BENDIX G-15 COMPUTER • PROGRAMMING SYSTEM

intercom 500

THE INTERCOM 500 PROGRAMMING SYSTEM FOR THE BENDIX G-15 GENERAL PURPOSE DIGITAL COMPUTER

SOME TERMS DEFINED...

A COMMAND is an instruction to the computer to perform specific operations. INTERCOM commands are listed at the end of the manual.

A PROGRAM is a set of commands which, when obeyed by the computer, result in the solution to a problem.

An INTERNALLY-PROGRAMMED COMPUTER is an electronic calculating machine with an internal memory in which the program and data may be stored and from which commands may be automatically obeyed.

A DIGIT is any arithmetic integer from 0 to 9. In some cases the letter "u" is used to represent in one digit the quantity normally written with the digits "10".

A WORD is a group of digits which represent either a numerical value or a command to the computer. Both numerical value words and command words may be stored in the internal memory.

An ADDRESS is a number which specifies a location in the computer's internal memory.

A FIXED POINT number is a positive or negative numerical value expressed in ordinary notation, such as "-327.65".

A FLOATING POINT number is a positive or negative numerical value expressed in scientific notation, such as "$-.32765 \times 10^{3}$".

INTERCOM 500 is the name given to a simple programming system for the Bendix G-15 Computer in which data, that is, numerical values, may be read into and out of the computer in either fixed point or floating point notation.

PROGRAMMING WITH INTERCOM 500

INTRODUCTION

INTERCOM 500 is an easy-to-use programming system which does not require specialized knowledge. Completely self-contained, it has facilities for computer control, input, output and program checking as well as program preparation.

INTERCOM 500 differs from INTERCOM 1000 in that it is a single-precision system, offering more speed and flexibility than the single-precision mode of INTERCOM 1000. This manual provides all information required to operate INTERCOM 500. However, because of the similarities with INTERCOM 1000, points of significant difference have been emphasized by means of a vertical line in the left margin.

A single INTERCOM command causes execution of a number of internal operations in the computer. Since the programmer need have no knowledge of the varied internal operations performed by each INTERCOM command, and since decimal points in numbers are handled automatically, the time and skill required for programming is greatly reduced.

Command Structure

The computer is given its instructions in the form of numerically expressed commands which can be held in the internal memory. Each command is expressed by seven digits.

FORM OF A COMMAND

Index Register | Operation Code | Address

The first digit represents an index register; if no index register is used, the first digit is zero and need not be

written. Index registers simplify the programming of automatic address modification and need be considered only when this feature is desired.

The next two digits consist of a code that specifies the operation to be performed. The operation codes are listed at the end of the manual.

The last four digits normally specify the location in the memory to which the operation refers.

During input, commands are converted to a binary form which can be interpreted faster than the binary-coded-decimal form used in INTERCOM 1000.

Internal Memory

The Bendix G-15 Computer uses a magnetic drum for its internal memory.

A location in the memory of the computer is specified by a four-digit number called an "address." The first two digits refer to a channel on the magnetic drum; the last two digits refer to the word position in the channel.

In INTERCOM 500 memory locations numbered from 0900 to 1899, inclusive, may be used by the programmer. If the selective print routine is not to be used, channel 08 is also available to the programmer. The memory locations not available to the programmer are used by the computer to hold instructions which control the operation of the INTERCOM system.

A command may be stored at, and executed from, any available address.

A numerical value also may be stored at any address in INTERCOM 500.

Additional data and command storage is provided by punched paper tape. An INTERCOM command permits any portion of the internal memory to be punched on paper tape at any time during the program; a second command permits punched paper tape to be read into the memory at high speed at any time during the program.

Command Sequence

Commands are normally obeyed in the numerical sequence of their memory locations. The computer is told the address of the first command to be obeyed. After execution of this command, the computer will automatically obey, in turn, the command in each following address.

Commands are available which transfer control to a command other than the next one in sequence. The computer will then obey commands in the new sequence.

A command to transfer control may be unconditional or may be contingent on the nature of a calculated value.

The address of the transfer of control command may, if desired, be remembered by the computer in order to return control later to the original command sequence. There are two "Mark Place and Transfer Control" commands for this purpose. For each of these two commands there is a "Return" command which transfers control back to the location immediately following the last corresponding "Mark Place and Transfer Control" command.

The two pairs of such commands make it possible to incorporate two levels of subprogram operation; that is, a first "Mark Place and Transfer" command can transfer control to a separate sequence of commands, and while in that subprogram, the second "Mark Place and Transfer" command can transfer control to still another sequence of commands.

Form of Input Data

Fixed point data may be read into the computer with any number of significant digits up to a maximum of five. Numbers may be either positive or negative. There may be any number of places in the data up to thirteen, and the decimal point may occur anywhere.

Example:

> The number "3 212 340." has seven places and has six significant digits. (Zeros before the first non-zero digit, or after the last non-zero digit, are not significant.)

Example: (Cont'd.)

It would be necessary to reduce the number of significant digits to five and the number "3 212 300." would be entered into the computer.

If floating point notation is used, the decimal fraction may be expressed with any number of digits up to the maximum of five.

The multiplier of the decimal fraction may range in value from 10^{-37} to 10^{37}. The exponent of 10 is expressed as an excess-fifty number preceding the decimal point.

Example:

The fixed point number -12.345 may be expressed in scientific form as $-.12345 \times 10^{2}$. If fixed point notation is used, there is no change in the form of the number during input. If scientific notation is used, 2 (the exponent of 10) is added to 50 and the number is written -52.12345.

Example:

The fixed point number .00012 may be expressed in scientific form as $.12 \times 10^{-3}$. If fixed point notation is used, there is no change in the form of the number during input. If scientific notation is used, -3 (the exponent of 10) is added to 50 and the number is written 47.12.

Form of Output Data

Data may be typed out by the computer as positive or negative decimal numbers in either fixed point or floating point notation. Up to five significant digits may be typed out.

If type-out is in floating point notation, its form and range are the same as during input.

A number typed out in fixed point notation may have as many as fourteen places. The number of these places, through a maximum of seven, to the right of the decimal point may be selected by the

programmer. A number, the magnitude of which exceeds the fixed point limit, will be typed out in floating point notation.

Decimal points in columns of data will be automatically lined up in a straight vertical line during type-out.

Numbers Too Large and Too Small

As a result of an arithmetic operation, a number may become too large to be handled by the computer. In that situation, an "overflow" is said to have occurred and computation automatically halts. The program must then be rewritten so that the capacity of the computer is not exceeded.

An overflow is unlikely to occur in the INTERCOM 500 programming system because all numerical values are handled internally in floating point form; there is no overflow unless the result of computation exceeds 10^{38}.

The significance of small numbers is not lost during computation since the internal exponent may become as small as 10^{-38}. Values with exponents smaller than 10^{-38} are considered to be equal to zero.

The Accumulator

A special location in the internal memory is called the accumulator. An arithmetic command causes a numerical value stored in the memory, to be added to, be subtracted from, be multiplied by, be divided by, or be divided into, the number in the accumulator. The result of such an arithmetic operation becomes the new contents of the accumulator.

The accumulator has the address 2101. For the convenience of the operator, the typewriter input sequence tests all commands typed in for an address equal to 2100. When this address is entered, it is replaced by 2101 and converted to the proper form before storing. In addition to these two addresses, any modulo 4 number + 1 (one plus a multiple of four) between 2100 and 2199 may be used. That is, 2105, 2109, ..., 2173, etc.

For squaring, negating, doubling, or taking the absolute value of the contents of the accumulator, the address 2173 yields the answer one drum cycle faster than other accumulator addresses.

Constants

The numerical constants zero and one are often needed in a program. They may be obtained without first storing them in the memory of the computer. A value of zero may be placed in the accumulator by executing the "Subtract" command with the address of the accumulator in the address portion of the command. If the accumulator does not contain zero, a value of one may be placed in it by executing the "Divide" command with the address of the accumulator in the address portion of the command.

A PROGRAMMING EXAMPLE

The portion of an INTERCOM 500 program which follows is for the calculation of $\frac{a^2-bc}{d}$ where a, b, c and d are stored at addresses 1100, 1101, 1102 and 1103, respectively.

	Command Location	Operation Code	Address
Clear accumulator and add b	0900	42	1101
Multiply b, in accumulator, by c	0901	44	1102
Store bc	0902	49	1104
Clear accumulator and add a	0903	42	1100
Multiply a, in accumulator, by a	0904	44	2101
Subtract bc from a^2	0905	41	1104
Divide a^2-bc, in accumulator, by d	0906	48	1103
Type out contents of accumulator in fixed point form	0907	33	2101

DESCRIPTION OF COMMANDS

In the descriptions following, the letter K stands for the index register number, if any; the letters ADDR stand for the four digits of the address.

In the following examples, even-numbered addresses have been used for compatibility with the INTERCOM 1000 manual; in INTERCOM 500 odd-numbered addresses are equally valid.

Arithmetic Commands

CLEAR AND SUBTRACT . . . . . K 40 ADDR

The contents of the accumulator are replaced by the contents of address ADDR, with the sign reversed.

Example:

> Address 1014 contains the number 23.456. After the command 40 1014 is obeyed, the accumulator contains -23.456. The contents of address 1014 are unchanged.

SUBTRACT . . . . . K 41 ADDR

The contents of address ADDR are subtracted from the contents of the accumulator. The difference replaces the previous contents of the accumulator.

Example:

> Address 1126 contains the number .0222 and the accumulator contains the number .0666. After the command 41 1126 is obeyed, the accumulator contains the number .0444. The contents of address 1126 are unchanged.

CLEAR AND ADD . . . . . .K 42 ADDR

The contents of the accumulator are replaced by the contents of address ADDR.

Example:

Address 1212 contains the number 321.5. After the command 42 1212 is obeyed, the accumulator contains 321.5 also.

