Computer Simulation:
A Simulation Language and Example

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Chapter 1

INTRODUCTION

The term "simulation" can be defined as the replacement of a given system by a substitute system, or "simulator", which responds to the external environment in a similar way as the original system. With the development of large scale data processors "simulation" of systems has become a field of important interest and study. Simulation studies have been made on such subjects as the nation's economy, mental activities of the brain and new digital computer systems. As digital computers become larger and faster, simulations will become more accurate and complex in their representation of the original system. In all simulation problems run on a computer it is necessary to write a program, which consists of a set of instructions to the computer, to direct the machine's operation and perform the desired simulation.

A program may be written in the following forms: machine-language coding, assembly language, or problem oriented languages. In machine language coding each individual instruction is written in the numerical language of the specific computer for which the program was intended. The assembly language allows the programmer to refer to computer functions or to memory storage addresses symbolically, with letters instead of numbers. Problem oriented languages allow the computer user to express a program in terms of the problem, instead of the computer.

To write programs in machine or assembly languages requires the programmer know most of the machine or symbolic instructions and their various ways of being modified. Since the program has to be written on an instruction-by-instruction basis, the process of developing a program can be complex, tedious, and slow.

Problem oriented languages allow the computer user freedom to think in terms of the problem and less in terms of the details of the computer. If the language used is machine independent, then the programs written in the problem oriented language will not become outdated as new computers are developed and marketed.

The purpose of this paper is to describe a machine independent, problem oriented language,BC NELIAC, which developed into being a useful language for writing programs for simulation problems. The most significant feature of BC NELIAC is that programs coded in the source language are self-documenting. Four other important features which make BC NELIAC useful for simulation problems are partword operations, chain expressions, ALGOL type source language, and fast compiling speed. Partword operations and chain expressions are explained in the section on BC NELIAC. Samples of the BC NELIAC source language are shown throughout this paper and in the appendix.

As a simulation example, the programming language, Intercom 500, used on the Bendix G-15 digital computer will be described. This simulation problem was chosen for two purposes: first, to consider the economy of operating a small scale Intercom Computer versus a large scale data processor simulating

Intercom 500, and second, to provide Intercom on a machine with a larger memory and faster operating speed. As an introduction to the paper a description of BC NELIAC will be given after which an explanation of Intercom 500 will be developed. Finally, the algorithm used in the simulation will be shown and a modification to the Intercom 500 language will be presented.

Chapter 2

BC NELIAC

2.1 Introduction

BC NELIAC is a problem oriented language which is used on the IBM 704 large-scale general purpose digital computer. It was developed by students at the University of California and is a modified version of the original Neliac created at the Naval Electronics Laboratory in San Diego, California. The most significant feature of Neliac is that the translator is written in its own language. This feature has allowed modifications to be made to Neliac quickly and easily. One of the main distinctions of BC NELIAC is the inclusion of some ALGOL-60 delimiters to the source language.[1]

The delimiters not only make the program more readable but allow the programmer greater ease in visualizing and writing the simulation program. Another important feature is chain expressions which has been added to BC NELIAC to simplify operations involving character manipulations and make the language less machine oriented.[2] This is an account of the more important features of BC NELIAC. The aim is to explain rather than to define the language.

1. The ALGOL 60 delimiters were added to the Neliac Load Source flow chart in the summer, 1961, by Ralph Love.

2. Chain expressions were added to the Neliac system in January 1962, by Niklaus Wirth.

2.2 Metalanguage

The syntax of BC NELIAC is described using the ALGOL metalanguage. It will be helpful to use this metalanguage in the following explanation of BC NELIAC. The basic symbols of this language are:

::= Metalinguistic connective meaning "is defined to be"

| Metalinguistic connective meaning "or"

< > Delimiting brackets which enclose metalinguistic variables.

Metalinguistic variables are a sequence of characters enclosed in the delimiting brackets < >. The symbols used for distinguishing the metalinguistic variables have been chosen to be words describing approximately the nature of the corresponding variable. This is done only for understanding and has no technical significance. In a formula a mark, which is not a variable, connective, or a delimiter denotes itself. Juxtaposition of marks and/or variables in a formula signifies juxtaposition of the marks and/or variables in the language being defined. Metalinguistic formulae are composed of metalinguistic connectives, variables enclosed within delimiting brackets, and an indication of juxtaposition.

Metalinguistic Formula example.

<identifier> ::= <letter>|<identifier><letter>|
<identifier><digit>

<letter> ::= A|B|C|...|Y|Z

<digit> ::= 0|1|2|...|8|9

The formula for identifier is recursive since <identifier> appears on both sides of the "defining connective." The metalinguistic variable <letter> indicates <identifier> can have the value A, or B, or C, etc. The marks <identifier> <digit> mean given some value of <identifier> another can be formed by juxtapositioning a value of the variable <digit>. If the values of digit are the arabic numerials then the following are illustrations of legitimate values of <identifier>:

A

AB

A1B

Y55A

XYZ799

The BC NELIAC reference language will be used in the program examples of this paper. In some cases the symbols used in the reference language are not available in the character set used with the IBM 704 digital computer. Rules for transliteration from the reference language to the hardware representation are included in the appendix.

2.3 Flowchart

The logical segment of the BC NELIAC program is the flowchart. It consists of two parts; the first part is a declaration or dimension list and the second part is the program logic. In the declaration portion variables are declared and in some cases set equal to initial values. The program logic portion is the actual program which specifies the operations to be performed on the variables defined in the declaration list. The program logic consists of a sequence of statements, which are separated by punctuation marks (usually commas.) By labelling single statements, with an identifier and a colon, they may be referred to from other points of the program.

Normally statements will be executed consecutively. This rule may be broken by introducing GO TO statements which explicitly specify the next statement to be executed, or DO statements which cause a subroutine to be executed and then control returned to the statement after the DO statement. The processing sequence of the program may be shortened by conditional statements, which may cause certain statements to be skipped.

If the program logic portion of a flowchart is called a compound tail then a flowchart has the form:

$\langle$flowchart$\rangle$ ::= $\langle$declaration list$\rangle$; $\langle$compound tail$\rangle$ ..

A BC NELIAC program consists of a sequence of flowcharts. The flowcharts are not independent logical segments. Variables declared or labels occuring in any flowchart may be referred to from within any arbitary flowchart; however, normally variables should be declared before they are called.

Flowchart example

```
A, B, C;
SUM:  A + B + C → A ..
```

2.4 Declaration Lists

All variables used in the program except labels and indices must be declared. Declaration lists serve to define certain properties of the variables in the program. Declaration of a variable may consist of a declaration identifier, alternate name, structure declaration, and value list. Each declaration is separated by a comma in the declaration list.

A declaration identifier is the name by which the declared variable will be referred. If more than one name is given to the identical variable, alternate names may be listed with a colon in between.

A variable is normally a computer word (36 bits for the IBM 704 Computer); however, the structure declaration contains information about the sub-structure of the variable, which may consist of several part words or a chain of characters. Names referring to partwords are included within a left brace and right brace in the declaration. Each partword name is followed by a definition of the part or subfield of the computer word it represents and is enclosed in parentheses. The partword limits specify the right most (lowest) and the left most (highest) bit belonging to the named partword.

A variable may consist of a chain of characters, symbols, or groups of bits which in the program will be treated as separate entities in the program logic. The structure declaration for a chain variable consists of the number of bits forming a character or symbol preceded by an asterisk and enclosed in parenthesis.

The value list may pre-assign a numerical value to a variable and/or define the dimension of a variable in the case of an array.

The value list consists of two parts, both of which may be empty. The first part defines the dimensions of the variable in the case of an array (if it is empty, the dimension is assumed to be 1) The second part is the number list in the case of an array, which degenerates to a number in the case of a single variable. If the number list is empty, the variable is pre-assigned the value 0.

Also, a variable may be assigned a predetermined location in the IBM 704 computer (absolute addressing), by following the variable with * <u>OCT</u> and an octal integer.

The declaration of a variable can have the following form:

declaration ::= ⟨declaration identifier⟩|
⟨structure declaration⟩|⟨alternate names⟩|
⟨value list⟩

Declaration Examples

Simple Variables

A, B, C

Alternate Names

A: A1: A2;
A: B: C4,

Partword

A: {B(7 ➤ 10), C(9 ➤ 12)} ,

Chain Variable

A (*6), B(*9),

Value List Assigned to Variable

A ← 5, B(3) ← 2,1,5,

Array

A(10), B(5),

Declaration List

A, B, C,

BLOCK OF WORDS (100),

WORD: ALTERNATE NAME 1: ALTERNATE NAME 2,

INSTRUCTION: { PREFIX (33 > 35), DECREMENT (18 > 32),
TAG (15 > 17), ADDRESS (0 > 14),
RIGHT WORD (0 > 17)} ,

2.5 Variables

Variables are combined with numbers, punctuation, and operational symbols to form expressions and statements. Variables can be declared as fixed point or floating point quantities. A subscripted variable designates values which are components of linear or single dimensional arrays. The array components of linear or single dimensional arrays. The array component referred to by a subscripted variable is specified by the actual numerical value of the subscript expression and will be an integer.

The letters I through N are reserved for variables of a particular type known as indices, and they must not be declared.

2.6 Expressions

Expressions are the major constituents of statements. There are five important types of expressions used in BC NELIAC. They are: arithmetic expressions, Boolean expressions, designational expressions, chain expressions, and logical expressions.

Arithmetic expressions are used to compute a numerical value by executing the indicated arithmetic operations on the actual numerical values of the variables of the expressions. The arithmetic expression is followed by a left to right arrow to denote replacement and a variable which is set equal to that which preceded the arrow.

Boolean expressions consist of a comparison of an arithmetic expression and a variable. Boolean expressions produce an output of true or false, depending on whether the condition stated is satisfied, or not.

Designational expressions may be either a label or a switch designator which consists of a label and subscript. They are normally used in GO TO statements.

Chain expressions are intended to simplify operations involving character manipulations. A variable will consist of a chain of characters when a chain declaration is applied to it. Two operations may be performed on chain variables — "catenate" and "obtain first character". The "catenating operation" will left shift a chain variable one character and add at the right another character. Its form is:

Variable 1 ++ Variable 2

The "obtain first character operation" will obtain the left most character of a chain variable, and has the form:

*Variable binary operator

The logical AND or OR functions of two variables is performed using the logical expression.

2.7 Program Logic

The program logic or compound tail portion of a flowchart consists of statements which are the unit of instructions, or sentences, of this algebraic language. As in written English their order of appearance is important. Statements may be chained together with commas in between thus forming unconditional statements, or they may be prefixed by conditions, thus forming conditional statements.

A compound statement may be formed by grouping a set of statements together with BEGIN preceding the first statement and END following the last statement. Any statement within a compound statement may itself be a compound statement.

A portion of the syntax for the program logic section is:

<compound tail> ::= <statement>|<statement>
<compound tail>

<statement> ::= <label> : <statement>|<unconditional statement>, | <conditional statement>

<compound statement> ::= BEGIN <compound tail> END

There are six important types of statements which will be discussed. They are assignment statements, GO TO statements, SWITCH statements, FOR statements, DO statements and conditional statements. The first five of these are considered unconditional statements.

2.7.1 Assignment Statements

The assignment statement specifies an expression to be evaluated and a variable which is to have the resulting value assigned to it. If the variable to the right of an arrow is designating a partial word, then the part(s) of the word not designated remain unaffected by the assignment statement.

An assignment statement is executed in the following steps:

1) the expression to the left of the arrow is evaluated
2) the subscript expression of the variable to the right of the left most arrow is evaluated
3) the variable is assigned the value of the expression
4) for each following variable steps 2 and 3 are performed sequentially.

If E is an expression, V is a variable, and L is the name of the statement, a labelled assignment statement has the form:

$$L:\ E \rightarrow V$$

Assignment Statement example

$$A[I] + B \rightarrow C[I](10 \rightarrow 15).$$

2.7.2 <u>GO TO</u> Statements and <u>SWITCH</u> Statements

Unconditional transfer of control statements are formed following the words <u>GO TO</u> with a designational expression. Thus, the next statement to be executed will be one having the value of the designational expression as its label.

A SWITCH statement consists of a separate label by which it may be referenced; and names a group of alternative points in a program to which control may be transferred as the result of a single GO TO statement. The switch statement has the following form:

.... GO TO L3. GO TO L2. SWITCH name :GO TO L1.

The selection of the actual point to which control is transferred depends on the value of the subscript expression of the switch designator in the GO TO statement. With increasing value of the subscript expression an earlier label in the SWITCH statement is chosen for the transfer.

GO TO Statement example

GO TO A.

GO TO B[J].

SWITCH Statement example

GO TO F. GO TO E. GO TO D. B: GO TO C.

2.7.3 FOR Statements

The FOR statement facilitates writing an iterative operation one or more times. The variable which determines the number of executions is an index. The index takes on values beginning with a first limit and is modified by an increment for each successive execution of the iterative operation. The execution of the FOR statement ends when a successive application of the increment would cause the index to pass beyond the second limit.

The FOR statement has the following form:

FOR index = first limit STEP increment UNTIL Second limit DO

BEGIN statement S END

FOR statement example

```
FOR I = 0 STEP 1 UNTIL B DO
    BEGIN C[I] * D[I] → E[I] END
```

2.7.4 DO Statements

A procedure or subroutine is a part of a program that is written only once but is to be executed at several points throughout the same program. A procedure is called for by a DO statement or procedure statement which effectively inserts the procedure body into the program taking the place of the DO statement. After the procedure has been executed the program continues with the next statement after the DO statement.

The format of the DO statement is:

DO Procedure Name,

The format of the PROCEDURE or subroutine is;

PROCEDURE Procedure Name:

BEGIN Statement S_1, S_2, S_3, END

DO Statement example

```
DO INCREMENT,
```

PROCEDURE or Subroutine example

```
PROCEDURE INCREMENT:
    BEGIN J+1 → J, I+2 → I END
```

2.7.5 Conditional Statements

Conditional statements cause statements to be executed or skipped depending on the results of a Boolean expression or comparison. The conditional statement consists of a Boolean expression preceded by the word <u>IF</u> and followed by the word <u>THEN</u>, a "true part", and a "false part." Both "true" and "false parts" are unconditional statements. They are normally terminated by a semicolon, or by a period if the last statement was a <u>GO TO</u> statement. If the comparison is satisfied, the statement following <u>THEN</u> is executed after which control is transferred to the beginning of the next statement following the false part, unless the <u>THEN</u> statement terminates with a <u>GO TO</u> statement. If the comparison is not satisfied the <u>ELSE</u> statement is executed after which control is transferred to the beginning of the next statement unless a <u>GO TO</u> statement terminates the "false part." Either "true" or "false parts" may be left vacuous by immediately terminating it with a semicolon.

The format of a conditional statement is:

```
IF Boolean Expression
    THEN unconditional statement, period or semicolon
    ELSE unconditional statement, period or semicolon
```

Conditional Statement example

```
IF A > B
    THEN A + B → C;
    ELSE GO TO D.
```

Chapter 3

INTERCOM 500

3.1 Intercom 500 computer

Intercom 500[1] is a programming system which is used on the Bendix G-15 digital computer. When Intercom 500 is stored in the G-15 memory, we essentially have an Intercom 500 digital computer. It is this computer that will be used as a simulation example. Included in the appendix is a BC NELIAC program simulating the Intercom 500 digital computer. The program has been tested and run successfully on the IBM 704 data processing system.

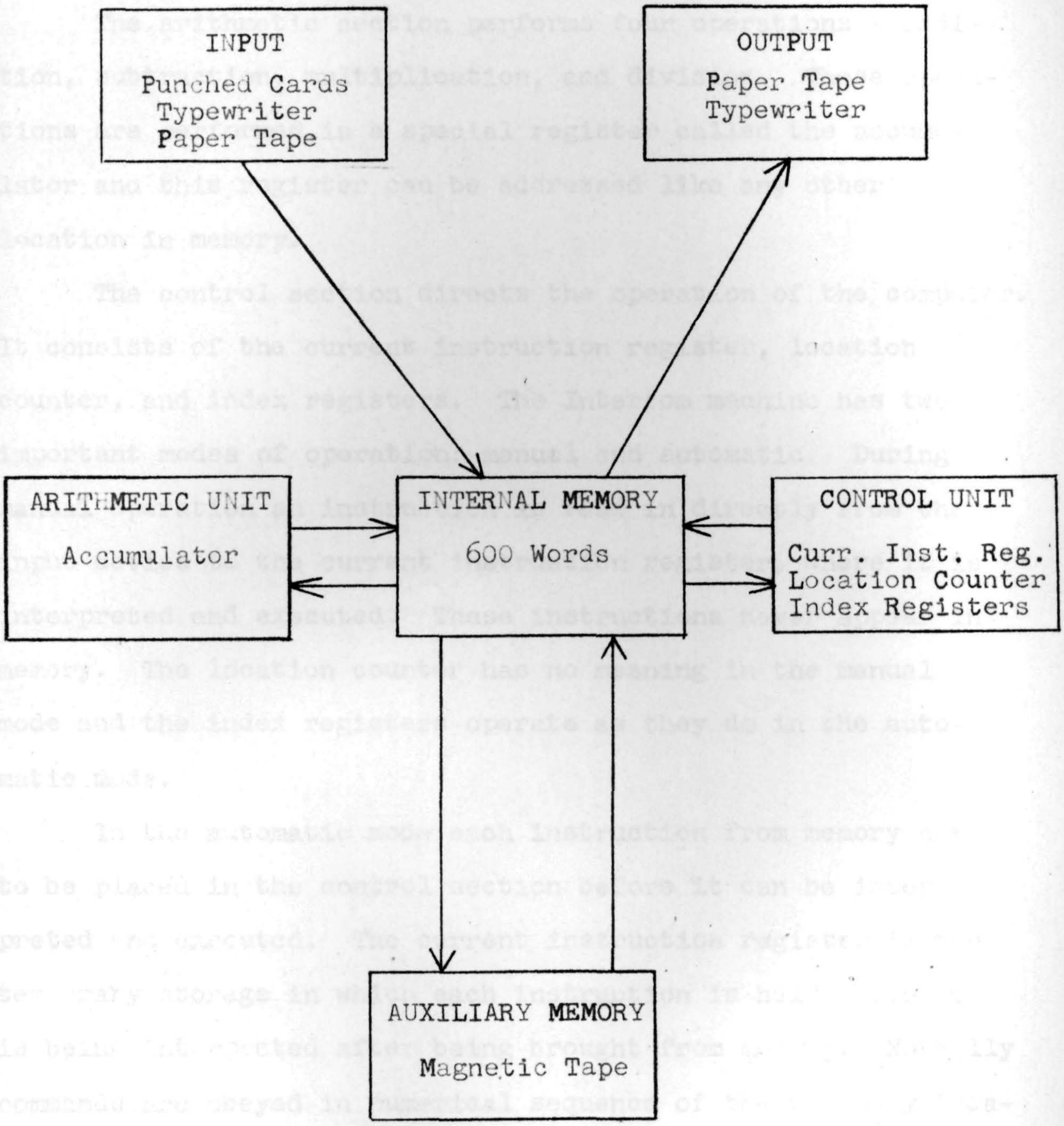
3.1.1 Computer Organization

The internal organization of the Intercom machine can be divided into five distinct functions: input, output, memory, arithmetic, and control. A diagram of the computer organization is shown in figure 1.

Three forms of input devices are available: paper tape, punched cards, and magnetic tape. The input information may consist of data or commands. Information may be put out in form of paper tape or on the typewriter.

The memory consists of 600 locations in which commands or data may be stored. Locations in the memory are specified by a four digit number called an "address." A command can be stored at, and executed from, any available address.

1. Intercom 500 card system



Intercom Computer Organization. Arrows represent direction of information flow.

Figure 1

Data also may be stored at any address.

