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SUBJECT: INITIAL OPERATION OF WWI TERMINAL EQUIPMENT WITH THE NEW IN-OUT
           SYSTEM

To: Group 61

From: F.E. Heart

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Abstract: A short description is given of the expected operational modes
           of WWI terminal equipment immediately following the installation
           of the system in August, 1952. This memo supersedes the material
           of M-1514.

A. Introduction

The object of this memorandum is to familiarize members of Group 61
with the operation of that part of the input-output system which will be
installed in WWI by September 1952. The memo is also intended for reference
use by programmers and hence detailed descriptions of the equipment are not
included. It is expected that detailed descriptions will appear later as
separate memos.

As of this writing, the exact si addresses corresponding to particular
pieces of equipment have not been chosen. Thus, no si addresses are indicated
in the memo; a list of these addresses will be distributed after final choices
have been made.

A description is given only of those modes of operation which will
be available subsequent to the initial installation period. In particular,
material on "block transfers" and the operation of the buffer and auxiliary
magnetic drums is omitted. The following units are discussed: scopes, camera,
light guns, time register, tape readers, tape punches, printers and magnetic
tape.

B. In-Out System

The in-out system consists largely of an in-out switch (IOS), an
in-out register (IOR), and in-out control (IOC). The IOS is an electronic
switch by which the computer selects the desired external unit and the desired
mode of operation. IOR acts as temporary storage and a buffer between the
computer and all external units. IOC performs all timing, interlock and control
functions necessary to proper sequencing of in-out operations.

The system will eventually utilize five orders:

    si - select unit and mode of operation (or perform   ⎞ To be
         special function)   ⎟
                                                           ⎬ installed
    rc - record   ⎟
                                                           ⎟ by September
    rd - read   ⎠

bo - block transfer out of computer } To be installed at

bi - block transfer into computer.   } later data

Generally, to use a piece of terminal equipment an si order is
used to select unit and mode, and the address of the si order specifies
the unit and mode of operation. This is followed by one or more of the
other above orders to actually transfer information.

C. Scopes

Display oscilloscopes are used to allow visual observation of
computed results, and also to allow photographic recording of data. Present
equipment consists of two magnetically-deflected 16" scopes, and several
5" scopes.

All scope displays are point-by-point displays. Each point to
be displayed requires sending an 11-digit binary X-deflections and an
11-digit binary Y-deflection to digital-to-analog scope "decoders." The
process of displaying a point consists of sending both a horizontal and
a vertical deflection to the scope decoders and of selecting one of sixteen
"scope intensification lines." Note that the "sixteen scope intensification
lines" are not 16 physically different oscilloscopes, but 16 scope lines,
any one or any combination of which may be manually selected at each physical
scope unit.

A single point display is accomplished by performing an si order
followed (sometime later) by an rc order:

        si - select proper scope line
           - transfer left-most 11 digits of AC (X-deflection) to
             horizontal decoder

        rc - transfer left-most 11 digits of AC (Y-deflection) to
             vertical decoder (address section of the rc has no
             significance)
           - start intensify process.

In order to select a new scope line, or change the horizontal
deflection of a selected scope, another si order is needed. If, however,
it is desired to display a vertical array of dots on a particular selected
scope (e.g., a y-axis), a single si order may be followed by several rc
orders merely to change the vertical deflection and intensify a new spot.

The scopes are normally calibrated as follows:

1) $x = 0$, $y = 0$

2) $x = 1-2^{-11}$, $y = 1-2^{-11}$

3) $x = -1+2^{-11}$, $y = 1-2^{-11}$

4) $x = -1+2^{-11}$, $y = -1+2^{-11}$

5) $x = 1-2^{-11}$, $y = -1+2^{-11}$
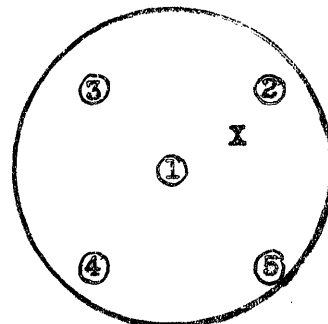
To display a point at $x = 1/2$, $y = 1/2$ (marked by "X" in above picture) the following program may be used:

Program			Constant	
A.1	ca	B.1	B.1	1/2
A.2	si.....			
A.3	rc	0		

The address of the si order selects the proper scope intensification line.