ADD . . . . . .K 43 ADDR

The contents of address ADDR are added to the contents of the accumulator. The sum replaces the previous contents of the accumulator.

Example:

Address 1322 contains the number 321.5 and the accumulator contains the number 210.3. After the command 43 1322 is obeyed, the accumulator contains the number 531.8. The contents of address 1322 are unchanged.

MULTIPLY . . . . . K 44 ADDR

The contents of the accumulator are multiplied by the contents of address ADDR. The product replaces the previous contents of the accumulator.

Example:

Address 1416 contains the number 20.3. The accumulator contains the number 4. After the command 44 1416 is obeyed, the accumulator contains the number 81.2. The contents of address 1416 are unchanged.

CLEAR AND ADD ABSOLUTE VALUE . . . . . K 45 ADDR

The contents of the accumulator are replaced by the absolute value of the contents of address ADDR.

Example:

Address 1544 contains the number -321.5. After the command 45 1544 is obeyed, the accumulator contains the number 321.5. The contents of address 1544 are unchanged.

INVERSE DIVIDE . . . . . K 47 ADDR

The contents of address ADDR are divided by the contents of the accumulator. The quotient replaces the previous contents of the accumulator.

Example:

> Address 1518 contains the number 126.6 and the accumulator contains the number 42.2. After the command 47 1518 is obeyed, the accumulator contains the number 3. The contents of address 1518 are unchanged.

DIVIDE . . . . . K 48 ADDR

The contents of the accumulator are divided by the contents of address ADDR. The quotient replaces the previous contents of the accumulator.

Example:

> Address 1518 contains the number 42.2 and the accumulator contains the number 126.6. After the command 48 1518 is obeyed, the accumulator contains the number 3. The contents of address 1518 are unchanged.

STORE . . . . . K 49 ADDR

The contents of the accumulator are stored at location ADDR, replacing the previous contents of ADDR.

Example:

> Address 1610 contains the number 6705 and the accumulator contains the number 833.3. After the command 49 1610 is obeyed, location 1610 contains the number 833.3 also.

Transfer of Control Commands

TRANSFER CONTROL IF ACCUMULATOR
POSITIVE OR ZERO. . . . . K 20 ADDR

Control is transferred to the command located in address ADDR only if the contents of the accumulator are either zero or positive. If the contents of the accumulator are negative, the next command obeyed will be the one in normal sequence.

Examples:

The command 20 1526 is stored in location 1318. The accumulator contains the number .0365. After execution of this command, the next command obeyed is from location 1526.

The command 20 1738 is stored in location 1210. The accumulator contains the number -.0365. After execution of this command, the next command obeyed is from location 1211.

TRANSFER CONTROL IF ACCUMULATOR
NEGATIVE . . . . . K 22 ADDR

Control is transferred to the command located in address ADDR only if the contents of the accumulator are negative. If the contents of the accumulator are zero or positive, the next command obeyed will be the one in normal sequence.

Examples:

The command 22 1442 is stored in location 1132. The accumulator contains the number -.0365. After execution of this command, the next command obeyed is from location 1442.

The command 22 1642 is stored in location 1144. The accumulator contains the number .0365. After execution of this command, the next command obeyed is from location 1145.

TRANSFER CONTROL IF ACCUMULATOR
ZERO . . . . . .K 23 ADDR

Control is transferred to the command in ADDR only if the contents of the accumulator are zero. If the accumulator contains a non-zero quantity, the next command obeyed will be the one in normal sequence.

Example:

> The command 23 1746 is stored in location 1161. The accumulator contains zero. After execution of this command the next command obeyed is from location 1746.

MARK PLACE AND TRANSFER I . . . . . K 26 ADDR

Control is transferred to the command in location ADDR. The address of the "Mark Place and Transfer" command is stored in a special register.

Example:

> The command 26 1877 is stored in location 1113. Upon execution of this command, the address 1113 is stored in a special register and the next command obeyed is from location 1877.

MARK PLACE AND TRANSFER II . . . . . .K 28 ADDR

Control is transferred to the command in location ADDR. The address of the "Mark Place and Transfer" command is stored in another special register.

RETURN TO MARKED PLACE I 16 0000

Control is transferred to the command located immediately subsequent to the last "Mark Place and Transfer I" command. This command has no meaning unless it is preceded in the program by a "Mark Place and Transfer I" command.

Example:

In the preceding example, the command 16 0000, situated at a later point in the program than the command 26 1877, would return control to the command located in address 1114.

RETURN TO MARKED PLACE II 18 0000

Control is transferred to the command located immediately subsequent to the last "Mark Place and Transfer II" command. This command is meaningless unless it is preceded in the program by a "Mark Place and Transfer II" command.

TRANSFER CONTROL, UNCONDITIONALLY . . . K 29 ADDR

Control is transferred to the command located in address ADDR.

Example:

The command 29 1623 is stored in location 1234. After execution of this command, the next command obeyed is from location 1623.

Input-Output Commands

PERMIT COMMAND TYPE-IN . . . . . .K 50 ADDR

Computation will halt. If a command, followed by (tab) Ⓢ , is now typed by the operator, the command will be stored in location ADDR and computation will be continued.

PERMIT TYPE-IN OF DATA . . . . . .K 51 ADDR

Computation will halt. If a number, followed by (tab) Ⓢ , is now typed by the operator, the number will be stored in location ADDR and computation will be continued.

Fixed or floating point numbers may be typed. A number written without an exponent is a fixed point number. These may contain up to 13 digits, with a maximum of five significant digits. The position of the decimal point must be indicated by a slash "/" or "." even though the number is an integer.

Example:

> The quantities written as 0, 3.5, 400.0, -.05, -700.5, and -8 in conventional notation are typed in as: 0/, 3/5, 400/0, -/05, -700/5, and -8/.

A number written with an exponent is a floating point number. Floating point numbers are written with a 2-digit, excess-fifty exponent followed by a one- to five-digit mantissa. A decimal point (not the slash) may be typed between the second and third digits for visual separation of exponent and mantissa, but no corresponding character enters the computer.

Example:

> The quantity written as 12.43 in conventional notation is typed, in scientific notation, as 52.1243.

Zeros may be entered with or without a decimal point or exponent.

Examples:

> 0, 0/, /0, and 500.

A floating point zero will have the hexadecimal form "00000zz".

PERMIT TYPE-IN OF FLOATING POINT
DATA . . . . . K 52 ADDR

Computation will halt. If a floating point number, followed by (tab) Ⓢ, is now typed by the operator, the number will be stored in location ADDR and computation will be continued.

TYPE FIXED POINT NUMBER AND TAB . . . . . .K 33 ADDR

The contents of location ADDR are typed out in fixed point notation with the decimal point properly positioned. The typewriter carriage moves to the next tab stop.

TYPE FIXED POINT NUMBER AND
RETURN CARRIAGE . . . . . K 38 ADDR

The contents of location ADDR are typed out in fixed point notation with the decimal point properly positioned. The typewriter carriage moves to the beginning of the next line.

Note: The format for fixed point output is held in locations 0714, 0715, and 0716. For information required to control this fixed point output format, see the INTERCOM 500 Technical Manual (A.S.P. 113), page 76.

TYPE FLOATING POINT NUMBER AND
TAB . . . . . K 32 ADDR

The contents of location ADDR are typed out in floating decimal point notation; the typewriter carriage moves to the next tab stop.

TYPE FLOATING POINT NUMBER AND
RETURN CARRIAGE . . . . . K 34 ADDR

The contents of location ADDR are typed out in floating decimal point notation; the typewriter carriage moves to the beginning of the next line.

READ PUNCHED TAPE PREPARED BY
COMPUTER . . . . . .K 55 ADDR

Punched tape, previously punched by the computer, is photoelectrically 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.

Any digits through u0 may be used in the least significant digit positions of ADDR to read a corresponding number of words up to and including 100. The use of 00 and any number in the range u1-u7 will cause 106 words to be read into 00-99 and u2-u7, leaving only u0 and u1. Note that this destroys the index register in the affected channel.

PUNCH PAPER TAPE . . . . . .K 39 ADDR

The contents of words 00 through ADDR-1 of the channel determined by the first two digits of ADDR are punched on paper tape. If words 00-03 of the channel to be punched are equal to zero*, a non-zero number (012023z) is copied into word 00 before punching begins.

POSITION TYPEWRITER PAPER . . . . . K 30 TB CR

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.

TYPE TABULATING NUMBER AND TAB . . . . .K 31 TABL

The number TABL is typed out without leading or following zeros. After the type-out the typewriter carriage will move to the next tab stop. TABL is a four-digit number ranging from 0000 to 3000.

The command is useful for the automatic numbering of rows of data since the numbers 1 to 3000 may be typed out.

TYPE COMMAND FROM MEMORY AND TAB . . . . .35 ADDR

The command in location ADDR will be converted to binary coded decimal, and typed out in the form:

"K Operation Code ADDR"

TYPE MEMORY IN HEXADECIMAL AND TAB . . . .37 ADDR

The contents of location ADDR are automatically typed out in hexadecimal form.

Special Commands

DO NOTHING 00 0000

This command is useful in a command sequence for reserving a location into which another command may be put conditionally.

* machine zero = .0000000

RING BELL 63 0000

The bell chimes once.

HALT AND PERMIT MANUAL OPERATION 67 0000

Computation is halted and the computer is put in the manual operating mode.

BREAKPOINT HALT 68 0000

Computation is halted. Automatic computation may be resumed by moving the Compute switch on the typewriter base from GO to the center position and back to GO.

COMPUTE AUTOMATICALLY . . . . . 69 ADDR

Computation is begun with the command in location ADDR, and proceeds automatically until the command "Halt and Permit Manual Operation" is obeyed.

PERFORM SUBROUTINE . . . . . .K 08 ADDR

The machine language subroutine, which begins at location ADDR, is executed.

