FROM ANALOG TO DIGITAL AND BACK

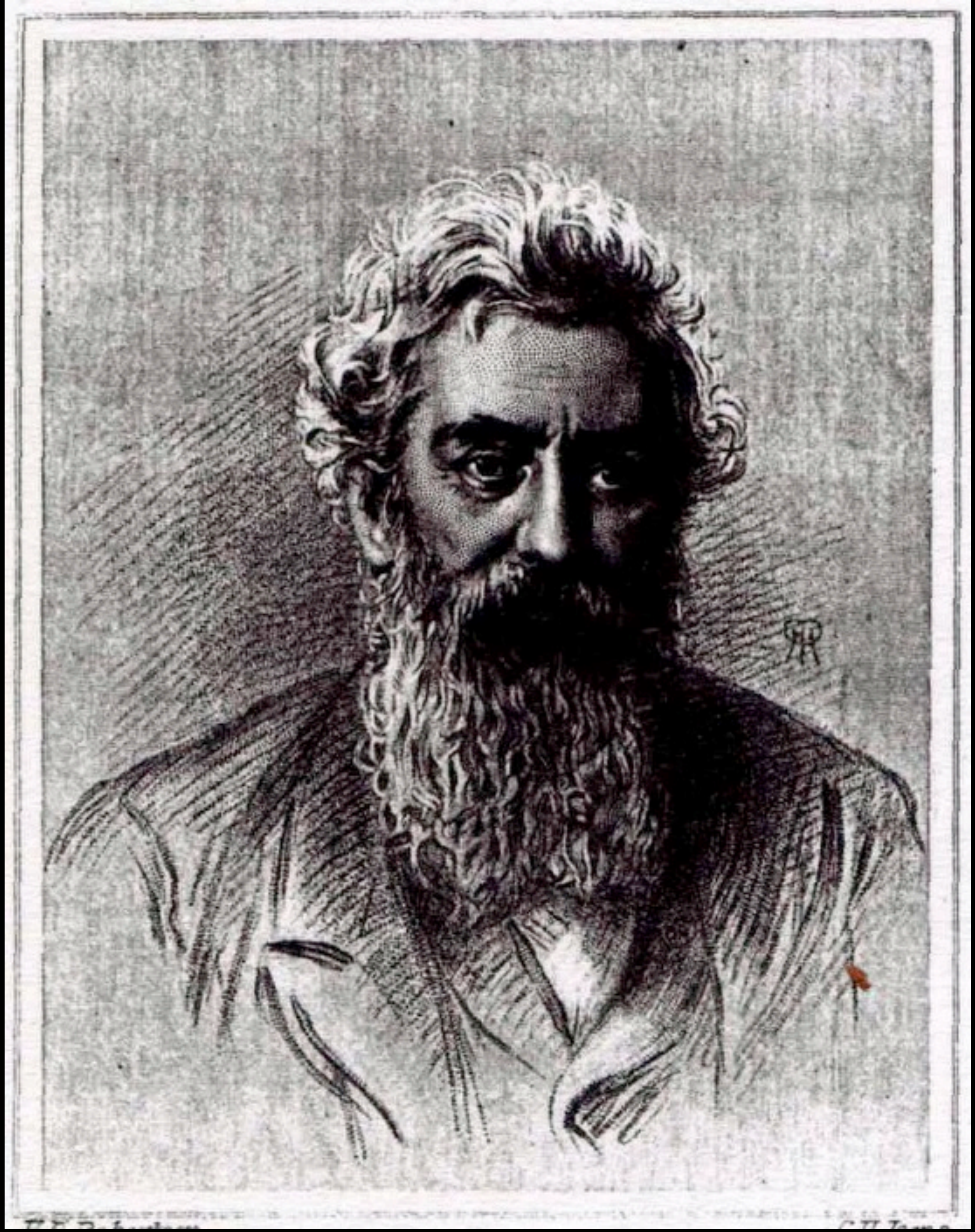
THE VIEW FROM 1945

GEORGE DYSON

SANDIA NATIONAL LABORATORIES
Neuro Inspired Computational Elements
25 February 2014

The difficulty is that most people who have been active in this field seem to believe that it is easier to write a new code than to understand an old one. . .

—John von Neumann, 23 April 1952



Alfred Smee (1818-1877)

INSTINCT AND REASON:

DEDUCED FROM

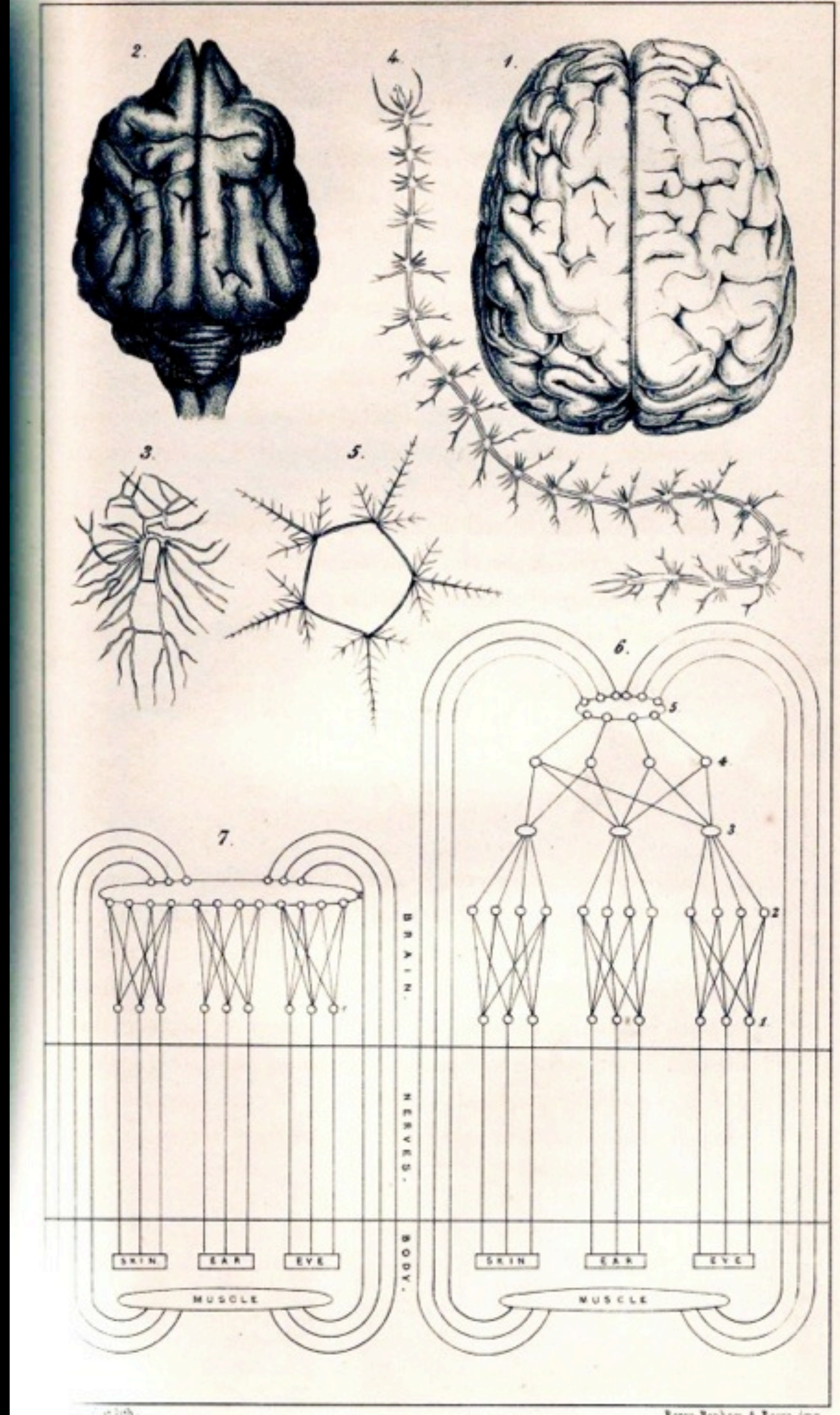
ELECTRO-BIOLOGY.

BY

ALFRED SMEE, F.R.S.

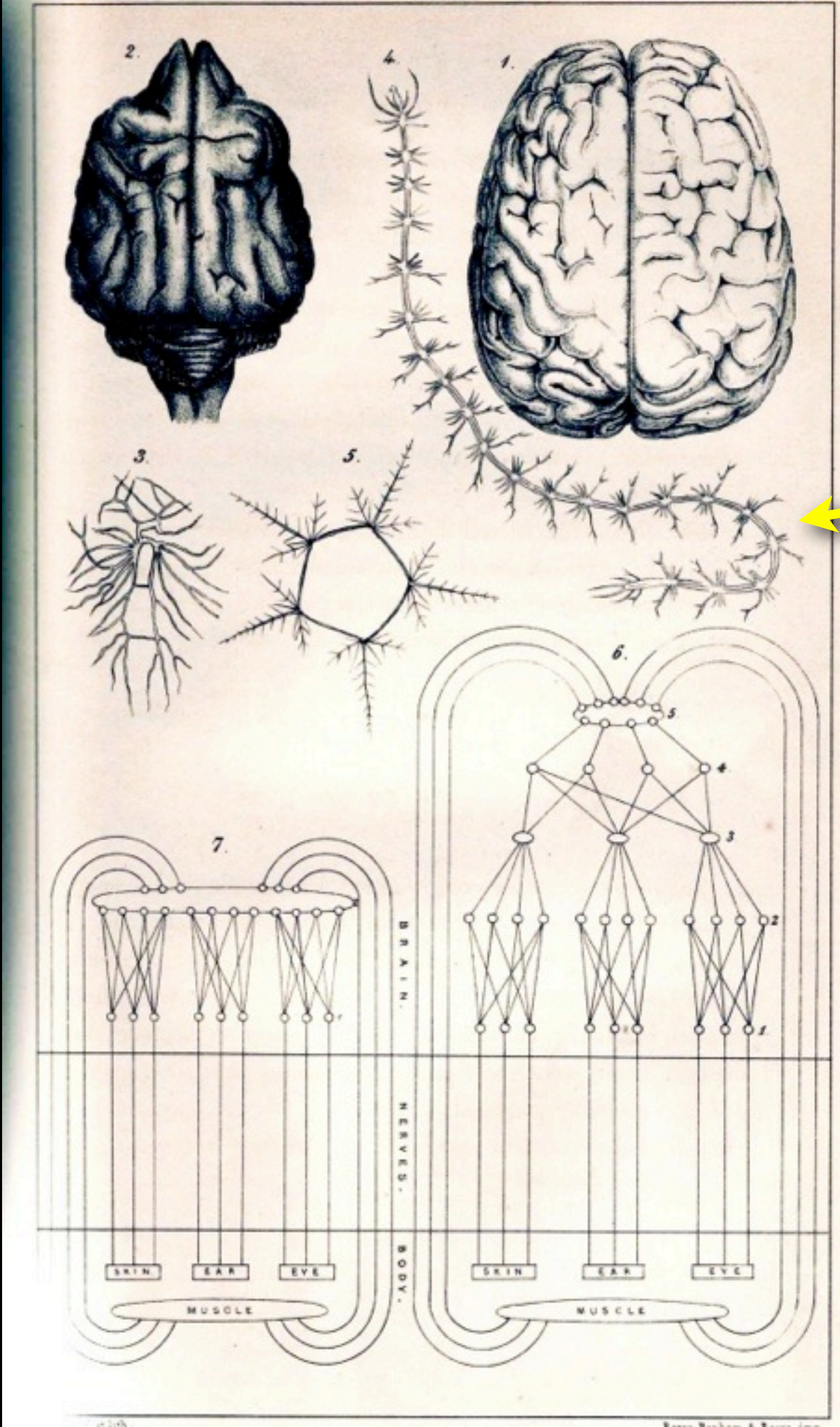
[1850]

[1850]



1.
2.
3.
4.
5.
6.
7.
BRAIN.
NERVES.
BODY.
SKIN
EAR
EYE
MUSCLE
SKIN
EAR
EYE
MUSCLE

[1850]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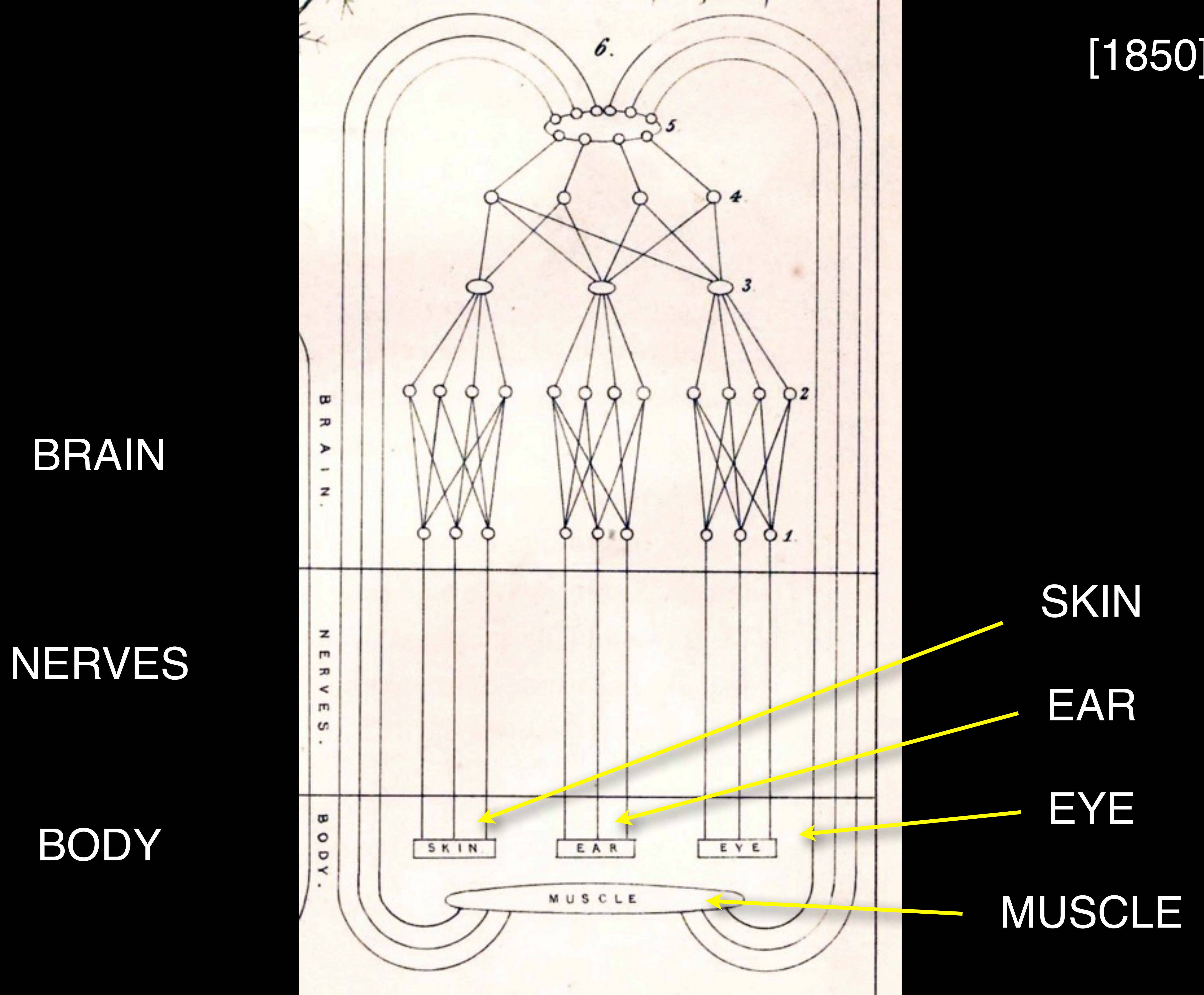
[1850]
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MUSCLE
BRAIN
NERVES
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EAR
EYE
MUSCLE

[1849]

PRINCIPLES

OF

THE HUMAN MIND,

DEDUCED FROM PHYSICAL LAWS;

TOGETHER WITH A LECTURE ON

ELECTRO-BIOLOGY,

OR

THE VOLTAIC MECHANISM OF MAN.

BY ALFRED SMEE, F.R.S.,

SURGEON TO THE ROYAL GENERAL DISPENSARY OF LONDON, AND LECTURER ON SURGERY, ETC., ETC.

22. When an image is produced by an action upon the external senses, the actions on the organs of sense concur with the actions in the brain; and the image is then a *Reality.*

23. When an image occurs to the mind without a corresponding simultaneous action of the body, it is called a *Thought.*

24. The power to distinguish between a thought and a reality, is called *Consciousness.*

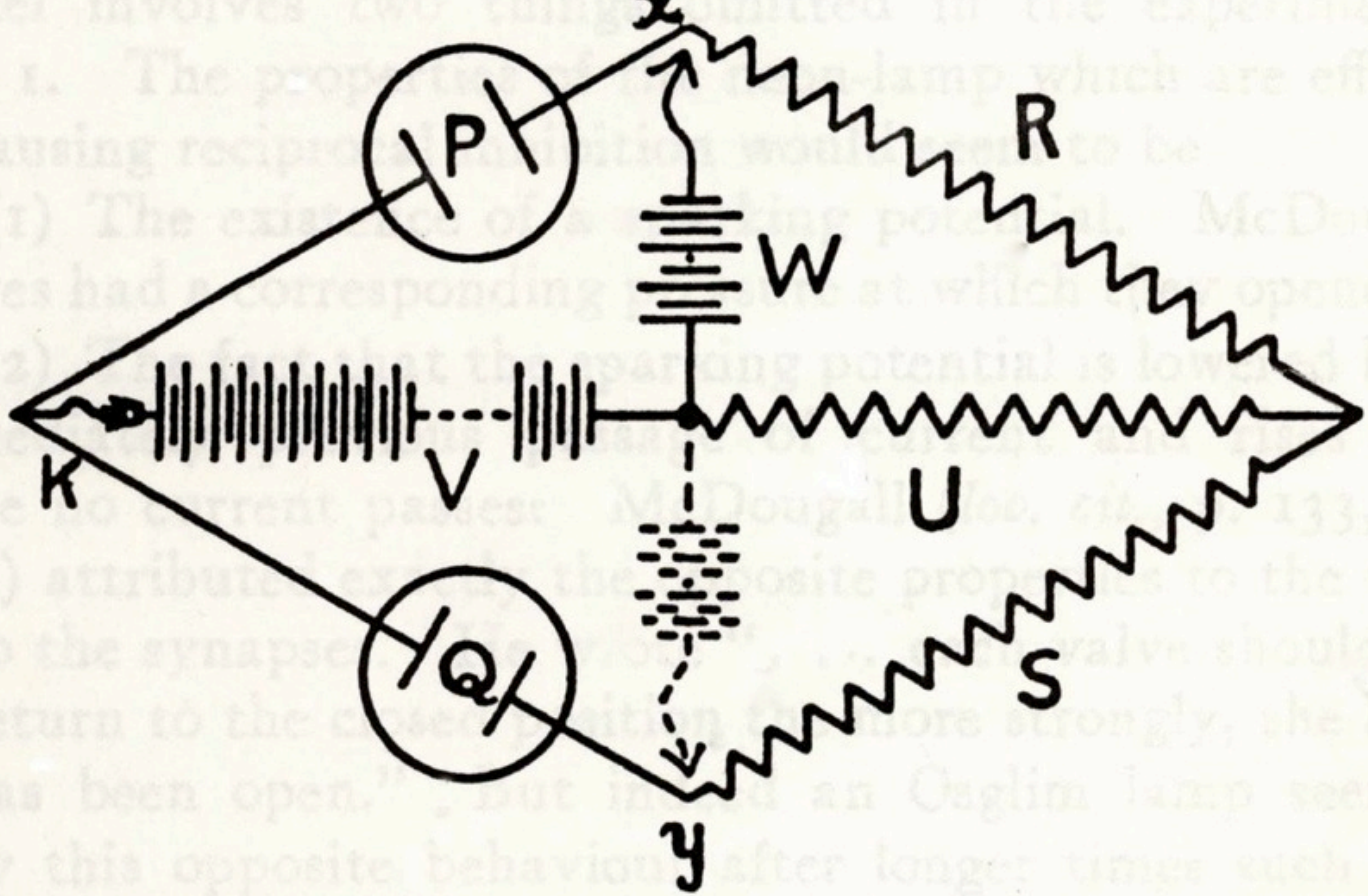


FIG. 1. Electrical Model illustrating a Mind having a Will but capable of only Two Ideas. See Analogies X., XI., XII., XIII.

[Lewis Fry Richardson, 1930]

Alan Turing
1912—1954

ON COMPUTABLE NUMBERS, WITH AN APPLICATION TO THE ENTSCHEIDUNGSPROBLEM

By A. M. TURING.

[Received 28 May, 1936.—Read 12 November, 1936.]

The "computable" numbers may be described briefly as the real numbers whose expressions as a decimal are calculable by finite means. Although the subject of this paper is ostensibly the computable *numbers*, it is almost equally easy to define and investigate computable functions of an integral variable or a real or computable variable, computable predicates, and so forth. The fundamental problems involved are, however, the same in each case, and I have chosen the computable numbers have valuable applications. In particular, it is shown (§ 11) that the Hilbertian Entscheidungsproblem can have no solution.

In a recent paper Alonzo Church† has introduced an idea of "effective calculability", which is equivalent to my "computability", but is very differently defined. Church also reaches similar conclusions about the Entscheidungsproblem‡. The proof of equivalence between "computability" and "effective calculability" is outlined in an appendix to the present paper.

1. *Computing machines*.

We have said that the computable numbers are those whose decimals are calculable by finite means. This requires rather more explicit definition. No real attempt will be made to justify the definitions given until we reach § 9. For the present I shall only say that the justification lies in the fact that the human memory is necessarily limited.

We may compare a man in the process of computing a real number to a machine which is only capable of a finite number of conditions $q_1, q_2, \ldots, q_R$ which will be called "m-configurations". The machine is supplied with a "tape" (the analogue of paper) running through it, and divided into

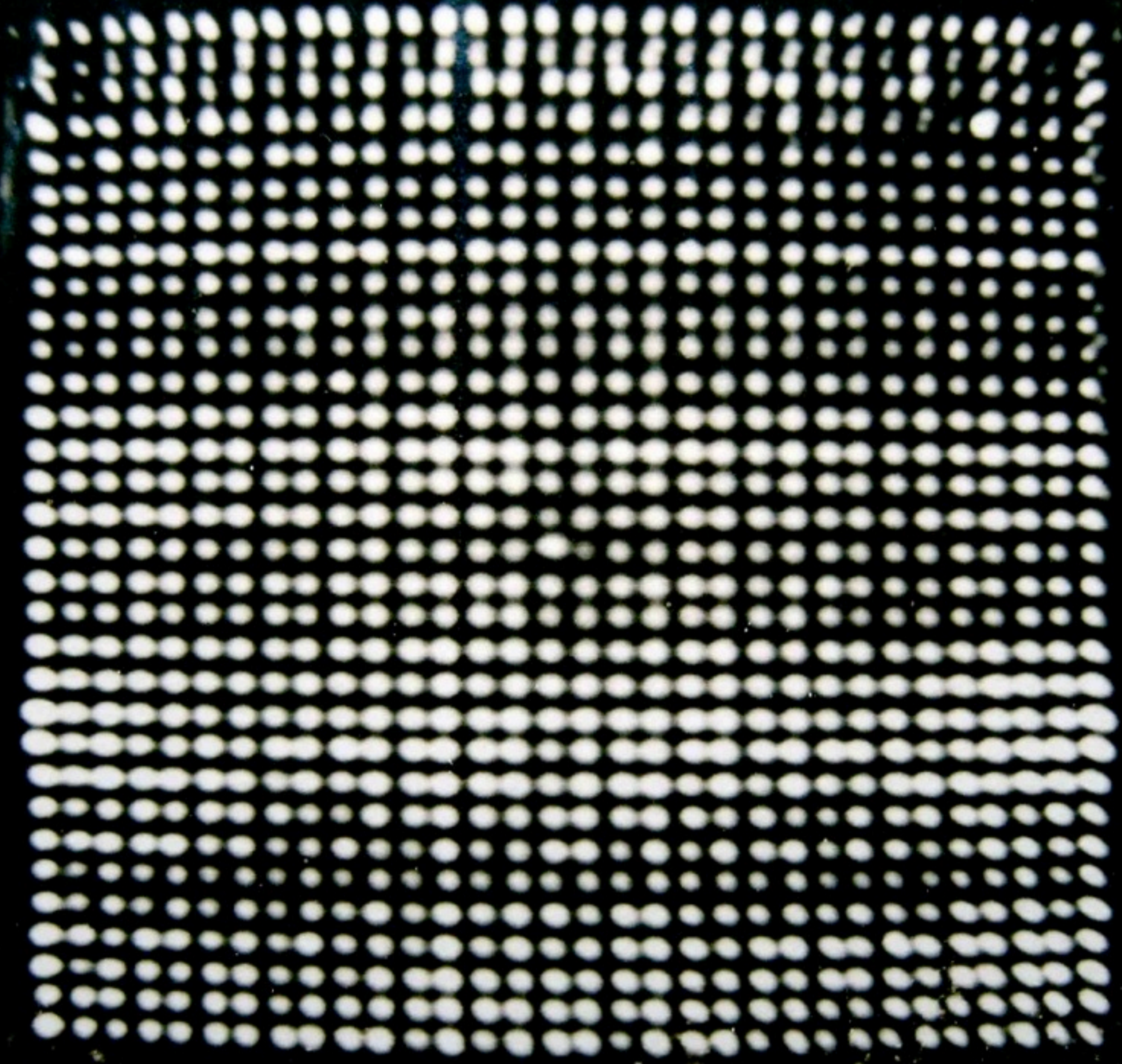
It is possible to invent a single machine which can be used to compute any computable sequence . . .

