# THE TYPOTRON

## A Novel Character Display Storage Tube

Technical Memorandum No. 347

**RESEARCH AND DEVELOPMENT LABORATORIES**

**HUGHES AIRCRAFT COMPANY** | *Culver City, California*

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Summary: This report describes the Typotron tube, a novel character writing storage tube, developed by the Electron Tube Laboratory of the Hughes Aircraft Company for the Lincoln Laboratory at M.I.T. This tube will display any one or any combination of the 63 characters available on the character matrix incorporated in the writing gun. The characters can be written in less than 50 microseconds, displayed indefinitely until erased at brightness up to a few hundred foot-lamberts. The methods used for character formation, selection, deflection and display are outlined. Included are schematic diagrams of the Typotron tube and photographs of its essential components and of completed tubes.

## I. INTRODUCTION

The Typotron* is one of a family of direct display storage tubes developed by the Electron Tube Laboratory of the Hughes Aircraft Company. These tubes have as a common feature a storage screen first used in the Haeff Memory Tube at the Naval Research Laboratory**. The characteristics of this screen have been improved by the work at the Hughes Electron Tube Laboratory to the point where it is now considered a practical item for manufacture.

Historically, the first storage tube developed in this laboratory is the one now known as the Memotron*. This tube provides, on a five inch face, a display which is similar to that of a standard CRT in every respect but one. In the standard CRT the writing spot makes a trace which quickly fades away in a time determined by the phosphor persistence characteristic. In the Memotron, the addition of a flood gun and a dielectric storage and control screen results in a display having infinite persistence. This means that the movement of the writing spot produces a bright trace which remains visible as long as normal voltages are supplied to the tube. This trace can be erased at any desired time by reducing momentarily the potential of one of the screen electrodes.

Concurrently with the development of the Memotron at the Hughes Aircraft Company, a group at Consolidated Vultee Aircraft Company in San Diego was building a tube which was named the "Charactron". This tube employed a conventional phosphor screen but incorporated a writing gun having a mask perforated with stencils of numeric and alphabetic characters. This gun had two deflection systems, the first directing the beam to any one of the characters and the second directing the resultant electron image of the character to any part of the viewing screen. This tube, with appropriate circuitry, can perform the function of an electronic typewriter for rapid display of data. Its principal shortcoming is the limited persistence of the displayed information.

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*Trade-mark applied for.

**A. V. Haeff, "A Memory Tube", Electronics, vol. 20, pp. 80-83, Sept., 1947.
S. T. Smith and H. E. Brown, "Direct Viewing Memory Tube", Proc. of the IRE, vol. 41, No. 9, Sept., 1953.

Samples of the Charactron and Memotron were sent for evaluation to the Lincoln Laboratory of M.I.T. in Cambridge, Mass., with the recommendation on the part of the personnel of this laboratory that a tube combining the character writing gun with the Hughes storage screen would produce desirable results not obtainable with either tube alone. A conference was arranged at which it was agreed that the Hughes Electron Tube Laboratory would develop and fabricate complete tubes using a character aperture stencil provided by the Convair group. This arrangement resulted in the first Typotron, a tube able to print data and retain it indefinitely until erased. The Typotron should be useful wherever printed data is to be displayed rapidly for use by a human operator, and no permanent record is required.

## II. BASIC PRINCIPLES OF OPERATION

Figure 1 is a schematic sketch of the basic elements of the Typotron tube. Referring to this figure and starting at the writing gun end of the tube, one can briefly describe the tube operation as follows. The writing gun, consisting of the cathode, the grid, focusing and anode cylinders, produces an electron beam which is directed through the two pairs of electrostatic deflection plates. These plates are called "Character selection plates" on the sketch of Fig. 1. By applying the proper voltages to these selection plates the beam can be directed through any one of the characters on the character matrix. This character matrix consists of a thin metal sheet which has been etched through to produce openings corresponding to the desired characters. The electron beam in passing through this metal stencil assumes the cross-section of the selected character. The beam then passes through the magnetic convergence coil. This coil, acting as a magnetic lens, focuses the selected character on the storage target and also converges the electron beam causing it to cross the axis of the tube at the approximate position of the deflection plates. By application of voltages to the deflection plates the character can be placed at any desired location on the storage target. Bombardment of the storage target by the high velocity character shaped beam serves to charge the target surface positive in the bombarded areas. This positive charging of the storage target dielectric material is called "writing".

In the Typotron tube the dielectric material of the storage target can assume either one of the two equilibrium potentials: 1) the potential of the flood gun cathode, or 2) the potential of the collector grid. The potential of the flood gun cathode (usually ground) corresponds to the unwritten condition. When bombarded by the relatively high velocity electrons of the writing gun the dielectric is charged by secondary emission and by bombardment conductivity to the collector potential, e.g. plus 175 volts. This corresponds to the written condition.

Figure 1 shows the flood gun mounted alongside one of the deflection plates. This flood gun produces a low velocity flood of electrons which covers the entire storage target. In the areas of the storage target which have been written positive, some of these flood electrons arrive at the target surface and others penetrate through the fine meshes of the storage target. The latter are accelerated to high velocity and are made to strike the viewing screen phosphor producing a continuously visible image of the character electrically stored on the storage target. In areas not written positive the flood electrons are repelled and cannot penetrate to the viewing screen.

Figure 2 is a schematic diagram of the arrangement of the various electrodes in the Typotron tube. Also shown on this diagram are some typical operating potentials of these electrodes.

## III. PERFORMANCE CHARACTERISTICS

The performance of a storage tube is dependent primarily upon two factors: (1) the storage target performance, and (2) the electron gun characteristics.

In the Typotron tube the storage target is the same as used in the "Memotron" tube. The essential characteristics and the performance attained for the storage target are as follows:

a. Persistence and Erasure. When the collector potential of the target is operated in the stable holding range the persistence of this storage tube is infinite. This merely means that the writing on the storage target remains indefinitely, without change, as long as the electrode potentials and the flood beam are maintained essentially constant.

The storage target is erased by momentarily dropping the collector voltage. The time required for erasure of the target is approximately 50 milliseconds.

b. Writing Speed. Writing speed is a function of the storage dielectric characteristics and of the current density delivered by the writing gun. In the "Typotron" tube the speed is expressed in terms of the time required to write one character. The speed is measured by holding the writing beam stationary on any given area of the storage target. Usually the target charges more slowly in the central area than around the edges. The measured writing speed for the tubes so far tested and delivered on the present contract is tabulated in Table 1. The tabulated values show two figures, corresponding to the speed attained on the central area and the speed of the best area of the target.

c. Brightness. The brightness of the written areas of the screen is a function of the following factors:

1) Phosphor efficiency.

2) Viewing screen potential.

3) Flood beam density.

4) Per cent transmission of the storage target assembly.

5) Storage grid bias voltage.

The phosphors used in the developmental Typotron tubes have all been yellow or green Zn-Cd sulfides so that the efficiency factor has remained essentially constant. The viewing screen potential obviously has a large effect on the amount of energy delivered to the phosphor and the higher this potential the brighter the screen. The practical upper limit to the viewing screen potential is in the range from 5 to 10 kv in the present design. This limit is determined by the potential at which field emission from the storage target becomes objectionable.

The flood beam density is determined by space-charge considerations. With the present flood gun design the total flood current is limited to approximately 1.3 to 1.6 milliamperes covering target area of 4.25" diameter. This current can be doubled by the addition of a second flood gun.

The bias voltage on the storage grid controls the amount of background illumination on unwritten areas of the target and at the same time influences to some extent the number of electrons which will penetrate the written areas.

The brightness attained in the experimental tubes is tabulated in Table 1.

d. Contrast. The contrast (ratio of the brightness of written areas to brightness of unwritten areas) is a function of the storage grid bias. The adjustment giving maximum contrast, however, may not necessarily be the best one since this condition may result in an undesirable reduction in brightness. The optimum contrast adjustment is a function of the ambient light in which the tube is to be viewed.

e. Resolution. The resolution of the present Typotron target structure is 50 to 60 written lines per inch. This resolution has been obtained on a considerable number of Memotron tubes using this same target construction and it appears to be quite adequate for clear presentation of the Typotron characters.

f. Electron Guns

1. Flood Gun. As mentioned under the heading of "Brightness", the flood gun delivers a flood beam of approximately 1.3 to 1.6 milliamperes covering the entire area of the target. The total accelerating potential used is nominally 200 volts.

2. Writing Gun. The Typotron writing gun uses a character matrix supplied by Consolidated Vultee Aircraft Corporation to the specifications of the Lincoln Laboratory. This matrix has a total of 64 characters arranged in 8 rows and 8 columns. (Actually 63 characters since one position is left vacant). The desired character is selected by application of the proper deflection voltage to the two pairs of deflection plates between the gun and the matrix. In Model 1 of the Typotron gun the selection sensitivity is approximately 12 volts per character. The magnetic convergence coil which is located between the matrix and the deflection plates rotates the beam 90 degrees so that the matrix image is turned 90 degrees on its side.

The deflection plates following the convergence coil have a deflection sensitivity for positioning the characters on the viewing screen of approximately 175 volts plate to plate per inch of deflection with a beam velocity of 2.7 kv. The two sets of plates have approximately equal sensitivity.

The appearance of the written characters on the tube face is shown in the photograph of Fig. 3. Actually, the appearance of the tube is somewhat better than that conveyed by the photograph due to photographic overexposure.

## TABLE 1

| Tube No. | Stable Range of Collector Voltage | Writing Speed (a): Central Area μ sec | Writing Speed (a): Best Area μ sec | Writing Speed (a): Collector Voltage | Gas Ratio: $I_{ion}/I_{elect}$ x $10^{-3}$ | Light Output: Ft.-Lamb. | Light Output: Viewing Screen Voltage (kv) |
|---|---|---|---|---|---|---|---|
| 248 | 145 to 175 | 25 | 10 | 170 | 0.2 | 280 | 10 |
| 254 | 160 - 190 | 24 | 16 | 190 | 0.25 | 175 | 9 |
| 258 | 145 - 190 | 30 | 10 | 190 | 0.16 | 230 | 9 |
| 265 | 155 - 190 | 35 | 25 | 190 | 0.12 | 90 | 9 |
| 268 | 135 - 170 | 40(c) | -- | 170 | 0.45 | 140 | 9 |
| 280 | 160 - 190 | 40(c) | 28 | 190 | 0.26 | 160 | 9 |
| 291(b) | 190 - 255 | 50(c) | -- | 250 | 0.34 | 130 | 9 |
| 292(d) | 135 - | 60(c) | -- | 200 | 0.11 | - | - |

(a) Microseconds required to write character.