BLOCK COPY . . . . . .K 81 CHWD

The contents of words u2-u7 and of 00-(WD-1) of channel CH are copied into the corresponding words of channel (08 + K). Note that if a channel having an index register is copied into, the index register stored in words u2-u7 of that channel will be disturbed.

Example:

> If it is desired to copy the first 50 words of channel 11 into the corresponding words of channel 12, write 4 81 1150. This will disturb the contents of index register 4.

INDEX REGISTERS

By use of an index register the computer can be instructed to obey the same group of commands a number of times, each time using data from a different set of addresses. Convenient means is also provided for tallying repetitive execution of a group of commands.

Each command which is used with an index register operates on the contents of an address, determined by adding a selected value to the address specified in the command. The command itself is left unchanged in the memory of the computer.

The same index register may be used with any number of commands. INTERCOM 500 provides ten index registers numbered from 1 to 9 and u in order that separate groups of commands in a program may have their effective addresses modified in different ways. The number of the index register is put in the K position of each command in which the address is to be modified by that index register.

Each index register is composed of two halves, named "W" and "C". Each half has three components: a base, a difference, and a limit. The base is that quantity which is picked up by a command using an index register to modify the address held in the command. The difference is that quantity by which the base is regularly incremented for address modification. The limit is the maximum quantity to which the base is allowed to increment. An indexed operation is terminated when the base value has been incremented to exceed the corresponding limit value.

The high-order ends of channels 9 through 18 contain index registers 1 through u, respectively. In each of these channels the six index register components occupy the following words:

u2	W Difference
u3	W Limit
u4	W Base
u5	C Base
u6	C Difference
u7	C Limit

In INTERCOM 1000 the two halves of an index register are independent and changes in one do not affect the other. In INTERCOM 500, however, the two halves are identical in function. Each may contain a 4-digit number in which the least significant two digits refer to a word and the most significant two digits refer to a channel. Incrementation of the word digits beyond 99 causes a change in the channel digits.

Upon execution of an INTERCOM 500 command which uses an index register, the 4-digit numbers currently held in the W base and in the C base of that register are summed. This total, plus the basic address held in the command, becomes the effective address.

Example:

> Consider that in Index Register 8, the W base is 0008, the C base is 0100, and the type-out command 8 33 1112 is obeyed by the computer.
>
> The computer will add 0008 to 0100 and add this total to 1112, the base address of the command. The command in memory will still read 8 33 1112, but the contents of 1220 will be typed out.

By using the two halves of an index register in conjunction so that the W half increments by one and the C half increments by 100, progression word-wise, channel-wise, or any combination, is possible.

Index Register Commands

To establish the initial state of index registers, six commands shown below are used. K is the number of the index register being initially loaded, and ABCD represents the value of 0000 through 3199 which may be loaded. The sum of the contents of the W and C halves of any one index register base must never exceed 3199.

ASSIGN W BASE	K 70 ABCD
ASSIGN W DIFFERENCE	K 71 ABCD
ASSIGN W LIMIT	K 72 ABCD
ASSIGN C BASE	K 73 ABCD
ASSIGN C DIFFERENCE	K 74 ABCD
ASSIGN C LIMIT	K 75 ABCD

To use the index registers in a program, commands are inserted which, in execution, increment the base and test whether the new base exceeds the corresponding limit. These increment commands contain the address of the command to which control is to be transferred as long as the base is equal to or less than the limit. When the base has exceeded the limit, the next command in sequence after the increment command is obeyed. These increment commands are shown below. K represents the index register and ADDR is the address of the command to be obeyed until indexing is completed.

INCREMENT W BASE	K 76 ADDR
INCREMENT C BASE	K 77 ADDR

The contents of any index register are disturbed when a subroutine is loaded into the channel containing that index register. The affected index register is again available after the subroutine is loaded, but it must be reset. An exception is the use of the PA-3 subroutine. When this subroutine is loaded into channel 17, index register 9 remains unavailable and must not be addressed.

Special Index Register Commands

Component parts of an index register are symbolized by D, as follows:

D	Component
0	Difference quantity for W half
1	Limit established for W half
2	Current base in W half
3	Current base in C half
4	Difference quantity in C half
5	Limit established for C half

For the purpose of reading out or transferring a component of an index register, or modifying the contents of an index register, a special accumulator called the Index Register Accumulator (IRA) has been established. The special index register commands use this IRA as follows:

CLEAR IRA AND ADD INDEX REGISTER D .. K 78 000D

The Index Register Accumulator is cleared and component D of index register K is added. This command must be followed with command 79.

Example:

To clear the IRA and bring in the current W base of index register 3, write: 3 78 0002. The next command must be K 79 000D.

COPY IRA INTO INDEX REGISTER D . . . . . .K 79 000D

The current contents of the Index Register Accumulator are copied into component D of index register K, replacing the previous contents.

Example:

To set the current contents of the IRA as the C limit for index register u, write: u 79 0005.

If it is desired to copy the effective contents of an index register into the IRA, with the option of adding a positive constant, the following command is used:

SET IRA . . . . . K 09 ABCD

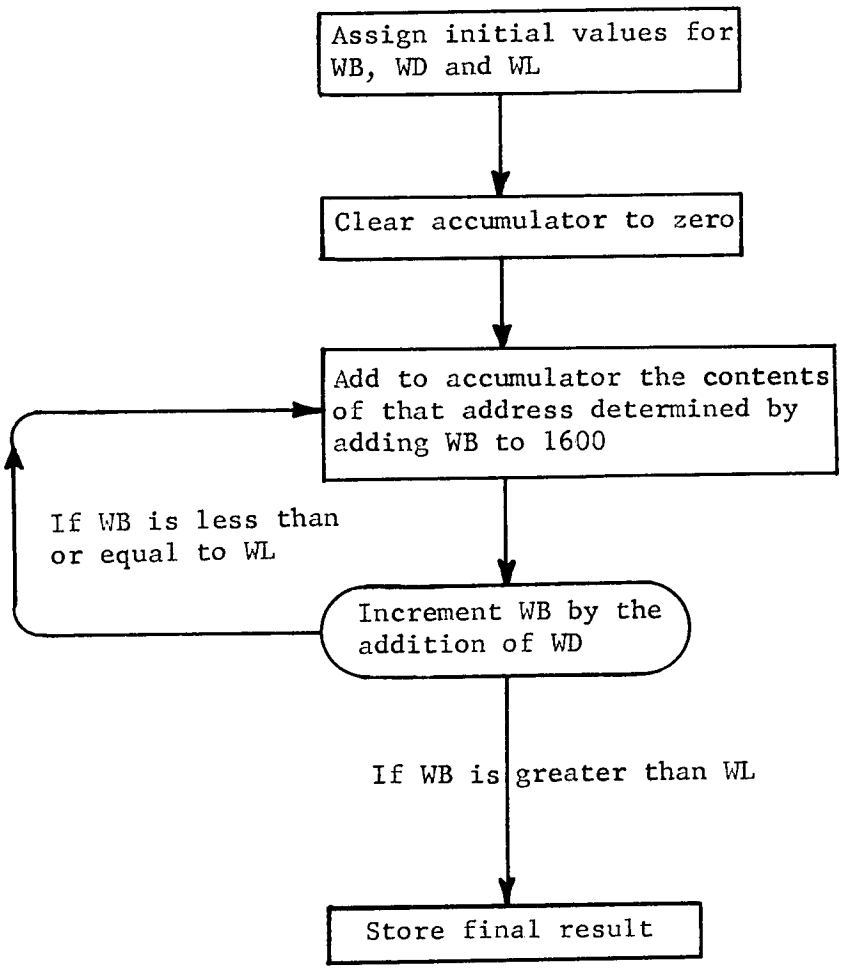
The Index Register Accumulator will be cleared and the sum of the W base and the C base of index register K, plus the quantity ABCD, will be placed in it. ABCD plus the W and C bases must not exceed 3199.

For information on accessing and loading index registers using floating point numbers, see the Index Register Utilization Subroutine, page 26.

AN EXAMPLE OF A PROGRAM WHICH USES AN INDEX REGISTER

A program is written below to find the sum of, and store, the contents of addresses 1600 to 1699. Notice that Index Register 1 will cause the command in location 1404 to add to the accumulator in turn the contents of addresses 1600 to 1699. The value zero is previously placed at address 1500.

A flow diagram of the problem is:



Example (Cont'd.)

Notes	Location	K	Operation Code	Address
Assign WB equal to 0000	1400	1	70	0000
Assign WD equal to 0001	1401	1	71	0001
Assign WL equal to 0099	1402	1	72	0099
Assign CB equal to 0000	1403	1	73	0000
Clear Accumulator	1404		42	1500
Add contents of address to accumulator	1405	1	43	1600
Increment Word Base	1406	1	76	1404
Store Accumulator	1407		49	1502

USE OF SUBROUTINES

A subroutine is a previously programmed sequence of commands which performs an often-used operation. Subroutines may be read into the computer from punched paper tape and stored in a channel in the memory.

Subroutines may be prepared from INTERCOM commands or may be prepared in basic machine language. The "Mark Place and Transfer" and "Return to Marked Place" commands permit subroutines written in INTERCOM form to be incorporated into INTERCOM programs. The "Perform Subroutine" command permits machine language subroutines to be incorporated into an INTERCOM program.

Many subroutines have been prepared in machine language for use with INTERCOM 500. In general, each permits a complex operation to be included in an INTERCOM program by writing a single command. These machine language subroutines may be considered to be optional extensions of the command list.

Mathematical Subroutines

A number of mathematical subroutines have been prepared in machine language for use with INTERCOM 500. Five commonly used groups are listed below. Each group requires one channel for internal storage. In the tables that list Mathematical Subroutines the groups are separated by horizontal lines.

In each subroutine, the value "x" must be first placed in the accumulator and the result appears in the accumulator.

The trigonometric, logarithmic and exponential subroutines are accurate to five decimal places.