— Alan Turing, 1936

John von Neumann
1903—1957

Let the whole outside world consist of a long paper tape. . .

— John von Neumann, 1948



[11 February 1953]


1915
Aug 22.


Edward Teller
John von Neumann
Eugene Wigner
Mariette (Kövesi)
von Neumann
Mary (Wheeler) Wigner
Angela (Turinsky)
Robertson
H. P Robertson


LOS ALAMOS
PROJECT
MAIN GATE
PASSES MUST BE
PRESENTED TO
GUARDS

I arrived yesterday afternoon. The drive here was very impressive, across a number of good class canyons and mesas. The place is very strange, and living conditions are still quite simple, it is an odd combination of an Army Post, a Western national Park with Lodge, and a few assorted other things. It is worth meditating about, although one should probably not sell one's soul to it... (By the way: computers are, as you suspected, quite in demand here, too)

—John to Klára von Neumann, 22 September 1943

Report on

THE ENIAC

(Electronic Numerical Integrator and Computer)

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

MAINTENANCE MANUAL

RESTRICTED

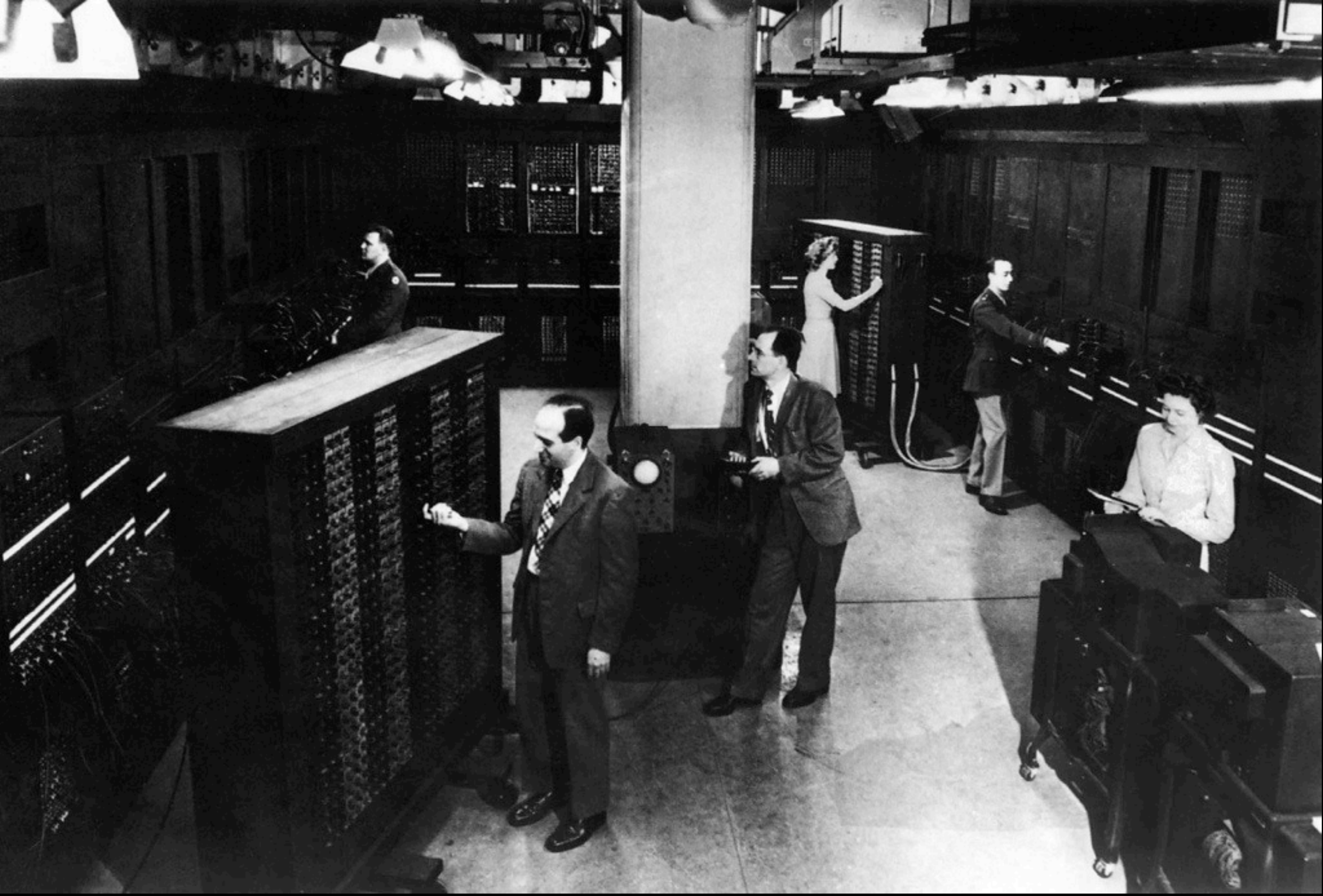
This document contains information affecting
the national defense of the United States
within the meaning of the Espionage Act, U.S.
C. 50: 31 and 32; its transmission or the
revelation of its contents in any manner to
an unauthorized person is prohibited by law.

UNIVERSITY OF PENNSYLVANIA

Moore School of Electrical Engineering

PHILADELPHIA, PENNSYLVANIA

June 1, 1946



[February 1946]

von Neumann Feynman Ulam [1949]

I am thinking about something much more important than bombs. I am thinking about computers.

— John von Neumann, 1946

[1945]

First Draft of a Report on the EDVAC

by

John von Neumann

Contract No. W-670-ORD-4926

Between the

United States Army Ordnance Department

and the

University of Pennsylvania

Moore School of Electrical Engineering
University of Pennsylvania

June 30, 1945

4.0 Elements, Synchronism Neuron Analogy

4.1 We begin the discussion with some general remarks:

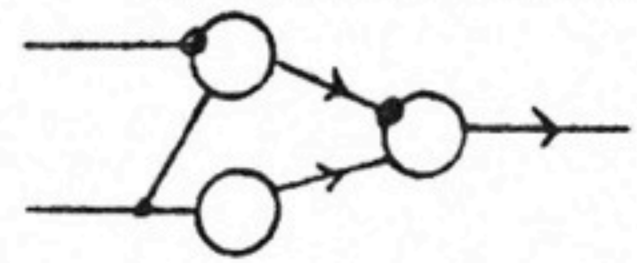
Every digital computing device contains certain relay like elements, with discrete equilibria. Such an element has two or more distinct states in which it can exist indefinitely. These may be perfect equilibria, in each of which the element will remain without any outside support, while appropriate outside stimuli will transfer it from one equilibrium into another. Or, alternatively, there may be two states, one of which is an equilibrium which exists when there is no outside

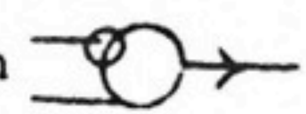
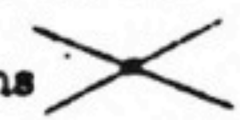
4.2 It is worth mentioning, that the neurons of the higher animals are definitely elements in the above sense. They have all-or-none character, that is two states: Quiescent and excited. They fulfill the requirements of 4.1 with an interesting variant: An excited neuron emits the standard stimulus along many lines (axons). Such a line can, however, be connected in two different ways to the next neuron: First: In an excitatory synapsis, so that the stimulus causes the excitation of that neuron. Second: In an inhibitory synapsis, so that the stimulus absolutely prevents the excitation of that neuron by any stimulus on any other (excitatory) synapsis. The neuron also has a definite reaction time, between the reception of a stimulus and the emission of the stimuli caused by it, the synaptic delay.

Following W. Pitts and W. S. MacCulloch ("A logical calculus of the ideas immanent in nervous activity", Bull. Math. Biophysics, Vol. 5 (1943), pp 115-133) we ignore the more complicated aspects

It should be observed, that the authors quoted above have shown, that most of these elements can be built up from each other. Thus O→→ is clearly equivalent to O→O→, and in the case of (2)→ at least = (2) →→ is equivalent to the network of Figure 2, However, it would seem to be misleading in our application, to represent these functions as if they required 2 or 3 E-elements, since their complexity in a vacuum tube realization is not essentially greater than that of the simplest E-element O→, cf. .

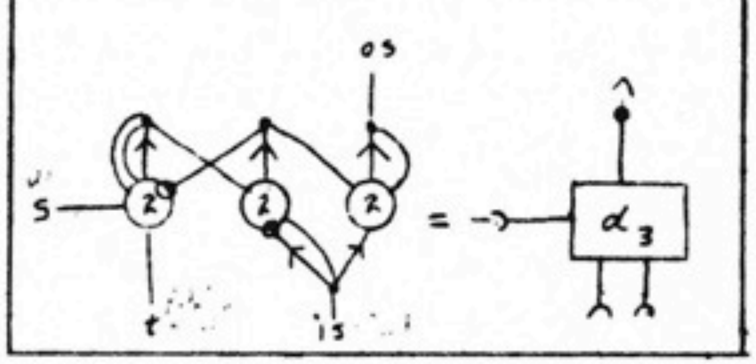
FIGURE 2



We conclude by observing that in planning networks of E-elements, all backtracks of stimuli along the connecting lines must be avoided. Specifically: The excitatory and the inhibitory synapses and the emission points---that is the three connections on  --- will be treated as one-way valves for stimuli---from left to right in the above picture. But everywhere else the lines and their connections  will be assumed to pass stimuli in all directions. For the delays  either assumption can be made, this last point does not happen to matter in our networks.

A <u>discriminator</u> is shown on Figure 8. A stimulus at the input t defines the moment at which the stimulus, which determines whether the later emission (at os) shall take place

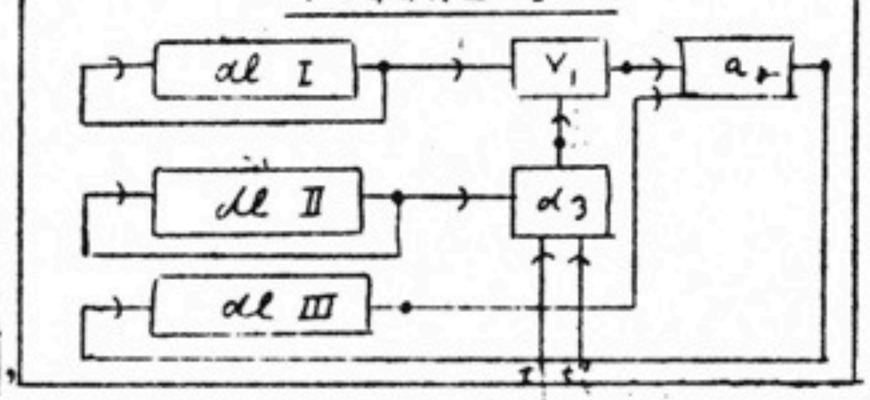
FIGURE 6



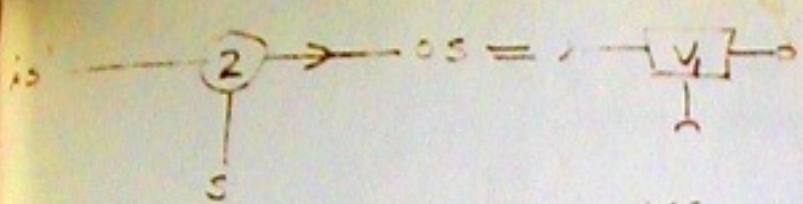
at all, must be received at the inputs. If these two stimuli coincide, the left (2) is excited. Considering its feedback, it will remain excited until it secceeds in stimulating the middle (2) . The middle (2) is connected to (is) in such a manner that it can be excited by the left (2) only at a moment at which (is) is stimulated, but at whose predecessor (is) was not stimulated--that is at the beginning of a sequence of stimuli at (is) . The middle (2) then quenches the left (2) , and together with (is) excites the right (2) . The middle (2) now becomes and stays quiescent until the end of this sequence of stimuli at (is) and beyond this, until the beginning of the next sequence. Hence the left (2) is isolated from the two other (2) , and thereby is ready to register the s, t stimuli for the next (is) sequence. On the other hand the feedback of the right (2) is such, that it will stay excited for the duration of this (is) sequence, and emit stimuli at os. There is clearly a delay 2t between the input at (is) and the output at os.

Now the <u>multiplier</u> network can be put together: Figure 9. The multiplicand circulates through [dl I] , the multiplier through [dl II],

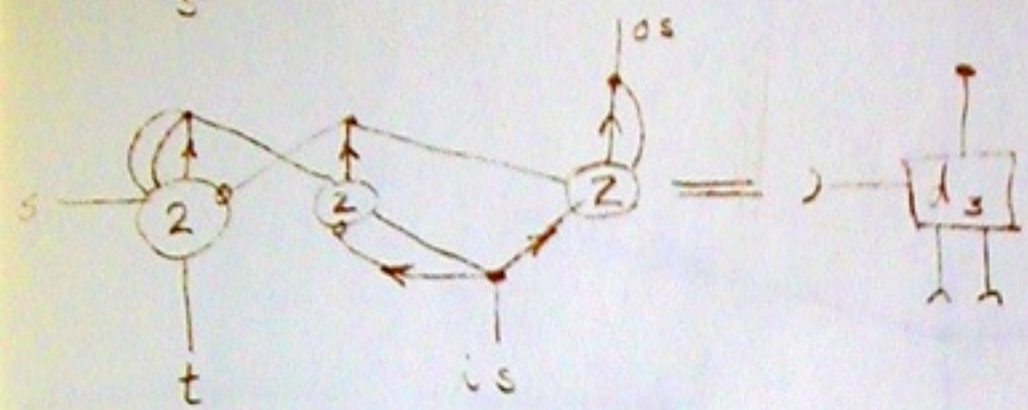
FIGURE 9



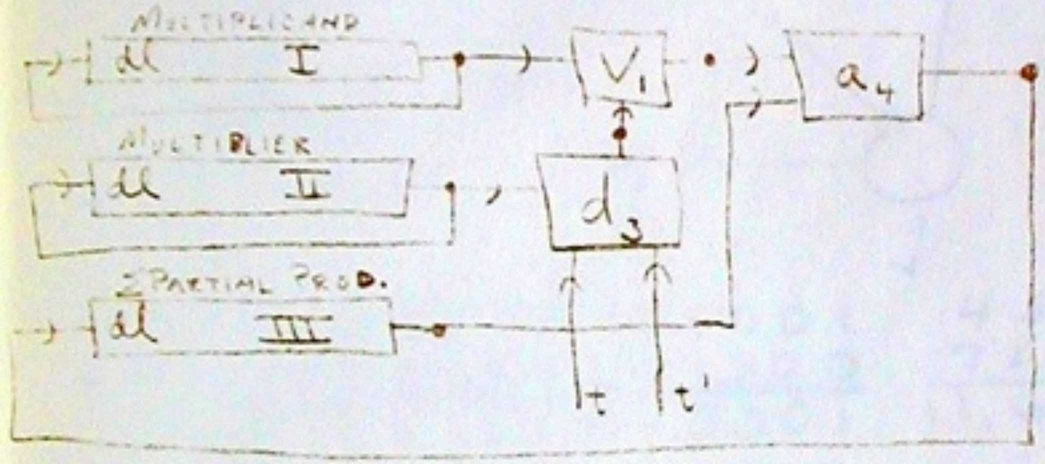
[June 1945]



Valve



Discriminator



Multiplier

361 ← MULTIPLICAND → 101101001
557 ← MULTIPLIER → 1000101101

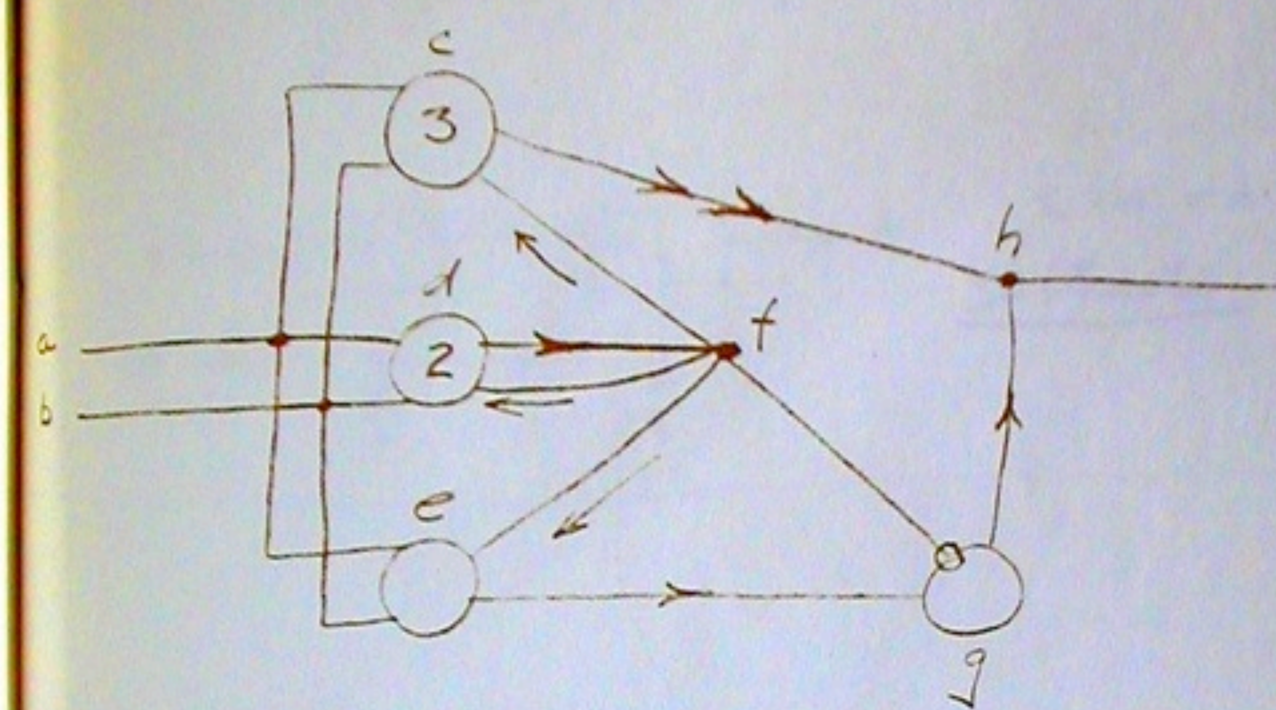
361	101101001	1
557	10110100100	4
2527	11100001101	16
1805	101101001000	32
1805	1001001010101	64
201,077	10110100100000	256
	11111101110101	4096
	101101001000000000	65536
	110001000101110101	131,072
		201,077

Left digit designates sign: 0 +, 1 −

P28 ? 29 ?

[June 1945]

ADDER




```
a  1000100001001     4361
b  1110001001000     7240
  10110101010001   11,601
```

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
a	✓	–	–	✓	–	–	–	–	✓	–	–	–	✓	–	X	X					
b	–	–	–	✓	–	–	✓	–	–	–	✓	✓	✓	–	X	X					
c	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–					
d	+	–	–	✓	–	–	–	–	–	–	–	–	✓	–	–	–					
e	✓	+	–	✓	✓	–	✓	–	✓	–	✓	✓	✓	✓	–	–					
f	–	–	–	–	✓	–	–	–	–	–	–	–	–	✓	–	–					
g	–	✓	–	–	–	✓	–	✓	–	✓	–	✓	✓	–	✓	–					
h	–	–	✓	–	–	+	✓	–	✓	–	✓	–	✓	✓	–	✓					
			1	0	0	0	1	0	1	0	1	0	1	1	0	1					

←

CorM { CA — Central Arithmetical Part (+, −, ×, ÷, $\sqrt{\ }$, $\sqrt[3]{\ }$, ln

CC — Central control (coded general control)

M — Memory (intermediate steps of CA, instructions from CC, specific functions, boundary values, steps of successive approx.

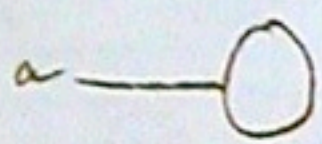
R — Recording medium (cards, tape

I — Input (usually from R to M)

O — Output (" " M to R)

delay t seconds ($\approx 10^{-6}$ sec) ; clock pulses $\frac{1}{5t}$ to $\frac{1}{2t}$, every $\frac{1}{t}$

E 

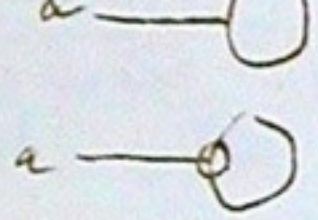
 Excited by pulse from a (Thresholds 1, 2, 3)

 Inhibited " " " a (Absolute inhibition)

 left to right only

"Standard number" 30 binary digits

[1945]



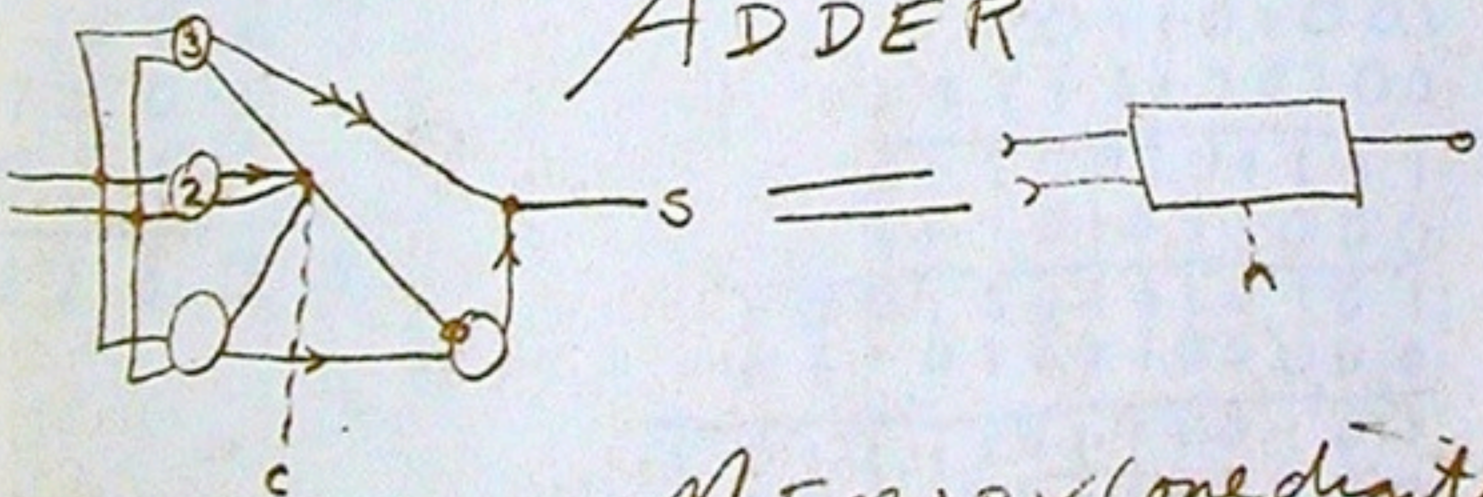
Excited by ...