The computer does not wait for completion of scope deflection and intensification; an interlock is present to put the computer in stop clock if any other in-out order is attempted before a previous scope operation is complete.

D. Camera

Cameras are available for obtaining photographic records of scope displays. The available equipment is:

1) One Polaroid Land Camera, suitable for immediate pictures on the 5" scope. This camera is manually operated, and is not actually part of WWI terminal equipment. Its operation will not be discussed.

2) One Fairchild 35 mm. camera, suitable for either a 16" scope or a 5" scope, and arranged for either manual operation or operation by a computer order.

When the Fairchild camera has been set up on the scope, with the aperture setting made, the actual sequence of events (whether by manual pushbutton or by computer order) may take two paths:

a) If the shutter is originally in the closed position,
the index operation is as follows:

> Open shutter
> Close shutter
> Index film

b) If the shutter is originally in the open position, the
index operation is as follows:

> Close shutter
> Index film
> Open shutter

The index cycle will be entirely performed (computer control)
by one si order. The si address will select camera and initiate the cycle.

A complete indexing takes about 1/5 second. An interlock is used
so that no additional in-out order can be performed until the camera operation
has been completed.

E. Light Guns

The "light gun" is a device for indicating to the computer which
of many displayed points is most interesting to the human operator. It
is expected that eventually several (up to 15) physical light guns will be
available.

During a scope display of a point, by an si and a rc order, the
IOR is cleared by the rc order. Each light gun will be electrically tied
to a different digit of IOR and to the sign digit (operation of the light
gun will place a 1 digit in the associated IOR position as well as the sign
digit) and if an rd order is then performed, the contents of IOR will be
transferred to AC where the programmer may do with it as he wishes. This
is the only case where an rd follows an rc without an intervening si order.

The sequence is as follows:

> si ⎫ - display point and
>
> rc ⎭ - IOR cleared
>
> Light gun input(s) to IOR
>
> rd - transfers IOR to AC and redisplays (the address
> section of the rd has no significance).

F. Time Register (TR)

        The "clock" or "time register" allows the use, by computer programs,
of increments of real time. The clock counts 1/4 second intervals from 0
to 8192 seconds, and then starts over. Note that this time is not directly
tied in any way to any standard time and thus may only be used to measure
time increments.

        A 16-digit flip-flop register (using only 15 digits) is used
to count 1/4 second pulses. These pulses are generated by use of a small
synchronous clock motor. (This motor drives a disk through which light is
passed at 1/4 second intervals, to be picked up by a photocell, amplified,
and counted in the flip-flop register.)

        The presently existing time register will not be tied into the
new in-out system. Its tie, as described below, will remain non-standard
until such time as a new time register is designed and built.

        The Time Register may be substituted for any toggle switch register
of Test Storage (TS) in much the same way that the five flip-flop registers
may be substituted for any register of TS. This is accomplished by connecting
a video cable to the appropriate jack of computer panel C6 and changing the
associated toggle switch.

        In use, the contents of TR are made available at the address of
the register of TS to which TR was attached. The TR may be interrogated
by computer orders such as ca, ad, cs, mh, dv, etc,; information may not
be transferred into it. The order which interrogates TR must itself be
in electrostatic storage. The TR may also be interrogated when the computer
is in PB. However, if the computer is restarted from the manual condition
on TP4 or TP5, and the next TP6 interrogates TR, an incorrect answer may result.

        Since the interrogation is by a normal computer order, the time
required is just the normal time for an order in ES whose address refers
to TS.

