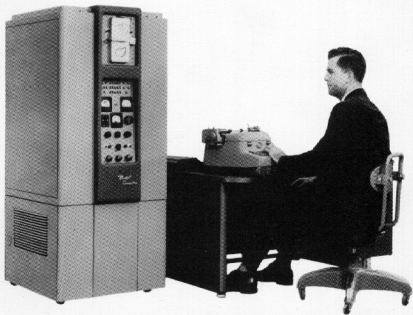


OPERATING MANUAL FOR THE

Bendix **G-15**

GENERAL PURPOSE DIGITAL COMPUTER



SUMMARY OF CONTENTS

	Pages		Pages
INTRODUCTION	1 - 2	ed in machine language form. This tape, the "program tape", may be inserted in the photo-reader and the program executed whenever desired. The program on tape is executed without the use of the Program Preparation Routine. The procedure is discussed in detail.	
<p>A program preparation routine may be read into the G-15 Computer to facilitate the preparation and check-out of a program. This term, and others which may be new to the reader, are explained.</p> <p>Part I of this manual describes use of the computer with the standard Program Preparation Routine. Part II discusses operation and control of the computer without such a routine.</p>			
PART I—COMPUTER OPERATION WITH THE PROGRAM PREPARATION ROUTINE			
How to Enter a Program From Typewriter	3 - 6		
<p>After a program has been coded by use of the commands described in the G-15 Coding Manual, the program may be typed into the computer. Both the commands and data may be in decimal form.</p> <p>This section describes the procedure for typing in and executing a program under control of the Program Preparation Routine.</p> <p>The operating instructions for the use of the Program Preparation Routine are tabulated and explained.</p>			
How to Check Out a Program	7-13		
<p>If the program does not work properly after it is first typed into the computer, it is necessary to find the errors in the program. This error-finding process is called "debugging". The procedure for "debugging" with the aid of the Program Preparation Routine is described.</p>			
How to Punch a Program Tape	14		
<p>After a program has been "debugged" and successfully executed, the computer may be instructed to punch the corrected program on an output tape; the program will be punched in machine language form.</p>			
PART II—DIRECT CONTROL OF COMPUTER OPERATION			
How to Initiate Operation From Face of Computer			17-21
<p>The controls and neon indicator lights on the front panel of the computer are explained. Directions are given for the use of the tape-handling assembly in reading and punching tape. The steps required to turn on the computer by means of the panel controls are listed.</p>			
How to Control Internal Operation From Typewriter			22-27
<p>The typewriter keys may be used to control the insertion and execution of a program without the use of a program preparation routine.</p> <p>The use of each typewriter switch and key is explained. The procedure is described by which information may be entered into the computer directly from the typewriter, and read out from the computer. The execution of a program one step at a time under typewriter control is discussed.</p>			
How to Insert and Execute Commands From Typewriter.....			28-30
<p>Commands may be typed into the computer in machine language form without the use of a program preparation routine. Directions for this procedure are given. Commands written in the G-15 Coding Manual, however, are in standard form. The method is described by which the operator may manually convert a command from standard form to machine language form for direct insertion into the computer from the typewriter.</p>			

INTRODUCTION

The Bendix Model G-15 Computer is a compact, general purpose, internally programmed, digital computer. It has been designed to be used both with and without a program preparation routine.

The standard Program Preparation Routine is provided in a punched tape magazine, and may be entered into the computer via the photo-reader. The routine performs many functions which aid in the initial preparation and checking of a program.

Operation of the computer with the standard Program Preparation Routine is described in Part I of this manual. Direct operation and control, without use of such a routine, is described in Part II.

Explanation of Special Terms

Certain terms used in this manual may be unfamiliar. These terms are defined below or in the Bendix G-15 Coding Manual.

standard command

A standard command is a command in the decimal form shown in the G-15 Coding Manual. Standard commands are entered into the computer by use of the standard Program Preparation Routine. The Program Preparation Routine converts the standard command into machine language and records the command on the magnetic drum.

machine language command

A machine language command is a command in the binary form that is actually recorded on the magnetic drum. Machine language commands may be entered into the computer directly without preparation or conversion routines.

sexadecimal system

Data input to the G-15 Computer is decimal, by use of the Program Preparation Routine; data output is decimal by use of a subroutine. However, internal computation is carried on in the binary number system. For convenience in handling binary numbers, the bits (that is, binary digits) that represent the magnitude of

a number may be divided into groups of four, from right to left. Each group of four bits is then considered to be a single character. The single character is determined according to the table on page 25. Since there are 16 possible characters, the name "sexadecimal" is applied to the enumerating system; however, the sexadecimal character representation may be considered to be a shorthand notation for the binary number system.

loading routine

A loading routine is a short sequence of commands which control the destination of input information. As the program is read into the input line (Line 19), the loading routine directs the transfer of input information from Line 19 to designated memory locations.

subroutine

A subroutine is an already-programmed sequence of commands which perform a general mathematical or logical operation. Subroutines are available in a "library" of punched tape magazines. A subroutine may be automatically copied from the magazine onto the program tape where it becomes a component of the complete program.

check sum

When information is read into the computer from punched tape or magnetic tape, it is possible to determine whether or not the information has been read correctly. The determination may be desirable as a tape imperfection, for example, may exist toward the center of the reel where it is unnoticed by the operator.

A specific G-15 command causes words that represent a block of input to be added together when they are written on the memory drum. The resulting sum, called a "check sum", may then be compared to the sum computed when the tape was prepared. If the two sums are identical, then information in the block has been correctly read.

number track

The number track is a channel on the magnetic drum which contains fixed timing signals for internal control. The number track signals are held in the first block of tape of "Test Routines" that are provided in punched tape magazines. When the computer is turned on, the information from this block is read by the photo-tape reader and transferred automatically to the number track channel on the drum.

Explanation of Standard Program Preparation Routine

The standard Program Preparation Routine in Magazine PPR permits programming by means of the standard commands listed in the G-15 Coding Manual and permits the input of data written as fixed point decimal numbers.

A program is typed into the computer in standard form. The Program Preparation Routine converts the program to machine language and provides facilities for checking out the program. The computer may then be instructed to punch an output tape on which the program is written in machine language. Note that the program can be executed without the presence of the Program Preparation Routine in the computer.

However, the program may be executed, in whole or in part, for check-out purposes immediately after it is typed into the computer.

Magazine PPR consists of three sections, as outlined below.

The first section permits:

- The use of standard commands by converting them to machine language form.

- The storage of commands and numbers in assigned memory locations.

- Program tape preparation including the collation of new programming with copies of subroutines from library tapes.

- Program inspection and correction during check-out.

- Punched tape duplication or type-out.

The second section permits:

- Input of positive and negative decimal numbers by converting the numbers from decimal to binary form after input.

- Input control of auxiliary routines.

The third section, which contains auxiliary routines that are read in when needed, permits:

- The simplified preparation of formats for type-out and of loading routines.

- The insertion and removal of break-points in the program.

- The repositioning of a program coded for particular drum channels to different channels.

- The listing and tracing of the program for use during "debugging".

The first section is stored in Lines 17, 16, 15 and 05 on the drum. The decimal to binary conversion routine is stored in Line 13. The control for auxiliary routines is entered into Line 14. The first section may be used independently of the subsequent sections.

Line 18 is used for working storage: Input from the photo-tape reader is transferred into Line 18 from Line 19 by the routine; commands are stored in Line 18 after conversion from standard to machine language form; information from other channels may be transferred to Line 18 for the examination, insertion or alteration of words.

The Program Preparation Routine stores format control words for standard output format in word positions 00 to 03 in Lines 02 and 03.

PART I

COMPUTER OPERATION WITH THE PROGRAM PREPARATION ROUTINE

HOW TO ENTER A PROGRAM FROM THE TYPEWRITER

To Enter and Execute Program by Use of Standard Program Preparation Routine

The computer is assumed to be on. If the computer is off, see page 21 for the turn-on procedure.

The sequence of steps, 7 through 15, may be varied by the operator.

1. Place the PPR magazine on the photo-reader. The tape must be rewound.
2. Put the Compute, Punch and Enable switches on the typewriter base to the center (off) positions.
3. With the Enable switch ON, type "p".* Put the switch off.

Wait until the photo-reader light goes off.

4. Put the Compute switch to GO (or BP).

Four blocks of information from the Program Preparation Routine will be read into the computer by the photo-reader. The blocks of information will be stored in Lines 17, 16, 15 and 05.

The following neon configuration will become steady on the control panel:

	●●●●	Source
Command Line	●●●●	Destination
	●●●●	Input-Output

After each block of tape is read, a checksum is automatically computed. If the reading is in error, the block of tape will be read again.

5. Put the Compute switch off, type "p".* with the Enable switch ON, put the Enable switch off and the Compute switch to GO (or BP).

The decimal to binary conversion routine and the input control for auxiliary routines are loaded into the computer.

6. Type "x 0 0 (tab) s".

Line 18 will be cleared to zero.

7. Type "y CD - (tab) s" where CD is the desired word position for the first command.
8. Type in commands in the standard form used in the coding manual; type "(tab) s" after each command.

The commands will enter Line 18. After a command is entered into the computer, the numbers in the N position of the command will be automatically typed out. N is the word position in Line 18 into which the next command typed will be entered.

9. To enter a sexadecimal constant into Line 18, type "z CD (tab) F G H I J K L (tab) s".

The number "F G H I J K L", in sexadecimal notation, will enter word position CD of Line 18.

Step 9 may be repeated as often as necessary.

10. To enter a decimal number into Line 18, type "E v C D (tab) s" where CD is the desired word position of the number.

The existing contents of CD, if any, will be typed out. The number typed in the E position is determined according to the table on page 6.

11. Type the decimal number, followed by "(tab) s".

Steps 10 and 11 may be repeated as often as necessary.

* Throughout this manual the keys which should be pressed with the Enable switch ON are shown underlined. After the keys are pressed, the Enable switch should be released to the center (off) position.