(b) This tube baked with slow leak originally; target has high stable range.

(c) Includes 8 μ-second rise time of pulse.

(d) Target of this tube partially contaminated with barium.



Note 1: All writing speed tests made with writing beam of 2 kv.

Note 2: Deflection sensitivity measurements on tubes 248, 254 and 258 with 2.7 kv beam gave approximately 160 to 180 volts per inch.

Note 3: Character selection sensitivity was from 10 to 13.7 volts per character for the same tubes for 2.7 kv beam.

However, it is quite obvious that the resolution and contrast of the target is quite adequate for easy reading of the characters displayed.

The photograph of Fig. 4 shows the appearance of the viewing screen when all of the 63 characters have been written in each of the individual positions available on the storage target. For this test, the deflection voltages were quantized in equal steps in the vertical and horizontal direction. The writing beam was defocused so that all the characters could be written at one time. The deflection voltage steps were then applied so that all characters were written in all positions shown. The resultant picture shows that the deflection registration is good and the linearity of deflection is sufficient to prevent overlapping of the character positions.

## IV. CONSTRUCTION DETAILS

The general appearance of the completed Typotron tube is shown in the photographs of Figs. 5 and 6. The outline drawing No. 410188, Fig. 18, indicates the relative positions of the essential parts of the tube. The following paragraphs describe some of the constructional details of the tube elements starting at the front or viewing screen end of the tube.

The phosphor viewing screen is deposited directly on the front flat face of the tube. This phosphor is of a ZnCdS material having a green or yellow fluorescence. The face of the tube is processed to make it conducting (and transparent) before the phosphor coating is deposited in order to apply a high accelerating potential directly to the viewing screen.

Placed 1/8" behind the viewing screen is the storage target assembly shown in the two photographs, Figs. 7 and 8. Figure 7 is a view looking at the contrast mesh and Fig. 8 shows the storage target assembly as viewed from the electron gun end of the tube. This assembly consists first of an electroformed nickel mesh screen known as the contrast grid which has 250 holes per inch. This mesh is obtained from the Buckbee-Mears Company of St. Paul, Minnesota. It is mounted taut on a 4-1/4" diameter stainless steel ring. On the side of this mesh away from the viewing screen the storage dielectric material is spray-coated to a thickness of approximately .002". It is important for uniformity of background that the coating of dielectric material be as uniform as possible. The Typotrons so far delivered have been hand sprayed. However, in order to secure target uniformity, to decrease the labor required for spraying and to keep lint and dirt from the storage targets, it is necessary that this spray coating operation be mechanized. A mechanical spray machine was designed and built and is now operating quite successfully.

The storage target assembly is completed by the addition of one other element, the collector grid. This grid is made of aluminum by a vacuum evaporation process, similar in some respects to the technique used for producing aluminum backed T.V. picture tubes. Electrically the collector is connected around its entire rim to the inwardly turned lip of the collector can. This collector can is supported so that its lip is about .020" above the storage dielectric material. The aluminum mesh collector drapes from this lip and lies in intimate contact over the whole surface of the dielectric material.

The collector can and the mounting ring for the nickel contrast mesh are assembled together as a unit by six glass beads and Kovar strips spaced uniformly around the periphery. This assembly is held in the front glass cylindrical section of the tube by welding three equally spaced perforated ears on the collector can to the three Kovar cup seals in the wall of the envelope. This gives a strong and rigid structure but still permits radial flexibility for the difference in expansion between the glass, the No. 321 stainless steel of the collector can, and the No. 430 stainless steel of the contrast mesh mounting ring. This construction is clearly visible in the photographs of Figs. 7 and 8.

The assembled electron guns are shown in the photographs Figs. 9, 10 and 11. The flood gun is mounted at the front end of the writing gun on the side of one of the deflection plates. This places it as near as possible to the axis of the tube. The writing gun is axial with the tube. As can be seen in the photographs, the various gun parts are assembled and held in alignment with multiform glass rods. One special feature of the flood gun is that the heater leads are brought back to the stem through a coaxial line. This was found necessary in order to reduce the deflection ripple produced in the writing beam by the magnetic field of the flood gun heater circuit.

For determining the proper positions of the deflection plates and their spacing, and the relative location of the external magnetic convergence coil, a special cylindrical test tube was built. This tube is shown in the photographs of Figs. 12 and 13. This test tube has a movable fluorescent screen so that the beam cross-section in any part of the tube can be observed. The effects of different locations and designs of the convergence coil, distortions, magnification, etc., and the proper location and spacings for the electrostatic deflection plates were determined using this tube. The magnetic convergence coil is shown around the tube in Fig. 13 and in the separate photograph of Fig. 14.

Soon after building the first tube it was decided that, in order to maintain proper alignment between the gun, the selection plates, the matrix, and the deflection plates, these elements should be assembled as a unit with the gun structure. For this purpose a non-magnetic stainless steel tube serves as a connecting structure between the matrix and the remaining elements. For ease of character selection it is essential that the rows and columns of the character matrix be orthogonal with the character selection plates. For simplicity of construction and operation the deflection plates are made orthogonal with the selection plates. Therefore, the magnetic rotation of the convergence was set at 90 degrees.

The complete Typotron gun, with its total of eight deflection plates and attached flood gun, requires a minimum of 18 leads. Since no stem to fit a 2-1/4" arm with more than 14 leads was available, it became evident that a stem would have to be developed and built for the purpose. The layout of the 23 lead stem developed for this tube is shown in the Typotron socket drawing No. 410189, Fig. 15. The photograph, Fig. 16, shows this stem and the mold in which it was made. Figure 17 is a photograph of the tubulated stem and of the specially built socket into which the leads of this stem can be plugged directly without a base. The stem also is shown in the photographs of Figs. 9 and 11 of the gun structure.

The exhaust, baking and processing of tube is carried out at as high a temperature as the glass envelope will withstand, approximately 440 degrees C. This is conducive to obtaining a good vacuum which is necessary for the stable operation and long life of storage tubes. The ratio of the ion current to the electron current, a measure of the gas pressure, is tabulated in Table 1 on page 5 of this report.

## V. FUTURE DEVELOPMENT

Further investigations in connection with the development of the 5" Typotron may be directed toward attainment of improved contrast, higher writing speed, and the complete elimination of the interaction between selection and deflection. The most important development for the future, however, seems to be the large screen tube. It is believed that Typotron tubes of large size will not merely permit larger displays of typewritten data but will also permit the presentation of a radar display which combines a PPI map of targets with printed data blocks identifying the important targets. Such a display should be very useful, for example, in the control of traffic around a large airport. Large Typotron tubes can utilize available envelopes in 15" and 19" sizes now being produced for color TV. The storage element used in the Hughes tube does not require a multiplicity of large, closely spaced grids and should therefore present no serious problem in the design of larger storage tubes. The total amount of flood gun current required will increase with the area of the tube, but this requirement can easily be met by increasing both the size and number of flood guns. Perhaps the most serious problem anticipated in the development of a large Typotron will be that of accurate character registration in all areas of the screen.

H. M. Smith /eh

H. M. Smith, Co-Head
Storage Tube Section
Electron Tube Laboratory

HMS/eh
Encs: Figs. 1-18

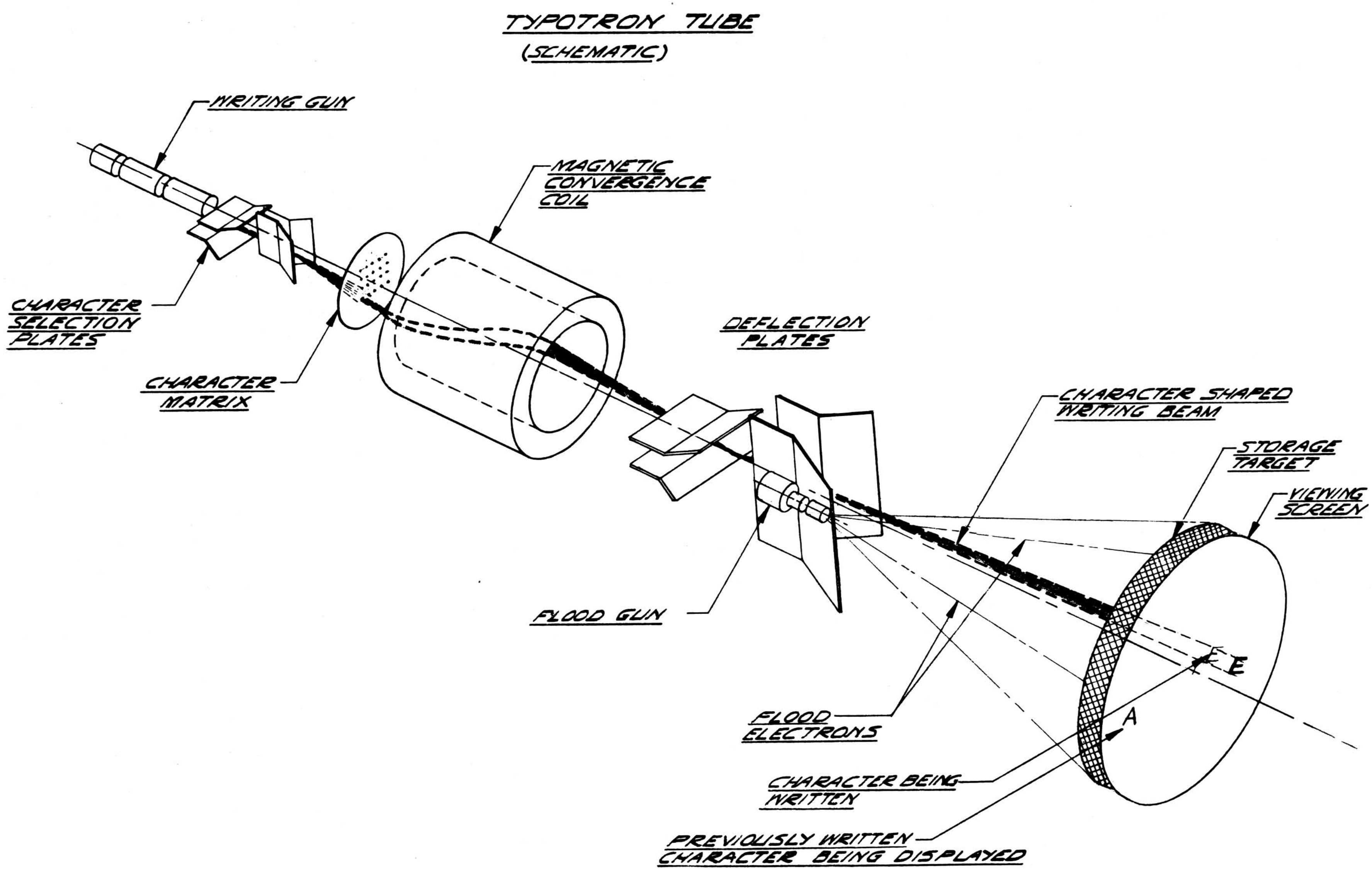
TYPOTRON TUBE
(SCHEMATIC)
WRITING GUN
MAGNETIC CONVERGENCE COIL
CHARACTER SELECTION PLATES
DEFLECTION PLATES
CHARACTER MATRIX
CHARACTER SHAPED WRITING BEAM
STORAGE TARGET
VIEWING SCREEN
FLOOD GUN
E
A
FLOOD ELECTRONS
CHARACTER BEING WRITTEN
PREVIOUSLY WRITTEN CHARACTER BEING DISPLAYED