Inhibited " " " a (Absolute inhibition)

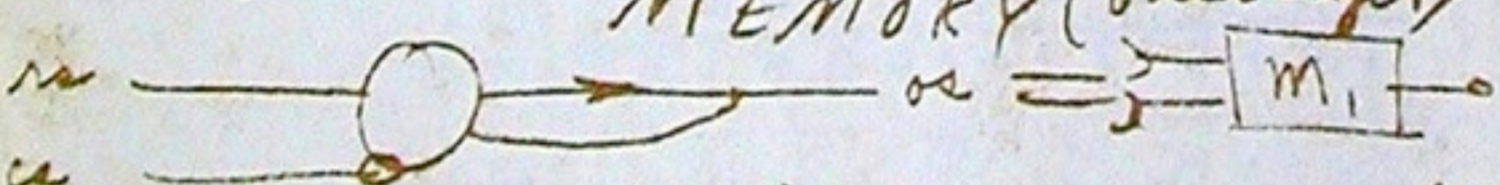
→ left to right only

"Standard number" 30 binary digits

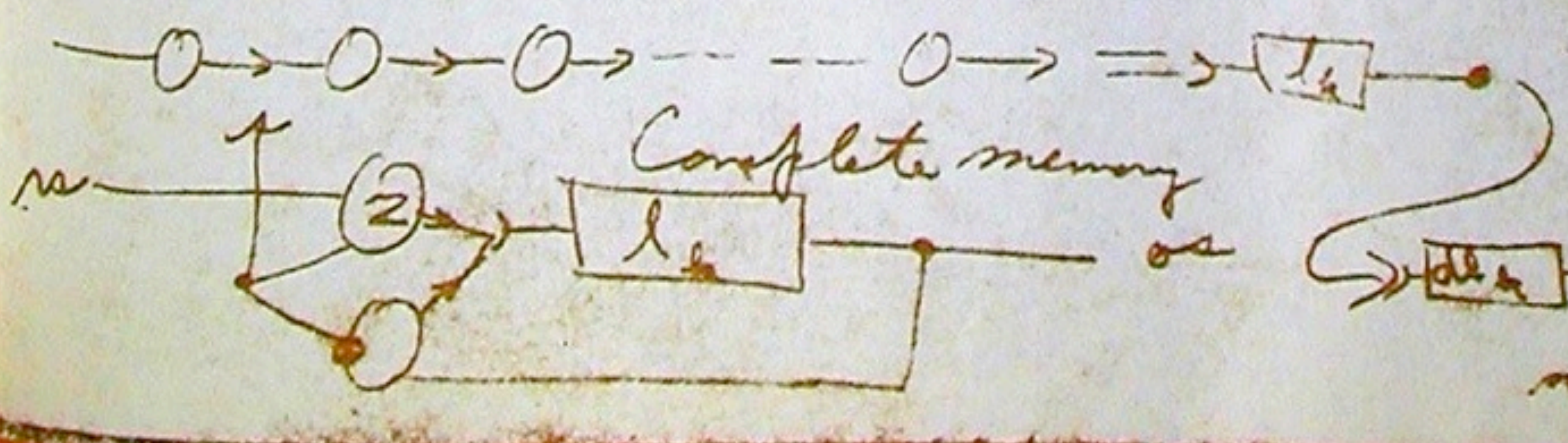
ADDER



MEMORY (one digit)



K units to remember k digits



(a tape or other or E-acting device)

The solution to which we allude must be sought along the lines of the iconoscope. This device in its developed form remembers the state of - 400 x 500 = 200,000 separate points, indeed it remembers for each point more than one alternative. As it is well known, it remembers whether each point has been illuminated or not, but it can distinguish more than two states: Besides light and no light it can also recognize--at each point--several intermediate degrees of illumination. These memories are placed on it by a light beam, and subsequently sensed by an electron beam, but it is easy to see that small changes would make it possible to do the placing of the memories by an electron beam also.

Thus a single iconoscope has a memory capacity of the same order as our desideratum for the entire M (-250,000), and all memory units are simultaneously accessible for input and output. The

He was in the right place at the right time with the right connections with the right idea, setting aside the hassle that will probably never be resolved as to whose ideas they really were. . .

—Willis Ware

Between 1946 and 1955 we crossed the country twenty-eight times by car...

—Klari von Neumann

Vladimir Kosma Zworykin, 1889-1982

OUTLINE OF WEATHER PROPOSAL

by

V. K. Zworykin

October, 1945

RCA LABORATORIES

RADIO CORPORATION OF AMERICA

PRINCETON N.J.

The importance of accelerating approximating and computing mathematics by factors like 10,000 or more, lies not only in that one might thereby do in 10,000 times less time problems which one is now doing, or say 100 times more of them in 100 times less time—but rather in that one will be able to handle problems which are considered completely unassailable at present.

— John von Neumann to Lewis L. Strauss,
20 October 1945

MINUTES OF E.C. MEETING

Date - November 12, 1945

Time - 12:45 P.M.

Place - Office of V. K. Zworykin

Present: G. W. Brown - RCA Laboratories
H. H. Goldstine - Army Ordnance Department
J. von Neumann - Institute for Advanced Study
J. A. Rajchman - RCA Laboratories
J. W. Tukey - Princeton University
A. W. Vance - RCA Laboratories
V. K. Zworykin - RCA Laboratories

I. Organization Discussion

J.W.T. will continue, for the present, at least, to contribute 2 days per week to the Bell Laboratories, with the expectation that no conflict with RCA will result. J.W.T. will

This [modular] sort of design is favorable for mass production...

'Words' coding the orders are handled in the memory just like numbers...

— First meeting of the IAS Electronic Computer Project, November 12, 1945

The Selective Electrostatic Storage Tube

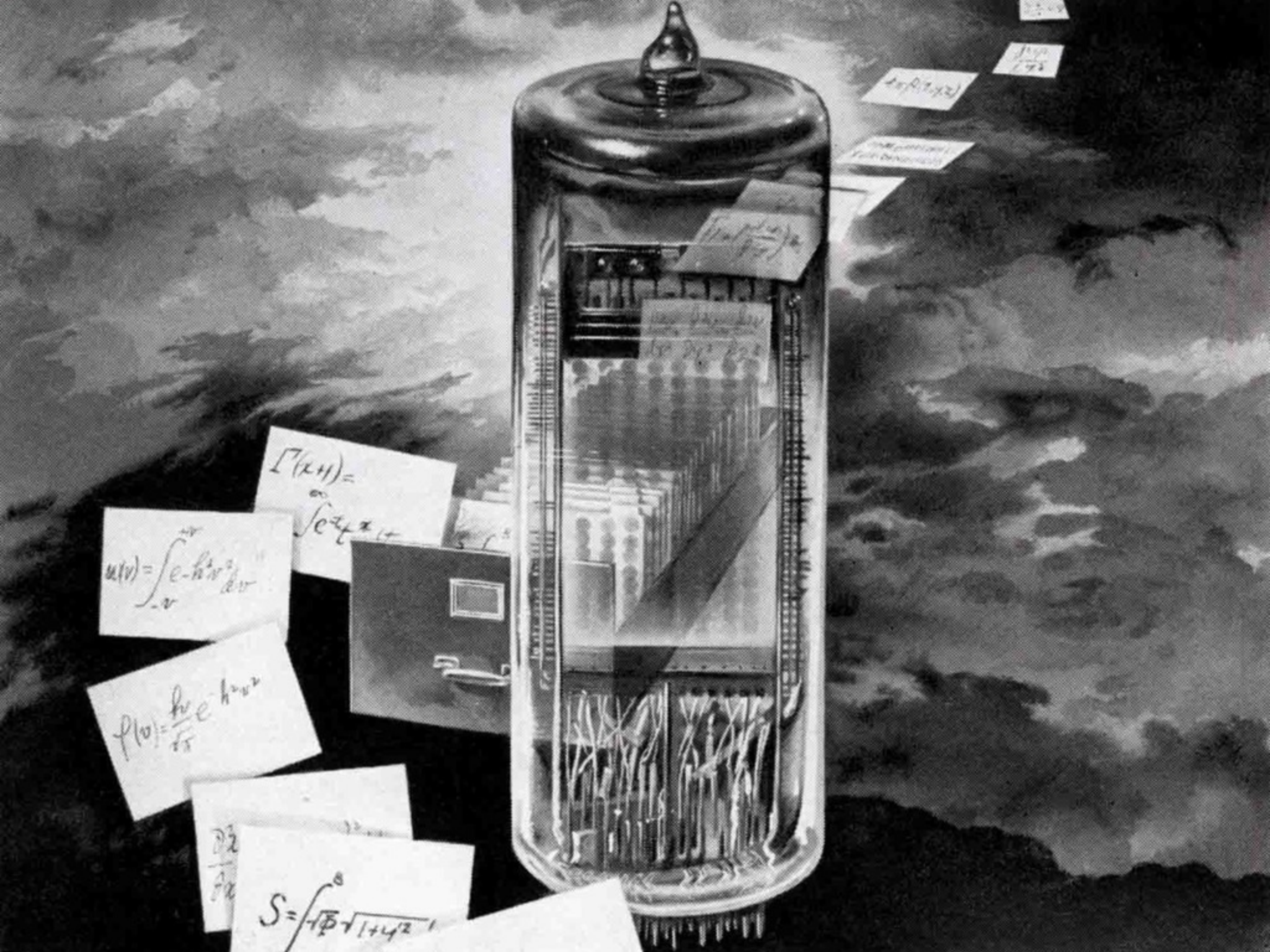
by

J. Rajchman

Reprinted from RCA REVIEW
March 1951, Vol. XII, No. 1

PRINTED IN THE U.S.A.

RADIO CORPORATION OF AMERICA
RCA LABORATORIES DIVISION
PRINCETON N.J.



[28 June 1946]