The arithmetic section performs four operations - addition, subtraction, multiplication, and division. These operations are performed in a special register called the accumulator and this register can be addressed like any other location in memory.

The control section directs the operation of the computer. It consists of the current instruction register, location counter, and index registers. The Intercom machine has two important modes of operation: manual and automatic. During manual operation an instruction is read in directly from the input device to the current instruction register, where it is interpreted and executed. These instructions never appear in memory. The location counter has no meaning in the manual mode and the index registers operate as they do in the automatic mode.

In the automatic mode each instruction from memory has to be placed in the control section before it can be interpreted and executed. The current instruction register is the temporary storage in which each instruction is held while it is being interpreted after being brought from memory. Normally commands are obeyed in numerical sequence of their memory location. The location counter is given the address of the first command to be obeyed after which it keeps a running record of the location in memory of the instruction being executed. The index registers are available when automatic address modification is desired. Each command which is used with an index register has its address modified by adding the contents of the index register to the address part of the instruction before the command is executed.

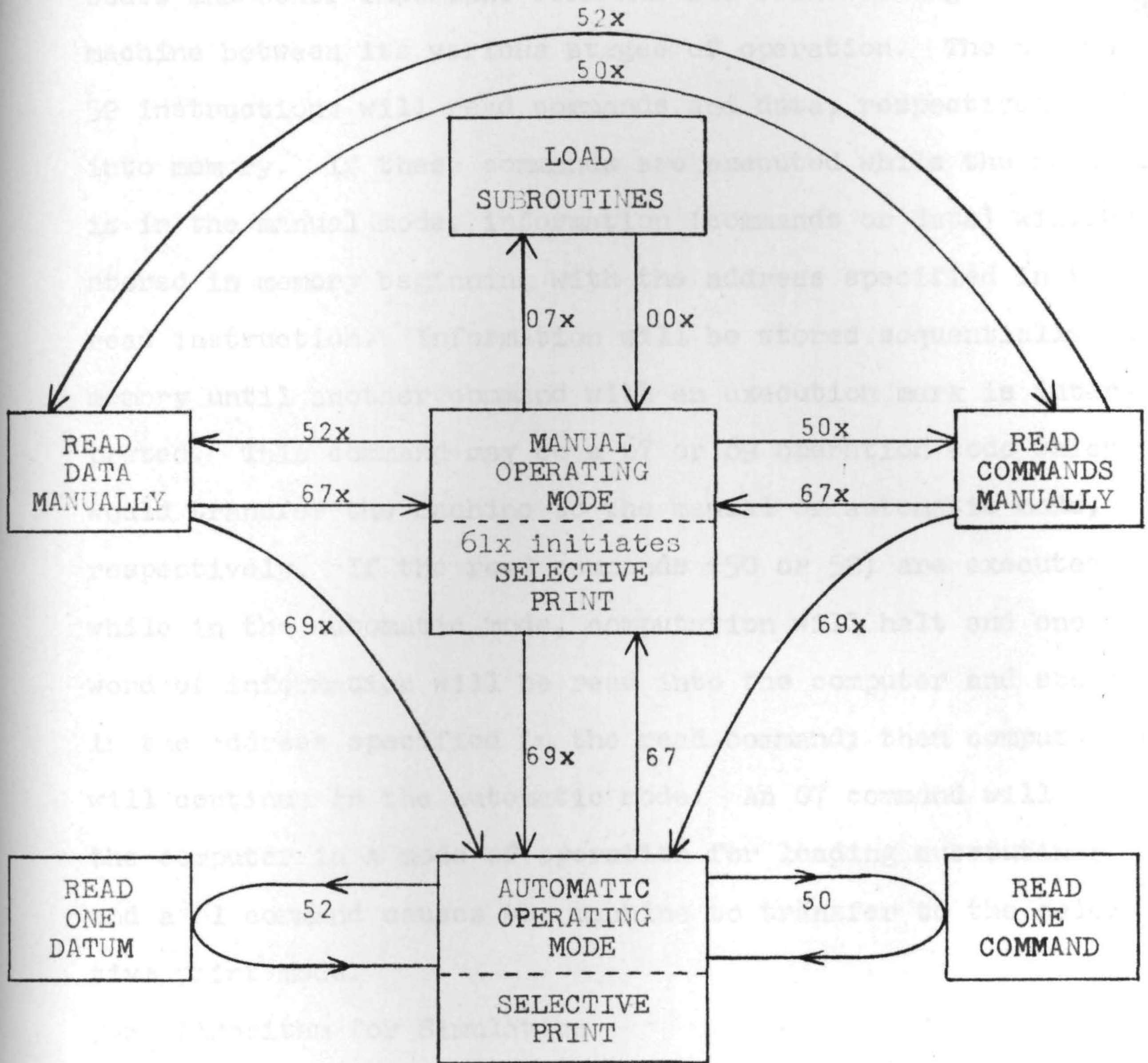
3.1.2 Command Structure

The machine instructions are in the form of numerically expressed commands which can be held in the internal memory. Each command is expressed by seven digits and sometimes an execution mark. The first digit of a command represents one of the ten index registers and may be left blank if no index is used. The next two digits specify the operation code which tells the machine what to do. The last four digits are termed the address part, and usually refer to a location in memory. If an instruction has an execution mark it will be interpreted and executed when it is read into the computer. The instruction will never appear in the internal memory and, therefore, not interfer in any way with the program.

3.1.3 Operation Codes

There are five major groups of operation codes available: arithmetic commands, transfer of control commands, input-output commands, index register commands, and special commands. The detail operation of these commands will be shown in the section on the simulation algorithm.

For a better understanding of the various modes in which the intercom machine will operate Figure 2 is given. Figure 2 is a block diagram showing the function of the input operation



Block diagram showing the function of the input operation codes and other important commands for transferring the machine between its various stages of operation. The "x" after an operation code indicates an execution mark.

Figure 2

codes and other important commands for transferring the machine between its various stages of operation. The 50 and 52 instructions will read commands and data, respectively, into memory. If these commands are executed while the machine is in the manual mode, information (commands or data) will be stored in memory beginning with the address specified in the read instruction. Information will be stored sequentially in memory until another command with an execution mark is interpreted. This command may be a 67 or 69 operation code which would transfer the machine to the manual or automatic mode, respectively. If the read commands (50 or 52) are executed while in the automatic mode, computation will halt and one word of information will be read into the computer and stored in the address specified in the read command; then computation will continue in the automatic mode. An 07 command will put the computer in a mode of operation for loading subroutines and a 61 command causes the machine to transfer to the selective print mode.

3.2 Algorithm for Simulation

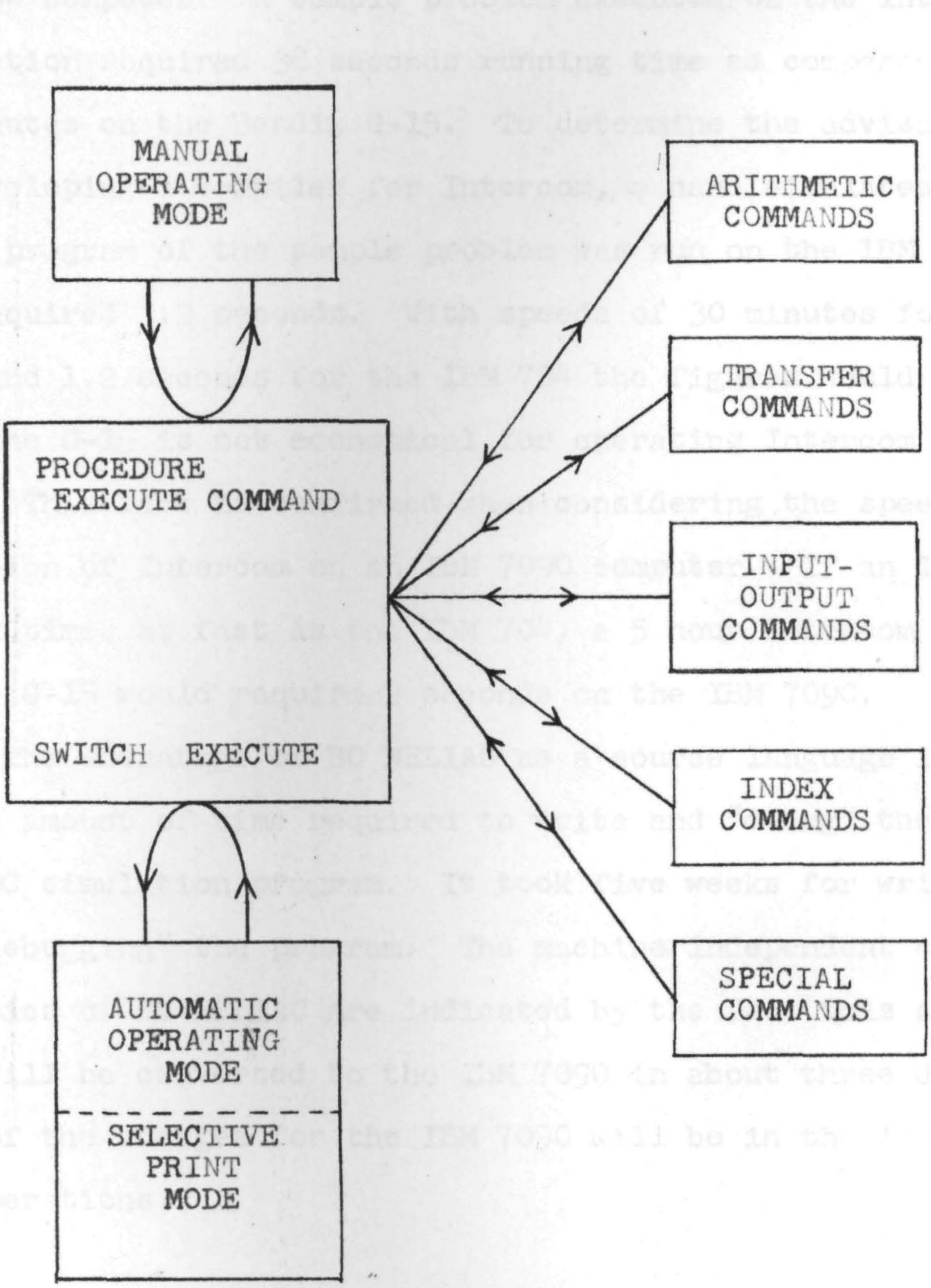
Essentially, all intercom commands can be executed in any one of three modes: manual, automatic, or selective print mode. When the computer is in the manual mode, commands will be executed as they are read into the machine. In the automatic mode it is expected that the program is stored in the internal memory. The location counter is given the location of the first command in the program after which commands of the program are automatically executed. The selective print mode is the same as the automatic mode except information concerning selected commands can be automatically typed out during computation. The computer is notified which command to type out by selectors provided in the program. The information typed will be the location of the command, the command itself, and the contents of the accumulator, if the contents of the accumulator is different than during the listing of a preceeding command.

Figure 3 is a block diagram showing the basic operation of the BC NELIAC program which simulates the intercom 500 machine. The heart of the program is a large switch (EXECUTE) which is called as a procedure or subroutine (EXECUTE COMMAND) by any one of the three machine operating modes. This switch in turn calls the correct operation code, executes the command, and returns control to the original machine operating mode (except in the case of a command which changes operating modes).

The following simplified program written in BC NELIAC illustrates the operation of the algorithm for the manual and automatic modes and describes the function of each operation code. Read card is a procedure which inputs one word of information to the machine. Execute Command is a subroutine which transfers the program to the proper operation code subroutine.

3.3 Conclusions

Since the IBM 704 digital computer has a larger memory than the Bendix G-15, provisions have been made for a total memory size of 23,500 words in the BC NELIAC simulation on the



Block diagram showing the basic operation of the BC NELIAC program which simulates the Intercom 500 machine. The lines with arrows show the flow of the program while executing an operation code.

Figure 3

IBM 704 computer. A sample problem executed on the Intercom Simulation required 38 seconds running time as compared to 30 minutes on the Bendix G-15. To determine the advisability of developing a compiler for Intercom, a hand simulated compiled program of the sample problem was run on the IBM 704 and required 1.2 seconds. With speeds of 30 minutes for the G-15 and 1.2 seconds for the IBM 704 the figures would indicate the G-15 is not economical for operating Intercom problems. This fact is confirmed when considering the speed of operation of Intercom on an IBM 7090 computer. If an IBM 7090 is six times as fast as the IBM 704, a 5 hour Intercom problem on the G-15 would require 2 seconds on the IBM 7090.

The advantage of BC NELIAC as a source language is shown by the amount of time required to write and "debug" the Intercom 500 simulation program. It took five weeks for writing and "debugging" the program. The machine independent characteristics of BC NELIAC are indicated by the fact this simulation will be converted to the IBM 7090 in about three days. Most of the changes for the IBM 7090 will be in the input-output operations.

Simplified Program of Intercom 500 Manual and Automatic Modes

```
(COMMENT  DECLARATION LIST)
   A:  ACCUMULATOR,
   CR:  COMMAND REGISTER:  INDEX(7 → 10), OP CODE(0 → 6),
                            ADDRESS(11 → 18)  ,
   EA:  EFFECTIVE ADDRESS,
   IR:  INDEX REGISTERS: W DIFFERENCE(10), W LIMIT(10),
                         W BASE(10), C BASE(10),
                         C DIFFERENCE(10), C LIMIT(10),
   IRA: INDEX REGISTER ACCUMULATOR,
   LC:  LOCATION COUNTER,
   M:  MEMORY(23500),
   MQ:  MQ REGISTER,
   MARK 1, MARK 2;
(COMMENT  PROGRAM LOGIC)
   MANUAL MODE: DO READ CARD, DO EXECUTE COMMAND,
                GO TO MANUAL MODE.
                (COMMENT  READ CARD INPUTS ONE WORD OF
                          INFORMATION TO THE MACHINE.
                          EXECUTE COMMAND TRANSFERS PROGRAM
                          TO PROPER OP CODE SUBROUTINE)
   AUTOMATIC MODE: STATE 1:  M[LC] → CR,
                             IF INDEX ≠ 0
                                THEN ADDRESS + W BASE [INDEX]
                                   + C BASE [INDEX] → EA;
                                ELSE ADDRESS → EA;
                   STATE 2:  DO EXECUTE COMMAND,
                   STATE 3:  LC + 1 → LC, GO TO STATE 1.
```

FUNCTION OF INTERCOM 500 OPERATION CODES

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
ARITHMETIC COMMANDS			
Clear and Add	42	CLA:	$\{M[EA] \to A\}$,
Clear and Subtract	40	CLS:	$\{- M[EA] \to A\}$,
Clear and Add Absolute	45	CAB:	$\{\lvert M[EA] \rvert \to A\}$,
Store	49	STO:	$\{A \to M[EA]\}$,
Add	43	FAD:	$\{A + M[EA] \to A\}$,
Subtract	41	FSB:	$\{A - M[EA] \to A\}$,
Multiply	44	FMP:	$\{A \times M[EA] \to A\}$,
Divide	48	FDP:	$\{A / M[EA] \to A\}$,
Inverse Divide	47	IFD:	$\{M[EA] / A \to A\}$,

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
TRANSFER OF CONTROL COMMANDS [2]			
Transfer	29	TRA:	{EA → LC, <u>GO TO</u> STATE 1.} ,
Transfer on Non-negative	20	TNN:	{<u>IF</u> A ≥ 0 <u>THEN</u> EA → LC, <u>GO TO</u> STATE 1.;} ,
Transfer on Negative	22	TRN:	{<u>IF</u> A < 0 <u>THEN</u> EA → LC, <u>GO TO</u> STATE 1.;} ,
Transfer on Zero	23	TZE:	{<u>IF</u> A = 0 <u>THEN</u> EA → LC, <u>GO TO</u> STATE 1.;} ,
Transfer Mark Place 1	26	TM1:	{LC → MARK 1, EA → LC, <u>GO TO</u> STATE 1.;} ,
Return to Marked Place 1	16	RT1:	{MARK 1 + 1 → LC, <u>GO TO</u> STATE 1.;} ,
Transfer Mark Place 2	28	TM2:	{LC → MARK 2, EA → LC, <u>GO TO</u> STATE 1.;} ,
Return to Marked Place 2	18	RT2:	{MARK 2 + 1 → LC, <u>GO TO</u> STATE 1.;} ,
Transfer to Machine Subroutine [3]	08	TSR:	{<u>DO</u> MACHINE SUB-ROUTINE,} ,

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
INDEX COMMANDS			
Assign Word Base	70	AWB:	{ADDR → W BASE [INDEX]} ,
Assign Word Difference	71	AWD:	{ADDR → W DIFFERENCE [INDEX]} ,
Assign Word Limit	72	AWL:	{ADDR → W LIMIT [INDEX]} ,
Assign Channel Base	73	ACB:	{ADDR → C BASE [INDEX]} ,
Assign Channel Difference	74	ACD:	{ADDR → C DIFFERENCE [INDEX]} ,
Assign Channel Limit	75	ACL:	{ADDR → C LIMIT [INDEX]} ,
Increment and Test [2] Word Base	76	ITW:	{W BASE [INDEX] + N DIFFERENCE [INDEX] → W BASE [INDEX], <u>IF</u> W BASE [INDEX] ≤ W LIMIT [INDEX] <u>THEN</u> ADDR → LC, <u>GO TO</u> STATE 1.;} ,

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
INDEX COMMANDS (cont.)			
Increment and Test Channel Base [2]	77	ITC:	{C BASE [INDEX] + C DIFFERENCE [INDEX] → C BASE [INDEX], IF C BASE [INDEX] ≤ C LIMIT [INDEX] THEN ADDR → LC, GO TO STATE 1.;} ,
Set Index Accumulator	09	SIA:	{EA → IRA} ,
Clear and Add Index to IRA [4]	78	CLI:	{ADDR × 11 + INDEX → I, IR[I] → IRA},
Store Index from IRA [4]	79	STI:	{ADDR × 11 + INDEX → I, IRA → IR[I]} ,

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
INPUT OUTPUT COMMANDS - Following descriptions not in NELIAC form.			
Originate Loading[1] Commands	50	ORG:	See sect. 3.1.3 for expl.
Read Command[2] Automatic	50	RCM:	See sect. 3.1.3 for expl.
Load Exponential Data[1]	52	LDD:	See sect. 3.1.3 for expl.
Read Exponential Data[2] Automatic	52	RED:	See sect. 3.1.3 for expl.
Punch Binary Cards	39	PBC:	Binary cards punched from ADDR/100 * 100 to ADDR-1.
Read Binary Cards	55	RBC:	Absolute binary cards read into memory.
Position Typewriter, Tabs and carriage return	30	PTC:	ADDR/100 → No. of carriage returns ADDR-ADDR/100*100 → No. of tabs.
Write Literal and Tab	31	WLT:	EA printed, and typewriter tabbed.
Write Location Counter and Tab	06	WLC:	LC-1 printed, and typewriter tabbed.
Write Command and Tab	35	WCT:	M[EA] printed as command and typewriter tabbed.
Write Memory and Tab	37	WMT:	M[EA] printed in octa, and typewriter tabbed.

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
INPUT OUTPUT COMMANDS (cont.)			
Write Floating Decimal and Tab	33	WFT:	M[EA] printed in floating decimal form, and typewriter tabbed.
Write Floating Decimal and Return Carriage	38	WFC:	M[EA] printed in floating decimal form, and typewriter carriage returned.
Write Exponential Data and Tab	32	WET:	M[EA] printed in exponential form, and typewriter tabbed.
Write Exponential Data and Return Carriage	34	WEC:	M[EA] printed in exponential form, and typewriter carriage returned.

