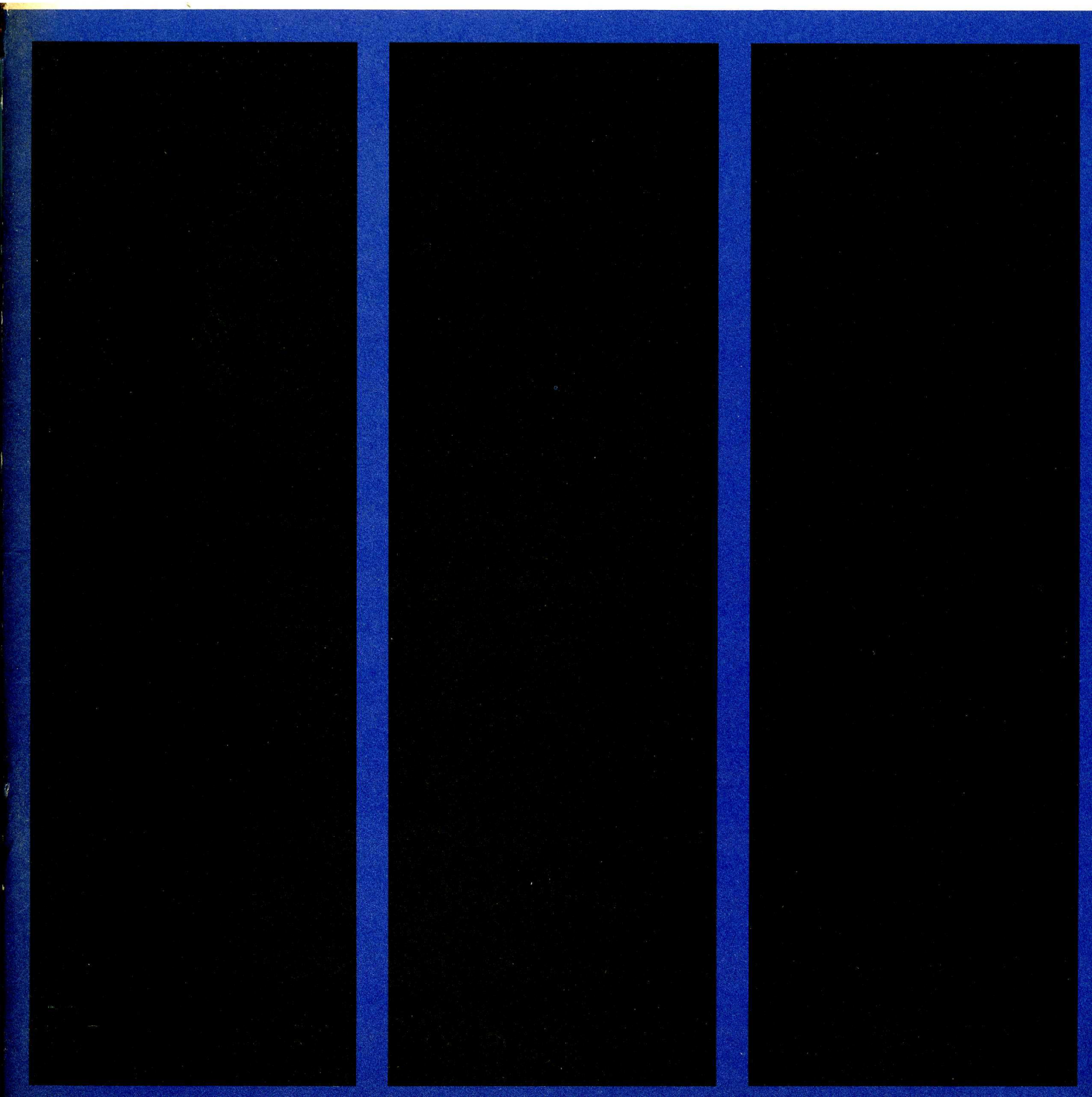
THE BUNKER-RAMO TRW-85 CONTROL/DISPLAY CONSOLE

General Information Manual

THE BUNKER-RAMO CORPORATION



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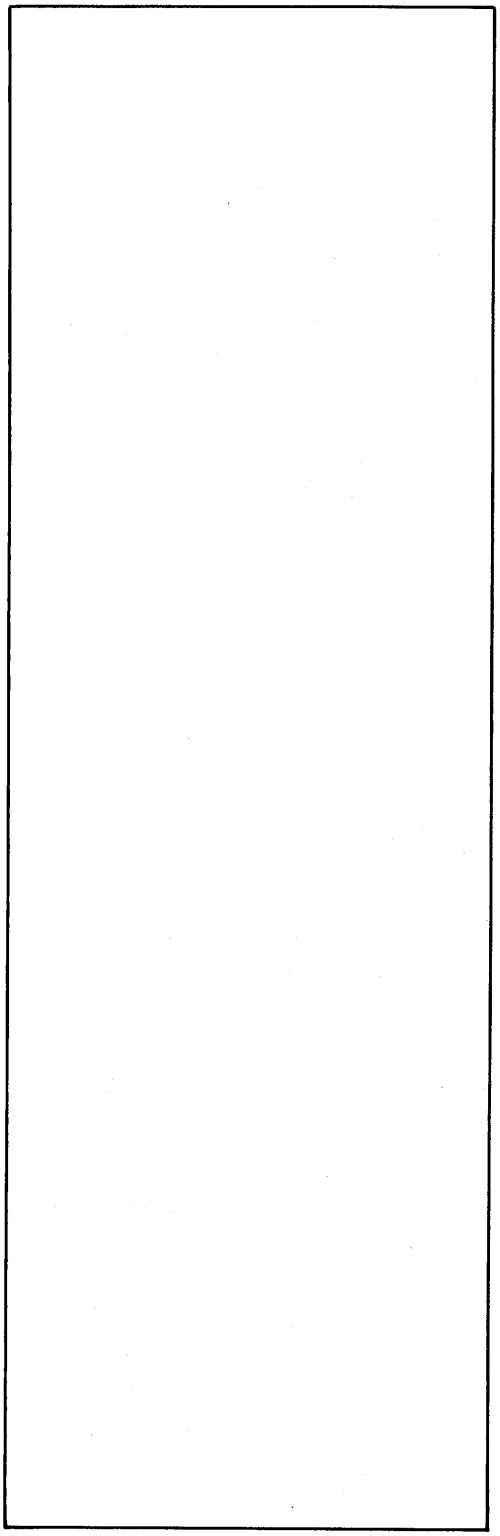
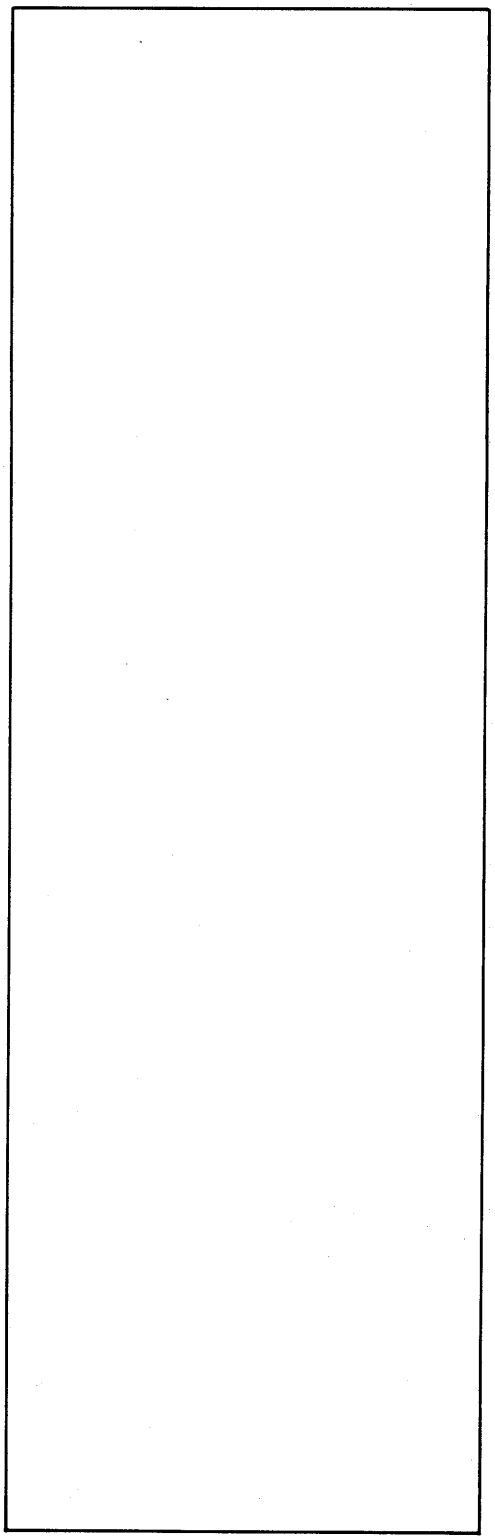
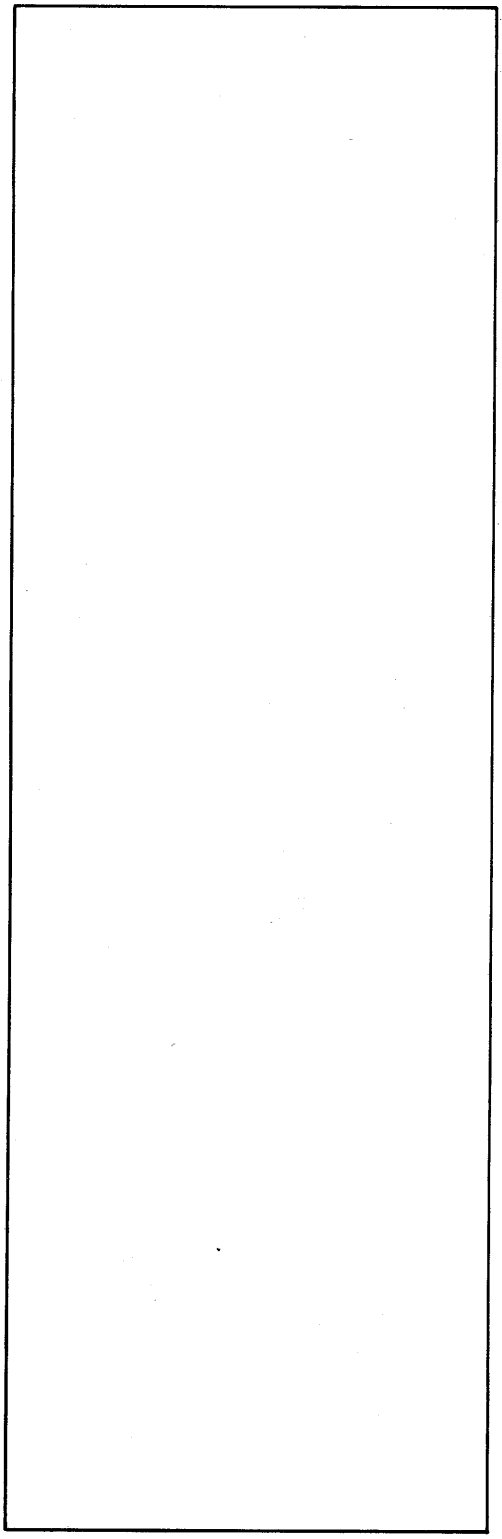
THE BUNKER-RAMO CORPORATION
8433 FALLBROOK AVENUE • CANOGA PARK, CALIFORNIA







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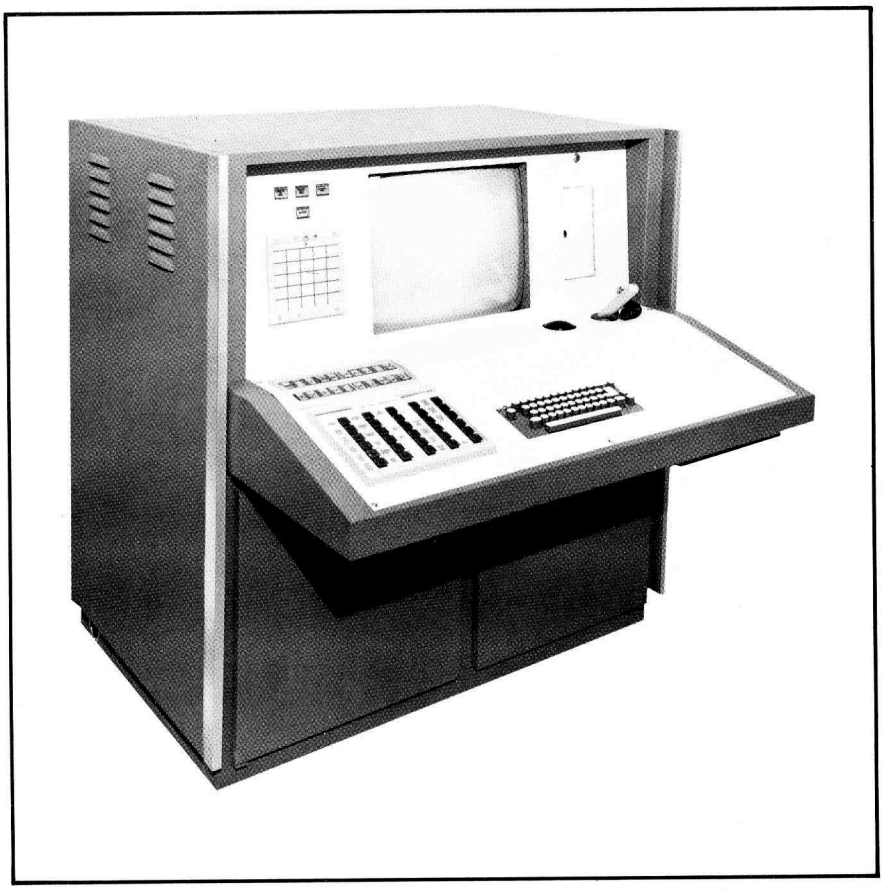