PRELIMINARY DISCUSSION OF THE LOGICAL DESIGN OF AN ELECTRONIC COMPUTING INSTRUMENT

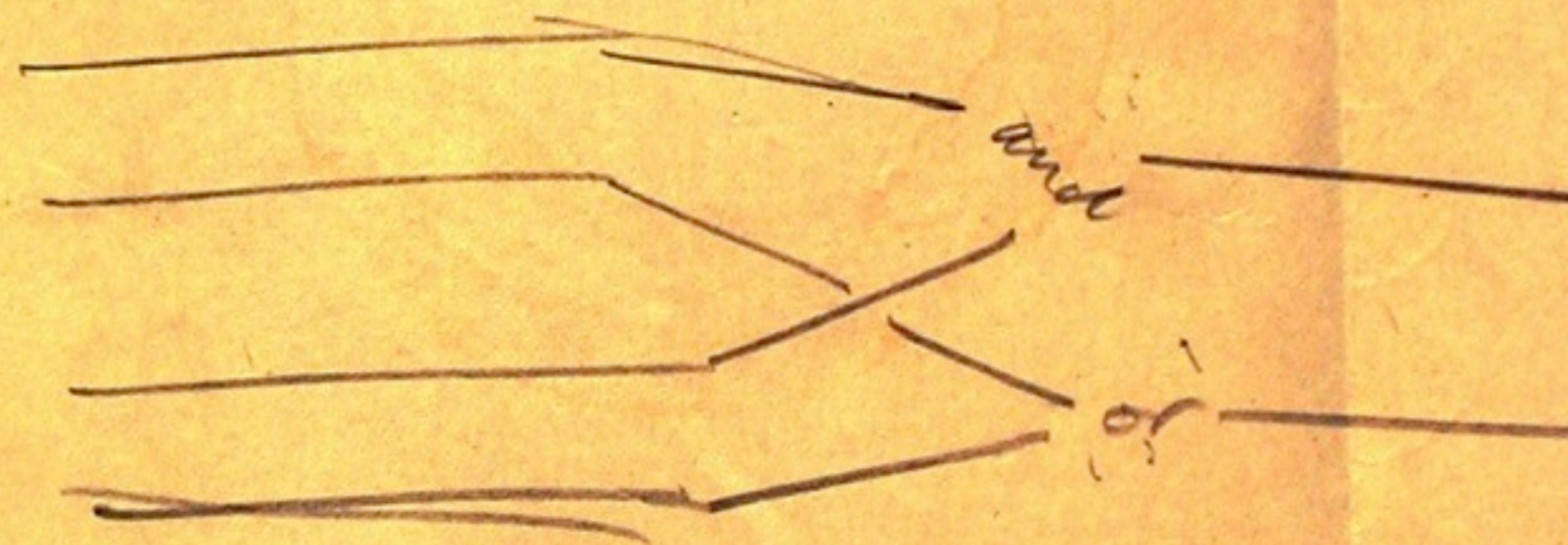
BY

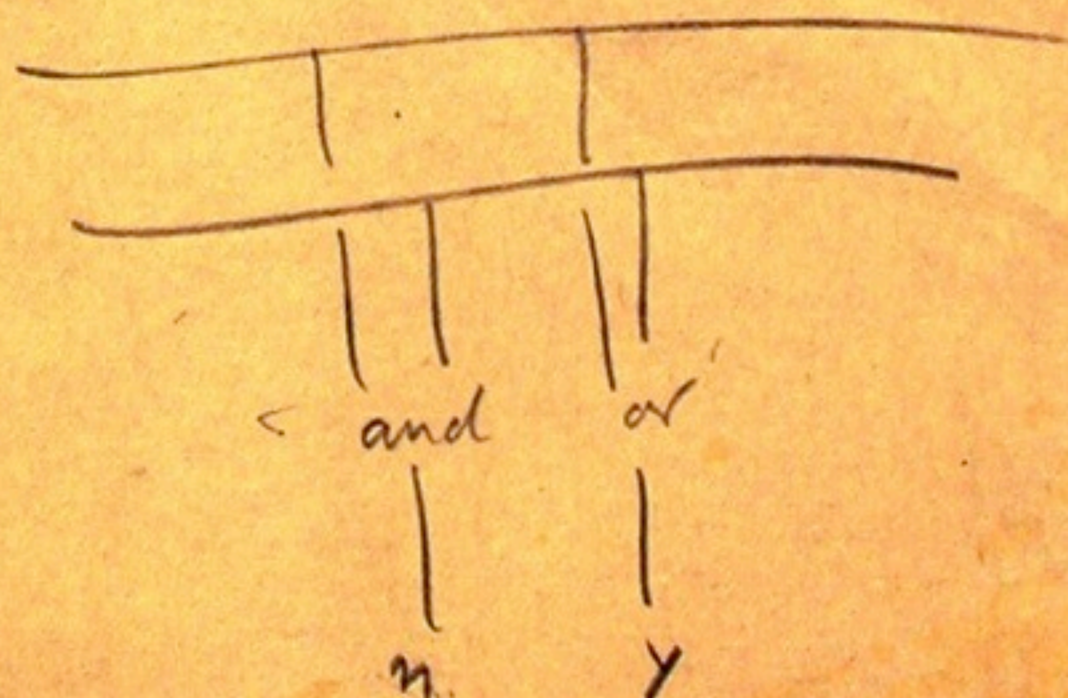
Arthur W. Burks

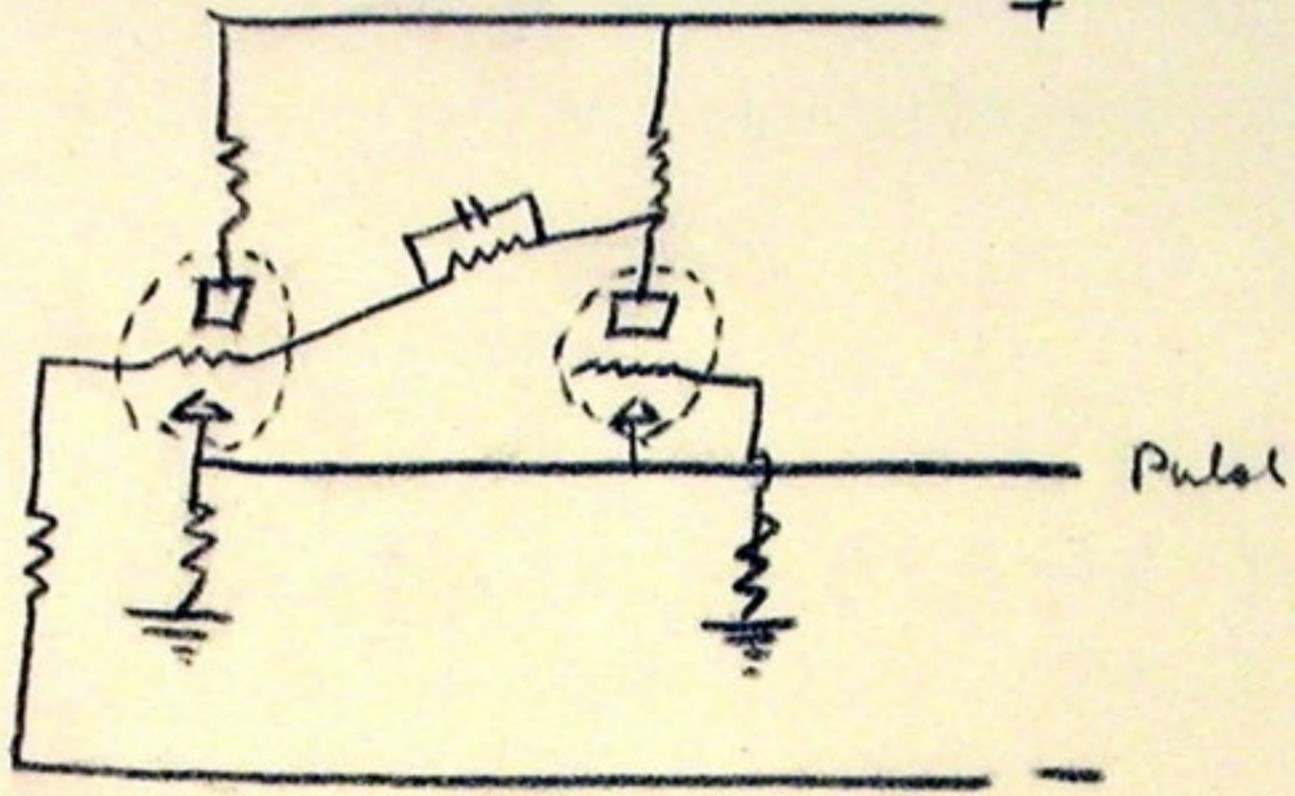
Herman H. Goldstine

John von Neumann

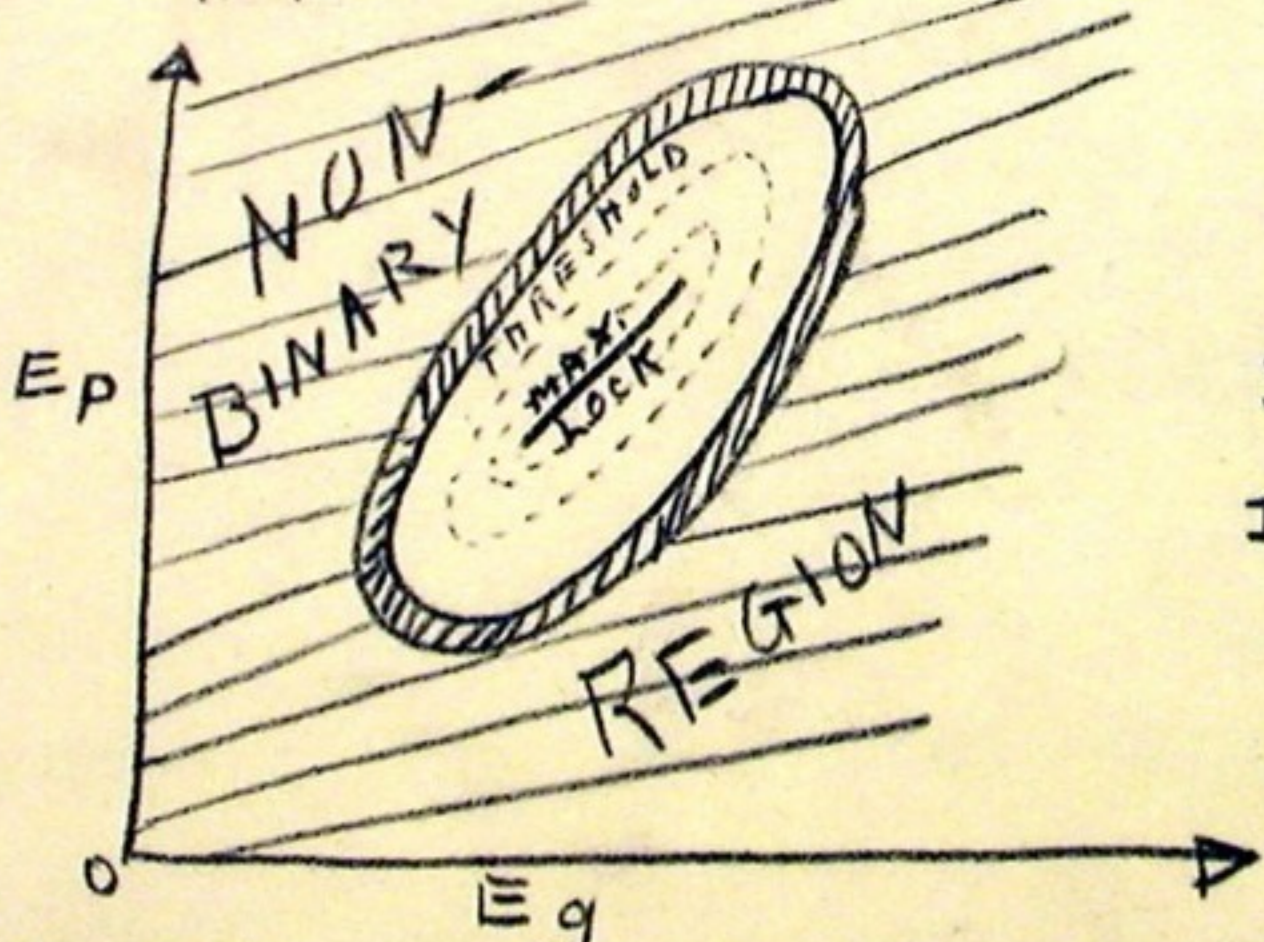
and

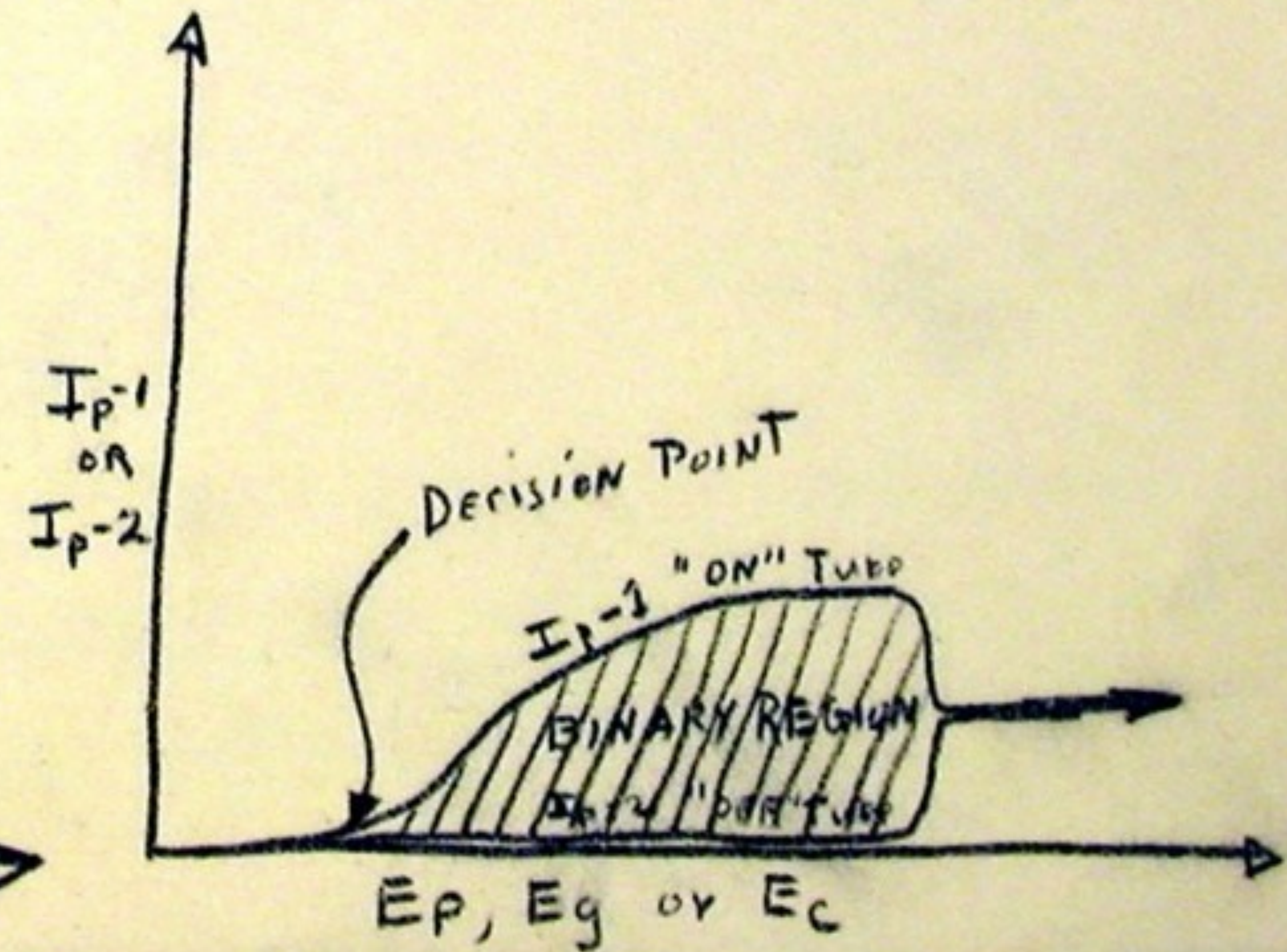






③ Electron-Tube Binary Cell Stability

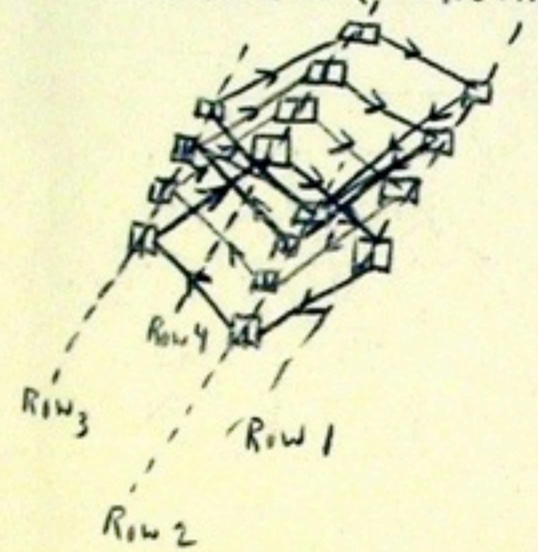




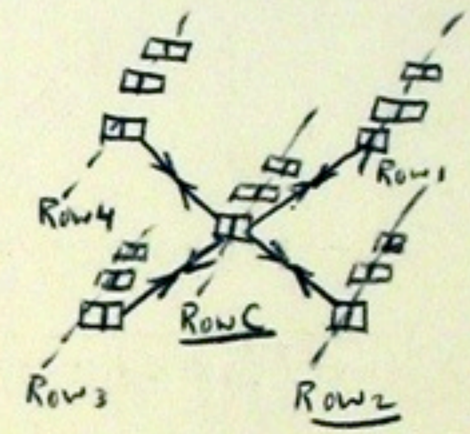
SKETCH 7 CONTINUED

D. Typical Combinations of Communicative Banks of Cells

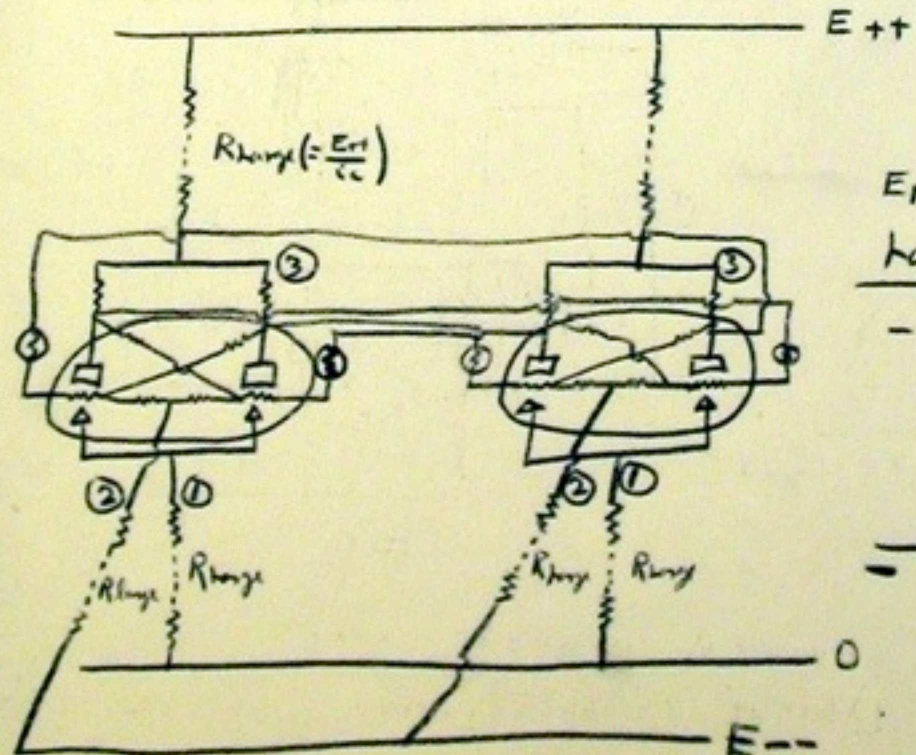
Circular, Exchange



CENTRAL EXCHANGE

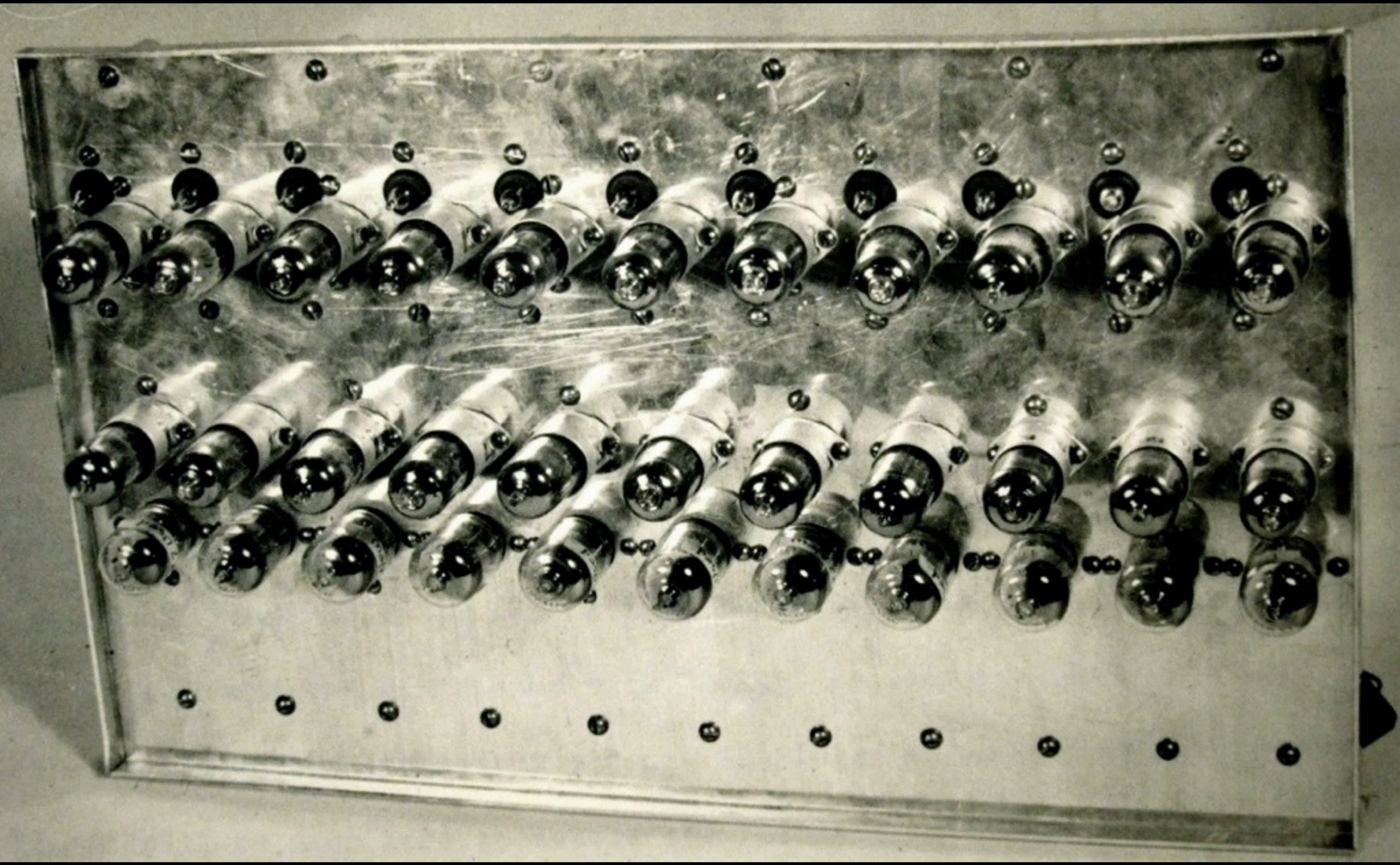


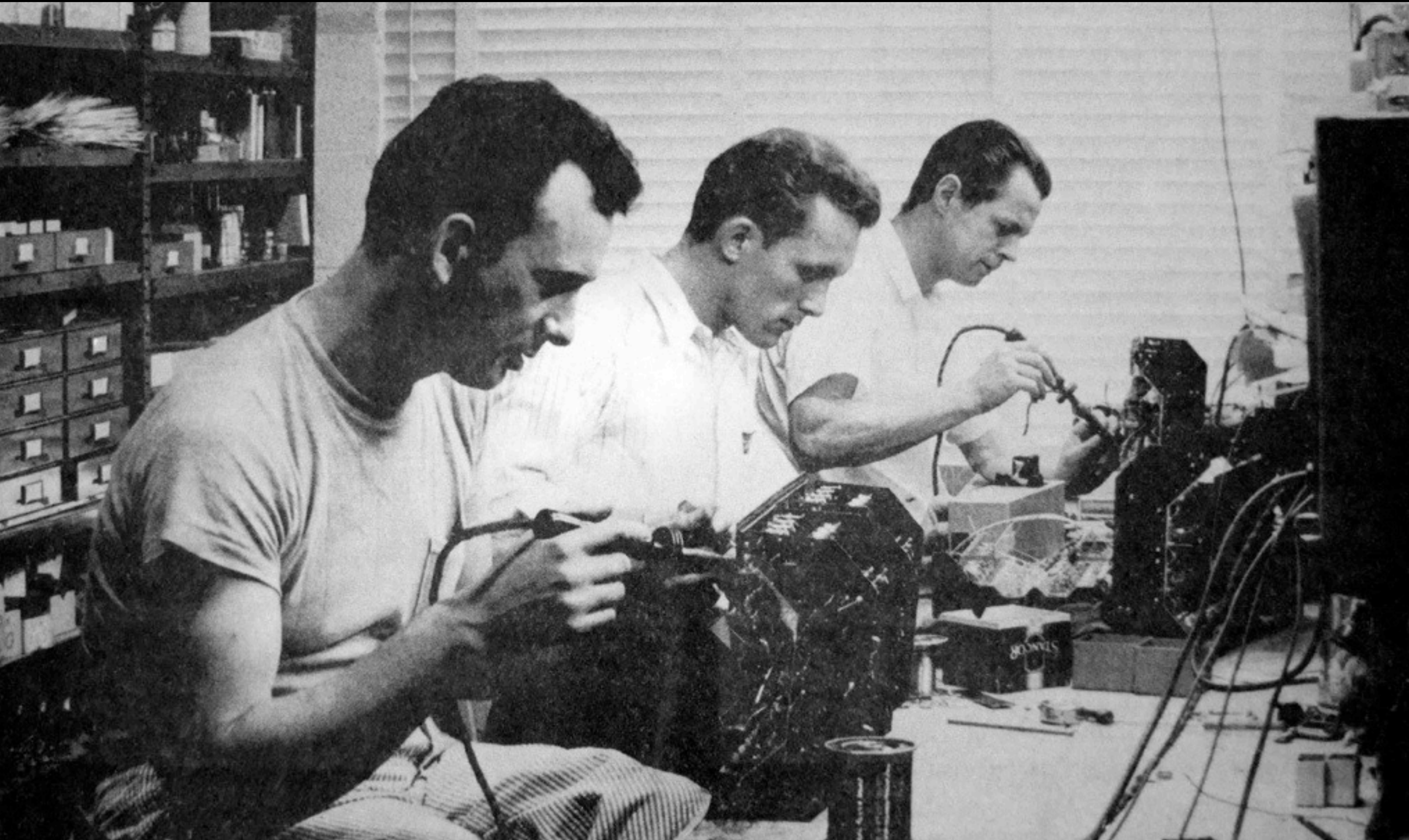
E.

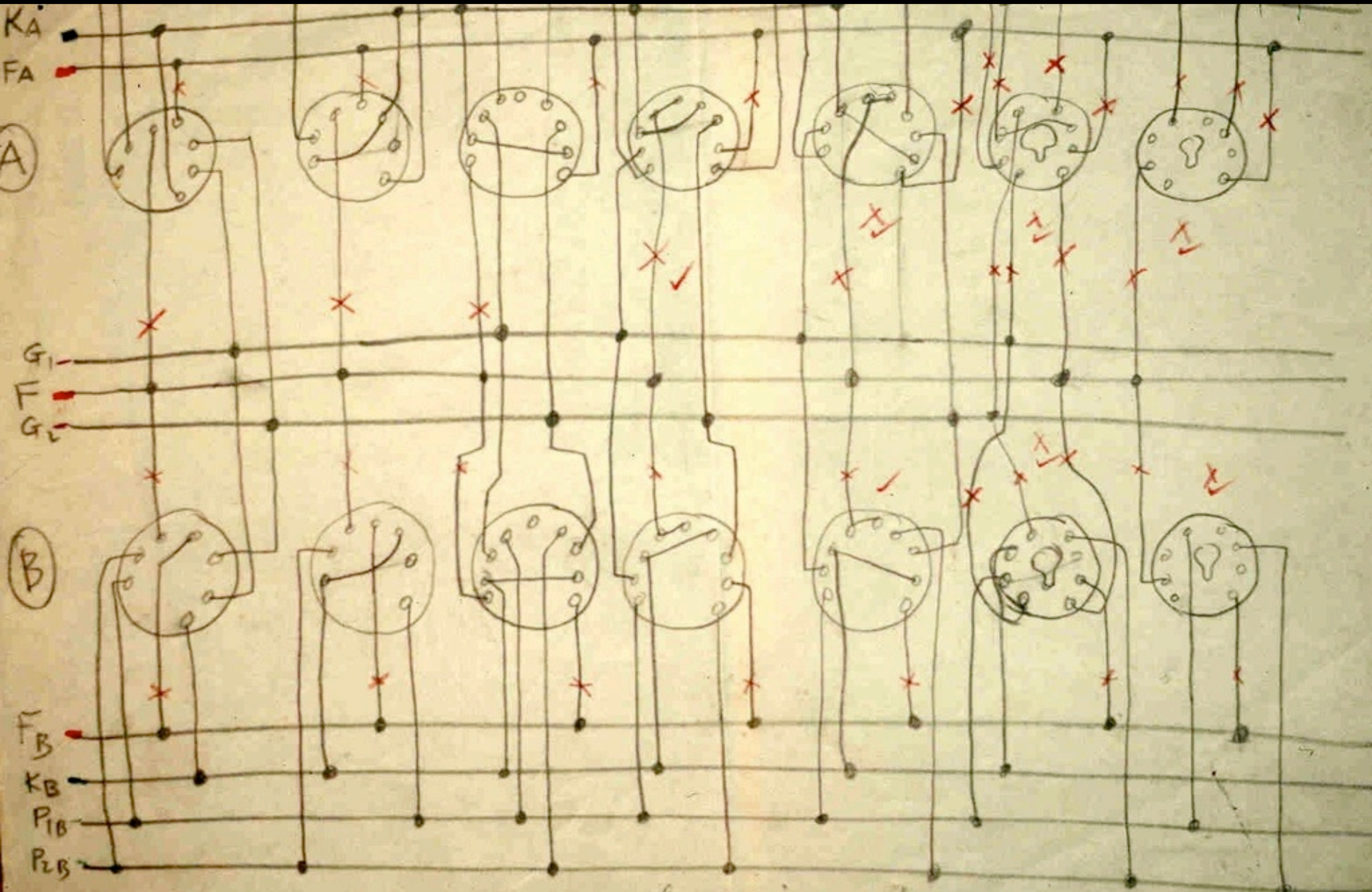


Circuit To Illustrate Effects of swinging Locked Binary cells

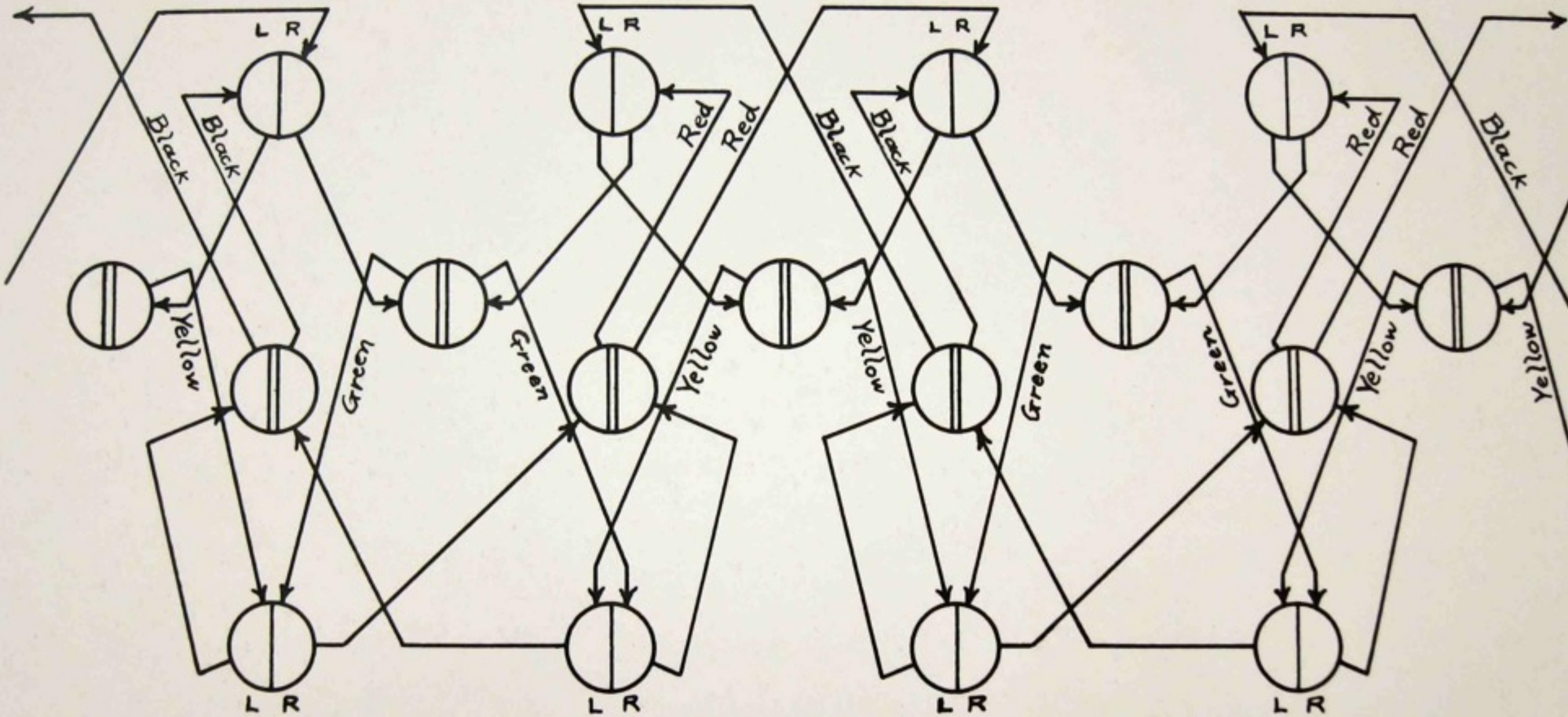
- Translation by Swinging points ①, ②, ③ simultaneously Does NOT Tend to unlock Toggle.
- Relative Shift of points ① and ② and ③ Does Affect Lock Threshold of Toggle