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
SPECIAL COMMANDS			
Exit to Manual Mode	67	MAN:	{GO TO MANUAL MODE.}
Exit to Automatic Mode	69	AUT:	{EA → LC, GO TO STATE 1.} ,
No Operation	00	NOP:	{GO TO STATE 3.} ,
Ring Bell	63	BEL:	{DO RING BELL,} ,
Breakpoint Halt	68	BPH:	{GO TO MONITOR. ENDJOB.} ,
Load Subroutines[1,3]	07	LSR:	{DO LOAD SUBROUTINES,}
Exit Loading Subroutines	00	ELS:	{DO EXIT LOAD SUB-ROUTINES,} ,
Block Copy	81	BLC:	See Bendix Intercom Reference Manual.
Initiate Selective Print[1]	61	ISP:	Initiate Selective Print.
End Selective Print	62	ESP:	End Selective Print

FUNCTION OF INTERCOM 500 OPERATION CODES (cont.)

Operation	Intercom 500 Operation Code	Symbolic Intercom Operation Code	Definition and/or Description
SPECIAL COMMANDS FOR IBM 704 INTERCOM			
Exit to Monitor Endjob	80	EJB:	{GO TO MONITOR ENDJOB.} ,
Read Clock	64	CLK:	{DO READ CLOCK,} ,
Load MQ	65	LDQ:	$\{M[EA] \rightarrow MQ\}$,
Store MQ	66	STQ:	$\{M\ Q \rightarrow M[EA]\}$,
SPECIAL COMMANDS FOR SYMBOLIC INTERCOM			
Exponential Data	-	EXD:	Used with exponential data
Mask-Selector	-	MSK:	Used with selectors for selective print.
Equals	-	EQU:	Assigns constant to symbol.
Block Started by Symbol	-	BSS:	Assigns block of storage to symbol.
End Symbolic Program	-	END:	Last card in symbolic program deck
Blank	-	—	Same as NOP

FUNCTION OF INTERCOM 500 OPERATION CODES (Footnotes)

1. Operation Code used only in the manual mode.

2. Operation Code(s) used only in the automatic mode.

3. See appendix

4. Component parts of an index register are symbolized by the contents of ADDR, as follows:

IF ADDR =	COMPONENT =
0	W DIFFERENCE
1	W LIMIT
2	W BASE
3	C BASE
4	C DIFFERENCE
5	C LIMIT

Chapter 4

SYMBOLIC INTERCOM 500

4.1 Source Language

An Intercom 500 program is a sequence of seven digit commands which instructs the Intercom computer to perform a particular task. Symbolic Intercom has been developed as a source language more convenient for the programmer to use. There are approximately seventy different operation codes in Intercom 500. Writing programs using the numerical form for operation codes creates a complexity which is overcome by Symbolic Intercom. In Symbolic Intercom a symbolic code can be used for each of the operation codes, e.g. ADD for operation code 43. Since the numerical-type code does not have any of the mnemonic qualities of an alphabetic code nor does it provide a format that one may easily scan in order to see the meaning of a group of instructions, the symbolic form will necessarily result in faster and more accurate coding.

An additional function of Symbolic Intercom is overcoming the necessity of doing absolute coding. In absolute coding every word (command or data) in storage is assigned a location number used as a means of making references. This reference is made through the use of the address portion of the command. With absolute coding the programmer must determine the storage allocation in advance of coding. Since the storage requirements cannot be accurately anticipated, a re-design of the program may be necessary after its completion. If memory space is limited, this re-design could cause rewriting of the program. Another problem occurs in absolute coding when an attempt is made to modify a program. Modifications usually entail insertions, deletions and re-arrangements of instructions. Every numerical reference made in the program to a location affected by the modifications must be changed so the program is still operative. This is a serious problem when there are several insertion and deletion areas. Every reference made must be tested to see how many of the different insertion and deletion areas affect it.

Symbolic-coding solves these problems of absolute coding because the basic method of referencing is changed. Instead of using an actual location number to indicate every reference made in the program, a location is given a name, or a symbol. This symbol has no numerical significance and no direct relationship to any particular storage-assignment scheme. The symbol is strictly a reference for the benefit of the programmer while writing his program.

A program which is given the name assembly program, defines where a symbolic program will sit in storage and what numerical location is assigned to each symbol. The assembly program also makes the translation between the symbolic operation code and the numeric operation code. Hence, if the input to the Intercom assembly program is Symbolic Intercom, the output will be Intercom 500.

In writing a symbolic program the following rules should be adhered to:

1. Every symbol is unique and independent of all other symbols.
2. If a symbol has been assigned to a particular location, all further references to this location may use the same symbol.
3. The locations of all instructions or data in a program having no reference made to them need no symbol assigned to them.

Included in the appendix is a BC NELIAC listing of the Symbolic Intercom assembly program. All Intercom 500 operation codes have a symbolic representation which are given in section 3.2 In addition, two psuedo operation codes have been added to the symbolic language - EQU and BSS. EQU allows the programmer to assign a constant to any symbol, and BSS provides for a block of storage to be assigned to a symbol. The accumulator can be addressed by the symbol ACC.

4.2 Algorithm

The Symbolic Intercom assembler is divided into two parts: first pass and second pass. In the first pass a storage cell, called the location counter, keeps track of the storage assignment of the current word in the program being assembled. The Intercom operation codes for read command or read data initialize the location counter. The location counter is increased by one for each word used by the program. The entire program is examined sequentially during the first pass and any location with a symbolic name has this name put in a symbol table along with the current value of the location counter. Also, each symbolic operation code is converted to the appropriate Intercom 500 numerical "op code".

The second pass again examines the input sequentially and for each symbol used as an address in an instruction, replaces it with the appropriate location counter value from the symbol table. At the completion of the second pass, all symbolic commands have been converted to Intercom 500 instructions, and a copy of the symbol table, multiply defined and/or undefined symbols are printed out.

Appendix A

Transliteration rules

This appendix presents a summary of equivalences between the character set used with the hardware representation BC NELIAC on the IBM 704 digital computer and the BC NELIAC Reference Language. All word delimiters must be separated by blanks in the hardware representation.

	Character Operator	Hardware Representation	Reference Language Symbols
Miscellaneous Operators	Blank		
	Replacement Operator	=	→
	Left Arrow	=	←
	Decimal Point	.	.
Punctuation Operators	Comma	,	,
	Period	.	.
	Semicolon	$	;
Arithmetic Operators	Add	+	+
	Subtract	-	-
	Multiply	*	X
	Divide	/	/
Relational Operators	Less	LSS	<
	Less or Equal	LEQ	≤
	Equal	EQU	=
	Greater or Equal	GEQ	≥
	Greater	GTR	>
	Not Equal	NEQ	≠
Logical Operators	And	AND	∧
	OR	OR	∨
Sequential Operators	GO TO	GO TO	GO TO
	IF	IF	IF
	FOR	FOR	FOR

Transliteration rules (cont.)

	Character Operator	Hardware Representation	Reference Language Symbols
Sequential Operators (cont.)	DO	DO	DO
	THEN	THEN	THEN
	ELSE	ELSE	ELSE
Separator Operators	STEP	STEP	STEP
	UNTIL	UNTIL	UNTIL
	COLON	CLN	:
	PERIOD	.	.
	COMMA	,	,
	SEMICOLON	;	;
Bracket Operators	Left Parentheses	(	(
	Right Parentheses	)	)
	Left Bracket	LBK	[
	Right Bracket	RBK	]
	BEGIN, or Left Brace	BEGIN or LBR	BEGIN or {
	END, or Right Brace	END, or RBR	END or }
Pseudo Operators	Shift	EXP	EXP
	Crutch Code	MCH	MCH
	Octal	OCT	OCT
	Alphabetic Characters	A...Z	A.....Z
	Numeric Characters	0...9	0.....9

Appendix B

OPERATION CODE LIMITATIONS

Due to hardware differences between the IBM 704 and Bendix G-15 the following operation codes will perform differently on the two machines:

Op Code 68: Breakpoint Halt: BPH

G-15: Computation is halted.

IBM 704: Transferred to Monitor Endjob.

Op Code 30: Position Typewriter, Tabs and Carriage Return: PTC

G-15: Paper in the typewriter carriage is automatically positioned by the execution of CR carriage returns, followed by TB tabs.

CR is a two digit number ranging from 00 to 28.

TB is a two digit number ranging from 00 to 28.

IBM 704: Same as G-15 except tab settings are pre-set and allow a maximum of six columns of printout.

Op Code 37: Write Memory and Tab: WMT

G-15: The contents of location ADDR are typed out in hexadecimal form.

IBM 704: The contents of location ADDR are typed out in octal form.

Op Code 39: Punch Binary Cards: PBC

G-15: The contents of words 00 through ADDR-1 of the channel determined by the first two digits of ADDR are punched on paper tape.

IBM 704: Same as G-15 except cards are punched and no index registers will be punched on the cards.

Op Code 55: Read Binary Cards: RBC

G-15: Punched tape, previously punched by the computer, is photo-electrically read and entered into the channel in the memory specified by the first two digits of ADDR. Information is entered in the channel beginning at word position 00 and ending with location ADDR-1.

IBM 704: Punch cards, previously punched by the computer, are stored in memory according to the absolute address on the column binary cards. ADDR has no significance.

INTERCOM CARD FORMAT

Intercom 500

Eighty column (numbered 1 - 80 from left to right) IBM cards are used with one word of data or one command contained on a card. The card format for Intercom 500 will have the following form:

COLUMN:	1 - 63	64	66	68	69	70	72	74	76	78[1]	80[2]
COMMAND CARDS:	COMMENT	K	O	P	A	D	D	R	S		-
DATA CARDS:	COMMENT	E	E	D		D	D	D	D	-	

K = Index Register

OP = Operation Code

ADDRS = Address

EE = EXCESS Fifty Exponent

DDDDD = Datum

The card format for Symbolic Intercom is the following form:

COLUMN:	1 - 6	8 - 10	12 - 20	25 - 72
WORD (DATA OR COMMAND):	SYMBOL[3]	OP CODE	VARIABLE FIELD[4]	COMMENT

1. A "minus" punched in column 78 on a data card indicates the data is negative.

2. A "minus" punched in column 80 on a command card indicates an execution mark.

3. An asterisk in column 1 of a command card indicates an execution mark.

4. Datum is indicated by an "op code" of EXD. The seven digit datum number is placed in the variable field (with a minus following the datum, if required.

Appendix D

USE OF MACHINE LANGUAGE SUBROUTINES IN SYMBOLIC INTERCOM

Loading Subroutines

After executing the command LOAD SUBROUTINES, the following commands may be executed to store in memory the desired subroutines.

SUBROUTINE	OP CODE	VARIABLE FIELD
Fraction Selector	FRS	FRACTN
Square Root and Cube Root	SQT	SQTCUB
Log	LOG	LOG
Power	PWR	POWER
Sin and Cosine	TRG	TRIG
Arctangent	ART	ARCTAN
Hyperbolics	HYB	HYPBOL
Index Register Utilization	IRU	IRU
Selective Print	LSP	SELPRT
Clears Index Registers	CIR	XREGS
Clears Index Registers and Memory	CLM	MEMORY

Transfer to Machine Language Subroutines.

SUBROUTINE	OP CODE	VARIABLE FIELD
Selects Floating Decimal Fraction Length	TSR	DECPTO TO DECPT7
Square Root of x	TSR	SQRT
Cube Root of x	TSR	CUBERT
$\log_e x$	TSR	LOGE

Transfer to Machine Language Subroutines (cont.)

SUBROUTINE	OP CODE	VARIABLE FIELD
$\text{Log}_2\ x$	TSR	LOG2
$\text{Log}_{10}\ x$	TSR	LOG10
e^x	TSR	EXP
2^x	TSR	PWR2
10^x	TSR	PWR10
n^m (fixed point base-fixed point exponent)	TSR	EXP1
a^m (floating point base-fixed point exponent)	TSR	EXP2
a^b (floating point base-floating point exponent)	TSR	EXP3
Sin x (radians)	TSR	SIN
Sin x (degrees)	TSR	SIND
Cos x (radians)	TSR	COS
Cos x (degrees)	TSR	COSD
Arctan x (radians)	TSR	ATAN
Arctan x (degrees)	TSR	ATAND
Sinh x and Cosh x	TSR	SINH
Tanh x	TSR	TANH
Fix Floating Point Number	TSR	FIX
Float Fixed Point Number	TSR	FLOAT

