Report on

THE ENIAC

(Electronic Numerical Integrator and Computer)

Developed under the supervision of the
Ordnance Department, United States Army

OPERATING MANUAL

UNIVERSITY OF PENNSYLVANIA

Moore School of Electrical Engineering

PHILADELPHIA, PENNSYLVANIA

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A REPORT ON THE ENIAC

(Electronic Numerical Integrator and Computer)

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ENIAC OPERATING MANUAL

by

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INTRODUCTION TO REPORT ON THE

ELECTRONIC NUMERICAL INTEGRATOR AND COMPUTOR (ENIAC)

0. INTRODUCTION

The Report on the ENIAC consists of five separately bound parts, as follows:

1) ENIAC Operating Manual

2) ENIAC Maintenance Manual

3) Part I, Technical Description of the ENIAC

Volume I - Chapters I to VI

4) Part I, Technical Description of the ENIAC

Volume II - Chapters VII to XI

5) Part II, Technical Description of the ENIAC

Included with the Operating Manual and Parts I and II of the Technical Descriptic are all drawings (see Table 0.3 below) which are required for understanding these reports. The Maintenance Manual assumes access to the complete file of ENIAC drawings.

Part I of the Technical Description is intended for those who wish to have a general understanding of how the ENIAC works, without concerning themselves with the details of the circuits; it assumes no knowledge of electronics or circuit theory. Part II is intended for those who require a detailed understanding of the circuits. Its organization, to a great extent, duplicates that of Part I so as to make cross referencing between the two parts easy.

The ENIAC Operating Manual contains a complete set of instructions for operating the ENIAC. It includes very little explanatory material, and hence assumes familiarity with Part I of the Technical Description of the ENIAC. The ENIAC Maintenance Manual includes description of the various test units and procedures for testing, as well as a list of common and probable sources of trouble. It assumes a complete understanding of the circuits of the ENIAC, i.e., a knowledge of both Parts I and II of the Technical Description of the ENIAC.

The Report on the ENIAC and the complete file of ENIAC drawings constitute a complete description and set of instructions for operation and maintenance of the machine. The drawings carry a number of the form PX-n-m. The following tables give the classification according to this numbering system.

TABLE 0.1

Values of n	Division
1	General
2	Test Equipment
3	Racks and Panels
4	Trays, Cables, Adaptors, and Load Boxes
5	Accumulators
6	High Speed Multiplier
7	Function Table
8	Master Programmer
9	Cycling Unit and Initiating Unit
10	Divider and Square Rooter
11	Constant Transmitter
12	Printer
13	Power Supplies

TABLE 0.2

Values of m	Subject
101-200	Wiring Diagrams
201-300	Mechanical Drawings
301-400	Report Drawings
401-500	Illustration Problem Set-Ups.

The reader of this report will be primarily interested in the types of drawings listed in the following paragraphs. A table on page 4 gives the corresponding drawing number for each unit of the ENIAC.

1) Front Panel Drawings. These drawings show in some detail the switches, sockets, etc., for each panel of each unit. They contain the essential instructions for setting up a problem on the ENIAC.

2) Front View Drawings. There is one of these drawings for each kind of panel used in the various units of the ENIAC. These show the relative position of the trays and the location of the various neon lights. Since these drawings show the neon lights, they can be used to check the proper operation of the various units.

3) Block Diagrams. These drawings illustrate the logical essentials of the internal circuits of each unit. That is, resistors, condensers, and some other electrical details are not shown; but complete channels (paths of pulses or gates representing numbers or program signals) are shown in all their multiplicity. These drawings will be of interest to those who are interested in Parts I and II of the Technical Report.

4) Cross-section Diagrams. These drawings are electronically complet except that only one channel is shown where there is more than one. Thus, these drawings show every resistor and condenser and any other electronic elements belonging to any circuit. These drawings will be of particular interest to the maintenance personnel and to those reading Part II of the technical report.

5) Detail Drawings. All other drawings of the ENIAC come under this heading. A complete file of drawings is available at the location of the ENIAC.

Table 0.3
ENIAC DRAWINGS

Unit	Front Panel	Front View	Block Diagram	Cross - Section
Initiating Unit	PX-9-302 9-302R	PX-9-305	PX-9-307	
Cycling Unit	PX-9-303 9-303R	PX-9-304	PX-9-307	
Accumulator	PX-5-301	PX-5-305	PX-5-304	PX-5-115
Multiplier	PX-6-302 6-302R 6-303 6-303R 6-304 6-304R	PX-6-309	PX-6-308	PX-6-112A 6-112B
Function Table	PX-7-302 7-302R 7-303 7-303R	PX-7-305	PX-7-304	PX-7-117 7-118
Divider and Square Rooter	PX-10-301 10-301R	PX-10-302	PX-10-304	
Constant Transmitter	PX-11-302 11-302R 11-303 11-303R 11-304 11-304R	PX-11-306	PX-11-307	PX-11-116 11-309 (C.T. and R.
Printer	PX-12-301 12-301R 12-302 12-302R 12-303 12-303R	PX-12-306	PX-12-307	PX-12-115
Master Programmer	PX-8-301 8-301R 8-302 8-302R	PX-8-303	PX-8-304	PX-8-102

Other drawings of particular interest:

Floor Plan	PX-1-302	IBM Punch and	PX-12-112
A.C. Wiring	PX-1-303	Plugboard	PX-12-305
IBM Reader and	PX-11-119	Pulse Amplifier and	PX-4-302
plugboard	PX-11-305	Block Diagram	PX-4-301

Interconnection of Multiplier and Accumulators PX-6-311
Interconnection of Divider and Accumulators PX-10-307

The front view drawings and the large front panel drawings (whose numbers do not end with "R") are bound as a part of the Operator's Manual.

Included with the report is a folder containing all the drawings listed in the above table except the large front panel (see above) drawings.

1. GENERAL INSTRUCTIONS FOR OPERATING PERSONNEL

1. Inform maintenance personnel immediately of any trouble and note same in the log book.

2. Occasionally check the filament fuse indicator lights (refer to front view drawings bound in this volume); if any are out turn off the d-c power (switch is located on a-c distribution panel, see PX-1-304).

3. If ENIAC shuts down from overheating do not try to restart; call maintenance personnel. If any panel runs consistently much hotter than the others, do the same.

4. The d-c power should be turned on only with operation switch (either on cycling unit or on the hand control) turned to "continuous". After the d-c has been on a few seconds it may be turned to either of the other two positions. Failure to follow this rule causes certain d-c fuses to blow, -240 and -415 in particular.

5. As a general matter certain units not being used may have their heaters turned off. In such cases it is unnecessary to remove the d-c power or even to turn off the d-c power when turning on these units. On the other hand th three panels of the constant transmitter must be turned on or off simultaneously.

6. Do not remove any covers, front or back.

7. Do not open d-c fuse cabinet with the d-c power turned on. This not only exposes a person to voltage differences of around 1500 volts but the

person may be burned by flying pieces of molten fuse wire in case a fuse should blow.

8. Padlocks are provided for locking the d-c power off. Lock the power off and carry the key with you as long as you are working on the machine.

9. Do not remove accumulator interconnector plugs, or function table or IBM machine connector cables, while the d-c is on. All other front panel plugs may be safely moved while the power is on.

10. Do not pull directly on wire or cable; always use the plug case as a grip.

11. Do not put sharp bends in cables or hang anything on them.

12. Do not leave cables dangling on the floor.

13. Do not pound or force plugs; if they do not respond to steady pressure notify maintenance personnel.

14. Do not leave IBM cable connectors or portable function table connectors lying out in the open, keep in the receptacles provided. Also, make use of the ramps to protect the cables of any such units which are connected to the ENIAC.

15. Do not force any switches.

16. Keep the door to the room closed to keep out dust, avoid stirring up or producing dust.

17. Always move the portable function tables with care. Keep the brakes on when not moving them.

2. PROBLEM SET UP REMARKS

2.1. NEED FOR SYSTEMATIC CHECKS

Since the ENIAC makes use of a hierarchy of channels (first, in that a

number of units may be carrying on computations simultaneously; second, in that it always handles ten to twenty digits of a number simultaneously; and third, in that certain units use a coded system giving four channels for each digit) running a standard check problem is not a sufficient check on the accuracy of the results. Thus, in arranging a problem for the ENIAC provision should be made for occasional systematic checks of all the units.

Procedures for systematic checking are described in some detail in the maintenance manual. Brief procedures will be outlined here for the numerical units. The following test procedures are not comprehensive tests and the experienced operator will perhaps use variations of them. In particular, the tests given below are not designed to check the operation of the various program controls. However, they are designed to check the numerical circuits in each unit and to a considerable extent check the program control used to carry out the test.

2.2. TESTING AN ACCUMULATOR

Cards should be prepared as follows:

1. P 11111 11111
2. P 00000 00001

The numbers should be so placed on a card that one group in the constant transmitter, say A_{LR}, corresponds to these numbers. Next, a master programmer stepper should be used to transmit the first number into the accumulators which are to be tested eighteen times. At this time the accumulators should read

M 99999 99998

and all stages of each decade have been checked as well as the delayed carry-over circuits. Now the stepper (used above) should cause the reader to read the next card and the number to be transmitted to the accumulators twice. This should

give

P 00000 00000

and checks the direct carry-over circuits. Note that this test assumes that the significant figure switch is set to "10". If this is not so the operator can modify the above procedure to take care of this.

This test does not check the following circuits (for a complete checking procedure see the maintenance manual):

Transmission circuits
Clearing circuits
Repeater ring
Input channels (except for the one used)
Program controls (except for the one used)

2.3. TESTING THE MULTIPLIER

The following set of cards should be prepared.

Card	Multiplier A_{LR} (say)	Multiplicand B_{LR} (say)
1	P 00000 00000	P 11111 11111
2	P 11111 11111	P 11111 11111
3	P 11111 11111	P 22222 22222
.....		
10	P 11111 11111	P 99999 99999
11	P 22222 22222	P 11111 11111
12	P 22222 22222	P 22222 22222
.....		
82	P 99999 99999	P 99999 99999
83	P 11111 11111	M 11111 11111
84	M 11111 11111	P 11111 11111
85	M 11111 11111	M 11111 11111

On a second set of cards, or on these same cards in different fields the proper answers should be punched. Note that these answers will depend upon when ten or twenty digit products are used, that is, whether the product accumulators are used as ten or twenty digit accumulators.

There are two methods of using these cards to check the numerical circuits of the multiplier. One is to have the answer on the same card and arrange for its transmission to the product accumulators with its sign changed (or the sign of one of the factors may be changed). In this case the whole sequence of cards in run and the presence of "zero" in the product accumulators indicates (with high probability since there could be compensating errors) that the numerical circuits are all right.

A second method is to run the test and cause the answers to be punched on other cards. These results may then be compared with standard answers by use of the reproducing punch.

This procedure does not check the following:

Rounding off circuits

Program controls (other than the one used).

2.4. TO TEST A FUNCTION TABLE

An accumulator is used to build up the argument. A program control on the function table has its function switch set to "-2" and a second switch has its argument set to "+2".

The programming is so arranged that the "-2" program is activated and the output sent to an accumulator associated with the printer. The result is punched on a card, "one" is added to the argument, and the process repeated.

The master programmer can be used to repeat the "-2" program 96 times and then alternately activate the "-2" and the "+2" program four more times. (Or various other schemes may be devised to obtain all 104 entries to the function table.) The cards punched in this manner can then be compared with a standard deck.

Note that the above check is not a systematic check of the numerical circuits as a whole. In other words this check should be repeated if any switches on the portable table (or on panel No. 2) are changed.

Furthermore, the above procedure does not check the various program controls of the function table.

2.5. TO TEST THE DIVIDER AND SQUARE ROOTER

The divider and square rooter can best be checked by performing test division problems and square root problems. Drawing PX-10-111 gives the neons which should be lit at various places in the process. The operator can check against this by going through the problem at one addition time.

2.6. CONSTANT TRANSMITTER TEST PROCEDURE .

The 1, 2, 2', 4 channels in the constant transmitter can all be checked simultaneously by reading cards with nine punches on them. Since it is undesirable that the same number be punched in all columns of a card (this weakens a card increasing the probability of "jamming" in the feeding mechanism of the IBM machines) it is suggested that cards be prepared as follows.

1) 9's in groups A_{LR} and B_{LR}
2) 9's in groups C_{LR} and D_{LR}
3) 9's in groups E_{LR} and F_{LR}

4) 9's in groups G_{LR} and H_{LR}

5) Four more cards similar to above but with minus punches.

The programming should be arranged so that the numbers are transmitted into accumulators when they can be inspected visually or perhaps punched on other cards and compared with a standard deck using the reproducing punch.

Note that J_{LR} and K_{LR} should be checked in a similar manner. (These only need be checked for the numbers used in the set-up provided they are re-checked any time that some of the switch settings are changed.)

This procedure does not check all the program controls.

2.7. PRINTER TEST PROCEDURE

The printer can be tested by causing all possible digits in each channel to be punched and by checking the PM delays. The following cards should be prepared.

1) P 01234 56789

2) P 11111 11101

3) P 11111 11011

. . . . . .

10) P 01111 11111

11) P 11111 11111

The programming should be arranged to cause the numbers on the test cards to be read by the IBM reader, transmitted to the printing accumulators, and the result punched. The resulting cards may be compared with a standard deck by use of the reproducing punch.

Card number one has the numbers 0 to 9 punched in it to prevent the same digit from being punched all across a card.

If any decades of the master programmer are used in printing they may be checked at this time by transmitting the program pulse (used to activate the above sequence) into each decade direct input.

This constitutes a complete test of the printer.

2.8. TESTING FOR TRANSIENT FAILURES

If transient failures are suspected a master programmer stepper should be used to repeat the appropriate test (such as one of those above) a large number of times.

In case of an accumulator this can be done using only one card (say, P 99999 99999) and using a second program control set to αC (receive on α and correct) to obtain the one pulse in the units decade.

For the multiplier it becomes necessary to punch the answers on the cards with the factors (see 2.3) and cause these to be transmitted to the product accumulators for each multiplication. If more than ten digit answers are used the adjusted answer to card 83 must be carefully prepared in order to get minus the answer from the constant transmitter to the product accumulators (since the constant transmitter only complements at most ten digits at a time).

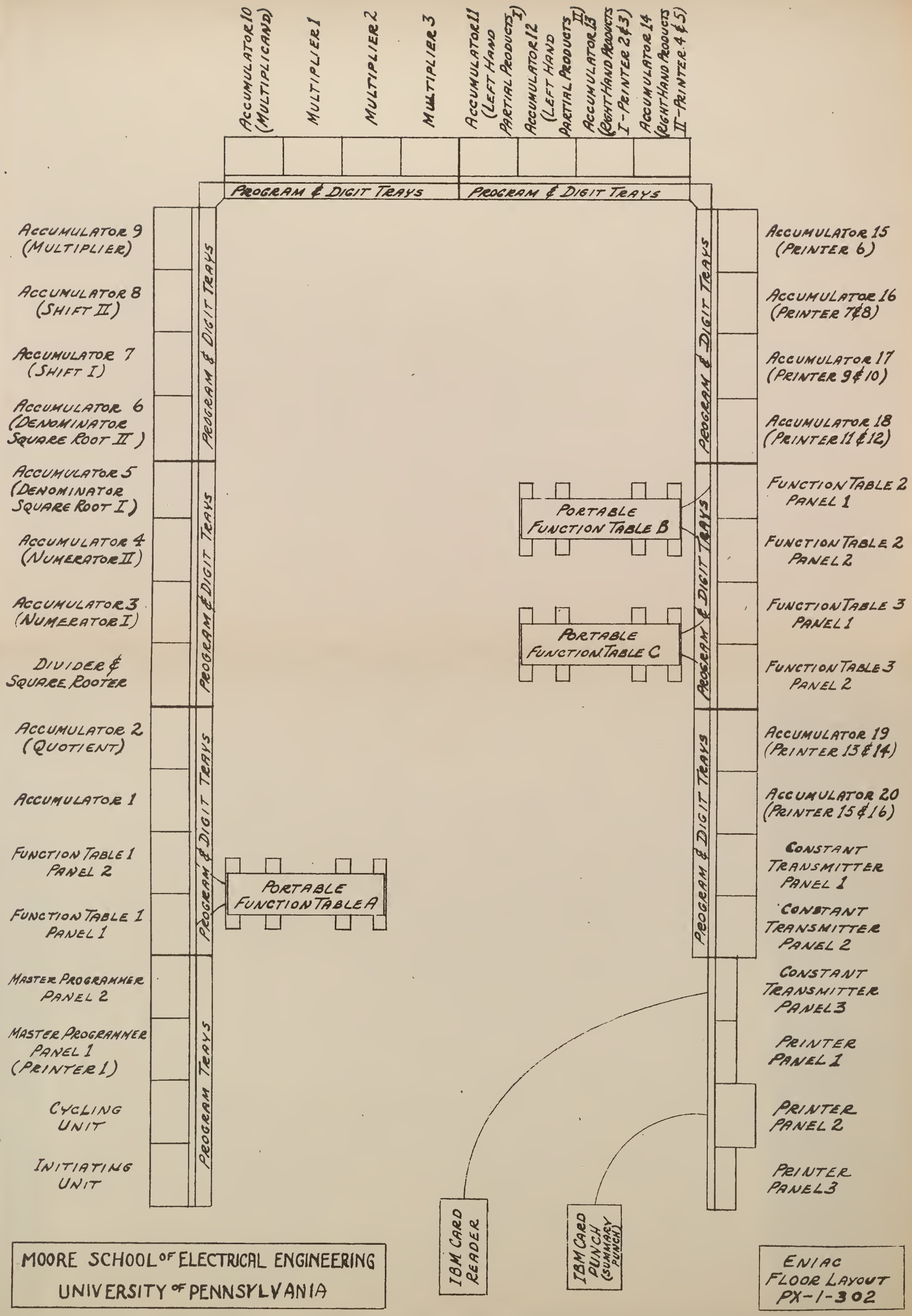
Repetition of a function table test is straight forward. It may be worth while to receive into a twenty digit accumulator and repeat the transmission 10^4 times, say, and see if the proper number is obtained.

The square root of zero is perhaps the easiest test to repeat on the divider-square rooter.

The constant transmitter can be caused to transmit any group repeatedly to some accumulator. Dust particles may cause transient relay failures, so avoid stirring up dust in the ENIAC room. Also, if any relay case is removed, always

replace in exactly the same position in order not to disturb dust inside the case.

Transient failures in the printer are probably relay failures. See maintenance manual for list of probable failures.



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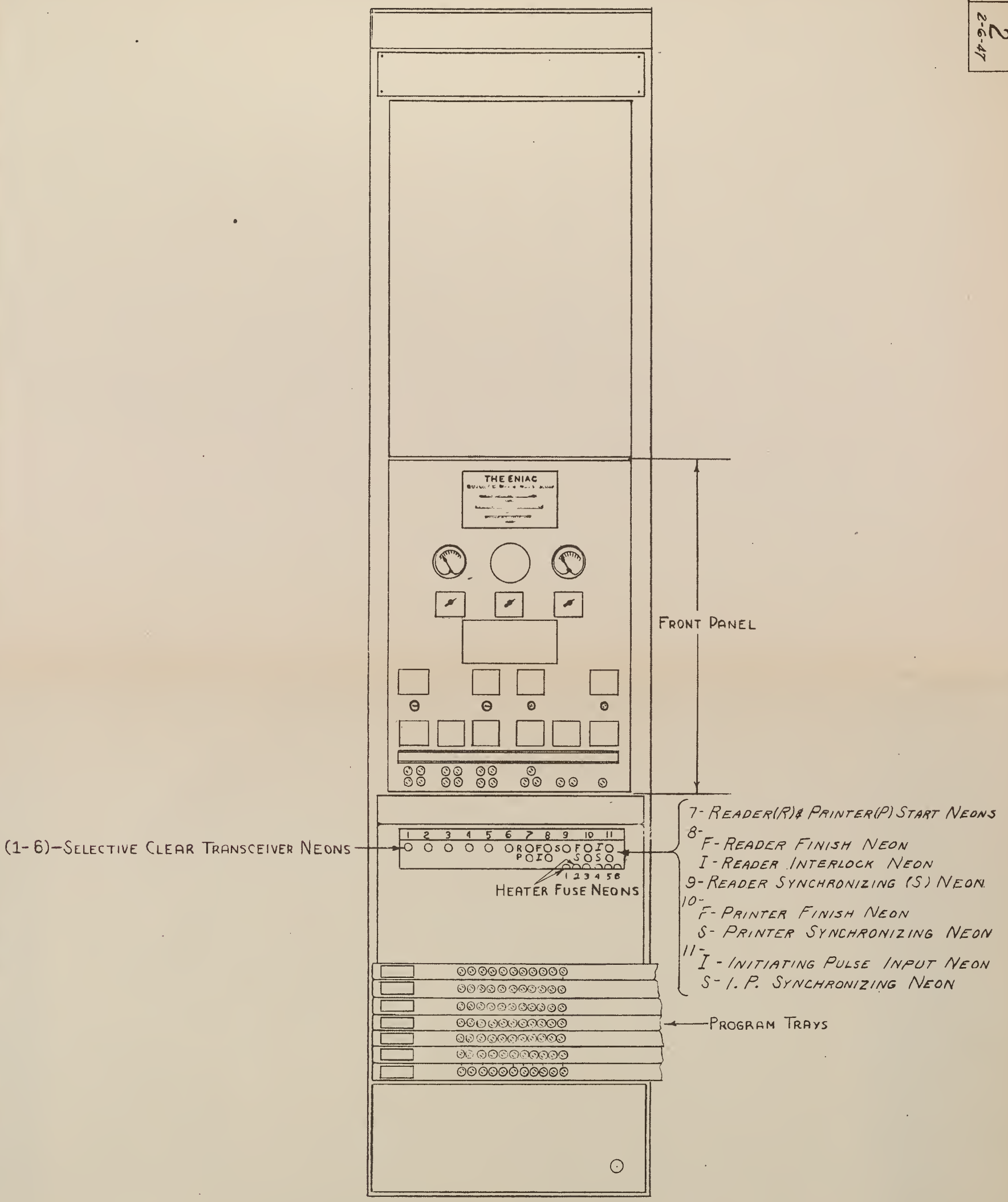
ENIAC
FLOOR LAYOUT
PX-1-302

