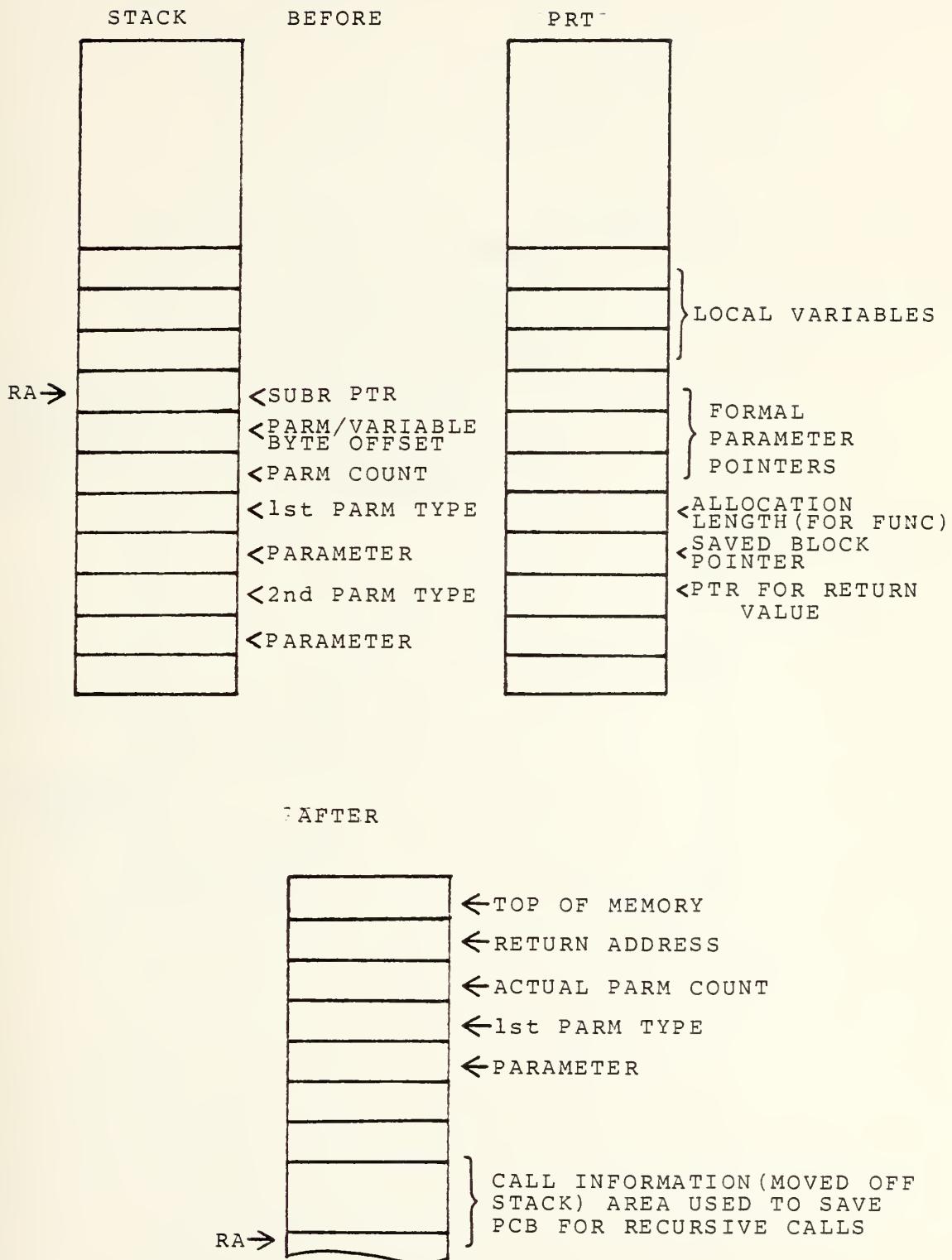


FIGURE 11



STACK CONFIGURATION FOR  
SV2 OPERATOR

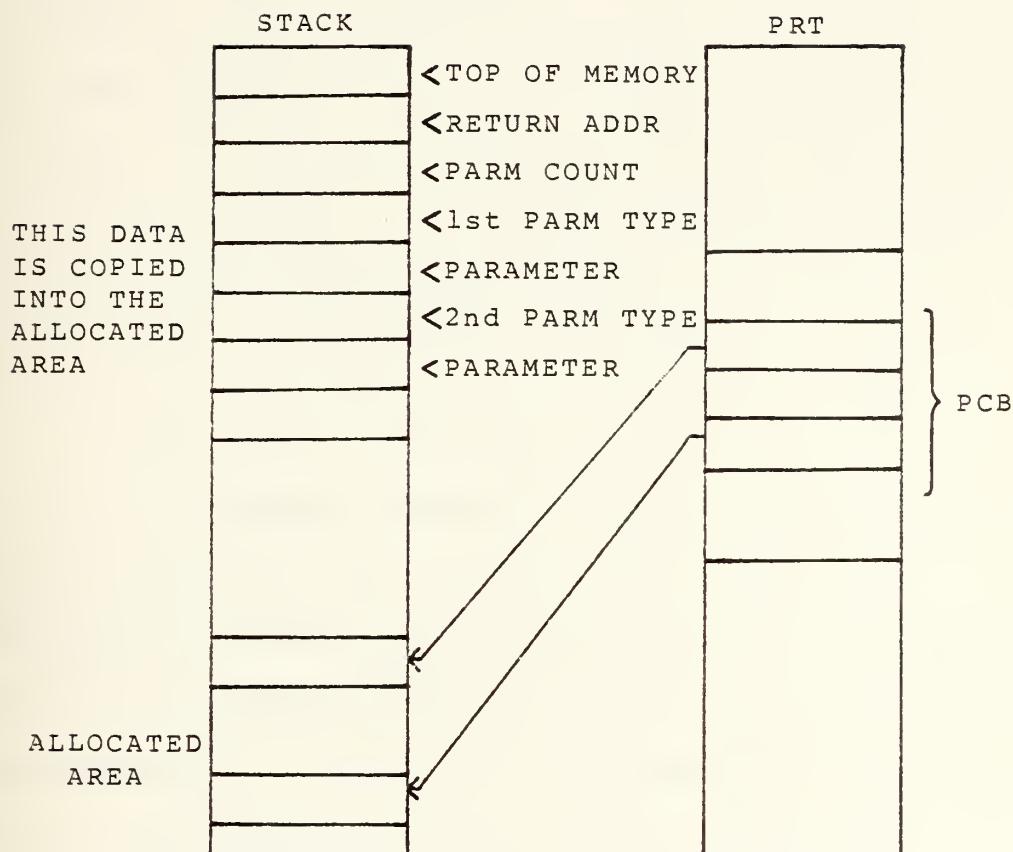


FIGURE 12



#### e. External Functions

The ALGOL-M grammar supports external function declarations and, although they have not been implemented, their design has been considered. External functions are conceived to be ALGOL-M intermediate files which could be declared and called from other ALGOL-M programs. The intermediate code for these files would be read from disk by the compiler and integrated into the program intermediate code as if the external subroutine had in fact been a normal program subroutine. The grammar would require modification in order to allow a subroutine to be compiled by itself.

#### f. Forward References

Forward subroutine references are supported by simply treating all undeclared identifiers as forward subroutine references during pass one of the compiler. If on pass two these references have not been resolved, then an undeclared variable error is generated by the compiler.

#### g. Built-in Functions

There are currently no built-in functions in ALGOL-M. However, their implementation has been considered. To implement built-in functions, a simple modification to the symbol table structure would be needed, allowing the built-in function names to be entered in the symbol table when it is initialized. There would be an operator associated with each function name in the symbol table which would indicate the run-time action to



be taken. This operator would be emitted each time the built-in function was referenced.

## 8. Input-Output

Two basic types of input-output (I/O) are implemented in the ALGOL-M language: console and disk. Console I/O refers to the device which is being used to provide commands to the system, typically a cathode-ray tube terminal or a teletype. Input is accomplished via ALGOL-M program READ statements and output via WRITE or WRITEON statements. Integer and decimal values, including signs and decimal points, are converted from their internal representation into ASCII characters which are provided to an operating system print routine for console output. String variables and constants are stored in the ALGOL-M pseudo-machine as ASCII strings and are sent character by character to the system print routine. Console input is accomplished via an operating system routine which reads one full console line into an ALGOL-M buffer. The interpreter examines the buffer and converts the ASCII characters in the buffer into the appropriate ALGOL-M internal decimal, integer or string format. The input value is then stored in the space allocated for its variable name.

The ALGOL-M READ or WRITE statement for disk I/O contains the name of the disk file to be used and, optionally, specifies the disk drive containing that file. The default drive is the currently loaded drive [4]. An



additional option is that any specific record on the file may also be specified in the ALGOL-M READ or WRITE statement. A file declaration statement is used to associate file identifier names with a specific entry in the ALGOL-M PRT. At run-time, space is allocated on the ALGOL-M stack for file control block (FCB) information necessary to interface file operations with the operating system. In addition to the FCB, space is also allocated for a 128 byte I/O buffer for each declared file. The routines to convert packed decimal and integer numbers from internal form to ASCII form, and vice-versa, which are used for writing to and reading from disk files are the same as those used for console I/O. Any number of files may be open simultaneously and, as with all run-time storage, the space allocated on the stack for file operations is recovered when the block is exited.

## 9. ALGOL-M Pseudo Operators

### a. Description of Interpreter Variables

The top item on the ALGOL-M stack is addressed by the variable RA while the next-to top item on the stack is addressed by the variable RB. The value contained in the first two bytes addressed by RA and RB are referenced by the variables ARA and ARB respectively. The contents of the low-order byte of ARA and ARB is referenced by the variable BRA or BRR respectively. The structure of the stack is shown in Figure 4. Decimal and string values may be represented on the stack by an address which yields the



actual storage area for the value, or by the actual value itself stored as one of the items on the stack. When a decimal or string value is stored on the stack, it is referred to as a temporary value. Temporary values are stored on the stack in preparation for storage into the area allocated to a specific identifier, or for use as a value in the evaluation of an expression.

The ALGOL-M compiler generates various pseudo operators which were chosen to allow effective run-time execution of the ALGOL-M pseudo machine. Following is a list of the pseudo operators and a brief description of the action taken at run-time when each operator is encountered in the ALGOL-M code area.

#### b. Literal Data References

An initial check is made of each one byte operator in the code area in order to determine if the high order bit of that byte is set to one. If the high order bit is set then the least significant 14 bits of that byte and the following byte are automatically added to the address of the beginning of the program reference table and placed on top of the stack. A check is then made of the second bit of the original byte and if it also is set to one the PRT address now on top of the stack is replaced by the contents of the two bytes pointed to by that address. These are referred to as LIT and LITLOD operators.

INT: (integer). The following two byte integer value is placed on the stack.



STR: (string). The program counter is incremented past the following string constant and the address of the next-to-last byte of the string constant is placed on the stack.

DECT: (decimal). The program counter is incremented past the following decimal constant and the address of the next-to-last byte of the decimal is placed on the stack. The next-to-last byte of the decimal constant contains the offset to the first byte of the constant which in turn contains the value of the number of bytes in which actual decimal digits are stored.

IM1: (load a one byte integer). The value of the following byte is converted to a two byte value and placed on the stack.

IM2: (load a two byte integer). The following two byte value is placed on the stack in reverse order.

### c. Allocation Operators

ALD: (allocate decimal). Storage for a decimal variable is allocated on the stack and the address of the allocated area is placed in the PPT entry for the specific decimal variable.

ALS: (allocate string). Storage for a string variable is allocated on the stack and the address of the allocated area is placed in the PPT entry for the specific string variable.

AID: (allocate intermediate decimal). The same action is taken as in ALD except the declared decimal length



is left on top of the stack in preparation for the next allocation which is expected to immediately follow in the code area. This operator is used when several decimal identifiers are declared in a single declaration statement.

AIS: (allocate intermediate string). The same action is taken as in the AID operator with the exception that string allocation is used.

#### d. Arithmetic Operators

ADI: (add integer). The integer values of the top two items on the stack are replaced by their integer sum.

ADD: (add decimal). The decimal value of the top item on the stack is loaded into decimal arithmetic register zero, and the value of the second item on the stack is loaded into decimal arithmetic register one. The two arithmetic registers are added with the result placed in register two. The original decimal values on the stack are replaced by the result of the arithmetic operation.

SBI: (subtract integer). The second integer value on the stack is subtracted from the integer value on top of the stack, both values are removed from the stack and the result of the operation is placed on top of the stack.

SBD: (subtract decimal). The same action is taken as in the ADD operator except the second item is subtracted from the top item on the stack.

MPI: (multiply integer). The same action is taken as in the SBI operator except the top two items are



multiplied.

MPD: (multiply decimal). The same action is taken as in the ADD operator except the top two items are multiplied.

DVI: (divide integer). The same action is taken as in the SBI operator except the top item is divided by the second item.

DVD: (divide decimal). The same action is taken as in the ADD operator except the top item is divided by the second item.

NEG: (negative). The sign of the decimal or integer on top of the stack is changed.

CI1: (convert integer). The integer on top of the stack is replaced by its decimal equivalent.

CI2: (convert integer). The same action is taken as with CI1 except the integer which is the second item on the stack is converted to a decimal.

LSS: (integer less than). The integer value (ARB) is compared with the integer value (ARA). Both values are removed from the stack. If ARB was less than ARA, the value one is placed on the stack, otherwise the value zero is placed on the stack.

DLSS: (decimal less than). The decimal on top of the stack is compared to the decimal which is the second item on the stack. If the value on top of the stack is less than the second value on the stack, both values are removed from the stack and replaced by the value one, otherwise they are replaced by the value zero.



GTR: (integer greater than). The same action is taken as in the LSS operator except a one is placed on the stack if ARB is greater than ARA.

DGTR: (decimal greater than). The same action is taken as in the PLSS operator except a one is placed on the stack if the second decimal item is greater than the top decimal item.

EQL: (integer equal to). The same action is taken as in the GTR operator except a one is placed on the stack if ARB is equal to ARA.

DEQL: (decimal equal to). The same action is taken as in the DGTR operator except a one is placed on the stack if the second decimal item is equal to the top decimal item.

NEQ: (integer not equal to). The same action is taken as in the EQL operator except a one is placed on the stack if ARB is not equal to ARA.

DNEQ: (decimal not equal to). The same action is taken as in the DEQL operator except a one is placed on the stack if the second decimal item is not equal to the top decimal item.

GEQ: (integer greater than or equal to). The same action is taken as in the NEQ operator except a one is placed on the stack if ARB is greater than or equal to ARA.

DGEQ: (decimal greater than or equal to). The same action is taken as in the DNEQ operator except a one is placed on the stack if the second decimal item is greater than or equal to the top decimal item.



LEQ: (integer less than or equal to). The same action is taken as in the GEQ operator except a one is placed on the stack if ARB is less than or equal to ARA.

DLEN: (decimal less than or equal to). The same action is taken as in the DGEQ operator except a one is placed on the stack if the second decimal value is less than or equal to the top decimal value.

NOT: (boolean not). This operator changes the result of any previous boolean operator by complementing the value of the one or zero which was placed on the stack by the previous operation.

AND: (boolean and). This operator checks the top two values left on the stack by any two previous boolean operations. If both values are one then both values are replaced with a one; otherwise both values are replaced with a zero.

OR: (boolean or). This operator checks the top two values left on the stack by any two previous boolean operations. If either value is a one then both values are replaced by a one; otherwise they are replaced by a zero.

#### e. String Operators

CAT: (concatenate). The two strings on top of the stack are combined to produce a new string consisting of the characters of the second string followed by the characters of the first string. The two original strings are popped from the stack and replaced by the resulting concatenated string.



SLSS: (string less than). The same action is taken as in the DLSS operator except that a character by character string comparison is made using the ASCII character collating sequence.

SGTR: (string greater than). The same action is taken as in the DGTR operator except a string comparison is made.

SEQL: (string equal to). The same action is taken as in the DEQL operator except a string comparison is made.

SNEQ: (string not equal to). The same action is taken as in the DNEQ operator except a string comparison is made.

SGEQ: (string greater than or equal to). The same action is taken as with DGEQ except a string comparison is made.

SLEQ: (string less than or equal to). The same action is taken as with DLEQ except a string comparison is made.

#### f. Stack Operators

XCH: (exchange). The value of the top two bytes on the stack (ARA) is exchanged with the value of the next-to-top two bytes on the stack(ARB).

POP: (pop the stack). The stack pointer (RA) is moved to the position of the stackpointer (RB) and RB is moved to point to the next item below its current position on the stack.



LOD: (load). The address value on the stack (ARA) is replaced by the two bytes pointed to by that address.

DCB: (decrement block by more than one level): The stack pointer (RA) is decremented to the address stored in the block level table and the index to the block level table is decreased by the value stored in the next two bytes in the code area. The stack pointer (RB) is moved below RA to the top of the second item on the stack.

BLI: (block level increment). The index to the block level array is increased by one and the address of the top item on the stack is stored in the block level array.

BLD: (block level decrement). The index to the block level array is decreased by one and the value of the stack pointer (RA) is changed to the address stored in the block level array.

S<sup>R</sup>R: (subtract stack values). This operator is used to subtract the second value on the stack from the top value on the stack using unsigned sixteen bit arithmetic. The two values are replaced by the result of the subtraction.

#### g. Array Operators

ROW: (allocate array storage). The number of array dimensions, the upper and lower bounds of each dimension, and the array type (integer, decimal, or string) are used to calculate the array displacement vector which is stored on the stack prior to allocation of storage for the



actual array elements.

SUB: (calculate the offset to a specific array element). The array subscript is used in conjunction with the displacement vector information stored at the beginning of the array storage area to calculate the address of the specific array element being referenced by the subscripted variable.

h. Program Control Operators

BRS: (branch absolute). The program counter is changed to an address one less than the address represented by the following two bytes in the code area.

BRC: (branch conditional). If the value on top of the stack is zero, the program counter is changed as in BRS; otherwise the program continues with the next operator in the code area.

BRA: (computed branch absolute). The program counter is changed relative to the start of the code area by the value on top of the stack.

XIT: (exit the interpreter). XIT caused return of control to the operating system.

i. Store Operators

STI: (store integer intermediate). The integer value which is the second item on the stack is stored in the PRT address which is the top item on the stack. The PRT address is then removed from the stack.

SDI: (store decimal intermediate). The same action is taken as with STI except a decimal value is stored



in the allocated area pointed to by the address on top of the stack.

· SSI: (store string intermediate). The same action is taken as in the SDI operator except a string value is stored.

SID: (store integer destruct). The same action is taken as in the SII operator except both the PRT address and the integer value are removed from the stack.

SDD: (store decimal destruct). The same action is taken as in the SID operator except the pointer to the decimal allocated area and the decimal value are removed from the stack.

SSD: (store string destruct). The same action is taken as in the SDD operator except the pointer to the string allocated area and the string value are removed from the stack.

#### j. Input/Output Operators

DMP: (dump). DMP signifies the end of writing a line to the console. A carriage return and line feed are output to the console via the operating system.

WIC: (write integer to console). The integer value on top of the stack is converted to ASCII characters and printed on the console.

WDC: (write decimal to console). The decimal value on top of the stack is converted to ASCII characters and printed on the console.

WSC: (write string to console). The ASCII



string value on top of the stack is printed on the console.

WID: (write integer to disk). The integer value on top of the stack is converted to ASCII characters and stored in the disk buffer allocated for the file name specified in the source WRITE statement.

WDD: (write decimal to disk). The decimal value on top of the stack is converted to ASCII characters and stored in the disk buffer allocated for the file name specified in the source WRITE statement.

WSD: (write string to disk). The ASCII string characters on top of the stack are stored in the disk buffer allocated for the file name specified in the source WRITE statement.

RCI: (read console integer). The console read buffer is scanned for the ASCII representation of an integer which is converted into internal form and placed on top of the stack.

RCD: (read console decimal). The console read buffer is scanned for the ASCII representation of a decimal value which is converted into internal form and placed on top of the stack.

RCS: (read console string). The console read buffer is scanned for an ASCII string or for any series of characters delimited by quotation marks which is placed on top of the stack.

RDI: (read disk integer). The disk buffer allocated to the file name appearing in the source language READ statement is scanned for the ASCII representation of an



integer which is converted to internal form and stored on top of the stack.

RDD: (read disk decimal). The same action is taken as in the RDI operator except a decimal value is placed on top of the stack.

RDS: (read disk string). The same action is taken as in the RDI operator except a string value is placed on top of the stack.

RCN: (load console buffer). The current line on the console is dumped into the console read buffer and the current program counter is stored in preparation for the possibility of a console error and the subsequent need to recover for repeated console input.

ECR: (error in console read). If characters remain in the console read buffer after all console read operations have been completed, an error condition exists and the program counter is reset to the start of the console read routine allowing the console input to be entered again as necessary.

OPN: (disk open). The address on top of the stack points to the allocated area for the file control block and disk buffer associated with the disk file name specified in the source language file declaration statement. The file name which is stored in the file control block is passed to the operating system which in turn opens that specific file for disk inout/output.

CLS: (disk close). The file name located in the file control block pointed to by the address of the top of



the stack is passed to the operating system which in turn closes that specific file to input/output.