In this manual a lower case letter is used for a key which is actually pressed and an upper case letter (A through N) is used when the letter takes the place of a number which should be typed.

12. Type "x 0 6 (tab) s".

A check sum is automatically obtained and typed out. The contents of Line 18 are punched on tape, for later use if desired. Line 18 is not cleared in the process.

13. Type "A B x 0 3 (tab) s" where AB is the number of the line in which it is desired to store the information from Line 18.

The contents of Line 18 are copied into Line AB. This instruction may be executed after Step 8, if it is desired to store commands only.

Steps 6 through 13 may be repeated for each additional line entered into the computer.

14. To give the computer a starting point for computation, type "BCD x 0 4 (tab) s" where CD is the word position of the first command and B is the command line. (B may be Lines 0, 1, 2, 3 or 4.)

15. If the Compute switch is at BP, move it to the center (off) position and then to GO (or BP).

The program will be executed.

Codes for Computer Instruction During Program Preparation

The instruction codes listed below are applicable when the first two sections of PPR have been loaded into the computer. Before typing the codes, the control panel neons must be in the configuration:

Command Line 000	00000 Source
	00000 Destination
	00000 Input-Output

In order to obtain this neon pattern:

- Put the Compute and Punch switches off, the Enable switch ON and type "s c 5 f".
- Put the Enable switch off and the Compute switch to GO (or BP).

If the Compute switch is at BP, the computer halts after a check sum is typed out. To resume operation, move the Compute switch to the center (off) position and back to BP. If the Compute switch is at GO, the computer does

not halt after a check sum is typed out.

Instruction codes that begin with the letter "w" continue to operate on additional blocks of tape without re-typing the codes. After the operations for the desired block or blocks are completed, put the Compute and Punch switches off, type "s f" and return the Compute switch to GO (or BP).

w 0 0 | tab | s

Read paper tape until a Stop code appears on the tape and copy information read into Line 18. Type out a check sum of the information on tape.

w 0 1 | tab | s

Read paper tape until a Stop code appears on the tape and copy information read into Line 18. Type out check sum. Type out information read.

w 0 2 | tab | s

Read paper tape until a Stop code appears on the tape and copy information read into Line 18. Type out check sum. Punch information read on new tape.

w 0 3 | tab | s

Read paper tape until a Stop code appears on the tape and copy information read into Line 18. Type out check sum. Type out information read and punch out new tape. (Put Punch switch ON after type-out of check sum.)

x 0 0 | tab | s

Clear Line 18 to zero.

x 0 1 | tab | s

Copy number track into Line 18. Type out check sum of number track. Punch number track on tape.

A B C D
 [] [] [] [] x 0 2 | tab | s

Copy contents of Line AB into Line 18. Type

out contents of word CD in Line AB in sexa-
decimal notation.

A B C D

				x	0	2	-	tab	s
--	--	--	--	---	---	---	---	-----	---

Copy contents of Line AB into Line 18. Type
out contents of word CD in Line AB in the form
of a standard command.

A B

		x	0	3	tab	s
--	--	---	---	---	-----	---

Copy contents of Line 18 into Line AB.

B C D

			x	0	4	tab	s
--	--	--	---	---	---	-----	---

Take next command from word CD of Line B.
Line B may be Lines 0, 1, 2, 3 or 4.

If the Compute switch is at BP, the com-
puter will halt prior to entering the pro-
gram.

x	0	5	tab	s
---	---	---	-----	---

Type out check sum of Line 18. Type out con-
tents of Line 18, starting at the highest num-
bered location in the line.

To obtain check sum only, put the Compute
switch to BP before typing "x 0 5 (tab) s".
After the check sum is typed out, put the
Compute switch off, type "f" and move the
switch to GO (or BP).

x	0	6	tab	s
---	---	---	-----	---

Type out check sum of Line 18. Punch contents
of Line 18 on tape, starting at the highest num-
bered location in the line.

x	0	7	tab	s
---	---	---	-----	---

Type out check sum of Line 18. Type out and
punch contents of Line 18 on tape, starting at
the highest numbered location in this line.

A leader will be punched after which the

computer will halt. The Punch switch must
then be put to the ON position. The con-
tents of Line 18 will be punched and typed
out. When punching is complete the Punch
switch must be put to the off position.

C D	+	F G H I J K L
z	tab	tab s

Enter the number "F G H I J K L", in sexadec-
imal notation, into word CD of Line 18.

After this instruction is typed, there will
be an automatic carriage return and Loca-
tion CD will be typed out. If this location
was not empty, its former contents will
be typed out.

C D		
y	-	tab s

Permit commands in standard decimal form to
be typed into Line 18. Put the first command
typed into word position CD of Line 18. Put
each following command into the word position
corresponding to the number in the N position
of the immediately preceding command.

After this instruction is typed, there will
be an automatic carriage return and Loca-
tion CD will be typed out. The first com-
mand may then be typed in. Automati-
cally, the computer will execute a carriage
return and type the number in the N posi-
tion of the command. The next command
may then be typed, followed by "(tab) s".
This next command will enter word posi-
tion N.

If a location in which a command is to be
stored is not empty, its contents will be
typed out as well as the location itself.
Inadvertent replacement of a stored word
may thus be avoided. The type-out will be
in standard decimal command form.

If a command of the form "T N C 28 31"
is typed, the number N + 1, instead of N,
will be automatically typed out; the next
command typed will then be entered into
word position N + 1.

C D	
y	tab s

This instruction may be typed instead of "yCD -

(tab) s". Operation will be the same but the original contents of a location will be typed out in sexadecimal form rather than standard decimal command form.

E	C	D
v		tab|s

Enter the decimal number about to be typed into word CD of Line 18.

A number typed in the E position of the above instruction will be interpreted according to the following table:

- E = 0 Single precision decimal fractions (8 digits should be typed).
- E = 1 Single precision integers (8 digits or less). Integer values will be multiplied by 2^{28} .
- E = 4 Double precision decimal fractions (14 digits should be typed).
- E = 5 Double precision integers (14 digits or less). Integer values will be multiplied by 2^{57} .

If no number is typed in the E position, E will be interpreted to be zero.

If double precision numbers are entered, CD must be an even number. The double precision number will then be stored in word positions CD and CD + 1.

After the instruction is typed, there will be an automatic carriage return and location CD will be typed out. The decimal number may then be typed, followed by "(tab) s".

If "00" is typed out instead of location CD, re-type the instruction. Now the carriage will return automatically and location CD will be typed out. ("00" will be typed out when the conversion routine, which is necessary for the execution of these instructions, is not properly stored in Line 13. The first typing of the instruction merely reads the conversion routine into Line 13 via the photo-reader.)

If, by error, when E = 0, more than eight digits are filled, or, if, when E = 4 or 5, an odd number is typed for CD, the computer will indicate the error by ringing the bell and typing out location CD.

An error may be corrected by re-typing the correct instruction.

Example Illustrating Decimal to Binary Conversion Routine

It is desired to enter into the computer the decimal fractions .25 and .875 into word positions 31 and 35, respectively.

1. Since these numbers are single precision, decimal fractions, type "0 v 3 1 (tab) s".

After the carriage return, 31 is typed out.

2. Type "2 5 0 0 0 0 0 0 (tab) s".

The decimal fraction .25 is converted, stored in Line 18, word position 31, and typed out in sexadecimal form.

3. Type "0 v 3 5 (tab) s".

After the carriage return, 35 is typed out.

4. Type "8 7 5 0 0 0 0 0 (tab) s".

The decimal fraction .875 is converted, stored in Line 18, word position 35, and typed out in sexadecimal form.

If the decimal to binary conversion routine in Line 13 has been erased, proceed as follows:

1. Type "0 v 3 1 (tab) s".

The decimal to binary conversion routine is read in from Magazine PPR and two zeros are typed out.

2. Re-type "0 v 3 1 (tab) s" and proceed as before.

After the carriage return, 31 is typed out.

HOW TO CHECK OUT A PROGRAM

To Check Out a Program by Means of the Standard Program Preparation Routine

After a program is composed, it may be entered into the computer and executed, in whole or in part, in the manner described in the preceding section. If there are errors in its composition, a program will not work properly and "debugging" will be required.

When Magazine PPR has been read into the computer (Steps 1 through 5 on page 3), instructions to the computer may be typed on the typewriter keyboard to aid in checking out the program. The instructions are listed on pages 4 through 6.

Programs may be divided into sections for "debugging" by insertion of break-points. The method for inserting and removing break-points is described on page 8.

An aid to "debugging" a section of a program is a tracing routine, which types out the progress of the solution step by step; another aid is a listing routine, which types out the commands of a program without executing them. The use of the tracing routine is described on page 8; the use of the listing routine is described on page 13.

As the errors in a program are discovered, the program may be corrected from the typewriter keyboard by means of the instruction codes. Notice that the procedure is to copy the line in need of correction into Line 18, to type in the corrections, and to then copy the corrected contents of Line 18 back to the original channel.

During "debugging" a line of the program may be inadvertently destroyed. If each line is punched on tape immediately after it is prepared, any information lost may be easily restored.

Subroutines already available on punched paper tape may be required for the program. A subroutine may be entered into the computer during program preparation or check-out by placing the subroutine magazine on the photo-tape reader and using the instructions on page 4. By use of one instruction the subroutine may be entered into Line 18 and by use of another

instruction may be copied into the desired line.

A portion of a program may be stored in one drum channel, "debugged", and then "repositioned" to another channel from which it will be executed (see page 11).

Another aid for isolating errors is the execution of a program one instruction at a time (see page 26).

After the program, which is the main routine of a program tape, is fully "debugged", the computer may be instructed to punch the corrected program tape (see page 14).

Auxiliary Routines for Use During Program Preparation and Check-Out

The auxiliary routines are available in the third section of Magazine PPR. If the first two sections of Magazine PPR have been read into the computer (see page 3), any one of the auxiliary routines may be read into the computer from punched tape by typing the appropriate instruction code. (If one of the instruction codes listed below is typed, and the first two sections of Magazine PPR have not been read into the computer, a bell will ring.)