1	2
12-18-45	2-6-47



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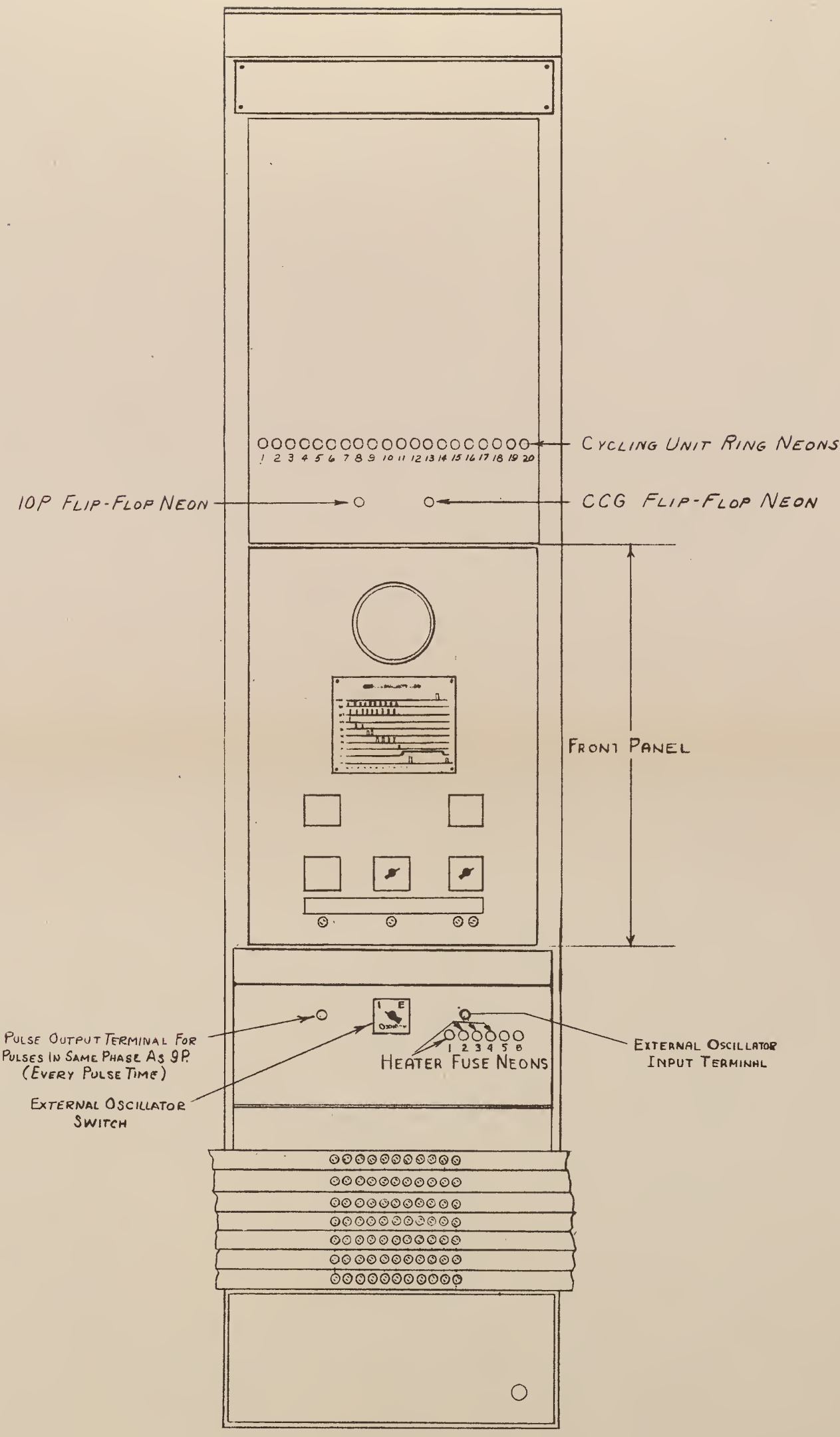
INITIATING UNIT FRONT VIEW
PX-9-305

1
6-47



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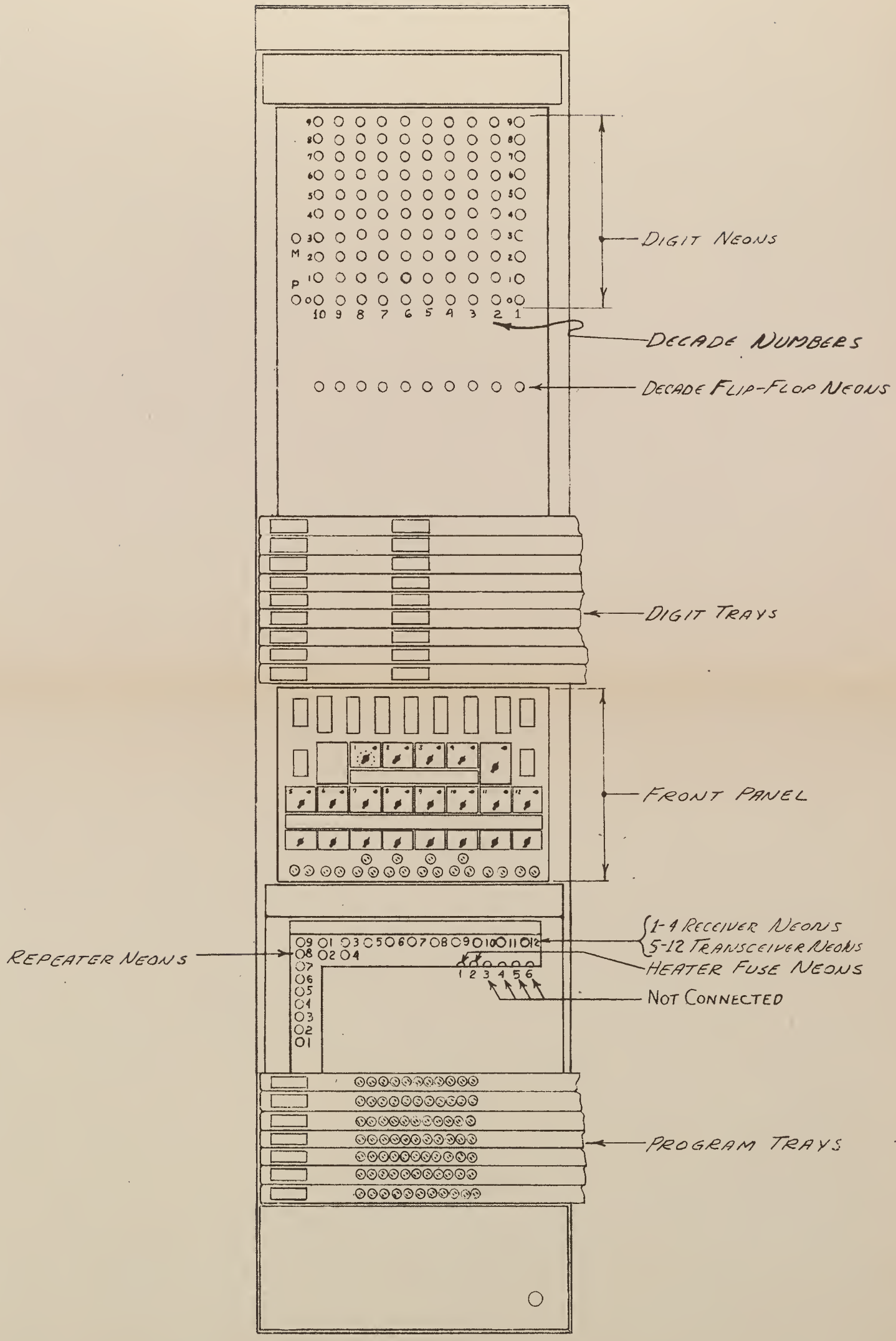
CYCLING UNIT
FRONT VIEW
PX-9-304



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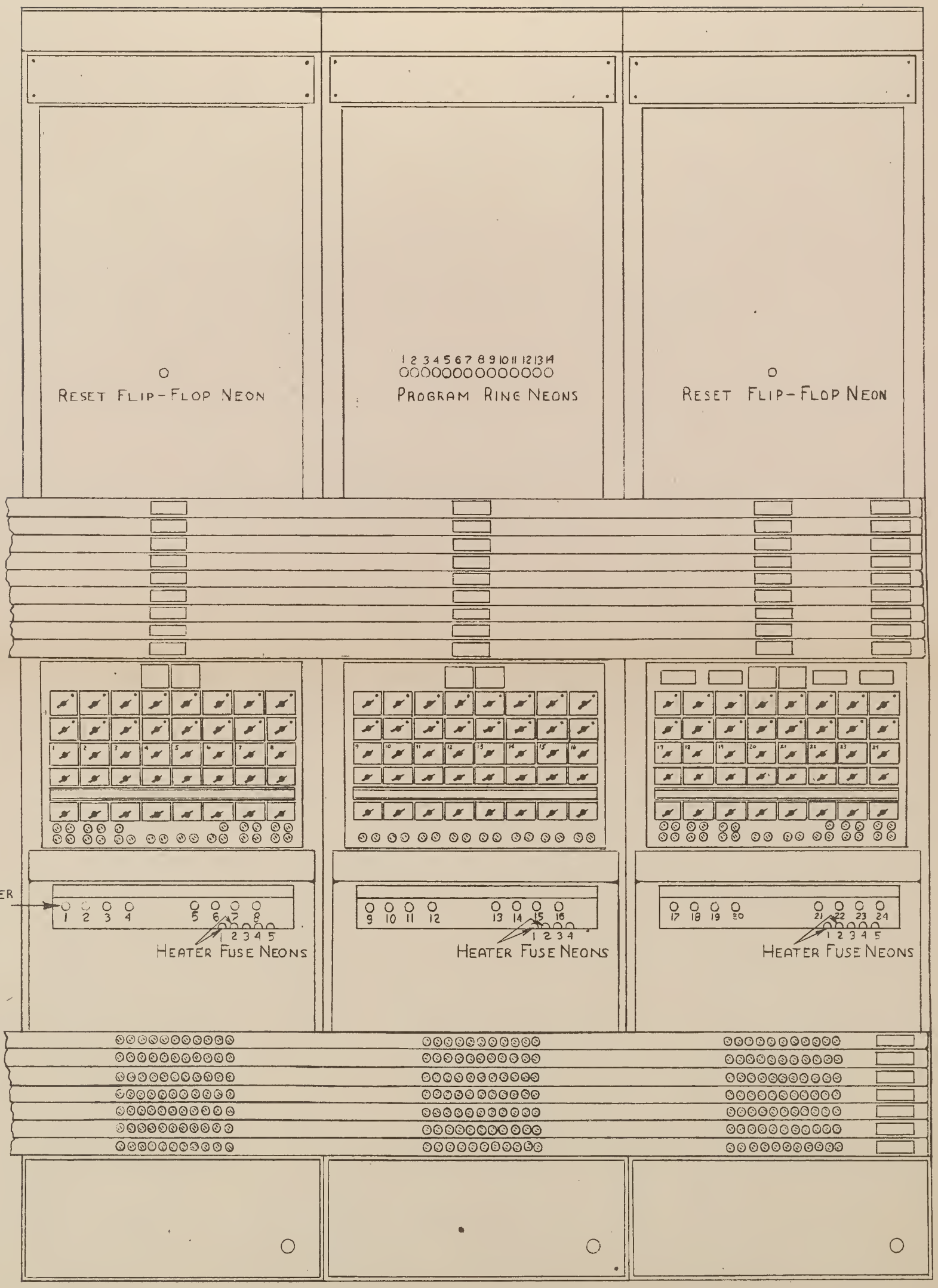
ACCUMULATOR
FRONT VIEW
PX-5-305



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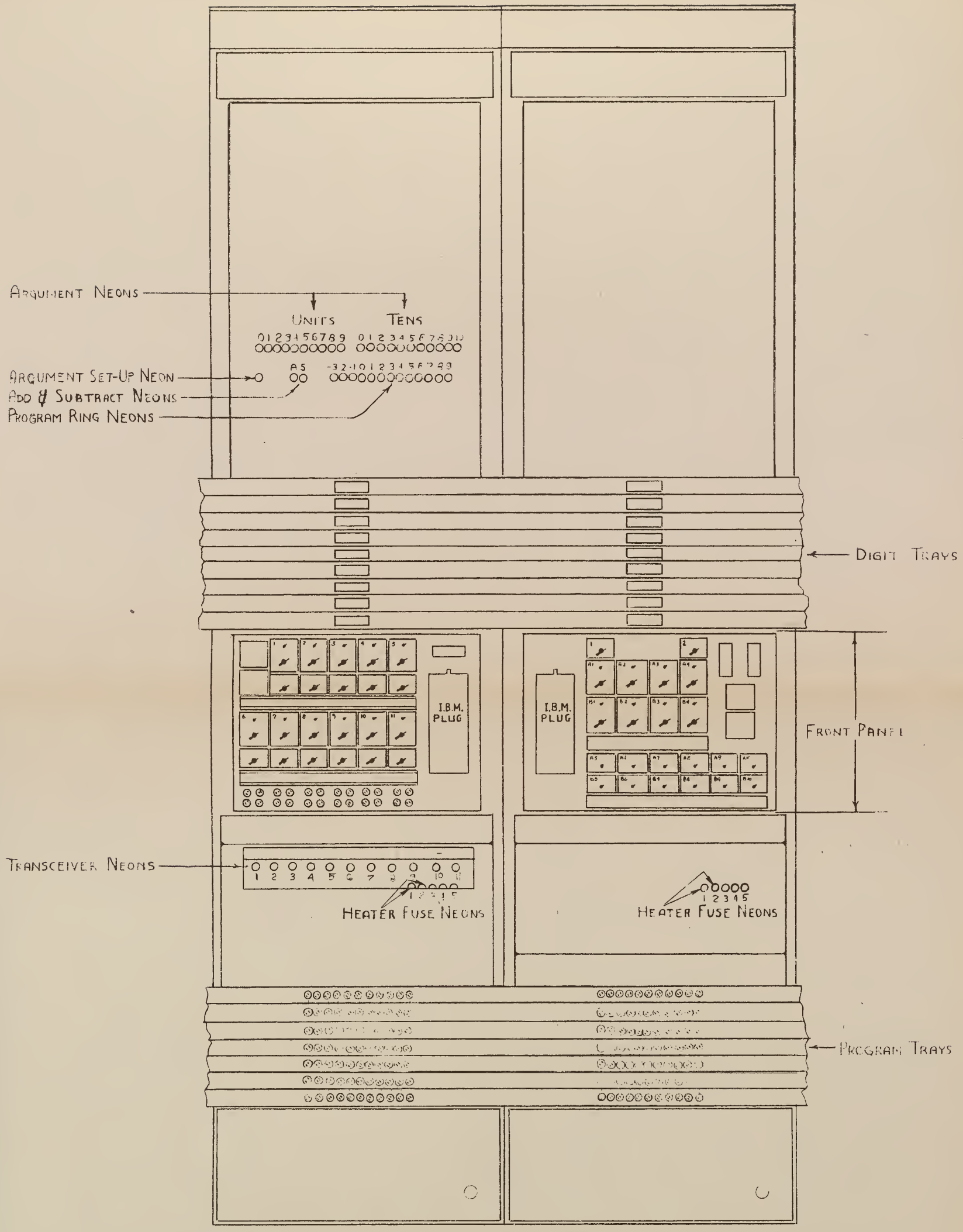
HIGH SPEED MULTIPLIER
FRONT VIEW
PX-6-309



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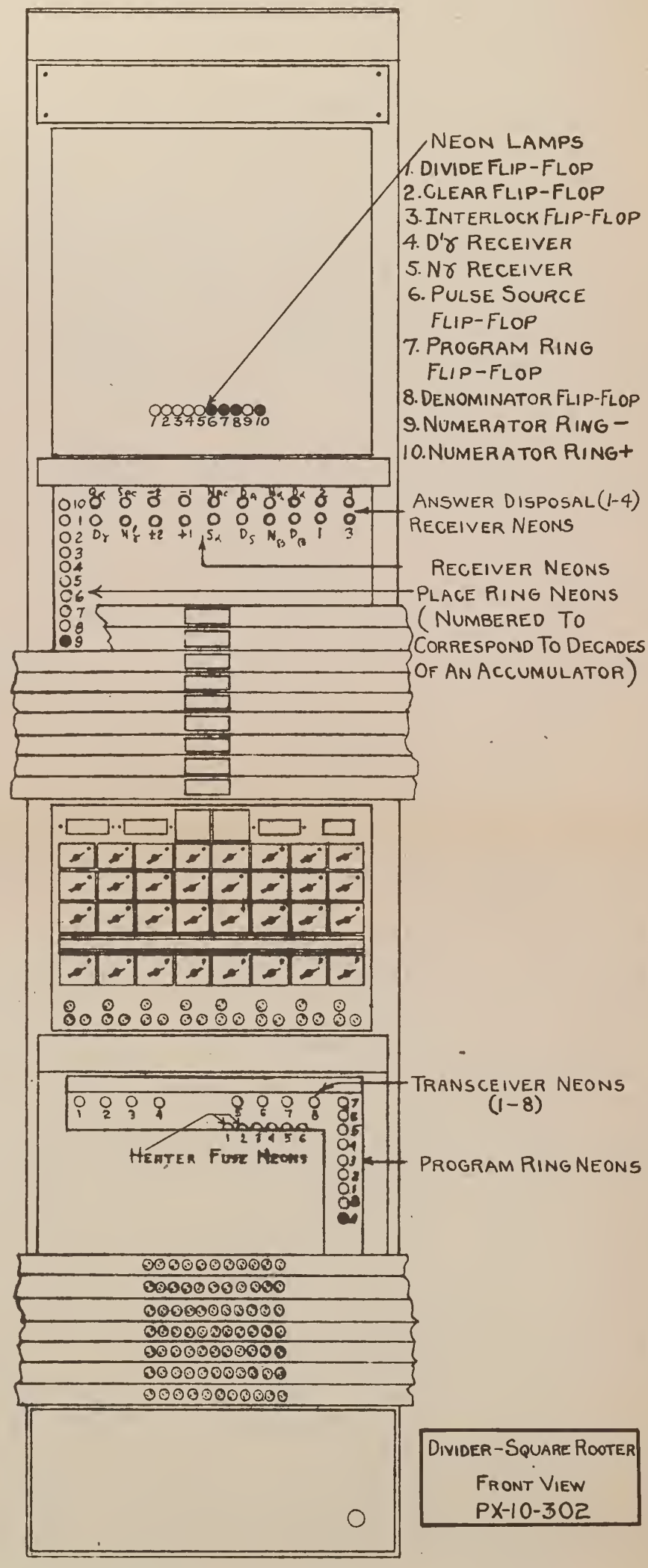
FUNCTION TABLE
FRONT VIEW
PX-7-305

NEONS ON DURING DIVISION

ADD. TIME	PROG. RING	PLACE RING	RECEIVER	1	2	3	4 D'γ	5 Nγ	6	7	8 D	9 N⁻	10 N⁺
I-1	A	9		(1)					ON	ON	ON		ON
2	B	9		ON					ON	ON	(2)	(3)	
3	1	9		"					ON	ON	"	"	
II-1	A	i*	D_A OR D_S	"				ON	ON		"	(3)	
2	A	i	−1 OR +1, Q∝	"					ON		"	"	
S 1	A	CYCLES	N_{AC}, S∝	"			ON		ON		"	"	
S 2	A	i−1	S_{AC}, N'γ	"					ON		"	CYCLES	
III 1	A	10-p	N_{AC}, S∝	"			ON				"	(3)	
2	B	"	S_{AC}, N'γ	"							"	CYCLES	
3	1	"	D_S OR D_A	"				ON			"	(3)	
4	2	"	D_S OR D_A	"				ON			"	"	
5	3	"	D_S OR D_A	"				ON			"	"	
6	4	"	D_S OR D_A	"				ON			"	"	
7	5	"	D_S OR D_A	"				ON			"	"	
8	6	"		"							"	"	
9	7	"	(+1 OR −1, Q∝)**	"							"	"	
IV-1	7	"		"		(4)			(5)		"		
2	7	"		"	(6)	"			"		"		
TRANSCEIVER OFF	A	9	1, 2, OR NEITHER	ON					ON	ON	ON		ON

NEONS ON DURING SQUARE ROOTING

ADD. TIME	PROG. RING	PLACE RING	RECEIVER	1	2	3	4 D'γ	5 Nγ	6	7	8 D	9 N⁻	10 N⁺
I-1	A	9		(1)					ON	ON	ON		ON
2	B	9							ON	ON	"		ON
3	1	9							ON	ON	"		ON
4	A	9	Dγ, +1						ON		"		ON
II-1	A	i*	D_S OR D_A					ON	ON		"	(3)	
2	A	i	+2 OR −2 Dγ						ON		"	"	
S 1	A	CYCLES	−1 OR +1 / S∝, N_{AC}				ON		ON		"	"	
S 2	A	i−1	−1 OR +1 / N'γ, S_{AC}				ON		ON		"	CYCLES	
III-1	A	10-p	−1 OR +1, S∝, N_{AC}				ON				"	(3)	
2	B	"	N'γ, S_{AC}								"	CYCLES	
3	1	"	D_A OR D_S					ON			"	(3)	
4	2	"	D_A OR D_S					ON			"	"	
5	3	"	D_A OR D_S					ON			"	"	
6	4	"	D_A OR D_S					ON			"	"	
7	5	"	D_A OR D_S					ON			"	"	
8	6	"									"	"	
9	7	"	(−2 OR +2, Dγ)**								"	"	
IV-1	7	"				(4)			(5)		"	"	
2	7	"			(6)	"			"		"	"	
TRANSCEIVER OFF	A	9	3, 4, OR NEITHER						ON	ON	ON		ON



DIVIDER-SQUARE ROOTER
FRONT VIEW
PX-10-302

FOOT NOTES

(1) ON IF PREVIOUS PROGRAM WAS A DIVISION.