RDB: (ready sequential block). The interpreter input/output routines are initialized to operate with the file control block and disk buffer area pointed to by the address on top of the stack. The address of the code to be executed upon reaching the end of a file is also initialized.

RDF: (ready random block). The same action is taken as with RDB with the addition that the specific record of the disk file is also taken from the top of the stack and the file control block is set up to conduct input/output from or to that specific record.

EDR: (end of record for read). At the end of a read statement the remainder of the record is skipped.

EDW: (end of record for write). At the end of a write statement the remainder of the record is filled with blanks and a line terminator is appended to the end of the record.

#### k. Subroutine Operators

PRU: (subroutine call). The two bytes of code following the PRU operator represent the address of the subroutine in the code area. This operator saves the return address at the top of memory, positions the stack pointer at the top of the first actual parameter (see Figure 10 for parameter format) and branches to the first statement in the subroutine.



SAV: (save actual parameters). The SAV operator expects the stack format illustrated in Figure 11. It copies the actual parameters to the top of memory and checks the PCB for a recursive call and if so it copies the PCB onto the top of the stack.

SV2: (copy actual parameters into formal parameters). The SV2 operator copies the actual parameters at the top of memory into allocated area for the formal parameters on top of the stack.

UNS: (unsafe parameters). The UNS operator checks the PCB to see if it is the end of a recursive call. If this is the case, UNS restores the PCB from the previous call. UNS also returns the value associated with the name of the subroutine to the top of the stack. In the case of procedures the returned value is zero.

RTN: (return). The RTN operator changes the value of the program counter to the value of the return address.



#### IV. CONCLUSIONS

This project has resulted in the construction of a high-level, block-structured, applications oriented compiler for micro-computers with 20k bytes of memory or more. When compared to a fully dynamic scheme, the stack storage allocation and retrieval scheme presented here appears to enhance program execution speed, reduce memory requirements, and simplify compiler implementation.

Timing tests with several benchmark programs have been conducted. These test programs were obtained from REF[7] and have been run with several versions of the BASIC programming language. The results (expressed as execution time in seconds) are summarized as follows:

BENCHMARK NUMBER	1	2	3	4	5	6	7
ALGOL-M	1.8	1.3	3.5	3.3	5.1	14.2	16.4
INTEGER BASIC	1.3	3.1	7.2	7.2	8.8	18.5	28.0
STANDARD BASIC	1.7	7.5	20.6	20.9	22.1	36.2	51.8

Listings of the seven benchmark programs are contained in Appendix A. The reason ALGOL-M appears slower in the first benchmark is that the grammar requires at least one executable statement in FOR loops when compared to BASIC which has FOR loops which can do nothing. The resulting ALGOL-M program executes 1000 extra assignment statements which the BASIC programs did not. Otherwise, the results



clearly indicate that the ALGOL-M language is not only well-structured but also executes rapidly in comparison with the very best BASIC interpreters. It is believed that the major reason that the ALGOL-M versions performed so well is the fact that the language supports integer arithmetic as opposed to most BASIC implementations which convert all constants and variables to floating point format. This allows ALGOL-M loop control counters to be incremented extremely rapidly. Comparisons for decimal calculations have not been done, and thus no conclusions can be drawn concerning relative speeds of calculation-dependent programs.



## V. RECOMMENDATIONS

There are several areas that could be enhanced in this implementation of ALGOL-M. Formatted I/O although defined in the grammar has not been implemented. The I/O definition is very similar to that of COBOL and implementation of this should not be too difficult. File I/O is implemented, but not tested. Debugging facilities in the run-time monitor are not currently implemented. However, the system is designed to provide the following information at run-time: the line number of the currently executing line and the value of each variable as it is altered.

The current version of ALGOL-M is designed to run on a system with at least 20k bytes of memory. A smaller system could be designed to run on a 16k system. This would involve deleting some of the more complicated sections of code such as dynamic arrays and recursive subroutines. The other features of the language which are not implemented are relatively minor, and are indicated in the program listings.



## APPENDIX A - BENCHMARK PROGRAMS

### Benchmark Program 1

```
300 PRINT "START"
400 FOR K=1 TO 1000
500 NEXT K
700 PRINT "END"
800 END

BEGIN
INTEGER A,K;
WRITE("START");
FOR K:=1 STEP 1 TO 1000 DO
    A:=0;
    WRITE("END");
END
```

### Benchmark Program 2

```
300 PRINT "START"
400 K=0
500 K=K+1
600 IF K<1000 THEN 500
700 PRINT "END"
800 END

BEGIN
INTEGER K;
WRITE("START");
K:=0;
WHILE K < 1000 DO
    K:=K+1;
    WRITE("END");
END
```

### Benchmark Program 3

```
300 PRINT "START"
400 K=0
500 K=K+1
510 A=K/K*K+K-K
600 IF K <1000 THEN 500
700 PRINT "END"
800 END

BEGIN
INTEGER A,K;
WRITE("START");
K:=0;
WHILE K<1000 DO
    BEGIN
        K:=K+1;
        A:=K/K*K+K-K;
    END;
    WRITE("END");
END
```



### Benchmark Program 4

```
300 PRINT "START"
400 K=0
500 K=K+1
510 A=K/2*3+4-5
600 IF K<1000 THEN 500
700 PRINT "END"
800 END
```

```
BEGIN
INTEGER A,K;
WRITE("START");
K:=0;
WHILE K<1000 DO
BEGIN
K:=K+1;
A:=K/2*3+4-5;
END;
WRITE("END");
END
```

### Benchmark Program 5

```
300 PRINT"START"
400 K=0
500 K=K+1
510 A=K/2*3+4-5
520 GOSUB 820
600 IF K<1000 THEN 500
700 PRINT "END"
800 END
```

```
BEGIN
INTEGER A,K;
PROCEDURE DONOTHING;
A:=0;
WRITE("START");
K:=0;
WHILE K<1000 DO
BEGIN
K:=K+1;
A:=K/2*3+4-5;
DONOTHING;
END;
WRITE("END");
END
```



Benchmark Program 6

```
300 PRINT "START"
400 K=0
430 DIM M(5)
500 K=K+1;
510 A=K/2*3+4-5
520 GOSUB 820
530 FOR L=1 TO 5
540 NEXT L
600 IF K<1000 THEN 500
700 PRINT "END"
800 END

BEGIN
INTEGER A,K,L;
INTEGER ARRAY M[1:5];
PROCEDURE DONOTHING;
BEGIN
A:=0;
END;
WRITE("START");
K:=0;
WHILE K<1000 DO
BEGIN
K:=K+1;
A:=K/2*3+4-5;
DONOTHING;
FOR L:=1 STEP 1 UNTIL 5 DO
A:=0;
END;
WRITE("END");
END
```

Benchmark Program 7

```
300 PRINT "START"
400 K=0
430 DIM M(5)
500 K=K+1
510 A=K/2*3+4-5
520 GOSUB 820
530 FOR L=1 TO 5
535 M(L)=A
540 NEXT L
600 IF K<1000 THEN 500
700 PRINT "END"
800 END
820 RETURN

BEGIN
TNTTEGER A,K,L;
INTEGER ARRAY M[1:5];
PROCEDURE DONOTHING;
BEGIN
A:=0;
END;
WRITE("START");
K:=0;
WHILE K<1000 DO
BEGIN
K:=K+1;
A:=K/2*3+4-5;
DONOTHING;
FOR L:=1 STEP 1 UNTIL 5 DO
M[L]:=A;
END;
WRITE("END");
END
```



## APPENDIX B - COMPILER ERROR MESSAGES

AS	Function/Procedure on left hand side of assignment statement.
BP	Incorrect bound pair subtype (must be integer).
DE	Disk error; no corrective action can be taken in the program.
DD	Doubly declared identifier, label, variable etc.
IC	Invalid special character.
ID	Subtypes incompatible (decimal values can not be assigned to integer variables).
IO	Integer overflow.
IT	Identifier is not declared as a simple variable or function.
NG	No ALG file found.
NI	Subtype is not integer.
NP	No applicable production exists.
NS	Subtype is not string.
PC	Undeclared parameter.
SO	Stack overflow.
SI	Array subscript is not of subtype integer.
TD	Subtype has to be integer or decimal.
TM	Subtypes do not match or are incompatible.
TO	Symbol table overflow.
TS	Undeclared subscripted variable.
UD	Undeclared identifier.
UF	Undeclared file/function.
UP	Undeclared procedure.



VO

Varc table overflow. Possibly caused by too many  
long identifiers.



## APPENDIX C - INTERPRETER ERROR MESSAGES

### ERROR MESSAGES

AB Array subscript out of bounds.  
AZ Attempt to allocate null decimal or string,  
default to 10 digits/characters.  
CE Disk file close error.  
DC Disk file create error.  
DW Disk file write error.  
DZ Division by zero, result set to 1.0.  
EF Disk end of file, no action specified.  
IO Integer overflow.  
NI No INT file found on directory.  
OV Overflow during decimal multiply.  
RE Attempt to read past end of record on blocked file.  
RU Attempt to random access a non-blocked file.  
SL Significant digits lost during decimal store,  
value set to 1.0.

### WARNING MESSAGES

II Invalid Console Input  
IL Non-significant digit lost during decimal store.  
SO Characters lost during string store.



## APPENDIX D ALGOL-M LANGUAGE MANUAL

This section describes the various elements of the ALGOL-M language. The format of the element will be shown, followed by a description and examples of use. The following notation is used:

Braces {} indicate an optional entry.

A vertical bar | indicates alternate choices, one of which must appear.

Ellipses "..." indicate that the preceding item may be optionally repeated.

Reserved words are indicated by capital letters.

Reserved words and other special symbols must appear as shown.

Items appearing in small letters are elements of the language which are defined and explained elsewhere in the language manual.



## ELEMENT:

arithmetic expression

## FORMAT:

integer|decimal

variable

{() arithmetic expression binary operator  
arithmetic expression ()}

{() unary operator arithmetic expression ()}

## DESCRIPTION:

Operators in ALGOL-M have an implied precedence which is used to determine the manner in which operators and operands are grouped. A-B/C causes the result of B divided by C to be subtracted from A. In this case B is considered to be "bound" to the "/" operator instead of the "-" operator which causes the division to be performed first. The implied precedence binds operands to the adjacent operator of highest precedence. The implied precedence of operators is as follows:



unary - , +

\*\*

\* , /

+ , -

Parentheses can be used to override the implied precedence in the same way as they are used in ordinary algebra. Thus the expression (A-B)/C will cause B to be subtracted from A and the result divided by C.

EXAMPLE:

(X + Y) \* (Z \* Y + X) \*\* 2

X + Y + Z \* X \* Y \* Z / 5.456 + I



## ARRAY declaration

### ELEMENT:

ARRAY declaration

### FORMAT:

```
INTEGER|DECIMAL|STRING {{expression}} ARRAY  
identifier ... bound pair list {,identifier}
```

### DESCRIPTION:

The array declaration dynamically allocates storage for arrays. The optional integer expression indicates the length of each array element. For strings, the maximum length is 255 characters and for decimals the maximum length is 18 digits. Integer lengths are not specified since storage adequate to represent all integer values between -10,384 and +10,384 is automatically allocated. Arrays are not automatically initialized to zero.

### EXAMPLE:

```
INTEGER ARRAY X[0:5,0:5];  
DECIMAL(10) APRAY X,Y[3:6,5:10];  
STRING ARRAY WORDS[Y+3:12];
```



## assignment statement

### ELEMENT:

assignment statement

### FORMAT:

variable := {variable :=} ... expression

### DESCRIPTION:

The expression is evaluated and stored into the variable. The types of permissible assignments are indicated by the following table:

		<u>expression</u>		
		integer	decimal	string
integer		yes	no	no
<u>variable</u>	decimal	yes	yes	no
string		no	no	yes

Multiple assignments are allowed with the expression being assigned to all of the listed variables.

### EXAMPLE:

X := Y + Z;

Y[1] := Y[2] := 50;



## balanced statement

ELEMENT:

balanced statement

FORMAT:

{label definition} simple statement -

{label definition} IF boolean expression THEN balanced  
statement ELSE balanced statement

DESCRIPTION: \*

If the boolean expression is true, the balanced statement to the left of the ELSE is executed. If the boolean expression is false, the balanced statement to the right of the ELSE is executed.

EXAMPLE:

```
IF A < B THEN A := 1 ELSE A := 2;  
  
IF B = C THEN  
  BEGIN  
    WRITE(B);  
    B := B + 1;  
  END  
ELSE  
  BEGIN  
    WRITE(C);  
    C := C + 1;  
  END;
```

PROGRAMMING NOTE:

A semicolon is not allowed after the statement



immediately preceding an ELSE.



block

ELEMENT:

block

FORMAT:

BEGIN {declaration;} ... statement; ... END;

DESCRIPTION:

The block is the foundation of the ALGOL-M language. Each time a new block is entered new variables may be declared. These variables are unique in the sense that a variable X declared in two different blocks represents two different variables. All storage within a block is dynamic and allocated when the block is entered and de-allocated when the block is departed. A block can be used any place a simple statement can be used.

EXAMPLE:

```
BEGIN
  X := 1;
  Y := 2;
END;

IF X = Y THEN
  BEGIN
    X := 3;
    Y := 4;
  END;
```

PROGRAMMING NOTE:



Declarations may not appear in case blocks. The final  
END, which matches the initial program BEGIN, is not  
followed by a semicolon.



boolean expression

ELEMENT:

boolean expression

FORMAT:

NOT boolean expression

boolean expression OR boolean expression

boolean expression AND boolean expression

{()} expression =|<|>|>=|<=|<> expression {()}

DESCRIPTION:

Integer-integer, decimal-integer, decimal-decimal, integer-decimal, and string-string comparisons are allowed in ALGOL-M. For integer-decimal and decimal-integer comparisons the integer value is converted to a decimal value prior to comparison. The result of a comparison of numerical values is based on the size of the numbers. The result of a comparison of string values depends on a character-by-character comparison where the first instance of a non-equal character establishes the boolean result. The collating sequence of the ASCII character set is used for string comparisons. Generally, numbers are followed by upper case letters which are followed by lower case letters.

EXAMPLE:



X > Y OR Y < Z;  
(X = Y) AND (Y = Z OR Z = 10);  
IF NOT X = 1 THEN WRITE("HELLO");



bound pair list

ELEMENT:

bound pair list

FORMAT:

{expression : expression{,expression : expression} ...}

DESCRIPTION:

Expressions in the bound pair list must be of type integer and greater than or equal to zero. There can be no more than 255 dimensions.

EXAMPLE:

[1:7,0:5]

{3:6,x:y}

{y\*3:z,1:12}



## CASE statement

### ELEMENT:

```
CASE statement
```

### FORMAT:

```
CASE expression OF  
  BEGIN  
    statement; ...  
  END;
```

### DESCRIPTION:

The CASE statement allows the programmer to chose one of several statements to be executed. The statement chosen depends on the value of the integer expression. The first statement is executed if the expression evaluates to zero. If the value of the expression is greater than the number of statements in the case block, the resulting action is undefined.

### EXAMPLE:

```
CASE X + Y OF  
  BEGIN  
    WRITE("CASE 0");  
    WRITE("CASE 1");  
  END;
```



## CLOSE statement

### ELEMENT:

CLOSE statement

### FORMAT:

CLOSE identifier {,identifier} ...

### DESCRIPTION:

This statement allows the programmer to explicitly close the file indicated. Closing a file results in the file being rewound (i.e., if it is reopened the file begins at the first record). Any number of files may be open at any one time. All files are implicitly closed at the end of the program.

### EXAMPLE:

CLOSE FILE1, FILE2;



constant

ELEMENT:

constant

FORMAT:

integer|decimal|string

DESCRIPTION:

A constant may be either an integer, decimal, or string constant. Integer constants are numbers with no decimal point ranging from -16,384 to +16,384. Decimal constants are numbers with a decimal point and may not exceed 18 digits in length. String constants may be composed of any combination of alphanumeric and special characters and may be up to 255 characters in length. Strings entered from the console or disk may be either enclosed in quotation marks or delimited with blanks. Strings used as constants in the program must be enclosed in quotation marks.

EXAMPLE:

10

10.5678

"EXAMPLE ONE"



declaration

ELEMENT:

declaration

DESCRIPTION:

See FILE declaration, ARRAY declaration, simple declaration, procedure declaration, and function declaration.



expression

ELEMENT:

expression

FORMAT:

boolean expression|arithmetic expression

DESCRIPTION:

See arithmetic expression and boolean expression.



## FILE declaration

### ELEMENT:

FILE declaration

### FORMAT:

```
FILE identifier ((expression)) {,identifier  
((expression))} ...
```

### DESCRIPTION:

The identifiers used in the FILE declaration are file identifiers which reference actual file names. The actual file names may be assigned at compile-time or at run-time. The optional integer expression following the file identifier is used to specify the record length in bytes for blocked records.

### EXAMPLE:

```
FILE TAPE1, TAPE2(128);
```



## FOR statement

### ELEMENT:

FOR statement

### FORMAT:

```
{label definition} FOR assignment statement  
· {STEP expression} UNTIL expression DO simple statement
```

### DESCRIPTION:

Execution of all statements within the simple statement are repeated until the indexing variable is greater than or equal to the value of the UNTIL expression. The indexing variable is incremented by the amount specified in the STEP expression and must be incremented by a positive amount. The UNTIL and STEP expressions are evaluated on each loop. If the optional STEP expression is omitted, a default value of one is used.

### EXAMPLE:

```
FOR I := 1 STEP 1 UNTIL 10 DO  
    X := Y;  
  
FOR INDEX := X + Y UNTIL X * Y DO  
    BEGIN  
        A := A + B;  
        WRITE(A);  
    END;
```



function call

ELEMENT:

function call

FORMAT:

identifier {(expression {,expression} ...)}

DESCRIPTION:

Functions may appear as primary elements in arithmetic or boolean expressions. Parameter passing is by value. Functions may be called recursively with no limit to the number of recursive calls allowed.

EXAMPLE:

```
X := RAND;  
Y := SQRT(5.6);  
C := FUNC * RND(2);
```



## function declaration

### ELEMENT:

```
function declaration
```

### FORMAT:

```
INTEGER!DECIMAL!STRING FUNCTION identifier  
{((identifier {,identifier} ...})  
{declaration; ...} simple statement;
```

### DESCRIPTION:

A function declaration may or may not include parameters. If parameters are included they must be declared before the simple statement which represents the body of the function. Parameters are passed by value and may be of type integer, decimal, or string. Functions return a value to the point of call. The value to be returned is assigned to the function name (which is used as a simple variable within the function) prior to the end of the function. Functions may be called recursively with no limit set as to the number of recursive calls which can be made. Variables may be declared within functions and are considered local to the function.

### EXAMPLE:

```
INTEGER FUNCTION VALUE(X);
```



```
INTEGER X;
BEGIN
  X := (X * 5) + (X * 2 );
  VALUE := X;
END;
```



## GOTO statement

### ELEMENT:

GOTO statement

### FORMAT:

```
label definition GO TO identifier|integer  
label definition GOTO identifier;integer
```

### DESCRIPTION:

Execution continues at the statement labeled with the identifier or integer following the GOTO or GO TO statement.

### EXAMPLE:

```
NEXT: GO TO 100;  
100: GOTO NEXT;
```

### PROGRAMMING NOTE:

GOTO statements can only be used to branch within the current block or to an outer block.



identifier

ELEMENT:

identifier

FORMAT:

letter {letter|number} ...

DESCRIPTION:

Identifiers begin with a letter and are continued with any alphanumeric characters. Although identifiers up to 255 characters may be used, only the first 31 characters are actually used to distinguish the identifiers.

EXAMPLE:

A

NAME

COUNTER1



IF statement

ELEMENT:

IF statement

DESCRIPTION:

See balanced statement or unbalanced statement.



label definition

ELEMENT:

label definition

FORMAT:

identifier;integer :

DESCRIPTION:

Label definitions are optional on all balanced or unbalanced statements.

EXAMPLE:

FINISH:

100:



procedure call

ELEMENT:

procedure call

FORMAT:

identifier {(expression {,expression} ...)}

DESCRIPTION:

Procedures can be called with or without parameters. Parameter passing is by value. Procedures can be called recursively with no limit set as to the number of recursive calls.

EXAMPLE:

```
COMPUTE;  
COMPARE("AAA", WORD);  
COUNT(1, 2, 3);
```



## ELEMENT:

```
procedure declaration
```

## FORMAT:

```
PROCEDURE identifier { (identifier {, identifier} ...) }  
{ declaration; ... } simple statement
```

## DESCRIPTION:

A procedure declaration may or may not include parameters. If parameters are included they must be declared before the simple statement which represents the body of the procedure. Parameters are passed by value and may be of type integer, decimal or string. Procedures do not return a value to the point of call. Procedures can be called recursively. Procedures are considered separate blocks within which local variables may be declared.

## EXAMPLE:

```
PROCEDURE OUTPUT;  
    WRITE ("HELLO");  
  
PROCEDURE COMPARE(X,Y);  
    INTEGER X,Y;  
    BEGIN  
        WRITE("THE LARGEST INTEGER IS ");  
        IF X > Y THEN  
            WRITE(X);  
        ELSE  
            WRITE(Y);  
    END;
```



## READ statement

### ELEMENT:

READ statement

### FORMAT:

READ (variable {,variable} ...) {ONENDFILE block}

### DESCRIPTION:

If the form of the READ statement is READ(), then the input device is the console. Otherwise a file action must be specified and the input device is the disk. A READ statement reads one or more variables at a time. The optional ONENDFILE section indicates action to be taken when the end of the specified file is reached.