The auxiliary routines facilitate and expedite program preparation and check-out. Additional routines may be added by the programmer without modification of the original tape in Magazine PPR.

The title and function of each auxiliary routine is listed below. The operating procedure for each is discussed on the following pages. The neon indicator panel must be in the PPR configuration shown on page 4 prior to typing the instruction for reading any of these routines into the computer.

The Break-Pointer inserts or removes a break-point from any selected memory location.

The Tracer permits a program to be executed with a type-out of each command in a program and the result of its execution.

The Formater provides a simple means of creating an output format.

The Auto-Loader permits the automatic preparation and punching of a loading routine for any Lines 00 to 18, inclusive.

The Repositioner permits programs, prepared and checked, in one line, to operate out of a different line.

The Lister provides a means for the automatic type-out of the commands of a program, in the order in which the commands would be executed, without their execution.

Operating Instructions for Auxiliary Routines

break-pointer

The "Break-Pointer" permits insertion or removal of break-points in any long line in the memory. By its use programs may be checked out in selected sections.

1. Type "0 1 x 0 8 (tab) s".

The routine will be read into the computer from Magazine PPR. The number "01" will be typed out.

2. Type "A B C D (tab) s".

A break-point will be inserted into word position CD of Line AB if there is no break-point in that location; if there is a break-point in that location it will be removed.

A single bell rings to indicate the insertion of a break-point; two bells ring to indicate the removal of a break-point.

3. Repeat Step 2 for further insertion or removal of break-points.
4. Type "s".

The computer is put in the position to accept another PPR instruction code.

tracer

The "Tracer" provides facilities for the type-out in standard form of each command in the program being checked, the execution of each command, and the type-out of the result of each execution. By the use of break-points type-out of any portions of the program may be skipped. The program is not disturbed by the tracing procedure.

Single or double precision words are typed out as specified by the command. All double precision type-outs occur with the least significant portion first. Multiply, divide, and shift commands cause double precision type-outs of the PN, MQ and MQ Registers, respectively.

Break-points may be inserted or removed by use of the instruction "A B C D - (tab) s".

The program may be traced if it is in Lines 00, 01, 02, 03, 04, 06, 07, 08, 09, 10 and 19.

If the program is in Line 05 or Lines 11 through 18, it should be moved from these lines by use of the "Repositioner" (see page 11) before the "Tracer" is used.

1. Type "0 2 x 0 8 (tab)s".

The routine will be read into the computer from Magazine PPR.

2. Break-points may be inserted in any selected locations. To insert a break-point in word CD of Line AB, type "ABCD-(tab)s".

A bell will ring to signal the insertion of a break-point.

3. Type "ABCD (tab)s" to begin tracing from word position CD of Line AB.

The command in word CD of Line AB will be executed and typed out in standard form. Succeeding commands in the program will be executed and typed out. The type-outs alternately stop and start at successive break-points in the program. During the non-type-out phase, computation is still under the control of the "Tracer" routine and is therefore slower than computation would normally be.

4. To execute a portion of the program being checked without the use of the "Tracer", put the Compute switch off and then to BP until the neon lights indicate S = 0000 and D = 0000; if the neon pattern is not obtained, put the Compute Switch off and back to BP again. Put the Compute switch off, type "s c B" (B is the command line for the program) and put the Compute switch to BP.

Each time the Compute switch is put off and back to BP another portion of

program (to next break-point) is executed.

5. To use the "Tracer" routine in the next portion of the program, when computation has halted, put the Compute switch off, type "s c 5 f", put the Compute switch to GO and repeat Step 3.
6. To put the computer in a position to accept another instruction code from the first section of Magazine PPR, put the Compute switch off and then to BP until the neon lights indicate S = 00000 and D = 00000; if this neon pattern is not obtained, put the Compute switch off and back to BP again. Put the Compute switch off, type "f" and put the Compute switch to GO.
7. If it is desired to use the second or third sections of Magazine PPR (see page 2), rewind the tape and follow Steps 2 through 5 on page 3.

EXAMPLE

It is desired to trace a program starting in word position 54 of Line 01. The program exits at word 95 of Line 01 to a subroutine and re-enters at word position 43 of Line 01. (the subroutine is not traced.)

1. Type "0 2 x 0 8 (tab) s".
2. Type "0195-(tab) s" and "0143-(tab) s".
3. Type "0154 (tab) s".

Tracing will begin at word position 54 of Line 01 with type-outs. Type-outs will stop at word 95 of Line 01 and will begin again at word 43 of Line 01.

4. Put the Compute switch to BP. After the Source neons indicate 00000 and the Destination neons indicate 00000, put the Compute switch off, type "s c 1" (01 is the command line of the program) and put the Compute switch to BP.

The subroutine portion of the program will be executed without the use of the "Tracer".

5. Put the Compute switch off, type "s c 5 f", put the Compute switch to GO and repeat Step 3 with a new starting position.

The "Tracer" will be used for the next portion of the program.

formater

The "Formater" permits an output format to be compiled by typing a digit for each format character. The routine is used when an output format different from standard format is desired.

1. Type "0 3 x 0 8 (tab) s".

The routine will be read into the computer from Magazine PPR. The number "03" will be typed out.

2. Type the proper succession of digits from the table below.
3. Type "1" to signify that the format is complete. No more than 37 format characters should be typed before the end code.

The format will be compiled and typed out in the form in which it should be inserted into the word positions for format control (See page 26). The computer will be put in position to accept another PPR instruction code.

To obtain another format, "0 3 x 0 8 (tab) s" must be typed again.

TABLE OF FORMAT CHARACTER CODES

Format Character	Code
Digit	0
End Code	1
Carriage Return	2
Period	3
Sign	4
Reload	5
Tab	6
Wait	7

EXAMPLE

Prepare the format for typing a Carriage Return, Tab, Sign, 3 digits, Period, 2 digits, Tab and End Code.

1. Type "0 3 x 0 8 (tab) s".
2. Type "2 6 4 0 0 0 3 0 0 6 1".

The type-out will be:
- . 5 u 0 0 1 8 1 1 0 0 0 0 0 0

This type-out constitutes the format control words in sexadecimal notation. The first word typed out should be entered into word position 03 of the format control line (See page 26). The second word typed out should be entered into word position 02 of the format control line.

auto-loader

The "Auto-Loader" permits the automatic preparation of a program loading routine and enables the loading routine to be punched on the program tape. In addition to commands to load the input program into specified lines the prepared loading routine will contain format control words for a standard output format and a command to halt operation of Accessory DA-1.

The "Auto-Loader" will prepare a loading routine for any lines in any order from Line 00 to Line 18, inclusive. In this process the "Auto-Loader" uses the short lines.

In BP operation the computer will halt after the program is loaded into the computer by the prepared loading routine. In GO operation the computer will execute the program immediately after it is loaded.

To prepare a loading routine which does not contain check sums for the lines loaded:

1. Type "0 4 x 0 8 (tab) s".

The routine will be read into the computer from Magazine PPR. The number "04" will be typed out. The neon lights will flicker.

2. Type "A B (tab)" where AB is the first channel on the drum to be filled. Repeat for other lines, AB, in the program, in the order desired. If the starting location is in a command line, this line must be entered last. The loading routine will operate out of this line.

3. After the last channel has been specified, type "s".
4. If the starting command line for the program is the last channel specified, type "NCD (tab)s" where N is the line (N = 0, 1, 2, 3, 4 or 5) and CD is the word position at which computation starts.

If a channel must be read into a command line to begin execution, type "A B / N C D (tab) s" where AB is the line containing the starting command and N is the command line into which the contents of Line AB are to be copied.

The loading routine will be automatically punched on tape.

The computer is automatically put in position to accept another PPR instruction code.

The "Auto-Loader" may be instructed to insert previously-determined check sums for the various lines controlled by the loading routine. A consequent error in reading the line from the program tape will cause a re-reading of the line. To prepare a loading routine with a check sum for a line, replace Step 2 of the procedure above with the step below:

2. Type "A B (tab) KKKKKKK (cr)"* where AB is the line to be loaded and "KKKKKKK" is the check sum in sexadecimal notation.

An identification number may be inserted in the loading routine, if desired. The "Auto-Loader" automatically adds a constant to the loading routine it prepares so that the sum of the contents of the line equals zero. Therefore, the number selected as the identification number will also be the check sum of the line.

To insert an identification number, after punching begins in Step 4, put the Compute switch off and type "s f". Put the Compute switch to BP and type "z 4 7 (tab) KKKKKKK (tab) s" where "KKKKKKK" is the desired identification number. Type "x 0 6 (tab) s".

The loading routine will then be punched on the program tape. The computer will be put in position to accept another PPR instruction code.

If an error is made at any time type "f" and revert to Step 1.

*(cr) denotes carriage return.

Note: The loading routine is compiled in Line 18. The designations of the lines to be loaded are stored in odd word locations beginning with word 49. The corresponding check sums are stored in even word locations beginning with word 48. The identification number for the loading routine is stored in word 47.

EXAMPLE I

It is desired to prepare a loading routine for lines 01, 11, 06 and 00 without check sums or identification number. Computation begins in word 43 of Line 00.

1. Type "0 4 x 0 8 (tab) s".
2. Type "0 1 (tab) 1 1 (tab) 0 6 (tab) 0 0 (tab) s".
3. Type "0 4 3 (tab) s".

The loading routine will be punched.

EXAMPLE II

It is desired to prepare a loading routine for Line 12 whose check sum is "-3y8z952" and for Line 10 whose check sum is "43uy125". Computation starts by transferring Line 12 to Line 01 and begins in word position 55 of Line 01. The identification number for the loading routine is "2100000".