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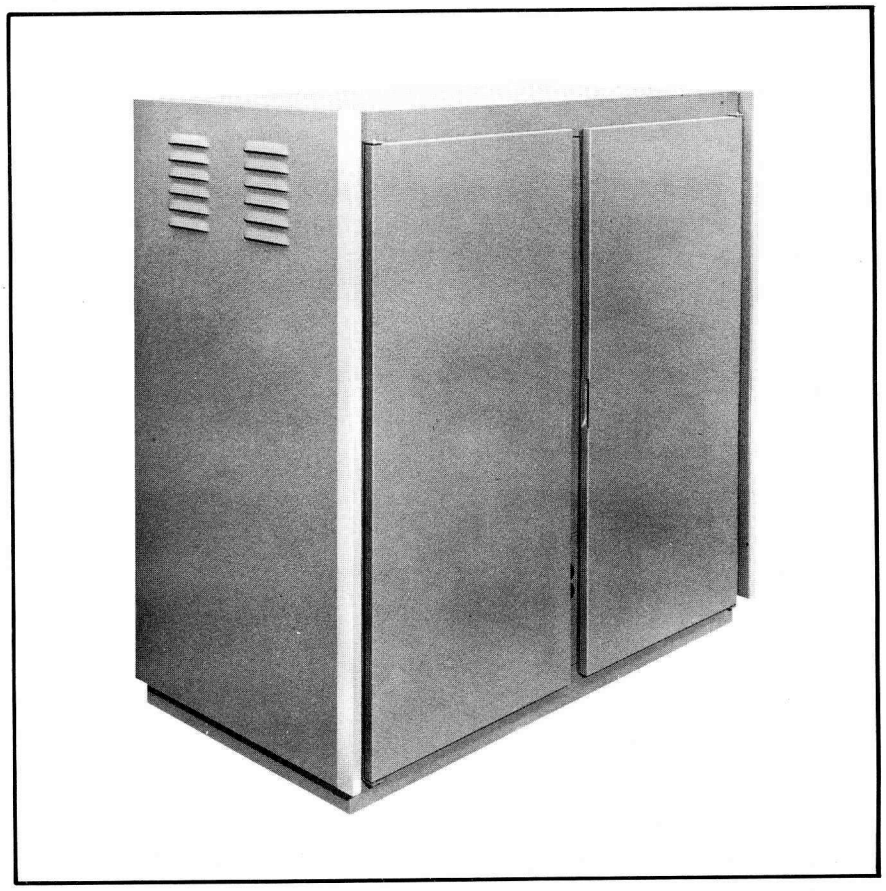


GENERAL DESCRIPTION 1

The TRW-85 is a man-machine, communications and control console capable of presenting visually to a computer user, a full range of alphabetic, numeric and graphical data. Displays may be generated by a computer or may be entered by an operator off-line by means of the TRW-85 controls. Most important, however, the TRW-85 allows direct communication between the operator and the computer, combining the calculating abilities of the electronic equipment with the intuition and judgment of the human user to produce a single integrated man-machine system.

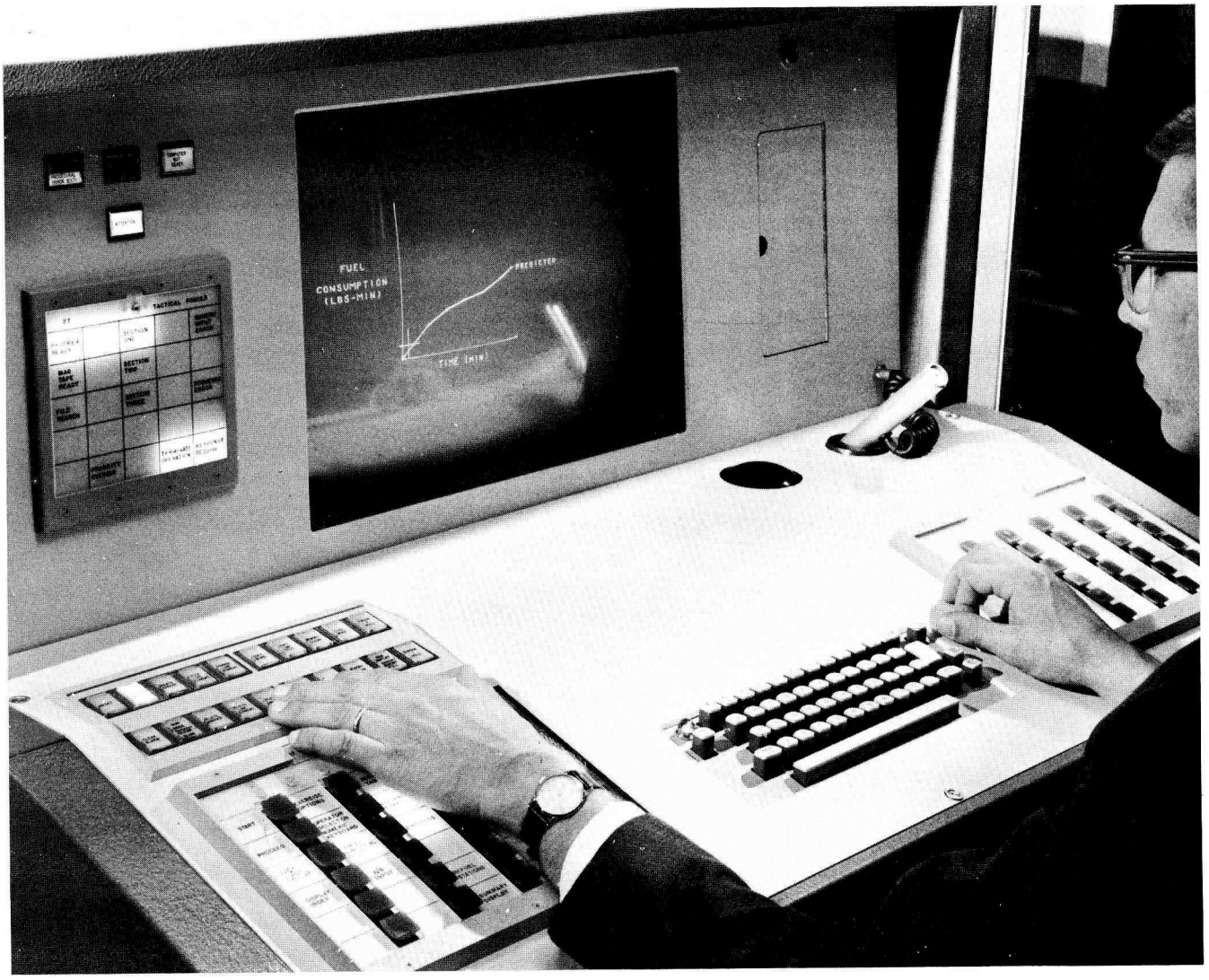
The computer may present results of calculation in the form of charts, graphs, tables, or any other chosen representation. An example of one kind of display that can be generated is shown in Figure 1. The operator evaluating these results may feed new data into the computer, and instantly see the effects of the changes he has made. He may directly manipulate data displayed on the screen, using a variety of controls at his disposal to arrive at desired results. These, in turn, may again be fed to the computer for further evaluation. Furthermore, the operator needs no specialized knowledge of computers or computer languages to communicate with the machine. He uses symbols and languages related to his particular application to perform desired functions.

Information to be used by the computer display system may be prepared on an off-line basis, without taking up any of the computer's calculating time. When the data is ready it may be instantly transmitted to the computer, evaluated, and the results displayed on the screen. The computer then goes on to do other work while the operator considers the new display and decides what action should be taken.

Visual and audio alarm signals are incorporated into the display unit, which may be programmed to demand operator attention under prescribed conditions. Critical conditions are thus assured of receiving top priority, regardless of whatever may occupy the display and the operator at a given moment.

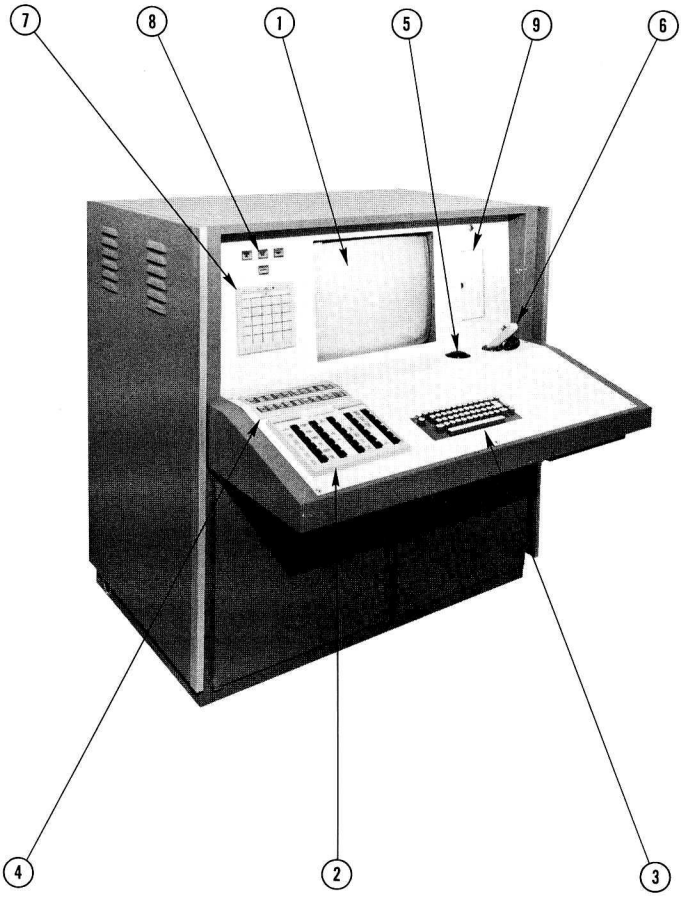
These capabilities make the TRW-85 an indispensable aid in such applications as on-line command and control, computer controlled checkout, spaceflight control, intelligence data analysis, air traffic control, program management, PERT layout and evaluation, process control, and information retrieval.

Figure 1. A TRW-85 Display



The TRW-85 consists of two units: a display unit and a digital unit. The display unit is a console type enclosure containing the CRT(Cathode Ray Tube) display screen and various controls, alarms, and indicators as shown below in Figure 2.

Figure 2. TRW-85 Features



1	ELECTRONIC DISPLAY	5	CURSOR CONTROL
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3	ALPHANUMERIC KEYBOARD	7	STATUS LIGHTS
4	CONTROL KEYBOARD	8	ERROR LIGHTS

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The main components of the TRW-85 are:

A program keyboard for communicating with a computer (a second program keyboard is optional). Each keyboard contains 30 keys and 30 associated lights.

An alphanumeric keyboard for manual entry of alphanumeric information consisting of letters, numerals and special characters.

A control keyboard for creating visual displays, manipulating and editing displayed data, and for performing other control functions.

A light gun for direct manipulation of single elements on the display.

A cursor control ball for positioning a cross-hair symbol at selected points on the display.

Twenty-five status indicator lights which may be turned on by a computer program to indicate the existence of prescribed conditions.

Five error and warning lights including a blinking warning light.

A digital unit containing the display memory, display control logic, and computer interface circuitry.

These components and the ways in which they react together to display information and control computer operation are described in the sections following.

CRT DISPLAY

A single gun, cathode ray tube displays the data stored in the memory unit. The electron beam which creates the picture is positioned on the CRT screen by a combination of electromagnetic deflection for gross positioning and electrostatic deflection for symbol generation.

The diagonal measurement of the CRT is 23 inches, nominal. It has the same characteristics as a type 23ASP4 television picture tube. The usable display area is 12 inches high by 16 inches wide, allowing for a 1/2 inch margin all around.

The tube is mounted into the screen panel of the TRW-85 display console, with its center approximately 38-1/2 inches from the surface of the floor. The screen is tilted away from the operator for easier viewing at an angle of 5° from vertical.

Reference to specific locations on the screen is made by means of a Cartesian coordinate system which uses the lower left hand corner of the usable screen area as its zero point. The X and Y coordinates are divided into equal units of 1/32 inch each. The 12 inch height of Y thus contains 384 increments, increasing in a vertical direction from zero; the 16 inch width of X contains 512 increments, increasing in a direction to the right of the screen from zero.

MEMORY UNIT

The TRW-85 display appears as a continuous image on the screen. In reality, however, the display is refreshed at a rate of up to 60 times a second, and may thus be updated at that rate by the computer. All the displayed information, along with its position on the screen, is stored in the display memory unit of the TRW-85.

The magnetic core memory unit contains 4096 words of 9 bits each, and is divided into two separate areas for display purposes. These are referred to as page A and page B, each page having a storage capacity of 2048 words. Page A and page B may be displayed separately or simultaneously, at the operator's option. The position of information on the screen does not depend on its location in memory. Either page, therefore, may contain information to be displayed on any part of the screen, and it is up to the operator or programmer to place information as he wishes it displayed: superimposed, or separated.

Access to memory is afforded the operator through the control and alphanumeric keyboards. When operating through the keyboards no memory addressing is required, since data will automatically be stored in the active page in successive memory locations. Data is stored starting with the first free memory location where all succeeding locations are clear.