G. Paper Tape Readers
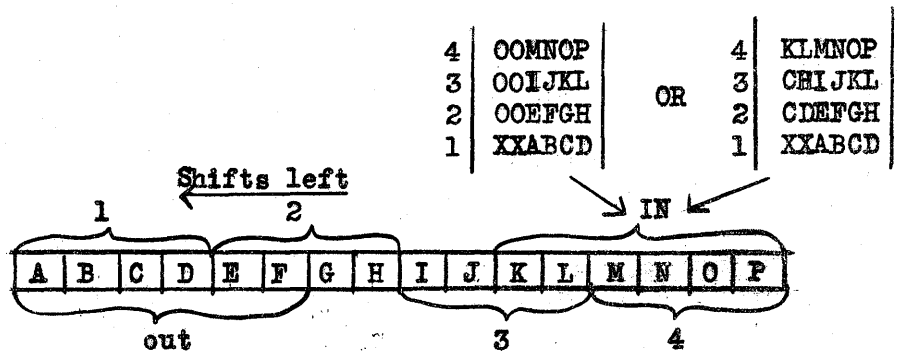
    1. Equipment

        Equipment will consist of one ERA Photoelectric reader and one
Flexowriter electromechanical reader.

    2. General Operation

        The input tape system will be more flexible under the new system
and will have three main modes of operation:

a) First, one may decide to operate in a line-by-line mode
using the Flexowriter reader. In this mode single units
of information are read in, and the reader physically
stops after each line of tape. In this mode a unit of
information is one six-digit <u>line</u> of tape.

b) Second, one may select a free-running mode using the ERA
reader, in which case the reader runs freely and feeds
information from tape to the computer. For this mode,
however, two sub-modes are available:

    1. A unit of information is equal to one six-digit
line of tape (normal).

    2. A unit of information is equal to one <u>word</u>,
or 4 four-digit lines of tape. This is a
new mode, called "automatic sexadecimal,"
in which the in-out system assembles four
lines of tape into a sixteen-digit word
before transferring it into the computer
proper as a single unit of information.

(NOTE: The IOR shifts to the left and therefore characters are read out of
the left-hand six digits in recording, and into the right-hand six digits
when reading. In the automatic sexadecimal mode, four six-digit characters
are read in but only four shifts take place between characters. Thus,
information must be stored on tape only in the four least significant digits
of each line, or the two remaining positions must have the correct redundant
information. Either of the following arrangements will operate correctly.
(X's indicate either 0 or 1 permissible.)

```
            4 | OOMNOP |        4 | KLMNOP |
            3 | OOIJKL |   OR   3 | CHIJKL |
            2 | OOEFGH |        2 | CDEFGH |
            1 | XXABCD |        1 | XXABCD |

         Shifts left                      IN
       1  ◄─── 2                      ╲  ╱
   ┌─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┬─┐
   │A│B│C│D│E│F│G│H│I│J│K│L│M│N│O│P│
   └─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┴─┘
          out              3       4
```

3. Specific Operation

In the following discussion of the reading modes, it should be noted that for each different mode of operation the address section of the si order is different.

Shown below is the programming necessary for utilizing a line-by-line mode and a free-running mode. Note that each rd order brings one unit of information into AC. Using a line-by-line mode (Flexowriter):

> si - select
>
> rd - read one unit into AC
>
> si - select
>
> rd - read one unit into AC
>
> si - select
>
> rd - read one unit into AC

Using a free-running mode (ERA):

> si - select
>
> rd - read one unit into AC
>
> rd - read one unit into AC
>
> rd - read one unit into AC
>
> rd - read one unit into AC
>
> rd - read one unit into AC
>
> si - stop

In this free-running mode, the rd orders must be spaced less than 7 ms apart in time. In a free-running mode, if information arrives before the computer is ready to accept it (rd order), a program alarm will result.

With the ERA reader, depending upon the address of the si order, a "unit of information" may be either one line of tape (6 digits) or 4 lines of tape (using only the 4 least significant digit positions of each line of tape). This permits automatic assembly of 4 lines of tape into a 16-digit word.

In an attempt to summarize, a list is presented of the three combinations which may be selected by the si order for tape readers: (In this list symbolic addresses have been given to the si orders in order to show which si orders are the same and which are different.)

Unit Selected	Line-by-line	Free-running	Information unit is one line	Information unit is four lines	Program
Flexo	X		X		si r_1　　select rd 0　1 line→AC si r_1　　select rd 0　1 line→AC
ERA		X	X		si r_2　　select rd 0　1 line→AC rd 0　1 line→AC rd 0　1 line→AC si r_3　　stop
		X		X	si r_4　　select rd 0　1 word→AC rd 0　1 word→AC rd 0　1 word→AC si r_3　　stop

H. Typewriters and Paper Punches

Typewriters and paper punches will be available to allow the computer to print or punch data. The equipment available will be two Flexowriter printers (new code) and two Flexowriter punches.