### EXAMPLE:

```
READ(WORDONE, X, VALUE2);  
READ FILE3 (WORDONE, X, VALUE2);
```

### PROGRAMMING NOTE:

The ONENDFILE section is currently not implemented.



reserved word list

ELEMENT:

reserved word list

FORMAT:

letter {letter} ...

DESCRIPTION:

The following words are reserved by ALGOL-M and may not be used as identifiers:

AND	ARRAY	BEGIN	CASE
CLOSE	DECIMAL	DO	ELSE
END	EXTERNAL	FILE	FUNCTION
GO	GOTO	IF	INITIAL
INTEGER	NOT	OF	ONENDFILE
OR	PIC	PROCEDURE	READ
STEP	STRING	TAB	THEN
TO	UNTIL	WHILE	WRITE
WRITEON			

Reserved words must be preceded and followed by either a special character or a space. Spaces may not be embedded within reserved words.



## simple statement

ELEMENT:

simple statement

FORMAT:

block;assignment statement;for statement;  
case statement;close statement;auto statement;  
while statement;read statement;write statement;  
procedure call;identifier

DESCRIPTION:

All ALGOL-M statements are free form and must be separated by semicolons.



## simple declaration

ELEMENT:

simple declaration

FORMAT:

```
INTEGER|DECIMAL|STRING {((identifier|integer))  
identifier {,identifier} ...}
```

DESCRIPTION:

Simple integer variables may be any value between -16,384 and +16,384. Simple decimal variables can be specified as any length from one to 18 digits with a default length of 10 digits. Simple string variables can be specified as any length from one to 255 characters with a default length of 10 characters.

EXAMPLE:

```
INTEGER X;  
DECIMAL(15) X,Y;  
STRING(33) WORDONE, WORDTWO, WORDTHREE;
```



## ELEMENT:

SPECIAL CHARACTERS

## DESCRIPTION:

The following special characters are used by ALGOL-M:

- ( open parenthesis
- ) close parenthesis
- \* asterisk
- + plus
- minus
- :
- :
- colon
- ;
- semicolon
- < less-than
- > greater-than
- = equal
- ,
- comma
- [ open bracket
- ] close bracket
- := assigned equal
- \*\* exponentiation
- % percentage

Any special character in the ASCII character set may appear in a string. Special characters, other than those listed above, will cause an error condition if used outside of a string.



TAB expression

ELEMENT:

TAB expression

FORMAT:

TAB expression

DESCRIPTION:

TAB is optionally used in a WRITE statement to cause spacing on the output line. The amount of spacing is specified by the integer expression following TAB.

EXAMPLE:

```
WRITE("NEXT NAME", TAB 5, NAME[I]);
```



unbalanced statement

ELEMENT:

unbalanced statement

FORMAT:

{label definition} IF boolean expression THEN statement

{label definition} IF boolean expression THEN balanced  
statement ELSE unbalanced statement

DESCRIPTION:

Unlike the balanced statement that will always have a balanced statement on either side of the ELSE in an IF THEN ELSE structure, an unbalanced statement may not even include the ELSE portion of the statement.

EXAMPLE:

```
IF S > Y THEN WRITE(X);  
IF X < Y THEN  
  IF Z > Y THEN  
    WRITE(Z)  
  ELSE  
    WRITE(X);
```

PROGRAMMING NOTE:

A semicolon is not allowed after the statement immediately preceding an ELSE.



variable

ELEMENT:

variable

FORMAT:

identifier {[bound pair list]}

DESCRIPTION:

A variable in ALGOL-M may be simple or subscripted and of type INTEGER, DECIMAL, or STRING.

EXAMPLE:

X

VALUE[2]

Z[1,X \* Y]



## WHILE statement

### ELEMENT:

```
WHILE statement
```

### FORMAT:

```
WHILE boolean expression DO simple statement
```

### DESCRIPTION:

WHILE statements continue executing the simple statement following the DO for as long as the boolean expression is true.

### EXAMPLE:

```
WHILE I > 0 DO
    I := I - 1;

WHILE X > 5 AND Y <> 8 DO
BEGIN
    X := X / 3;
    WRITE(X);
END;
```



## WRITE statement

### ELEMENT:

WRITE statement

### FORMAT:

```
WRITE|WRITON {file option}  
(expression|tab expression|pic definition|string  
{,expression|tab expression|pic definition|string} ...)
```

### DESCRIPTION:

The WRITE option indicates the output will start printing on a new line, while the WRITEON option will continue printing on the same line. If the form of the statement is WRITE() or WRITEON(), the output device is the console. Otherwise, a file option must be specified and the output device is the disk.

### EXAMPLE:

```
WRITE(X);  
WRITE("THE NUMBER IS",X + Y);  
WRITE("ANSWER", TAB 5, X * Y);
```

### PROGRAMMING NOTE:

The PIC definition is not currently implemented.



## APPENDIX E ALGOL-M LANGUAGE STRUCTURE

In the following sections, the syntax of the language will be listed in BNF notation followed by the semantic actions (offset with asterisks) associated with that production. The description will be given in terms of compiler data structures and the ALGOL-M machine code generated. Items enclosed in brackets and separated by slants are alternative semantic actions. N/A indicates no action. This notation is similar to that used in REF 6 and REF 10.

- 1 <program> ::= <block> -'  
  \* <block>; XTT; {eof indicator}
- 2 <block> ::= <block head> <block end>  
  \* <block head>; <block end>
- 3 <block head> ::= <block head> <declaration> ;  
  \* <block head>; <declaration>
- 4                 ; <begin>  
  \* <block>
- 5 <begin> ::= begin  
  \* BLT
- 6 <block end> ::= <block body> ; end  
  \* BLD
- 7 <block body> ::= <statement>  
  \* <statement>
- 8 <block body> ; <statement>  
  \* <block body>; <statement>
- 9 <declaration> ::= <file declaration>  
  \* <file declaration>



```

10          ! <simple declaration>
*<simple declaration>

11          ! <simple declaration> <initial option>
*<simple declaration>; <initial option>

12          ! <array declaration>
*<array declaration>

13          ! <array declaration> <initial option>
*<array declaration>; <initial option>

14          ! <subprogram declaration>
*<subprogram declaration>

15          ! <external declaration>
*{Not implemented}

16 <simple declaration> ::= <declaration head>
                           <identifier>
*<declaration head>; LIT {identifier address}
*[ALD/ALS/ N/A for integers]

17 <initial option> ::= <initial head> <constant> )
*<initial head>; <constant>

18 <initial head> ::= initial (
N/A

19          ! <initial head> <constant> ,
*<initial head>; <constant>

20 <declaration head> ::= <declaration type>
*<declaration type>

21          ! <declaration head> <identifier>
           ,
*<declaration head>; LIT {identifier address};
*[ALD/ALS/ N/A for integers]

22 <declaration type> ::= string
*TM1 {string default size};

23          ! string <size option>
*<size option>

24          ! integer
N/A

25          ! decimal
*TM1 {decimal default size};

```



```

26          | decimal <size option>
* <size option>

27  <size option> ::= ( <variable> )
* LITLOAD {variable address};

28          | ( <integer> )
* <integer>

29  <statement> ::= <balanced statement>
* <balanced statement>

30          | <unbalanced statement>
* <unbalanced statement>

31  <balanced statement> ::= <simple statement>
* <simple statement>

32          | <if clause> <true part> else
32          | <balanced statement>
* <if clause>; <true part>; <balanced statement>

33          | <label definition>
33          | <balanced statement>
* <label definition>; <balanced statement>

34 <unbalanced statement> ::= <if clause> <statement>
* <if clause>; <statement>

35          | <if clause> <true part>
35          | else <unbalanced statement>
* <if clause>; <true part>; <unbalanced statement>

36          | <label definition>
36          | <unbalanced statement>
* <label definition>; <unbalanced statement>

37  <true part> ::= <balanced statement>
* <balanced statement>; BRS {address of end of
* current statement}

38  <label definition> ::= <identifier> :
N/A

39          | <integer> :
N/A

40  <simple statement> ::= <block>
* <block>

```



```

41           | <assignment statement>
*<assignment statement>

42           | <for statement>
*<for statement>

43           | <while statement>
*<while statement>

44           | <read statement>
*<read statement>

45           | <write statement>
*<write statement>

46           | <case statement>
*<case statement>

47           | <go to statement>
*<go to statement>

48           | <close statement>
*<close statement>

49           | <procedure call>
*<procedure call>; PRO;

50           | <identifier>
*IM2 {subroutine address}; PRO; POP;

51 <assignment statement> ::= <left part> <expression>
    *<left part>; <expression>; [SIT/SID]

52           | <left part>
52           .           <assignment statement>
*<left part>; <assignment statement>

53   <left part> ::= <variable> :=
    *<variable>; [LT1/LTLOAD1]

54   <expression> ::= <arithmetic expression>
    *<arithmetic expression>

55           | <if expression> <expression>
N/A

56   <arithmetic expression> ::= <term>
    *<term>

57           | <arithmetic expression> +

```



```

57          <term>
*<arithmetic expression>; <term>; [ADI/ADD] - 

58          | <arithmetic expression> -
58
*<arithmetic expression>; <term>; [SBT/SBD] 

59          | <arithmetic expression>
59          | | <term>
*<arithmetic expression>; <term>; CAT; 

60          | - <term>
*<term>; NEG 

61          | + <term>
*<term>

62  <term> ::= <primary>
*<primary>

63          | <term> * <primary>
*<term>; <primary>; [MLI/MLD] 

64          | <term> / <primary>
*<term>; <primary>; [DVI/DVD] 

65  <primary> ::= <primary element>
*<primary element>

66          | <primary> ** <primary element>
*<primary>; <primary element>; IXP 

67  <primary element> ::= <variable>
*LITLOAD {address of simple variable}/ N/A for
*subscripted variables/ IM2 {subroutine
*address in code area}; PRO

68          | <constant>
*<constant>

69          | <procedure call>
*<procedure call>

70          | ( <assignment statement> )
*<assignment statement>

71          | ( <expression> )
*<expression>

72  <constant> ::= <integer>
*INT; {constant}

```



```

73           | <decimal>
    *DEC; {constant}

74           | <string>
    *STR; {constant}

75   <variable> ::= <identifier>
N/A . . .

76           | <subscripted variable>
    *<subscripted variable>

77   <file declaration> ::= <file head> <file name>
    *{not implemented}

78   <file head> ::= file
    *{not implemented}

79           | <file head> <file name> ,
    *{not implemented}

80   <file name> ::= <string> <length option>
    *{not implemented}

81           | <string>
    *{not implemented}

82           | <identifier> <length option>
    *{not implemented}

83           | <identifier>
    *{not implemented}

84   <length option> ::= [ <identifier> ]
    *{not implemented}

85           | [ <integer> ]
    *{not implemented}

86   <array declaration> ::= <array list>
86           <bound pair list>
    *<array list>; <bound pair list>;
    *LIT {# of arrays(m)}; LIT {type of
    *array};
    *followed by:
        (1) LIT {array location}
        (2) m=m-1 if m=0 then halt else step(1)

```



```

87  <array list> ::= <array head> <identifier>
   *<array head>

88  <array head> ::= <declaration type> array
   *<declaration type>

89           | <array head> <identifier> ,
   *<array head>

90  <bound pair list> ::= <bound pair head>
91      <bound pair> ]
92  *<bound pair head>; <bound pair>

93  <bound pair head> ::= [
N/A

94          | <bound pair head> <bound pair> ,
95  *<bound pair head>; <bound pair>

96  <bound pair> ::= <expression> : <expression>
   *<expression>; <expression>

97  <subscripted variable> ::= <subscript head>
98      <expression> ]
99  *<subscript head>; <expression>

100 . <go to statement> ::= <go to> <identifier>
101  *DCB {# of blocks to decrement}/NOP;NOP
   *followed by BRS {branch address}

102           | <go to> <integer>
103  *DCB {# of blocks to decrement}/NOP;NOP
   *followed by BRS {branch address}

104  <go to> ::= go to
N/A

105           | goto
N/A

106  <read statement> ::= <read head> <variable> )
107  *<read head>; LIT/LITLOAD {address of variable};
108  *RDI/RCI; SID/SDD/SSD
   *if console I/O then ECR

```



```

102    <read head> ::= read (
  *RCN

103                | read <file option> ( .
  *{not implemented}

104                | <read head> <variable> ,
  *<read head>; same as production 101

105    <write statement> ::= <write head> <expression> )
  *<write head>; <expression>; [WIC/WDC/WSC/WID
  *WDD/WID]

106                | <write head> <tab expression> )
  *{not implemented}

107                | <write head> <pic definition> )
  *{not implemented}

108    <write head> ::= write (
  *DMP
  |
  | write <file option> (
  *{not implemented}

110          | writeon (
  N/A
  |
  | writeon <file option> (
  *{not implemented}

112          | <write head> <expression> ,
  *<write head>; <expression>; [LIT/LITLOAD]

113          | <write head> <tab expression> ,
  *{not implemented}

114          | <write head> <pic definition> ,
  *{not implemented}

115    <file option> ::= <identifier>
  N/A

116          | <identifier> <rec option>
  N/A
  |
  | <string>
  N/A
  |
  | <string> <rec option>
  N/A

119    <rec option> ::= , <identifier>
  N/A

```



```

120           | , <integer>
N/A

121   <pic definition> ::= <pic head> <pic list> )
*{not implemented}

122   <pic head> ::= pic <string>
*{not implemented}

123           | pic <identifier>
*{not implemented}

124   <pic list> ::= ( <expression>
*{not implemented}

125           | <pic list> , <expression>
*{not implemented}

126   <tab expression> ::= tab <expression>
*{not implemented}

127   <if clause> ::= if <boolean expression> then
*{<boolean expression>; BSC {branch address}

128   <if expression> ::= <if clause> <expression> else
*{not implemented}

129   <boolean expression> ::= <boolean term>
*{<boolean term>

130           | <boolean expression> or
130           | <boolean term>
*{<boolean expression>; <boolean term>; BUR

131   <boolean term> ::= <boolean primary>
*{<boolean primary>

132           | not <boolean primary>
*{<boolean primary>; NOT0

133           | <boolean term> and
133           | <boolean primary>
*{<boolean term>; <boolean primary> AND0

134   <boolean primary> ::= <logical expression>
*{<logical expression>

135           | ( <boolean expression> )
*{<boolean expression>

136   <logical expression> ::= <expression> <relation>
136           | <expression>
*{<expression>; <expression>; [string, integer,
*{or decimal relational operator]

```



```

137   <relation> ::= =
      N/A

138   .     | <
      N/A

139   .     | >
      N/A

140   .     | <comp>
      N/A

141   <comp> ::= < >
      N/A

142   .     | < =
      N/A

143   .     | > =
      N/A

144 <while statement> ::= <while clause> <do statement>
  *<while clause>; <do statement>; BRS
  *{branch location}

145 <while clause> ::= <while> <boolean expression>
  *<boolean expression>; BSC {branch address}

146 <while> ::= while
      N/A

147 <for statement> ::= <for clause> <step expression>
  <until clause> <do statement>
  *<for clause>; <step expression>; <until clause>;
  *<do statement>; BRS {branch address}

148 <for clause> ::= for <assianment statement>
  *<assianment statement>; BRS {branch address};
  *LIT {counter variable}; LITLOAD {counter variable}

149 <step expression> ::= step <expression>
  *<expression>; ADT; STD; LITLOAD {counter variable}

150 <until clause> ::= <until non-term> <expression>
  *<until non-term>; <expression>; LEQ; BSC
  *{branch address}

151 <until non-term> ::= until
  *{IM1 {one}; ADT; STD; LITLOAD {counter variable}/
    N/A if there is a step expression}

152 <do statement> ::= do <simole statement>
  *<simole statement>

```



```

153  <close statement> ::= close <identifier>
    *{not implemented}

154          | <close statement> , <identifier>
    *{not implemented}

155  <subprogram declaration> ::= <subprogram heading>
155                                <simple statement>
    *<subprogram heading>; <simple statement>; LIT
    *{subroutine PRT address}; UNS; RTN; LIT{SBP};
    *LIT 0; SID;

156  <subprogram heading> ::= <function heading>
    *<function heading>

157          | <procedure heading>
    *<procedure heading>

158  <function heading> ::= <paramless function>
    *<paramless function>

159          | <function & params>
    *<function params>; SV2

160  <procedure heading> ::= <paramless proc>
    *<paramless proc>

161          | <proc & params>
    *<proc & params>; SV2

162  <paramless function> ::= <declaration type>
162                                function <identifier> ;
    *<declaration type>

163  <function & params> ::= <function head>
163                                <identifier> ) ;
    *<function head>

164          | <function & params>
                <declaration> ;
    *<function params>; <declaration>

165  <function head> ::= <declaration type> function
165                                <identifier> (
    *<declaration type>

166          | <function head> <identifier> ,
    *<function head>

167  <paramless proc> ::= procedure <identifier> ;
    *IM1 {parameter count}; IM1 {local variable &
    *parameter offset}; LIT {base of PCB}; SAV; BLI
    *if this is a non-integer function then
    *LITLOAD {length of return value};
    *LIT {PRT address of function}; {ALD/ALS}

```



```

168   <proc & params> ::= <procedure head> <identifier>
168   ) ;
*<procedure head>; same as production 167

169           | <proc & params> <declaration>
169           ;
*<proc params>; <declaration>

170   <procedure head> ::= procedure <identifier> (
*BLI;

171           | <procedure head> <identifier> ,
N/A

172 <procedure call> ::= <call heading> <expression> )
*<call heading>; <expression>; IM2
*{address of subroutine in code area}; PRO

173   <call heading> ::= <identifier> (
N/A

174           | <call heading> <expression> ,
*<expression>

175   < declaration> ::= <declaration type> external
175           function <external list>
*{not implemented}

176           | external procedure
176           <external list>
*{not implemented}

177   <external list> ::= <identifier>
*{not implemented}

178           | <external list> , <identifier>
*{not implemented}

179   <case statement> ::= <case heading> <case block>
*<case heading>; <case block>;
*do n times(n=number of statements in case block)
    BPS {address of case statement(n)}

180   <case heading> ::= case <expression> of
*<expression>; LIT {3}; MPI; IM2
*{address of end of case block}; SBR; BFA

181   <case block> ::= begin <case block body> ; end
N/A

182   <case block body> ::= <statement>
*<statement>; BRS {address of end of case block}
183           | <case block body> ; <statement>
*same as production 182

```



## ALGOL-M PROGRAM LISTINGS

```

100h: /*load point for compiler*/

/*
 * ***** system literals *****
 */
/* ****

declare false      literally '0',
true       literally '1',
lit        literally 'literally',
bdos      lit '5h',      /* entry point to disk operating system */
startbdos address initial(5h), /*adr of ptr to top of bdos */
max based startbdos address,
boot      lit '0',       /* exit to return to operating system */
ps:stacksize lit '48',     /* stack sizes for parser */
intresize  lit '128',
del       lit 'declare',
proc      lit 'procedure',
fileeof   lit '1',
rfile     lit '20',
identsize lit '32',
addr      lit 'address',
forever   lit 'while true',
varcsize  lit '100',
indexsize lit 'address',
statesize lit 'address',
maxoncount lit '25',
cr        lit '13',
lf        lit '0ah',
stringdelim lit '22h',
questionmark lit '3fh',
tab       lit '09h',
colin    lit '3ah',
comment   lit '0',
conbuffsize lit '82',
eolchar   lit '0dh',
hashtblsize lit '64',
sourceresize lit '128',
hashmask  lit '63',
contchar   lit '5ch',
eoffiller  lit 'lah',
percent   lit '25h';

declare maxrno  literally '132',/* max read count */
maxino   literally '190',/* max look count */
maxpno   literally '190',/* max push count */
maxsno   literally '373',/* max state count */
starts   literally '1',/* start state */
prodno   literally '183',/* number of productions */
semic    literally '8',/* semicolon */
colonc   literally '13',/* colon */
doe     literally '18',/* do */
eofc    literally '24',/* eof */
endc    literally '26',/* end */
string   literally '49',/* string */
decimal  literally '52',/* decimal */
integerc literally '33',/* integer */
proc    literally '54',/* procedure */
identifier lit '55',/* identifier */
termino  literally '55';/* terminal count */

declare sbloc      address initial(80h),
sourcebuff based sbloc(sourceresize) byte,
sourceptr    byte    initial(sourcebuffsize),
buffptr      byte    initial(255),
errorcount   address initial 0,
linebuff(conbuffsize) byte,
lineptr      byte    initial(0),