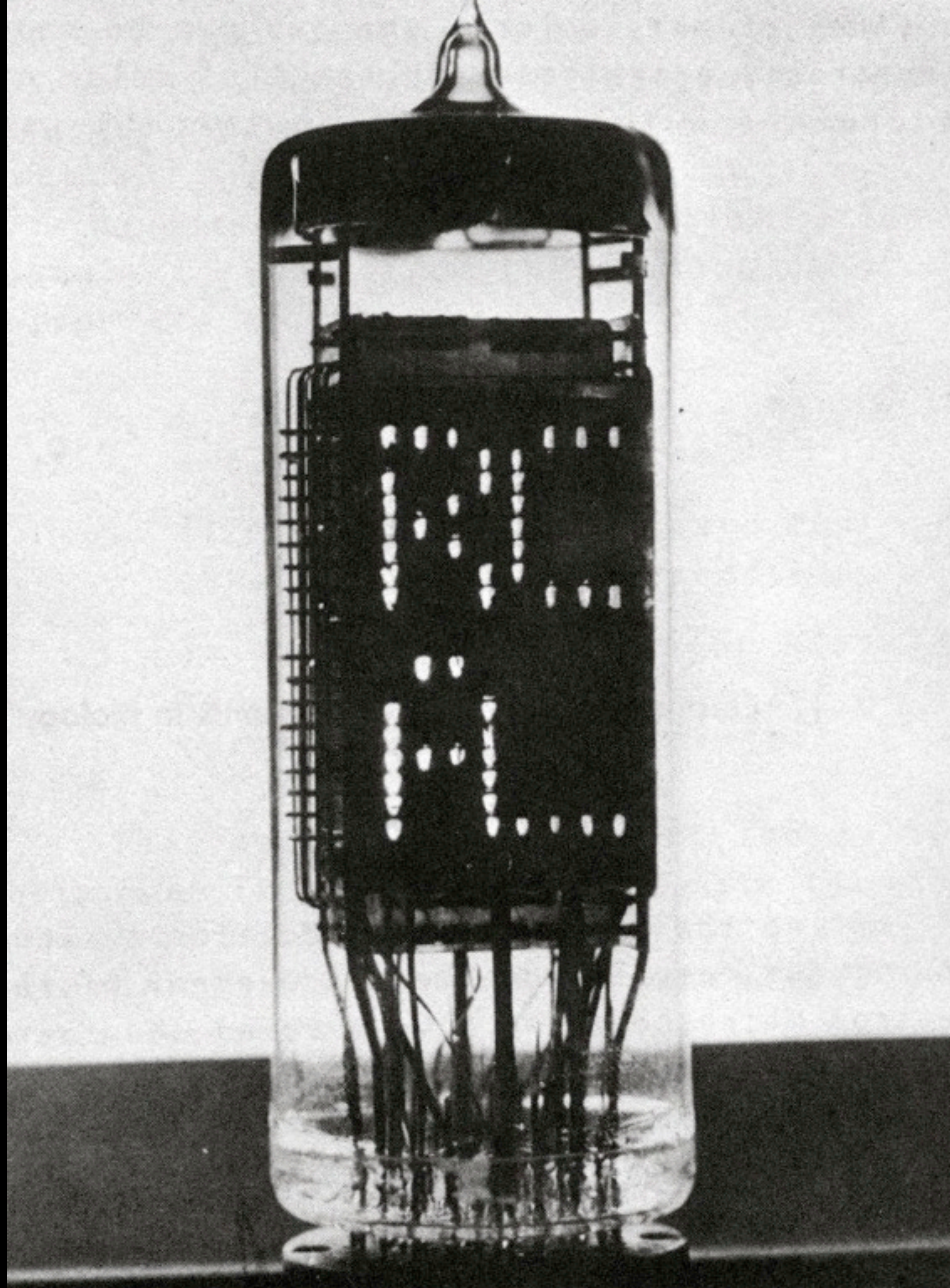


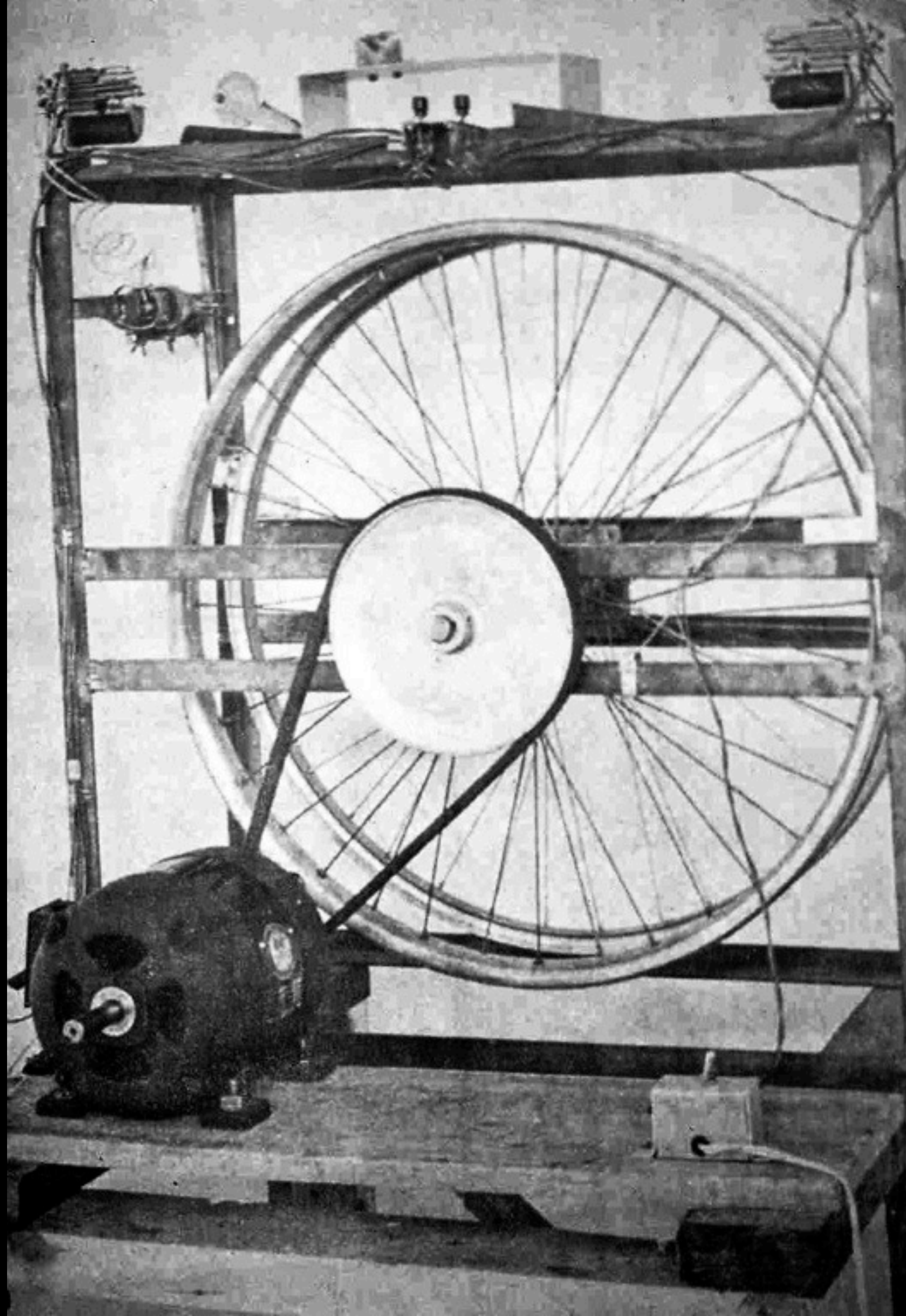


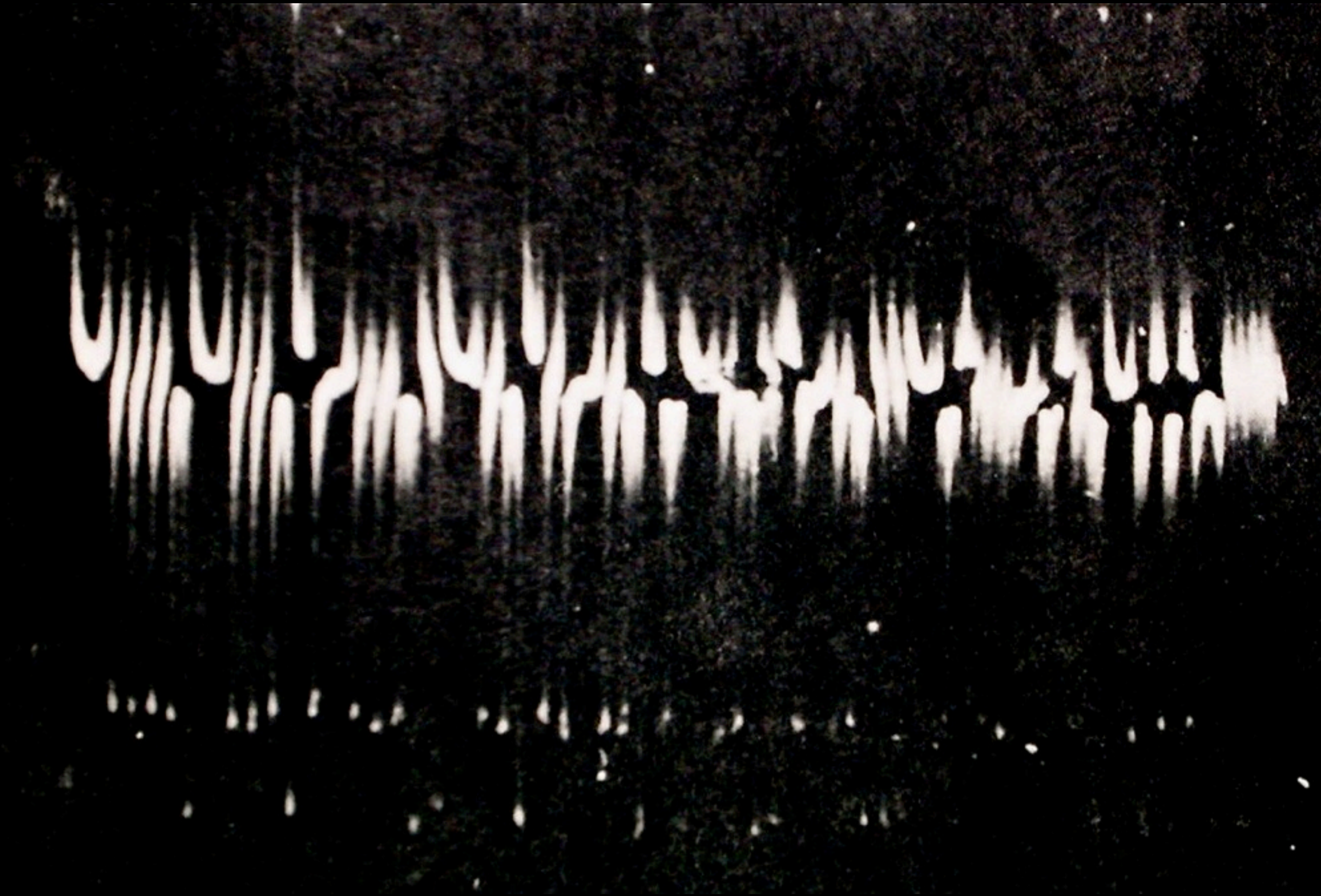
Fred: If you have time, please
1. tighten all nuts.



ELECTRONIC COMPUTER PROJECT Institute for Advanced Study Princeton, N.J.		
SHIFTING REGISTER No. 7 FUNCTIONAL DIAGRAM C-3-1063		
DATE: March 3, 1948	DRAWN BY: Peter Panagos	CHECKED BY:







5CP1-A, 5CP7-A, 5CP11-A

OSCILLOGRAPH TUBES

Electrostatic Deflection	**HV Accelerator Electrode**	**Maximum Diameter, 5-11/32"**
Electrostatic Focus	**"Zero First-Anode-Current" Gun**	**Maximum Length, 17-1/8"**

TENTATIVE DATA

The 5C-series of cathode-ray tubes consists of three, five-inch types--5CP1-A, 5CP7-A, and 5CP11-A--utilizing electrostatic deflection and electrostatic focus. They differ one from the other only in the spectral-energy emission and persistence characteristics of their respective phosphors P1, P7, and P11.

The types in this series are designed with a high-voltage accelerator electrode (anode No.3). This electrode permits the use of a high-intensity, fluorescent spot with minimum sacrifice in deflection sensitivity, and with slight increase in spot size.

The electron gun employed in these types has a grid No.2 operated at constant high voltage so that the beam current will not be affected by changes in anode-No. I voltage. It also has an anode No. I which takes negligible current. As a result of these features, the spot can be sharply focused on the screen and remains sharp when beam current is varied over a wide range. The very small anode-No. I current permits the use of a low-current voltage-divider system and hence the use of a smaller filter capacitor.

Other design features of these types include a large useful screen surface in relation to bulb diameter; separate base-pin connections for each of the four deflecting electrodes; balanced deflecting-electrode input capacitances to minimize "cross-talk" and to eliminate the necessity for neutralizing circuits; and the diheptal 12-pin base which enables these types to be operated at their rated maximum values under reduced atmospheric pressure equivalent to an altitude of 40000 feet.

The types in the 5C-series are intended primarily for use in balanced electrostatic-deflection circuits, and when so used, give best definition. However, they may be used with unbalanced deflection because of design features which minimize spot and pattern distortion usually characteristic of such operation.

• RCA-5CP1-A •

Medium-Persistence Type

The 5CP1-A is designed particularly for general oscillographic applications in which a high-intensity trace is needed.

It has a green-fluorescence, medium-persistence screen which has high visual efficiency, and exceptionally good brightness contrast between the scanned line and the background. Under

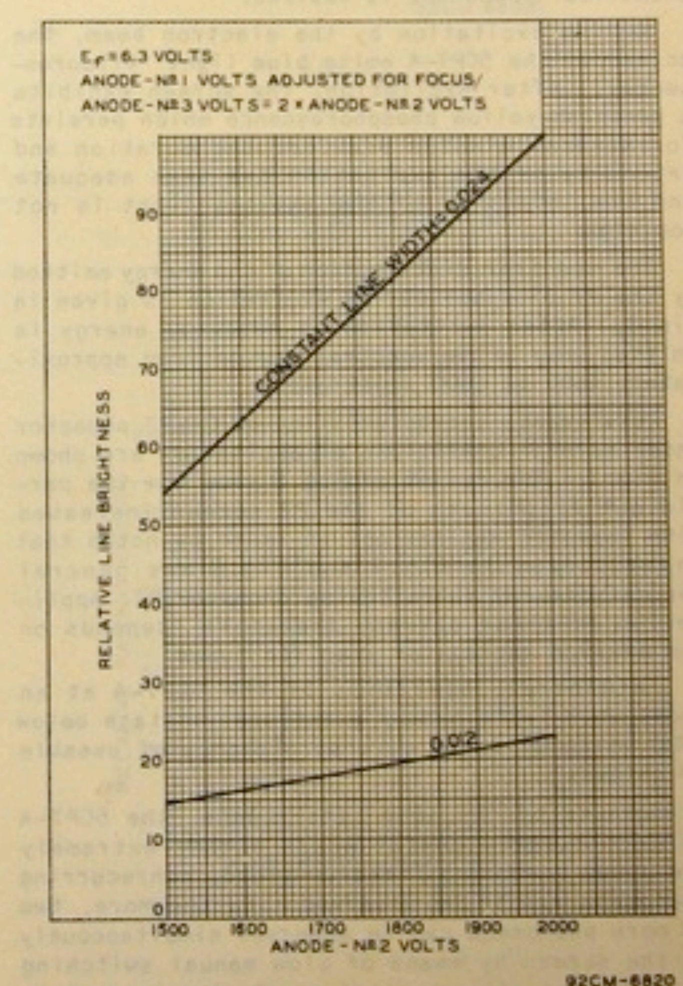
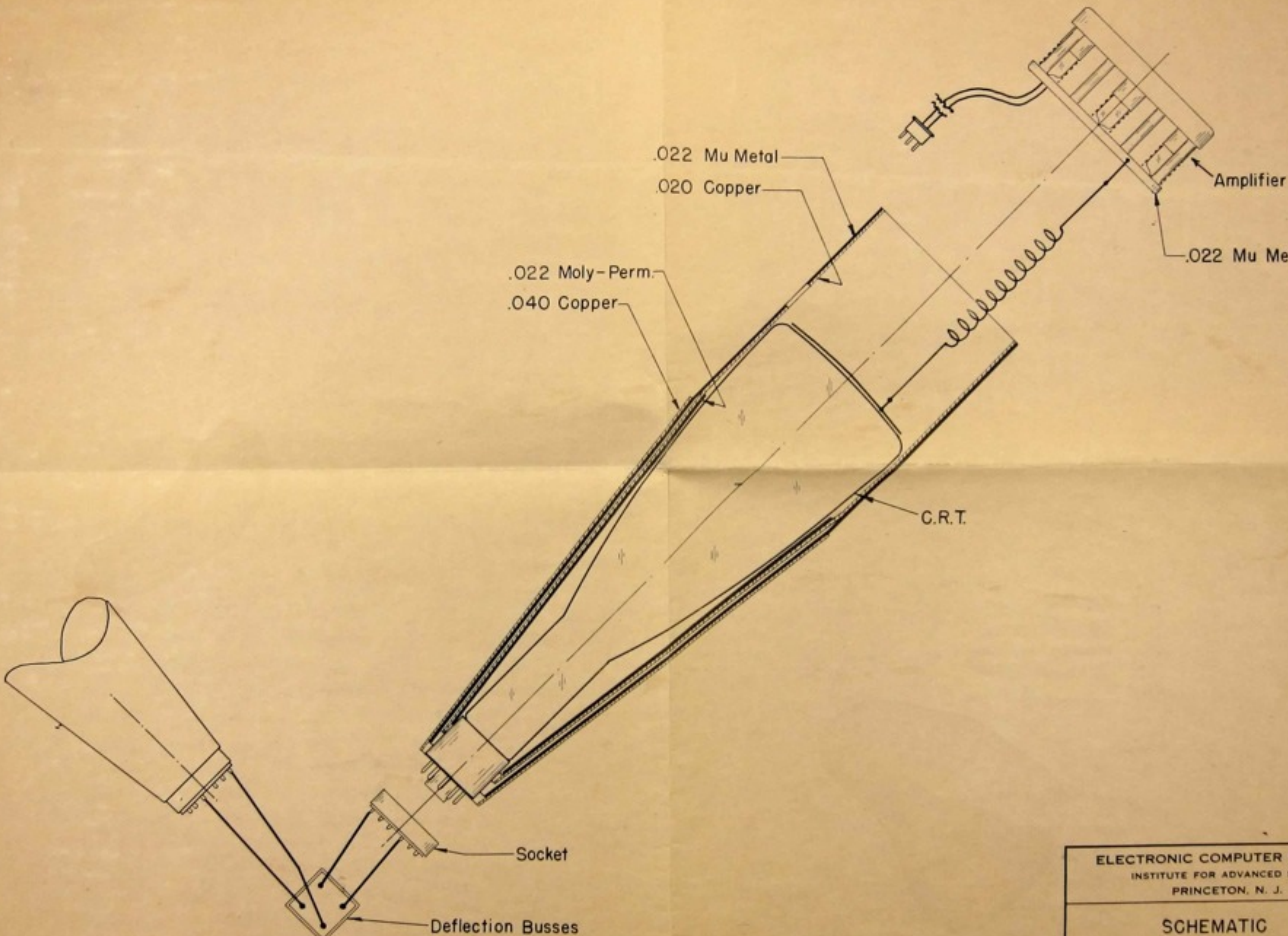


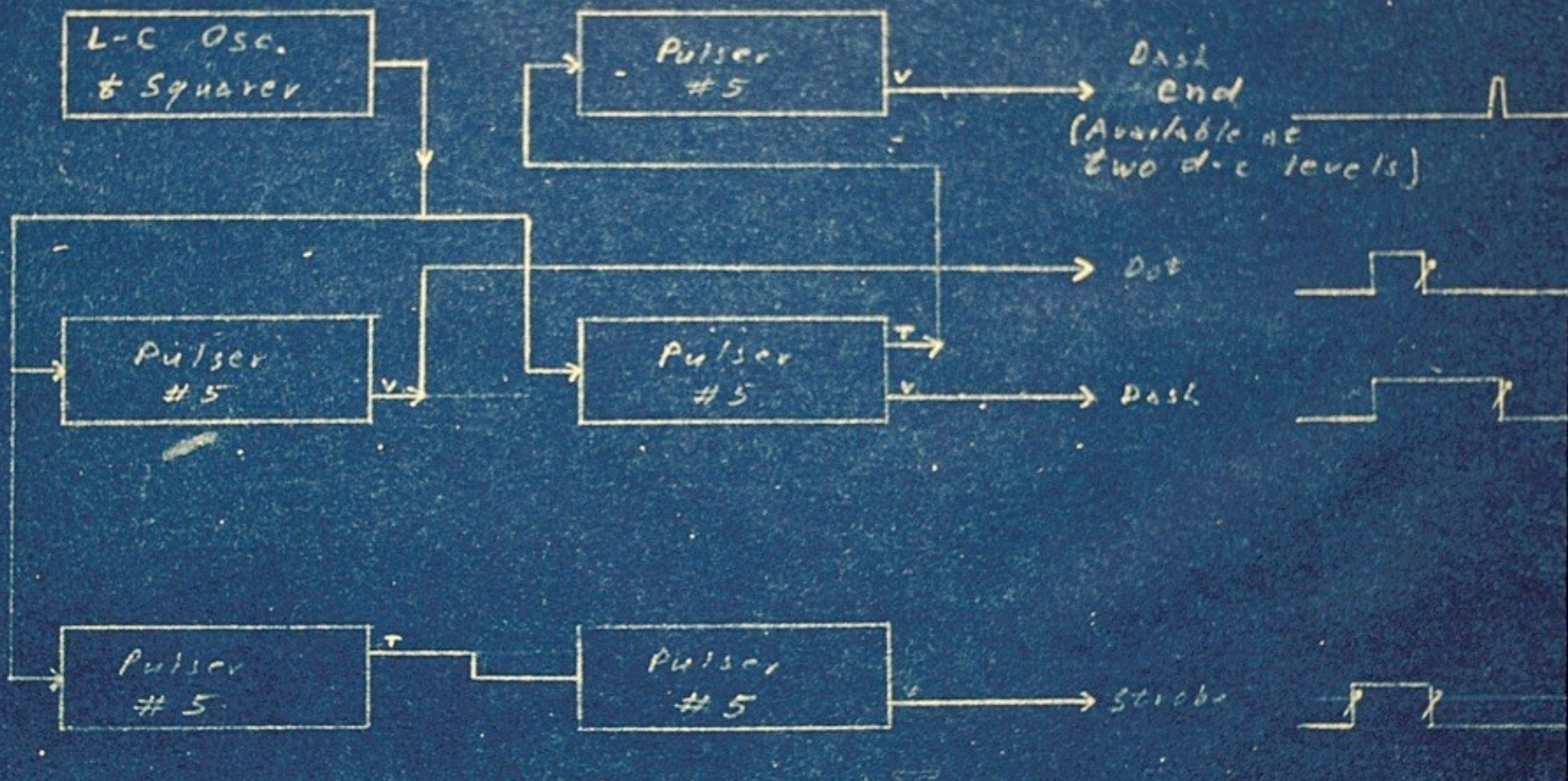
Fig. 1 - Characteristics of Type 5CP1-A



ELECTRONIC COMPUTER PROJECT
INSTITUTE FOR ADVANCED STUDY
PRINCETON, N. J.

SCHEMATIC
WILLIAMS TUBE ASSY

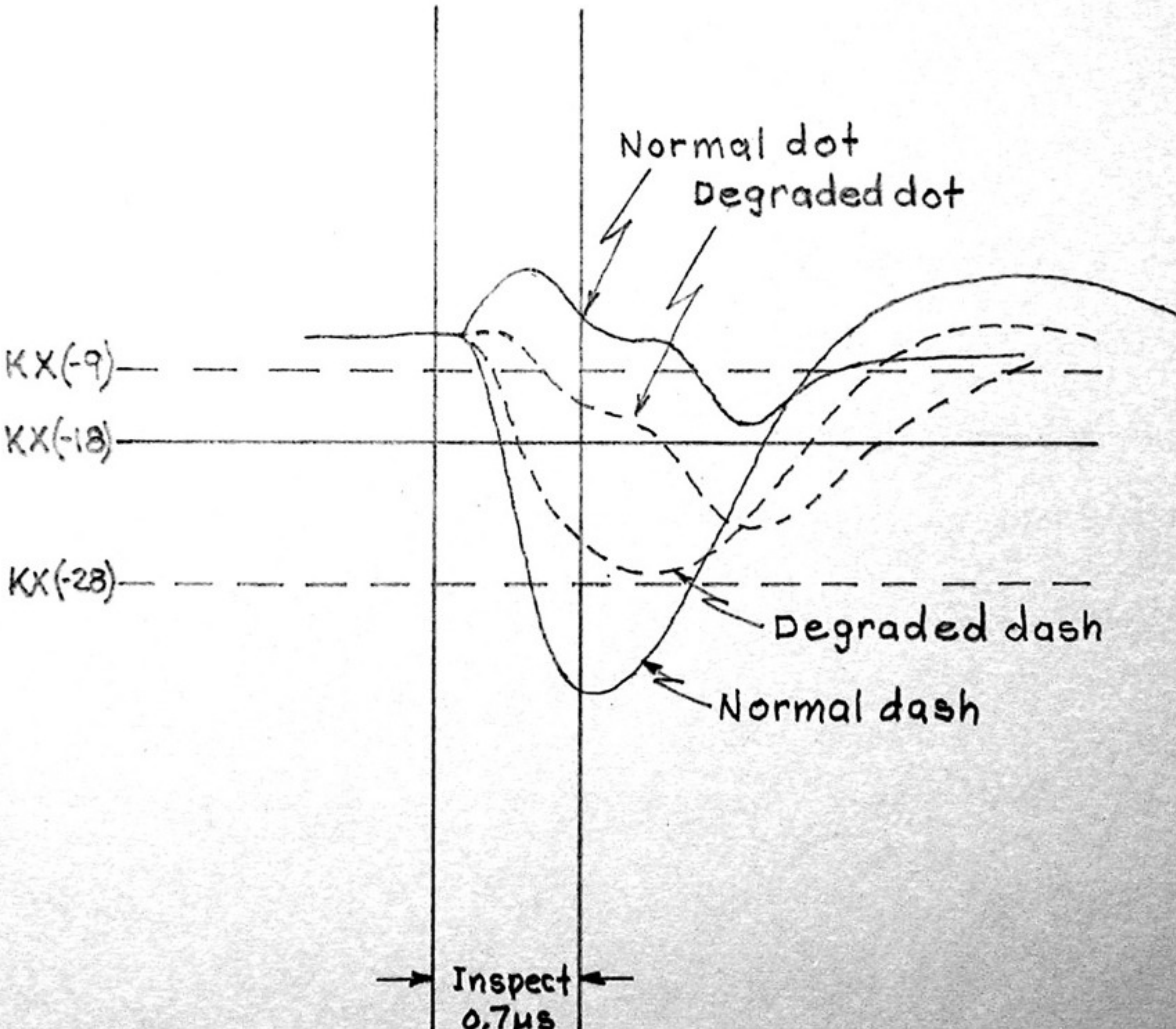
DATE	DRAWN BY		INITIAL
5-11-53	Emslie	B1481	