When the last available location in a page has been filled, a MEMORY FULL indicator will light up on the keyboard. The operator then may switch to the alternate page, until that too is filled.

The computer may address the memory at random, and transfer blocks of information into or from it. Specific addresses must be given for data transfer from computer to memory unit, as described in Section 4, "Computer Generated Displays."

DATA DISPLAY

The TRW-85 Display Console can display both graphic and alphanumeric information. Graphic information is generated by means of line segments and dots, interconnected as desired. Alphanumeric information consists of alphabetic letters, numerals, and special characters and symbols shown in Figure 3.

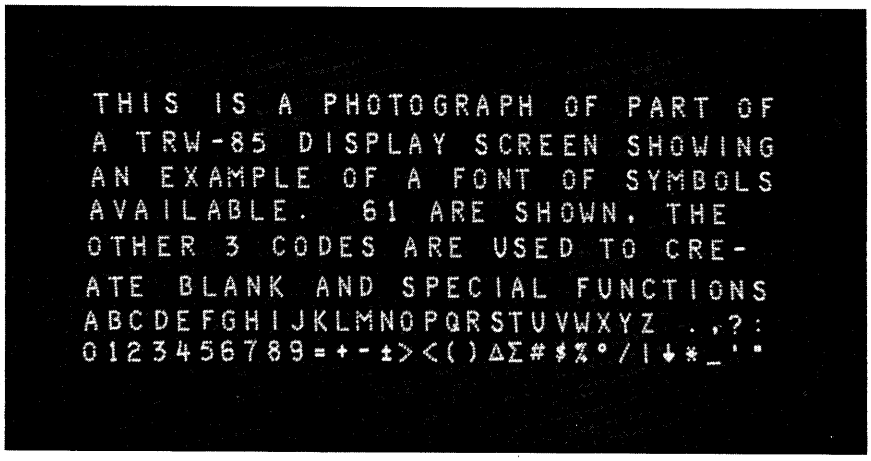


Figure 3.
Alphanumeric Keyboard Symbols

Alphanumeric characters and symbols may be displayed in either of two sizes - normal or large. The size of a character may be controlled by the computer, or by the operator through the alphanumeric keyboard.

Any character, symbol, or line segment may be made to blink so as to call immediate attention to it. This may be done manually, by use of the light gun, or under computer control.

CURSOR AND CURSOR CONTROL

Data displayed on the CRT by the computer is positioned on the screen by specifying appropriate coordinates of X and Y; these coordinates are stored in memory as part of the display information. During manual operations, when data is entered through the alphanumeric keyboard or the control keyboard, a cursor is used to automatically indicate the coordinates and thereby position the data as desired on the CRT.

The cursor is a crosshair marking electronically generated on the display screen when the CURSOR MODE key is actuated on the control keyboard. By use of the Cursor Control ball located in the desk top of the display unit, the cursor may be moved on the screen in any desired direction. The operator positions the cursor at the spot where he wishes data displayed, and the coordinates of this position are automatically recorded in the display memory. Data may then be entered through the keyboards and is displayed on the screen starting at the position indicated by the cursor.

LIGHT GUN

The light gun is a hand-held, photo-electric device used to point at information being displayed on the screen to identify it to the console or the computer. When the gun is actuated and pointed at a symbol being displayed, the symbol's storage location is noted by the display logic and recorded in a special register. The operator having identified the memory location he wants to reach, can now cause various operations to be performed on that location and those succeeding it.

By using the light-gun together with switches on the control keyboard, the operator can delete a symbol, a word, or whole lines of text, change the position of displayed data, and replace data with new or corrected information. The light-gun may also be used for clearing portions of memory.

STATUS LIGHTS

The TRW-85 is equipped with 25 status lights for monitoring computer activities without displaying data on the CRT screen. The lights are arrayed in five rows of five lights each, labeled by means of a changeable Mylar overlay. Any light, or combination of several lights, may be programmed to turn on under computer control. The programmer may set up whatever conditions he chooses to monitor computer operations in progress. When a light comes on, the operator can tell at a glance that certain conditions have been fulfilled and that action may be required on his part. The use of the status lights is explained more fully in Section 4, "Computer Generated Displays."

ERROR LIGHTS

A group of error lights, located immediately above the status lights is used for common trouble shooting purposes (see Figure 4). A PROCEDURE ERROR EXTERNAL light comes on when the computer receives a meaningless command from the display unit. The PROCEDURE ERROR INTERNAL light indicates that the operator has used an incorrect display procedure, or given the display unit an instruction it cannot execute.

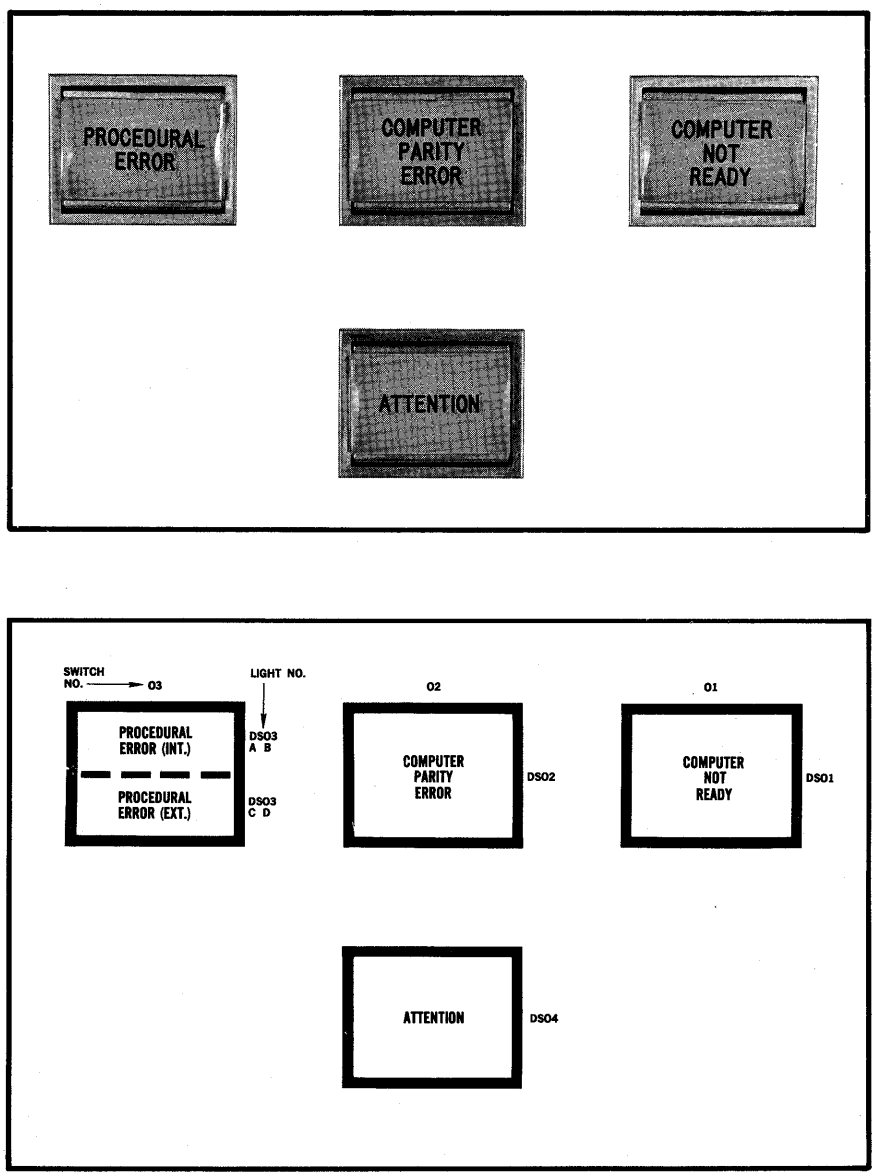
A COMPUTER PARITY ERROR light is turned on whenever the computer transmits data containing a parity error to the display unit.

A COMPUTER NOT READY light will flash on if the computer fails to acknowledge messages sent to it by the display unit. This light will turn off by itself as soon as a response is received from the computer.

A red ATTENTION light will blink on and off whenever any of the other error lights are lit, alerting the operator to the fact that a condition exists which requires his attention.

The error lights are actually illuminated switches. The operator may depress them to turn them off when he has perceived the nature of the trouble; he may then take whatever corrective action is necessary.

Figure 4. Error and Warning Lights



AUDIBLE ALARM

An audible alarm is included in the TRW-85 system, to provide for situations where instantaneous operator response is necessary. The alarm is under computer control and will turn on when pre-programmed conditions are met.

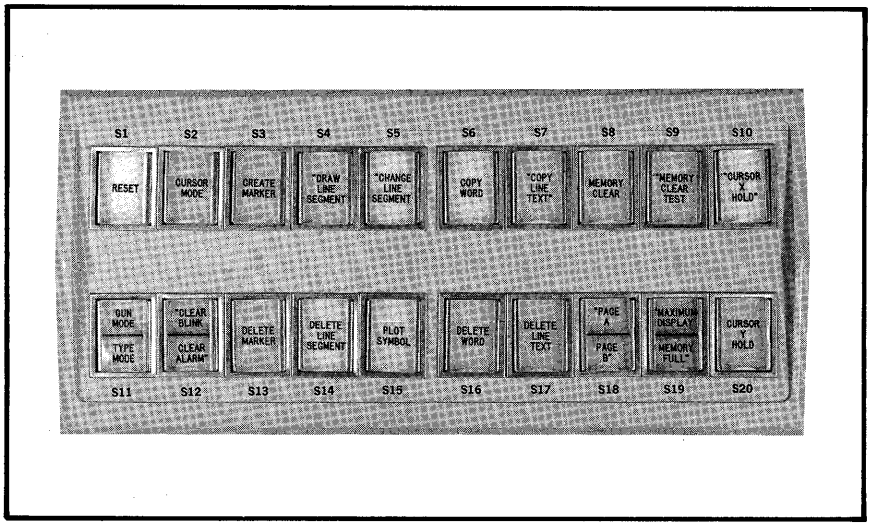
To turn the alarm off, the operator depresses the CLEAR ALARM switch on the control keyboard.

CONTROL KEYBOARD

The control keyboard consists of twenty switches, some of which double as indicators. The switches and indicators are identified in Figure 5.

The control keyboard controls the functions of the various console components. The operator uses it in conjunction with the alphanumeric keyboard, the light gun, and the cursor, to communicate with the display memory and create displays on the screen.

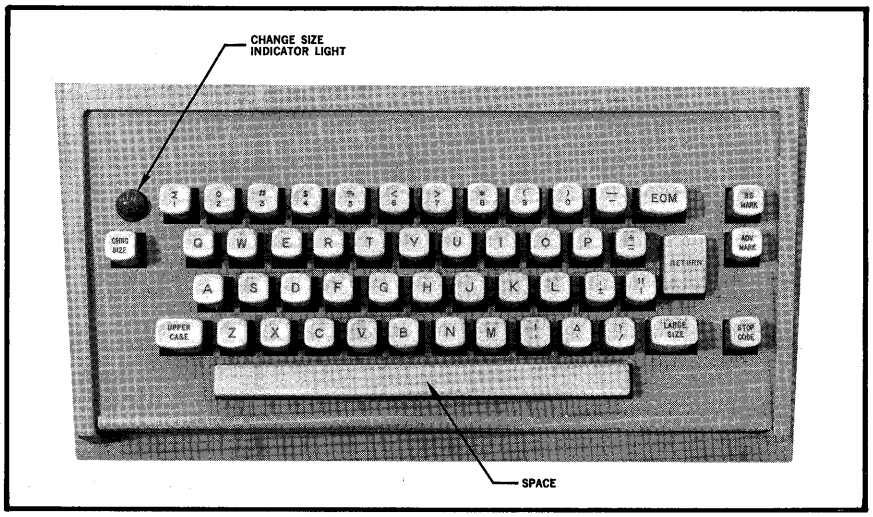
Figure 5. Control Keyboard



ALPHANUMERIC KEYBOARD

The alphanumeric keyboard is similar to an ordinary typewriter keyboard, except for a few specialized symbols and keys. It is used in much the same way as a typewriter, with the printed message appearing on the CRT screen instead of paper. Operation of the alphanumeric keyboard and the meaning of the special symbols and keys, is discussed in Section 3, "Manual Operation of the Display Console." A diagram of the alphanumeric keyboard is shown in Figure 6.

Figure 6. Alphanumeric Keyboard



PROGRAM KEYBOARD

The display unit console is equipped with either one or two program keyboards, each containing 30 keys, and 30 associated lights. A plastic overlay is placed over the keyboard, identifying the function of each key.

The program keyboard is for communications between the operator and the computer. Each key, when actuated, causes the computer to perform some pre-programmed operation, such as displaying data, accepting data from the display memory, processing data in various ways, etc. The operator need have no knowledge of how the computer works or how it is programmed: the function of each key is plainly described on the overlay, and depressing the key will cause the function to be executed.

Up to 64 overlays may be used with each keyboard, and up to 30 functions may be contained in each overlay, yielding a total of 1920 different activities which may be initiated from the console by depressing a button; up to 3840 if two keyboards are used. All the routines for performing these functions may be stored simultaneously in the computer, provided it has sufficient storage space. Changing the identification overlays to correspond to a new set of routines is accomplished in seconds. The nature of the operations performed is entirely up to the user or computer programmer, who assigns any desired meaning to the keys and overlays. More detailed descriptions of the program keyboard and its operations will be found in Section 5.