Appendix E

SYMBOLIC INTERCOM 500 ASSEMBLER

```
DIMENSIONING

FLOWCHART NUMBER  00001

    $START SIN CLN SYMBOLIC INTERCOM 500 CLN
       MCH 0772000 OCT 205, IOH PRINT (50,0,), FORTY ONE = N,
       ZERO= I, GO TO FIRST PASS..

FLOWCHART NUMBER  00002

       (COMMENT   SIMPLE VARIABLE DIMENSION LIST                         )
       BCD DIGIT (4),
       CALL PUNCH,
       CHARACTER,
       CM1,CM2,CM3,CM4,CM5,CM6,CM7,CM8,
       DIGIT,
       LOCATION COUNTER,
       NUMB,
       PROGRAM LENGTH,
       SYMB,
       SYMBOL TABLE LENGTH,

       IR CLN LBR INDEX REGISTER(30=35) RBR ,
       O CLN LBR OP TEN(30=35) RBR ,
       P CLN LBR OP UNIT(30=35) RBR ,
       ADDR 1 CLN LBR CH TEN(30=35) RBR ,
       ADDR 2 CLN LBR CH UNIT(30=35) RBR ,
       ADDR 3 CLN LBR WD TEN(30=35) RBR ,
       ADDR 4 CLN LBR WD UNIT(30=35) RBR ,
       SIGN VALUE CLN LBR DATA SIGN(30=35) RBR = OCT -206060606060,
       X CLN LBR X MARK(30=35) RBR ,

       (COMMENT   ARRAY DIMENSION LIST                                   )
       COMMENT A (900),
       COMMENT B (900),
       COMMENT C (900),
       COMMENT D (900),
       COMMENT E (900),
       COMMENT F (900),
       COMMENT G (900),
       COMMENT H (900),
       EX MARK (900),
       OPERATION (900),
       SYMBOL FIELD (900),
       MULTIPLY DEFINED SYMBOLS (26),
       UNDEFINED SYMBOLS (26),

       (COMMENT   LOGICAL VARIABLE DIMENSION LIST                        )
       BCD NUMB (*6),
       COMMAND OP CODE (*6) (900),
       DATA (*6),
       NAME (*6),
       SYMBOL (*6),
       VARIABLE FIELD A (*6) (900),
       VARIABLE FIELD B (*6) (900),

       (COMMENT   CONSTANT DIMENSION LIST                                )
       ALL BLANK = OCT -206060606060,
       ASTERISK = OCT -146060606060,
       BCD 9 = OCT 11,
```

```
COMMA = OCT 73,
EEND = OCT 25452460606O,
LAST OP CODE = 69,
LDD OP = OCT 05020000000O,
MAXIMUM COMMAND CODE = OCT 08030000000O,
MINUS SIGN = OCT -00606060606O,
ORG OP = OCT 05000000000O,
PART BLANK = OCT 6060,
PUNCH CALL = OCT -07644523306O,
SHORT BLANK = OCT 60,

ZERO = 0,
ONE = 1,
FOUR = 4,
FIVE = 5,
TEN = 10,
FORTY ONE = 41,
ONE THOUSAND (3) = 1000, 100, 10,

OPERATION TABLE (74) = OCT  234321606060,    (COMMENT  CLA = 42  )
                       OCT -226346606060,    (COMMENT  STO = 49  )
                       OCT  262124606060,    (COMMENT  FAD = 43  )
                       OCT  266222606060,    (COMMENT  FSB = 41  )
                       OCT  264447606060,    (COMMENT  FMP = 44  )
                       OCT  262447606060,    (COMMENT  FDP = 48  )
                       OCT -235121606060,    (COMMENT  TRA = 29  )
                       OCT -237125606060,    (COMMENT  TZE= 23   )
                       OCT  234362606060,    (COMMENT  CLS = 40  )
                       OCT  312624606060,    (COMMENT  IFD = 47  )
                       OCT -234545606060,    (COMMENT  TNN = 20  )
                       OCT -235145606060,    (COMMENT  TRN = 22  )
                       OCT -054647606060,    (COMMENT  NOP = 00  )
                       OCT -234401606060,    (COMMENT  TM1 = 26  )
                       OCT -116301606060,    (COMMENT  RT1 = 16  )
                       OCT -234402606060,    (COMMENT  TM2 = 28  )
                       OCT -116302606060,    (COMMENT  RT2 = 18  )
                       OCT -236251606060,    (COMMENT  TSR = 08  )
                       OCT  256724606060,    (COMMENT  EXD = 91  )
                       OCT  316366606060,    (COMMENT  ITW = 76  )
                       OCT -262563606060,    (COMMENT  WET = 32  )
                       OCT -262523606060,    (COMMENT  WEC = 34  )
                       OCT -262663606060,    (COMMENT  WFT = 33  )
                       OCT -262623606060,    (COMMENT  WFC = 38  )
                       OCT  216622606060,    (COMMENT  AWB = 70  )
                       OCT -112524606060,    (COMMENT  RED = 52  )
                       OCT -112344606060,    (COMMENT  RCM = 50  )
                       OCT  216463606060,    (COMMENT  AUT = 69  )
                       OCT -042145606060,    (COMMENT  MAN = 67  )
                       OCT  216624606060,    (COMMENT  AWD = 71  )
                       OCT  216643606060,    (COMMENT  AWL = 72  )
                       OCT -076323606060,    (COMMENT  PTC = 30  )
                       OCT  232122606060,    (COMMENT  CAB = 45  )
                       OCT  212322606060,    (COMMENT  ACB = 73  )
                       OCT  212324606060,    (COMMENT  ACD = 74  )
                       OCT  212343606060,    (COMMENT  ACL = 75  )
                       OCT  316323606060,    (COMMENT  ITC = 77  )
                       OCT  254122606060,    (COMMENT  EJB = 80  )
                       OCT -264323606060,    (COMMENT  WLC = 06  )
                       OCT -262363606060,    (COMMENT  WCT = 35  )
                       OCT  316247606060,    (COMMENT  ISP = 61  )
                       OCT -046242606060,    (COMMENT  MSK = 90  )
                       OCT  256247606060,    (COMMENT  ESP = 62  )
```

```
                    OCT -264363606060,     (COMMENT  WLT = 31   )
                    OCT -072223606060,     (COMMENT  PBC = 39   )
                    OCT -112223606060,     (COMMENT  RBC = 55   )
                    OCT  234331606060,     (COMMENT  CLI = 78   )
                    OCT -226331606060,     (COMMENT  STI = 79   )
                    OCT -223121606060,     (COMMENT  SIA = 09   )
                    OCT  224323606060,     (COMMENT  BLC = 81   )
                    OCT  234342606060,     (COMMENT  CLK = 64   )
                    OCT  222543606060,     (COMMENT  BEL = 63   )
                    OCT  224730606060,     (COMMENT  BPH = 68   )
                    OCT -032450606060,     (COMMENT  LDQ = 65   )
                    OCT -226350606060,     (COMMENT  STQ = 66   )
                    OCT -264463606060,     (COMMENT  WMT = 37   )
                    OCT -036251606060,     (COMMENT  LSR = 07   )
                    OCT -036247606060,     (COMMENT  LSP = 00   )
                    OCT  233151606060,     (COMMENT  CIR = 00   )
                    OCT  234344606060,     (COMMENT  CLM = 00   )
                    OCT  265162606060,     (COMMENT  FRS = 01   )
                    OCT -225063606060,     (COMMENT  SQT = 02   )
                    OCT -034627606060,     (COMMENT  LOG = 03   )
                    OCT -076651606060,     (COMMENT  PWR = 04   )
                    OCT -235127606060,     (COMMENT  TRG = 05   )
                    OCT  215163606060,     (COMMENT  ART = 06   )
                    OCT  307022606060,     (COMMENT  HYB = 07   )
                    OCT  315164606060,     (COMMENT  IRU = 12   )
                    OCT  254362606060,     (COMMENT  ELS = 00   )
                    OCT -206060606060,     (COMMENT  BLANK      )
                    OCT  226262606060,     (COMMENT  BSS = 82   )
                    OCT  255064606060,     (COMMENT  EQU = 83   )
                    OCT -065127606060,     (COMMENT  ORG = 50   )
                    OCT -032424606060,     (COMMENT  LDD = 52   )

OPERATION CODE (*6) (74) =
                    OCT  040200000000,     (COMMENT  CLA = 42   )
                    OCT  040900000000,     (COMMENT  STO = 49   )
                    OCT  040300000000,     (COMMENT  FAD = 43   )
                    OCT  040100000000,     (COMMENT  FSB = 41   )
                    OCT  040400000000,     (COMMENT  FMP = 44   )
                    OCT  040800000000,     (COMMENT  FDP = 48   )
                    OCT  020900000000,     (COMMENT  TRA = 29   )
                    OCT  020300000000,     (COMMENT  TZE = 23   )
                    OCT  040000000000,     (COMMENT  CLS = 40   )
                    OCT  040700000000,     (COMMENT  IFD = 47   )
                    OCT  020000000000,     (COMMENT  TNN = 20   )
                    OCT  020200000000,     (COMMENT  TRN = 22   )
                    OCT  000000000000,     (COMMENT  NOP = 00   )
                    OCT  020600000000,     (COMMENT  TM1 = 26   )
                    OCT  010600000000,     (COMMENT  RT1 = 16   )
                    OCT  020800000000,     (COMMENT  TM2 = 28   )
                    OCT  010800000000,     (COMMENT  RT2 = 18   )
                    OCT  000800000000,     (COMMENT  TSR = 08   )
                    OCT  090100000000,     (COMMENT  EXD = 91   )
                    OCT  070600000000,     (COMMENT  ITW = 76   )
                    OCT  030200000000,     (COMMENT  WET = 32   )
                    OCT  030400000000,     (COMMENT  WEC = 34   )
                    OCT  030300000000,     (COMMENT  WFT = 33   )
                    OCT  030800000000,     (COMMENT  WFC = 38   )
                    OCT  070000000000,     (COMMENT  AWB = 70   )
                    OCT  050200000000,     (COMMENT  RED = 52   )
                    OCT  050000000000,     (COMMENT  RCM = 50   )
                    OCT  060900000000,     (COMMENT  AUT = 69   )
                    OCT  060700000000,     (COMMENT  MAN = 67   )
```

```
                    OCT 07010000000,  (COMMENT  AWD = 71  )
                    OCT 07020000000,  (COMMENT  AWL = 72  )
                    OCT 03000000000,  (COMMENT  PTC = 30  )
                    OCT 04050000000,  (COMMENT  CAB = 45  )
                    OCT 07030000000,  (COMMENT  ACB = 73  )
                    OCT 07040000000,  (COMMENT  ACD = 74  )
                    OCT 07050000000,  (COMMENT  ACL = 75  )
                    OCT 07070000000,  (COMMENT  ITC = 77  )
                    OCT 08000000000,  (COMMENT  EJB = 80  )
                    OCT 00600000000,  (COMMENT  WLC = 06  )
                    OCT 03050000000,  (COMMENT  WCT = 35  )
                    OCT 06010000000,  (COMMENT  ISP = 61  )
                    OCT 09000000000,  (COMMENT  MSK = 90  )
                    OCT 06020000000,  (COMMENT  ESP = 62  )
                    OCT 03010000000,  (COMMENT  WLT = 31  )
                    OCT 03090000000,  (COMMENT  PBC = 39  )
                    OCT 05050000000,  (COMMENT  RBC = 55  )
                    OCT 07080000000,  (COMMENT  CLI = 78  )
                    OCT 07090000000,  (COMMENT  STI = 79  )
                    OCT 00900000000,  (COMMENT  SIA = 09  )
                    OCT 08010000000,  (COMMENT  BLC = 81  )
                    OCT 06040000000,  (COMMENT  CLK = 64  )
                    OCT 06030000000,  (COMMENT  BEL = 63  )
                    OCT 06080000000,  (COMMENT  BPH = 68  )
                    OCT 06050000000,  (COMMENT  LDQ = 65  )
                    OCT 06060000000,  (COMMENT  STQ = 66  )
                    OCT 03070000000,  (COMMENT  WMT = 37  )
                    OCT 00700000000,  (COMMENT  LSR = 07  )
                    OCT 00000000000,  (COMMENT  LSP = 00  )
                    OCT 00000000000,  (COMMENT  CIR = 00  )
                    OCT 00000000000,  (COMMENT  CLM = 00  )
                    OCT 00100000000,  (COMMENT  FRS = 01  )
                    OCT 00200000000,  (COMMENT  SQT = 02  )
                    OCT 00300000000,  (COMMENT  LOG = 03  )
                    OCT 00400000000,  (COMMENT  PWR = 04  )
                    OCT 00500000000,  (COMMENT  TRG = 05  )
                    OCT 00600000000,  (COMMENT  ART = 06  )
                    OCT 00700000000,  (COMMENT  HYB = 07  )
                    OCT 01020000000,  (COMMENT  IRU = 12  )
                    OCT 00000000000,  (COMMENT  ELS = 00  )
                    OCT 00000000000,  (COMMENT  BLANK     )
                    OCT 08020000000,  (COMMENT  BSS = 82  )
                    OCT 08030000000,  (COMMENT  EQU = 83  )
                    OCT 05000000000,  (COMMENT  ORG = 50  )
                    OCT 05020000000,  (COMMENT  LDD = 52  )

SYMBOL TABLE  (41) =     OCT  265121236345, OCT  242523476300,
(COMMENT                      FRACTN             DECPTO             )
     OCT 242523476301, OCT  242523476302, OCT  242523476303,
(COMMENT DECPT1               DECPT2             DECPT3,            )
     OCT 242523476304, OCT  242523476305, OCT  242523476306,
(COMMENT DECPT4               DECPT5             DECPT6             )
     OCT 242523476307, OCT  315164606060, OCT  263167606060,
(COMMENT DECPT7               IRU                FIX                )
     OCT 264346216360, OCT -225063236422, OCT -225051636060,
(COMMENT FLOAT                SQTCUB             SQRT               )
     OCT 236422255163, OCT -034627606060, OCT -034627256060,
(COMMENT CUBERT               LOG                LOGE               )
     OCT-034627026060, OCT -034627010060, OCT -074666255160,
(COMMENT LOG2                 LOG10              POWER              )
     OCT 256747606060, OCT -076651026060, OCT -076651010060,
(COMMENT EXP                  PWR2               PWR10              )
```

```
     OCT 256747016060, OCT 256747026060, OCT 256747036060,
  (COMMENT  EXP1          EXP2              EXP3             )
     OCT -235131276060, OCT -223145606060, OCT -223145246060,
  (COMMENT  TRIG          SIN               SIND             )
     OCT 234662606060, OCT 234662246060, OCT 215123632145,
  (COMMENT  COS           COSD              ARCTAN           )
     OCT 216321456060, OCT 216321452460, OCT 307047224643,
  (COMMENT  ATAN          ATAND             HYPBOL           )
     OCT -223145306060, OCT -232145306060, OCT 212323606060,
  (COMMENT  SINH          TANH              ACC              )
     OCT -222543475163, OCT -275125276260, OCT -042544465170,
  (COMMENT  SELPRT        XREGS             MEMORY           )
  WORD SPACE A (250),

  SYMBOL TABLE VALUE (41)= OCT 000000000000, OCT 000000100000,
  (COMMENT                FRACTN            DECPTO           )
     OCT 000000010000, OCT 000000020000, OCT 000000030000,
  (COMMENT  DECPT1        DECPT2            DECPT3,          )
     OCT 000000040000, OCT 000000050000, OCT 000000060000,
  (COMMENT  DECPT4        DECPT5            DECPT6           )
     OCT 000000070000, OCT 000100000000, OCT 000100000000,
  (COMMENT   DECPT7       IRU               FIX              )
     OCT 000100010000, OCT 000200000000, OCT 000211070000,
  (COMMENT  FLOAT         SQTCUB            SQRT             )
     OCT 000201040000, OCT 000300000000, OCT 000301070000,
  (COMMENT  CUBERT        LOG               LOGE             )
     OCT 000300100000, OCT 000307010000, OCT 000400000000,
  (COMMENT  LOG2          LOG10             POWER            )
     OCT 000402020000, OCT 000400100000, OCT 000407020000,
  (COMMENT  EXP           PWR2              PWR10            )
     OCT 000401010000, OCT 000401020000, OCT 000401030000,
  (COMMENT   EXP1         EXP2              EXP3             )
     OCT 000500000000, OCT 000504020000, OCT 000503110000,
  (COMMENT  TRIG          SIN               SIND             )
     OCT 000502060000, OCT 000502030000, OCT 000600000000,
  (COMMENT  COS           COSD              ARCTAN           )
     OCT 000602040000, OCT 000602050000, OCT 000700000000,
  (COMMENT  ATAN          ATAND             HYPBOL           )
     OCT 000700110000, OCT 000701000000, OCT 020100010000,
  (COMMENT  SINH          TANH              ACC              )
     OCT 000000010000, OCT 000000020000, OCT 000000030000,
  (COMMENT  SELPRT        XREGS             MEMORY           )
  WORD SPACE B (250),

$DIMENSIONING CLN ..

ASSEMBLER

FLOWCHART NUMBER 00003

  $FIRST PASS CLN
     READ PROGRAM CLN
        I + ONE = I, IOH READ (51,0, SYMBOL FIELD, OPERATION, VARIABLE
        FIELD A, VARIABLE FIELD B, CM1,CM2,CM3,CM4,CM5,CM6,CM7,CM8),
        IF OPERATION EQU EEND
           THEN I = PROGRAM LENGTH, VARIABLE FIELD A = CALL PUNCH(*1),
              N - ONE = SYMBOL TABLE LENGTH,
              GO TO CONVERT SYMBOL TABLE TO BCD.$
        FOR J EQU 0 STEP 1 UNTIL 73 DO
           BEGIN IF OPERATION EQU OPERATION TABLE LBK J RBK
              THEN GO TO CHECK PSEUDO OP.$ END ,
           IOH PRINT (52,0, OPERATION), GO TO ENDJB.
```

```
CHECK PSEUDO OP CLN
   IF J GTR LAST OP CODE
      THEN GO TO PSEUDO OPERATION LBK J-70 RBK.$
   OPERATION CODE LBK J RBK = COMMAND OP CODE LBK I RBK ,
STORE CARD CLN
   SYMBOL FIELD = SYMBOL FIELD LBK I RBK , OPERATION
   = OPERATION LBK I RBK , VARIABLE FIELD A
   = VARIABLE FIELD A LBK I RBK ,  VARIABLE FIELD B
   = VARIABLE FIELD B LBK I RBK , CM1 = COMMENT A LBK I RBK ,
   CM2 = COMMENT B LBK I RBK , CM3 = COMMENT C LBK I RBK ,
   CM4 = COMMENT D LBK I RBK , CM5 = COMMENT E LBK I RBK,
   CM6 = COMMENT F LBK I RBK , CM7 = COMMENT G LBK I RBK ,
   CM8 = COMMENT H LBK I RBK , IF SYMBOL FIELD EQU ASTERISK
      THEN MINUS SIGN = EX MARK LBK I RBK , GO TO READ PROGRAM.
      ELSE ALL BLANK = EX MARK LBK I RBK $
   IF SYMBOL FIELD NEQ ALL BLANK
      THEN DO ENTER SYMBOL IN TABLE, $$
   LOCATION COUNTER + ONE = LOCATION COUNTER, GO TO READ PROGRAM.

   GO TO LDD.   GO TO ORG.   GO TO EQUAL.
PSEUDO OPERATION CLN  GO TO BSS.

   BSS CLN
      LDD OP = COMMAND OP CODE LBK I RBK , IF SYMBOL FIELD
      = SYMBOL FIELD LBK I RBK NEQ ALL BLANK
        THEN DO ENTER SYMBOL IN TABLE, $$
      DO CONVERT ADDRESS, LOCATION COUNTER + NUMB - ONE
      = LOCATION COUNTER = NUMB, VARIABLE FIELD A
      = VARIABLE FIELD B LBK I RBK ,
      CONVERT LOCATION COUNTER TO BCD CLN
        FOR J EQU 0 STEP 1 UNTIL 2 DO
           BEGIN NUMB /ONE THOUSAND LBK J RBK = BCD DIGIT LBK J RBK
           * ONE THOUSAND LBK J RBK = DIGIT, NUMB - DIGIT
           = NUMB, END ,
      NUMB = BCD DIGIT LBK 3 RBK , FOR J EQU 1 STEP 1 UNTIL 3 DO
        BEGIN BCD DIGIT(*6) ++ BCD DIGIT LBK J RBK (*6)
        = BCD DIGIT(*6), END ,
      BCD DIGIT *2 EXP 12 +PART BLANK = VARIABLE FIELD A LBK I RBK ,
      OPERATION = OPERATION LBK I RBK , CM1 = COMMENT A LBK I RBK ,
      CM2 = COMMENT B LBK I RBK , CM3 = COMMENT C LBK I RBK ,
      CM4 = COMMENT D LBK I RBK , CM5 = COMMENT E LBK I RBK,
      CM6 = COMMENT F LBK I RBK , CM7 = COMMENT G LBK I RBK ,
      CM8 = COMMENT H LBK I RBK , MINUS SIGN = EX MARK LBK I RBK ,
      GO TO READ PROGRAM.
   EQUAL CLN
      IOH PRINT (60,0, SYMBOL FIELD, OPERATION, VARIABLE FIELD A,
      CM1, CM2, CM3, CM4, CM5, CM6, CM7, CM8),
      DO ENTER SYMBOL IN TABLE, DO CONVERT ADDRESS,
      NUMB = SYMBOL TABLE VALUE LBK N-1 RBK , I - ONE = I,
      GO TO READ PROGRAM.
   LDD CLN
      DO CONVERT ADDRESS, NUMB = LOCATION COUNTER, LDD OP
      = COMMAND OP CODE LBK I RBK , GO TO STORE CARD.
   ORG CLN
      DO CONVERT ADDRESS, NUMB = LOCATION COUNTER, ORG OP
      = COMMAND OP CODE LBK I RBK , GO TO STORE CARD.

CONVERT SYMBOL TABLE VALUE TO BCD CLN
   FOR I EQU 41 STEP 1 UNTIL SYMBOL TABLE LENGTH DO
      BEGIN FOR J EQU ZERO STEP 1 UNTIL 2 DO
      BEGIN SYMBOL TABLE VALUE LBK I RBK / ONE THOUSAND LBK J RBK
         = BCD DIGIT LBK J RBK * ONE THOUSAND LBK J RBK = DIGIT,
```

```
          SYMBOL TABLE VALUE LBK I RBK - DIGIT
          = SYMBOL TABLE VALUE LBK I RBK , END ,
       SYMBOL TABLE VALUE LBK I RBK = BCD DIGIT LBK 3 RBK ,
       FOR J EQU 1 STEP 1 UNTIL 3 DO
          BEGIN BCD DIGIT(*6) ++ BCD DIGIT LBK J RBK (*6)
          = BCD DIGIT (*6), END ,
       BCD DIGIT * 2 EXP 12 = SYMBOL TABLE VALUE LBK I RBK , END ,
    ZERO = I,
SECOND PASS CLN
    I + ONE = I, IF I EQU PROGRAM LENGTH
       THEN IOH PRINT (55,0,), GO TO WRITE TABLES ON TAPE 9.$
    IF COMMAND OP CODE LBK I RBK GTR MAXIMUM COMMAND CODE
       THEN VARIABLE FIELD A LBK I RBK = DATA,
          FOR J EQU 0 STEP 1 UNTIL 5 DO
             BEGIN *DATA = INDEX REGISTER LBK J RBK , DATA += DATA END ,
          VARIABLE FIELD B LBK I RBK = DATA, FOR J EQU 0 STEP 1 UNTIL 2
             DO BEGIN *DATA = WD UNIT LBK J RBK , DATA += DATA, END ,
          GO TO WRITE OUTPUT TAPES.$
    OUTPUT COMMAND CLN
       *COMMAND OP CODE LBK I RBK = OP TEN, COMMAND OP CODE LBK I RBK
       += COMMAND OP CODE LBK I RBK , * COMMAND OP CODE LBK I RBK
       = OP UNIT, EX MARK LBK I RBK = X,
       VARIABLE FIELD A LBK I RBK = NAME = SYMB(*1),
       IF SYMB EQU ALL BLANK
          THEN ZERO = NAME $$
       IF *NAME GTR BCD 9
          THEN BEGIN DO BUILD SYMBOL,
             FOR K EQU SYMBOL TABLE LENGTH STEP -1 UNTIL 0 DO
                BEGIN IF SYMB EQU SYMBOL TABLE  LBK K RBK
                   THEN SYMBOL TABLE VALUE LBK K RBK (*1) = BCD NUMB,
                      GO TO OUTPUT BCD VARIABLE FIELD.$ END ,
             SYMB = UNDEFINED SYMBOLS LBK M RBK , M + ONE = M,
             ZERO = BCD NUMB, END $
          ELSE BEGIN RIGHT ADJUST CLN
             IF NAME(0=5) EQU SHORT BLANK
                THEN NAME / 2 EXP 6 = NAME, GO TO RIGHT ADJUST.$
             IF NAME(6=11) NEQ COMMA
                THEN NAME * 2 EXP 12 = NAME $$
             FOR J EQU ZERO STEP 1 UNTIL 3 DO
             BEGIN *NAME = CH TEN LBK J RBK , NAME += NAME, END ,
             IF *NAME = CHARACTER EQU COMMA
                THEN NAME += NAME, *NAME = INDEX REGISTER,
                   GO TO WRITE OUTPUT TAPES.
                ELSE ZERO=INDEX REGISTER, GOTO WRITE OUTPUT TAPES. END $
       OUTPUT BCD VARIABLE FIELD CLN
          FOR K EQU 0 STEP 1 UNTIL 3 DO
             BEGIN *BCD NUMB = CH TEN LBK K RBK ,
                BCD NUMB += BCD NUMB, END ,
       OUTPUT INDEX CLN
          IF J NEQ FIVE
             THEN GO TO CHECK INDEX.$
          IF CHARACTER EQU COMMA
             THEN *VARIABLE FIELD B LBK I RBK = INDEX REGISTER,
                GO TO WRITE OUTPUT TAPES.$
          IF *VARIABLE FIELD B LBK I RBK EQU COMMA
             THEN VARIABLE FIELD B LBK I RBK = NAME, NAME += NAME,
                *NAME = INDEX REGISTER, GO TO WRITE OUTPUT TAPES.
             ELSE ZERO = IR, GO TO WRITE OUTPUT TAPES.
          CHECK INDEX CLN
             IF CHARACTER NEQ COMMA
                THEN ZERO = IR, GO TO WRITE OUTPUT TAPES.$
             NAME += NAME, *NAME = INDEX REGISTER,
```

```
   WRITE OUTPUT TAPES CLN
      SYMBOL FIELD LBK I RBK = SYMBOL FIELD, OPERATION LBK I RBK
      = OPERATION, VARIABLE FIELD A LBK I RBK = VARIABLE FIELD A,
      VARIABLE FIELD B LBK I RBK = VARIABLE FIELD B,
      COMMENT A LBK I RBK = CM1, COMMENT B LBK I RBK = CM2,
      COMMENT C LBK I RBK = CM3, COMMENT D LBK I RBK = CM4,
      COMMENT E LBK I RBK = CM5, COMMENT F LBK I RBK = CM6,
      COMMENT G LBK I RBK = CM7, COMMENT H LBK I RBK = CM8,
      WRITE TAPE 5 CLN
         IOH PRINT (53,5, CM1,CM2,CM3,CM4,CM5,CM6,CM7,CM8, IR, O, P,
         ADDR 1, ADDR 2, ADDR 3, ADDR 4, SIGN VALUE, X),
      WRITE TAPE 9 CLN
         IOH PRINT (54,0, IR, O, P, ADDR 1, ADDR 2, ADDR 3, ADDR 4,
         SIGN VALUE, X, SYMBOL FIELD, OPERATION, VARIABLE FIELD A,
         VARIABLE FIELD B, CM1,CM2,CM3,CM4,CM5,CM6,CM7,CM8),
         ALL BLANK = SIGN VALUE, GO TO SECOND PASS.
      WRITE TABLES ON TAPE 9 CLN
         FOR J EQU 41 STEP 1 UNTIL SYMBOL TABLE LENGTH DO
            BEGIN SYMBOL TABLE LBK J RBK = SYMB,
               SYMBOL TABLE VALUE LBK J RBK = NUMB, IOH PRINT (56,0,
               SYMB, NUMB), END ,
         IF L NEQ ZERO
            THEN IOH PRINT (57,0,), FOR J EQU 0 STEP 1 UNTIL L-1 DO
               BEGIN MULTIPLY DEFINED SYMBOL LBK J RBK = SYMB,
               IOH PRINT (58,0, SYMB), END$$
         IF M NEQ ZERO
            THEN IOH PRINT (59,0,), FOR J EQU 0 STEP 1 UNTIL M-1 DO
               BEGIN UNDEFINED SYMBOLS LBK J RBK = SYMB,
                  IOH PRINT (58,0, SYMB), END $$
      EXIT ASSEMBLER CLN
         MCH 0770000 OCT 205, MCH 0772000 OCT 205,
         IF CALL PUNCH EQU PUNCH CALL
            THEN GO TO RETRN.  (COMMENT  WRITE T-5 ON T-9 BCD CARD IMAGES)
            ELSE GO TO RETRN.. (COMMENT  START INTERCOM 500 INTERPRETER)

ASSEMBLER SUBROUTINES

FLOWCHART NUMBER  00004

    $PROCEDURE   ENTER SYMBOL IN TABLE CLN
      BEGIN SYMBOL FIELD(*1) = NAME, FOR J EQU 0 STEP 1 UNTIL 5 DO
         BEGIN *NAME = CHARACTER,
            IF CHARACTER EQU SHORT BLANK
               THEN GO TO EXIT.
               ELSE SYMBOL ++ CHARACTER = SYMBOL $
            EXIT CLN
               NAME += NAME, END ,
      ADJUST CHARACTERS LEFT CLN
         IF *SYMBOL EQU ZERO
            THEN SYMBOL ++ SHORT BLANK = SYMBOL,
               GO TO ADJUST CHARACTERS LEFT.$
         SYMBOL = SYMBOL TABLE LBK N RBK (*1), LOCATION COUNTER
         = SYMBOL TABLE VALUE LBK N RBK , FOR J EQU 0 STEP 1 UNTIL N-1 DO
            BEGIN IF SYMBOL TABLE LBK J RBK EQU SYMBOL TABLE LBK N RBK
               THEN SYMBOL TABLE LBK N RBK
                  = MULTIPLY DEFINED SYMBOLS LBK L RBK , L + ONE = L,
                  GO TO EXIT SYMBOL TABLE ENTRY.$ END ,
         EXIT SYMBOL TABLE ENTRY CLN
            N + ONE = N, ZERO = SYMBOL, END ,

   PROCEDURE CONVERT ADDRESS CLN
      BEGIN VARIABLE FIELD A = NAME, IF *NAME = NUMB GTR BCD 9
```

```
          THEN BEGIN DO BUILD SYMBOL, FOR K EQU N-1 STEP -1 UNTIL 0 DO
                    BEGIN IF SYMB EQU SYMBOL TABLE LBK K RBK
                         THEN SYMBOL TABLE VALUE LBK K RBK = NUMB,
                              GO TO EXIT CONVERT ADDRESS.$ END ,
               ZERO = NUMB, END $
          ELSE BEGIN CONVERT BCD NUMBER TO BINARY CLN
                    NAME += NAME, IF *NAME = BCD NUMB EQU COMMA
                         THEN GO TO EXIT CONVERT ADDRESS.$
                    IF BCD NUMB NEQ SHORT BLANK
                         THEN BCD NUMB + NUMB * TEN = NUMB,
                              GO TO CONVERT BCD NUMBER TO BINARY.$ END $
     EXIT CONVERT ADDRESS CLN
          END ,
PROCEDURE     BUILD SYMBOL CLN
     BEGIN FOR J EQU ZERO STEP 1 UNTIL 5 DO
          BEGIN *NAME = CHARACTER,
               IF CHARACTER EQU SHORT BLANK
                    THEN GO TO EXIT BUILD SYMBOL.$
               IF CHARACTER EQU COMMA
                    THEN GO TO EXIT BUILD SYMBOL.$
               SYMBOL ++ CHARACTER = SYMBOL, NAME += NAME, END ,
     EXIT BUILD SYMBOL CLN
          IF *SYMBOL EQU ZERO
               THEN SYMBOL ++ SHORT BLANK = SYMBOL,
                    GO TO EXIT BUILD SYMBOL.$
          SYMBOL = SYMB(*1), ZERO = SYMBOL, END ,..
```