```



```

lineno      address.
pass1       byte initial(true),
pass2       byte initial(false),
noinfile    byte initial(false),
rfcbaddr   address initial('5ch'),
rfcb_based  rfcbaddr(33) byte,
wfcb(33)   byte initial(0,' ', 'ain', 0, 0, 0, 0),
cursourcerecsize byte initial(sourcerecsize),
nolook      byte,
production  byte,
arr$loc(5)  address,
arr$num     byte,
sub$proc$loc address,
sub$proc$var$num byte,
arr$dim     byte,
diskoutbuff(intrecsize) byte;

/* the following global variables are used by the scanner */

declare token      byte,      /* type of token just scanned */
hashcode     byte,      /* has value of current token */
nextchar     byte,      /* current character from getchar */
accum(identsize) byte,      /* holds current token */
cont        byte;      /* indicates accum was full, still more */

/********************* symbol table global variables *****/
/* ***** symbol table global variables ***** */
/********************* symbol table global variables *****/

declare base      address, /* base of current entry */
hashtable(hashtblsize) address,
sbtbltop    address, /*current top of symbol table*/
sbtbl      address,
ptr based base byte, /*first byte of entry */
aptraddr   address, /*utility variable to access table*/
addrptr based aptraddr address,
byteptr based aptraddr byte,
printname  address, /*set prior to lookup or enter*/
symhash    byte,
prev$blk$level(12) byte,
prev$index  byte initial(255),
step$flag   byte,
blk$ent    byte initial(0),
blk$level  byte initial(1);

declare read1 data(0,39,12,15,53,55,2,49,32,53,53,5,8,8,19,20,26,27,31
,34,35,39,40,42,43,48,53,55,19,20,26,27,31,34,35,39,40,42,43,48,53
,53,53,33,53,53,15,53,53,23,2,3,9,20,28,49,52,53,53,53,2,3,9,20,49
,52,53,53,49,53,2,3,9,20,49,52,53,53,2,49,53,55,2,49,53,2,2,2,49,53
,11,14,54,51,55,13,7,4,55,55,2,13,14,2,14,14,2,8,11,7,11,7,11,11,2,8
,4,6,10,24,53,53,16,7,11,2,7,11,17,7,11,7,49,53,11,19,29,27,31,34,35
,39,40,42,43,48,53,53,32,53,14,8,19,20,27,31,33,34,35,39,40,42,43,44
,45,47,48,50,53,54,55,4,11,1,12,15,21,7,11,7,11,4,11,1,7,12,15,32,7
,13,36,2,3,9,20,29,30,49,52,53,55,8,8,8,2,2,2,23,39,49,52,53,18,11
,53,33,44,43,47,50,54,7,11,55,7,11,8,11,41,55,38,50,51,46,22,37,7,22
,19,27,31,34,35,39,40,42,43,48,55,7,3,5,9,0);

declare look1 data(0,12,15,0,15,0,2,0,2,0,11,0,14,0,8,17,32,0,2,14,0,14
,0,11,0,14,0,11,0,11,0,2,14,17,0,6,10,0,5,10,0,6,10,0,6,10,0,6,10,0
,6,10,0,16,0,16,0,16,0,17,0,11,0,25,0,25,0,11,0,11,0,33,44,45,47,50
,54,0,11,0,53,0,46,0,33,44,45,47,50,54,0,32,0,22,0,46,0,3,5,9,0);

declare apply1 data(0,0,1,0,0,0,0,0,131,145,0,0,149,0,0,0,0,44,0,14,15
,40,93,0,37,93,143,0,37,142,0,0,0,27,150,0,3,4,32,95,0,0,0,3,4,6,22,24
,35,36,39,36,94,95,112,122,130,134,135,137,0,0,7,8,10,16,17,0,11,18
,0,26,0,124,0,3,4,3,14,15,27,32,37,40,93,95,96,101,143,150,0,0,0,0
,63,0,0,0,0,0,0,0,0,0,0,0,0,42,46,0,61,0,0,0,0,14,15,37,40
,93,101,143,0,0,3,72,0,30,0,31,33,0,0,0,0,0,0,0,0,0,0,125,0,0,0
,0,0,0,0,0,0,0,0,14,13,27,37,40,93,101,143,150,0,0,0,52,0,0,0,0,0
);

declare read2(254) address initial

```







```

/********************* global procedures *****/
mon1: procedure(f,a);
    declare f byte,
    a address;
    go to bdos;
end mon1;

mon2: procedure (f,a) byte;
    declare f byte, a address;
    go to bdos;
end mon2;

mon3:procedure;
    /*used to return to the system*/
    goto boot;
end mon3;

move: procedure (a,b,l);
    /* moves from a to b for l bytes (l < 255) */
    declare (a,b) address,
    (s based a, d based b,l) byte;
    do while (l:=l - 1) > 255;
        d=s; b=b + 1; a =a + 1;
    end;
end move;

fill: proc (a,char,n);
    /* move char to a n times */
    declare a addr,(char,n,dest based a) byte;
    do while (n := n -1) > 255;
        dest = char;
        a = a + 1;
    end;
end fill;
end fill;

read: procedure;
    declare toggle(3) byte;
    toggle = 1;
    call mon1(10,.toggle);
end read;

printchar: procedure(char);
    declare char byte;
    call mon1(2,char);
end printchar;

print: procedure(a);
    declare a address;
    call mon1(9,a);
end print;

diskerr: procedure;
    call print('.de    $');
    goto boot;
end diskerr;

open$sourcefile: procedure;
    call move('.alg',rfcbaddr+9,3);
    rfcb(32) = 0;
    if mon2(15,rfcbaddr) = 255 then
        do;
        call print('.ne $');
        go to boot;
        end;
    end open$sourcefile;

close$int$file: procedure ;
    /* closes a file */
    if mon2(16,.wfcb) = 255 then

```



```

        call diskerr;
end close$int$file;

setup$int$file: procedure;
/* setup$int$file creates a new file */
if nointfile then /*only make file if this toggle is off */
    return;
call move(.rfcb,.wfcb,9);
wfcb(32)=0;
call mon1(19,.wfcb);
if mon2(22,.wfcb) = 255 then
    call diskerr;
end setup$int$file;

rewind$source$file:proc;
/*cp/m does not require any
action prior to reopening*/
return;
end rewind$source$file;

read$source$file:proc byte;
declare dcnt byte;
if(dcnt:=mon2(rfile,rfcbaddr)) > fileeof then
    call diskerr;
    return dcnt;
end read$source$file;

write$int$file: procedure;
if nointfile then
    return;
call mon1(26,.diskoutbuff);
if mon2(21,.wfcb) <> 0 then
    call diskerr;
call mon1(26,80h); /* reset dma address */
end write$int$file;

crlf: procedure;
call printchar(cr);
call printchar(lf);
end crlf;

printdec: procedure(value);
declare value address, l byte, count byte;
declare deci(4) address initial(1000,100,10,1);
declare flag byte;
flag = false;
count = 30h;
do l = 0 to 3;
    do while value >= deci(i);
        value = value - deci(i);
        flag= true;
        count = count + 1;
    end;
    if flag or (l>= 3) then
        call printchar(count);
    else
        call printchar(' ');
end;
return;
end printdec;

print$prod:proc;
call print(' prod = $');
call print$dec(production);
call crlf;
end print$prod;

print$token:proc;
call print(' token = $');
call print$dec(token);
call crlf;
end print$token;

```



```

emit:proc(objcode);
    declare objcode byte;
    if(buffptr:=buffptr+1) >= intrecsize then /*write to disk*/
        do;
            call write$int$file;
            buffptr=0;
        end;
    diskoutbuff(buffptr)=objcode;
end emit;

clear$line$buff:procedure;
    call fill(.linebuff,' ',conbuffsize);
end clear$line$buff;

listline: procedure(length);
    declare (length,i) byte;
    call print$dec(lineno);
    call print$dec(prev$index+1);
    call print$char(' ');
    do i = 0 to length;
        call printchar(linebuff+i);
    end;
    call crlf;
end listline;

/*********************************************
/* the following variables are used by the parser */
/********************************************

declare listprod      byte initial(false),
       loweroupper byte initial(true),
       listsource   byte initial(false),
       debugln     byte initial(false),
       listtoken   byte initial(false),
       errset      byte initial(false),
       compiling   byte,
       codesize    address, /* used to count size of code area */
       prtc       address initial(Offfeh), /* used to count size of prt */
       /* variables used during for loop code generation */

       forcount    byte initial(0),
       randomfile  byte,
       fileio      byte initial(false);

/*********************************************
/*          scanner procedures           */
/********************************************

getchar: procedure byte;
    declare addeof data ('eof', eolchar,1f); /* add to end if left off */

next$source$char: procedure byte;
    return sourcebuff(sourceptr);
end next$source$char;

checkfile: procedure byte;
    do forever;
        if (sourceptr:=sourceptr+1)=cursourcerecsize then
            do;
                sourceptr=0;
                if read$source$file=fileeof then
                    return true;
            end;
        if(nextchar:=next$source$char)<>1f then
            return false;
        end;
    end checkfile;

if checkfile or (nextchar = eoffiller) then
    do; /* eof reached */
        call move(.adde,f,$block,5);

```



```

sourceptr = 0;
nextchar=next$source$char;
end;
linebuff(lineptr:=lineptr + 1)=nextchar; /*output line*/
if nextchar = eolchar then
  do:
    lineno = lineno + 1;
    if listsource then
      call listline(lineptr-1);
    lineptr = 0;
    call clearlinebuff;
  end;
if nextchar = tab then
  nextchar = ' ';
return nextchar;
end getchar;

getnoblank: procedure;
  do while((getchar = ' ') or (nextchar = eoffiller));
  end;
end getnoblank;

title:procedure;
  call print('algoal-m vers 1.0$');
  call crlf;
end title;

print$error:proc;
  call printdec(errorcount);
  call printchar(' ');
  call print('error(s) detected$');
  call crlf;
end print$error;

error: procedure(errcode);
  declare errcode address;
  i byte;
  errorcount=errorcount+1;
  call print('****');
  call print$dec(lineno);
  call print(' error $');
  call printchar(' ');
  call printchar(high(errcode));
  call printchar(low(errcode));
  call crlf;
  call print$prod;
  if token=eofc then
    do:
      call print$error;
      call mon3;
    end;
end error;

initialize$scanner: procedure;
  declare count byte;
  call open$sourcefile;
  lineno,lineptr = 0;
  call clear$line$buf;
  sourceptr = 128;
  call getnoblank;
  do while nextchar = '$';
  call get$no$blank;
  if(count := (nextchar and 3fh) - 'a') <= 4 then
    do case count:
      if pass1 then listsource = true;
      listprod = true;
      noinfile = true;
      listtoken = true;
      debugln = true;
    end; /* of case */
  call getnoblank;

```



```

    end;
end initialize$scanner;

/*********************************************************************
/*                      scanner                               */
/********************************************************************

scanner: procedure;

putinaccum: procedure;
  if not cont then
    do;
      accum(accum := accum + 1) = nextchar;
      hashcode = (hashcode + nextchar) and hashmask;
      if accum = 31 then cont = true;
    end;
  end putinaccum;

putandget: procedure;
  call putinaccum;
  call getnoblank;
end putandget;

putandchar: procedure;
  call putinaccum;
  nextchar = getchar;
end putandchar;

numeric: procedure byte;
  return(nextchar - '0') <= 9;
end numeric;

lowercase: procedure byte;
  return (nextchar >= 61h) and (nextchar <= 7ah);
end lowercase;

decimalpt: proc byte;
  return nextchar = '.';
end decimalpt;

conv$to$upper: proc;
  if lowercase and lowertoupper then
    nextchar=nextchar and 5fh;
end conv$to$upper;

letter: procedure byte;
  call conv$to$upper;
  return ((nextchar - 'a') <= 25) or lowercase;
end letter;

alphanum: procedure byte;
  return numeric or letter or decimalpt;
end alphanum;

spoolnumeric: procedure;
  do while numeric;
    call putandchar;
  end;
end spoolnumeric;

setup$next$call: procedure;
  if nextchar = ' ' then
    call getnoblank;
  cont = false;
end setup$next$call;

lookup: procedure byte;
declare maxrwing lit '9';

```



```

declare vocab data(0,'<','(',')+',5dh,7ch,'*',')',';',','-','/','.',',','>'
      ,':','5bh','=','**',':=','do','go','if','of','or','to','eof','and'
      ,'end','for','not','pic','tab','case','else','file','goto','read'
      ,'step','then','array','begin','close','until','while','write'
      ,'string','decimal','initial','integer','writeon'
      ,'comment','external','function','procedure');
declare vloc data(0,1,16,32,53,81,111,117,152,168,177);
declare vnum data(0,1,16,24,31,38,44,45,50,54);
declare count data(0,14,7,6,6,5,0,4,1,0);
declare ptr address, (field based ptr) (9) byte;
declare i byte;

compare: procedure byte;
    declare i byte;
    i = 0;
    do while (field(i) = accum(i := i + 1)) and i <= accum;
        end;
    return i > accum;
end compare;

if accum > maxrwlng then
    return false;
ptr=vloc(accum)+.vocab;
do i=vnum(accum) to (vnum(accum)+count(accum));
    if compare then
        do;
            if i=50 then
                token=comment;
            else
                token=i;
            return true;
        end;
    ptr=ptr+accum;
end;
return false;
end lookup;

```

```

//****************************************************************************
/*          scanner main code           */
//****************************************************************************

```

```

do forever;
    accum, hashcode, token = 0;
    do while nextchar=eolchar;
        call getnoblank;
        end;
    if(nextchar = stringdelim) or cont then
        do; /* found string */
            token = string;
            cont = false;
            do forever;
                do while getchar <> stringdelim;
                    call put$inaccum;
                    if cont then return;
                    end;
                call getnoblank;
                if nextchar <> stringdelim then
                    return;
                call put$inaccum;
            end; /* of do forever */
        end; /* of recognizing a string */

else if numeric or decimalpt then
    do; /* have digit */
        token = integer;
        do while nextchar='0'; /*elim leading zeros*/
            nextchar=getchar;
        end;
        call spoolnumeric;
        if decimalpt then

```



```

        do;
        token=decimal;
        call putandchar;
        call spoolnumeric;
        end;
        if accum=0 then
            hashcode, accum(accum := 1) = '0';
        call setup$next$call;
        return;
    end; /* of recognizing numeric constant */

else if letter then
    do; /* have a letter */
        do while alphanum;
            call putandchar;
            end;
        if not lookup then
            do;
                token = identifier;
                call setup$next$call;
                return;
            end;
        else /* is a rw but if comment skip */
            if token = comment then
                do;
                    do while nextchar <> ';';
                        nextchar = getchar;
                        end;
                    call get$no$blank;
                    end;
            else
                do;
                    call set$up$next$call;
                    return;
                end;
            end;
    end; /* of recognizing rw or ident */

else
    do; /* special character */
        if nextchar = 25h then
            do;
                nextchar=getchar;
                do while nextchar <> 25h;
                    nextchar = getchar;
                end;
                call get$no$blank;
            end;
        else
            do;
                if nextchar = ':' then
                    do;
                        call putandchar;
                        if nextchar = '=' then
                            call putandget;
                    end;
            else
                if nextchar = '*' then
                    do;
                        call putandchar;
                        if nextchar = '*' then
                            call putandget;
                    end;
                else call putandget;
                if not lookup then
                    call error('ic');
                call setup$next$call;
                return;
            end;
        end;
    end; /* of recognizing special char */
end; /* of do forever */
end scanner; /* end of scanner */

```



```

*****procedures for synthesizer*****
*****procedures for synthesizer*****


initialize$symtbl:proc;
    if pass1 then
        do:
    /* fill hashtable with 0's */
        call fill(.hashtable,0,shl(hashtblsize,2));
        sbtbl = .memory;
        end;
    /*Initialize pointer to top of symbol table*/
    sbtbltop = max - 2;
end initialize$symtbl;

setaddrptr:proc(offset); /*set ptr for addr reference*/
    declare offset byte;
    aptraddr = base + ptr + offset; /*position for addr reference*/
end setaddrptr;

set$blk$level:proc(level);
    declare level byte;
    call setaddrptr(6);
    byteptr = level;
end set$blk$level;

gethash:proc byte;
    declare hash byte,
            i      byte;
    hash = 0;
    aptraddr = base + 2;
    do i = 1 to ptr;
        hash = (hash + byteptr(i)) and hashmask;
    end;
    return hash;
end gethash;

nextentry:proc;
    base = base + ptr + 8;
end nextentry;

setlink:proc;
    aptraddr = base + 1;
end setlink;

hashtbl$of$symhash:proc address;
    return hashtable(symhash);
end hashtbl$of$symhash;

limits:proc(count);
    /*check to see if additional sbtbl will overflow limits of
     memory. If so then punt else return */
    declare count byte; /*size being added is count */
    if sbtbltop <= (sbtbl + count) then
        do:
            call error('to');
            call mon3;
        end;
    end limits;

setaddr:proc(loc);
    /*set the address field and resolved bit*/
    declare loc address;
    call setaddrptr (4);
    addrptr = loc;
end setaddr;

lookup$current$blk:proc(chk$blk) byte;
    declare chk$blk byte;
    len byte;
    n based printname byte;

```



```

base=hashtbl$of$symhash;
do while base <> 0;
    call setaddrptr(6);
    if byteptr < chk$blk then
        return false;
    if byteptr = chk$blk then
        do;
            if (len:=ptr) = n then
                do while (ptr(len + 2) = n(len));
                    if (len := len - 1) = 0 then
                        return true;
                end;
            end;
            call setlink;
            base = addrptr;
        end;
        return false;
    end lookup$current$blk;

lookup:proc byte;
declare test$blk byte,
      test$index byte;
test$index = prev$index+1;
test$blk = blk$level;
do while (test$index := test$index - 1) <> 255;
    if lookup$current$blk(test$blk) then
        return true;
    test$blk = prev$blk$level(test$index);
end;
return false;
end lookup;

enter:proc;
/*enter token reference by printname and symhash
into next available location in the symbol table.
set base to beginning of this entry and increment
sbtbl. also check for symbol table full. */
declare l byte,
      n based printname byte;
call limits(l:=n+8);
base = sbtbl; /*base for new entry*/
call move(printname + l,sbtbl + 3,(ptr := n));
call setaddrptr(3);/*set resolve bit to 0*/
byteptr = 0;
call setlink;
addrptr = hashtbl$of$symhash;
hashtable(symhash) = base;
call set$blk$level(blk$level);
sbtbl = sbtbl + 1;
end enter;

getlen:proc byte; /*return length of the p/n */
return ptr;
end getlen;

gettype:proc byte; /*returns type of variable*/
call setaddrptr(3);
return byteptr;
end gettype;

setsubtype:proc(stype);/*enter the subtype in sbtbl*/
declare stype byte;
call setaddrptr(7);
byteptr=stype;
end setsubtype;

get$parm: proc byte;
    call setaddrptr(10);
    return byteptr;
end getparm;

get$subtype:proc byte; /*return the subtype*/
call setaddrptr(7);

```



```

        return byteptr;
end getsubtype;
setype:proc (type); /*set typefield = type*/
    declare type byte;
    call setaddrptr (3);
    byteptr = type;
end setype;

getaddr:proc address;
    call setaddrptr(4);
    return addrptr;
end getaddr;

do; /* block for parser */

/* pneumonics for ALGOL-M machine */

declare nop lit '0', str lit '1', int lit '2', xch lit '3',
lod lit '4', deb lit '5', dmp lit '6', xit lit '7',
sld lit '8', als lit '9', aid lit '10', ais lit '11',
adi lit '12', add lit '13', sbi lit '14', sbd lit '15',
mpi lit '16', mpd lit '17', dvi lit '18', dvd lit '19',
dneg lit '21', neg lit '22', cil lit '23', ci2 lit '24',
deci lit '25', pop lit '26', imi lit '27', lm2 lit '28',
cat lit '31', bli lit '32',
brs lit '34', bsc lit '35', lss lit '36', dlss lit '37',
sissa lit '38', gtr lit '39', dgtr lit '40', sgtr lit '41',
eq1 lit '42', deql lit '43', seq1 lit '44', neq lit '45',
dneq lit '46', sneq lit '47', geq lit '48', dgeq lit '49',
sgeq lit '50', leq lit '51', dleq lit '52', sleq lit '53',
inot lit '54', dnot lit '55', snot lit '56', iand lit '57',
dand lit '58', sand lit '59', ior lit '60', dor lit '61',
sor lit '62', wic lit '63', wdc lit '64', wsc lit '65',
wid lit '66', wdd lit '67', wsd lit '68', sbr lit '69',
bra lit '70', row lit '71', sub lit '72', rcl lit '73',
red lit '74', rcs lit '75', rdi lit '76', rdd lit '77',
rds lit '78', ren lit '79', ecr lit '80', sil lit '81',
sdi lit '82', ssi lit '83', sld lit '84', sdd lit '85',
sad lit '86', opn lit '87', cls lit '88', rdb lit '89',
rdf lit '90', edr lit '91', edw lit '92', pro lit '93',
sav lit '94', sv2 lit '95', uns lit '96', rtn lit '97';

declare state           statesize,
statestack(psstacksize) statesize,
hash(psstacksize)       byte,
symloc(psstacksize)    address,
srloc(psstacksize)    address,
var(psstacksize)       byte,
type(psstacksize)      byte,
stype(psstacksize)     byte,
varc(varcsize)         byte,
varindex               byte,
(sp,mp,mppl,no look) byte,
onstack(maxoncount)   byte,
ciabling              byte initial(2),
clab2                 byte initial(23),
clable                byte,
str$size               byte initial(10),
dec$size               byte initial(9),
u                      byte,
pvnum                 byte initial(0),
saveparm               address,
parme based saveparm byte,
fpcount                byte,
parmbase               address,
proc$type              byte,
(ptest,1)               byte,
pcount                 byte initial(0),
type$temp              byte,
fflag                  byte,
lpcount                byte,
sident                 address;