MANUAL OPERATION OF THE DISPLAY CONSOLE 3

The main purpose of the TRW-85 Display Console is to graphically present data processed by the computer, in a format which is meaningful and instantly comprehensible to the user. Once the computer has displayed the data, it is free to proceed with other operations, such as gathering and processing additional data to update the display it has created.

While the computer is occupied, the operator can evaluate the display, take any action which may be desirable in light of the information presented, and request further action from the computer through the program keyboards.

The operator may also wish to alter certain aspects of the display or generate a new display manually for transmittal to the computer. This can be accomplished without taking up the computer's operating and processing time. When the display is ready for transmittal it may then be sent to the computer by activating the appropriate keys on the program keyboard.

DISPLAY GENERATION

To generate or modify a display manually, the operator places information in the display unit memory, using the control keyboard, the alphanumeric keyboard, the cursor control, and the light gun. Data thus placed in memory is automatically displayed on the CRT screen.

Displays usually consist of both alphanumeric and graphic information displayed concurrently. For example, a map may be displayed (graphic information) with names of cities spelled out (alphanumeric information). To create such a display the operator works, essentially, with three display elements: line segments, dots, and the alphanumeric characters (including special characters and symbols) contained on the alphanumeric keyboard.

Page Selection

Before entering information for display on the CRT screen the operator should select the memory page in which he wishes to store the information, by depressing the PAGE A/PAGE B key on the control keyboard. If the entire memory area is to be used, the MAXIMUM DISPLAY key is activated. Both keys have indicators associated with them, which light up to show the area of memory selected.

The dual page capability provides several advantages to the TRW-85 user. Two different displays can be carried in memory, for example, and produced at will by pushing a button. Page A could be used to display data processed by the computer, and page B to compose messages to the computer; or the two pages may be used to superimpose information: charts representing conditions at different times could be overlaid on one another to show developments over a period of time. Or, a display may be broken up into two pages to simplify its structure, so that essential information could be displayed on one page, while supplementary, but less critical, information could be displayed on the other.

When the page being displayed is full, the MEMORY FULL indicator will light up. The operator may then switch to the alternate page.

CURSOR AND CURSOR CONTROL

Displays are stored in memory along with the associated coordinates required to place them correctly on the CRT screen. It should be reemphasized that there is no connection between the location of information on the screen and its storage location in memory, except that alphanumeric data, which is displayed sequentially, is normally stored sequentially in memory. The operator places the display he creates at the spot he selects on the screen by means of the cursor and the cursor control mechanism.

The cursor consists of two perpendicular lines, about one inch in length, arranged to form a cross-hair pattern on the display screen. The cursor appears at the upper, left-hand corner of the usable display area when the CURSOR MODE key on the control keyboard is depressed. The cursor can then be moved on the screen in any direction, by rotating the cursor control ball which protrudes through the desk top of the console. To move the cursor in a true horizontal line, the CURSOR Y HOLD button is depressed, allowing no vertical motion. If a true vertical movement of the cursor is desired the CURSOR X HOLD button is depressed, allowing no horizontal movement. This feature is particularly useful when the cursor must be positioned on a precise horizontal or vertical from a previously displayed point. When the cursor has been moved to the desired spot on the CRT screen, the operator may proceed to draw lines, dots or write alphanumeric characters at that spot. The coordinates of the cursor are automatically recorded by the display logic, and stored as part of the display information.

Drawing Dots

To place a dot on the CRT, the operator moves the cursor to the desired position, then depresses the PLOT SYMBOL key on the control keyboard. The dot will be placed at the center of the cross-hair. To draw successive dots, the operation is repeated as desired, until all dots have been placed on the screen.

Drawing Lines

To draw a line on the CRT, the operator places the cursor at the point where he wants the line to begin and pushes the DRAW LINE SEGMENT key on the control panel. He then moves the cursor to the position where the line terminates or changes direction, and depresses the DRAW LINE SEGMENT key a second time. A line will be drawn between the points. To continue the same line in a different direction, the operator merely moves the cursor to a new terminal point and again pushes the key. To draw a second, unconnected line, the operator may depress the RESET key, and then repeat the procedure.

For maximum accuracy, horizontal or vertical line segments should not be over three inches long, since longer segments may waver slightly. When drawing a diagonal line, neither the X nor Y component should be longer than 3 inches. For example, a 45° diagonal should not be longer than 4.25 inches. The width of a line is approximately 0.02 inch. Line drawing time is 50 to 60 microseconds, depending on line length. Automatic brightness control assures uniform appearance of the lines. A manual control for adjusting line brightness enables the operator to bring the lines up to any desired intensity independently of other display elements.

ALPHANUMERIC KEYBOARD

To create an alphanumeric display, the operator first creates a cursor, and positions it at the point where words or characters are to appear on the screen. He then creates a marker symbol (inverted arrow) by depressing the CREATE MARKER key on the control keyboard. The marker will appear at the center of the cursor. The operator may now proceed to type words and characters on the alphanumeric keyboard just as he would on an ordinary typewriter. The characters will appear on the screen as they are typed. As each character is typed the marker is replaced by the character, and advances to the next character position. When it is desired to begin typing a new line, the CARRIAGE RETURN key will return the marker and position it just below the first character of the preceding line. In this way the operator may continue typing information which will be stored in memory and displayed on the screen, until he has completed his message or filled up the screen.

The operator can be automatically prevented from accidentally destroying data placed in memory by the computer. The means of doing this will be discussed in Section 5, "Operator-Computer Communications."

An ADVANCE MARKER key and a BACKSPACE MARKER key allow the marker to be moved forward and backward through displayed characters to any desired point, without displacing more than one character at a time. The location to which the marker is moved will be temporarily vacated, and the marker will be displayed in place of the character previously occupying that location. As soon as the marker is advanced or retreated again, however, the original contents of the memory location is restored, and the character again displayed on the screen. If any alphanumeric key is depressed while the marker is in a location previously occupied by a character, the new character will replace the one previously there. This, then, is a useful error correction feature: if the operator makes a typing error, he has only to backspace the marker and retype the correct character. To replace segments of data larger than a single character or two, however, even more convenient methods are available. These are indicated briefly in the following discussion, "Light Gun Uses," and in greater detail in Section 5, "Operator-Computer Communications."

Character Size

The alphanumeric keyboard characters can be displayed in two sizes: the regular size occupies a rectangle, about 3/16 inch high by 1/8 inch wide, and the large size, 5/16 inch high by 7/32 inch wide. To display a single letter in the large size, the operator holds down the LARGE SIZE key, on the alphanumeric keyboard, while typing the desired letter. To display a block of letters in large size, the operator depresses the CHANGE SIZE key on the alphanumeric keyboard. The amber light indicator above the key will be turned on, and all characters typed will be displayed in large size, until the operator depresses the key again, changing the size back to normal.

Upper Case

Some alphanumeric characters are doubled up on a single key, although they have different code representations. The UPPER CASE key is used to display the character occupying the top position on the key.

E. O. M. Key

The E. O. M. key signals an End of Message, and deletes the marker symbol from memory and from the display. The E. O. M. key generates a code which is stored in memory in place of the marker code. The DELETE MARKER key on the control keyboard may also be used to delete the marker symbol from memory, but does not store any code in its place. The E. O. M. code also serves to terminate such operations as deletion of words and lines of text. More detailed discussion of the E. O. M. code, the STOP code, and other codes stored in memory, will be found in Section 5 dealing with Operator-Computer Communications.

LIGHT GUN USES

The light gun is a photoelectric device, hand actuated by a button in its handle, which identifies a given item of information displayed on the screen to the internal logic of the display unit. Through such identification it becomes possible to manipulate an item of information in various ways, by using the console control keys associated with the light gun unit. The address of information identified by the light gun is also available to the computer on demand.

A character can be made to blink by light-gunning it, i. e., pointing the light gun at it and actuating the button in its handle. When this is done, all characters blinking under computer control (see Section 4) will cease to blink, and the light-gunned character will start blinking.

When the operator releases the light-gun switch, the character light-gunned will continue to blink, and the GUN MODE indicator on the control panel will light up. The display unit is now in light-gun mode, which allows the following operations to be performed:

Create Marker	Change Line Segment
Copy Word	Delete Line Segment
Delete Word	Clear Memory
Copy Line Text	Stop Computer Generated Blinks
Delete Line Text	Any Computer Function

The light-gun mode is terminated automatically in some instances, and may be terminated manually at any time by depressing the CLEAR BLINK/CLEAR ALARM key on the control keyboard. Gun mode may also be terminated by depressing the gun button while the light gun is resting in its socket (or not aimed at any display element). When the light-gun mode is terminated, the GUN MODE indicator turns off, and characters which were blinking under computer control will resume blinking.

Since some light gun operations may depend on or affect computer generated data, a full discussion of these procedures is deferred to Section 5 "Operator-Computer Communications."

Only one character at a time, or one line segment, may be light-gunned. If an actuated light gun is aimed at a succession of characters, the first character aimed at will be tagged as the light-gunned symbol by the display unit.

COMPUTER GENERATED DISPLAYS 4

The TRW-85 is designed to operate with most digital computers in the medium to large-scale range. However, a certain amount of special purpose interface logic is necessary to adapt the TRW-85 to the characteristics of any particular computer. Space for the interface circuitry is provided in the digital unit, and is installed when the identity of the companion computer has been established.

The computer creates displays on the CRT screen in the same way the operator does -- by placing data in the display unit's memory. Special codes are stored in memory to give the position of displayed information, characters to be displayed, terminal coordinates for line segments, etc. When the operator uses the various keys and controls already briefly enumerated, these codes are generated automatically by the console logic and stored in display memory to generate the desired display. When the computer generates a display, on the other hand, it must place the required codes explicitly in the display memory: where the operator automatically positions data on the screen by indicating its placement with the cursor, the computer must calculate the exact coordinates to place its data.

In addition to displaying alphanumeric and graphic information on the screen, the computer may activate the status lights and the audible alarm. The computer may also be programmed to receive commands from the program keyboards of the display console (see "Operator-Computer Communications," Section 5).

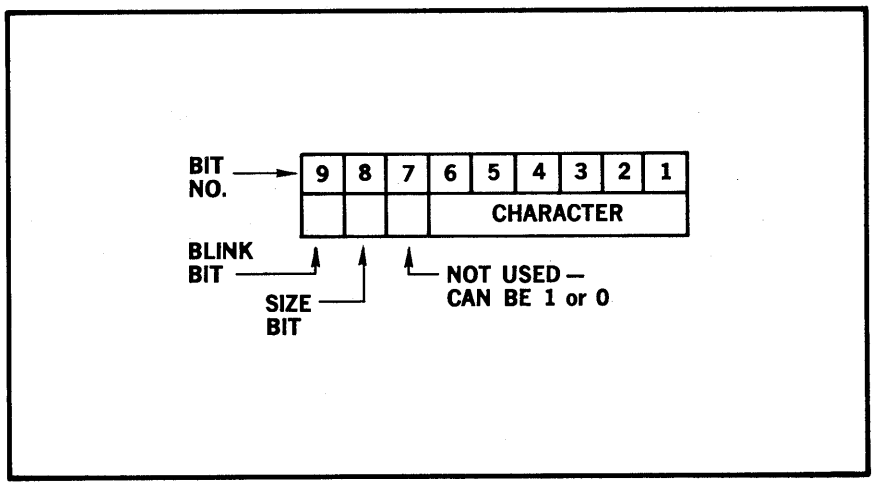
The codes necessary to furnish information to the console and to generate data displays on the CRT screen are discussed in this section.

DATA AND CONTROL CODES

The TRW-85 display memory contains 4096 words of 9 bits each. Each word may represent an alphanumeric character or symbol for display, or other information such as coordinates or special purpose codes. Memory addresses are 0020_8 - 3777_8 for page A, and 4000_8 - 7777_8 for page B.

A general representation of a data word is shown in Figure 7.

Figure 7. Data Word Format



The least significant six bits represent the actual code of the character to be displayed. Bit 7 is not used for data codes, and may be a 1 or a 0 as desired. Bit 8 determines the size of the character to be displayed: a 0 in this bit position will display the character in its normal size; a 1 in bit 8 will display a large size character on the CRT screen. Bit 9 is a blink bit; a 1 in the 9th bit position will cause the displayed character to blink on the screen.

Octal codes for the least significant six bits, and the characters they represent, are shown in Table A, Appendix 1.

In addition to the data codes there are eight codes representing control and special information. These codes occupy more than six bits, as explained below (See also Table B, Appendix 1).

Four of the special control and symbol codes may be generated through the alphanumeric keyboard (Space, E.O.M., Stop, and Carriage Return). The other four codes are generated when appropriate keys are depressed on the control keyboard (Position Code, Coordinate Data, Line Code, and Plot Code).

Position Code

POSITION CODE ×01 111 111 (177_8)

The position code signals to the display unit that the two succeeding locations contain Y and X coordinates, respectively. The position code and the coordinates associated with it thus place data on the screen at a predetermined position. Data which follows the position and coordinate codes will be displayed on the screen starting at the location specified by the coordinates. Thus, the first character of a line of text would be placed at the designated spot, and succeeding characters will follow it (another position code is not required). In the case of a graphic line segment, the coordinates would represent the point of origin of the line. The ninth bit position is not used by this code and may be either 1 or 0.