(2) ON IF DENOMINATOR IS POSITIVE WHEN RECEIVED IN DENOMINATOR ACCUMULATOR.

(3) IF BEFORE DENOMINATOR IS ADDED TO OR SUBTRACTED FROM NUMERATOR, THE NUMERATOR IS POSITIVE, NEON #4 IS ON; OTHERWISE NEON #3 IS ON.

(4) GOES ON WHEN INTERLOCK PULSE IS RECEIVED.

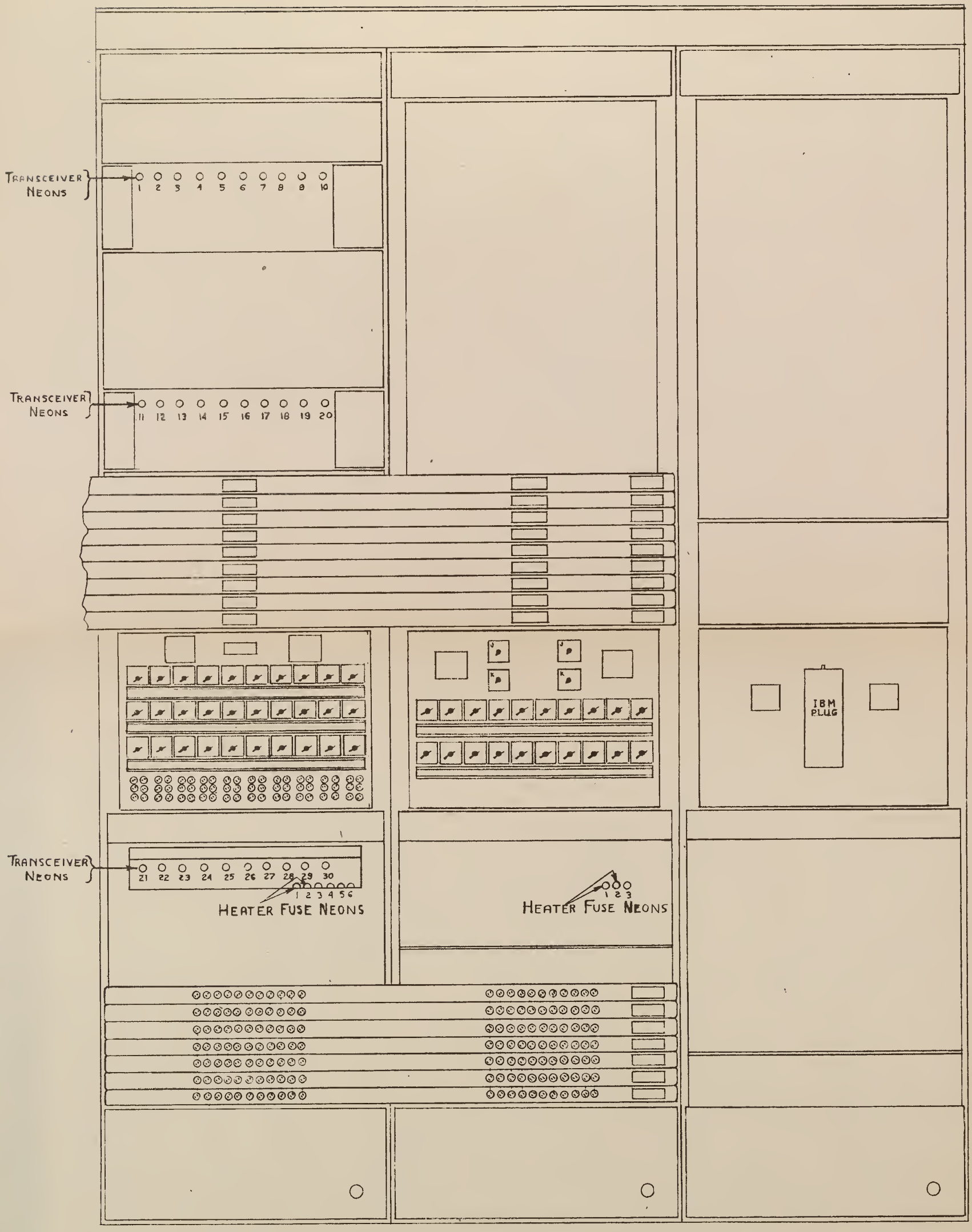
(5) GOES ON ONE ADDITION TIME AFTER III-9

(6) GOES ON: a- IN NI CASE, TWO ADDITION TIMES AFTER III-9.
b- IN I CASE, IN WHICHEVER OCCURS LATER: TWO ADDITION TIMES AFTER III-9 OR ONE ADDITION TIME AFTER NEON 7

* $9 \geq i \geq 10-p$ WHERE p IS THE SETTING OF THE PLACES SWITCH.

** ONLY IF NO OVERDRAFT RESULTS.

I-47



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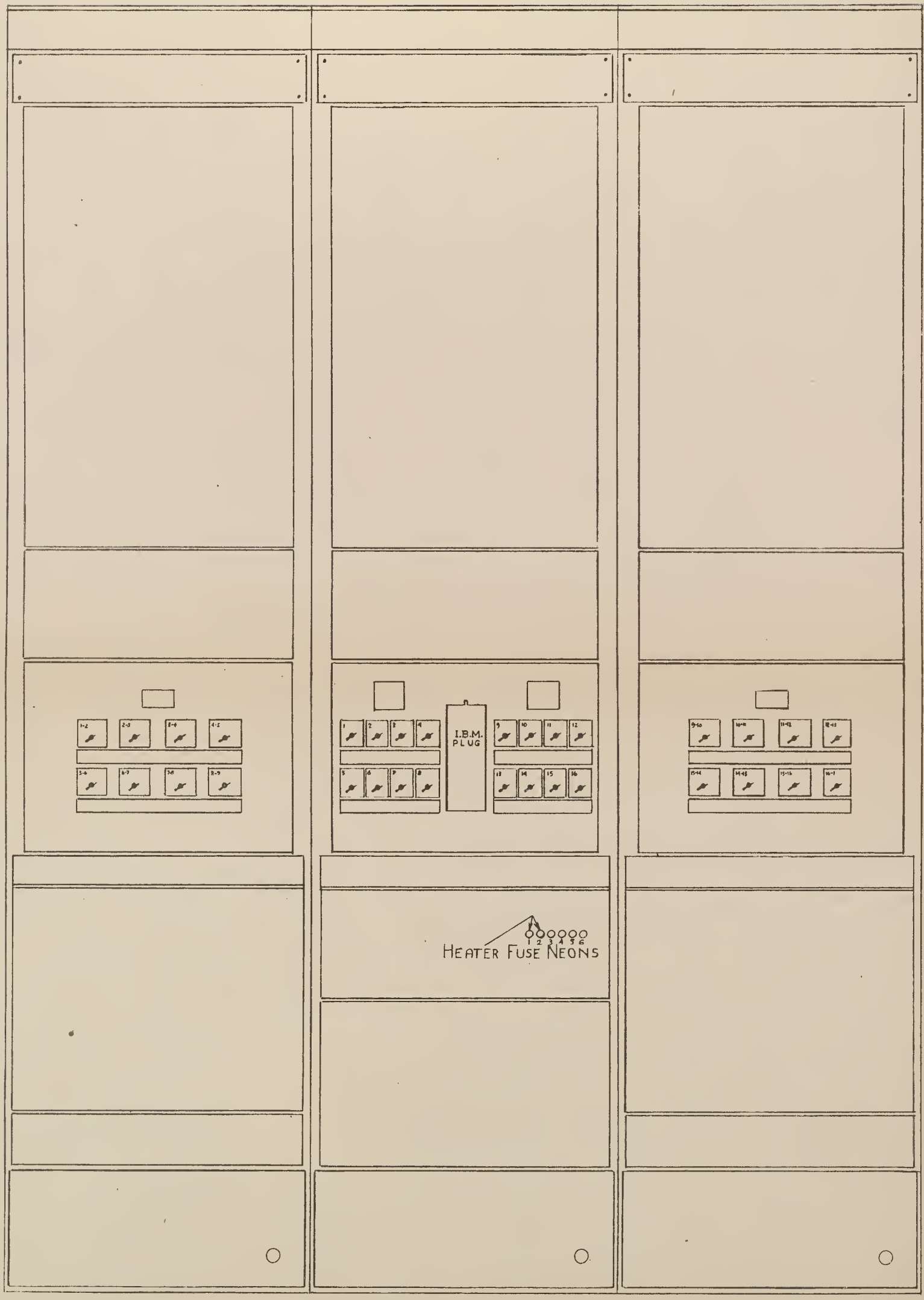
CONSTANT TRANSMITTER
FRONT VIEW
PX-11-306

-47



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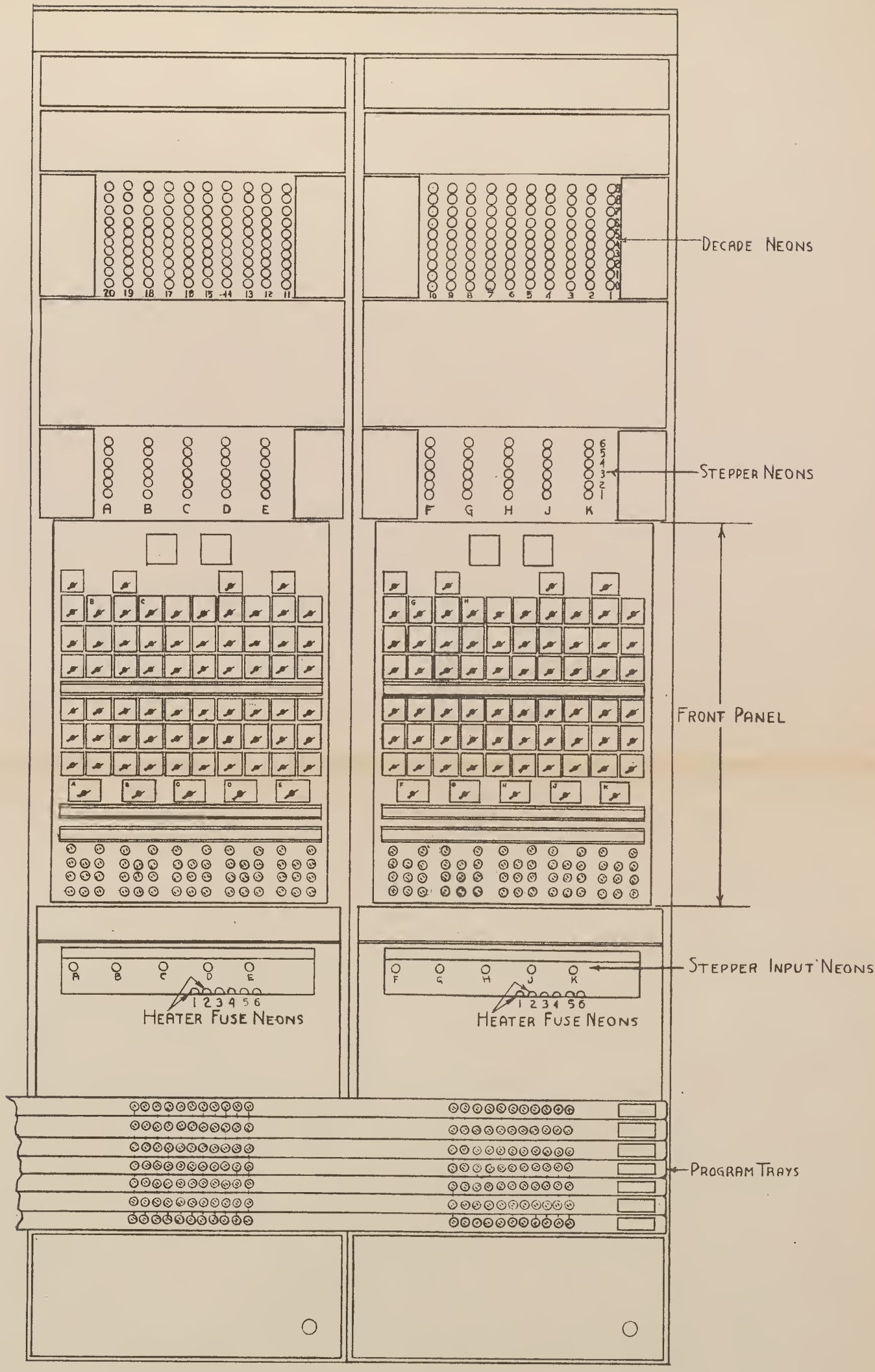
PRINTER
FRONT VIEW
PX-12-306



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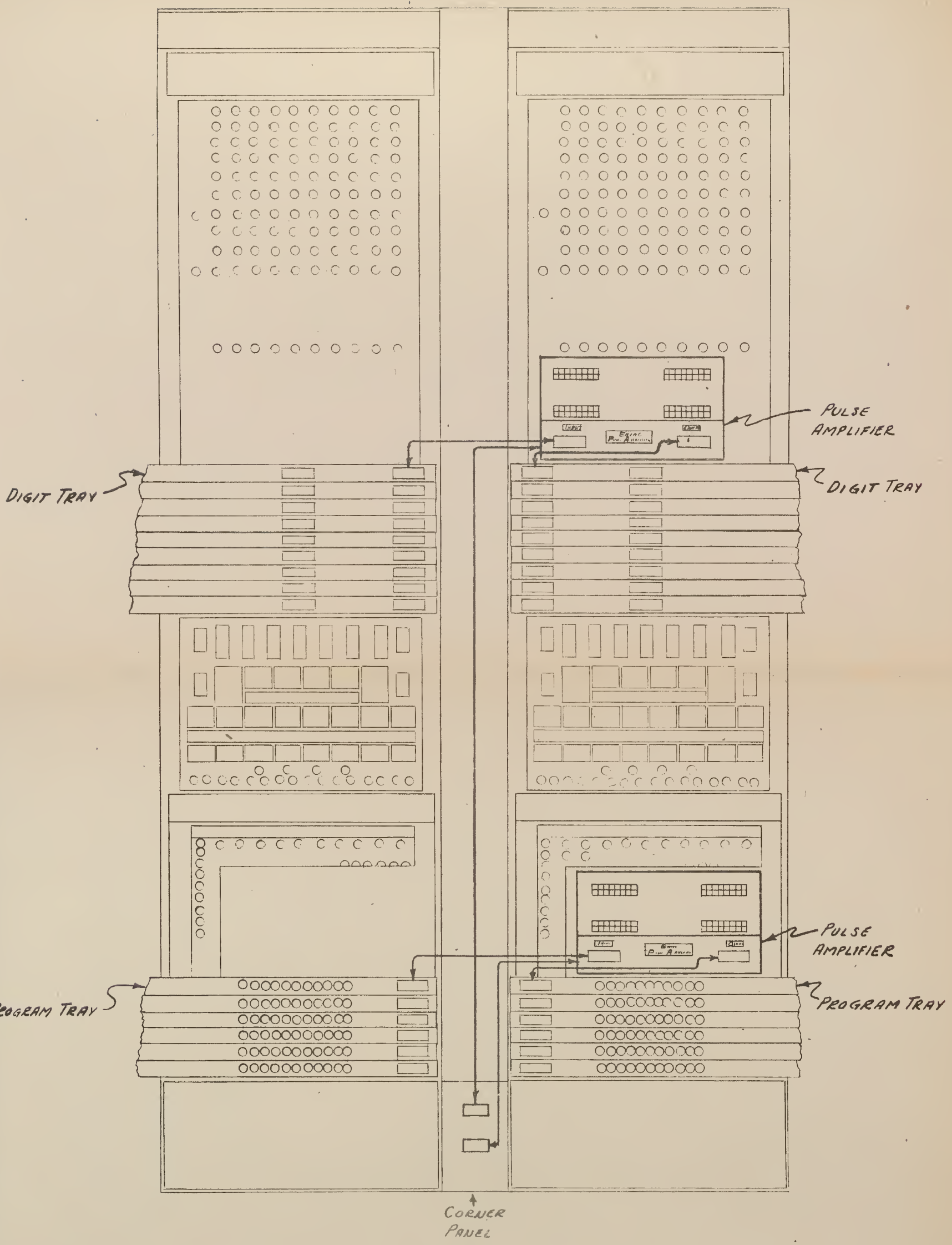
MASTER PROGRAMMER FRONT VIEW
PX-8-303



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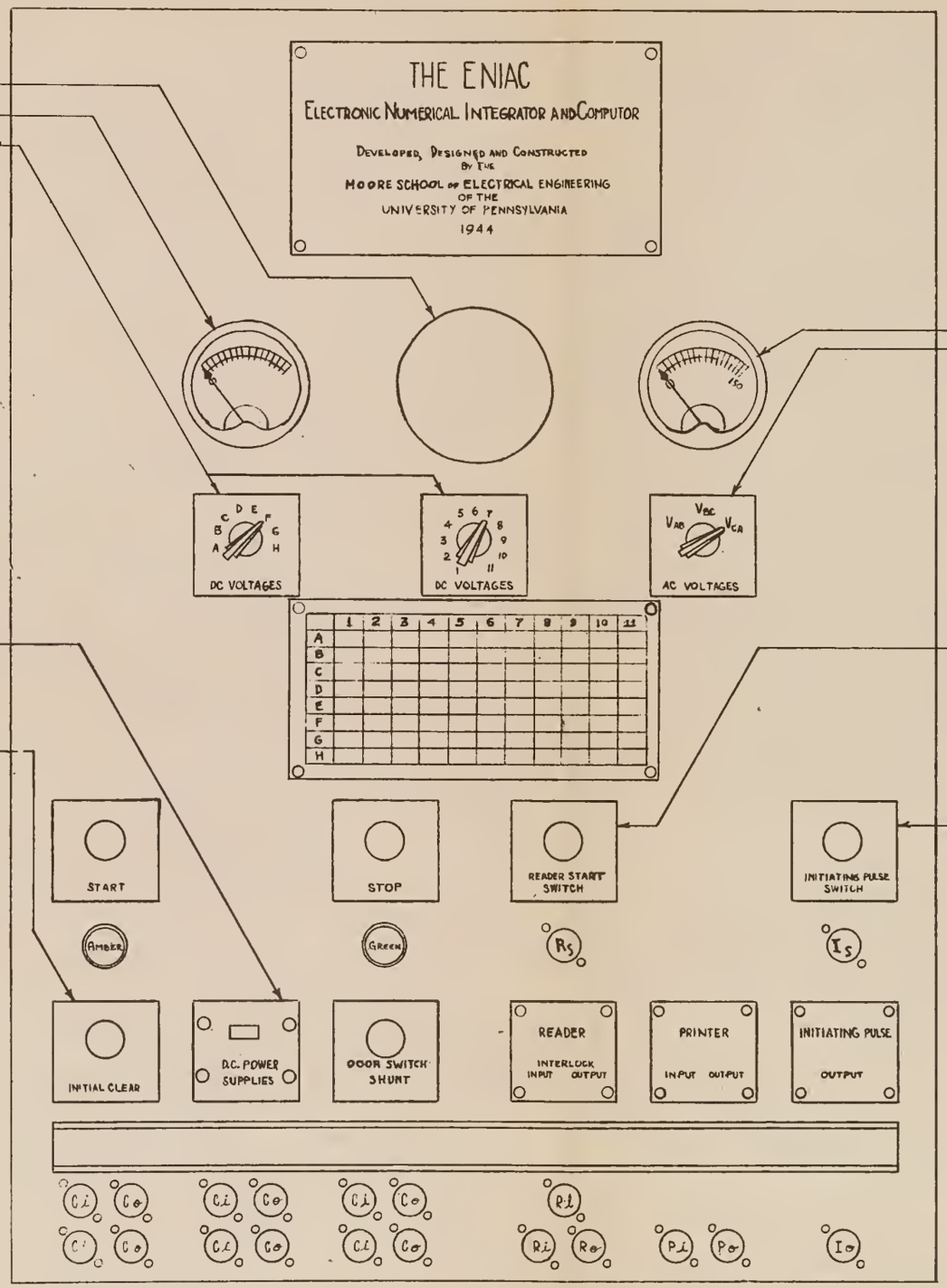
PULSE AMPLIFIER
INTERCONNECTION DIAGRAM
PX-4-302



D-C voltage hum oscilloscope

D-C voltage meter

D-C voltage selector switches

D-C voltage chart

White numbers on the voltage chart indicate voltages at the ends of a power supply. Black numbers indicate voltage pairs in which at least one voltage is derived from a bleeder tap.

Behind the voltage chart are the oscilloscope adjustments.

The d-c voltage amplitude and the a-c hum amplitude of every voltage of the ENIAC may be measured with respect to some other voltage at this panel.

Start and stop switches

Pushing the start switch turns the amber light on and starts the initiating sequence for the ENIAC, turning on the d-c power supplies, the heaters of the various panels, and the fans, and operating the initial clear. When this sequence has been completed, showing that the ENIAC is ready to operate, the green light goes on.

Pushing the stop switch turns the ENIAC off, including the heaters, the d-c power supplies, and the fans.

D-C power supplies clock

This shows the number of hours the d-c power supply filaments have been on.

Initial clear switch

Though the ENIAC is initially cleared whenever the start switch is operated, an initial clear switch is provided so that the operator can clear the machine without turning it off.

The operation selector switch on the cycling unit must be set at Cont. for initial clearing to take place.

Selective clear program controls

C_i - program pulse input terminal for selective clear program control.

C_o - program pulse output terminal for selective clear program control.

Whenever a program pulse is supplied to a C_i, all accumulators set to SC will be cleared, and a program pulse will be emitted from the corresponding C_o one addition time later. For neon bulbs of associated transceivers see PX-9-305.

Door Switch Shunt

Ordinarily the ENIAC will not operate with any of the doors off. This is a safety feature, since removing the doors exposes dangerous voltages. If it is necessary to operate the ENIAC with the doors off, this may be done by holding this switch closed.