FLOWCHART NUMBER 00005

```
CONTROL
    50(14H1SYMBOLIC MODE///)
    51(C6,1XC3,1XC6,C3,4X8C6)
    52(27H  ILLEGAL OPERATION CODE = C3)
    53(8C6,14X9(1XC1))
    54(3X9C1,3XC6,1XC3,1XC6,C6,5X8C6)
    55(///13H SYMBOL TABLE/X)
    56(3XC6,5XC4)
    57(///25H MULTIPLY DEFINED SYMBOLS/X)
    58(3XC6)
    59(///18H UNDEFINED SYMBOLS/X)
    60(15XC6,1XC3,1XC6,11X8C6)
```

Appendix F

BC NELIAC SIMULATION OF INTERCOM 500

```
DIMENSIONING

FLOWCHART NUMBER  00001

    $START INTERCOM 500 INTERPRETER CLN
        FORMAT ADDRESS = PRINTOUT LBK 32766 RBK , FIRST PRINT VARIABLE = L,
        FIRST FORMAT = M, GO TO PERMIT MANUAL OPERATION..


FLOWCHART NUMBER  00002

     (COMMENT  VARIABLE DIMENSION LIST                                        )

            ACCUMULATOR = 0.0*0,
            ADDR,
            ADDRESS (7),
            ADDRESS SEPARATION,
            BCD NUMBER (4),
            CHL (7),
            COL 64 CLN LBR COLUMN 64(30=33), COLUMN K(30=35) RBR ,
            COL 66 CLN LBR COLUMN 66(30=33), COLUMN O(30=35) RBR ,
            COL 68 CLN LBR COLUMN 68(30=33), COLUMN P(30=35) RBR ,
            COL 69 CLN LBR COLUMN 69(30=33), COLUMN C(30=35) RBR ,
            COL 70 CLN LBR COLUMN 70(30=33), COLUMN H(30=35) RBR ,
            COL 72 CLN LBR COLUMN 72(30=33), COLUMN L(30=35) RBR ,
            COL 74 CLN LBR COLUMN 74(30=33), COLUMN W(30=35) RBR ,
            COL 76 CLN LBR COLUMN 76(30=33), COLUMN D(30=35) RBR ,
            COMMAND A,
            COMMAND B,
            COMMENT1 CLN C1, COMMENT2 CLN C2, COMMENT3 CLN C3,
            COMMENT4 CLN C4, COMMENT5 CLN C5, COMMENT6 CLN C6,
            COMMENT7 CLN C7, COMMENT8 CLN C8, COMMENT9 CLN C9,
            COMMENT10 CLN C10, COMMENT11 CLN C11,
            DATUM (7) = 0.0*0,,,,,,,
            EMPTY WORD CLN EW,
            EXCUTE,
            EXPONENT,
            FIRST SELECTOR A,
            FIRST SELECTOR B,
            FRACTION SELECTOR CHANNEL CLN FRAC SEL CHANNEL,
            INDEX (7),
            INDEX REGISTER ACCUMULATOR CLN IRA,
            INDEX REGISTER COMPONENT ADDRESS CLN IR COMP ADDRESS,
            INDEX REGISTER UTILIZATION CHANNEL CLN IRU CHANNEL,
            J TEMPORARY STORAGE CLN JTS,
            LAST WORD,
            LOCATION,
            LOG CHANNEL,
            MARK PLACE 1,
            MARK PLACE 2,
            MEMORY (*128) * OCT 65000,    CELL * OCT 65000,
            MODE,
            MQ,
            NUMBER,
            OP CODE (7),
            PAST ACCUMULATOR,
            POWER CHANNEL,
            PROGRAM STORAGE,
            SECOND SELECTOR,
            SECOND SELECTOR A,
            SECOND SELECTOR B,
```

```
        SELECTOR = 1,
        SIGN,
        STORAGE,
        SUBROUTINE,
        TAB = 1,
        TABL (7),
        WD (7),
        W DIFFERENCE (11),
        W LIMIT (11),
        W BASE (11),
        C BASE (11),
        C DIFFERENCE (11),
        C LIMIT (11),
(COMMENT   CONSTANT DIMENSION LIST                                )
        ADDR INCREMENT = OCT 13000,
        AUTOMATIC = 1,
        BLANK = OCT -206060606060,
        BCD 100 = OCT 010000,
        CARRIAGE RETURN FORMAT CLN LBR CR (24=35) RBR
          = OCT 000060746134,
        COMMAND FORMAT (4) = OCT  103060606023, OCT -064444130274,
                             OCT -050273016734, OCT  024503736060,
        FIRST FORMAT = 32767,
        FIRST PRINT VARIABLE = 32765,
        FIXED POINT FORMAT (9) = OCT 260200330773, OCT 260200330173,
              OCT 260200330273, OCT 260200330373, OCT 260200330473,
              OCT 260200330573, OCT 260200330673, OCT 260200330773,
              OCT 260200330073,
        FLOAT CONSTANT = OCT 233000000000,
        FLOATING POINT FORMAT = OCT 250200330773,
        FLOATING POINT TWO = 2.0*0,
        FLOATING POINT TEN = 10.0*0,
        LAST FORMAT WORD = OCT 347777777777,
        LAST PRINT CALL WORD = OCT 002100070011,
        LIST ALL COMMANDS = 1,
        LOCATION FORMAT (4) = OCT  010530606060, OCT  234644442145,
                              OCT  246043462313, OCT -050573606060,
        LOG E 2 = 0.69314718*0,
        MANUAL = 0,
        MAXIMUM FIXED POINT NUMBER = 1.0*10,
        MINUS = OCT -006060606060,
        OCTAL FORMAT (2) = OCT 036704304623, OCT -231342010373,
        ONETAG = OCT 100000,
        OP CODE MASK = OCT 177,
        OUTPUT CONSTANT = OCT 65000,
        PERFORMED = 1,
        TAB FORMAT CLN LBR TB (6=23) RBR = OCT -206000000067,
        TABL FORMAT = OCT 010567450573,
        ZERO = 0,
        ONE = 1,
        TWO = 2,
        THREE = 3,
        EIGHT = 8,
        TEN = 10,
        ELEVEN = 11,
        TWENTY = 20,
        TWENTY ONE = 21,
        TWENTY SIX = 26,
        THIRTY NINE = 39,
```

```
        FORTY TWO = 42,
        FIFTY FIVE = 55,
        SIXTY FIVE = 65,
        SEVENTY ONE = 71,
        SEVENTY TWO = 72,
        SEVENTY SIX = 76,
        SEVENTY SEVEN = 77,
        NINTY SEVEN = 97,
        ONE HUNDRED = 100,
        ONE HUNDRED TWO = 102,
        EIGHT HUNDRED = 800,
        TEN THOUSAND (4) = 10000, 1000, 100, 10,
  (COMMENT   SUBROUTINE DIMENSION LIST                                       )
        ARCTAN * OCT 65504,
        ATAND * OCT 65476,
        COS * OCT 65266,
        COSD * OCT 65251,
        CUBE ROOT * OCT 65171,
        EXPT * OCT 66050,
        EXP1 * OCT 66165,
        EXP2 * OCT 66227,
        EXP3 * OCT 66301,
        FIX * OCT 65100,
        FLOAT * OCT 65105,
        LOG 2 * OCT 66356,
        LOG 10 * OCT 66345,
        LOG E * OCT 66356,
        POWER 2 * OCT 66301,
        POWER 10 * OCT 66301,
        READ CARDS * OCT 70030,
        READ CLOCK * OCT 70312,
        SIN * OCT 65270,
        SIND * OCT 65253,
        SINH COSH * OCT 65607,
        SQRT * OCT 65112,
        TANH * OCT 65716,
 $DIMENSIONING CLN
    ACCUMULATOR ADDRESS CLN       MCH 0000000 ACCUMULATOR,
    DATUM ADDRESS CLN             MCH 1000000 DATUM,
    ENTER SELECTIVE PRINT CLN     MCH 0020000 START SELECTIVE PRINT,
    FORMAT ADDRESS CLN            MCH 0000000 FORMAT,
    LOCATION ADDRESS CLN          MCH 1000000 ADDRESS,
    TABL ADDRESS CLN              MCH 1000000 TABL,
    TRANSFER TO EXIT RC CLN       MCH 0020000 EXIT RETURN CARRIAGE,
    W DIFFERENCE ADDRESS CLN      MCH 0000000 W DIFFERENCE,
    WD ADDRESS CLN                MCH 1000000 WD,
    CHL ADDRESS CLN               MCH 1000000 CHL,
    OP CODE ADDRESS CLN           MCH 1000000 OP CODE,
    INDEX ADDRESS CLN             MCH 1000000 INDEX,
    FORMAT CLN  MCH 7460606 OCT 06060, MCH 0000000 00, MCH 0000000 00,
           MCH 0000000 0, MCH 0000000 0, MCH 0000000 0, MCH 0000000 0,
           MCH 0000000 0, MCH 0000000 0, MCH 0000000 0, MCH 0000000 0,
           MCH 0000000 0, MCH 0000000 0, MCH 0000000 0, MCH 0000000 0,
           MCH 0000000 0, MCH 0000000 0, MCH 0000000 0, MCH 0000000 0,
           MCH 0000000 0, MCH 0000000 0, MCH 0000000 0, MCH 0000000 0,
           MCH 0000000 0, MCH 0000000 0, MCH 00000000, MCH 00000000,..
```

OPERATING MODES AND EXECUTE COMMAND SWITCH

FLOWCHART NUMBER 00003

```
    $PERMIT MANUAL OPERATION CLN                          (COMMENT   OP CODE = 67)
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
       MANUAL = MODE, IOH PRINT (8,0,),
       READ INSTRUCTION CLN
          DO READ CARD, DO COMMAND CARD CONVERSION, IOH PRINT (4,0, INDEX,
          OP CODE, ADDR, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11), PERFORMED
          = ADDRESS SEPARATION, DO EXECUTE COMMAND, GO TO READ INSTRUCTION.
    PROCEDURE   READ CARD CLN
       BEGIN IOH READ (1,0, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11, COL 64,
       COL 66, COL 68, COL 69, COL 70, COL 72, COL 74, COL 76,SIGN,EXCUTE),
       FOR J EQU 0 STEP 1 UNTIL 7 DO
          BEGIN IF COL 64 LBK J RBK EQU BLANK
             THEN ZERO = COL 64 LBK J RBK $$ END , END ,

    COMPUTE AUTOMATICALLY CLN                             (COMMENT   OP CODE = 69)
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
       AUTOMATIC = MODE, IOH PRINT (9,0,), DO GET ADDRESS, I = LOCATION,
       COMMAND EXECUTION CLN
          MEMORY LBK LOCATION RBK AND OP CODE MASK = OP CODE,
          DO EXECUTE COMMAND, LOCATION + ONE = LOCATION,
          GO TO COMMAND EXECUTION.
    PROCEDURE   EXECUTE COMMAND CLN
       BEGIN GO TO EXECUTE LBK OP CODE RBK.
       GO TO BLOCK COPY.  GO TO ENDJOB. GO TO COPY IRA INTO IRD.
       GO TO CLEAR IRA AN ADD IRD.  GO TO INCREMENT C BASE.
       GO TO INCREMENT W BASE.  GO TO ASSIGN C LIMIT.
       GO TO ASSIGN C DIFFERENCE.  GO TO ASSIGN C BASE.
       GO TO ASSIGN W LIMIT. GOTO ASSIGN W DIFFERENCE.  GOTO ASSIGN W BASE.
       GO TO COMPUTE AUTOMATICALLY.  GO TO BREAKPOINT HALT.
       GO TO PERMIT MANUAL OPERATION.  GO TO STORE MQ.  GO TO LOAD MQ.
       GO TO CLOCK.  GO TO RING BELL.  GO TO STOP SELECTIVE PRINT.
       GO TO INITIATE SELECTIVE PRINT.  GO TO ERROR.  GO TO ERROR.
       GO TO ERROR.  GO TO ERROR.  GO TO ERROR.  GO TO READ PAPER CARDS.
       GO TO ERROR. GOTO ERROR. GOTO PERMIT TYPE IN OF FLOATING POINT DATA.
       GO TO ERROR. GOTO PERMIT COMMAND TYPE IN.  GOTO STORE.  GOTO DIVIDE.
       GO TO INVERSE DIVIDE. GOTO ERROR.  GOTO CLEAR AN ADD ABSOLUTE VALUE.
       GO TO MULTIPLY.  GO TO ADD.  GO TO CLEAR AN ADD.
       GO TO SUBTRACT.  GO TO CLEAR AN SUBTRACT.  GO TO PUNCH PAPER CARDS.
       GO TO TYPE FIX POINT NUMBER AN RC. GOTO TYPE MEMORY IN OCTAL AN TAB.
       GO TO ERROR.  GO TO TYPE COMMAND FROM MEMORY AN TAB.
       GO TO TYPE FLOAT POINT NUMBER AN RC.
       GO TO TYPE FIXED POINT NUMBER AN TAB.
       GO TO TYPE FLOATING POINT NUMBER AN TAB.
       GO TO TYPE TABULATING NUMBER AN TAB. GOTO POSITION TYPEWRITER PAPER.
       GO TO TRANSFER.  GO TO MARK PLACE 2 AN TRANSFER.
       GO TO ERROR.  GO TO MARK PLACE 1 AN TRANSFER.  GO TO ERROR.
       GO TO ERROR.  GO TO TRANSFER ON ZERO.  GO TO TRANSFER ON MINUS.
       GO TO ERROR.  GO TO TRANSFER ON PLUS AN ZERO.
       GO TO ERROR.  GO TO RETURN TO MARK PLACE 2.
       GO TO ERROR.  GO TO RETURN TO MARKED PLACE 1.  GO TO ERROR.
       GO TO ERROR.  GO TO ERROR.  GO TO ERROR.  GO TO ERROR.  GO TO ERROR.
       GO TO SET IRA.  GO TO PERFORM SUBROUTINE.  GO TO LOAD SUBROUTINES.
       GO TO TYPE LOCATION OF LAST COMMAND EXECUTED.  GO TO ERROR.
       GO TO ERROR.  GO TO ERROR.  GO TO ERROR.  GO TO ERROR.
    EXECUTE CLN   GO TO NO OPERATION.
    EXIT COMMAND CLN  END ,..
```