Coordinate Data Codes

COORDINATE DATA CODES ××× ××× ×××

A coordinate data code represents distance along an axis in the Cartesian system, in the Y or the X direction. The zero point is at the lower left hand corner of the usable screen area, and the measurements increase vertically for Y, and to the right for X. Measurements are in units of 1/32 of an inch. The nine bits in a coordinate data word are used according to conventional binary number notation. The least significant bit in the 9-bit word represents a distance of 1/32 inch, and each succeeding bit represents double the distance of the preceding bit. Therefore, a 1 in the various bit positions has the following values:

Bit 1 = 1/32"	Bit 6 = 1"
Bit 2 = 1/16"	Bit 7 = 2"
Bit 3 = 1/8"	Bit 8 = 4"
Bit 4 = 1/4"	Bit 9 = 8"
Bit 5 = 1/2"	

The binary codes required to place the character A, for example, at a screen position which has the coordinates Y = 7-31/32 inches and X = 5-13/16 inches are derived in the following way:

$$Y = 7\frac{31}{32} = \frac{255}{32} \qquad X = 5\frac{13}{16} = 5\frac{26}{32} = \frac{186}{32}$$

$$255_{10} = 377_8 = 011\ 111\ 111_2 \qquad 186_{10} = 272_8 = 010\ 111\ 010_2$$

In this method, coordinates are reduced to improper fractions with a common denominator of 32. The octal number equivalent of the decimal numerator is then found by referring to a standard octal-decimal

integer conversion table. The octal number is then converted by writing down the binary triad equivalent of each octal digit, a transform every computer programmer is able to perform automatically.

With the Y and X coordinates in the example converted to binary, the following codes must be placed in the display memory by the computer.

Position Code	X01 111 111	(Position code = 177_8)
Y Coordinate	011 111 111	(7-31/32)
X Coordinate	010 111 010	(5-13/16)
Character Code	100 110 001	(Letter "A" = 61_8: See Appen. 1, Table A)

Note that there is no code that distinguishes Y from X coordinates. The display unit always considers the first code following a position code to by a Y coordinate, and the next code to represent X. Also note, since the character code has a 1 in bit 9, that the character displayed will blink. The last six bits of the code, 110 001, are the binary equivalent of 61_8, which Table A lists as the proper code for displaying the character "A".

Line Code

LINE CODE ×11 111 111 (377_8)

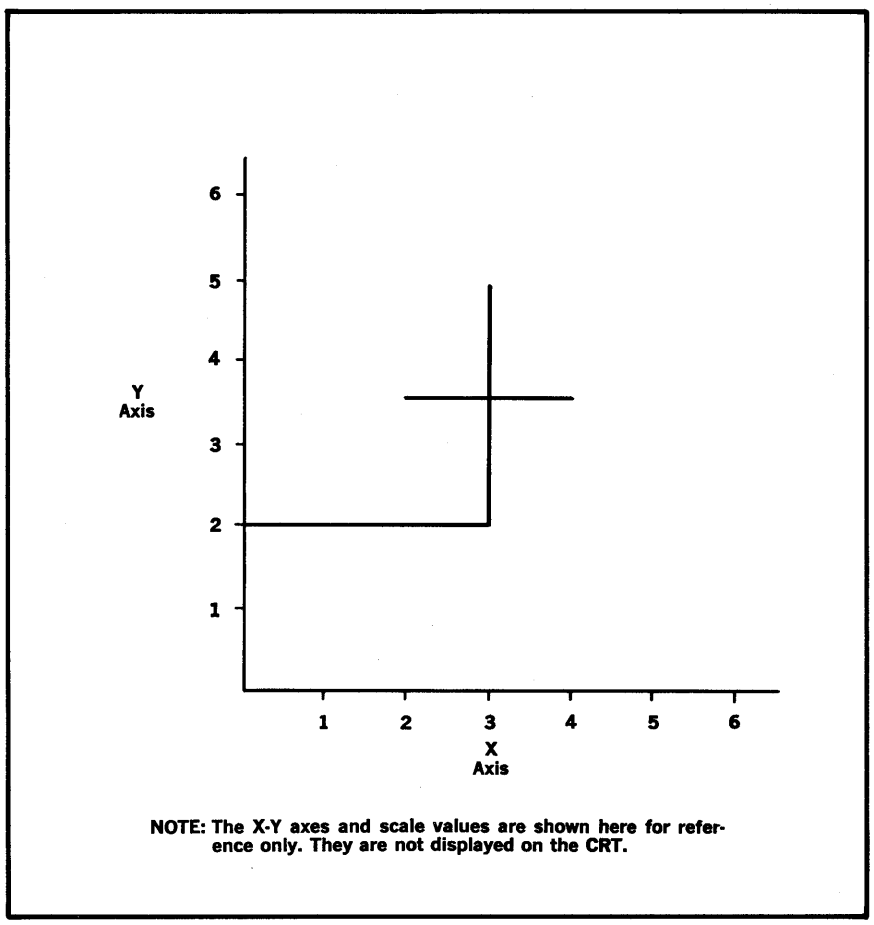
The line code is used to draw line segments on the display screen. It is followed by a Y coordinate and an X coordinate (in that order), and usually follows either a position code or another line code. The coordinates following the line code determine the terminal point of a line segment. Thus, to draw a line on the CRT, two reference coordinates are required: the initial set, following a position code, and the terminal set following a line code. A second line segment which connects to the first can be drawn by giving a second line code and a second pair of coordinates, without a second position code. A second, unconnected line segment, however, would require a new position code.

To illustrate: a line 3 inches long must be drawn from the Y axis, 2 inches above the X axis and parallel to it. A second line is to be drawn, from the terminal point of the first, and perpendicular to it, to a point 3 inches up. A third line, 2 inches long, is parallel to the first line, bisects the second and is in turn bisected by it. The sequence of instructions to draw the three lines follows:

Position Code	×01 111 111	First line initial point
Y Coordinate	001 000 000	Y = 2"
X Coordinate	000 000 000	X = 0"
Line Code	×11 111 111	First line terminal point
Y Coordinate	001 000 000	Y does not change
X Coordinate	001 100 000	X = 3"
Line Code	×11 111 111	Second line terminal point
Y Coordinate	010 100 000	Y = 5"
X Coordinate	001 100 000	X does not change
Position Code	×01 111 111	Third line initial point
Y Coordinate	001 110 000	Y = 3-1/2"
X Coordinate	001 000 000	X = 2"
Line Code	×11 111 111	Third line terminal point
Y Coordinate	001 110 000	Y does not change
X Coordinate	010 000 000	X = 4"

The drawing resulting from these instructions is shown in Figure 8.

Figure 8. Line Drawing Example



Plot Code

PLOT CODE ×00 111 111 (77_8)

The plot code may be used to place a dot on the CRT screen in the same manner as a data code. If the dot symbol follows a position code (and its associated coordinates) it will be placed at the spot indicated by the coordinates. If it appears in the middle of a data sequence, it will follow the preceding character, and will be placed in the center of the slot normally reserved for a character. As in data codes, a 1 in the ninth bit position will cause the dot to blink, and bit 8 controls the size. For accurate placement of the dot, however, it is recommended that bit 8 be left a zero so that the dot will be displayed in small size.

Carriage Return Code

CARRIAGE RETURN CODE ××1 010 000 (120_8)

When a line of text is generated by the computer, only one position code and one pair of coordinates is required to position it on the screen. The first character or symbol will be placed at the point indicated by the coordinates, and succeeding characters will follow it on the same Y coordinate and along the X coordinate (in other words, on a straight line). If the text extends beyond a single line, it is not necessary to use another position code for the second line position. Instead, a carriage return code is used, followed by a Y coordinate only, to show the new line coordinate. The X coordinate is assumed to be the same as the one following the last position code. As many lines of text as are required may be generated by repeated use of the carriage return code at the end of each line. The Y coordinate which follows the carriage return code, determines the spacing between the lines, and may be set at any desired value. A carriage return generated manually from the alphanumeric keyboard automatically inserts a Y coordinate that is 12 units (3/8 inch) less than the preceding Y coordinate.

End of Message Code

END OF MESSAGE CODE 010 000 000 (200_8)

The end of message code is used to indicate the last displayed memory location on a given page. Thus, if only half of the A page is being used, an E.O.M. code may be inserted at the last memory location. From a practical point of view, the E.O.M. code serves to reduce the refresh time of a given page. When no E.O.M. code is present in a memory page, the entire page will be displayed, and refreshed, whether it contains data, or not. Thus, if the whole page is not in use, the E.O.M. code will prevent refreshing of unused locations, and speed up the rate at which the useful area is refreshed.

The E.O.M. code may be generated from the alphanumeric keyboard, and may be erased manually as well. When the operator types data into a location containing an E.O.M. code, the E.O.M. code is automatically deleted. A special symbol (¬) is displayed when an E.O.M. code is stored in memory.

Stop Code

STOP CODE ××0 010 000 (20_8)

The stop code is used to protect computer generated data from being accidentally erased by the operator. The stop code symbol (↯), however, is not displayed during normal operations, to avoid cluttering up the screen. The symbol appears when the light gun button is actuated, since the only way the operator can modify computer generated data is to place the display unit in light gun mode. Bits 8 and 9 control the size and blinking of the stop code symbol (↯), as in normal data symbols. The exact use of the stop code is explained under "Alphanumeric Communication" in Section 5.

Space Code

SPACE CODE 000 000 000 (000_8)

The space code is used to insert blanks into a sequence of data symbols stored in display memory. It is also inserted in memory when the space bar on the alphanumeric keyboard is actuated.

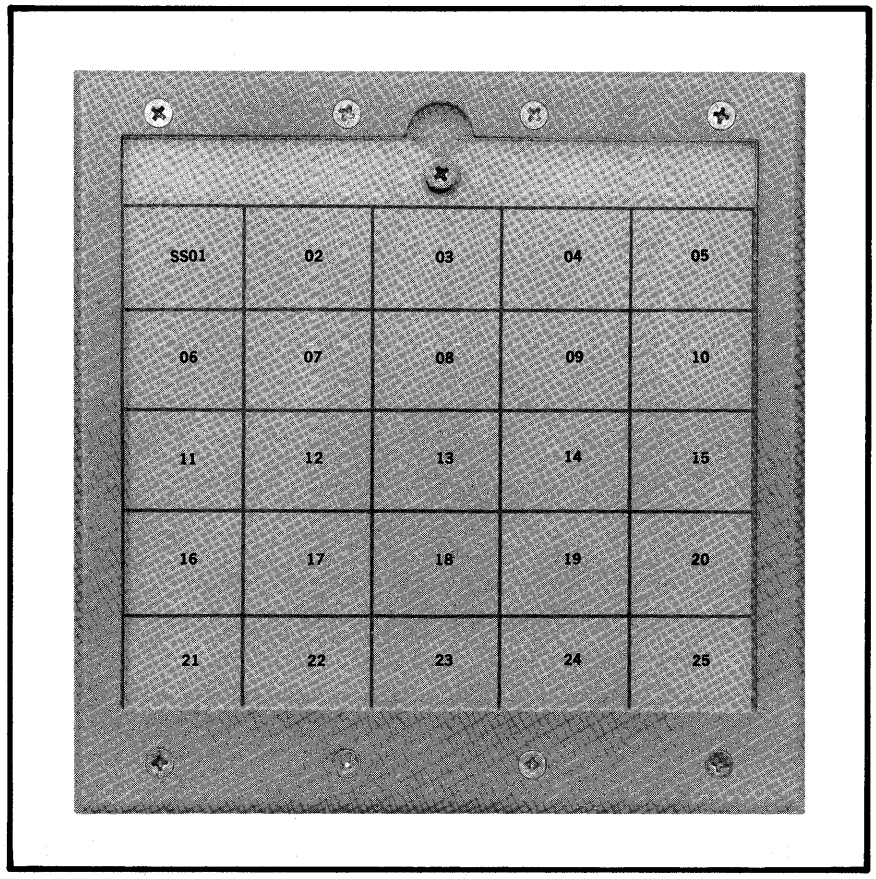
COMPUTER CONTROLLED STATUS LIGHTS

A computer connected to the TRW-85 Control/Display Console may be used to monitor and control several sources of information from on-line devices. This information may be processed by the computer and output to control the devices, and it may be used simultaneously to create a display on the CRT screen. Several operations dealing with different aspects of a given problem, or even with different problems, may thus occur side by side. It may not be desirable to display all this activity at once, but on the other hand, conditions may develop in any one of these operations which call for immediate operator action. The status lights are used to help the operator select the program which requires attention. Once identified, the operator may then abstract data from the program and display it on the CRT screen.

The status-light display consists of 25 light indicators, arranged in five rows of five lights each. The lights are under computer control and can be turned on by computer programming to indicate conditions of which the operator should be informed. A thin plastic overlay is provided, which may be labeled by the user to indicate the function of each light.

The status lights are numbered SS01-SS25, as shown in Figure 9. The light register number and the data bit which controls each light is shown in Table C, Appendix 1. The word format for addressing the lights is dependent on the computer used, and cannot be completely defined until the characteristics of the computer are known.

Figure 9. Status Light (SS) Identification



AUDIBLE ALARM

The audible alarm is addressed in the same manner as a status light (see Table C) and may be programmed to indicate any condition to which immediate response is required. The alarm may be turned off from the keyboard by depressing the CLEAR BLINK/CLEAR ALARM key.

OPERATOR-COMPUTER COMMUNICATIONS 5

One of the major advantages of the TRW-85 lies in its ability to provide for constant communications between the various elements of a man-machine system. The man at the controls of the display console can correct or update data displayed by the computer. The computer can request additional data from the console operator, alert him to various conditions, and request his attention by means of status lights and the alarm. Finally the operator can, at the touch of a switch, call into operation a variety of pre-stored programs to deal with virtually any contingency.