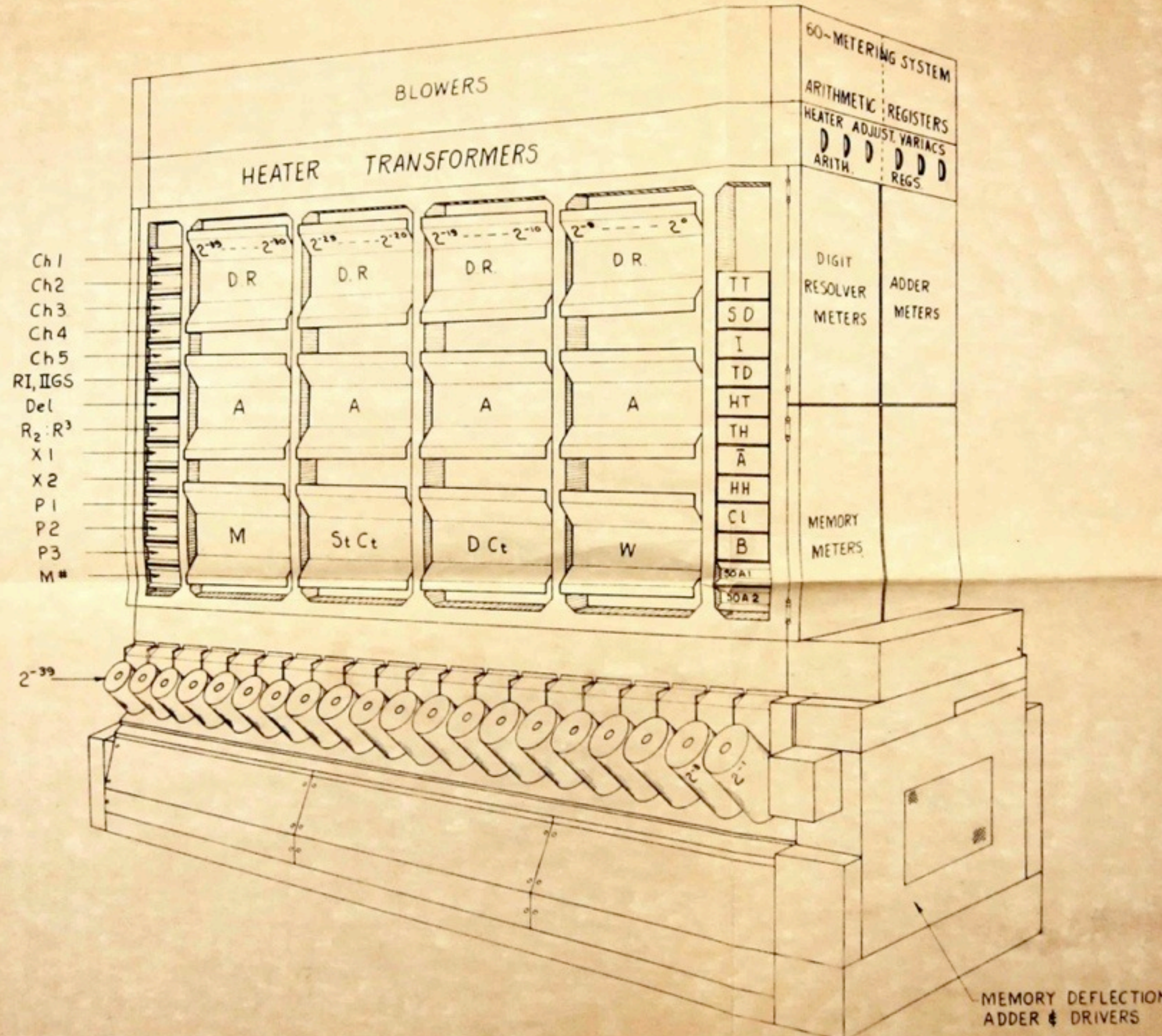


Clock

Figure 5.5

Williams Memory Tube
12 July 48


Normal dot
Degraded dot
KX(-9)
KX(-18)
KX(-28)
Degraded dash
Normal dash
Inspect
0.7μs

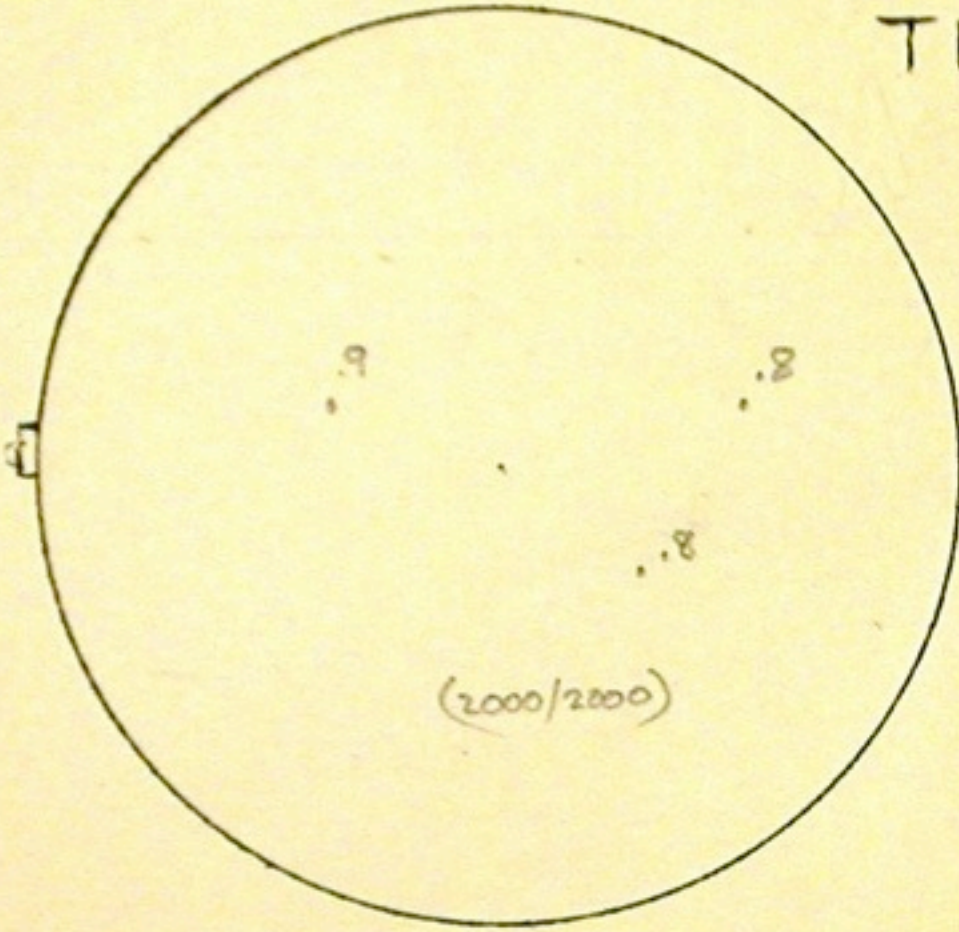

60~METERING SYSTEM
ARITHMETIC
REGISTERS
HEATER ADJUST. VARIACS
ARITH.
REGS.
BLOWERS
HEATER TRANSFORMERS
Ch 1
Ch2
Ch3
Ch4
Ch5
RI, IIGS
Del
R2 : R3
X 1
X 2
P 1
P 2
P3
M#
D.R
D.R
D.R
D.R
A
A
A
A
M
St Ct
D Ct
W
TT
S D
I
TD
HT
TH
A
HH
Cl
B
SOA1
SOA2
DIGIT
RESOLVER
METERS
ADDER
METERS
MEMORY
METERS
2-39
MEMORY DEFLECTION
ADDER & DRIVERS

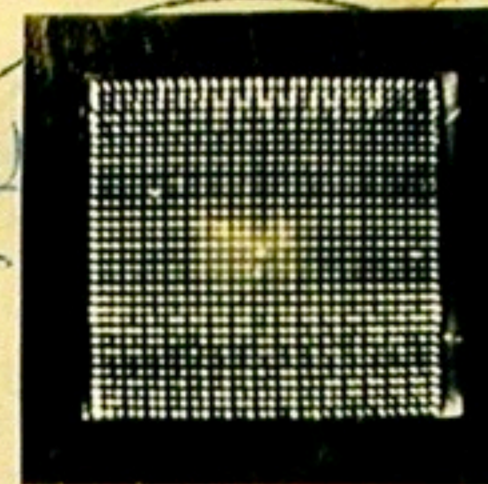
D51 came out

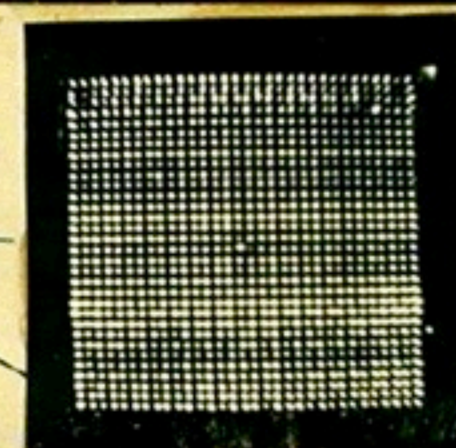
Stage

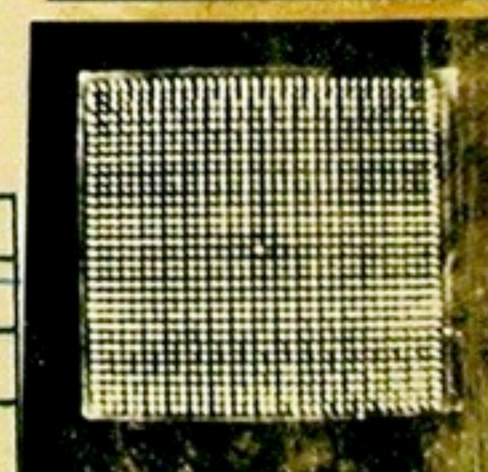
36

TUBE # D68 !









0.1 (10,6)

.8

.8

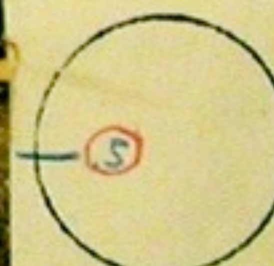
.9

.8

11 Feb. 53

5

AFTER 1 SPARKING



AFTER 2 SPARKINGS

Flaw Focus ________ v.

Rack Read Around							
	Position					Foc.	T.W.
	1	2	3	4	5	v.	M.A.
2000/2000							
1000/2000	10,000	>10,000	4000	2000	3000	65	.08

Worst Flaw .8

Worst 2000/2000 R.A. ,

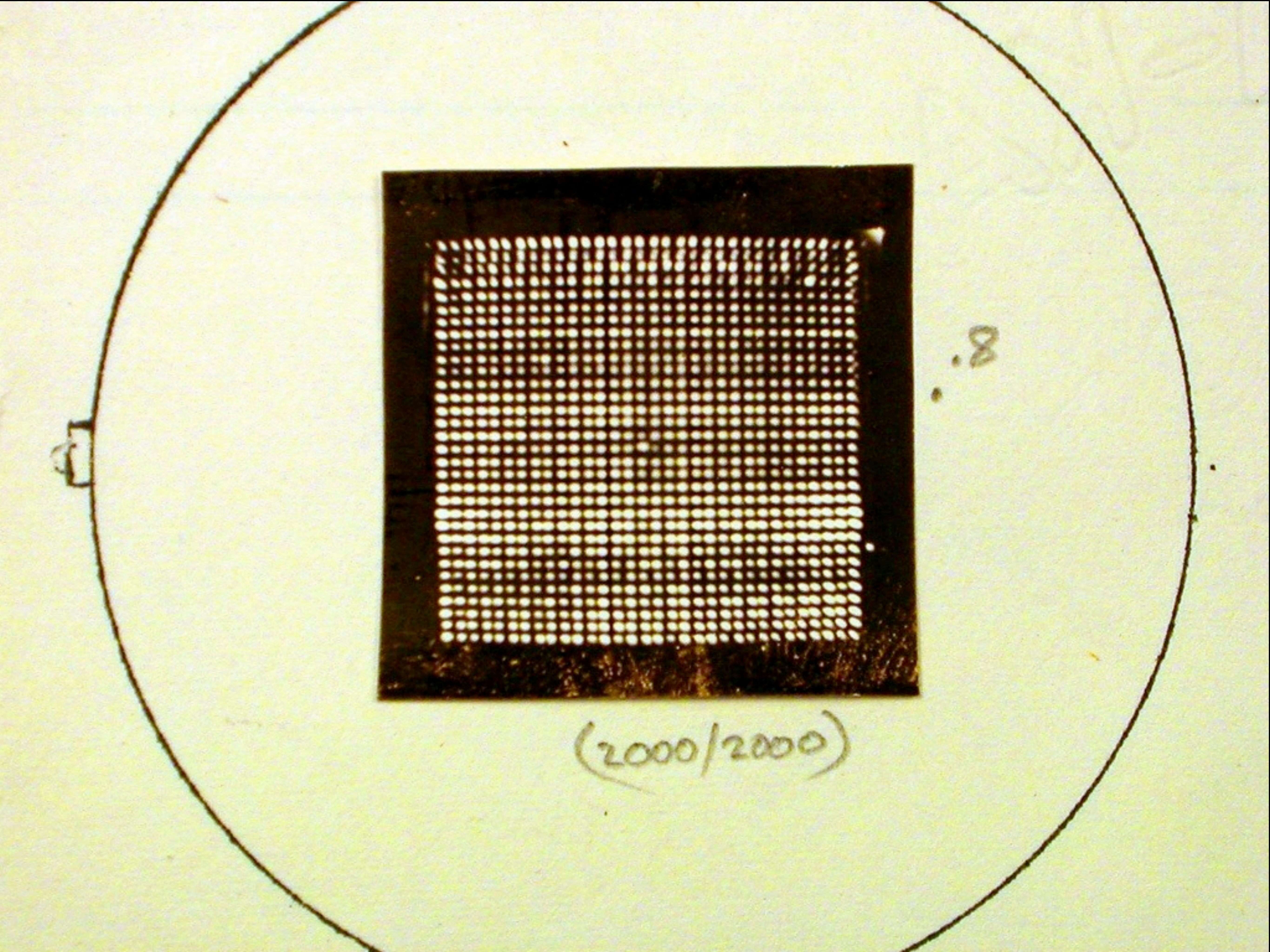
Worst 1000/2000 R.A. 100

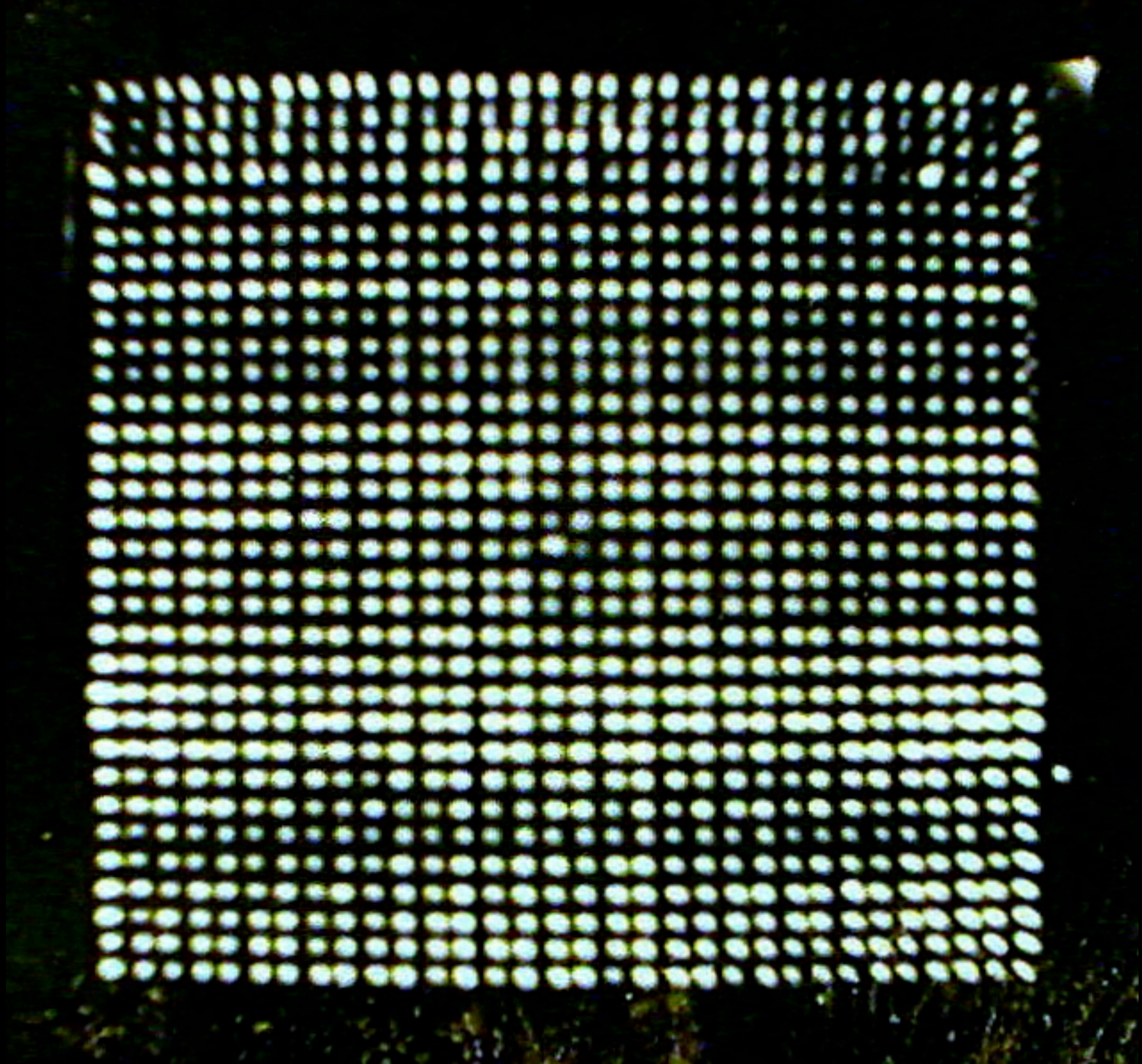
Machine: Date ________ R.A. ________

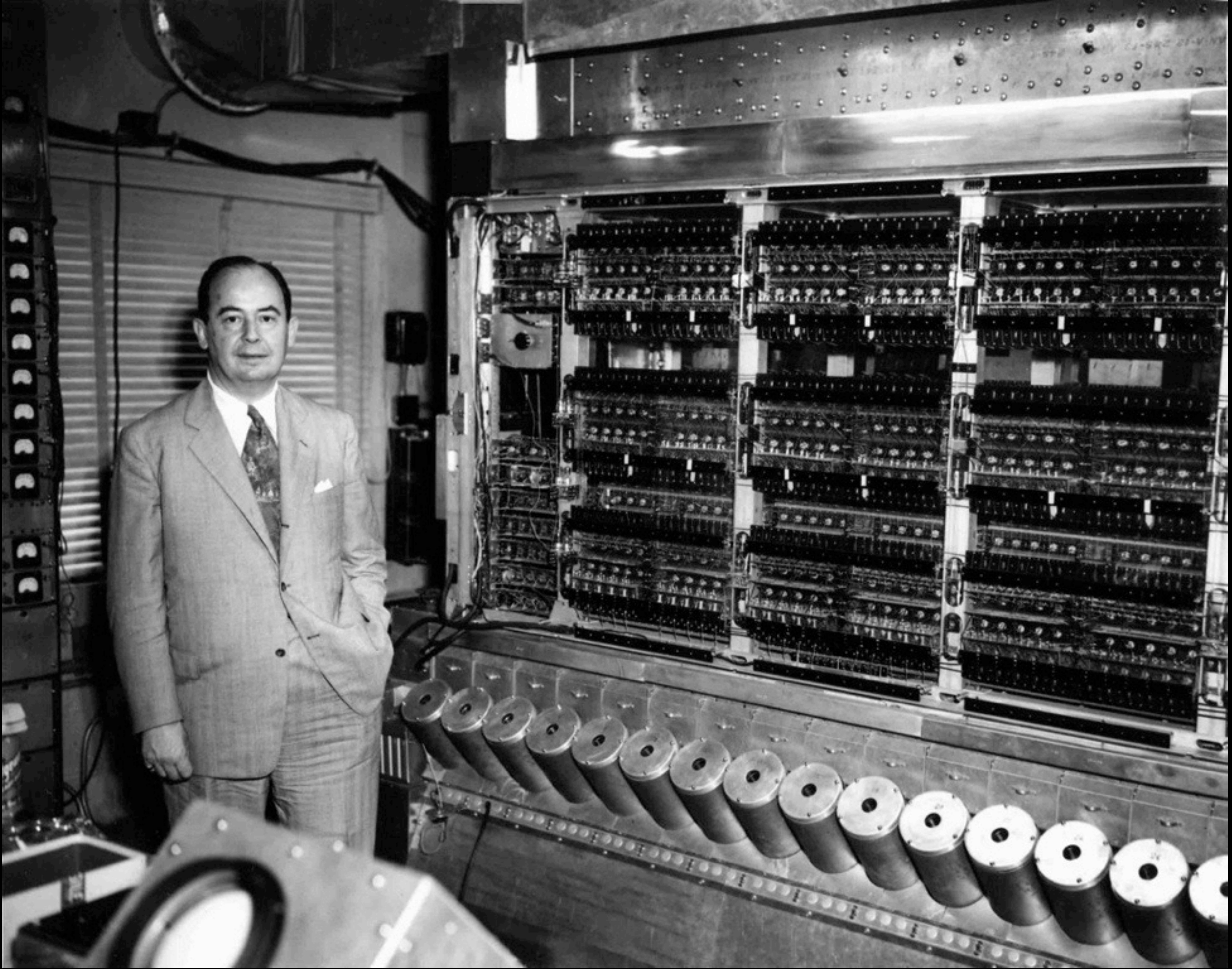
Date	R.A.
31 Oct 52	>32
11 Nov	>32
9 Dec	>32

Comments:

Flaw at 10,6 (obvious) 9 Feb 53

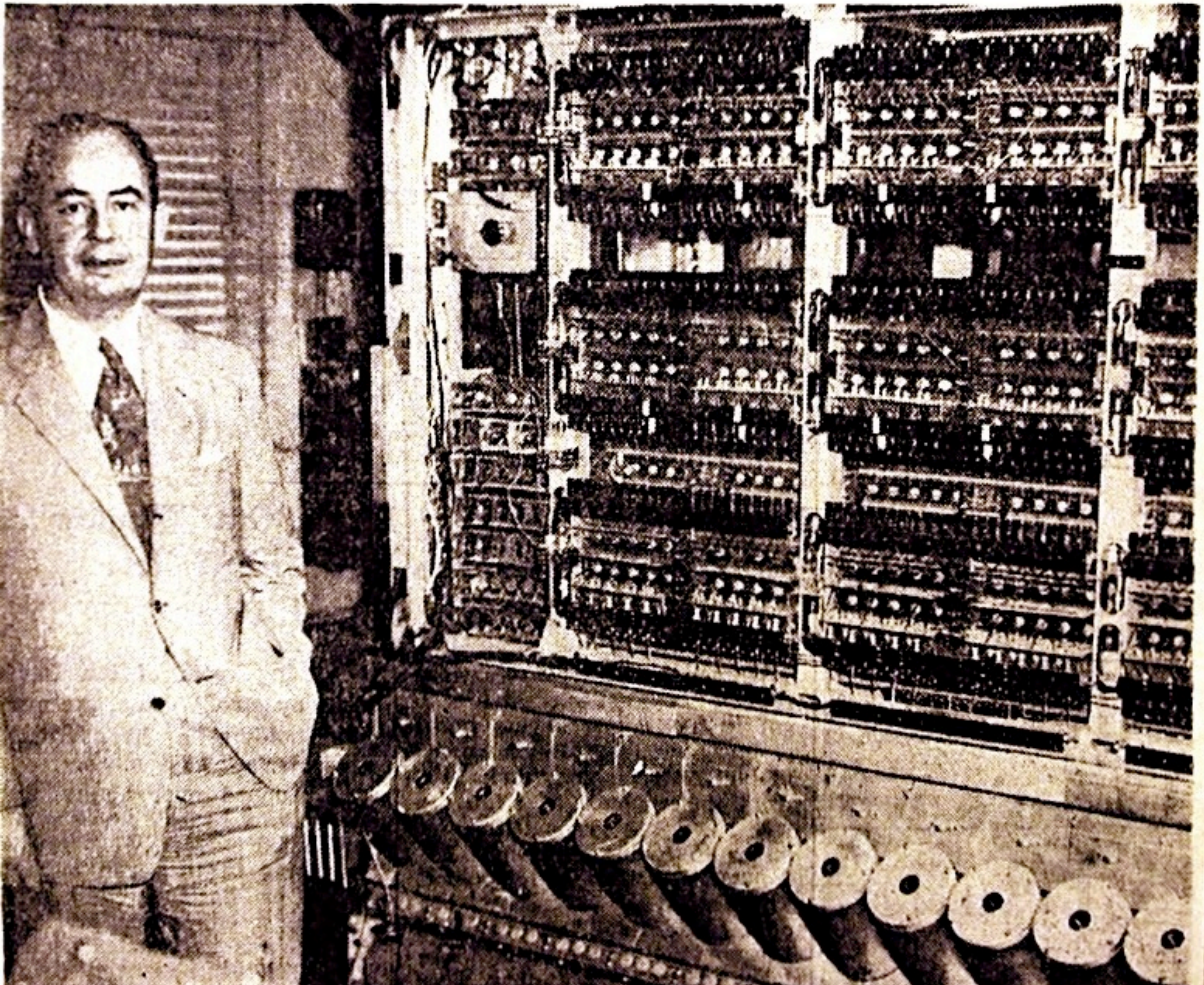

.8
(2000/2000)