Figure 1

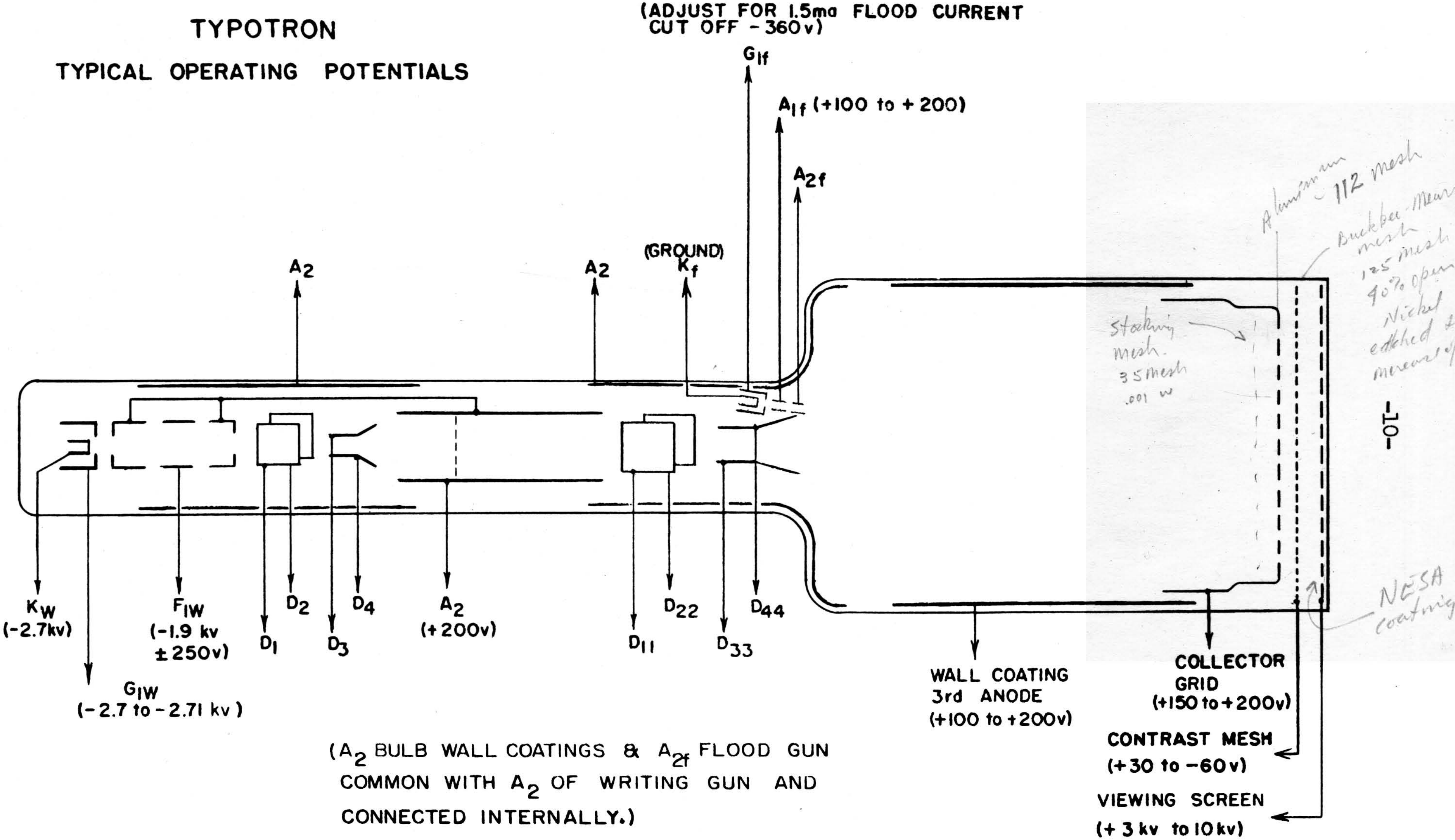
TYPOTRON
TYPICAL OPERATING POTENTIALS
(ADJUST FOR 1.5ma FLOOD CURRENT CUT OFF - 360v)
$G_{1f}$
$A_{1f}$ (+100 to + 200)
$A_{2f}$
(GROUND) $K_f$
$A_2$
$A_2$
$K_W$ (-2.7kv)
$G_{1W}$ (-2.7 to -2.71 kv)
$F_{1W}$ (-1.9 kv ±250v)
$D_1$
$D_2$
$D_3$
$D_4$
$A_2$ (+200v)
$D_{11}$
$D_{22}$
$D_{33}$
$D_{44}$
WALL COATING 3rd ANODE (+100 to +200v)
COLLECTOR GRID (+150 to +200v)
CONTRAST MESH (+30 to -60v)
VIEWING SCREEN (+3 kv to 10 kv)
($A_2$ BULB WALL COATINGS & $A_{2f}$ FLOOD GUN COMMON WITH $A_2$ OF WRITING GUN AND CONNECTED INTERNALLY.)
Aluminum 112 mesh
Buckbee Mears mesh 125 mesh 40% open Nickel
Stacking mesh. 35 mesh .001 w
NESA coating