```



```

initialize$synthesize:procedure;
  codesize, onstack, clable = 0;
  prev$index = 255;
  blk$cnt = 0;
  blk$level=0;
end initialize$synthesize;

synthesize: proc;

/* **** synthesize local declarations **** */

declare simvar      lit '0bh';
     subvar       lit '99';
     pro          lit '93';
     ext$proc    lit '03';
     bit$in$func lit '05';
     const        lit '06';
     lab          lit '07';
     integer      lit '08';
     str          lit '1';
     file!       lit '0ch';
     func         lit '0dh';
     parm        lit '10h';

declare (typesp, typemp, typemp1)      byte,
        (b, temp)           byte,
        (stypesp, stypemp, stypemp1) byte,
        (hashsp, hashmp, hashmp1)   byte,
        (symlocsp, symlocmp, symlocmp1) address,
        (srlocsp, srlocmp)       address;

/*
***** code generation proc's ****
*/

```

---

```

copy:procedure;
  typesp = type(sp);
  typemp1 = type(mpp1);
  typemp = type(mp);
  stypesp = stype(sp);
  stypemp1 = stype(mpp1);
  stypemp = stype(mp);
  symlocsp = symloc(sp);
  symlocmp1 = symloc(mpp1);
  symlocmp = symloc(mp);
  hashmp = hash(mp);
  hashmp1 = hash(mpp1);
  hashsp = hash(sp);
  srlocsp = srloc(sp);
  srlocmp = srloc(mp);
end copy;

setsymlocsp: procedure(a);
  declare a address;
  symloc(sp) = a;
end setsymlocsp;

setsymlocmp: procedure(a);
  declare a address;
  symloc(mp) = a;
end setsymlocmp;

settypesp: procedure(b);
  declare b byte;
  type(sp) = b;
end settypesp;

```



```

setstypep: procedure(b);
  declare b byte;
  type(sp) = b;
end setstypep;

setstypemp: procedure(b);
  declare b byte;
  type(mp) = b;
end setstypemp;

settypemp: procedure(b);
  declare b byte;
  type(mp) = b;
end settypemp;

sethashmp: procedure(b);
  declare b byte;
  hash(mp) = b;
end sethashmp;

sethashsp: procedure(b);
  declare b byte;
  hash(sp) = b;
end sethashsp;

setsrlocsp: procedure(a);
  declare a address;
  srloc(sp) = a;
end setsrlocsp;
setsrlocmp: proc(a);
  declare a byte;
  srloc(mp)=a;
end setsrlocmp;

getsrloc: proc byte;
  call setaddrptr(8);
  return addrptr;
end getsrloc;

generate: proc(objcode);
  /*writes generated code and counts size
  of code area. */
  declare objcode byte;
  codesize = codesize + 1;
  if not pass1 then
    call emit(objcode);
end generate;

gen$int$v: proc(a);
  declare a byte;
  call generate(lmi);
  call generate(a);
end gen$int$v;

incr$blk$level: proc;
  prev$blk$level(prev$index := prev$index+1) = blk$level;
  blk$level = blk$cnt + 1;
  blk$cnt = blk$cnt+1;
  call generate(bli);
end incr$blk$level;

decr$blk$level: proc;
  blk$level = prev$blk$level(prev$index);
  prev$index = prev$index-1;
  call generate(bld);
end decr$blk$level;

calc$varc: procedure(b) address;
  declare b byte;
  return var(b) + .varc;
end calc$varc;

```



```

set lookup: procedure(a);
  declare a byte;
  printname = calc$varc(a);
  symhash = hash(a);
end set lookup;

lookup$only: procedure(a) byte;
  declare a byte;
  call set lookup(a);
  if lookup$current$blk(blk$level) then
    return true;
  base$flag = true;
  return false;
end lookup$only;

full$lookup: proc(a) byte;
  declare a byte;
  call set lookup(a);
  if lookup then
    return true;
  return false;
end full$lookup;

normal$lookup: procedure(a) byte;
  declare a byte;
  if lookup$only(a) then
    return true;
  call enter;
  return false;
end normal$lookup;

countprt: proc address;
/*counts the size of the prt */
  return (prtct := prtct + 2);
end countprt;

gentwo: proc(a);
/* writes two bytes of object code on disk for literals */
  declare a address;
  call generate(high(a));
  call generate(low(a));
end gentwo;

literal: proc(a);
  declare a address;
  call gentwo(a or 8000h);
end literal;

setcname: proc;
  printname = clabing;
  symhash = clable and hashmask;
end setcname;

enter$compiler$label: proc(b);
  declare b byte;
  if pass1 then
    do:
      call setcname;
      call enter;
      call *addr(codesize + b);
    end;
end enter$compiler$label;

set$compiler$label: proc;
  declare x byte;
  clable = clable + 1;
  call setcname;
  if pass2 then
    x = lookup;
end set$compiler$label;

compiler$label: proc;

```



```

call set$compiler$label;
call gen$two(getaddr);
end compiler$label;

set$enter: proc(a);
    declare (a,b) byte;
    b=cable;
    cable=a;
    call enter$compiler$label(0);
    cable=b;
end set$enter;

branch$clause: proc(a);
    declare a byte;
    call generate(a);
    call compiler$label;
    call settypemp(cable);
end branch$clause;

process$case$label: proc(a);
    declare (a,b,x) byte;
    b=cable;
    cable=a;
    call generate(brs);
    call setcname;
    if pass2 then
        x=lookup;
    call gen$two(getaddr);
    cable=b;
end process$case$label;

case$state: proc;
    call process$case$label(type(mp-2));
    n=n+1;
    cable=cable+1;
    call enter$compiler$label(0);
end case$state;

litload:proc(a);
    declare a address;
    call gentwo(a or 0c000h);
end litload;

step$gen: proc;
    call generate(adi);
    call generate(sid);
    call enter$compiler$label(0);
    call litload(sident);
end step$gen;

chktyp1: proc(a); /* check mp.sp to see if they are both decimal */
    declare a byte; /* both integer, one of each, or neither */
    if (stypemp=int) and (stypesp=int) then
        call generate(a);
    else
        if (stypemp=dec) and (stypesp=dec) then
            call generate(a+1); /* generate decimal operator */
        else
            if (stypemp=dec) and (stypesp=int) then
                do:
                    call generate(c11); /* convert integer to decimal */
                    call generate(n+1);
                end;
            else
                if (stypemp=int) and (stypesp=dec) then
                    do:
                        call generate(c12);
                        call generate(a+1);
                        call settypemp(dec);
                    end;
                else
                    if typemp<>true or pass2 then

```



```

        call error('mf');
end chktyp1;

chktyp2: proc byte;
  if stypesp <> stypemp then
    do;
      call error('mn');
      return false;
    end;
  return true;
end chktyp2;

chktyp3: proc byte;
  call setstypemp(stypesp);
  if (stypesp=int) or (stypesp=dec) then
    return true;
  call error ('mf');
  return false;
end chktyp3;

chktyp5: proc byte;
  if (stypemp>str) or (stypesp<str) then
    return false;
  else
    return true;
end chktyp5;

chktyp6: proc;
  if pass2 then
    do;
    if (stypemp=int) and (stypesp=dec) then
      call error('id');
    if (typemp>simvar) and (typemp>subvar) and (typemp>file1) then
      do;
        if (typemp>func) or ('not fflag') then
          call error('as');
        end;
      end;
    end;
  end;
end chktyp6;

gencont: proc(subtype);
  declare (i,subtype) byte;
  gen$accum: proc;
  if pass2 then
    do i=1 to accum;
      call emit(accum(i));
    end;
  end gen$accum;
  call generate(subtype);
  call settypemp(const);
  call setstypemp(subtype);
  if subtype=int then
    do;
      if accum>5 then
        call error('lo');
      call gen$accum;
      if pass2 then
        call emit(0);
      codesize=codesize+2;
    end;
  else
    do forever;
      if subtype=str then
        do i = 1 to accum;
          call generate(accum(i));
        end;
      else
        do;
          call gen$accum;
          codesize=codesize+(accum+1)/2;
        end;
      if cont then
        call scanner;
    end;
  end;

```



```

    else
        do;
            if subtype=dec then
                call gentwo(0);
            else
                codesize = codesize + 2;
                call generate(0);
                return;
            end;
        end;
    end;
end gencon;

process$store: proc(a);
    declare a byte;
    if chktyp5 then
        call generate(a+2);
    else
        call chktyp1(a);
end process$store;

gen$loc: proc(a,b);
    declare a byte,
          b address;
    if a = int then
        call literal(b);
    else
        call litload(b);
end gen$loc;

get$field: proc;
    gen$read: proc(a);
        declare a byte;
        if stypempl=int then
            do;
                call generate(a);
                call generate(sid);
            end;
        else
            if stypempl=dec then
                do;
                    call generate(a+1);
                    call generate(sdd);
                end;
            else
                do;
                    call generate(a+2);
                    call generate(sad);
                end;
            end;
        end gen$read;

        call gen$loc(stypempl,symlocmpl);
        if fileio then
            call gen$read(rd1);
        else
            call gen$read(rc1);
    end get$field;

put$field: proc(a);
    declare a byte;
    if fileio then
        a=a+3;
    if stypempl=int then
        do;
            if typempl=subvar then
                call generate(lod);
                call generate(a);
        end;
    else
        if stypempl=dec then
            call generate(a+1);
        else
            call generate(a+2);
    end put$field;

```



```

process$proc: proc(a);
    declare a byte;
    call settypeemp(a);
    if pass2 then
        do;
            call setsrlocmp(srlocmp:=getsrloc);
            call setsstypeemp(getsubtype);
            parmbase=base+ptr+1;
        end;
    end;
end process$proc;

process$ident:proc(a) byte;
    declare a byte;
    if full$lookup(a) then
        return gettype;
    else
        if pass2 then
            do;
                call error('ud');
                return false;
            end;
        else
            return func;
    end;
end process$ident;

process$array:proc(a);
    declare (a,b) byte;
    if ((b:=process$ident(a)) <> subvar) and pass2 then
        do;
            if b<>0 then
                call error('lu');
            end;
        else
            do;
                call setsstypeemp(getsubtype);
                call setsymlocmp(symlocmp:=getaddr);
                call settypeemp(subvar);
            end;
        end;
    end;
end process$array;

process$ident$dc1:proc(a,b,c);
    dc1(a,b,c) byte;
    pnum=pnum+1;
    if not normal$lookup(a) then
        do;
            call settype(b);
            call setaddr(countptr);
            call setsubtype(c);
        end;
    else
        if pass1 then
            do;
                if gettype=parm then
                    do;
                        call settype(b);
                        call setsubtype(c);
                        ptest=ptest-1;
                    end;
                else
                    call error('dd');
                end;
            end;
        end;
    end;
end process$ident$dc1;

proc$av: proc;
    call gen$int$v(pcount);
    call gen$int$v((pnum+3)*2);
    call literal(symlocmp);
    call generate(av);
    call generate(b11);
    if proc$type=func then
        do;
            if stypemp<> int then

```



```

    do;
        call litload(symloemp+4);
        call literal(symloemp);
        if stypeemp=dec then
            call generate('alld');
        else
            call generate('als');
    end;
end proc$av;

check$parm: proc(a);
    declare a byte;
    b address;
    if pass2 then
        do;
            b=base;
            base=parmbase;
            if a <> getsubtype then
                call error('pm');
            parmbase=base+ptr+8;
            base=b;
        end;
        call generate(im1);
        call generate(a);
    end check$parm;

proc$pro: proc;
    call generate(im2);
    call gen$two(srloemp);
    call generate(pro);
end proc$pro;

process$proc$del: proc(a,b,c);
    declare (a,b,c) byte;
    call process$ident$del(a,b,c);
    pnum,pcount=0;
    call setsymloemp(symloemp:=getaddr);
    if pass1 then
        prct=prct+4;
    if (proc$type:=b) = func then
        do;
            call literal(symloemp+4);
            call generate(xch);
            call generate(sid);
        end;
    call branch$clause(brs);
    if pass1 then
        do;
            call setaddrptr(8);
            addrptr=codesize;
            sbtbl=sbtbl+3;
            saveparm=sbtbl-1;
        end;
    call incr$blk$level;
end process$proc$del;

process$var: proc(a);
    declare (a,b) byte;
    if (b:=process$ident(a)) = simvar then
        do;
            call setsymlosp(symlosp:=getaddr);
            call settypesp(simvar);
            call settypesp(getsubtype);
        end;
    else
        if b=func then
            call process$proc(func);
        else
            if b<> 0 then
                call error('ip');
    end process$var;

```



```

process$simvar$del: proc(a,b):
    declare (a,b) byte;
    call process$ident$del(a.simvar,stypemp);
    if stypemp<>int then
        do:
            call literal(getaddr);
            if stypemp=dec then
                call generate(b);
            else
                call generate(b+1);
        end;
    end process$simvar$del;

process$label1:proc:
    if pass1 then
        do:
            if full$look$up(mp) then
                call error('dd');
            else
                do:
                    call enter;
                    call setaddr(codesize);
                    call settype(lab);
                    call set$blk$level(blk$level);
                end;
        end;
    end;
end process$label1;

resolve$label1:proc;
    declare (chk$blk,tindex) byte;
    if pass2 then
        do:
            if ((not full$lookup(sp)) or (gettype <> lab)) then
                call error('ul');
            call setaddrptr(6);
            chk$blk=byteptr;
            tindex=prev$index;
            if blk$level <> chk$blk then
                do:
                    do while prev$blk$level(tindex) > chk$blk:
                        tindex=tindex-1;
                    end;
                    call generate(dcb);
                    call generate(prev$index+1-tindex);
                end;
            else
                call gen$two(nop);
            end;
        end;
    else
        call gen$two(nop);
    call generate(brs);
    call gen$two(getaddr);
end resolve$label1;

process$array$del: proc(a):
    declare a byte;
    call process$ident$del(a.subvar,stypemp);
    arr$loc(arr$num)=getaddr;
    arr$num=arr$num+1;
end process$array$del;

close$file: proc(a):
    declare a byte;
    if process$ident(a) then /* not implemented */
    else call error('uf');
end close$file;

assign$stmt: proc:
    call chktyp6;
    if (lpcount:=lpcount-1)<>0 then /* tests multiple assign stmts */
        call process$store(sit);
    else

```



```

    call process$store(sid);
end assignment;

/* execution of synthesize begins here---- */

if listprod then
  call print$prod;
  call copy;
  do case production; /* call to synthesize handles one prod */
endif;

/*case 0 not used : */

/*      1  <program> ::= <block> ... */

if pass1 then
  do:
    pass1 = false;
    if errorcount > 0 then
      do:
        call print$error;
        call mon3;
      end;
    call rewind$source$file;
    call gentwo(codesize+i); /* plus one to include the exit */
    call gentwo(countptr);
  end;
else
  do:
    call print$error;
    call generate(exit);
    call generate(7fh);
    call write$int$file;
    call close$int$file;
    call mon3;
  end;

/*      2  <block> ::= <block head> <block end> */

;

/*      3  <block head> ::= <block head> <declaration> ; */

/*      4          | <begin> */

;

/*      5  <begin> ::= begin
call incr$blk$level;

/*      6  <block end> ::= <block body> ; end
call decr$blk$level;

/*      7  <block body> ::= <statement>
;

/*      8          | <block body> ; <statement>
;

/*      9  <declaration> ::= <file declaration>
;

/*      10         | <simple declaration>
;

/*      11         | <simple declaration>
| <initial option>
;

/*      12         | <array declaration>
;

/*      13         | <array declaration> <initial option>
;

/*      14         | <subprogram declaration>
;

/*      15         | <external declaration>
;

```



```

/*
16  <simple declaration> ::= <declaration head>
16      <identifier>
17
17      call process$simvar$del(sp,a14);
18  <initial option> ::= <initial head> <constant> )
18
19  <initial head> ::= initial (
19      | <initial head> <constant> ,
19
20  <declaration head> ::= <declaration type>
20
21      | <declaration head> <identifier>
21
21      call process$simvar$del(mpp1,aid);
21
22  <declaration type> ::= string
22      do;
22          call setstype$p(str);
22          call gen$int$v(str$size);
22      end;
23
23          | string <size option>
23      do;
23          call setstypemp(str);
23      end;
24
24          | integer
24          call setstype$p(int);
25
25          | decimal
25      do;
25          call setstype$p(dec);
25          call gen$int$v(dec$size);
25      end;
26
26          | decimal <size option>
26          call setstypemp(dec);
27
27  <size option> ::= ( <variable> )
27      if stypemp!=int then
27          call litload(symlocmp1);
27      else
27          call error('si');
28
28          | ( <integer> )
28      do;
28          call move(calc$varc(mpp1),.accum,7);
28          call gencon(int);
28      end;
29
29  <statement> ::= <balanced statement>
29
30
30          | <unbalanced statement>
30
31  <balanced statement> ::= <simple statement>
31
32
32          | <if clause> <true part> else
32          | <balanced statement>
32      call set$enter(stypemp1);
33
33          | <label definition>
33          | <balanced statement>
33
34  <unbalanced statement> ::= <if clause> <statement>
34      call set$enter(stypemp);
35
35          | <if clause> <true part>
35          | else <unbalanced statement>
35      call set$enter(stypemp1);
36
36          | <label definition>
36          | <unbalanced statement>
36
37  <true part> ::= <balanced statement>
37
37      do;
37          call branch$labelise(brs);
37          call set$enter(type(sp-1));
37      end;
38
38  <label definition> ::= <identifier> :
38      call process$label();
39
39          | <integer> :
39      call process$label();

```



```

/*
40  <simple statement> ::= <block>                                */
/*
41          ;                                         | <assignment statement>    */
/*
42          ;                                         | <for statement>        */
/*
43          ;                                         | <while statement>       */
/*
44          ;                                         | <read statement>        */
/*
45          ;                                         | <write statement>       */
/*
46          ;                                         | <case statement>        */
/*
47          ;                                         | <go to statement>       */
/*
48          ;                                         | <close statement>       */
/*
49      call generate(pop);                                         | <procedure call>    */
/*
50          do;                                                 | <identifier>           */
51          if ((process$ident(sp) <> pro) and pass2) then      */
52              call error('nf');                                 */
53              call process$proc(pro);                           */
54              call proc$pro;                                  */
55              call generate(pop);                            */
56          end;                                              */
57
58
59
60
61
62
63
64
65
66
67

```

(left part) <assignment statement>

(variable) :=

+ <term>

- <term>

! <term>

+ <term>

- <term>

! + <term>

+ <term>

! <term>

\* <primary>

/ <primary>

(primary element)

\*\* <primary element>

(primary element)

(variable)



```

        :
    else
        if typesp(> subvar then
            call proc$pro:
/*      68           | <constant> */;
/*      69           | <procedure call> */;
/*      70           | ( <assignment statement> ) */;
/*      71           | ( <expression> ) */;
        do;
            call setstypemp(stypemp:=stypemp1);
            call settypeemp(stypemp1);
        end;
/*      72 <constant> ::= <integer> */;
        call gencon(int);
/*      73           | <decimal> */;
        call gencon(decimal);
/*      74           | <string> */;
        call gencon(string);
/*      75 <variable> ::= <identifier> */;
        call process$var(sp);
/*      76           | <subscripted variable> */;
        :
/*      77 <file declaration> ::= <file head> <file name> */;
        :
/*      78 <file head> ::= file */;
        :
/*      79           | <file head> <file name> , */;
        :
/*      80 <file name> ::= <string> <length option> */;
        :
/*      81           | <string> */;
        :
/*      82           | <identifier> <length option> */;
        call process$ident$dc1(mp,file1.9);
/*      83           | <identifier> */;
        call process$ident$dc1(sp,file1.9);
/*      84 <length option> ::= ' <identifier> ' & */
        if process$ident(mp)=int then;
/*      85           | ' <integer> ' & */
        call gencon(int);
/*      86 <array declaration> ::= <array list> <bound pair list> */;
        do;
            call gen$int$sv(arr$dim);
            call gen$int$sv(arr$num);
            call gen$int$sv(stypemp);
            call generate(row);
            do while (arr$num := arr$loc(arr$num))>>255;
                call literal(arr$loc(arr$num));
            end;
        end;
/*      87 <array list> ::= <array head> <identifier> */;
        call process$array$dc1(sp);
/*      88 <array head> ::= <declaration type> array */;
        arr$num=0;
/*      89           | <array head> <identifier> , */;
        call process$array$dc1(mppl);
/*      90 <bound pair list> ::= <bound pair head> <bound pair> & */
        arr$dim=arr$dim+i;
/*      91 <bound pair head> ::= ' */
        arr$dim=0;
/*      92           | <bound pair head> <bound pair> , */;
        arr$dim=arr$dim+i;
/*      93 <bound pair> ::= <expression> : <expression> */;
        if (stypemp(> int) or (stypep(> int)) then
            call error('bp');
/*      94 <subscripted variable> ::= <subscript head> */;
        expression &
        do;
            if stypemp1(> int) then
                call error('sh');
            call litload(symloemp);