Subroutine	Word Position to be Used in "Perform Subroutine" Command
Square Root of x	97
$Log_{10}x$	71
Log_e x	17
Log_2 x	08
10^x	72
e^x	22
2^x	08
Sine x (radians)	42
Sine x (degrees)	39
Cosine x (radians)	26
Cosine x (degrees)	23
Arctan x (radians)	24

EXAMPLE OF MATHEMATICAL SUBROUTINES

Consider that the sine-cosine subroutine has been stored in channel 16. The program steps to find the sine of an angle in degrees, and store the result in the memory, would be:

1.	Transfer angle, in degrees, from ADDR to accumulator	42 ADDR
2.	Perform subroutine	08 1639
3.	Store sine of angle from accumulator to ADDR	49 ADDR

The three commands are programmed in sequential memory positions.

Subroutine to Internally Control Size of Decimal Fraction During Fixed Point Type-Out

When the command "Type Fixed Point Number" is executed, a number of places specified by the programmer will be typed after the decimal point. For example, if the programmer has specified four places, and the numbers to be typed out have values in the memory of 12.3 and 12.3456789, the type-out will be "12.3000" and "12.3456."

The number of type-out places specified can be changed during computation under program control. In order to do so, the "Fraction Selector" subroutine must be read into the memory of the computer. The subroutine may be placed in any available channel.

After the subroutine has been read into the memory, the command "Perform Subroutine" may be executed to specify a new number of type-out places after the decimal point. The first two digits of the address portion of the "Perform Subroutine" command would be the channel in which the "Fraction Selector" subroutine has been placed. The latter two digits of the address specify the number of places to be typed after the decimal point, according to the following table:

Type-Out Places After Decimal Point	Word Position to be Used in "Perform Fraction Selector Subroutine" Command
0	08
1	01
2	02
3	03
4	04
5	05
6	06
7	07

Example:

The "Fraction Selector" subroutine has been read into channel 16. For subsequent fixed point type-outs to have three places typed after the decimal point, the command "08 1603" would be executed.

AN EXAMPLE OF A PROGRAM WHICH USES MATHEMATICAL SUBROUTINES

In this program, each time the operator types in a positive number, x, followed by "(tab) Ⓢ ",* the computer calculates $\sqrt{1 - e^{-x}}$. The computer types out the result and rings the bell to indicate that it is ready for type-in of the next value of x.

The square root subroutine has been previously entered in channel 16. The subroutine for the calculation of e^x has been previously entered in channel 17.

*The earlier model typewriter has no Ⓢ key; wherever the Ⓢ key is indicated, use the s key on the alphabetical keyboard

AN EXAMPLE OF A PROGRAM WHICH USES
MATHEMATICAL SUBROUTINES (CONT'D.)

	Location	Operation Code	Address
Ring bell	1100	63	0000
Permit type-in of x in fixed point notation	1101	51	1200
Clear and subtract x	1102	40	1200
Find e^{-x}	1103	08	1722
Store e^{-x}	1104	49	1202
Divide accumulator by itself to obtain 1	1105	48	2101
Subtract e^{-x} from 1	1106	41	1202
Find square root of $1 - e^{-x}$	1107	08	1697
Type out answer in fixed point notation	1108	38	2101
Transfer control, unconditionally	1109	29	1100

Index Register Utilization Subroutine

This subroutine converts between the number form used in index registers and floating point number form. It permits use of the contents of an index register component as a floating point number, and allows a component of an index register to be set from a floating point number. It also contains a command permitting paper tape to be reversed by one block.

The subroutine has two entry points:

Word 01 is used when a number in index register form is to be converted to floating point form. When this entry point is used, the subroutine goes to the IRA for input, and leaves output in the accumulator.

Word 00 is used when a number in floating point form is to be converted to index register form. This entry point causes the subroutine to go to the accumulator for input and to leave the output in the IRA.

To Set an Index Register Component from A Floating Point Number:

1. Clear the accumulator (2101) and add the floating point number:

```
K   42   ADDR
```

2. Transfer to conversion subroutine:

```
0   08   CH00
```

3. The IRA now contains the number in the form used in index registers. It must be stored in an index register component with:

```
K   79   000D  (for D, see "Index Registers")
```

To Obtain an Index Register Value as a Floating Point Number:

1. Clear the IRA and add the index register component:

```
K   78   000D  (for D, see "Index Registers")
```

2. Transfer to conversion subroutine:

```
0   08   CH01
```

3. The accumulator (2101) now contains the value in floating point form, and can be stored with:

```
K   49   ADDR
```

If an index register is set with a number larger than 3199, an error loop will result and "z0z Y00" will be typed out.

This subroutine also permits reversing the paper tape by one block with the command:

```
0   08   CH16
```

CH represents the channel containing this subroutine.

OPERATING THE G-15 COMPUTER WITH INTERCOM 500

OPERATING MODES

INTERCOM 500 has two operating modes: manual and automatic. The desired mode may be selected from the typewriter keyboard.

The manual mode may be used in any program except one containing a pair of commands to initiate a subroutine. In the manual mode, individual commands may be typed and executed one at a time as on a desk calculator, or data and commands may be typed on the keyboard and stored in the computer's memory.

In the automatic mode, computation proceeds in the normal manner. Commands stored in the computer's memory are executed in the order specified by the program.

Any command, including input-output commands, may be executed in either operating mode. Additional data, for example, may be read into the computer from punched tape and stored in the memory by execution of the command "Read Punched Tape," in either the manual or automatic mode.

The entire INTERCOM 500 system, including interpreter and subroutines, is on one paper tape. Therefore, operation does not require changing tape magazines.

TO ENTER AND EXECUTE A PROGRAM FROM THE TYPEWRITER

To Prepare the Computer for Operation

The computer is assumed to be on. If the computer is off, see page 41 for the turn-on procedure.

1. Place the INTERCOM 500 magazine on the photo-reader. Be sure the tape is rewound.

2. Put the Punch and Compute switches on the typewriter base to the center (off) positions.

3. Hold the Enable switch on the typewriter base to the ON position and type "p". Put the Enable switch off. Wait until the photo-reader light remains off.

4. Move the Compute switch on the typewriter base to GO. Wait for the photo-reader light to remain off. When the bell rings, the computer is in the manual operating mode ready for operation.

To Clear Memory

The computer must be in the manual operating mode.

1. Put the Compute switch in the center (off) position. Hold the Enable switch ON and type "p." Put the Enable switch off.
   Wait for the photo-reader light to remain off.

2. Put the Compute switch to GO.
   Wait for the neon indicator lights to remain steady.

3. If the INTERCOM 500 memory, including index registers, is to be cleared to zero, type "3 (tab) Ⓢ". If the index registers are to be cleared to zero, but the remainder of the INTERCOM memory retained, type "2 (tab) Ⓢ.

4. Type "(tab) Ⓢ".
   Wait for the photo-reader light to remain off and the bell to ring. The computer is returned to the manual operating mode.

To Select Fixed Point Fraction Length

During the type-out of data in fixed point notation, seven decimal places will be printed to the right of the decimal point unless the following instructions are used.

The computer must be in the manual operating mode.

1. Put the Compute switch in the center (off) position. Hold the Enable switch ON and type "p." Put the Enable switch off.
   Wait for the photo-reader light to remain off.

2. Put the Compute switch to GO.
   Wait for the neon indicator lights to remain steady.

3. Type "-D (tab) Ⓢ " where D indicates the number of decimal places to be printed after the decimal point according to the following table:

D	Number of Places
8	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7

Wait for the photo-reader light to remain off. The computer is returned automatically to the manual mode.

To Load Subroutines

The computer must be in the manual operating mode.

1. Put the Compute switch off and the Enable switch ON. Type "p". Put the Enable switch off.
   Wait until the photo-reader light remains off.

2. Put the Compute switch to GO.
   Wait for the bell to ring.

3. For each subroutine to be read into the memory, type "N (tab) Ⓢ " where N specifies the subroutine and the channel in which it is to be stored. (See "Values of N for Subroutine Input".)
   Wait for the photo-reader light to remain off.

4. Repeat Step 3 for each subroutine to be entered.

5. Type "(tab) Ⓢ " and the computer will return to the manual mode.

Example:

> If in Step 3, under "To Load Subroutines", it is desired to read the square root subroutine into channel 14 in the memory, "2 14 u0 (tab) ⓢ " would be typed.

The loading process for subroutines disturbs the index register contained in the high-order end of the channel into which the subroutine is loaded. Therefore, when the subroutine is:

Placed in Channel	The Disturbed Index Register Is
09	1
10	2
11	3
12	4
13	5
14	6
15	7
16	8
17	9
18	u

Note that after loading any subroutine, except the PA-3 Accessory subroutine, the index register is available but must be reset. It is most convenient to load any subroutines other than the PA-3, clear index registers, and then, if it is used, load the PA-3 subroutine. If index registers are cleared after loading the PA-3 subroutine, the PA-3 subroutine will be destroyed.

VALUES OF N FOR SUBROUTINE INPUT	
The values of N tabulated below are for use in Steps 3 and 4 of the section "To Load Subroutines". The letters "CH" represent the number of the channel in memory in which the subroutine is to be stored. The subroutines may be loaded in any order.	
Subroutine	N
Fraction Selector	1 CH u0
Square Root of x	2 CH u0
Log_e x Log_2 x Log_{10} x	3 CH u0
e^x 2^x 10^x	4 CH u0
Sin x (degrees) Sin x (radians) Cos x (degrees) Cos x (radians)	5 CH u0
Arctan x (radians)	6 CH u0
Index Register Utilization	12 CH u0

To Type Data into Desired Memory Locations

The computer must be in the manual operating mode.

1. Type "52 ADDR (tab) Ⓢ ", where ADDR is the first memory location to be used for data storage. (For fixed point notation, the 51 command may be used.)
   Location ADDR will be typed out followed by a tab.