A-C voltage meter

A-C voltage selector switch

By means of this switch and meter the three phases of one of the two bus systems supplying 110 volts a-c to the filament transformers of the various units may be measured.

R_i - pulse input terminal for reader interlock

R_i - pulse input terminal for reader

R_o - program pulse output terminal for reader

These terminals have to do with the operation of the IBM card reader. Whenever a pulse is supplied to R_i the IBM reader starts to put a new card in position. After the card is read and the relays have set up the constant transmitter gates the information is ready to be taken from the constant transmitter. A pulse is emitted from R_o after the constant transmitter is ready and after a pulse has been received on R_i. The operation of the constant transmitter program controls is described on PX-11-302.

Reader start switch

R_s - Terminal for paralleling the reader start switch

Operation of the reader start switch starts IBM card reader. After the card has been read a pulse is emitted from R_o.

R_s is a terminal for paralleling the reader start switch with a switch which may be carried anywhere around the ENIAC and which is connected to this terminal via a program line which has no load box, or by means of a special cable.

Initiating pulse switch

I_s - Terminal for paralleling the initiating pulse switch

I_o - Program pulse output terminal for initiating pulse

Whenever the initiating pulse switch is pushed a single program pulse (i.e., a gated CPP) is emitted from I_o. This pulse may be used to initiate any sequence of operations set up on the ENIAC.

I_s is a terminal for paralleling the initiating pulse switch with a switch which may be carried anywhere around the ENIAC and which is connected to this terminal via a program line which has no load box, or by means of a special cable.

Note: Portable Control Station is shown on PX-9-303.

P_i - pulse input terminal for printer

P_o - program pulse output terminal for printer

Whenever a pulse is received on Pi the IBM punch starts to operate and the printer relays start to pick up. A pulse is emitted from P_o as soon as the relays are set up. Any time after this pulse is emitted P_i may again be stimulated, but this will not cause a second punching until the first is finished.

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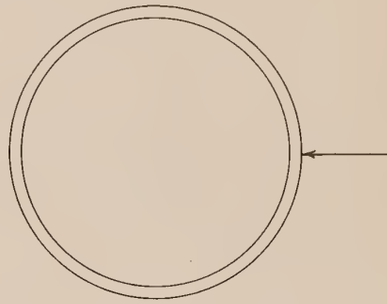
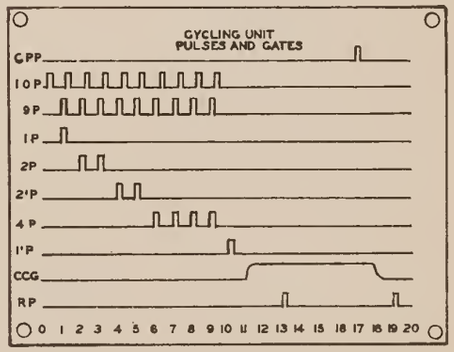
INITIATING UNIT FRONT PANEL

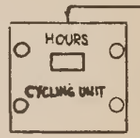
MATERIAL	FINISH	SCALE

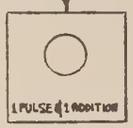
Drawn by:	Checked by:	Approved by:	
J. EDELSACK DEC. 1944	avb 11/1/45	H. L. 7-16-45	PX-9-302

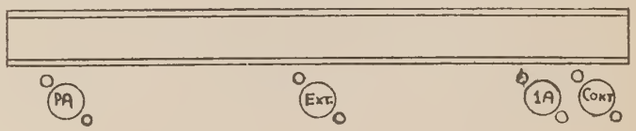
2 1



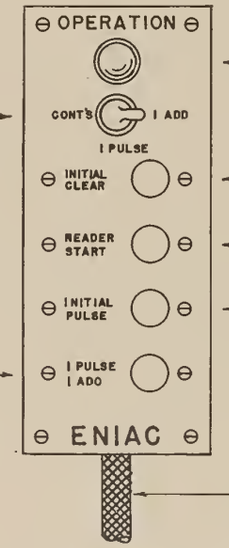








Oscilloscope on which can be seen the cycling unit pulses and gates, the selective clear gate (SCG) (when it is programmed), or any external signal transmitted to the terminal marked "Ext.". The cycling unit pulses and gates to be seen are shown on the accompanying chart, behind which are the oscilloscope adjustments. The oscilloscope input switch selects the signal to be shown on the oscilloscope. A signal may be transmitted to the terminal "Ext." on a program line which has no load box.



Operation Selector Switch
The control by this switch and the 1 pulse - 1 add. push button is the same as that provided by the switch on the cycling unit front panel. Note: The switch which is not being used must be set to "1 pulse".

Green Pilot Light
Same as on Initiating Unit Front Panel

Push Buttons
Control provided is the same as provided by corresponding push buttons on Initiating Unit Front Panel - See PX-9-302.

1 Pulse - 1 Add-Push Button

Cable

Portable Control Station

Heater switch.

Heater clock

Push button for 1 pulse time or one addition time

PA- Terminal for paralleling this push button

Operation selector switch

1A and Cont. - Terminals for paralleling the operation selector switch

--The cycling unit has three modes of operation, selected by the switch or its associated terminals (1A, Cont.):

1) Cont. - The pulses and gates are given out continuously.
2) 1 Add. - The pulses and gates for one addition time are emitted whenever the push-button for 1 pulse time or 1 addition time is pushed.
3) 1 Pulse - The pulses and gates for one pulse time are emitted whenever the push-button for 1 pulse time or 1 addition time is pushed.

--Portable push buttons may be used in connection with terminals PA, 1A, and Cont. These may be plugged into a program line which has no load box and that line plugged into the terminals.

1) A push button connected to PA parallels the 1 pulse and 1 Add. push button.
2) Push buttons connected to 1A and Cont. enable the operator to parallel the operation selector switch. When this switch is set to the 1 Pulse position, holding closed the button connected to 1A gives the 1 addition time mode of operation, while holding closed the button connected to Cont. gives continuous operation.

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CYCLING UNIT FRONT PANEL		
MATERIAL	FINISH	SCALE
Drawn by: J.EDELSACK DEC 1944	Checked by: [illegible] 1/11/45	Approved by:

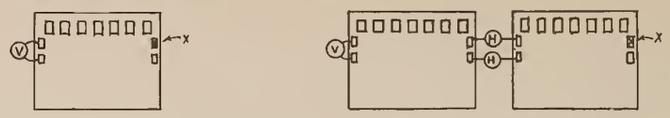
PX-9-303

The digit terminals are to be connected to the digit trunks (trays) (see PX-5-305) by the digit cables for receiving and transmitting numbers. The operation of these terminals is governed by the program controls of the accumulator. (Thus digit pulses transmitted on a trunk to which the α terminal is connected are received only if the accumulator is programmed to receive on α).

Multiplication by powers of ten may be accomplished by means of shifters (PX-4-104) which transpose the digit wires. Shifters must be placed only in digit input terminals, not in digit output terminals.

Deleters (PX-4-109) are used in connection with the significant figures switch; they may be placed only in digit output terminals.

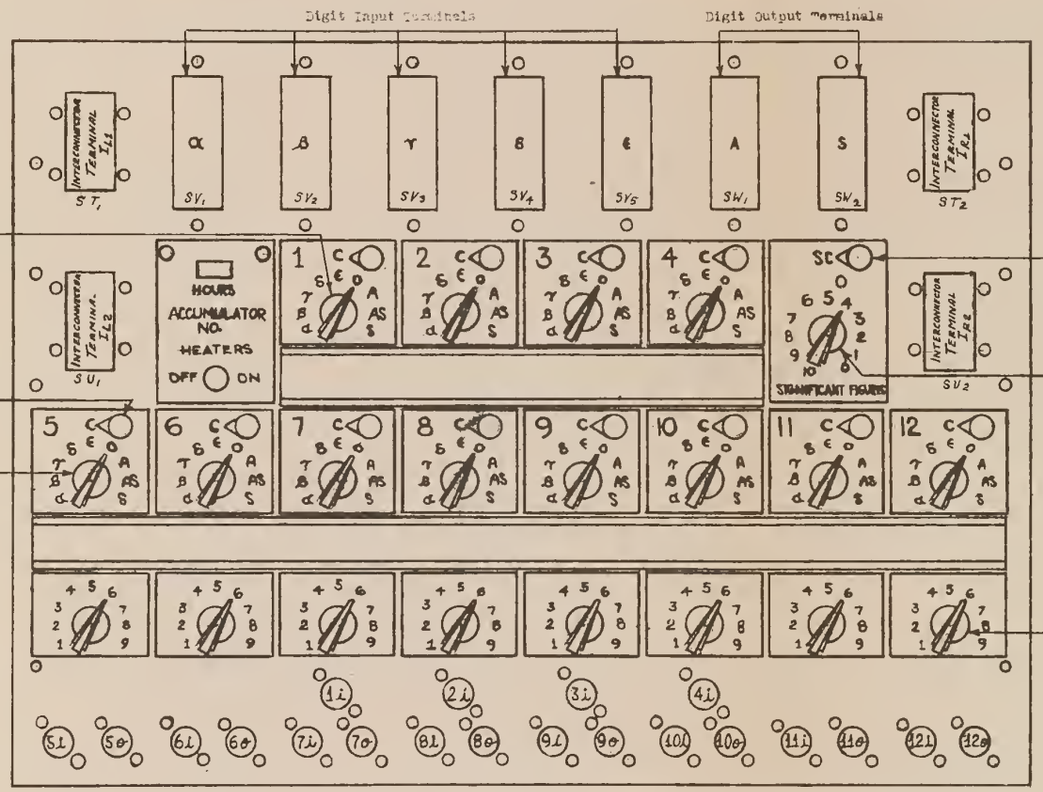
Accumulator Interconnection - Diagram



10 decade accumulator — 20 decade accumulator

V: Acc. interconnector cable (vertical) (PX-5-121)
H: Acc. interconnector cable (horizontal) (PX-5-110)
X indicates position of acc. interconnector terminal load box (PX-5-109)

Note: Each of the 24 program controls of the 20 decade accumulator governs the operation of all decades and of the common programming circuits of both accumulators.



Switches 1-4: Operation switches for non-repeat program controls.

Clear correct switch

Switches 5-12: Operation switches for repeat program controls.

Selective clear switch
If this switch is set to SC the accumulator is cleared whenever a program pulse is transmitted to one of the selective clear inputs of the initiating unit.

Significant figures switch
This switch determines which decade (if any) is cleared to 5 instead of 0 whenever the accumulator is cleared and on which line the subtract pulse is transmitted on a subtract transmission. It does not govern the deletion of non-significant digits; this must be done by means of deleters (PX-4-109) (When the switch is set to m, deleter number m should be used, etc.)

If the switch is set to m, decade 10-m (counting from the right) is cleared to 5, and the subtract pulse is transmitted on digit line 11-m.

When a 20 decade accumulator is formed, the two significant figure switches are to be used as follows:

(A) When 9 or less significant figures are desired, the left hand switch is set to the number desired and the right hand switch to 10.

(B) When 10 or more significant figures are desired, the left hand switch is set to 10 and the right hand switch set so that the sum of the two switch readings equals the number of significant figures desired.

Repeat switches for repeat program controls 5-12
Each switch governs the number of addition times its repeat program control operates.

Terminals 1i, 2i,...., 4i
Program pulse input terminals for non-repeat program controls 1-4 respectively.

Terminals 5i,.....12i
Program pulse input terminals for repeat program controls 5-12 respectively.

Terminals 5o , 6o 12o
Program pulse output terminals for repeat program controls 5-12 respectively.

Non-repeat program controls 1-4.

These operate for one addition time and emit no program output pulse.
Each control consists of
1) Program pulse input terminal (when stimulated with program pulse causes program control to program operation in accordance with its switch settings)
2) Operation switch
3) Clear-correct switch
4) Associated receiver (For neon bulbs see PX-5-305)

Repeat program controls 5-12.

These operate for n additions times, where n is the setting of the repeat switch.
Each control consists of
1) Program pulse input terminal (when stimulated with program pulse causes program control to program operation in accordance with its switch settings).
2) Program pulse output terminal (emits program pulse at end of nth addition time)
3) Operation switch
4) Clear-correct switch
5) Repeat switch
6) Associated transceiver (For neon bulbs see PX-5-305)

Operation switches and clear-correct switches:
These operate together in the following manner:

Operation switch setting	Operation programmed by operation switch	Operation programmed by clear-correct switch if set to C.
α β γ δ ϵ	Receive on α digit input terminal Receive on β digit input terminal Receive on γ digit input terminal Receive on δ digit input terminal Receive on ϵ digit input terminal	A correct pulse (an internally gated 1' pulse) is placed in the units decade at each addition time.
O A AS S	Nothing Transmit on add digit output terminal Transmit on both add and subtract digit output terminal Transmit on subtract digit output terminal	The accumulator is cleared at the end of the last addition time of the program.

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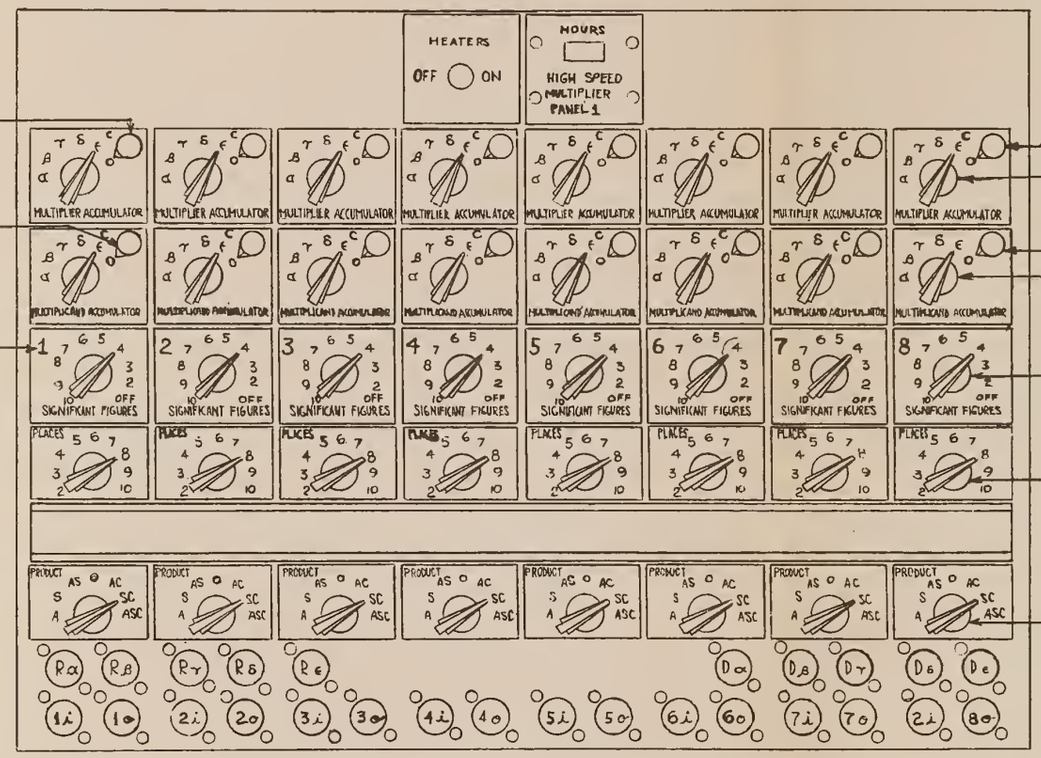
ACCUMULATOR FRONT PANEL

MATERIAL	FINISH	SCALE

Drawn by:	Checked by:	Approved by:	
J. EDELSACK DEC. 1944	AWB 10/12/45		PX-5-301 Was PX-5-301A



Multiplier Acc. Clear Switch

Multiplicand Acc. Clear Switch

Number of the program control to which the switches in a given column belong and to which the corresponding numbered program input and program output terminals belong.

Multiplier Accumulator Clear Switch

This governs the clearing of the multiplier acc. by means of the static cable running into the multiplier acc. PM plug-in unit. If this switch is set on C, the multiplier is cleared during the last addition time of the multiplication.

Multiplier Accumulator Receive Switch

Whenever a program pulse is received on a program input terminal of a given program control, a pulse is immediately emitted from $R\alpha - R\varepsilon$, or not at all, accordingly as the multiplier acc. function switch of that program control is set on $\alpha - \beta$, or C respectively. These pulses may be used to cause the multiplier acc. to receive the multiplier during the next addition time by having them transmitted to properly set multiplier acc. program controls, i.e. by connecting $R\alpha - R\varepsilon$ to five program pulse inputs of the multiplier acc. (#9) and setting the corresponding operation switches to receive on $\alpha - \varepsilon$ respectively.

It is to be noted that all 24 multiplier program controls cause pulses to be emitted on $R\alpha - R\varepsilon$ so that only five multiplier acc. program controls are required to receive all 24 multipliers.

Multiplicand Accumulator Clear Switch

This operates the same as the multiplier acc. clear switch except that it governs the clearing of the multiplicand acc.

Multiplicand Accumulator Receive Switch

This functions the same as the multiplier acc. receive switch except that it gives out program pulses on terminals $D\alpha$ to $D\varepsilon$ and may be used with the multiplicand acc. (#10).

Significant Figure Switch

Multiplier Places Switch

Product Disposal Switch

Terminals $1i, 2i, \ldots, 24i$
Program pulse input terminals for program controls 1-24 respectively.

Terminals $1o, 2o, \ldots, 24o$
Program pulse output terminals for program controls 1-24 respectively.

Terminals $R\alpha - R\varepsilon$
Program pulse output terminals associated respectively with $\alpha, \beta, \gamma, \delta, \varepsilon$ on the 24 multiplier accumulator function switches.

Terminals $D\alpha - D\varepsilon$
Program pulse output terminals associated respectively with $\alpha, \beta, \gamma, \delta, \varepsilon$ on the 24 multiplicand accumulator function switches.

There are 24 multiplier program controls, each consisting of

1) Program pulse input terminal (when stimulated with program pulse causes program control to program multiplication in accordance with its switch settings).
2) Program pulse output terminal (emits program pulse on completion of multiplication).
3) Multiplier acc. receive switch
4) Multiplier acc. clear switch
5) Multiplicand acc. receive switch
6) Multiplicand acc. clear switch — Described on this drawing
7) Significant figures switch
8) Places switch — Described on PX-6-303
9) Product disposal switch — Described on PX-6-304
10) Associated transceiver — For neon bulbs see PX-6-309

The high-speed multiplier operates in conjunction with four or six associated accumulators. These are the multiplier acc. (#9), the multiplicand acc. (#10), the left-hand partial products acc. (#11 and perhaps #12) and the right-hand products acc. (#13 and perhaps #14). For a diagram showing the interconnections of the high-speed multiplier with its associated accumulators see PX-6-311.

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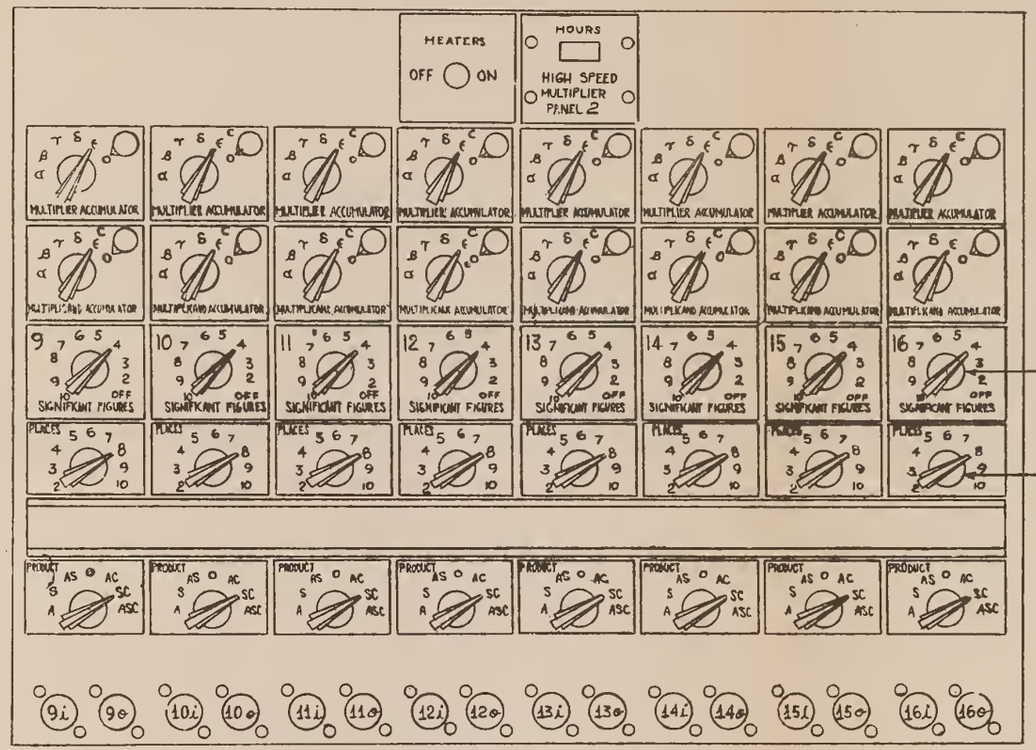
HIGH-SPEED MULTIPLIER FRONT PANEL NO.1

MATERIAL	FINISH	SCALE

Drawn by:	Checked by:	Approved by:	
J.EDELSACK DEC. 1944	AWB 11/6/45		PX-6-302



Significant Figures Switch

This switch may be used to give a variable round-off; i.e., a product which is rounded off in a different place for each program control. This switch governs the addition of 5 pulses into the proper place of the left-hand product acc. (#11, 12) during the second addition time of the multiplication.

It does not control the deletion of the non-significant digits of the product nor the placing of the subtract pulse in the proper channel of the product on a subtract transmission. Since these very with the setting of the significant figures switch, they must be taken care of at the accumulator which receives the product. Hence in cases where every product is to be rounded-off to the same number of places, it is best to use the round-off facilities of the right-hand product acc. (#13, 14).