Figure 2

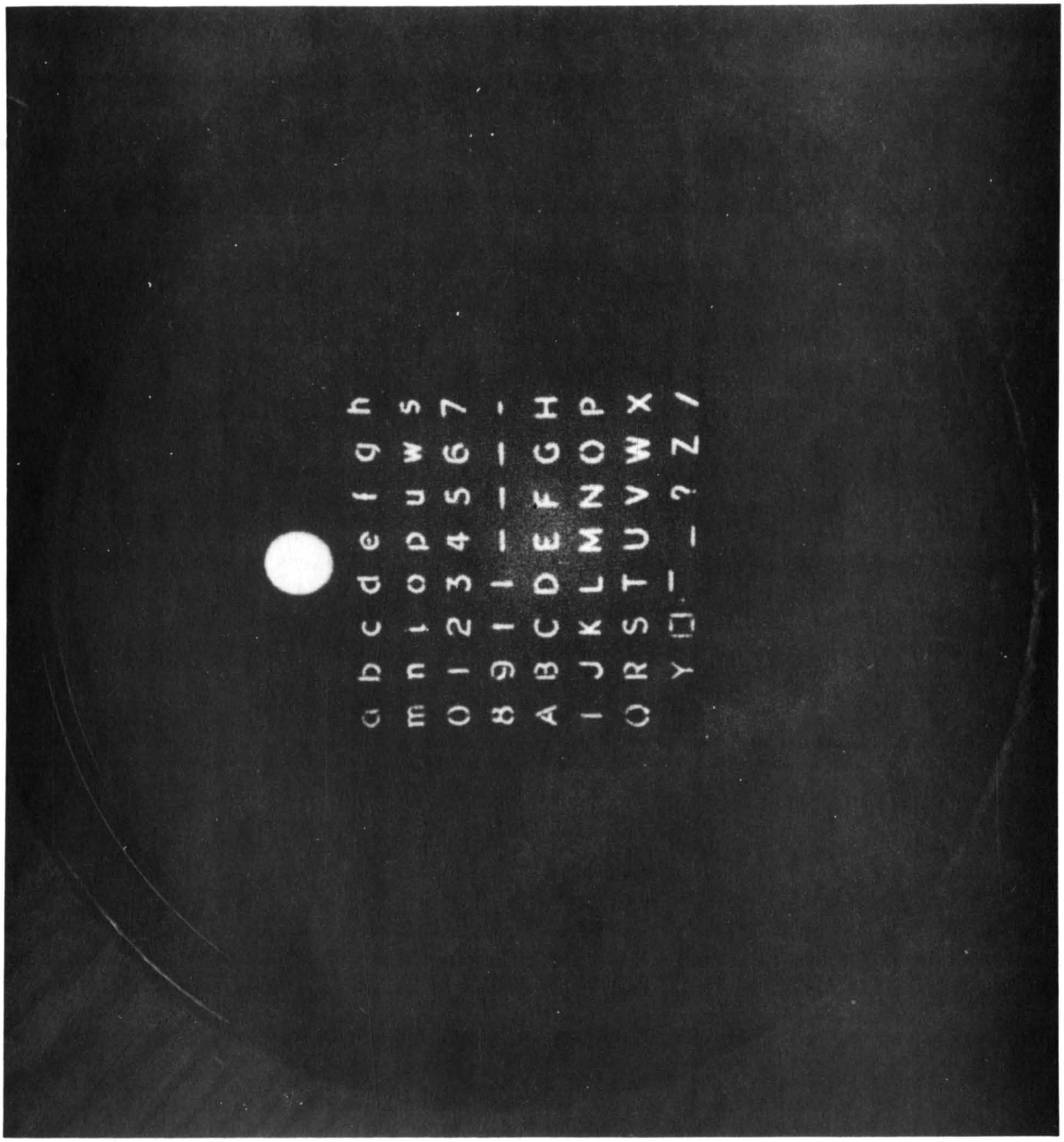

Figure 3

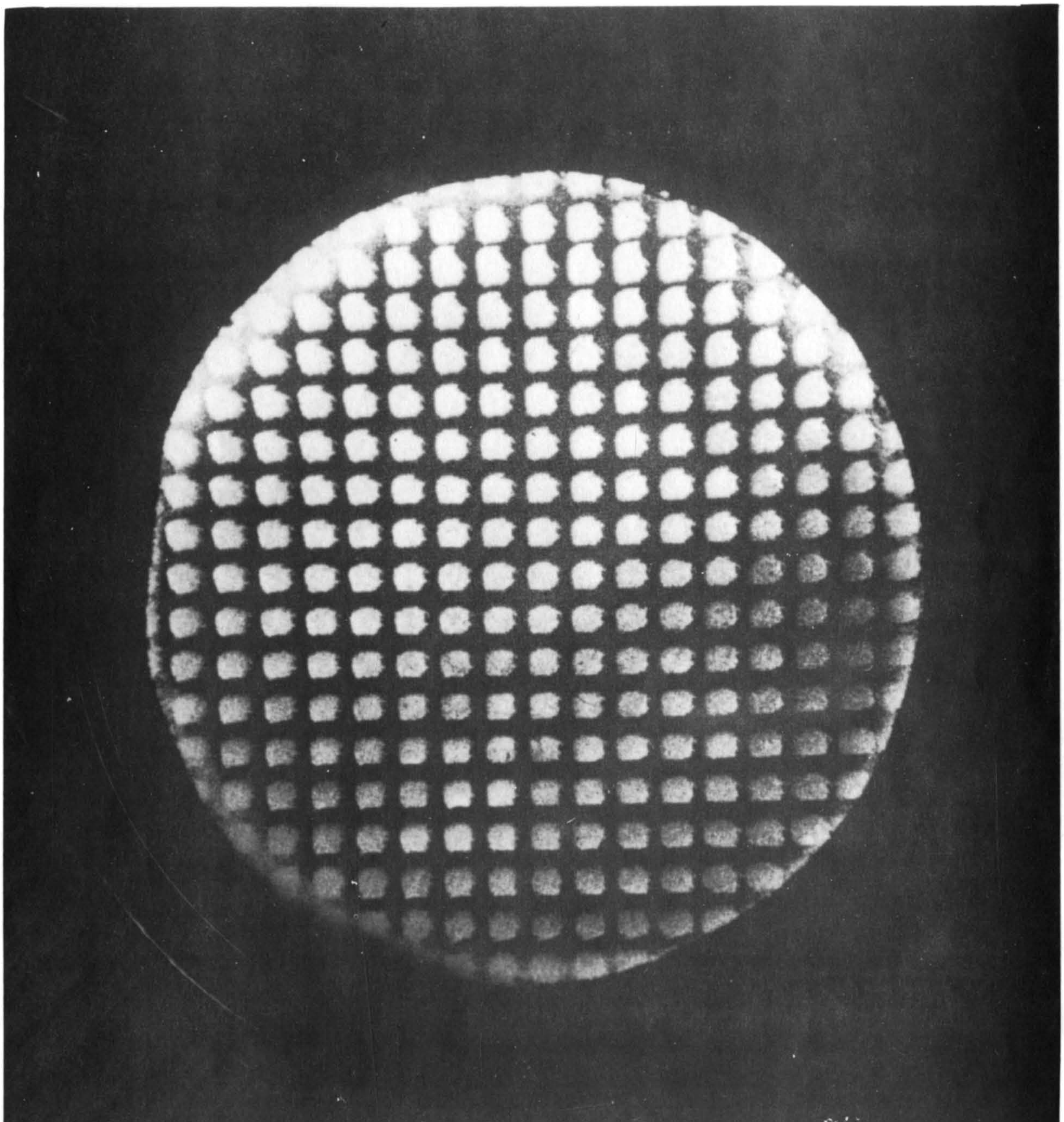

Figure 4

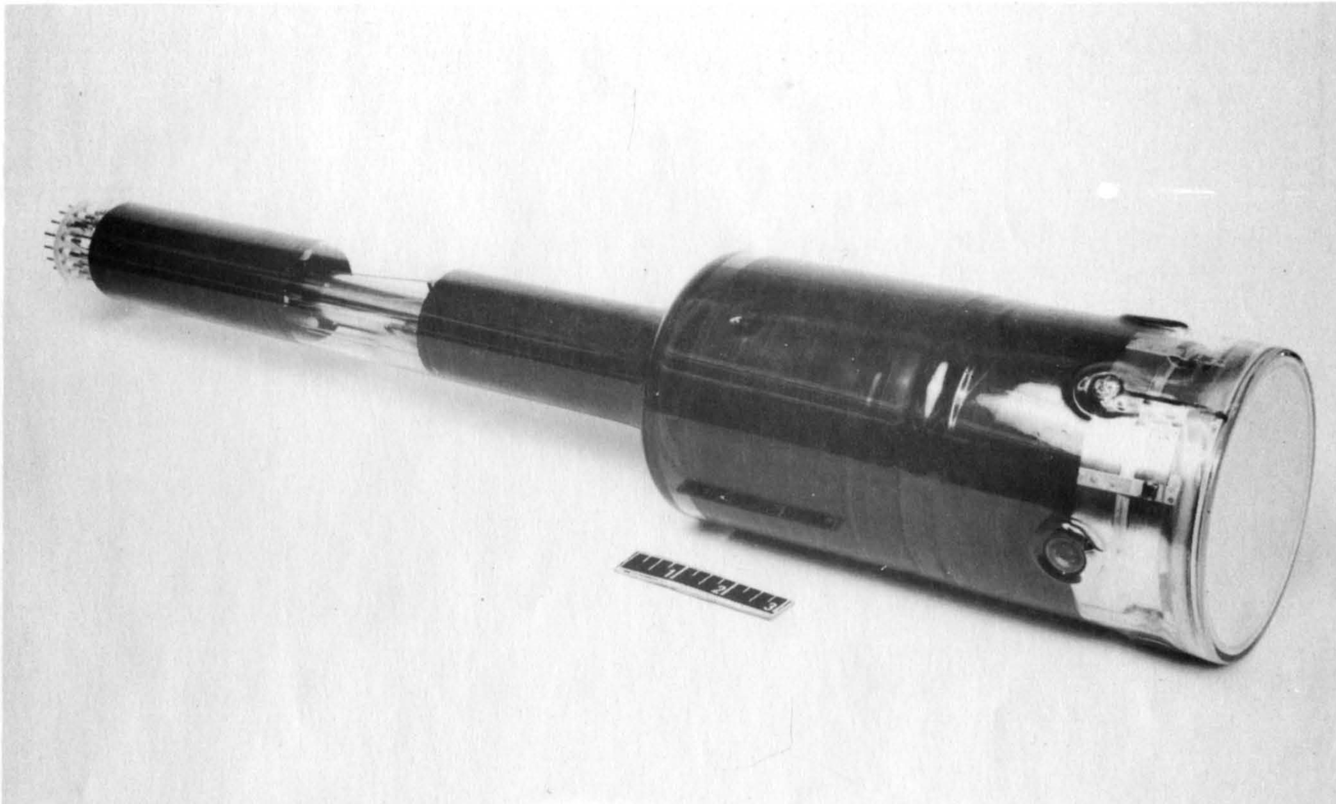

Figure 5

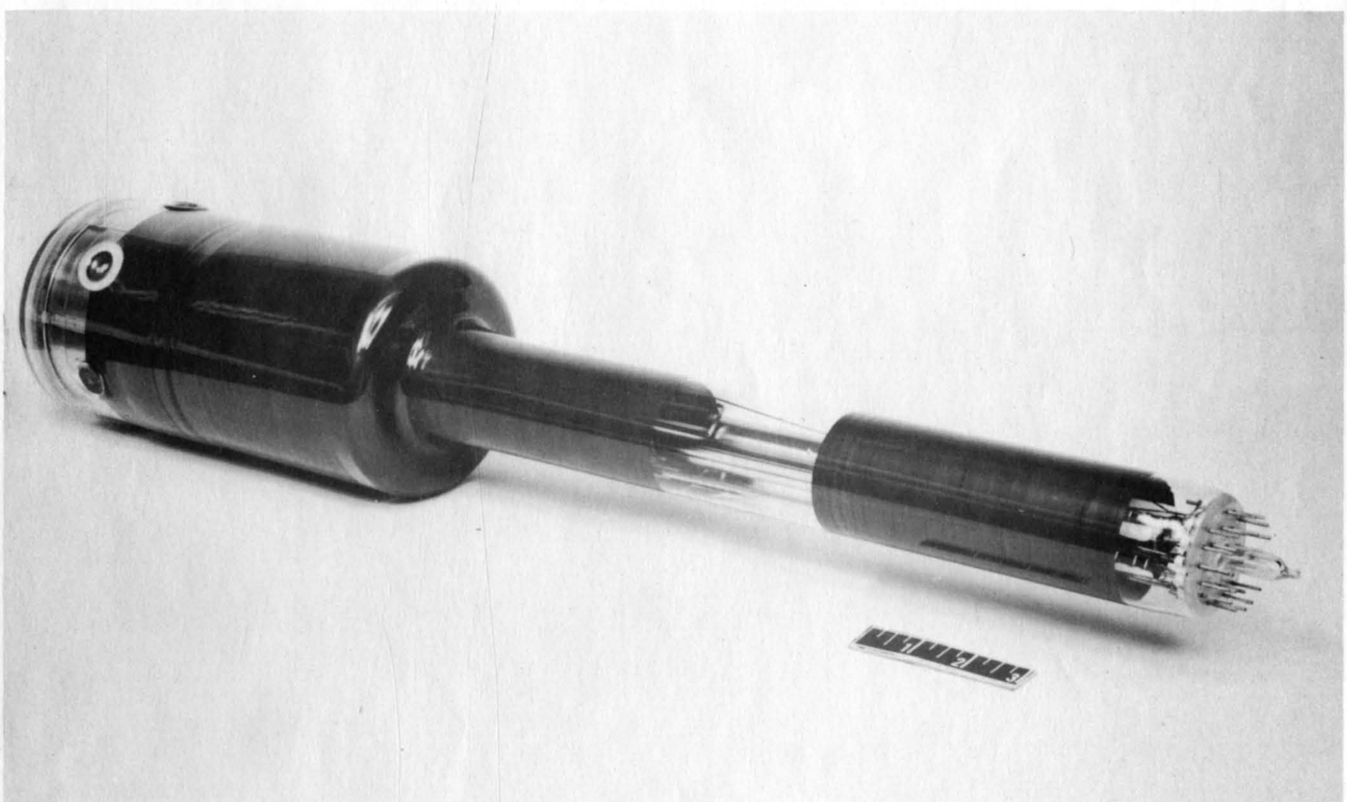