2. Type data which is to be entered into consecutive addresses in the memory. Type "(tab) Ⓢ " at the end of each number.

   The decimal point* must always be typed if fixed point notation is used.

   To enter a zero in fixed point notation, type ".(tab) Ⓢ ".* To enter a zero in floating point notation type "(tab) Ⓢ ".

   The first number typed will be stored at location ADDR. The computer will retype the number in floating point notation, in order to verify proper entry of the number. The carriage will return.

   ADDR + 1 will be typed out. The second number typed will be entered into location ADDR + 1. Following numbers will similarly be entered into consecutive word locations.

3. Type "0 67 0000 / / (tab) Ⓢ ".
   The computer is returned to the manual operating mode.

*On the typewriter keyboard, the decimal point for fixed point input is entered by pressing the fixed decimal point key; this key has imprinted on it a hollow decimal point for lower case and a / (slash) for upper case. Either may be typed without change in effect.

To Type Commands into Desired Memory Locations

The computer must be in the manual operating mode.

1. Type "50 ADDR (tab) Ⓢ " where ADDR is the first of a consecutive group of memory locations to be used for command storage.
   Location ADDR will be typed out followed by a tab.

2. Type commands to be stored in consecutive memory locations. Type "(tab) Ⓢ " after each command.
   After (tab) Ⓢ is typed, the computer will retype the command. The carriage will return to the left and the consecutive address will be typed out. Another command may now be typed.

3. Type "0 67 0000 / / (tab) ⓢ".
   The computer is returned to the manual operating mode.

The computer can also be returned to manual mode as follows:

> Turn the Compute switch off, set the Enable switch to ON, and type "ⓢ cf." Then turn the Enable switch off and move the Compute switch to GO.

To Change From the Manual to the Automatic Operating Mode

After the program has been fully loaded into the memory, the computer may be instructed to compute automatically, obeying each command in sequence. To do so:

> Type "69 ADDR (tab) ⓢ " where ADDR is the location of the command at which computation is to begin.

TO CHECK OUT A PROGRAM

Additional commands and facilities are provided by INTERCOM 500 to control and to interrogate the computer during execution of a program. They are useful in the location and correction of errors made in writing the program.

To Put the Computer in the Manual Mode

The computer may be put in the manual operating mode at any time by the procedure below.

1. Move the Compute switch on the typewriter base to BP. When the neon indicator lights become steady, return the switch to the center position.

2. Hold the Enable switch on the typewriter base in the ON position and type " ⓢ cf".

3. Release the Enable switch back to the center position and move the Compute switch to GO.

To Execute Commands in the Manual Mode

(Programs containing a pair of commands to initiate a subroutine must not be executed in the manual mode.)

The computer must be in the manual operating mode.

Individual commands may be executed directly from the typewriter keyboard. The result of an arithmetic command will remain in the accumulator after execution. The command itself is not stored in the memory. The procedure is:

1. Type the command followed by (tab) Ⓢ.
   The computer will execute the command and halt in the manual operating mode.

2. Repeat Step 1 as often as desired.

To Execute Stored Commands, One at a Time

A stored program may be executed one command at a time for check-out purposes. The computer must initially be in the manual operating mode.

1. Put the Compute switch on the typewriter base to BP.

2. Type "69 ADDR (tab) Ⓢ" where ADDR is the location of the first command to be executed.

3. Put the Compute switch to the center position and back to BP.

4. Repeat Step 3 for each command in the program. Each time the switch is moved back and forth one command will be executed.
   The computer is in the automatic operating mode.

To execute the remainder of the program without halting between commands, put the Compute switch to GO.

To revert to the manual mode, follow the procedure "To Put the Computer in the Manual Mode."

To Inspect a Program

Put the computer in the manual mode.

Three additional commands, useful in checking a program, are:

TYPE MEMORY IN HEXADECIMAL AND TAB . . . .37 ADDR

The contents of location ADDR are automatically typed out in hexadecimal form. (A floating point zero will have the form "00000zz".)

TYPE COMMAND FROM MEMORY AND TAB . . . . .35 ADDR

The command in location ADDR will be typed out in the form:

"K Operation Code ADDR"

TYPE LOCATION OF LAST COMMAND
EXECUTED 06 0000

The memory location of the last command executed will be typed out. The typewriter carriage will move to the next tab stop.

To List Selected Commands During Computation

Information concerning selected commands can be automatically typed out during computation. The information typed will be the location of the command, the command itself, and the contents of the accumulator under certain conditions. These are: if the operation code of the command executed is in the 40's or is 20, 22, or 23, and if the contents of the accumulator are different than during the listing of a preceding command with one of these operation codes.

Selective listing must not be done on programs containing a pair of commands to initiate a subroutine.

It must be noted that the selective listing process occupies channel 08, making this channel unavailable to the programmer.

In the type-out of a command with an index register, the address of the command will be incremented by sum of the bases of the index register.

Any portion of a command may serve as the basis of selection. The computer is notified which commands to type out by two "selectors," each consisting of seven characters.

The first selector holds the digital values which, if found in a corresponding portion of a command in the program, will cause the command to be listed. Z's are placed in the second selector in digit positions corresponding to the digit positions which are to be examined in commands.

Examples:

> If the first selector is 0 49 0000 and the second selector is 0 zz 0000, all commands which have the operation code 49 will be listed during computation.
>
> If the first selector is 2 000 000 and the second selector is z 000 000, all commands with index register 2 will be listed during computation.

The operating procedure is:

The computer must be in the manual operating mode. The INTERCOM 500 Master magazine must be in position on the photo-reader.

1. Put the Compute switch in the center (off) position. Hold the Enable switch ON and type "p." Put the Enable switch off.
   Wait for the photo-reader light to remain off.

2. Put the Compute switch to GO.
   Wait for the neon indicator lights to remain steady.

3. Type "1 (tab) Ⓢ ".
   Wait for the photo-reader light to remain off.

4. Type "(tab) Ⓢ ".
   Wait for bell to ring. The computer is now returned to the manual operating mode.

5. Type "61 0000 (tab) Ⓢ ".
   Wait for the input-output neons to be in the configuration 0●●00.

6. To list every command, type "(tab) Ⓢ ". To list selected commands, type "FIRST SELECTOR (tab) SECOND SELECTOR (tab) Ⓢ ".
   The bell will ring.

7. Type "69 ADDR (tab) Ⓢ " where ADDR is the location of the command at which computation is to begin.
   The computation, with listing of selected commands, will proceed.

To terminate listing:

1. Put the computer in the manual mode.

2. Type "620000 (tab) Ⓢ ". This command terminates listing.
   The computer is now in the manual operating mode.

If further listing is required after the "620000 (tab) Ⓢ " has been typed, the above sequence may be re-entered at Step 5 as necessary. Preparatory Steps 1-4 are required only once each time INTERCOM 500 is loaded.

During, or subsequent to selective listing, data may still be entered in fixed or floating point form using operation code 51.

See pg. 59 for a summary of memory preparation and program inspection procedures.

Breakpoint Operation

A program may be executed a portion at a time by placing a "Breakpoint Halt" command (page 16) in the program in each place where computation is to be interrupted.

When later desired, computation can be made to be continuous by replacing each "Breakpoint Halt" command with a "Transfer Control, Unconditionally" command.

To Alter a Program

Automatic computation may be halted and the computer put in the manual operating mode in order to type in new commands or data. After the program is modified, the computer may be instructed to return to the point in the program at which operation was interrupted and resume computation in the automatic mode. The procedure is:

1. Put the computer in the manual operating mode.

2. Type the command "060000 (tab) Ⓢ " to determine location of last command executed.

3. Type the command "49 ADDR (tab) Ⓢ " in order to store the contents of the accumulator in any empty location ADDR.

4. Make program alterations.

5. Type the command "42 ADDR (tab) Ⓢ " in order to return the contents of ADDR to the accumulator.

6. Type "69 ADDR (tab) Ⓢ " where ADDR is the location of the next command to be executed. (See Step 2.) The computer returns to the point at which computation was interrupted and resumes computation.

Automatic Error Detection

The computer automatically checks the accuracy of the information read from the INTERCOM Tape Magazine. If a reading error occurs, the tape is reversed automatically and the block of information in which the error was detected is read again.

Programming errors such as the following will also be detected:

Any internal computation in which the result exceeds 10^{38}.

Square root of a negative number.

Division by zero.

Log of zero or log of a negative number.

Use of 00 or a number greater than u0 in the DR portion of the magnetic tape input-output routines.

Detection of an error causes the bell to ring three times, the characters "z0z Y00" are automatically typed out, and the computer halts. To cause a type-out of the location of the error and to resume computation, move the Compute switch to center and then back to GO.

To Recover Operating Control

If the computer does not respond to a command or to a typed instruction in the proper manner, control may have been lost due to an operator error.

Control may be recovered by one of the two methods indicated below:

1. If the test light is on, the following sequence in Method 1 must be performed twice:

   Move the Compute switch on the typewriter base to the center position.

   Hold the Enable switch ON and type " ⓢ cf".

   Release the Enable switch back to the center position and move the Compute switch to GO. The bell will ring once to indicate return to the manual mode.

   If the computer does not return to the manual mode, use Method 2.

2. Put the "rewind" toggle switch in the rewind position until the tape in the INTERCOM magazine is fully rewound.

   Follow the procedure "To Prepare the Computer for Operation" on page 29, beginning with the second step.

To Turn on the Computer

When the computer is turned on, it may be checked for proper operation by the use of a test routine which is provided in a punched tape magazine.

The procedure to turn on and check the computer is:

1. Place the "Test Routine" magazine on the photoreader. Be sure the tape in the magazine is rewound.

2. Put the Enable, Punch and Compute switches on the typewriter base in the center (off) positions.

3. Turn on the Start switch.
   Wait for the AC meter to read 6.3 volts and the amber AC light to become bright.

4. Press the Reset button until the red DC lamp lights.
   Wait until the photo-reader light remains off and the green "Ready" lamp lights.