FLOWCHART NUMBER 00004

```
    $PERMIT COMMAND TYPE IN CLN                        (COMMENT   OP CODE = 50)
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
       IOH PRINT (6,0,),
       READ COMMAND CLN
          DO READ CARD, DO GET ADDRESS, I = ADDRESS,
          DO DO COMMAND CARD CONVERSION, IF EXCUTE EQU BLANK
             THEN IOH PRINT (3,0, ADDRESS, INDEX, OP CODE, ADDR, C1,C2,
                C3,C4,C5,C6,C7,C8,C9,C10,C11), CHL * 2 EXP 18 + WD
                * 2 EXP 11 + INDEX * 2 EXP 7 + OP CODE = MEMORY LBK I RBK $
             ELSE IOH PRINT (4,0, INDEX, OP CODE, ADDR, C1,C2,C3,C4,C5,
                C6,C7,C8,C9,C10,C11), PERFORMED = ADDRESS SEPARATION,
                DO EXECUTE COMMAND, ADDRESS - ONE = ADDRESS $
       CHECK MODE CLN
          IF MODE EQU MANUAL
             THEN ADDRESS + ONE = ADDRESS, GO TO READ COMMANDS.
             ELSE GO TO EXIT COMMAND.
       READ COMMANDS CLN
          DO READ CARD, DO COMMAND CARD CONVERSION, IF EXCUTE EQU BLANK
             THEN IOH PRINT (3,0, ADDRESS, INDEX, OP CODE, ADDR, C1,C2,
                C3,C4,C5,C6,C7,C8,C9,C10,C11), CHL * 2 EXP 18 + WD
                * 2 EXP 11 + INDEX * 2 EXP 7 + OP CODE
                = MEMORY LBK ADDRESS RBK , ADDRESS + ONE = ADDRESS,
                GO TO READ COMMANDS.
             ELSE IOH PRINT (4,0, INDEX, OP CODE, ADDR, C1,C2,C3,C4,C5,
                C6,C7,C8,C9,C10,C11), PERFORMED = ADDRESS SEPARATION,
                DO EXECUTE COMMAND, GO TO READ COMMANDS.

    PERMIT TYPE IN OF FLOATING POINT DATA CLN          (COMMENT   OP CODE = 52)
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
       IOH PRINT (7,0,),
       READ DATUM CLN
          DO READ CARD, DO GET ADDRESS, I = ADDRESS, IF EXCUTE EQU BLANK
             THEN DO DATUM CARD CONVERSION, IOH PRINT (5,0, ADDRESS,
                DATUM, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11), DATUM
                = MEMORY LBK I RBK $
             ELSE DO COMMAND CARD CONVERSION, IOH PRINT (4,0, INDEX,
                OP CODE, ADDR, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11),
                PERFORMED = ADDRESS SEPARATION, DO EXECUTE COMMAND,
                ADDRESS - ONE = ADDRESS $
       CHK MODE CLN
          IF MODE EQU MANUAL
             THEN ADDRESS + ONE = ADDRESS, GO TO READ DATA.
             ELSE GO TO EXIT COMMAND.
       READ DATA CLN
          DO READ CARD, IF EXCUTE EQU BLANK
             THEN DO DATUM CARD CONVERSION, IOH PRINT (5,0, ADDRESS,
                DATUM, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11), DATUM
                = MEMORY LBK ADDRESS RBK , ADDRESS + ONE = ADDRESS,
                GO TO READ DATA.
             ELSE DO COMMAND CARD CONVERSION, IOH PRINT (4,0, INDEX,
                OP CODE, ADDR, C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11),
                PERFORMED = ADDRESS SEPARATION, DO EXECUTE COMMAND,
                GO TO READ DATA..
```

FLOWCHART NUMBER 00005

```
$CLEAR AN SUBTRACT CLN                                  (COMMENT  OP CODE = 40)
   DO GET ADDRESS, ZERO - MEMORY LBK I RBK = ACCUMULATOR,
   GO TO EXIT COMMAND.

 SUBTRACT CLN                                           (COMMENT  OP CODE = 41)
   DO GET ADDRESS, ACCUMULATOR - MEMORY LBK I RBK = ACCUMULATOR,
   GO TO EXIT COMMAND.

 CLEAR AN ADD CLN                                       (COMMENT  OP CODE = 42)
   DO GET ADDRESS, MEMORY LBK I RBK = ACCUMULATOR, GO TO EXIT COMMAND.

 ADD CLN                                                (COMMENT  OP CODE = 43)
   DO GET ADDRESS, ACCUMULATOR + MEMORY LBK I RBK = ACCUMULATOR,
   GO TO EXIT COMMAND.

 MULTIPLY CLN                                           (COMMENT  OP CODE = 44)
   DO GET ADDRESS, ACCUMULATOR * MEMORY LBK I RBK = ACCUMULATOR,
   GO TO EXIT COMMAND.

 CLEAR AN ADD ABSOLUTE VALUE CLN                        (COMMENT  OP CODE = 45)
   DO GET ADDRESS, MEMORY LBK I RBK (*1) = ACCUMULATOR,
   GO TO EXIT COMMAND.

 INVERSE DIVIDE CLN                                     (COMMENT  OP CODE = 47)
   DO GET ADDRESS, MEMORY LBK I RBK / ACCUMULATOR = ACCUMULATOR,
   GO TO EXIT COMMAND.

 DIVIDE CLN                                             (COMMENT  OP CODE = 48)
   DO GET ADDRESS, ACCUMULATOR / MEMORY LBK I RBK = ACCUMULATOR,
   GO TO EXIT COMMAND.

 STORE CLN                                              (COMMENT  OP CODE = 49)
   DO GET ADDRESS, ACCUMULATOR = MEMORY LBK I RBK , GOTO EXIT COMMAND..
```

FLOWCHART NUMBER 00006

```
    $TRANSFER ON PLUS AN ZERO CLN                       (COMMENT   OP CODE = 20)
       IF ACCUMULATOR GEQ ZERO
          THEN DO GET ADDRESS, I-ONE = LOCATION, GO TO EXIT COMMAND.
          ELSE GO TO EXIT COMMAND.
     TRANSFER ON MINUS CLN                              (COMMENT   OP CODE = 22)
       IF ACCUMULATOR LSS ZERO
          THEN DO GET ADDRESS, I-ONE = LOCATION, GO TO EXIT COMMAND.
          ELSE GO TO EXIT COMMAND.
     TRANSFER ON ZERO CLN                               (COMMENT   OP CODE = 23)
       IF ACCUMULATOR EQU ZERO
          THEN DO GET ADDRESS, I-ONE = LOCATION, GO TO EXIT COMMAND.
          ELSE GO TO EXIT COMMAND.
     TRANSFER CLN                                       (COMMENT   OP CODE = 29)
       DO GET ADDRESS, I-ONE = LOCATION, GO TO EXIT COMMAND.
     MARK PLACE 1 AN TRANSFER CLN                       (COMMENT   OP CODE = 26)
       LOCATION = MARK PLACE 1, DO GET ADDRESS, I-ONE = LOCATION,
       GO TO EXIT COMMAND.
     MARK PLACE 2 AN TRANSFER CLN                       (COMMENT   OP CODE = 28)
       LOCATION = MARK PLACE 2, DO GET ADDRESS, I-ONE = LOCATION,
       GO TO EXIT COMMAND.
     RETURN TO MARKED PLACE 1 CLN                       (COMMENT   OP CODE = 16)
       MARK PLACE 1 = LOCATION, GO TO EXIT COMMAND.
     RETURN TO MARK PLACE 2 CLN                         (COMMENT   OP CODE = 18)
       MARK PLACE 2 = LOCATION, GO TO EXIT COMMAND..
```

FLOWCHART NUMBER 00007

```
$ASSIGN W BASE CLN                                    (COMMENT   OP CODE = 70)
   DO COMMAND SEPARATION, ADDR = W BASE LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 ASSIGN W DIFFERENCE CLN                              (COMMENT   OP CODE = 71)
   DO COMMAND SEPARATION, ADDR = W DIFFERENCE LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 ASSIGN W LIMIT CLN                                   (COMMENT   OP CODE = 72)
   DO COMMAND SEPARATION, ADDR = W LIMIT LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 ASSIGN C BASE CLN                                    (COMMENT   OP CODE = 73)
   DO COMMAND SEPARATION, ADDR = C BASE LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 ASSIGN C DIFFERENCE CLN                              (COMMENT   OP CODE = 74)
   DO COMMAND SEPARATION, ADDR = C DIFFERENCE LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 ASSIGN C LIMIT CLN                                   (COMMENT   OP CODE = 75)
   DO COMMAND SEPARATION, ADDR = C LIMIT LBK INDEX RBK ,
   GO TO EXIT COMMAND.

 INCREMENT W BASE CLN                                 (COMMENT   OP CODE = 76)
   DO COMMAND SEPARATION, INDEX = I, IF W BASE LBK I RBK
   + W DIFFERENCE LBK I RBK = W BASE LBK I RBK LEQ W LIMIT LBK I RBK.
      THEN ADDR - ONE = LOCATION, GO TO EXIT COMMAND.
      ELSE GO TO EXIT COMMAND.

 INCREMENT C BASE CLN                                 (COMMENT   OP CODE = 77)
   DO COMMAND SEPARATION, INDEX = I, IF C BASE LBK I RBK
  + C DIFFERENCE LBK I RBK = C BASE LBK I RBK LEQ C LIMIT LBK I RBK
      THEN ADDR - ONE = LOCATION, GO TO EXIT COMMAND.
      ELSE GO TO EXIT COMMAND.

 CLEAR IRA AN ADD IR D CLN                            (COMMENT   OP CODE = 78)
   DO COMMAND SEPARATE, WD * ELEVEN + INDEX = I,
   W DIFFERENCE LBK I RBK = IRA, GO TO EXIT COMMAND.

 COPY IRA INTO IR D CLN                               (COMMENT   OP CODE = 79)
   DO COMMAND SEPARATE, WD * ELEVEN + INDEX = I,
   IRA = W DIFFERENCE LBK I RBK , GO TO EXIT COMMAND.

 SET IRA CLN                                          (COMMENT   OP CODE = 09)
   DO GET ADDRESS, I = IRA, GO TO EXIT COMMAND..
```

FLOWCHART NUMBER 00010

```
    $TYPE LOCATION OF LAST COMMAND EXECUTED CLN      (COMMENT  OP CODE = 06)
       LOCATION - ONE = ADDRESS LBK TAB RBK,
       LOAD LOCATION VARIABLE ADDRESS IN PRINTOUT CALL CLN
          LOCATION ADDRESS - TAB = PRINTOUT LBK L RBK , L- ONE = L,
       LOAD LOCATION FORMAT CLN
          FOR J EQU 0 STEP 1 UNTIL 3 DO
             BEGIN LOCATION FORMAT LBK J RBK = FORMAT LBK M RBK ,
                M - ONE = M, END ,
          TAB + ONE = TAB, GO TO EXIT COMMAND.
    POSITION TYPEWRITER PAPER CLN                  (COMMENT  OP CODE = 30)
       DO GET ADDRESS, I = STORAGE / ONE HUNDRED = CHL * ONE HUNDRED
       = NUMBER, STORAGE - NUMBER = WD, IF WD NEQ ZERO
          THEN BEGIN IF WD GEQ TEN
             THEN WD / TEN = BCD NUMBER * TEN = NUMBER, BCD NUMBER
                * 2 EXP 6 + WD - NUMBER = WD $$
                WD = CR, CARRIAGE RETURN FORMAT = FORMAT LBK M RBK ,
                M - ONE = M, DO RETURN CARRIAGE, END $
          ELSE TAB + CHL = TAB, GO TO EXIT OP CODE 30.
          IF CHL NEQ ZERO
             THEN CHL + ONE = TAB $
             ELSE GO TO EXIT COMMAND.
          EXIT OP CODE 30 CLN
             CHL * TWENTY = NUMBER, IF NUMBER EQU ONE HUNDRED
                THEN BCD 100 = TB $
                ELSE NUMBER / TEN * 2 EXP 6 = TB $
             TAB FORMAT = FORMAT LBK M RBK , M-ONE=M, GO TO EXIT COMMAND.
    TYPE TABULATING NUMBER AN TAB CLN              (COMMENT  OP CODE = 31)
       DO GET ADDRESS, I = TABL LBK TAB RBK ,
       LOAD TABL ADDRESS IN PRINTOUT CALL CLN
          TABL ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD TABL FORMAT CLN
          TABL FORMAT = FORMAT LBK M RBK , M - ONE = M,
          TAB + ONE = TAB, GO TO EXIT COMMAND.
    TYPE FLOATING POINT NUMBER AN TAB CLN          (COMMENT  OP CODE = 32)
       DO GET ADDRESS, MEMORY LBK I RBK = DATUM LBK TAB RBK ,
       LOAD FL PT NUM ADDRESS IN PRINTOUT CALL CLN
          DATUM ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD FL PT NUM FORMAT CLN
          FLOATING POINT FORMAT = FORMAT LBK M RBK , M - ONE = M,
          TAB + ONE = TAB, GO TO EXIT COMMAND.
    TYPE FIXED POINT NUMBER AN TAB CLN             (COMMENT  OP CODE = 33)
       DO GET ADDRESS, MEMORY LBK I RBK = DATUM LBK TAB RBK ,
       LOAD FP NUM ADDRESS IN PRINTOUT CALL CLN
          DATUM ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD FP NUM FORMAT CLN
          IF DATUM LBK TAB RBK LSS MAXIMUM FIXED POINT NUMBER
             THEN FIXED POINT FORMAT = FORMAT LBK M RBK $
             ELSE FLOATING POINT FORMAT = FORMAT LBK M RBK $
             M - ONE = M, TAB + ONE = TAB, GO TO EXIT COMMAND..
```

FLOWCHART NUMBER 00011

```
    $TYPE FLOAT POINT NUMBER AN RC CLN                   (COMMENT   OP CODE = 34)
       DO GET ADDRESS, MEMORY LBK I RBK = DATUM LBK TAB RBK ,
       LOAD FL PT NUMB ADDRESS IN PRINTOUT CALL CLN
          DATUM ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD FL PT NUMB FORMAT CLN
          FLOATING POINT FORMAT = FORMAT LBK M RBK , M - ONE = M,
          DO RETURN CARRIAGE, GO TO EXIT COMMAND.

    TYPE COMMAND FROM MEMORY AN TAB CLN                  (COMMENT   OP CODE = 35)
       DO GET ADDRESS, CELL LBK I RBK (7=10) = INDEX LBK TAB RBK ,
       CELL LBK I RBK AND OP CODE MASK = OP CODE LBK TAB RBK ,
       CELL LBK I RBK (18=26) = CHL LBK TAB RBK , CELL LBK I RBK (11=17)
       = WD LBK TAB RBK ,
       LOAD COMMAND VARIABLE ADDRESSES IN PRINTOUT CALL CLN
          FOR J EQU 0 STEP 1 UNTIL 3 DO
             BEGIN INDEX ADDRESS LBK J RBK - TAB = PRINTOUT LBK L RBK ,
                L - ONE = L, END ,
       LOAD COMMAND FORMAT CLN
          FOR J EQU 0 STEP 1 UNTIL 3 DO
             BEGIN COMMAND FORMAT LBK J RBK = FORMAT LBK M RBK ,
                M - ONE = M, END ,
          TAB + ONE = TAB, GO TO EXIT COMMAND.

    TYPE MEMORY IN OCTAL AN TAB CLN                      (COMMENT   OP CODE = 37)
       DO GET ADDRESS, MEMORY LBK I RBK = DATUM LBK TAB RBK ,
       LOAD OCTAL VARIABLE ADDRESS IN PRINTOUT CALL CLN
          DATUM ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD OCTAL FORMAT CLN
          OCTAL FORMAT = FORMAT LBK M RBK ,
          OCTAL FORMAT  LBK 1 RBK = FORMAT LBK M-1 RBK , M - TWO = M,
          TAB + ONE = TAB, GO TO EXIT COMMAND.

    TYPE FIX POINT NUMBER AN RC CLN                      (COMMENT   OP CODE = 38)
       DO GET ADDRESS, MEMORY LBK I RBK = DATUM LBK TAB RBK ,
       LOAD FP NUMB ADDRESS IN PRINTOUT CALL CLN
          DATUM ADDRESS - TAB = PRINTOUT LBK L RBK , L - ONE = L,
       LOAD FP NUMB FORMAT CLN
          IF DATUM LBK TAB RBK LSS MAXIMUM FIXED POINT NUMBER
             THEN FIXED POINT FORMAT = FORMAT LBK M RBK $
             ELSE FLOATING POINT FORMAT = FORMAT LBK M RBK $
             M - ONE = M, DO RETURN CARRIAGE, GO TO EXIT COMMAND.

    PROCEDURE   RETURN CARRIAGE CLN
       BEGIN LAST PRINT CALL WORD = PRINTOUT LBK L RBK ,
       LAST FORMAT WORD = FORMAT LBK M RBK , TRANSFER TO EXIT RC
       = PRINTOUT LBK L-1 RBK ,
       PRINTOUT CLN
          IOH PRINT (10,0, EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,
          EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW,EW),
       EXIT RETURN CARRIAGE CLN
          ONE = TAB, FIRST PRINT VARIABLE = L, FIRST FORMAT = M, END ,..
```

FLOWCHART NUMBER 00012

```
$PUNCH PAPER CARDS CLN                                   (COMMENT   OP CODE = 39)
    DO GET ADDRESS, I = STORAGE, ONETAG - STORAGE - ADDR INCREMENT
    = ORIGIN, STORAGE / ONE HUNDRED * ONE HUNDRED + ADDR INCREMENT
    = STORAGE, ONETAG - STORAGE = STORAGE * 2 EXP 18 + ORIGIN = LIMITS,
    DO PUNCH CARDS, GO TO EXIT COMMAND.
    PROCEDURE PUNCH CARDS CLN
       BEGIN DO PUNCH,
          LIMITS CLN EMPTY WORD,
          ORIGIN CLN MCH 0000000 OCT 100, END ,

 READ PAPER CARDS CLN                                    (COMMENT   OP CODE = 55)
    DO READ CARDS, EMPTY WORD, GO TO ENDOFFILE RETURN.
    GO TO ERROR RETURN. GO TO EXIT COMMAND.
    ENDOFFILE RETURN CLN
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
          IOH PRINT (14,0,), GO TO ENDJB.
    ERROR RETURN CLN
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
          IOH PRINT (15,0,), GO TO ENDJB..
```

FLOWCHART NUMBER 00013

```
$BLOCK COPY CLN                                      (COMMENT    OP CODE = 81)
   DO COMMAND SEPARATION, ADDR - ONE = LAST WORD,
   INDEX * ONE HUNDRED + EIGHT HUNDRED = J,
   FOR I EQU CHL STEP 1 UNTIL LAST WORD DO
      BEGIN MEMORY LBK I RBK = MEMORY LBK J RBK , J + ONE = J, END ,
   CHL - EIGHT HUNDRED / ONE HUNDRED = I, INDEX = J,
   FOR K EQU 0 STEP 1 UNTIL 5 DO
      BEGIN W DIFFERENCE LBK I RBK = W DIFFERENCE LBK J RBK ,
         I + ELEVEN = I, J + ELEVEN = J, END ,
   GO TO EXIT COMMAND.
ERROR CLN
   IF TAB NEQ ONE
      THEN DO RETURN CARRIAGE, $$
      IOH PRINT (13,0, OP CODE), GO TO ENDJB.
NO OPERATION CLN                                     (COMMENT    OP CODE = 00)
   GO TO EXIT COMMAND.
RING BELL CLN                                        (COMMENT    OP CODE = 63)
   IF TAB NEQ ONE
      THEN DO RETURN CARRIAGE, $$
      IOH PRINT (11,0,), GO TO EXIT COMMAND.
CLOCK CLN                                            (COMMENT    OP CODE = 64)
   DO READ CLOCK, MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.
LOAD MQ CLN                                          (COMMENT    OP CODE = 65)
   DO GET ADDRESS, MEMORY LBK I RBK = MQ, GO TO EXIT COMMAND.
STORE MQ CLN                                         (COMMENT    OP CODE = 66)
   DO GET ADDRESS, MQ = MEMORY LBK I RBK , GO TO EXIT COMMAND.
BREAKPOINT HALT CLN                                  (COMMENT    OP CODE = 68)
   IF TAB NEQ ONE
      THEN DO RETURN CARRIAGE, $$
      IOH PRINT (12,0,), GO TO ENDJB.
ENDJOB CLN                                           (COMMENT    OP CODE = 80)
   IF TAB NEQ ONE
      THEN DO RETURN CARRIAGE, $$
      ZERO = LIMITS, DO PUNCH CARDS, GO TO ENDJB..
```