Figure 6

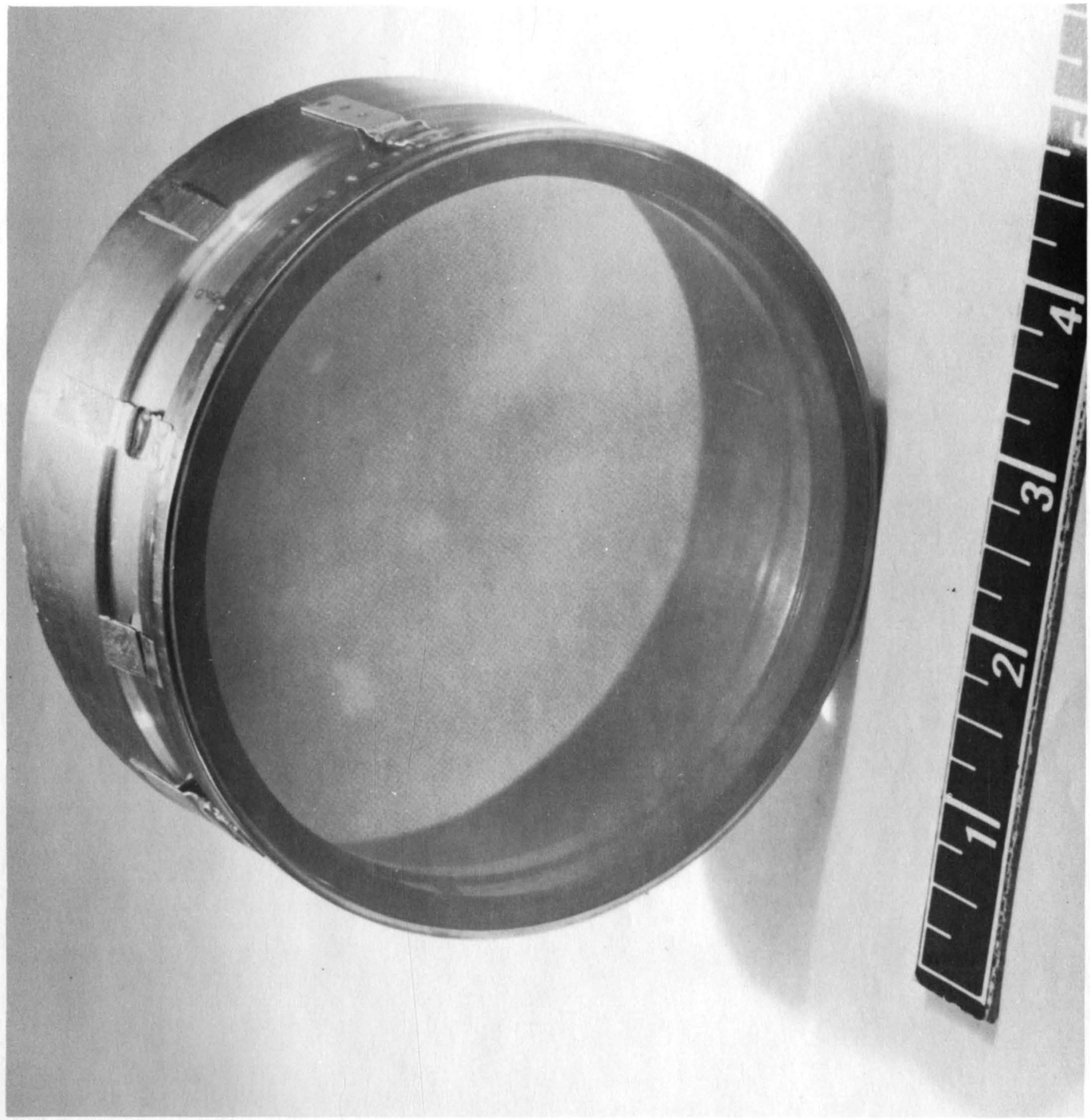


Figure 7

Figure 8

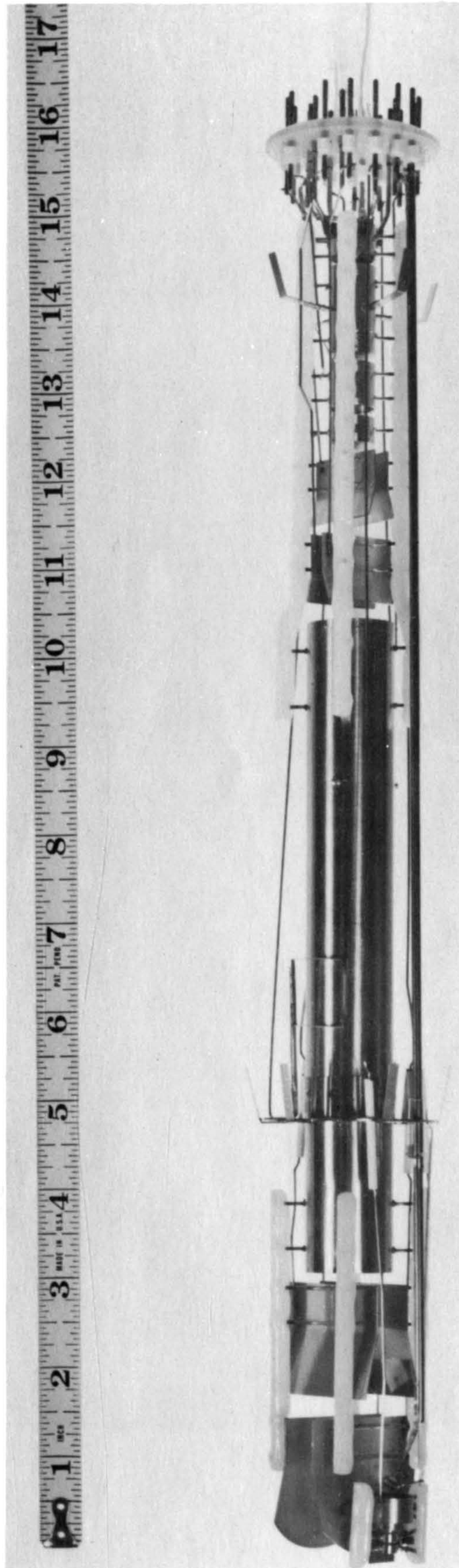

Figure 9

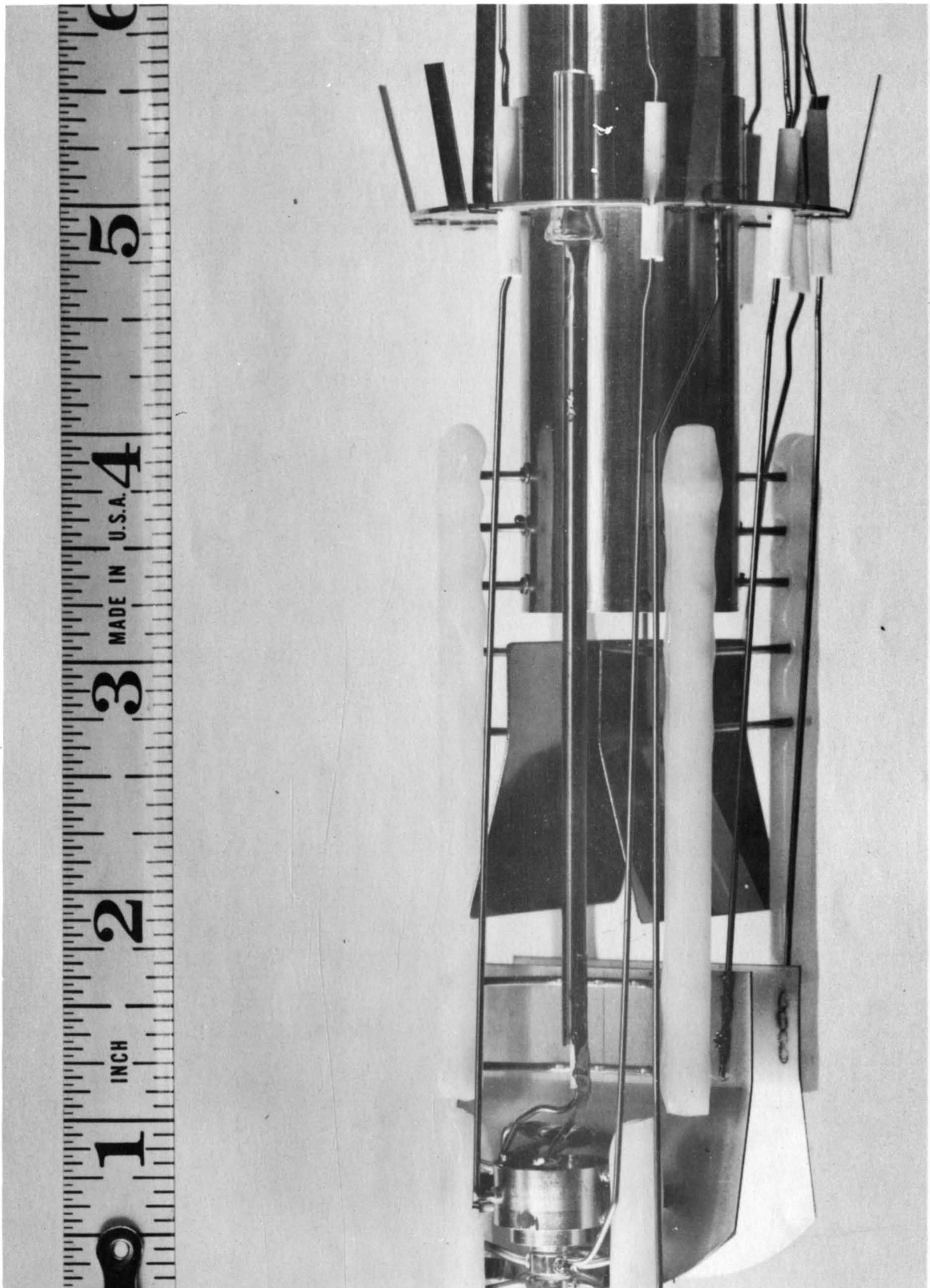


Figure 10