The operator communicates with the computer in one of three ways:

1. Directly, through the program keyboard. The operator may call for specific action by the computer, executing a pre-stored program by depressing a switch on the keyboard.

2. Through the alphanumeric and control keyboards. The operator may compose messages to the computer on the CRT screen and transfer them to the computer for processing, either through the program keyboard or according to a prearranged schedule.

3. In the light-gun mode. By changing some computer created displays, using the light gun and other devices at his control, the operator can manipulate data, reprocess it, and arrive at the optimum solution to a given set of circumstances.

The specific operations involved in these three modes are discussed in this section.

PROGRAM KEYBOARDS

The display console may be equipped with either one or two program keyboards, each containing 30 keys and 30 lights (see Figure 10). A thin plastic overlay containing labels for each of the keys is placed over the keyboard. Besides visually identifying the functions of the keys, the overlay serves a second purpose: generating a coded message which identifies the overlay to the computer.

Along the top edge of the overlay a unique pattern of up to 6 holes is punched for identification. The holes are sensed by means of pins protruding through the surface of the program keyboard. There are 8 pins, but the right-most and left-most are always depressed by the overlay. When depressed, these inform the console that an overlay is in place. Only the center 6 pins, therefore, are used in detecting the overlay identification code.

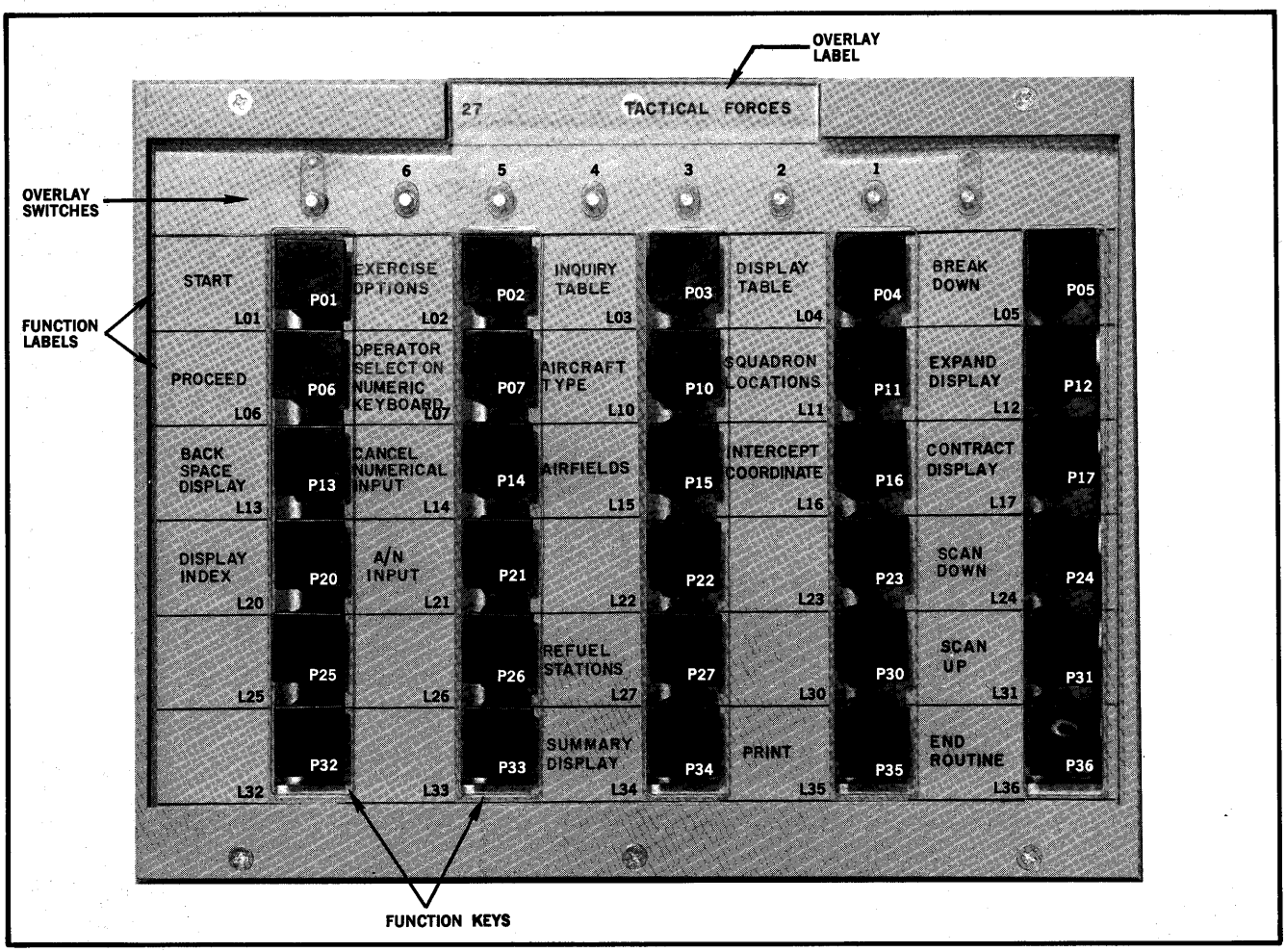
When a program key is actuated, a 12-bit message is composed and sent to the computer for decoding. The six most significant bits of the message are generated by the hole pattern in the overlay; the least significant bits by the program key itself. The code word causes the computer to execute a pre-stored program or take any other action previously arranged for by the programmer.

Thus the operator can cause any of thirty programmed sequences to be executed by the computer by depressing a key on the program keyboard. Furthermore, it requires only seconds to change an overlay, thereby changing the code word emitted by each key so that an entirely new function may now be performed. Since the six-bit identification of the overlay can be represented in 64 different combinations, it follows that up to 1920 different programs may be controlled through a single keyboard. This capacity is doubled where two keyboards are used, and the operator can command up to 60 separate computer actions at any one time.

The overlays may be clearly labeled with the function each key performs for that overlay, and can be quickly changed by simply lifting the plastic cover and exchanging one overlay for another (see Figure 11).

The program keyboard operates by means of an interrupt system, which requests computer attention whenever a program key is depressed. If the computer cannot be interrupted immediately for some reason, the error light labeled COMPUTER NOT READY will be turned on. The light will turn off automatically when the computer is ready to accept the interrupt signal. Normally this will occur before the operator has perceived the light. The COMPUTER NOT READY light may be extinguished manually, by depressing the switch over the light, but doing so will erase the information in the output register, cancelling the effect of the program key.

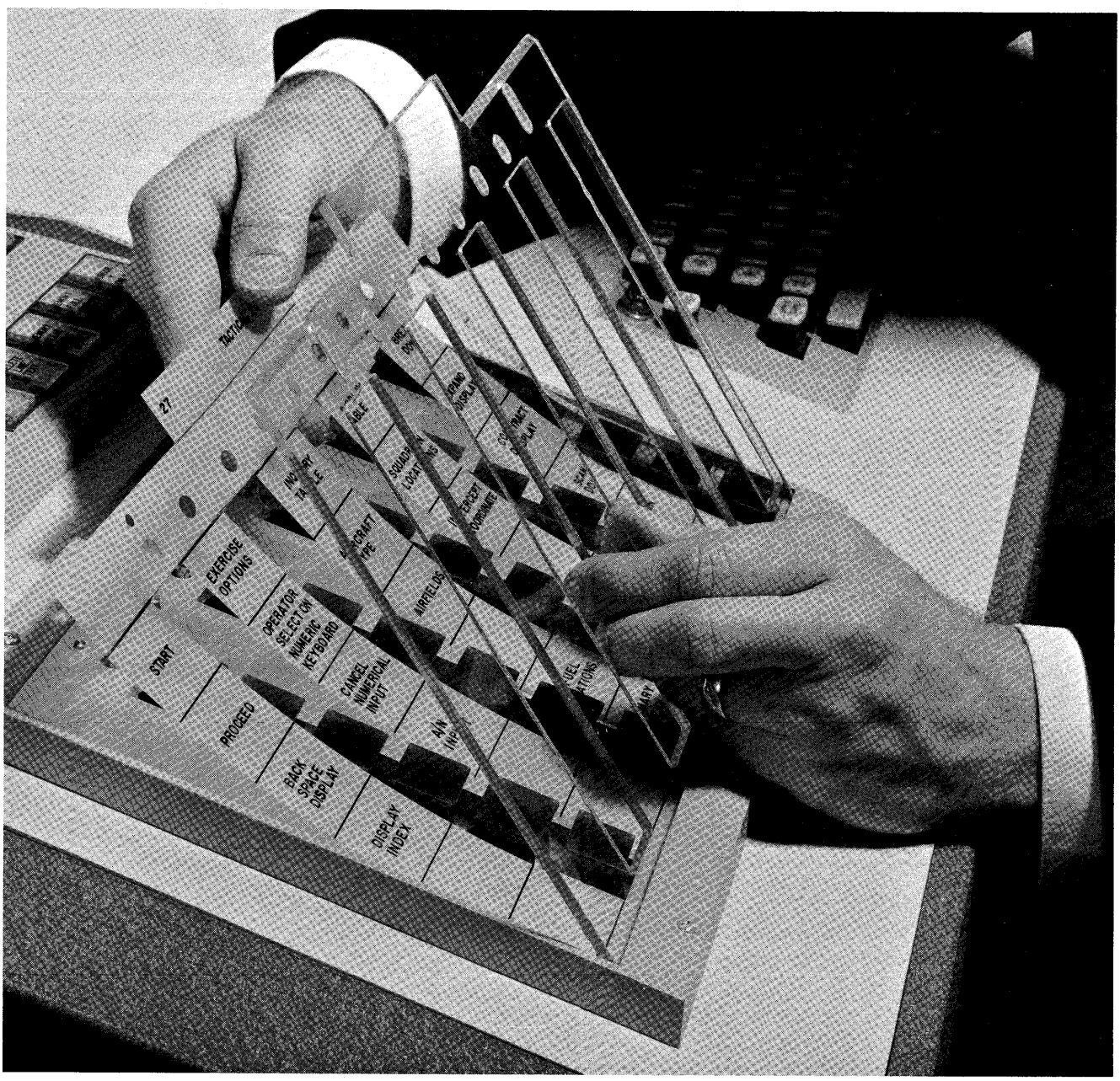
Figure 10. Program Keyboard (L) and Key (P) Identification L. H. Keyboard



The interrupt of computer operation is controlled by bit number 5 of light register 12_8, which also controls status light SS01. When the bit has been set to "1" by the computer, the console may initiate an interrupt sequence. When the computer has set the bit to "0", the console will not start the interrupt sequence and the program keyboard message will remain in the output register until RESET or COMPUTER NOT READY is depressed.

The uses of the program keyboard are varied. Typically, some of the keys in each overlay will be used to start computer processing of data placed on the screen by the operator. Others will be used to ask for computer generated displays, to manipulate data within the computer, and so on. The user is limited only by his imagination and the capabilities of the associated computer, in assigning functions to the keys.

Figure 11. Program Keyboard Overlay



ALPHANUMERIC COMMUNICATION

The controls with which a user creates a display on the CRT screen have already been discussed (see Manual Operation of Display Console). After a display has been created, i.e., data and control codes have been stored in display memory, the information may be transferred to the computer for processing. The computer's operations on the data may be automatic or controlled through the program keyboard.

It is also possible for the computer to request information. The computer may be programmed to place a display on the screen in which certain items of information are left blank, and must be filled in by the operator through the alphanumeric keyboard. For example, in an air traffic control application, the control tower may use a computer to calculate the approach of a landing aircraft. When the procedure is initiated the computer could be programmed to place a message on the screen reading CURRENT ALTITUDE_____FT. CURRENT SPEED _____KNOTS. These blank spots would be filled in by the operator when an aircraft requested landing instructions, and reported its altitude, speed and position.

The marker symbol would be contained in the data stored in display memory, at the location where the first character entered by the operator is to be stored. The following locations should contain the underline symbol, so that the message appears on the screen with a blank space underlined. Since the marker is already present on the screen the operator may type information without having to pause and create the marker manually. As information is typed, the character typed will replace the marker, and the marker will replace the next underline symbol. In order to protect the computer generated data from accidental destruction, the blank spaces in memory should begin and terminate with a stop code. When the marker reaches the stop code, it will automatically be transferred to the next location in memory containing an underline code, i.e., to the next location where the operator is to insert data. If no underline code exists between the stop code and the end of memory, the marker will be deleted, preventing the operator from typing data into occupied memory cells. When the operator deliberately wants to change the data displayed by the computer, however, he may do so by using the light gun.

LIGHT GUN MODE

The light gun as it relates to manual operation of the Display Console has been explained briefly in Section 3. Many of these preliminary comments are repeated in the following discussion which explains the various functions that can be performed when the Console is in light gun mode.

The main purpose of the light gun is to enable the operator to identify some item of data displayed on the screen, regardless of where in memory such data is stored. This cannot be done without the light gun, since the operator has no other means of reaching a specific memory location; creating a marker on the screen, for example, by creating a cursor and then depressing the CREATE MARKER key, will not reach the desired memory location, even if the marker is positioned on the screen directly superimposed on the character to be changed. A marker created by the console, without the light gun, is always stored in the first unused memory location, following the last location in which data was previously stored.