Julian
Bigelow
Herman
Goldstine
J. Robert
Oppenheimer
John
von Neuman

Fastest 'Mechanical Brain' Unveiled



BEHAVIOR, PURPOSE AND TELEOLOGY

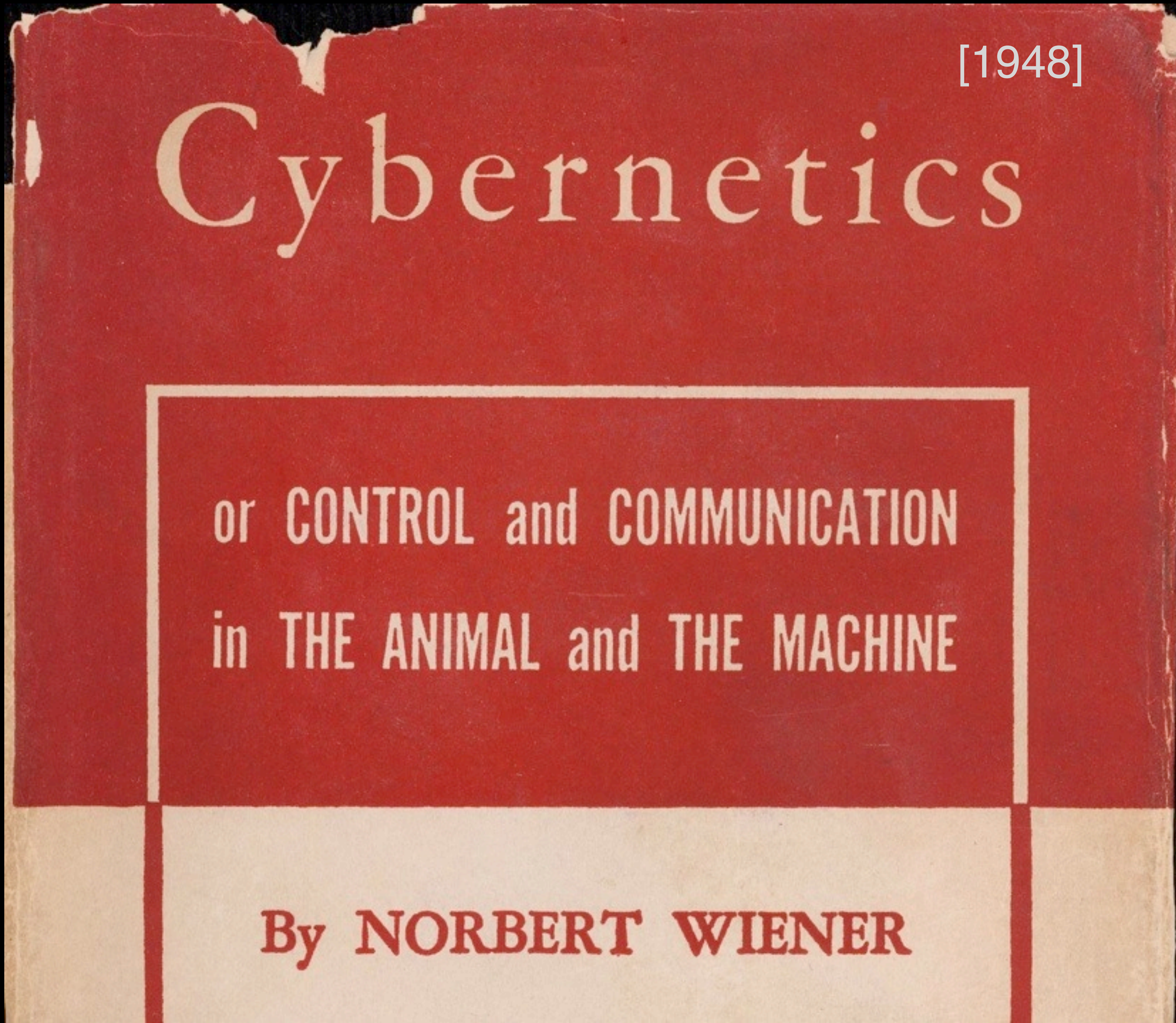
This essay has two goals. The first is to define the behavioristic study of natural events and to classify behavior. The second is to stress the importance of the concept of purpose.

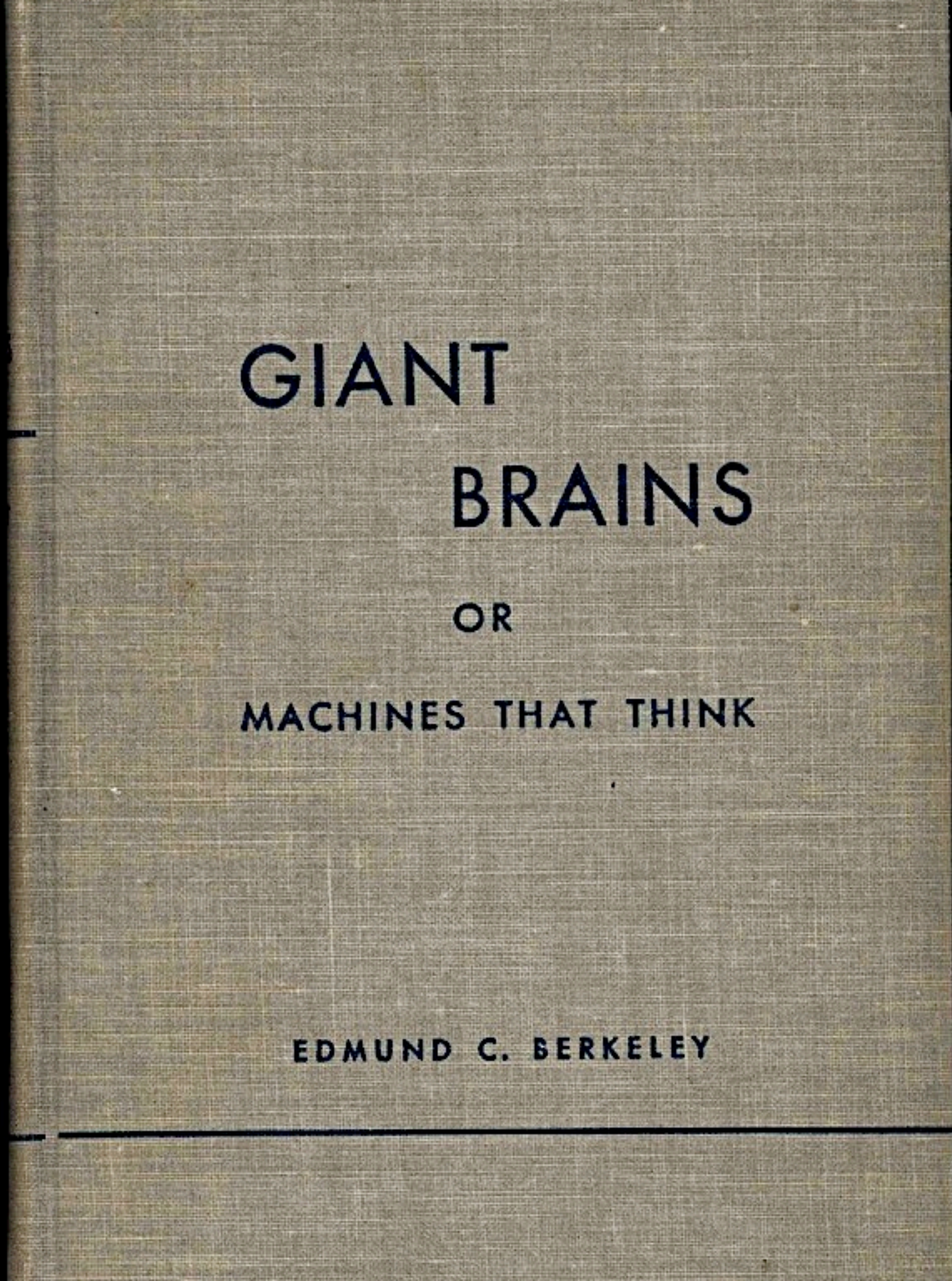
Given any object relatively abstracted from its surroundings for study, the behavioristic approach consists in the examination of the output of the object and of the relations of this output to the input. By output is meant any change produced in the surroundings by the object. By input, conversely, is meant any event external to the object that modifies this object in any manner.

Julian Bigelow, Arturo Rosenblueth, and Norbert Wiener, 1943

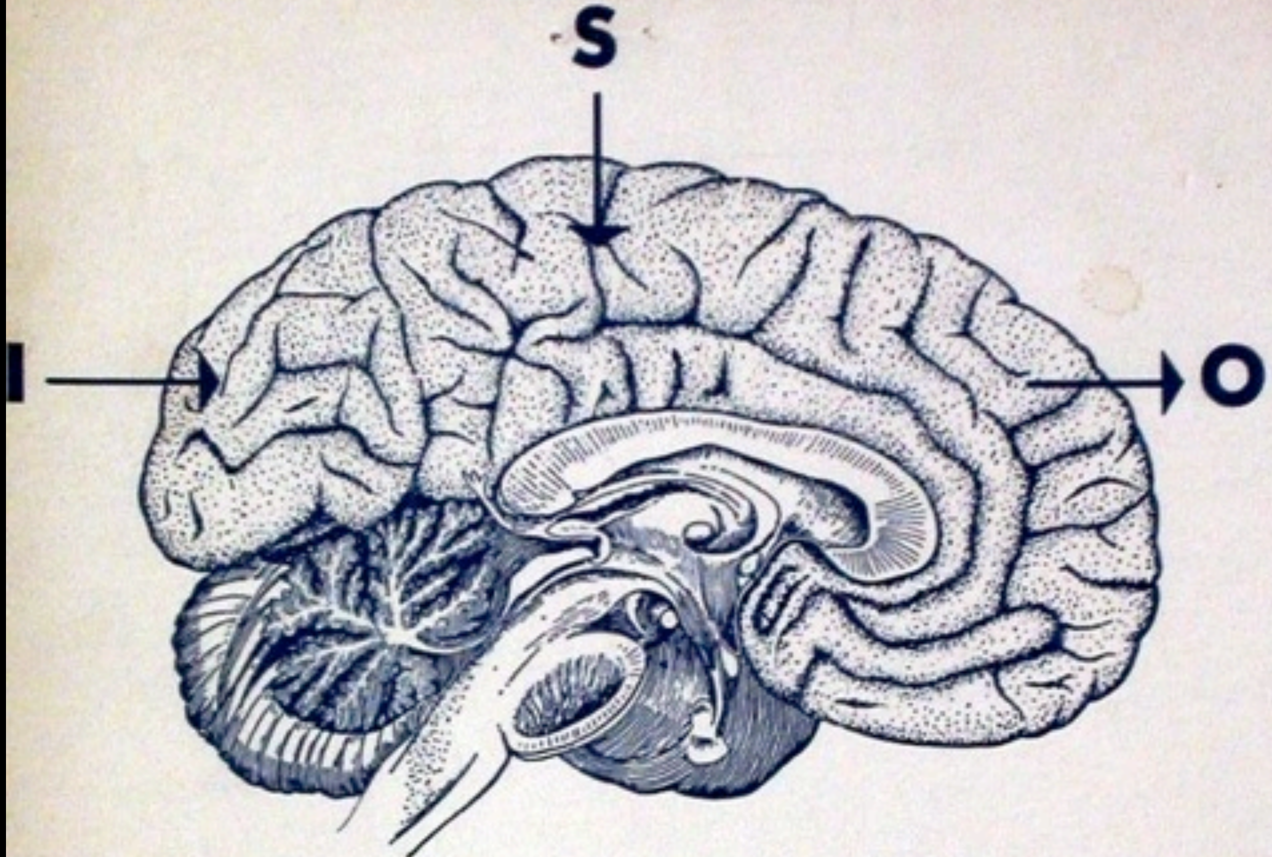
A further comparison of living organisms and machines . . . may depend on whether or not there are one or more qualitatively distinct, unique characteristics present in one group and absent in the other. Such qualitative differences have not appeared so far.

[1948]


Cybernetics
or CONTROL and COMMUNICATION
in THE ANIMAL and THE MACHINE
By NORBERT WIENER



[1949]

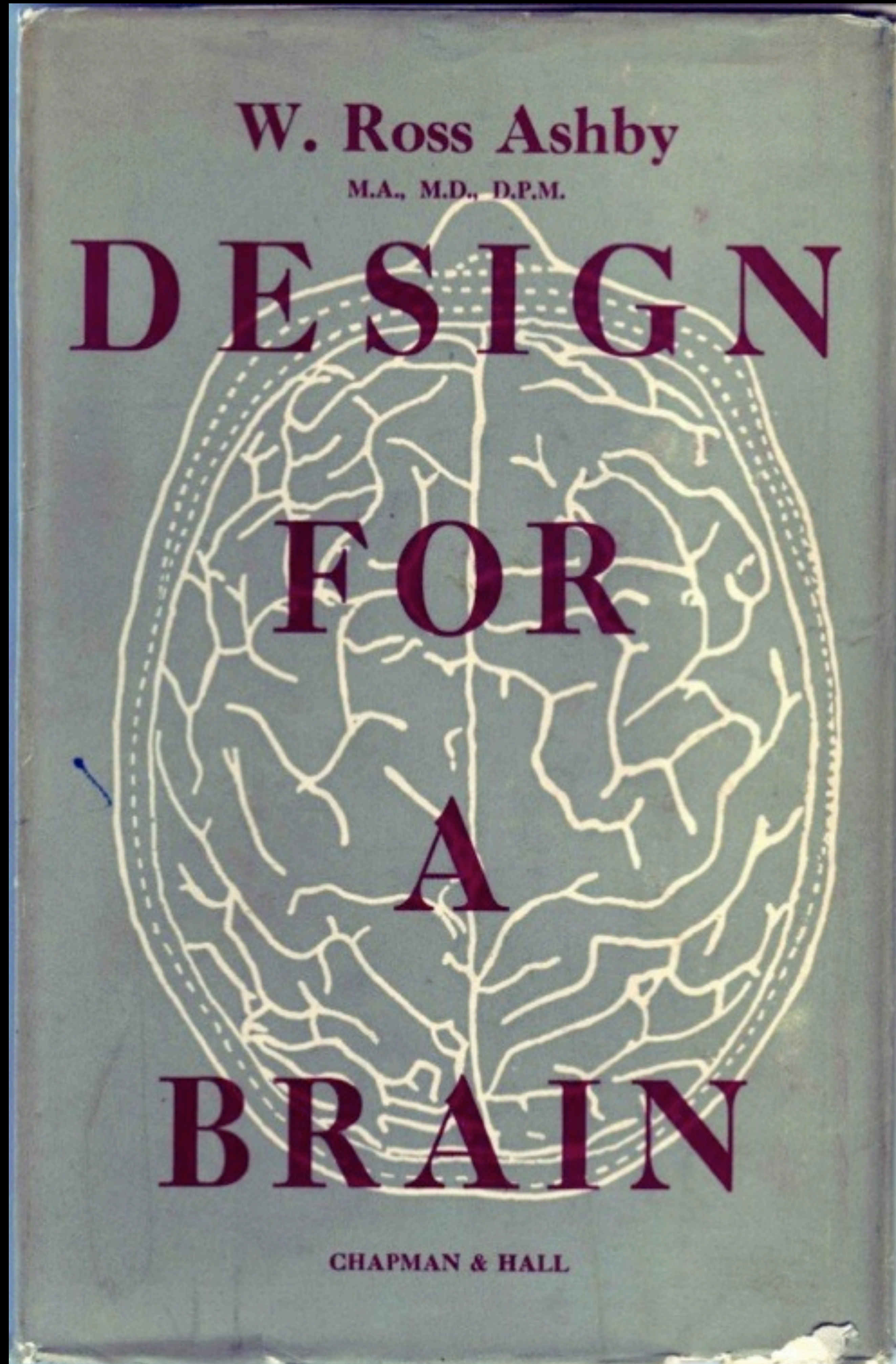


Descriptive Specification for the development of an Adaptive Memory Component

Presented to: Aeronautical Research Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base
Ohio

Presented by: Development Engineering
Defense Electronic Products
Radio Corporation of America
Camden, New Jersey

[1959]



[1952]

Ashby's Law of Requisite Variety

Any effective control system must be as complex as the system it controls.

Paradox of Mechanical Intelligence

Any system sufficiently complex to behave intelligently will be too complicated to understand.

NATIONAL PHYSICAL LABORATORY

SYMPOSIUM No. 10

Mechanisation of Thought Processes

VOLUME I

LONDON: HER MAJESTY'S STATIONERY OFFICE

Price £2. 10s. 0d. net for two volumes

(not to be sold separately)

[1958]

RELIABLE ORGANIZATIONS OF UNRELIABLE ELEMENTS

By

John von Neumann

Princeton, N. J.

[1951]

Lectures on

Probabilistic logics and the synthesis of reliable organisms from unreliable components.

delivered by

Professor J. von Neumann
of
The Institute for Advanced Study
Princeton, N. J.

at the
California Institute of Technology
January 4-15, 1952

Notes by
R. S. Pierce

Figure 29.

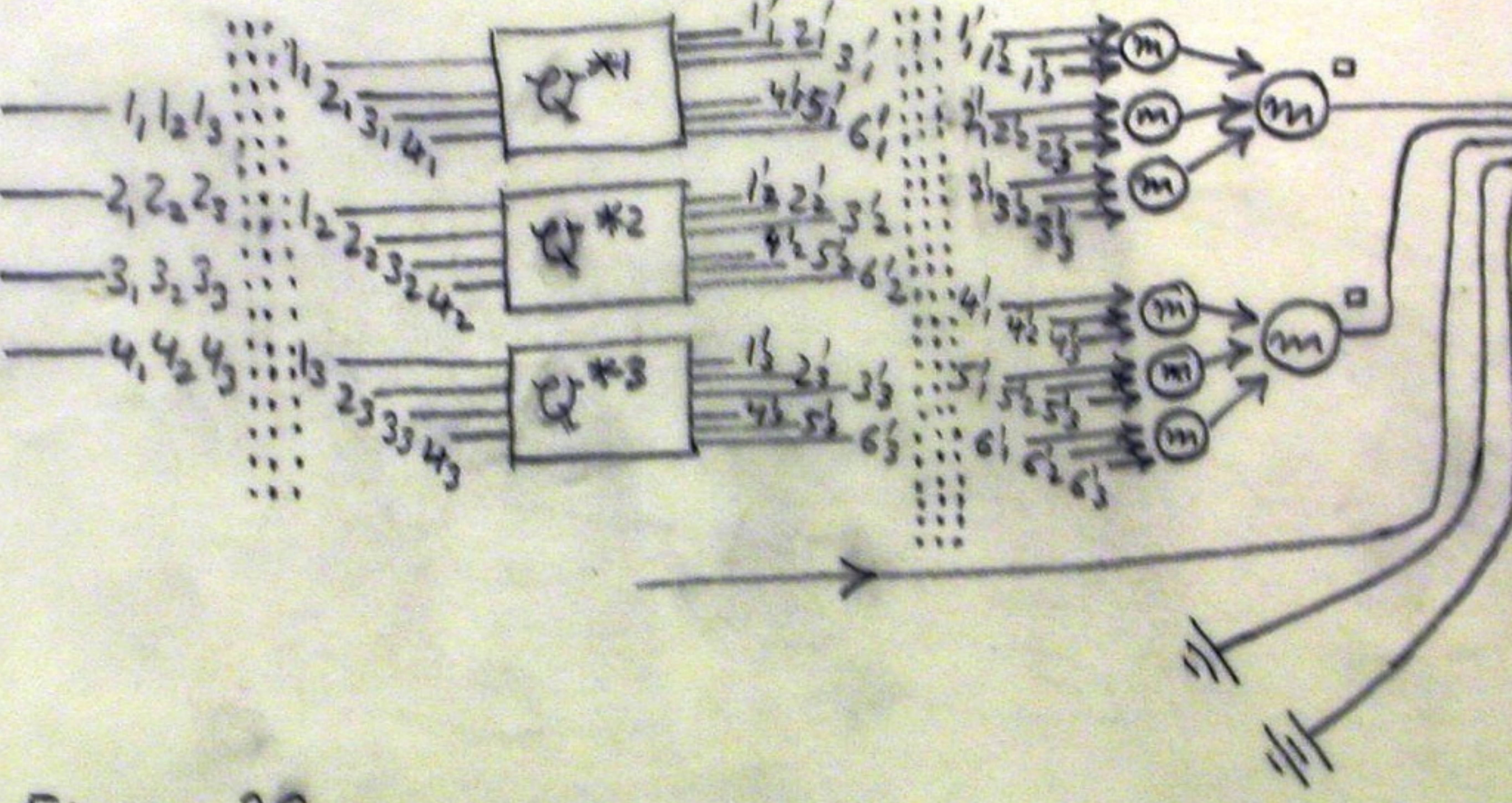
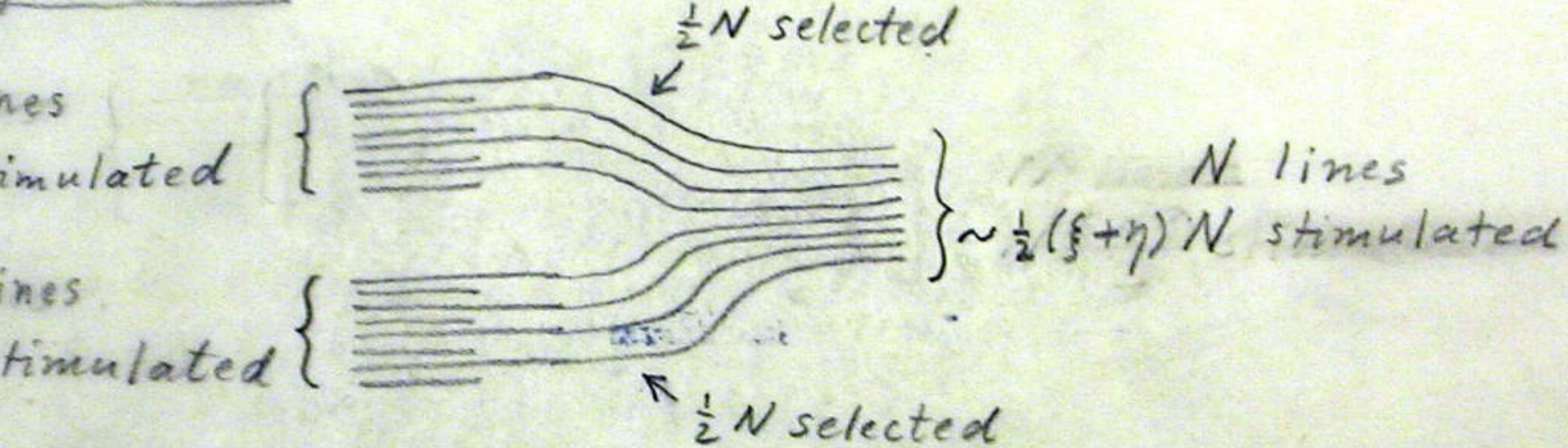


Figure 30.

gure 40.



gure 41.