1. Put the Compute switch to BP.
2. Type "0 4 x 0 8 (tab) s".
3. Type "1 2 (tab) -3 y 8 z 9 5 2 (cr)" and type "1 0 (tab) 4 3 u y 1 2 5 (cr) s".
4. Type "1 2 / 1 5 5 (tab) s".
5. When punching begins, put the Compute switch off and type "s f".
6. Put the Compute switch to GO and type "z 4 7 (tab) 2 1 0 0 0 0 0 (tab) s".
7. Type "x 0 6 (tab) s".

repositioner

The "Repositioner" permits a program, which is coded to use a certain portion of the memory, to be executed using a different portion of the memory. A program which uses any group of long lines may be changed to any other group of long lines (Lines 00 through 19); for example, subroutines programmed for one line may be repositioned to another line. If a program will ultimately use some of the same lines used by the Program Preparation Routine, the program may be first coded and checked out in other lines of the memory. The full facility of PPR is then available for the check-out procedure. The "Repositioner" changes the S and D numbers of commands in the program.

A program has been coded and checked out in convenient lines. To use different lines for the final program, the procedure is:

1. Type "A B 0 0 x 0 2 - (tab) s".

The contents of the line to be repositioned, AB, will be copied into Line 18. Word CD in this line will be typed out in standard command form.

2. Type "0 6 x 0 8 (tab) s".

The routine will be read into the computer from Magazine PPR. The number "06" will be typed out.

3. Type "M M N N (tab) s", where MM is the line number to be changed to NN.

The "Repositioner" will search Line 18 for all references to Line MM and change each to NN. The location number of each is typed out. Commands in which D is equal to 31 will remain unchanged. The computer is put in position to accept another PPR instruction code.

4. Since the computer cannot distinguish a number from a command, compare the location number type-outs of the addresses that were changed with the locations containing numerical information on the coding sheets. Restore any changed hexadecimal numbers by means of the appropriate "z" instruction (page 5).

5. Since D is equal to 31 in commands for command channel selection, and "31" commands are unchanged, use the appropriate "y" instruction (page 5) to change these commands from transfer of control to Line MM to transfer of control to Line NN.

6. For further changes in the same line:

Repeat Step 2.

Repeat Step 3 with appropriate MM and NN numbers.

Repeat Step 4.

Repeat Step 5 if transfer of control from one command line to another is involved.

7. Punch the repositioned line by means of the instruction "x 0 6 (tab) s" (page 5).

The contents of Line 18 will be punched on tape. The computer will be put in position to accept another PPR instruction code.

8. Repeat similar steps for other lines in program. (See Example below.)

EXAMPLE

A program is to ultimately use Lines 00, 01, 05 and 17. For check-out purposes the problem is coded to use Lines 00, 01, 04 and 06. The four lines of coding have been converted to machine language and are stored temporarily in Lines 00, 01, 04 and 06. The S and D numbers referring to Lines 00 and 01 do not require changing; those referring to Lines 04 and 06 require changing.

1. Type "0 4 0 0 x 0 2 - (tab) s".

The contents of Line 04 will be copied into Line 18.

2. Type "0 6 x 0 8 (tab) s".

3. Type "0 4 0 5 (tab) s".

Line 18 will be searched for all references to Line 04 and each will be changed to Line 05. The addresses of the changed locations will be typed out.

4. Use the appropriate "z" instruction code to restore any hexadecimal constants that were changed.

5. Use the appropriate "y" instruction code to change any transfer of control to Line 04 to transfer of control to Line 05.

6. Type "0 6 x 0 8 (tab) s".

7. Type "0 6 1 7 (tab) s".

Line 18 will be searched for all references to Line 06 and each will be changed to Line 17. The addresses of the changed locations will be typed out.

8. Repeat Step 4.

9. Type "x 0 6 (tab) s".

The contents of Line 18 will be punched on tape.

10. Type "0 6 0 0 x 0 2 - (tab) s".

The contents of Line 06 will be copied into Line 18.

11. Repeat Steps 2 through 9.

12. Type "0 0 0 0 x 0 2 - (tab) s".

The contents of Line 00 will be copied into Line 18.

13. Repeat Steps 2 through 9.

14. Type "0 1 0 0 x 0 2 - (tab) s".

The contents of Line 01 will be copied into Line 18.

15. Repeat Steps 2 through 9.

lister

The "Lister" permits the automatic type-out of the commands of a program in standard form without their execution. If other facilities of PPR are needed after the use of this routine, it is necessary to read in the first two sections of PPR again.

1. Type "0 7 x 0 8 (tab) s".

The routine is read into the computer from Magazine PPR. A carriage return will occur.

2. Type "A B C D (tab)", where AB is the line to be listed and CD is the starting location. Put the Compute switch off and back to GO.

Type "B(cr)", where B is the command line from which the program would be executed. Put the Compute switch off and back to GO.

Line AB will be copied into Line 18 for listing. The addresses of empty locations will be typed out. If this information is desired, wait for the computer to halt. If this information is not desired, put the Compute switch to BP, and wait until the computer halts.

3. Put the Compute switch off and back to GO.

The commands which make up the program will be typed out in standard form. The program will not be executed. When a command is typed out, it will be cleared from Line 18. When a test command is encountered, a carriage return will occur and listing will continue with the address in the "N" portion of the command. (The N + 1 number is stored for future reference.) Listing will continue until an empty location, a transfer of control to a different command line, or a transfer of a new line of information to line B is encountered. In these cases, the most recently stored N + 1 number will then be used to start listing another branch of commands. When listing of other branches is com-

pleted or when the command, "next command from AR", is encountered, a bell will ring.

4. When listing stops, type "C D (tab)" and put the Compute switch off and back to GO; CD will be the new location in the line at which listing is to begin again. (Type only the two digits that represent this word position.)

Listing will resume beginning with word position CD in the line.

5. Type "- (tab)" and put the Compute switch off and back to GO.

The computer will type out all unlisted non-zero locations both as sexadecimal numbers and as decimal commands. Step 2 may then be repeated for the listing of another line.

6. Listing may be halted and started at a new address at any time during operation of the listing routine. To do so put the Compute switch to BP, wait for the computer to halt, put the Compute switch off, type "s f" and put the Compute switch to GO. Steps 2 and 3 or Step 4 may then be repeated.
7. To put the computer in a position to accept another PPR instruction code, rewind the tape in Magazine PPR and follow Steps 2 through 5 on page 3.

The line to be listed may be on punched tape. In this case the procedure is:

1. Type "0 7 x 0 8 (tab) s".
2. Change tape magazines on the photo-reader and type "p".

A block of information is read from tape into Line 19 each time "p" is typed.

3. Type "s c 5 f" and put the Compute switch to GO.
4. Proceed to Step 2 above and type "1 9 C D (tab)". Put the Compute switch off and back to GO. Follow the subsequent directions.

HOW TO PUNCH A PROGRAM TAPE

To Punch a Program Tape

A program tape prepared for the G-15 Computer may be divided functionally into three parts: the loading routine, the main routine and the subroutines. The standard Program Preparation Routine facilitates the punching of each portion.

One of the auxiliary routines, the "Auto-Loader", permits the automatic preparation and punching of the loading routine (see page 10). The main routine is punched on the tape one line at a time.

Subroutines may be punched on this tape, after they are read into the computer, by using the appropriate instruction codes on page 4. An important subroutine is the Input-Output Subroutine. This routine provides for decimal to binary conversion during input, binary to decimal conversion during output, and insertion of the proper characters for standard output format into Lines 02 and 03.

The instructions for punching the program tape are:

1. Punch the loading routine on tape in the manner described on page 10.
2. Type "A B C D x 0 2 - (tab) s".

The contents of Line AB will be copied into Line 18. Word CD in Line AB will be typed out.

3. Put the Compute switch to GO and type "x 0 6 (tab) s".

The check sum of Line AB will be typed out. Line AB, which was copied into Line 18, will be punched.

4. Repeat Steps 2 and 3 for remaining lines of the main routine.
5. Repeat Steps 2 and 3 for subroutines used.

Instead of the above steps, subroutines may be copied directly onto the program tape from subroutine tape magazines by means of the "w 0 0" and "x 0 6" instruction codes described on pages 4 and 5, respectively.

To Execute Program from Program Tape

1. Place the program tape magazine in position on the photo-reader. The tape must be rewound.
2. Put the Compute and Punch switches to the center (off) positions.
3. With the Enable switch ON, type "p". Put the Enable switch off.

Wait until the photo-reader light goes off.

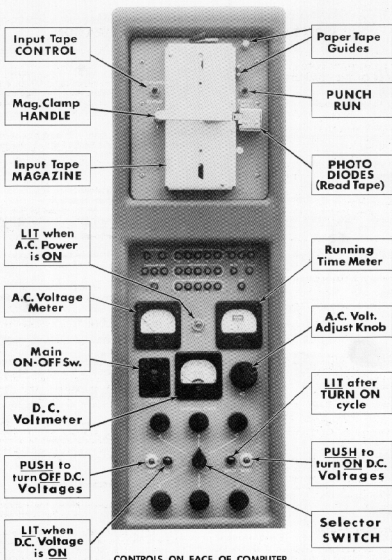
4. Put the Compute switch to GO (or BP).

The computer automatically begins at Line 23, word position 00, and executes the program.

SUMMARY OF PPR INSTRUCTION CODES

w 00	.....	Read tape, type out check sum.
w 01	.....	Read tape, type out check sum, type out information read.
w 02	.....	Read tape, type out check sum, punch information read.
w 03	.....	Read tape, type out check sum, type out and punch information read. (Punch switch must be ON after check sum type-out.)
x 00	.....	Clear Line 18.
x 01	.....	Type out check sum, punch number track.
ABCD x 02	—	Line AB to Line 18, type out word CD as a standard decimal command.
ABCD x 02	.....	Line A B to Line 18, type out word CD in sexadecimal form.
AB x 03	.....	Line 18 to Line AB.
BCD x 04	.....	Next command from Line B (B = 0, 1, 2, 3 or 4), word CD.
x 05	.....	Type out check sum, type out contents of Line 18.
x 06	.....	Type out check sum, punch contents of Line 18.
x 07	.....	Type out check sum, type out and punch contents of Line 18. (Punch switch must be ON after check sum type-out.)
y CD	—	Decimal command input into word CD of Line 18, type out previous contents of CD as a standard decimal command.
y CD	.....	Decimal command input into word CD of Line 18, type out previous contents of CD in sexadecimal form.
z CD (tab) ± FGHIJKL	.....	Sexadecimal number input into word CD of Line 18.
EvCD	.....	Decimal number input into word CD of Line 18:
		E=0 Single precision fractions.
		E=1 Single precision integers.
		E=4 Double precision fractions.
		E=5 Double precision integers.