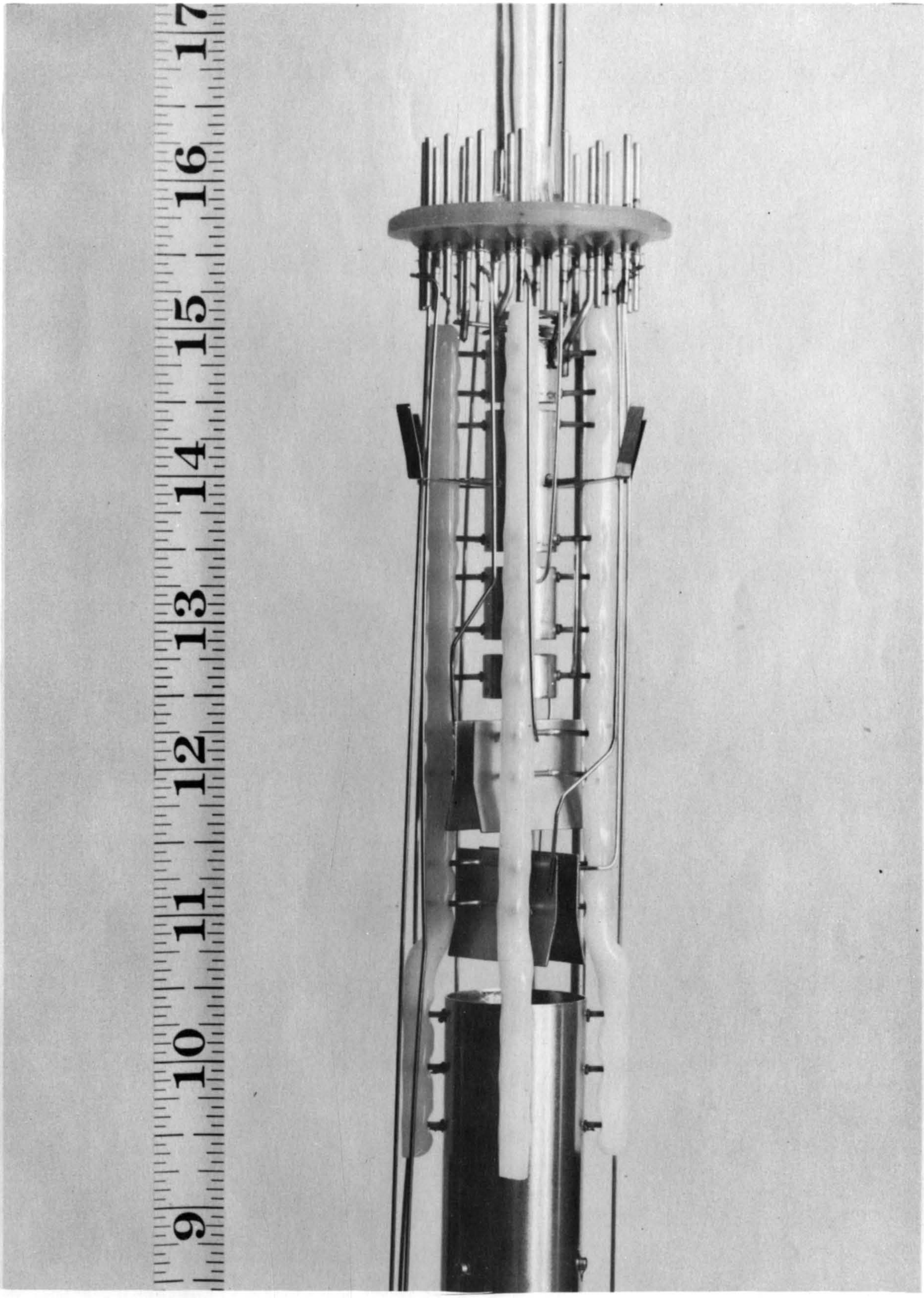


Figure 11

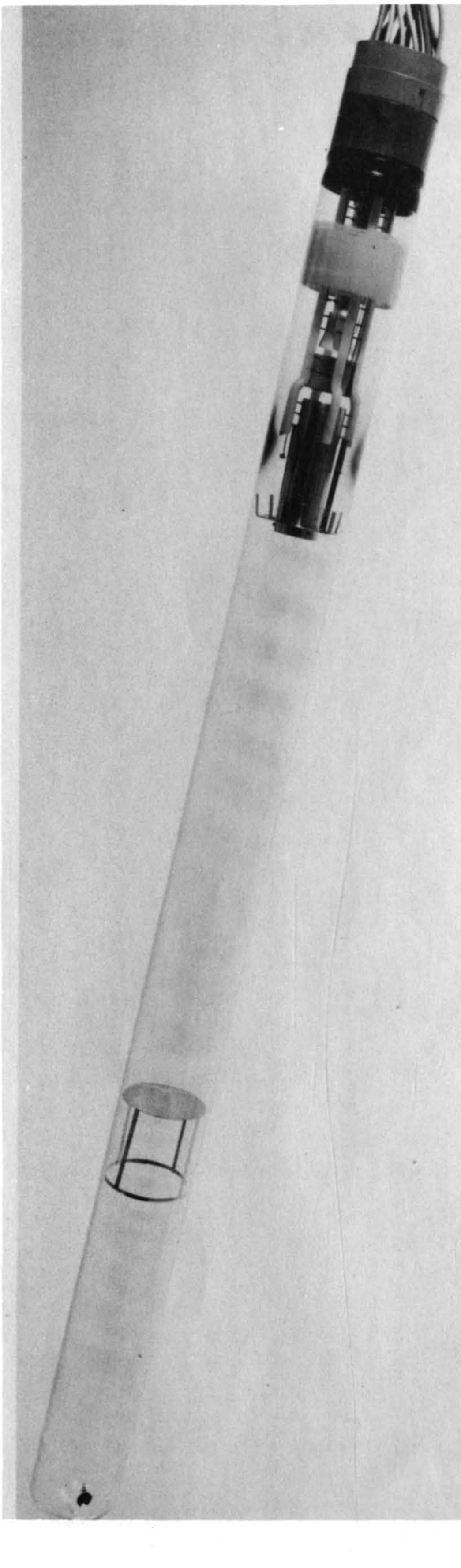

Figure 12

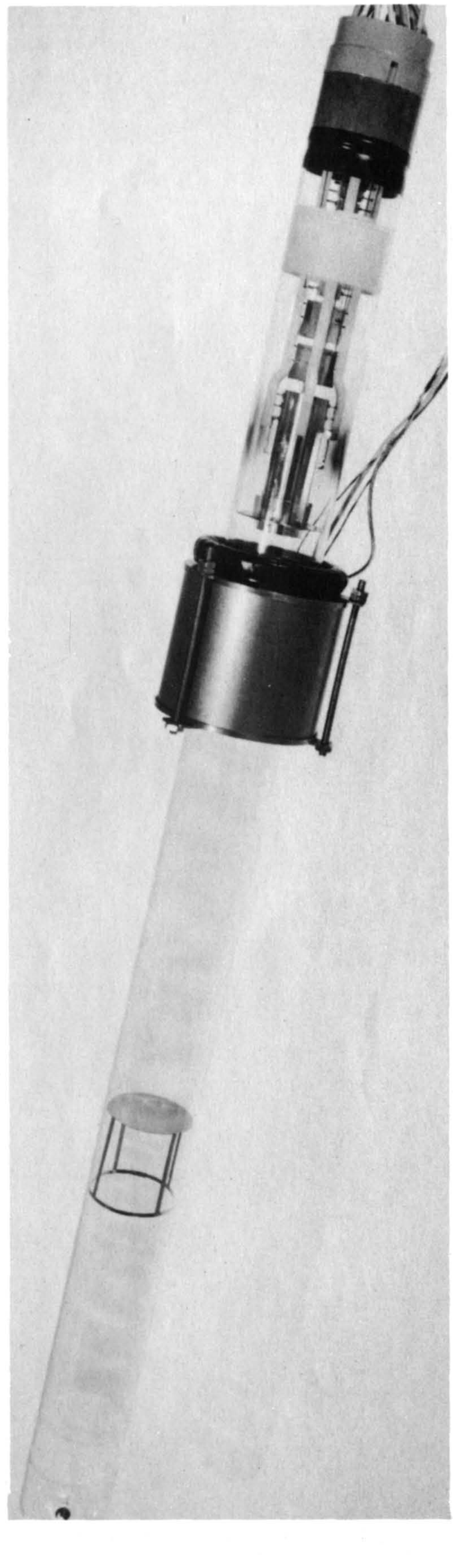

Figure 13


Figure 14

<u>TYPOTRON PIN CONNECTIONS</u> - (Revised 2/19/54)