5. Move the Compute switch to GO.
   The number "1" will be typed out. Wait for the display panel neons to remain steady.

6. Type "0000005 (tab) Ⓢ".
   Wait for the photo-reader light to remain off and the display panel neons to remain steady.

7. Type "0000006 (tab) Ⓢ".
   Bells ring at repeated intervals to signify successful procedure of each test in the routine.

   Proper computer operation is indicated if no type-out occurs before the following is typed out:

-1122334	445566.7	778899
-uuvvwwx	xxyyzz.0	2345

8. At completion of the type-out put the Compute switch to the center position and remove the "Test Routine" magazine.

USING AUXILIARY EQUIPMENT WITH INTERCOM 500

The INTERCOM 500 programming system includes input-output facilities for Flexowriter tape, magnetic tape, punched cards, and graph plotting.

Magnetic tape input-output is provided by Accessory MTA-2. By its use the effective working memory of the computer is greatly increased in size. One to four magnetic tape units may be connected to, and controlled by, the computer. Punched card input-output is provided by Accessory CA-1 with the IBM-026 card-handling unit. Punched tape may be processed independently of the computer by a Flexowriter. Graph plotting is provided by Accessory PA-3.

The auxiliary equipment is controlled by subroutines which are available on the INTERCOM 500 tape.

The additional input-output commands permitted by each subroutine are listed in the table below. The table specifies the memory channel in which each subroutine must be entered.

Note in the following pages that a command for auxiliary equipment input-output usually requires the coding of a pair of command words. When this is true, the two command words must be programmed consecutively. Programs containing such commands must not be selectively listed, or executed in the manual mode.

TO LOAD AUXILIARY EQUIPMENT SUBROUTINES

The procedure for loading auxiliary equipment subroutines into the computer from the tape is the same as entering mathematical subroutines. (See "To Load Subroutines", page 31). If desired, the mathematical and auxiliary equipment subroutines required for a program may be entered in the same loading operation.

The table below lists the auxiliary equipment subroutines on the tape and the value of N for each. With the exception of the magnetic tape routine, these subroutines must be stored in specific memory channels.

Note that loading any subroutine disturbs the index register in the high-order end of the channel designated in N. After the PA-3 subroutine has been loaded, index register 9 remains unavailable; in all other cases the affected register is again available, but must be reset.

AUXILIARY EQUIPMENT SUBROUTINES

Accessory	Subroutine Commands	N
Flexowriter	Read Data Tape Prepared by Flexowriter Read Command Tape Prepared by Flexowriter	7 17 u0
Flexowriter	Punch Data Tape to be Tabulated by Flexowriter	8 16 u0
MTA-2	Write on Magnetic Tape Read Magnetic Tape Write File Number on Magnetic Tape Reverse Magnetic Tape One Block Search Magnetic Tape for File Number	9 CH u0
CA-1	Read Data Card Punch Data Card	10 16 u0
CA-1	Read Command Card	11 17 u0
PA-3	Plot Pen-Down Plot Pen-Up Reset Residuals	x 17.00 or 13 17 00

TO USE THE FLEXOWRITER

Information may be entered into the internal memory from paper tape which was punched by a Flexowriter Model 35-4. The subroutine for reading Flexowriter tape must first be read into channel 17 in the memory; the following commands are then available:

READ DATA TAPE PREPARED 08 1717
BY FLEXOWRITER . . . . . K 57 ADDR

Numbers written in floating point notation on punched tape are read into consecutive addresses in the memory beginning with location ADDR. Tape will be read until a Stop code occurs on the tape. K may refer to any register.

READ COMMAND TAPE PREPARED 08 1717
BY FLEXOWRITER . . . . . K 56 ADDR

Commands on punched tape are read into consecutive addresses in the memory beginning with location ADDR. Tape will be read until a Stop code occurs on the tape. K may refer to any index register.

The computer can be instructed to punch a tape to be later tabulated by a Flexowriter. The subroutine for punching a Flexowriter tape must first be read into channel 16 in the memory. The following command is then available:

PUNCH DATA TAPE TO BE TABULATED 08 1675
BY FLEXOWRITER . . . . . K N ADDR

The contents of N memory locations are punched on tape in floating decimal point form beginning with location ADDR. N is a two-digit number from 01 to 99. K may refer to any index register.

One hundred word positions may be punched out, if desired, by writing u0 in the N position of the command.

Operating Instructions for Input from Punched Tape Prepared on Flexowriter

The tape may be punched on a Flexowriter Model 35-4. After punching, the tape is read into the computer via the photo-reader. Data and commands are punched on separate sections of tape. Data is punched in the floating decimal point form described on page 4.

Prepare the tape in the following manner:

1. Run out seven inches or more of blank, sprocketed tape.

2. If data is being punched, each word must contain seven digits. If a number is negative, the minus sign precedes the first digit. A zero is punched in the form "50.00000".

   If commands are being punched, each word must contain seven digits. If no index register is used in a command, zero is punched in the K position.

3. For data or commands, punch the first four words which are to be entered in consecutive memory locations in the following form:

   word(tab)word(tab)word(tab)word(carriage return)/

   Continue to punch in the same form consecutively located groups of four words. Do not mix data and commands. After a section with a maximum of 100 words has been punched, punch "wwwwwww (tab)" or "zzzzzzz (tab)", repeated a sufficient number of times to complete the last four word group; that is, "wwwwwww (tab)" or "zzzzzzz (tab)" must be written one, two, three, or four times. Then punch "stop 2".

   The "w" codes are used when additional consecutive input of the same type already entered follows immediately on the tape. The "z" codes are used when input is ended; control will be restored to normal INTERCOM computation.

4. If a punching error is detected in a group of four words before the following "/" or "stop 2" has been typed, the error may be corrected by retyping the four-word group involved. If the error is detected after the corresponding "/" or "stop 2" has been typed, it is necessary to either retype the entire section or reproduce the tape on the Flexowriter up to the error.

5. After "stop 2" is punched, run out seven or more inches of blank,sprocketed tape.

   Addresses in which the commands or numbers are to be stored are not punched. The information from tape is put in a set of consecutive addresses specified by the "Read Flexowriter Tape" command.

The "w" codes and the "z" codes are not stored in the memory of the computer.

Example:

Copy for ten words of command input with no additional input following:

```
0421102 (tab)  0441104 (tab)  0441106 (tab)
   0491108 (carriage return)
/ 1700000 (tab)  1710001 (tab)  1720099 (tab)
   0421100 (carriage return)
/ 1431600 (tab)  1761404 (tab)  zzzzzzz (tab)
   zzzzzzz (tab)  (stop 2)
```

TO USE MAGNETIC TAPE

Accessory MTA-2 provides magnetic tape input-output facilities. Tape is searched at a rate of 2600 characters per second. Information is written on tape or read from tape at a rate of 430 characters per second. 300,000 words may be stored on a single tape reel.

One to four magnetic tape units may be connected to, and controlled by, the computer. The letter M in a magnetic tape command refers to the number of the magnetic tape unit on which the command operates. M may be 0, 1, 2 or 3.

When the magnetic tape subroutine is in channel CH in the memory, the following additional commands are available:

```
                                          08 CH70
WRITE ON MAGNETIC TAPE . . . . . K M2 AD00
```

The contents of the memory channel determined by the first two digits of AD00 are recorded on tape in tape unit M. The last two digits of AD00 must be 00. The group of words recorded by a single command is called a block. New information must not be written on top of earlier-recorded information.

```
                                          08 CH70
READ MAGNETIC TAPE . . . . . .K M1 ADDR
```

A block of information is read from tape in tape unit M and is entered into the internal memory. Information is entered in the

channel specified by the first two digits of ADDR, beginning at word position 00 and ending with word position ADDR-1.

```
                                                    08 CH70
WRITE FILE NUMBER ON MAGNETIC TAPE . . . . K M3 FILE
```

The number FILE is written on tape in tape unit M. FILE is an arbitrary number from 0000 to 3000.

File numbers must be sequential and in order of increasing magnitude. A file number may be written after any number of blocks.

The file number 0000 must be recorded at the beginning of every tape reel; the file number 3000 is usually recorded at the end of the reel to prevent the tape from running off the reel.

Compatibility with the Magnetic Tape Service Routine or the Magnetic Tape Test Routine limits the last File Block to be a three digit number of less than 1000. If files are written with larger numbered File Blocks, those routines will not be usable with the particular reel of tape.

```
                                                    08 CH70
REVERSE MAGNETIC TAPE ONE BLOCK . . . . . .K M4 0000
```

Tape in tape unit M is moved one block in the reverse direction.

```
SEARCH MAGNETIC TAPE FOR                            08 CH70
FILE NUMBER . . . . . .K M5 FILE
```

Tape in tape unit M will search for, and will stop at, file number FILE.

```
                                                    08 CH70
SEARCH FOR BLANK TAPE . . . . . .0 M6 0000
```

Tape unit M will search for and stop in blank tape.

AN EXAMPLE OF A PROGRAM WHICH USES MAGNETIC TAPE

Assume the MTA-2 subroutine to be in channel 18. The contents of channel 16 in the memory will be written on magnetic tape in tape unit 1, and then the first fifty words, recorded on the tape after file number 0036, will be read into channel 16.

```
08 1870     The contents of channel 16 are written
12 1600     on tape.

08 1870     The tape searches at high speed and
15 0036     halts at file number 0036.

08 1870     Information is read from tape and
11 1650     stored in memory positions 1600 to
            1649.
```

Operating Instructions for Magnetic Tape

One to four MTA-2 units may be connected to the computer. Each has a switch labeled "Tape Unit" with positions numbered from one to four. The switch setting is used to identify the tape unit addressed in commands. The number in the M position of a magnetic tape command determines the tape unit in which the command operates. Tape unit switch settings one to four correspond to M numbers of 1, 2, 3 and 0, respectively. For example, a command with 2 in the M positions will control the unit or units that have their unit switches set at 2. Thus, information may be recorded simultaneously on more than one tape. However, only one tape at a time may be read during input.