All instructions followed by (tab) s.



CONTROLS ON FACE OF COMPUTER

PART II

DIRECT CONTROL OF COMPUTER OPERATION

HOW TO INITIATE OPERATION FROM THE FACE OF THE COMPUTER

Power Control Panel

The power controls are on the front panel of the computer. The function of each is described below.

When the START switch is pushed up, AC power is supplied to the computer. As a result of the application of power:

Filament voltage, indicated by the amber AC light, gradually increases, reaching full value after about one minute.

The magnetic drum rotates.

The blower system operates.

The hours-elapsed time meter starts.

The AC knob permits adjustment of the line voltage. The knob should be set so that the AC meter reads 100% (6.3 volts) during operation.

When the green RESET button is pressed, DC power is turned on and two blocks of tape are automatically read. The button should be held down until the red DC pilot lamp lights.

When the green READY indicator is lit, the computer is ready for operation.

When the red DC OFF button is pressed, the DC power is turned off.

The SELECTOR SWITCH connects the DC voltmeter to the voltage controls marked A, B, C, D, E and F. The six voltage controls should be adjusted so that the DC voltmeter reads 100% at each selector switch setting.

Indicator Light Panel

A set of neon lamps, mounted above the control panel, indicates the internal state of the

computer. These lights blink on and off during computation. When computation has ceased, after a halt command, a break-point, or a single cycle operation, the resultant steady neon configuration provides information about the last command that was executed.

The various neons on the panel may be grouped by function into command indicators, control indicators, and input-output indicators.

command indicators

The nature of the last command executed is indicated by the sets of lights labeled "SOURCE", "DESTINATION", "CHARACTERISTIC" and "DB-PR".

The SOURCE neons indicate in binary form the number in the S position of the command.

The DESTINATION neons indicate in binary form the number in the D position of the command.

The DB-PR neon is lit if the command is double precision.

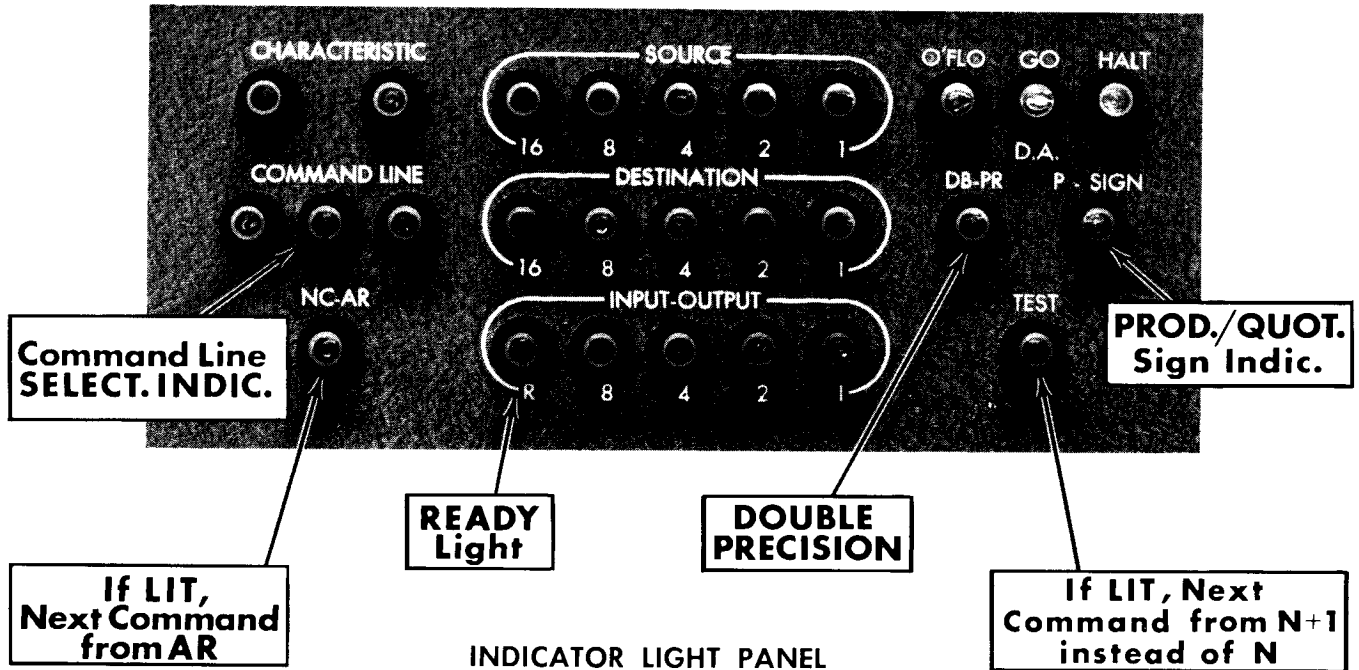
For commands written in machine language, and for single-precision commands written in the standard coding system, the CHARACTERISTIC neons indicate the number in the C position of the command, in binary form.

For double precision commands written in the standard coding system, the CHARACTERISTIC neons indicate a number in binary form four less than the number in the C position of the command.

control indicators

A set of eight neons shows the current state of the control circuitry in the computer.

The HALT light indicates that computation is not proceeding. (The computer is also halted if the light is off and Compute switch on the typewriter base is in the center position.)



The O'FLO light indicates that an arithmetic overflow from Register PN, Register MQ or Register AR has occurred. If Accessory DA-1 is attached to the computer, an overflow within the DA-1 may also cause the neon to light.

The COMMAND LINE neons indicate the channel on the magnetic drum from which commands are being executed. They are interpreted as follows:

Line zero	.....	0	0	0
Line one	.....	0	0	●
Line two	.....	0	●	0
Line three	.....	0	●	●
Line four	.....	●	0	0
Line five	.....	●	0	●
Line nineteen	.....	●	●	0
Line twenty-three	.....	●	●	●

The NC-AR neon is lit when the next command to be executed will be taken from Register AR.

The TEST neon is lit during execution of one of the "test" commands listed in the coding manual, if as a result of the test the next command to be executed is taken from location N + 1 instead of N.

The P-SIGN neon indicates the sign in the special sign register associated with Registers ID, PN and MQ. Therefore, the light will indicate the sign of a product or quotient. The sign is negative when the neon is lit.

The GO-D. A. neon is lit when the Digital Differential Analyzer is in operation.

input-output indicators

The state of the input-output system is indicated by five neon lights.

When the "R" or "Ready" light is on, the computer is ready to accept external instructions or an input-output command; when off, the computer is executing an input or output command.

The remaining four neons indicate the nature of the input-output operation. The various neon configurations and their meanings are explained in the following table.

Input-Output Indicators

	8	4	2	1
"Ready"	0	0	0	0
Permit Type-in	●	●	0	0
Read Punched Tape	●	●	●	●
Read Punched Cards via CA-1	●	●	●	0
Read Magnetic Tape	●	●	0	●
Type Line 19	●	0	0	●
Punch Line 19 on Tape	●	0	●	0
Punch Line 19 on Cards via CA-1	●	0	●	●
Type out AR	●	0	0	0
Write on Magnetic Tape	0	0	0	●
Search Magnetic Tape, Forward	0	●	0	●
Search Magnetic Tape, Reverse	0	●	0	0

Tape-Handling Assembly

tape reader

The photo-tape reader is mounted above the neon indicator panel. Input tape is held in a metal magazine which fits into place on the tape reader. The magazine contains two reels; during reading, tape passes from the lower reel, past a set of photo-electric diodes mounted on the computer, and onto the upper reel. The magazine is held in place by a clamp handle; the diode assembly moves when the clamp handle is lifted in order to facilitate insertion of the tape.

When putting punched tape on the reel of a magazine or onto the tape rewind hub (supplied with the computer), attach the tape so that the narrow side, as measured from the sprocket holes, is toward the computer. The tape should be attached in such a manner that the first character read is not a Stop code.