1. $A_1$, flood
2. H, flood
3. H and K, flood
4. $G_1$, flood
5. $A_2$, write; matrix; $A_2$, flood
6. $D_1$ (selector)
7. $D_2$ (selector)
8. $D_3$ (selector)
9. Internal connection, do not use.
10. $D_4$ (selector)
11. $D_{11}$ (deflector)
12. $D_{22}$ (deflector)
13. $D_{33}$ (deflector)
14. $D_{44}$ (deflector) — may be connected
15. Internal connection, do not use.
16. H, write
17. H, write
18. No connection
19. Cathode, write
20. $G_1$ write
21. No connection
22. $A_1$ focus, write
23. No connection

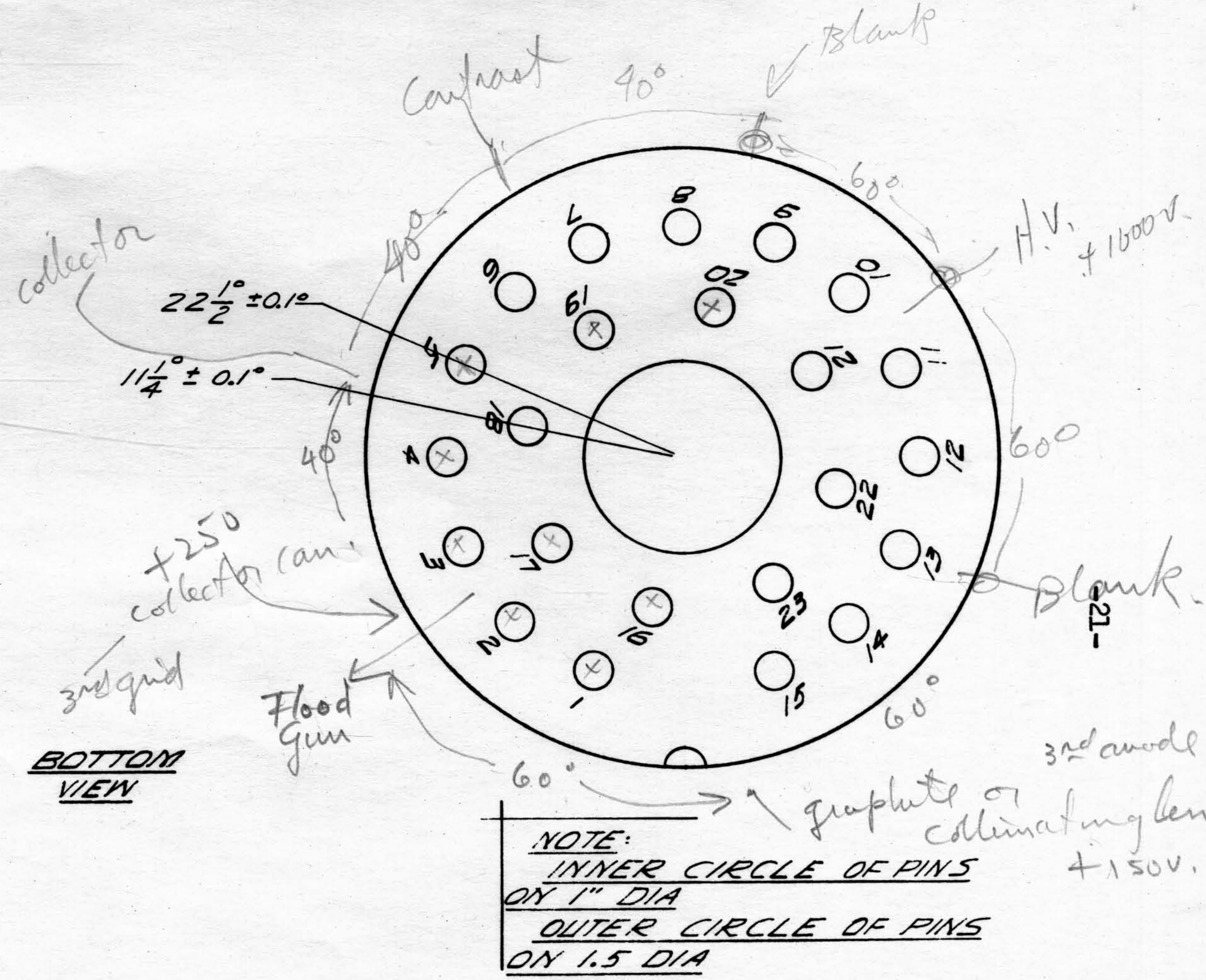


Figure 15

TYPOTRON SOCKET

SCALE-2X | A McINTYRE
DATE 1-4-54
410189-A

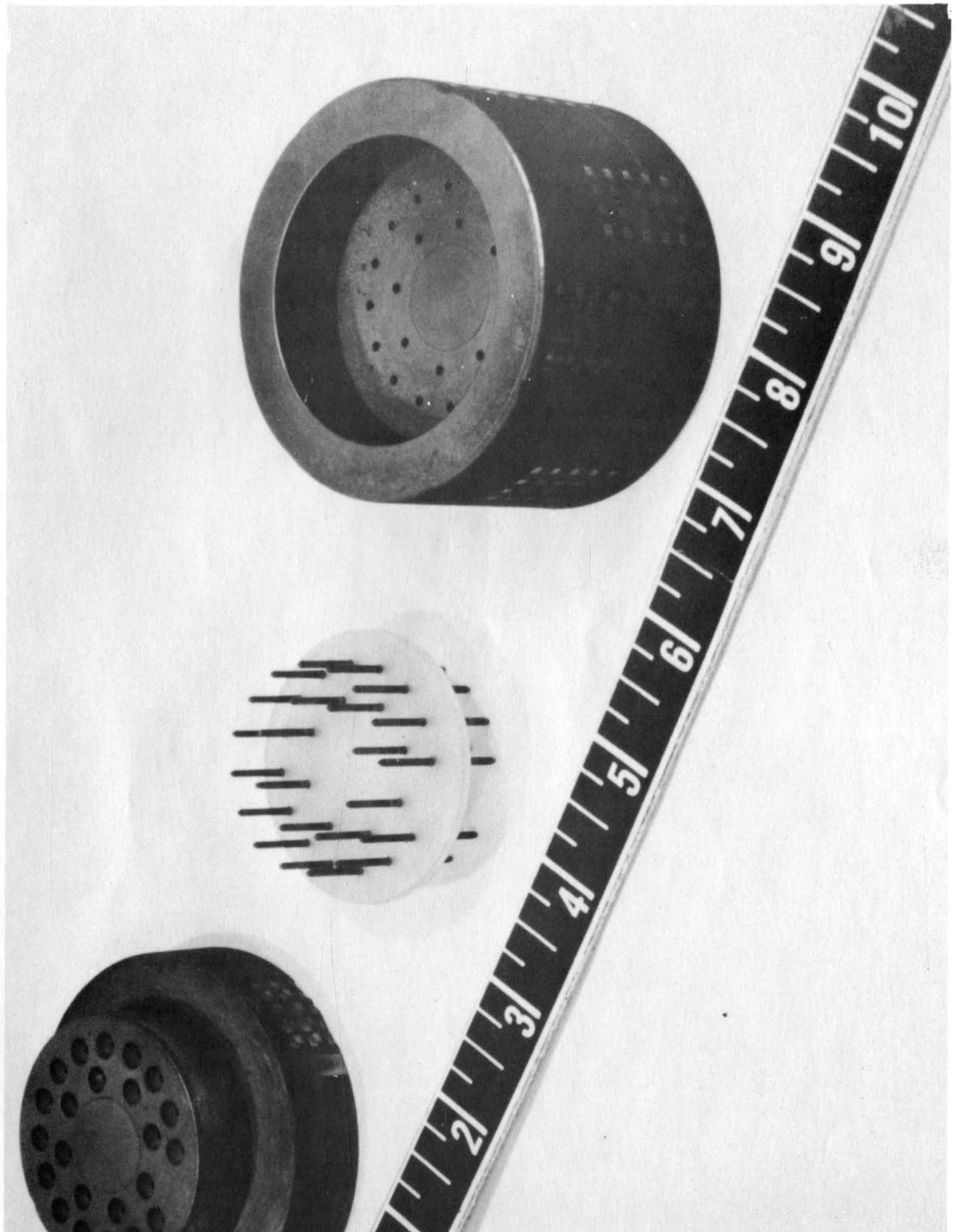


Figure 16

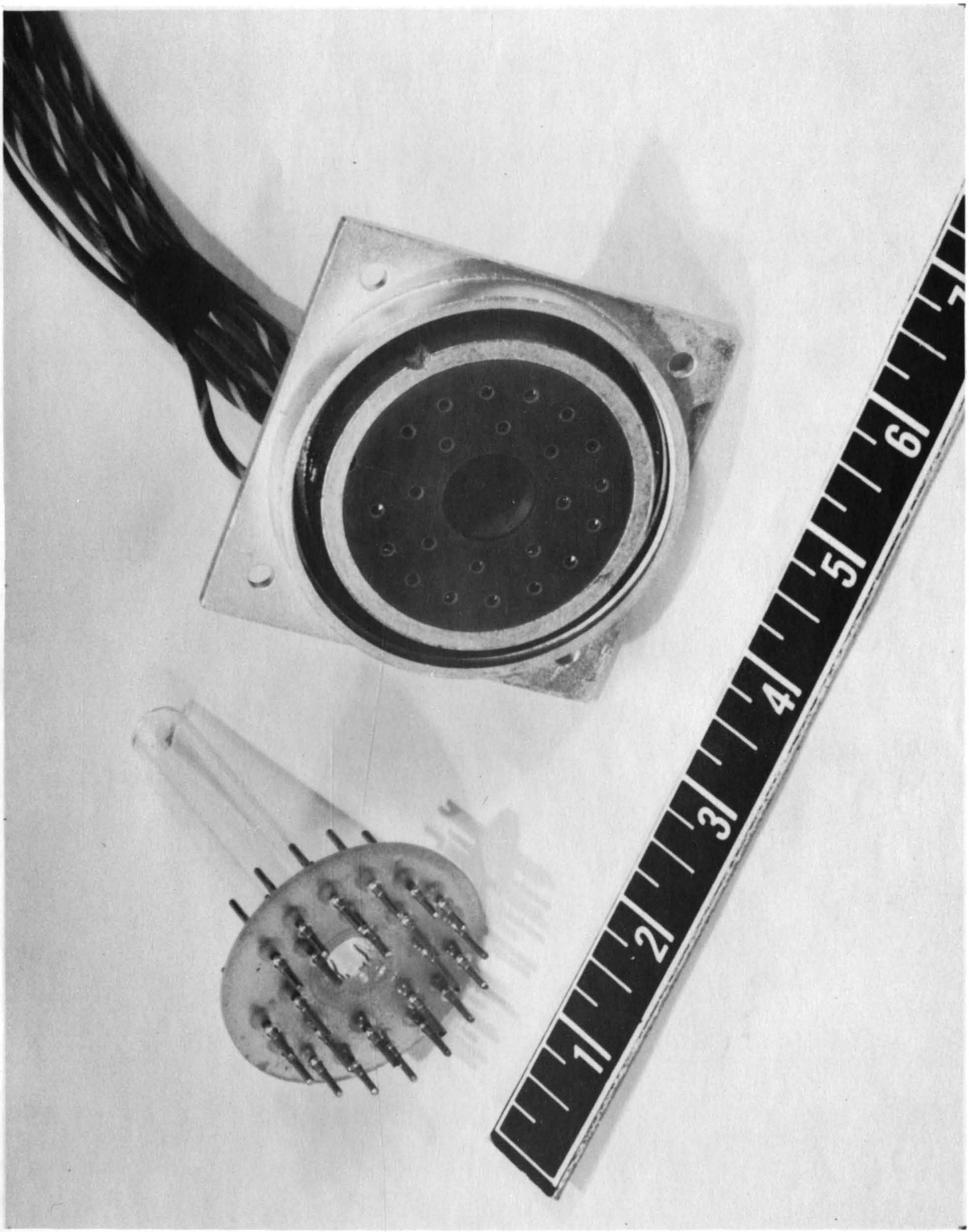

Figure 17

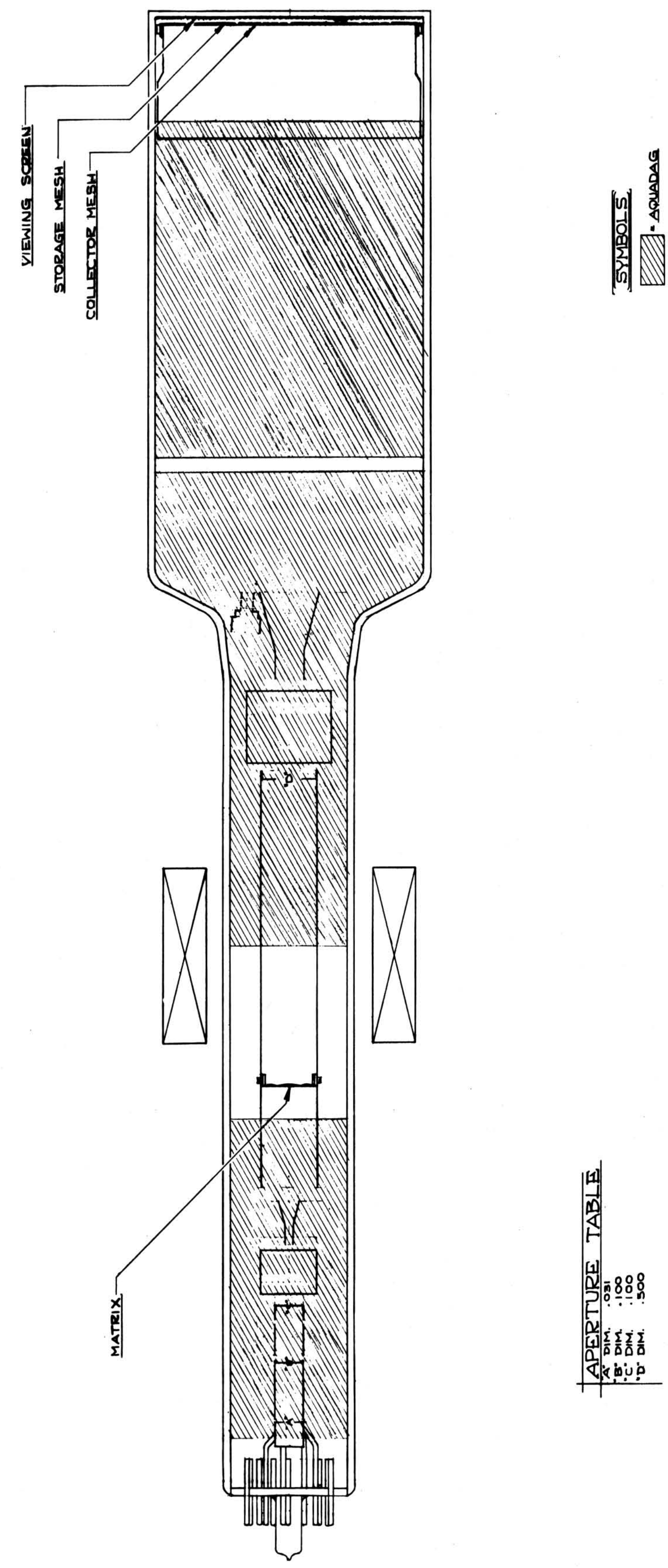
VIEWING SCREEN
STORAGE MESH
COLLECTOR MESH
MATRIX
SYMBOLS
= AQUADAG
APERTURE TABLE
'A' DIM. .031
'B' DIM. .100
'C' DIM. .100
'D' DIM. .500

Figure 18

| Time | Heater Current (each heater) | HF | Grid No. 1 Bias: Writing Gun | Grid No. 1 Bias: Flood Gun* |
|---|---|---|---|---|
| 2 min. | .4 amp. | on | 0 | 0 |
| 2 min. | .5 amp. | on | 0 | 0 |
| 2 min. | .6 amp. | on | 0 | 0 |
| 2 min. | .65 amp. | on | 0 | 0 |
| 2 min. | .7 amp. | on | 0 | 0 |
| 2 min. | .8 amp. | off | +5 | +50 |
| 1 min. | .85 amp. | off | 0 | 0 |
| 25 min. | .675 | off | +2.5 | See below |
| Thereafter | .65 | off | +2.5 | See below |

*Apply voltage to 1st grid and 1st anode of flood gun tied together.

D. Target Bombardment

1. Commence anytime after the 1 min. - at - .85 amp. step in activation schedule. Apply variable negative bias to flood gun grid and following voltages to other electrodes:

| Electrode | Voltage |
|---|---|
| Viewing Screen | 1000 volts |
| Collector | 250 volts |
| Contrast | 250 volts |
| Anode No. 2 | 250 volts |
| Anode No. 1 (Flood Gun) | 250 volts |
| Top Deflection Plates | 250 volts |
| Collimating Lens | 150 volts |

Adjust bias on flood gun grid to provide 4 ma. current to the 250 volt supply. (Caution: Do not operate near zero bias.) It may be necessary to raise the voltage on the collector and connected electrodes above 250 volts momentarily to cause the storage surface to go positive. Return to 250 volts.