Places Switch

This governs the number of places of the multiplier that are to be used in the multiplication. The multiplier digits are used from left to right, so that the most significant digits are used first. The places referred to are the places of the multiplier acc. counted from the left.

The places switch is completely independent of the significant figures switch. The reason for this is that all digits of the multiplicand are used in the multiplication process. The only purpose of the places switch is to save time.

Time schedule for multiplication

A multiplication requires from 6 to 14 addition times (depending upon the setting of the places switch) including the time required for receiving the multiplier and multiplicand, but not including the time required for disposal of the product.

Addition time (Program input pulse received at end of 0th addition time)	Operation
1	Multiplier and multiplicand received
2	Five round-off pulses transmitted to left-hand product acc. (#11, 12)
3	Multiplicand multiplied by first place (10th decade) of multiplier and left and right hand components transmitted to left and right hand product acc.
p+2	This is continued up to the p+2d addition time, where p setting of places switch
p+3	Complement corrections are made when necessary.
p+4	Accumulated left hand products are added into accumulated right hand products.

(Program output pulse and answer disposal pulsesemitted at end of p+4th addition time)

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HIGH-SPEED MULTIPLIER FRONT PANEL NO. 2			
MATERIAL	FINISH		SCALE
Drawn by: J.EDELSACK DEC. 1944	Checked by:	Approved by:	PX-6-303

Important note concerning the partial products digit output terminals

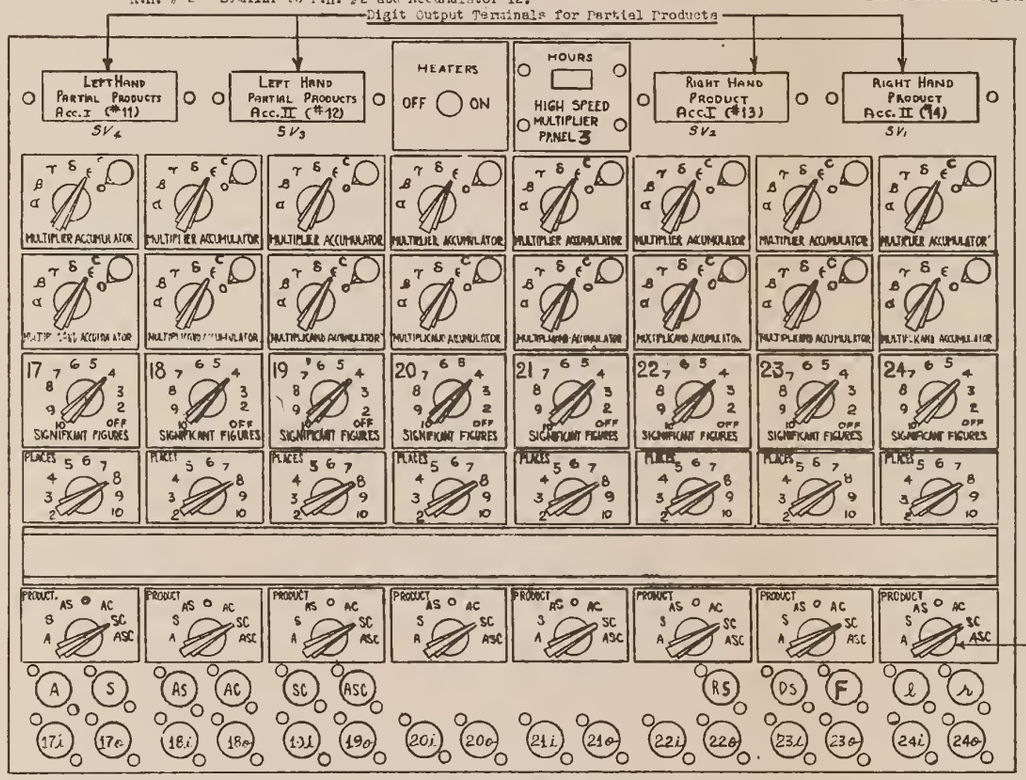
These terminals are to be semi-permanently connected to the α digit input terminals (see note on terminals l,r) of the product accumulators (#11, 12, 13, 14) by trays or cables not used for any other purpose. No load boxes are to be used. The digit pulses emitted from these terminals are not supplied from transmitters, but from inverter tubes which cannot be connected in parallel with anything else and which have their own resistors. Hence the α digit input terminals of the product accumulators cannot be used for receiving any other numbers.

No shifters or deleters are to be used. Accumulators 11 and 12 and accumulators 13 and 14 are paired when more than eight places is desired in the product.

The load on these outputs must be kept as small as possible. Recommended method of connection is:

L.H. #1 By special cable to Accumulator 11.
L.H. #2 By short cable to tray (only one tray), and short cable to Accumulator 12.
R.H. # 1 By special cable to Accumulator 13.
R.H. # 2 Similar to L.H. #2 and Accumulator 12.

See also drawing PX-6-311



Terminals A-ASC
Program output terminals associated respectively with A, S, AS, AC, SC, ASC, on product disposal switch.

Terminals RS, DS, F
Program pulse output terminals for transmitting pulses used in the programming of each multiplication:

DS - A program pulse is emitted at the end of the p+2d addition time if the multiplier is negative. Semi-permanent connections must be established so that this pulse programs the multiplicand acc. to transmit subtract and the right hand product accumulator I(#13) to receive.

RS - A program pulse is emitted at the end of the p+2d addition time if the multiplicand is negative. Semi-permanent connections must be established so that this pulse programs the multiplier acc. (#9) to transmit subtract and the left hand partial products acc. I (#11) to receive.

F - A program pulse is emitted at the end of the p+3d addition time. Semi-permanent connections must be established so that this pulse programs the left hand partial products accumulator (#11, 12) to transmit add (without shifting) and clear and programs the right hand product accumulator (#13, 14) to receive, or vice-versa.

Terminals l,r
Receiver cathode follower buffer output lines. These are to be used to program the product acc. to receive the partial products. The following semi-permanent connections are to be established.

1. l is to be connected via acc. interconnector cable (Mult.) (TX-5-131) into the interconnector terminals I_{11} and I_{12} of left-hand partial products acc. I (#11). The α digit input terminal is to be used to receive the partial products.
2. r is to be similarly connected into right-hand product accumulator I (#13). Likewise, the α digit input terminal is to be used to receive the partial products.

Product disposal switch

This switch operates in conjunction with program pulse output terminals A through ASC and provides program facilities for the disposal of all 2^4 products using at most 6 program controls of the right-hand product accumulator (#13, 14).

At the end of the p+4th addition time (i.e., at the same time as the program output pulse is emitted) a program pulse is emitted from A-ASC according to the setting of the product disposal switch of the program control being used.

Semi-permanent connections may be established by connecting A through ASC to six program pulse inputs of the right-hand product acc. (#13, 14) and setting the corresponding operation switches and clear-correct switches to transmit on A-ASC. The program control output pulse may be used to stimulate that unit of the ENIAC which is to receive the transmitted product.

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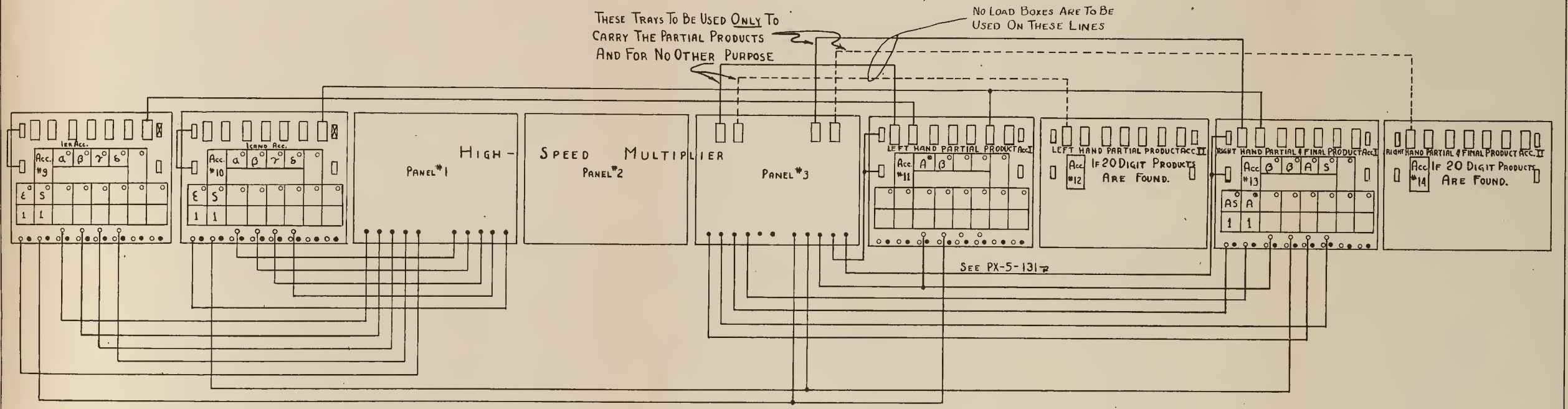
HIGH-SPEED MULTIPLIER FRONT PANEL NO. 3

MATERIAL	FINISH	SCALE

Drawn by:	Checked by:	Approved by:	
J.EDELSACK DEC. 1944			PX-6-304

1



NOTE— HORIZONTAL LINES ABOVE THE UNITS REPRESENT DIGIT TRAYS. THE DOTTED LINES REPRESENT TRAYS WHICH NEED BE USED ONLY WHEN 20 DIGIT PRODUCTS ARE FOUND.

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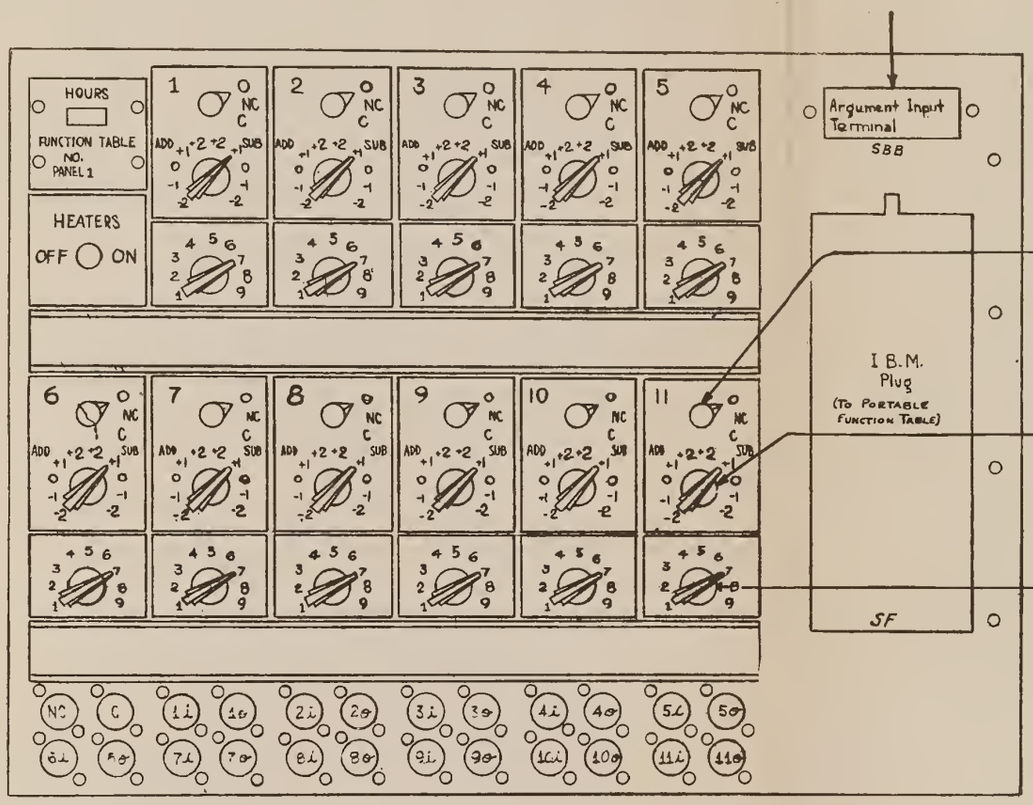
INTERCONNECTION OF HIGH-SPEED MULTIPLIER WITH ASSOCIATED ACCUMULATORS ~ PX-6-311

Argument input terminal

This input is open for reception of the two-digit argument during the 2nd addition time of operation. The units place is received on line 1, the tens place on line 2, Shifters (PX-4-104) should be used in this terminal to shift the argument if it comes from other decades than the 5th and 6th. The other lines of this terminal are unconnected, so a deleter is not required.

The accumulator which transmits the argument may be programmed from terminals NC and C.

The function table automatically clears its argument at the end of each operation.



There are eleven program controls on each function table. Each program control consists of a program pulse input terminal (which, when stimulated with a program pulse, causes the program control to program the looking up of a function value), a program pulse output terminal (which emits a pulse on completion of the operation), the three switches described below, and an associated transceiver (for neon bulbs see PX-7-305).

Argument reception switch

This switch operates in conjunction with program pulse output terminals NC and C and may be used to program an accumulator or accumulators to transmit the argument.

At the end of the 1st addition time a program pulse is emitted from NC or C if this switch is set on NC or C respectively. Semi-permanent connections may be established by connecting NC and C to program input terminals of the argument accumulator and setting the corresponding operation switches to transmit and transmit-and clear respectively.

Operation switch

This switch determines whether the function value (add) or its complement (subtract) is transmitted.

It also determines whether the function value of the argument received, or the function value of one of the neighboring arguments, is transmitted. Thus positions-2, -1, 0, +1, +2 give f(a-2), f(a-1), f(a), f(a+1), f(a+2) respectively, where a is the argument.

Operation repeat switch

This switch determines the number of times the function value is transmitted.

Note that 4 addition times are required for the function table to set up, receive the argument, etc. This loss of time must be taken account of in programming the accumulator which receives the value of the function. Thus if that accumulator is programmed with the same pulse that programs the function table with its repeat switch set to 9, it could receive the value of the function only 5 times.

Terminals 1i, 2i,.....11i
Program pulse input terminals for program controls 1-11 respectively

Terminals 1o , 2o ,.....11o
Program pulse output terminals for program controls 1-11 respectively

Terminal NC
Program pulse output terminal associated with NC on argument reception switch.

Terminal C
Program pulse output terminal associated with C on argument reception switch.

Time Schedule for Function Table

Addition time	Operation
(Program input pulse received at end of Cth addition time)	
1	Circuits set up
2	Argument received
3	Argument modified by the addition of 0 to 4 pulses. At 4th pulse time portable function table starts to set up.
4	Function table finishes setting up
5	Value of function transmitted
r+4	This is continued up to the r+4th addition time, where r is the setting of the function repeat switch.
(Program output emitted at end of r+4th addition time)	

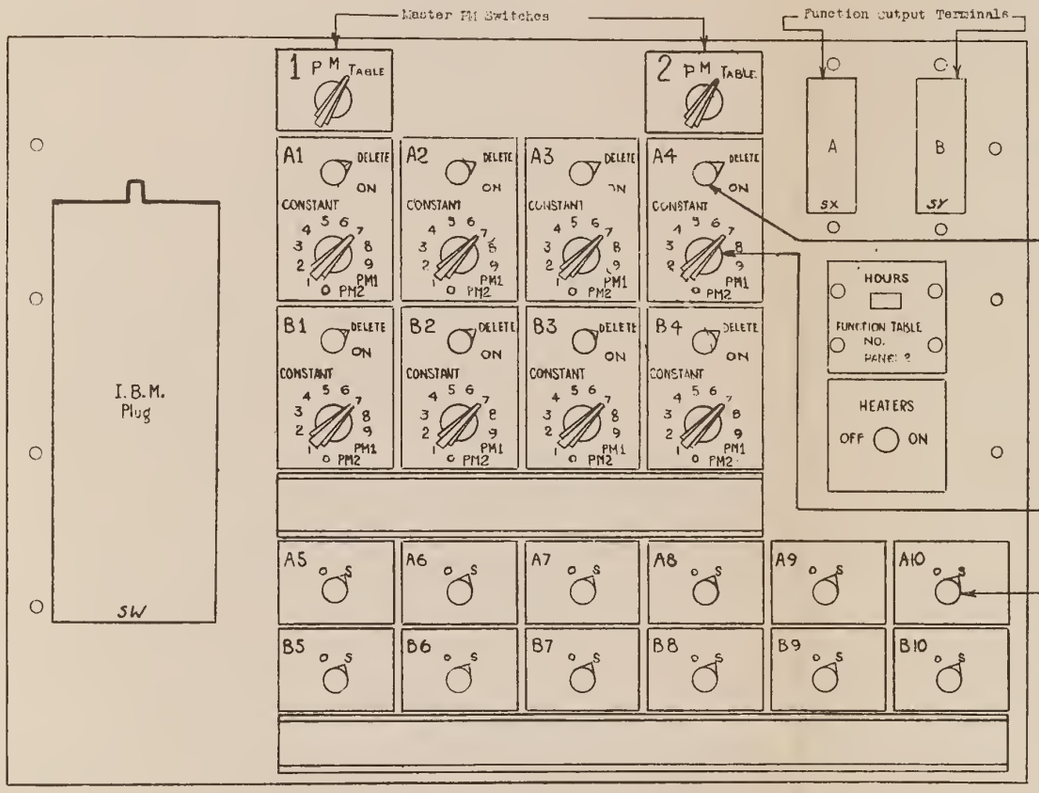
MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

FUNCTION TABLE FRONT PANEL NO. 1

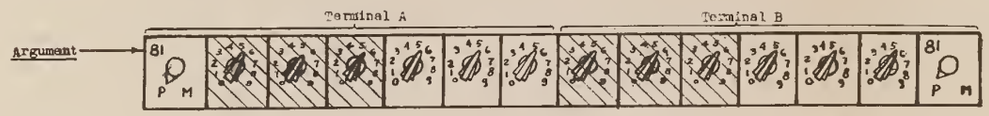
MATERIAL	FINISH	SIZE

Drawn by:	Checked by:	Approved by:	
J.EBELSACK DEC. 1944	awb 10/25/45		PX-7-302

1



Sample row of switches on portable function table showing connection to function output terminals.



For a positive number, set PM to P and set the number on the switches.
For a negative number, set PM to M and set the complement of the number with respect to 10^n on the switches.

Function output terminals

The digit pulses representing the value of the function are transmitted from these terminals. A connection table appears below. These terminals are to be connected to the digit trunks (trsys) (see NX-7-305) by the digit cables for transmission of the function value to another unit of the ENIAC.

It is to be noted that the division of the eight constant digit switches and the 12 function table entries into the groups A and B was an arbitrary one, and by means of special adaptors (PX-4-110) those can be regrouped in any manner.

Table showing connections of function output terminals

Line	Terminal A	Terminal B
12	Ground	Ground
11	PM	PM 2
10 (Billions place)	Constant digit switch A4	Constant digit switch B4
9	Constant digit switch A3	Constant digit switch B3
8	Constant digit switch A2	Constant digit switch B2
7	Constant digit switch A1	Constant digit switch B1
6	Left hand six entries of portable function table and: Subtract pulse switch A10	Right hand six entries of portable function table and: Subtract pulse switch B10
5	Subtract pulse switch A9	Subtract pulse switch B9
4	Subtract pulse switch A8	Subtract pulse switch B8
3 (Hundreds Place)	Subtract pulse switch A7	Subtract pulse switch B7
2 (Tens Place)	Subtract pulse switch A6	Subtract pulse switch B6
1 (Units Place)	Subtract pulse switch A5	Subtract pulse switch B5

Digit delete switch

When the digit delete switch is set to delete the constant digit switch is disconnected from its function output terminal, otherwise it is left connected.

Digits which are constant for all the values of a function may be set up on the constant digit switches.

If these switches are set to PM1 or PM2, the outputs of the corresponding master PM switches are fed through these switches to the output terminals. This feature is used when some of the left hand places of a function with both positive and negative values are zeros; these switches then supply zeros when the transmitted number is positive and nines when the transmitted number is negative, thus avoiding the use of shifters at the receiving terminals.

Constant digit switch

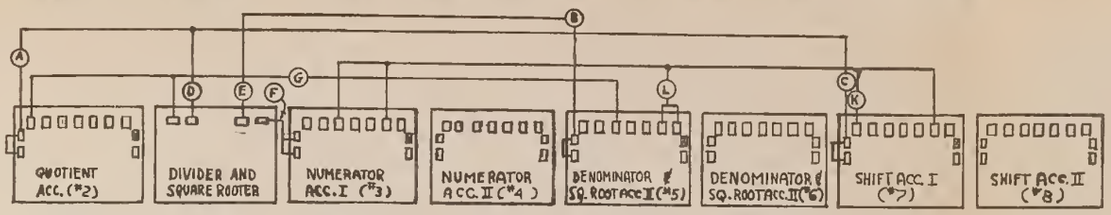
Subtract pulse switch

On a subtract transmit these switches feed a subtract pulse onto their corresponding function output terminal lines if they are set to 8. Thus the switch corresponding to the units digit of the function should be set to 8; the others feeding onto the same digit trunk should be set to 0.

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA			
FUNCTION TABLE FRONT PANEL NO. 2			
MATERIAL	FINISH		SCALE
Drawn by: J.EDELSACK DEC.1944	Checked by: AWB 11/6/45	Approved by:	PX-7-303

1

Diagram Showing Semi-permeneat Connections to be Made Between Divider-Square-Rooter and its associated Accumulators



(In dividing the quotient is built up here. This acc. is not used in square-rooting.)

(The numerator or quantity to be square-rooted is to be placed here.)