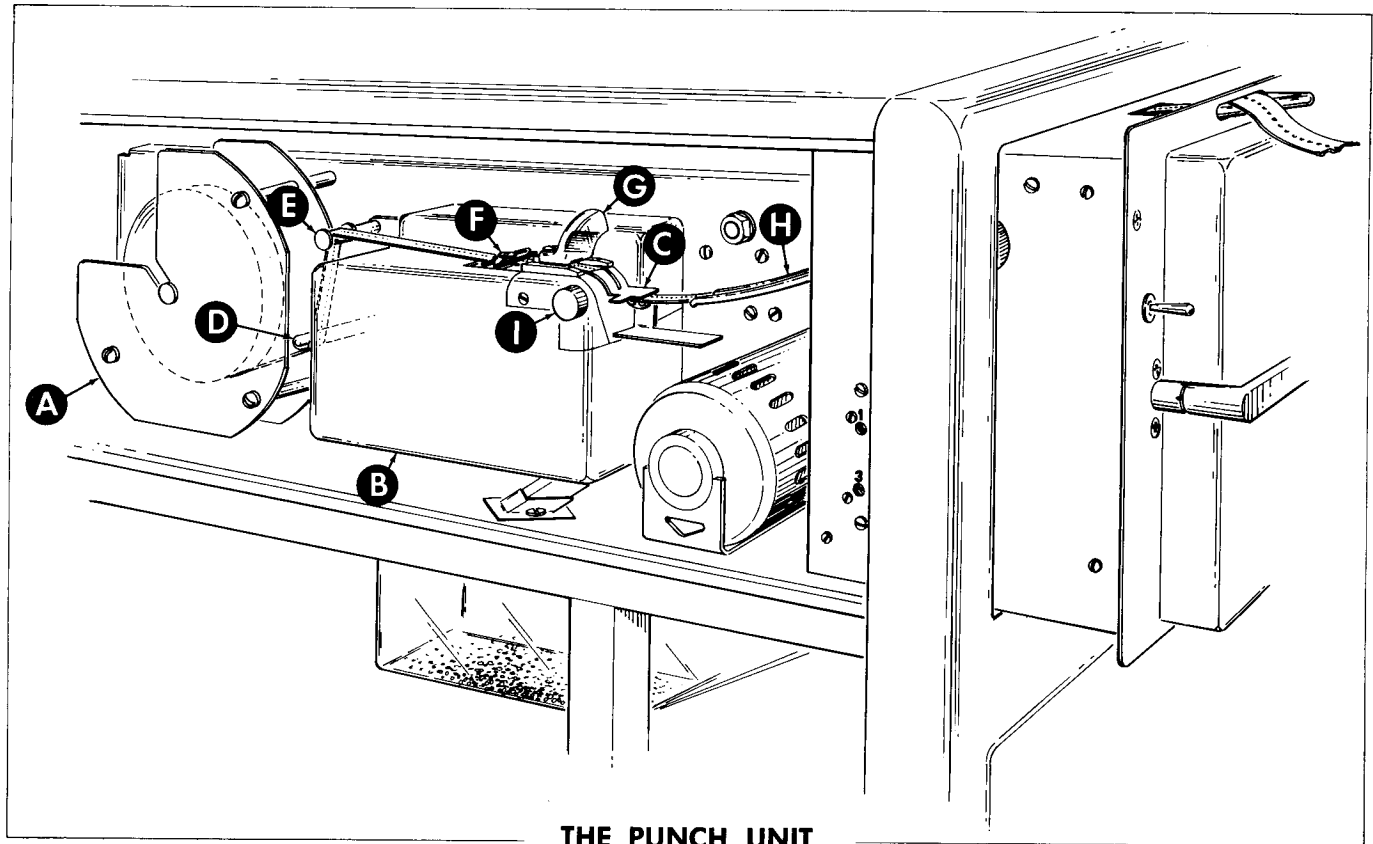
Two toggle switches are provided on the assembly. One provides control of tape positioning. If the Forward-Rewind toggle switch is pushed up, tape will move from the lower to upper reel; if the toggle switch is pushed down, the tape will move in the reverse direction.

The second toggle switch, labeled "Punch Run", mounted above the photo-diode assembly, causes the punch unit to punch out a leader of blank, sprocketed paper tape.

tape punch

The tape punch unit is located in the drawer behind the tape-reader assembly. The drawer slides open when the magazine clamp handle is pulled.

To insert a new tape roll for the punch unit, open both the drawer and the left panel of the computer.



THE PUNCH UNIT

The procedure for inserting a new roll of blank paper tape is:

- 1) Tear off the beginning part of the tape in order to remove the white adhesive portion.
- 2) Remove the small hub which rests in the punched tape holder (A) behind the punch unit (B). (Care should be taken to prevent the metal hub, which is conductive, from dropping into the computer circuitry.)
- 3) Place the blank tape reel on the hub and place the hub and tape into the tape holder (A) with the loose end of the tape unrolling from the bottom of the reel in a counterclockwise direction.
- 4) Depress the punch unit feed guide (C).
- 5) Guide the tape under the lower tape guide (D) between the punch unit and the tape holder.
- 6) Pass the tape over the tape tension arm (E), under the tape supply arm (F), and under the transparent chad chute (G).
- 7) Thread the tape up the tape chute (H). Operate the knob (I) on the punch unit that moves the tape toward the outside of the photo-reader assembly.
- 8) Feed out tape leader by pressing the punch toggle switch. The computer must be turned on for the tape to be fed out.

A chad box is provided underneath the punch unit. Periodically, this box should be emptied and the supply of blank paper tape on the roll checked. When the end of a roll of tape reaches the tape supply arm (F), a switch causes the punch unit to cease operation automatically.

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 that is provided in a punched-tape magazine.

1. Place the Test Routine magazine in position on the photo-reader. The tape must be rewound.
2. Put the typewriter control switches, Enable, Punch and Compute in the center (off) positions.
3. Turn on the Start switch.

Wait for the AC Meter to read 100% (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 control panel neons to remain steady.

6. Type "0000005 (tab)s".

Wait for the photo-reader light to remain off and the control panel neons to remain steady.

7. Type "0000007 (tab)s".

Bells ring at repeated intervals to indicate successful procedure of each test.

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

```
-1 1 2 2 3 3 4 4 4 5 5 6 6 . 7 7 7 8 8 9 9  
-u u v v w w x x x y y z z . 0 2 3 4 5
```

8. After this type-out occurs three times, put the Compute switch off, rewind the tape and remove the Test Routine Magazine.

When DC power only is turned off, the starting procedure is the same as outlined above except that Step 3 must be omitted.

To Load Program When Computer Is On

1. Put the typewriter control switches, Enable, Punch and Compute in the center (off) positions.
2. Place program tape magazine in position on the photo-reader.
3. With the Enable switch ON, type "p". Put the switch off.

The loading routine of the program will be read into Line 19. Wait until the photo-reader light goes off.

4. Put the Compute switch to GO (or BP).

HOW TO CONTROL INTERNAL OPERATION FROM THE TYPEWRITER

SWITCHES (on Typewriter Base)

The COMPUTE switch has three positions. The first position, marked GO, indicates that the execution of a program is to proceed until a programmed stop occurs. The center position, off, is not labeled. The Compute switch should be off whenever the Enable switch is used. The third position, marked BP, will cause computation to proceed until a command coded for breakpoint has been executed, after which the computer will halt.

If the computer is halted with the switch in either of the marked positions, computation may be resumed by moving the switch to the center position and back to either GO or BP.

The PUNCH switch has two positions. When a type-out command is given with the Punch switch ON, both type-outs and punch-outs occur; when the Punch switch is off, only type-outs occur.

Punch-out, with no type-out, is accomplished by giving the punch command with the Punch switch in either position.

The ENABLE switch has two positions. If the switch is in the center, or off, position, the typewriter will operate, but pressing any of the keys specified in the first group below will in no way affect the operation of the computer. If the switch is in the ON position, the typewriter keys in the first group below will be effective.

CONTROL KEYS (with Enable Switch ON)

In using the keys, lower case characters are typed.

Throughout this manual, keys which should be pressed with the Enable switch ON are shown underlined. After pressing the keys, put the Enable switch off.

s.....stop input-output

The computer will be put in the "Ready" state.

In the "Ready" state, input to or output from the computer is halted and the computer is

ready to accept a new input-output command if instructed to do so.

q.....permit type-in

The "permit type-in" state of the input-output circuitry will be established. After pressing the key, information may be typed into Line 23.

The computer should be in the "Ready" state before the key is pressed.

p.....photo-read

The photo-reader will read punched tape until a Stop code is detected on the input tape. Information is entered into Line 19 via Short Line 23 in the manner discussed under "Read-In Control".

After the tape has halted, the computer will be in a position to execute the command in word position 00 of Line 23.

b.....back-up photo-tape

The tape in the photo-reader is moved in the reverse direction to the beginning of the last block read. The contents of Lines 23 and 19 are altered.

The computer should be in the "Ready" state before the key is pressed.

f.....first word of command line

The computer will be put in position to execute the command in word 00 of the active command line.