```



```

        call generate(subt);
    end;
/* 95   <subscript head> ::= <identifier> '
   call process$array(mp);                                */
/* 96   | <subscript head> <expression> ,                */
   if stype$mp1 > int then
      call error('sh');
/* 97   <go to statement> ::= <go to> <identifier>          */
   call resolve$label;                                     */
/* 98   | <go to> <integer>                                */
   call resolve$label;
/* 99   <go to> ::= go to
   :
   | goto
   :
/* 100  <read statement> ::= <read head> <variable> )      */
do:
   call get$field;
   if fileio then
      do:
         fileio=false;
      end;

      else
         call generate(ecr);
   end;
/* 102  <read head> ::= read (
   call generate(rcn);
/* 103  | read <file option> (
   :
   | <read head> <variable> ,
/* 104  call get$field;
/* 105  <write statement> ::= <write head> <expression> )
   call put$field(wic);
/* 106  | <write head> <tab expression> )
   :
/* 107  | <write head> <pic definition> )
   :
/* 108  <write head> ::= write (
   call generate(dmp);
/* 109  | write <file option> (
   :
   | writeon (
   :
   | writeon <file option> (
   :
   | <write head> <expression> ,
   call put$field(wic);
/* 113  | <write head> <tab expression> ,
   :
   | <write head> <pic definition> ,
   :
/* 115  <file option> ::= <identifier>
   if process$ident(sp) = filel then;
/* 116  | <identifier> <rec option>
   if process$ident(mp) = filel then;
      else call error('uf');
/* 117  | <string>
   :
   | <string> <rec option>
   :
/* 119  <rec option> ::= . <Identifier>
   if ((process$ident(sp) = simvar) and (getsubtype = int)) then;
      else call error ('ini');
/* 120  | . <integer>
   call gencon(int);
/* 121  <pic definition> ::= 'pic head' <pic list> )
   :
/* 122  <pic head> ::= pic <string>
   :
   | pic <identifier>
   if (process$ident(sp) = simvar and getsubtype = str) then;
      else call error('ini');

```



```

/*
124  <pic list> ::= ( <expression>
/*          ;
/*          | <pic list> , <expression>
/*
126  <tab expression> ::= tab <expression>
/*
127  <if clause> ::= if <boolean expression> then
call branch$clause(bsc);
/*
128  <if expression> ::= <if clause> <expression> else
/*
129  <boolean expression> ::= <boolean term>
/*
130          ;
/*          | <boolean expression> or
130          <boolean term>
/*
call chktyp1(bor);
/*
131  <boolean term> ::= <boolean primary>
/*
132          ;
/*          | not <boolean primary>
if chktyp3 then
    call generate(noto);
/*
133          ;
/*          | <boolean term> and
133          <boolean primary>
/*
call chktyp1(ando);
/*
134  <boolean primary> ::= <logical expression>
/*
135          ;
/*          | ( <boolean expression> )
call setstypemp(stypemp1);
/*
136  <logical expression> ::= <expression> <relation>
/*          <expression>
/*
136          if (stypemp==str) and (stypesp==str) then
            call generate(typemp1+2);
        else
            call chktyp1(typemp1);
/*
137  <relation> ::= =
call settypesp(eq1);
/*
138          ;
/*          | <
call settypesp(lss);
/*
139          ;
/*          | >
call settypesp(gtr);
/*
140          ;
/*          | <comp>
/*
141  <comp> ::= < >
call settypemp(neq);
/*
142          ;
/*          | <=
call settypemp(leq);
/*
143          ;
/*          | >=
call settypemp(geq);
/*
144  <while statement> ::= <while clause> <do statement>
do:
    call generate(brs);
    call gen$two(symlocmp);
    call set$enter(typep);
end;
/*
145  <while clause> ::= <while> <boolean expression>
call branch$clause(bsc);
/*
146  <while> ::= while
call setsymlocmp(codesize);
/*
147  <for statement> ::= <for clause> <step expression>
/*          <until clause> <do statement>
do:
    call generate(brs);
    call gen$two(symlocmp);
    call set$enter(type(sp-1));
end;
/*
148  <for clause> ::= for <assignment statement>
do:
    if (stypesp>>simvar) or (stypesp>>int) then
        call error('ini');
    call generate(brs);
    call compiler$label;
    call setsymlocmp(codesize);
    call literal(symlosp);
    call litload(silent:=symlosp);

```



```

        end;
/* 149  <step expression> ::= step <expression> */
    do:
        if stypesp>int then
            call error('ini');
        step$flag=true;
        call step$gen;
    end;
/* 150  <until clause> ::= <until non-term> <expression> */
    do:
        call generate(leg);
        call branch$clause(bsc);
    end;
/* 151  <until non-term> ::= until */
    if not step$flag then
        do:
            call gen$int$v(1);
            call step$gen;
        end;
    else
        step$flag=false;
/* 152  <do statement> ::= do <simple statement> */
;
/* 153  <close statement> ::= close <identifier> */
    call close$file(sp);
/* 154  <subprogram declaration> ::= <subprogram heading> */
    call close$file(sp);
/* 155  <subprogram declaration> ::= <subprogram heading> */
    <simple statement> */
    do:
        call literal(symlocmp);
        call generate(uns);
        call generate(rtn);
        call decr$blk$level;
        call set$enter(typemp);
        call literal(symlocmp+2);
        call gen$int$v(0);
        call generate(s1d);
        pnum,pcount=0;
        fflag=false;
    end;
/* 156  <subprogram heading> ::= <function heading> */
    fflag=true;
/* 157  ; <procedure heading> */
;
/* 158  <function heading> ::= <paramless function> */
;
/* 159  <function heading> ::= <function & params> */
    do:
        call generate(sv2);
        if ptest<>0 and pass1 then
            call error('pd');
    end;
/* 160  <procedure heading> ::= <paramless proc> */
;
/* 161  <procedure heading> ::= <proc & params> */
    do:
        call generate(sv2);
        if ptest<>0 and pass1 then call error('pd');
    end;
/* 162  <paramless function> ::= <declaration type> function */
/* 162  <declaration type> ::= <identifier> */
    call process$proc$def1(sp-1,func,stypemp);
/* 163  <function & params> ::= <function head> <identifier> */
    do:
        call process$ident$def1(mppl,param,0);
        parme,ptest=(pcount+1);
        call process$av;
    end;
/* 164  <function & params> ::= <function head> <declaration type> */
    do:
        call process$proc$def1(sp-1,func,stypemp);
    end;
/* 165  <function head> ::= <declaration type> function */
;
```



```

/*
 165      <identifier> :          */
/* 166      call process$proc$de1(sp-1,func,$typemp);
   | (function head) <identifier> .           */
/* do:
   call process$ident$de1(mppl,parm,0);
   pcount=pcount+1;
 end;
 167  <paramless proc> ::= procedure <identifier> :      */
do:
   call process$proc$de1(mppl,pro,0);
   call proc$av;
end;
 168  <proc & params> ::= <procedure head> <identifier> : ;  */
do:
   call process$ident$de1(mppl,parw,0);
   parme,ptest=(pcount:=pcount+1);
   call proc$av;
end;
 169      | <proc & params> <declaration> :           */
/* 170  <procedure head> ::= procedure <identifier> (           */
/*   call process$proc$de1(mppl,pro,0);                      */
/* 171      | <procedure head> <identifier> .           */
do:
   pcount=pcount+1;
   call process$ident$de1(mppl,parm,0);
end;
 172  <procedure call> ::= <call heading> <expression> ;      */
do:
   pcount=pcount+1;
   call checkparm($typemp1);
   call proc$pro;
   if fpcount<>pcount and pass2 then
      call error('pe');
   end;
 173  <call heading> ::= <identifier> (           */
do:
   if ((b:=process$ident(mp))<>func) and (b<>pro) then
      call error('up');
   call process$proc(b);
   fpcount=getparm;
   pcount=0;
   end;
 174      | <call heading> <expression> .           */
do:
   pcount=pcount+1;
   call checkparm($typemp1);
end;
 175  <external declaration> ::= <declaration type> external */
/* 175      function <external list>           */
/* ;           */
 176      | external procedure           */
/* 176      <external list>           */
/* ;           */
 177  <external list> ::= <identifier>           */
/* ;           */
 178      | <external list> , <identifier>           */
/* ;           */
 179  <case statement> ::= <case heading> <case block>           */
do:
   do i=1 to n;
      call process$case$label(clabel-i);
   end;
   call set$enter($typemp1);
end;
 180  <case heading> ::= case <expression> of           */
do:
   if $typemp1<>int then
      call error('ini');
   call gen$int$v(3);
   call generate(mp1);
   call set$complier$label();
   call set$typemp(clabel);

```



```

    call generate(im2);
    call gen$two(getaddr-4);
    call generate(sbr);
    call generate(bra);
    elable=elable+1;
    call enter$compiler$label(0);
    n=0;
  end;
/* 181  <case block> ::= begin <case block body> end      */
;
/* 182  <case block body> ::= <statement>                  */
/* 183  <case block body> ; <statement>                   */
/*      call case$state;                                */
/*      call case$state;                                */
end; /*of case statement*/
end synthesize;

/********************* error recovery routines *****/
/*          error recovery routines           */
/********************* error recovery routines *****/

noconflict: proc (cstate) byte;
  declare cstate statesize, (i,j,k) indexsize;
  j= index1(cstate);
  k= j + index2(cstate) - 1;
  do i = j to k;
    if read1(i) = token then return true;
  end;
  return false;
end noconflict;

recover: proc statesize;
  declare tsp byte, rstate statesize;
  do forever: tsp = sp;
    do while tsp <> 255;
      if noconflict(rstate:=statestack(tsp)) then
        do: /* state will read token */
          if sp <> tsp then sp = tsp - 1;
          return rstate;
        end;
      tsp = tsp - 1;
    end;
    call scanner;
  end;
end recover;

/********************* lexical parser routines *****/
/*          lexical parser routines           */
/********************* lexical parser routines *****/

do: /*block for declarations*/
  declare (i,j,k) indexsize, index byte;

initialize: procedure;
  call title;
  call initialize$scanner;
  call initialize$symbol;
  call initialize$synthesizer;
end initialize;

getini: procedure indexsize;
  return index1(state);
end getini;

getin2: procedure indexsize;
  return index2(state);
end getin2;

```



```

incsp: procedure;
  if (sp := sp + 1) = length(statestack) then
    call error('so');
end incsp;

lookahead: procedure;
  if no look then
    do:
      call scanner;
      no look = false;
      if listoken then
        call print$token;
      end;
    end lookahead;

set$varc$1: procedure();
  declare i byte;
  /* set varc, and increment varindex */
  varc(varindex)=i;
  if(varindex:=varindex+1) > length(varc) then
    call error('vo');
  end set$varc$1;

/* initialize for input - output operations */
call move(.rfcb,.wfcb,9); /* put filename in write fcb */
call setup$int$files; /* create an output file for code generated */
call initialize;

do forever:
  do while pass1 or pass2;
    /* initialize variables */
    compiling,no look=true; state=starts;
    sp=255;
    varindex,var = 0;

    do while compiling;
      if state<=maxrno then /* read state */
        do:
          call incsp; statestack(sp)=state;
          l=getin1; call lookahead;
          j=l+getin2-1;
          do l=1 to j;
            if read1(i)=token then /* save token */
              do; var(sp)=varindex;
              /* copy accumulator to proper position */
              do index = 0 to accum;
                call set$varc$1(accum(index));
              end;
              hash(sp)=hashcode;
              /* save relative table location */
              state=read2(1);
              no look=true;
              l=j;
            end; else
              if l=j then
                do:
                  call error('np');
                  if(state := recover)=0 then compiling=false;
                end;
              end;
            end; else
          end: if state>maxpno then /* apply production state */
            do:
              mp=sp-getin2; mp1=mp+1;
              production = state-maxpno;
              call synthesis1;
              sp=mp; l=getin1;
              varindex=var(sp);

```



```

j=statestack(sp):
    do while (k:=apply1(i)) > 0 and j > k;
    i=i+1;
    end;
if state:= apply2(i))=0 then compiling = false;
end; else
if state<= maxno then /* lookahead state */
do;
    i=getin1; call lookahead;
    do while (k:=look1(i)) > 0 and token > k;
    i=i+1;
    end;
    state=look2(i);
    end; else
/* push state */
do; call incsp;
statestack(sp)=getin2;
state=getin1;
end;
end; /* of while compiling */
end; /* of while pass1 or pass2*/
listsource = false;
listprod = false;
listtoken = false;
call initialize;

pass2 = true;
end; /* of do forever*/
end; /* of block for parser */
end; /* of block for declarations*/

```

eof



```

100h: /*load point for interp program*/
declare /*global literals*/
    lit      literally      'literally',
    true    lit      '1',
    false   lit      '0',
    forever lit      'while true',
    or     lit      '0dh',
    if     lit      '0ah';

declare /*op codes for algol-n machine instructions*/
    deci   lit      '25',
    str    lit      '1',
    int    lit      '2',
    dcb    lit      '5',
    brs    lit      '34',
    bsc    lit      '35',
    iml    lit      '27',
    im2    lit      '28';

declare /*interface points for cp/m and interrupt*/
    bdos   lit      '05h',
    boot   lit      '0h',
    diskbuffloc lit      '80h',
    feblobc lit      '5ch',
    diskbuffend lit      '100h',
    bdosbegin address initial(06h),
    max    based bdosbegin address,
    buff   address initial(diskbuffend),
    cbar   based buff byte,
    filename address initial(feblobc),
    fnp    based filename byte;

declare /*build variables*/
    prtbase address,
    prt$addr address,
    prt$entry based prt$addr address,
    codebase address,
    codeptr address,
    stackbase address,
    curchar byte,
    switch  byte initial(false),
    bld$flag byte,
    b      based codeptr byte,
    a      based codeptr address,
    templ  address,
    t1    based templ byte,
    temp2  address,
    t2    based temp2 byte;

/* declarations for interpreter */
declare contz   lit      'lah',
    quote    lit      '22h',
    what    lit      '63';

declare eolchar  lit      '0dh',
    eoffiller lit      'lah',
    Intrecsize lit      '128',
    Diskrecsize lit      '128',
    stringdelim lit      '22h',
    conbufsize lit      '80',
    console   lit      '0',
    nrstack   lit      '48', /*stack size times 4*/
    max$blk$level lit      '10',
    negative  lit      '0',
    positive  lit      '1';

declare ra      address,
    rb      address,
    rc      address;

```



```

c          based      rc      byte,
twobyteoprand based      rc      address,
sb          address,
st          address,
bra         based      ra      byte,
ara         based      ra      address,
arb         based      rb      address,
brb         based      rb      byte,
mpr         address,
med         address;

declare inputbuffer
buff$space(combuffsize)
inputindex
combuffptr
com$char
inputptr
input$char  based
num$read
printbufflength
printbufferloc
tabpos1
tabpos2
tabpos3
tabpos4
printbuffer
printpos
printbuffend
rereadaddr
inputtype
field$length
sign

declare fileaddr
fcf
fcbadr
eofaddr
bufferSend
record$pointer
buffer
nextdiskchar
reg$length
block$size
blk$level
error$flag
blk(max$blk$level)
bytes$written
firstfield
eofra
eofrb

declare (r0,r1,r2) (11)
(sign0,sign1,sign2)
(decp$pt0,decp$pt1,decp$pt2)
ctr
no$shift
base
b$byte  based base
b$addr  based base
hold
l$byte  based hold
l$addr  based hold
ptr$one
ptr$two
p$one   based ptr$one
p$two   based ptr$two
stacktop
ret$addr based stacktop
pcb$ptr
pcb$value based pcb$ptr
counter
move$ent
ret$value

```



```

testvalue           address,
tad1               address,
tad2               address,
tad3               address,
r$ptr              byte,
overflow            byte,
signif$no          byte,
e$flag             byte,
s$flag             byte,
zero$result        byte;

/*cp/m interface routines*/
mon1:procedure(function,parameter):
  declare function byte;
  parameter address;
  goto bdos;
end mon1;

mon2:procedure(function,parameter) byte:
  declare function byte;
  parameter address;
  goto bdos;
end mon2;

mon3:procedure;
  goto boot;
end mon3;

printchar:procedure(char):
  declare char byte;
  call mon1(2,char);
end printchar;

print:procedure(buffer);
  declare buffer address;
  call mon1(9,buffer);
end print;

crlf:procedure;
  call printchar(cr);
  call printchar(lf);
end crlf;

/* procedures for build */

open$int$file:procedure:
  fnp(9) = 'a';
  fnp(10) = 'l';
  fnp(11) = 'n';
  fnp(32) = 0;
  if mon2(15,filename) = 253 then
    do;
      call print('.nl   $');
      call crlf;
      call mon3;
    end;
end open$int$file;

read$int$file:procedure byte;
  return mon2(20,filename);
end read$int$file;

/*global procedures*/
incbuf:procedure:
  if(buff := buff+1) >= diskbuffend then
    do;
      buff = diskbuffloc;

```



```

        if read$int$file <> 0 then
            char = 7fh;
        end;
end incbuf;

sto$char$inc:procedure:
    b = char;
    codeptr = codeptr+1;
end sto$char$inc;

next$char:procedure byte;
    call incbuf;
    return curchar := char;
end next$char;

get$two$bytes:procedure;
    b(1) = next$char;
    b = next$char;
end get$two$bytes;

inc$codeptr$two:procedure;
    codeptr = codeptr + 1 + 1;
end inc$codeptr$two;

getparm:procedure address;
    return shl(double(nextchar),8) + nextchar;
end getparm;

pack$decimal:procedure(loc$one, loc$two);
    declare switch byte,
        loc$one address,
        loc$two address;

    pack:procedure;
    if (switch := not switch) then
        p$two = shl(p$one-30h,4); /* odd */
    else
        do;
            p$two = p$two or (p$one-30h); /* even */
            ptr$two = ptr$two + 1;
        end;
    end pack;

    ptr$one = loc$one;
    ptr$two = loc$two;
    switch = false;
    temp1 = ptr$two;
    p$two = 0;
    ptr$two = ptr$two + 1;
    temp2 = ptr$two;
    p$two = 0;
    ptr$two = ptr$two + 1;
    do while p$one <> 0;
        if (p$one >= '0') and (p$one <= '9') then
            do;
                call pack;
                t1 = t1 + 1;
            end;
        else
            if p$one = '.' then
                t2 = t1; /* left offset to decpt */
            else
                do;
                    error$flag = true;
                    return;
                end;
        end;
        if ((ptr$one := ptr$one+1) >= diskbuffend) and bid$flag then
            do;
                ptr$one = diskbuffloc;
                if read$int$file <> 0 then
                    do;
                        p$one(2) = 7fh;
                    return;

```



```

        end;
    end;
end;
if switch then
  do;
    t1 = t1 + 1;
    ptr$two = ptr$two + 1;
  end;
t2 = t1 - t2; /* right offset to decpt */
t1 = t1 / 2;
ptr$two = t1 + 2;
ptr$two = ptr$two + 1;
ptr$two = positive; /* this field used for dec sign */
end pack$decimal;

/* procedures for Interp */

readchar:procedure byte;
  return mon2(1,0);
end readchar;

read:procedure(a);
  declare a address;
  call mon1(10,a);
end read;

open:procedure byte;
  return mon2(16,fileaddr);
end open;

close:procedure byte;
  return mon2(16,fileaddr);
end close;

diskread:procedure byte;
  return mon2(20,fileaddr);
end diskread;

diskwrite:procedure byte;
  return mon2(21,fileaddr);
end diskwrite;

make:procedure byte;
  return mon2(22,fileaddr);
end make;

delete:procedure;
  call mon1(19,fileaddr);
end delete;

setdma:procedure;
  call mon1(26,buffer);
end setdma;

select:procedure(drive);
  declare drive byte;
  call mon1(14,drive);
end select;

mask:procedure(location) address;
  declare location address;
  l based location address;
  return l and 0ffff;
end mask;

check$int$sign:procedure(value) byte;
  declare value address;
  if rol(high(value),1) then
    return negative;
  else
    return positive;
end check$int$sign;

```



```

check$int:procedure(stack$loc1 byte;
    declare stack$loc address;
    if not(rol(high(stack$loc),2)) then
        return true;
    else return false;
end check$int;

check$temp:procedure(stack$loc1 byte;
    declare stack$loc address;
    if (rol (high(stack$loc),1)) and
        (rol(high(stack$loc),2)) then
        return true;
    else return false;
end check$temp;

set$up$neg:procedure;
    if not check$int$sign(ar3) then
        ar3 = ar3 or 4000h;
    if not check$int$sign(arb) then
        arb = arb or 4000h;
end set$up$neg;

check$neg:procedure;
    if not check$int$sign(arb) then
        arb = arb and 0ffffh;
end check$neg;

pop$stack:procedure;
    declare num byte;
    ra = rb;
    if check$temp(arb) then
        rb = rb - (bit-2);
    else rb = rb - 2;
end pop$stack;

push$stack:procedure(num);
    declare num byte;
    rb = ra;
    ra = ra + num;
end push$stack;

move:procedure(source,dest,count);
    declare source address;
    dest address;
    count byte;
    schar based source byte;
    dchar based dest byte;
    do while(count := count - 1) <> 255;
        dchar = schar;
        source = source + 1;
        dest = dest + 1;
    end;
end move;

fill:procedure(dest,char,n);
/*fill locations starting at dest with char for n bytes*/
    declare dest address;
    n byte;
    d based dest byte;
    char byte;
    do while (n:=n-1) <> 0ffh;
        d = char;
        dest = dest + 1;
    end;
end fill;

error$msg:procedure(msg);
    declare msg address;
    call print$char(' ');
    call print$char(high(msg));
    call print$char(low(msg));
end error$msg;