Recording information on a section of tape does not automatically erase old information on that section of tape. Therefore, new information cannot be written on top of old information; to re-use a tape reel, it must first be demagnetized.

Tape motion may be manually initiated and stopped from the tape unit. The rotary selector switch for doing so has five positions:

A	Automatic
S	Stop
F	Forward Motion
S	Stop
R	Reverse Motion

The "Hi-Lo" toggle switch permits selection of one of two speeds for manual tape motion, either 7 1/2 or 45 inches per second.

Before turning on the computer make sure that, on all tape units, the on-off switch is off, the run-standby switch is in standby, and the rotary selector switch is at S.

To Turn on the Magnetic Tape Unit

1. Put the computer in the manual operating mode.

2. On the typewriter base, put the Enable switch ON, the Compute switch off, type " Ⓢ ", and put the Enable switch off.

3. On the tape unit, put the on-off switch to the on position. After about two minutes, put the run-standby switch in the run position. Put the rotary selector switch in the A position.

4. Put the Enable switch ON, type " Ⓢ cf", put the Enable switch off and the Compute switch to GO.
   The computer is returned to the manual mode.

To Turn Off the Magnetic Tape Unit

If the tape unit is not required by the computer for a considerable length of time, it may be turned off. The tape unit should always be turned off before the computer is turned off. The procedure is:

1. On the typewriter base, put the Enable switch ON, the Compute switch off, type " Ⓢ ", and put the Enable switch off.

2. On the tape unit, put the rotary selector switch in the S position, the run-standby toggle switch in the standby position, and the on-off toggle switch in the off position.

3. Put the Enable switch ON, type " Ⓢ cf", put the Enable switch off and the Compute switch to GO.
   The computer is returned to the manual mode.

TO USE PUNCHED CARDS

Accessory CA-1, with the IBM-026 card-handling unit, provides punched card input-output facilities. Standard eighty-column cards may be read or punched under control of INTERCOM commands.

Cards being read may contain either data or commands, but not both.

Data cards are both read and punched in floating decimal point notation. In INTERCOM 500, a card may contain from one to eight words of data or commands.

After the data card subroutine has been entered into channel 16 in the memory, the following commands may be programmed:

```
                                                  08 1605
READ DATA CARD . . . . . .K ON ADDR
```

Data from one card in the IBM-026 is read into the memory of the computer in consecutive locations beginning at location ADDR. The digit N specifies the number of words held on the card. K may refer to any index register.

```
PUNCH DATA CARD . . . . . .08 1610
```

The contents of the accumulator are punched on a card by the IBM-026 unit.

The number of words punched on a single card is determined by the program card in the IBM-026.

After the command card subroutine has been read into channel 17 in the memory, the following command may be programmed:

```
                                                  08 1775
READ COMMAND CARDS . . . . . .K ON ADDR
```

Commands from cards in the IBM-026 are read into the memory of the computer in consecutive word locations beginning at location ADDR. The digit N specifies the number of commands held on each card. K may refer to any index register.

Operating Instructions for Punched Card Input-Output

If the computer is on, prior to using any control on the 026 unit, put the Compute switch off, the Enable switch ON, type " Ⓢ ", and put the Enable switch off. After making any change on the 026, put the Enable switch ON, type " Ⓢ cf", put the Enable switch off and move the Compute switch to GO. The computer will then be in the manual operating mode.

IBM-026 Operation

Controls on the IBM-026 unit should be set in the following positions:

> The "on-off" switch on the left of the unit in the ON position.
>
> Toggle switches on the keyboard in the upper position.
>
> The Column 1 switch on the back of the accessory in the "SKIP" position.
>
> The program control lever with the right side depressed.

For input, press the "REL" key three times and press the program control lever to the left, to put the first card in position to be read.

For output, press the "REL" key once, the program control lever to the left and the "REL" key once again, to put the first card in position to be punched.

Put a few blank cards at the end of a set of cards to be used.

Information Cards

Data is both read and punched in floating point notation.

On data cards for INTERCOM 500, each word consists of ten columns. The first two are blank; the third column holds the sign; the next two, the exponent in excess-fifty form; and the last five the decimal fraction. One to eight words may be punched on a single card.

On command cards, each command consists of ten columns. The first three columns are blank; the fourth column contains the index register number or the number "zero", if no index register is used; the next two columns hold the operation code; and the last four columns the address. One to eight commands may be held on a single card.

The last command card processed must contain one word or more of "z punches" to signify end of input. The last input card processed is made consistent in form with the earlier-processed cards by placing "z punches" after the last command in all columns corresponding to columns normally read.

Program Control Cards

A program control card must be mounted in the IBM-026 for either input or output. The control card specifies which columns on information cards are to be processed. Instructions for preparing program control cards are listed below. Note that it is possible to use the same control card for input of data and commands.

Input or output program control cards are mounted on the drum in the program unit of the IBM-026 in the manner described in the 026 Operating Manual.

To Prepare an Output Program Control Card

Columns on the output data card which are not to be punched are said to be "skipped". On the program control card, for each set of consecutive columns to be skipped, put an "eleven-punch" in the first column and "twelve-punches" in each following column.

To Prepare an Input Program Control Card

1. Place a "zero-punch" in each column on the control card that corresponds to the first digit of a word being read on the information card. Place "hold" or "twelve-punches" in each of the remaining, consecutive columns of the word to be read.

2. Place a "two-punch" in each column on the control card that corresponds to the last digit of a word on the information card.

3. The control card may specify that certain columns on the information cards are not to be read. When columns are not read they are said to be "skipped." For each set of consecutive columns to be skipped, put an "eleven-punch" on the control card in the column corresponding to the first column to be skipped. In each remaining consecutive column to be skipped, put a "hold" or "twelve-punch."

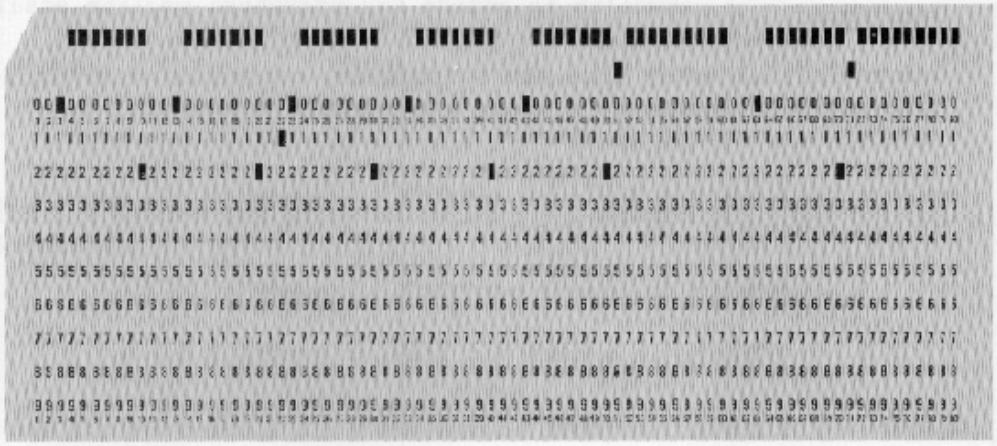
4. Put a "one-punch" on the program control card, if specified in the table below:

If Number of Words Read from the Information Card is:	Put a "One-Punch" in The Second Column After That "Two-Punch" Which Indicates the End of the:
5	1st Word
6	2nd Word
7	3rd Word
8	4th Word
If four or fewer words are to be read from the information card, no "one-punch" is required.	

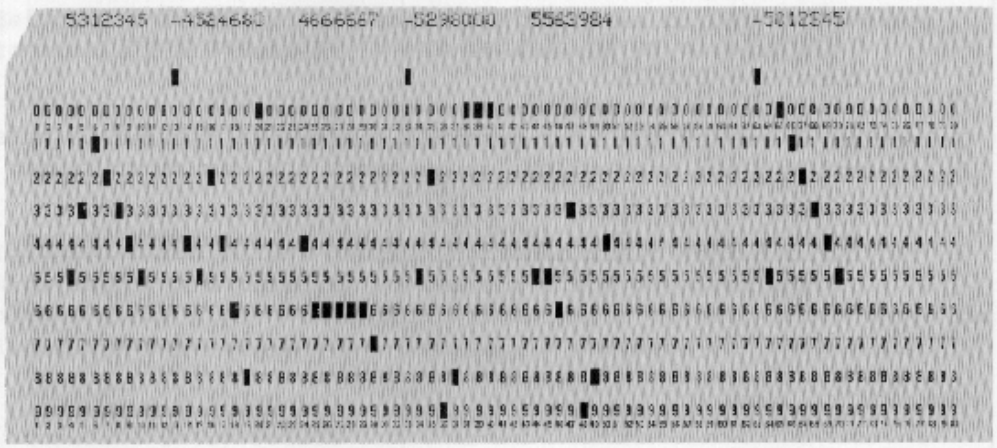
Sample Input Cards

The control card shown will read in the information from the sample data card. The six numbers are read from Columns 3-10, 13-20, 23-30, 33-40, 43-50, and 63-70. The "zero-punch" in columns 3, 13, 23, 33, 43, and 63 indicates the first digit of a word. The "two-punch" in Columns 10, 20, 30, 40, 50, and 70 indicates the end of each number. A "one-punch" is put in Column 22, the second column after the end of the second word, because there are six words to be read. An "eleven-punch" in Columns 51 and 71 indicates the beginning of columns to be skipped. In all cases, a "twelve-punch", or "hold," indicates continuation of a field established with a "zero" or "eleven-punch".