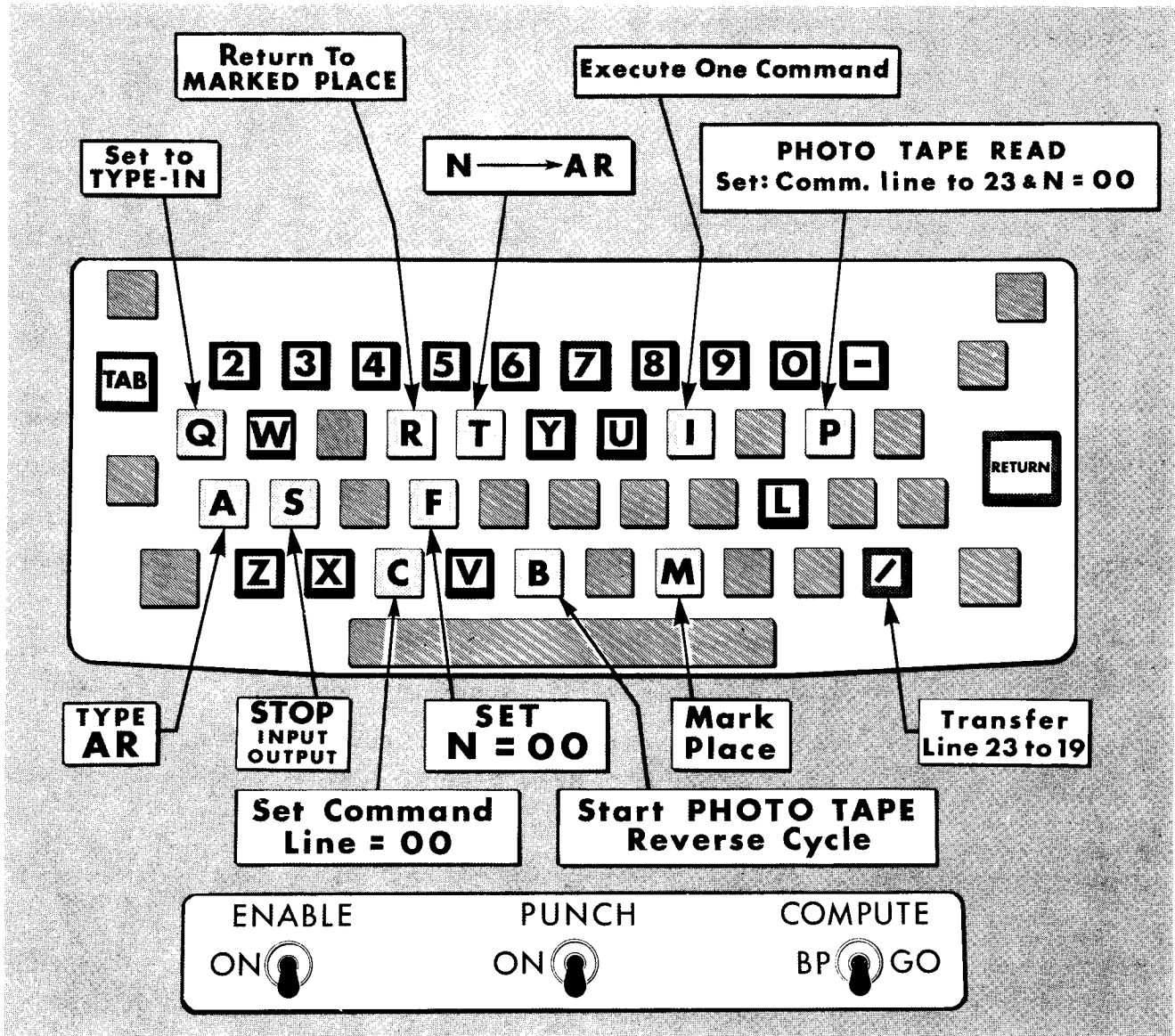
t.....copy command location

The word position of the next command that the computer would normally obey will be copied, in binary form, into the most significant 8 bits of Register AR.

a.....AR type-out

The contents of Register AR will be typed out after the Enable switch is returned to the center position. After typing, Register AR will be cleared of its contents.

The computer must be in the "Ready" state before the key is pressed. The form of the type-out is discussed under "Read-Out Control".



TYPEWRITER CONTROL KEYS AND SWITCHES

c command line selection

A new command line will be selected; the number of the command line is determined by the key pressed after "c", according to the table opposite.

The "s" key should be pressed to obtain the "Ready" state before pressing the following keys. The Enable switch must be ON for the typing of s, c and the subsequent digit.

Keys	Permit Execution of Commands in
<u>C</u> 0	Line 00
<u>C</u> 1	Line 01
<u>C</u> 2	Line 02
<u>C</u> 3	Line 03
<u>C</u> 4	Line 04
<u>C</u> 5	Line 05
<u>C</u> 6	Line 19
<u>C</u> 7	Line 23

i.....initiate single cycle

The next command only will be executed; the computer will halt after execution of the command.

If the next command is an input-output one, the computer should be in the "Ready" state before the key is pressed.

m..... mark place

The word position of the command that would normally be obeyed next will be stored in word 107 of Line 00.

The contents of Register AR will be stored in word 107 of Line 01.

r..... return to marked place

The word position of the next command to be executed will be taken from word 107 of Line 00.

The contents of word 107 of Line 01 will be transferred to Register AR.

CONTROL KEYS (with Enable Switch Off)

The computer must be in the "permit type-in" state for the following control keys to be effective.

/ (slash).....transfer 23 to 19

The contents of Short Line 23 will be transferred into word positions 00, 01, 02 and 03 of Line 19. The contents of Line 19 will be shifted in the manner discussed in the section "Read-In Control".

— (minus sign).....insert negative sign

A negative sign will be inserted in the input sign register. If a negative sign is not inserted, the sign in the input sign register will be positive.

(tab).....shift line 23

The contents of Line 23 are shifted one bit position in the manner discussed under "Read In Control". The sign is transferred from the input sign register to bit position one of word 00.

(carriage return).....shift line 23

The internal effect in the computer is the same as pressing the Tab key.

s..... stop typewriter input

The "permit type-in" state will be terminated; the computer will then be ready to accept a new input-output command, if instructed to do so.

If the computer is not in the "permit type-in" state, pressing the key will have no effect.

DATA INPUT KEYS

0 to 9
u to z

Four binary digits will be entered into the computer when a data input key is pressed. This information is entered into Short Line 23, and from Short Line 23 to Long Line 19 in the manner discussed under "Read-In Control".

The keys represent values from 0 to 15. If no program preparation routine is in use, input is hexadecimal. Decimal numbers may be entered from the keys by use of the standard program preparation routine.

Numbers and their signs may be directly typed into the computer. If a minus sign is typed, the sign of the number will be negative. If a plus sign, or no sign at all, is typed, the sign of the number will be positive.

The Tab or Carriage Return (CR) key must be pressed when a number has been completely typed.

Key	Binary Digits	Decimal Equivalent
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
u	1010	10
v	1011	11
w	1100	12
x	1101	13
y	1110	14
z	1111	15

Read-In Control

The use of the typewriter keys in order to enter sexadecimal data and machine language commands directly into the computer is explained below. The procedure is rarely used since Routine PPR permits standard commands and decimal data to be typed into the computer.

Pressing the Q key, with the Enable switch on, permits the input-output circuitry to accept information from the typewriter. When a numerical character is typed, it is converted into a four-bit digit and entered into bit positions 1 to 4 of word 00 in Short Line 23.

Pressing a second numerical key again enters a four-bit digit into bit positions 1 to 4 and shifts earlier-entered digits to the bit positions numbered four greater. Seven digits may be entered in this manner, filling bit positions 1 through 28 of word 00. (Bit positions are counted starting with the least significant bit, that is, from right to left.) If the space or "+" key is pressed, nothing happens internally; if the "-" key is pressed, a "one" bit, representing a minus sign, is stored in an input sign register.

When the Tab or CR key is pressed, the contents of Short Line 23 will be shifted one bit; a shift within a word will be toward the higher-numbered bit positions. This shift between words will be from bit position 29 to bit position 1 of the higher-numbered word.

Each shift will result in the loss of the contents of the highest-numbered bit position of the line: bit 29 of word 03. The sign (+ or -) will be transferred from the input sign register to bit position 1 of word 00. After the transfer, the sign in the register will become positive.

As additional digits are typed, the contents of word 00 will be shifted four bits at a time, first into word 01 and then into words 02 and 03 of Line 23. Line 23 will be full when it contains 4 seven-digit words and their signs. The Slash key is then pressed in order to transfer the contents of Line 23 to word positions 00 to 03 of Line 19.

The same information is now in both Line 23 and Line 19. As additional characters are typed, and the shifting process continues, the new information typed into Line 23 will replace old information that has already been copied into Line 19. When four new words are in Line 23, the Slash key is pressed again and once more information from Line 23 is transferred into word positions 00 to 03 of Line 19. Earlier-entered information in Line 19 is pushed ahead four word positions, that is, moved to new word positions numbered four greater.

The procedure can be continued until Line 19 is full, which will occur when 108 words of information have been entered. When Line 19 is full, its contents should be transferred to some other line before any additional information is typed in.

Input from punched tape is similarly processed. Again data flows into Short Line 23 and when Line 23 is full, its contents flow into Line 19. Control codes signifying Slash, Tab, Carriage Return and Stop exist on the tape. (These control codes have been automatically written on the tape by the computer.) A Stop code on the tape halts it before, or when, Line 19 is full.

Read-Out Control

The computer may be instructed to read out information either from Line 19 or from Register AR. The order of read-out is from the

highest-numbered to the lowest-numbered word and from the most significant to the least significant digit. The line or register is cleared of its contents by the read-out. The process, which is automatic when an output instruction is given, is described below.

Output from Line 19 is from the four most significant bit positions of word position 107. The digit corresponding to those four bits is read out and all other bits in Line 19 are automatically shifted four bit positions so that a new digit enters the most significant four bit positions of word 107. The shifting and reading continues until all the words in Line 19 have been read out. The format of type-out or punch-out is under the control of the programmer. For example, tabs, periods or carriage returns may be inserted where desired, or certain digits may be ignored during type-out.

format

Format control for the read-out of Line 19 is held in word positions 00 to 03 of Line 02, and for the read-out of Register AR in word positions 00 to 03 of Line 03. The specific words in these positions for a specific format are determined by the rules given on page 23 of the G-15 Coding Manual. When the Program Preparation Routine is in service, an automatic means for compiling these format words is provided (page 10).

A standard format may be used in which each word of output is typed out as a sign and seven digits.

When Register AR is read out, in standard format, the type-out is followed by a carriage return. When Line 19 is read out, each group of four words typed is followed by a carriage return. Words typed on the same line are separated from each other by tabs.

The first section of Magazine PPR inserts the proper format control words for standard format.

To specify standard format, the following six hexadecimal words are held in Lines 02 and 03:

Line	Word Position	Word
02	03	800000x
02	02	0000034
02	01	00000x0
02	00	0000110
03	03	—8w00000
03	02	1000000

automatic tape preparation

The contents of Line 19 may be directly punched on tape by execution of either the "Punch Line 19" command, or the "Type Line 19" command with the Punch switch ON. The commands are described in the G-15 Coding Manual.

The form of punch-out, as well as type-out, is determined by the format control words. Control characters such as Reload and Stop that are necessary in the read-in process will be punched on the tape by the format control words.

For proper positioning during the reading of information punched by the computer, non-zero information should be in, at least, one of the first four words of Line 19.

After a block of tape has been punched, several inches of blank, sprocketed tape should be run before a second Punch command is executed.

zero suppression

Zero suppression occurs when information is being typed out, but is not simultaneously being punched out from the computer. Zeros to the left of the decimal point which appear before the first non-zero digit are not typed out. The zeros are replaced by spaces.

One-Step Operation

A program, or portion of a program, may be executed one step at a time, and, if desired, the contents of Register AR typed out. The computer is instructed from the typewriter to execute a single command and halt.

To do so, perform the following steps, beginning with a selected point in the program:

1. On the typewriter base, put the Compute switch off and the Enable switch ON.
2. Type "i".

The next command will be executed and the computer will halt.

The neon configuration indicating the internal state of the computer may now be examined.

Repeat Step 2 if read-out of Register AR is not yet wanted.