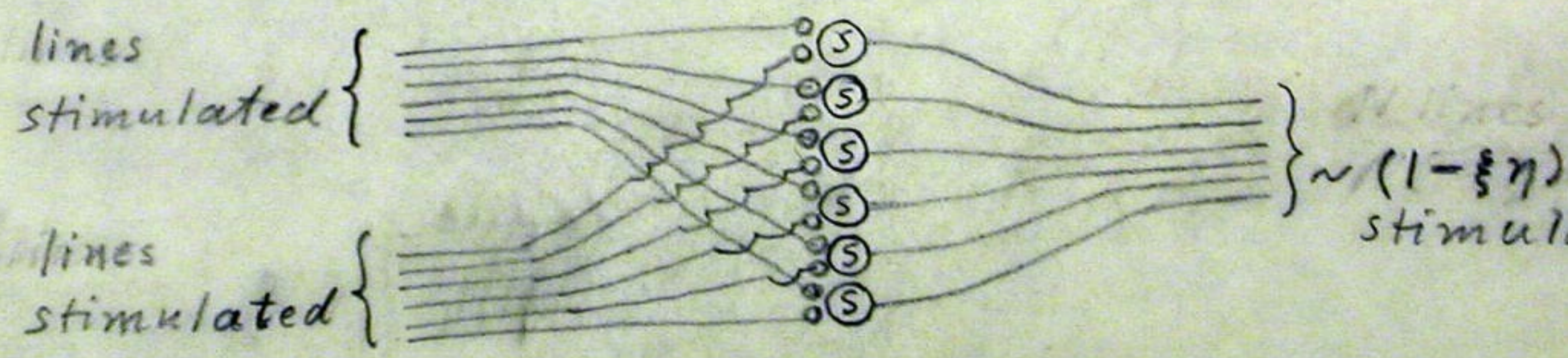
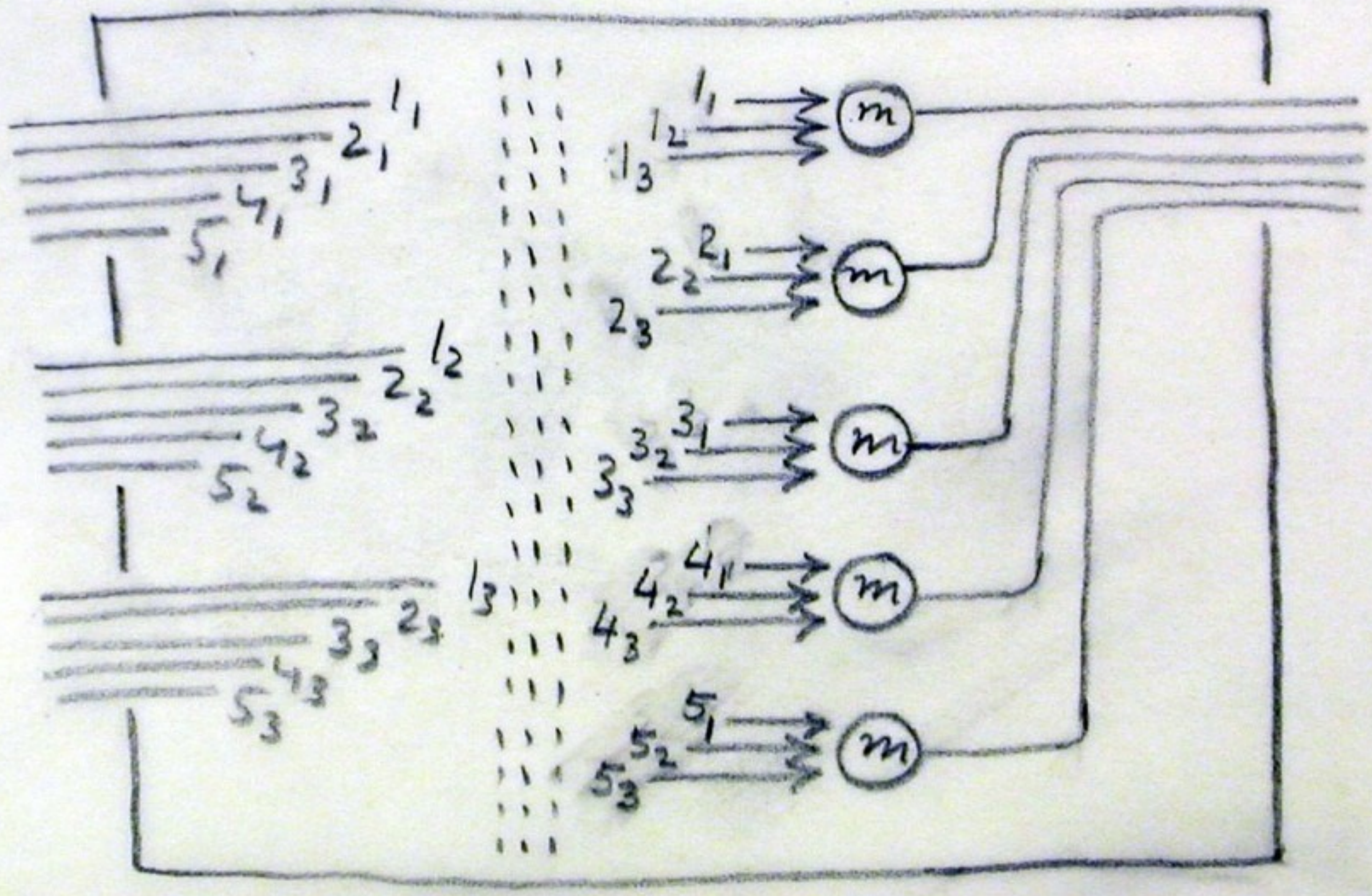


Figure 30.



It is perfectly possible that the simplest and only practical way to actually say what constitutes a visual analogy consists in giving a description of the connections of the visual brain . . .

A new, essentially logical, theory is called for in order to understand high-complication automata and, in particular, the central nervous system. It may be, however, that in this process logic will have to undergo a pseudomorphosis to neurology to a much greater extent than the reverse.

—John von Neumann, 1951

24,28

1

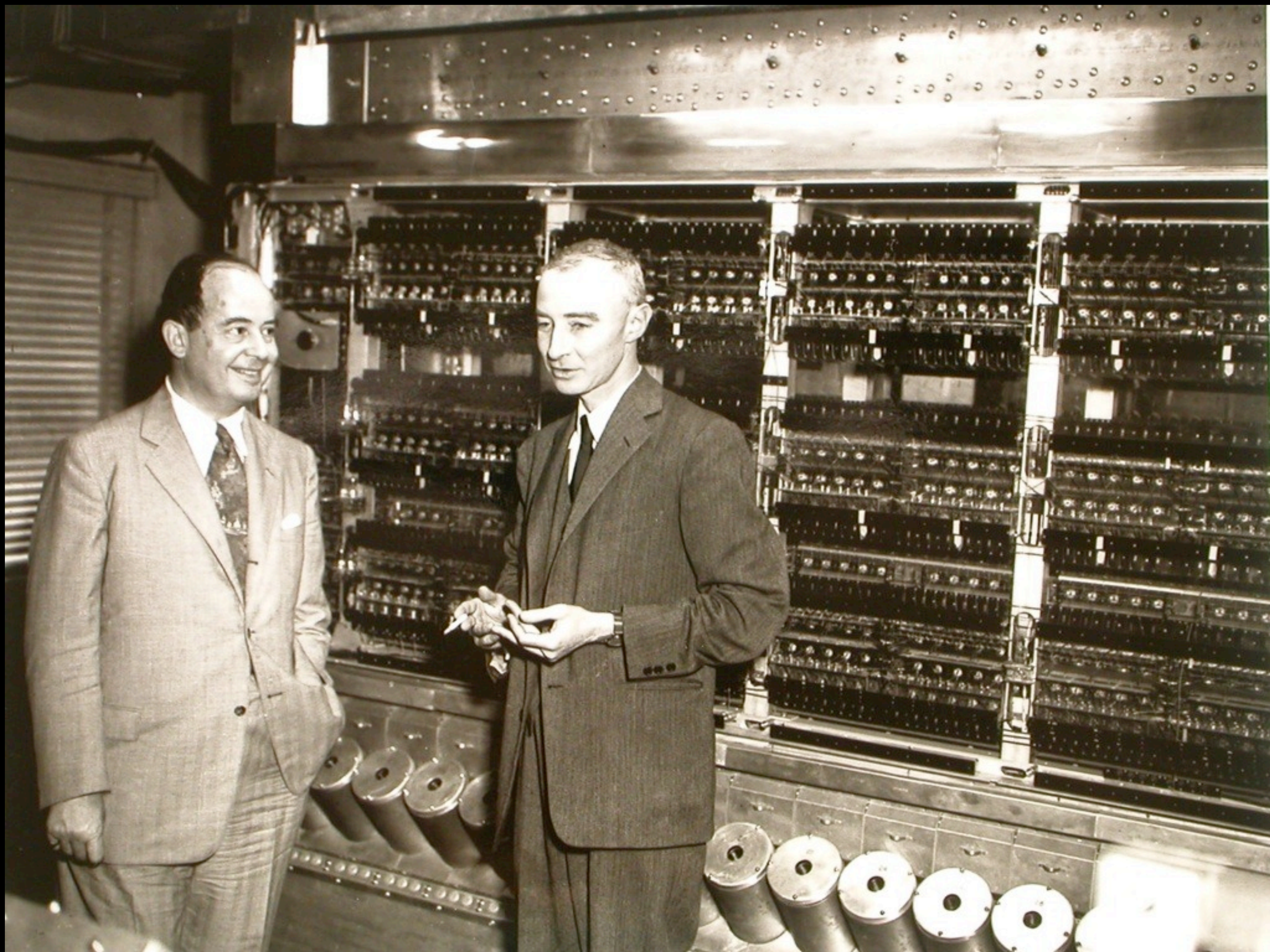
Machine Log

Nov 6, 1951 - MARCH 17, 1952

stop at (18, 8)

over to

[March 3-4, 1953]



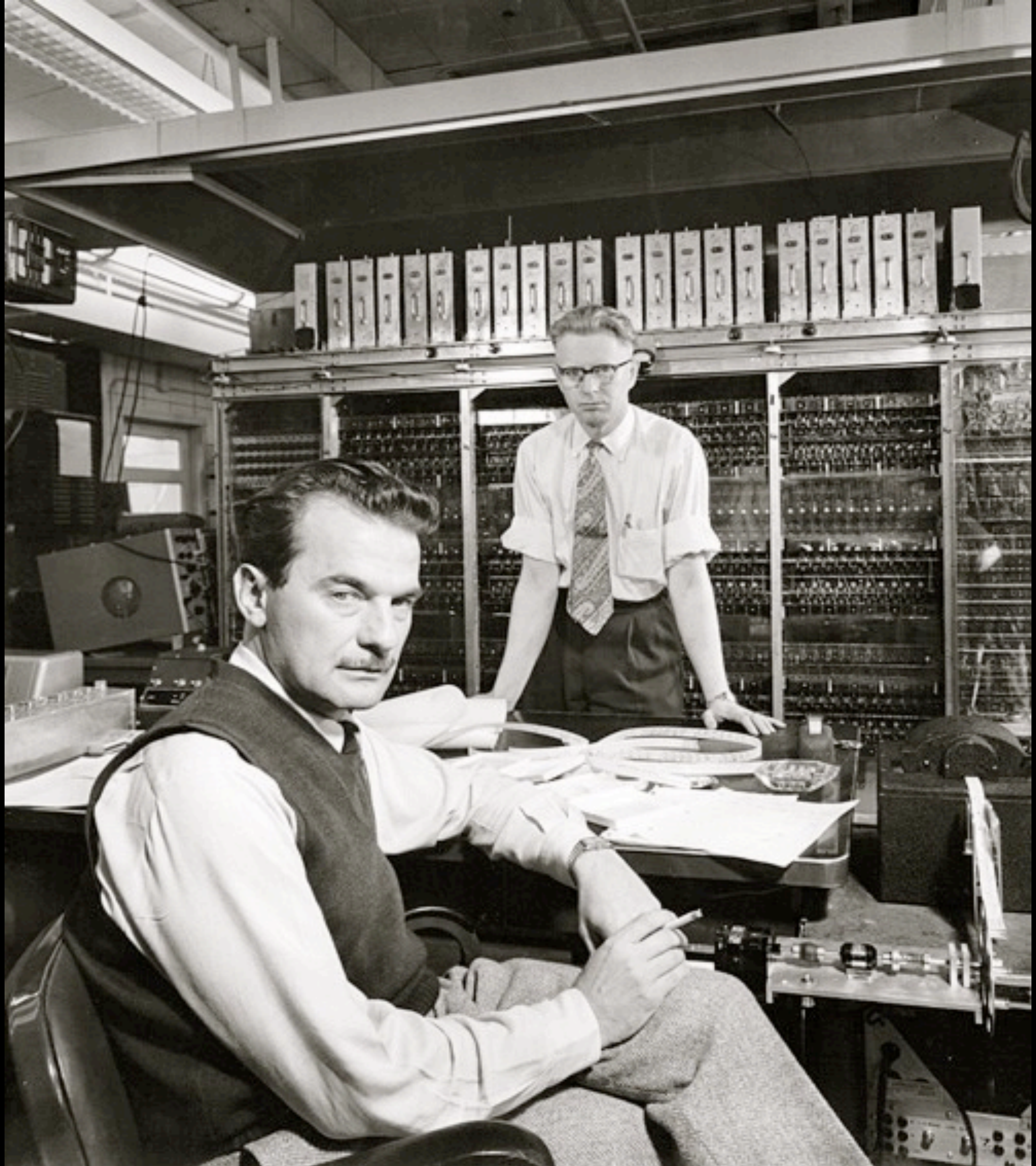
Stan Ulam

Nick Metropolis

Nick Metropolis


Stan Ulam
Nick Metropolis

Nicholas Metropolis
(1915-1999)



John von Neumann’s idea to put numbers and instructions in the same kind of memory was a wonderful advance, but it doesn't follow that numbers and instructions have to be interconfusible.

.

— Robert Richtmyer to Nicholas Metropolis, 11 January 1956

Francoise Claire Stan Ulam John von Neumann

Ch. I

P1 1) Wiener!

2) Hixon lecture. Pasadena '52 lecture.

P3 3) Turing!

4) Hixon lecture.

P4 5) Not Turing!

6) Boolean algebra.

7) Pitts-McCulloch!

8) Pasadena '52 lecture.

P5 9) Ref. 7), 8).

10) Ref. 7), 8).

11) Ref. 7), 8). Kleene!

P6 12) Hixon lecture.

P7 13) Ulam!

P8 14) Calling for stronger results.


Julian Bigelow
Herman Goldstine

The MANIAC machine didn't have anything like a pulser in it — no clocks, no pulsers, no nothing. It was all of it a large system of on-and-off, binary gates. No clocks.

You don't need clocks. You only need counters. There's a difference between a counter and a clock. Time is not the variable you keep track of. The sequence is what you keep track of. And that's enormously different from a clock. A clock keeps track of time — and a modern general purpose computer keeps track of events.

Sequence is different from time.

No time is there.

—Julian Bigelow, 1999


Julian Bigelow
(1913–2003)

The design of an electronic calculating machine... turns out to be a frustrating wrestling-match with problems of interconnectability and proximity in three dimensions of space and one dimension of time... The reason that modern electronic computer designers find themselves in this sort of log-jam is that most known and understood calculating processes that can be expressed by "programming" are essentially serial. Therefore, in effect, only one thing is going on in the computer at a time . . .

Thousands of very refined logical elements are built, each capable of making a "flip" to store or divulge a bit of information (or equivalently to make a logical gating decision) at a very fast rate for which great premium is paid, and then they are interconnected in such a way that on the average almost all of them are waiting for one (or a very few of their number) to act. Expressed differently, the average duty cycle of each cell is scandalously low . . .

Electronic computers "eat up" instructions very rapidly, and therefore some way must be found of forming batches of instructions very efficiently, and of "tagging" them efficiently, so that the computer is kept effectively busier than the programmer... Highly recursive, conditional and repetitive routines are used because they are notationally efficient (but not necessarily unique) as descriptions of underlying processes. . .

Serial order along the time axis is the customary method of carrying out computations today... but in forming any model of real world processes for study in a computer, there seems no reason why this must be initiated by pairing computer-time-sequences with physical time parameters of the real-world model. In general, it should also be possible to trace backward or forward from results to causes through any path-representation of the process. . .

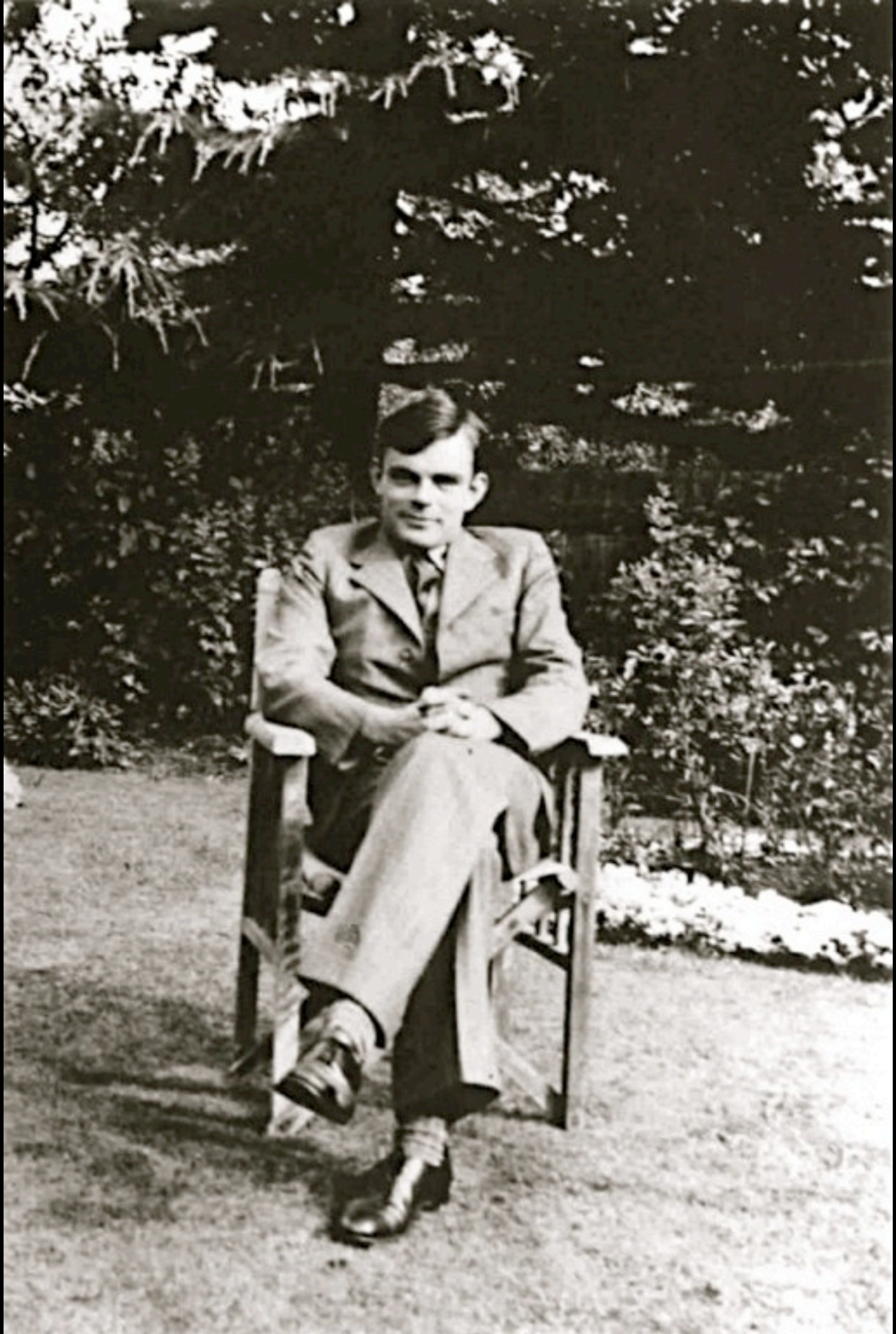
—Julian Bigelow, “Theories of Memory,” Tenth Anniversary AFOSR Scientific Seminar, Cloudcroft, New Mexico, June 1965

If the only demerit of the digital expansion system were its greater logical complexity, nature would not, for this reason alone, have rejected it.

—John von Neumann, 1951

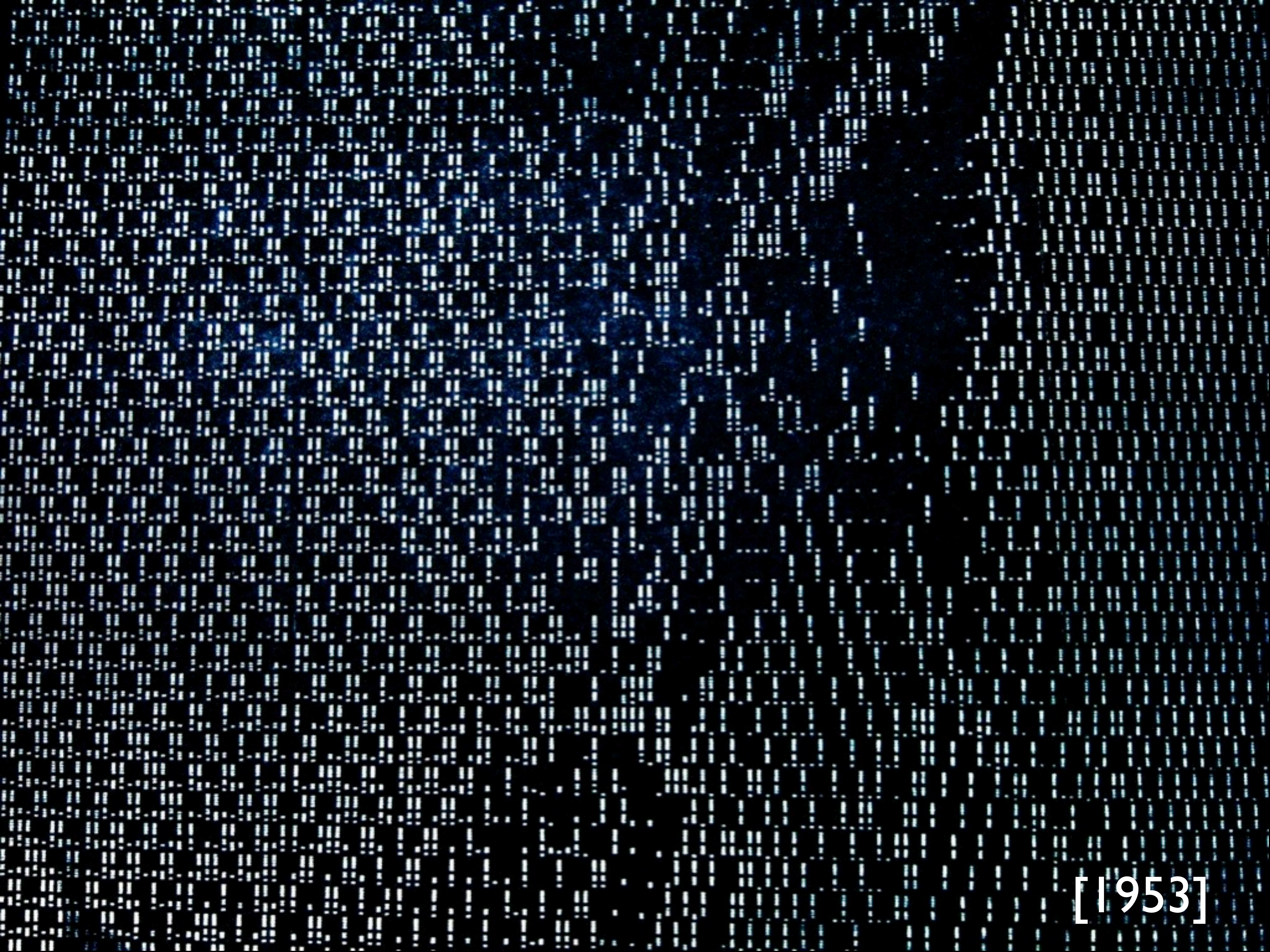
What makes you so sure that mathematical logic corresponds to the way we think?

—Stan Ulam



Machines which are largely random in their construction in this way will be called 'Unorganized Machines.' The machine is made up from a rather large number N of similar units [and] can behave in a very complicated manner when the number of units is large . . . This suggests that the cortex of the infant is an unorganized machine. . .

—Alan Turing, 1948


[1953]

Special Thanks to

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Von Neumann Family

Ulam Family

Bigelow Family

& others....

gdyson@ias.edu