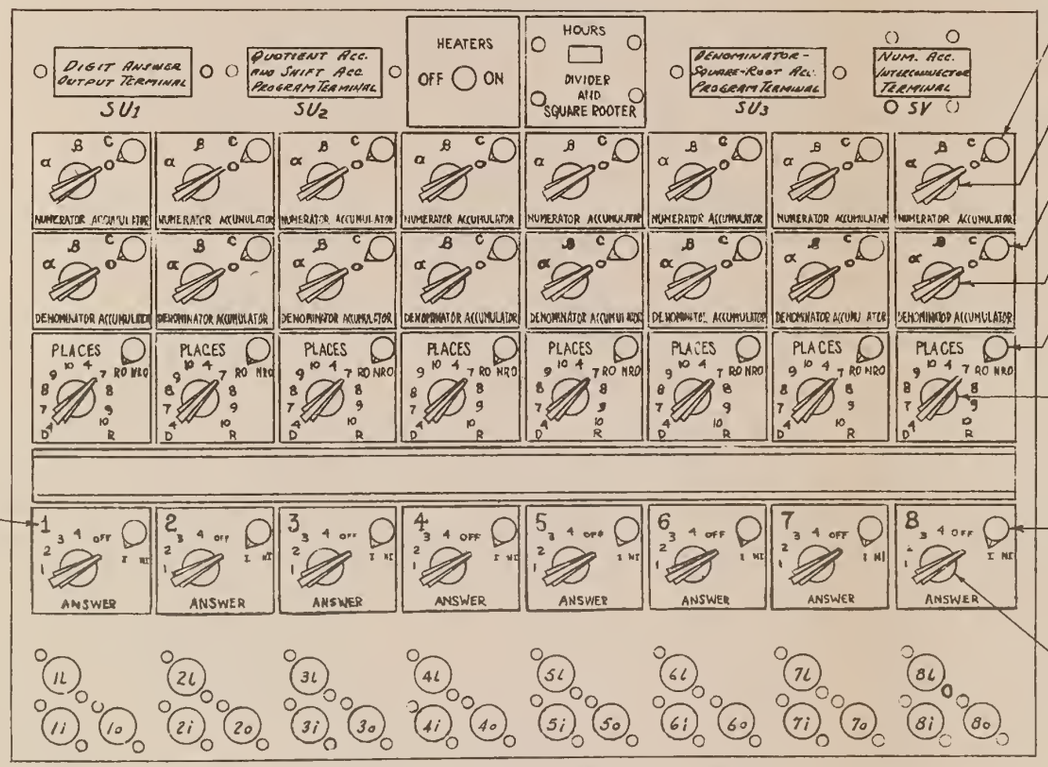
(In dividing the denominator is to be placed here. In square rooting twice the square root is built up here.)

Notes on cables:

No digit tray load box is to be used on any of these connections

(A) Accumulator interconnector cable (quotient) (PX-5-134)
(B) Acc. interconnector cable (denom.S.R.) (PX-5-136)
(C) Acc. interconnector cable (shift) (PX-5-135)
(D) Standard digit cable, with adapters (divider) (PX-4-114) plugged into program terminal.
(E) Standard digit cable, with adapters (divider) (PX-4-114) plugged into program terminal.
(F) Acc. interconnector cable (divider) (PX-5-137)
(G) Trunk to transmit digit pulses for quotient and square root.
This trunk is not to be used for any other purpose, since the pulses emitted are not supplied from transmitters but from inverter tubes which cannot be connected in parallel with anything else. These inverters have their own load resistors, so no load box is to be used in connection with them.
(K) Standard digit trunk (with load box) using +1 shifter in α input of the shift accumulator.
(L) Standard digit trunk transfer (with load box).

There are eight divider square rooter program controls, each consisting of a program pulse input terminal (which, when stimulated with a program pulse, causes the program control to program an operation , in accordance with its switch settings), a program pulse output terminal (which emits a program pulse on completion of the operation, including interlocking) the eight switches described below, and an associated transceiver (for neon bulbs see PX-10-302).



Number of the program control to which the switch and pulse terminals in a given column belong.

Terminals 1i, 2i,.....8i - Program pulse input terminals for program controls 1-8 respectively. When stimulated with program pulse causes program control to program division or square-root in accordance with its switch settings.

Terminals 1l, 2l,.....8l - Interlock pulse input terminal.
If the interlock switch of a given program control is set at NI, these terminals are not used.
If the interlock switch is set at I, a pulse must have been received on any interlock terminal since the last non-interlock operation or initial clearing of the divider before a program output pulse is emitted. The interlock pulse may be a program pulse or a digit pulse or pulses.

Terminals 1o, 2o,.....8o - Program pulse output terminals for program controls 1-8 respectively. Emits program pulse after both the operation is completed and an interlock pulse is received (if interlock switch is set at I).

Numerator Accumulator Clear Switch
This governs the clearing of the remainder by means of the static cable running into the numerator accumulator PM plug-in unit. If this switch is set on C, the numerator accumulator is cleared of its remainder during the last addition time of the division or square root.

Numerator Accumulator Receive Switch
When semi-permanent corrections are made, this switch programs the numerator accumulator to receive on the α and β digit input terminals during the first addition time of the dividing or square-rooting.

Denominator-Square-Root accumulator Clear Switch
This switch operates the same as the numerator accumulator clear switch except that it governs the clearing of the denominator-square-root accumulator.

Denominator-Square-Root Accumulator Receive Switch
When semi-permanent connections are made, this switch programs the denominator and square root accumulator to receive on the α and β digit input terminals during the first addition time of the dividing or square-rooting.

Round-Off Switch
When set to RO this switch causes the answer to be rounded off in the last place.
Note: Even when the number (s) operated on are such as to give an exact answer this switch must be set to RO to give the correct answer.

Divide-Square-Root and Places Switch
This switch selects which process is carried out and the number of places (counting from the 10th decade, i.e. the highest place) of the answer.
Note: The digit answer output terminal is so wired that the answer is built up starting in the 9th decade (counting from the right). For ordinary operation the numerator (or number to be rooted) and denominator should be placed so that there is a 0 in the 10th decade of their accumulators. If the number to be rooted has an odd (even) number of places to the left of the decimal point it should be placed so that the left-hand digit is in an odd (even) numbered decade. Hence the answer will have at least one place less than the setting of the places switch.

Interlock Switch
This switch is used whenever another operation or set of operations is carried on simultaneously with the division or square-rooting.
An average division (in which there is a zero in the 10th decade of the answer accumulator) or square-rooting takes $13p$ addition times, where p is the setting of the places switch.
If interlocking is used, and the interlock pulse arrives after the operation has been completed, a program output pulse is emitted during the second addition time following.

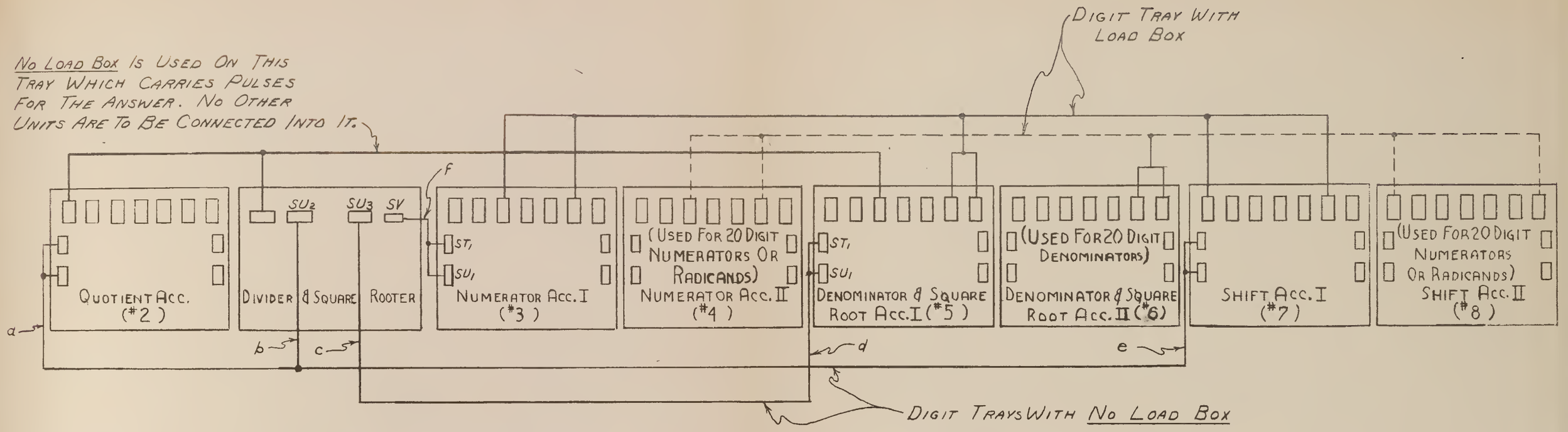
Answer Disposal Switch
This switch may be used to program transmission of the quotient or twice the square-root during the first addition time following the completion of the operation. The program control output pulse will then be used to stimulate that unit of the ENIAC which is to receive the answer.
Positions 1 and 2 are normally used to govern the quotient accumulator. The operation they perform is determined by adapter (divider) (PX-4-114). Thus if PX-4-114A is used
Disposal 1 - Causes quotient acc. to add transmit.
Disposal 2 - Causes quotient acc. to add transmit and clear.
Similarly, positions 3 and 4 are normally used to govern the denominator-square-root accumulator.

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

DIVIDER AND SQUARE ROOTER FRONT PANEL

MATERIAL	FINISH	SCALE

Drawn by:	Checked by:	Approved by:	
J. EDELSACK DEC. 1944	AWB 10/15/45		PX-10-301



Item	Description	Refer To
ST_1, SU_1	Accumulator Interconnector Terminals	PX-5-105
SU_2, SU_3, SV	Divider & Square Rooter Programming Terminals	PX-10-108
d	Special Cable From Digit Tray To ST_1 & SU_1 On Quotient Acc.	PX-5-134
b, c	Adaptors From SU_2 To Digit Tray Or From SU_3 To Digit Tray	PX-4-114A, A & AC Adaptor PX-4-114B, A & S Adaptor PX-4-114C, AC & SC Adaptor
d	Special Cable From Digit Tray To ST_1 & SU_1 On The Denom. & Sq. Root Acc.	PX-5-136
l	Special Cable From Digit Tray To ST_1 & SU_1 On The Shift Acc.	PX-5-135
f	Special Cable From SV To ST_1 & SU_1 On The Numerator Acc.	PX-5-137

Moore School of Electrical Engineering
University of Pennsylvania

Interconnection Of Divider & Square Rooter With Associated Accumulators ~ PX-10-307

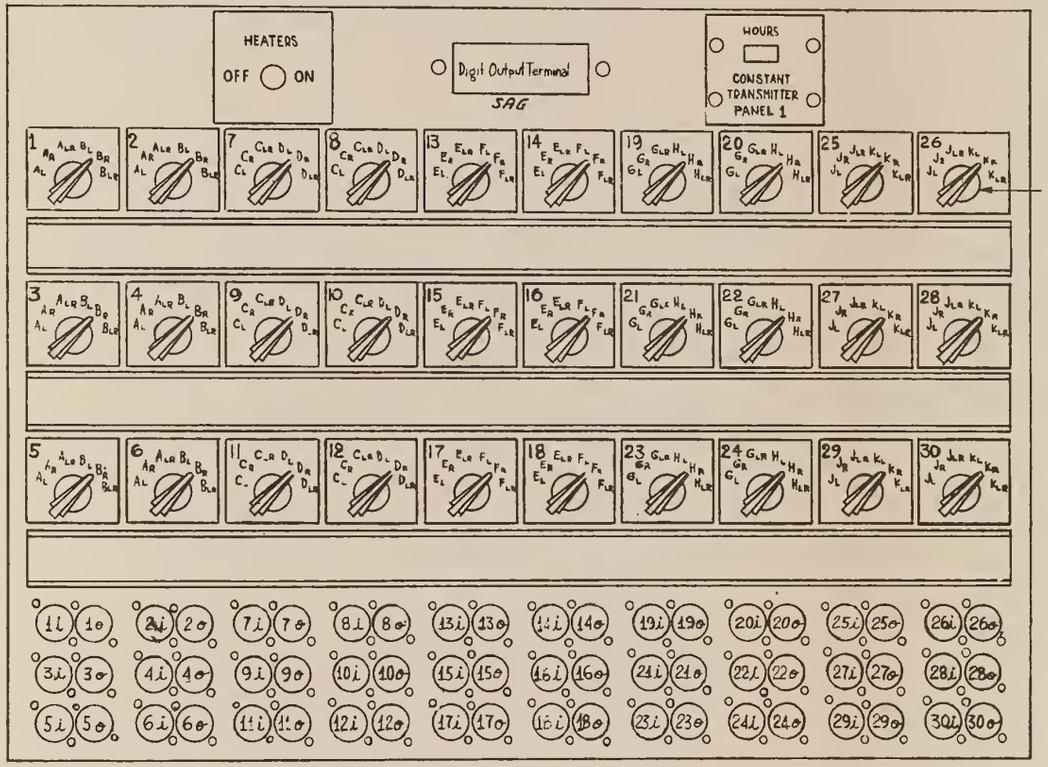
Digit Output Terminal

Whenever the transmission of a constant is programmed digit pulses representing this constant are emitted from this terminal. This terminal is to be connected to a digit trunk (tray) (See PX-11-306) by a digit cable for transmission of the constant to another unit of the ENIAC.

A table showing the connecting of this terminal for left-hand and right-hand five digit groups, and combined left and right-hand ten digit sets, appears below. It should be noted that a left-hand five-digit group would be received in the left-hand half of an accumulator and a right-hand five-digit group would be received in the right-hand half if no shifter were used.

Line	10-digit number (LR)	5-digit left-hand number (L)	5-digit right-hand number (R)
12	Ground	Ground	Ground
11	PM (of L)	PM (of L)	PM (of R)
10	Billions place	Ten-thousandths place	PM* (of R)
9	. . . . .	. . . . .	PM* (of R)
8	. . . . .	. . . . .	PM* (of R)
7	. . . . .	Tens place*	PM* (of R)
6	. . . . .	Units place	PM* (of R)
5	. . . . .	Nothing	Ten-thousandths place
4	. . . . .	Nothing	. . . . .
3	Hundreds place	Nothing	. . . . .
2	Tens place	Nothing	Tens place
1	Units place	Nothing	Units place

*Thus 0 pulses are transmitted on these lines when the constant is positive, 9 pulses when it is a complement. Hence it is unnecessary to use a shifter on a receiving accumulator to receive this constant into the units to ten-thousands decades of that accumulator.



Terminals 1i, 2i,..... 30i
Program pulse input terminals for program controls 1-30

Terminals 1 , 2 ,.....,30
Program pulse output terminals for program controls 1-30

General Explanation of the Constant Transmitter

The constant transmitter has a capacity of 100 digits and 20 signs. These are divided into 10 sets (A,B,.....G, J,K,) each consisting of 10 digits and 2 signs. Eight of these sets (A,B,....G) are supplied from IBM cards through the IBM reader when proper connections are made on the IBM reader plug board (see PX-11-305). Two of these sets (J,K) are supplied from the constant set switches and PM set switches of panel 2 (see PX-11-303).

Each set may be further divided into two groups, a left-hand group and a right-hand group, each consisting of 5 digits and a sign. This division must remain fixed throughout a given set-up. For example, if the C set is divided into five-digit groups, then any or all of the constant selector switches 7 to 12 may be set to C_L or C_R but not to C_{LR}. Conversely, if the E set is not divided, then any or all of the constant selector switches 13 to 18 may be set to E_{LR} but not to E_L or E_R.

The IBM reader is programmed from the initiating unit (see PX-9-302). The IBM reader controls and plug-board are described on PX-11-305.

Constant Transmitter Program Controls

There are 30 constant transmitter program controls, each capable of transmitting certain of the constants over the digit output terminal. Only one program control can be used at a time, hence only one number can be transmitted at a time.

Each program control consists of

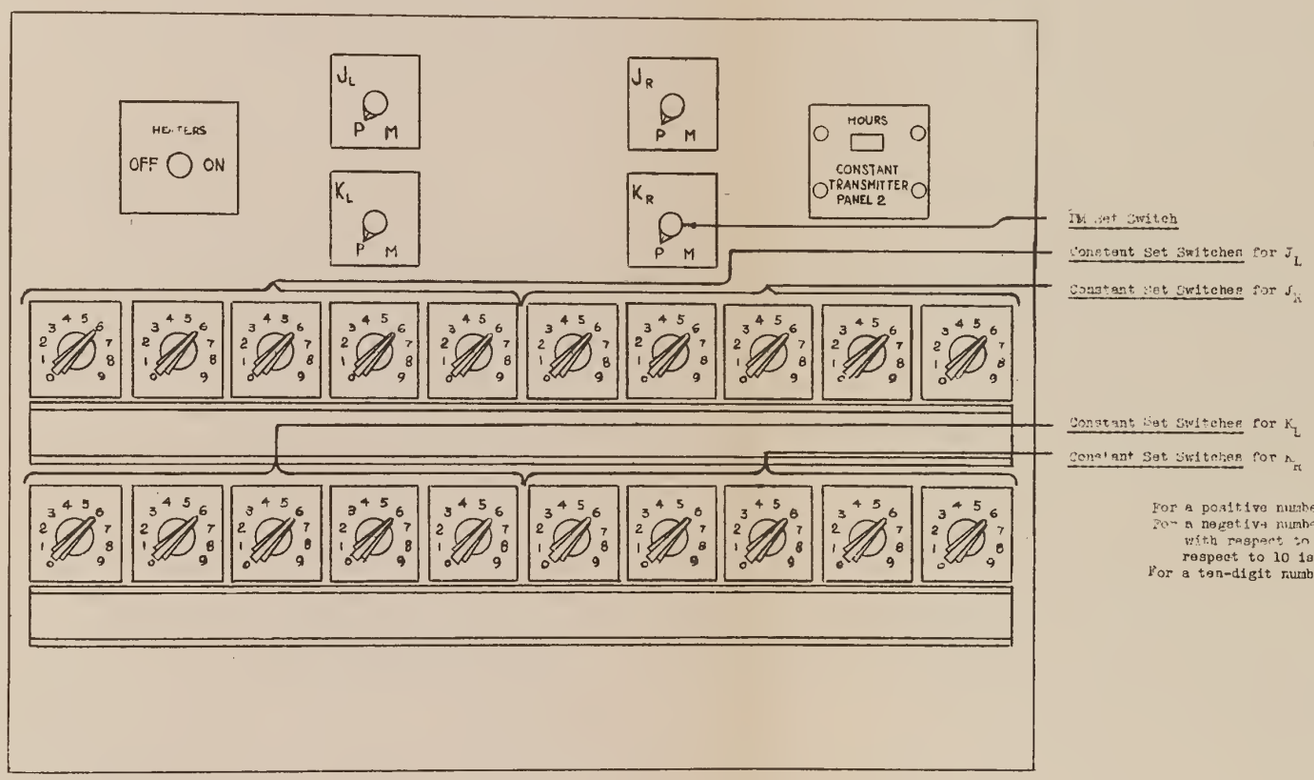
1) Program pulse input terminal (when stimulated with program pulse causes program control to program transmission of number set on its constant selector switch)
2) Constant selector switch
3) Program pulse output terminal (emits program pulse after constant has been transmitted, i.e., one addition time after the program pulse input terminal has received a pulse.
4) Associated transceiver (for neon bulbs see PX-11-306)

Program controls 1-24, which transmit constants read from the IBM cards, cannot be used during the operation of the card reader, except during the first 50 addition times of this operation. That is, after a pulse is supplied to Ri on the initiating unit front panel (see PX-9-302), these controls may be used during the 50 subsequent addition times, but not thereafter until a pulse is emitted from Ro.

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA		
CONSTANT TRANSMITTER FRONT PANEL NO.1		
MATERIAL	FINISH	SCALE
Drawn by: J.EDELSACK DEC. 1944	Checked by: JWM 11/1/45	Approved by:

1

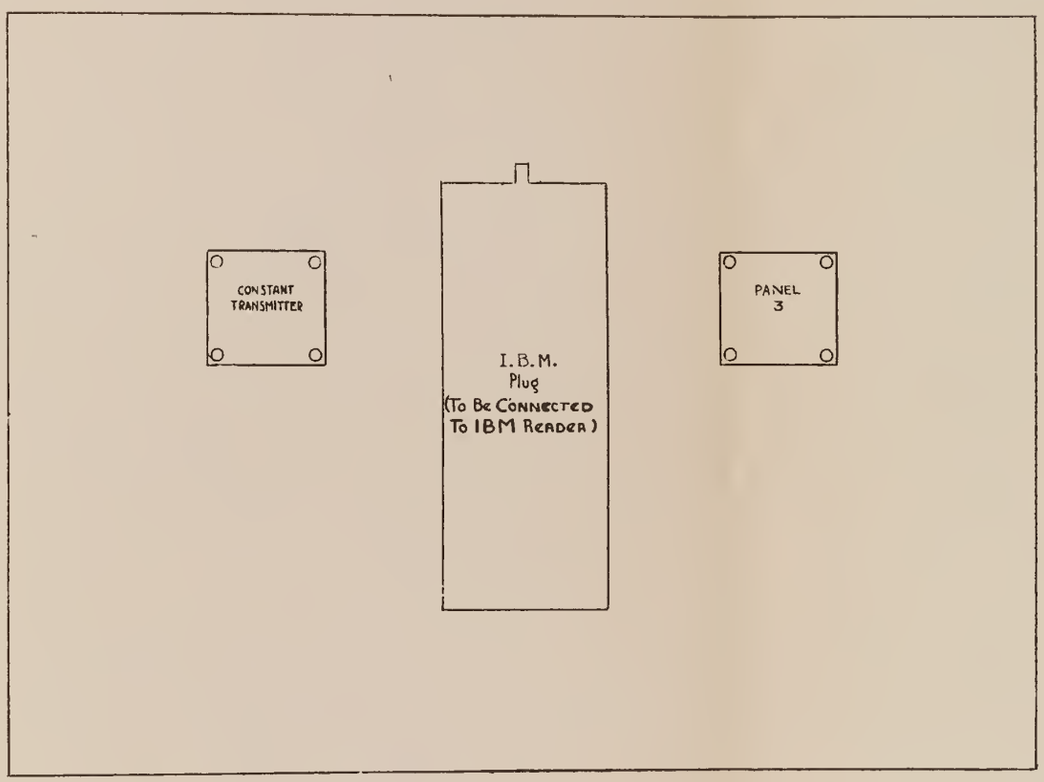
PX-11-302

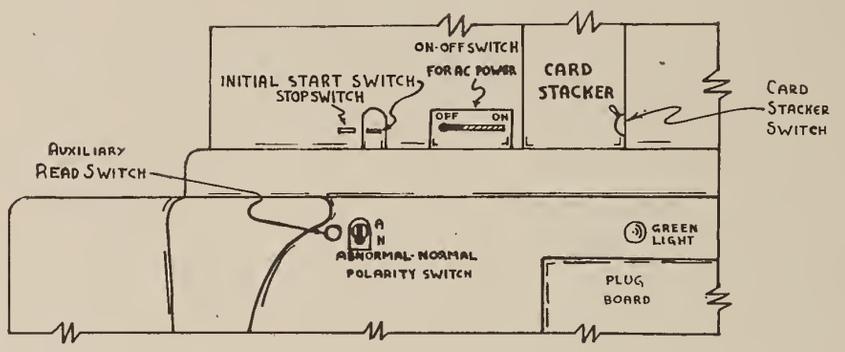


For a positive number, set the PM to P and set the number on the switches.
For a negative number, set the PM to M and set the complement of each digit with respect to 9 on all but units switch where the complement with respect to 10 is set.
For a ten-digit number, both PM switches should be set to the sign of the number.