To type out the contents of Register AR after a command has been executed, proceed to Step 3.

3. Type "m s a".

The contents of Register AR will be typed out in sexadecimal form.

4. Type "r".

The contents of Register AR, which were destroyed by the type-out, will be restored.

5. Return to Step 2.

HOW TO INSERT AND EXECUTE COMMANDS FROM THE TYPEWRITER

Direct Read-In of a Machine Language Command

An example is given below of how a command in machine language form may be directly typed into the computer and executed. It should be noted that no program preparation routine is used.

Assume that it is desired to check the sum of Line 01 against a known value. (Information in Line 01 may have been inadvertently destroyed by an erroneous command.) To do so, press the typewriter keys shown on the left below. The purpose of each step is explained beside these keys.

s a The contents of Register AR are typed out, followed by zeros. This operation clears Register AR.

s c 7 The computer is put in position to execute commands in Line 23.

q The computer is put in position to enter into Line 23 the subsequent digits that are typed.

010143 x (tab)s

This word enters word position 00 of Line 23. These digits are the machine language equivalent of the standard

command "u010110129", a block command which sums up Line 01 in Register AR. The method of transforming a standard command into a machine language command is described below.

f The computer is put in position to execute the command in word position 00 of the previously selected command line.

i The computer will execute the command in word position 00 of Line 23 and then halt.

s a The contents of Register AR will be typed out.

To Manually Convert a Standard Command to Machine Language Form

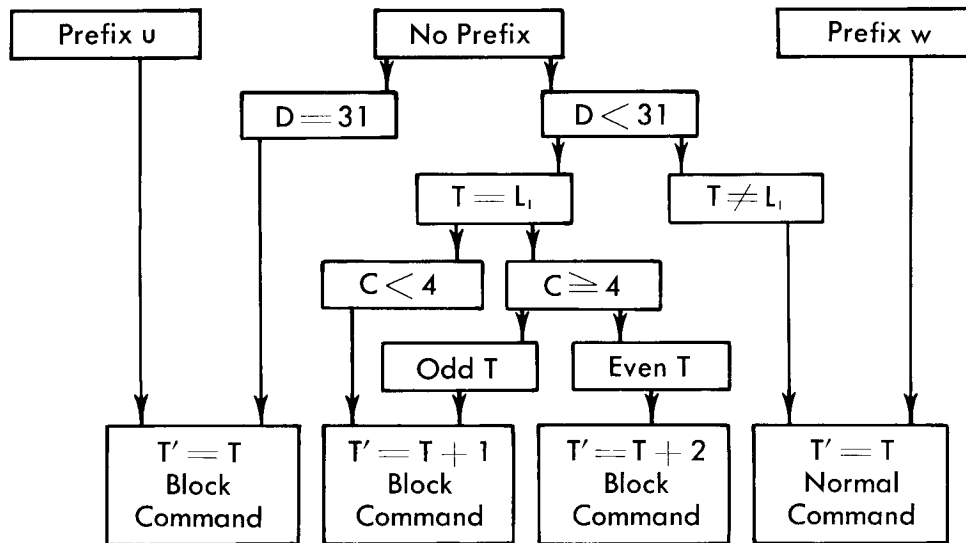
The standard commands listed in the G-15 Coding Manual are used in conjunction with the Program Preparation Routine, PPR. When a standard command is typed into the computer, it is converted to machine language form before being stored.

The following chart shows how a standard command from the G-15 Coding Manual may be converted into machine language form. The conversion may be useful for direct insertion of a command into the computer without the use of any preparation or conversion routines, for checking purposes, or in planning the programming of a command modification.

Conversion of a Standard Command to Machine Language

<i>Description</i>	<i>Example</i>
	T N C S D
	The command u 01 00 0 19 05- will be changed to machine language form.
1. Write numbers in S and D position of command as five-bit binary numbers.	1. S = 19 = 10011 D = 05 = 00101
2. If C = 0 or 4, write 00 If C = 1 or 5, write 01 If C = 2 or 6, write 10 If C = 3 or 7, write 11	2. C = 00
3. From the chart (page 30) determine the number T' and whether the command is block or normal. Write the number T' as a 7-bit binary number.	3. T' = 01 = 0000001 (Block command)
4. In Step 3, if the command is determined to be a normal command, place a "1" digit to the left of T'; if the command is a block command, place a "0" digit to the left of T'.	4. Since the command is a block command, place a "0" digit to the left of T'. T _{new} = 00000001.
5. Write the number in the N position as a 7-bit binary number.	5. N = 00 = 0000000
6. If the command is followed by a negative sign (signifying breakpoint), place a "1" digit to the left of N; otherwise, place a "0" digit to the left of N.	6. N _{new} = 10000000
7. Write the binary equivalent of T _{new} N _{new} C S D in that order.	7. T _{new} N _{new} C S D 00000001 10000000 00 10011 00101
8. Divide the 28 binary digits into 7 groups of four bits apiece.	8. 0000 0001 1000 0000 0010 0110 0101
9. Write the hexadecimal equivalent of each group of four bits from the table on page 25.	9. 0180265
10. If C = 4, 5, 6 or 7, add a negative sign as suffix.	10. C = 0; therefore, there is no suffix. The machine language command is: 0180265.

**DETERMINATION OF T' FOR CONVERSION
OF A STANDARD COMMAND TO MACHINE LANGUAGE**



CODE NUMBERS OF LINES AND REGISTERS

LONG LINES	CODE NUMBER USED IN G-15 COMMANDS
0	00
1	01
2	02
3	03
4	04
5	05
6	06
7	07
8	08
9	09
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
SHORT LINES	
20	20
21	21
22	22
23	23
REGISTERS	
MQ	24
ID	25
PN	26
AR	28

CHARACTERS APPEARING ON G-15 PUNCHED TAPE

—	0
—	1
—	2
—	3
—	4
—	5
—	6
—	7
—	8
—	9
—	u
—	v
—	w
—	x
—	y
—	z
—	Minus
—	Carriage Return
—	Tab
—	Stop (s)
—	Transfer Line 23 to 19 (/)
—	Period
—	Space
—	Wait

The Last Word

1. After the main power switch has been turned off, permit the drum to stop rotating before again turning on the computer (approximately 3 minutes).
2. Remember that the contents of the magnetic drum memory of the computer are destroyed when the DC-OFF button is pressed.
3. The electric typewriter may be turned off without stopping the computer by means of an on-off switch located on the right side of the typewriter.
4. If accessory DA-1 is connected to the G-15 computer, the command, "Turn Off DA-1", must be executed in order to use the computer without the accessory.

To execute this command, after turning on the computer, with the Compute switch off, type "s c 7 f q 0 1 8 0 6 7 z (tab) s i".

If the "Auto-Loader" routine in Magazine PPR is used, this command will be automatically added to the program tape.

5. If a program fails to work on automatic computation, but does work properly during single-cycle operation, it is likely that one of the following statements applies:
 - a. A "Ready" test has been omitted between successive input-output operations.
 - b. An input-output operation has followed too closely the typing of the "s" key after a typewriter input.
6. Since the Program Preparation Routine uses words 00, 01, 02, 03 and u7 in Line 02 and words 02 and 03 in Line 03 for format control for standard output format, any information in these locations will be destroyed.
7. Remember that the Forward-Rewind toggle switch (page 19) must be restored to the neutral position after use.

INDEX

AC Knob.....	17	Punch Switch.....	22
Auto-Loader.....	10, 11	Read-In Control.....	25
Auxiliary Routines.....	7-13	Read-Out Control.....	25, 26
Break-Pointer.....	8	Ready.....	17, 18
Characteristic Neons.....	17	Registers, Code Numbers of.....	31
Characters, G-15 Punched Tape.....	32	Repositioner.....	11, 12
Check-out.....	7	Reset Button.....	17
Check Sum.....	1	Selector Switch.....	17
Codes, PPR Instruction.....	4-6, 15	Sexadecimal System.....	1
Command Indicators.....	17	Single Cycling.....	26, 27
Command Line Neons.....	18	Source Neons.....	17
Compute Switch.....	22	Standard Command.....	1
Control Indicators.....	17, 18	Start Switch.....	17
Conversion, Decimal to Binary.....	6	Subroutine.....	1
Conversion, Standard Command to Machine Language.....	28-30	Tape-Handling Assembly.....	19
DB-PR Neon.....	17	Tape Preparation.....	14, 26
DC OFF Button.....	17	Tape Punch.....	19, 20
Destination Neons.....	17	Tape Reader.....	19
Enable Switch.....	22	Terms, Special.....	1
Enter Program.....	3	Test Neon.....	18
Execute Program.....	3, 14	Tracer.....	8, 9
Format.....	26	Turn-On Procedure.....	21
Formatter.....	9, 10	Typewriter Control Keys.....	22-25
GO-D. A. Neon.....	18	A Key.....	22
Halt Light.....	17	B Key.....	22
Indicator Light Panel.....	17, 18	C Key.....	23
Input-Output Indicators.....	18, 19	Carriage Return Key.....	24
Lines, Code Numbers of.....	31	Data Input Keys.....	24, 25
Lister.....	13	F Key.....	22
Loading Routine.....	1	I Key.....	24
Machine Language Command.....	1, 28	M Key.....	24
NC-AR Neon.....	18	Minus Sign Key.....	24
Number Track.....	1	P Key.....	22
O'FLO Light.....	18	Q Key.....	22
One-Step Operation.....	26, 27	R Key.....	24
Power Control Panel.....	16, 17	S Key.....	22, 24
Program Preparation Routine.....	2	Slash Key.....	24
P-Sign Neon.....	18	T Key.....	22
Punch Program Tape.....	14	Tab Key.....	24
		Zero Suppression.....	26

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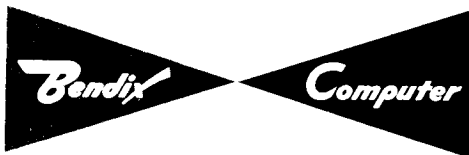
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