```



```

warning:procedure(warncode):
  declare warncode address;
  call crlf;
  call print(.,'warning $');
  call error$msg(warncode);
end warning;

error:procedure(errcode):
  declare errcode address;
  call crlf;
  error$flag = true;
  call print(.,'error $');
  call error$msg(errcode);
end error;
/* file processing routines for use with cp/m */
/*****
initial$disk$buffer:procedure:
  call fill(buffer,eoffiller,128);
end initial$disk$buffer;

buffer$status$byte:procedure byte:
  return fcb(33);
end buffer$status$byte;

set$buffer$status$byte:procedure(status):
  declare status byte;
  fcb(33) = status;
end set$buffer$status$byte;

write$mark:procedure byte:
  return buffer$status$byte;
end write$mark;

set$write$mark:procedure:
  call set$buffer$status$byte(buffer$status$byte or 01h);
end set$write$mark;

clear$write$mark:procedure:
  call set$buffer$status$byte(buffer$status$byte and 0feh);
end clear$write$mark;

active$buffer:procedure byte:
  return shr(buffer$status$byte,1);
end active$buffer;

set$buffer$inactive:procedure:
  call set$buffer$status$byte(buffer$status$byte and 0fdh);
end set$buffer$inactive;

set$buffer$active:procedure:
  call set$buffer$status$byte(buffer$status$byte or 02h);
end set$buffer$active;

set$random$mode:procedure:
  call set$buffer$status$byte(buffer$status$byte or 80h);
end set$random$mode;

random$mode:procedure byte:
  return rol(buffer$status$byte,1);
end random$mode;

disk$eof:procedure:
  if eofaddr = 0 then
    call error('ef');
  rc = eofaddr + 1;
  ra = eofra;
  rb = eofrb;
  goto eofexit;
end disk$eof;

```



```

fill$file$buffer:procedure;
  if diskread = 0 then
    do;
      call set$buffer$active;
      return;
    end;
  if not random$mode then
    do;
      call disk$eof;
      return;
    end;
  call initialize$disk$buffer;
  call set$buffer$active;
  return;
end fill$file$buffer;

write$disk$if$req:procedure;
  if write$mark then
    do;
      if diskwrite <> 0 then
        call error('dw');
      call clear$write$mark;
      if random$mode then
        call set$buffer$inactive;
      else
        call initialize$disk$buffer;
    end;
    record$pointer = buffer;
  end write$disk$if$req;

atSend$disk$buffer:procedure byte;
  return (record$pointer := record$pointer + 1) >= buffer$end;
end atSend$disk$buffer;

var$block$size:procedure byte;
  return block$size <> 0;
end var$block$size;

store$rec$ptr:procedure;
  fcaddr(18) = record$pointer;
end store$rec$ptr;

write$as$byte:procedure(char);
  declare char byte;
  if var$block$size and (byteswritten := byteswritten+1)
    > block$size then
    call error('er');
  if atSend$disk$buffer then
    call write$disk$if$req;
  if not active$buffer and random$mode then
    do;
      call fill$file$buffer;
      feb(32) = feb(32) - 1; /* reset record no */
    end;
  nextdiskchar = char;
  call set$write$mark;
end write$as$byte;

set$file$addr:procedure;
  prt$addr = mask(ra);
  fileaddr = prt$entry;
  eofaddr = fcaddr(19);
  call pop$stack;
end set$file$addr;

set$file$pointers:procedure;
  buffer$end = (buffer := fileaddr + 33) + diskrecsize;
  recordpointer = fcaddr(18);
  block$size = fcaddr(17);
  call setdma;
end set$file$pointers;

setup$file$exit:procedure;

```



```

if open = 255 then
  do:
    if make = 255 then
      call error('me');
    end;
end setup$file$extent;

disk$open:procedure:
  declare (filename, buff, blk$size) address.
  i,j byte,
  char based buff byte;
inc$j:procedure byte:
  return (j := j + 1);
end inc$j;

prt$addr = mask(ra);
call pop$stack;
blk$size = ra;
call pop$stack;
buff = mask(ra);
call pop$stack;
buff = buff - char;
fileaddr,prt$entry = ra;
buffer = ra + 0;
call fil1 ((filename := ra + 1), ' ', 11);
if char(2) = ':' then
  do:
    bra = (char(1) and 0fh) - 1;
    i = char - 2;
    buff = buff + 2;
  end;
else
  i = char;
if i > 12 then
  i = 12;
buff = buff + 1;
j = 255;
do while (char(inc$j) <> '.') and (j < 8):
  end;
call move (buff,filename,j);
if i > inc$j then
  call move (.char(j),filename+8,i-j);
call setup$file$extent;
ara(19) = 0;
ara(18) = ra + 256;
ara(17) = blk$size;
ra = ra + 168;
end disk$open;

set$eof$stack:procedure:
  eofra = ra;
  eofrb = rb;
end set$eof$stack;

setup$disk$io:procedure:
  call set$file$addr;
  call set$file$pointers;
  bytes$written = 0;
  firstfield = true;
end setup$disk$io;

random$setup:procedure:
  declare bytecount address.
    record address,
    extent byte;
  if not var$block$size then
    call error('ru');
  ara = ara - 1;
  call set$random$mode;
  call set$buffer$inactive;
  call write$disk$if$req;
  bytecount = blocksizes * ara;
  recordpointer = (bytecount and 7fh) + buffer - 1;

```



```

call store$rec$ptr;
record = shr(bytecount,7);
extent = shr(record,7);
if extent <> fcb(12) then
  do;
    if close = 255 then
      call error('ce');
      fcb(12) = extent;
      call setup$file$extent;
    end;
  fcb(32) = low(record) and 7fh;
  call pop$stack;
end random$setup;

get$disk$char:procedure byte;
if at$end$disk$buffer then
  do;
    call write$disk$if$req;
    call fill$file$buffer;
  end;
  if not active$buffer then
    call fill$file$buffer;
  if nextdiskchar = eoffiller then
    call disk$eof;
  return nextdiskchar;
end get$disk$char;

disk$close:procedure;
call set$file$pointers;
call write$disk$if$req;
prt$addr = mask(ra);
if close = 255 then
  call error('ce');
prt$entry = 0;
end disk$close;

clear$print$buff:procedure;
  call fill((printbuffer := printbufferloc), ' ', 72);
end clear$print$buff;

dump$print$buff:procedure;
  declare temp address,
        char based temp byte;
  temp = printbuffend;
  do while char = ' ';
    temp = temp - 1;
  end;
  call crlf;
  do printbuffer = printbufferloc to temp;
    call printchar(printpos);
  end;
  call clear$print$buff;
end dump$print$buff;

load$print$buff:procedure(char);
  declare char byte;
  printpos = char;
  if (printbuffer := printbuffer + 1) >
    printbuffend then
    call dump$print$buff;
end load$print$buff;

output:procedure(dest,char);
  declare dest byte,
        char byte;
  if dest = console then
    call print$char(char); /* to console */
  else
    call write$as$byte(char); /* to disk */
end output;

write$dec:procedure(source,dest);

```



```

declare source address,
    num byte,
    num$digits byte,
    char byte,
    index byte,
    dest byte,
    count byte;
store$one:procedure;
    if (switch := not switch) then
        do:
            char = shr(h$byte,4) or '0';
            if (count=0) and (char='0') then:
            else
                call output(dest,char);
        end;
    else
        do:
            call output(dest,(h$byte and 0fh) or '0');
            hold = hold + 1;
        end;
        count = count + 1;
    end store$one;

hold = source;
sign = h$byte(1);
if sign or 00h then
    call output(dest,' ');
else call output(dest,'-');
count = 0;
hold = hold - h$byte;
num$digits = h$byte * 2;
hold = hold + 1;
num = num$digits - h$byte;
switch = false;
hold = hold + 1;
do index = 1 to num$digits+1:
    if count = num then
        do:
            call output(dest,'.');
            count = 100;
        end;
    else
        call store$one;
    end;
end write$dec;

write$str:procedure(hold,dest):
    declare hold address,
        h based hold byte,
        dest byte,
        index byte;
    hold = hold - h;
    do index = 1 to h:
        call output(dest,h(index));
    end;
end write$str;

write$int:procedure(value,dest):
    declare value address, i byte, count byte;
    declare decint(5) address initial(10000,1000,100,10,1);
    declare (flag,dest) byte;
    sign = check$int$sign(value);
    if sign = negative then
        do:
            value = -value and 0ffffh /* mask off next to left bit */
            call output(dest,'-');
        end;
    else call output(dest,' ');
    flag = false;
    do i = 0 to 4:
        count = 30h;
        do while value >= decint(i):
            value = value - decint(i);

```



```

        flag=true;
        count=count+1;
    end;
    if flag or (l >= 4) then
        call output(dest,count);
    else
        call output(dest,' ');
    end;
end write$int;

write$to$disk:procedure(type);
/* type 0-integer,type 1-decimal,type 2-string */
declare type byte;
if type = 0 then
    call write$int(ara,1);

if type = 1 then
    call write$dec(ara,1);

if not firstfield then /* separate fields with commas */
    call write$a$byte(',');
else firstfield = false;

if type = 2 then
    do:
        call write$a$byte(quote); /* strings put in quotes */
        call write$str(ara,1);
        call write$a$byte(quote); /* add trailing quotes */
    end;
call pop$stack;
end write$to$disk;

concatenate:procedure;
declare (size1,size2,t$size) byte;
temp1 = mask(ra);
call pop$stack;
if not check$temp(ara) then
    do:
        temp2 = mask(ra);
        temp2 = temp2 - t2;
        size2 = t2 + 1;
        call move(temp2,ra,size2);
    end;
else
    do:
        size2 = bra;
        ra = ra - bra;
    end;
temp1 = temp1 - ti;
size1 = ti;
call move(temp1+1,ra+size2,size1);
t$size = size1 + size2;
bra = t$size - 1;
ra = ra + t$size;
bra = t$size;
bra(1) = 0c0h; /* set temp bits */
end concatenate;

convert$to$int:procedure(loc,size) address;
declare decint(5) address initial (10000,1000,100,10,1),
        loc address,
        hold address,
        h based hold byte,
        num address,
        (i,j,size) byte;
num = 0;
j = 5;
hold = loc + size - 1;
if size > 5 then
    call error('in');
else
    do:
        do i = 1 to size:

```



```

        num = num + (h - 30h) * decint(j:j-1);
        hold = hold - 1;
    end;
    if num <= 14383 then
        return num;
    else
        call error('io');
    end;
end convert$ToInt;

one$left:procedure;
declare ctr byte;
if shr(b$byte(1),4) = 0 then
    do:
        do ctr = 1 to 9;
        b$byte(ctr) = shl(b$byte(ctr),4) or shr(b$byte(ctr+1),4);
        end;
    end;
    else noshift = true;
end one$left;

one$right:procedure;
declare ctr byte,
        index byte;
ctr = 11;
do index = 1 to 10;
    ctr = ctr-1;
    b$byte(ctr) = shr(b$byte(ctr),4) or shl(b$byte(ctr-1),4);
end;
end one$right;

shift$right:procedure(count);
declare(count,ctr) byte;
do ctr = 1 to count;
    call one$right;
end;
end shift$right;

shift$left:procedure(count);
declare count byte;
noshift = false;
do ctr = 1 to count;
    call one$left;
    if noshift then
        return;
end;
end shift$left;

leading$zeroes:procedure(addr) byte;
declare count byte,
        ctr byte,
        addr address;
count = 0;
base = addr;
do ctr = 1 to 9;
    if (b$byte(ctr) and 0f0h) <> 0 then
        return count;
    count = count + 1;
    if (b$byte(ctr) and 0fh) <> 0 then
        return count;
    count = count + 1;
end;
if base = .r9 then
    do:
        call error('dz');
        b$byte(9) = 10h;
        decpt0 = 1;
        return 16;
    end;
    return count;
end leading$zeroes;

r1$greater:procedure byte;

```



```

declare (i,ctr) byte;
do ctr = 1 to 9;
  if r1(ctr) > (i := (99h-r0(ctr))) then
    return true;
  if r1(ctr) < i then
    return false;
end;
e$flag = true;
return true;
end ri$greater;

align:procedure;
  declare (x,y) byte;

right$op:procedure(addr);
  declare addr address;
  if noshift then
    do;
      base = addr;
      call shift$right(y := x - ctr);
    end;
  end right$op;

y = 0;
if dec$p0 > dec$p1 then
  do;
    base = .r1;
    call shift$left(x := dec$p0 - dec$p1);
    dec$p1 = dec$p1 + ctr-1;
    call right$op(.r0);
    dec$p0 = dec$p0 - y;
  end;
else
  do;
    base = .r0;
    call shift$left(x := dec$p1 - dec$p0);
    dec$p0 = dec$p0 + ctr-1;
    call right$op(.r1);
    dec$p1 = dec$p1 - y;
  end;
end align;

add$r0:procedure(second,dest);
  declare (second, dest) address, (index,cy,a,b,i) byte;
  hold = second;
  base = dest;
  cy = 0;
  ctr = 10;
  do index = 1 to 11;
    a = r0(ctr);
    b = h$byte(ctr);
    i = dec(a + cy);
    cy = carry and 1;
    i = dec(i + b);
    cy = (cy or carry) and 1;
    b$byte(ctr) = i;
    ctr = ctr - 1;
  end;
  if cy then
    do;
      ctr = 10;
      do index = 1 to 11;
        i = b$byte(ctr);
        i = dec(i + cy);
        cy = carry and 1;
        b$byte(ctr) = i;
        ctr = ctr - 1;
      end;
    end;
  end add$r0;

compliment:procedure(numb);
  declare numb byte;

```



```

do case numb:
    hold = .r0;
    hold = .r1;
    hold = .r2;
end;
if sign$0(numb) then sign0(numb) = negative;
else sign$0(numb) = positive;
do ctr = 0 to 10:
    h$byte(ctr) = 99h - h$byte(ctr);
end;
end compliment;

right$justify:procedure(numb):
    declare (numb,i) byte;
    do case numb:
        base = .r0;
        base = .r1;
        base = .r2;
    end;
    i = 0;
    do while (((i:=i+2) < decpt0(numb)) and (b$byte(9)=0));
        call shift$right(2);
    end;
    decpt0(numb) = decpt0(numb) - (i-2);
end right$justify;

set$mult$div:procedure;
    noshift = false;
    if (sign0 and sign1) or
        (not sign0 and not sign1) then
        sign2 = positive;
    else sign2 = negative;
    call fill (.r2,0,10);
end set$mult$div;

add$series:procedure(count):
    declare (i,count) byte;
    do i = 1 to count:
        call add$r0(.r2,.r2);
    end;
end add$series;

multiply:procedure(value):
    declare value byte;
    if value <> 0 then
        do:
            if noshift then
                call error('ov');
            call add$series(value);
        end;
        base = .r0;
        call one$left;
    end multiply;

divide:procedure;
    declare (i,j,k,x,lz0,lz1) byte;
    call set$mult$div;
    s$flag = true;
    e$flag = false;
    if (lz0 := leading$zeroes(.r0)) <>
        (lz1 := leading$zeroes(.r1)) then
        do:
            if lz0 > lz1 then
                do:
                    base=.r0;
                    call shift$left(i:=lz0-lz1);
                    decpt0 = decpt0 + i;
                    x = lz1;
                end;
            else
                do:
                    base = .r1;
                    call shift$left(i:=lz1-lz0);

```



```

        decpt1 = decpt1 + i;
        x = lz0;
    end;
end;
else x = lz1;
decpt2 = 19 - x + decpt1 - decpt0;
call compliment(0);
do i = x to 19;
    j = 0;
    do while r1$greater and s$flag;
        call add$reg0(.r1,.r1);
        j = j + 1;
        if e$flag = true then s$flag = false;
    end;
    k = shr(i,1);
    if i then
        r2(k) = r2(k) or j;
    else r2(k) = r2(k) or shl(j,4);
    base = .r0;
    call one$right;
end;
end divide;

check$result:procedure;
if r2 = 99h then
    do:
        call compliment(2);
        sign2 = sign2 xor 1;
    end;
else
    do:
        if r2 <>0 then
            call error('ov');
        if not s$flag then
            sign2=positive;
    end;
end check$result;

check$sign:procedure;
s$flag=false;
if sign0 and sign1 then
    do:
        sign2 = positive;
        return;
    end;
sign2 = negative;
if not sign0 and not sign1 then
    do:
        s$flag=true;
        return;
    end;
if sign0 then call compliment(1);
else call compliment(0);
end check$sign;

add:procedure;
call check$sign;
call add$reg0(.r1,.r2);
call check$result;
decpt2 = decpt0;
end add;

copy$reg2$onsstack:procedure;
declare count byte;
        1 byte;
call right$justify(2);
call pop$stack;
count = 0;
base = .r2;
i = 10 - (decpt2+1)/2;
do while (b$byte = 0) and (count < i);
    base = base + 1;
    count = count+ 1;

```



```

end;
ra = rb + 2;
bra(0) = (count := 10 - count);
bra(1) = dec$pt2;
call move(base, ra+2, count);
bra(count+2) = count+2;
bra(count+3) = sign2 or 0c0h; /* set sign and temp bits */
ra = ra + count + 2;
end cpy$reg2$onsstack;

load$reg:procedure(source, reg$num);
  declare source address,
        reg$num byte,
        count byte;
  hold = source;
  if not check$temp(h$addr) then
    hold = mask(hold);
  sign0(reg$num) = h$byte(1);
  hold = hold - h$byte;
  count = h$byte;
  do case reg$num;
    base = .r0;
    base = .r1;
    base = .r2;
  end;
  call fill(base, 0, 11);
  hold = hold + 1;
  dec$pt0(reg$num) = h$byte;
  hold = hold + 1;
  call move(hold, base+10-count, count);
end load$reg;

set$up$regs:procedure;
  noshift = false;
  call load$reg(ra, 0);
  call load$reg(rb, 1);
  call right$justify(0);
  call right$justify(1);
end set$up$regs;

step$ins$cnt:procedure(num);
  declare num byte;
  rc=rc+num;
end step$ins$cnt;

branch$absolute:procedure;
  call step$ins$cnt(1);
  rc=twobyteoprnd - 1;
end branch$absolute;

get$code$addr:procedure(offset) address;
  declare offset address;
  return codebase + offset;
end get$code$addr;

get$pri$addr:procedure(offset) address;
  declare offset address;
  return pribase + offset;
end get$pri$addr;

load:procedure(addr);
  declare addr address;
  a based addr address;
  prt$addr = mask(addr);
  a = prt$entry;
end load;

store$dec:procedure(source, dest);
  declare (source, dest, dest$sign) address,
        (unit$sto, avail$sto, sig$bytes) byte,
        s based source address;

```



```

        d based dest address,
        dect byte,
        sign based dest$sign byte;
if check$temp(s) then
    temp1 = source;
else temp1 = mask(source);
temp2=mask(dest);
availsto = t2 - 2;
dest$sign = temp2+1;
t2(1) = t1(1) and 01h; /*mask off temp bits */
source= (temp1:=temp1-t1);
dest=temp2-t2;
amtsto = t1;
dect = t1(1);
    sig$bytes = ((amtsto * 2 - dect) + 1) / 2;
if amtsto <= availsto then
    do;
        call fill(dest,00h,t2);
        call move(source,dest,t1+2);
    end;
else if sig$bytes <= availsto then
    do;
        call move (source,dest,t2);
        temp2 = dest;
        t2 = availsto;
        t2(1) = (availsto - sig$bytes) * 2;
        if dect then
            t2(1) = t2(1) + 1;
        call warning('ill');
    end;
else
    do;
        hold = dest;
        h$addr = 0101h;
        h$byte(2) = 10h;
        sign = positive;
        call error('s1');
    end;
end store$dec;

store$int:procedure(dest,value);
declare (dest,value) address;
prt$addr=mask(dest);
prt$entry=value;
end store$int;

store$str:procedure(source,dest);
declare (dest,source) address,
        s based source address,
        d based dest address;
if check$temp(s) then
    temp1 = source;
else temp1 = mask(source);
temp2 = mask(dest);
dest = temp2 - t2;
source = temp1 - t1;
if t1 <= t2 then
    do;
        call fill(dest,20h,t2);
        call move(source,dest,t1);
    end;
else
    do;
        call move(source,dest,t2);
        call warning('so');
    end;
end store$str;

allocate$str:procedure;
if bra = 0 then
    do;
        call error('az');
        bra = 10;