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA			
CONSTANT TRANSMITTER FRONT PANEL NO. 2			
MATERIAL	FINISH		SCALE
Drawn by: J. EDELSACK DEC. 1944	Checked by:	Approved by:	PX-11-303

1





Note: Do not change polarity switch while motor-generator is on.

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA		
CONSTANT TRANSMITTER FRONT PANEL NO.3		
MATERIAL	FINISH	SCALE
Drawn by: J.EDELSACK DEC.1944	Checked by:	Approved by:

PX-11-304

The Polarity Switch

Located on the front of the IBM Reader is a double pole double throw switch which changes the polarity on the holding coils of the relays which control the group selection and the reset control. By changing this switch one can either wire these circuits on the plug board in the manner indicated there or in the reverse manner. This gives the following types of control:

(A) With the polarity switch in normal position.
The common terminal "C" is then wired to some hub of the #1 reading brushes and the group selection hubs are wired to hubs of the digit selector. Thus, all controlling is done by various punches in one column. The variety of things controled is given by plugging to different digits (12, 11, 0,.....,9) of the digit selector.

(B) With the polarity switch in abnormal position.
In this case "C" is wired to some digit on the digit selector and the group selection hubs are wired to various columns. Here, all the control is obtained by a certain punch (for example, a 12 punch) with different things being controlled by plugging to different columns.

Plugging Illustrations

(a) This shows the common hub "C" wired to column 21. The two hubs above and below C are connected so the wire could have gone to either of them. Note that besides the wire (a) one could connect this upper hub for C to some other column, say 2, getting an "or" control. That is, if a certain number (12, 11, 0,....,9) is punched in column 21 or column 2 then whatever hub under group selection was plugged to that number of the digit selector causes the corresponding group selection relays to operate.

(b) This wire causes the reset control to operate whenever there is a 12 punch in column 21; that is, a card with such a punch is called a master card.

(c and d) These leads cause information in storage relay groups 6 and 7 to be held as long as cards come through without a 12 punch in column 21. Whenever a card with a 12 punch in column 21 (a master card) comes along the information in groups 6 and 7 will be dropped and new information will be put in from this master card. Immediately, the reader will go on to read the next card.

(e) If a card has a 6 punched in column 21 this lead causes group selection relays for group 12 to be activated giving a circuit from C through B instead of A.

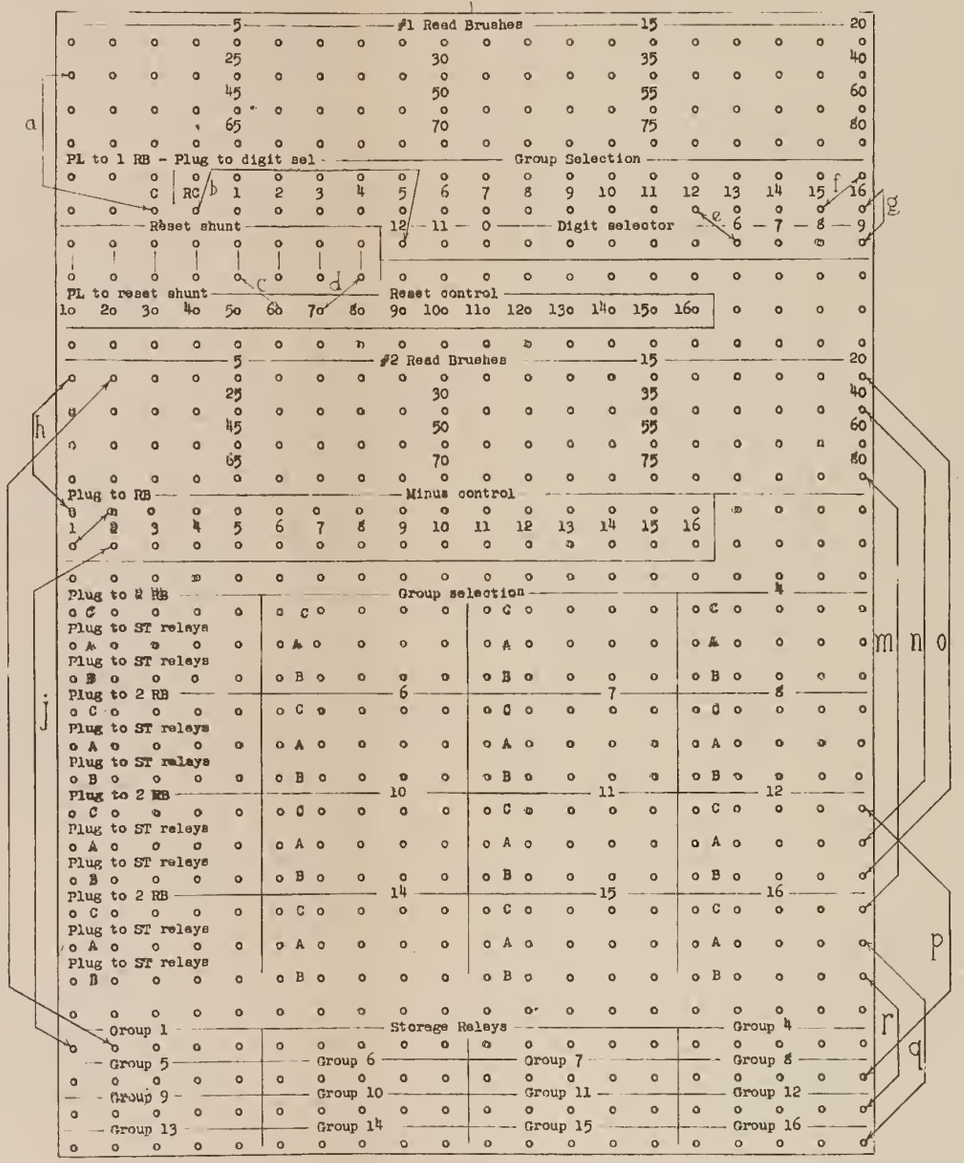
(f and g) If a 9 is punched in column 21 groups 15 and 16 group selection relays will be activated. Diagonal leads such as (f) enable one to operate as many groups as desired from just one punch.

(h, j, and K) This shows the plugging to handle ten digit negative numbers. The PM punch is in column 1 and, by the diagonal connection in the minus control, the PM relays for groups 1 and 2 are operated by this one punch. The first digit reaches the storage relays through (j). (k) illustrates the plugging for the rest of the digits.

(n, o, and p) If there is a 6 punch in column 21 the digit from column 20 will go to the fifth digit of group 8. Otherwise, the digit from column 40 will go there.

(m, q, and r) If there is a 9 punch in column 21 the digit in column 80 will be the fifth digit of group 12. Otherwise, it will be the fifth digit of group 16.

NOTE: If during the course of a computation the IBM reader should run out of cards the starting relay (see PX-11-307) will be closed so the moment new cards are dropped in, the reader will go through a cycle. To make sure that the reader does not fail to feed this first card the stop button should be held down until the cards are firmly in place.



#1 Read Brushes

The #1 Read Brushes read the card before the #2 Read Brushes do. The #1 brushes are used for control purposes and the #2 brushes for reading the numbers and their PM's.

Group Selection

The hubs numbered from one to sixteen control the group selection relays whose terminals are located on the lower half of the plug board. These are double hubs, that is, the hub above and below the number are common. The single hub located to the left of these and labeled RC controls the reset control. The features of group selection and reset control are described below. For details see the IBM reader wiring diagram PX-11-119.

Reset Control and Reset Shunt

Certain groups of relays (depending upon plug board arrangements) may be caused to hold their information while a sequence of "detail" cards are read. This is accomplished by connecting the corresponding terminals under Reset Control to any of the Reset Shunt terminals. To change the information which is being held in these relays a "master" card is inserted in the sequence of cards. A particular punch on this master card can cause the held information to drop out and as the master card passes the #2 Reading Brushes new information can be stored in these relays until the next master card comes along. Whenever such a master card is read the Reader will immediately read the next detail card before it gives out a computing signal to the ENIAC.

WARNING: The detail cards either must not contain information in the fields corresponding to the relays that are holding master card information or else group selection must be used to prevent such information from disturbing the held relays.

Group Selection Relays

There are sixteen five pole double throw relay switches, called the group selection relays. The common terminals are labeled "C" and normally the circuit is through the terminals labeled "A". When activated (picked up) the circuit is through "B". These circuits are isolated (internally) from the other circuits of the reader so there are many other possible plugging arrangements other than those indicated on the plug board.

Minus Control

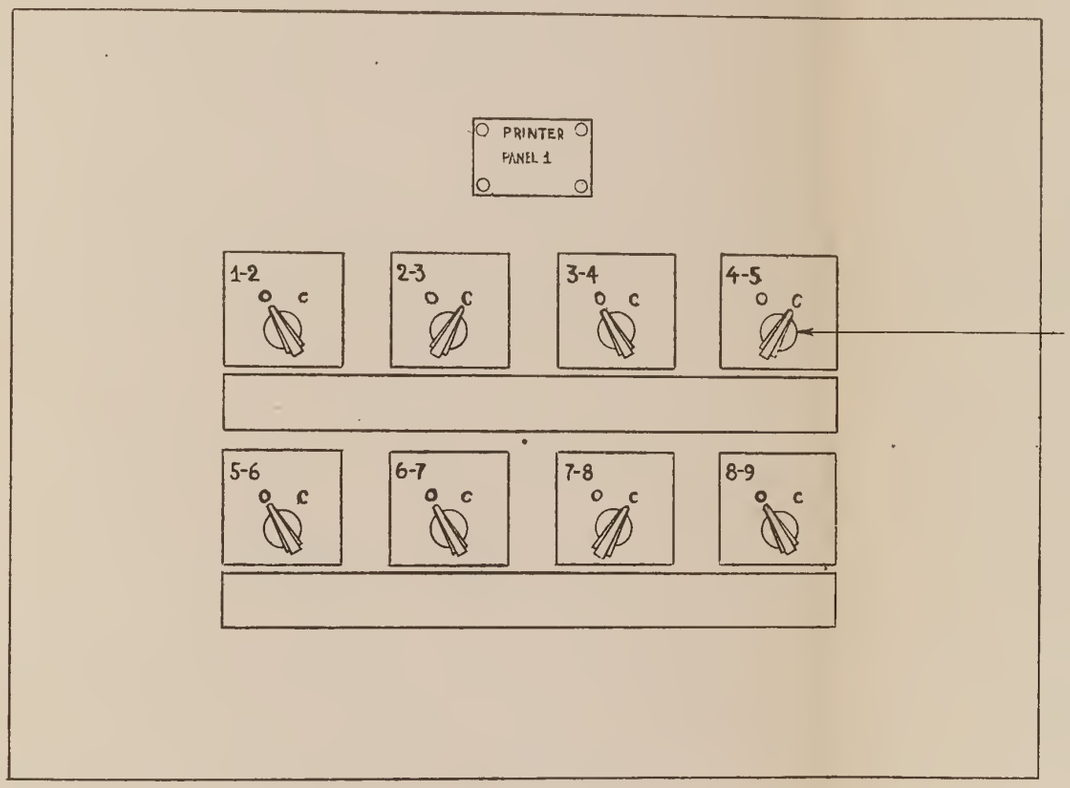
By means of cams in the Reader these terminals connect to the PM relays of the Constant Transmitter only when the IBM card is in positions 11 and 12, that is, when the PM punches would be under the #2 Read Brushes. The two hubs, above and below the group number, are common. Usually, the punch for minus indication will occur in the same column that a digit punch appears. Thus, the same reading brush will indicate the PM of the number and later as the positions zero to nine pass under the brush indicate the digit punched. Other cams (called coding cams) energize the numerical circuits only during the zero to nine part of the cycle enabling the digit punch in that column to cause the proper relays to be set up in the Constant Transmitter. The coding cams consist of two groups, one group is used for positive numbers and the other group causes complements (with respect to 10^{n}-1) to be set up by storage relays. The PM relays determine which set of coding cams are used.

Storage Relays

The storage relays are located in the Constant Transmitter There are essentially four relays associated with each digit. That is, four relays representing respectively 1, 2, 2^{1}, and 4 can, in various combinations, represent any digit from zero to nine. These four relays are indirectly (through vacuum tube circuits) associated with the 1, 2, 2^{1}, and 4 pulses sent out by the cycling unit. That is, each relay opens a gate tube which through an inverter opens a second gate tube. This second gate tube passes the 1, 2, 2^{1}, or 4 pulses.

For positive numbers the hubs of the #2 reading brushes can be wired directly to the hubs of the storage relays in any order whatsoever. Negative numbers must be handled in groups which are multiples of five. To indicate the negative number there will be an 11 or 12 punch in some column. The wire from the hub representing this column must go to the minus control hubs of all the storage relay groups used for this negative number. There must also be a connection to the hub corresponding to this digit in the storage relays. See the examples shown to the left.

MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA			
I. B. M. READER PLUG BOARD			
MATERIAL	FINISH		SCALE
—	—		—
Drawn by: J. CUMMINGS Aug 4, 1945	Checked by: D. Fuchs 12-7-45	Approved by:	PX-11-305



Coupling switch

This switch couples two groups of digits together when it is set to the C position. It provides for the carryover when an ENIAC complement is converted to a true value.

The switches on this drawing and PX-12-303 are set for the arrangement shown in the table below.

Table Showing Original Set of Decadas Connected to the Printer

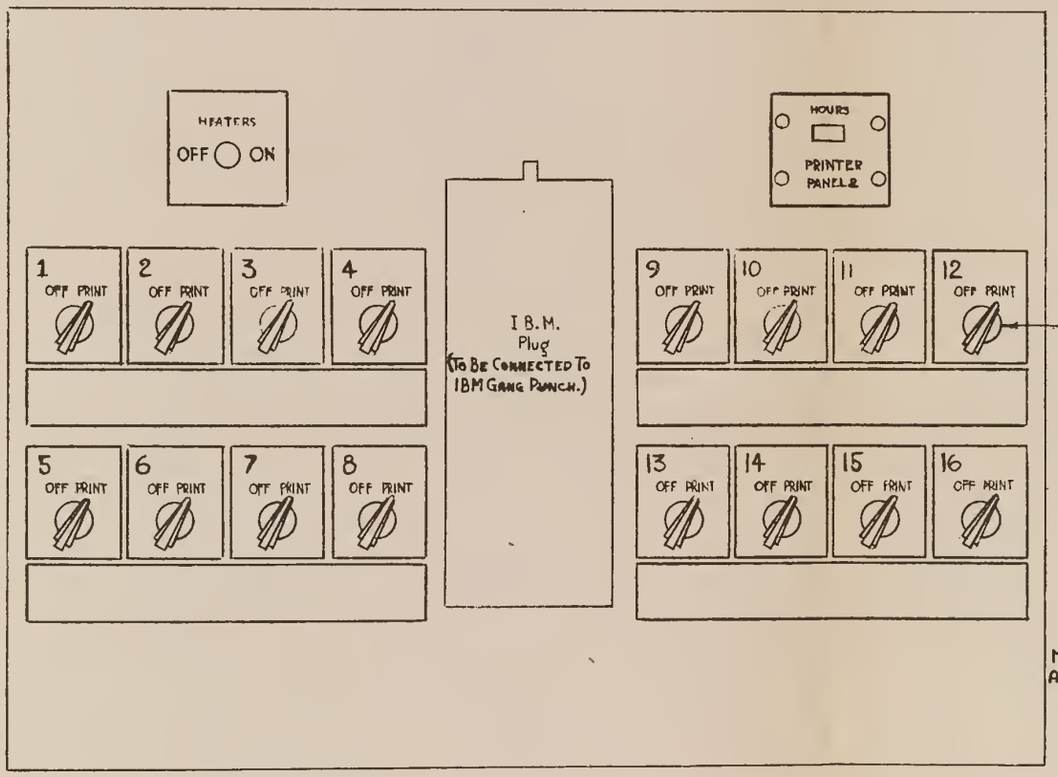
Printer Group	Decades from
1	Master Programmer, Panel 1, Decadas 14-18
2	Accumulator 13, Decades 6-10
3	Accumulator 13, Decades 1-5
4	Accumulator 14, Decades 6-10
5	Accumulator 14, Decades 1-5
6	Accumulator 15, Decades 6-10
7	Accumulator 16, Decades 6-10
8	Accumulator 16, Decades 1-5
9	Accumulator 17, Decades 6-10
10	Accumulator 17, Decades 1-5
11	Accumulator 18, Decades 6-10
12	Accumulator 18, Decades 1-5
13	Accumulator 19, Decades 6-10
14	Accumulator 19, Decades 1-5
15	Accumulator 20, Decades 6-10
16	Accumulator 20, Decades 1-5

MOORE SCHOOL OF ELECTRICAL ENGINEERING
UNIVERSITY OF PENNSYLVANIA

PRINTER FRONT PANEL NO. 1

MATERIAL	FINISH	

Drawn By:	Checked By:	Approved By:	
J. EDELSACK DEC. 1944	A.W.P. 10/31/45		PX-12-301



General Explanation of Printer

The printer operates from the static outputs of accumulator and master programmer decades. The cables connecting the decade static terminals to the printer lie in a trough at the top of the front of the machine. A table, showing the original set of connections, appears on PX-12-301. Every accumulator decade and PM unit and every master programmer decade has a static output terminal.

The numbers to be printed are divided into sixteen groups of 5 digits and a PM, numbered from 1 to 16. The printing switches determine which groups are connected to the IBM gang punch. Drawing PX-12-305 shows the IBM gang punch plug board and gives instructions for connecting it up.

Any group of five digits and a PM may be connected to an adjacent group by means of the coupling switch, so that 10 digit, 15 digit, etc. numbers may be punched.

When the number to be printed is a complement (i.e., the PM counter registers 9), the true value of the number is punched along with an 11 punch to indicate that it is negative.

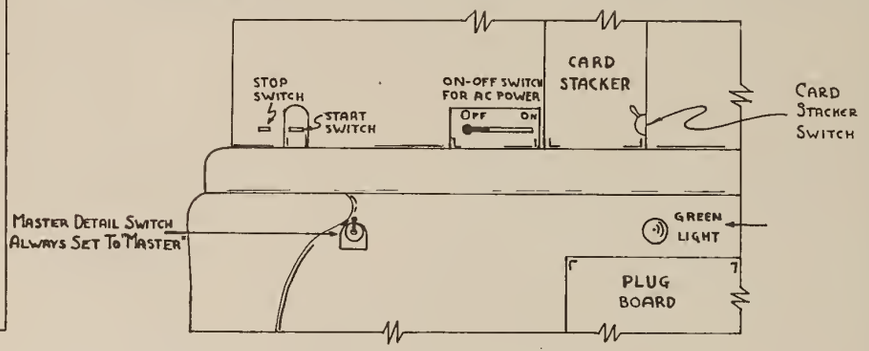
Whenever information in the master programmer is printed adaptor PX-12-114 B must be used at the printer plugs on panel 2 so as to ground the unused PM lead going into the printer.

The printer is programmed from the initiating unit (see PX-9-302). Controls on the IBM gang punch are explained on PX-12-305.

Printing switch

This switch connects (in the "Print" position) or disconnects (in the "off" position) the voltage supply to the buffer tubes of its group, so that these tubes do (or do not) operate the relays when the printer is programmed. For the group of digits to be punched it is necessary not only that this switch be set to "Print" but also that proper connections be made on the IBM gang punch plug board (see PX-12-305).

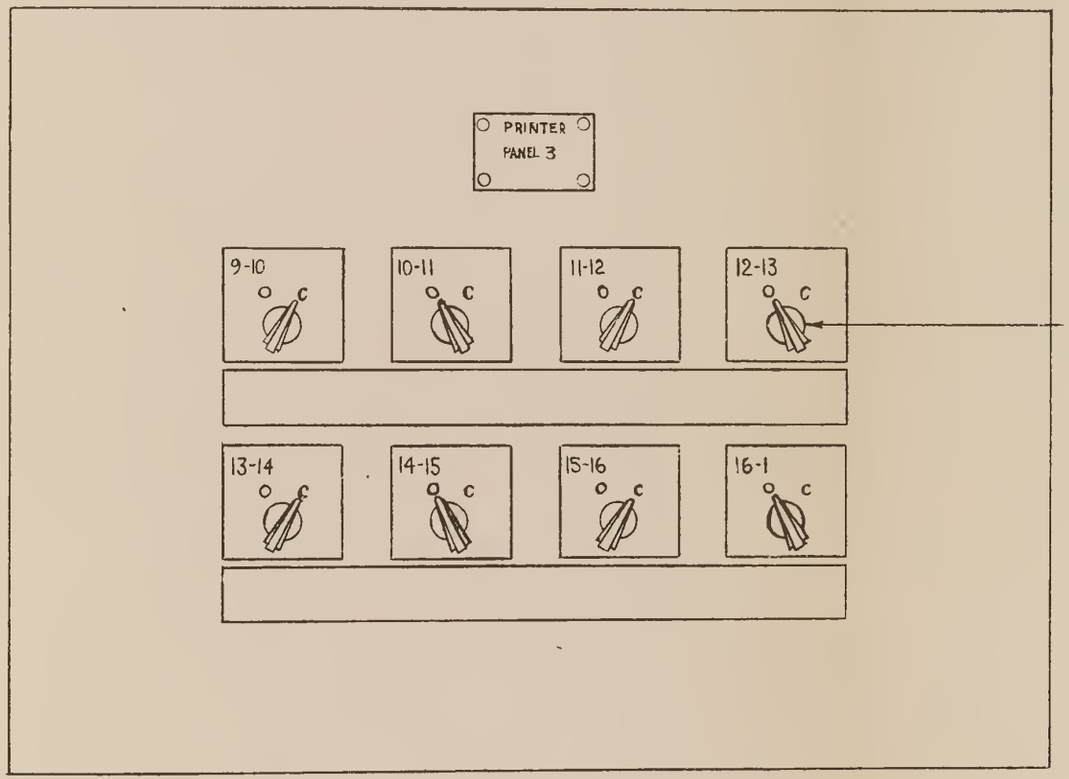
This switch must be turned off if the decades to which the group is connected are not turned on.