To enter the light gun mode, the operator points the activated light gun at a character, symbol, or line segment on the screen. The symbol thus identified will start blinking, so that the operator has positive confirmation of his action. All other blinking symbols, that is symbols generated by the computer with a 1 in the ninth bit position, will

stop blinking until the gun mode is terminated. When the operator releases the light gun enable button, the light-gunned character will continue blinking, and the gun mode will have been initiated. The operator may now perform any of the operations described below. The GUN MODE indicator on the control keyboard will light up and remain illuminated until gun mode is terminated.

The operations which may be performed in the gun mode are:

Create Marker	Change Line Segment
Copy Word	Delete Line Segment
Copy Line Text	Clear Memory
Delete Word	Stop Computer Generated Blink
Delete Line Text	Any Computer Function

All these functions may be used by the operator to change and edit the display.

Create Marker

A marker symbol will replace the light-gunned symbol, in display memory and on the screen, when the CREATE MARKER key is depressed while the console is in the light gun mode. If a key is now depressed on the alphanumeric keyboard, the appropriate character will replace the marker, and the marker will advance to the next memory location in the normal manner. In this manner, data displayed on the screen and stored in memory can be changed one character at a time. It is also possible to advance the marker without changing the data, by using the ADVANCE MARKER key. As the marker advances, it will be replaced by the symbol which occupied that location originally.

The marker will continue to move through memory and on the display screen, until it reaches the last memory location, unless it is stopped by one of the following:

1. A position code. This indicates that the marker has come to a location where a different section of the display is stored. The marker is deleted automatically, when this happens, to avoid unintentional destruction of display information.

2. A stop code. As described previously, the marker will be transferred to the next memory location containing an underline code. The display logic here assumes that information is to be inserted into locations identified for that purpose with underline codes. If no such space exists (no underline code) the marker is deleted.

3. An E.O.M. code, while using the ADVANCE MARKER key. Here again the intention is to prevent the operator from advancing beyond the present limit of his message, while using the ADVANCE MARKER key. Note that the E.O.M. code will not stop the marker when the operator is actually typing data; in this case, data codes will replace the E.O.M. code.

The operator may manually terminate the operation at any time by depressing the DELETE MARKER key.

Copy Word

If it is desired to transfer a word of text displayed on the screen from one spot to another, this may be done by placing a marker at the new position where the word is to appear, light-gunning the first letter to be transferred, and depressing the COPY WORD key on the control keyboard. The copied word is not destroyed by this operation.

The copying operation is automatically halted when the end of a word is reached. While the function is intended mainly to copy a word of text, it may also be a formula, or any other type of alphanumeric information. For purposes of word copying, a word is any sequence of alphanumeric characters terminated by a space, an E.O.M. code, a stop code, a carriage return, or a position code. Each of these codes could conceivably terminate a word of text, and thus any of them will stop the copying process. The space, E.O.M., stop, and carriage return codes will all be copied to the new location before the copying process stops; the Y coordinate associated with the carriage return will not be copied, since it would be erroneous in the new location. Instead, a new Y coordinate is inserted which is 12 units (3/8 inch) less than the coordinate of the line on which the marker was placed. When a word copying process halts because of a space, stop, or carriage return code the gun mode is not terminated; instead the first character of the succeeding word is considered to be a light-gunned character. Thus to copy the succeeding word to the new location the operator need only depress the COPY WORD key again; he does not have to create a new marker or light-gun another character.

On the other hand, a position code or an E.O.M. code, when encountered by the marker, terminate not only the copying operation but the light gun mode as well. The position code indicates that the information following it is displayed in an entirely different spot on the screen from preceding information and may have no connection with the information being transferred. Therefore, automatic copying does not take place. The position code is not copied, but left undisturbed, and the operator can, if he chooses, return to the light gun mode by pointing the gun at another character. The E.O.M. code indicates that the end of active memory has been reached.

Copy Line Text

A whole line of alphanumeric information may be copied at one time, in the same manner used for copying a word: a marker is placed at the position to which the line is to be moved, the first character of the line to be moved is light-gunned, and the COPY LINE TEXT key is depressed. The operation will copy all codes encountered, including space, E.O.M. and stop codes. When a carriage return is encountered it is copied with a new Y coordinate appropriate to the new location, and the operation halts. The first character of the succeeding line is now considered to be light-gunned, and may be copied by depressing the COPY LINE TEXT key again.

A position code, when encountered, stops the operation and terminates the light gun mode.

Delete Word

A word may be deleted from display memory (and erased from the screen) by light-gunning its initial character and depressing the DELETE WORD key on the control keyboard. A space, carriage return, E.O.M. code, position code, or a stop code will terminate the deletion process. In case of a space or carriage return, the first character of the succeeding word assumes the light gun mode, and the next word may be erased by depressing the DELETE WORD key a second time. A stop code, a position code, or an E.O.M. code will terminate the light gun mode automatically.

Delete Line Text

The same procedure may be used to delete an entire line of textual information from display memory, except that the DELETE LINE TEXT key is used instead of the DELETE WORD key. In the case of line erasures, the space code will not stop the process. A carriage return will stop the operation and the first character of the next line will assume the light gun mode. If the key is activated a second time, the next line will be erased. A stop code, an E.O.M. code or a position code will stop the operation and terminate the light gun mode.

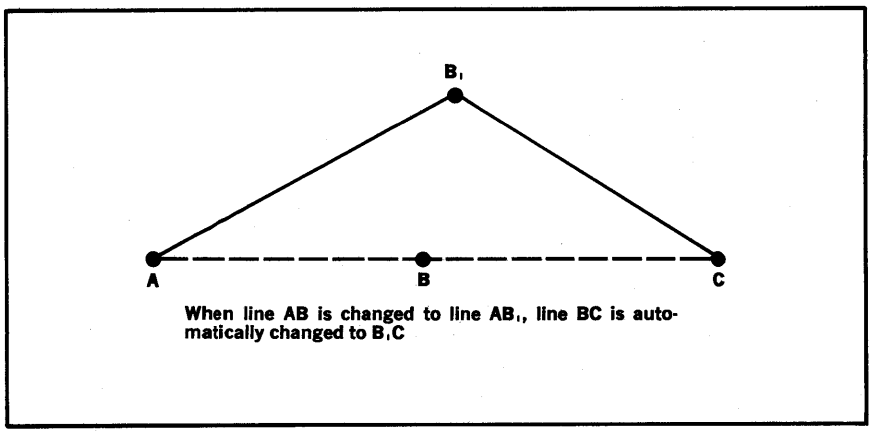
It should be noted that none of the codes which terminate either the "delete word" or the "delete line text", are themselves deleted. All these codes are left unchanged, so that only the data to be deleted is affected, but none of the control information surrounding the data.

Change Line Segment

So far all operations for making corrections discussed here are used to change alphanumeric text. The two following operations deal with graphic representations. To avoid confusion, the functions and the keyboard switches controlling them, are labeled LINE SEGMENT when a graphic line is involved, and LINE TEXT when the reference is to a line of alphanumeric copy.

A line segment is a portion of a displayed drawing defined by two sets of coordinates stored in memory. It may be created either manually, or by computer program. The position of a line segment may be changed by replacing in memory the coordinates of its terminal point with new coordinates. To do this, the cursor is placed on the spot which will become the new terminal point of the line. The line segment is then light-gunned and the CHANGE LINE SEGMENT key is depressed. The line segment will assume its new position, between its original starting point and the new terminal point. If a second line was connected to the first at the terminal point of the first line, the second line will be moved so that it remains connected to the first. Figure 12 shows the effect of this procedure on two connected lines. In the example, line AB was light gunned, and the cursor was at point B1 when the CHANGE LINE SEGMENT key was actuated.

Figure 12. Line Segment Change



When line AB is changed to line AB1, line BC is automatically changed to B1C

Delete Line Segment

A line segment may be deleted from the screen and from memory by a similar procedure. The line segment to be removed is light-gunned, and the DELETE LINE SEGMENT key is depressed. This procedure will delete the line code from memory but will not affect the coordinates, thus leaving unaffected any lines connected to the deleted line at either end.

Memory Clear

The display memory, or any portion of it, may be cleared whenever the information it displays is no longer useful. Two interlocked keys are provided for this function: the MEMORY CLEAR TEST key and the MEMORY CLEAR. When the MEMORY CLEAR TEST key is depressed by itself, characters within the clearing limits will be erased from the screen but not from memory, allowing the operator to check visually the effect of the operation. The display will reappear as soon as the MEMORY CLEAR TEST key is released. When the operator is satisfied that no information is affected which he wants preserved, he may then depress the MEMORY CLEAR TEST and the MEMORY CLEAR keys together. The using of two deys not only allows the operator to make certain that information being erased is no longer needed by the display, but also prevents the unintentional erasing of a display if the CLEAR key should be accidentally actuated.

The limits of the clearing operation are set by the operator through the use of the marker symbol, the light gun, and the E.O.M. code. Clearing will take place only within the memory page selected for display (page A or B), except when the MAXIMUM DISPLAY key has been depressed, activiting the entire memory.

The entire page (or the entire memory) is cleared, from the first location to the last, except:

1. If the page contains an E.O.M. code, memory is cleared from the first location to the E.O.M. code.

2. If the page contains a marker, memory is cleared from the first location to the marker.

3. If a memory page contains a light-gunned symbol, memory is cleared beginning with the light-gunned symbol and up to a marker, an E.O.M. code, or the last memory location on the page.

Thus, the lower limit of the clearing operation, if not the first location in memory, is set by the light gun. The upper limit, if not the last memory location, is specified by a marker or an E.O.M. code, whichever has the lower memory address.

The E.O.M. code itself is not cleared from memory. Note too that the light gun mode is not essential to the clearing operation, except where the operator wishes to start at some location other than the first location of the active memory page.

Clearing a Blink

A symbol on the screen (or a line segment), which blinks under computer control (a 1 in the ninth position of its word format) can be stopped from blinking by the operator. The blinking symbol is light-gunned, and the CLEAR BLINK/CLEAR ALARM key is depressed. The symbol will stop blinking, and a 0 will be inserted into the blink bit of its stored code word.

GENERAL SPECIFICATIONS 6

DIMENSIONS

Digital Unit	- 48" high, 46" wide, 24" deep.
Display Unit	- 48" high, 46" wide, 30" deep, excluding control panel overhang of 18".

WEIGHT

Digital Unit	- 600 pounds
Display Unit	- 750 pounds

ELECTRICAL REQUIREMENTS

115 Volts, 60 cycle, single phase, AC.

POWER CONSUMPTION

1.8 KW average; 2 KW maximum.

ENVIRONMENTAL TOLERANCE

Operating	- temperature	60°F - 85°F.
	- humidity	20% - 90%, excluding condensation.
	- pressure	sea level to 8000 ft above sea level.
Non-Operating	- temperature	32° F to 120° F.
	- humidity	10% to 100% (including condensation).
	- pressure	sea level to 25,000 ft above sea level.

RELIABILITY

Mean Time Between Failure, Digital Unit - 295 hours.
Display Unit - 280 hours.
System - 148 hours.

These figures assume normal preventive maintenance.

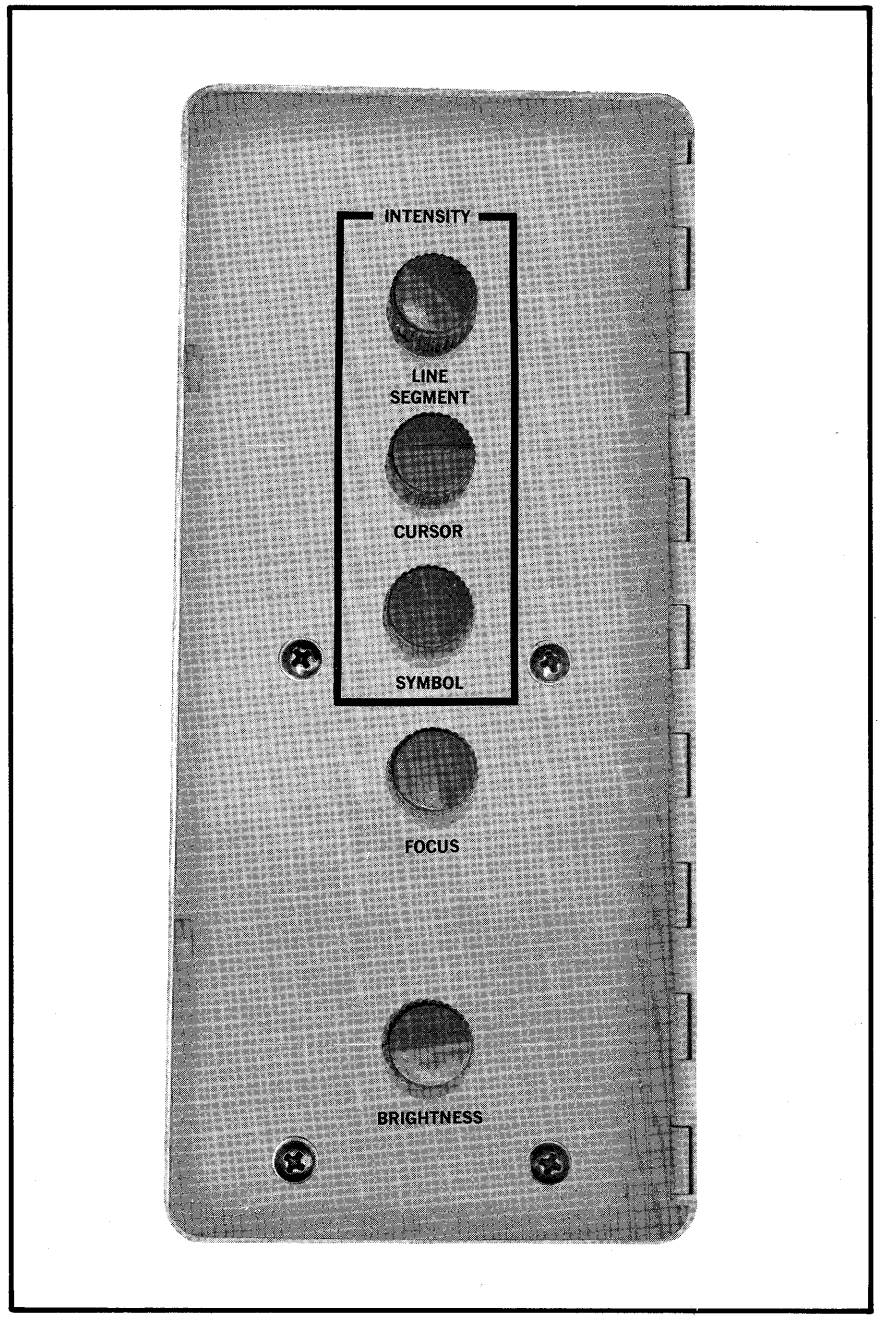
SPECIAL CONTROLS

Special controls (Figure 13) are provided for testing indicator lamps, adjusting panel lamp intensity, adjusting overall display brightness and focus, and for adjusting line, cursor, and symbol brightness independently.