```



```

    end;
    call push$stack(bra:=bra+1);
    bra = brb;
end allocate$str;

allocate$dec:procedure:
    declare store byte;
    if bra = 9 then
        do;
            call error('az');
            bra = 9;
        end;
    ctr = bra;
    store = (bra+1)/2+2;
    call push$stack(store);
    bra = store;
    ara = ara or 0100h;
end allocate$dec;

set$up$alloc:procedure;
    prt$addr = mask(ra);
    call pop$stack;
end set$up$alloc;

find$rb:procedure;
    if check$temp(ara) then
        rb = ra - (bra + 2);
    else rb = ra - 2;
end find$rb;

sav$pcb:procedure;
    if move$cnt = 6 then
        return;
    call push$stack(2);
    call move(pebptr,ra,move$cnt);
    peb$value1 = ra;
    ra = ra + move$cnt;
    ara = move$cnt;
end sav$pcb;

unsave:procedure;
    call move(temp1:=ra-ara,hold,ara);
    ra = temp1;
end unsave;

calc$row:procedure;
    declare (index,num,v,a$size,type) byte,
            (num$arrays,num$dim,alloc$len,count,i) byte,
            d (10) byte;
    type = bra; /* 1-int,2-dec,3-str */
    call pop$stack;
    num$arrays = bra;
    call pop$stack;
    num$dim = bra;
    call pop$stack;
    v = 0;
    a$size = 1;
    d(num$dim) = 1;
    if num$dim = 1 then
        do;
            a$size = bra - brb + 1;
            v = brb;
            call pop$stack;
            call pop$stack;
        end;
    else
        do index = 1 to num$dim;
            i = num$dim - index;
            a$size = a$size * (num := bra - brb + 1);
            d(i) = num * d(i+1);
            v = v + brb * d(i+1);
            call pop$stack;
            call pop$stack;
        end;
    end;

```



```

end;
if type = int then
    call push$stack(2);
else
    alloc$len = bra;
do count = 1 to num$arrays:
    call step$ins$ent(1):
    bra = c(1);
    bra(1) = c and 3fh;
    prt$addr = ara + prt$base;
    prt$entry = ra or 4000h; /* set addr bits */
    bra = num$dim;
    if num$dim <> 1 then
        do index = 1 to num$dim - 1;
            i = num$dim - index;
            ra = ra + 1;
            bra = d(i);
    end;
    ra = ra + 1;
    bra = v;
    ra = ra + 1;
    bra = alloc$len;
    if type = int then
        do;
            bra = 2;
            ra = ra + 1;
            hold = ra;
            ra = ra + a$size * 2;
            h$addr = ra;
        end;
    end;
else
    if type = decl then
        do;
            bra = (bra+1)/2 + 4;
            ra = (hold := ra+1) + 2;
            bra = alloc$len;
            do index = 1 to a$size;
                call allocate$dec;
                call push$stack(2);
                bra = ctr; /* reset to allocated length */
            end;
            call pop$stack;
            h$addr = ra;
        end;
    end;
    else
        if type = str then
            do;
                bra = bra + 3;
                ra = (hold := ra + 1) + 2;
                bra = alloc$len;
                do index = 1 to a$size;
                    call allocate$str;
                    call push$stack(2);
                    ara = arb;
                end;
                call pop$stack;
                h$addr = ra;
            end;
        end;
    call step$ins$ent(1);
end; /*count*/
end calc$row;

calc$sub:procedure;
declare array$addr address;
    location address;
    a$byte based array$addr byte,
    a$addr based array$addr address,
    (1,num$dim) byte,
    offset address;
array$addr = mask(ra);
call pop$stack;
offset = ara;
num$dim = n$byte;

```



```

do i = 2 to num$dim;
  call pop$stack;
  array$addr = array$addr + 1;
  offset = arr * a$byte + offset;
end;
array$addr = array$addr + 1;
offset = (offset - a$byte+1) * a$byte(1);
array$addr = array$addr + 2;
if (location:=array$addr+offset) > a$addr then
  call error('ab');
ara = location or 4000h;
end calc$sub;

decrement$blk:procedure(num);
  declare num byte;
  ra = blk((blk$level:=blk$level-num) + 1);
  call find$rb;
end decrement$blk;

add$int:procedure(int1,int2) address;
  declare (int1,int2) address;
  return int1 + int2;
end add$int;

sub$int:procedure(int1,int2) address;
  declare (int1,int2) address;
  return int1 - int2;
end sub$int;

mul$int:procedure(int1,int2) address;
  declare (int1,int2) address;
  return int1 * int2;
end mul$int;

div$int:procedure(int1,int2) address;
  declare (int1,int2) address;
  return int1 / int2;
end div$int;

exit$interp:procedure;
  call crlf;
  call mon3;
end exit$interp;

console$read:procedure;
  call crlf;
  call printchar('-');
  call printchar('>');
  call printchar(' ');
  call read(.inputbuffer);
  if buff$space(1) = contz then
    call exit$interp;
    num$read = buff$space;
    conbuffptr = .buff$space;
    buff$space(buff$space+1) = eolchar;
end console$read;

more$cons$input:procedure byte;
  return conbuffptr < .buff$space( num$read );
end more$cons$input;

console$input$error:procedure;
  rc = rereadaddr /* reset program counter */;
  call warning ('ii');
  goto error$exit; /* return to outer level */;
end console$input$error;

get$cons$char:procedure byte;
  conbuffptr = conbuffptr + 1;
  return cons$char;
end get$cons$char;

```



```

next$input$char:procedure byte;
  if inputtype = 0 then /* read from disk */
    /* do forever:
       if (buff$space(inputindex) := getdiskchar) = 1f then
         do:
           if var$blocksize then
             call error('re');
           end;
        else
          return next$disk$char;
        end */;
  if inputtype = 1 then /* input from console */
    return get$cons$char;
end next$input$char;

get$field:procedure;
  declare hold byte,
        delim byte;
  field$length = 0;
  do while (hold := next$input$char) = ' ';
    end;
  if inputtype = 0 then
    inputptr = .buf$space;
  if inputtype = 1 then
    inputptr = conbuffptr;
  if hold <> quote then
    delim = ' ';
  else
    do:
      delim = quote;
      hold = next$input$char;
    end;
  do while (hold <> delim) and (hold <> eolchar);
    field$length = field$length + 1;
    hold = next$input$char;
  end;
end get$field;

get$int$field:procedure;
  declare sign byte;
  call get$field;
  if input$char = '-' then
    do:
      sign = 1;
      inputptr = inputptr + 1;
      field$length = field$length - 1;
    end;
  else
    if input$char = '+' then
      do:
        sign = 0;
        inputptr = inputptr + 1;
        field$length = field$length - 1;
      end;
    else
      sign = 0;
  call push$stack(2);
  ara = convert$to$int(inputptr, field$length);
  if error$flag then
    call console$input$error;
  if sign then
    ara = -ara and 0ffffh; /* set neg bit and conv to neg int */
end get$int$field;

get$str$field:procedure;
  call get$field;
  cons$char = field$length+1;
  input$ptr = conbuffptr - cons$char;
  input$char = field$length;
  call push$stack(2);
  ara = conbuffptr or 4000h;
end get$str$field;

```



```

get$dec$field:procedure:
  call get$field;
  call push$stack(2);
  curchar = 0; /* set binary 0 as end of dec */
  if input$char = '+' then
    do:
      sign = 1;
      inputptr = inputptr + 1;
    end;
  else
    if input$char = '-' then
      do:
        sign = 0;
        inputptr = inputptr + 1;
      end;
    else
      sign = 1;
  call pack$decimal(inputptr.ra);
  if error$flag then
    call console$input$error;
  ra = p'two - 1;
  bra(1) = sign or 0c0h; /* set sign and temp bits */
end get$dec$field;

initialize$execute:procedure:
  stacktop=3050h;
  med, rc = codebase;
  mpr = prtbase;
  st, sb = stackbase;
  ra = (rb := sb) + 2;
  bld$flag = false;
end initialize$execute;

/*set up machine*/

call print('algol-m Interpreter-vers 1.0$');
call crlf;
call open$int$file;
bld$flag = true;
call incbuf; call incbuf; /* skip codesize */
prtbase = .memory;
codebase = getparm + prtbase;
codeptr=codebase;

/*load machine*/

do while next$char <> 7fh;
if curchar >= 128 then
  do:
    call sto$char$inc;
    call incbuf;
    call sto$char$inc;
  end;
else
  if curchar = str then
    do:
      call sto$char$inc;
      templ = codeptr;
      char = 0; /* set initial length to zero */
      call sto$char$inc;
      do while next$char <> 0;
        call sto$char$inc;
        t1 = t1+1;
      end;
      char = t1+1;
      call sto$char$inc;
      char = 0; /*must make str lenght an addr quantity */
      call sto$char$inc;
    end;
  else
    if curchar = int then
      do:
        call sto$char$inc;

```



```

    hold = buff + 1;
    field$length = 0;
    do while next$char <> 0;
        field$length = field$length + 1;
    end;
    a = convert$to$int(hold,field$length);
    codeptr = codeptr + 2;
end;

else
    if curchar = deci then
do;
    call sto$char$inc;
    call incbuf;
    call pack$decimal(buff,codeptr);
    codeptr = ptr$two + 1;
    buff = ptr$one + 2;
end;
else
    do;
        call sto$char$inc;
        if (curchar = brs) or (curchar = bsc) then
            do;
                call get$two$bytes;
                a = a + codebase;
                call inc$codeptr$two;
            end;
        else
            if (curchar = im1) or (curchar = deb) then
                do;
                    call incbuf;
                    call sto$char$inc;
                end;
            else
                if curchar = im2 then
                    do;
                        call incbuf;
                        call sto$char$inc;
                        call incbuf;
                        call sto$char$inc;
                    end;
                end;
            end;
        end;
    end;
stackbase = codeptr;

/* start of interp */

execute:procedure;
do forever;
    if rol(c,1) then /* must be lit or lit-lod */
        do;
            call push$stack(2);
            bra = c(1); /* load in reverse order */
            bra(1) = c and 3fh; /* mask bits 10 */
            ara = (ara + prf$base) or 4000h; /* set 01 addr bits */
            if rol(c,2) then call load(ra);
            call step$ins$ent();
        end;
    else
do case c;

/* 0 case 0 not used*/
;

/* 1 str */
    do;
        call push$stack(2);
        call step$ins$ent(1);
        rc = rc + c + 1;
        ara = rc or 4000h;
        call step$ins$ent(1);
    end;

```



```

/* 2 int */
do:
    call push$stack(2);
    call step$ins$cnt(1);
    ara = two$byte$oprnd;
    call step$ins$cnt(1);
end;

/* 3 xch */
do:
    hold = ara;
    ara = arb;
    arb = hold;
end;

/* 4 lod */
call load(ra);

/* 5 dec */
do:
    call step$ins$cnt(1);
    call decrement$blk(c);
end;

/* 6 dmp */
call crlf;

/* 7 exit */
return;

/* 8 ald */
do:
    call set$up$alloc;
    call allocate$dec;
    prt$entry=ra or 4000h;
end;

/* 9 als */
do:
    call set$up$alloc;
    call allocate$str;
    prt$entry=ra or 4000h;
end;

/* 10 aid */
do:
    call set$up$alloc;
    call allocate$dec;
    prt$entry=ra or 4000h;
    call push$stack(2);
    bra = ctr;
end;

/* 11 als */
do:
    call set$up$alloc;
    call allocate$str;
    prt$entry=ra or 4000h;
    call push$stack(2);
    ara = arb;
end;

/* 12 add */
do:
    call set$up$neg;
    arb = add$int(arb,ara);
    call check$neg;
    call pop$stack;
end;

/* 13 add */
do:

```



```

        call set$up$regs; /* puts values of top two items */
                           /* in reg0 and reg1 respectively*/
        call align;
        call add;
        call cpy$reg2$ons$stack;
    end;

/*14 sbi */
do:
    call set$up$neg;
    arb = sub$int(arb,ara);
    call check$neg;
    call pop$stack;
end;

/* 15 sbd */
do:
    call set$up$regs; /* puts values of top two items */
                       /* in reg0 and reg1 respectively*/
    call align;
    call compliment(0);
    if sign0 then sign0 = negative;
    else sign0 = positive;
    call add;
    call cpy$reg2$ons$stack;
end;

/*16 mpt */
do:
    call set$up$neg;
    arb = mul$int(arb,ara);
    call check$neg;
    call pop$stack;
end;

/*17 mpd */
do:
    call set$up$regs; /* puts values of top two items */
                       /* in reg0 and reg1 respectively*/
    declare (i,index) byte;
    call set$mult$div;
    decpt2 = decpt0 + decpt1;
    i = 10;
    do index = 1 to 10;
        call multiply(r1(i:=i-1) and 0fh);
        call multiply(shr(r1(i),4));
    end;
    call cpy$reg2$ons$stack;
end;

/*18 dvi */
do:
    call set$up$neg;
    arb = div$int(arb,ara);
    call check$neg;
    call pop$stack;
end;

/*19 dvd */
do:
    call set$up$regs; /* puts values of top two items */
                       /* in reg0 and reg1 respectively*/
    call divide;
    call cpy$reg2$ons$stack;
end;

/*20 */
/* not used */
;

/*21 */
/* not used */
;

```



```

/*22 neg */
do:
    if check$int(ar) then
        ar = -ar and 0ffffh;
    else if check$temp(ar) then
        ar = ar xor 0100h; /*change sign bit*/
    else
        do:
            hold = mask(ar);
            h$addr = h$addr xor 0100h;
        end;
    end;

/*23 c11 */
/* not implemented */
;

/*24 c12 */
/* not implemented */
;

/*25 deci */
do:
    call push$stack(2);
    call step$ins$cnt(1);
    rc=rc + c + 2;
    ar = rc or 4000h;
    call step$ins$cnt(1);
end;

/*26 pop */
    call pop$stack;

/*27 lm1 */
do:
    call push$stack(2);
    call step$ins$cnt(1);
    ar=c;
end;

/*28 lm2 */
do:
    call push$stack(2);
    call step$ins$cnt(1);
    bra=c(1); /* load in reverse */
    bra(1)=c;
    call step$ins$cnt(1);
end;

/*29 */
/* not used */
;

/*30 */
/* not used */
;

/*31 cat */
    call concatenate;

/*32 b1l */
    blk(blk$level:=blk$level+1) = ra;

/*33 b1d */
    call decrement$blk(1);

/*34 brs */
    call branch$absolute;

/*35 boc */
    if bra = 0 then
        call branch$absolute;

```



```

        else
        do;
        call step$ins$ent(2);
        call pop$stack;
        end;

/*36 lss*/
do;
if brb < bra then
    brb=1;
else brb=0;
call pop$stack;
end;

/*37 dss */
/* not implemented */

/*38 siss */
/* not implemented */

/*39 gtr */
do;
if brb > bra then
    brb=1;
else brb=0;
call pop$stack;
end;

/*40 dgtr */
/* not implemented */

/*41 sgtr */
/* not implemented */

/*42 eq1 */
do;
if brb = bra then
    brb=1;
else brb=0;
call pop$stack;
end;

/*43 deql */
/* not implemented */

/*44 seq1 */
/* not implemented */

/*45 neg */
do;
if brb <> bra then
    brb = 1;
else brb = 0;
call pop$stack;
end;

/*46 dneg */
/* not implemented */

/*47 dneg */
/* not implemented */

/*48 geq */
do;
if brb >= bra then
    brb = 1;
else brb = 0;
call pop$stack;
end;

/*49 dgeq */
/* not implemented */

/*50 sgeq */
/* not implemented */

```



```

/*51 leq */
do;
    if brb <= bra then
        brb = 1;
    else brb= 0;
    call pop$stack;
end;
/*52 dleq */
/* not implemented */

/*53 sleq */
/* not implemented */

/*54 inot */
do;
    if bra = 0 then
        bra = 1;
    else bra = 0;
end;
/*55 dnot */
/* not implemented */

/*56 snot */
/* not implemented */

/*57 iand */
do;
    if (bra=0) or (brb=0) then
        brb=1;
    else brb=0;
    call pop$stack;
end;
/*58 dand */
/* not implemented */

/*59 sand */
/* not implemented */

/*60 ior */
do;
    if (bra=0) and (brb=0) then
        brb=1;
    else brb=0;
    call pop$stack;
end;
/*61 dor */
/* not implemented */

/*62 sor */
/* not implemented */

/*63 wic */
do;
    call write$int(arra,0);
    call pop$stack;
end;

/*64 wdc */
do;
    if check$temp(arra) then
        call write$dec(arra,0);
    else
        call write$dec(mask(arra),0);
    call pop$stack;
end;

/*65 wsc */
do;
    if check$temp(arra) then
        call write$str(arra,0);
    else
        call write$str(mask(arra),0);

```



```

        call pop$stack;
    end;

/*66 wid */
    call write$to$disk(0);

/*67 wdd */
    call write$to$disk(1);

/*68 wsd */
    call write$to$disk(2);

/*69 sbr */
    do;
        arb = ara - arb;
        call pop$stack;
    end;

/*70 bra */
    do;
        rc = code$base + ara;
        call pop$stack;
    end;

/*71 row */
    call calc$row;

/*72 sub */
    call calc$sub;

/*73 rci */
    call get$int$field;

/*74 red */
    call get$dec$field;

/*75 rcs */
    call get$str$field;

/*76 rdi */
    do;
        inputtype = 0;
        call get$int$field;
    end;

/*77 rdd */
    do;
        inputtype = 0;
        call get$dec$field;
    end;

/*78 rds */
    do;
        inputtype = 0;
        call get$str$field;
    end;

/*79 rcm */
    do;
        inputtype = 1;
        rereadaddr = rc;
        call console$read;
    end;

/*80 ecr */
    if more$cons$input then
        call console$input$error;

/*81 sli */
    do;
        call store$int(rb,ara);
        rb = rb - 2;
    end;

```



```

/*82 sdi */
    do:
        call store$dec(ra,rb);
        rb = rb - 2;
    end;

/*83 ssi */
    do:
        call store$str(ra,rb);
        rb = rb - 2;
    end;

/*84 sid */
    do:
        call store$int(rb,ara);
        call pop$stack;
        call pop$stack;
    end;

/*85 sdd */
    do:
        call store$dec(ra,rb);
        call pop$stack;
        call pop$stack;
    end;

/*86 ssd */
    do:
        call store$str(ra,rb);
        call pop$stack;
        call pop$stack;
    end;

/*87 opn */
    call disk$open;

/*88 cls */
    do:
        call set$file$addr;
        call disk$close;
        call pop$stack;
    end;

/*89 rdb */
/* ready sequential block */
    do:
        call setup$disk$io;
        call set$eof$stack;
    end;

/*90 rdf */
/* ready random block */
    do:
        call setup$disk$io;
        call random$setup;
        call set$eof$stack;
    end;

/*91 edr*/
/* end of record for read */
/* advances to next line feed */
    do:
        if var$block$size then
            do while get$disk$char <> lf;
            end;
            call store$rec$ptr;
        end;

/*92 edw */
/* end of record for write */
    do:
        if var$block$size then

```



```

        do while bytes$written < (blocksize - 2);
        call write$8$byte(' ');
        end;
        call write$8$byte(cr);
        call write$8$byte(lf);
        call store$rec$ptr;
    end;

/*93 proc */
    do;
        stacktop = stacktop - 2;
        ret$addr = rc ;
        rc = ara + codebase;
        call pop$stack;
    end;

/*94 sav */
    do;
        declare (i,num) byte;
        pcbptr = mask(ra);
        call pop$stack;
        move$cnt = ara;
        call pop$stack;
        if ara <> 0 then
            do;
                hold = ra;
                counter = 2 * ara + 1;
                do i = 1 to counter;
                    call pop$stack;
                end;
                num = hold - ra ;
                if (temp1 := stacktop - num) <= ra then
                    call error('mo');
                call move(ra+2,temp1,num);
                call fill(temp1-2,00h,2);
            end;
        else
            call pop$stack;
            blk(biklevel:=biklevel+1)=ra;
            if pcb$value(1) = 0 then
                pcb$value(1) = 1;
            else
                call sav$pcb;
        end;
    end;

/*95 sv2 */
    do;
        declare i byte,
              parm$count address;
        tad1 = rs;
        tad2 = rb;
        tad3.ra = stacktop - 2;
        rb = ra - 2;
        parm$count = ara;
        call pop$stack;
        pcbptr = pcbptr + 4 + parm$count * 2;
        do i = 1 to parm$count;
            testvalue = ara;
            call pop$stack;
            if testvalue = int then
                call store$int('.pcbptr,ara);
            else
                if testvalue = deci then
                    call store$dec(ra,pcbptr);
                else
                    call store$str(ra,pcbptr);
            call pop$stack;
            pcbptr = pcbptr - 2;
        end;
        ra = tad1;
        rb = tad2;
        tad3 = 0;
    end;

```



```

/*96 uns */
do;
    hold = mask(ra);
    ret$value = h$addr;
    call decrement$blk(1);
    if h$addr(1) <> 1 then
        call unsave;
    else
        h$addr(1) = 0;
    call decrement$blk(1);
    call push$stack(2);
    if check$int(ret$value) then
        ara = ret$value;
    else
        do;
            templ = mask(.ret$value);
            call move(templ - t1,ra,t1+2);
            ra = ra + t1;
            bra(1) = bra(1) or 0e0h;
        end;
    end;

/*97 rtn */
do;
    rc = _ret$addr;
    stacktop = stacktop + 2;
end;

end; /*end case*/
call step$inst$cnt(1);
error$flag = false;
end; /* of do for ever */

end execute;

mainline:
    call crlf;
    call initialize$execute;

eofexit: /* on end of file of current disk file come here */
errorexit: /* regroup on console input error */
    call execute;
    call exit$interp;

eof

```



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