MOORE SCHOOL OF ELECTRICAL ENGINEERING UNIVERSITY OF PENNSYLVANIA		
PRINTER FRONT PANEL NO. 2		
MATERIAL	FINISH	SCALE
Drawn by: J. EDELSACK DEC. 1944	Checked by: aws 1/1/45	Approved by:

1

PX-12-302



Coupling switch.
See PX-12-301 for an explanation of this switch

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PRINTER FRONT PANEL NO.3			
MATERIAL	FINISH		
Drawn by: J. EDELSACK DEC. 1944	Checked by:	Approved by:	PX-12-303

PLUG BOARD FOR GANG PUNCH

Computer Result Exit

These hubs connect directly to the digit relays in the printer. To punch positive numbers they can be plugged to the punch magnet hubs in any desired arrangement. Thus, it is possible to place the digits coming from the group 1 relays in any five of the eighty columns on the IBM card.

Minus Indication.

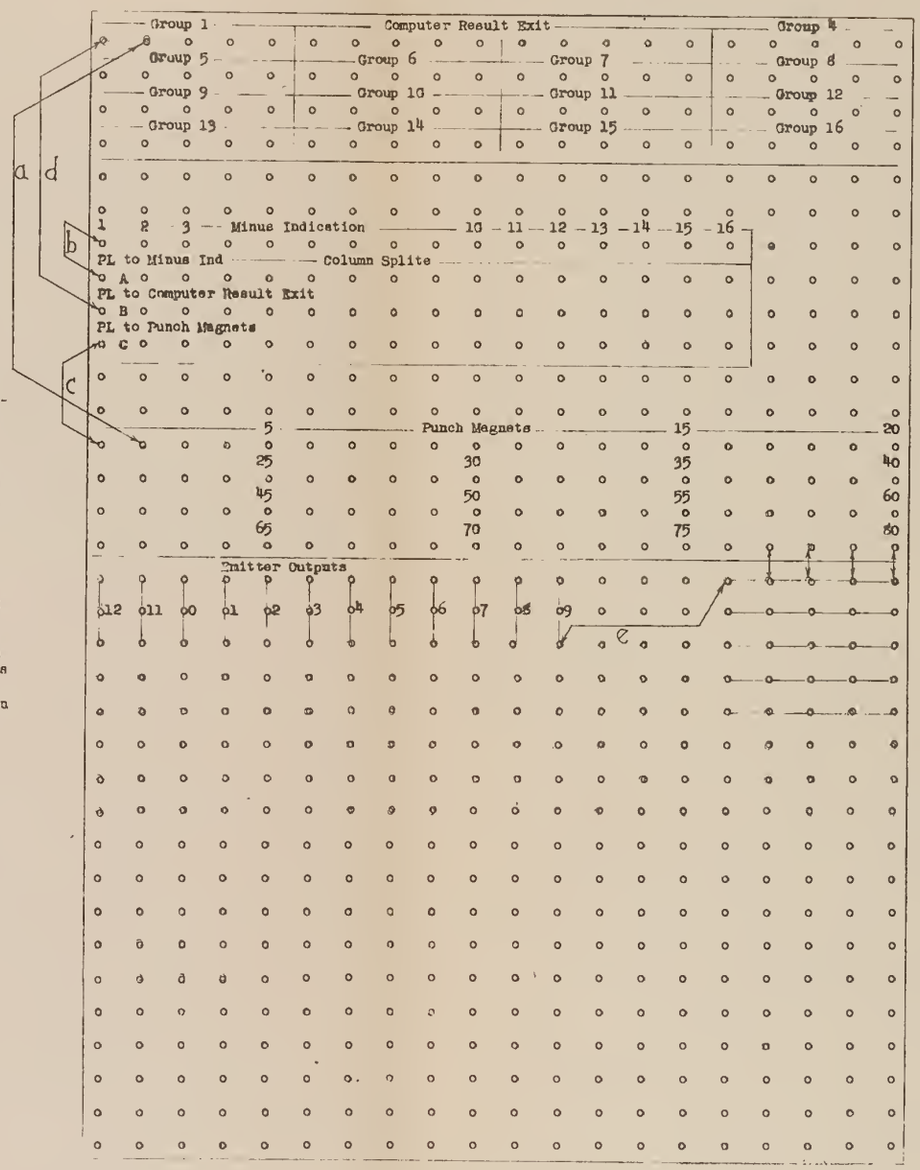
The sixteen hubs under minus indication go directly to the PM relays of the sixteen groups. The minus indication of any group could be punched in any of eighty columns on the card simply by connecting the corresponding minus indication hub with the particular column hub of the punch magnets.

Usually, however, the minus indication will appear above some digit of the number on the card. To place the minus indication (an 11 punch) above the first digit of the number the minus indication of the corresponding group is plugged to one of the terminals labeled "A" under column splits. The hubs "B" and "C" directly under the A-hub used are to be plugged, respectively, to the digit hub (Computer Results Exit) above which the minus punch is desired and to the corresponding hub of the punch magnets.

The column splits is simply a sixteen pole double throw relay switch. This switch is controlled by a cam in the IBM punch which causes the "C" hubs to be connected to the respective "A" hubs during the 11 position of the card and to the "B" hubs during the 0,.....,9 position of the card.

Emitter Outputs

If one of these hubs is plugged to a punch magnet hub the corresponding number will be punched in that column of the card. The five rows of five common hubs to the right of the emitter outputs enable one to punch the same number in more than three columns. The connection labeled (e) on the diagram causes nines to be punched in the columns 77,.....,80 on the card. Connections such as these cause the corresponding number to be punched in every card. This can be used to give identifying numbers to the cards or to punch dates on the cards. Alphabetic punching cannot be done on this machine.



Plugging Illustrations

(a) This illustrates the type of plugging in columns where no minus indication is desired.

(b, c, and d) When the 11 position of the card is under the punches there is a connection through leads (c) and (d) from the punch magnet hub to the minus indication. If the group 1 PM relays were activated a signal will arrive at this time causing the 11 to be punched in column 1 on the card. If the 11 punch indicating a negative number were desired in column 2 leads (a) and (c) must be interchanged at the punch magnet hubs and leads (a) and (d) interchanged at the computer exit hubs. Then the first column of the computer exit comes directly to the first column punch and the second column leads go through the minus indication hubs and the column split.

(e) These connections will cause nines to be punched in the last four columns on the card.

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I.B.M GANG PUNCH PLUG BOARD			
MATERIAL	FINISH		SCALE
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Drawn by: J. Cummings Aug 4 1945	Checked by: [signature] 12 7 45	Approved by:	PX-12-305

Stepper terminals

A_i,.....,K_i	Stepper program pulse input terminals
A_1o,.....A_6o;..K_1o....K_6o	Stepper program pulse output terminals
Adi,....,Kdi	Stepper direct input terminals
Acdi,....Kcdi	Stepper clear direct input terminals

Decade terminals

Ddi20,....Ddi1	Decade direct input terminals

General Explanation of Steppers and Decades

A stepper is a six stage ring counter. It has the following associated with it:

1) Stepper program pulse input terminal
2) Six stepper program pulse output terminals, one associated with each stage of the stepper.
3) A group of decades(of from 0 to 5, depending upon the stepper and the settings of the decade associator switches. The n ($n=0,\ldots,5$) decades of each group are interconnected by a direct carry-over circuit (there is no delayed carry-over circuit) enabling them to count (not accumulate) $10^n - 1$ pulses.
4) Stepper clear switch
5) Stepper direct input terminal
6) Stepper clear direct input terminal
7) Each decade has a direct input terminal

The operation of a stepper and its associated equipment is as follows:

At the end of the initial clear each stepper is left on the 1st stage and each decade is cleared to 0.

Suppose a program pulse is received on a stepper program pulse input terminal. One addition time later a program pulse is emitted from the program pulse output terminal corresponding to the stage the stepper is on at the time it is emitted and a program pulse is sent to the units decade of the group of associated decades.

Whenever a group of decades counts to the number set on those decade switches corresponding to the position of the stepper, one addition time later these decades are cleared to zero and the stepper is either stepped to the next position, or (if it is on the position set on its stepper clear switch) cleared to the first position. Though the decades will count either program pulses or digit pulses, any pulse which might cause this clearing and stepping action must be a program pulse.

The decades count both the pulses supplied to the associated stepper's program pulse input terminal (with a one addition time delay) and those supplied to the decade direct input terminals. No set-up is permissible which might lead to pulses being supplied to a decade from both sources simultaneously, or from a decade direct input terminal and a carry-over from a previous decade simultaneously.

An example illustrating a common application of a stepper in programming will show how items 1 through 4 operate together. Consider stepper D, and suppose that decades 12 and 13 are associated with it and that its stepper clear switch is set to 4. Then four two-digit numbers ($n_1,\ldots,n_4$) may be set up on the decade switches, each number associated with the corresponding stage (1,.....4) of the stepper and hence with the corresponding program pulse output terminals ($D_1o,\ldots,D_4o$). Whenever a program pulse is received on D_i a pulse is emitted from one of the output terminals (one addition time later). The first n_1 pulses received on D_i are emitted from D_1o; the next n_2 pulses received on D_i are emitted from D_2o... ..., the last n_4 pulses received on D_i are emitted from D_4o, and the stepper and its associated decades are then left in their original state, ready to repeat the process. The time schedule of these operations is as follows:

Program Pulse	Operation
0	Input program pulse (to Di)
1	Output program pulse emitted (from $D_1o,\ldots D_4o$) Decade stepped to next stage
2	In case the decades register the number set up on the decade switches, all decades (associated with stepper D) are cleared to zero and the stepper (D) is stepped to the next stage or (if it is on the position 4) it is cleared to the first stage.

To disassociate a decade from its stepper pull out gate tube 63 in the stepper plug-in unit. See block diagram PX-8-304.

Terminals A_i, B_i,.....K_i — Stepper program pulse input terminals

Terminals A_1o.....K_1o — Stepper program pulse output terminals associated with Stage 1

A_2o.....K_2o — Stage 2.....

A_6o.....K_6o — Stage 6

One addition time after a program pulse is supplied to an input terminal (such as Di) a program pulse is emitted from the output terminal corresponding to the stage the stepper is on at the time it is emitted (thus if the stepper is at position 4, when the pulse is emitted it comes from D_4o), and a unit is added to the contents of the associated decades.

Terminals Acdi,.....Kcdi — Stepper clear direct input terminals.

A pulse supplied to this terminal will clear the stepper to the first position. If a clearing pulse and a stepping pulse arrive at the same time, the stepper will be cleared, not stepped.

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MASTER PROGRAMMER FRONT PANEL NO. 1			
MATERIAL	FINISH		SCALE
Drawn by: J. EDELSACK DEC. 1944	Checked by: J.M.B 10/12/45	Approved by:	PX-8-301

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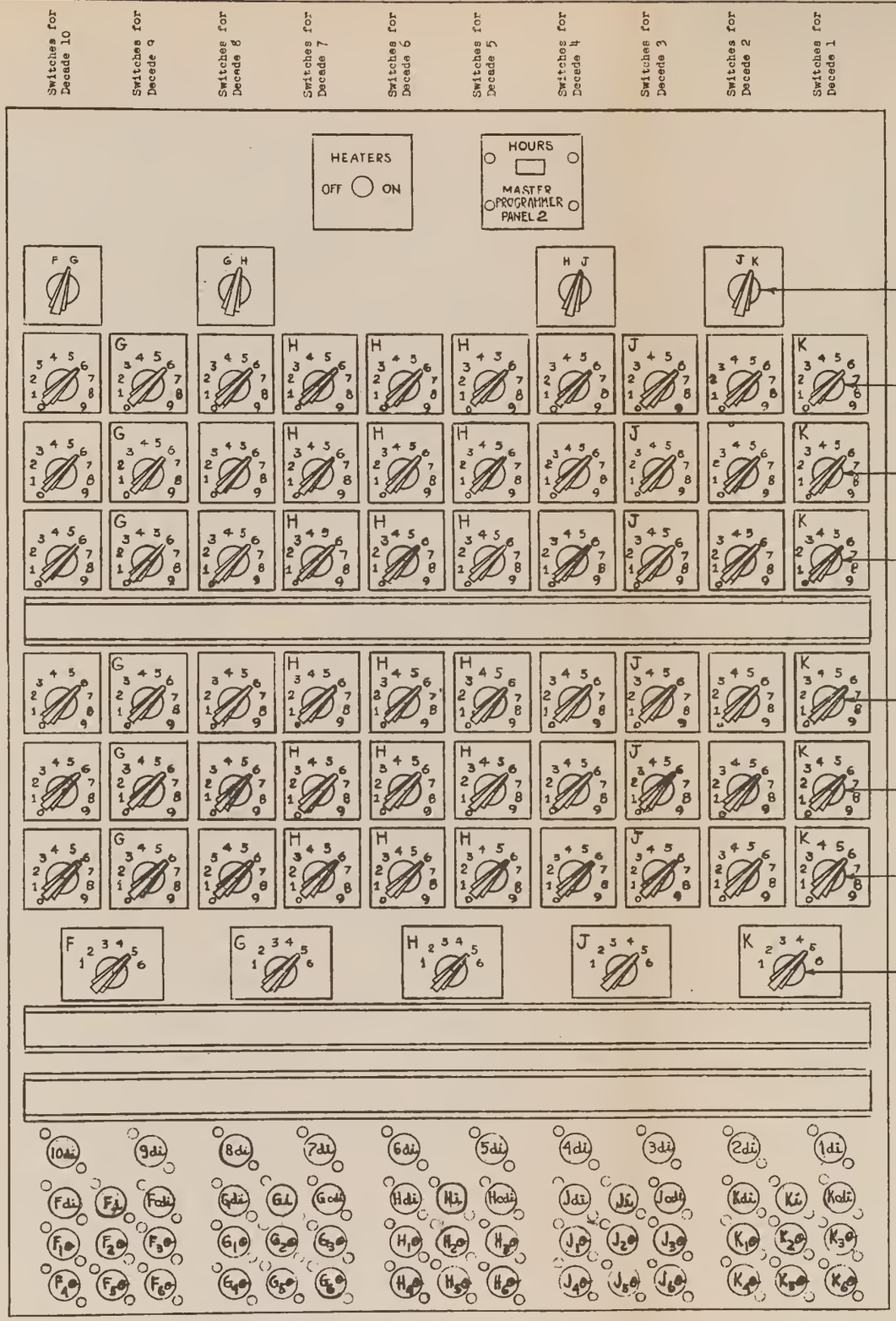

To disassociate a decade from its stepper pull out gate tube 63 in the stepper plug-in unit - See Block Diagram PX-8-304.

Decade Associator Switches
Decades provided with these switches may be connected to the decades associated with either of two steppers. Thus if the J-K switch is set to K, decade 2 is connected in series with decade 1, while if it is set to J decade 2 is made the units decade associated with stepper J, and decade 3 (formerly the units decade associated with that stepper) becomes the tens decade of that stepper, i.e., is put in series with decade 2.

Decade switches associated with the 1st stages of the steppers.

Decade switches associated with the 2nd stages of the steppers.

Decade switches associated with the 3rd stages of the steppers.

Decade switches associated with the 4th stages of the steppers.

Decade switches associated with the 5th stages of the steppers.

Decade switches associated with the 6th stages of the steppers.

Stepper clear switch
This switch determines the number of stages of the stepper and associated decade switches which are used. After the stepper gets to the stage set on its clear switch and counts to the number set on the corresponding decade switches it clears to its first position instead of stepping to the next position.

Terminals Adi,....,Kdi - Stepper direct input terminals.
Pulses supplied to one of these terminals will be counted by the stepper. These pulses may be either program pulses or digit pulses. If digit pulses are used the stepper clear switch must be set to 6.

The stepper will count modulo c, where c is the setting of the stepper clear switch.

A program pulse is emitted from one of the stepper program pulse output terminals one addition time after a program pulse is received on the stepper program pulse input terminal . This pulse is emitted from the terminal corresponding to the state of the stepper at the time it is emitted. The stepper may be stepped or cleared at the same time without effecting that pulse.

No pulse should be supplied to this terminal at the same time as a stepping action is caused by the decades.

TERMINALS 1di, 2di, ...,20di - Decade direct input terminals associated respectively with decades 1, 2,....,20. (counted from right to left)

Pulses supplied to these terminals will be counted by the decades. These pulses may be either program or digit pulses, though any pulse which steps the decades to the number set up on the decade switches corresponding to position of the stepper must be a program pulse., and any pulse which causes a carry-over must be a program pulse.
No program pulse should be supplied to the decade direct input of the units decade of a stepper one addition time following the reception of a program pulse on the program pulse input terminal of that stepper.
Pulses can be fed into the direct input terminals of decades other than the units decade only at times when there are no carry-over pulses from previous decades of the set.

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MASTER PROGRAMMER FRONT PANEL NO. 2

MATERIAL	FINISH	SCALE

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J.EDELSACK DEC.1944			PX-8-302

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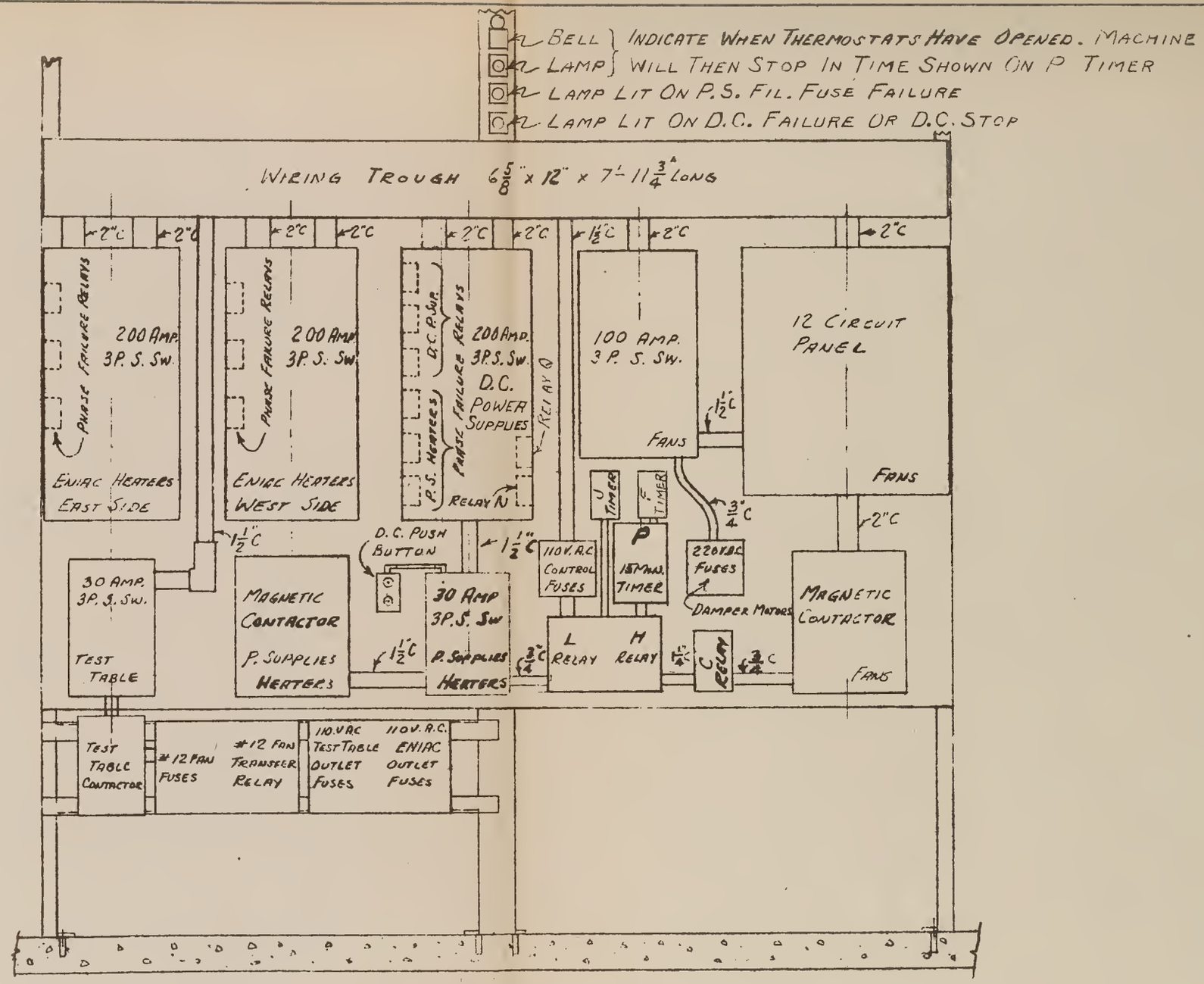

REVISIONS

F & P TIMERS REVISED.
Q RELAYS, INDICATING LAMPS & BELL ADDED.
J. Cummings 1-30-46 | 1

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A. C. POWER DISTRIBUTION RACK

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