SAFETY FEATURES

Interlocks turn off high voltage to the cathode ray tube when the access doors are opened. Override for these interlocks is provided for maintenance purposes. High-impact safety glass is bonded to the face of the CRT.

Figure 13. Special Controls



APPENDIX 1
PROGRAMMING CODE TABLES

TABLE A

CHARACTER CODES

In all characters shown the 7th bit may be one or zero. The 8th and 9th bits control the symbol size and blinking, respectively. The Plot Point should always be displayed in small size (bit 8 set to zero) so it will be accurately placed on the CRT display.

6-Bit Character Code (Octal)	Symbol	6-Bit Character Code (Octal)	Symbol
00	⌐ (E.O.M.)	40	-
01	1	41	J
02	2	42	K
03	3	43	L
04	4	44	M
05	5	45	N
06	6	46	O
07	7	47	P
10	8	50	Q
11	9	51	R
12	0	52	%
13	=	53	$
14	±	54	*
15	↓ (Marker)	55	"
16	'	56	Δ
17	|	57	>
20	↯ (Stop Code)	60	+
21	/	61	A
22	S	62	B
23	T	63	C
24	U	64	D
25	V	65	E
26	W	66	F
27	X	67	G
30	Y	70	H
31	Z	71	I
32	#	72	<
33	,	73	.
34	(	74	)
35	_ (Underline)	75	:
36	Σ	76	?
37	° (Degree)	77	• (Plot Point)

TABLE B

CONTROL AND SPECIAL SYMBOL CODES

Code Name	Bit Number									Symbol Displayed
	9	8	7	6	5	4	3	2	1	
Position code	×	0	1	1	1	1	1	1	1	none
Coordinate data	×	×	×	×	×	×	×	×	×	none
Line code(a)	×	1	1	1	1	1	1	1	1	none
Carriage Return	×	×	1	0	1	0	0	0	0	none
Space	0	0	0	0	0	0	0	0	0	Space
End of message	0	1	0	0	0	0	0	0	0	¬
Stop code(b)(c)	×	×	0	0	1	0	0	0	0	↯
Plot code(b)	×	0	0	1	1	1	1	1	1	•

NOTES

× Means the bit position may contain either 1 or 0.

(a) A 1 in bit 9 will cause line segment to blink.

(b) Bits 8 and 9 control size and blink.

(c) Stop code symbol is displayed only when the light gun enable button is depressed.

TABLE C

STATUS LIGHT AND ERROR LIGHT CODES

Status Light No.	Light Register No. (Octal Address)	Data Bit No.
*SS01	12	5
02	12	6
03	12	7
04	13	1
05	13	2
06	13	3
07	13	4
08	13	5
09	13	6
10	13	7
11	14	1
12	14	2
13	14	3
14	14	4
15	14	5
16	14	6
17	14	7
18	15	1
19	15	2
20	15	3
21	15	4
22	15	5
23	15	6
24	15	7
25	16	1

Error Light No.	Register No.	Data Bit No.
DS03 (Procedure error-external)	16	7

	Register No.	Data Bit No.
Audible Alarm	16	2

*SS01 controls interrupt of computer by display console

TABLE D1

PROGRAM KEYBOARD CODES - LEFT KEYBOARD

Program Keyboard Light No.	Light Register No. (Octal Address)	Data Bit No.
L01	02	1
02	02	2
03	02	3
04	02	4
05	02	5
06	02	6
07	02	7
10	03	1
11	03	2
12	03	3
13	03	4
14	03	5
15	03	6
16	03	7
17	04	1
20	04	2
21	04	3
22	04	4
23	04	5
24	04	6
25	04	7
26	05	1
27	05	2
30	05	3
31	05	4
32	05	5
33	05	6
34	05	7
35	06	1
36	06	2

TABLE D2

PROGRAM KEYBOARD CODES - RIGHT KEYBOARD

Program Keyboard Light No.	Light Register No. (Octal Address)	Data Bit No.
L41	06	3
42	06	4
43	06	5
44	06	6
45	06	7
46	07	1
47	07	2
50	07	3
51	07	4
52	07	5
53	07	6
54	07	7
55	10	1
56	10	2
57	10	3
60	10	4
61	10	5
62	10	6
63	10	7
64	11	1
65	11	2
66	11	3
67	11	4
70	11	5
71	11	6
72	11	7
73	12	1
74	12	2
75	12	3
76	12	4

APPENDIX 2
SAMPLE DISPLAYS

Figure 14. PERT Chart

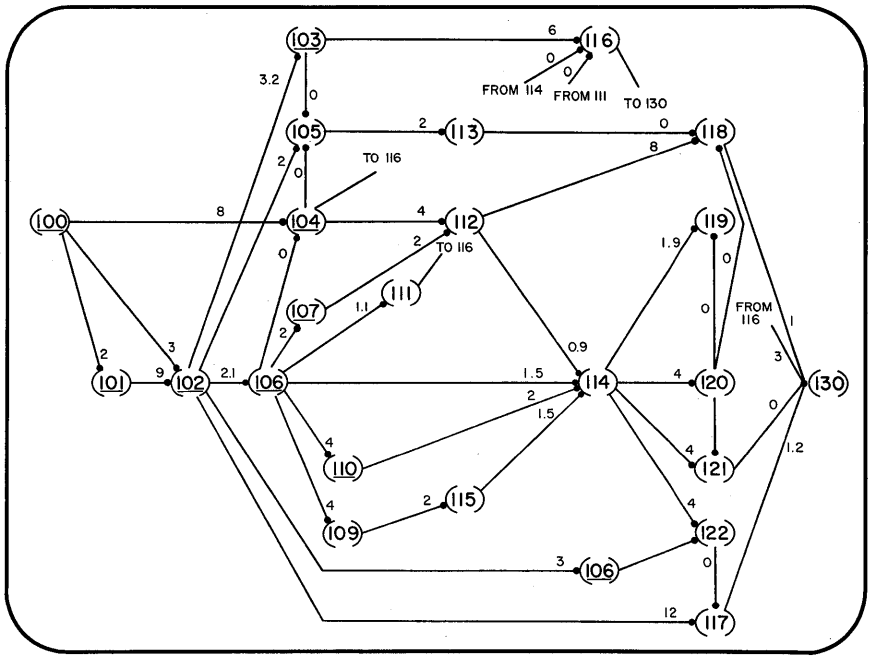


Figure 15. Production Graph

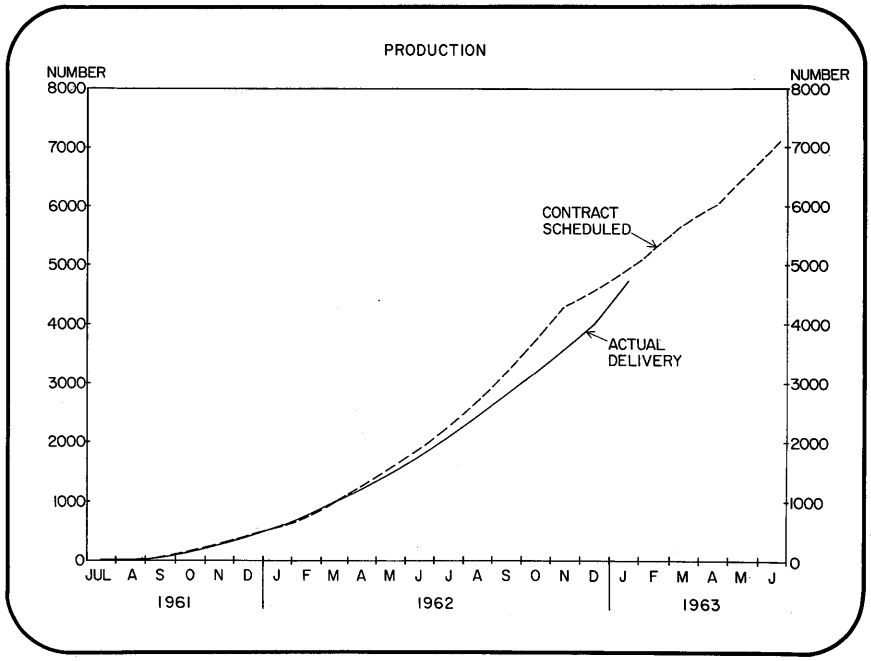


Figure 16. Bar Graph

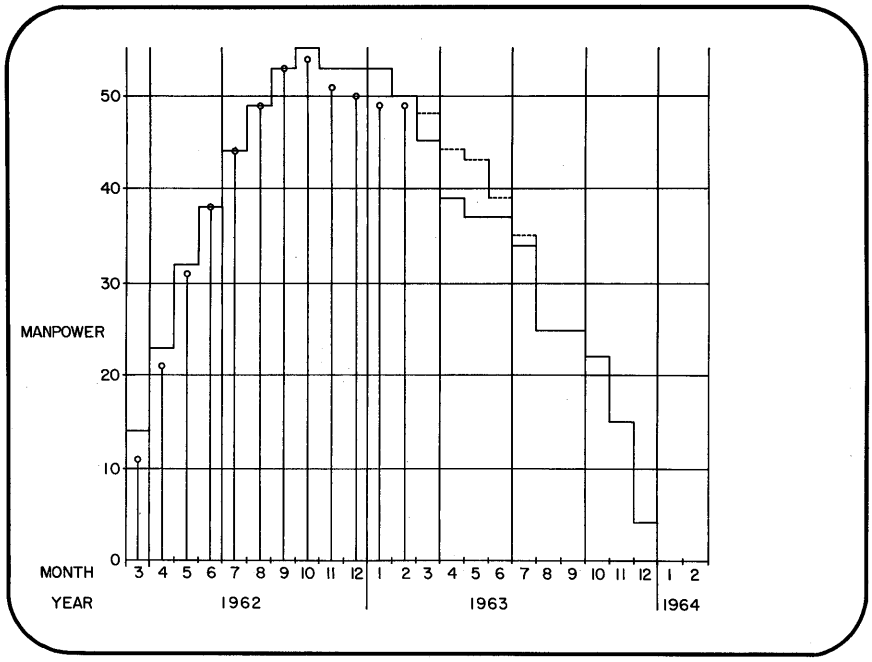
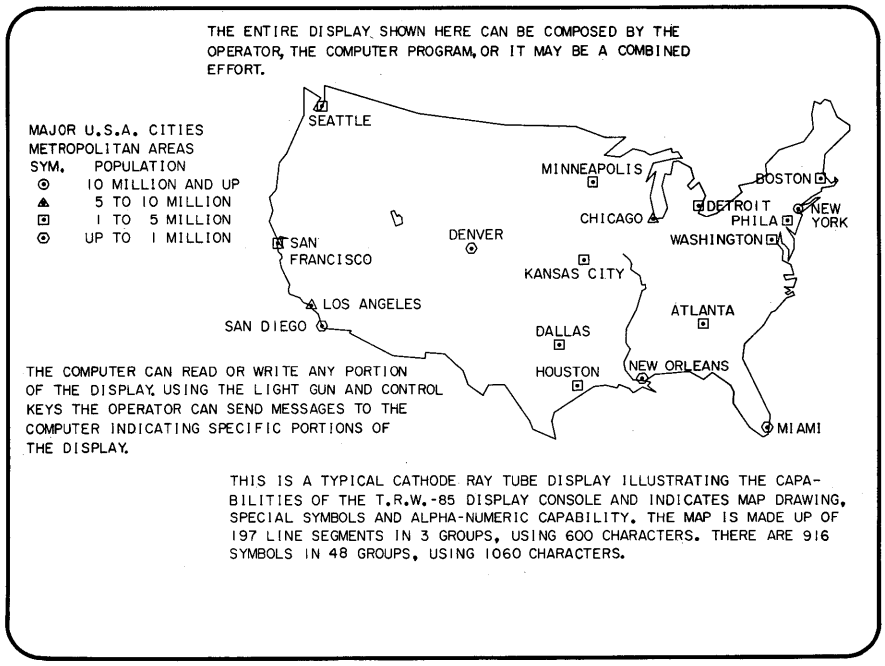


Figure 17. Population Map



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