FLOWCHART NUMBER 00014

```
    $LOAD SUBROUTINES CLN                                   (COMMENT    OP CODE = 07)
       IF TAB NEQ ONE
          THEN DO RETURN CARRIAGE, $$
       IOH PRINT (16,0,),
       READ SUBROUTINE CLN
          DO READ CARD, DO COMMAND CARD CONVERSION,
          GO TO CALL SUBROUTINE LBK OP CODE RBK .
          GO TO CALL INDEX REGISTER UTILIZATION.
          GO TO CALL ERROR.  GO TO CALL ERROR.  GO TO CALL ERROR.
          GO TO CALL ERROR.  GO TO CALL HYPERBOLICS.  GO TO CALL ARCTAN.
          GO TO CALL SIN COS.  GO TO CALL POWER.  GO TO CALL LOG.
          GO TO CALL SQUARE ROOT.  GO TO CALL FRACTION SELECTOR.
       CALL SUBROUTINE CLN  GO TO EXIT LOADING SUBROUTINES.
       EXIT LOADING SUBROUTINES CLN                                 (COMMENT     N = 0)
          IF SIGN EQU MINUS
             THEN FIXED POINT FORMAT LBK WD RBK = FIXED POINT FORMAT,
                IOH PRINT (17,0, WD), GO TO EXIT COMMAND.$
          IF WD EQU ZERO
             THEN IOH PRINT (18,0,), GO TO EXIT COMMAND.$
          IF WD EQU ONE
             THEN IOH PRINT (29,0,), GO TO READ SUBROUTINE.$
          IF WD EQU TWO
             THEN IOH PRINT (34,0,) FOR J EQU 0 STEP 1 UNTIL 65 DO
                BEGIN ZERO = W DIFFERENCE LBK J RBK, END,
                GO TO READ SUBROUTINE.$
          IF WD EQU THREE
             THEN IOH PRINT (35,0,) FOR J EQU 0 STEP 1 UNTIL 65 DO
                BEGIN ZERO = W DIFFERENCE LBK J RBK, END,
                FOR J EQU 0 STEP 1 UNTIL 23500 DO
                   BEGIN ZERO = MEMORY LBK J RBK , END ,
                GO TO READ SUBROUTINE.$
       CALL FRACTION SELECTOR CLN                                   (COMMENT     N = 1)
          IOH PRINT (28,0, CHL), CHL = FRAC SEL CHANNEL,
          GO TO READ SUBROUTINE.
       CALL SQUARE ROOT CLN                                         (COMMENT     N = 2)
          IOH PRINT (19,0, CHL), GO TO READ SUBROUTINE.
       CALL LOG CLN                                                 (COMMENT     N = 3)
          IOH PRINT (20,0, CHL), CHL = LOG CHANNEL, GO TO READ SUBROUTINE.
       CALL POWER CLN                                               (COMMENT     N = 4)
          IOH PRINT (21,0,CHL), CHL = POWER CHANNEL, GO TO READ SUBROUTINE.
       CALL SIN COS CLN                                             (COMMENT     N =05)
          IOH PRINT (22,0, CHL), GO TO READ SUBROUTINE.
       CALL ARCTAN CLN                                              (COMMENT     N = 6)
          IOH PRINT (23,0, CHL), GO TO READ SUBROUTINE.
       CALL HYPERBOLICS CLN                                         (COMMENT     N = 7)
          IOH PRINT (27,0, CHL), GO TO READ SUBROUTINE.
       CALL INDEX REGISTER UTILIZATION CLN                          (COMMENT     N =12)
          IOH PRINT (25,0, CHL), CHL = IRU CHANNEL, GO TO READ SUBROUTINE.
       CALL ERROR CLN
          IOH PRINT (26,0, OP CODE), GO TO ENDJB..
```

FLOWCHART NUMBER 00015

```
    $PERFORM SUBROUTINE CLN                    (COMMENT    OP CODE = 08)
      DO GET ADDRESS, I = STORAGE / ONE HUNDRED = CHL * ONE HUNDRED
      = NUMBER, STORAGE-NUMBER = SUBROUTINE, IF SUBROUTINE LEQ TWENTY SIX
        THEN GO TO SUBROUTINE TRANSFER LBK SUBROUTINE RBK .$
      IF SUBROUTINE EQU THIRTY NINE            (COMMENT   SUBROUTINE = WD = 39)
        THEN MCH 0500000 ACCUMULATOR, DO SIND, MCH 0601000 ACCUMULATOR,
          GO TO EXIT COMMAND.$
      IF SUBROUTINE EQU FORTY TWO              (COMMENT   SUBROUTINE = WD = 42)
        THEN MCH 0500000 ACCUMULATOR, DO SIN, MCH 0601000 ACCUMULATOR,
          GO TO EXIT COMMAND.$
      IF SUBROUTINE EQU SEVENTY ONE            (COMMENT   SUBROUTINE = WD = 71)
        THEN MCH 0500000 ACCUMULATOR, DO LOG 10, MCH 0601000 ACCUMULATOR,
          GO TO EXIT COMMAND.$
      IF SUBROUTINE EQU SEVENTY TWO            (COMMENT   SUBROUTINE = WD = 72)
        THEN MCH 0500000 FLOATING POINT TEN, MCH 0560000 ACCUMULATOR,
          DO POWER 10, MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.$
      IF SUBROUTINE EQU NINTY SEVEN            (COMMENT   SUBROUTINE = WD = 97)
        THEN MCH 0500000 ACCUMULATOR, DO SQRT, MCH 0601000 ACCUMULATOR,
          GO TO EXIT COMMAND.
        ELSE GO TO ERROR TRANSFER.

        GOTO COS TRANSFER.     GOTO ATAND TRANSFER.
        GOTO ARCTAN TRANSFER. GOTO COSD TRANSFER.  GOTO EXPT TRANSFER.
        GOTO ERROR TRANSFER.  GOTO ERROR TRANSFER.  GOTO ERROR TRANSFER.
        GOTO ERROR TRANSFER.  GOTO LOG E TRANSFER.  GOTO ERROR TRANSFER.
        GOTO ERROR TRANSFER.  GOTO CUBERT TRANSFER. GOTO EXP3 TRANSFER.
        GOTO EXP2 TRANSFER.   GOTO EXP1  TRANSFER.  GOTO TANH TRANSFER.
        GOTO SINH TRANSFER.  GOTO CHECK SUBROUTINE. GOTO SELECT FRACTION.
        GOTO SELECT FRACTION. GOTO SELECT FRACTION. GOTO SELECT FRACTION.
        GOTO SELECT FRACTION. GOTO SELECT FRACTION. GOTO FLOAT TRANSFER.
      SUBROUTINE TRANSFER CLN  GOTO FIX TRANSFER.

      SELECT FRACTION CLN
        FIXED POINT FORMAT LBK SUBROUTINE RBK = FIXED POINT FORMAT,
          GO TO EXIT COMMAND.
      FIX TRANSFER CLN                         (COMMENT   SUBROUTINE = WD = 00)
        IF CHL EQU IRU CHANNEL
          THEN MCH 0500000 ACCUMULATOR, DO FIX, MCH 0601000 IRA,
            GO TO EXIT COMMAND.$
        IF CHL EQU FRAC SEL CHANNEL
          THEN GO TO SELECT FRACTION.
          ELSE GO TO ERROR TRANSFER.
      FLOAT TRANSFER CLN                       (COMMENT   SUBROUTINE = WD = 01)
        IF CHL EQU IRU CHANNEL
          THEN MCH 0500000 IRA, DO FLOAT, MCH 0601000 ACCUMULATOR,
            GO TO EXIT COMMAND.$
        IF CHL EQU FRAC SEL CHANNEL
          THEN GO TO SELECT FRACTION.
          ELSE GO TO ERROR TRANSFER.
      CHECK SUBROUTINE CLN                     (COMMENT   SUBROUTINE = WD = 08)
        IF CHL EQU LOG CHANNEL
          THEN MCH 0500000 ACCUMULATOR, DO LOG 2, MCH 0241000 LOG E 2,
            MCH 4600000 ACCUMULATOR, GO TO EXIT COMMAND.$
        IF CHL EQU POWER CHANNEL
          THEN MCH 0500000 FLOATING POINT TWO, MCH 0560000 ACCUMULATOR,
            DO POWER 2, MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.$
        IF CHL EQU FRAC SEL CHANNEL
          THEN GO TO SELECT FRACTION.
```

```
      ELSE GO TO ERROR TRANSFER.
SINH TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 09)
   MCH 0500000 ACCUMULATOR, DO SINH COSH, GO TO ERROR TRANSFER.
   MCH 0601000 ACCUMULATOR, MCH 4600000 MQ, GO TO EXIT COMMAND.
TANH TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 10)
   MCH 0500000 ACCUMULATOR, DO TANH, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
EXP1 TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 11)
   MCH 0500000 ACCUMULATOR, MCH 0560000 MQ, DO EXP1,
   MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.
EXP2 TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 12)
   MCH 0500000 ACCUMULATOR, MCH 0560000 MQ, DO EXP2,
   MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.
EXP3 TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 13)
   MCH 0500000 ACCUMULATOR, MCH 0560000 MQ, DO EXP3,
   MCH 0601000 ACCUMULATOR, GO TO EXIT COMMAND.
LOG E TRANSFER CLN                     (COMMENT   SUBROUTINE = WD = 17)
   MCH 0500000 ACCUMULATOR, DO LOG E, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
EXPT TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 22)
   MCH 0500000 ACCUMULATOR, DO EXPT, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
COSD TRANSFER CLN                      (COMMENT   SUBROUTINE = WD = 23)
   MCH 0500000 ACCUMULATOR, DO COSD, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
ARCTAN TRANSFER CLN                    (COMMENT   SUBROUTINE = WD = 24)
   MCH 0500000 ACCUMULATOR, DO ARCTAN, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
ATAND TRANSFER CLN                     (COMMENT   SUBROUTINE = WD = 25)
   MCH 0500000 ACCUMULATOR, DO ATAND, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
COS TRANSFER CLN                       (COMMENT   SUBROUTINE = WD = 26)
   MCH 0500000 ACCUMULATOR, DO COS, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
CUBERT TRANSFER CLN                    (COMMENT   SUBROUTINE = WD = 26)
   MCH 0500000 ACCUMULATOR, DO CUBE ROOT, MCH 0601000 ACCUMULATOR,
   GO TO EXIT COMMAND.
ERROR TRANSFER CLN
   IOH PRINT (26,0, SUBROUTINE), GO TO ENDJB..
```

FLOWCHART NUMBER 00016

```
    $INITIATE SELECTIVE PRINT CLN                    (COMMENT   OP CODE = 61)
       COMMAND EXECUTION = PROGRAM STORAGE, ENTER SELECTIVE PRINT
       = COMMAND EXECUTION,
       READ CARD SELECTORS CLN
          DO READ CARD, IOH PRINT (24,0, COL 64, COL 66, COL 68, COL 69,
          COL 70,COL 72,COL 74,COL76,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11),
       CONVERT SELECTOR CLN
          COLUMN K = SECOND SELECTOR A, FOR J EQU 0 STEP 1 UNTIL 1 DO
             BEGIN COLUMN O LBK J RBK + SECOND SELECTOR A * 2 EXP 6
                = SECOND SELECTOR A, END ,
          COLUMN C = SECOND SELECTOR B, FOR J EQU 0 STEP 1 UNTIL 3 DO
             BEGIN COLUMN H LBK J RBK + SECOND SELECTOR B * 2 EXP 6
                = SECOND SELECTOR B, END ,
          IF SELECTOR EQU ONE
             THEN TWO = SELECTOR, SECOND SELECTOR A = FIRST SELECTOR A,
                SECOND SELECTOR B = FIRST SELECTOR B,
                GO TO READ CARD SELECTORS.$
          IF SECOND SELECTOR A NEQ ZERO
             THEN GO TO EXIT COMMAND.$
          IF SECOND SELECTOR B EQU ZERO
             THEN LIST ALL COMMANDS = SECOND SELECTOR $$
             GO TO EXIT COMMAND.
       START SELECTIVE PRINT CLN
          IOH PRINT (30,0,), IF SECOND SELECTOR EQU LIST ALL COMMANDS
             THEN GO TO LIST PROGRAM.$
       LIST SELECTED COMMANDS CLN
          IF MEMORY LBK LOCATION RBK AND OP CODE MASK = OP CODE / TEN
          = BCD NUMBER EQU TWO
             THEN GO TO SELECTIVE PRINT TRANSFER.$
          IF BCD NUMBER EQU ONE
             THEN GO TO SELECTIVE PRINT TRANSFER.$
          IF OP CODE EQU SEVENTY SIX
             THEN GO TO SELECTIVE PRINT TRANSFER.$
          IF OP CODE EQU SEVENTY SEVEN
             THEN GO TO SELECTIVE PRINT TRANSFER.$
          ACCUMULATOR = PAST ACCUMULATOR, DO EXECUTE COMMAND,
          DO GET ADDRESS, DO CONVERT COMMAND TO BCD,
          IF SECOND SELECTOR A AND COMMAND A NEQ FIRST SELECTOR A
             THEN GO TO EXIT SELECT COMMANDS.$
          IF SECOND SELECTOR B AND COMMAND B NEQ FIRST SELECTOR B
             THEN GO TO EXIT SELECT COMMANDS.$
          PRINT SELECTED COMMAND CLN
             I = ADDR, IF ACCUMULATOR NEQ PAST ACCUMULATOR
                THEN IOH PRINT (31,0, LOCATION, INDEX, OP CODE, ADDR,
                   ACCUMULATOR)$
                ELSE IOH PRINT (32,0, LOCATION, INDEX, OPCODE, ADDR)$
          EXIT SELECT COMMANDS CLN
             LOCATION + ONE = LOCATION, GO TO LIST SELECTED COMMANDS.
          SELECTIVE PRINT TRANSFER CLN
             DO GET ADDRESS, DO CONVERT COMMAND TO BCD,
             IF SECOND SELECTOR A AND COMMAND A NEQ FIRST SELECTOR A
                THEN GO TO EXECUTE TRANSFER COMMAND.$
             IF SECOND SELECTOR B AND COMMAND B NEQ FIRST SELECTOR B
                THEN GO TO EXECUTE TRANSFER COMMAND.$
             I = ADDR, IOH PRINT (32,0, LOCATION, INDEX, OP CODE, ADDR),
             EXECUTE TRANSFER COMMAND CLN
                DO EXECUTE COMMAND, LOCATION + ONE = LOCATION,
```

```
GO TO LIST SELECTED COMMANDS.
PROCEDURE   CONVERT COMMAND TO BCD CLN
   BEGIN BCD NUMBER * TEN = NUMBER, INDEX * 2 EXP 12 + BCD NUMBER
      * 2 EXP 6 + OPCODE - NUMBER = COMMAND A,
   I = STORAGE, FOR J EQU 0 STEP 1 UNTIL 3 DO
      BEGIN STORAGE / TEN THOUSAND LBK J RBK = BCD NUMBER LBK J RBK
         * TEN THOUSAND LBK J RBK = NUMBER,
         STORAGE - NUMBER = STORAGE, END ,
   BCD NUMBER = COMMAND B, FOR J EQU 1 STEP 1 UNTIL 3 DO
      BEGIN COMMAND B * 2 EXP 6 + BCD NUMBER LBK J RBK
         = COMMAND B, END ,
   COMMAND B * 2 EXP 6 + STORAGE = COMMAND B, END ,

LIST PROGRAM CLN
   IF MEMORY LBK LOCATION RBK AND OP CODE MASK = OP CODE / TEN
   = STORAGE EQU TWO
      THEN GO TO PRINT TRANSFER.$
   IF STORAGE EQU ONE
      THEN GO TO PRINT TRANSFER.$
   IF OP CODE EQU SEVENTY SIX
      THEN GO TO PRINT TRANSFER.$
   IF OP CODE EQU SEVENTY SEVEN
      THEN GO TO PRINT TRANSFER.$
   ACCUMULATOR = PAST ACCUMULATOR, DO EXECUTE COMMAND,
   DO GET ADDRESS, I = ADDR, IF ACCUMULATOR NEQ PAST ACCUMULATOR
      THEN IOH PRINT (31,0, LOCATION, INDEX, OP CODE, ADDR,
         ACCUMULATOR)$
      ELSE IOH PRINT (32,0, LOCATION, INDEX, OP CODE, ADDR)$
      LOCATION + ONE = LOCATION, GO TO LIST PROGRAM.
   PRINT TRANSFER CLN
      DO GET ADDRESS, I = ADDR, IOH PRINT (32,0, LOCATION, INDEX,
      OP CODE, ADDR), DO EXECUTE COMMAND, LOCATION + ONE
      = LOCATION, GO TO LIST PROGRAM.

STOP SELECTIVE PRINT CLN                          (COMMENT   OP CODE = 62)
   IOH PRINT (33,0,), PROGRAM STORAGE = COMMAND EXECUTION, ZERO
   = FIRST SELECTOR A = FIRST SELECTOR B = SECOND SELECTOR A
   = SECOND SELECTOR B = SECOND SELECTOR, ONE = SELECTOR,
   GO TO EXIT COMMAND..
```

FLOWCHART NUMBER 00017

```
     $ PROCEDURE  COMMAND CARD CONVERSION CLN
         BEGIN COLUMN 64 = INDEX, COLUMN 66 * TEN + COLUMN 68 = OP CODE,
         COLUMN 70 * TEN + COLUMN 72 = CHL, IF COL 69 NEQ BLANK
          THEN COLUMN 69 * ONE HUNDRED + CHL = CHL $$
          COLUMN 74*TEN + COLUMN 76 = WD, CHL*ONE HUNDRED+WD = ADDR, END ,
      PROCEDURE   DATUM CARD CONVERSION CLN
         BEGIN COLUMN 64 * TEN + COLUMN 66 - FIFTY FIVE = EXPONENT,
         COLUMN 68 = NUMBER, FOR J EQU 0 STEP 1 UNTIL 3 DO
            BEGIN COLUMN 70 LBK J RBK + NUMBER * TEN = NUMBER, END ,
         FLOAT NUMBER CLN
            NUMBER + FLOAT CONSTANT = DATUM, FLOAT CONSTANT + DATUM = DATUM,
            IF EXPONENT LSS ZERO
               THEN ZERO - EXPONENT = EXPONENT,
                  FOR J EQU 1 STEP 1 UNTIL EXPONENT DO
                     BEGIN DATUM / FLOATING POINT TEN = DATUM, END ,
                     GO TO EXIT CONVERSION.$
             IF EXPONENT GTR ZERO
               THEN FOR J EQU 1 STEP 1 UNTIL EXPONENT DO
                  BEGIN DATUM * FLOATING POINT TEN = DATUM, END ,$$
         EXIT CONVERSION CLN
            IF SIGN EQU MINUS
            THEN ZERO - DATUM = DATUM $$ END ,
      PROCEDURE   GET ADDRESS CLN
         BEGIN IF ADDRESS SEPARATION NEQ PERFORMED
            THEN CELL LBK LOCATION RBK (7=10) = INDEX,
               CELL LBK LOCATION RBK (18=26) = CHL,
               CELL LBK LOCATION RBK (11=17) = WD $$
         IF CHL EQU TWENTY ONE
            THEN OUTPUT CONSTANT - ACCUMULATOR ADDRESS = I,
               GO TO EXIT GET ADDRESS.$
         IF WD GEQ ONE HUNDRED TWO
            THEN WD - ONE HUNDRED TWO = WD * ELEVEN + CHL - EIGHT
               = IR COMP ADDRESS, OUTPUT CONSTANT + IR COMP ADDRESS
               - W DIFFERENCE ADDRESS = I, GO TO EXIT GET ADDRESS.$
         IF INDEX EQU ZERO
            THEN ONE HUNDRED * CHL + WD = I $
            ELSE ONE HUNDRED * CHL + WD + W BASE LBK INDEX RBK
               + C BASE LBK INDEX RBK = I $
         EXIT GET ADDRESS CLN
            ZERO = ADDRESS SEPARATION, END ,

      PROCEDURE   COMMAND SEPARATION CLN
         BEGIN IF ADDRESS SEPARATION NEQ PERFORMED
            THEN CELL LBK LOCATION RBK (7=10) = INDEX,
               CELL LBK LOCATION RBK (18=26) * ONE HUNDRED = CHL,
               CELL LBK LOCATION RBK (11=17) + CHL = ADDR $
            ELSE CHL * ONE HUNDRED = CHL + WD = ADDR $ END ,

      PROCEDURE   COMMAND SEPARATE CLN
         BEGIN IF ADDRESS SEPARATION NEQ PERFORMED
            THEN CELL LBK LOCATION RBK (7=10) = INDEX,
               CELL LBK LOCATION RBK (18=26) = CHL,
               CELL LBK LOCATION RBK (11=17) = WD $$ END ,..
```