Each character to be printed or punched requires that the computer send one six-digit binary character to the output unit. If punching has been selected, the holes punched in tape will have a one-to-one correspondence to the six digits transferred. If printing is selected, the six digits are decoded according to the new Flexowriter code, (this code was chosen somewhat arbitrarily and built into the Flexowriter equipment by the manufacturer), and the corresponding character will be printed. Thus, if punching, any six digits are permissible (64 combinations); when printing, these six digits must form one of about 50 arbitrary code characters. (If an unacceptable character is attempted, the computer will not hang-up, and a short delay is the only result.)

The transfer of six-digit binary characters from the computer to the external units will be performed one character at a time:

	si - select unit (If punching, also decides if 7th hole is to be punched or not)
some time later	rc - print or punch one character from AC (six left-hand digits)
some time later	rc - print or punch one character from AC (six left-hand digits)
some time later	rc - print or punch one character from AC (six left-hand digits)
some time later	rc - print or punch one character from AC (six left-hand digits)

An example of printing June 1952 will be given to illustrate the sequence:

Program

A.1	si ---	B.1	10×2^{-15}	C.1	-22×2^{-4}	shift down
A.2	cs B.1	B.2	0×2^{-15}	C.2	22×2^{-4}	j
A.3	ts B.2	B.3	ca c.1	C.3	-30×2^{-4}	shift up
A.4	ca B.3			C.4	14×2^{-4}	u
A.5	ts A.6			C.5	24×2^{-4}	n
A.6	ca c.1			C.6	2×2^{-4}	e
A.7	rc 0			C.7	8×2^{-4}	space
A.8	ao A.6			C.8	-4×2^{-4}	1
A.9	ao B.2			C.9	-17×2^{-4}	9
A.10	cp A.6			C.10	-1×2^{-4}	5
	End			C.11	-7×2^{-4}	2

An example of punching in 6-6-4 form:

A.1	si ---		B.1	(word to be punched)
A.2	ca B.1			
A.3	rc 0			
A.4	cl 6			
A.5	rc 0			
A.6	cl 6			
A.7	cl 30			
A.8	rc 0			

End

I. <u>Magnetic Tape</u>

Magnetic tape will be used for storage of temporary results, storage of subprograms, storage of results to be printed, etc. Equipment consists now of one Raytheon-built magnetic tape assembly, but it is expected that four such units will be available.

A rather complete description of "interim-system operation is available as M-1337.

1. General Description

a) Magnetic Tapes are about 800 feet long.

b) Normal running speed of 30 inches/second. It is possible to store 100 lines/inch at maximum density recording.

c) Six channels are available on tape, and for reliability they are used in pairs (3 pairs), but only two pairs are used for actual information, with a third being used for a marker channel. Thus, to store a 16 binary digit word, requires 8 lines.

d) Tape may be run forward or backward, all under computer control.

e) Tape can be erased, and rerecorded, with certain restrictions.

2. Operation

The operation of the Magnetic Tape system will be much simpler with a new in-out system. The price of this simplicity will be a slight loss of flexibility. It will be possible to record and read only complete 16-digit words. Furthermore, although recording and reading will be possible in either direction, it will be somewhat difficult to read in a direction opposite to the recording direction.

The recording sequence for a single block of information will be as follows:

	si - select 1 out of 4 units
	- select tape direction
	- start unit
some time later	- record block mark
	rc - record 16 digits of AC on 8 lines of tape
some time later	rc - record 16 digits of AC on 8 lines of tape
some time later	rc - record 16 digits of AC on 8 lines of tape
some time later	si - stop

Reading Magnetic Tape (recorded in the above manner) is also done word-by-word:

si - select unit and direction

- start unit, which runs until it finds a block mark, then sends information to IOR

rd - read one word from 8 lines of tape to AC

rd - read one word from 8 lines of tape to AC

rd - read one word from 8 lines of tape to AC

si - stop

Since the magnetic tape is free-running until told to stop, the computer must attempt to perform rd orders before new information (the start of another word) arrives under the heads. If information arrives before the computer is prepared to accept it, a program alarm is given.

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