CONTROL CARD



DATA CARD



TO USE THE PA-3 ACCESSORY

The PA-3 Graph Plotter Accessory subroutine must be loaded into channel 17. In this channel it occupies the locations normally occupied by index register 9; therefore, this index register is not available when the plotter subroutine is in memory. If an attempt is made to clear or address index register 9 when the plotter subroutine is in memory, it will disturb the subroutine. The subroutine is read from the INTERCOM 500 tape with either the "x17u0" or the "1317u0" command.

Data Input

Before initial entry into the subroutine, constants which indicate scaling, coordinate system, and initial values must be selected and stored in channel 17.

The desired scaling for each axis is indicated by the magnitude of two constants, as follows:

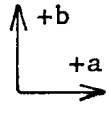
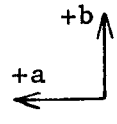
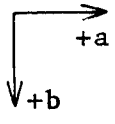
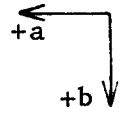
S_a = (Change in a axis per inch of graph) x 10^{-2}.

S_b = (Change in b axis per inch of graph) x 10^{-2}.

Example:

If a axis is to be plotted at 20 units per inch,
$S_a = 0.2$.
If b axis is to be plotted at .25 units per inch,
then $S_b = 0.0025$.

Selection of one of the four possible coordinate systems is made by controlling the sign of the scale constants, as shown below:

Sign of S_a	Sign of S_b	Coordinate System
+	+	
-	+	
+	-	
-	-	

These scaling constants are stored as follows:

S_a	17.30
S_b	17.31

Initial values are selected by storing constants in the following locations:

a_o	17.20
b_o	17.21

When the subroutine is first loaded from the INTERCOM 500 tape, a and b equal zero.

Before the first and all subsequent entries to the subroutine, terminal values must be stored in channel 17, as follows:

a_1	17.81
b_1	21.01 (accumulator)

The above information concerning input areas sets the plotter up with the b axis parallel to the direction of paper travel. To plot a graph with a axis parallel to paper travel, interchange the locations used for a and b for all three pairs of input data.

Subroutine Entry Points

Three types of entry points are provided:

Location	Use
08.1700	*Normal entry: pen is dropped before and lifted after movement.
08.1709	*Pen-up entry: pen is not dropped during movement. Used for dashed lines, automatic reset to new initial values, or to reach an isolated point area.

Location	Use
08.1705	Resets residuals: no pen motion results. Used after manually resetting the pen to a new initial location, and before further plotting.

*On G-15's not modified for the pen-up feature, these two entry points produce the same result - pen movement with no lifting.

After exit from the subroutine, the accumulator contains $(a_1 - a_o) / S_a$.

Error Indications

If excessive right or left motion of the slide is programmed, a mechanical stop is reached. If either component of motion is computed to exceed 40.95 inches, no plotter motion occurs in that direction; however, no error indication interrupts the program.

Normal indications occur in case of overflow.

DATA INPUT SUMMARY

	**Location	Data
Initial Entry Only	17.20	a_o
	17.21	b_o
	17.30	$\pm S_a$*
	17.31	$\pm S_b$
Each Entry	17.81	a_1
	21.01	b_1

*Signs determine coordinate system.

**Reverse the two locations in each pair in order to orient a axis parallel to paper travel.

OPERATING SUMMARY

TO PREPARE FOR OPERATION

The following steps are required to load initially the INTERCOM 500 system.

1. INTERCOM 500 tape magazine, rewound, in the photoreader. Punch and Compute switches off, Enable switch to ON.

2. Type "p". Wait for photoreader to remain off.

3. Enable switch off. Compute switch to GO. When bell rings, computer is in manual operating mode.

At this time, the interpreter portion of the system is available. Any command except a double-command to initiate a subroutine may be executed by typing the command followed by "(tab) Ⓢ". A semi-automatic mode of operation is possible if it is desired to type in data or commands. (Otherwise, to use INTERCOM 500 services, the second loader must be read in.)

Semi-Automatic Operation

Permit Data Type-In . . . . . 051 ADDR // (tab) Ⓢ
Permit Floating Point Data Type-In. 052 ADDR // (tab) Ⓢ
Permit Command Type-In . . . . . 050 ADDR // (tab) Ⓢ

After use of one of these commands, it is possible to return to manual operation with the command:

Permit Manual Operation . . . . . 067 0000 // (tab) Ⓢ

To change to automatic mode, use the command:

Compute Automatically . . . . . 069 ADDR // (tab) Ⓢ

TO USE INTERCOM 500 SERVICES

After the initial loading of the system tape, as described above, the second loader must be read in to utilize INTERCOM 500 services:

1. Computer in manual operating mode. Compute switch off, Enable switch ON.

2. Type "p". Wait for photoreader to remain off.

3. Enable switch off, Compute switch to GO.

Services available after reading the second loader are: clear memory, load subroutines, list selected commands, and select fixed point fraction length. Any of these services may be requested in any sequence within the limitation that either of the last two return the computer to manual mode and therefore end the sequence. Either of the first two services may be selected, followed by the other of the two or one of the last two services.

If both of the last two services are required, the second loader must be read in again after the first of the two is executed. If neither of the last two services is desired, the computer must be returned to manual mode by typing "(tab) Ⓢ ".

To Clear Memory

To clear entire memory, including index registers, type "3 (tab) Ⓢ ". To clear index registers only, type "2 (tab) Ⓢ ". (Clearing index registers after the PA-3 subroutine has been loaded will destroy that subroutine). Computer does not return to manual mode. To return to manual mode, use one of the last two services, or type "(tab) Ⓢ ".

To Load Subroutines

Type "N (tab) Ⓢ " where N is the subroutine call code, then wait for photoreader light to remain off. Repeat this operation for each subroutine to be loaded. Computer does not return to manual mode. To return to manual mode, use one of the last two services, or type "(tab) Ⓢ ".

To List Selected Commands During Computation

1. Type "1 (tab) Ⓢ ".

2. Type "(tab) Ⓢ ". Computer is returned to the manual mode.

3. Type "61 0000 (tab) Ⓢ ".

4. To list every command, type "(tab) Ⓢ ". To list selected commands, type "FIRST SELECTOR (tab) SECOND SELECTOR (tab) Ⓢ " (Begin computation at this point.)

5. To terminate listing, put computer in manual mode and type "62 0000 (tab) Ⓢ ". Computer is now in manual mode.

   For further listing, this sequence may be entered at Step 3; Steps 1 and 2 need be performed only once.

To Indicate Places After the Decimal Point

Type "-D (tab) Ⓢ " where D indicates the number of places to be typed after the decimal point. Computer returns to manual mode automatically.

TO CHANGE FROM AUTOMATIC TO MANUAL OPERATING MODE

1. Move Compute switch to BP.

2. Turn Compute switch off and turn Enable switch ON.

3. Type " Ⓢ cf".

4. Turn Enable switch off and move Compute switch to GO.

SUBROUTINES

	TO CODE	TO LOAD
Function	Word Position	N
Fraction Selector	08, 01-07	1 CH u0
$\sqrt{x}$	97	2 CH u0
$\text{Log}_e\ x$ $\text{Log}_2\ x$ $\text{Log}_{10}\ x$	17 08 71	3 CH u0
e^x 2^x 10^x	22 08 72	4 CH u0
Sin x (degrees) Sin x (radians) Cos x (degrees) Cos x (radians)	39 42 23 26	5 CH u0
Arctan x (radians)	24	6 CH u0
Read Flexowriter command or data tape	17	7 17 u0
Punch data tape for Flexowriter tabulation	75	8 16 u0
Mag. tape input-output Reverse mag. tape Search mag. tape	70	9 CH u0
Read data card Punch data card	05 10	10 16 u0
Read command card	75	11 17 u0

SUBROUTINES (Cont'd.)

	TO CODE	TO LOAD
Function	Word Position	N
Index Register Utilization		
IRA ⟶ Floating Point	01	12 CH u0
Floating Point ⟶ IRA	00	
PA-3 Graph Plotter		
Pen-Up	09	13 17 u0
Pen-Down	00	or
Reset Residuals	05	x 17 u0

COMMAND LIST

COMMAND LIST (Cont'd.)

APPENDIX: SUBROUTINE SPECIFICATIONS

1. Subroutines may be stored in any of the words 00 through 99 of channels 09 through 18.

2. All subroutines are executed from channel 05 .

3. Subroutines should be written so that upon exit the overflow flip-flop is left in a reset state. Then, channel 06 should be transferred to channel 05 and control transferred to word u7 of the new channel 05. The form of the last command in a subroutine should be:

L	U	L+1	u7	0	06	05

4. The following short channel locations should not be destroyed by the execution of any subroutines: 2001, 2002, 2003, 2101, 2203, and 2202.

Offices

Boston 16
607 Boylston Street
COngress 2-9110

Chicago 11
919 N. Michigan Avenue
MIchigan 2-6692

Cleveland 13
55 Public Square
CHerry 1-7789

Dallas 1
1511 Bryan Street
RIverside 7-8805

Denver 3
655 Broadway
Suite 910
ALpine 5-1403

Detroit 37
12950 West Eight Mile Road
JOrdan 6-8789

Kansas City 11, Mo.
3430 Broadway
VAlentine 1-8681

Los Angeles
291 S. La Cienega Blvd.
Beverly Hills, California
OLeander 5-9610

New York 17
205 East 42nd Street
Room 1205
ORegon 9-6990

San Francisco
1330 Broadway
Suite 1121
Oakland 12, California
GLencourt 2-3664

Tucson
P. O. Box 4333
University Station
AXtel 8-5826

Washington 6, D. C.
1000 Connecticut Avenue, N.W.
STerling 3-0311

CANADA
Computing Devices of Canada
P. O. Box 508
Ottawa 4, Ontario, Canada
TAlbot 8-2711

OTHER COUNTRIES
Bendix International Division
205 E. 42nd Street
New York 17, New York
MUrray Hill 3-1100

Bendix Computer Division
LOS ANGELES 45, CALIFORNIA

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