FLOWCHART NUMBER 00020

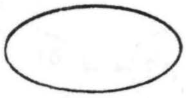
```
    CONTROL
      1(10C6,C3,2(C1,1X)3C1,5(1XC1))
      3(2XN5,3X2(N2,1X)N5,5X10C6,C3)
      4(8H EXECUTE2X2(N2,1X)N5,5X10C6,C3)
      5(2XN5,2XE15.7,2X10C6,C3)
      6(/7H  STORE4X10HK OP  ADDR)
      7(/18H  STORE       DATA)
      8(12H1MANUAL MODE///11X10HK OP  ADDR)
      9(15H1AUTOMATIC MODE///)
      10(24C1)
      11(/11H  DING DONG/X)
      12(/53H  BREAKPOINT HALT NOT ALLOWED. TRANSFERRED TO ENDJOB.)
      13(/12H  OP CODE = N2,36H NOT DEFINED. TRANSFERRED TO ENDJOB.)
      14(/57H  END OF FILE WHILE READING CARDS. TRANSFERRED TO ENDJOB.)
      15(/51H  ERROR WHILE READING CARDS. TRANSFERRED TO ENDJOB.)
      16(/18H  LOAD SUBROUTINES)
      17(35H      FIXED POINT FRACTION LENGTH = N1,/26H  EXIT LOADING SUBRO
1      UTINES/X)
      18(36H      FIXED POINT FRACTION LENGTH = 7  /26H  EXIT LOADING SUBRO
1      UTINES/X)
      19(42H      SQUARE ROOT AND CUBE ROOT IN CHANNEL N3)
      20(20H      LOG IN CHANNEL N3)
      21(22H      POWER IN CHANNEL N3)
      22(24H      SIN COS IN CHANNEL N3)
      23(23H      ARCTAN IN CHANNEL N3)
      24(10H SELECTOR 2(1XC1)C1,1X5C1,5X10C6,C3)
      25(43H      INDEX REGISTER UTILIZATION IN CHANNEL N3)
      26(/17H  SUBROUTINE N = N2,36H NOT DEFINED. TRANSFERRED TO ENDJOB.)
      27(37H      HYPERBOLIC FUNCTIONS IN CHANNEL N3)
      28(34H      FRACTION SELECTOR IN CHANNEL N3)
      29(35H      SELECTIVE PRINT IN CHANNEL   8)
      30(22H BEGIN SELECTIVE PRINT//11H   LOCATION7X7HCOMMAND10X11HACCUMUL
1      ATOR/17X10HK OP  ADDR)
      31(4XN5,7X2(N2,1X)N5,5XE15.7)
      32(4XN5,7X2(N2,1X)N5)
      33(/20H END SELECTIVE PRINT/X)
      34(17H      CLEAR MEMORY)
      35(37H      CLEAR MEMORY AND INDEX REGISTERS)
```

Appendix G

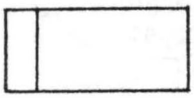
A SYNTACTICAL FLOWCHART

for BC NELIAC

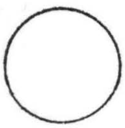
As an aid in understanding the syntactical rules of BC NELIAC a flowchart similar to the ALGOL 60 Flowchart has been developed. The shapes of enclosure on the chart have the following meanings:



Metalinguistic variables appear in ellipses and indicate the enclosed variable is defined at that place on the chart.



Metalinguistic variables appearing in rectangles means the variable is defined elsewhere on the chart. Grid co-ordinates for the definition appear at the left of the rectangle.



Basic symbols are enclosed in circles.

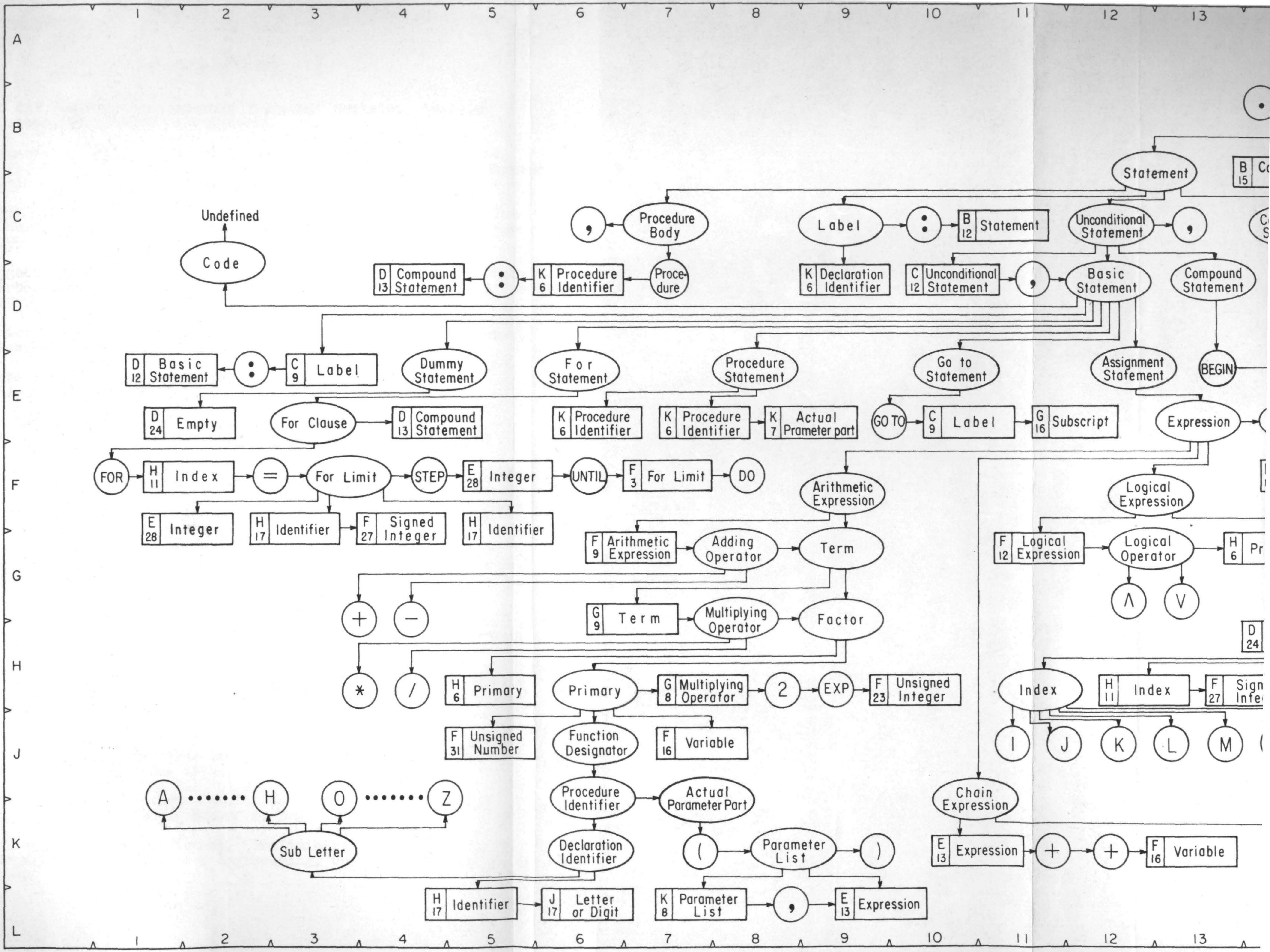
↓

Vertical arrows indicate a definition of a metalinguistic variable follows.

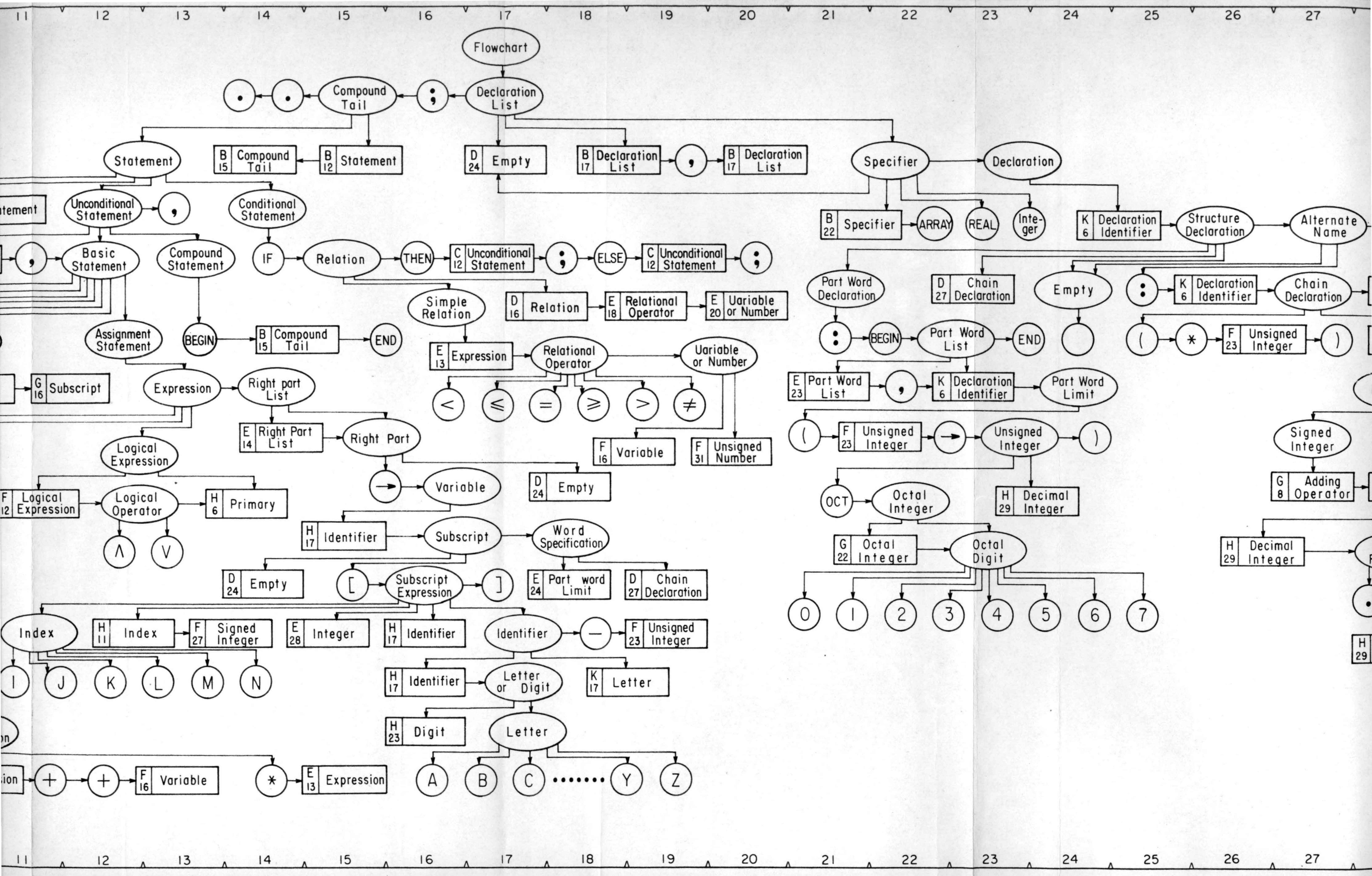
→

Horizontal arrows connect the basic symbols metalinguistic variables which form a definition.

Every metalinguistic formula used to describe BC NELIAC appears on the syntactical flowchart.



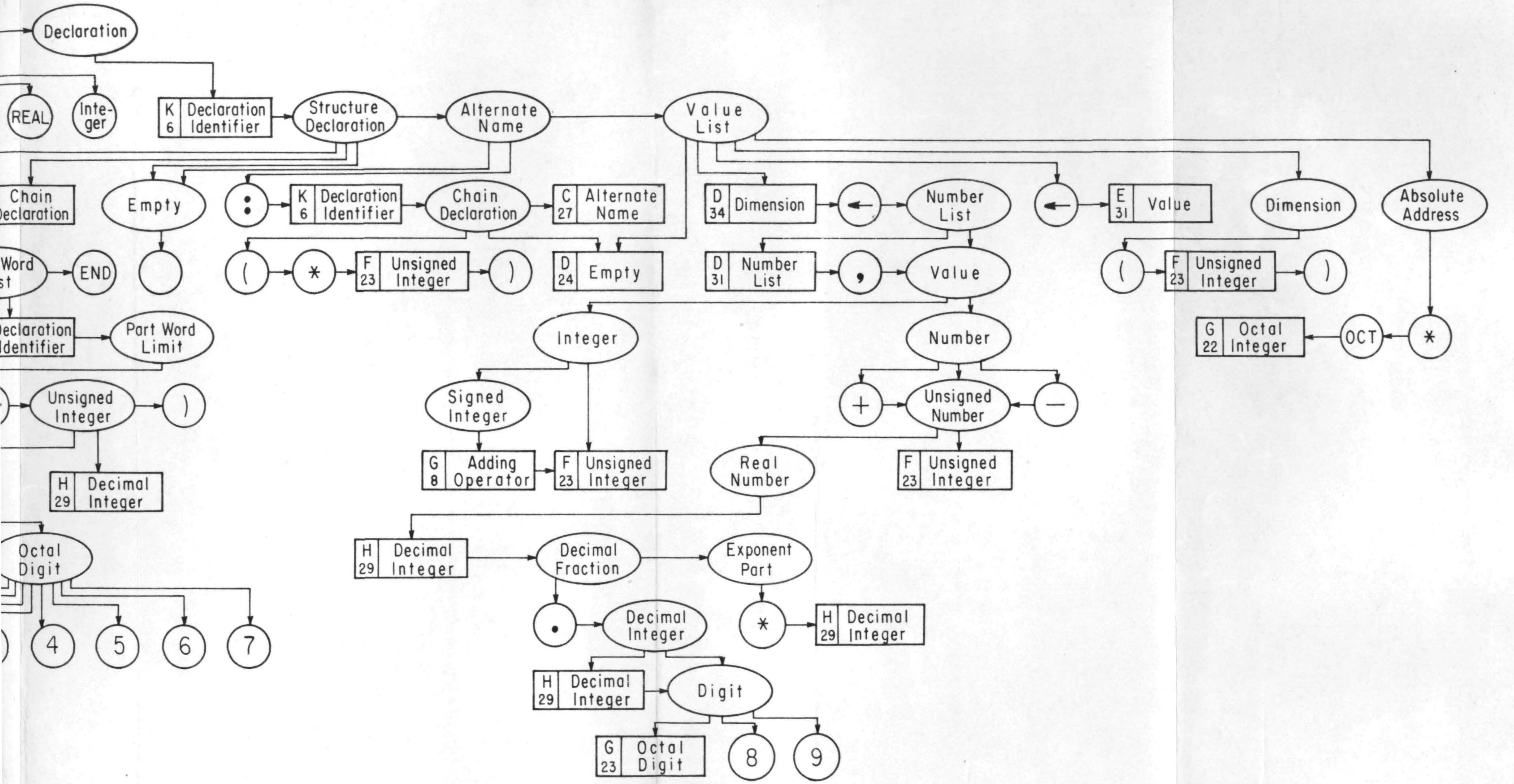
Statement
Procedure Body
Label
Statement
Unconditional Statement
Undefined
Code
Compound Statement
Procedure Identifier
Procedure
Declaration Identifier
Unconditional Statement
Basic Statement
Compound Statement
Basic Statement
Label
Dummy Statement
For Statement
Procedure Statement
Go to Statement
Assignment Statement
BEGIN
Empty
For Clause
Compound Statement
Procedure Identifier
Procedure Identifier
Actual Prameter part
GO TO
Label
Subscript
Expression
FOR
Index
=
For Limit
STEP
Integer
UNTIL
For Limit
DO
Arithmetic Expression
Logical Expression
Integer
Identifier
Signed Integer
Identifier
Arithmetic Expression
Adding Operator
Term
Logical Expression
Logical Operator
+
−
Term
Multiplying Operator
Factor
*
/
Primary
Primary
Multiplying Operator
2
EXP
Unsigned Integer
Index
Index
Unsigned Number
Function Designator
Variable
I
J
K
L
M
A
H
O
Z
Procedure Identifier
Actual Parameter Part
Chain Expression
Sub Letter
Declaration Identifier
(
Parameter List
)
Expression
+
+
Variable
Identifier
Letter or Digit
Parameter List
,
Expression



11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Flowchart
Declaration List
;
Compound Tail
.
.
Statement
B 15 Compound Tail
B 12 Statement
D 24 Empty
B 17 Declaration List
,
B 17 Declaration List
Specifier
Declaration
tement
Unconditional Statement
,
Conditional Statement
B 22 Specifier
ARRAY
REAL
Inte- ger
K 6 Declaration Identifier
Structure Declaration
Alternate Name
,
Basic Statement
Compound Statement
IF
Relation
THEN
C 12 Unconditional Statement
;
ELSE
C 12 Unconditional Statement
;
Part Word Declaration
D 27 Chain Declaration
Empty
:
K 6 Declaration Identifier
Chain Declaration
Simple Relation
D 16 Relation
E 18 Relational Operator
E 20 Uariable or Number
Assignment Statement
BEGIN
B 15 Compound Tail
END
E 13 Expression
Relational Operator
Uariable or Number
:
BEGIN
Part Word List
END
(
*
F 23 Unsigned Integer
)
G 16 Subscript
Expression
Right part List
<
≤
=
≥
>
≠
E 23 Part Word List
,
K 6 Declaration Identifier
Part Word Limit
E 14 Right Part List
Right Part
F 16 Variable
F 31 Unsigned Number
(
F 23 Unsigned Integer
Unsigned Integer
)
Signed Integer
Logical Expression
→
Variable
D 24 Empty
F 12 Logical Expression
Logical Operator
H 6 Primary
OCT
Octal Integer
H 29 Decimal Integer
G 8 Adding Operator
Λ
V
H 17 Identifier
Subscript
Word Specification
G 22 Octal Integer
Octal Digit
H 29 Decimal Integer
D 24 Empty
[
Subscript Expression
]
E 24 Part word Limit
D 27 Chain Declaration
Index
H 11 Index
F 27 Signed Integer
E 28 Integer
H 17 Identifier
Identifier
—
F 23 Unsigned Integer
0
1
2
3
4
5
6
7
I
J
K
L
M
N
H 17 Identifier
Letter or Digit
K 17 Letter
H 29
H 23 Digit
Letter
ion
+
+
F 16 Variable
*
E 13 Expression
A
B
C
Y
Z
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

NELIAC

SYNTACTICAL CHART



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