2. Continue for total of 30 minutes (independent of 25 min. cathode aging).

E. Getter Degassing and Flashing

1. Heat each getter in turn near to the flashing point.
2. Flash one getter on the gun before tipoff.
3. Flash remaining getters after tipoff.

Scope: This instruction covers the exhaust and associated processing of 5" storage tubes, when reference to it is made on the finished tube assembly instruction.

Equipment:

1. Trolley exhaust station including:
   (a) Oven Model No._________.
   (b) Mercury Diffusion Pump, G. E. Nottingham, or equivalent.
   (c) Vacuum Pump, Kinney Size CVM 3153, or equivalent.
   (d) Oven Control and Thermocouple, Minneapolis Honeywell Brown Pyrovane, or equivalent.

2. High Frequency Generator and Induction Heating Equipment including:
   (a) Lepel $2\frac{1}{2}$ KW Generator Model T-$2\frac{1}{2}$-1, or equivalent.
   (b) Coils, as required, to heat tube per schedule below.

3. Power Supplies, as required, for activation schedule below.

Procedure:

A. Bakeout
   0 1. Start backer pump.
   1/4 2. Start diffusion pump.
   1/2 3. When mercury has begun to circulate in diffusion pump, turn on oven and bring temperature up to 440°C in no less than 30 minutes.
   1 1/2 4. Hold at 440°C for $1\frac{1}{2}$ hours.
   3 1/4 5. Lower temperature to 150°C in no less than 60 minutes and begin high frequency heating at once, opening oven no farther than necessary to make connections.

B. High Frequency Heating
   1/2 {Set up + R.F.} 1. Apply HF for 20 minutes in each coil position required. Adjust coil and generator controls to provide a temperature of 700°C on the first grid of the writing gun and at least a dull glow on other cylinders. On the Typotron, the barrel surrounding the matrix must not be heated beyond a dull glow visible only under low ambient illumination. The flood gun grid shall be brought as near to 700°C as possible. Avoid overheating support plates upon which centering springs are mounted.

1/12 C. Cathode Activation and Aging Schedule
   1. Apply HF again to writing gun grid and wait 5 minutes before starting activation.
   2. Activate and age per following schedule: